# ERICSSON Review

1
1972

# ERICSSON REVIEW

Vol. 49 1972

RESPONSIBLE PUBLISHER: CHR. JACOBÆUS, DR. TECHN.
EDITOR: SIGVARD EKLUND, DHS
EDITOR'S OFFICE: S-126 11 STOCKHOLM 32
SUBSCRIPTIONS: ONE YEAR $1.80; ONE COPY $0.60

## CONTENTS

# ERICSSON REVIEW

Vol. 49 No. 1 1972

RESPONSIBLE PUBLISHER: CHR. JACOBÆUS, DR. TECHN.
EDITOR: SIGVARD EKLUND, DHS
EDITOR'S OFFICE: S-126 25 STOCKHOLM 32
SUBSCRIPTIONS: ONE YEAR $1.80; ONE COPY $0.60

## CONTENTS

On cover: Rotterdam telephone exchange DC II housing, among other equipment, the computer-controlled transit equipment AKE 13.

# Fields of Application for PCM Systems

E OHLSSON, TELEFONAKTIEBOLAGET LM ERICSSON, STOCKHOLM

UDC 621.376.56
LME 8436

*In the article PCM Transmission*[1] *a summary was given of the characteristics of p.c.m. systems. The following article is concerned with how advantage can be taken of these characteristics when introducing p.c.m. primary multiplex systems into telephone networks, and some of the problems to be considered in doing so.*

*PCM* is used principally to increase the number of telephone circuits on existing multi-pair cables between stations in the lower stages of the switching hierarchy, i.e. between local exchanges and primary centres. The increase in the traffic-handling capacity of a 100-pair cable employed by a varying number of 30-channel p.c.m. systems is shown in fig. 1. A 15-fold increase in the traffic-handling capacity is seen to be theoretically possible. In practice, however, the number of pairs that can be used simultaneously for p.c.m. transmission is limited by crosstalk between these pairs. For this reason, a 10-fold increase of capacity would seem a more adequate approximation of the maximum that can be achieved on existing cables.

Fig. 2 shows basic cost patterns for physical, p.c.m. and f.d.m. carrier circuits. It will be seen that p.c.m. is the most competitive within a range whose lower limit is set by physical circuits and whose upper limit is set by f.d.m. carrier circuits. The points where the cost lines intersect are determined not only by purchase price and installation costs, but also by the number of circuits, previous investments, transmission plan, signalling method, etc. Consequently, the economic limits vary with the transmission systems. Statistics suggest, however, that p.c.m. primary multiplex systems will yield the greatest economic advantages over route lengths of between 5 and 50 km.

## Application Problems

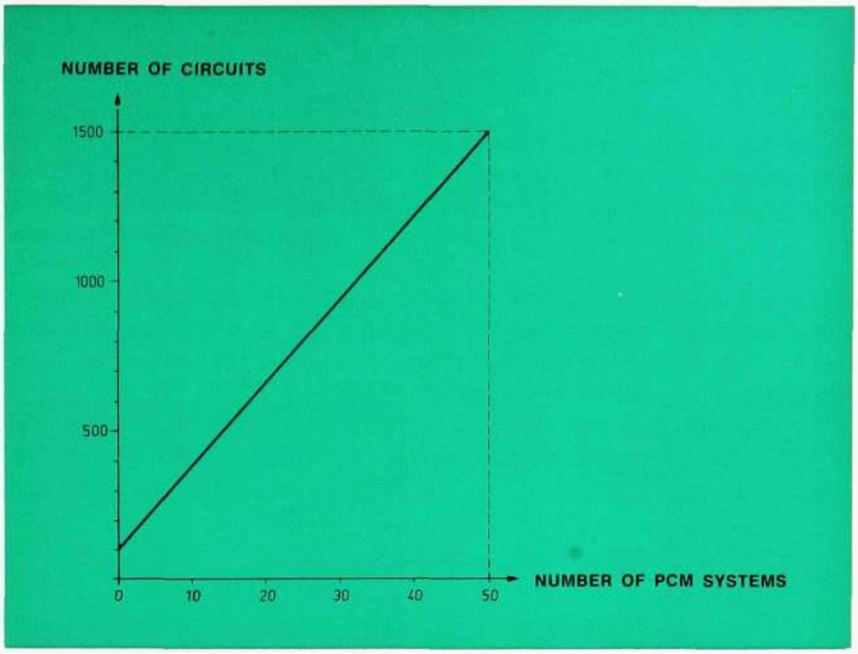
This section discusses some problems of importance which should be considered when introducing p.c.m. The p.c.m. system developed by L M Ericsson, as shown in the article *PCM* Transmission,[1] comprises

- *terminal multiplexing equipment*
- *h.f. line equipment* (whose line terminating equipment is included in the terminal station, the intermediate repeaters being placed at suitable intervals along the route).

On the *multiplex side* the problems mainly relate to the interconnection between p.c.m. equipment and exchange equipment, e.g. in regard to signalling co-operation and speech-channel termination. A p.c.m. signalling unit of normal design provides 1 or 2 pairs of *E* and *M* wires towards the relay set on the exchange side; the relay set must then be adapted to the conditions presented. If the same type of relay set is to be used for p.c.m. as for physical circuits, the signalling unit in the p.c.m. system has to be modified. The p.c.m. system then becomes dependent on the station and signalling schemes. To obtain a high degree of flexibility between p.c.m. and exchange equipments of different

Fig. 1

Number of circuits on a 100-pair cable as a function of the number of p.c.m. systems employed



makes, it is essential that the interface between signalling unit and relay set be defined and standardized.

The transmission of speech signals between the p.c.m. system and the exchange can be effected on a two-wire or four-wire basis. Through connection on a voice-frequency basis between p.c.m. and f.d.m. carrier or physical circuits normally presents no problems. However, it should be observed that tones outside the speech band (hum, carrier leaks) affect the signal amplitude and may thus give rise to faulty decision levels in the quantization process.

On the *line side* a consideration of primary importance is the cable characteristics at high frequencies (approx. 1 MHz). To calculate the repeater spacing and the maximum permissible number of p.c.m. systems, data on the cable loss and near-end and far-end crosstalk must be available. The cable loss can be measured or calculated from data on wire diameter, capacitance and type of insulation. Far-end crosstalk has proved to be relatively uncritical. When using

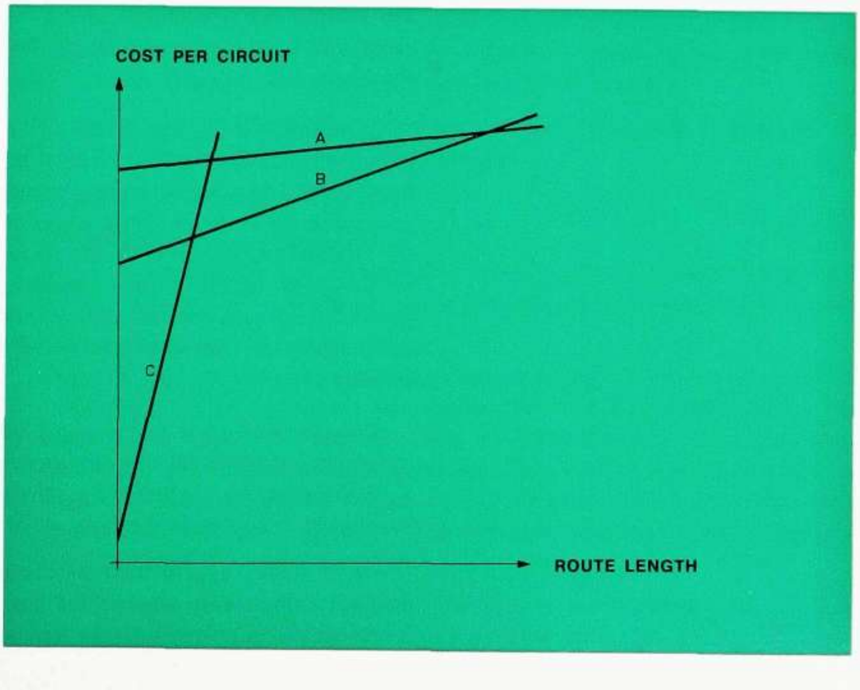


Fig. 2

Basic cost patterns for
- **A** f.d.m. carrier circuit
- **B** p.c.m. circuit
- **C** physical circuit

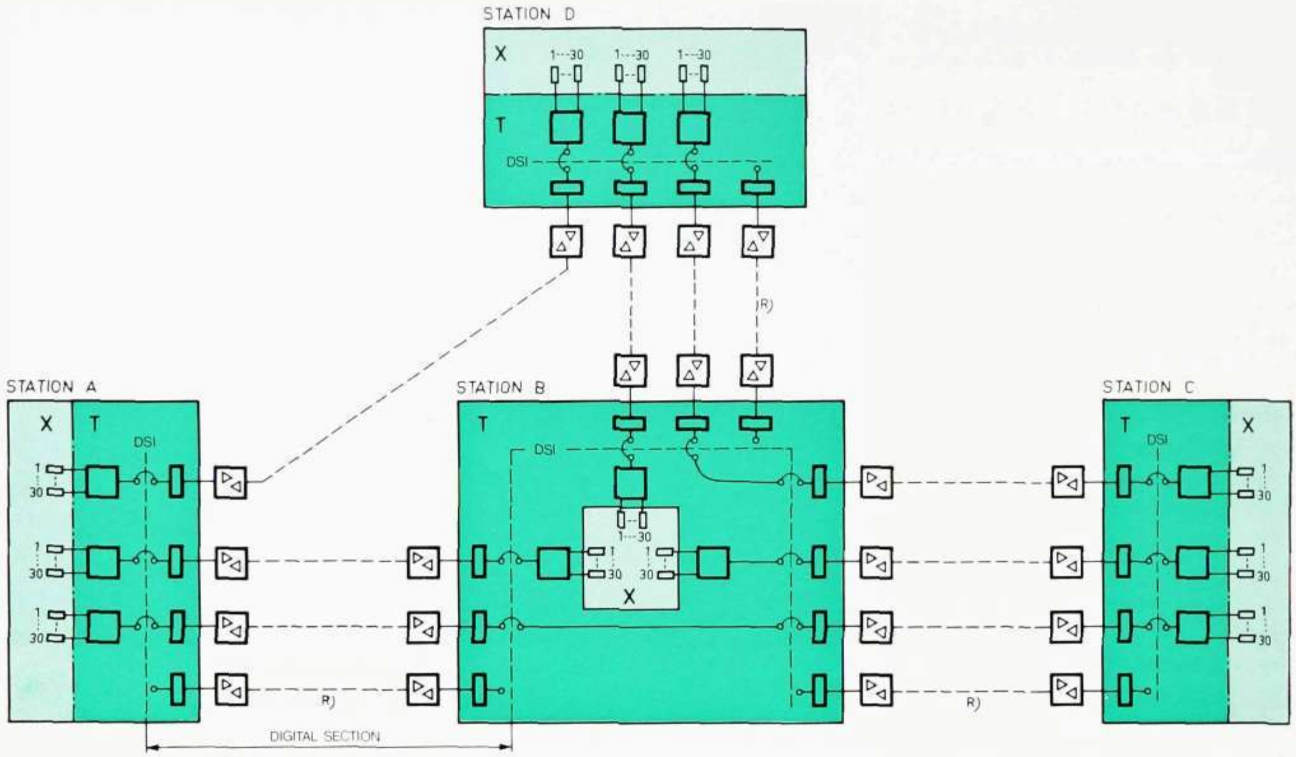


**Fig. 3**
**Example of a p.c.m. network**

□ **Multiplexing equipment**
▯ **Line terminating equipment**
▷◁ **Digital two-way repeater**
▭ **Relay sets**
**DSI** **Digital section interface**
**R)** **Reserve line system**
**T** **Transmission equipment**
**X** **Switching equipment**

double-cable operation, therefore, all cable pairs can normally be employed for p.c.m. In single-cable operation, however, near-end crosstalk sets a limit to the number of p.c.m. systems that can be permitted to operate in parallel. The data on near-end crosstalk should be given in the form of median value and standard deviation, and preferably for different categories of pair combinations within the same, adjacent or non-adjacent units, subunits or layers. From these data the permissible number of parallel p.c.m. systems at a given repeater spacing can be calculated with a certain confidence level. When selecting pairs for p.c.m., those lying far apart should first be chosen for the two directions of transmission, since the near-end crosstalk attenuation increases with the physical distance between the pairs. In addition, there is a risk of the pairs being transposed within the cable beyond the limits set by the cable design on account of the splicing method employed on the route. However, it should be observed that the largest contributions of near-end crosstalk energy are made by the cable closest to the repeaters, 80—90 % of the energy originating from the nearest cable length of about 300 m. It is therefore essential to keep a close check on the positions of the pairs in the cable length next to the repeaters.

To minimize interference from the station, the use of electrostatically screened cables, one for each direction of transmission, is recommended for connecting the line terminating equipment to the main cable. By this means good protection from station disturbances is achieved at moderate costs. In addition, the incoming signal level should be increased by reducing the repeater spacing to 50—60 % of the normal repeater spacing. Should all these measures still prove insufficient, consideration should be given to providing those pairs in the cable which are not used for p.c.m. transmission with suppressor units of a suitable design.

When *designing a p.c.m. network*, one of the objectives should be to arrange the multiplex and h.f. line as independent equipments, so that a given multiplex equipment can be connected to any digital line. One way to achieve this which has found frequent application is to divide the h.f. line into digital sections.

Fig. 3 shows a simplified network consisting of four stations. The intermediate repeaters are power-fed from the line terminating equipment. Repeater fault location is effected over a separate pair in the cable, which is common to all the systems operating in parallel. The line equipments operating within a digital section are identical in design, irrespective of whether they terminate or are through connected at the ends of the section. If the number of line systems terminating at a station is large (e.g. station *B*), it may be convenient to concentrate all line terminating equipments in one bay and to fit a distribution shelf to serve as central patching point in the station. In smaller stations (e.g. stations *A*, *C* and *D*) savings in space can be made by placing the multiplex and line terminating equipments in the same bay.

Reserve routes can easily be arranged in a network providing alternative routes. In case of a fault, e.g. in the cable between *A* and *D* (fig. 3), the multiplex terminals at *A* and *D* can be connected to free line systems in the digital sections *AB* and *BD* respectively. In this manner a standby route is obtained which has the same transmission quality as the regular route. In addition, this can be done at little extra cost, since the line system forms only a minor part of the total cost.

## Network Planning

A network can be described with the aid of the following data.[2]

- The cable run matrix showing the distances between switching points in the network.
- The junction matrix showing the division of the exchanges into tandem areas and the possible routes between the exchanges.
- The route matrix containing a specification of the types, number and class of junctions on each route and cable run in the network.

The route matrix can be determined on the basis of cable run and junction matrices as well as information regarding traffic between the stations, cost of transmission and exchange equipment and regarding permissible attenuation, loop resistance and grade of service in the network.

Most local multi-exchange networks have been planned to use physical circuits. The introduction into the network of p.c.m., whose characteristics differ from those of physical circuits, affects the optimum network structure. The impact will of course depend on the density of p.c.m. systems.

In the initial stages of its introduction p.c.m. will form a small part of the network. It may, therefore, be realistic to introduce p.c.m. on suitable routes, while retaining the basic network structure.

When planning the introduction of p.c.m. into the network at a future stage of development, however, consideration should be given to the advantages which can be obtained by changing the structure of the network.

As far as network planning is concerned the main differences between p.c.m. circuits and physical circuits are in their having:

- different cost patterns (see fig. 2)
- different attenuation characteristics
  In p.c.m. attenuation is independent of length (2—3 dB between 2-wire terminals), whereas in physical circuits it increases proportionally with length.
- different signalling methods.
  In p.c.m. the signalling pulses are regenerated, together with the other pulses constituting the line signal, in the regenerative repeaters. Consequently, the route length does not affect signalling reliability. In physical circuits conditions are different. Over short distances with a loop resistance of less than about 1 500 ohms signalling can be effected by means of d.c. current on the speech wire. For longer distances it is necessary to resort to more sophisticated, and thus more expensive, signalling methods.

The examples given below illustrate how p.c.m. can influence the network structure.

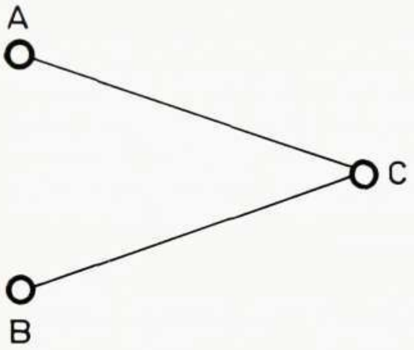


**Fig. 4**
**Cable runs**

Since the cost of physical circuits is proportional to length, laying the cable along the shortest path between two stations, is often economically justified. In fig. 4, for example using physical circuits, constructing a new cable run between *A* and *B* may be justified rather than utilizing the existing—but longer—runs *AC* and *CB*. When using p.c.m., however, it is generally more economical to use an existing, even though longer, cable run and thus avoid constructing a new one.

Every tandem area is served by a tandem exchange. Its location is determined by balancing the costs of junctions between local exchanges and their tandem exchange and those of junctions between tandem exchanges belonging to different tandem areas. The permissible attenuation between tandem exchanges is generally small, which necessitates the use of heavy-gauge wires in the pair cable even at relatively short distances. Consequently, in a network using physical circuits tandem exchanges are located close to each other. When using p.c.m. on the route between the tandem exchanges a fixed attenuation is obtained irrespective of the path length; at the same time the cost increase with length is insignificant. In the case of p.c.m., therefore, tandem exchanges should be placed where the telephone density in the tandem areas is highest, thus permitting savings to be made on the junctions between local exchanges and their tandem exchange, without entailing any appreciable increase in the cost of junctions between tandem exchanges.

The traffic between two exchanges can be handled in different manners and the junctions be classified as *t* = direct and *h* = high-usage circuits depending on the routing method employed (see fig. 5).

The class of circuits and the number of circuits on the high-usage route are mainly determined by the traffic volume to be handled and the ratio between the incremental cost for direct and tandem circuits.

The effect of the introduction of p.c.m. into the network is that the average cost ratio is reduced, which means that class *h* will increase at the expense of class *t*. Consequently, the number of direct high-usage routes will increase. Only the traffic rejected from these routes will be routed over the tandem exchange, which is thus relieved. In many city networks with heavily loaded tandem exchanges this is particularly desirable.

This effect is further strengthened by the accumulated need for direct or alternative routing due to the limited range of d.c. loop signalling, p.c.m. being capable of meeting this need without additional expense for signalling equipment.

The network structure as well as the type number and class of circuits will therefore be strongly affected by the introduction of p.c.m.

## Economic Aspects

### *Timing of Investments*

When comparing p.c.m. on existing cable and physical circuits on new cable consideration should be given to time when investments are to be made.

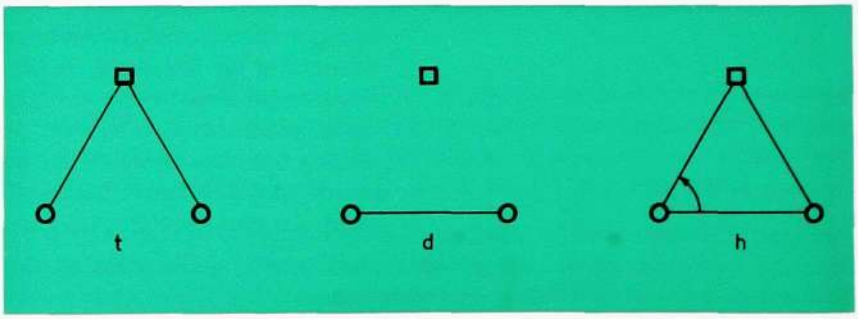
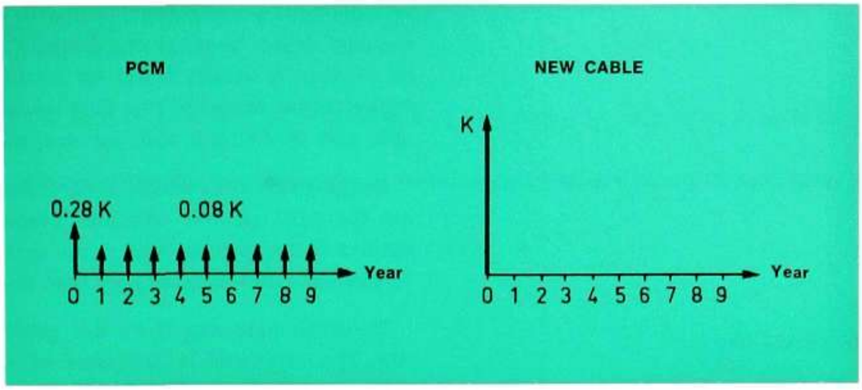


**Fig. 5**
**Traffic routing methods**

**t: all traffic routed in tandem exchange**
**d: all traffic routed direct between exchanges**
**h: part of traffic routed direct over high-usage route, the rejected part being routed via tandem exchange**

**Fig. 6**
**Cost/time diagram for p.c.m. on new cable**



The planning period for a new cable, on account of the high cable-laying costs, is between 5 and 15 years. The expenses for the whole cable are made initially, though only part of the cable pairs are put into service, and it is not until the end of the planning period that all the pairs will contribute to the returns.

As p.c.m. multiplexing equipment is comparatively easily installed, the first-in plant capacity of this type of equipment need not exceed the requirements of the first 1 or 2 years. In the case of the p.c.m. line plant system, however, the first-in installation of cable should cover the requirements of a longer period, say, 10 years. The requisite number of cable pairs is then selected, deloaded and jointed to the repeater housings. The installation of the regenerative repeaters, however, can be timed along the same lines as that of the multiplex terminals. Pairs which, although jointed to the repeater housings, are not yet used for p.c.m. transmission, can be utilized as physical circuits by plugging in loading coils at the repeater positions if, as is usual, the repeater spacing is the same as the loading spacing.

Fig. 2 shows that the main part of the costs is related to the multiplex terminals. The capital expenditure involved in the provision of these and of the line repeaters will therefore be spread over the whole planning period.

This can be illustrated with the following calculation: the total expenses on a certain route are assumed to be equal irrespective of whether the need for junctions is provided for by introducing p.c.m. on existing cables or by means of physical circuits using new cable, the moments when they occur being different according to fig. 6.

The p.c.m. expenses are evenly distributed over the period, with the exception of the cost of line plant (20 % of the total cost), which occurs at the start, i.e. in year zero.

The present value of the expenses calculated on the basis of an interest rate of 10 % is 0.74 K for p.c.m. and K for new cable. Making allowance for the time factor in the example considered, the p.c.m. alternative yields a cost reduction of 26 %.

## *Urban, Rural and Long-Distance Networks*

In urban networks with large-capacity routes the actual cable cost per pair is lower than in rural networks with small-capacity routes; on the other hand, the cable-laying and accommodation costs are higher in urban areas than in rural areas. Consequently, a comparison of physical circuits and p.c.m. will result in about the same prove-in distance in either case. However, since rural routes are longer than urban routes, the percentage of the routes where it is economical to use p.c.m. will be larger in rural networks than in urban networks. When comparing p.c.m. with f.d.m. carrier systems, the situation is different. *FDM* systems have a cost pattern similar to that of p.c.m. In f.d.m. systems, however, the cost of the terminal multiplexing equipment is higher, whereas that of the line system is usually lower on account of its longer repeater spacings and/or larger circuit capacity. For long routes, where the line plant forms a considerable part of the total cost, f.d.m. systems will therefore be economical.

In rural networks small f.d.m. systems (12-, 24-, 60- and 120-circuit systems) are the most suitable solution. These systems start being economically competitive in comparison with p.c.m. on routes which are longer than 50—100 km. In special cases this point may even lie outside this range.

In urban networks there are generally many junctions on the same cable run. The cable run is composed of several routes, which then branch out to different stations in the network, giving rise to a great demand for simple and cheap through-connecting facilities at the switching centres. One of the advantages of p.c.m. is that the channel capacity of the system is well suited to the size of the route, so that the entire p.c.m. line signal can be through connected at the switching centres. *FDM* systems, whose capacity is determined to suit the number of junctions on the cable runs, are usually so large (960 and 2 700 circuits) that direct through connection at line frequencies would lead to poor occupation efficiency. To avoid this, the line frequency band has to be split up into smaller batches of channels (e.g. 60 or 12), which are then through connected in the basic frequency band at the interconnection points. The cost of the additional equipment involved is a disadvantage of the f.d.m. alternative; consequently, p.c.m. can compete with large f.d.m. systems in spite of the fact that the price per channel in both system types can be of the same magnitude for point-to-point circuits.

*FDM* systems may find special application in urban networks, for example to interlink rapidly expanding suburbs with the central exchange. Thereby a large number of circuits follow the same route over a long distance. When introducing several long-distance stations into the urban network it is also convenient to interconnect these with f.d.m. systems because of the predominance of f.d.m. carrier techniques in long-distance networks. Unused capacity in f.d.m. systems may well be used for local traffic.

In long-distance networks primary p.c.m. multiplex systems are generally inadequate because of the great demands for channels and the distances involved in these networks. In the future, when higher-order p.c.m. multiplex systems and digital line systems for higher speeds will be available, p.c.m. may present an economical alternative to f.d.m. even in long-distance networks.

## Summary

The article shows that p.c.m. techniques offer new facilities to provide economically for the increase in circuit capacity required by the rapid growth of telephone traffic.

By using p.c.m. techniques transmission and signalling qualities are achieved which are virtually independent of the length of the junction circuits.

When planning p.c.m. networks a large number of interdependent factors have to be defined to arrive at the optimum solution. The iterative methods[2] developed for physical circuits have recently been widened and adapted so as to apply also to networks using p.c.m. This has made it possible to foresee the consequences of different solutions, which is an essential aid when having to decide between alternative courses of action regarding the construction of a p.c.m. network.

## References

1. Widl, W.: *PCM Transmission.* Ericsson Rev.*49*(1972): 1, pp. 9—13.
2. Rapp, Y.: *Some Economic Aspects on the Long-Term Planning of Telephone Networks.* Ericsson Rev.*45*(1968): 3, pp. 122—136.

# PCM Transmission

W. WIDL, TELEFONAKTIEBOLAGET LM ERICSSON, STOCKHOLM

UDC 621.376.56
LME 8436
8405
100

*PCM techniques are a combination of pulse code modulation and time division multiplex transmission and, like f.d.m. carrier techniques, permit utilization of a single transmission circuit for more than one telephone channel.*

*L M Ericsson has developed a pulse code modulation system for the transmission of 30 telephone channels over a four-wire circuit. The p.c.m. system, which meets CCITT standards, comprises PCM Multiplexing Equipment ZAK 30/32 and PCM Line Equipment ZAD 2.*

*In this article a comparison is made between p.c.m. and f.d.m. carrier systems. In addition, standardization and future prospects are discussed. This issue of Ericsson Review also contains an article on p.c.m. applications,*[1] *where some typical network problems and economic aspects are touched upon.*

*A technical description of the operating principles and design of the ZAK 30/32 PCM Multiplexing Equipment and the ZAD 2 PCM Line Equipment will be given in a subsequent issue of this journal.*

Economic considerations often make it necessary to utilize a single physical circuit or radio channel for more than one telephone channel. The method most commonly used up to the present time, the frequency division multiplexing method, is based on the possibilities offered by f.d.m. carrier techniques to transmit two or more simultaneous telephone conversations placed in different frequency bands over the same circuit. The frequency translation of the speech signals required for this purpose is achieved by modulation and demodulation using different carrier frequencies.

Another multiplexing method, using pulse code modulation, permits two or more telephone channels to be transmitted over the same circuit on a time division multiplex basis.

The basic principle of the *pulse code modulation method* involves the periodic sampling of voice-frequency signals, e.g. within a telephone channel. The analogue voltage obtained at each sampling instant is converted into a number of digital pulses arranged within one time slot. The signal transmitted to line consists of a series of such time slots which at the receiving terminal are reconverted into a series of analogue signals, permitting the reconstruction of the speech information in analogue form.

*Time division multiplex* is obtained by cyclical sampling of different telephone channels followed by cyclical transmission of time slots over one and the same transmission medium. See fig. 1, which has been taken from an earlier article on p.c.m.[2]

## Characteristics of PCM Techniques

A comparison between p.c.m. and f.d.m. carrier techniques shows fundamental differences, especially in respect of transmission characteristics. The

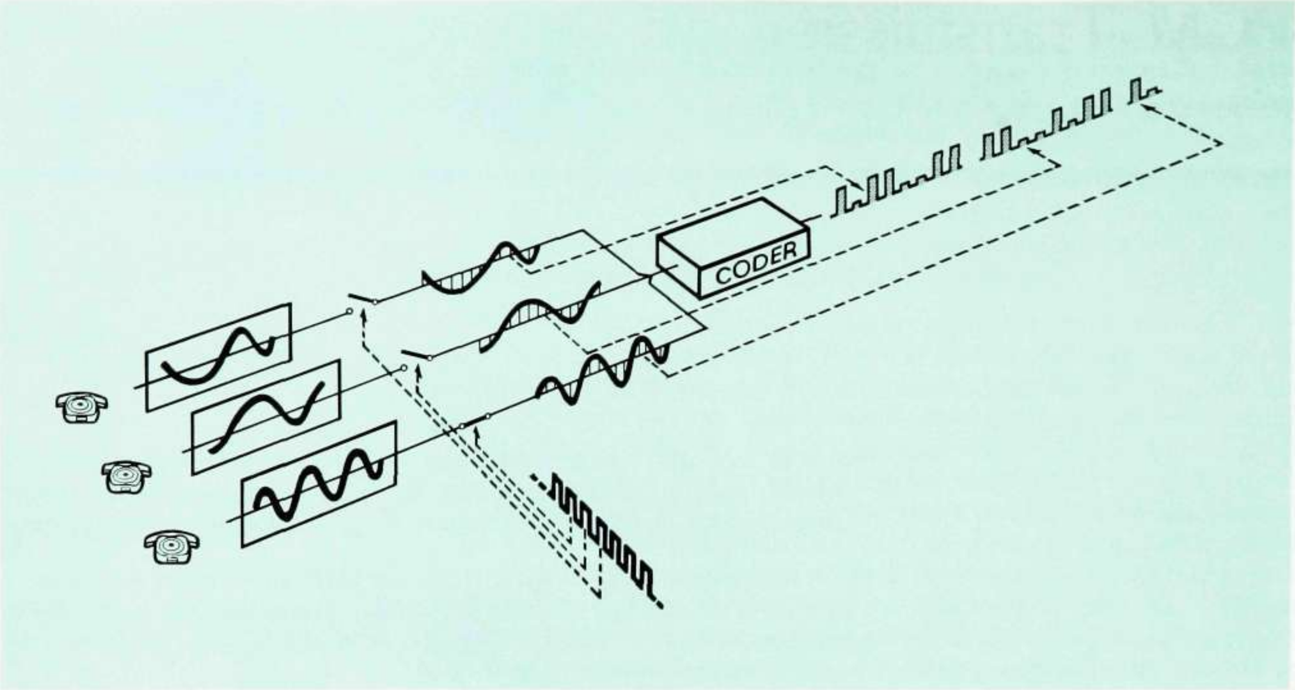


**Fig. 1**
**Principle of pulse code modulation**

p.c.m. line signal consists of digital pulses, which can be regenerated by relatively simple digital repeaters. If these repeaters are placed at regular intervals along the route, a transmission line is obtained where the signal-to-noise ratio, attenuation and distortion are almost independent of the number of repeaters employed. The length of a digital line is limited mainly by accumulated imperfections in pulse regeneration (e.g. jitter).

When analogue information is transmitted over f.d.m. carrier systems, however, noise, harmonic distortion and equalization errors accumulate in each repeater section; consequently, the transmission of analogue signals imposes stringent demands on the precision and equalizing capacity of the repeaters.

Since digital line systems are less sensitive to interference than analogue line systems, a lower error rate is obtained when using digital transmission. The less stringent demands on the quality of the transmission medium imposed by digital systems, however, are gained at the cost of increased demands for bandwidth. This increased need for bandwidth can be met by using for p.c.m. transmission such media as are not normally used for wideband traffic, e.g. physical fourwire circuits with one pair for each direction of transmission.

One of the characteristics of a digital line system using pair-type cable is that the repeater spacing is determined mainly by the loss and crosstalk characteristics of the line system.

If a separate cable is used for each direction of transmission, far-end crosstalk between different line systems predominates. With a normal repeater spacing of a few kilometres, however, the effect of far-end crosstalk is so insignificant that all the cable pairs in a cable can be used for p.c.m. transmission.

However, if the same cable is used for both directions of transmission, the repeater spacing is limited by near-end crosstalk between the line signals in the send and receive paths. To obtain a sufficiently low near-end crosstalk at a certain repeater spacing, widely interspaced cable pairs are chosen for the two directions of transmission. Consequently, it is in most cases impossible to use all the available pairs in a cable for p.c.m. transmission.

The coding process used by p.c.m. techniques involves the representation of an infinite number of analogue voltage values by a finite number of quantized samples converted into digital bit combinations. At the receiving terminal some of the decoded voltage values will differ from the originally transmitted values. This error causes a type of distortion that is characteristic of p.c.m. transmission: quantization noise. By choosing an appropriate non-linear coding method, however, transmission performance within the dynamic speech range is not impaired.

In f.d.m. carrier transmission the h.f. repeaters handle the sum of a large number of analogue signals. If the combined signal exceeds the overload level of the repeaters, non-linear distortion is introduced. This circumstance complicates the multiplexing of different types of analogue signals, such as speech and video signals, on a single line facility.

Among the advantages of p.c.m. transmission is its capability of comprising all types of signals which are represented in digital form. Thus the line signal may consist of pulses belonging to speech, sound-program, video or data signals. The line signal also includes all the information needed for the administration of the connection, such as synchronization, signalling and supervision. Since each channel has been allotted an individual time slot in which pulses of definite width and amplitude are transmitted, there can be no overload of the repeaters due to voltage addition.

A large proportion of the p.c.m. equipment performs digital operations and thus can exploit the advantages offered by digital circuitry, such as reliability, long service life, simple testing and possibility of miniaturization. Also, digital links are well suited, both functionally and regarding circuit design techniques, for future applications, e.g. integrated communication systems.

## International System Standardization

*PCM* systems are characterized by a number of fundamental parameters, such as sampling rate, overload level and type of non-linear coding. Also, to make international p.c.m. traffic possible, the p.c.m. equipments involved are required to employ the same pulse configurations (time slots, frames, etc.), equivalent routines (framing, multiframing, etc.) and compatible line signals (data speed, pulse shape, etc.). In consequence of different evaluations in the USA and Europe, the standardization work that has been conducted for several years by the CCITT has resulted in two distinct types of p.c.m. primary multiplexing equipment:

- The European 30-channel system (CEPT) with a nominal gross digit rate of 2.048 Mb/s and code type A = 87.6 as specified in Recommendation G.732.
- The North-American 24-channel system (ATT) with a gross digit rate of 1.544 Mb/s and code type $\mu = 255$ as specified in Recommendation G.733.

The coding and voice-frequency characteristics of these systems have been specified in detail in Recommendations G.711 and G.712.

The primary multiplex systems form the basis of a hierarchy of multiplex and line equipments. The data rate of a second-order digital line system permits the combination (multiplexing) of four data flows generated in primary p.c.m. multiplex systems. Multiplexing is effected by means of second-order digital multiplexing equipment (see fig. 2). The existence of two different primary systems is also reflected in different draft recommendations for second-order digital multiplexing equipment, such as

- a European 120-channel system with a gross digit rate of 8.448 Mb/s as specified in Recommendation G.742.
- a North-American 96-channel system with a gross digit rate of 6.312 Mb/s as specified in Recommendation G.743.

**Fig. 2**

**Primary and secondary stages of digital hierarchy**

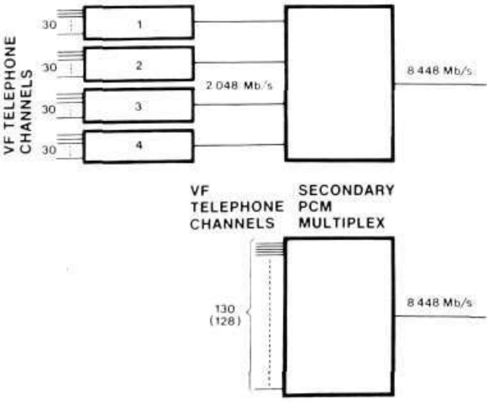
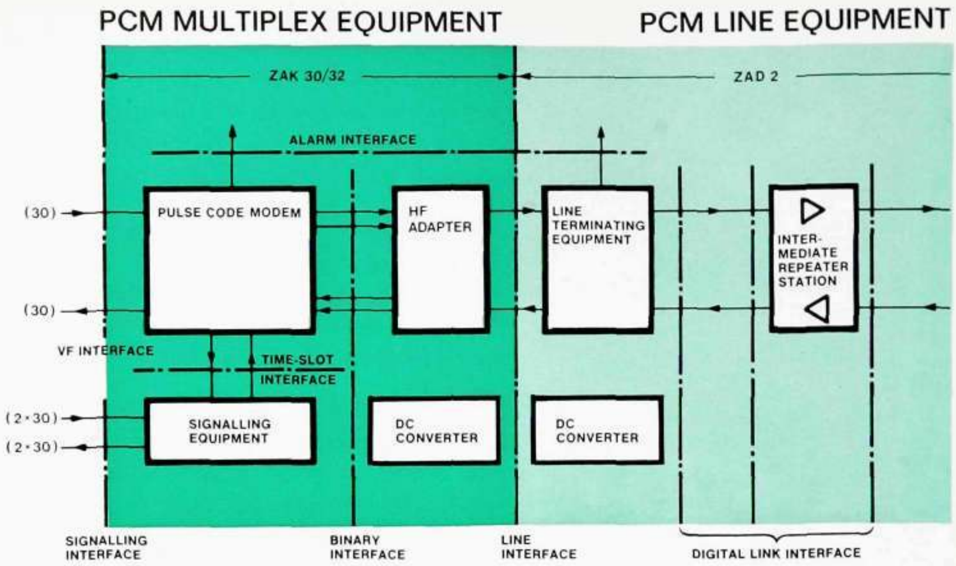


**Fig. 3**
**Block diagram of p.c.m. system**



The data flow for a second-order line system can also be generated by a second-order p.c.m. multiplexing equipment by direct coding of a number of v.f. telephone channels. The simple frame format employed in direct coding permits a more effective utilization of the transmission medium in comparison with digital multiplexing. A second-order p.c.m. multiplexing equipment for 128 or 130 telephone channels is being studied by the CCITT (see fig. 2).

## Basic Design of L M Ericsson's PCM System

The p.c.m. system consists of multiplexing equipment *ZAK 30/32* and line equipment *ZAD 2*, as shown in fig. 3. The choice of interfaces and equipment blocks has been made in view of present and future demands for flexibility.

Thus a v.f. interface has been established at the boundary between the p.c.m. multiplex and the exchange, and a digital link interface *(DLI)* between the multiplex and the line equipment.

The multiplex is divided into main equipment blocks such as pulse-code modem, signalling equipment, h.f. adapter and terminal alarm equipment by appropriately chosen interfaces. Via the time slot interface various types of signalling units as well as data interface adapters can be connected. The binary interface and the digital link interface are designed for interconnection with different types of line systems, second-order digital multiplexing equipment or entrance equipment for radio links.

The p.c.m. line equipment comprises line terminating equipment and dependent repeaters arranged between the cable sections.

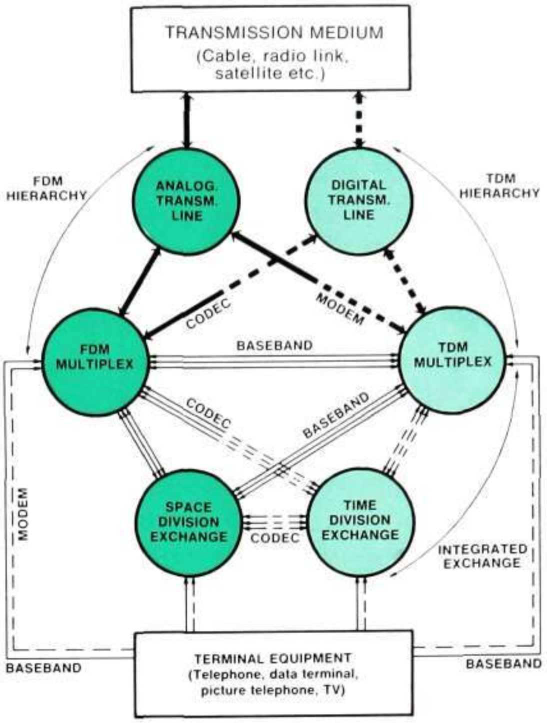
The system is extremely flexible; the units are of the plug-in type and complementary additions are easily made when required.

## Prospects

As previously mentioned, the primary multiplex systems constitute the basis of a hierarchy of multiplex terminals and transmission lines. In the immediate future the main field of application of primary multiplex systems is restricted to short-haul communication over symmetric pair cables. The design of digital line systems for higher data rates and other transmission media both admits larger numbers of telephone channels and permits the transmission of wideband signals generated in wideband data terminals, visual telephone and television terminals. In a few years digital line systems using analogue and digital repeaters and suitable for data rates up to several hundred Mb/s will offer economical solutions to long-haul communication problems. These systems will also play a prominent part in creating future integrated communication networks.

**Fig. 4**
**Interaction FDM-TDM**

←– – –→ Digital time slot signal
⬅■ ■ ■ ■➡ Multiplexed digital signal
←——→ Analogue baseband signal
⬅━━➡ Multiplex analogue signal



However, on account of existing and planned investments in f.d.m. carrier networks, the development of p.c.m. systems will be reduced to co-existence with f.d.m. carrier systems for a long time to come. This co-existence involves the interchange of information between f.d.m. and p.c.m. systems. Fig. 4 shows schematically various forms of interworking between frequency-division-multiplex and time-division-multiplex networks. The unmodulated signals—here termed baseband signals—generated by the various subscriber terminals connected to the network are routed via space-division-multiplex and time-division-multiplex exchanges and multiplexed for transmission in f.d.m. or p.c.m. systems. Interworking between f.d.m. and p.c.m. networks in its simplest form is effected in the baseband.

Another method of co-ordination involves the adaptation of p.c.m. signals to f.d.m. links, i.e. it requires frequency translation for transmission over existing analogue transmission lines. This method may be necessary e.g. when creating a digital data network based on the line links of an existing f.d.m. network. Given a favourable economic development of digital transmission lines, it may prove advantageous to adapt f.d.m. links to digital links by the coding of wideband f.d.m. signals.

*PCM* encoding and decoding of baseband signals permits p.c.m. exchanges to be incorporated into f.d.m. networks. Thus p.c.m. exchanges may come into use as, for example, group selectors even before the formation of p.c.m. networks.

In estimating the future prospects of p.c.m. techniques it should be taken into consideration that f.d.m. carrier systems have attained a very high degree of technical perfection after decades of development, a development which in the case of p.c.m. techniques has only just begun and which will be greatly influenced by circuit technology and the pace at which new subscriber terminal sets will be introduced, thereby increasing the demand for interoffice communication.[3]

## References

1. OHLSSON, E.: *Fields of Application for PCM Systems*. Ericsson Rev. *49*(1972): 1, pp. 2—8.
2. EINARSSON, G.: *An Experimental 24-Channel System with Pulse Code Modulation*. Ericsson Rev. *43*(1966): 42—48.
3. ERICSSON, T. & JOHANSSON, U.: *Digital Transmission over Coaxial Cables*. Ericsson Tech. *27*(1971): 4, pp. 191—272.

# DC Distribution for Power Supply of Telecommunication Equipments

A. ÖREVIK, TELEFONAKTIEBOLAGET L M ERICSSON, STOCKHOLM

UDC 621.311.4
621.395.722
LME 787

*Ericsson Review No. 4, 1968, contained the first of a series of articles dealing with L M Ericsson's power supply systems for telecommunication equipments. The first article, which presented a general description of the various systems, has been followed by others dealing with thyristor rectifiers, series converters, electronic equipments for signal generation, and diesel generator sets. The present article deals with the distribution of direct current from the central power supply system to the telecommunication equipment. The article describes the various items of distribution equipment and the method of cable laying and presents some general recommendations for dimensioning of the system. It also describes new earthing principles which are coming into increasing use.*

*The block schematic in fig. 1 symbolizes a complete power supply plant including the distribution to an automatic telephone exchange of conventional type. The green field indicates the extent of the equipment described in this article. The legend to the figure contains references to the earlier articles in the series.*

## Design Requirements

### *Reliability and Life Expectancy*

Extremely high requirements of reliability and life expectancy are placed on all telecommunication equipment today. The requirements as regards the DC distribution are as follows:

☐ The electrical stability of the system must be satisfactory and the voltage drops low.

☐ The cabling must not give rise to troublesome crosstalk or hazardous transients.

☐ A fault, e.g. short-circuiting in the distribution network, must have as limited as possible an effect on the operation of the telecommunication equipment.

☐ Faults must be indicated, and there must be means for rapid fault tracing.

☐ When the distribution voltage deviates from the permissible range, an indication must be obtained.

☐ The satisfactory properties of the system must be maintained during the entire life of the equipment.

L M Ericsson meet these demands in the following manner:

- The distribution network contains a minimum of joints.
- The terminating devices are stable and have a low contact resistance.
- The fuse units have low power dissipation.

**Fig. 1**

**Power supply system with series converters**
**Ericsson Rev. No. 4 1968**[1]

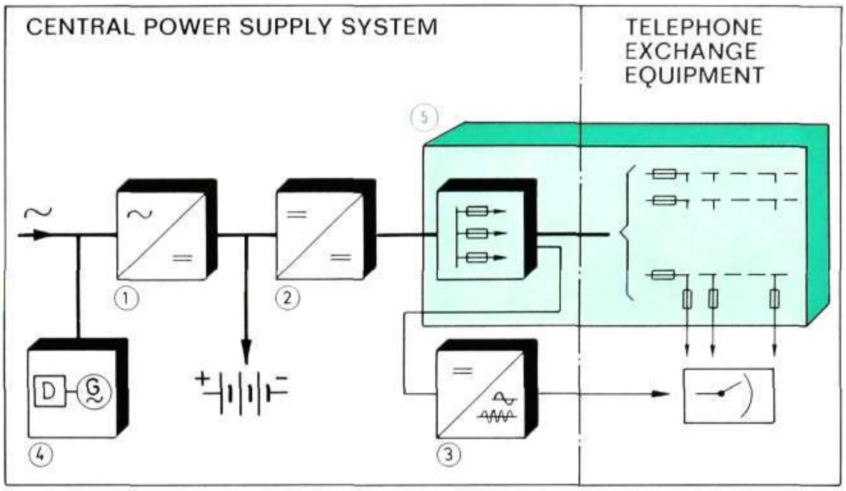
① **Thyristor rectifier**
**Ericsson Rev. No. 3 1969**[2]

② **Series converter**
**Ericsson Rev. No. 1 1970**[3]

③ **Electronic equipment for generation of ringing signals and tones**
**Ericsson Rev. No. 4 1969**[4]

④ **Diesel generator set**
**Ericsson Rev. No. 4 1971**[5]

⑤ **DC distribution**



- The cable laying is done on principles which result in low impedance.
- The telecommunication equipment is sectioned and the various sections are individually fed.
- Within each feed circuit the sizes of fuses are chosen so as to ensure adequate selectivity.
- An alarm is issued on blowing of a fuse.
- The distribution voltage is supervised and an alarm is issued at "too high" or "too low" voltage.
- The supply of spare parts is ensured during the entire life of the plant.

L M Ericsson have developed a complete range of products for the DC distribution. Some of the products contain purchased components. These have been carefully selected and subjected to thorough tests in L M Ericsson's laboratories prior to acceptance as standard components.

## *Simple Installation*

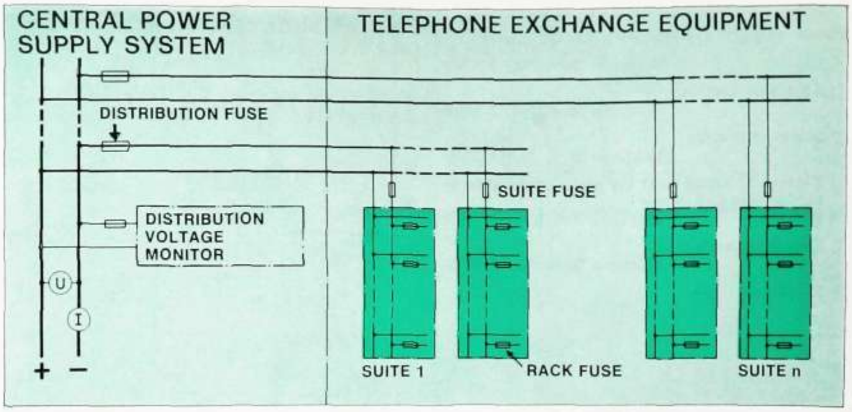
Attention has been paid in the design of the power supply systems to the special conditions governing the installation of telecommunication equipments. Installation must often be done at places to which the transport of equipment and personnel is both expensive and takes a long time. It cannot be expected that qualified craftsmen will always be available on site. The products have therefore been so designed that installation can take place with tools of "screwdriver and spanner" type, i.e. simple tools which can easily be replaced on site if required.

## *Flexibility*

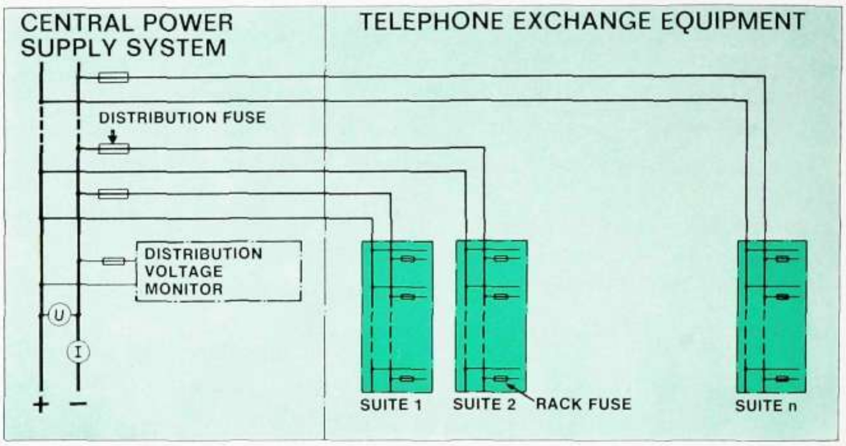
The detailed planning of a power supply system is often done by personnel who have access solely to the building drawings. If, on closer study of the building in conjunction with the start of installation, it proves that the installation would be simplified by changing the relative positions of the various units, or that a later extension would be facilitated, the alteration can usually be effected without the need for additional deliveries of equipment and without change of the equipments already delivered.

Apparently insignificant details not shown in the available building drawings may constitute an obstacle on the planned distribution routes. For this reason L M Ericsson usually use cable instead of busbars for the distribution also in large plants. This also avoids the need for joints in the conductors.

**Fig. 2**
**The distribution network for large and small exchanges**



LARGE EXCHANGES



SMALL EXCHANGES

## Distribution Principle

For conventional telephone exchanges the distribution is arranged on the principle shown in fig. 2.

## Distribution Rack

### *Structure*

The distribution rack is based on the same modular principle as other units in the central power supply system — rectifiers, converters etc. The rack thus consists of a number of standardized functional units containing standardized components. Fig. 3 shows the structure of a combined distribution and battery rack. The figure shows how the individual fuses are combined into fuse units and how the fuse units, installed with other associated equipment — instrument unit, distribution voltage monitor etc. — form the complete rack.

The fuses at the bottom of the rack serve for the protection of batteries and battery cables. Four batteries can be connected, each with max. 800 A fuse. The other fuses protect the DC distribution, the maximum number of such fuses being six 100—400 A, sixteen 6.3—100 A and twenty 0.1—6.3 A.

The instruments and the distribution voltage monitor are placed in the door, in which are also placed the units for the common functions of the system. A typical such unit is the alarm relay set, which receives the alarm signals from the entire central power supply system and transmits them onward with the desired degree of urgency.

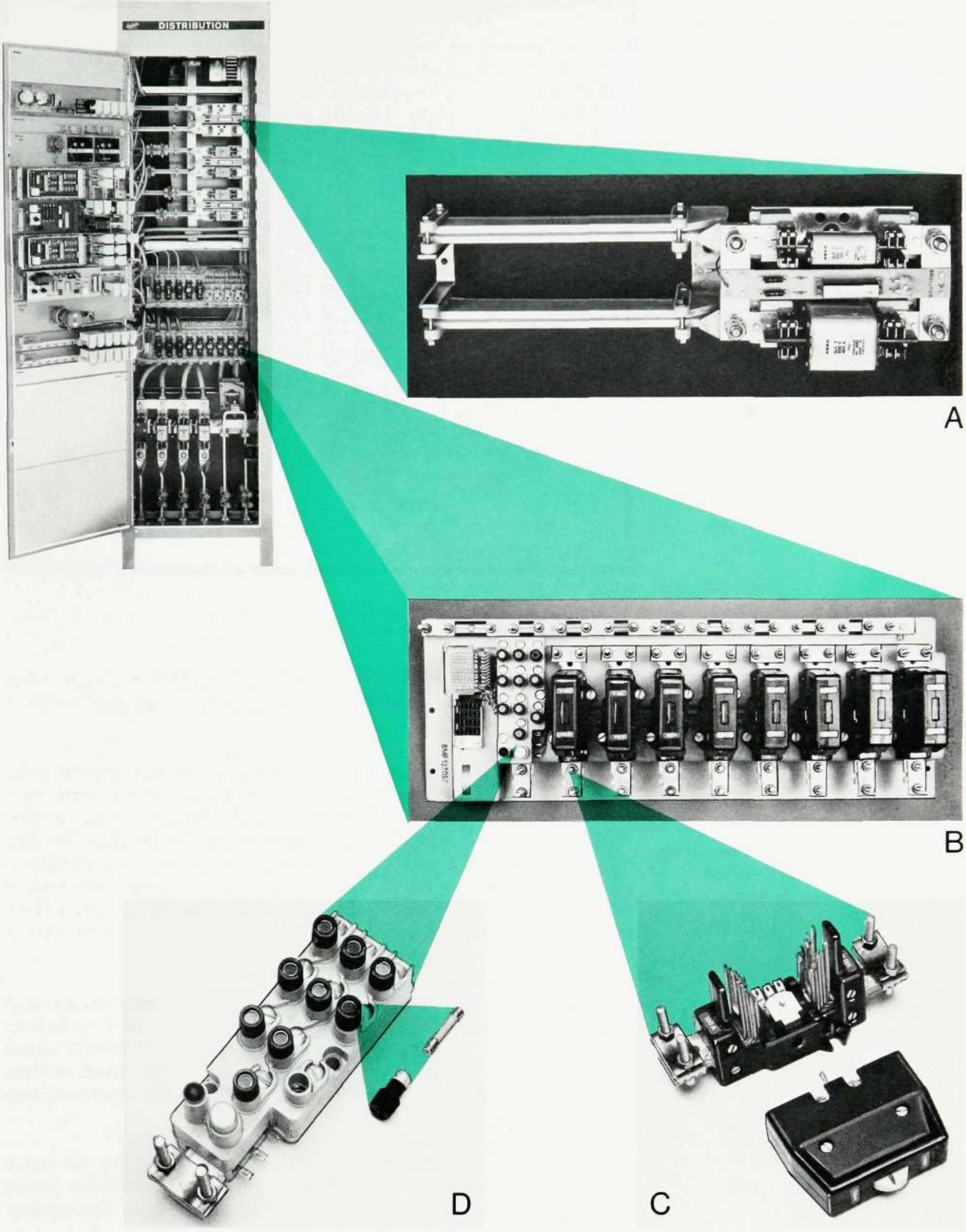


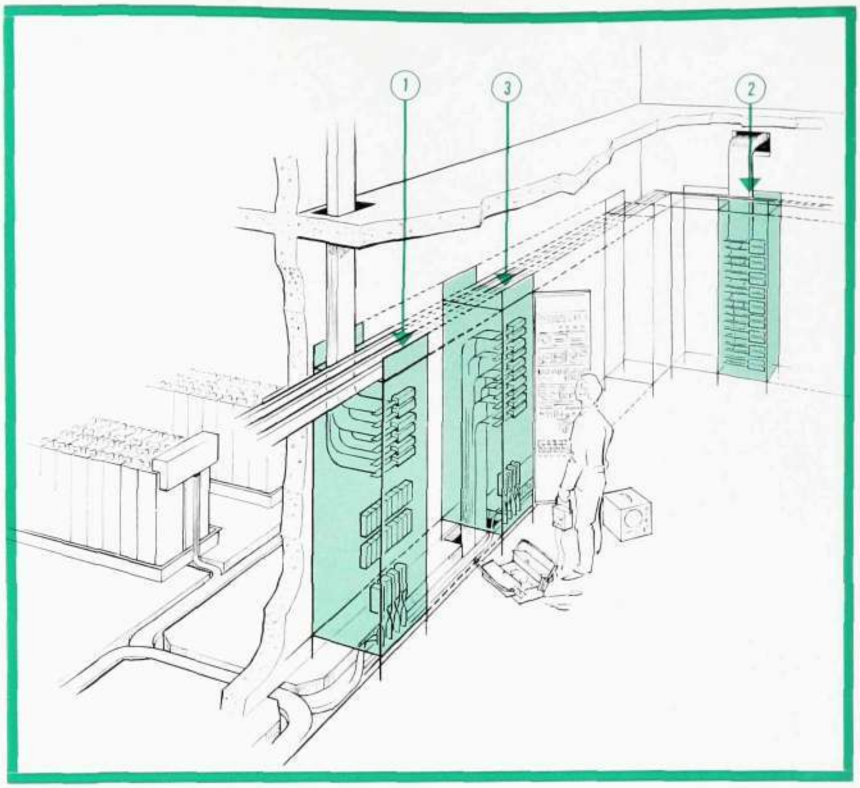
**Fig. 3**
**Distribution rack BMG 211**

- **A** Fuse unit 694100
  Fuses 100-400 A
- **B** Fuse unit BMF 123057
- **C** Fuse holder NFS 5132
  Fuse NGG 503, 6.3—100 A
- **D** Fuse block NFS 21301
  Fuse NGH 272, 0.1—6.3 A

Fig. 4

System with several separate distribution racks

① Original installation BMG 211
② First extension BMG 214
③ Second extension BMG 212



The racks have been standardized for 600, 1200 and 1800 A. In cases when battery connection is not required, a rack accommodates eighteen 100—400 A fuses.

Distribution of current exceeding 1800 A is done from several separate racks. Fig. 4 shows how a system initially intended for about 1000 A has later been extended on two occasions. The first delivered distribution rack has facilities for battery connection and contains the common units for the plant. The first extension consists of a pure distribution rack and the necessary number of rectifiers and converters. For the next extension a further battery connection is required, so that an additional combined distribution and battery rack has been installed. The distribution racks are placed so as to allow the most suitable distribution route.

The wide flexibility in the placing of units, which has been made use of in connection with the equipment extensions, is characteristic of the converter system, which does not require a central point through which the entire current must pass. Every distribution rack delivers current from the nearest rectifiers and converters. Through the busbar system, which interconnects all units, only moderate currents flow.

The cell switch system does not offer the same flexibility. The call switch and parts of the busbar system are passed by the entire distribution current and are therefore dimensioned from the outset for the calculated final capacity.

From all distribution racks the cables can be run both upwards and downwards.

Distribution equipments for currents up to 200 A do not require a special rack. These equipments are enclosed with other equipment — rectifiers, converters etc. — and placed at the top of the racks, the distribution cables being run upwards.

## *Instrumentation*

A standard distribution rack is equipped with a voltmeter and an ammeter. The instruments are square, measuring 96×96 mm, with quadrant scales. The voltmeter has a suppressed zero point and calibration takes place at nominal voltage, which in practice gives the instrument an accuracy better than ±1% within the part of the scale of greatest interest. A still higher accuracy can be obtained if the instrument is calibrated against a precision instrument during operation. Set-screw correction of the deflection can then be done in the course of the calibration. With the aid of a switch the voltmeter can also be used for measurement of battery voltage.

The ammeter measures the entire distribution current from the rack with an accuracy of ±1.5%.

One or both instruments can be replaced by combined indicating and recording instruments with the same building-in dimensions as the simple pointer instruments. The combined instrument records the deflection on a 65 mm wide paper tape with one dot every third second. The accuracy is ±1.5% both for reading and recording. The paper roll is driven by a synchronous motor fed via an inverter from the DC voltage. Recording can consequently take place also during mains failures.

## *Distribution Voltage Monitor*

The monitor supervises the voltage level and issues an alarm if the predetermined voltage limits are not maintained. It can also be used for disconnection of rectifiers etc.

The voltage sensing unit consists of an electronic measuring relay with an accuracy of ±1%.

## *Fuse Unit with 0.1—100 A Fuses*

The fuse unit for the rated current range 0.1—100 A is shown in fig. 3 B. In its basic form it comprises 9 optional fuse-holders within the range 6.3—100 A (fig. 3 C). Any of the holders, however, can be replaced by a fuse block containing 10 fuses within the range 0.1—6.3 A (fig. 3 D). If the unit consists exclusively of such blocks, accordingly, it will contain 90 fuses, each for max. 6.3 A.

On blowing of a fuse an alarm is issued. Each fuse holder — or fuse block — can be made to issue an alarm of different degree of urgency. Change of the degree of urgency is simply effected by moving wires on a terminal block. Connection of the alarm wires to the remaining equipment in the plant is done by plug and jack.

The substructure, which holds together the various units, is made of glass-fibre-reinforced polyester. This reduces the risk of unintentional contact with earthed metal parts. The fixing holes for the fuse units have threaded steel bushings.

### Fuse Holder for 6.3—100 A

The fuse holder for rated currents of 6.3—100 A (fig. 3 C) has fork contacts of silver-plated cadmium copper. Each fork has 10 individually sprung contact points. Connection to the fuse holder can be effected with a busbar or cable. The max. cable area is 150 mm$^2$.

The termination points for the fuse holder are shaped in the form of clamps. To ensure a proper grip on terminating cables the fixed contact portion has sawtoothed serrations which penetrate into the softer copper conductor. The need for subsequent adjustment owing to slow "subsidence" of the cable has been eliminated through the insertion in the joint of a resilient element which ensures a permanent pressure of about 800 newtons (approx. 80 kp).

The insulation of the fuse holder consists of glass-fibre-reinforced polyester. The fuses have silver fuse elements. The fusing characteristics follow the recommendations in IEC Publication 66. The fuse element is attached to knife-blade contacts of the fuse with screws, so that a fuse which has blown can be fitted with a new element. For the holding of spares detached fuse elements constitute a cheaper and less bulky alternative to complete fuses. The insulating material in the body of the fuse is a glass-fibre-reinforced alkyd resin.

The alarm device of the fuse holder operates through the melting of a resistance wire in parallel with the fuse element. A spring-loaded pin is then released, which actuates an alarm contact placed on the fuse-holder. A visual indication of alarm is produced by means of a white plastic segment which becomes visible on the black back of the fuse (fig. 3 C).

## Fuse Block for 0.1—6.3 A

The fuse block for rated currents within the range 0.1—6.3 A (fig. 3 D) functions as 10 individual fuses fed from a common bottom contact.

The cartridge fuses in the block are sized 5×25 mm and have indicating elements which drop out on blowing of a fuse (DIN 41576).

The fuse block contains an electronic alarm circuit which, via a thyristor, delivers a positive signal through two separate outlets (fig. 5). One outlet is used for transmission of alarms and the other for lighting a lamp on the outside of the rack. On transmission of alarm a lamp also lights on the fuse block, indicating that one of the block fuses has blown. Final tracing of the blown fuse in done by inspecting the indicating elements. An alarm is transmitted until acknowledged by pressing a button on the block. The outgoing conductors from the individual fuses terminate on screw terminals located immediately beside the respective fuses. The terminals take 0.5—2.5 mm² conductors. Conductors of up to 6 mm², however, can be terminated on the three front terminals if cable lugs are fitted to the conductors. A busbar or cable of maximum area 150 mm² can be used as negative feeder.

The actual block is made of injection-moulded self-extinguishing thermoplastic with high temperature resistance.

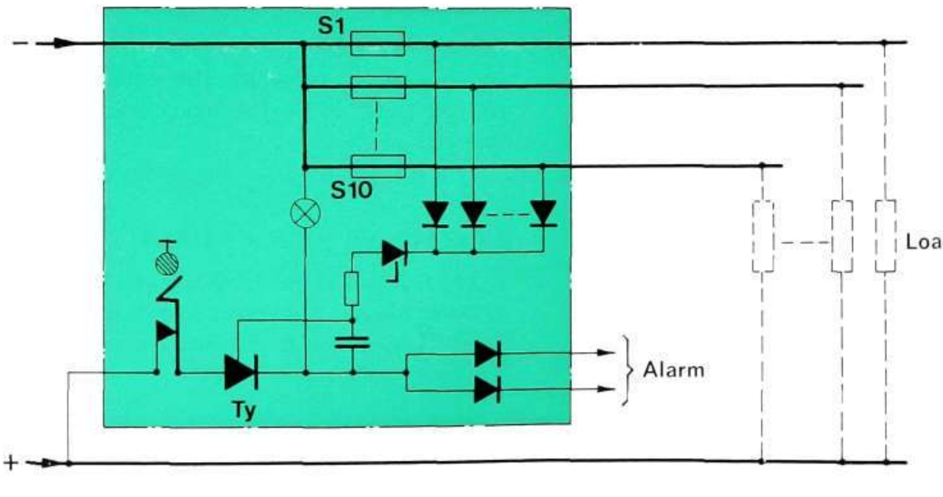


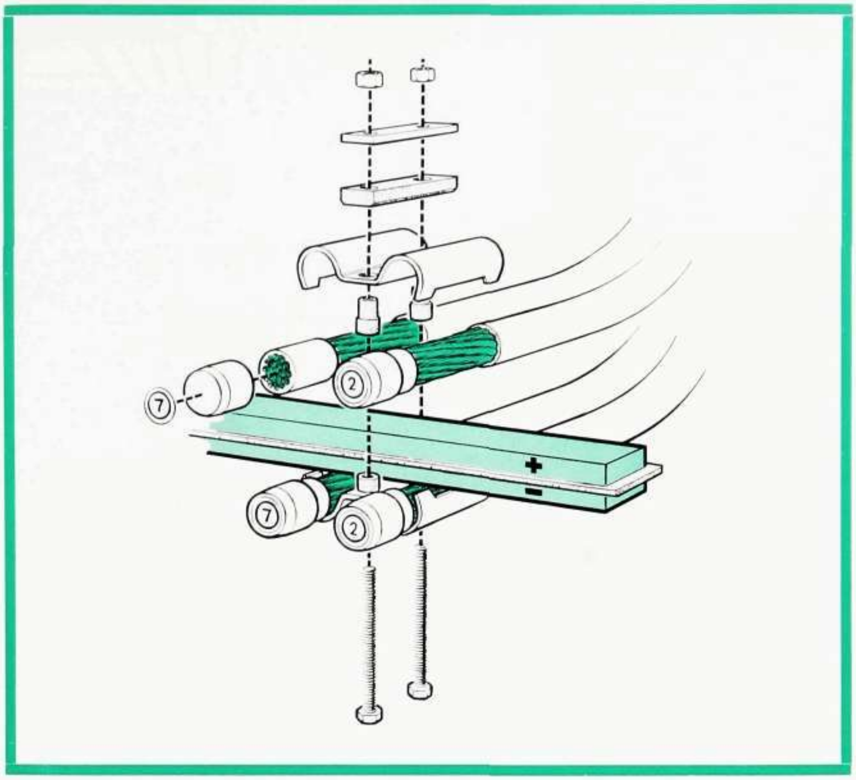
**Fig. 5**

**Electronic alarm circuit for fuse block NFS 21301**

**S1—S10 Fuses 0.1—6.3 A**
***Ty* Thyristor**

**On blowing of a fuse the thyristor is fired from positive via the load (overload, short-circuit etc.) through the diode gate, zener diode and resistor to the thyristor gate. Owing to its threshold effect the zener diode prevents unwarranted firing in the event of current surges. The resistor in combination with the capacitor has a transient-suppressing effect.**

Fig. 6
Cable clamp NEY 93202



## *Fuse Unit with 100—400 A Fuses*

The 100—400 A fuse unit is the largest in the distribution system. It comprises two holders for grip type fuses complying with DIN 43620 (fig. 3 A). Fork contacts of silver-plated copper, each with 6 separately sprung contact points, ensure efficient contact performance. The contact pressure is achieved by means of steel springs.

The two holders have been supplemented by an alarm relay of dry-reed type. As long as both fuses are intact, the two windings of the relay are short-circuited by their respective fuses. On blowing of a fuse the relay operates and transmits an alarm signal.

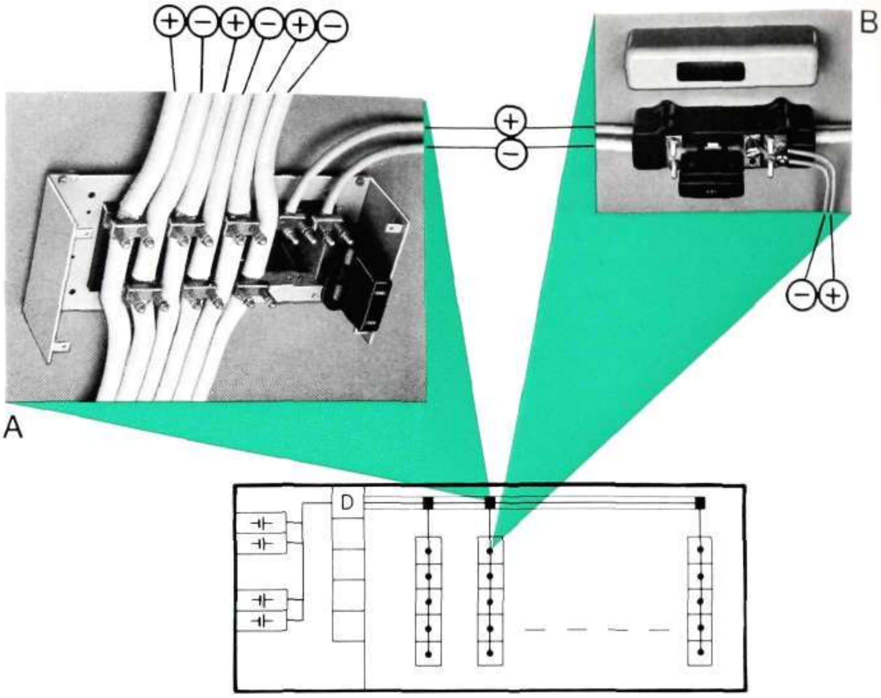
Outgoing distribution cables terminate on silver-plated copper busbars. Each fuse has two such busbars, one for negative and one for positive, separated by a 2 mm thick insulator. Six 150 mm$^2$ cables can be terminated on each busbar.

The termination is effected with pressure terminals which press the cables directly against the busbars with high pressure. The form of the terminal, which has given it the name "gull-wing", will be seen from fig. 6. The active parts are the two steel clamps, with bolts of high-strength steel, which press the cables against the intermediate busbars. The steel clamp has been given a form which matches as closely as possible to that of the stripped cable. The cable is gripped around an angle of 180° and within that angle has small possibility of changing its shape when exposed to pressure. The flat busbar, however, will exercise a different pressure on the various wires in the cable. The points at which the pressure exceeds the stress/strain values of the copper will yield, with slow cold flow as a result — "the cable subsides". This phenomenon is well known from conventional clamps, which for that reason require subsequent tightening, as a rule at least twice within the course of a month or so, to maintain adequate contact pressure. To eliminate the need for subsequent tightening the steel clamp has been made resilient. The special hardening process to which the parts are subjected results in a final product which does not fail even if exposed to abnormally high bending strains.

Fig. 7

Cable layout with marked cable routes, suite fuse blocks and rack fuses

**A** Suite fuse block BMG 1023
**B** Rack fuse NFS 5111



Protection against corrosion is provided by an epoxy resin finish. Electroplating processes such as galvanizing, nickel-plating or the like have been avoided in view of the risk of hydrogen embrittlement which these processes always give rise to.

The installation requires no special tools.

Laboratory measurements on these clamp joints show that the contact resistance between cable and busbar is low and that the change of resistance with time is negligible. Comparative measurements on crimped cable lugs terminated with a bolt show nearly 7 times higher resistances, 20 $\mu$ohms with cable lug against 3 $\mu$ohms with "gull-wing".

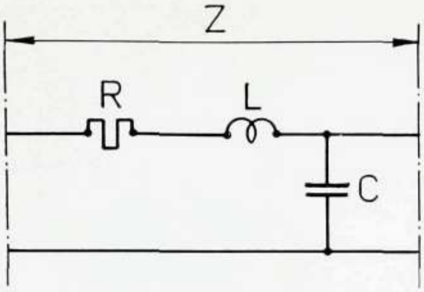
With termination both of positive and negative cables of one outgoing distribution pair in one clamp, it is natural that the two cables should be placed close together also in cable runways.

## The Distribution Network

Distribution from the central power equipment to the switchroom is done with extramultiwire plastic-insulated copper cable type RK. For mediumsized and large plants the areas 70 and 150 mm$^2$ have been standardized. If larger areas are required, a number of 150 mm$^2$ cables are connected in parallel. The cables are carried on vertical runways of ladder type and on horizontal aluminium runways of trough type.

The horizontal runways are usually placed as shown in fig. 7. At each end of the suite there is a suite fuse block, which forms part of the runway. The cables coming from the power supply system are stripped (over an average distance of about 25 mm) and attached with clamps to the busbars in the block, one for positive and one for negative. The cables then continue uncut to the block at the end of the next suite. The block, which accommodates three cable pairs in parallel, has the terminals so arranged that the cables are automatically placed as alternate positive and negative cables.

Every switching equipment rack contains one or two rack fuses, the sockets of which permit the feeder cables to continue uncut to the next rack fuse in the suite on the same principles as for the suite fuses.



| Method of laying | **R** Ω/m | **L** μH/m | **$X_L$** Ω/m | **C** pF/m | **$X_C$** Ω/m | **Z** Ω/m |
|---|---|---|---|---|---|---|
| Closely spaced | $0,24\cdot10^{-3}$ | 0,45 | $2,8\cdot10^{-3}$ | 200 | $0,8\cdot10^{6}$ | $2,8\cdot10^{-3}$ |
| 100 mm spacing | $0,24\cdot10^{-3}$ | 1,14 | $7,1\cdot10^{-3}$ | 10 | $16\cdot10^{6}$ | $7,1\cdot10^{-3}$ |

**Fig. 8**
**Equivalent circuit and impedances for different methods of laying**

## *Low Impedance*

Troublesome crosstalk may be caused by, among other factors, too high an impedance to voice-frequency currents in the distribution network.

The dependence of the impedance on the method of laying is illustrated in fig. 8. The table shows the impedances at 1000 Hz for a loop with 150 mm$^2$ cables laid close together and for a loop in which they are spaced 100 mm apart.

The total impedance ($Z$) is entirely predominated by the inductive component ($X_L$) of the reactance. From the crosstalk aspect the effect both of the capacitive component ($X_C$) and of the resistance ($R$) may be disregarded in practice.

The table shows that the total impedance ($Z$) (= the reactance) is about 2.5 times higher if the cables are spaced 100 mm apart than if spaced close together.

The Swedish Telecommunications Administration has measured the reactances for different cable laying methods with close spacing. The results are shown in fig. 9 in the form of ratios. The measurements were reported in Tele 1958, No. 3[6].

| Method of cable laying | | Ratio |
|---|---|---|
| One cable per pole | ⊕⊖ | 1 |
| Two cables per pole | ⊕⊕⊖⊖ | 0.92 |
| | ⊕⊕<br>⊖⊖ | 0.62 |
| | ⊕⊖⊖⊕ | 0.55 |
| | ⊕⊖⊕⊖ | 0.44 |
| | ⊕⊖<br>⊖⊕ | 0.38 |
| Three cables per pole | ⊕⊕⊕⊖⊖⊖ | 0.88 |
| | ⊕⊕⊕<br>⊖⊖⊖ | 0.44 |
| | ⊕⊖⊕<br>⊖⊕⊖ | 0.24 |
| | ⊕⊖⊕⊖⊕⊖ | 0.24 |

**Fig. 9**
**Ratios between reactance and different cable laying methods**

The principle for laying of distribution cables is that shown at the bottom of the table (cf. fig. 7 A).

## *Busy Hour Current—Maximal Current*

Busy hour current is defined as the mean value of the current during the busy hour (the one of the 24 hours of a day in which the traffic is heaviest).

Maximal current is defined as the current which would be attained if all traffic-carrying devices which can be occupied simultaneously were occupied. The maximal current might possibly be attained, for example, during a peak traffic test in a telephone exchange.

The busy hour current is always less than the maximal current, but the relation between them is dependent on the nature of the telecommunications equipment.

The busy hour current is used for determination of the requirement of rectifiers and converters, for calculation of the necessary battery capacity, and for thermal dimensioning of conductors.

The maximal current is used for calculations of voltage drop.

## *Conductor Area*

As a rule the conductor area is determined by the maximum permissible voltage drop.

### Specification of Requirements

By way of illustration of the method of calculation we may take the requirements applying to a 48 V telephone exchange, the specification for which states: "Allowing for installation of the exchange to full capacity and for maximum current load, the positive and negative conductors shall be such that, at nominal voltage, the difference between the voltage in negative conductors at two arbitrarily selected rack fuses does not exceed 0.8 V and that the difference in voltage at two corresponding points in the positive conductor does not exceed 0.6 V."

### Positive Conductor

Having regard both to low traffic devices situated in the immediate vicinity of the distribution rack (the voltage drop to which may be disregarded) and to heavy traffic devices far out in the distribution network, accordingly, 0.6 V is the highest voltage drop which can be permitted in the positive conductor from the distribution rack (the common distribution point) to an arbitrary rack fuse.

### Fuses

Of the 0.8 V voltage drop permitted in the negative conductor according to the specification, 0.2 V refers to the voltage drops in distribution fuses and suite fuses.

### Positive and Negative Conductors

The maximum permissible voltage drop in positive and negative conductors together will consequently be $0.6+0.6 = 1.2$ V.

### Lowest Voltage

The same specification contains an additional requirement which may affect the dimensioning of the distribution cable: "The voltage at the rack fuse must not fall below 44 V during power failure."

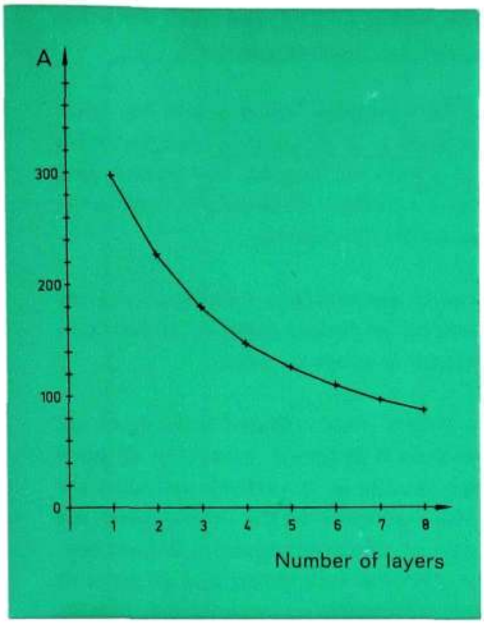


**Fig. 10**

**Permissible continuous current for a 150 mm$^2$ PVC-insulated cable with close spacing in different numbers of layers on a vertical runway of ladder type or on a trough type horizontal runway of 3 mm thick aluminium. The curve assumes equal current through all cables.**

For plant working on the ordinary full float system or separate charging system this requirement implies that conductor area and battery size cannot be calculated independently of one another. The lower the total voltage drop can be maintained from the battery to the most remote rack fuse, the better the battery capacity can be utilized, i.e. the cheaper the battery will be. If a standby time of 3 busy hours is required, for example, a 48 V battery with 24 cells can be utilized to an textent of 52% provided that the voltage drop can be maintained below 1 V (discharge to 45 V). If the voltage drop is increased to 2 V, the battery can only be utilized to an extent of 40% (discharge to 46 V). It should be noted in the calculation that investment in cable is more advantageous than investment in batteries, since the life of batteries is limited.

Both the cell switch system and the converter system provide greater freedom as regards the total voltage drop, and as a rule the whole of the above-mentioned value of 1.2 V can be utilized in the distribution network.

The voltage drop is usually divided in such a manner that 0.2—0.4 V is consumed between suite fuse and rack fuse and the remaining 0.8—1.0 V between distribution fuse and suite fuse.

If the power room is remote from the switchroom, it may be advisable to move the distribution rack, the common point, nearer to the switchroom. The cable saving must then be weighed against the greater expense in the form of additional equipment for protection of the feed up to the distribution rack.

The converter system offers a unique possibility of placing the power supply equipment at a great distance from the consumption point. The voltage regulating converters then sense the voltage in the distant distribution rack and automatically compensate for the voltage drop in the feeder to it.

## Thermal Check

After the cable areas have been calculated having regard to the maximum permissible voltage drop, a check is made that the cables have not been underdimensioned thermally.

In determining the maximum permissible current in the cable, attention must be paid to the accumulation of cables on horizontal and vertical runways. The maximum permissible continuous current specified in the safety regulations of different countries can usually not be used. For example, according to the Swedish regulations for 150 mm$^2$ cable, a current of 325 A is allowed.

In L M Ericsson's laboratories measurements have been made in order to determine the maximum permissible continuous current for different methods of laying. Fig. 10 indicates the permissible current for 150 mm$^2$ PVC-insulated cable. The values apply per cable and are based on an ambient temperature of 35°C and a maximum conductor temperature of 70°C.

## *Dimensioning of Fuses*

The sizes of fuses should be chosen so that the busy hour current does not exceed 50%, and the maximum current does not exceed 75%, of the rated current. To guarantee selectivity the ratio between two successive fuses should be at least 2.5:1 (4:1 is recommended). The following combination of fuses is commonly used:

Distribution fuse 400 A
Suite fuse 100 A
Rack fuse 16 A

## Earthing

In recent years increasing attention has been paid to the earthing of telecommunication equipment. Administrations in different countries have employed different earthing principles. Both within CCITT and IEC work has been done with the object of producing a uniform recommendation.

The earthing here described is based on principles which are being introduced for telecommunication equipments when L M Ericsson is responsible for the earthing system. The principles cannot always be adopted. The reasons may be national regulations, which in some cases specify a different form of earthing, or that administrations have elaborated their own systems.

The earlier principle of two separate earth electrodes, a telecommunication earth electrode and a power earth electrode for protective earthing of the racks of power supply equipments, has been difficult to adopt in practice.

The new earthing system contains as a central point a shared main earth bar or a shared earth ring conductor. To this central point are connected all parts of the telecommunication equipment which require to be earthed, including the racks of the power supply equipment. Also connected to the central point are telecommunication earth electrodes, sheaths of telecommunication cables, neutral wire of the incoming mains supply (if a neutral wire exists) and all parts of the building which can improve the contact with earth, e.g. water pipes, heating system, earth for lightning conductor, and the reinforcement in the building.

Electrical equipment not installed in direct contact with the telecommunication equipment, such as fans, lighting fittings etc., are however earthed in their respective subdistribution boards, in a 4-conductor system in the conventional manner to the neutral wire and in a 5-conductor system to a special earthing conductor.

Fig. 11 illustrates the earthing principle employed at a large exchange. The figure shows a plant to which the mains supply takes place at high voltage and with step-down transformer within the building. At smaller exchanges the transformer is usually placed outside the building and is used also by other consumers. Provided that the transformer, irrespective of its location, is connected as shown in the figure and that the supply is on a 4-conductor basis (3 phases and neutral wire), this earthing principle can usually be adopted.

A shared earth ring conductor is made of copper with minimum area 50 mm$^2$. It is installed indoors in the basement of the building in such a way as to form a ring surrounding the part of the building to be used for the installation of telecommunication equipment. To this conductor are connected at regular intervals the reinforcement bars of the building, which should be welded together so as to form an electrically conductive network. In a concrete building the reinforcement bars, if connected together in this way, function as a Faraday cage and protect the telecommunication equipment against external non-cable-borne disturbances and atmospheric overvoltages.

The use of shared earth ring conductors in small exchanges is not usually warranted. A simple shared main earth bar provides an adequate result in such cases.

A shared earth ring conductor cannot be installed in old exchanges, and here too therefore a shared main earth bar is used.

A detail of the earthing principle which it is worthwhile pointing out is the earthing of the floor cabinets of the power supply equipment. All of these cabinets are connected to the shared earth ring conductor. No earthing conductor from the supplying subdistribution board must be connected.

For the earthing of telecommunication equipments it should be noted that all material which is buried in the soil must be made of hotgalvanized steel and *not of copper*. This is because a lead-sheathed telephone cable and an

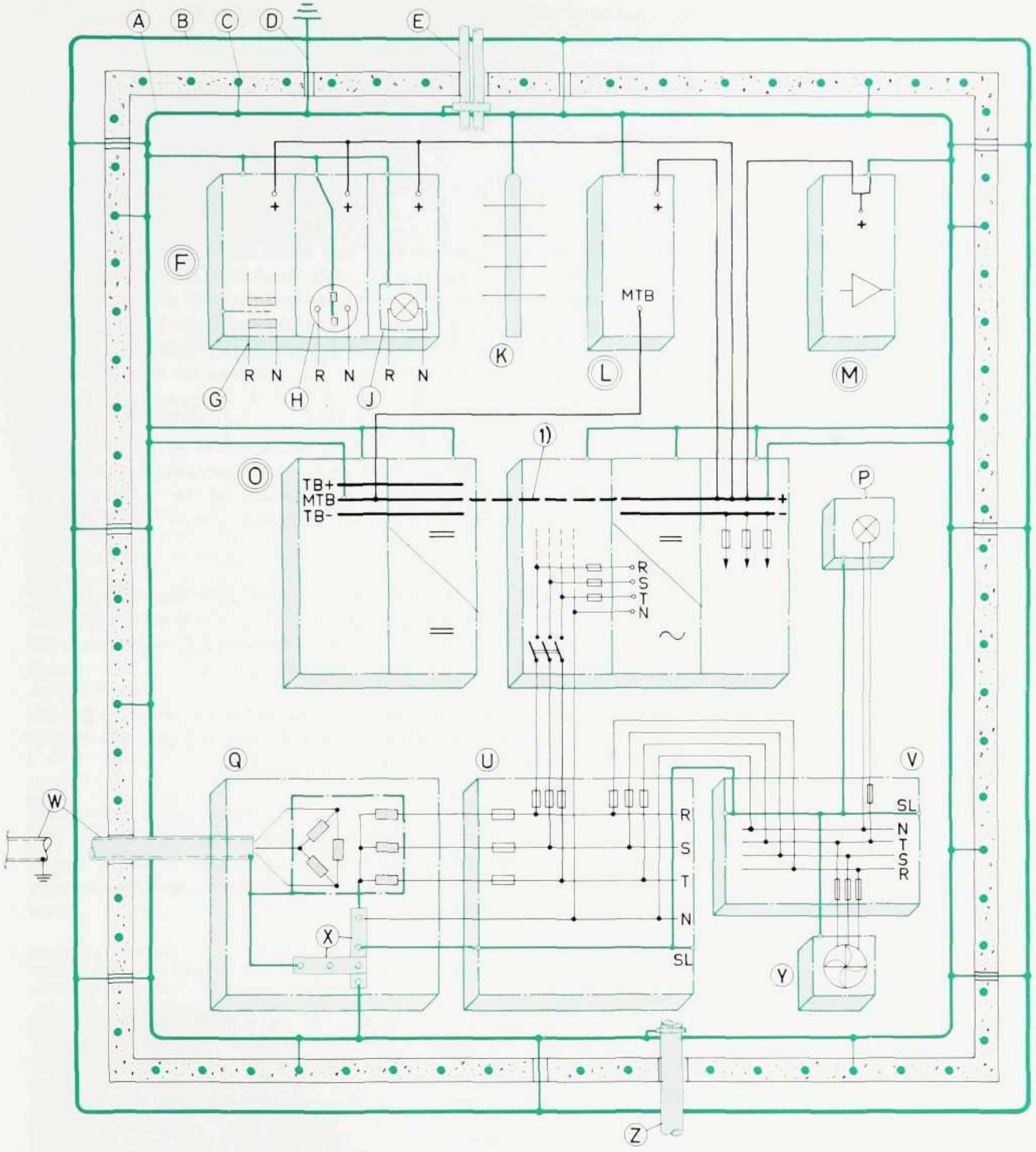


Fig. 11

Earthing principle with shared earth ring conductor

| | |
|---|---|
| **A** | **Shared earth ring conductor** |
| **B** | **Earth electrode for ligtning conductor** |
| **C** | **Reinforcement in outer wall** |
| **D** | **Earth electrode (usually not required if a lightning conductor earth electrode exists)** |
| **E** | **Lead-sheathed telephone cables** |
| **F** | **Switching equipment** |
| **G** | **Mains-connected apparatus** |
| **H** | **Wall socket** |
| **J** | **Rack lighting** |
| **K** | **MDF** |
| **L** | **Telex** |
| **M** | **Transmission** |
| **O** | **Central power supply equipment for telephony, telex and transmission (two blocks)** |
| **P** | **Ceiling light fitting** |
| **Q** | **High voltage room** |
| **U** | **Main distribution board** |
| **V** | **Subdistribution board** |
| **W** | **Incoming metal-sheathed high voltage cable with non-insulating outer sheath** |
| **X** | **Insulated copper busbar** |
| **Y** | **Air conditioning** |
| **Z** | **Water pipe** |
| **R**<br>**S**<br>**T** | **Phase conductors** |
| **N** | **Neutral wire** |
| **SL** | **Earth conductor** |

**1) Connected in plants where equalization currents occur between the different power supply systems. In such cases the common positive conductors of the systems are earthed only at one point.**

earthing rod of copper function as a battery in which moist soil constitutes the electrolyte. The lead sheath and the earthing rod are electrically interconnected via the shared main earth bar, i.e. the "earth battery" is short-circuited. From the lead sheath, which constitutes the negative pole of the battery, a transfer of material takes place as a result of which the sheath is exposed to serious corrosion damage.

## Summary

L M Ericsson have developed a complete equipment program for distribution of direct current to telecommunication plants. Apart from the obvious requirements of reliability and long life, special attention has been paid to simplicity of installation and flexibility in adaptation to the particular building. As the equipments are to a large extent based on the modular principle, they can be easily adapted to most telecommunication plants without the need for special design.

In the design of the equipments attention has been paid to the low voltage levels which characterize this particular application. Special connectors ensure good electrical stability without the need for special tools for installation. All fuses have low power dissipation and are fitted with devices which issue an alarm on blowing of a fuse.

Earthing principles have been introduced which are generally usable for different types of telecommunication equipments. They provide advantages especially in complex plants comprising telephone exchanges, telex exchanges, transmission equipment etc.

The cabling network is dimensioned in accordance with rules which provide adequate margins. The cable laying is done in such a way that not troublesome crosstalk or hazardous transients occur.

Both in the planning and the dimensioning of the distribution network the network is treated as an integrated part of the total power supply system. This method results in technically and economically well balanced power supply equipments, the quality of which fully complies with the high requirements placed on today's telecommunications.

## References

1. LJUNGBLOM, A.: *L M Ericsson Power Supply systems for Telecommunication Equipments*. Ericsson Rev. *45*(1968): 4, pp. 142—162.
2. WOLPERT, T.: *L M Ericsson's Thyristor-Controlled Rectifiers for Power Supplies*. Ericsson Rev. *46*(1969): 3, pp. 84—101.
3. EKELUND, F., BJÖRCK, D. & WOLPERT, T.: *L M Ericsson's Booster Converters for Power Supply*. Ericsson Rev. *47*(1970): 1, pp. 16—27.
4. VAGO, F.: *Electronic Equipment for Generation of Ringing Signals and Tones*. Ericsson Rev. *46*(1969): 4, pp. 154—164.
5. NORSTRÖM, L.-E.: *Diesel Generating Set for Telecommunication Equipments*. Ericsson Rev. *48*(1971): 4, pp. 153—160.
6. LINDÉN, M.: *Något om ackumulatorbatterianläggningars impedans*. Tele 1958: 3, s. 190—194.

# ERICSSON News

## from All Quarters of the World

# World Premiere in Rotterdam Opening of AKE 13 exchange

The first computer-controlled transit exchange for fully automatic switching of international and national trunk traffic was opened in Rotterdam on December 22, 1971. Some 350 persons were present at the opening ceremony, including the Director General of the Netherlands PTT, Henrik Reinoud, Marcus Wallenberg, Chairman of the Board, and Björn Lundvall, President of L M Ericsson.

The new exchange, which was developed, manufactured and installed by L M Ericsson, is also the first in the world to be controlled by several co-operating computers. It has been in traffic since the end of October 1971 and meets an urgent need in the quickly expanding Rotterdam region, which includes the largest port in the world.

Purchaser and responsible for the operation of the exchange is the Netherlands PTT.

The initial capacity of the exchange is 2400 incoming and the same number of outgoing lines. More than half a million national and international calls can be switched in 24 hours. An extension consisting of 600 incoming and 600 outgoing lines will be put in operation this year and, according to the plans, the exchange will thereafter be extended roughly each second year.

The new AKE exchange in Rotterdam and an LME-designed transit centre type ARM together function as district centre and transit point for the automatic international traffic. The expected increase of this traffic will in the future be dealt with by the AKE 13 exchange.

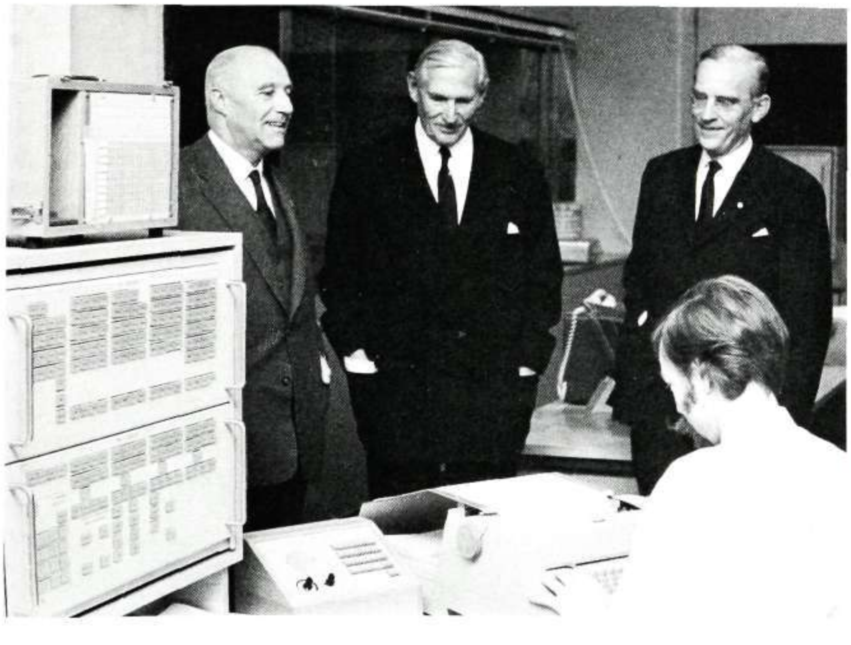
At the opening of the new exchange in Rotterdam the Netherlands Administration had arranged an elegant scenic description of the development of telephony up to the computer technique. It was desired in this way to emphasize that the Rotterdam exchange constitutes a milestone in the history of the Netherlands PTT.

In his opening address Mr Björn Lundvall, President of LME, stated that the design of the AKE system represents several hundred man-years of qualified engineering and programming work and that the new feature of the AKE 13 system is that all functions in the switching network (code switches) for setting up of connections are initiated and controlled by a large number of computers. On reliability grounds the computers work in pairs. All incoming signals preceding the calls are analysed by the computers, translated and forwarded on the basis of the very large number of data stored in the programmed memories of the computers. For storage of this data more than 15 million magnetic cores are required and the programs contain about 120,000 instructions.

The ability, like an experienced telephone operator, to carry out learned instructions existed already in L M Ericsson's automatic telephone systems from 1923 and to an even greater extent in the 1950 system. The AKE system also has the important ability of — like a telephone operator — being able to learn new tasks

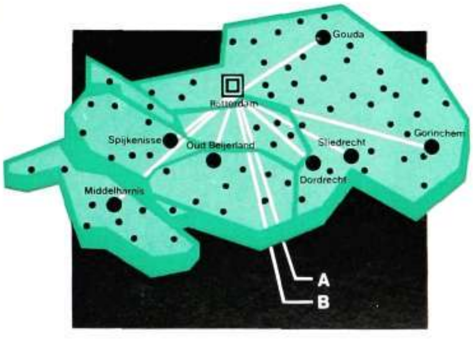
*(cont. p. 32)*

**From the opening of the AKE exchange in Rotterdam. (From left) Henrik Reinoud, Director General of the Netherlands PTT, Marcus Wallenberg, Chairman of the Board, and Björn Lundvall, President of L M Ericsson.**



**Map of the Rotterdam district**

- ▣ **International and district centre**
- ● **Group centre**
- • **Terminal exchange**
- A **Traffic to and from other districts**
- B **Traffic to and from other countries**



# From L M Ericsson's Order Book

## Thailand

A contract for delivery and installation of automatic telephone exchange equipment has been signed between the Thailand Telephone Administration and Ericsson Telephone Corporation Far East AB, Bangkok.

The order comprises switching equipment of crossbar type for installation in thirty provincial towns. The project also includes instruction and training of operating and maintenance personnel, which will be arranged by L M Ericsson both in Thailand and in Sweden. The installation is to be completed by the middle of 1974. The total value of the order is around 15 Mkr.

This contract brings orders received by L M Ericsson for switching equipment up to altogether 41,000 subscriber lines in some 50 towns throughout the whole of Thailand, and also 20,000 subscriber lines in Bangkok.

## Iraq

From the Iraq PTT L M Ericsson have received an order comprising deliveries of cable and extension of local cable plant in five towns. The total value of the order is 17.3 Mkr.

The work will commence during the first half of 1972 and is to be entirely completed during 1973.

## Poland

L M Ericsson have signed a contract with the Polish Foreign Trade Organization ELEKTRIM under which L M Ericsson will adapt two of its interlocking systems for use on the Polish railways and for licence manufacture in Poland. An earlier contract for manufacture of railway signalling equipment on licence in Poland was signed by the company 25 years ago.

L M Ericsson will also deliver a reference plant complying with these two systems as well as certain components required for the licence manufacture. The company will also purchase certain Polish manufactured safety relays of LME type.

The manufacture of the equipment covered by the contract will take place at a factory in Katowice, which, before the second world war, was owned by the Ericsson Group and now belongs to the Polish ZWUS Group.

Through this contract L M Ericsson have strengthened their position in Poland as supplier both of technique and equipment within the railway signalling field.

## Official Opening of Finnish factory at Jorvas

On February 8 the Finnish President, Urho Kekkonen, officially opened the new factory of O/Y L M Ericsson A/B at Jorvas. The Ericsson Group was represented by, among others, Marcus Wallenberg, Chairman of the Board, and Björn Lundvall, President.

**Among those present at the opening of the Greater London Council PABX were Mr Desmond Plummer of GLC (centre), Mr Björn Lundvall, President of L M Ericsson (left) and the Swedish Ambassador, Leif Belfrage (right).**

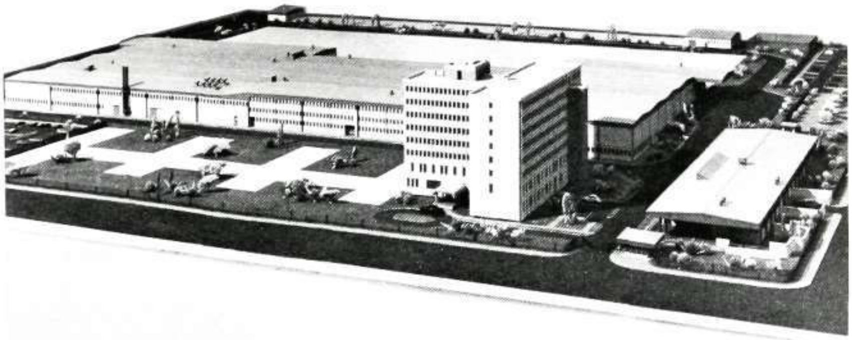
## New PABX for Greater London Council

A PABX, probably the largest of its kind in the world, was recently cut over by the Greater London Council. It was manufactured and installed by L M Ericsson and is equipped for 6000 internal extensions, all of which can be directly in-dialled without the assistance of an operator.

The PABX has 192 incoming lines, which is estimated to be some 70 less than would be required in a corresponding conventional PABX and consequently implies a considerable saving of costs.

The new PABX replaces an earlier manual exchange with a capacity of 3000 lines.

**At the end of last year the Mixed Commission for Technological and Scientific Co-operation between the Soviet Union and Sweden met in Stockholm, in conjunction with which a visit was paid to L M Ericsson at Midsommarkransen. (From left) M. D. Jakolev, Ambassador of the Soviet Union to Sweden, M. P. Kovaljov and M. R. Kuzmin, both from the Soviet Delegation.**



**From the first Transatlantic video telephone conversation exchanged between Washington and Tanum in Sweden at the beginning of December last year. The photograph was taken at the COMSAT building in Washington. The picture telephones used for the conversation, which was conducted via INTELSAT IV, were of L M Ericsson make.**

**The Venezuelan Ambassador, Dr Otmaro Silva (right), in conversation with Arne Stein, Executive Vice President of L M Ericsson, during his visit to the company in the middle of January.**

**In January this year L M Ericsson were visited by the Lebanese Ambassador, Mounir Ghandour, here seen with (left) First Secretary Aboul Hassan, S. O. Tonnæus, Head of *L M Ericsson's Lebanese subsidiary and* (right) Hans Augustinson, L M Ericsson.**

**At Leganés outside Madrid a new factory is being built for L M Ericsson's Spanish subsidiary Industrias de Telecomunicación S.A. The factory, a model of which is here shown, will have an area of 41,000 $m^2$ and is expected to be completed this autumn. Transfer from the present factory at Getafe will take place successively during the first half of 1973.**

**Mr J. Trnka, Department Manager of the Prague PTT, signs his name in the guest book under the watching eye of Mr V. *Oulik, also of the Prague PTT, during a visit* to L M Ericsson's exhibition.**

# Nils Rönnblom In Memoriam

Nils Rönnblom, former Departmental Director of the Swedish Telecommunications Administration, died on Jan. 10, 1972.

The name of Nils Rönnblom will always be linked with the conversion of the Swedish telephone network to automatic operation. He was taken on by the Telecommunications Administration after graduating as M. Sc. in 1926 and from the start was employed on automatic switching technique. He was soon transferred to the Board of Telecommunications and played an important part in the formation of the Swedish automatic telephone network from its early stages onwards. For several decades Rönnblom had a decisive influence on the various stages of conversion of local, rural and national networks to automatic operation.

Nils Rönnblom realized before anyone else in our country the importance of dimensioning exchanges and outside plant for the traffic to be handled. He tried to get away from the rules-of-thumb available to the technicians of the twenties and guided the Swedish technique towards methods based on operations analysis and probability calculus. I think that it was a great satisfaction to him to see how this aspect of telecommunications technique grew up into a Swedish speciality.

Nils Rönnblom had many friends at L M Ericsson. We all remember the impressive knowledge he possessed in his field. He was an admirable person to work with. He always paid respect to the points of view of others and was ready to understand the motives underlying different opinions on technical questions. Many of us have also discussed with Nils Rönnblom the most varying questions outside our joint field of work. He had a wide knowledge, but what we most remember was his deep insight into life in general. We shall always preserve a warm memory of him.

*Chr. Jacobæus*

# Change of Name

The ERGA Division, the Telephone Sets and PABX Division, has changed its name to the "Subscribers Equipments Division", thereby clearly expressing the scope of its activities.

# New Company

GNT Automatic A/S, the Danish manufacturing and sales company associated with L M Ericsson, have reformed their Electronic Instruments Division into an independent company, Elmi A/S, located in Gentofte. The new company will deal with the development, production and sale of electronic measuring instruments specially adapted for use in telephony.

The head of the company is Mr P. C. Beyer.

# Solid State Conference

Dr C. Jacobæus, Executive Vice President of L M Ericsson, was invited to deliver the opening address at the Solid State Conference of the American Institute of Electrical and Electronical Engineers in February 1972 in Philadelphia. His address was entitled "The relevance of solid state to telecommunications" and, in revised form, will later be published in Ericsson Review.

# Telephone Exchange for Instructional Purposes

During the autumn of 1971 the L M Ericsson Training Department put into use a new training exchange for instruction in telecommunications. In the past years L M Ericsson's training activities have broadened and grown in extent and they comprise, apart from the training of customers' representatives, also introductory courses and advanced courses in telecommunications.

The new exchange is an entirely authentic exchange comprising systems ARF 102 and ARM 201/2. The instructors can set up different kinds of faults which the students have to trace.

---

*World Premiere in Rotterdam ...*
*(cont. from p. 29)*

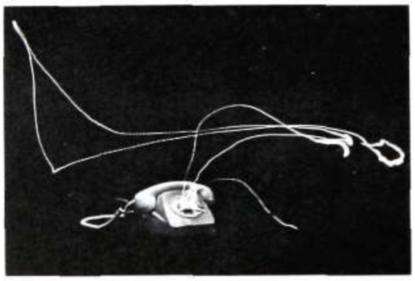
solely by changing the instructions in a simple way. This flexibility is becoming of increasing value in the large transit centres of today, which serve complex networks with a wide requirement for changes in traffic routing, signalling etc.

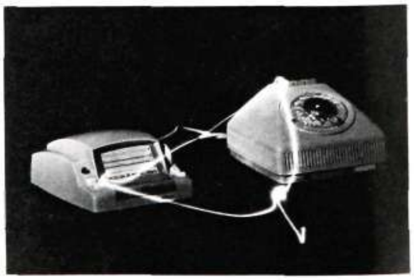
The AKE system also meets very high requirements in respect of operation and maintenance. L M Ericsson's first computer-controlled AKE exchange has been in operation at Tumba outside Stockholm since 1968 and has shown extremely satisfactory operational and maintenance results.

---

**How a person's hand moves** during a telephone call, from dialling until the handset is replaced, is seen from the picture below (left). The picture on the right shows how much simpler the movement is when using a loudspeaking ERICOVOX telephone combined with the automatic MAGICALL.

A lamp attached to the caller's hand produced the traces of light on the photograph. The two photographs were taken during identical telephone calls during which another person enters the room and takes part in the conversation.





# The Ericsson Group

## *Subsidiaries, associated companies and technical offices*

### EUROPE

DENMARK

**L M Ericsson A/S** *DK-2600 Glostrup*, Kirkebjerg Allé 86, tel: (01) 96 6133, tgm: ericsson københavn, telex: 19020 "ERICSSON KH"

**GNT AUTOMATIC A/S** *DK-2860 Søborg*, Telefonvej 6, tel: (01) 69 5188, tgm: nortelmatic, telex 27064, "GNT AUTOMATIC KH"

**Dansk Signal Industri A/S** *DK-2650 Hvidovre*, Stamholmen 175, Avedøre Holme, tel: (01) 49 0333, tgm: signaler københavn, telex: 16503, "16503 DSI DK"

FINLAND

**Oy L M Ericsson Ab** *SF-02420 Jorvas*, tel: (90) 2991, tgm: ericssons, telex: 12546, "LME SF"

FRANCE

**Société Française des Téléphones Ericsson**
*F-92 Colombes*, 36, Boulevard de la Finlande, tel: Paris (1) 781 3535, tgm: ericsson colombes, telex: 62179, "ERICSSON CLOMB"

*F-75-Paris 17e*, 147, rue de Courcelles, tel: Paris (1) 227 9530, tgm: eric paris, telex: 29276, "ERICSSON PARIS"

**Etablissements Ferrer-Auran S.A.** *13 Marseille, (10ème)*, 88, Avenue de la Capelette, tel: (91) 47 4851, telex: 42579, "RINGMARS 318"

GREAT BRITAIN

**Swedish Ericsson Company Ltd.** *Morden, Surrey*, Crown House, London Road, tel: (01) 542 1001, tgm: teleric, telex: 935979, "SWEDERIC LDN"

**Swedish Ericsson Telecommunications Ltd.** *Morden, Surrey*, Crown House, London Road, tel: (01) 542 1001, tgm: teleric, telex: 935979, "SWEDERIC LDN"

**Production Control (Ericsson) Ltd.** *Morden, Surrey*, Crown House, London Road, tel: (01) 542 1001, tgm: productrol, telex: 935979, "SWEDERIC LDN"

**Swedish Ericsson Rentals Ltd.** *Morden, Surrey*, Crown House, London Road, tel: (01) 542 1001, tgm: celefon, telex: 935979 "SWEDERIC LDN"

IRELAND

**L M Ericsson Ltd.** *Dublin 2*, 32, Upper Mount Street, tel: (01) 619 31, tgm: ericsson, telex, 5310, "LMI EI"

ITALY

**FATME, Soc. per Az.** *1-00100 Roma*, C. P. 4025 A. tel: (06) 4694, tgm, fatme, telex: 61327, "61327 FATME"

**SETEMER, Soc. per Az.** *1-00198 Roma*, Via G. Paisiello 43, tel: (06) 86 8854, tgm: setemer

**SIELTE, Soc. per Az.** *I-00100 Roma*, C.P. 5100, tel: (06) 577 8041, tgm: sielte, telex: 61225, "61225 SIELTE"

NETHERLANDS

**Ericsson Telefoonmaatschappij N.V.** *Rijen (N.Br.)*, P. O. B. 8, tel: (01612) 3131, tgm: erictel, telex: 54114, "ETMRY NL"

*Voorburg 2110*, P. O. B. 60, tel: (070) 81 4501, tgm: erictel den haag, telex: 31109, "ERICTEL DEN HAAG"

NORWAY

**A/S Elektrisk Bureau** *Oslo 3, P.B.* 5055 Maj, tel: (02) 46 1820, tgm: teleb, telex: 11723, "TELEB N"

**A/S Industrikontroll** *Oslo 6*, Grensevejen 86/88, 3. etg., tel: (02) 67 8394,

**A/S Norsk Kabelfabrik** *Drammen*, P.O.B. 369, tel: (02) 83 7650, tgm: kabel, telex: 18149, "KABEL N".

**A/S Telesystemer** *Oslo 6*, Tvetenveien 32, Bryn, tel: (02) 68 7200, tgm: telesystemer, telex: 16900, "ALARM N"

POLAND

**Telefonaktiebolaget L M Ericsson, Technical Office** *Warszawa*, Ul. Nowy Swiat 42, tel: 26 4926, tgm: tellme, telex: 813710, "813710 TELLME PL"

PORTUGAL

**Sociedade Ericsson de Portugal Lda.** *Lisboa 1*, Rua Filipe Folque 7, 1°, tel: 56 3212, tgm: ericsson

SPAIN

**Industrias de Telecomunicación, S.A.** *Getafe*, Paseo Felipe Calleja 6, tel: 295 2100, tgm: ericsson, telex: 22666, "ERIGE E"

**L M Ericsson, S.A.** *Madrid 5*, Bernadino Obregón 25, tel: 467 8700, tgm: ericofon, telex: 23333, "23333 LMESA E"

SWEDEN

**Telefonaktiebolaget L M Ericsson,** *S-126 11 Stockholm 32*, tel: (08) 19 0000, tgm, telefonbolaget, telex: 17440, "LME S"

**ELLEMTEL Utvecklings Aktiebolag** *S-127 25 Skärholmen* Box 249, tel: (08) 97 0220

**Bjurhagens Fabrikers AB** *S-200 12 Malmö*, Fack, tel: (040) 93 4770, telex: 3123, "BJURHAG S"

**AB Rifa** *S-161 11 Bromma 11*, Fack, tel: (08) 26 2600, tgm: elrifa, telex: 10308, "ELRIFA STH"

**L M Ericsson Instruktionsteknik AB** *S-117 47 Stockholm 44*, tel: (08) 68 0870, tgm: instruktec

**L M Ericsson Telemateriel AB** *S-135 01 Stockholm-Tyresö 1*, Fack, tel: (08) 712 0000 tgm: ellem, telex: 10920, "10920 LMSBO/S"

**Sieverts Kabelverk AB** *S-172 87 Sundbyberg*, tel: (08) 28 2720, tgm: sievertsfabrik, telex: 1676, "SIEVKAB S"

**Svenska Radio AB** *S 102 20 Stockholm 12*, Fack, tel: (08) 22 31 40, tgm: svenskradio, telex: 10094 "SRA S"

**AB Thorsman & Co.** *S-611 01 Nyköping 1*, Box 149, tel: (0155) 810 00, tgm: thorsmanco

**AB Transvertex** *S-145 53 Norsborg*, Fittja industriområde, tel: (08) 710 0935

SWITZERLAND

**Ericsson A.G.** *8061 Zurich*, Postfach, tel: (051) 41 6608, tgm: telericsson, telex: 52669, "ERIC CH"

TURKEY

**Ericsson Türk Ticaret Ltd.** Sirketi *Ankara*, Rumeli Han, Ziya Gökalp Cad. tel: 12 3170, tgm: ellem

WEST GERMANY

**Deutsche Ericsson G.m.b.H. Telematerial,** *4 Düsseldorf 1*, Postfach 2628, tel: (0211) 35 3594, tgm: erictel: telex: 8587912, "ERIC D"

**Ericsson Centrum G.m.b.H.** *3 Hannover*, Dornierstrasse 10, Postfach 1809, tel: (0511) 63 1018, tgm: ericen, telex: 0922913, "ERICE D"

### ASIA

INDIA

**Ericsson India Limited**
*Calcutta*, P.O.B. 2324, tel: (032) 45 4494, tgm: inderic, telex: 0217165

*New Delhi 16*, L25, South Extension Part II, tel: (011) 62 6505, tgm: inderic

INDONESIA

**Ericsson Telephone Sales Corporation AB**
*Djakarta*, P.O.B. 2443, tel: (07) 463 97, tgm: javeric, telex: 4414 "JAVERIC DKT 4414"

*Bandung*, Djalan Ir. H. Djuanda 151, tel: (082) 820 94, tgm: javeric

IRAQ

**Telefonaktiebolaget L M Ericsson, Iraq Branch** *Baghdad* P.O.B. 2388, Alwiyah, tel: 947 14, tgm: ellemco

KUWAIT

**Telefonaktiebolaget L M Ericsson, Technical Office** *Kuwait, State of Kuwait*, P.O.B. SAFAT No. 5979, tel: 42 0074, tgm: erictel

LEBANON

**Société Libanaise des Téléphones Ericsson** *Beyrouth* B.P. 8148, tel: 25 2627, tgm: ellem, telex: ELLEM 20876 LE

MALAYSIA

**Ericsson Talipon SDN BHD** *Shah Alam, Selangor, Batu Tiga Industrial Estate*, P.O.B. 28, Tel: Kuala Lumpur 36 1821, tgm: kuleric, telex: 265, "ERICMAL KL"

**Telecommunication Manufacturers (Malaysia) SDN BHD** *Shah Alam, Selangor, Batu Tiga Industrial Estate*, P.O.B. 28, tel: Kuala Lumpur 36 1821, tgm: kuleric, telex: 265, "ERICMAL KL"

PAKISTAN

**L M Ericsson Telephone Company, Technical Office** *Karachi*, P.O.B. 7398, tel: (90) 51 6112, tgm: ericsson

SINGAPORE

**Telephone Industries of Singapore Private Ltd.** *Singapore 1*, P.O.B. 3079, tel: 98 1155, tgm: telsin, telex: 21727 "TELSIN RS 21727"

THAILAND

**Ericsson Telephone Corp. Far East AB** *Bangkok*, P.O.B. 824, tel: (02) 580 41, tgm: ericsson, telex: 2274, "THAIERIC"

### AFRICA

ALGERIA

**Société Algérienne des Téléphones Ericsson** *El Biar (Algers)*, 4, rue Mouloud Hadjen, tel: 78 2692, tgm: eric alger

A. R. EGYPT

**Telefonaktiebolaget L M Ericsson, Technical Office** Egypt Branch *Cairo* P.O.B. 2084, tel: (02) 465 83, tgm: ericgypt, telex: 2009, "ELLEME UN"

ETHIOPIA

**Telefonaktiebolaget L M Ericsson, Technical Office** *Addis Ababa*, P.O.B. 3366, tel: (01) 492 60, tgm: ericsson, telex: 21090 "MOSFIRM ADDIS"

MOROCCO

**Société Marocaine des Téléphones Ericsson** *Casablanca*, 87, Rue Karatchi, tel: 788 75, tgm: ericsson

TUNISIA

**Telefonaktiebolaget L M Ericsson, Technical Office,** *Tunis*, Boite Postale 780, tel: (01) 24 0520, tgm: ericsson, telex: 695, "ERICSSON TUNIS".

ZAMBIA

**Ericsson Telephone Sales Corporation AB**
*Lusaka*, P.O.B. 2762, tel: (011) 744 42, tgm: ericofon

*Ndola*, P.O.B. 2256, tel: (026) 3885, tgm: ericofon

### AMERICA

ARGENTINE

**Cia Ericsson S.A.C.I.** *Buenos Aires* Casilla de Correo 3550, tel: 33 2071, tgm: ericsson, telex: 0122196, "CATEL BA"

**Cia Argentina de Teléfonos** S.A. *Buenos Aires*, Belgrano 894, tel: 33 2076, tgm: catel, telex: 0122196, "CATEL BA"

**Cia Entrerriana de Teléfonos S.A.** *Buenos Aires*, Belgrano 894, tel: 33 2076, tgm: catel, telex: 0122196, "CATEL BA"

**Industrias Eléctricas de Quilmes S.A.** *Quilmes FNGR*, 12 de Octubre 1090, tel: 253 2775, tgm: indelqui buenosaires, telex: 0122196, "CATEL BA"

BRAZIL

**Ericsson do Brasil Comércio e Indústria S.A.**
*São Paulo*, Rua da Coroa 500, tel: (011) 298 2322 tgm: ericsson, telex: 021817, "ERICSSON SPO"

*Rio de Janeiro*, Caixa Postal 3601-ZC-00, tel: (021) 221 4777, tgm: ericsson, telex: 031839, "ERICSSON RIO"

**Fios e Cabos Plásticos do Brasil S.A. (FICAP)** *Rio de Janeiro*, caixa postal: 1828, tel: (021) 391 4550, tgm: ficap, telex: 031485, "FICAP RIO"

CANADA

**L M Ericsson Limited** *Montreal 381, Quebec*, 2300 Laurentian Boulevard St. Laurent, tel: (514) 331 3310, tgm: caneric, telex: 05-267682, (TWX) 610-421-3311, "CANERIC MTL"

CENTRAL AMERICA

**Telefonaktiebolaget L M Ericsson, Oficina Tecnica de Centroamérica** *San Salvador*, Apartado 188, tel: 21 7640, tgm: ericsson, telex: 20087, "ERICSAL 20087"

CHILE

**Cia Ericsson de Chile S.A.** *Santiago*, Casilla 10143, tel: (04) 825 55, tgm: ericsson, telex: 40598, "40598 ERICH CL"

COLOMBIA

**Ericsson de Colombia S.A.** *Bogotá*, Apartado Aéreo 4052, tel: (92) 41 1100, tgm: ericsson, telex: 044507, "ERICSSON BOG"

**Fábricas Colombianas de Materiales Eléctricos Fácomec S.A.** *Cali*, Apartado Aéreo 4534, tel: 42 1061, tgm: facomec, telex: 55673, "FACOMEC CLO"

COSTA RICA

**Telefonaktiebolaget L M Ericsson,** Technical Office *San José*, Apartado 10073, tel: 21 1466, tgm: ericsson, telex: 283, "283 LME-CR"

ECUADOR

**Teléfonos Ericsson C.A.**
*Quito*, Casilla 2138, tel: 52 4000, tgm: ericsson

*Guayaquil*, Casilla 376, tel: 30 0900 tgm: ericsson

*Cont. on next page*

## *Subsidiaries, associated companies and technical offices* (Cont. from preceding page)

MEXICO

**Teléfonos Ericsson S.A.** *Mexico D.F.*, Apartado Postal M-9958, tel: 566 8955 *tgm: coeric*, telex: 017234, "ERICSSON TLA" PARA COERIC

**Latinoamericana de Cables S.A. de C.V.** *Mexico 12 D.F.*, Apartado Postal 12737, tel: 549 0844 tgm: latincasa, telex: 017234, "ERICSSON TLA" PARA LATINCASA

**Teleindustria, S.A.** *Mexico 1, D.F.*, Apartado Postal 1062, tel: 565 7033 tgm: ericsson, telex: 017234 "ERICSSON TLA"

**Telemontaje, S.A. de C.V.** *Mexico 1, D.F.*, Apartado Postal 1062, tel: 576 4044, tgm: ericssonmexicodf, telex: 017234, "ERICSSON TLA" PARA TELEMONTAJE

PANAMA

**Telefonaktiebolaget L M Ericsson, Oficina Técnica de Panamá** *Panama 5, R.P.* Apartado 4349, tel: 64 3600, tgm: ericsson, telex: 368674 "368674 SONITEL''

PERU

**Cia Ericsson S.A.** *Lima*, Apartado 2982, tel: 31 1005, tgm: ericsson, telex: 3540202, "ERICSSON 3540202''

**Soc. Telefónica del Perú, S. A.** *Arequipa*, Apartado 112-1012, tel: 6060 tgm: telefonica

EL SALVADOR

**Telefonaktiebolaget L M Ericsson, Technical Office** *San Salvador*, Apartado 188, tel: 21 7640, tgm: ericsson

URUGUAY

**Cia Ericsson S.A.** *Montevideo*, Casilla de Correo 575, tel: 91 2611, tgm: ericsson, telex: 398228, "ROULEMENT UY'' PARA MELANDER

USA

**The Ericsson Corporation** *New York, N.Y. 10017*, 100 Park Avenue, tel: (212) 685 4030, tgm: erictel, telex: 620484, "ERICTEC 620484''

**Ericsson Centrum Inc.** *New York, N.Y. 10016*, 16, East 40th Street, tel: (212) 679 1000, tgm: erictel, telex: 620149, "ETELSAC 620149''

VENEZUELA

**Cia Anónima Ericsson** *Caracas*, Apartado 70516, tel: (02) 34 4661, tgm: ericsson, telex: 22734, "22734 ERIC VEN''

**Alambres y Cables Venezolanos C.A. (ALCAVEL)** *Caracas*, Apartado del Este 62107, tel: (02) 33 9791, tgm: alcave, telex: 22845, "ALCAVE VE"

### AUSTRALIA & OCEANIA

AUSTRALIA

**L M Ericsson Pty Ltd.**
*Broadmeadows, Victoria 3047*, P.O.B. 41, tel: (03) 309 2244, tgm: ericmel, telex: AA 30555, "ERICMEL''

*Rushcutters Bay N.S.W. 2011*, 134 Barcom Avenue, tel: (02) 31 0941, tgm: ericsyd, telex: AA 21358 "ERICSYD''

*Boroko, Papua New Guinea*, P.O.B. 5602, tel: Port Moresby 565 66, tgm: ericpor, telex: Port Moresby 153

**Teleric Pty. Ltd.**
*Broadmeadows, Victoria 3047*, P.O.B. 41, tel: (03) 309 2244, tgm: teleric, telex: AA 30555, "ERICMEL''

*Rushcutters Bay N.S.W. 2011*, 134 Barcom Avenue, tel: (02) 31 0941, tgm: teleric, telex: AA 21358, "ERICSYD''

**Conqueror Cables Pty. Limited** *Dee Why, N.S.W. 2099*, P.O.B. 69, tel: (02) 982 3344, tgm concab sydney, telex: AA 24305

**A.E.E. Capacitors Pty. Ltd.** *Preston, Victoria 3072*, 202 Bell Street, P.O.B. 95, tel: (03) 480 1211, tgm: engiquip melbourne, telex: 31001

---

## *Representatives*

### EUROPE

AUSTRIA

**Electro-Diesel Handelsaktiengesellschaft, Abteilung Telecom** *1160 Wien*, Postfach 98, tel: (0222) 43 5956, tgm: teleric, telex: 75976, "75976 TELECOM A"

BELGIUM

**Allumage Lumière S.A.** *Bruxelles 7*, 128-130 Chaussée de Mons, tel: 23 9425, tgm: allumalux, telex: 21582, "ALLUMALUX BRU''

GREECE

**Angelos Cotzias** *Athens, 18*, Omirou Street, tel: (021) 62 6031, tgm: cotziasan, telex: 215252, "215252 CTZS GR"

ICELAND

**Johan Rönning** *Reykjavik*, P.O.B. 5300, tel: 840 00, tgm: rönning, telex: 2040, "ROENNG IS''

SPAIN

**TRANSA Transacciones Canarias S.A.**

*Las Palmas de Gran Canarias*, Tomas Morales 36, tel: 21 8304, tgm: transa, telex: 95052, "MAVAC E''

*Santa Cruz de Tenerife*, Paseo José, 4—5, tel: 24 1118, tgm: transa, telex: 95024, "MAVAC E"

YUGOSLAVIA

**Merkantile Inozemna Zastupstva** *Zagreb* P.O.B. 02-1027, tel: (041) 41 6655, tgm: merkantile, telex: 21139, "21139 YU MERTIL''

*Beograd*, Ul. 7. Jula br. 18, tel: (011) 62 1773, tgm: merkantile, telex: 11506, "YU MERKAN''

### ASIA

BAHRAIN & TRUCIAL STATES

**Yusuf Bin Ahmed Kanoo** *Bahrain, Arabian Gulf*, tel: 40 8188, tgm: kanoo, telex: BHN 215

BURMA

**Myanma Export Import Corp., Agency Div.** *Rangoon*, P.O.B. 404, tel: 112 58, tgm: myanimport, telex: UBMEIC BM 2005

CAMBODIA

**Comin Khmere S.A.** *Phnom-Penh*, P.O.B. 625, tel: 233 34, tgm: engineer

CYPRUS

**S.A. Petrides & Sons Ltd.** *Nicosia*, P.O.B. 4522, tel: 427 88, tgm: armature, telex: 2308, "ARMATURE''

HONG KONG AND MACAO

**Swedish Trading Co. Ltd.** *Hong-Kong*, P.O.B. 108, tel: 23 1091, tgm: swedetrade

IRAN

**Irano Swedish Company A. B.** *Teheran*, Khiabane Sevom Esfand 29, tel: 31 4160, tgm: iranoswede

JORDAN

**The Arab Trading & Development Co.** *Amman*, P.O.B. 6141, tel: 259 81, tgm: aradeve

KUWAIT

**Morad Yousuf Behbehani** *Kuwait, State of Kuwait*, P.O.B. 146, tel: 42 7071, tgm: barakat, telex: 2048, "BEHBEHANI KUWAIT''

LEBANON

**Swedish Levant Trading** *Beyrouth*, P.O.B. 931, tel: 23 1624, tgm: skefko

PAKISTAN

**Panasian Marketing Service Ltd.** *Karachi*, P.O.B. 3941, tel: (90) 51 2051, Ext. 53, tgm: *panasian*

PHILIPPINES

**Asia Industries Inc.** *Makati, Rizal*, M.C.C. Post Office 1322, tel: 87 7011, tgm: usi asia, telex: 7222233, "7222233 AII PH"

SAUDI ARABIA

**Engineering Projects & Products Co. Ltd. (Eppco)**

*Riyadh*, P.O.B. 987, tel: 222 22, tgm: eppcol

*Yeddah*, P.O.B. 1502, tel: 4567, tgm: eppcol

*Dammam*, P.O.B. 450, tel: 222 22, tgm: eppcol

SYRIA

**Constantin Georgiades** *Damas*, P.O.B. 2398, tel: 266 73, tgm: georgiades

TAIWAN

**Trans-Eurasia Enterprise, Ltd.** *Taipei*, P.O.B. 3880, tel: 51 7038, tgm: esbtrading

REPUBLIC OF VIETNAM

**Vo Tuyen Dien-Thoai Vietnam** *Saigon*, P.O.B. 1049, tel: 226 60, tgm: telerad

**International Business Representative** *Saigon*, 26—28, Hai Ba Trung Street, tel: 226 60, tgm: ibur

### AFRICA

ETHIOPIA

**Mosvold Company (Ethiopia) Ltd.** *Addis Ababa*, P.O.B. 1371, tel: (01) 101 00, tgm: mosvold, telex: 21090, "MOSFIRM ADDIS''

KENYA, TANZANIA, UGANDA

**The Old East African Trading Co. Ltd.** *Nairobi, Kenya*, P.O.B. 30013, tel: 271 61, tgm: broche, telex: 22261, "OLDEAST NAIROBI''

LIBERIA

**Liberian Telecommunications Authority** *Monrovia*, Corner Ashmun & Lynch Streets, tel: 222 22, tgm: radiolibe

LIBYA

**ADECO African Development & Engineering Co***Tripoli*, P.O.B. 2390, tel: 339 06, tgm: *adeco*

MALAWI

**Business Machines Ltd.**, *Limbe*, P.O.B. 5557, tel: Blantyre 513 52, tgm: falt, telex: 342, "FALT LIMBE"

MOZAMBIQUE

**J. Martins Marques & Ca. Lda** *Lourenço Marques*, P.O.B. 2409, *tel*: 24953, tgm: marquesco

NIGERIA

**Communications Associates of Nigeria Ltd. (Comsac)**, *Yaba (Lagos)*, P.M.B. 1069, tel: Lagos 442 74, tgm: comdec lagos

SOUTH AFRICA
NAMIBIA

**Dryden Communications (Pty.) Ltd.** *Johannesburg, South Africa*, P.O.B. 2440, tel: 838 5454, tgm: qualsteels, telex: 430094, "430094 SA"

SUDAN

**El Rahad Trading Corporation** *Khartoum*, P.O.B. 866, tel: 776 95, tgm: suconto, telex: BHN 251

ZAIRE

**I.P.T.C. (Zaire) Ltd.** *Kinshasa*, P.O.B. 8922, tel: 253 45, tgm: induexpan, telex: 327, "IPTC KIN"

### AMERICA

BAHAMA ISLANDS

**Anglo American Electrical Company Ltd.** *Freeport, Grand Bahama*, P.O.B. 104

BOLIVIA

**Prat Ltda** *La Paz*, Casilla 4790, tel: 277 12, tgm: prat, telex: PRAT BX 5363

COSTA RICA

**Tropical Commission Co. Ltd.** *San José*, Apartado 661, tel: 22 5511, tgm: troco

DOMINICAN REPUBLIC

**Humberto Garcia, C. por A.** *Santo Domingo*, Apartado 771, tel. 682 3645, tgm: gartier

GUATEMALA

**Nils Pira** *Ciudad de Guatemala*, Apartado 36, tel: (021) 622 57, tgm: nilspira

GUYANA

**General Supplies Agency** *Georgetown*, P.O.B. 375, tgm: benwlks

HONDURAS

**Quinchón Leon y Cia** *Teguicigalpa*, Apartado 85, tel: 251 71, tgm: quinchon

NETHERLANDS ANTILLES

**S.E.L. Maduro & Sons Inc. Merchandise Dept.** *Willemstad, Curaçao* P.O.B. 304, tel: 130 00, tgm: madurosons, telex: CU 92

NICARAGUA

**Roberto Teran G.** *Managua*, Apartado 689, tel: 224 00, tgm: roteran

PANAMA

**Sonitel, S.A.** *Panama 5, R.P.*, Apartado 4349, tel: 64 3600, tgm: sonitel, telex: 368674, "368674 SONITEL''

**Mr. Tore Korch** *Panama 5, R. P.*, Apartado 4349, tel: 64 36 00, tgm: sonitel, telex: 36 86 74, "36 86 74 SONITEL" FOR MR KORCH

PARAGUAY

**S.A. Comercial e Industrial H. Petersen** *Asunción*, Casilla 592, tel: 44 124, tgm: pargtrade

EL SALVADOR

**Dada-Dada & Co.** *San Salvador* Apartado 274, tel: 21 7940, tgm: dada

SURINAM

**W.E. van Romondt's Trading Company Ltd.** *Paramaribo*, P.O.B. 1837, tel: 728 31, tgm: vanromondt

TRINIDAD, W.I.

**Leon J. Aché Ltd.** *Port-of-Spain*, P.O.B. 276, tel: 323 57, tgm: achegram

### AUSTRALIA & OCEANIA

NEW ZEALAND

**ASEA Electric (NZ) Ltd.** *Wellington C. 1.*, P.O.B. 3239, tel: 706 14 tgm: asea, telex: 3431, "ASEAWELL NZ 3431''

SATHERLUND & KROOK

ERICSSON
Review

2
1972

# ERICSSON REVIEW

Vol. 49 No. 2 1972

RESPONSIBLE PUBLISHER: CHR. JACOBÆUS, DR. TECHN.
EDITOR: SIGVARD EKLUND, DHS
EDITOR'S OFFICE: S-126 25 STOCKHOLM
SUBSCRIPTIONS: ONE YEAR $1.80; ONE COPY $0.60

## CONTENTS

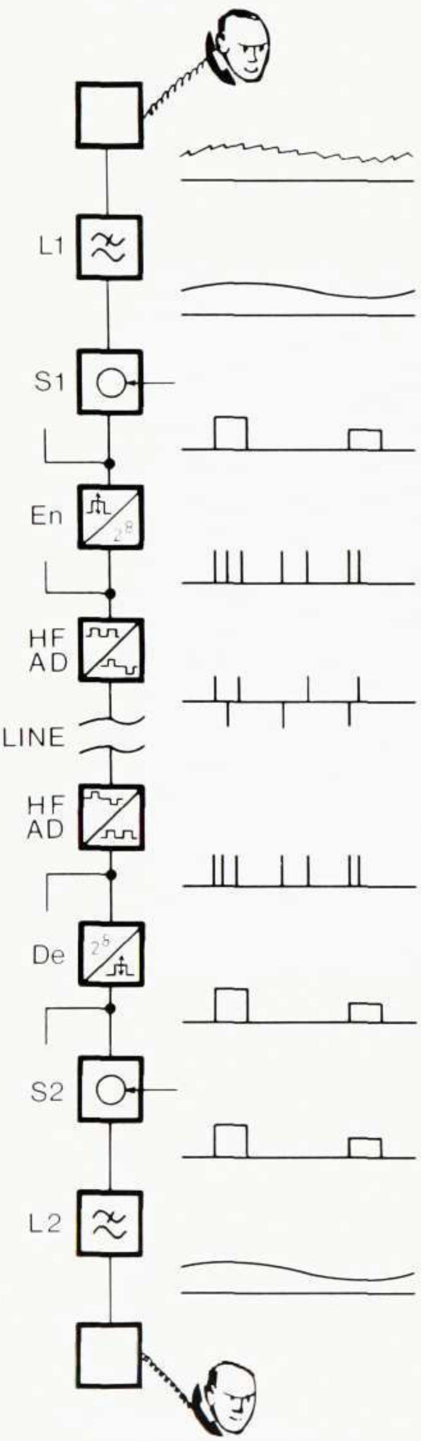
On cover: L M Ericsson's DIALOG telephone with pushbutton unit for electronic dial pulsing.

# PCM Multiplexing Equipment ZAK 30/32

S. LINDQUIST, H. J. FRIZLEN & J. Å. CARLSSON, TELEFONAKTIEBOLAGET LM ERICSSON, STOCKHOLM

UDC 621.376.56
LME 84362

**Fig. 1**
**Simplified block diagram showing main functions of p.c.m. multiplex system**



*Earlier Ericsson Review articles have briefly described two p.c.m. systems developed by L M Ericsson*[1, 2]. *The later of the two — comprising the ZAK 30/32 multiplexing equipment and ZAD 2 line equipment — is now in production. It has been designed in conformity with CCITT recommendations. The present article gives an account of the electrical and mechanical design of the ZAK 30/32 multiplexing equipment.*

Arrangements have been made to reduce the need for maintenance. To minimize component-failure rates, the multiplex has been designed so as to ensure low component-temperature rises. This has been achieved by derating and by facilitating natural air circulation by means of a sufficiently spacious equipment construction practice in conjunction with the use of ventilation units.

If nevertheless a fault should occur, it is easily located by means of a lamp panel indicating the type of fault involved. With the aid of the lamp panel and a fault catalogue most faults can be readily pin-pointed and cleared by replacement of the apparatus unit concerned.

A large number of short-circuit-proof test jacks and break-type test points on the face of the units simplify checking and more accurate inspections.

The multiplexing equipment has been divided into a number of assemblies which have been made interchangeable so as to ensure flexibility in application.

## Basic Principles of PCM

Since a large number of papers have been written on the basic principles of p.c.m., these will only be treated briefly in this article.

The speech channel, filtered in a low-pass filter L1, is sampled at regular intervals by a sampling gate S1 which is operated at the sampling rate fs. The p.a.m. pulses thus obtained are converted into binary code words in the encoder En. After signal processing in an adapting unit (h.f. adapter), whereby the d.c. component is eliminated from the pulse train, the code words are transmitted over the line facility.

At the receiving terminal the original code words are restored, which are then reconverted into a train of p.a.m. pulses in the decoder De. The p.a.m. pulse is passed via a distribution gate S2 to a low-pass filter L2, where the speech signal is recovered.

Time division multiplexing is effected by connecting two or more channels, each with its associated filter and sampling gate, to the common encoder. The sampling gates associated with the different channels operate sequentially and the encoder is fast enough to code one sample before the next arrives.

After encoding, signalling pulses and framing information are inserted. The framing signal is a distinctive pattern which enables the receiving terminal to identify and separate the different channels.

**Fig. 2**
**Simplified 32-time-slot frame structure as recommended by CCITT**

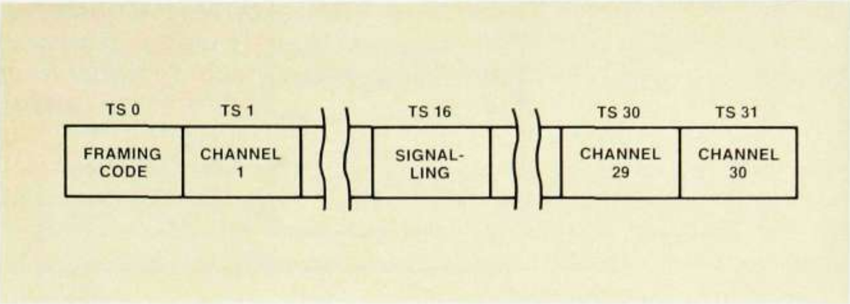
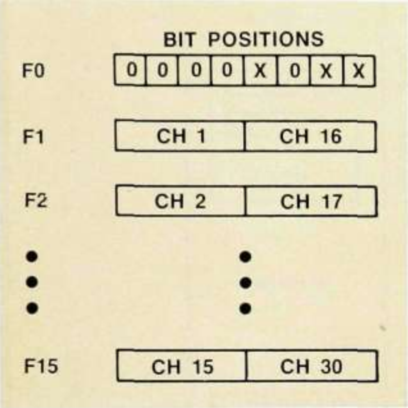


**Fig. 3**
**Allocation of signalling information for 30 speech channels organized in multiframe**



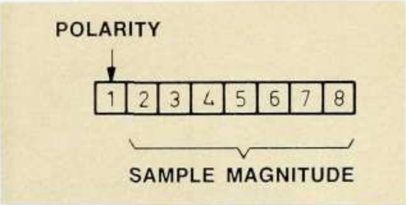
## CCITT Recommendations for PCM Systems using 32 Time Slots

The information is arranged in a frame of 32 time slots in accordance with CCITT recommendations. The first time slot (TS 0) is primarily used for transmitting the framing information, while TS 16 is assigned to carry the signalling information for all 30 speech channels. The remaining 30 time slots are normally used for coded speech.

Each time slot comprises 8 bit positions. Consequently, one 8-bit TS 16 will not be sufficient to contain the signalling information for 30 speech channels. Instead, the signalling channels can be arranged to use TS 16 in turn, the information being organized in a signalling-frame (multiframe) structure as shown in fig. 3.

Frame 0 (F 0) consists of the signalling-frame alignment code, 0000, followed by 4 bits for special purposes. Then follow the signalling bits in accordance with the signalling-frame organization. The figure shows a case where 4 signalling bits are allocated to each speech channel.

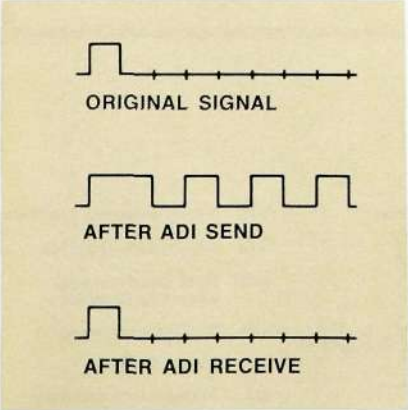
**Fig. 4**
**Disposition of 8 bits within a code word**



The speech samples are converted into 8-bit code words. Companding is applied according to the 13-segment law. The first bit in each code word indicates polarity, the remaining 7 bits representing the sample magnitude in binary form — see fig. 4.

If the input voltage to the encoder is close to zero — which will be the case, for example, in the idle-circuit condition — the last 7 bits will be zeros. The encoder therefore normally produces more zeros than ones. However, the digital line repeaters require the ones to occur at a certain density with regard to timing recovery. To reduce the probability of long sequences of zeros occurring, the output signal from the encoder is passed through the ADI (alternate digit inverter), which inverts bits 2, 4, 6 and 8. When the signal is passed through a further, similar ADI in the receive path, the original signal is reconstituted — see fig. 5.

**Fig. 5**
**Principle of alternate digit inversion**



## *System Design of L M Ericsson PCM Multiplexing Equipment ZAK 30/32*

The make-up and basic principle of the p.c.m. terminal multiplexing equipment are illustrated by means of the block diagram, fig. 6. The equipment is divided into the following main assemblies:

☐ pulse-code modem
☐ h.f. adapter
☐ signalling equipment
☐ terminal alarm unit
☐ d.c. converter
☐ data interface adapter

Mechanically, the multiplexing equipment is designed as a self-contained

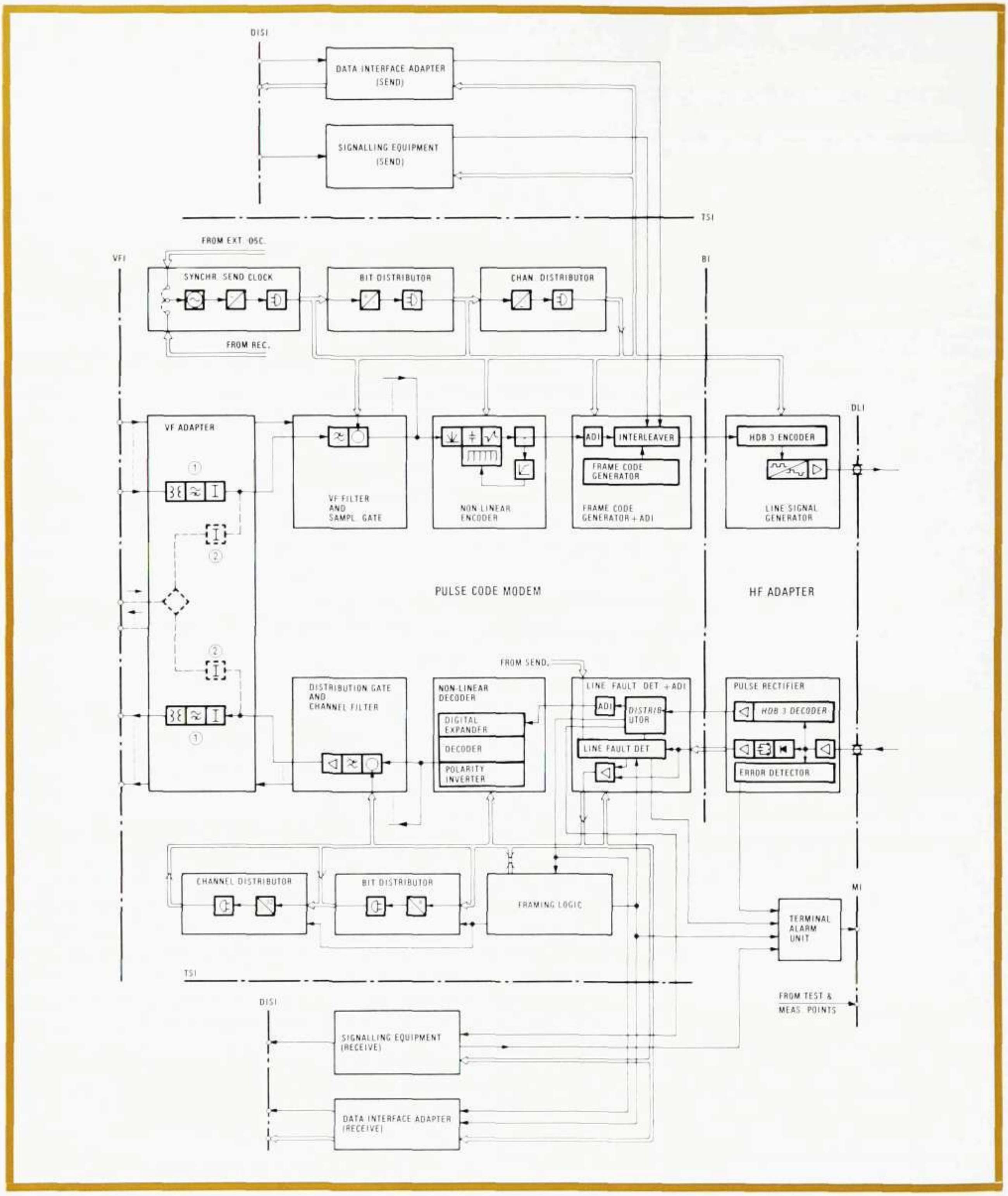


**Fig. 6**
**Block diagram of ZAK 30/32 p.c.m. multiplex**

**Transformer**
**Pad**
**Low-pass filter**
**Analogue gate**
**Full-wave rectifier**

**Hold circuit**
**Comparator**
**Flip-flop logic**
**Gate logic**
**Digital compressor**

**Reference voltage generator**
**Bipolarizer**
**Oscillator**
**Digital frequency divider**
**Pulse rectifier**

**Resonant circuit**
**Pulse shaper**
**Amplifier**
⟹ **Clock signal distribution**
→ **Other signal**

| | |
|---|---|
| **VFI** | **Voice-frequency interface** |
| **DLI** | **Digital link interface** |
| **DISI** | **Data interface and signalling interface** |
| **TSI** | **Time-slot interface** |
| **BI** | **Binary interface** |
| **MI** | **Maintenance interface** |

shelf stack accommodating all the above-mentioned units as well as the line terminating equipment. The signalling unit, which comes in a number of different versions, is connected to the multiplex shelf stack by means of plugs and sockets.

A considerable part of the equipment consists of digital apparatus units. Since these are made up of integrated t.t.l.-type components, partly in m.s.i. form, they occupy little space considering the functions they fulfil. Ceramic encapsulation has been chosen, tests having proved it to give the highest degree of reliability.

## *Pulse-code modem*

The entire sending section is controlled by a common timing equipment consisting of a send clock, bit distributor and channel distributor. The send clock can either be controlled internally by a crystal unit or externally by an oscillator or by the clock signal extracted from the incoming signal in the receive path. This feature is particularly valuable when the equipment is to be used in integrated networks.

The incoming v.f. signal is connected via the v.f. interface (VFI) to the v.f. adapter, which is available in two different versions, one for two-wire operation (dashed lines in diagram) and the other for four-wire operation. The unit includes a high-pass filter serving to eliminate any hum that might occur in the input signal. In addition, there are circuits for wetting the contacts of the relay sets in the associated exchange. The channel pads cover a range of 0—15 dB in 0.5 dB steps. To prevent harmful voltage surges from the associated wire pairs from reaching the sampling gates, the v.f. adapter has been provided with zener-diode protection.

From the v.f. adapter the signal is fed into an LC-type low-pass filter, which eliminates frequencies above 3.4 kHz.

After passing through the low-pass filter, the signal is sampled by the sampling gate at a rate of 8000 times per second. The sampling gate consists of a field-effect transistor. The samples, which are in the form of 3-$\mu$s p.a.m. pulses, are converted into 8-bit code words by the non-linear encoder. Between each two samples the encoder input is earthed, whereby crosstalk due to parasitic charges in the p.a.m. circuit is prevented.

The non-linear encoder works on the principle of successive approximation. Compression is effected by means of a digital network which converts the comparator answers into corresponding control conditions to the reference-voltage network. The main advantage of a digital compressor is its good reproducibility.

The encoder's zero level is adjusted during operation by means of an automatic zero-setting procedure, which obviates the need for periodic adjustment.

The output signal from the encoder is passed through the ADI, to be subsequently interleaved with the framing code, the signalling information and, where applicable, the information issued by the data interface adapter.

The receiving section can be considered as the reverse of the sending section. The input signal received from the h.f. adapter consists of the clock signal and the message signal. The line fault detector ascertains whether the clock signal is present. If not, the send clock is connected instead and an alarm is given. The reason why the send clock is connected is that this procedure provides a simple method to cause the receiver logic to perform certain functions, such as releasing all signalling relays.

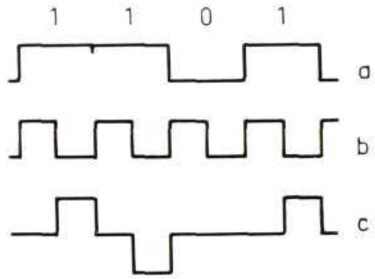


**Fig. 7**
**Relationship between unipolar pulse train (a), clock signal (b) and bipolar pulse train (c)**

Under normal operating conditions the clock signal received from the h.f. adapter is amplified and then fed into a timer consisting of framing logic, bit distributor and channel distributor. This timer is common to the whole receiving section, whose functions it controls by means of clock pulses. The information stream is distributed to the appropriate functional units. The part of the information to be applied to the decoder is passed through the ADI, whereby the speech code is restored to the form it had at the encoder output.

The non-linear decoder reproduces the p.a.m. pulses, which are then distributed to the respective channels by the distribution gates. In the same units each of the 30 original speech signals is recovered by a low-pass filter and amplified in a subsequent monolithic channel amplifier. The amplifier outputs are protected by zener diodes against any transients from the line.

## *HF Adapter*

The interchange of digital signals within the terminal is usually effected in the form of a unipolar pulse train in the nonreturn-to-zero (NRZ) mode, as shown in fig. 7 a. This signal form, which is the most suitable one for the type of circuits employed, is less appropriate for the transmission pulses over long distances. An h.f. adapter is therefore inserted between the pulse-code modem and the transmission medium to provide the requisite signal conversion.

In those cases where the transmission medium is a pair-type cable a bipolar pulse train is employed on the line system.

To enable data to be transmitted in a simple way without the need for code restriction, special types of bipolar pulse trains have now come into use. A number of similar variants are available, e.g. HDB 3, which have as a common feature that in long strings of zeros a number of extra pulses are inserted. These pulses help keep the clock circuits in the regenerative repeaters and in the receiving section of the h.f. adapter going. In the receive path the inserted pulses are removed. The original one-pulses can be discriminated from those added by changing the polarity selection when transmitting the inserted pulses.

The h.f. adapter used in the ZAK 30/32 p.c.m. multiplex has been designed for the HDB-3 code as well as the classical bipolar code (AMI). A change between the code types is effected by strapping.

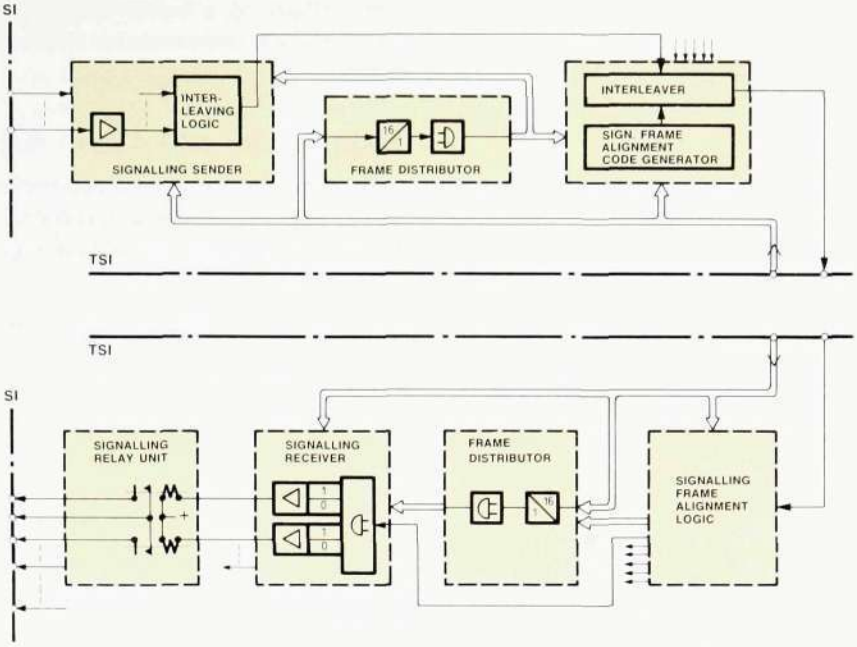
The signals exchanged between pulse-code modem and h.f. adapter comprise message signals represented by unipolar NRZ pulses and a clock signal in the form of a 2.048 MHz square wave. The exchange of information between h.f. adapter and line system is done in bipolar form over a 75-ohm digital link interface. Fig. 7 shows the relation between the different signal codes.

## *Signalling Equipment*

Time slot 16 (TS 16), which is used for the transmission of signalling information, can be regarded as a data channel having a data rate of 64 kb/s. It can be used for different types of signalling, such as channel-associated signalling.

To facilitate the use of alternative signalling arrangements, a special internal interface, termed time-slot interface, has been established in the ZAK 30/32 multiplex. Physically, the interface consists in a socket strip in the modem shelf stack, to which the equipment relating to the signalling time slot can be connected by means of plugs. Among the signalling terminations developed by L M Ericsson is equipment for E and M signalling with 1 or 2 signalling channels per speech channel.

**Fig. 8**
**Block diagram for E and M signalling**



The apparatus units making up the E and M signalling equipment are shown in fig. 8.

In the send path each of the 30 or 60 signalling channels is passed through an individual input amplifier incorporated in the signalling sender. When a relay contact in the associated exchange relay set is closed, a current is passed through the input amplifier concerned, causing the amplifier output voltage to be low. The amplifier outputs are scanned in turn under the control of the clock signal and control signals from the frame distributor. If the output voltage is low, a "0" pulse is fed to an interleaving logic, otherwise a "1" pulse. The signalling information from all the signalling channels handled by one signalling sender is interleaved to form one signal. The composite signals from several signalling senders are in turn interleaved with each other. After being completed with the signalling frame alignment code in the signalling frame alignment code generator, the pulse train thus obtained is applied to the interleaver in the send path of the pulse-code modem to be combined with the p.c.m. speech pulses.

In the receive path the signalling pulses from the different signalling channels are distributed to memory elements consisting of bistable flip-flops, one for each signalling channel.

Each flip-flop is followed by a buffer amplifier, which is in turn connected to a dry-reed relay. If the memory flip-flop contains a 'one', the associated relay contact unit opens, a 'zero' causing a contact closure. Thereby the output relays are in the same condition as the exchange relays associated with the sending equipment.

In the event of a fault occurring in the p.c.m. connection, all output relays are automatically released.

To cope with signalling schemes involving large numbers of relay operations or relatively high load currents, regular-size reed relays have been used.

## *Data Interface Adapter*

PCM techniques are extremely well suited for data transmission. The ZAK 30/32 multiplex can be provided with a data interface adapter, which is used to insert digital data pulses instead of coded speech in up to 4 time slots. The data rate is 64 kb/s per channel. The data pulses are assumed to come in bursts of 8 pulses each, a fact which generally necessitates the addition of external equipment comprising a buffer storage. The interface adapter and this additional equipment are interconnected by means of balanced pairs with the aid of line drivers.

## Maintenance and Alarm Arrangements

The need for preventive maintenance in the p.c.m. system has been minimized. The functional and operational condition of the multiplex terminals and the line system is supervised, fault indication being effected by means of several alarm types.

At the v.f. interface attenuation distortion in the speech band, quantization distortion and idle-channel noise are measured about once a year at the 4-wire or 2-wire interconnection point.

These measurements can be carried out in much the same way as in the case of f.d.m. carrier systems, i.e. either automatically using automatic transmission measuring equipment or manually. Thus a good picture of the operating characteristics of the v.f. filters, the encoder and decoder is obtained.

A yearly frequency check of the send clock is made to ascertain that the tolerance is not exceeded. In systems using an external master clock this check is omitted.

Otherwise the system is supervised by means of built-in alarm circuits for indication of five fault types:

- failure of power supply
- failure of p.c.m. line signal at receive input
- bipolar error rate $>10^{-4}$ at receive input
- loss of frame alignment
- loss of signalling frame alignment

In addition, information regarding loss of frame alignment and signalling frame alignment can be transmitted from the p.c.m. terminal at the remote end. A fault location scheme permits a fault to be traced to the send equipment, line system or receive equipment by means of a looping facility at the digital link interface. In most cases the fault can then be traced to an apparatus unit or group of units, its exact position being determined by replacing the board assembly concerned. Faulty boards are sent to a repair centre or returned to L M Ericsson for automatic testing in Ericsson's performance test console.

Only a few non-reproducible faults require fault location by testing using an oscilloscope. Fault location test points for digital and p.c.m. signals permit all significant points in the system to be checked. These test points have standardized electrical characteristics designed for standardized measuring instruments. Fault location is simplified by fault locating instructions and flow charts showing the routine to be followed for each specific fault type.

The five above-mentioned fault types initiate alarms which are combined in the p.c.m. terminal alarm unit into a summation alarm. Should one or more of the fault types occur, the summation alarm signal, after a few seconds' delay, is extended to the bay alarm unit as an urgent or non-urgent alarm. The indication as urgent or non-urgent can be chosen according to the operational conditions of the system. Also, if work has to be carried out on the terminal, the normal alarm indication can be temporarily changed into a reminder indication.

The alarm can be extended from the bay to a central supervisory position, where applicable via the suite end cabinet.

To permit a more selective evaluation of the various fault conditions, e.g. with the aid of data handling, the fault types occurring in

- the local terminal
- the remote terminal
- the receive path

are separately grouped.

These three alarm categories can also be transmitted per p.c.m. system to a control station, which may be common to several p.c.m. stations.

A further aid for fault registration at a terminal is a test box for external connection to the terminal. This test box contains, among other things, counters for

- bipolar errors
- bipolar error rate $>10^{-4}$
- loss of frame alignment
- loss of signalling frame alignment
- overload indicator

Finally, there is a telephone unit which can be placed on the bay upright. In addition to giving access to a speaker circuit, it can serve for monitoring purposes to check the speech quality of a channel or idle-channel noise.

## Mechanical Design

A partly new construction practice has been developed for p.c.m. equipment. The following part of this article gives a brief description of the basic constructional elements. The main attention, however, is focused on applications for p.c.m.

### *Construction Practice*

The construction practice for p.c.m. equipment is a further development of the M4 construction practice [3] used for L M Ericsson f.d.m. carrier transmission equipment. The bay design has only been slightly modified; the width has been reduced to 600 mm.

The shelf, however, differs considerably from the M4 shelf. The connectors for printed-wiring boards as well as the wiring method are identical with those used in stored-programme-controlled telephone exchanges [4]. In addition, maintenance facilities, i.e. lamps, test and break jacks, have been moved to the front edges of the apparatus units.

Each shelf or shelf stack contains a well-defined pre-wired functional block, which is connected to the station cabling by means of plugs and sockets. This basic design philosophy from M4 has not been changed.

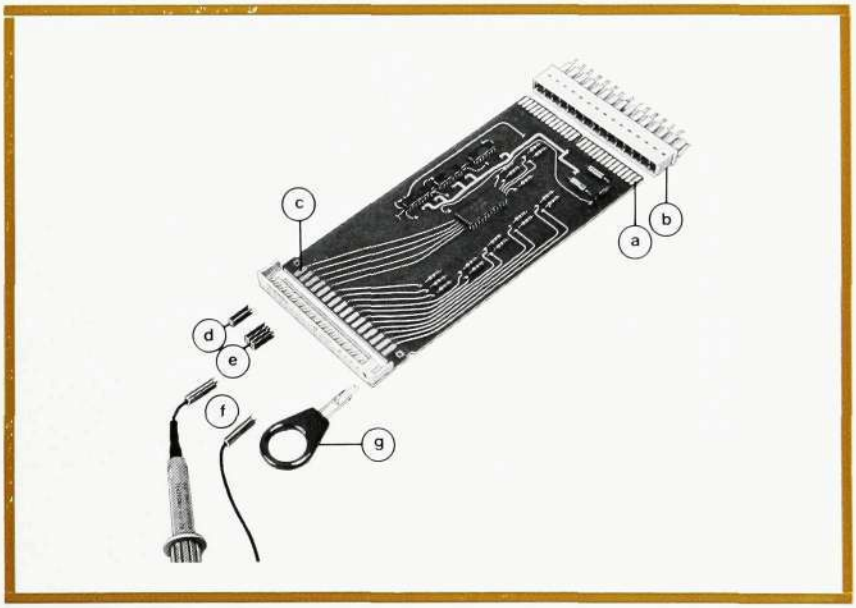


**Fig. 9**

**Typical apparatus unit**

**The rear edge of the board is provided with 28 gold-plated contacts (a) for connection to a socket strip (b) at the rear of the shelf. Also the front edge of the board has contacts (c), 16 in number, which serve either as test points or for connection of U-links. Connections between certain sections of the wiring pattern of the board can be made by short-circuiting the appropriate antipodal front contacts by means of a small plastic-encased U-link, which may be single (d) or double (e). U-links and test plugs are guided into position by the handle on the front edge of the board.**

**Special test plugs (f) are available for connection of oscilloscopes and balanced instruments to the test points.**

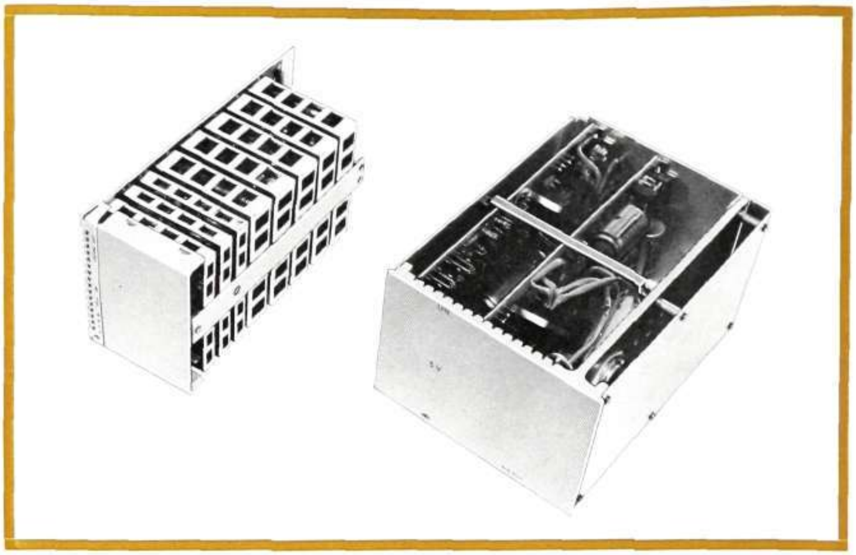
**The board is removed from its mounting position by means of a unit extractor (g), which is inserted in a slot in the handle.**

Fig. 10

Special apparatus designs

**Left: encoder consisting of a number of child boards soldered to a mother board.**

**Right: d. c. converter with flat-front heat sink.**



The most important new design features are:

- bay width of 600 mm
- decentralized power supply
- through-ventilated shelves
- break and test points placed on apparatus fronts.

In the following sections a brief account is given of the basic mechanical building blocks, exemplified with applications to p.c.m. transmission equipment.

## *Apparatus Units*

Most of the apparatus units making up the p.c.m. transmission equipment consist of double-sided printed-board assemblies having the dimensions 98.5× 207.6 mm (see fig. 9).

Electrically, it is not always possible to construct all apparatus units on standard boards. Two units having a special mechanical design, an encoder and a d.c. converter, are shown in fig. 10.

## *Shelf*

The total width of the shelf is 510 mm, which gives a mounting capacity of 68 width modules of $6\frac{2}{3}$ mm each. The shelf height is n×120 mm, where n =

**Fig. 11**

**Shelf**

**The basic shelf construction comprises two vertical side members (a) joined together by four horizontal bars (b). These are provided with slots to mount the guides (c) for the printed-board assemblies.**

**The rear part of the shelf is a socket mounting plate (d) accommodating up to thirty-four 28-pole socket strips (e) per shelf.**

**Station cables are connected to the shelf by means of card-type connectors (f) which are plugged into receptacles of the same type as those used for the apparatus units.**

**A *ventilation unit* (g) serves both as an air inlet for the shelf above (middle section) (h), and as an outlet for heated air from the shelf below (side sections) (j).**

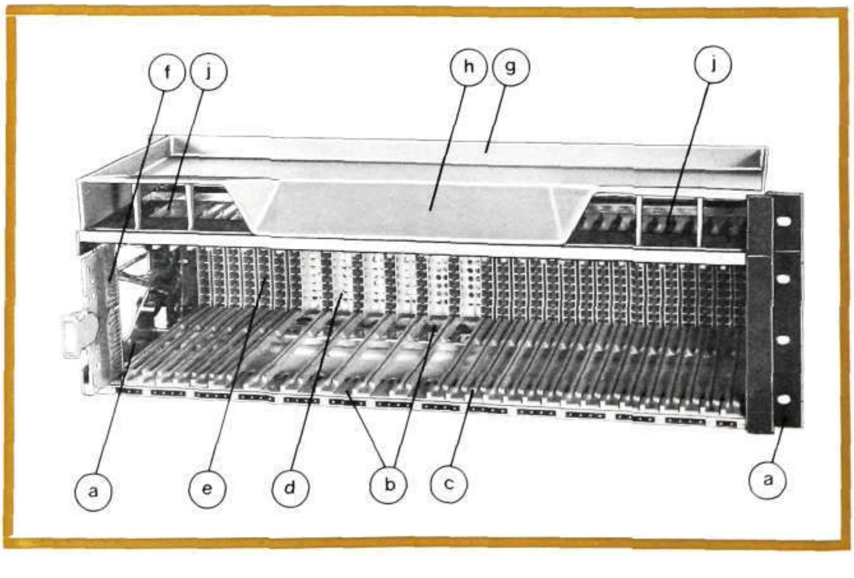
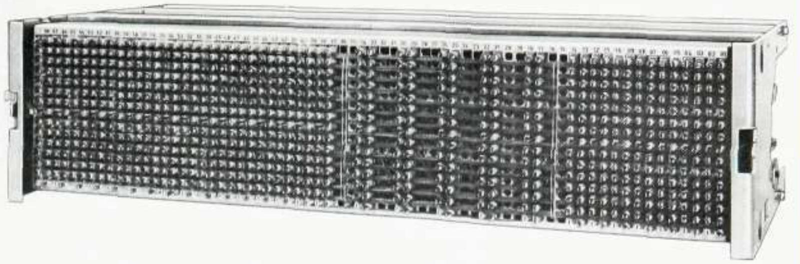


**Fig. 12**
Wired rear side of a shelf



1, 2, 3 or 4. The depth is 236 mm. A single shelf is shown in fig. 11 (n = 1). The same figure shows a ventilation unit, which serves to prevent excessive temperatures within the shelf assembly. It is placed at strategical points in the bay, as shown in fig. 16.

Fig. 12 shows the rear side (wiring face) of a shelf.

The following practical shelf applications are provided for p.c.m.:

- modem shelf stack
- signalling shelf
- line terminating shelf
- distribution shelf

## Modem Shelf Stack

The modem shelf stack consists of four mechanically joined shelves combined with a ventilation unit.

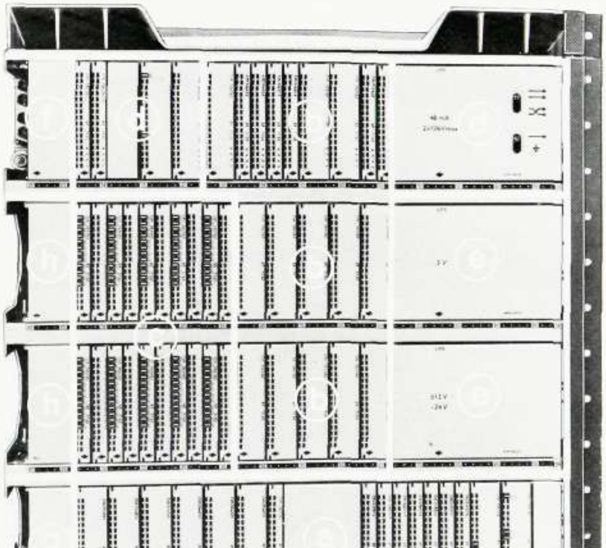


**Fig. 13**
**Modem shelf stack**

**consisting of: send equipment (a) receive equipment (b) and v. f. adapter (c), which can be either for 2-wire or 4-wire operation.**

**The line terminating equipment, here included at d, can alternatively be housed in a separate shelf. A data interface adapter comprising three units can then be put in its place.**

**DC converters (e) for 5 V and ±12 V/—24 V.**

**The mounting positions on the left-hand side are covered by dummy fronts, behind which are located:**

- **Coaxial jacks (f) for the digital link interface and for connection of an external clock signal to a synchronized oscillator**
- **Socket strips (g) for connection of a signalling shelf and a PCM test box**
- **Socket strips (h) for termination of v. f. pairs from the exchange**

Fig. 14

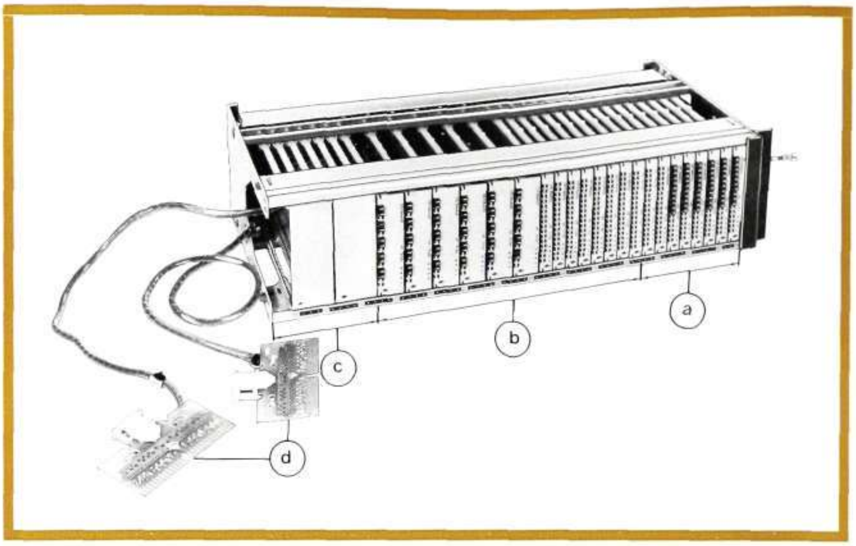
Signalling shelf for 60 E and M signalling circuits

(a) Send equipment

(b) Receive equipment

(c) Socket strips for termination of the station cabling (mounted behind the dummy fronts)

(d) Card-type connectors connect the shelf to the modem shelf stack



It accommodates the multiplexing equipment between the time-slot interfaces in fig. 6 as well as the line terminating equipment dealt with in the article describing the ZAD 2 line equipment[2]. The disposition of the multiplexing equipment is shown in fig. 13, where also alternative arrangements of the equipment are indicated.

## Signalling Shelves

Different types of signalling shelves can be connected to the modem shelf stack according to the type of relay sets employed in the exchange and the number of signalling channels required.

Fig. 14 shows a 60-channel signalling shelf for E and M signalling.

Another 60-channel signalling equipment has been designed for L M Ericsson's ARF 102 exchange using d.c. loop signalling. It is accommodated in two stacked shelves.

Other signalling shelf variants are being developed.

A common feature of the signalling shelves is that they receive their operating voltages from the associated modem shelf stack. For this reason their mounting position in the bay is direct under the modem shelf stack.

## Line Terminating Shelf

The line terminating shelf is described in the article on the ZAD 2 equipment[2].

## Distribution Shelf

The distribution shelf (fig. 15) is used at larger stations to facilitate traffic routing between various multiplex terminals and line systems.

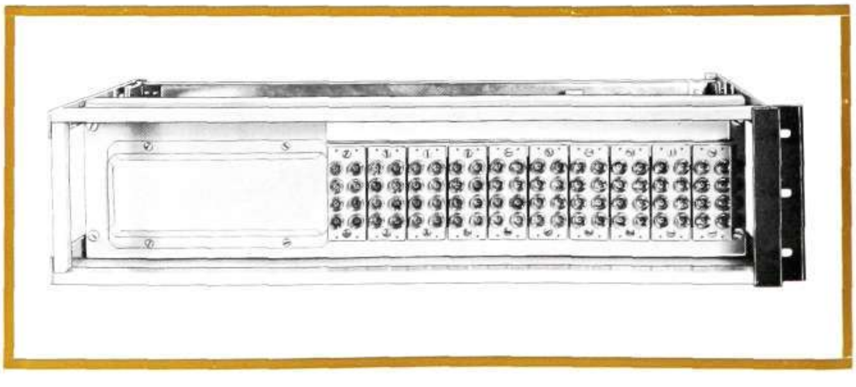


Fig. 15

Distribution shelf

Each p. c. m. terminal is allotted one strip providing 2×4 coaxial jacks for connection to line terminating equipment by means of one U-link per direction of transmission.

Fig. 16

**Bay equipped with four multiplex and line terminals**

**The cover strip on the left-hand bay upright contains certain common items:**

**(a) alarm lamps**

**(b) designation chart**

**(c) coaxial U-link panel**

**(d) telephone unit**

**(e) circuit breakers**

**In the case shown the bay is jointed to an M4 suite cabinet (f).**

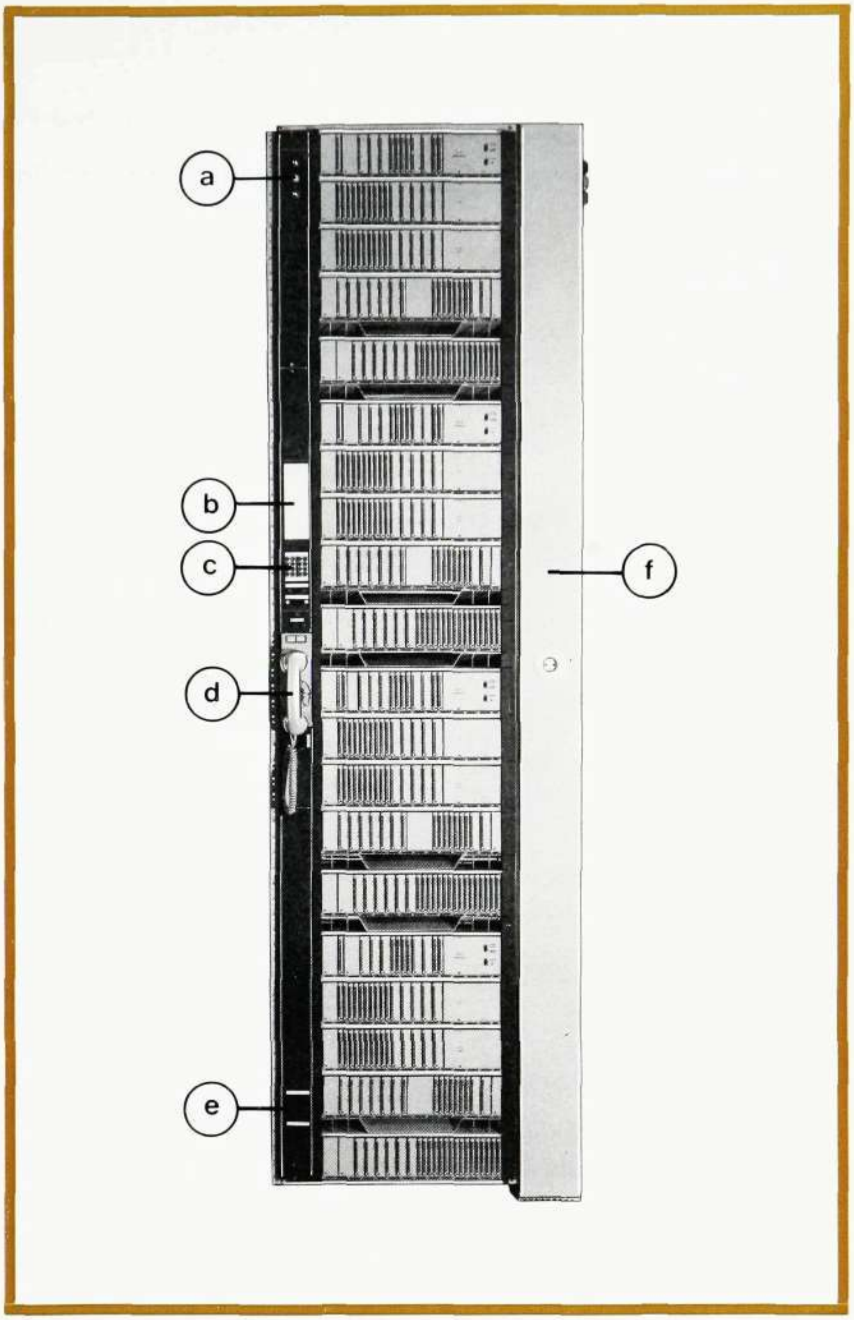
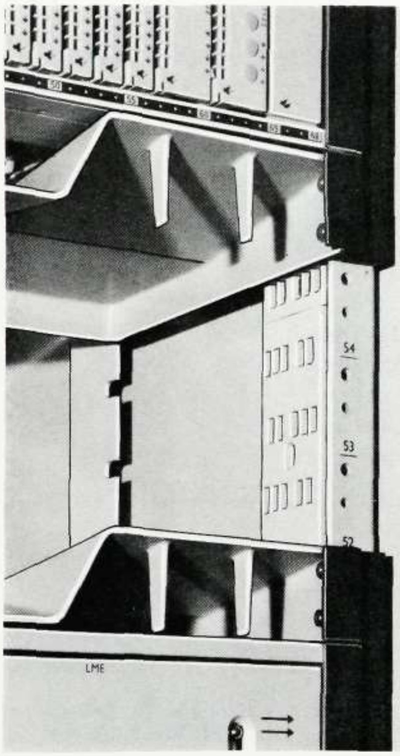


Fig. 17

**Busbars in right bay upright**

**Behind the protection cover are 2×5 insulated copper busbars for distribution of primary power, etc.**



## *Bays*

The bay is 240 mm deep and 600 mm wide. It comes in two heights, 2743 mm and 2143 mm, providing 67 and 52 height modules of 40 mm respectively.

Fig. 16 shows a 67-module bay equipped with 4 modem shelf stacks and 4 signalling shelves.

All internal current distribution, e.g. of primary power and alarms, is effected with the aid of plastic-encased busbars as shown in fig. 17. This permits all shelf assemblies relevant to the p.c.m. system to be housed in a bay frame in any desired combination. At the time of installation the bay is therefore equipped according to the size of the station concerned, availability of reserve line systems, type of signalling, data channels, expansion rate, etc.

The mechanical design offers a high degree of flexibility to the benefit of both supplier and users. The equipment can readily be expanded as required.

# Technical Data

### *VF Interface*

| | *4-W point* | *2-W point* |
|---|---|---|
| Frequency band | 300—3400 Hz | 300—3400 Hz |
| Nominal impedance | 600 Ω bal. | 900 Ω bal. |
| Minimum input level, send | -7 alt. -14 dBr | -3.5 dBr |
| Maximum output level, receive | +4 dBr | +0.5 dBr |
| Adjustment range send/receive | 15 dB | 15 dB |
| Overload level | +3 dBmO | |
| Companding law | logarithmic (A = 87.6 approximated by 13 segments) | |
| Number of speech circuits | 30 | |
| Number of signalling circuits | 30 or 60 | |
| Provision has been made for CEPT-specified extension to | 90 or 120 | |

### *Data Interface*

Facility for transmission of up to four 64-kb/s data channels without code restriction instead of telephone channels in up to four time slots.

### *Digital Link Interface*

| | |
|---|---|
| Gross digit rate | 2.048 Mb/s |
| Line codes, bipolar | HDB 3 or AMI |
| Pulse amplitude | ±2.37 V |
| Impedance | 75 Ω unbal. |

### *Digital System Parameters*

| | |
|---|---|
| Sampling rate | 8 kHz |
| Number of bits per sample | 8 |
| Number of time slots per frame | 32 |
| Number of frames per signalling frame | 16 |
| Speech code | bipolar with ADI for even bit positions |

### *Power Supply*

| | |
|---|---|
| Battery | 24, 36, 48 or 60 V d.c. |
| Mains operation using bay-mounted rectifier | 110, 127 or 220 V (48—65 Hz a.c.) |

### *Dimensions*

Multiplex terminal with 5 shelves and 2 ventilation units

| | |
|---|---|
| Height | 680 mm |
| Width | 480 mm |
| Depth | 236 mm |

Bay

| | | |
|---|---|---|
| Height | 4 systems | 2743 mm |
| | 3 systems | 2143 mm |
| | 1 system | 823 mm |
| Width | | 600 mm |
| Depth | | 240 mm |

# References

1. Widl, W.: *PCM Transmission*, Ericsson Rev. 49(1972): 1, pp. 9—13.
2. Arras, J. & Tarle, H.: *PCM Line Equipment ZAD 2*. Ericsson Rev. 49(1972): 2, pp. 47—55.
3. Axelsson, K.: *The M4 Method of Construction Used in Mechanical Design*. Ericsson Rev. 43(1966): 2, pp. 83—93.
4. Rejdin, A.: *Construction Practice for Electronics Equipment in Stored-Programme-Controlled Telephone Exchanges*. Ericsson Rev. 47(1970): 2, pp. 50—59.

# PCM Line Equipment ZAD 2

J. ARRAS & H. TARLE, TELEFONAKTIEBOLAGET LM ERICSSON, STOCKHOLM

UDC 621.376.56:
621.37.037.37
LME 84367

*As shown in a previous article, PCM Transmission*[1], *L M Ericsson's 30-channel p.c.m. system comprises multiplexing equipment ZAK 30/32*[2] *and line equipment ZAD 2, which meet CCITT and CEPT recommendations for transmission of 30 telephone channels using a line signal having a gross digit rate of 2.048 Mb/s.*

*The multiplexing and line equipments, which have been designed as independent functional packages using standardized interfaces, are compatible with similar equipment of other manufacture.*

*The line system constitutes a digital link between two p.c.m. multiplex terminals and consists of*
- *line terminating equipment interconnecting the line with the multiplexing equipment via the digital link interface (75 ohms)*
- *intermediate repeaters inserted between the cable sections via the line interface (120 ohms) and power-fed from the line terminating equipment over the cable.*

*This article outlines the functional and mechanical design as well as the maintenance and supervision of the p.c.m. line equipment.*

## Line System Configuration

The *ZAD 2* PCM Line Equipment has been developed for use on existing twin cables and multiple-twin quad cables; it comprises line terminating and intermediate repeater equipment.

The line terminating repeater equipment is accommodated in bays and includes equipment that matches the line to a standardized interface for line signals representing 30 telephone-type channels.

The intermediate repeater equipment consists of dependent repeater stations accommodated in housings which can be installed in manholes or footway boxes or directly in the ground. The repeater housings, which contain regenerative repeaters for regeneration of the bipolar line signal, can be placed along the route at intervals up to 4 km coinciding with the loading-coil spacings of existing v.f. junction circuits.

Two sets of line terminating equipment and intermediate repeater equipment for the transmission of 30 telephone channels in the 'go' and 'return' direction form a digital section. An example of two digital sections joined to form a digital link between two multiplex terminals is shown in fig. 1.

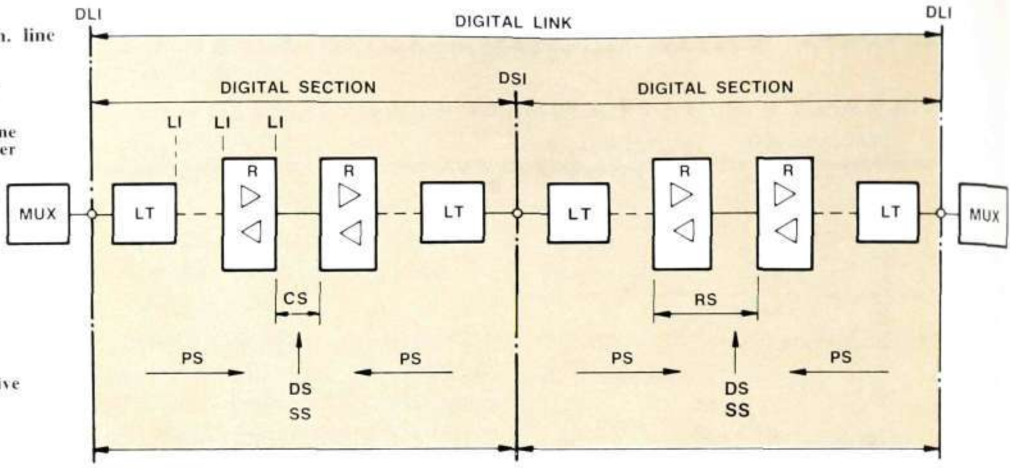
The digital sections have been designed as identical self-contained functional systems, each with its own power and alarm system, but with a common supervisory system.

To a digital section can be connected in series any other section, radio link or p.c.m. multiplexing equipment conforming to the interface conditions defined by CCITT and CEPT. Also data terminals, with the aid of data interface adapters, can be connected for the transmission of data flows with high bit rates.

Fig. 1

Block diagram showing ZAD 2 p.c.m. line equipment with interfaces

| | |
|---|---|
| **MUX** | **PCM multiplexing equipment for 30 circuits** |
| **LT** | **Line terminating equipment for one p. c. m. system at terminal repeater station** |
| **R** | **Two-way regenerative repeater at intermediate repeater station** |
| **DLI** | **Digital link interface** |
| **DSI** | **Digital section interface** |
| **LI** | **Line interface** |
| **RS** | **Repeater section** |
| **PS** | **Power section** |
| **SS** | **Supervisory section for regenerative repeaters** |
| **CS** | **Cable section** |
| **DS** | **Dead section** |



# Electrical Design

## *Line Terminating Equipment*

The line terminating equipment comprises sending and receiving sections serving to adapt the digital line signal to a standardized 75-ohm coaxial interface, viz. the digital link interface *(DLI)* or the digital section interface *(DSI)*. See fig. 2.

The sending section consists of a transformer unit 75/120 ohms for impedance matching between the *DLI/DSI* and the transmission cable. The receiving section consists of a regenerative repeater, which detects and regenerates the pulse train received from the line before it is applied to the *DLI* or *DSI*.

The line terminating equipment is usually fitted with additional equipment for power feeding of intermediate repeaters and for fault location.

Fig. 2

Block diagram of ZAD 2 line terminating and dependent repeater equipment

| | |
|---|---|
| **A** | **Transformer unit** |
| **B** | **Power feeding unit** |
| **C** | **One-way regenerative repeater** |
| **D** | **Two-way regenerative repeater** |
| **DLI** | **Digital link interface** |
| **DSI** | **Digital section interface** |
| **F** | **Fault-location filter** |
| **L** | **Loading coil** |
| **$M_1$** | **Measuring point for line signal supervision** |
| **$M_2$** | **Measuring point for station identification signal** |
| **$M_3$** | **Measuring point for location of cable faults** |
| **Tel** | **Service telephone unit** |

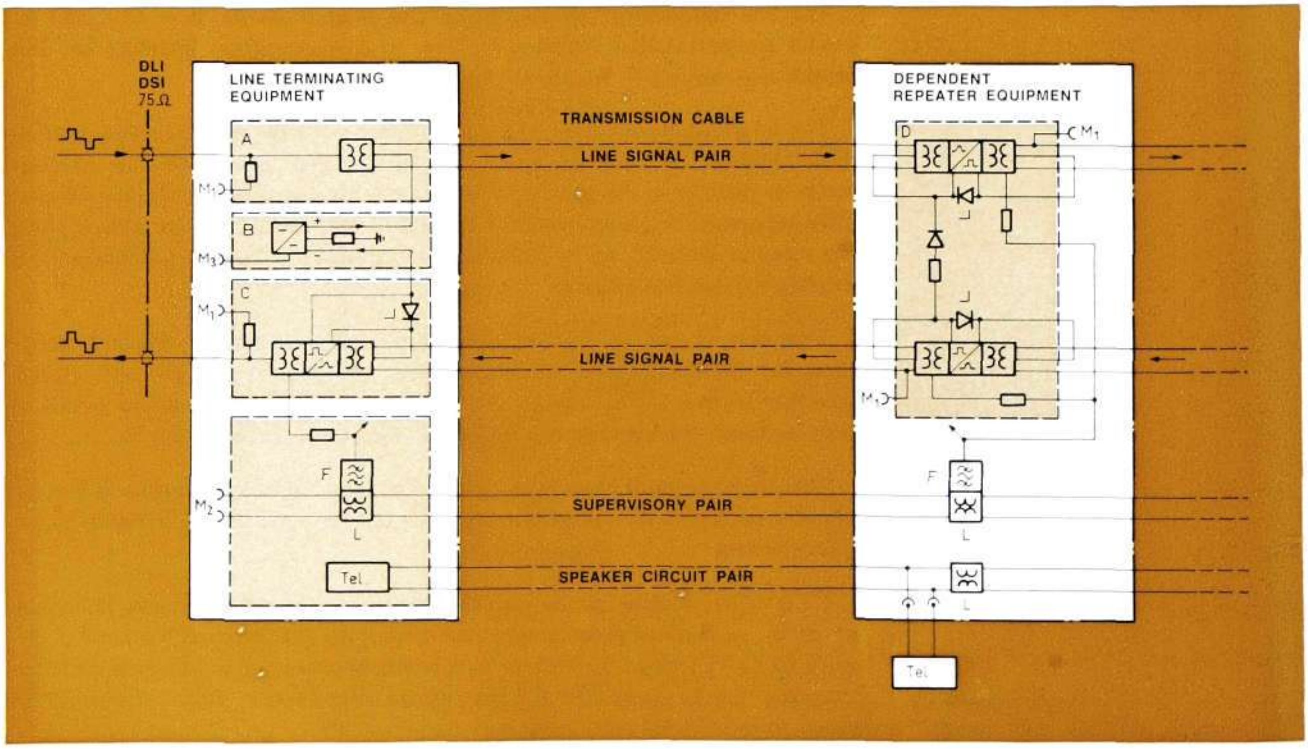
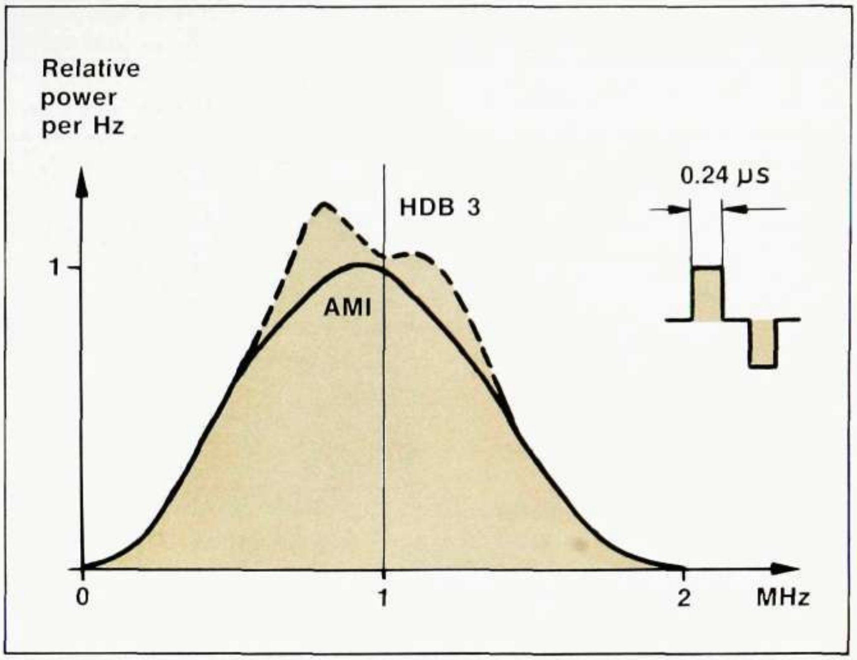


Fig. 3

**Power spectrum (approx.) of the line signal when consisting of a binary pulse train using HDB-3 code or AMI code**



## *Dependent Repeater Station*

Dependent repeater stations — see block diagram, fig. 2 — accommodate up to 6 alt. 24 two-way regenerative repeaters, which can be arranged for transmission in one direction or opposite directions with single-cable and double-cable operation respectively. The diagram also shows a band-pass filter associated with the repeater outputs for location of faulty regenerative repeaters from the terminal repeater stations.

## *Regenerative Repeaters*

The digital link is designed for the transmission of a bipolar pulse train having a bit rate of 2.048 Mb/s. One of the bipolar codes recommended by the CCITT or CEPT (AMI or HDB) can be used as transmission code. The codes transmit each signal element carrying information "one" in the form of a positive or negative pulse with half the signal-element width, information "zero" being transmitted as a space in the pulse train. Due to its statistical character the line signal has a continuous power spectrum with its maximum energy centred around 1 MHz. See fig. 3.

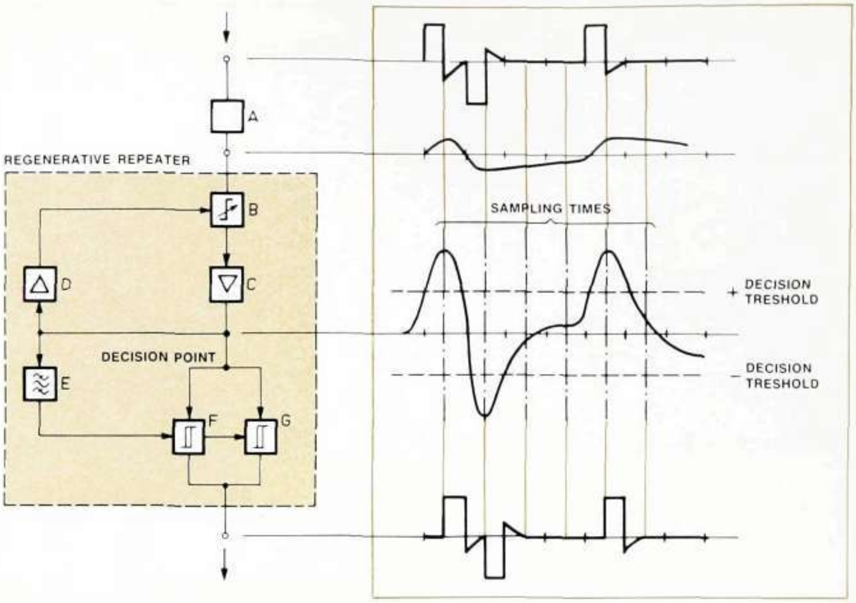
In the line cable the pulse train is exposed to attenuation and distortion. In addition, interference is introduced from neighbouring systems (near-end cross-talk) and environment. The regenerative repeaters serve to reconstruct the original pulse train from the received signal and to retransmit this signal. To this end the repeaters must perform three basic functions: equalization, timing recovery and pulse regeneration. These functions are illustrated in fig. 4, where only one direction of transmission is represented.

The equalizer *(B)* serves to provide automatic compensation for the effects of varying cable attenuation in a range of 0—35 dB at 1 MHz in such a manner that the signal produced at the decision point always has the proper shape and amplitude. The equalizing network is controlled by an automatic gain control *(D)*, which samples the amplitude of the signal at the decision point. The working range of the automatic equalizer is slightly increased by providing a negative afterkick on the trailing edges of the pulses transmitted to line. See fig. 4.

Fig. 4

**Block diagram of one-way regenerative repeater and relevant pulse shapes of the line signal. (The propagation times of the line signal have been neglected in the figure.)**

- **A** Cable section
- **B** Equalizer
- **C** Fixed-gain amplifier
- **D** Automatic gain control
- **E** Timing circuit
- **F, G** Pulse regenerating circuits



The requisite timing information is extracted from the pulse train at the decision point via a narrow-band LC filter *(E)*. If the pattern density of the incoming pulse train is too low during a long time interval, the output signal from the filter will fall to too low a value. This makes it necessary to impose a code restriction on the pulse train, limiting the number of consecutive zeros to a maximum of 15. In those cases which do not allow of a code restriction an HDB (High Density Bipolar) code can be used which introduces an easily identified artificial pulse pattern into any long sequences of consecutive zeros.

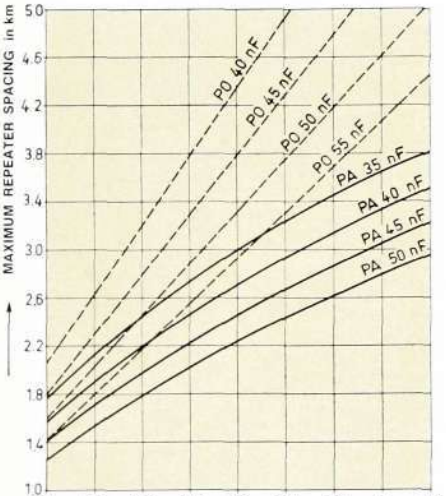
Pulse regeneration is effected in two identical circuits, *F* and *G*, one regenerating only positive and the other only negative pulses. The operation of circuits *F* and *G* is controlled by the output signal from filter *E*, the first operation of an operating cycle consisting in sampling of the signal at the decision point at fixed times. The design of circuits *F* and *G* is such that pulse regeneration cannot be affected by reflections or interference at the output of the regenerative repeater.

Fig. 5

**Maximum repeater spacing as a function of wire diameter, wire insulation and capacitance of the transmission cable pairs**

**PA = Paper-insulated wire**

**PO = Polyethylene-insulated wire**



## *Cable Type and Repeater Spacing*

The equipment has been designed for operation on two unloaded symmetric pairs. The wire pairs — paper-insulated as well as plastic-insulated — can have diameters varying between 0.5 and 1.4 mm. The pairs can be located in the same or in separate twin cables or multiple-twin quad cables.

The maximum repeater spacing, corresponding to 35 dB attenuation of the line signal at 1 MHz, is a function of the wire diameter, the capacitance and insulation material in the transmission cable employed. This is illustrated in fig. 5. The dependent repeater next to the exchange, however, should normally be located at a distance equalling half the nominal repeater spacing, which reduces the effect of exchange relay noise.

## *Power Feeding*

As previously mentioned, each digital section is self-supporting as regards the power feeding of all the repeaters of the section. The repeaters are power fed in series over the phantom circuit, as shown in fig. 2, from power feeding units located at one or both of the line terminals of the section. Fig. 1 illustrates how longer connections can be divided into several power sections, each comprising 7 to 8 dependent repeater stations. If required, an intermediate power section can be power fed via a separate pair in the cable from an additional power feeding unit at one of the line terminals.

The power feeding unit provides a 48 mA constant-current d.c. supply for voltages up to ± 106 volts balanced to earth. The voltage drop in cable and repeaters limits the distance between power feeding stations to 25—50 km when transmitting over pairs having 0.6—1.0 mm conductors.

To prevent injuries to maintenance staff carrying out cable work, the power feeding unit has been fitted with facilities which automatically limit the voltage supplied to a maximum of 275 volts under normal operating conditions and to a maximum open-circuit voltage of 6 volts in case of a cable break. In addition, switches are provided to connect outgoing branches to earth, thereby reducing the risk of induced voltages interfering with fault-location work on the cable.

## *Power Supply*

The line terminating equipment can be strapped to permit operation from station batteries having nominal voltages of 24 to 60 volts. Alternatively, the equipment can operate from mains supplies of 110, 127 or 220 volts when using a mains supply unit common to the whole bay.

## *Overvoltage Protection*

To protect the line terminating and dependent repeater equipment against overvoltages induced from lightning and power distributing networks, exposed apparatus units have been provided with built-in diode protectors. Where exceptionally high disturbing voltages are encountered, the standard protection can easily be supplemented with gas-filled discharge tubes. These can be plugged into holders included in the standard equipment.

## *Fault-Location and Speaker Equipment*

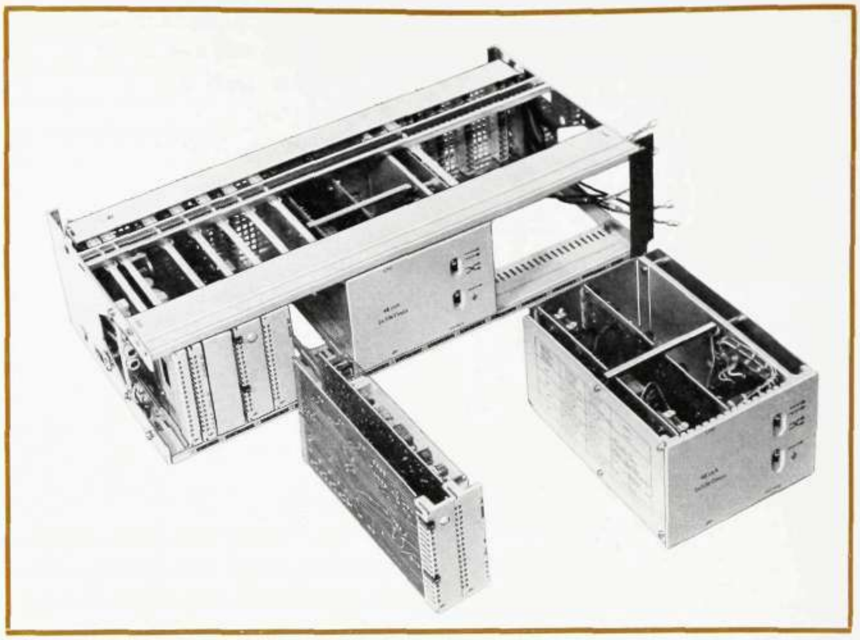
- To facilitate supervision and fault location, the equipment has been provided with a number of measuring points on the apparatus fronts for connection to portable instruments. The *transmission performance* of the digital link can be checked without interrupting traffic by means of a portable and easily operated signal and error detector with a counter as well as with an oscilloscope, which are connected to external measuring points on regenerative repeaters in terminal and intermediate repeater stations.

- In the event of an *excessive pulse error rate* an alarm is given by the receiving multiplex terminal. If the fault is traceable to one of the regenerative repeaters on the link (in a terminal or intermediate repeater station), the location of this repeater can be determined from the terminal repeater using a portable instrument. Normally, the supervision of the two directions of transmission requires both terminals to participate. However, provision has been made for remote repeater supervision from only one controlling station. During fault location the digital link is taken out of service and the repeaters on the link are tested in turn by means of an individually distinct pulse train for each repeater station. A return signal will be received from the repeater under test via a supervisory pair common to all the repeaters on the link. The level of the returned signal, which is compared with a reference value, permits the repeater performance to be assessed.

  The spectrum of the h.f. pulse train contains one out of 18 available v.f. components. If the repeater being tested functions correctly, the v.f. component will be transmitted by a band-pass filter in the repeater station concerned and passed on to the common loaded supervisory pair. For digital links involving more than 18 repeaters in series supervision can be arranged by using more than one supervisory pair.

Fig. 6

**Line terminating shelf equipped with a set of apparatus units for termination and power feeding of one system as well as a fault-location filter. In front of the shelf, *in extracted position*, a further set of units including power feeding**



- An *interruption of the power feeding loop* for the regenerative repeaters will produce an alarm at the power feeding terminal. The location of the break can be determined from this terminal with the aid of a portable indication instrument after reversal of the polarity of the power-feeding voltage. A current contribution is obtained from each repeater pair up to the break, the sum of these contributions indicating the location of the fault.

  The location method allows the same accuracy of measurement for all cable sections involved irrespective of the distance to the supervising station.

  A power failure alarm can be indicated as urgent or non-urgent, as desired. An alarm lamp is provided on a unit adjacent to the power feeding unit. Further alarm lamps are located at the top of the bay, from where the alarm can be extended to a central supervisory position or station.

  Also the voltage and current supplied by the power feeding unit can be measured by means of the indicating instrument, without interfering with service.

- For *communication between repeater stations* during installation and fault-location work, the equipment has been provided with facilities for setting up an omnibus speaker circuit on a loaded cable pair. At dependent repeater stations access to the speaker circuit is obtained by means of a portable telephone unit; the line terminals can be equipped with telephone units with pushbutton switches permitting selection between two speaker circuits.

## Mechanical Design
### *Line Terminating Equipment*

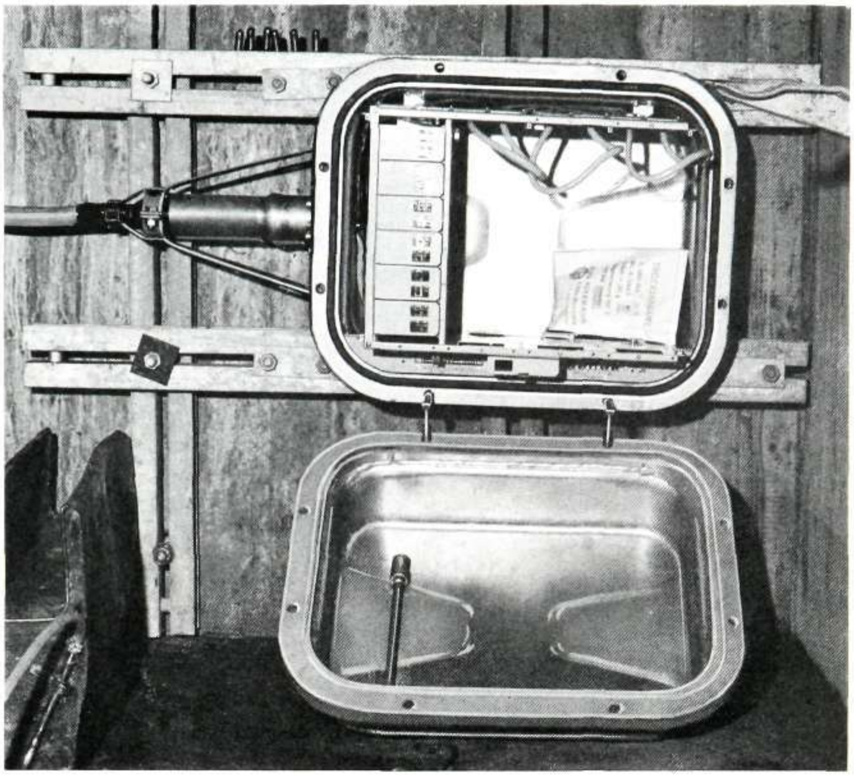
The line terminating repeater equipment is assembled into plug-in-type units accommodated in shelves for bay mounting.

For a description of the construction practice reference should be made to the article on PCM Multiplexing Equipment ZAK 30/32.[2]

To achieve a high degree of flexibility in station expansion, the line terminating equipment can alternatively be mounted in a ZAK 30/32 multiplex shelf stack or in a separate line terminating shelf. The shelf and shelf stack can be mounted in the same bay or in separate bays.

**Fig. 7**

**Dependent repeater housing for 24 systems mounted in a manhole and equipped with a shelf containing 6 two-way regenerative repeaters**



The line terminating shelf (see fig. 6) contains equipment for termination of two digital sections (60 circuits) including power feeding equipment and a fault-location filter.

The transmission cable is introduced into the shelf via a connecting unit with holders for plug-in overvoltage protectors. Parallel distribution of power to and alarms from different shelves is effected via bars in the right-hand bay upright.

The interconnection between p.c.m. multiplex and line terminating equipment is effected by means of coaxial U-links inserted in a panel in the left-hand bay upright or, in large-capacity stations, in a digital distribution frame.

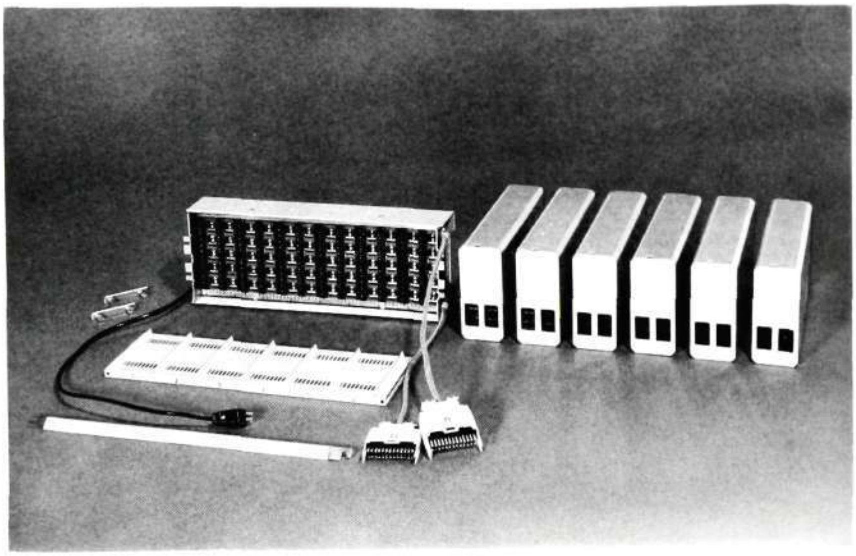
## *Dependent Repeater Equipment*

Regenerative repeaters can be accommodated in airtight containers for installation in manholes or direct burial in the ground. Two types of repeater housing are available, one accommodating up to 6 and the other up to 24 two-way regenerative repeaters as well as a fault-location filter. The repeaters are connected to the transmission cable via colour-coded polyethylene-insulated pairs in stub cables which can be provided with pneumatic resistors, thus permitting the repeater housings to be pressurized via the transmission cable. Fig. 7 shows a manhole containing a repeater housing for 24 systems. The housing mounts pre-wired shelves (see fig. 8), where a few strap connections at the time of installation make it possible to use identical regenerative repeaters that require no strapping. This arrangement permits simple and quick replacement of any defective repeater. The regenerative repeaters in a dependent repeater shelf can easily be looped or patched out for lining-up and fault tracing using cables fitted with plug-in-type connectors.

All apparatus units are of the plug-in type and enclosed in cases providing protection against rough handling in the field. Unused repeater positions can be equipped with loading-coil units for physical circuits, which permits maximum utilization of existing cable pairs.

Fig. 8

Construction details of repeater shelf and 6 two-way regenerative repeaters for installation in a dependent repeater housing. The shelf frame at the rear mounts socket strips and fuse strips with plug-in overvoltage protectors



## Maintenance

Routine maintenance has been reduced to a minimum; the regenerative repeaters are not affected by variations in the parameters of the transmission medium. No calibration in any form or other correction is therefore required.

In the event of an interruption of transmission caused by a cable fault, which is the commonest cause of failures, or in case of a repeater failure, the location of the fault can quickly be determined as previously described.

Provision is also made for supervision of cable breaks from a central supervisory position. Looping facilities and bridging test points are provided both in terminal and intermediate repeater equipments. Full interchangeability of regenerative repeaters providing automatic cable equalization without the need for strapping permits rapid and simple fault clearance.

## Technical Data

### *Electrical Data*

| *Line signal* | *DLI and DSI* | *LI* |
|---|---|---|
| Gross digit rate | 2.048 Mb/s | 2.048 Mb/s |
| Pulse amplitude | ±2.37 V | ±3.0 V |
| Impedance | 75 ohms unbal. | 120 ± 30 ohms bal. |
| Pulse pattern | bipolar | bipolar |
| Line codes | HDB 3 or AMI | |
| *Regenerative repeaters* | | |
| Range of automatic cable equalization | 0—35 (0—37) dB at 1 MHz | |
| Feeding voltage per 1-way repeater | 10.6 V at 48 mA | |
| *Power supply* | | |
| Primary power source: | | |
| Battery | 24, 36, 48 or 60 V d.c. +20%, —15% | |
| or | | |
| Mains 48—65 Hz | 110, 127 or 220 V a.c. ± 10% | |
| Power feeding of regenerative repeaters | | |
| Nominal, constant current | 48 mA d.c. | |
| Total feeding voltage | max. ± 106 V bal. d.c. | |

## *Mechanical Data*

### *Terminal Repeater Station*

Line terminating shelf, complete for termination of two digital links, including one fault-location filter.

| | |
|---|---|
| Height | 120 mm |
| Width | 480 mm |
| Depth | 236 mm |
| Weight | c. 3 kg |

Bay including alarm and speaker equipment

| | | |
|---|---|---|
| Height | (20 line terminating shelves) | 2743 mm |
| alt. | (16 line terminating shelves) | 2143 mm |
| alt. | ( 6 line terminating shelves, wall mounting) | 835 mm |
| Width | | 600 mm |
| Depth | | 240 mm |

### *Dependent Repeater Station*

| | Large | Small |
|---|---|---|
| Number of 2-way regenerative repeaters | 24 | 6 |
| Number of circuits | 720 | 180 |
| Number of fault-location filters | 1 | 1 |
| Housing dimensions | | |
| Height | 315 mm | 310 mm |
| Width | 480 mm | 280 mm |
| Length | 610 mm | 430 mm |
| Length of stub cable | 5 m (12 m) | 5 m (12 m) |
| Weight | c. 66 kg | c. 30 kg |

## *Environmental Conditions*

| | |
|---|---|
| Ambient temperature range | |
| Line terminal | +10°C to +40°C |
| Regenerative repeaters in dependent repeater housing | —30°C to +70°C |
| Humidity | |
| Line terminal | up to 90% |
| Dependent repeater stations | up to 100% |

## References

1. WIDL, W.: *PCM Transmission*. Ericsson Rev. *49*(1972): 1, pp. 9—13.

2. LINDQUIST, S., FRIZLEN, H. J. & CARLSSON, J. A.: *PCM Multiplexing Equipment ZAK 30/32*. Ericsson Rev. *49*(1972): 2, pp. 34—46.

# Pushbutton Unit for Electronic Dial Pulsing

G. WIKLUND, TELEFONAKTIEBOLAGET L M ERICSSON, STOCKHOLM

UDC 621.395.652:
621.395.636
LME 8223
8311
8329

*Telephone sets for pushbutton dialling have been dealt with in an earlier number of Ericsson Review*[1]*, which also discussed the technical requirements for introduction of v.f. code signalling.*

*The advantages of v.f. code signalling for the subscribers are considerable and pushbutton dialling has extended as quickly as the technical facilities have permitted.*

*In view of the increased demand for pushbutton telephones from subscribers in areas with conventional switching technique, L M Ericsson have developed a pushbutton unit with a built-in buffer store and counter. Pushbutton telephones can thus be allotted to subscribers who so desire before the exchanges have been converted for v.f. code signalling.*

## Introduction

With a pushbutton unit for electronic dial pulsing the convenience of pushbutton dialling can be combined with the simple switching equipment required for conventional dialling. No investments or alterations need be made in the existing exchange and the telephone administration can therefore offer its subscribers a pushbutton dialling service by installing a DIALOG telephone with the dial replaced by a pushbutton unit for transmission of dial pulses. L M Ericsson are working on adaptation of the loudspeaking ERICOVOX telephone for the same purpose. Pushbutton telephones for dial pulsing as well as rotary dial telephones can be connected at will to the same circuit.

## Design Features

Both the external design of the telephone set and its transmission circuit are the same as for the conventional DIALOG.

The mechanical design of the pushbutton unit is identical to that of the standardized type for v.f. code signalling[1]. The eleventh and twelfth buttons, however, are eliminated as, with a pushbutton unit for dial pulsing, there is no need for a signalling code other than that used for conventional dialling.

The electronics of the pushbutton unit for conversion of decimal to binary information, storage, decoding and transmission of dial pulses, is placed on a printed circuit board and consists of:

| | |
|---|---|
| *Clock pulse generator* | for control of logic circuits |
| *Code converter* | for feed of the binary code to the store |

**Fig. 1**

**DIALOG with pushbutton unit for electronic dial pulsing**

**Fig. 2**

**ERICOVOX with pushbutton unit for electronic dial pulsing**

| | |
|---|---|
| *Store* | four parallel dynamic shift registers of MOS type with storage of 20 bits per register. Two bits per register are required for indication of positions for start of digit transmission and digit sequence. The total storage capacity is thus 18 decimal digits |
| *Code converter* | for decimal output of the stored binary information |
| *Drive circuit* | for control of make and break contacts of the pulsing relay |
| *Feed circuit* | with battery for supply of the electronic circuits and pulsing relay circuits. |

## Switching Processes

The pulsing unit is connected on raising of the handset. The battery circuit is connected via a microswitch and the electronics unit sends a control pulse for clearing of the logic circuits and short-circuiting of the telephone transmission circuit. The short-circuit, which lasts for about 150 ms, ensures operation of the line relay.

When a button is pressed, a decimal digit is transmitted in binary form to the shift register store. On every depression of a button the common switch sends a start signal to initiate the storage process. The coded number is shifted through the registers, decoded and transmitted to the output unit, which controls the pulsing relay RLB among other items. During the transmission of pulses the short-circuiting contact RLA is closed. The transmission of pulses is blocked during the interdigital pause and the digital input is thus cycled continuously through the shift register. Through the special marking code $\alpha$ and $\beta$, the next digit to be transmitted is located and the input information is placed in the correct sequence.

The electronic dial unit can be strapped for a dialling frequency of 10 or 20 Hz and for the most common break ratio. The interdigital pause can be strapped for 400 or 800 ms and, at 20 Hz, for 200 ms.

Both the electronic circuits and the short-circuiting and pulsing relays require a reliable and stable supply. The telephone set, therefore, has a built-in

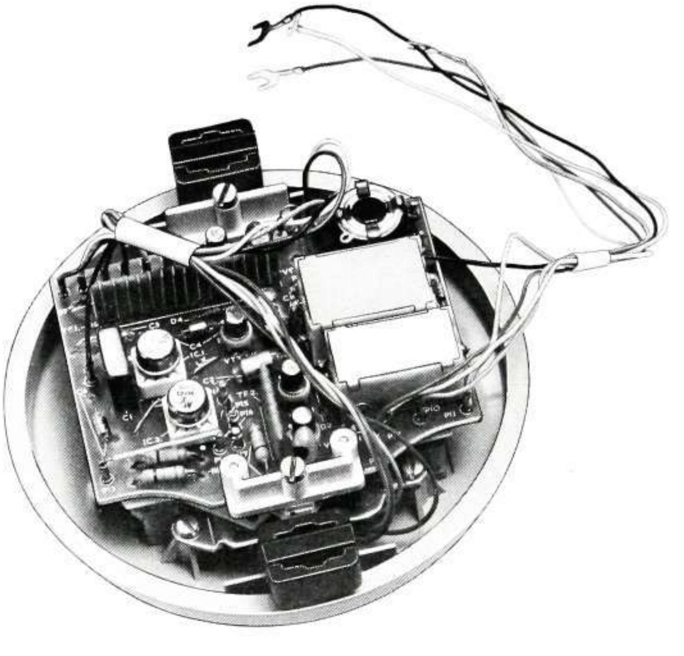


**Fig. 3**

**Pushbutton unit with electronics**

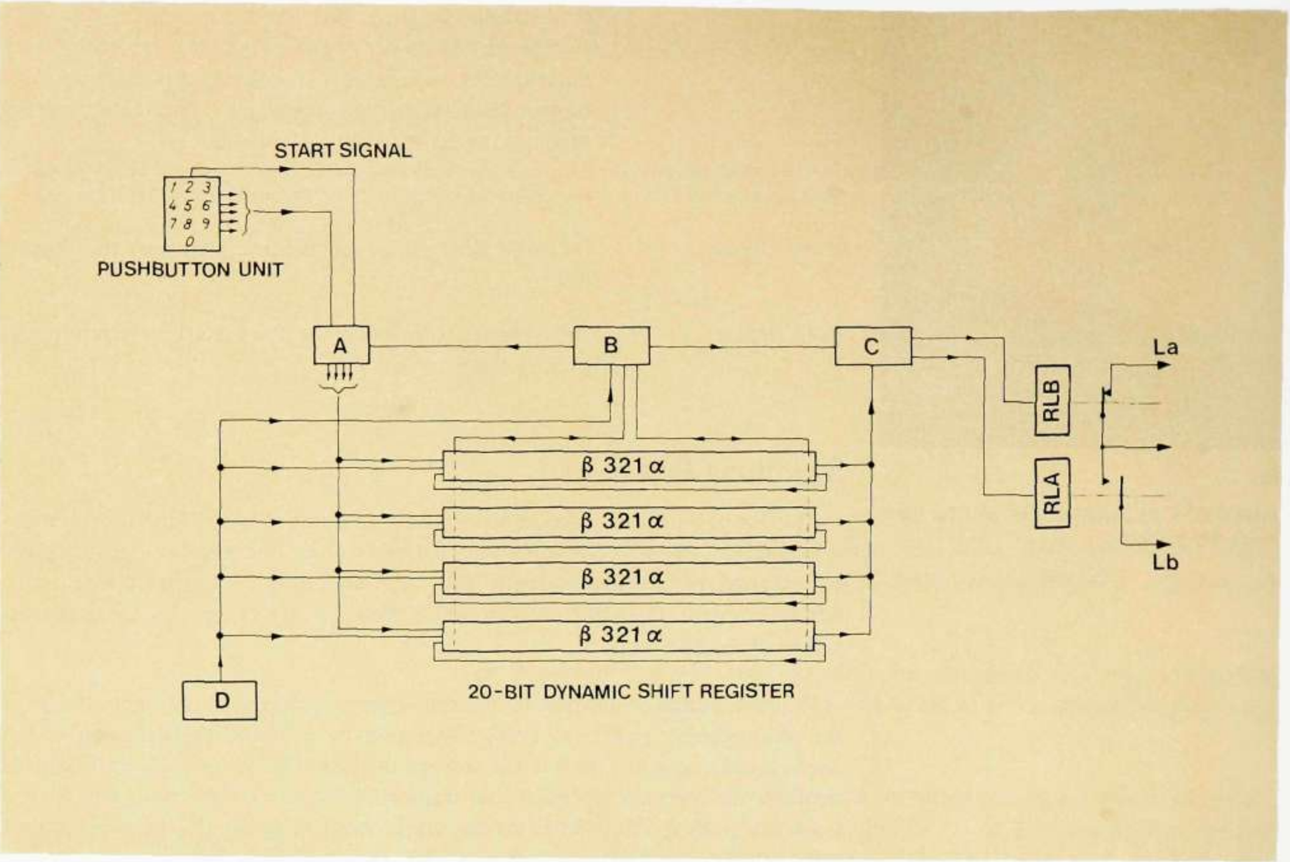


**Fig. 4**

**Block schematic for MOS circuits and digit transmission**

| | |
|---|---|
| **A** | **Conversion and input unit** |
| **B** | **Control logic** |
| **C** | **Output and relay control unit** |
| **D** | **Clock pulse generator** |
| **RLA** | **Relay for short-circuiting of the transmission circuit of the telephone set** |
| **RLB** | **Pulsing relay** |
| α | **Indication of position for start of digit transmission** |
| **1, 2, 3** | **Digital information stored in the memory (max. 18 digits)** |
| β | **Indication of position for next digit** |

Ni-Cd battery, which is charged from the exchange as soon as the handset is raised. The battery is rated for 5.0 V and its capacity is 150 mAh, which theoretically corresponds to about 3000 keying operations without interruption for conversation. In practice the battery is charged both during the period of waiting for final connection and during conversation. The energy used for a 6-digit subscriber's number is replaced within 52 s at a charging current of 10 mA from the exchange during conversation. Through the use of a rectifier bridge the charge is unaffected by the polarity of the circuit.

## Time Process

In a register-controlled system the setting-up of a connection may be divided into two phases. The first phase consists of dialling and transmission of the pulses corresponding to the digit dialled. The second phase consists of setting-up of switching devices.

The average time taken to dial a digit of a subscriber's number is 550 ms with a dial adjusted to 100 ms/pulse. To this time must be added the inter-digital pause and, with conventional dialling, also the time taken to rotate the dial to the finger-stop and the subscriber's reaction time.

As the digital information from pressure of a pushbutton reaches the store within 1 ms, the subscriber can key the entire number without intermission. The transmission of the information starts practically immediately and continues as long as the information exists in the store. The subscriber's reaction time on dialling of each individual digit will therefore have no significance.

Below is shown a time comparison (in seconds) between pushbutton dialling and conventional dialling of a 6-digit number.

| | *Pushbutton dialling* | *Conventional dialling* |
|---|---|---|
| Subscriber's reaction time before dialling a digit | 2.0 | 2.0 |
| Dial rotation time and reaction time | 0 | 3.3 |
| Pulsing time | 3.3 | 3.3 |
| Interdigital pause | 2.4 | 2.4 |
| Total | 7.7 | 11.0 |

*Switching times in crossbar system*

| | |
|---|---|
| Setting-up of I-GV | 0.7 |
| Setting-up of II-GV | 0.7 |
| Setting-up of SL | 1.1 |
| Through-connection | 0.6 |
| Total | 3.1 |

During the setting-up of the connection expensive common equipment in the exchange is connected to the individual subscriber's line. With electronic dial pulsing the time of occupation of this equipment is reduced by more than 20%.

## Reference

1. Billing, R.: *Keyset for Telephone with V. F. Code Signalling*. Ericsson Rev. *46*(1969): 2, pp. 49—58.

# Pushbutton Dialling —
## Human Reaction to Geometry of Pushbutton Sets and Force-Displacement Characteristic of Buttons

S. E. MAGNUSSON & K. L. JOHANSSON, TELEFONAKTIEBOLAGET L M ERICSSON, STOCKHOLM

UDC 621.395.631.1
65.015.11
LME 8223 1023

*According to previous public opinion polls the majority of subscribers seem to prefer pushbuttons to a dial. It has also been shown that dialling is very much quicker with pushbuttons than with a conventional dial. It remains, then, to decide on the optimal dimensioning of a pushbutton set on the basis of human reactions and signalling conditions.*

*An account is here presented of the investigation which formed the basis for the dimensioning of the buttons, the distance between buttons, and their force-displacement characteristic, in the pushbutton set developed by L M Ericsson for desk telephones. By means of interviews the optimal size of buttons and the distance between them, and the preference for one of two force-displacement characteristics, were established. The signalling results from the two pushbutton sets with different force-displacement characteristics were compared, and it was found that the set preferred by the subjects interviewed also gave the best signalling result.*

*The findings from the investigation have been used in the design of the telephone pushbutton set described in Ericsson Review No. 2/1969.*[1]

## Size of Buttons and Distance between Them

Ten pushbutton sets, *A, B, C, D, E, F, G, H, I* and *J*, each with 12 buttons, in 3×4 pattern, were mounted in conventional desk telephones (fig. 1). The dimensions of the buttons and the distances between them will be seen from table 1.

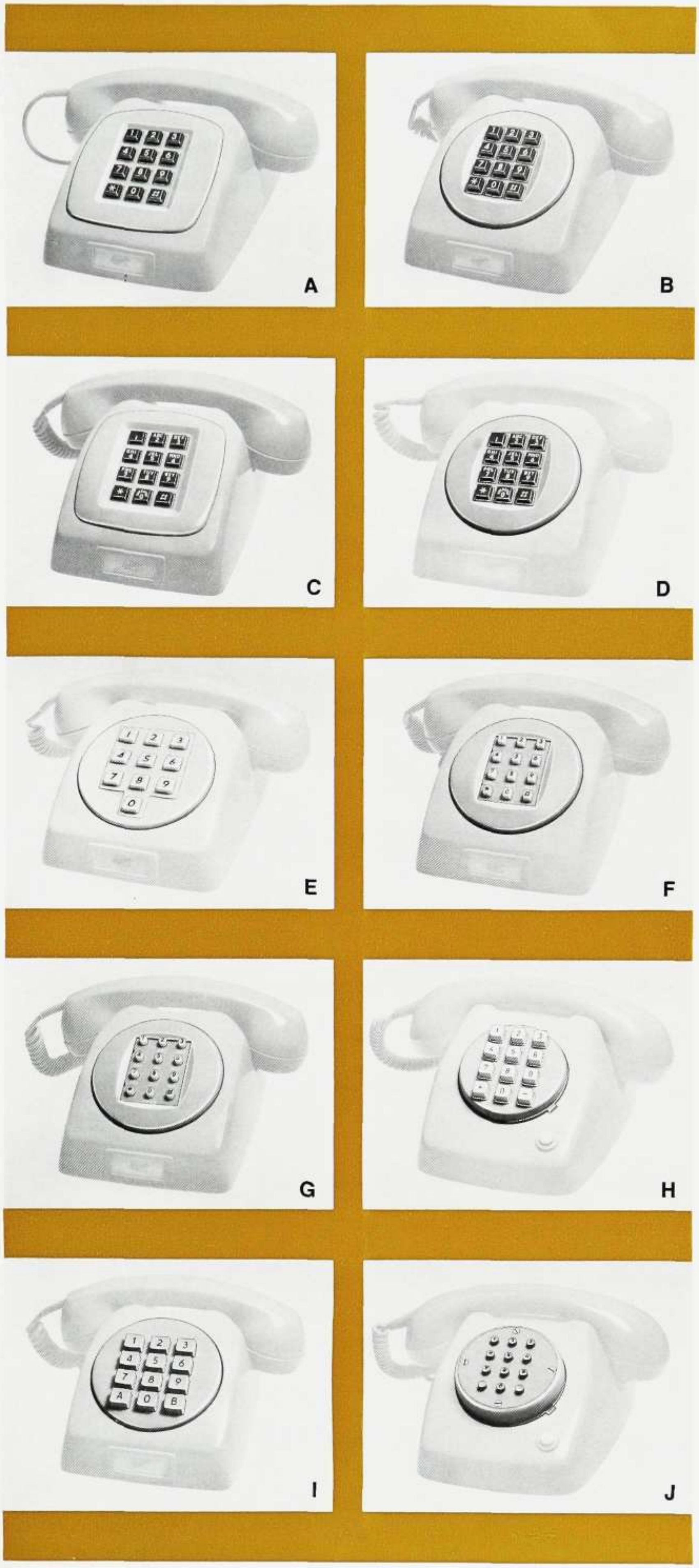
Forty-five employees of L M Ericsson were interviewed, 15 of whom were women engaged on general office tasks, 15 men from technical departments, and 15 men from sales departments.

**Table 1**

| Tel. | Distance between buttons mm | | Button size (top surface) mm | | Button travel |
|---|---|---|---|---|---|
| | Hor. | Vert. | Hor. | Vert. | mm |
| *A* | 16.8 | 16.8 | 9 | 7.5 | 3.2 |
| *B* | 15.5 | 15.5 | 9 | 7.5 | 3.2 |
| *C* | 16.8 | 16.8 | 11 | 9.6 | 3.2 |
| *D* | 15.5 | 15.5 | 11 | 9.6 | 3.2 |
| *E* | 19.7 | 19.7 | 12 | 12 | 2.5 |
| *F* | 15.5 | 15.5 | 6 | 6 | 3.2 |
| *G* | 15.5 | 15.5 | ø 6 | ø 6 | 3.2 |
| *H* | 17 | 17 | 10 | 10 | 5.0 |
| *I* | 21 | 17 | 14.8 | 12.8 | 5.0 |
| *J* | 14 | 14 | ø 6 | ø 6 | 3.2 |

**Fig. 1**

**The ten pushbutton sets used for the investigation of size, placing etc. of the buttons**



The following questionnaire was answered concerning the 10 pushbutton sets.

We need your help in judging ten different pushbutton telephones.

For every telephone please carry out the following three actions:

Action 1. Take a good look at the telephone set (its appearance).

Action 2. Key the following numbers. Wait about 10 seconds between each two numbers.

8 3 9 4 1 2
7 1 2 8 0 0 5
1 0 2 7 5
0 7 1 0—4 5 1 3 8 6
3 9 6 2 8 1
0 0 9 4 7—3 1 9 2 8 1 7 3
5 7 1 1 8

Action 3. Assign scores as stated under 3.1—3.4.

3.1 Grade the appearance using the scale 0—4, where 4 = *very good* and 0 = *very bad*. Decimals may be used.

| Tel. | *A* | *B* | *C* | *D* | *E* | *F* | *G* | *H* | *I* | *J* |
|---|---|---|---|---|---|---|---|---|---|---|
| Score | | | | | | | | | | |

3.2 Grade your impression how it feels to push the buttons, using the scale 0—4, where 4 = *very good* and 0 = *very bad*. Decimals may be used.

| Tel. | *A* | *B* | *C* | *D* | *E* | *F* | *G* | *H* | *I* | *J* |
|---|---|---|---|---|---|---|---|---|---|---|
| Score | | | | | | | | | | |

3.3 Is the distance between the buttons (mark with a cross)

| Tel. | too small | just right | too large |
|---|---|---|---|
| *A* | | | |
| *B* | | | |
| *C* | | | |
| *D* | | | |
| *E* | | | |
| *F* | | | |
| *G* | | | |
| *H* | | | |
| *I* | | | |
| *J* | | | |

3.4 Is the size of buttons (mark with a cross)

| Tel. | too small | just right | too large |
|---|---|---|---|
| *A* | | | |
| *B* | | | |
| *C* | | | |
| *D* | | | |
| *E* | | | |
| *F* | | | |
| *G* | | | |
| *H* | | | |
| *I* | | | |
| *J* | | | |

Action 2 was introduced in order to stimulate the subjects as far as possible to test the pushbutton sets in a normal manner before expressing an opinion.

None of the subjects had had special training on a calculator or the like.

Only one telephone was presented to each subject at a time. In order as far as possible to avoid systematic trends, the order of sequence in which the telephones were presented to each subject was chosen at random.

## Results

### *Appearance and Function*

Fig. 2 shows a graphic representation of the mean opinion scores.

The question concerning the appearance of the telephone set was intended chiefly to test the aesthetic impression of different pushbutton sets in a telephone. As the casing and handset of telephones *H* and *J* differed from the others, which may have affected the opinion, the scores for these two telephones in respect of appearance were not recorded.

### *Size of Buttons and Distance between Them*

The percentages of subjects who judged the dimensions of the buttons and the distances between them to be "too small", "just right" and "too large" will be seen from table 2.

## Discussion

From fig. 2 it will be seen that pushbutton sets *A*, *B*, *C*, *D* and *E* were considered to be of most favourable appearance.

As regards function, pushbutton sets *A*, *B*, *C* and *D* were considered best.

**Fig. 2. Graphic representation of mean values of scores in respect of appearance and function of the pushbutton sets.**

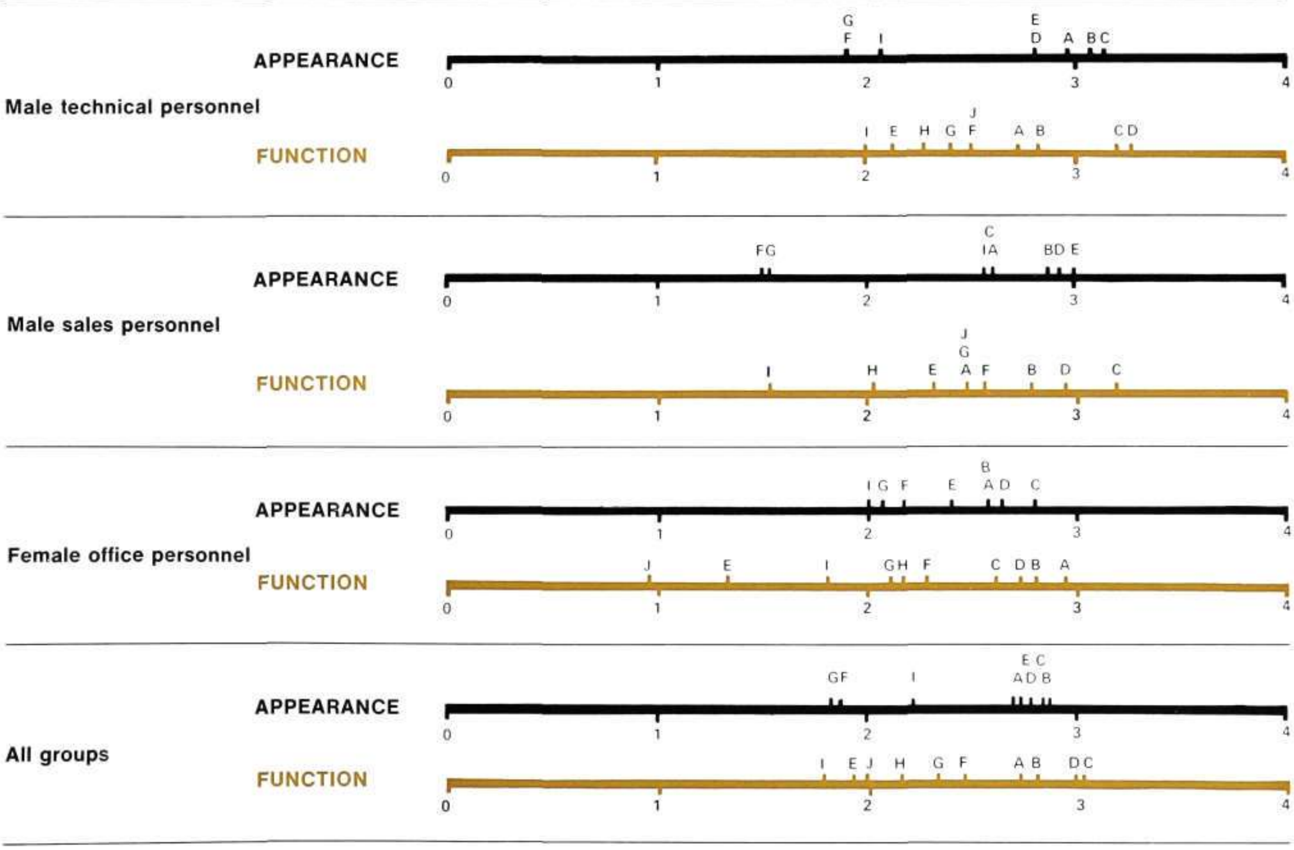


Table 2

| | Opinions on *distance* between buttons, % | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Too small | | | | Just right | | | | Too large | | | |
| Tel. | 15 Male technical personnel | 15 Male sales personnel | 15 Female office personnel | 45 All grps | 15 Male technical personnel | 15 Male sales personnel | 15 Female office personnel | 45 All grps | 15 Male technical personnel | 15 Male sales personnel | 15 Female office personnel | 45 All grps |
| *A* | 27 | 7 | 27 | 20 | 73 | 93 | 60 | 76 | 0 | 0 | 13 | 4 |
| *B* | 47 | 33 | 53 | 44 | 53 | 67 | 47 | 56 | 0 | 0 | 0 | 0 |
| *C* | 33 | 7 | 33 | 24 | 67 | 93 | 67 | 76 | 0 | 0 | 0 | 0 |
| *D* | 67 | 47 | 60 | 58 | 33 | 53 | 40 | 42 | 0 | 0 | 0 | 0 |
| *E* | 0 | 0 | 7 | 2 | 67 | 60 | 53 | 60 | 33 | 40 | 40 | 38 |
| *F* | 0 | 0 | 13 | 4 | 87 | 80 | 74 | 80 | 13 | 20 | 13 | 16 |
| *G* | 6 | 0 | 7 | 5 | 87 | 87 | 73 | 82 | 7 | 13 | 20 | 13 |
| *H* | 20 | 7 | 13 | 13 | 80 | 87 | 87 | 85 | 0 | 6 | 0 | 2 |
| *I* | 20 | 7 | 13 | 13 | 60 | 53 | 87 | 67 | 20 | 40 | 0 | 20 |
| *J* | 0 | 27 | 33 | 20 | 100 | 60 | 54 | 71 | 0 | 13 | 13 | 9 |
| | Opinions on *size* of buttons, % | | | | | | | | | | | |
| | Too small | | | | Just right | | | | Too large | | | |
| *A* | 13 | 20 | 20 | 18 | 87 | 80 | 80 | 82 | 0 | 0 | 0 | 0 |
| *B* | 13 | 20 | 13 | 16 | 87 | 80 | 87 | 84 | 0 | 0 | 0 | 0 |
| *C* | 7 | 7 | 7 | 7 | 93 | 93 | 80 | 89 | 0 | 0 | 13 | 4 |
| *D* | 7 | 13 | 13 | 11 | 93 | 87 | 80 | 87 | 0 | 0 | 7 | 2 |
| *E* | 7 | 7 | 0 | 4 | 73 | 87 | 80 | 80 | 20 | 6 | 20 | 16 |
| *F* | 67 | 73 | 80 | 73 | 33 | 20 | 20 | 25 | 0 | 7 | 0 | 2 |
| *G* | 87 | 80 | 87 | 84 | 13 | 20 | 13 | 16 | 0 | 0 | 0 | 0 |
| *H* | 0 | 13 | 27 | 13 | 100 | 87 | 73 | 87 | 0 | 0 | 0 | 0 |
| *I* | 0 | 0 | 0 | 0 | 33 | 27 | 60 | 40 | 67 | 73 | 40 | 60 |
| *J* | 87 | 100 | 100 | 96 | 13 | 0 | 0 | 4 | 0 | 0 | 0 | 0 |

A certain correlation in the scores would appear to exist between the size of buttons and the distance between them, as appears also from table 2. Table 2 shows that the following figures appear to be optimal:

☐ In view of the preferred size of button the distance from the centre of a button to the centre of an adjacent button should be approx. 17 mm both horizontally and vertically.

☐ Size of button 9—11 mm horizontally and 7.5—10 mm vertically.

Of the pushbutton sets investigated, *A*, *C* and *H* lie within the optimal range. Among sets *A*, *C* and *H*, *A* has the smallest buttons (9×7.5 mm) and therefore the largest distance between buttons. A larger distance would presumably reduce the risk of unintentional actuation of adjacent buttons. As the opinions on set *A* had throughout been favourable, and as—within the range of the preferred dimensions—this set may be expected to give rise to the least number of errors due to simultaneous pushing of two buttons, it was selected for further investigation in respect of force-displacement characteristic.

*Note.* As regards button travel, earlier investigations by, for example, *R. L. Deininger*, *K. Tajima* and *H. Nakazawa* have indicated an optimum around 3 mm.

## Pressure Characteristic

Two pushbutton sets *A1* and *A2*, exactly similar to *A* above but with different force-displacement characteristic, were investigated. The sets were mounted in conventional desk telephones. *A1* had a virtually linear force-displacement characteristic while *A2* had a tactile breakthrough characteristic as shown in fig. 3.

Fifty LME employees gave their opinion on the operation of the two pushbutton sets, and their signalling results were measured and examined. Each subject was asked to key 15 listed 7-digit telephone numbers. The digits were grouped on the principle used in the Swedish telephone directory for the local area in which the subjects have their daily work (xxx xx xx). Each subject completed the entire test for one pushbutton set at a time, and the order of sequence for the pushbutton sets was changed for each new subject.

For the last ten numbers on the list the signalling time for each digit and the pause between each two digits was measured. The number of errors in keying was also recorded.

Each subject stated which pushbutton set he or she preferred.

During the entire test, including answering of the questionnaire, the subjects were ignorant of their previous signalling results.

## Results

The mean time and standard deviation ($\sigma$) for all subjects and for each digit and pause will be seen from fig. 4.

As might be expected, the length of pause, and to some extent also the length of signal, is dependent on the position of the digit in the seven-digit

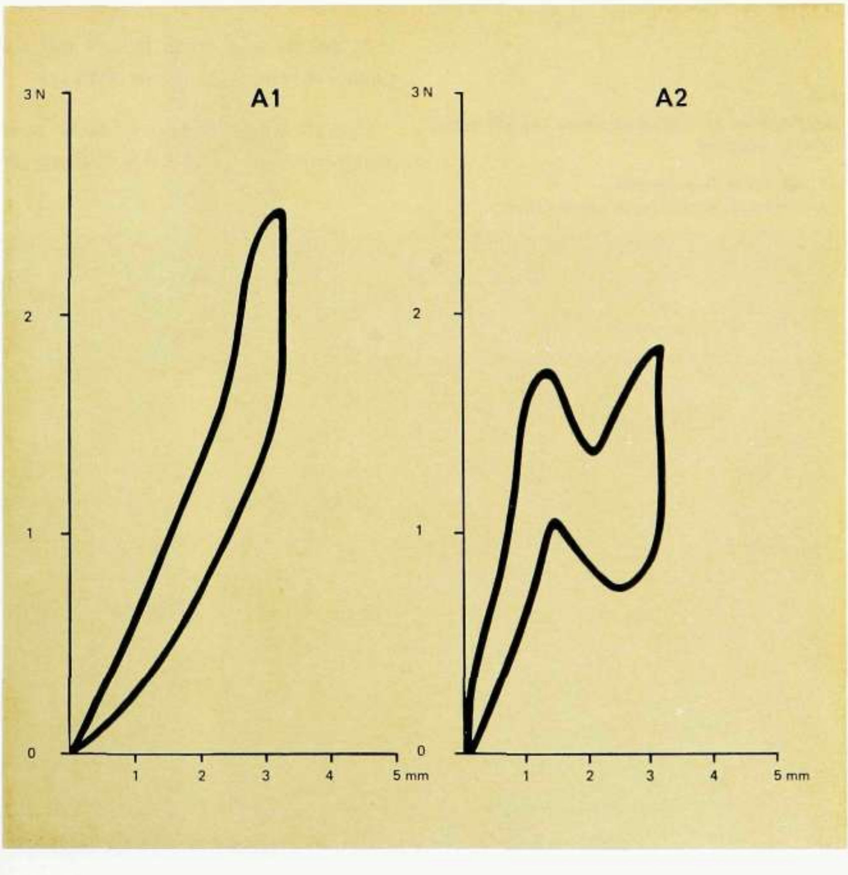


**Fig. 3**
**Force-displacement characteristic**

**The difference in the maximum pressure required is due to design reasons, in order to produce the same electrical contact pressure in both cases.**

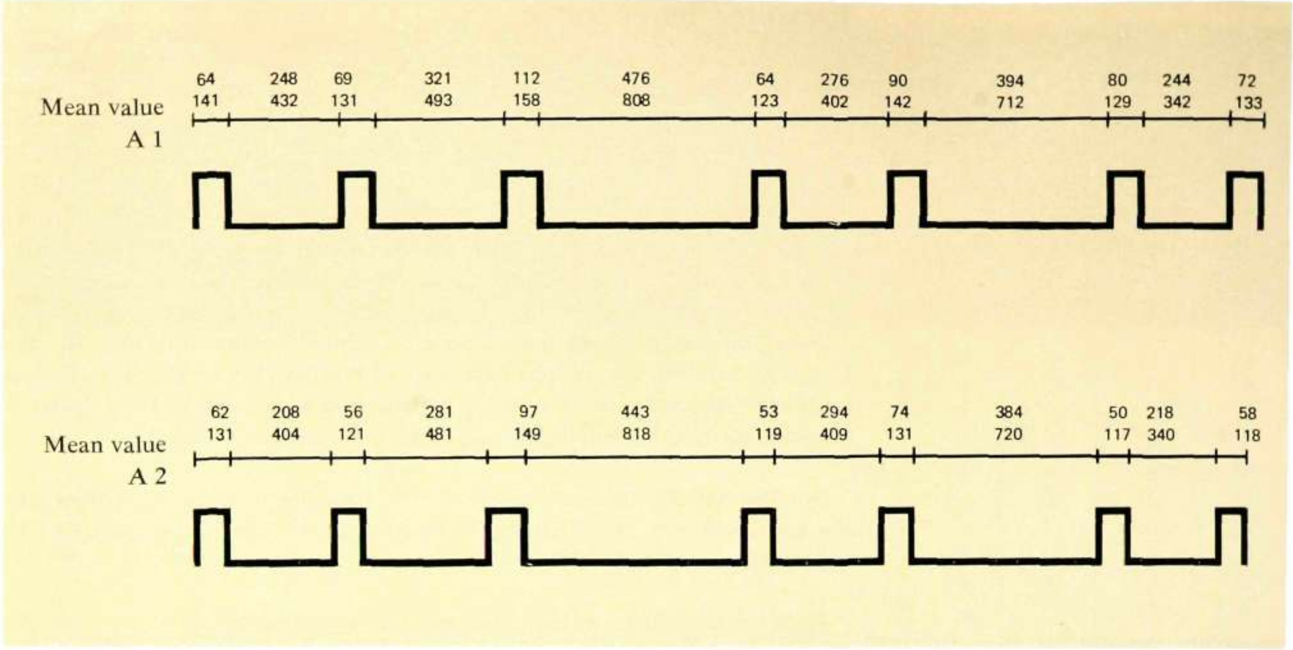


**Fig. 4**

**Mean value and standard deviation for all subjects**

All times in ms

number. Histograms of the signalling times for all subjects and for all digits were drawn up (fig. 5).

As will be seen from fig. 4 and 5, with pushbutton set *A2* the signalling times were rather shorter and there was less standard deviation (σ) than with *A1* (significant at 10 % level). There were also less signalling times below 40 ms for *A2* than for *A1*.

For further investigation of these conditions, histograms of signalling times for the, on average, 10 % quickest and 10 % slowest subjects, respectively, were drawn up (fig. 6).

It will be seen from figs. 5 and 6 that pushbutton set *A2* gives rise to fewer signals shorter than 40 ms than *A1*.

For all subjects (fig. 5) there were 1.4 % signals shorter than 40 ms from pushbutton set *A1* and 0.6 % from set *A2*.

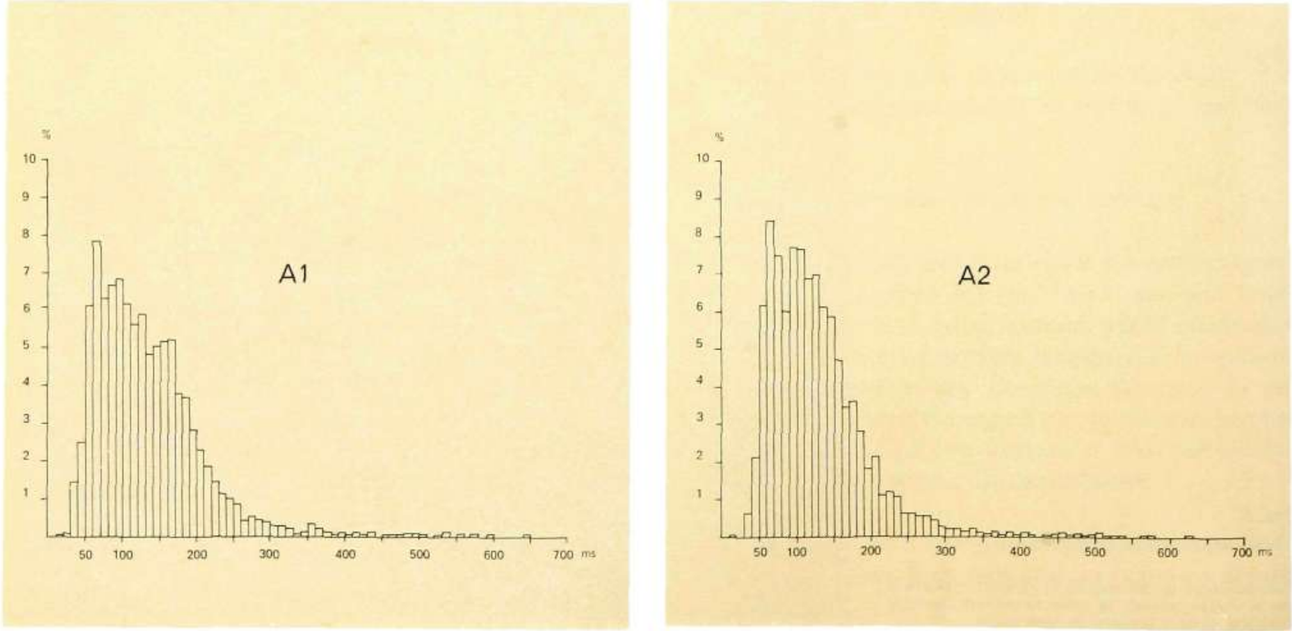


**Fig. 5**

**Distribution of signalling times for all digits lumped together**

A1 with linear characteristic
A2 with tactile breakthrough characteristic

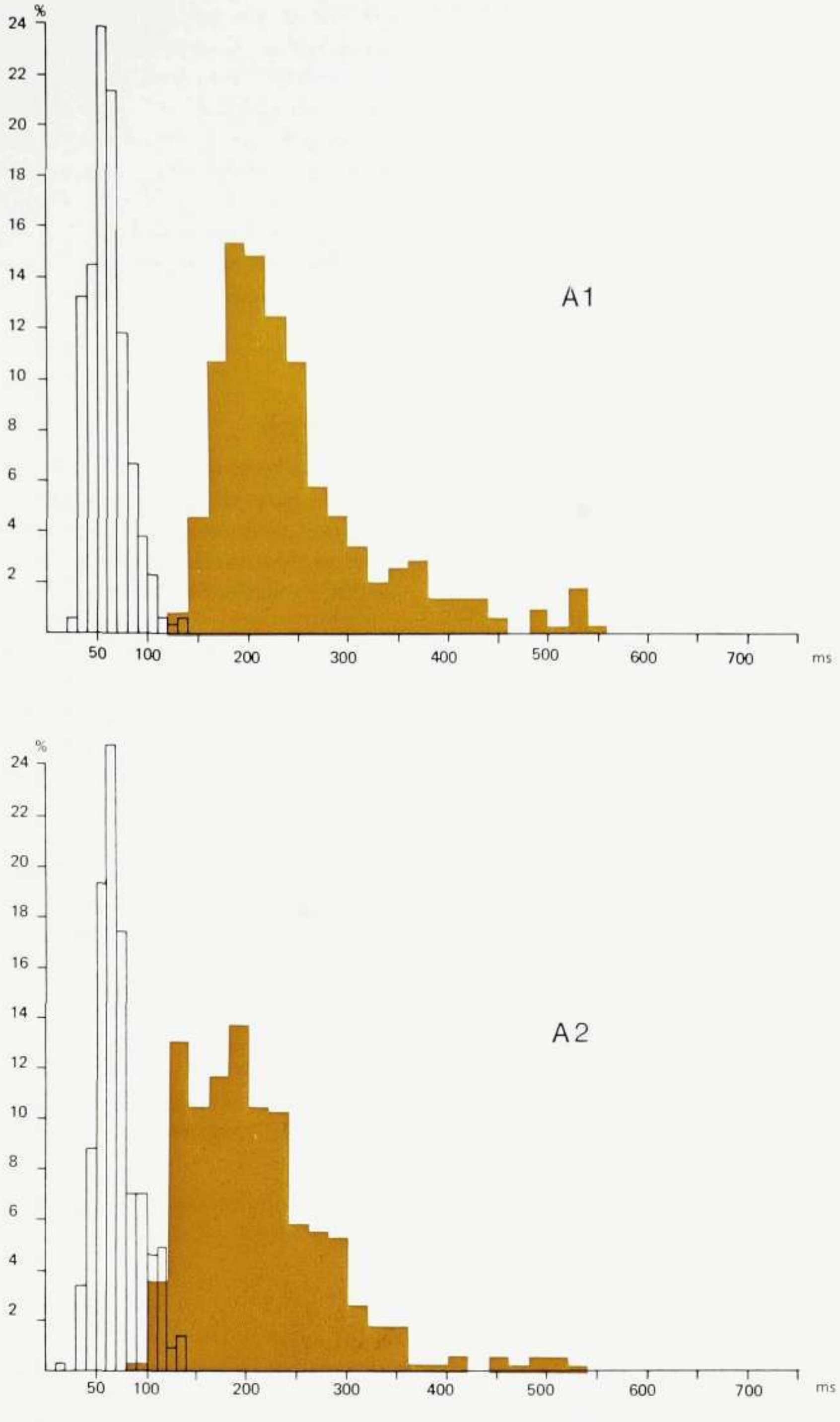


**Fig. 6**
**Distribution of signalling times for all digits**

☐ **The 10% quickest subjects**

🟧 **The 10% slowest subjects**

For the, on average, 10 % quickest subjects (fig. 6) 14 % of the signals were shorter than 40 ms from pushbutton set *A1* and 4 % from set *A2*.

The number of errors due to absence of digit signal (button not fully pressed) was about 0.2 % of all digit signals for both pushbutton sets. Around 0.3 % wrong digits were recorded for both sets.

75 % of all subjects preferred pushbutton set *A2* to *A1*.

## Discussion

No difference in percentage error of keying was found between pushbutton sets *A1* and *A2*. This must be considered reasonable, since the two sets have the same size of buttons and the same distance between buttons.

On the other hand a not insignificant difference in signalling time with the two pushbutton sets is observable. Pushbutton set *A2*, with force-displacement characteristic of tactile breakthrough type gives rise to less standard deviation in signalling times and, in particular, fewer extremely short signalling times (below 40 ms) than *A1*. This result should be of value, as it is known from experience that signals shorter than 40 ms may be difficult to detect with certainty in the signal receiver, especially in data transmission.

Of special interest is that 75 % of the subjects, without a knowledge of their signalling results, preferred pushbutton set *A2*, with which they achieved the best signalling result.

## Summary

Ten pushbutton sets with different sizes of buttons and different distances between buttons, mounted in conventional desk telephones, were investigated by means of interviews. Three groups of 15 persons each were questioned. The optimal dimensions of buttons and the optimal distance between buttons as judged by subscribers can be derived from the results of the investigation.

Based on the optimal dimensions resulting from the investigation a comparison was made between a linear force-displacement characteristic and a characteristic of tactile breakthrough type. The latter gave rise to less standard deviation in the digit signalling times and to fewer extremely short signalling times, and was also preferred by 75 % of the subjects.

The design of L M Ericsson's new pushbutton set as regards the size of buttons and the distance between them, and the force-displacement characteristic and button travel, has been based on the results of this experiment and on known investigations of optimal button travel.

## References

1. BILLING, R.: *Keyset for Telephone with V. F. Code Signalling*. Ericsson Rev. *46*(1969): 2, pp. 49—58.

# ERICSSON News

## from All Quarters of the World

# Operations 1971

Consolidated net sales of the Ericsson Group during 1971 were 3,759 Mkr., an increase of 19% over 1970 sales (3,160 Mkr.).

Order bookings during 1971 totalled 4,294 Mkr., which exceeded by 14.4% the very high total attained during the preceding year (3,753 Mkr.), and the order backlog at the end of the year amounted to 4,099 Mkr. (3,611 Mkr.) — an increase of 13.5%.

Income before special adjustments and taxes was 477 Mkr., equal to 12.7% of sales. The corresponding figures for 1970 were 499 Mkr. and 15.8%. The decrease in income is entirely attributable to the foreign exchange losses due to devaluation of the US dollar in relation to the currencies of Japan and the West European countries. Since the parent company has substantial dollar receivables, the change in exchange rates affected earnings for the year. The subsidiaries in Latin America also suffered substantial foreign exchange losses, partly as a result of continuing internal devaluations, as in Brazil and Argentina, and partly because of the close link between these countries' currencies and the dollar. The foreign exchange losses amounted to 33.1 Mkr.

After special adjustments (160.7 Mkr.) and allocations to taxes, 144.6 (164.3) Mkr., and deduction of 39.2 (17.6) Mkr. representing minority interests in earnings, the reported net income for the Group was 132.3 (175.1) Mkr.

The decrease was due to the fact that special adjustments were made in larger amounts than in the preceding year (141.9 Mkr.) and to an increase in minority interests in earnings. This increase resulted partly from the favourable development of earnings in subsidiaries with substantial minority ownership and partly from the sale to the public during the year of 26% of the shares in the former wholly owned Brazilian subsidiary.

The Board's proposal concerning a dividend of Kr. 5.50 per share was approved by the Annual Meeting.

The orientation of the Group's business in recent years has been increasingly international. While the percentage of sales in Sweden has been decreasing, sharp growth has occurred in the industrialized countries of Western Europe and Latin America. The rate of growth in other parts of the world, taken as a whole, has been more moderate.

**Geographical distribution of order bookings in 1971 by main market areas**

| | Mkr. | % |
|---|---|---|
| Sweden | 863 | 20.1 |
| Europe (excluding Sweden) | 1,986 | 46.3 |
| Latin America | 933 | 21.7 |
| Australia, Asia and Africa | 445 | 10.4 |
| USA and Canada | 67 | 1.5 |
| | 4,294 | 100.0 |

A very considerable expansion of the Group's production capacity has taken place both in Sweden and abroad. Capital expenditures for property, plant and equipment thus rose during 1970 and 1971 to 273 and 402 Mkr. respectively, after having averaged 150 Mkr. annually during the preceding five-year period.

Production facilities completed by the Group during the year, including two large plants in Finland and Mexico, added 180,000 m² of factory and warehouse space, an increase of 20%.

Technical development work within the Ericsson Group has increased steadily and during the last decade has required a larger share of expanding resources than was the case earlier. The number of parent company employees involved in such work more than doubled during this period. Substantial additional space has been provided for technical offices and laboratories. Paralleling these trends, the subsidiaries have also been equipped with substantially increased technical resources.

Research and development in telecommunications is currently characterized by very large investments in the field of switching technique. Intensive work is on the way on the part of telecommunications administrations and manufacturers to evaluate the optimum technical and economic qualities for automatic telephone exchange systems of the future. This activity is affected both by the introduction of computer – control to handle the switching processes and by the increased use of digital transmission systems in telephone networks. It is likely that a number of different solutions will be offered and tested during the first half of the seventies but that the choice of systems will not occur until later.

The number of employees within the Group was 66,900, of whom 29,200 within Sweden.

From the signing of the contract between Companhia Telefônica Brasileira and Ericsson do Brasil. (Left) The Head of CTB, General Siqueira de Meneses, (right) Gunnar Vikberg, President of EDB.

# Important contract for LME in Brazil

L M Ericsson's Brazilian subsidiary, Ericsson do Brasil, has signed a contract with the largest Brazilian telephone company, Companhia Telefônica Brasileira (CTB), under which Ericsson do Brasil (EDB) will deliver substantial quantities of telephone exchange equipment for the extension of the telephone network of São Paulo. The contract covers deliveries during the period up to 1976 and comprises equipment for around 500,000 new subscriber lines. The Brazilian Minister of Communication, Col. Hygino Caetano Corsetti, denotes this as the most comprehensive contract ever concluded between two Brazilian enterprises.

Within the framework of this contract CTB have signed a delivery contract with Ericsson do Brasil covering telephone exchange equipment of L M Ericsson crossbar type to a value of 195 million kronor.

During the period up to 1976 CTB intend to bring about a very considerable expansion of the telephone network within their operating area. Up to one million new subscribers will be added to the company's network in the course of this expansion.

The contracted equipment will be manufactured at Ericsson do Brasil's factory at São Jose dos Campos outside São Paulo.

# Large order from British Post Office

During the period up to 1978 the British Post Office Corporation will invest nearly 500 million kronor in expansion of its equipment for automatic switching of international telephone traffic. This implies a fourfold increase of capacity.

Within the scope of the orders placed by the Post Office Corporation for this heavy expansion L M Ericsson have received an order, in the face of international competition, for equipment and installation of crossbar switching systems to a value of about 170 million kronor. The equipment to be delivered by L M Ericsson will be installed in London. The cut-over will take place in stages, starting during the latter part of 1974.

This order is one of the largest ever received by L M Ericsson for equipment for a single telephone exchange.

L M Ericsson's market in Great Britain has hitherto been limited to the private sector and during 1971 represented a value of around 40 million kronor.

## Norwegian Telecommunications Administration orders computer-controlled telephone exchange for Oslo

A/S Elektrisk Bureau, the Norwegian subsidiary of the Ericsson Group, have received an order for a computer-controlled telephone exchange of type AKE 13 from the Norwegian Telecommunications Administration. The value of the order is around 30 million kronor.

This will be the first public telephone exchange delivered by L M Ericsson to the Oslo area. It will be ready for putting into service during 1976.

The computer-controlled telephone exchange for Oslo will handle both national and international traffic. It will be of the same type as the exchange earlier delivered by L M Ericsson to Rotterdam and cut over at the end of last year. The AKE 13 system implies control of the switching network by a number of computers.

Earlier orders to L M Ericsson for computer-controlled telephone exchanges for national and international traffic have been received for Helsinki, Copenhagen and Stockholm.

## New intercom telephone

The front cover of the 1971 annual report (see page 69) shows a new intercom telephone, ERICOM 30001, developed by L M Ericsson Telemateriel AB. Marketing of this intercom will start this year. The telephone is designed both for loudspeaking and non-loudspeaking conversation. With the telephone placed on a desk one speaks in a microphone at the top and receives the answer from the loudspeaker at the bottom. If one raises the telephone to the ear the microphone and loudspeaker functions are switched over. The number is keyed on the keyset and, from the system point of view, the telephone forms part of L M Ericsson's normal series of switching systems for intercom telephones.

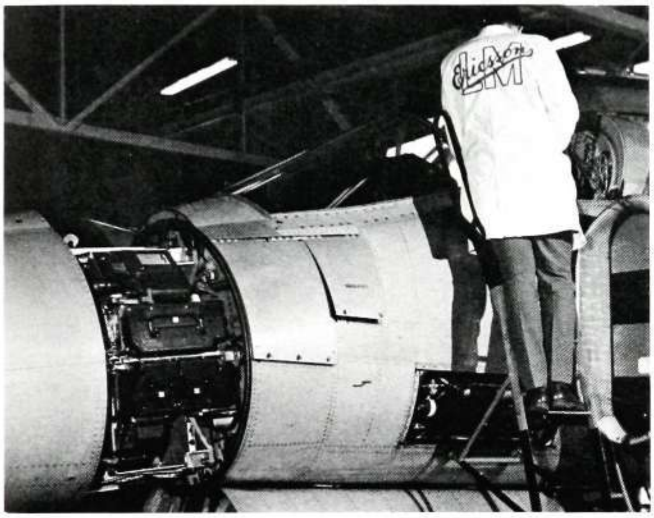
Increasing numbers of markets outside Sweden have started to accept the intercom telephone as the most rational method of internal communication. Of the total sales of intercom

*(cont. p. 72)*

In March L M Ericsson was visited by the Costa Rican Ambassador to Bonn, Sr. Manuel Blanco-Cervantes, and his son Sr. Jorge Blanco. Mr Gösta Lindström (left) shows a model of the Midsommarkransen plant.

In mid-April this year L M Ericsson was visited by the Tunisian Minister of Communications, Habib Ben Cheikh (centre). On his left, partly concealed, is Rune Häggö, head of LME's Technical Office in Tunis, Dr Chr. Jacobæus, Executive Vice President of LME, and (right) the Chief Engineer of the Tunisian PTT, Ben Lakhal Zouhir.

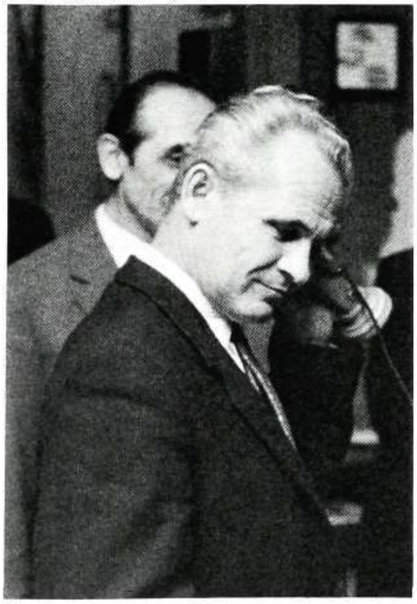
►



Delivery of the first fighter aircraft J73 "Viggen" took place in June 1971. The radar and display equipment was made by L M Ericsson.

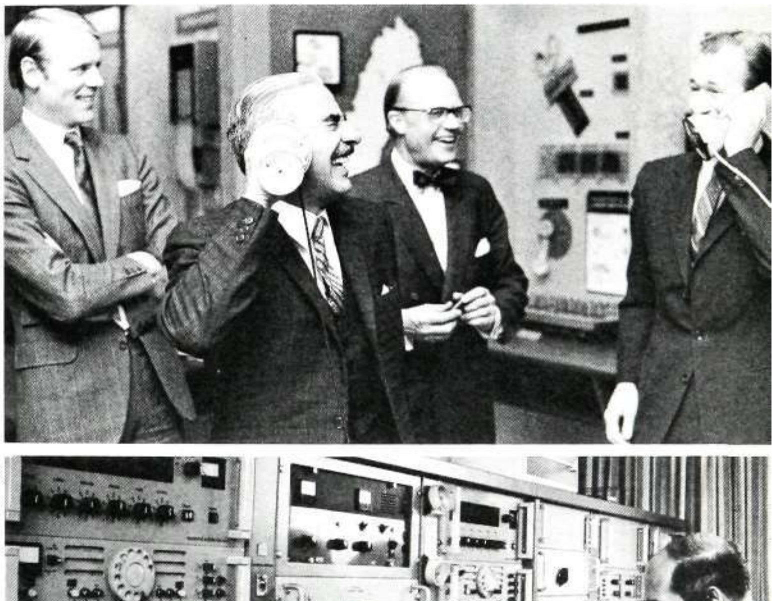
At the end of April L M Ericsson was visited by some representatives of the Finnish Ministry of Communications and PTT. Secretary of State Klaus Häkkänen is seen trying out L M Ericsson's picture telephone. Standing at the desk (from right) Director General Oiva Saloila (PTT), Mr Yngve Ollus, Oy L M Ericsson Ab (partly hidden), Deputy Director General Veikko Johansson (PTT), Chief Engineer Stig Poulsen, Oy L M Ericsson Ab, Governmental Counsellor Reino Auvinen, Mr Björn Lundvall, President of L M Ericsson, and Mr Hubert Lindström, L M Ericsson.

ČSSR Ambassador Pavel Džunda tries out L M Ericsson's 1878 telephone during a visit to Midsommarkransen in April. (Partly concealed) Commercial Counsellor Ernst Gajdoš.



General Ahmed Sadek, of the Egyptian Signal Corps, conducting a cheerful telephone conversation with Lars Edmark, L M Ericsson. (Left) Nils Jensen of Svenska Radio AB and (centre) K-G Kahnlund, LME.

►



Ericsson marine radio on board the British cruise liner "Cunard Adventurer". The system was developed and installed by the Norwegian subsidiary of the group, A/S Elektrisk Bureau.

►

# Giuseppe Marchesi In Memoriam

On January 24, 1972, Dr Giuseppe Marchesi, Chairman of the Board of the Italian subsidiaries of the Ericsson Group, Setemer, Fatme and Sielte, died at the age of 70 years. Dr Marchesi started his work in 1937 at a time when the main financial interests of the Group in Italy were associated with the telephone operating company SET within the area south of a line Formia — Foggia. SET were taken over by the Italian State on October 31, 1957, and their area today constitutes the fifth zone in the state-dominated operating company SIP. For many years Dr Marchesi was a close colleague of the Chairman of the Board at that time, Commendatore Protto — an outstanding figure in the development of the Italian companies. During that time Dr Marchesi became well acquainted with the companies' work and their problems.

The sale of SET was followed by a period of vigorous development both for the manufacturing company Fatme and for the sales and outside plant construction company Sielte, as a result of which both companies moved out of their old, unmodern premises on Via Appia Nuova. A new factory and new office and laboratory premises were built for Fatme on Via Anagnina, while Sielte obtained modern and efficient premises in a building of their own at Campo Boario in Rome. The many difficult problems arising in conjunction with these large building projects, especially in a city with as many historical monuments as Rome, were solved in an exemplary manner by Dr Marchesi.

The sale of SET implied a radical change in the work of the Italian companies. The primary question was to preserve and develop the position of Fatme and Sielte as suppliers to the Italian telephone network. Dr Marchesi was intensively engaged in this important work and the result is manifested today in the construction, now starting, of a new factory at Pagani in the vicinity of Naples. This enterprise is naturally founded on the confidence which Fatme and Sielte were able to establish with the Italian telephone administrations as suppliers of the Ericsson Group products.

Owing to the changes in the companies' activities many complicated legal questions had also to be examined and solved. With his thorough legal training and experience Dr Marchesi personally handled the majority of these questions and brought them to a successful conclusion.

Dr Marchesi devoted much time to staff questions, especially during the severe conflicts between the parties on the Italian labour market in recent years. The companies he served had for many years a reputation of being good employers. Fatme's new factory was equipped with kindergartens for working mothers with small children, and the company was a pioneer in many social respects.

Side by side with a strong feeling for the responsibility of the enterprise towards its employees in a country undergoing rapid changes, Dr Marchesi had a clear notion of what was fair play in the relations between the parties and was definitely opposed to the increasing tendencies to violence at places of work as means of pressure on people with a different way of thinking.

On the surface he was often strongly critical of the conditions and developments in his country. At bottom, however, as a Roman, he was conscious of and convinced that, with the sense of balance that was a mark of their character, his people, who had undergone so many trials and changes in the course of thousands of years, would be able to solve the present problems in a constructive manner.

Dr Marchesi was a good friend of many of us.

Peace upon his memory.

*Björn Lundvall*

# Changed Telephone Number to Head Office, Midsommarkransen

At the beginning of April a new PABX was cut over at the Headquarters at Midsommarkransen. With its 5400 extension lines, against earlier about 4000 lines, the new code switch exchange has a very much greater capacity. The numbers of incoming and outgoing lines have been greatly increased.

**New telephone number:**

**08/719 0000**

But it is not only the telephone number that is new.

Push-button telephones have been introduced throughout, and another important innovation is the possibility of "in-dialling", which means that an external subscriber can dial an extension direct, i.e. without assistance of an operator, provided naturally that the extension number is known. For example, extension XYZ has number 3738. He can be dialled direct on number 719 3738, i.e. by dialling, after 719, his 4-digit internal number instead of 0000.

All persons working at Midsommarkransen with regular telephone contact with persons outside the company have, therefore, been asked to notify their internal telephone number to these persons so that they can make use of the in-dialling facility.

# New Chairman of the Group's Italian Subsidiaries

Sr. Luigi Baggiani, member of the boards of Fatme and Setemer, has been appointed chairman of the boards of these companies and of the board of Sielte as from February 16, 1972. He succeeds the former chairman of these boards, Dr Giuseppe Marchesi.

*(New intercom . . . cont. from p. 70)*

lines by L M Ericsson Telemateriel AB in 1971 73% were for the export market.

# The Ericsson Group

## *Subsidiaries, associated companies and technical offices*

## EUROPE

### DENMARK

**L M Ericsson A/S** *DK-2600 Glostrup*, Kirkebjerg Allé 86, tel: (01) 96 6133, tgm: ericsson københavn, telex: 19020 "ERICSSON KH"

**GNT AUTOMATIC A/S** *DK-2860 Søborg*, Telefonvej 6, tel: (01) 69 5188, tgm: nortelmatic, telex: 27064, "GNT AUTOMATIC KH"

**Dansk Signal Industri A/S** *DK-2650 Hvidovre*, Stamholmen 175, Avedøre Holme, tel: (01) 49 0333, tgm: siqnaler københavn, telex: 16503, "16503 DSI DK"

**ELMI A/S** *DK-2820 Gentofte*, Kirkebjerg Allé 90, tel: (01) 45 42 11, tgm: elmiworks, telex: 16600, "FOTEX DK" att. ELMIWORKS

### FINLAND

**Oy L M Ericsson Ab** *SF-02420 Jorvas*, tel: (90) 2991, tgm: ericssons, telex: 12546, "LME SF"

### FRANCE

**Société Française des Téléphones Ericsson**
*F-92 Colombes*, 36, Boulevard de la Finlande, tel: Paris (1) 781 3535, tgm: ericsson colombes, telex: 62179, "ERICSSON CLOMB"

*F-75-Paris 17e*, 147, rue de Courcelles, tel: Paris (1) 227 9530, tgm: eric paris, telex: 29276, "ERICSSON PARIS"

**Etablissements Ferrer-Auran S.A.** *13 Marseille, (10ème)*, 88, Avenue de la Capelette, tel: (91) 47 4851, telex: 42579, "RINGMA 42579 F"

**RIFA S/A**
*F-62206 Boulogne sur Mer*, B.P 146/3, tel: (2) 31 9206, telex: 11431, "BORIFA 11431 F"

*F-92 Boulogne sur Seine*, 5, Rue Vauthier, tel: (1) 603 0640, telex: 20781, "FARIFA 20781 F"

### GREAT BRITAIN

**Swedish Ericsson Company Ltd.** *Morden, Surrey*, Crown House, London Road, tel: (01) 542 1001, tgm: teleric, telex: 935979, "SWEDERIC LDN"

**Swedish Ericsson Telecommunications Ltd.** *Morden, Surrey*, Crown House, London Road, tel: (01) 542 1001, tgm: teleric, telex: 935979, "SWEDERIC LDN"

**Production Control (Ericsson) Ltd.** *Morden, Surrey*, Crown House, London Road, tel: (01) 542 1001, tgm: productrol, telex: 935979, "SWEDERIC LDN"

**Swedish Ericsson Rentals Ltd.** *Morden, Surrey*, Crown House, London Road, tel: (01) 542 1001, tgm: celefon, telex: 935979 "SWEDERIC LDN"

### IRELAND

**L M Ericsson Ltd.** *Dublin 2*, 32, Upper Mount Street, tel: (01) 619 31, tgm: ericsson, telex, 5310, "LMI EI"

### ITALY

**FATME, Soc. per Az.** *1-00100 Roma*, C. P. 4025 A. tel: (06) 4694, tgm, fatme, telex: 61327, "61327 FATME"

**SETEMER, Soc. per Az.** *1-00198 Roma*, Via G. Paisiello 43, tel: (06) 86 8854, tgm: setemer

**SIELTE, Soc. per Az.** *I-00100 Roma*, C.P. 5100, tel: (06) 577 8041, tgm: sielte, telex: 61225, "61225 SIELTE"

### NETHERLANDS

**Ericsson Telefoonmaatschappij N.V.** *Rijen (N.Br.)*, P. O. B. 8, tel: (01612) 3131, tgm: erictel, telex: 54114, "ETMRY NL"

*Voorburg 2110*, P. O. B. 60, tel: (070) 81 4501, tgm: erictel den haag, telex: 31109, "ERICTEL DEN HAAG"

### NORWAY

**A/S Elektrisk Bureau** *Oslo 3, P.B.* 5055 Maj, tel: (02) 46 1820, tgm: teleb, telex: 11723, "TELEB N"

**A/S Industrikontroll** *Oslo 6*, Grensevejen 86/88, 3. etg., tel: (02) 67 8394,

**A/S Norsk Kabelfabrik** *Drammen*, P.O.B. 369, tel: (02) 83 7650, tgm: kabel, telex: 18149, "KABEL N".

**A/S Telesystemer** *Oslo 6*, Tvetenveien 32, Bryn, tel: (02) 68 7200, tgm: telesystemer, telex: 16900, "ALARM N"

### POLAND

**Telefonaktiebolaget L M Ericsson, Technical Office** *Warszawa*, Ul. Nowy Swiat 42, tel: 26 4926, tgm: tellme, telex: 813710, "813710 TELLME PL"

### PORTUGAL

**Sociedade Ericsson de Portugal Lda.** *Lisboa 1*, Rua Filipe Folque 7, 1°, tel: 56 3212, tgm: ericsson

### SPAIN

**Industrias de Telecomunicación, S.A.** *Getafe*, Paseo Felipe Calleja 6, tel: 295 2100, tgm: ericsson, telex: 22666, "ERIGE E"

**L M Ericsson, S.A.** *Madrid 5*, Bernadino Obregón 25, tel: 467 8700, tgm: ericofon, telex: 23333, "23333 LMESA E"

### SWEDEN

**Telefonaktiebolaget L M Ericsson,** S-126 25 *Stockholm*, tel: (08) 719 0000, tgm, telefonbolaget, telex: 17440, "LME S"

**ELLEMTEL Utvecklings Aktiebolag** *S-127 25 Skärholmen* Box 249, tel: (08) 97 0220

**Bjurhagens Fabrikers AB** S-200 12 *Malmö*, Fack, tel: (040) 93 4770, telex: 3123, "BJURHAG S"

**AB Rifa** *S-161 11 Bromma 11*, Fack, tel: (08) 26 2600, tgm: elrifa, telex: 10308, "ELRIFA STH"

**L M Ericsson Instruktionsteknik AB** *S-117 47 Stockholm 44*, tel: (08) 68 0870, tgm: instruktec

**L M Ericsson Telemateriel AB** *S-135 01 Stockholm-Tyresö 1*, Fack, tel: (08) 712 0000 tgm: ellem, telex: 10920, "10920 LMSBO/S"

**Sieverts Kabelverk AB** *S-172 87 Sundbyberg*, tel: (08) 28 2720, tgm: sievertsfabrik, telex: 1676, "SIEVKAB S"

**Svenska Radio AB** S *102 20 Stockholm 12*, Fack, tel: (08) 22 31 40, tgm: svenskradio, telex: 10094 "SRA S"

**AB Thorsman & Co.** *S-611 01 Nyköping 1*, Box 149, tel: (0155) 810 00, tgm: thorsmanco

**AB Transvertex** *S-145 53 Norsborg*, Fittja industriområde, tel: (08) 710 0935

### SWITZERLAND

**Ericsson A.G.** *8061 Zurich*, Postfach, tel: (051) 41 6608, tgm: telericsson, telex: 52669, "ERIC CH"

### TURKEY

**Ericsson Türk Ticaret Ltd.** Sirketi *Ankara*, Rumeli Han, Ziya Gökalp Cad. tel: 12 3170, tgm: ellem

### WEST GERMANY

**Deutsche Ericsson G.m.b.H. Telematerial,** *4 Düsseldorf 1*, Postfach 2628, tel: (0211) 35 3594, tgm: erictel: telex: 8587912, "ERIC D"

**Ericsson Centrum G.m.b.H.** 3 *Hannover*, Dornierstrasse 10, Postfach 1809, tel: (0511) 63 1018, tgm: ericen, telex: 922913, "922913 ERICE D"

## ASIA

### INDIA

**Ericsson India Limited**
*Calcutta*, P.O.B. 2319, tel: (032) 45 4494, tgm: inderic, telex: 7165, "ERICCU CA 7165"

*New Delhi 24*, No. 15,Community Center, Suraj Parbat, tel: (011) 63 1637, tgm: inderic

### INDONESIA

**Ericsson Telephone Sales Corporation AB**

*Djakarta*, P.O.B. 2443, tel: (07) 463 97, tgm: javeric, telex: 4414 "JAVERIC DKT 4414"

*Bandung*, Djalan Ir. H. Djuanda 151, tel: (082) 820 94, tgm: javeric

### IRAQ

**Telefonaktiebolaget L M Ericsson, Iraq Branch** *Baghdad* P.O.B. 2388, Alwiyah, tel: 947 14, tgm: ellemco

### KUWAIT

**Telefonaktiebolaget L M Ericsson, Technical Office** *Kuwait, State of Kuwait*, P.O.B. SAFAT No. 5979, tel: 42 0074, tgm: erictel

### LEBANON

**Société Libanaise des Téléphones Ericsson** *Beyrouth* B.P. 8148, tel: 25 2627, tgm: ellem, telex: ELLEM 20876 LE

### MALAYSIA

**Ericsson Talipon SDN BHD** *Shah Alam, Selangor, Batu Tiga Industrial Estate*, P.O.B. 28, Tel: Kuala Lumpur (03) 36 1821, tgm: kuleric, telex: 265, "ERICMAL KLTX 265"

**Telecommunication Manufacturers (Malaysia) SDN BHD** *Shah Alam, Selangor, Batu Tiga Industrial Estate*, P.O.B. 28, tel: Kuala Lumpur (03) 36 1821, tgm: kuleric, telex: 265, "ERICMAL KLTX 265"

### PAKISTAN

**L M Ericsson Telephone Company, Technical Office** *Karachi*, P.O.B. 7398, tel: (90) 51 6112, tgm: ericsson

### SINGAPORE

**Telephone Industries of Singapore Private Ltd.** *Singapore 1*, P.O.B. 3079, tel: 98 1155, tgm: telsin, telex: 21727 "TELSIN RS 21727"

### THAILAND

**Ericsson Telephone Corp. Far East AB** *Bangkok*, P.O.B. 824, tel: (02) 580 41, tgm: ericsson, telex: 2274, "THAIERIC"

## AFRICA

### ALGERIA

**Société Algérienne des Téléphones Ericsson** *El Biar (Algers)*, 4, rue Mouloud Hadjen, tel: 78 2692, tgm: eric alger

### A. R. EGYPT

**Telefonaktiebolaget L M Ericsson, Technical Office** Egypt Branch *Cairo* P.O.B. 2084, tel: (02) 465 83, tgm: ericgypt, telex: 2009, "ELLEME UN"

### ETHIOPIA

**Telefonaktiebolaget L M Ericsson, Technical Office** *Addis Ababa*, P.O.B. 3366, tel: (01) 492 60, tgm: ericsson, telex: 21090 "MOSFIRM ADDIS"

### MOROCCO

**Société Marocaine des Téléphones Ericsson** *Casablanca*, 87, Rue Karatchi, tel: 788 75, tgm: ericsson

### TUNISIA

**Telefonaktiebolaget L M Ericsson, Technical Office,** *Tunis*, Boite Postale 780, tel: (01) 24 0520, tgm: ericsson, telex: 695, "ERICSSON TUNIS".

### ZAMBIA

**Ericsson Telephone Sales Corporation AB**
*Lusaka*, P.O.B. 2762, tel: (011) 744 42, tgm: ericofon

*Ndola*, P.O.B. 2256, tel: (026) 3885, tgm: ericofon

## AMERICA

### ARGENTINE

**Cia Ericsson S.A.C.I.** *Buenos Aires* Casilla de Correo 3550, tel: 33 2071, tgm: ericsson, telex: 0122196, "CATEL BA"

**Cia Argentina de Teléfonos** S.A. *Buenos Aires*, Belgrano 894, tel: 33 2076, tgm: catel, telex: 0122196, "CATEL BA"

**Cia Entrerriana de Teléfonos S.A.** *Buenos Aires*, Belgrano 894, tel: 33 2076, tgm: catel, telex: 0122196, "CATEL BA"

**Industrias Eléctricas de Quilmes S.A.** *Quilmes FNGR*, 12 de Octubre 1090, tel: 253 2775, tgm: indelqui buenosaires, telex: 0122196, "CATEL BA"

### BRAZIL

**Ericsson do Brasil Comércio e Indústria S.A.**
*São Paulo*, Rua da Coroa 500, tel: (011) 298 2322 tgm: ericsson, telex: 021817, "ERICSSON SPO"

*Rio de Janeiro*, Caixa Postal 3601-ZC-00, tel: (021) 221 7477, tgm: ericsson, telex: 031839, "ERICSSON RIO"

**Fios e Cabos Plásticos do Brasil S.A. (FICAP)** *Rio de Janeiro*, caixa postal: 1828, tel: (021) 391 4550, tgm: ficap, telex: 031485, "FICAP RIO"

### CANADA

**L M Ericsson Limited** *Montreal 381*, Quebec, 2300 Laurentian Boulevard St. Laurent, tel: (514) 331 3310, tgm: caneric, telex: 05-267682, (TWX) 610-421-3311, "CANERIC MTL"

### CENTRAL AMERICA

**Telefonaktiebolaget L M Ericsson, Oficina Tecnica de Centroamérica** *San Salvador*, Apartado 188, tel: 21 7640, tgm: ericsson, telex: 20087, "ERICSAL 20087"

### CHILE

**Cia Ericsson de Chile S.A.** *Santiago*, Casilla 10143, tel: (04) 825 55, tgm: ericsson, telex: 40598, "40598 ERICH CL"

### COLOMBIA

**Ericsson de Colombia S.A.** *Bogotá*, Apartado Aéreo 4052, tel: (92) 41 1100, tgm: ericsson, telex: 044507, "ERICSSON BOG"

**Fábricas Colombianas de Materiales Eléctricos Fácomec S.A.** *Cali*, Apartado Aéreo 4534, tel: 42 1061, tgm: facomec, telex: 55673, "FACOMEC CLO"

### COSTA RICA

**Telefonaktiebolaget L M Ericsson, Technical Office** *San José*, Apartado 10073, tel: 21 1466, tgm: ericsson, telex: 283, "283 LME-CR"

### ECUADOR

**Teléfonos Ericsson C.A.**
*Quito*, Casilla 2138, tel: 52 4000, tgm: ericsson

*Guayaquil*, Casilla 376, tel: 30 0900 tgm: ericsson

*Cont. on next page*

## *Subsidiaries, associated companies and technical offices (Cont. from preceding page)*

MEXICO

**Teléfonos Ericsson S.A.** *Mexico D.F.*, Apartado Postal M-9958, tel: 566 8955 tgm: coeric, telex: 017234, "ERICSSON TLA" PARA COERIC

**Latinoamericana de Cables S.A. de C.V.** *Mexico 12 D.F.*, Apartado Postal 12737, tel: 549 0844 tgm: latincasa, telex: 017234, "ERICSSON TLA" PARA LATINCASA

**Teleindustria, S.A.** *Mexico 1, D.F.*, Apartado Postal 1062, tel: 565 7033 tgm: ericsson, telex: 017234 "ERICSSON TLA"

**Telemontaje, S.A. de C.V.** *Mexico 1, D.F.*, Apartado Postal 1062, tel: 576 4044, tgm: ericssonmexicodf, telex: 017234, "ERICSSON TLA" PARA TELEMONTAJE

PANAMA

**Telefonaktiebolaget L M Ericsson, Oficina Técnica de Panamá** *Panama 5, R.P.* Apartado 4349, tel: 64 3600, tgm: *ericsson*, telex: 368674 "368674 SONITEL''

PERU

**Cia Ericsson S.A.** *Lima*, Apartado 2982, tel: 31 1005, tgm: ericsson, telex: 3540202, "ERICSSON 3540202''

**Soc. Telefónica del Perú, S. A.** *Arequipa*, Apartado 112-1012, tel: 6060 tgm: telefonica

EL SALVADOR

**Telefonaktiebolaget L M Ericsson, Technical Office** *San Salvador*, Apartado 188, tel: 21 7640, tgm: ericsson

URUGUAY

**Cia Ericsson S.A.** *Montevideo*, Casilla de Correo 575, tel: 91 2611, tgm: ericsson, telex: 398228, "ROULEMENT UY'' PARA MELANDER

USA

**The Ericsson Corporation** *New York, N.Y. 10017*, 100 Park Avenue, tel: (212) 685 4030, tgm: erictel, telex: 620484, "ERICTEC 620484''

**Ericsson Centrum Inc.** *New York, N.Y. 10016*, 16, East 40th Street, tel: (212) 679 1000, tgm: erictel, telex: 620149, "ETELSAC 620149''

VENEZUELA

**Cía Anónima Ericsson** *Caracas*, Apartado 70516, tel: (02) 34 4661, tgm: ericsson, telex: 21530, ''21530 ERIC VEN''

**Alambres y Cables Venezolanos C.A. (ALCAVEL)** *Caracas*, Apartado del Este 62107, tel: (02) 33 9791, tgm: alcave, telex: 22845, ''22845 ALCAVE VE''

### AUSTRALIA & OCEANIA

AUSTRALIA

**L M Ericsson Pty Ltd.**
*Broadmeadows, Victoria 3047*, P.O.B. 41, tel: (03) 309 2244, tgm: ericmel, telex: AA 30555, "ERICMEL''

*Rushcutters Bay N.S.W. 2011*, 134 Barcom Avenue, tel: (02) 31 0941, tgm: ericsyd, telex: AA 21358 "ERICSYD''

*Boroko, Papua New Guinea*, P.O.B. 5602, tel: Port Moresby 565 66, tgm: ericpor, telex: Port Moresby 153

**Teleric Pty. Ltd.**
*Broadmeadows, Victoria 3047*, P.O.B. 41, tel: (03) 309 2244, tgm: teleric, telex: AA 30555, "ERICMEL''

*Rushcutters Bay N.S.W. 2011*, 134 Barcom Avenue, tel: (02) 31 0941, tgm: teleric, telex: AA 21358, "ERICSYD''

**Conqueror Cables Pty. Limited** *Dee Why, N.S.W. 2099*, P.O.B. 69, tel: (02) 982 3344, tgm concab sydney, telex: 24305, ''CONCAB AA 24305''

**A.E.E. Capacitors Pty. Ltd.** *Preston, Victoria 3072*, 202 Bell Street, P.O.B. 95, tel: (03) 480 1211, tgm: engiquip melbourne, telex: 31001, ''AEEMELB AA 31001''

---

## *Representatives*

### EUROPE

AUSTRIA

**Electro-Diesel Handelsaktiengesellschaft, Abteilung Telecom** *1160 Wien*, Postfach 98, tel: (0222) 43 5956, tgm: teleric, telex: 75976, "75976 TELECOM A"

BELGIUM

**Allumage Lumière S.A.** *Bruxelles 7*, 128-130 Chaussée de Mons, tel: (02) 23 9425, tgm: allumalux, telex: 21582, "ALLUMALUX BRU''

GREECE

**Angelos Cotzias** *Athens, 18*, Omirou Street, tel: (021) 62 6031, tgm: cotziasan. telex: 215252, "215252 CTZS GR"

ICELAND

**Johan Rönning** *Reykjavik*, P.O.B. 5300, tel: 840 00, tgm: rönning, telex: 2040, "ROENNG IS''

CANARY ISLANDS

**TRANSA Transacciones Canarias S.A.**

*Las Palmas de Gran Canarias*, Tomas Morales 36, tel: 21 8304, tgm: transa, telex: 95052, ''95052 CASTI E''

*Santa Cruz de Tenerife*, Tirso de Molina, 2 ''Edificio Dulcinea'', tel: 22 9440, tgm: transa

YUGOSLAVIA

**Merkantile Inozemna Zastupstva**
*Zagreb* P.O.B. 02-1027, tel: (041) 41 6655, tgm: merkantile, telex: 21139, "21139 YU MERTIL''

*Beograd*, Ul. 7. Jula br. 18, tel: (011) 62 1773, tgm: merkantile, telex: 11506, "YU MERKAN''

### ASIA

BAHRAIN & TRUCIAL STATES

**Yusuf Bin Ahmed Kanoo** *Bahrain, Arabian Gulf*, tel: 40 8188, tgm: kanoo, telex: BHN 215

BURMA

**Myanma Export Import Corp., Agency Div.** *Rangoon*, P.O.B. 404, tel: 112 58, tgm: myanimport, telex: UBMEIC BM 2005

CAMBODIA

**Comin Khmere S.A.** *Phnom-Penh*, P.O.B. 625, tel: 233 34, tgm: engineer

CYPRUS

**S.A. Petrides & Sons Ltd.** *Nicosia*, P.O.B. 4522, tel: 427 88, tgm: armature, telex: 2308, "ARMATURE''

HONG KONG AND MACAO

**Swedish Trading Co. Ltd.** *Hong-Kong*, P.O.B. 108, tel: 23 1091, tgm: swedetrade

IRAN

**Irano Swedish Company A. B.** *Teheran*, Khiabane Sevom Esfand 29, tel: 31 4160, tgm: iranoswede

JORDAN

**The Arab Trading & Development Co.** *Amman*, P.O.B. 6141, tel: 259 81, tgm: aradeve

KUWAIT

**Morad Yousuf Behbehani** *Kuwait, State of Kuwait*, P.O.B. 146, tel: 42 7071, tgm: barakat, telex: 2048, "BEHBEHANI KUWAIT''

LEBANON

**Swedish Levant Trading** *Beyrouth*, P.O.B. 931, tel: 23 1624, tgm: skefko

PAKISTAN

**Panasian Marketing Service Ltd.** *Karachi*, P.O.B. 3941, tel: (90) 51 2051, Ext. 53, tgm: panasian

PHILIPPINES

**Asia Industries Inc.** *Makati, Rizal*, M.C.C. Post Office 1322, tel: 87 7011, tgm: usi asia, telex: 7222233, "7222233 AII PH"

SAUDI ARABIA

**Engineering Projects & Products Co. Ltd. (Eppco)**

*Riyadh*, P.O.B. 987, tel: 222 22, tgm: eppcol

*Yeddah*, P.O.B. 1502, tel: 4567, tgm: eppcol

*Dammam*, P.O.B. 450, tel: 222 22, tgm: eppcol

SYRIA

**Constantin Georgiades** *Damas*, P.O.B. 2398, tel: 266 73, tgm: georgiades

TAIWAN

**Trans-Eurasia Enterprise, Ltd.** *Taipei*, P.O.B. 3880, tel: 51 7038, tgm: esbtrading

REPUBLIC OF VIETNAM

**Vo Tuyen Dien-Thoai Vietnam** *Saigon*, P.O.B. 1049, tel: 226 60, tgm: telerad

**International Business Representative** *Saigon*, 26—28, Hai Ba Trung Street, tel: 226 60, tgm: ibur

### AFRICA

ETHIOPIA

**Mosvold Company (Ethiopia) Ltd.** *Addis Ababa*, P.O.B. 1371, tel: (01) 101 00, tgm: mosvold, telex: 21090, "MOSFIRM ADDIS''

KENYA, TANZANIA, UGANDA

**The Old East African Trading Co. Ltd.** *Nairobi, Kenya*, P.O.B. 30013, tel: 271 61, tgm: broche, telex: 22261, "OLDEAST NAIROBI''

LIBERIA

**Telecommunications Authority** *Monrovia*, P.O.B. 9039, tel: 222 22, tgm: radiolibe, telex: 4211 TLX BOOTH LIB

LIBYA

**ADECO African Development & Engineering Co***Tripoli*, P.O.B. 2390, tel: 339 06, tgm: adeco

MALAWI

**Business Machines Ltd.**, *Limbe*, P.O.B. 5557, tel: Blantyre 513 52, tgm: falt, telex: 342, "FALT LIMBE"

MOZAMBIQUE

**J. Martins Marques & Ca. Lda** *Lourenco Marques*, P.O.B. 2409, tel: 24953, tgm: marquesco

NIGERIA

**Communications Associates of Nigeria Ltd. (Comsac)**, *Ilupeju (Lagos)*, P.M.B. 1129, tel: 322 06 tgm: comdec lagos

SOUTH AFRICA
NAMIBIA

**Dryden Communications (Pty.) Ltd.** *Johannesburg, South Africa*, P.O.B. 2440, tel: 838 5454, tgm: qualsteels, telex: 430094, "430094 SA"

SUDAN

**El Rahad Trading Corporation** *Khartoum*, P.O.B. 866, tel: 776 95, tgm: suconto, telex: BHN 251

ZAIRE

**I.P.T.C. (Zaire) Ltd.** *Kinshasa*, P.O.B. 8922, tel: 253 45, tgm: induexpan, telex: 327, "IPTC KIN"

### AMERICA

BAHAMA ISLANDS

**Anglo American Electrical Company Ltd.** *Freeport, Grand Bahama*, P.O.B. 104

BOLIVIA

**Prat Ltda** *La Paz*, Casilla 4790, tel: 277 12, tgm: prat, telex: PRAT BX 5363

COSTA RICA

**Tropical Commission Co. Ltd.** *San José*, Apartado 661, tel: 22 5511, tgm: troco

DOMINICAN REPUBLIC

**Humberto Garcia, C. por A.** *Santo Domingo*, Apartado 771, tel. 682 3645, tgm: gartier

GUATEMALA

**Nils Pira** *Ciudad de Guatemala*, Apartado 36, tel: (021) 622 57, tgm: nilspira

GUYANA

**General Supplies Agency** *Georgetown*, tel: 638 38, P.O.B. 375, tgm: benwiks

HONDURAS

**Quinchón Leon y Cía** *Tegucigalpa*, Apartado 85, tel: 251 71, tgm: quinchon

NETHERLANDS ANTILLES

**S.E.L. Maduro & Sons Inc. Merchandise Dept.** *Willemstad, Curaçao* P.O.B. 304, tel: 130 00, tgm: madurosons, telex: CU 92

NICARAGUA

**Roberto Teran G.** *Managua*, Apartado 689, tel: 224 00, tgm: roteran

PANAMA

**Sonitel, S.A.** *Panama 5, R.P.*, Apartado 4349, tel: 64 3600, tgm: sonitel, telex: 368674, "368674 SONITEL''

**Mr. Tore Korch** *Panama 5, R. P.*, Apartado 4349, tel: 64 36 00, tgm: sonitel, telex: 36 86 74, "36 86 74 SONITEL" FOR MR KORCH

PARAGUAY

**S.A. Comercial e Industrial H. Petersen** *Asunción*, Casilla 592, tel: 44 124, tgm: pargtrade

EL SALVADOR

**Dada-Dada & Co.** *San Salvador* Apartado 274, tel: 21 7940, tgm: dada

SURINAM

**W.E. van Romondt's Trading Company Ltd.** *Paramaribo*, P.O.B. 1837, tel: 728 31, tgm: vanromondt

TRINIDAD, W.I.

**Leon J. Aché Ltd.** *Port-of-Spain*, P.O.B. 276, tel: 323 57, tgm: achegram

### AUSTRALIA & OCEANIA

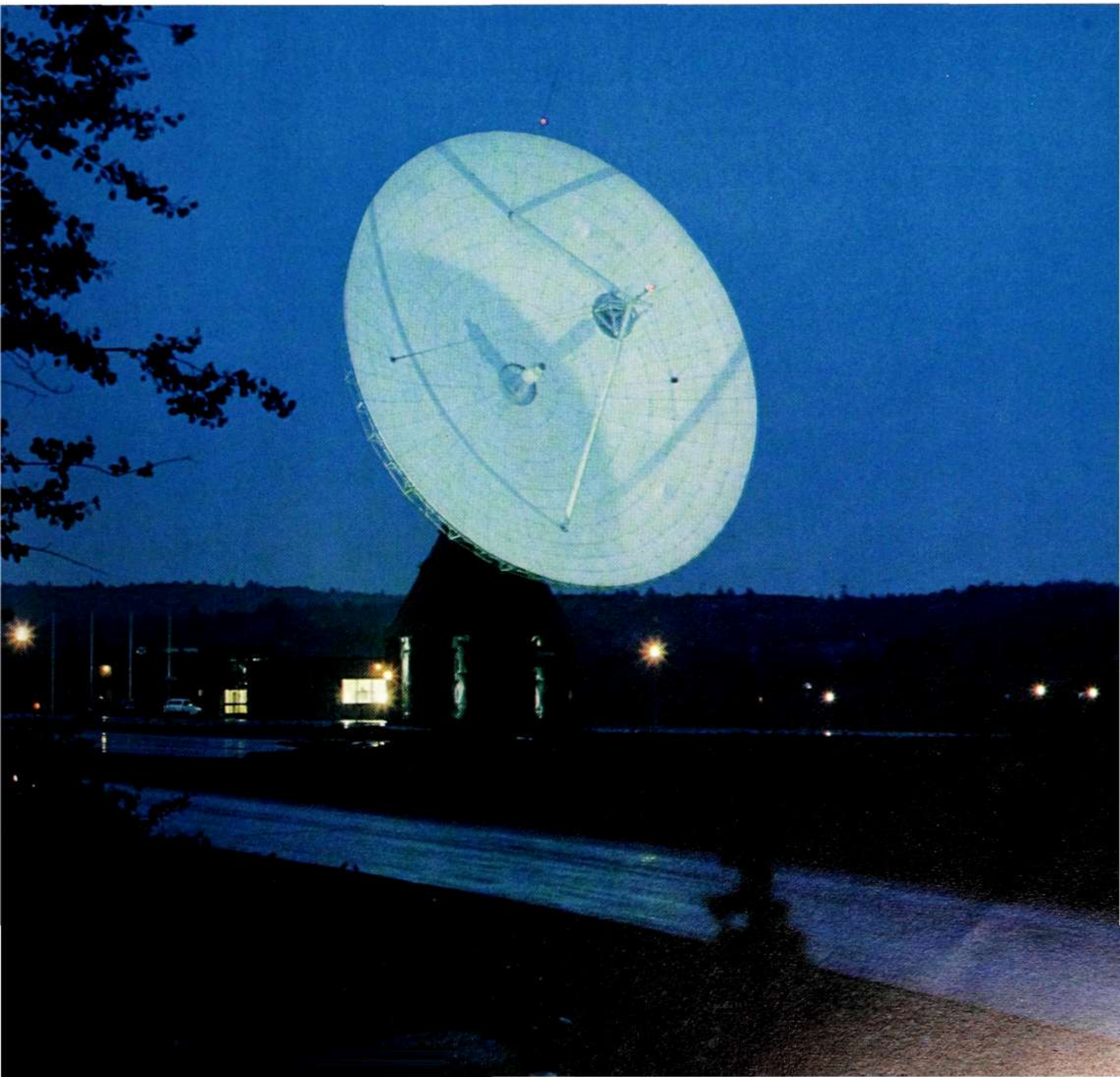
NEW ZEALAND

**ASEA Electric (NZ) Ltd.** *Wellington C. 1.*, P.O.B. 3239, tel: 706 14 tgm: asea, telex: 3431, "ASEAWELL NZ 3431''

SÄTHERLUND & KROOK

ERICSSON
Review

3
1972



# ERICSSON REVIEW

Vol. 49 No. 3 1972

RESPONSIBLE PUBLISHER: CHR. JACOBÆUS, DR. TECHN.
EDITOR: SIGVARD EKLUND, DHS
EDITOR'S OFFICE: S-126 25 STOCKHOLM
SUBSCRIPTIONS: ONE YEAR $1.80; ONE COPY $0.60

## CONTENTS

On cover: Aerial at Tanum on the Swedish west coast for transmission of telephony via telesatellite between the Scandinavian countries and the USA.

# Six Years of Controlled Corrective Maintenance (CCM) in the Rotterdam Telephone District

J. A. HAMERS, CHIEF OF COMMON TECHNICAL & ADMINISTRATIVE AFFAIRS, INTERNAL PLANT, PTT TELEPHONE DISTRICT ROTTERDAM

UDC 621.395.342.004.5
654.153.048
LME 1540

*On April 2nd 1972 six years had passed since the new method of Controlled Corrective Maintenance (CCM) was introduced in the Dordrecht and Zwijndrecht maintenance areas of the Rotterdam district. Ericsson Review No. 2, 1968, contained an article entitled "The Introduction of a New Maintenance Method into the Telephone Area of Rotterdam and Its Influence on the Maintenance Organization".*

*In that article some plans for the future were also presented, e. g. the possibility of considerably extending the number of lines in the Dordrecht maintenance sector, with preserved service quality and without increase of staff, the formation of a common group which should be used in exchanges mainly during periods of extensive specialized work and for location of difficult faults. CCM specialists should also be incorporated in the common group for coordination of results, formulation of guiding rules etc. Traffic route testers should be introduced on a large scale, maintenance sectors concentrated etc. The following account will explain how these plans have been realized.*

## Extent of CCM

*CCM* has now been completely and successfully introduced in the Rotterdam District and also in a number of sectors (maintenance areas) in other districts.

CCM will be introduced throughout the Netherlands during the following year and, from then on, each sector in the country will be equipped with traffic route testers, *TRT*.

## General Principles for Fault Tracing

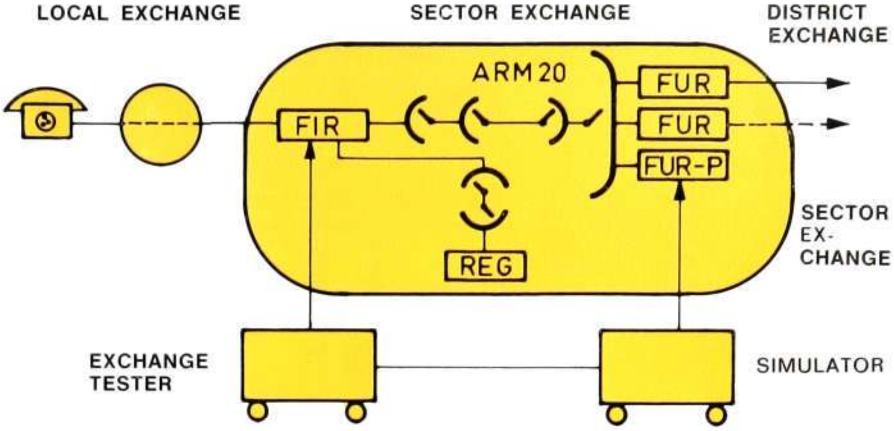
In the Rotterdam district altogether 27 TRT are at present installed. Attended or unattended exchanges not having TRT of their own are instead equipped with remote A+B selectors, except the very small exchanges which have test numbers directly connected to TRT units in their superior sector exchanges.

All Ericsson crossbar exchanges type ARF and ARM 20 include the normal test and supervision facilities of those systems.

*On internal traffic* the occurrence of too low a service quality is indicated by a TRT and the *SL-GV* tester is used to trace the faults, as the faulty connection can be held by this device.

**Fig. 1**

**Testing with the aid of a simulator**



*On sector traffic*, e. g. from one terminal exchange ARF to another terminal exchange via a sector exchange, a TRT may also be used to indicate poor service quality. In this case the *SL-GV* tester could be used for fault tracing, but then it would be necessary to send a man to the calling terminal exchange as the tester is situated in that exchange. Should it then prove necessary to hold a faulty line for further tests, the time supervision would have to be disconnected from the outgoing trunk junction sets. When starting fault tracing the time supervision is generally disconnected from all outgoing trunk junction sets in the terminal exchange concerned, which is easy as their number is limited. *REG* can, however, not be held during fault tracing.

Instead, the TRT usually situated in the sector exchange with remote selectors in the terminal exchanges could be used as a tool for fast fault tracing and it would then not be necessary to send a man to the terminal exchange.

*On district traffic* the same method of manual disconnection of the time supervision cannot be used as the number of trunk junction sets involved is often very high.

As no signal could be made available for automatic disconnection of time supervision during test traffic, a simulator was instead introduced, which has proved to be an important aid especially for testing the registers.

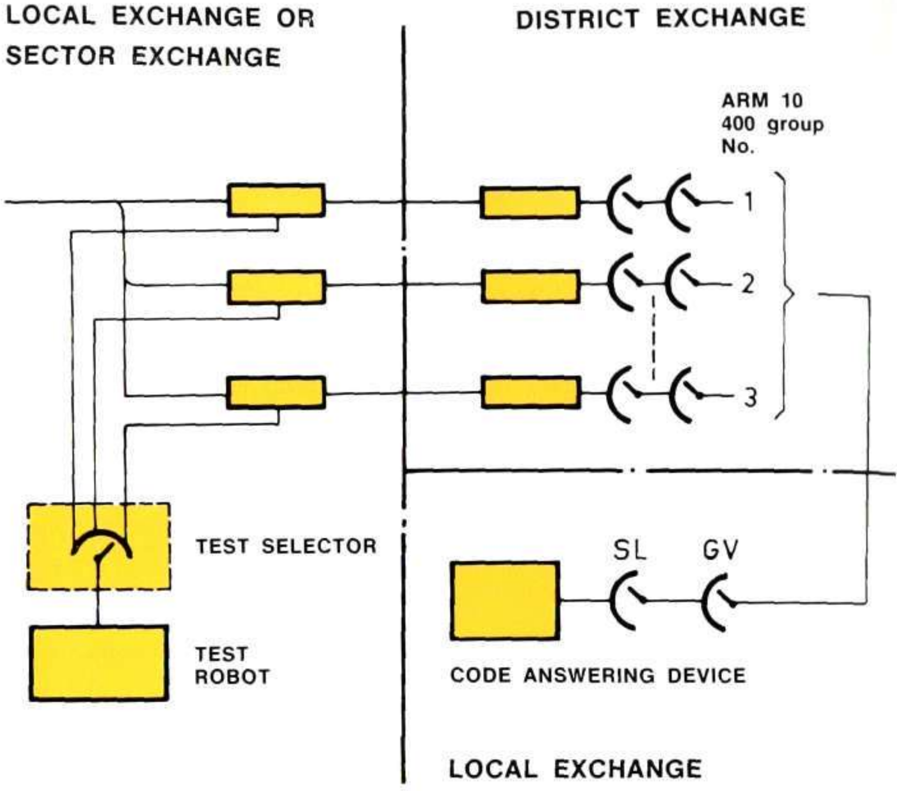
The normal ARM 20 test robot is then connected to an incoming junction set *FIR*, (fig. 1). The simulator, which is connected to *FUR-P*, is reached with a special code. It can receive digit information and return all backward MFC signals for testing the registers for every type of traffic. The last two digits of the code inform the simulator about the type of traffic to be tested.

## Improvements in Test Aids and Methods

A *Centralograph (Cph)* for REG-P has been introduced. If *REG-P* is used in the ordinary way for testing registers, it will stop at a fault. It is then possible to determine in which *REG* and in which program the fault appeared, but data are furnished only from a single event. The use of *Cph* means that *REG-P* can continue automatically after a fault has been printed out. Roughly the same information as is normally shown on the lamps is printed, viz. "REG No.", "Program No." and "Type of fault". In the case of an unattended exchange or

Fig. 2

Selector for test robot



when testing at night time, data from several events will be available and a conclusion can consequently be reached more quickly. The types of faults which appear during the night seem to differ from those during the day, e. g. sticking of relays. The centralograph connected to the *REG-P* has been a great help in finding some of these faults. (See fig. 9 b for Dordrecht where the trial began at the beginning of 1971.)

*A new recording possibility in Cph of TRT* has been introduced, i.e. a print "Route Busy". This recording is of interest when testing the trunk traffic to terminal exchanges and has been made possible by the use of free contacts on the *VL*-relays, which have been wired to the *IDF* where the TRT is connected. About 20 wires are required for this purpose. Print-out due to route congestion can thus be eliminated.

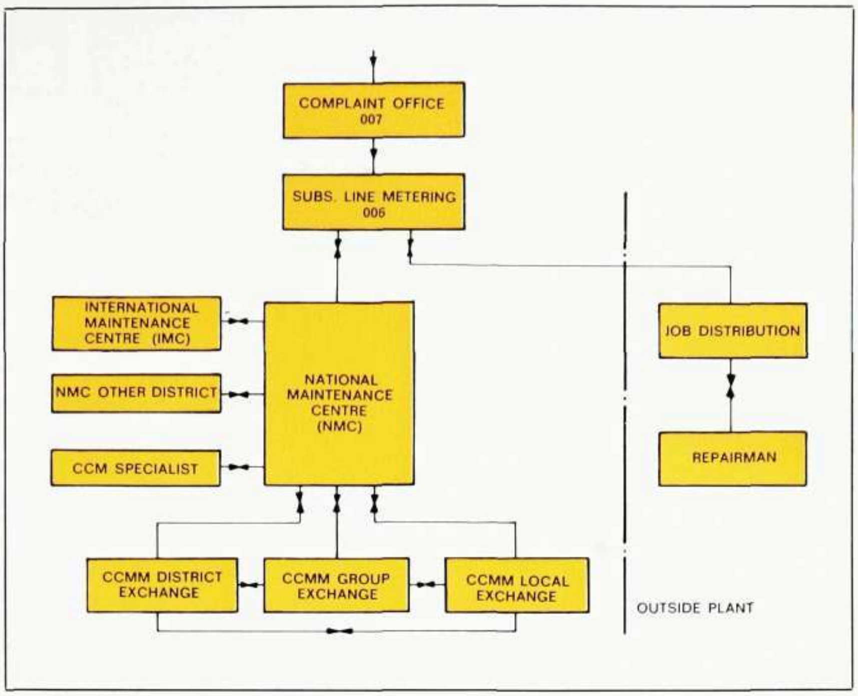
*Location of faults on traffic through the District Centre DC I* is based on the following principles.

The introduction of TRT in AGF exchanges for supervising the service quality made the hitherto used robots of our own design superfluous for this purpose. Instead they are now used in combination with a special access selector for junction sets for fault tracing on traffic via the district exchange (fig. 2).

Owing to the special design of DC I—an ARM 10 exchange with the junctions distributed over different 400 groups, each 400 group having its own registers—most of the circuits from the local and sector exchanges are distributed over several 400 groups. This means that the effect of a fault in one 400 group should have little influence on the total service quality, from one local exchange via the DC I to another local exchange. However, in order to pinpoint such faults, one line per 400 group at a time is connected by means of the above-mentioned access selector to the test robot (in ARF exchanges to the SL-GV tester), which generates traffic to an automatic device in the other local exchange. In this way

**Fig. 3**

**Organization for controlled corrective maintenance**



the quality of the traffic via DC I can be judged per 400 groups, as the results are recorded on different meters. This makes it much easier to locate any faults which occur.

The above procedure is at present used only for traffic via ARM 10, but the same procedure will later be used also for traffic via ARM 20.

## Organization

The diagram in fig. 3 (fig. 7 in the previous article)—illustrating the organization for controlled corrective maintenance—is still valid as regards the flow of communication. In other respects, however, new ideas have appeared and the Dordrecht area, for example, is not organized in the same way as outlined in the previous article. Fig. 4 shows the present organization in the Rotterdam telephone district.

The maintenance area of Centrum includes, for example, 30,000 lines AGF, 3 bypath exchanges ARF 90, 17,000 lines ARF, a transit exchange (3,680 lines ARF) and two CABX's. In the maintenance centre 4 TRT's are installed, which also supervise the functional quality of the Schiebroek I (10,000 lines AGF) and Schiebroek II (8,000 lines ARF exchanges). A more detailed plan of the organinization for this area is shown in fig. 5.

In such a large area the quality supervision specialist (CCMM) must have an assistant at his disposal for reading, writing down and evaluating the meter results etc.

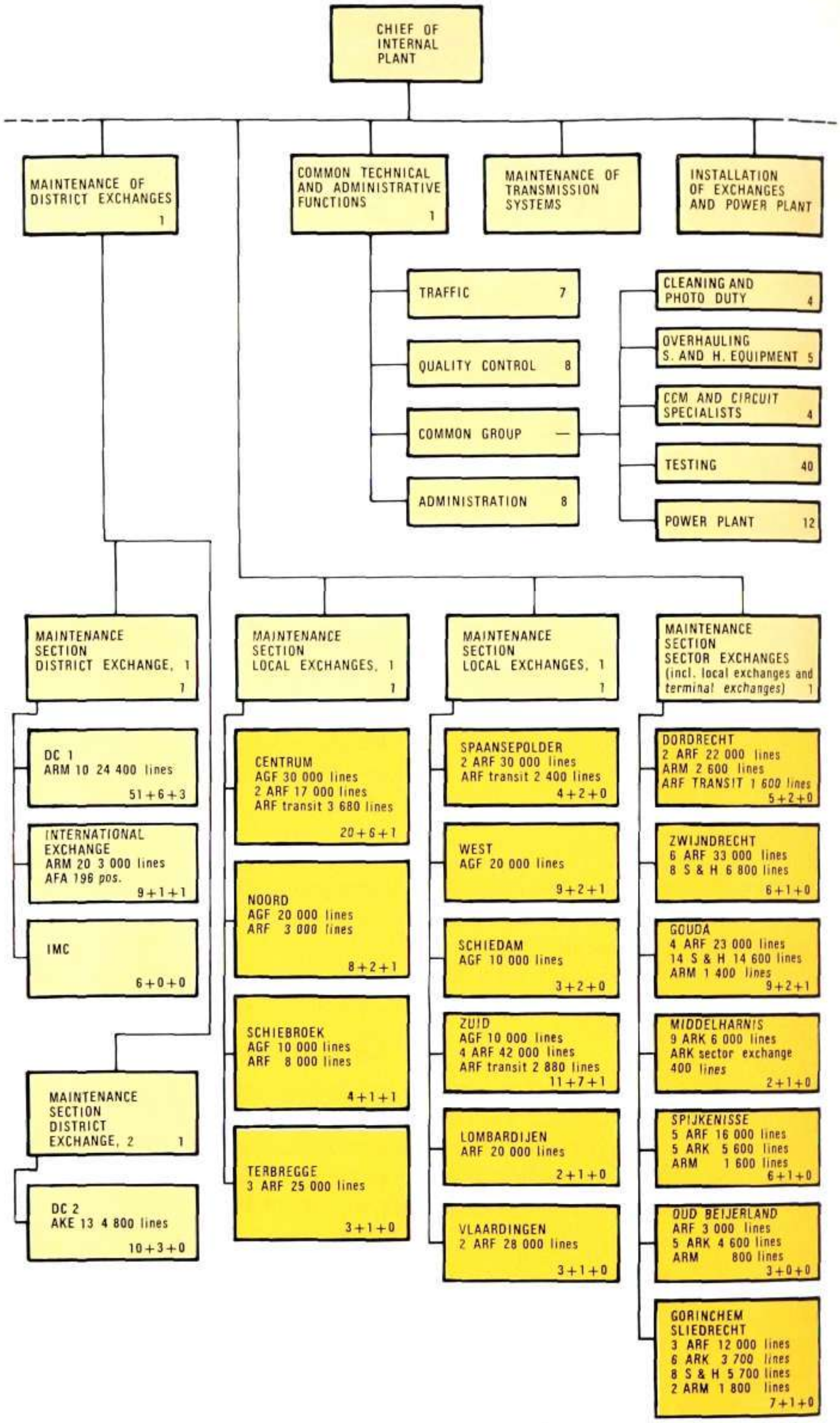
There are three operational chiefs, one for the AGF exchanges, one for the ARF exchanges and one for work on the MDF and "first aid" to the power supply.

Coordination of fault clearing work takes place between the CCM specialist and operational chief 1 or 2.

Fig. 4

Maintenance organization Rotterdam district

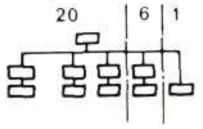
🟨 Maintenance area



Note 1. All AGF exchanges are equipped with ARF 90 by-path exchanges for the connection to the trunk network.

Note 2. The total number of exchange staff in a maintenance area is shown as follows:

Compare with fig. 5



E. g. Centrum 20+6+1
Chief
Chief operations 1 and 2
CCMM and his assistant
Repairmen
Number of men occupied full-time with MDF-work
Number of men occupied full-time with cleaning duty

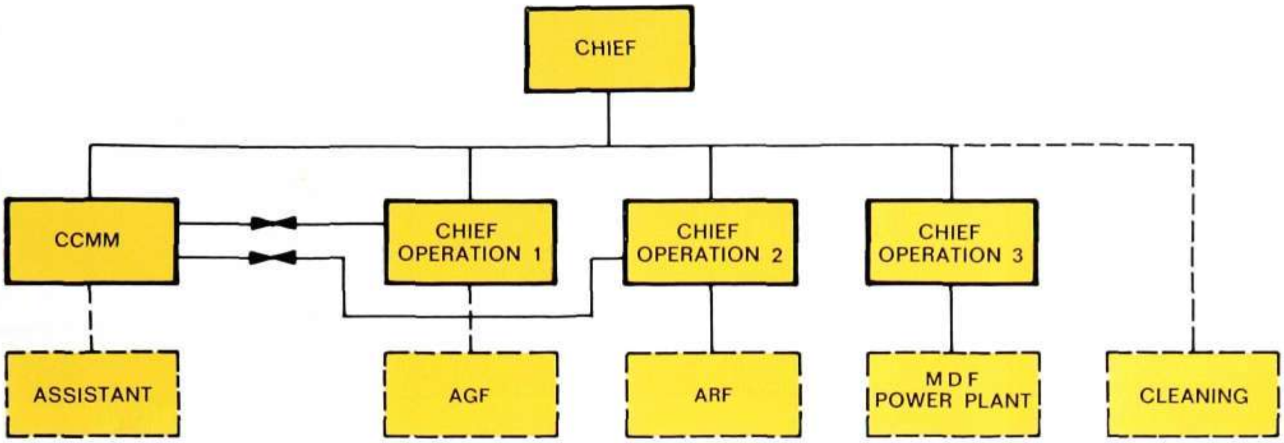


**Fig. 5**

**Organization of a maintenance area**

—▶◀— **Coordination of fault clearing work**

For small areas operations 1 and 2 may be combined and for very small areas the task of the CCM specialist may be combined with that of the operational chief. The Dordrecht area is organized like that (fig. 6), which, however, is not the best organization but a result of too small a maintenance area. A merger with the Zwijndrecht area will therefore be considered in the future.

New exchanges are incorporated in existing maintenance areas, whereby these are automatically extended. Further reorganization will follow after, among other things, a study by a committee, including a representative of the staff and an industrial psychologist, of the consequences for the staff concerned.

Two important concentrations have already been realized, viz. the maintenance areas of Centrum A and Centrum B have been combined to form the new Centrum area and a joint chief has been appointed for the small sectors Sliedrecht and Gorinchem.

The common group for the maintenance of the sector and local exchanges has begun to assume more definite shape and contains at present the following five subgroups:

| | |
|---|---|
| 1. For cleaning and photographic duties | 4 persons |
| 2. For overhauling of S & H equipment | 5 persons |
| 3. For CCM and circuit specialisation | 4 persons |
| 4. For testing | 40 persons |
| 5. For maintenance of power plant | 12 persons |

The group for CCM and circuit specialisation — which is indispensable for correct coordination of the procedures and for thorough investigation of circuit faults and various disturbances — must be finally organized. The idea of a separate testing group was completely new for the Netherlands but has proved to be very effective. Such a group acquires experience which can never be achieved through any other form of organization. At first the introduction of this concept encountered much opposition, as the attractive work would then be carried out by a separate test group.

**Fig. 6**

**Organization of the Dordrecht area**

**2 ARF 22 000 lines**
**ARM 20 2 600 lines**
**Transit exchange ARF 1 600 lines**
**2 TRT**

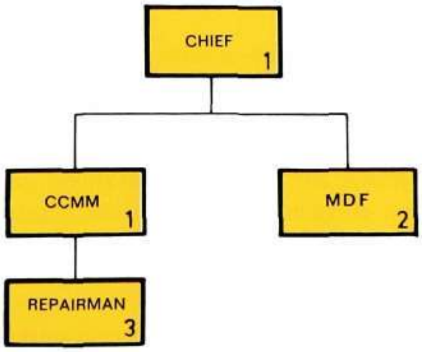
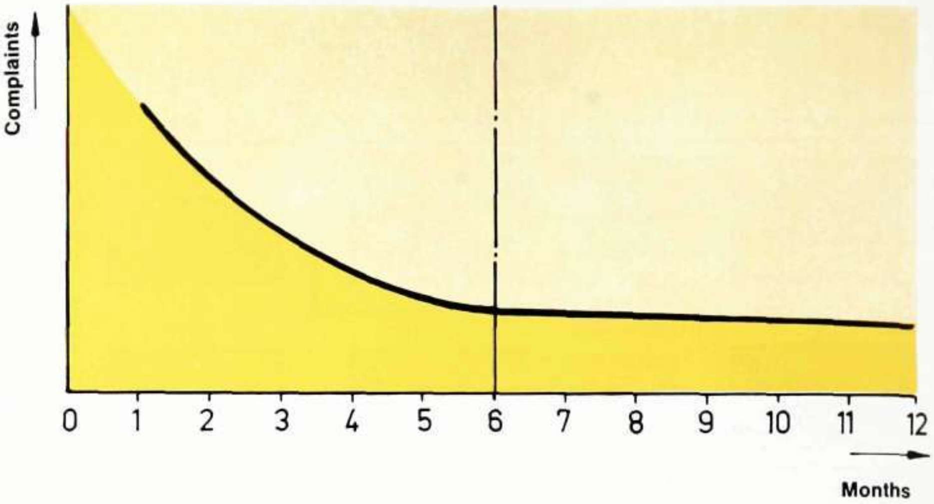


Fig. 7

Subscriber complaints



## Installation and Tests

The installation of new exchanges and the extension of existing ones are carried out either by L M Ericsson or by the Administration's installation group. In the first case tests are generally carried out jointly between the staff of L M Ericsson and the Administration's test group, and in the second case completely by the Administration's test group. During 1971 more than 52,000 lines were tested and put into service in the Rotterdam district.

The experience from Dordrecht shows that an exchange has a running-in period of about six months, during which a number of justified complaints are made by the subscribers (fig. 7). For a 10,000-line exchange, for example, this means that one man must work with the clearing of such faults for about six months after the exchange has been put into operation.

The aim has been to cut down this running-in period, and this has been achieved. By intensifying the testing procedures and acquiring a new load tester —which makes it possible to perform the tests under conditions similar to real traffic—an improved result was reached with the 12,000-line exchange in Groenoord, installed by L M Ericsson and tested jointly with the Administration. This exchange could be left unattended after only one month.

## Other Means for Decreasing Maintenance

Dust is an enemy of all types of automatic exchange. Therefore much attention is paid to the elimination of it. New and old equipment, for example, is cleaned by staff withdrawn from other duties. This is done before putting the equipment into operation.

The ordinary cleaning staff are also specialised in the treatment of floors, thus greatly facilitating the removal of dust.

*Proper screening and over-pressure* in the switchroom are essential for reducing the maintenance effort. In new buildings, and when structural alterations are carried out in existing buildings, close attention is given to these points. It would also be desirable that all telephone buildings in the future should be provided with removable partition walls of very simple construction.

*A correct method for programming the TRT* is essential but is still causing the

Administration some concern. The following two possibilities, for example, exist for Dordrecht:

- Sequential test diagrams may be used, based on a large number of samples (about 2,000 connections). Such a high sampling rate is necessary, as the acceptable fault rate is set quite low (0.2 %). Consequently quite a long time is spent on each program.

  In the case of Dordrecht about 1½ months would be required to work through the different program once. This is too long an interval between samplings of, for example, trunk traffic.

- Instead, a smaller number of samples (about 500 connections) may be taken in order to establish whether the trunk traffic is of reasonable quality or not. In this way it is possible to supervise the routes more frequently, which for Dordrecht means about once every ten days.

At this moment it is not yet quite clear which method will prove to be the best one. A group of specialists is at present studying the question and will issue their recommendations within a year. This group includes several maintenance specialists and also three statisticans.

In Dordrecht smaller samples on the routes are taken during the daytime, whereas sampling for the sequential test diagrams is carried out during the night.

When a second TRT unit was installed in Dordrecht, the increased capacity made it possible to sample the local traffic in and between the two 10,000 groups. If this is done during the weekend, a good idea of the overall quality of the local exchange is obtained and, when faults occur, programs can be run from 2,000 group to 2,000 group for further information.

## Training and Staff Requirements

In general the staff have reacted in a positive way to the new maintenance method. But, they are still skeptical of large organisational units, as this would diminish the number of "chief" positions.

The practical training of the staff functions is better than before. Having passed a lower technical school and an industrial training course a young man in the test group will first learn how to adjust relays and crossbar switches. When a considerable time has been spent on this type of work, he will start testing work and thereafter receive theoretical training in the general part of the ARF system. After he has obtained a practical knowledge of the system, he will be given further detailed system training as well as a course in TRT. A course on the ARM 20 system combined with practical training may follow.

When he has worked in a test group for a certain period, he will also receive training in the new maintenance method before he is definitely transferred to an exchange. This training may consist, for example, of a shorter or longer period of work in the CCM office and/or assistance to a CCM specialist.

Fault tracing on equipment during its operation requires much more preparation than fault tracing during testing. The staff in the test group must therefore receive such training before working in an exchange.

It is of great importance that the staff continue to derive mental satisfaction from their work. Therefore some brainwork must remain and it is consequently not planned to introduce a centralograph in the ARF exchanges.

Over the last 6-year period the staff decreased by 10 %, whereas the capacity of the exchanges increased by about 75 %. At the moment the local exchanges comprise approx. 425,000 lines. The maintenance of them, as well as of the sector exchanges, is carried out by about 160 men. The overhaul group (for S & H) and the test group consist together of about 45 men.

## Results

Some results from the service quality measurements performed with TRT units were presented in the previous article. In order to give an idea of the quality of the telephone exchanges as experienced by the subscribers since the introduction of CCM, some comparative figures are given below for faults reported in 1969, 1970 and 1971 (Table 1).

The figures in table 1 show up two striking facts:

1) The number of faults in the telephone exchanges amounted in 1970 and 1971 to 3.1 % and 3.2 %, respectively, of the total number of true faults reported by subscribers.

2) The number of faults per working line in the telephone exchanges reported by subscribers in 1971 as compared to 1969 decreased by 39 %.

**Table 1**

| | 1969 | 1970 | 1971 |
|---|---|---|---|
| Number of exchange lines (capacity) per 31 dec. | 334,255 | 390,355 | 426,755 |
| Number of working lines per 31 dec. | 285,602 | 321,789 | 356,497 |
| Degree of utilization | 85.5 % | 82.4 % | 83.5 % |
| Number of subscriber complaints | 159,050 | 169,542 | 173,544 |
| Thereof true faults | 121,952 | 128,598 | 135,305 |
| True faults as a percentage of subscriber complaints | 76.8 % | 75.9 % | 78.0 % |
| Number of true faults per working line (based on **average** no. of working lines during the year) | 0.45 | 0.43 | 0.40 |
| Number of true faults found in: | | | |
| — exchanges | 5,788 | 4,003 | 4,349 |
| in % of total true faults | 4.7 % | 3.1 % | 3.2 % |
| — local network | 11,819 | 16,148 | 19,214 |
| in % of total true faults | 9.7 % | 12.5 % | 14.2 % |
| — subscriber's instruments (including instruments belonging to PABX) | 85,101 | 88,580 | 90,274 |
| in % of total true faults | 69.9 % | 68.9 % | 66.7 % |
| — PABX installations | 19,244 | 19,867 | 21,468 |
| in % of true faults | 15.7 % | 15.5 % | 15.9 % |
| Number of true faults in exchanges per working line (based on **average** no. of working lines during the year) | 0.0210 | 0.0132 | 0.0128 |

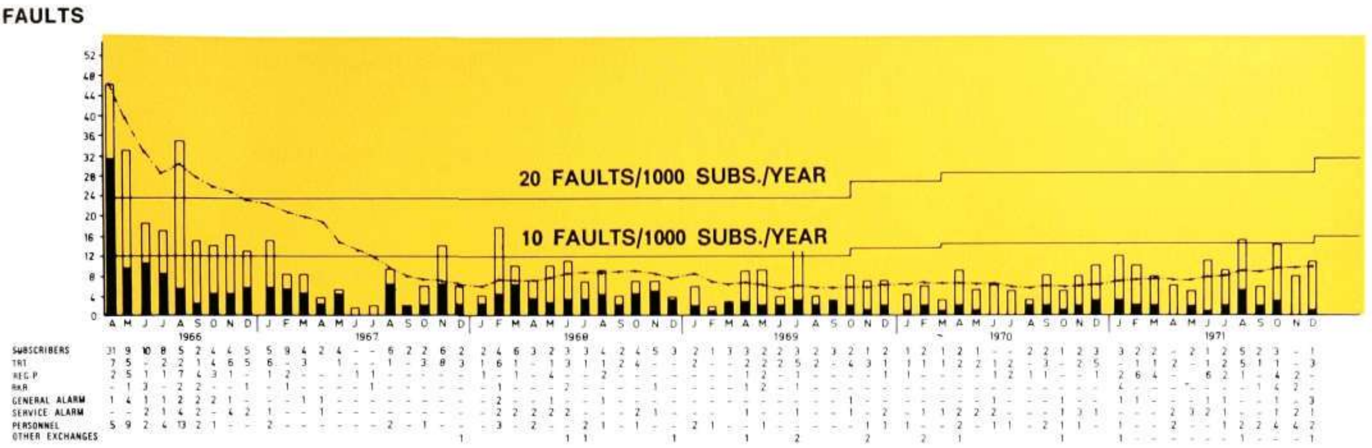


**Fig. 8**

**Fault statistics Dordrecht local ARF 10, 19 000 lines**

- ▮ **Reported by subscribers**
- ▯ **Other sources**
- -- **Progressive average**

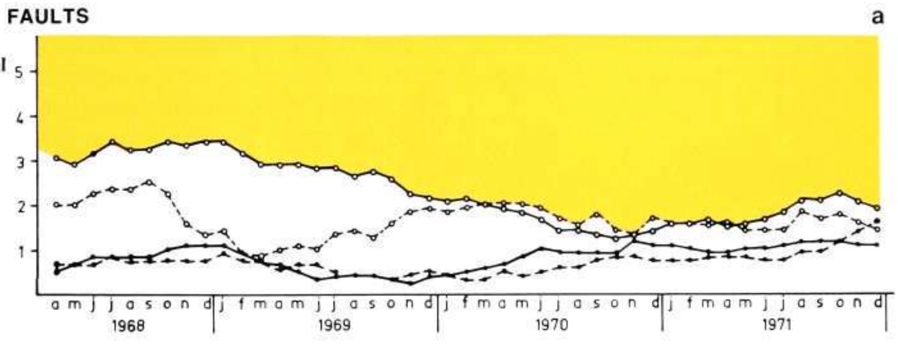
Based on the above average values for the Rotterdam District in 1971, about 220 faults should have been reported by subscribers connected to the Dordrecht local exchange. As will be seen from fig. 8, the actual number was 23, confirming that the quality of service for Dordrecht is much higher than the average in Rotterdam.

An analysis of the principal sources of fault indications is shown in fig. 9 a and 9 b. Based thereon it is possible to check whether the maintenance efforts are carried out in a correct manner or not.

The best result was reached in 1970 and the first half of 1971. The number of faults reported by subscribers and indicated by TRT was then of the same order and decreasing, while the number of faults indicated by the service alarm and observed by the exchange staff was increasing.

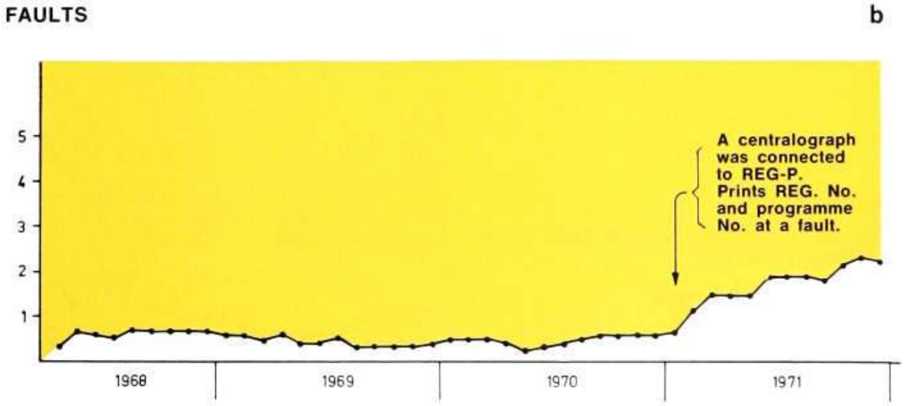
**Fig. 9**

**Annual progressive average of faults local exchange Dordrecht**



**a. Faults reported/indicated by**

- o—o—o **Subscribers**
- o-o-o **TRT**
- •—• **Service alarm**
- •-•-• **Personnel**



**b. Faults reported/indicated by**

- •—• **REG-P**

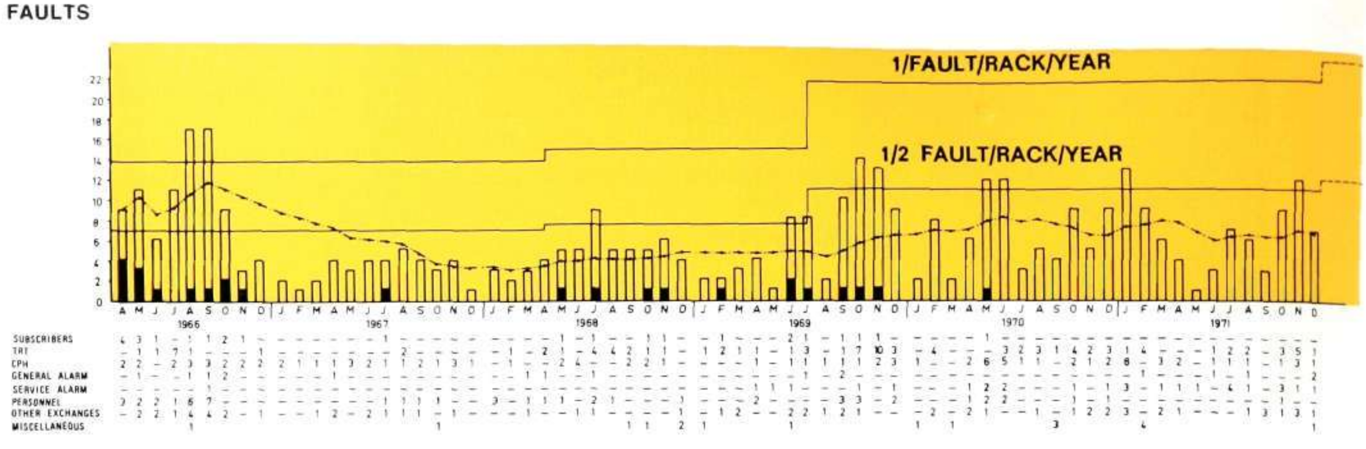


Fig. 10

Fault statistics Dordrecht ARM 20

- ▮ Reported by subscribers
- ☐ Other sources
- -- Annual progress average

Extension work was carried out in the exchange during the second half of 1971. It is intended to consolidate the picture in 1972.

Fig. 10 shows the faults in the sector exchange of Dordrecht with breakdown by source of indication. The number of faults per annum has increased as a result, among other things of the many extensions and modifications carried out in this exchange.

An analysis of the four principal sources of fault indications has been made in order to check whether the maintenance method is suitable or not (fig. 16). The best result was reached in 1971.

TRT was the principal fault indicator, closely followed by Cph, and the number of faults indicated by the service alarm was increasing. It is expected that this trend will continue.

Finally, fig. 12 shows how the number of subscriber complaints has developed. In 1970 there were comparatively few complaints and the increase in 1971 is due to an incorrect interference in the adjustment of the PBX relays. In its old design the PBX circuit is very sensitive and must be adjusted with great precision.

It may be said that the optimum has been reached in Dordrecht, taking all circumstances into account. In spite of structural alterations and extensions of the building, disturbances from extension activities in the equipment and the inability to introduce the best organization, the fact remains that an outstandingly good quality has been achieved with a minimum of staff.

By including the present maintenance area of Zwijndrecht in the Dordrecht area it may be possible to achieve further savings.

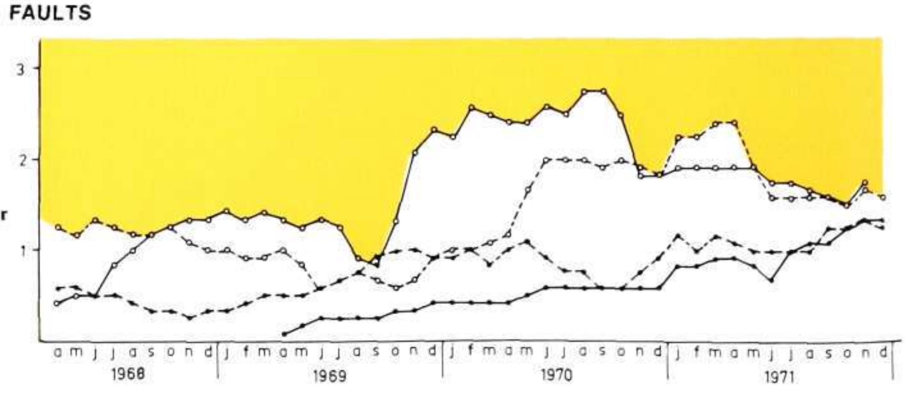


Fig. 11

Annual progressive average of faults sector exchange Dordrecht

Faults reported/indicated by

- o—o—o TRT
- o-o-o CPH
- —•— Service alarm
- -•-• Other exchanges

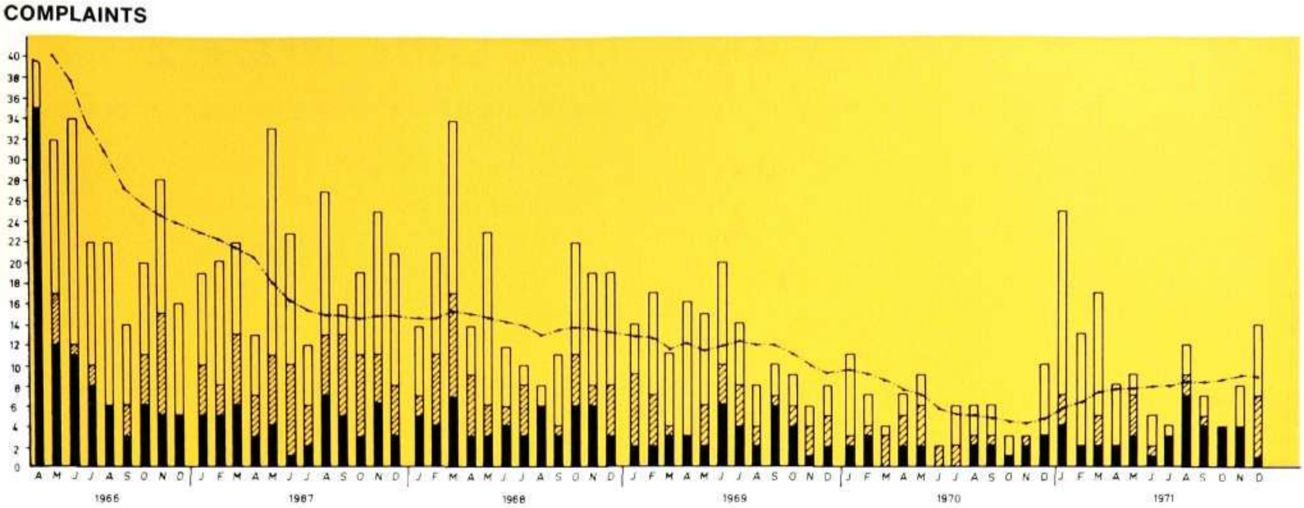


**Fig. 12**

**Subscriber complaints Dordrecht**

- ■ **Fault found**
- ▨ **Fault in other exchange**
- ☐ **No fault found**
- — — **Annual progressive average**

# Conclusion

The application of the CCM method results in great improvements in the service quality of telephone exchanges, at the same time as the number of maintenance hours per line can be reduced. As an example it may be mentioned that the number of maintenance hours per line and year in the Dordrecht local exchange during 1971 was 0.075.

The method requires vocational training of the maintenance staff and should certainly benefit by a still closer contact between maintenance people from different administrations. An international exchange of CCM data and test results compiled on a standard basis would, for example, be most helpful to the men in the field.

Finally it may be mentioned that all telephone switching systems are in principle suited to the application of CCM, but certain mechanical systems require at the same time some preventive maintenance, the degree of which mainly depends on the design of the selectors.

# Reference

1. Hamers, J. A.: *The Introduction of a New Maintenance Method into the Telephone Area of Rotterdam and its Influence on the Maintenance Organization.* Ericsson Rev. *45* (1968): 2, pp. 46—60.

# Electronic Traffic Measuring Unit, MET 2

R. PALLINI, FATME, ROME & M. BUCHMAYER, TELEFONAKTIEBOLAGET L M ERICSSON, STOCKHOLM

UDC 621.395.31
LME 8076

*Telephone traffic — and particularly the L.D. portion — is growing at an increasing rate, resulting in more and more complex networks. As a consequence telephone administrations require more and better aids for the economic utilization of the expensive exchange and line equipment. An important aid would be a modern traffic flow measuring device which could make simultaneous measurements of traffic flow at all relevant switching points even in large exchanges under the control of an efficient automatic program. The measured results should be shown in a form which is suitable either for subsequent processing in a computer or for human language print-out.*

*The following is a brief description of a portable, fully electronic traffic measuring device meeting these demands. This device, called* **MET 2**, *which has been developed within the Ericsson Group, provides a high accuracy of measurement also when mean occupation and observation times are short.*

## Measuring Capacity and Method

The MET 2 permits simultaneous measurement of traffic on a maximum of 15,000 circuits distributed over 250 measuring routes. A route is divided into two groups of 30 circuits each. Consequently one route comprises $2 \times 30 = 60$ circuits.

The exchange has one measuring resistance for each circuit. These resistances are connected in parallel within each group of 30 circuits. The measurement is carried out as repeated scannings of measuring points at intervals of 4.5 seconds. Each measuring point represents the traffic on one route (fig. 1). During scanning, an exchange potential is connected to all the resistances of seized circuits within the route. In order to secure a high accuracy of measurement, an electronic comparative measurement within each group of max. 30 circuits takes place in the analogue-digital converter and the results for the two groups are automotically added in the data register. In this way a record is obtained which covers the total number of seized circuits within the entire route (max. $2 \times 30$ circuits).

Since the measuring principle requires only a limited amount of cabling, it is economically advantageous to centralize the measurement also in large exchanges.

In order to permit traffic measurement on circuits with different measuring resistances or potentials, the routes have been divided into 16 groups. The design of the equipment permits variations in resistance and potential between the different groups, but of course these values must be the same within a single group.

## Accuracy of Measurement

The accuracy of measurement is mainly influenced by two factors, viz:

- measuring errors originating from the design and electrical characteristics of the circuits to be measured
- measuring errors originating from the measuring method.

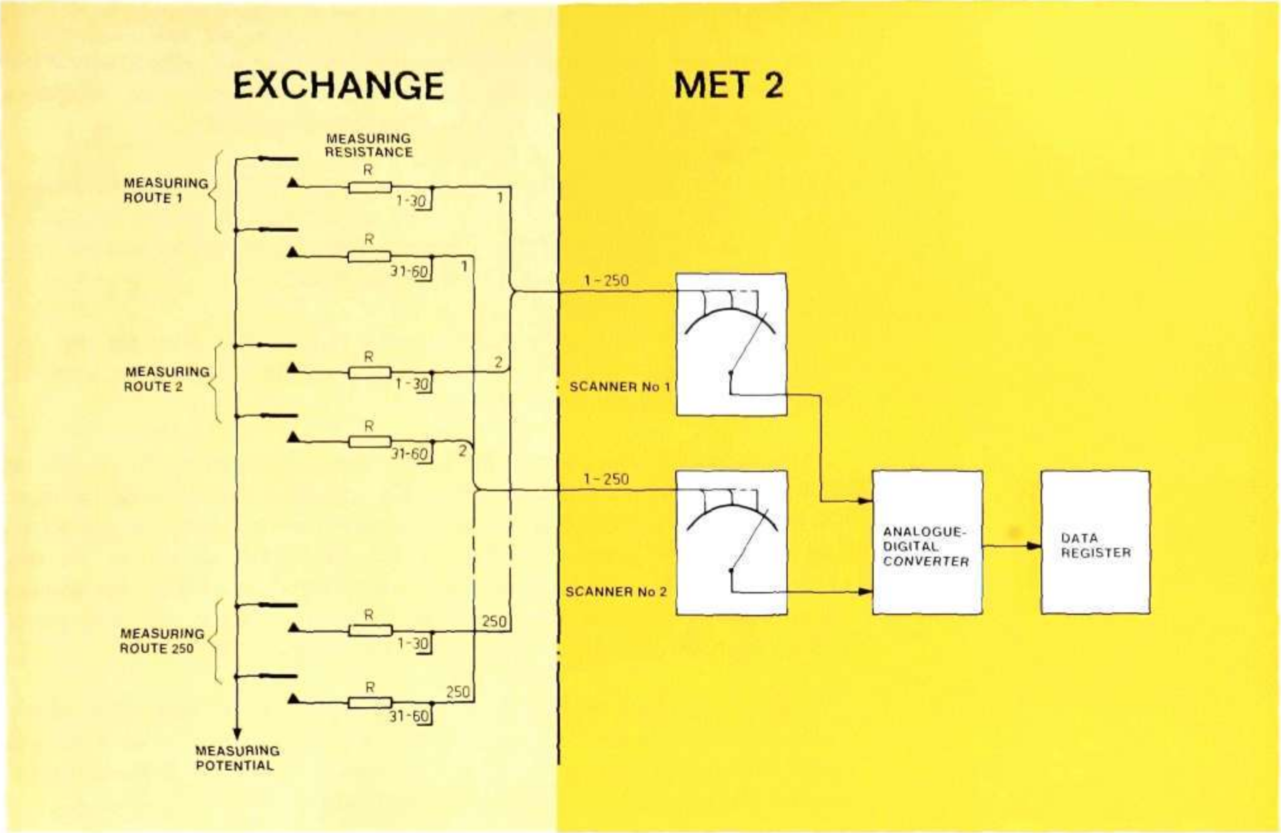


**Fig. 1**

**Scanning of measuring routes**

The design of the measuring circuits of the MET 2 and the route distribution applied make the error of measurement per scanning interval negligible, provided that the variations in the measuring resistances of the exchange are acceptable. The fast operation of the system has made it possible to use a scanning interval of 4.5 seconds, which ensures in general a very high statistical accuracy of measurement. Calculations based on conventional statistical methods have shown that the statistical uncertainty at a measuring period of 1 h normally does not exceed a few per mille.

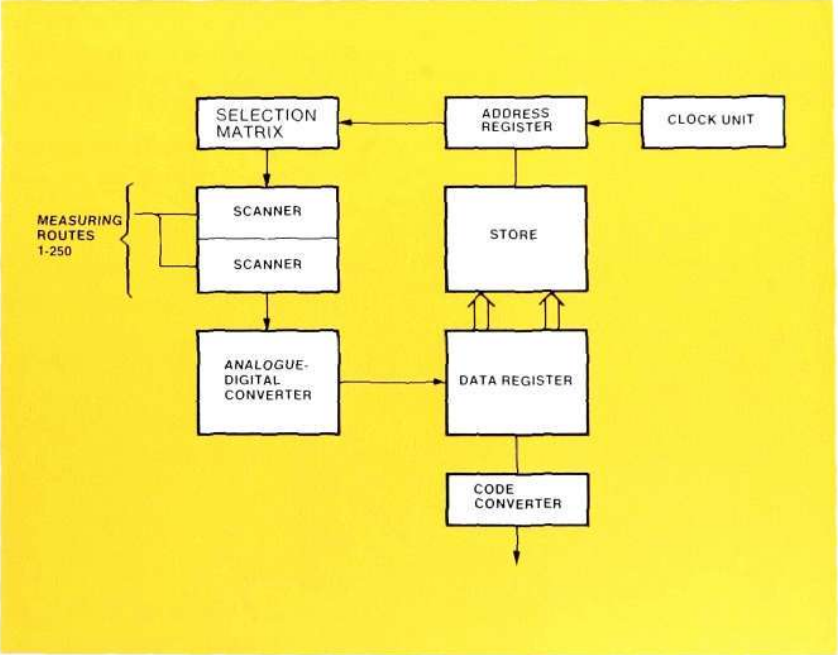


**Fig. 2**

**Block diagram for MET 2**

## Function

As mentioned earlier, traffic measurements are based on cyclical scanning at 4.5 second intervals and on a grouping of up to 250 routes, each covering a maximum of 2×30 circuits (i.e. max. 15,000 measuring points).

A scanning cycle is started by the clock unit (fig. 2) controlling the measuring sequence. The clock unit activates the address register, which informs the store about the first route to be measured. The address register sets the scanner, via a selection matrix, to measure the first route.

Should the store contain a previously measured traffic value for this particular route, this value is now transferred to the data register for updating, using a binary code and parity check.

The measuring principle implies that the voltage detected by the scanner on the outlet — which is related to the number of seized devices along the route — is converted in the analogue-digital converter into a number of pulses corresponding to the number of seized devices. The pulses are sent to the data register and are there added to previously stored information. Then the updated information is sent back to the store by means of a binary code with parity check. Thereafter the next route to be measured is addressed.

This cycle is repeated until the last test route has been scanned, which occurs within about 0.5 second. The clock unit is then blocked for about 4 seconds until the next scanning cycle starts. This 4-second interval is utilized to print out the measured values, erasing the stores if necessary.

Print-outs may be timed to occur once every third, fifteenth or sixtieth minute. On such print-out updated information in the data register need not be retransferred to the store, but is delivered straight to the code converter for conversion into the desired output code, e.g. the CCITT telex code No. 2.

## Programming

The following measurement programs may be set up on the control and supervisory panel of the MET 2 unit:

- Day for start of measurement (up to 8 days ahead).
- Time for start and stop of two daily observation periods (which may vary in length between 15 minutes and 24 hours).
- Length of the observation period (daily measurements may be programmed for a period lasting up to eighty 24-hour periods or for an indefinite period).
- Suppression of all measurement activities within part of an observation period (two arbitrary 24-hour periods per week).
- Print-out rate (once every 3rd, 15th or 60th minute).
- Integration interval causing the erasing of store contents once every hour or after each print-out.

## Equipment

The MET 2 is built up of electronic components. Integrated circuits of *DTL* (*D*iode *T*ransistor *L*ogic) type are mainly used for the logical functions,

**Fig. 3**

**Printed boards with integrated circuits and discrete components**

whereas the scanner contains high stability silicon transistors. Components are mounted on plug-in type printed circuit boards (fig. 3). Ferrite core stores containing 1024 words of 8 bits each are mounted on a plug-in unit. Fig. 4 shows the printed circuit boards and the ferrite core unit mounted on three shelves.

The control and supervisory panel is located at the front of the unit and is easily accessible (fig. 5). It is used, e.g., for the setting-up of the various measuring programs, for checking of store contents and for alarm functions of different kinds.

The dimensions of the MET 2 unit are 710×554×445 mm and it weighs only 43 kg. It is thoroughly protected against mechanical impact and other environmental interferences. All external connections are made over plugs and jacks, thus reducing setting-up and taking-down times when moving the MET 2 unit to another exchange. Whenever the unit has been moved, the equipment can be easily recalibrated with a potentiometer, thus compensating the effects of variations in cabling conditions.

The results of measurements are fed out to a conventional tape punch. Together with the power unit, which generates the required direct current, this punch is cord-connected to the MET 2 by plug and jack.

## Control, Supervision and Alarms

The necessary operating sequences are set up on the control and supervisory panel (fig. 5).

In addition to the programming of automatic processes already described, an operator may set up manual commands on this panel, i.e. for operations

**Fig. 4 (left)**

**Traffic measuring equipment MET 2, rear view with cover removed, containing three shelves**

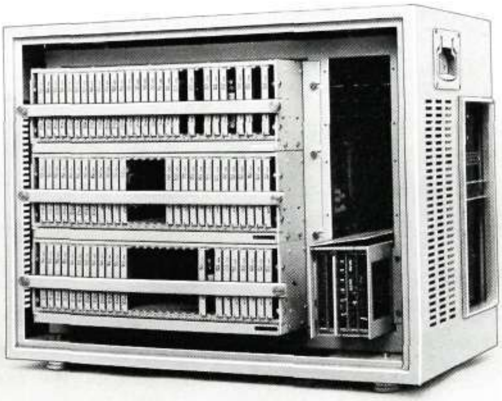


**Fig. 5**

**Traffic measuring equipment, MET 2, front view, control and supervisory panel. Dimensions 710×554×445 mm, weight 43 kg.**

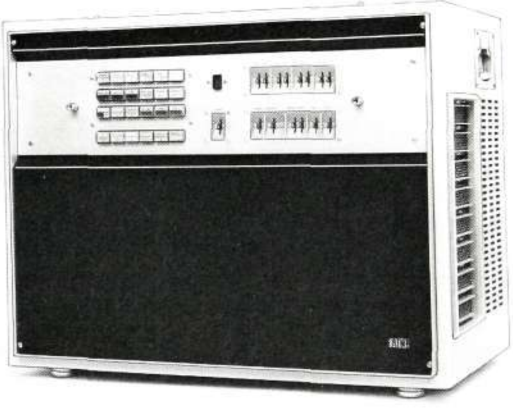
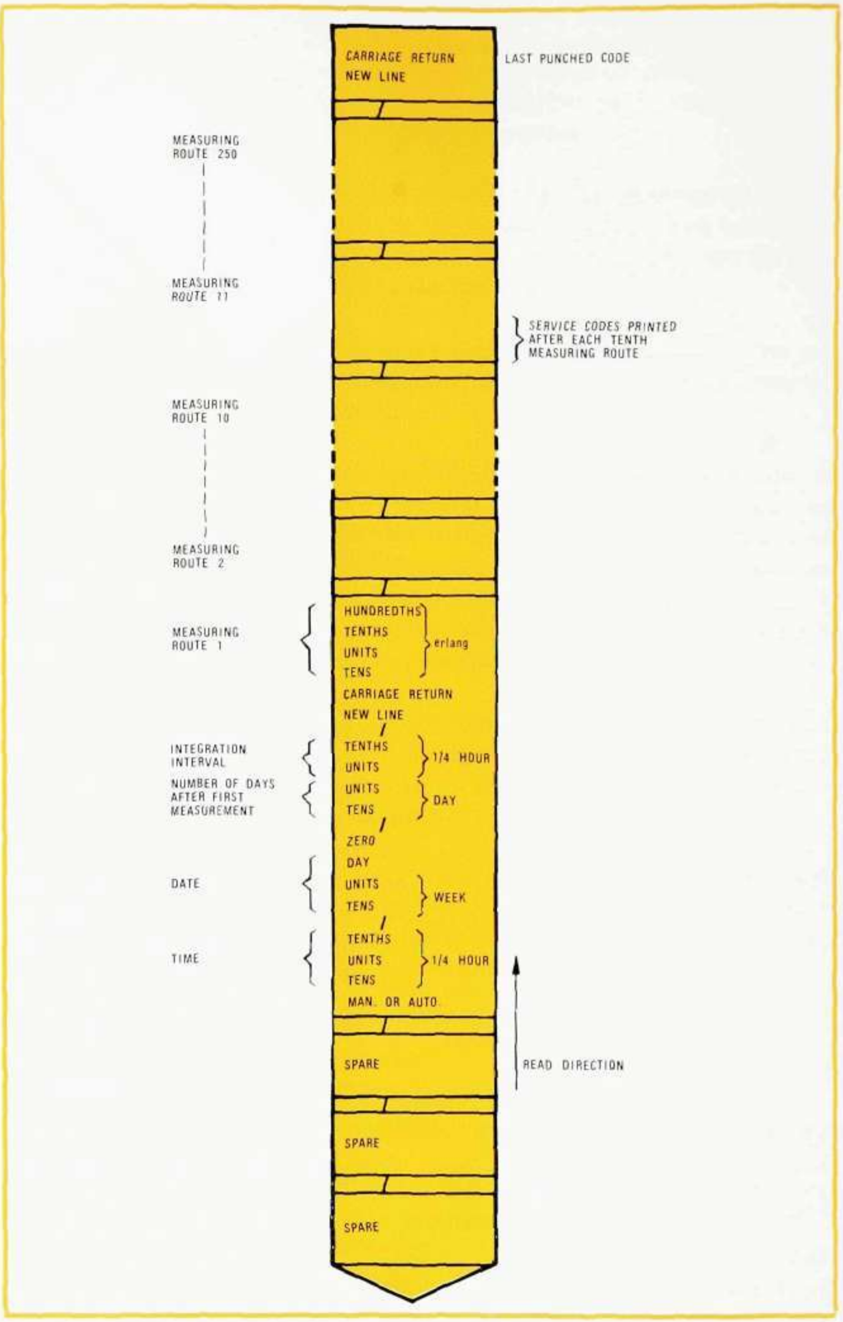


Fig. 6

Principle for the print-out



such as reading of data, updating of information, scanning of routes, punching and erasing of data contained in the store.

The manual ordering of, e.g., a data output is carried out by pressing the "*Manual Punching*" key. This starts a punching cycle similar to the automatic version, but with blocked route scanning.

The correct functioning of the measuring process is continuously supervised and, if a fault — e.g. a short-circuited wire — is detected, an alarm is given and suitable information is inserted in the print-out. It is then possible to locate the faulty route by means of a simple manipulation on the control panel.

Alarms are also issued in case of parity fault, blown fuse, end of paper tape in the punch, and in case of incorrect distribution of routes. In addition to the alarms indicated on the supervisory panel, alarms of two different levels of urgency are transmitted to the centralized alarm equipment of the exchange concerned.

In order to prevent measuring errors the MET 2 is designed in such a way that measurement is stopped in case of power failures. When the power has been restored, measurement is not resumed until a manual order has been given.

## Data Print-Out

Fig. 6 shows a print-out on a tape. The principle for the print-out is done according to CCITT's telex code No. 2.

Each group of 4 digits is separated from the subsequent group by an oblique stroke. If a fault has been discovered during a measuring sequence (e.g. a parity fault), a question mark is printed instead of the oblique stroke.

Two extra codes are printed after the print-out of every 10th route. They are used either for further processing in a computer or for print-out of the punched tape in human language in a teleprinter. In the latter case the codes are interpreted as carriage return and line feed.

## Summary

— Traffic engaging up to 15,000 circuits, distributed over 250 measuring routes, can be measured simultaneously. This quantity corresponds to a local exchange of some 50,000 lines in a multi-exchange area.

— The modular build-up of the scanning equipment allows a flexible capacity adapted to individual requirements. (The scanner multiple may be extended in steps of 16 routes).

— The scanning interval for each of the 15,000 points is only 4.5 seconds, ensuring a high accuracy of measurement also at short times of mean occupation and observation.

— The equipment may be programmed for automatic traffic measurement at predetermined times during up to eighty 24-hour periods, or during an unlimited period.

— The measured results actuate a tape punch, the tape of which is either used for subsequent processing in a computer or for print-out on a teleprinter.

— Electronic components are used in the build-up of the MET 2, which weighs only about 43 kg.

— It is transportable and the measuring wires from the exchange are connected over plugs and jacks.

— Several exchanges in an area may share the same MET 2 unit, provided that a compatible measuring program has been prepared for the exchanges concerned.

## References

DE GUZZIS, G.: *Apparecchiatura MET 2 per il rilievo del traffico telefonico; struttura e funzionamento.* Notiziario tecnico FATME N. 9 — dicembre -71.

PALLINI, R.: *La misura del traffico telefonico con il MET 2. Metodo e precisione.* Notiziario tecnico FATME N. 9 — dicembre -71.

# Radio System for the ESRO Satellite TD 1A

R. WEDBERG, SVENSKA RADIO AB, STOCKHOLM

UDK 621.396.946:629.783
LME 85102
852

*ESRO's largest scientific satellite hitherto, TD 1A, was launched on March 12, 1972, by an American Thor Delta rocket. The TD 1A satellite was developed by the industrial consortium MESH, of which Saab-Scania is a member with L M Ericsson's subsidiary Svenska Radio AB as subcontractor. The radio system of the satellite was developed by Svenska Radio AB.*

Sunday, March 12, 1972 was a great day for the European Space Research Organization (ESRO). On that day was launched Europe's largest satellite hitherto, *TD 1A*, by an American Thor Delta rocket from the Vandenberg base in California. The launching was of great interest also for the Ericsson Group, as the radio system of the satellite was developed by its subsidiary Svenska Radio AB (SRA).

This new advance in space research was the fruit of a lengthy period of development. ESRO had requested tenders as early as 1966, and after long negotiations the work was entrusted to the industrial consortium *MESH*, consisting of four European companies, Engins Matra, France, Entwicklungsring Nord, Germany, Saab-Scania, Sweden, and Hawker Siddley Dynamics, Great Britain. Svenska Radio AB has participated within the TD 1A project as subcontractor to Saab-Scania.

The satellite, which is the largest developed in Europe, is of respectable size also by international standards: its weight is 472 kg, max. width 4.4 m, max. height 2.1 m and max. depth 1.0 m.

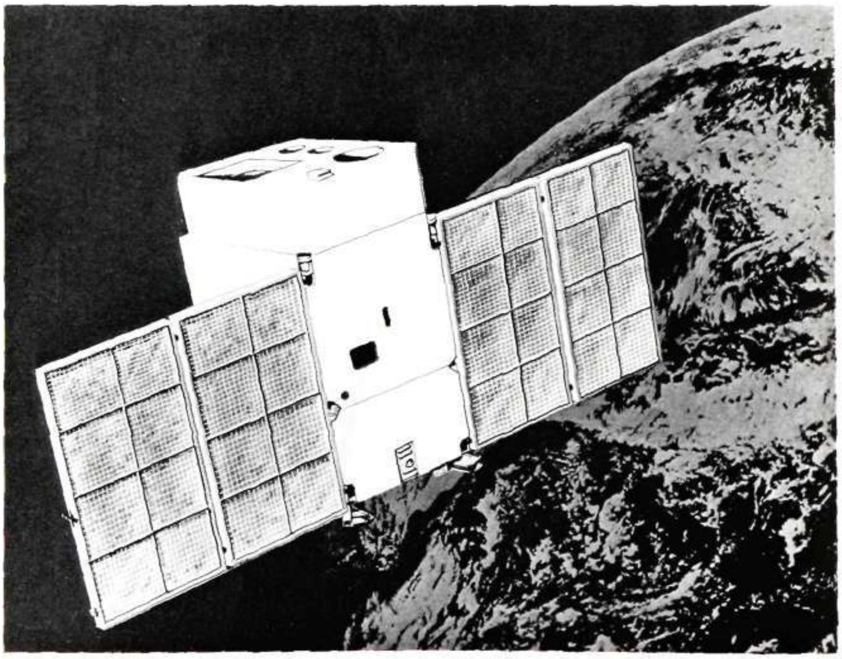
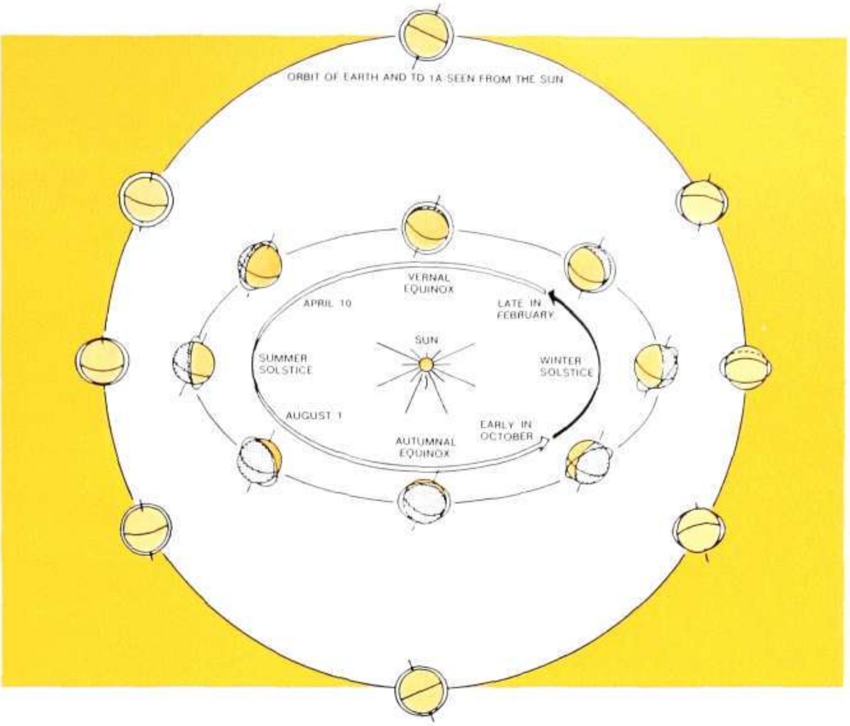


**Fig. 1**
**The TD 1A satellite in orbit (drawing)**

Fig. 2

**The orbit of TD 1A in relation to the sun**

**The outer ellipse is the orbit of the sun-illuminated earth. The viewer is at a great distance from the sun.**
**The circle is the orbit of the sun-illuminated earth as seen by a viewer placed on the sun. It is clearly seen that the satellite orbit is sun-illuminated from the end of February until the beginning of October.**



## Function and Orbit of the Satellite

The object of the satellite is to measure and record cosmic ultraviolet radiation, gamma radiation and X radiation. For this purpose the satellite has been equipped with seven measuring units, two of which were specially designed for measurement of ultraviolet radiation from stars.

In order to maximize the efficiency of the measurements made by the satellite, it was decided to place it at an altitude of 550 km in a circular orbit over the polar regions of the earth. The inclination of the orbit is slightly more than 90° and, by arranging for the launching at the beginning of March before the vernal equinox, the satellite's orbit will be constantly sun-illuminated during a period of rather more than 6 months (fig. 2), which is of extreme value for carrying out the measurements.

The TD 1A satellite is attitude-stabilized in such a way that its surface, covered with solar cells, is always directed towards the sun. The attitude control system also causes the satellite to rotate one revolution round the sun-stabilized axis for every revolution round the earth. The measuring units, the sensors of which point away from the earth, will thus scan the entire heavens within a period of six months, i.e. a complete map will be obtained of the phenomena recorded by the masuring unit.

## The Telecommunications System

The telecommunications system has three main functions, to collect and transmit measured data to ground stations, to detect, identify and order commands transmitted from ground stations, and to transmit a tracking signal used for accurate determination of orbit. The radio system developed by SRA has an important role in all these three tasks. Several of the units are duplicated in order to ensure optimum reliability.

Data measured by the satellite are arranged in suitable digital form by an encoder. The signals from the encoder are then recorded on a tape recorder.

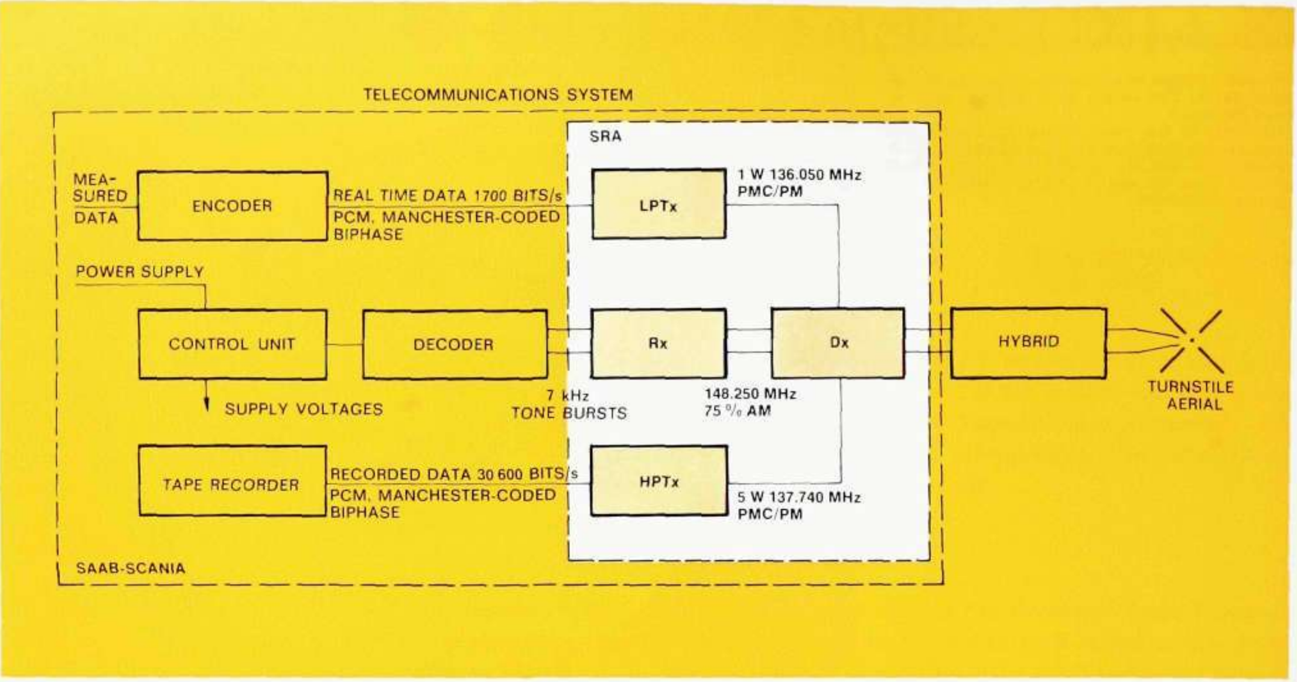


**Fig. 3**

**Radio system of TD 1A integrated with the other units in the telecommunications system**

The data can be transmitted both directly from the encoder and from the tape recorder.

In this way, during passage over a ground station, real time data can be obtained by reception of the signals from the encoder and of measured data from earlier parts of the orbit by playback of the information stored in the tape recorder. In practice this has been done by arranging that the tape recorder can store measured data from an entire revolution round the earth with a good margin to spare, which means that the satellite need be contacted only once per revolution to obtain access to all data. As the number of ground stations is limited, this arrangement contributes considerably to raising the degree of utilization of the satellite.

The commands (e.g. start of a given unit or measuring equipment) are sent to the satellite by radio from a ground station. The decoder of the telecommunications system is designed for 280 different commands, 244 of which are used for ordering different satellite functions.

The tracking signal is obtained from one of the transmitters in the telecommunications system. The direction to the satellite can be determined with the aid of interferometer aerials at a ground station. The directional information is used, among other purposes, for accurate determination of the orbit of the satellite and for control of the directional aerials used for reception of measured data and transmission of commands.

## The Radio System

The radio system for ESRO satellite TD 1A consists of four units, a low power transmitter, *LPTx*, a high power transmitter, *HPTx*, a receiver, *Rx* and a diplexer, *Dx*.

To ensure a very reliable transmission of measured data to the ground stations, the transmitters are duplicated, i.e. the *LPTx* unit contains two low power transmitters, *LPTx 1* and *LPTx 2*, and the *HPTx* unit contains two high power transmitters *HPTx 1* and *HPTx 2*. The switching from, for example, transmitter 1 to transmitter 2 is done, when desired, by transmission of a command from a ground station. The command is received by two identical receivers, *Rx 1* and *Rx 2*, in the *Rx* unit. The reason for having two receivers is the same as for the transmitters — increased reliability. A difference exists, however, in that the two receivers work simultaneously, so that, in the event of a fault in one receiver, the possibility of receiving commands is not entirely lost.

The diplexer contains two duplex filters which have somewhat different functions and are thus not duplicated for purposes of reliability. The transmitter power from the respective diplexer output is switched to a 90°, 3 db hybrid, which divides the power into two equal parts, each of which is taken to one dipole of the turnstile aerial. As the two signals from the hybrid are displaced 90° in phase, a circular polarized wave is obtained from the turnstile aerial, which is received and analysed in the ground station.

Fig. 3 shows a block diagram of the radio system and the connections to other units of the telecommunications system.

## *Low Power Transmitter, LPTx*

The main task of the low power transmitter is to transmit real time data to the ground station. For this purpose measured data are collected and ordered by the encoder so that, for modulation of the low power transmitter, a PCM signal (Manchester-coded biphase) is obtained at 1 700 bits/s. This signal is used to control the phase modulator of the transmitter so that a digitally phase-modulated high frequency signal (136,050 MHz) with power 1 W is obtained.

Real time data are important for operation of the satellite in addition to scientific data, real time data are transmitted concerning the state of operation of the satellite, such as supply voltages on different units, current consumption, temperatures and the like. The signal from the low power transmitter must also be able to serve as tracking signal so as to obtain the satellite's position in its orbit by interferometric reception at a ground station. The determination of position is important both for control of directional aerials which receive the data-modulated signal and for correlation of received data with well defined orbit positions. By using a modulating PCM signal of biphase type one obtains a transmitter spectrum with modulation sidebands and a partially suppressed carrier. When the modulation level is about ± 65°, the sideband level within ± 200 Hz from the carrier frequency will be approx. 35 db lower than the non-modulated carrier level. At the same time 25 % of the transmitter power remains in the suppressed carrier and this is sufficient for use as tracking signal. The satellite need accordingly not be equipped with a separate tracking transmitter.

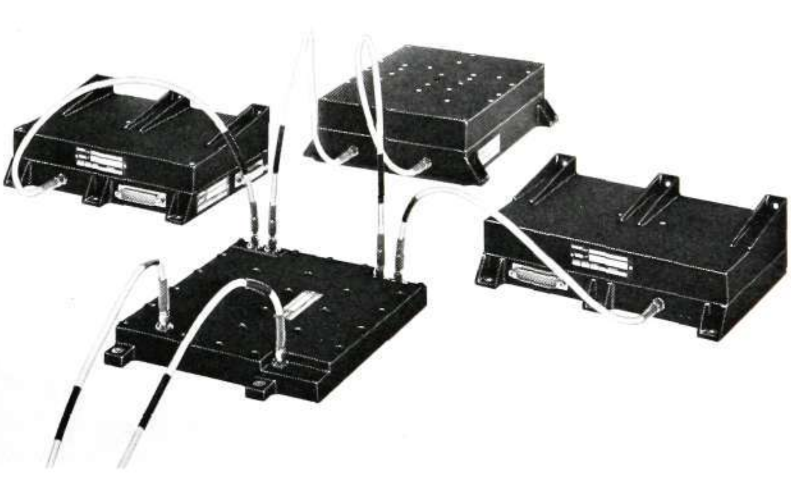


**Fig. 4**

**Radio system of TD 1A connected for bench testing**

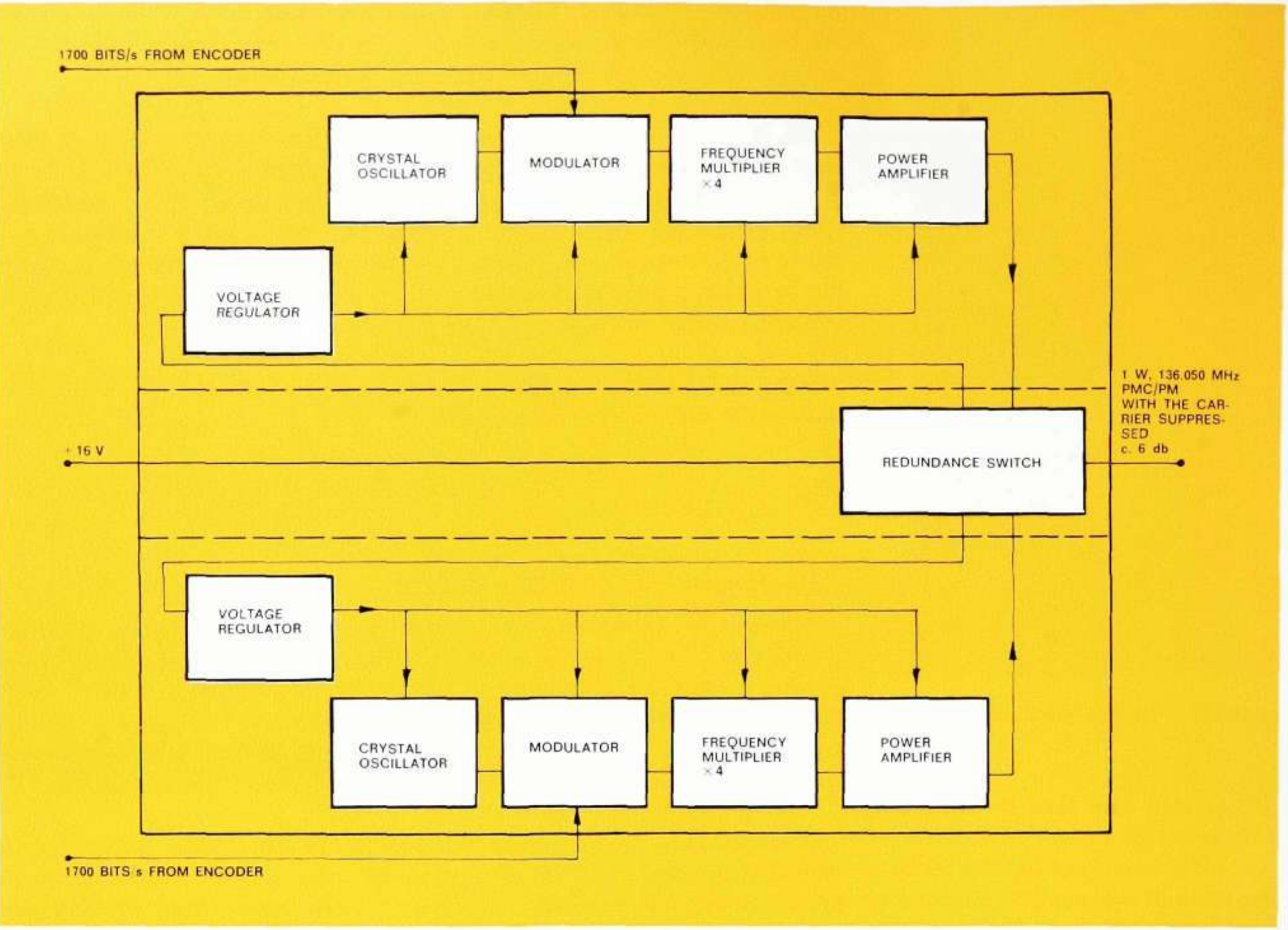


**Fig. 5**

**Block diagram for low power transmitter LPTx**

## *High Power Transmitter, HPTx*

The function of the high power transmitter is to transmit recorded data to ground stations. It differs from the low power transmitter both in its transmission frequency (137,740 MHz) and in its considerably higher data speed, 30,600 bits/s. In order to ensure a satisfactory signal-to-noise ratio in the ground station at this high data speed, a transmitter power of about 5 W is required. The high data speed is necessary in order, during passage over a ground station (approx. 7 min), to be able to transmit measured data from an entire revolution round the earth (approx. 90 min). The high power transmitter does not work continously but is started on command from the ground station over which the satellite is passing. The reason for this is the necessity to economize the expansive power generated by the solar cells on the satellite. A 5 W high power transmitter could very well perform the tasks of the low power transmitter, but would in such case need to operate continuously, thus considerably increasing the power consumption.

## *Command Receiver, Rx*

The command receiver receives and detects the command signals transmitted from the ground stations.

A command consists of a 7 000 Hz pulse-duration-modulated tone. The code used contains four characters consisting of 18, 36, 54 or 72 cycles of the tone respectively. The tone bursts are used for amplitude modulation (degree of modulation 75 %) of a 148,250 MHz carrier. The carrier power is about 200 W. The command signal is sent by directional aerials at the ground station to the satellite and is detected by the command receiver.

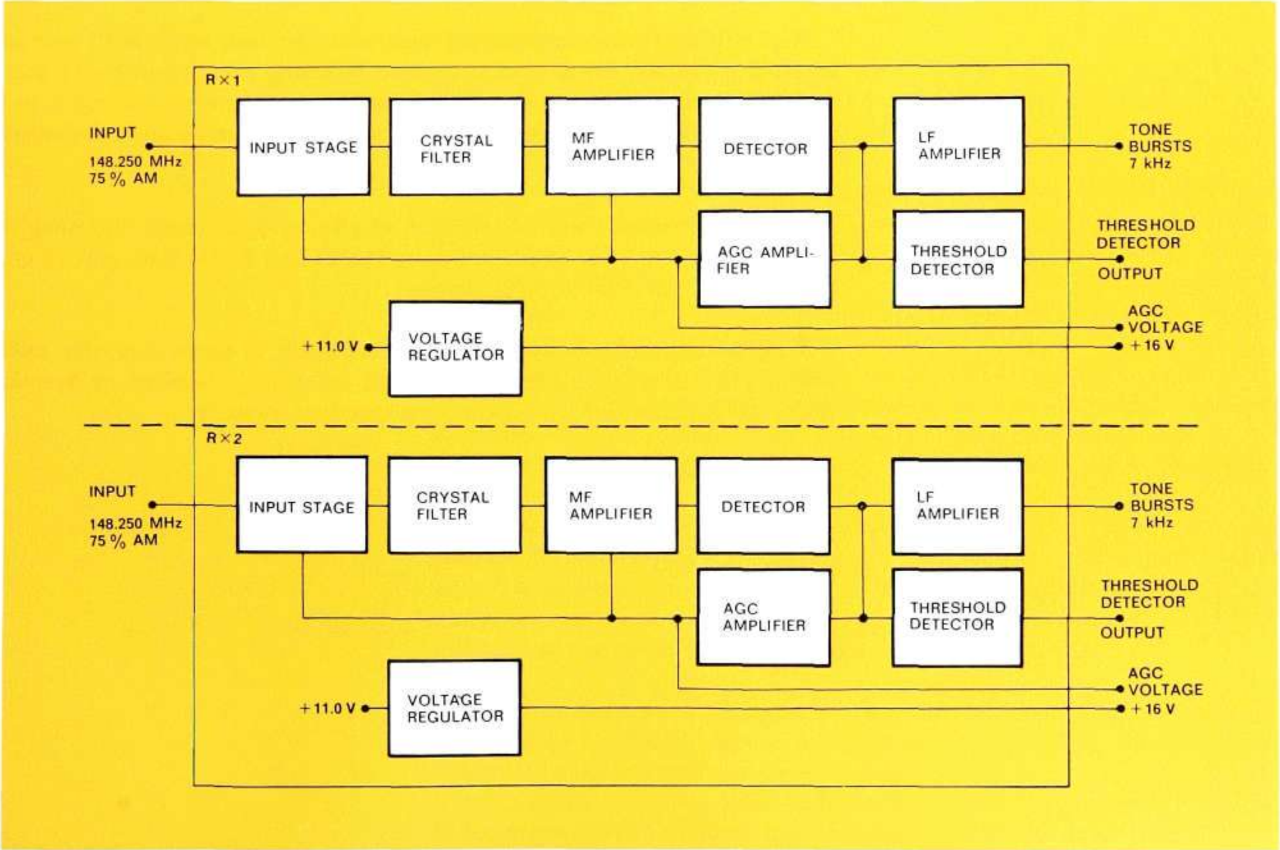
**Fig. 6**

**The high power transmitter HPTx opened for inspection**

Owing to the polarization characteristics of the combination hybrid-turnstile aerial each command is sent twice, first with right-hand circular polarization and then with left-hand circular polarization. Under fully ideal circumstances all received signals would then be received on the first occasion by *Rx 1* and on the second by *Rx 2*. In practice both receivers will receive signals owing, among other factors, to finite isolation in the hybrid. The further processing of the detected signals is done in the decoder following the receiver.

**Fig. 7**

**Block diagram of the command receiver Rx**



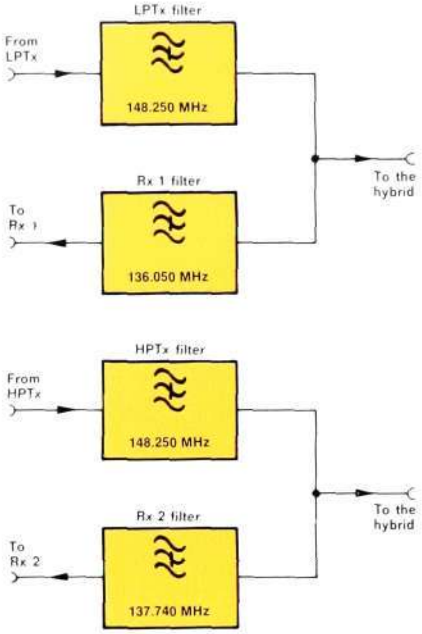


**Fig. 8**

**Block diagram of the diplexer Dx**

## *The Diplexer, Dx*

The diplexer for the TD 1A radio system consists of two duplex filters, each designed for connecting one transmitter and one receiver to a common point. Each duplex filter contains two band-stop filters. Originally each filter was designed as a bandpass filter with helix resonators but, as these showed corona problems in the pressure range 0.01—1 mm Hg, bandstop filters were chosen instead. Despite the relatively low working frequency (136—150 MHz) they could be made in stripline. This means that dielectric material always exists around each filter circuit and that the filters are entirely free from corona effect. It also proved that tuning of these filters was not necessary once the pattern had been established, i.e. the filter can be entirely without moving parts. This reduces the risk of failures so considerably that the filters need not be duplicated for purposes of reliability.

## Experience of the System

The work on the development of the TD 1A radio system has been both exacting and inspiring and has provided considerable experience of the type of project implied in the development of satellite electronics in international collaboration.

In the course of development it was necessary throughout to take into consideration the special and very high requirements placed on the satellite electronics. The mere purchase of components required much work as, from the reliability aspect, complete traceability all the way back to the manufacturer's processes was necessary for every individual.

To ensure a very high reliability a special workshop was arranged at Svenska Radio AB with extremely accurately controlled atmosphere (a so-called "clean room") in which the units were mounted by specially selected and trained personnel with great experience of such work. Each operation was documented and inspected by inspectors.

Prior to delivery the manufactured units were rigorously tested in all environments in which they would have to operate, including vibration with 20 g acceleration to simulate the stresses during launching. Tests were also made in a vacuum chamber with both high and low environmental temperature to simulate the conditions in space.

Each test procedure was documented, as also were the results of testing of each specified function. Inspectors from MESH and ESRO took part in and supervised the tests on several occasions.

Very thorough preparations have thus been made to ensure a reliable radio system and it is gratifying to know that all information received by Svenska Radio AB indicates that the radio system functions perfectly.

# Digital Transmission over Coaxial Cables

T. ERICSSON & U. JOHANSSON, TELEFONAKTIEBOLAGET LM ERICSSON, STOCKHOLM

UDC 621.3765:
621.37.037.37
LME 815
84367

*There are many indications that the telecommunication networks of the future will increasingly use digital techniques. A first step towards a digitalization of transmission equipment in the telecommunication network is now being made with the introduction of p.c.m. in certain local networks[1]. This is primarily concerned with speech information, and only a very modest number of speech channels — to be precise, 30 — are multiplexed.*

*In the future, digital transmission is likely to be employed also for a variety of other services, and multiplex systems of considerably higher order will be introduced. An ever-increasing need for digital line systems with very high transmission capacities may therefore be expected. The purpose of this article is to present a number of views as to how such digital line systems should be appropriately designed.*

## Basic Concepts

An *h.f. line system* consists of a transmission medium — coaxial cable, pair cable or similar medium — with appurtenant equipment, such as repeaters. The primary function of a line system is to reproduce at the receiving end the input signal which has been applied to it. Since there are always various types of disturbances — linear and non-linear distortion, thermal noise, impulse noise, etc. — it is fundamentally impossible to achieve an exact reproduction. The appurtenant equipment serves to counteract the disturbing phenomena to which the line is subjected, such that a reproduction of acceptable quality is obtained at the receiving end. (Besides the h.f. line system, a complete transmission system includes terminal multiplexing equipment, which is not dealt with in this article.)

Current line systems are mainly so-called analogue line systems, i.e. they are designed for the transmission of analogue signals, usually speech. Since in most cases it is desirable to transmit a large number of speech channels over the same transmission medium, it is necessary to use some sort of multiplexing technique. The method commonly used is frequency division multiplexing.

The 30-channel p.c.m. line systems that are now beginning to appear are specimens of a different class of line systems. Since the p.c.m. method is used to transmit analogue signals in digital form (digital information), the line system is called *digital line system*. The multiplexing method, too, is different; instead of frequency division multiplexing, use is made of time division multiplexing.

The term "digital line system" generally denotes a line system for transmitting information in digital form, usually — but not necessarily — as a sequence of binary symbols, zeros and ones. This need not, therefore — as in the case of p.c.m. — be speech information. Data, being digital in form from the outset, constitutes in fact a better example of information suitable for digital transmission.

There are several reasons why the majority of line systems now being used are of the analogue type. The first and main reason is that conventional techniques are well suited to analogue signal processing (linear filters, coils, capacitors, analogue modulators). Another reason is that up to now most of the information to be transmitted has been speech; using an analogue line system for the transmission of analogue information seems a very natural course of action. However, there are good grounds for expecting these conditions to change in the future. First, modern electronics shows a rapid development towards digital techniques. Second, the mere fact that there is an ever-increasing need to transmit other information than speech is a good enough reason to question whether analogue transmission really is the best method of transmitting information. As far as switching exchanges and multiplex terminals are concerned, we know already that digital techniques would in many cases offer considerable advantages. These advantages would undoubtedly be accentuated if the transmission method, too, was based on digital techniques.

In this article we shall concern ourselves with line systems of very high capacity — many times larger than the current 30-channel p.c.m. line systems. One of the questions we shall examine is whether large-capacity digital line systems can form a realistic alternative to the 12 MHz (2700-circuit) and 60 MHz (10,800-circuit) line systems now in production as well as to any future analogue systems having still larger capacities.

One of the first questions to be answered is what kind of transmission medium is suitable. Current analogue systems use coaxial cable — with normal-diameter (2.6/9.5 mm) and small-diameter (1.2/4.4 mm) pairs. For future systems — both analogue and digital — a number of alternative transmission media have been discussed:

- waveguides
- optical fibres
- new types of coaxial cable

Concerning waveguides and optical fibres it can be said that these media offer potential advantages of considerable interest. Both media have a theoretical transmission capacity which meets all currently foreseeable needs with room to spare. However, as yet they are only at an experimental stage, and consequently no application to line systems is imminent. It is therefore reasonable to expect coaxial cable — possibly in some new design — to continue to be the predominant transmission medium for some time to come — at least for the next 10 to 20 years — irrespective of whether transmission is effected in analogue or digital form. In our study of digital line systems we shall, therefore, confine ourselves to the coaxial-cable medium and, in particular, examine the properties of the cables standardized by the CCITT — viz. the previously mentioned normal-and small-diameter coaxial cables — as well as the so-called microcoaxial cable (0.65/2.8 mm). (As an alternative to microcoaxial cable, the so-called screened pair cable is at present under study. This alternative has, however, not been included in our investigation.)

Another fundamental question is how the digital information is to be represented on the line, i.e. what modulation technique (or code) is to be used. The number of possible alternatives is unlimited. Amplitude-shift keying (a.s.k.), frequency-shift keying (f.s.k.) and phase-shift keying (p.s.k.) are some well-known examples.

The modulation method used in current p.c.m. systems on pair cable is a.s.k., that is, the binary message signal is represented on the line by different pulse amplitudes.

Many factors point to the probability of a.s.k. being the most suitable modulation technique also for digital transmission on coaxial cable. First, a. s. k. is capable of simple technical realization. Second, it can be theoretically demonstrated that no other modulation technique has any fundamental advantages over a.s.k. with respect to transmission over coaxial cables. In this article we shall therefore assume that the modulation method to be used is a.s.k.

There are various types of a.s.k. We shall not attempt to justify any one of these in particular — the choice from among them must be based on a number of detailed technical considerations regarding repeater design, synchronization method, etc., and should preferably be postponed until more tangible projects concerning these matters have been made. We shall, however, study how the following parameters — fundamental in every a.s.k. system — are to be chosen, namely

— symbol rate, *B*

— number of signal levels, *K*.

The signification of these quantities is shown in fig. 1.

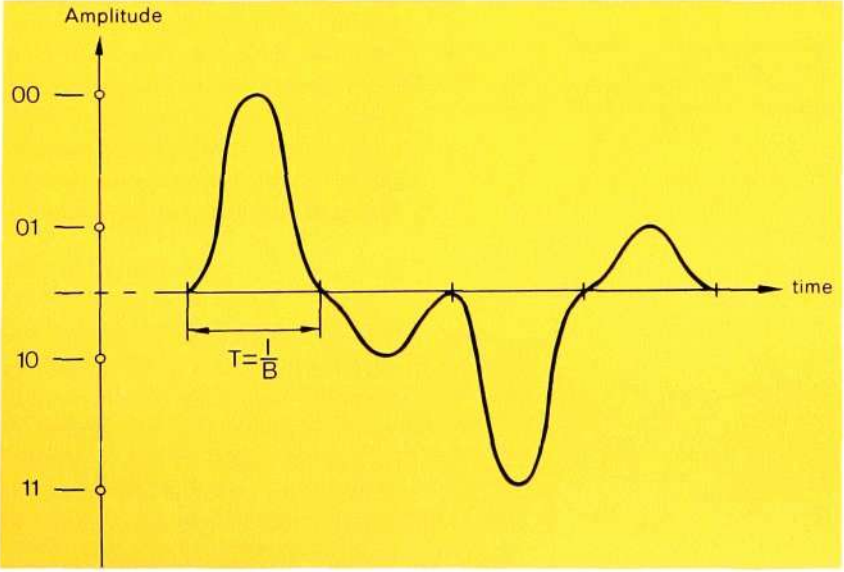


**Fig. 1**

**Example of signal representation of the binary sequence 0010 1101 in a.s.k. with four signal levels (K=4). Note that each signal represents $\log_2 4=2$ binary symbols. In an a.s.k. system with K signal levels each signal generally represents $\log_2$ K binary symbols.**

With the aid of $B$ and $K$, the *information rate*, $R$, for an a.s.k. system can be defined according to

$$R = B \log_2 K \text{ b/s}$$

It is easily ascertained that $R$ denotes the number of binary symbols per second transmitted over the line. This quantity thus constitutes a natural measure of the transmission capacity of the system (not to be confused with channel capacity in the sense of information theory). It should be observed, however, that a certain part of the digital stream must be reserved for synchronizing and other purposes. The effective information rate is therefore somewhat lower than $R$.

Another question of a fundamental nature is what repeater design is to be used. As previously mentioned, repeaters serve to counteract the disturbances encountered on the line. In particular, it is necessary to amplify the signal at regular intervals so as to compensate for losses introduced by the line. Usually, however, the repeaters also provide further signal processing.

In analogue line systems the repeater employed is normally of the analogue type. Such repeaters provide only linear signal processing, i.e. the signal is amplified and is then filtered in a linear filter. It can be shown that when using this type of repeaters the signal-to-noise ratio at the receiving terminal will be inversely proportional to the route length. In other words: to double the range, the output power of each repeater must be doubled. (This is true provided that only thermal noise is considered. When also the effects of so-called intermodulation noise are taken into account, a slightly more rapid decrease in the signal-to-noise ratio is obtained.)

One of the advantages of digital line systems is that they permit digital repeaters (also termed regenerative repeaters) to be used. Among the characteristic features of a digital repeater is the fact that it provides non-linear signal processing. In principle this can be accomplished in many different ways. In practice it is usually arranged by supplementing an analogue repeater with equipment for signal detection and signal regeneration. The function of the detector is to reconstruct the digital input signal. The reconstituted digital signal is subsequently used for the generation of a new output signal for application to line, in exactly the same manner as previously effected by the sending terminal equipment. The system is generally designed such that the probability of an error being committed by the detector is very low — $10^{-9}$ is a typical error rate. In this manner an almost exact signal reconstruction is achieved in each digital repeater. A consequence of this is that the signal quality is virtually independent of the length of the transmission line. Thus, when transmitting speech, for example, the transmission quality is determined almost entirely by the distortion introduced by analogue-to-digital conversion at the sending terminal (mainly quantization noise).

In this connection it may be worth mentioning that, whereas it is fundamentally impossible to use digital repeaters in an analogue line system, it is quite possible — and often economically advantageous (see below) — to use analogue repeaters in a digital line system. Consequently, one has greater freedom as regards the choice of repeaters when designing a digital line system than when designing an analogue one. In our investigation we shall avail ourselves of this freedom and, among other things, try to find the best possible combination of analogue and digital repeaters.

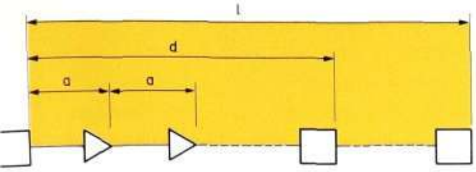


**Fig. 2**

**Schematic model of a digital line system including both analogue and digital repeaters**

☐ **Digital repeater**

▷ **Analogue repeater**

# System Design

A digital line system is shown schematically in fig. 2. A central question is how to choose the parameters of the line system. The objective is to choose them such that the total system cost per unit of length and unit of information rate is as low as possible (cf the concept of cost per channel-kilometre in connection with f.d.m. systems). Among the fundamental parameters to be determined are the following:

- symbol rate
- number of signal levels
- repeater spacing
- coaxial cable type.

At the same time as a low system cost is aimed at, certain fundamental requirements must, however, be met, such as transmission performance and repeater output power. If only digital repeaters are employed, repeater spacings are determined by the transmission performance requirement. This is not the case, however, when analogue and digital repeaters are combined, which then makes it possible to compensate for an increase in the distances between digital repeaters by a decrease in the distances between analogue repeaters, or vice versa. Advantage can be taken of this freedom in choosing repeater spacings to minimize the line cost.

If the cost per length unit is denoted by $Q$ and the information rate by $R$, our measure of performance — system cost per length unit and information rate unit — can be expressed as

$$Q/R = \left[\ \alpha + \left(\frac{1}{a} - \frac{1}{d}\right) \cdot \beta + \frac{1}{d} \cdot \gamma\ \right] / R$$

where

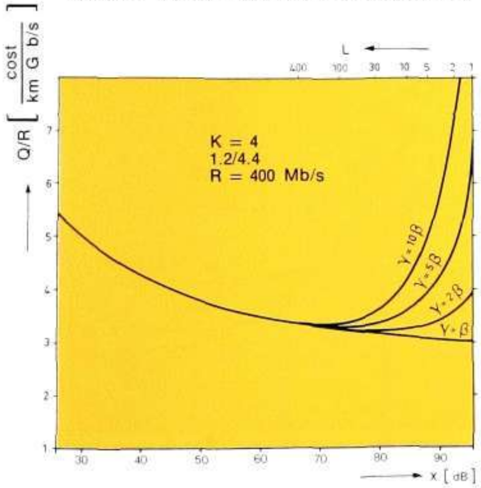
$\alpha$ = cable cost per km
$\beta$ = cost per analogue repeater
$\gamma$ = cost per digital repeater
$a$ = spacing of analogue repeaters
$d$ = spacing of digital repeaters

We shall illustrate below how $Q/R$ depends on certain system parameters. The material presented is based on estimates of costs and techniques in 1980. In these calculations the costs of mechanics and electronics as well as installation have been included.

Fig. 3 illustrates the dependence of $Q/R$ on the loss per cable section, measured, at the band edge. The loss is proportional to the length of the cable section, for which reason the abscissa might also be graduated in the parameter "spacing of analogue repeaters" ($a$). Furthermore, the number of cable sections, $L$, between two digital repeaters is connected with the loss by the transmission performance requirement. Consequently, it is also possible to graduate the abscissa in number of cable sections, which also has been done. Thus the previously discussed relation between the repeater spacings $a$ (analogue) and $d$ (digital) is shown indirectly in fig. 3, $a$ and $d$ being related to each other according to the equation $d = L \cdot a$. It should also be noted that $L = 1$ refers to a purely digital system without analogue repeaters.

**Fig. 3**

**The diagram shows how the system cost depends on the band-edge loss, X, for a few different cost relations, $\gamma/\beta$, between digital and analogue repeaters. The information rate is 400 Mb/s and small-diameter coaxial cable is used. L-1 is the number of analogue repeaters inserted between two digital ones.**



The figure includes curves corresponding to a few different values of the quotient between the cost per digital repeater, $\gamma$, and the cost per analogue repeater, $\beta$. We see that if the two repeater types are equal in cost, $\gamma/\beta = 1$, only digital repeaters should be used. If, however, analogue repeaters are cheaper, a lower system cost will be obtained when using a combination of analogue and digital repeaters. If, for example, $\gamma/\beta = 5$, the use of analogue repeaters will result in the total system cost being reduced to half the cost of a purely digital system.

Another interesting observation can be made from fig. 3, namely that the choice of $L$ is rather uncritical. If, for example, $\gamma/\beta = 5$, the lowest system cost will be obtained if about 100 analogue repeaters are inserted between two digital ones. If, instead, only 20 analogue repeaters are inserted per digital repeater section, this will change the total system cost only insignificantly.

Fig. 4 illustrates how the cost depends on the information rate at given distances between the analogue repeaters. An extremely important observation can be made, namely that the distances between the analogu repeaters must not be chosen too large. If so, this will involve a substantial increase in system cost. This is due to the fact that it is very difficult by means of digital repeaters to compensate for what the analogue repeaters have once failed to do. The reverse, i.e. an unnecessarily dense spacing of analogue repeaters, however, has far less severe economic consequences. When designing a digital line system it is therefore advisable "to be on the safe side" where repeater spacings are concerned.

For each given information rate there is an optimum repeater spacing. Fig. 5 illustrates how $Q/R$ varies with $R$ provided that these optimum repeater spacings are used throughout. The curves in fig. 5 thus form envelopes of families of curves of the kind given in fig. 4.

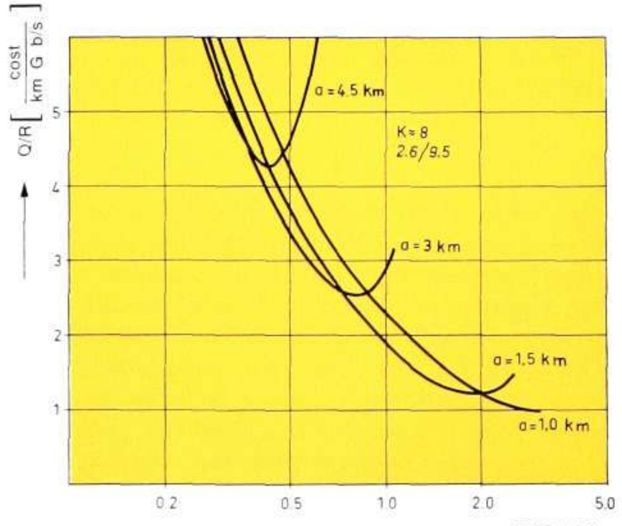
Three cable types have been studied, and we can now see from fig. 5 which cable is suitable at a given information rate.

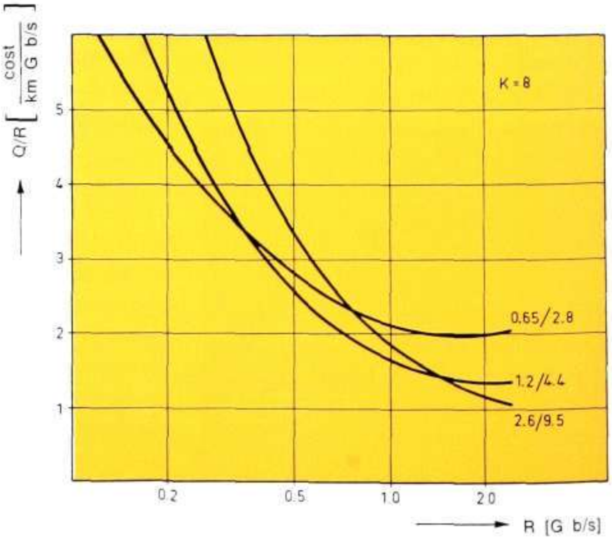
**Fig. 4 (left)**

**System cost as a function of information rate for different digital repeater spacings. The number of signal levels is 8 and normal-diameter coaxial cable is used.**

**Fig. 5**

**System cost as a function of information rate for different cable types, the number of signal levels being 8.**





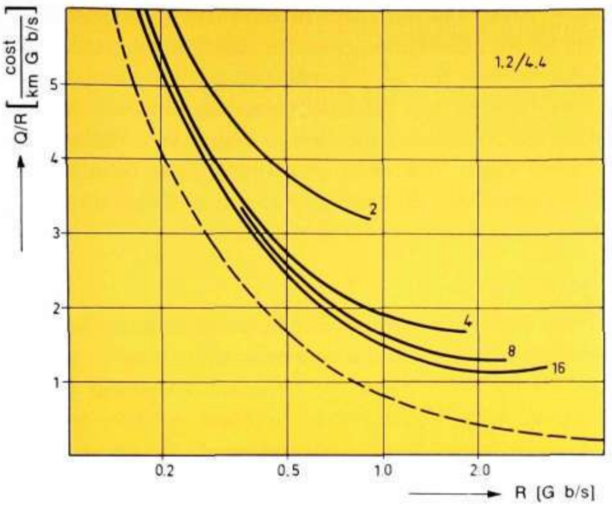


**Fig. 6 (left)**

**System cost as a function of information rate for a few multilevel a.s.k. systems. Small-diameter coaxial cable is used. The dashed curve shows the cable's share in the system cost.**

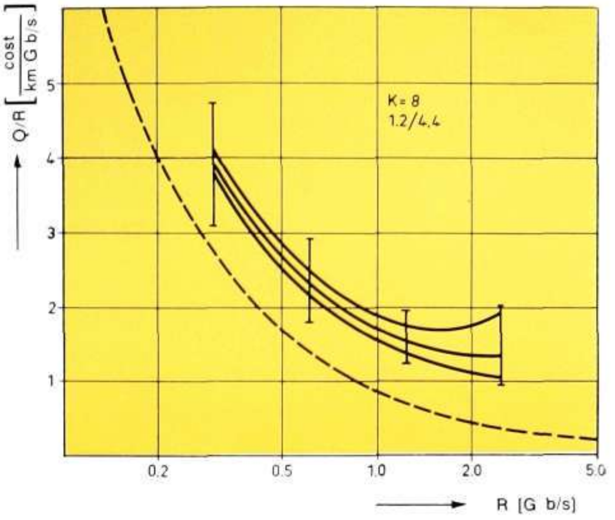


**Fig. 7**

**The diagram shows the variation in total system cost obtained with varying cable and repeater costs. The uppermost unbroken curve corresponds to a twofold increase in the costs of the repeater electronics. The lowest corresponds to a decrease of the same costs by half. The columns show the total variation range when also the cable cost is varied by ± 25 %.**

We see that microcoaxial cable should be used at low information rates and normal-diameter coaxial cable at very high rates. Small-diameter coaxial cable is most advantageous within a range from about 300 Mb/s to about 1.5 Gb/s but can be used far outside this range with no marked increase in costs.

Fig. 6 illustrates how the number of signal levels affects the total system cost. We see that 4, 8 and 16 signal levels involve about the same costs, whereas a purely binary system is less advantageous. The dashed line denotes the cable cost and represents, therefore, a cost that cannot be reduced, however cheap the electronic equipment employed may be. When using low information rates, the cable forms the greater part of the cost. Around the optimum, however, the costs of cable and electronic equipment are reasonably balanced.

On the basis of the graphs shown (as well as a number of similar diagrams which have not been included from considerations of space) it is now possible to calculate the optimum digital line system characteristics. The result is the following:

| | |
|---|---|
| — Cable type | small-diameter coaxial |
| — Nominal information rate | 1.8 Gb/s* |
| — Symbol rate | 600 Mbauds |
| — Number of signal levels | 8 |
| — Distance between analogue repeaters | 0.7 km |
| — Loss per cable section (measured at the band edge) | 60 dB |
| — Number of analogue repeaters between two digital ones | approx. 40 |
| — Output power | 0.05 W |
| — Noise figure per repeater | 9 dB |
| — Error probability per digital section | $10^{-9}$ |

* Corresponding to about 18 000 telephone channels

We have chosen *small-diameter coaxial cable* because this transmission medium appears appropriate for all information rates. In addition, we have chosen the number of signal levels to be 8, though according to fig. 6 a number of 16 would yield a slightly lower system cost. The difference is, however, so small that it would hardly justify the consequent increase in degree of technical complexity. Output power, noise figure and error probability have been fixed at "reasonable" values (when compared with existing analogue and digital systems). The other parameters have been chosen so as to minimize $Q/R$.

It should be observed that any changes in prices and technical know-how will, of course, produce a corresponding shift in the optimum. Up to now — as far as analogue line systems are concerned — there has been a development towards systems of ever-increasing capacity. A similar development is likely to occur in the case of digital line systems. As previously mentioned, the above figures apply to 1980.

Since all forecasts are based on rather uncertain estimates regarding future cable and repeater costs, it is essential to examine how sensitive they are to changes in these quantities. We have attempted to illustrate this matter in fig. 7. The three unbroken curves represent three different conditions regarding the electronics part of the repeater costs — the uncertain part of any forecast. The middle curve represents the original forecast, the other two curves showing the results when halving and doubling respectively the cost of electronics. It will be seen that these variations in the conditions involve comparatively insignificant changes in the total cost. This is especially true of low information rates, where cable costs are predominant.

We have also tried to illustrate the effects of variations in the cable cost. The columns in the diagram show the extreme values that can be reached if a 25-per cent increase or decrease of the cable cost is added to the above-mentioned variations in repeater costs. We see that the results are considerably more sensitive to variations in cable cost than to variations in the cost of electronics.

Generally speaking, however, our results may be said to be remarkably stable, considering the variations in economic conditions. This is due to the fact that the cable cost is a predominating factor in most technically plausible cases. Consequently, the information rate should be driven towards the limit of technical feasibility. In our forecast for 1980, therefore, the difficult point is to predict what technology will be able to do at that time rather than to judge at what price it can be done.

## Comparison with FDM Systems

How, then, does a digital line system compare with an analogue one? There are many aspects that can — and should — be noted. Besides costs, mention may be made of such concepts as reliability, compatibility with other systems as well as possibilities of expansion and introduction of new facilities. In this article, however, we shall confine ourselves to a simple comparison of costs. We wish to emphasize that this comparison is far from complete.

For a comparison of costs to be meaningful, line systems of the same capacity and quality should be compared. The transmission capacity of an analogue line system is usually expressed in number of speech circuits. In the case of digital line systems it is natural to use the information rate, $R$, as a measure of capacity. Thus, if we wish to compare an analogue and a digital line system, we must first calculate a conversion factor between the information rate and the number of speech circuits at a given transmission performance.

It is reasonable to start from the relations prevailing in current p.c.m. systems. In these each speech circuit is represented by 64 kb/s. Furthermore, the system requires certain additional information bits for signalling and synchronizing purposes. Such functions must, of course, also be included in a larger digital system. To make allowance for this requirement, we have therefore estimated that each speech circuit will need about 100 kb/s for representation on a digital line system.

Using this figure, it will be seen that in speech transmission the channel km cost figures for digital and analogue line systems are almost exactly equal. This applies to small- and normal-diameter coaxial cable and to all reasonable values of transmission capacity. Microcoaxial cable is not likely ever to be used for analogue line systems. That the system cost is equal in low-capacity systems is by no means surprising, since in those systems the cable cost is predominant. It is so much the more surprising that the result holds true also of high-capacity systems, where the costs of electronics are substantial.

Digital representation of a telephone channel requires considerably larger bandwidth than analogue representation. If 8 signal levels are used, about 20 kHz is required per speech channel, i.e. about 5 times as much as when using analogue representation. Since the attenuation per km in a coaxial cable increases with increasing frequency, a digital signal is, therefore, subjected to severer attenuation than an analogue one. On the other hand, a digital signal is far less sensitive to noise. Now these two effects happen to balance each other, the result being that the requisite repeater spacing is about the same, irrespective of whether digital or analogue representation is used. This accounts for the costs being the same for analogue and digital line systems when transmitting speech signals, even for large-capacity line systems.

It should be observed in this connection that the p.c.m. method is a fairly simple but, basically, presumably rather inefficient technique for the analogue-to-digital conversion of speech. In the future it may very well become possible to develop more efficient methods which would provide a more favourable conversion factor than the one we have used as a basis for our investigation.

In respect of other information than speech a comparison is more difficult to make since less practical experience is available. Concerning videophone it has been mentioned that a videophone channel would call for about 300 speech channels in an analogue line system but only about 100 in a digital one. When combining these figures with the above result regarding speech transmission, it will be found that videophone on an analogue line system would be about three times as expensive as on a digital line system. Similar results may be expected in the case of television transmission.

One more type of information to be considered is data. Here, as mentioned previously, a digital line system has an essential advantage over an analogue system, since data is presented in digital form from the outset. In data transmission on an f.d.m. facility the highest data rate that can be employed is generally about 4.8 kb/s. A possible data rate for use in data transmission on a p.c.m. facility is 48 kb/s. Hence, data transmission on a digital line system would be feasible at a cost of only about 10 % of that involved in data transmission on an analogue line system. However, this comparison should be taken with some caution since it is obvious that data transmission in an f.d.m. system can be organized a great deal more efficiently than assumed in our investigation. For example, certain batches of telephone channels, such as groups, supergroups or mastergroups, can be reserved for data transmission. Such a batch exclusively reserved for digital transmission, however, when considered as a separate unit, would show close resemblance with a digital line system.

## Summary

Our conclusions with regard to digital line systems can be summarized as follows:

- In the next 10 to 20 years the coaxial cable will probably be the most suitable transmission medium; waveguides and optical fibres may be regarded as possible alternatives in the remote future.
- The modulation method should be multilevel amplitude-shift keying (a.s.k.); 4, 8 or 16 levels should be used.
- At low information rates microcoaxial cable is the most advantageous; at high rates normal-diameter. Small-diameter coaxial cable constitutes a good compromise for all rates.
- For video and data transmission the transmission costs on a digital line system would be lower than on an analogue one. In the case of speech transmission the costs would be about the same for digital and analogue facilities.

We wish to emphasize that our investigation only applies to *line systems;* exchanges and multiplex terminals have not been considered here. In an overall assessment of the advantages and disadvantages of digital line systems these factors should also be included.

## References

1. Ohlsson, E.: *Fields of Application for PCM Systems*. Ericsson Rev. *49* (1972): 1, pp. 2—8.
2. Widl, W.: *PCM Transmission*. Ericsson Rev. *49* (1972): 1, pp. 9—13.
3. Lindquist, S., Fritzlen, H. J. & Carlsson, J. Å.: *PCM Multiplexing Equipment ZAK 30/32*. Ericsson Rev. *49* (1972): 2, pp. 34—46.
4. Arras, J. & Tarle, H.: *PCM Line Equipment ZAD 2*. Ericsson Rev. *49* (1972): 2, pp. 47—55.
5. Ericson, T. & Johansson, U.: *Digital Transmission over Coaxial Cables*. Ericsson Techn. *27* (1971): 4, pp. 191—272.

ERICSSON News

from All Quarters of the World

## Interim report 1972
# Order bookings up 7%

Order bookings during the first half of 1972 totalled $ 507,000,000, an increase of 7 % over the $ 427,900,000 recorded in the corresponding period of 1971. Orders from Swedish customers accounted for 14 %, the European market outside Sweden for 49 %, Latin America 29 % and other markets for 8 %.

General business conditions on the Group's principal markets did not noticeably change during the period. Investments in public telecommunications networks generally continued at a high rate, but some national governments cut back expenditures for this purpose in their budgets. The general business conditions caused a reduction in the demand among telephone administrations for subscriber switchboards and transmission systems. The demand for telecommunications equipment in manufacturing and commerce, as well as for cable and wire in building and construction, was adversely affected by retrenched business spending on plant and equipment.

Competition on the world market did not essentially change during the past half-year. Price levels are still being held down, especially by the Japanese manufacturers, and the technological competion is becoming keener in consequence of the increasingly intensive R & D pursued by the leading telecommunications industries.

The order backlog, which had amounted to $ 852,200,000 on January 1, rose to $ 959,000,000 as of June 30.

Group sales totalled $ 400,282,000, exceeding the sales of $ 324,475,000 during the same period of 1971 by 17 %. Swedish sales were rather lower than during the earlier year.

A high rate of production by Group plants led to sharply increased deliveries. Inventories of finished goods and the value of installations in progress increased moderately.

Selling, administrative, research and development expenses rose by 11.3 % over the first half of 1971. This is a significantly lower rate of increase than in 1970 and 1971, when these expenses went up by about 16 % per annum.

Group income before special adjustments and taxes amounted to $ 40,577,000 corresponding to 10.1 % (11.2 %) of sales.

Consistent with the method used in annual reporting, income after minority interests and taxes was $ 17,973,000 ($ 15,941,000), equal to $ 1.46 ($ 1.30) per share.

## Automatization of Swedish telephone network complete

Since the replacement of the manual exchanges in the Arjeplog area in June 1972 by automatic exchanges, the automatization of the Swedish telephone network has now been completed.

The period for conversion of the network to automatic operation has covered roughly 50 years and during the whole of this time L M Ericsson has supplied large quantities of equipment for automatic exchanges to the Telecommunications Administration. The company has manufactured and installed all 500-line selector stations in the Swedish network and some of the crossbar exchanges, complying with the systems developed by the Administration.

The event was celebrated by the Administration at a dinner at Arjeplog, where L M Ericsson was represented by, among others, the Head of the Group, Björn Lundvall, who, in expressing his congratulations to the Administration and to Director General Bjurel presented a picture, the motif of which — from Brunkebergs Torg in 1912, the year in which the telephone came to Arjeplog — has close associations with the work of the Telecommunications Administration. The building at Brunkebergs Torg 2, which has now disappeared, was for many years the residence of the Royal Board of Telegraphs — as from 1953 the Board of Telecommunications — and the neighbouring building with telephone tower on Malmskillnadsgatan housed in 1912 the largest telephone exchange in the world at that time, owned by the Stockholm General Telephone Company and manufactured by L M Ericsson. A telephone environment of ancient lineage!

**Björn Lundvall with L M Ericsson's memorial gift at the dinner at Arjeplog. At the table: (from left) Director General Per Øvregard, Norwegian PTT, Mrs Ingeborg Bjurel, Bengt Olov Norling, Ministry of Communications, and Mrs Klara Lundmark who since 1927 had operated the manual exchange at Adolfström in the Arjeplog area.**

# Important USA order

MCI Communications Corporation has signed an agreement with the L M Ericsson Telephone Company under which, during the coming 30 months, the latter is to deliver transmission equipment to MCI to a value of about 30 million kronor. Within the scope of this agreement the USA corporation has signed a contract for delivery of such equipment from L M Ericsson to a value of more than 10 million kronor.

The equipment is intended for a telecommunications system which will link New York with Chicago and Washington and a number of intermediate cities. The system constitutes a part of a nationwide communication network which MCI plans to build in the USA. Equipments now on order are expected to be ready for putting into operation in the summer of 1973.

This order and the agreement are important for L M Ericsson as they represent the company's first entry on the USA market within the transmission field.

## Swedish companies participate in European space company

A European company for work on telesatellites has been formed in Geneva. Behind the new company, Eurosat S.A., are 55 companies from nine European countries. The share capital of Eurosat S.A. amounts to 3.5 millions Swiss francs.

Swedish interests which took part in the preparatory work for the formation of the new company were the L M Ericsson Telephone Company, Saab-Scania AB and Stockholms Enskilda Bank.

The chairman of the board of Eurosat S.A. was Professor Werner Nestel from West Germany. P. P. J. Blussel, from France, has been appointed president of the company. The Swedish interests are represented on the board by Dr Christian Jacobæus, L M Ericsson, and Dr Tore Gullstrand, Saab-Scania.

The reason for the formation of Eurosat S.A. was the need for a European company which can undertake assignments in conjunction with telesatellites for practical use. Research and development in the telesatellite field have been conducted within Europe over a period of many years, primarily within the framework of ESRO (European Space Research Organization). There have also been local projects in various countries and extensive collaboration between the countries. No enterprise corresponding to that now formed has existed.

The main tasks of Eurosat will be to promote the establishment of operational satellite systems, especially for European regional requirements, and in consultation with the authorities concerned to organize the supply of such systems, to promote the export of regional systems to areas outside Europe, and finally to undertake or participate in the financing required for the setting up and operation of such systems.

The aforementioned Swedish Group participating in Eurosat S.A. has been extended and now comprises also Volvo Flygmotor AB, Standard Radio & Telefon AB and Philips Teleindustri AB.

## International telephony symposium in Stockholm

The human aspects of telephony were illustrated at an international symposium at Stockholm in June, "6th International Symposium on Human Factors in Telecommunication". This was the first occasion on which the symposium was held in Sweden. It was attended by around 100 delegates from 15 countries. The opening address, "Transmission and service level — are our present standards correct?", was held by Dr Christian Jacobæus of L M Ericsson. *Transmission* here signifies the quality of speech and *service level* signifies the grade of service (or congestion) in the network. For both factors there are today certain standards, but how will they be established in the future? A change of standard has a great effect on the design of the telephone network, and thus on its cost. The design and structure of telephone networks have hitherto been conditioned chiefly by technical possibilities and economy. In the future, human aspects may be taken into account to a greater extent than at present. One cannot weigh improved transmission conditions against a better service level without taking into consideration the human factor.

One of the subjects discussed during the four-day symposium was the international transmission of telephony. The subject was not limited to spoken telephony, but visual communication, e. g. videotelephony, data transmission and telegraphy were also touched upon. Another section related to new telephone services and their use, e. g. call-back and transfer of calls, and the use of alarm facilities. Some papers dealt with the effect of the telecommunications system on the social structure. In the United Kingdom, for example, an attempt has been made to evaluate the possibility of negotiations between parties in different parts of the country via a conference telephone system, with or without video transmission.

Another matter that was brought up was the problem of instructions to subscribers which exists and which prevents the rational use of new telephone services. An easily understood instruction for coin-box telephones, for example in the form of symbols, has undoubtedly been desired by many tourists in foreign countries.

Among other subjects may be mentioned the design of telephone directories and of telephone sets and systems with the aim of making them easier to use.

**Some participants at the symposium: (From left) J. E. Karlin, Bell Telephone Labs, H. Oden, Standard Electric Lorenz AG, G. Wikell and N. Gleiss from the Swedish Telecommunications Administration, and Eric Ericsson from L M Ericsson.**

---

The first symposium of this kind was held in 1961 at Cambridge and has been followed every second year by symposia at Copenhagen, the Hague, Bad Wiessee and London. The hosts at this year's symposium were the Swedish Telecommunications Administration and L M Ericsson jointly.

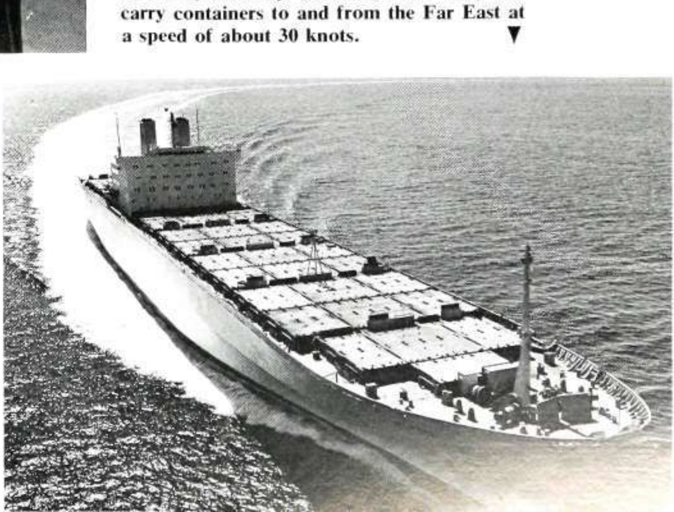
In conjunction with the first delivery of telephone cable for about 5 Mkr to the Iraq PTT from Latinoamericana de Cables, Mexico, a showing of the factory was arranged for persons invited from the Mexican government, industry and press. In the photograph (right) the head of the company, Joaquin Blix, is demonstrating to the Mexican Minister of Industry, Carlos Torrex Mango (centre) and the Chairman of the Board of L M Ericsson, Dr Marcus Wallenberg, a telephone cable of the type delivered.

Teleindustria S A — part-owned L M Ericsson subsidiary in Mexico — has held a board meeting at Midsommarkransen. The photograph shows two newly elected members of the board, Bernardo Quintana, industrialist and new chairman of the board, and Carlos Abedrop, banker, with the president of L M Ericsson, Björn Lundvall (far right). In the background (from left) Harald Mohlström and Executive Vice President Arne Stein, LME.

In August L M Ericsson was visited by the Director General of the Zambia PTT, Philemon Ngoma. ►

In August L M Ericsson was visited by Jukka I. Wallenius (far left), Director General of the Finnish PTT, in the company of the Head of OY L M Ericsson AB, Yngve Ollus (far right). (Centre) Hubert Lindström and Bertil Persson, both of LME. ▼

L M Ericsson Telemateriel AB have delivered to the largest Swedish container vessel, m/s NIHON, 30,000 tons dw. and with a capacity of 2200 containers, a P.A.B.X. for 50 extensions and with an exchange line for shore connection, also a fire alarm system comprising 240 heat detectors, 100 smoke detectors and 40 alarm pushbuttons. m/s NIHON, built by Öresundsvarvet AB, will carry containers to and from the Far East at a speed of about 30 knots. ▼



Peter Wallenberg, Vice President of AB Atlas Copco, was elected deputy member of the board of L M Ericsson at the annual general meeting in 1972. He succeeds Marc Wallenberg Jr who died in November 1971.

---

Mr Lennart Nilsson took up the post of Head of L M Ericsson S.A., Madrid, in April.

Mr Nilsson's last assignment was with Teléfonos Ericsson C.A., Ecuador, the new head of which is Rina Rinnan, earlier at Compania Anónima Ericsson, Caracas.

---

Mr Rolf Neuendorff has been appointed President of the Group's Cable Works in the Argentine, Industrias Eléctricas de Quilmes, in succession to Mr Lars Gräslund, who is returning to Sweden.

---

Mr Jan Andersson has succeeded Mr Bo Gustafsson as President of Fios e Cabos Plásticos do Brasil Cable Works at Rio de Janeiro.

## Grants for electronics research

The board of the Telefonaktiebolaget L M Ericsson Foundation for the Promotion of Electronics Research has made grants out of the year's funds to 12 applicants, amounting altogether to 38,045 kronor.

## 273 million telephones in the world in 1971

The number of telephones in the world on January 1, 1971, was 272.7 million, an increase during 1970 of 17.6 million or 6.9 %.

The United States (with the exception of Hawaii), with 119,671,000 telephones in service, has 43.9 % of the world total. The corresponding figure for Sweden was 4,505,802 telephones, 1.65 % of the world total.

The world telephone density, i.e. the number of telephones per 100 inhabitants, increased during 1970 from 7.1 to 7.4. The leading position among industrial countries was held by the United States with 58.34, followed by Sweden with 55.67. Among cities Washington DC held first place with 116.9, and outside the United States Stockholm was in the lead with 91.9, followed by Zurich with 78.6.

More than 500 telephone conversations per person and year were recorded for the United States (779.0), Canada (738.8), Sweden (674.0), Iceland (593.0) and the Bahama Islands (512.4).

These figures come from AT & T's "The World's Telephones", from which the table below is also taken.

| | Total tel. in millions 1.1.1971 | Per cent increase from 1970 | 1961 | Total tel. per 100 pop. 1.1.1971 |
|---|---|---|---|---|
| USA | 120.2 | 4.3 | 61.7 | 58.35 |
| Sweden | 4.5 | 4.6 | 63.2 | 55.67 |
| Switzerland | 3.0 | 6.3 | 82.4 | 48.26 |
| Canada | 9.8 | 4.9 | 70.3 | 45.23 |
| New Zealand | 1.3 | 5.0 | 69.5 | 44.14 |
| Denmark | 1.7 | 6.1 | 58.2 | 34.42 |
| Australia | 3.9 | 8.7 | 72.7 | 31.18 |
| Norway | 1.1 | 5.0 | 54.6 | 29.41 |
| United Kingdom | 15.0 | 7.3 | 81.0 | 26.68 |
| Netherlands | 3.4 | 9.3 | 111.4 | 26.00 |
| Finland | 1.2 | 8.4 | 94.7 | 25.21 |
| Japan | 26.2 | 13.4 | 280.1 | 25.14 |
| Germany, Federal Republic | 13.8 | 11.1 | 130.8 | 22.43 |
| Belgium | 2.0 | 4.2 | 76.7 | 20.83 |
| Austria | 1.4 | 7.0 | 103.5 | 19.29 |
| Italy | 9.4 | 9.9 | 142.7 | 17.38 |
| France | 8.8 | 8.1 | 101.3 | 17.19 |

## New company within the cable sector

A new company, Kabeldon AB, has been formed jointly by Sieverts Kabelverk AB and AB Liljeholmens Kabelfabrik. The company takes over the work of the Cable Accessories Division in Alingsås, earlier conducted by Sieverts Kabelverk.

The object of the new company, in which the two interested parties have equal shares, is to create improved competitivity through increased resources. The manufacturing schedule will comprise, among other items, cable boxes, cable cabinets, cable laying materials, light fittings, and miscellaneous cable accessories. The company employs some 180 persons.

The President of Kabeldon AB is Stig Jacobsson, earlier head of the Cable Accessories Division of Sieverts Kabelverk.

Sieverts Kabelverk is a member of the L M Ericsson Group, while Liljeholmens Kabelfabrik is an ASEA enterprise. The two companies are the main manufacturers of power cable in Sweden.

## Ericsson Technics

Ericsson Technics No. 2, which was recently issued, contains two papers.

The first by G. Salomonsson, *An Equalizer with Feedback Filter,* discusses the possibilities of using the feedback periodic filter as an equalizer. It is shown that such an equalizer of finite order is as good as a semi-infinite transversal filter if the input signal is finite. Methods for iterative adjustment of the coefficients of the filter and for determining the position of the main pulse are discussed.

The second paper, by F. Sellberg, *Large-Signal Calculations on IMPATT Oscillators with Voltage Waveforms Giving Close-to-Optimum Efficiency,* presents an approximative treatment of the theory for the function of the IMPATT oscillator in a new way. The IMPATT oscillator is a semiconductor diode which is biassed to avalanche breakdown in the reverse direction, so generating microwave power. By taking into consideration resistive losses in diode and external circuit a better theoretical agreement has been attained with experimental experience than before. At the same time the possibility of designing IMPATT diodes with higher efficiency than hitherto is indicated.

# The Ericsson Group

## *Subsidiaries, associated companies and technical offices*

### EUROPE

DENMARK

**L M Ericsson A/S** *DK-2600 Glostrup*, Kirkebjerg Allé 86, tel: (01) 96 6133, tgm: ericsson københavn, telex: 19020 "ERICSSON KH"

**GNT AUTOMATIC A/S** *DK-2860 Søborg*, Telefonvej 6, tel: (01) 69 5188, tgm: nortelmatic, telex: 27064, "GNT AUTOMATIC KH"

**Dansk Signal Industri A/S** *DK-2650 Hvidovre*, Stamholmen 175, Avedøre Holme, tel: (01) 49 0333, tgm: signaler københavn, telex: 16503, "16503 DSI DK"

**ELMI A/S** *DK-600 Gentofte*, Kirkebjerg Allé 90, tel: (01) 45 42 11, tgm: elmiworks, telex: 16600, "FOTEX DK" att. ELMIWORKS

FINLAND

**Oy L M Ericsson Ab** *SF-02420 Jorvas*, tel: (90) 2991, tgm: ericssons, telex: 12546, "LME SF"

FRANCE

**Société Française des Téléphones Ericsson**
*F-92 Colombes*, 36, Boulevard de la Finlande, tel: Paris (1) 781 3535, tgm: ericsson colombes, telex: 62179, "ERICSSON CLOMB"

*F-75-Paris 17e*, 147, rue de Courcelles, tel: Paris (1) 227 9530, tgm: eric paris, telex: 29276, "ERICSSON PARIS"

**Etablissements Ferrer-Auran S.A.** *13 Marseille, (10ème)*, 88, Avenue de la Capelette, tel: (91) 47 4851, telex: 42579, "RINGMA 42579 F"

**RIFA S/A**
*F-62206 Boulogne sur Mer*, B.P 146/3, tel: (21) 31 9206, telex: 11431, "BORIFA 11431 F"

*F-92 Boulogne sur Seine*, 5, Rue Vauthier, tel: (1) 603 0640, telex: 20781, "FARIFA 20781 F"

**Thorsmans S.a.r.l.**
*F-75018 Paris*, 3, Passage ruelle, tel: 607 6974

GREAT BRITAIN

**Swedish Ericsson Company Ltd.** *Morden, Surrey*, Crown House, London Road, tel: (01) 542 1001, tgm: teleric, telex: 935979 "SWEDERIC LDN"

**Swedish Ericsson Telecommunications Ltd.** *Horsham Sussex*, Viking House, Foundry Lane, tel: (0403) 641 66 tgm: teleric, telex: 877522, "SWEDERIC HORSHAM"

**Production Control (Ericsson) Ltd.** *Horsham Sussex*, Viking House, Foudry Lane, tel: (0403) 641 66, tgm: productrol, telex: 877522, "SWEDERIC HORSHAM"

**Swedish Ericsson Rentals Ltd.** *Horsham Sussex*, Viking House, Foundry Lane, tel: (0403) 641 66, tgm: celefon, telex: 877522, "SWEDERIC HORSHAM"

**Thorsman & Co. Ltd.**
*Charley Lancs. PR6 OLP*. Thor House, Yerrow Mill, tel: (02572) 4999

**E. B. Marine Communications Ltd.** *Morden, Surrey*, Crown House, London Road, telex: 935979

IRELAND

**L M Ericsson Ltd.** *Dublin 2*, 32, Upper Mount Street, tel: (01) 619 31, tgm: ericsson, telex, 5310, "LMI EI"

ITALY

**FATME, Soc. per Az.** *1-00100 Roma*, C. P. 4025 A. tel: (06) 4694, tgm, fatme, telex: 61327, "61327 FATME"

**SETEMER, Soc. per Az.** *1-00198 Roma*, Via G. Paisiello 43, tel: (06) 86 8854, tgm: setemer

**SIELTE, Soc. per Az.** *I-00100 Roma*, C.P. 5100, tel: (06) 577 8041, tgm: sielte, telex: 61225, "61225 SIELTE"

NETHERLANDS

**Ericsson Telefoonmaatschappij N.V.** *Rijen (N.Br.)*, P. O. B. 8, tel: (01612) 3131, tgm: erictel, telex: 54114, "ETMRY NL"

*Voorburg 2110*, P. O. B. 60, tel: (070) 81 4501, tgm: erictel den haag, telex: 31109, "ETMVB NL"

NORWAY

**A/S Elektrisk Bureau** *N-1360 Nesbru*, P.B. 98, tel: (02) 78 8060, tgm: teleb, telex: 11723, "TELEB N"

**A/S Industrikontroll** *Oslo 6*, Grensevejen 86/88, 3. etg., tel: (02) 67 8394, tgm: indtroll

**A/S Norsk Kabelfabrik** *Drammen*, P.O.B. 369, tel: (02) 83 7650, tgm: kabel, telex: 18149, "KABEL N".

**A/S Telesystemer** *Oslo 6*, Tvetenveien 32, Bryn, tel: (02) 68 7200, tgm: telesystemer, telex: 16900, "ALARM N"

POLAND

**Telefonaktiebolaget L M Ericsson, Technical Office** *Warszawa*, Ul. Nowy Swiat 42, tel: 26 4926, tgm: tellme, telex: 813710, "813710 TELLME PL"

PORTUGAL

**Sociedade Ericsson de Portugal Lda.** *Lisboa 1*, Rua Filipe Folque 7, 1°, tel: 56 3212, tgm: ericsson

SPAIN

**Industrias de Telecomunicación, S.A.** *Getafe*, Paseo Felipe Calleja 6, tel: 295 2100, tgm: ericsson, telex: 22666, "ERIGE E"

**L M Ericsson, S.A.** *Madrid 5*, Bernadino Obregón 25, tel: 467 8700, tgm: ericofon, telex: 23333, "23333 LMESA E"

SWEDEN

**Telefonaktiebolaget L M Ericsson,** *S-126 25 Stockholm*, tel: (08) 719 0000, tgm, telefonbolaget, telex: 17440, "LME S"

**ELLEMTEL Utvecklings Aktiebolag** *S-127 25 Skärholmen* Box 249, tel: (08) 97 0220

**Bjurhagens Fabrikers AB** *S-200 12 Malmö*, Fack, tel: (040) 93 4770, telex: 3123, "BJURHAG S"

**AB Rifa** *S-161 11 Bromma 11*, Fack, tel: (08) 26 2600, tgm: elrifa, telex: 10308, "ELRIFA STH"

**L M Ericsson Instruktionsteknik AB** *S-117 47 Stockholm 44*, tel: (08) 68 0870, tgm: instruktec

**L M Ericsson Telemateriel AB** *S-135 01 Stockholm-Tyresö 1*, Fack, tel: (08) 712 0000 tgm: ellem, telex: 10920, "10920 LMSBO/S"

**Sieverts Kabelverk AB** *S-172 87 Sundbyberg*, tel: (08) 28 2720, tgm: sievertsfabrik, telex: 1676, "SIEVKAB S"

**Svenska Radio AB** *S 102 20 Stockholm 12*, Fack, tel: (08) 22 31 40, tgm: svenskradio, telex: 10094 "SRA S"

**AB Thorsman & Co.** *S-611 01 Nyköping 1*, Box 149, tel: (0155) 810 00, tgm: thorsmanco

**AB Transvertex** *S-145 53 Norsborg*, Fittja industriområde, tel: (08) 710 0935

SWITZERLAND

**Ericsson A.G.** *8061 Zurich*, Postfach, tel: (01) 41 6608, tgm: telericsson, telex: 52669, "ERIC CH"

TURKEY

**Ericsson Türk Ticaret Ltd. Sirketi** *Ankara*, Rumeli Han, Ziya Gokalp Cad. tel: 12 3170, tgm: ellem

WEST GERMANY

**Ericsson Centrum G.m.b.H.** *3 Hannover*, Dornierstrasse 10, Postfach 1809, tel: (0511) 63 1018, tgm: ericen, telex: 922913, "922913 ERICE D"

**E B Marine Nachrichtentechnik GmbH,** *Hamburg 70*, Mühlenstieg 5, tel: (0411) 652 9831, telex: 212076

**Thorsman & Co GmbH,** *D-4796 Salzkotten*, Lange Strasse 4, Postfach 96, tel: (05258) 8450

### ASIA

INDIA

**Ericsson India Limited**
*Calcutta*, P.O.B. 2319, tel: (032) 45 4494, tgm: inderic, telex: 7165, "ERICCU CA 7165"

*New Delhi 24*, No. 15,Community Center, Suraj Parbat, tel: (011) 63 1637, tgm: inderic

INDONESIA

**Ericsson Telephone Sales Corporation AB**
*Djakarta*, P.O.B. 2443, tel: (07) 463 97, tgm: javeric, telex: 4414 "JAVERIC DKT 4414"

*Bandung*, Djalan Ir. H. Djuanda 151, tel: (082) 820 94, tgm: javeric

IRAQ

**Telefonaktiebolaget L M Ericsson, Iraq Branch** *Baghdad* P.O.B. 2388, Alwiyah, tel: 960 07, tgm: ellemco

KUWAIT

**Telefonaktiebolaget L M Ericsson, Technical Office** *Kuwait, State of Kuwait*, P.O.B. SAFAT No. 5979, tel: 42 0074, tgm: erictel

LEBANON

**Société Libanaise des Téléphones Ericsson** *Beyrouth* B.P. 8148, tel: 25 2627, tgm: ellem, telex: ELLEM 20876 LE

MALAYSIA

**Ericsson Talipon SDN BHD** *Shah Alam, Selangor, Batu Tiga Industrial Estate*, P.O.B. 28, Tel: Kuala Lumpur (03) 36 1821, tgm: kuleric, telex: 265, "ERICMAL KLTX 265"

**Telecommunication Manufacturers (Malaysia) SDN BHD** *Shah Alam, Selangor, Batu Tiga Industrial Estate*, P.O.B. 28, tel: Kuala Lumpur (03) 36 1821, tgm: kuleric, telex: 265, "ERICMAL KLTX 265"

PAKISTAN

**L M Ericsson Telephone Company, Technical Office** *Karachi*, P.O.B. 7398, tel: (90) 51 6112, tgm: ericsson

THAILAND

**Ericsson Telephone Corp. Far East AB** *Bangkok*, P.O.B. 824, tel: (02) 51 8191, tgm: ericsson, telex: 2274, "THAIERIC"

### AFRICA

A. R. EGYPT

**Telefonaktiebolaget L M Ericsson, Technical Office** Egypt Branch *Cairo* P.O.B. 2084, tel: (02) 465 83, tgm: ericgypt, telex: 2009, "ELLEME UN"

ETHIOPIA

**Telefonaktiebolaget L M Ericsson, Technical Office** *Addis Ababa*, P.O.B. 3366, tel: (01) 492 60, tgm: ericsson, telex: 21090 "MOSFIRM ADDIS"

MOROCCO

**Société Marocaine des Téléphones Ericsson** *Casablanca*, 87, Rue Karatchi, tel: 788 75, tgm: ericsson

TUNISIA

**Telefonaktiebolaget L M Ericsson, Technical Office,** *Tunis*, Boite Postale 780, tel: (01) 24 0520, tgm: ericsson, telex: 695, "ERICSSON TUNIS".

ZAMBIA

**Ericsson Telephone Sales Corporation AB**
*Lusaka*, P.O.B. 2762, tel: (011) 744 42, tgm: ericofon

*Ndola*, P.O.B. 2256, tel: (026) 3885, tgm: ericofon

### AMERICA

ARGENTINA

**Cia Ericsson S.A.C.I.** *Buenos Aires* Casilla de Correo 3550, tel: 33 2071, tgm: ericsson, telex: 0122196, "CATEL BA"

**Cía Argentina de Teléfonos** S.A. *Buenos Aires*, Belgrano 894, tel: 33 2076, tgm: catel, telex: 0122196, "CATEL BA"

**Cía Entrerriana de Teléfonos S.A.** *Buenos Aires*, Belgrano 894, tel: 33 2076, tgm: catel, telex: 0122196, "CATEL BA"

**Industrias Eléctricas de Quilmes S.A.** *Quilmes FNGR*, 12 de Octubre 1090, tel: 253 2775, tgm: indelqui buenosaires, telex: 0122196, "CATEL BA"

BRAZIL

**Ericsson do Brasil Comércio e Indústria S.A.**
*São Paulo*, Rua da Coroa 500, tel: (011) 298 2322 tgm: ericsson, telex: 021817, "ERICSSON SPO"

*Rio de Janeiro*, Caixa Postal 3601-ZC-00, tel: (021) 221 7477, tgm: ericsson, telex: 031839, "ERICSSON RIO"

**Fios e Cabos Plásticos do Brasil S.A. (FICAP)** *Rio de Janeiro*, caixa postal: 1828, tel: (021) 391 4550, tgm: ficap, telex: 031485, "FICAP RIO"

CANADA

**L M Ericsson Limited** *Montreal 381, Quebec*, 2300 Laurentian Boulevard St. Laurent, tel: (514) 331 3310, tgm: caneric, telex: 05-267682, (TWX) 610-421-3311, "CANERIC MTL"

CENTRAL AMERICA

**Telefonaktiebolaget L M Ericsson, Oficina Tecnica de Centroamérica** *San Salvador*, Apartado 188, tel: 21 7640, tgm: ericsson, telex: 20087, "ERICSAL 20087"

CHILE

**Cia Ericsson de Chile S.A.** *Santiago*, Casilla 10143, tel: (04) 825 55, tgm: ericsson, telex: 40598, "40598 ERICH CL"

COLOMBIA

**Ericsson de Colombia S.A.** *Bogotá*, Apartado Aéreo 4052, tel: (92) 41 1100, tgm: ericsson, telex: 044507, "ERICSSON BOG"

**Fábricas Colombianas de Materiales Eléctricos Fácomec S.A.** *Cali*, Apartado Aéreo 4534, tel: 42 1061, tgm: facomec, telex: 55673, "FACOMEC CLO"

COSTA RICA

**Telefonaktiebolaget L M Ericsson, Technical Office** *San José*, Apartado 10073, tel: 21 1466, tgm: ericsson, telex: 283, "283 LME-CR"

ECUADOR

**Teléfonos Ericsson C.A.**
*Quito*, Casilla 2138, tel: 52 4000, tgm: ericsson

*Guayaquil*, Casilla 376, tel: 30 0900 tgm: ericsson

*Cont. on next page*

## Subsidiaries, associated companies and technical offices (Cont. from preceding page)

MEXICO

**Teléfonos Ericsson S.A.** *Mexico D.F.*, Apartado Postal M-9958, tel: 566 8955 tgm: coeric, telex: 017234, "ERICSSON TLA" PARA COERIC

**Latinoamericana de Cables S.A. de C.V.** *Mexico 12 D.F.*, Apartado Postal 12737, tel: 549 0844 tgm: latincasa, telex: 017234, "ERICSSON TLA" PARA LATINCASA

**Teleindustria, S.A.** *Mexico 1, D.F.*, Apartado Postal 1062, tel: 565 7033 tgm: ericsson, telex: 017234 "ERICSSON TLA"

**Telemontaje, S.A. de C.V.** *Mexico 1. D.F.*, Apartado Postal 1062, tel: 576 4044, tgm: ericsson, telex: 017234, "ERICSSON TLA" PARA TELEMONTAJE

PANAMA

**Telefonaktiebolaget L M Ericsson, Oficina Técnica de Panamá** *Panama 5, R.P.* Apartado 4349, tel: 64 3600, tgm: ericsson, telex: 368674 "368674 SONITEL"

PERU

**Cia Ericsson S.A.** *Lima,* Apartado 2982, tel: 31 1005, tgm: ericsson, telex: 3540202, "ERICSSON 3540202"

**Soc. Telefónica del Perú, S. A.** *Arequipa*, Apartado 112-1012, tel: 6060 tgm: telefonica

EL SALVADOR

**Telefonaktiebolaget L M Ericsson, Technical Office** *San Salvador*, Apartado 188, tel: 21 7640, tgm: ericsson

URUGUAY

**Cia Ericsson S.A.** *Montevideo*, Casilla de Correo 575, tel: 91 2611, tgm: ericsson, telex: 398228, "ROULEMENT UY" PARA MELANDER

USA

**The Ericsson Corporation** *New York, N.Y. 10017*, 100 Park Avenue, tel: (212) 685 4030, tgm: erictel, telex: 620484, "ERICTEC 620484"

**Ericsson Centrum Inc.** *New York, N.Y. 10016*, 16, East 40th Street, tel: (212) 679 1000, tgm: erictel, telex: 620149, "ETELSAC 620149"

VENEZUELA

**Cía Anónima Ericsson** *Caracas*, Apartado 70516, tel: (02) 34 4661, tgm: ericsson, telex: 21530, "21530 ERIC VEN"

**Alambres y Cables Venezolanos C.A. (ALCAVE)** *Caracas*, Apartado del Este 62107, tel: (02) 33 9791, tgm: alcave, telex: 22845, "22845 ALCAVE VE"

### AUSTRALIA & OCEANIA

AUSTRALIA

**L M Ericsson Pty Ltd.**
*Broadmeadows, Victoria 3047*, P.O.B. 41, tel: (03) 309 2244, tgm: ericmel, telex: *AA 30555*, "ERICMEL"

*Rushcutters Bay N.S.W. 2011*, 134 Barcom Avenue, tel: (02) 31 0941, tgm: ericsyd, telex: AA 21358 "ERICSYD"

*Boroko, Papua New Guinea*, P.O.B. 5602, tel: Port Moresby 565 66, tgm: ericpor, telex: Port Moresby 153

**Teleric Pty. Ltd.**
*Broadmeadows, Victoria 3047*, P.O.B. 41, tel: (03) 309 2244, tgm: teleric, telex: AA 30555, "ERICMEL"

*Rushcutters Bay N.S.W. 2011*, 134 Barcom Avenue, tel: (02) 31 0941, tgm: teleric, telex: AA 21358, "ERICSYD"

**Conqueror Cables Pty. Limited** *Dee Why, N.S.W. 2099*, P.O.B. 69, tel: (02) 982 3344, tgm concab sydney, telex: 24305, "CONCAB AA 24305"

**A.E.E. Capacitors Pty. Ltd.** *Preston, Victoria 3072*, 202 Bell Street, P.O.B. 95, tel: (03) 480 1211, tgm: engiquip melbourne, telex: 31001, "AEEMELB AA 31001"

## Representatives

### EUROPE

AUSTRIA

**Electro-Diesel Handelsaktiengesellschaft, Abteilung Telecom** *1160 Wien*, Postfach 98, tel: (0222) 43 5956, tgm: teleric, telex: 75976, "75976 TELECOM A"

BELGIUM

**Allumage Lumière S.A.** *Bruxelles 7*, 128-130 Chaussée de Mons, tel: (02) 23 9425, tgm: allumalux, telex: 21582, "ALLUMALUX BRU"

GREECE

**Angelos Cotzias** *Athens, 18*, Omirou Street, tel: (021) 62 6031, tgm: cotziasan, telex: 215252, "215252 CTZS GR"

ICELAND

**Johan Rönning** *Reykjavik*, P.O.B. 5300, tel: 840 00, tgm: rönning, telex: 2040, "ROENNG IS"

CANARY ISLANDS

**TRANSA Transacciones Canarias S.A.**

*Las Palmas de Gran Canarias*, Tomas Morales 36, tel: 21 8304, tgm: transa, telex: 95052, "95052 CASTI E"

*Santa Cruz de Tenerife*, Tirso de Molina, 2 "Edificio Dulcinea", tel: 22 9240, tgm: transa

YUGOSLAVIA

**Merkantile Inozemna Zastupstva** *Zagreb* P.O.B. 02-1027, tel: (041) 41 6655, tgm: merkantile, telex: 21139, "21139 YU MERTIL"

*Beograd*, Gospodar Jevremova 46 tel: (011) 63 2878, tgm: merkantile, telex: 11263, "YU MERKAN"

### ASIA

BAHRAIN & UNITED ARAB EMIRATES

**Yusuf Bin Ahmed Kanoo** *Bahrain, Arabian Gulf*, tel: 40 8188, tgm: kanoo, telex: BHN 215

BURMA

**Myanma Export Import Corp., Agency Div.** *Rangoon*, P.O.B. 404, tel: 112 58, tgm: myanagent telex: UBMEIC BM 2005

CAMBODIA

**Comin Khmere S.A.** *Phnom-Penh*, P.O.B. 625, tel: 233 34, tgm: engineer

CYPRUS

**S.A. Petrides & Sons Ltd.** *Nicosia*, P.O.B. 4522, tel: 427 88, tgm: armature, telex: 2308, "ARMATURE"

HONG KONG AND MACAO

**Swedish Trading Co. Ltd.** *Hong-Kong*, P.O.B. 108, tel: 23 1091, tgm: swedetrade

IRAN

**Irano Swedish Company A. B.** *Teheran*, Khiabane Sevom Esfand 29, tel: 31 4161, tgm: iranoswede

JORDAN

**The Arab Trading & Development Co.** *Amman*, P.O.B. 6141, tel: 259 81, tgm: aradeve

KUWAIT

**Morad Yousuf Behbehani** *Kuwait, State of Kuwait*, P.O.B. 146, tel: 42 7071, tgm: barakat, telex: 2048, "BEHBEHANI KUWAIT"

LEBANON

**Swedish Levant Trading** *Beyrouth*, P.O.B. 931, tel: 23 1624, tgm: skefko

OMAN

**Muscat Trading Company** *Muscat* P.O. B. 127, tel. 458, tgm: tijarah, telex: MB 258 MUSTRAD

PAKISTAN

**Panasian Marketing Service Ltd.** *Karachi*, P.O.B. 3941, tel: (90) 51 2051, Ext. 53, tgm: panasian

PHILIPPINES

**Asia Industries Inc.** *Makati, Rizal*, M.C.C. Post Office 1322, tel: 87 7011, tgm: usi asia, telex: 7222233, "7222233 AII PH"

SAUDI ARABIA

**Engineering Projects & Products Co. Ltd. (Eppco)**

*Riyadh*, P.O.B. 987, tel: 222 22, tgm: eppcol

*Yeddah*, P.O.B. 1502, tel: 222 22, tgm: eppcol

*Dammam*, P.O.B. 450, tel: 222 22, tgm: eppcol

SYRIA

**Constantin Georgiades** *Damas*, P.O.B. 2398, tel: 266 73, tgm: georgiades

TAIWAN

**Trans-Eurasia Enterprise, Ltd.** *Taipei*, P.O.B. 3880, tel: 51 7038, tgm: esbtrading

REPUBLIC OF VIETNAM

**Vo Tuyen Dien-Thoai Vietnam** *Saigon*, P.O.B. 1049, tel: 226 60, tgm: telerad

**International Business Representative** *Saigon*, 26—28, Hai Ba Trung Street, tel: 226 60, tgm: ibur

### AFRICA

ETHIOPIA

**Mosvold Company (Ethiopia) Ltd.** *Addis Ababa*, P.O.B. 1371, tel: (01) 101 00, tgm: mosvold, telex: 21090, "MOSFIRM ADDIS"

KENYA, TANZANIA, UGANDA

**The Old East African Trading Co. Ltd.** *Nairobi, Kenya*, P.O.B. 30013, tel: 271 61, tgm: broche, telex: 22261, "OLDEAST NAIROBI"

LIBERIA

**Telecommunications Authority** *Monrovia*, P.O.B. 9039, tel: 222 22, tgm: radiolibe, telex: 4211 TLX BOOTH LIB

LIBYA

**ADECO African Development & Engineering Co***Tripoli*, P.O.B. 2390, tel: 339 06, tgm: adeco

MALAWI

**Business Machines Ltd.,** *Limbe*, P.O.B. 5557, tel: Blantyre 513 52, tgm: falt, telex: 342, "FALT LIMBE"

MOZAMBIQUE

**J. Martins Marques & Ca. Lda** *Lourenço Marques*, P.O.B. 2409, tel: 24953, tgm: marquesco

NIGERIA

**Communications Associates of Nigeria Ltd. (Comsac),** *Ilupeju (Lagos)*, P.M.B. 1129, tel: 322 06 tgm: comdec lagos

SOUTH AFRICA
NAMIBIA

**Dryden Communications (Pty.) Ltd.** *Johannesburg, South Africa*, P.O.B. 2440, tel: 838 5454, tgm: qualsteels, telex: 430094, "430094 SA"

SUDAN

**El Rahad Trading Corporation** *Khartoum*, P.O.B. 866, tel: 776 95, tgm: suconto, telex: BHN 251

ZAIRE

**I.P.T.C. (Zaire) Ltd.** *Kinshasa*, P.O.B. 8922, tel: 253 45, tgm: induexpan, telex: 327, "IPTC KIN"

### AMERICA

BAHAMA ISLANDS

**Anglo American Electrical Company Ltd.** *Freeport, Grand Bahama*, P.O.B. 104

BOLIVIA

**Prat Ltda** *La Paz*, Casilla 4790, tel: 277 12, tgm: prat, telex: PRAT BX 5363

COSTA RICA

**Tropical Commission Co. Ltd.** *San José*, Apartado 661, tel: 22 5511, tgm: troco

DOMINICAN REPUBLIC

**Humberto Garcia, C. por A.** *Santo Domingo*, Apartado 771, tel. 682 3645, tgm: gartier

GUATEMALA

**Nils Pira** *Ciudad de Guatemala*, Apartado 36, tel: (021) 622 57, tgm: nilspira

GUYANA

**General Supplies Agency** *Georgetown*, tel: 638 38, P.O.B. 375, tgm: benwiks

HONDURAS

**Quinchón Leon y Cía** *Teguicigalpa*, Apartado 85, tel: 251 71, tgm: quinchon

NETHERLANDS ANTILLES

**S.E.L. Maduro & Sons Inc. Merchandise Dept.** *Willemstad, Curaçao* P.O.B. 304, tel: 130 00, tgm: madurosons, telex: CU 92

NICARAGUA

**Roberto Teran G.** *Managua*, Apartado 689, tel: 224 00, tgm: roteran

PANAMA

**Sonitel, S.A.** *Panama 5, R.P.*, Apartado 4349, tel: 64 3600, tgm: sonitel, telex: 368674, "368674 SONITEL"

**Mr. Tore Korch** *Panama 5, R. P.*, Apartado 4349, tel: 64 36 00, tgm: sonitel, telex: 36 86 74, "36 86 74 SONITEL" FOR MR KORCH

PARAGUAY

**S.A. Comercial e Industrial H. Petersen** *Asunción*, Casilla 592, tel: 44 124, tgm: pargtrade

EL SALVADOR

**Dada-Dada & Co.** *San Salvador* Apartado 274, tel: 21 7940, tgm: dada

SURINAM

**W.E. van Romondt's Trading Company Ltd.** *Paramaribo*, P.O.B. 1837, tel: 728 31, tgm: vanromondt

TRINIDAD, W.I.

**Leon J. Aché Ltd.** *Port-of-Spain*, P.O.B. 276, tel: 323 57, tgm: achegram

### AUSTRALIA & OCEANIA

NEW ZEALAND

**ASEA Electric (NZ) Ltd.** *Wellington C. 1.*, P.O.B. 3239, tel: 706 14 tgm: asea, telex: 3431, "ASEAWELL NZ 3431"

SATHERLUND & KROOK

ERICSSON Review

4
1972

# ERICSSON REVIEW

Vol. 49 No. 4 1972

RESPONSIBLE PUBLISHER: CHR. JACOBÆUS, DR. TECHN.
EDITOR: SIGVARD EKLUND, DHS
EDITOR'S OFFICE: S-126 25 STOCKHOLM
SUBSCRIPTIONS: ONE YEAR $1.80; ONE COPY $0.60

## CONTENTS

On cover: The new LM Ericsson manual exchange ADG 101 in hotel reception surroundings.

# Centralized Maintenance in Zagreb Telephone District

P. BALASTRIN & A. MANOLA, PTT, ZAGREB

UDC 621.395.722.004.5
LME 154
834

*Centralized controlled corrective maintenance on the principles developed by L M Ericsson for transit centres is being introduced in stages in the Zagreb telephone district. Satisfactory results in the form of higher service reliability and reduced staff have been found already after completion of the first stage. This article describes in broad outline the transition to the new method and its effect on the maintenance organization. Readers who wish to make a closer study of maintenance questions and of controlled corrective maintenance methods, as well as of the associated equipments for national and international traffic, are referred to the bibliography at the end of this article.*

## Structure of Yugoslavian Telephone Network

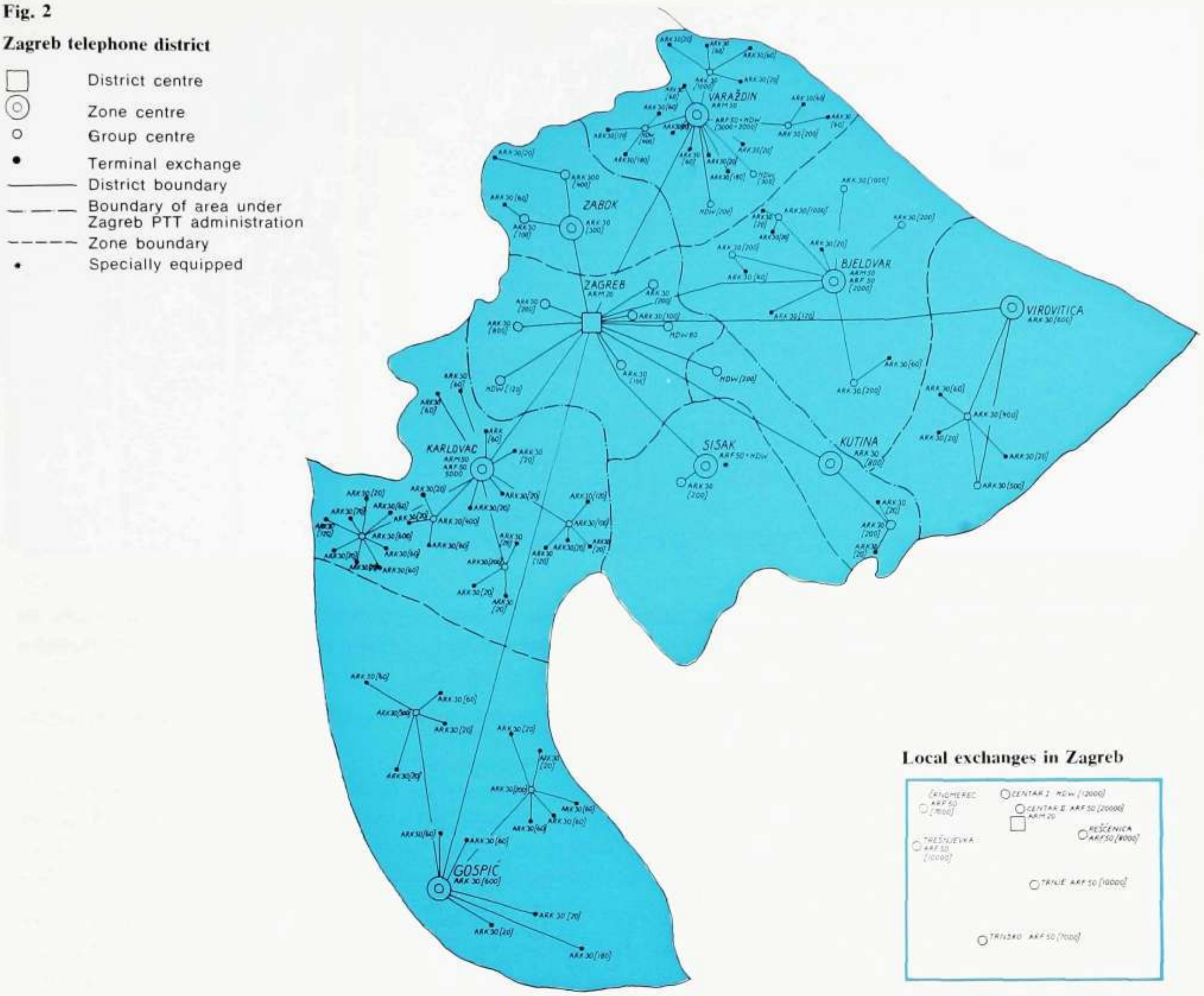
For operation of the fully automatic telephone traffic Yugoslavia is at present divided into 17 districts or transit areas (fig. 1). Each district comprises a central zone, with a transit centre of higher order, and a number of subordinate zones

**Fig. 1**

**Telephone districts with district centres, Yugoslavia**

**Fig. 2**

**Zagreb telephone district**



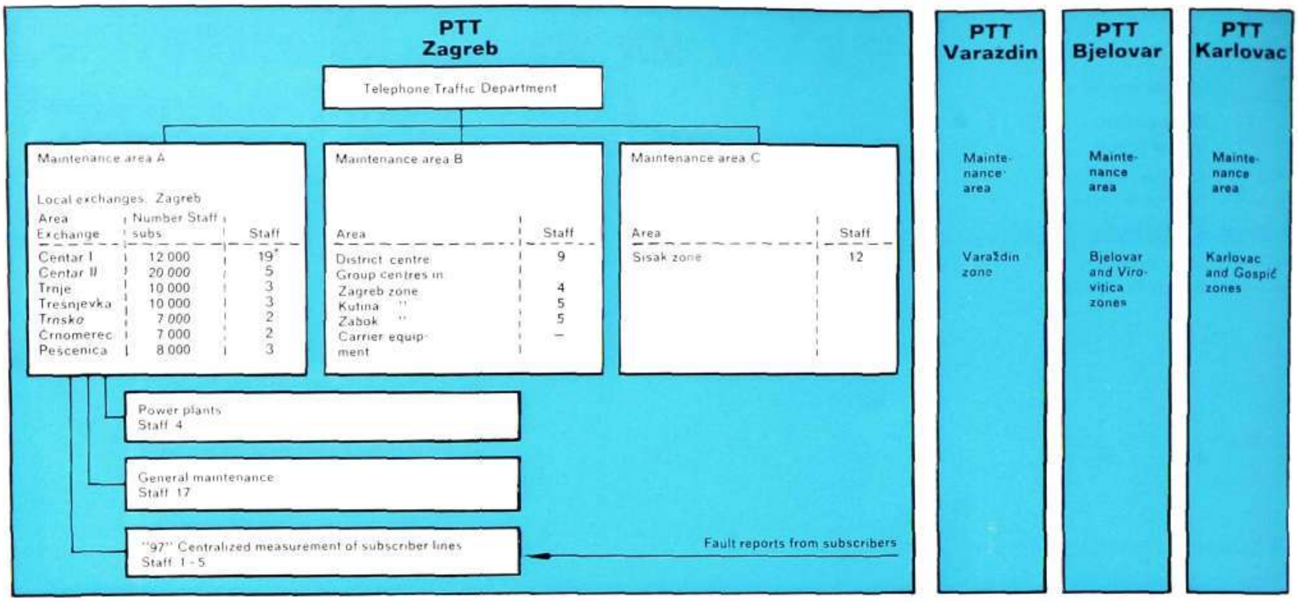
with zone centre, group centres and terminal exchanges in a star-shaped network. This article deals with the Zagreb district with its nine zones (fig. 2).

Most of the maintenance equipment is located in Zagreb (Centar II exchange) and serves chiefly the Zagreb zone. At the Centar II exchange there are also traffic route testers and important alarm functions for the entire district, as well as the equipment for remote measurement of subscriber lines which is under construction.

## Establishment of a Maintenance Centre

Fig. 3 shows the present organization for the maintenance service in the district. All local exchanges of systems ARF 50 and HDW (Hebdrehwähler) in Zagreb are attended. Apart from the permanent maintenance staff, there is a group of technicians who carry out large scale tests of the ARF 50 exchanges. The ARF 20 transit centre is also attended, whereas the group centres and terminal exchanges in the Zagreb zone are unattended. The majority of group centres and terminal exchanges in the other zones of the district are unattended and their maintenance is carried out by staff from their superior zone centre.

In the larger local exchanges of type ARF 50 the maintenance was earlier carried out on a fixed schedule, which included setting up of a specific number of test connections from the automatic exchange tester. At the transit centre, on the other hand, the maintenance work followed mainly new lines from the



| Area Exchange | Number Staff subs | Staff |
|---|---|---|
| Centar I | 12 000 | 19* |
| Centar II | 20 000 | 5 |
| Trnje | 10 000 | 3 |
| Tresnjevka | 10 000 | 3 |
| Trnsko | 7 000 | 2 |
| Crnomerec | 7 000 | 2 |
| Pescenica | 8 000 | 3 |

| Area | Staff |
|---|---|
| District centre | 9 |
| Group centres in |  |
| Zagreb zone | 4 |
| Kutina " | 5 |
| Zabok " | 5 |
| Carrier equipment | — |

| Area | Staff |
|---|---|
| Sisak zone | 12 |

**Fig. 3**

**Maintenance organization, Zagreb district**

* **Earlier step-by-step system (approx. 45 years)**

outset, as the necessary supervisory equipments — such as centralograph, statistical counters and automatic exchange and rate testers — already existed in that exchange.

The zone and group centres earlier worked exclusively on the preventive maintenance principle.

With earlier preventive maintenance methods it was difficult to attain a high and uniform quality of service for the automatic telephone traffic concurrently with a saving of maintenance staff. In conjunction with the extension of the exchanges it proved increasingly that modernization in this sphere was necessary.

As early as 1967, therefore, it was decided to establish a maintenance centre at which centralized supervision could be introduced in the Zagreb district in accordance with the controlled corrective maintenance method elaborated by L M Ericsson. This maintenance centre, which was planned in collaboration between the Zagreb PTT and L M Ericsson, contains, among other items, traffic route testers and the necessary equipment for service supervision, route alarm etc. This equipment is described in the following sections.

## *Introduction of Traffic Route Tester*

One of the chief aids in the new maintenance method is the automatic traffic route tester *TVP* which generates artificial traffic. In the largest local exchange in Zagreb, Centar II, there are five TVP for testing of the traffic routes in the district. The service supervision position in the maintenance centre contains equipment for recording and control of TVP. To permit centralized testing of all traffic routes in the local Zagreb area, all other ARF 50 exchanges are equipped with relay selectors *FVA*, *FVB* and, if necessary, test number group selectors *PGV* (fig. 4).

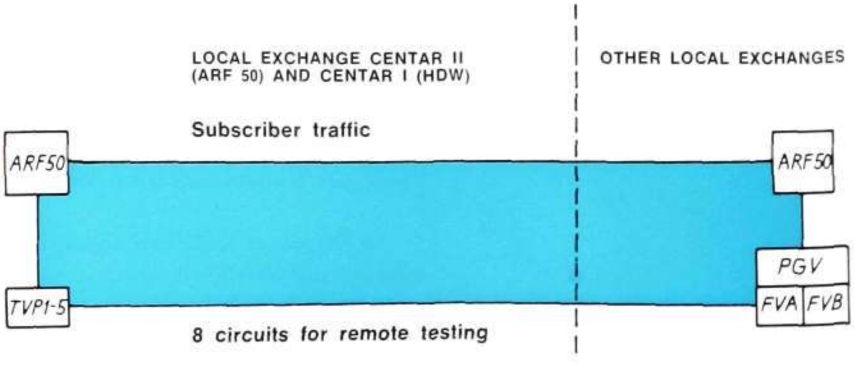
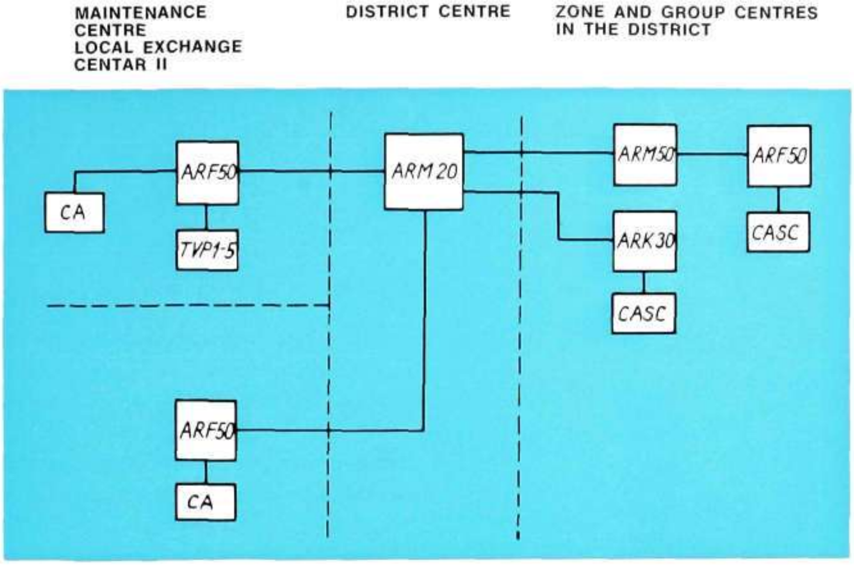


**Fig. 4**

**Remote testing within Zagreb local area**

**Fig. 5**

**Remote testing with primary and secondary calls within the district**

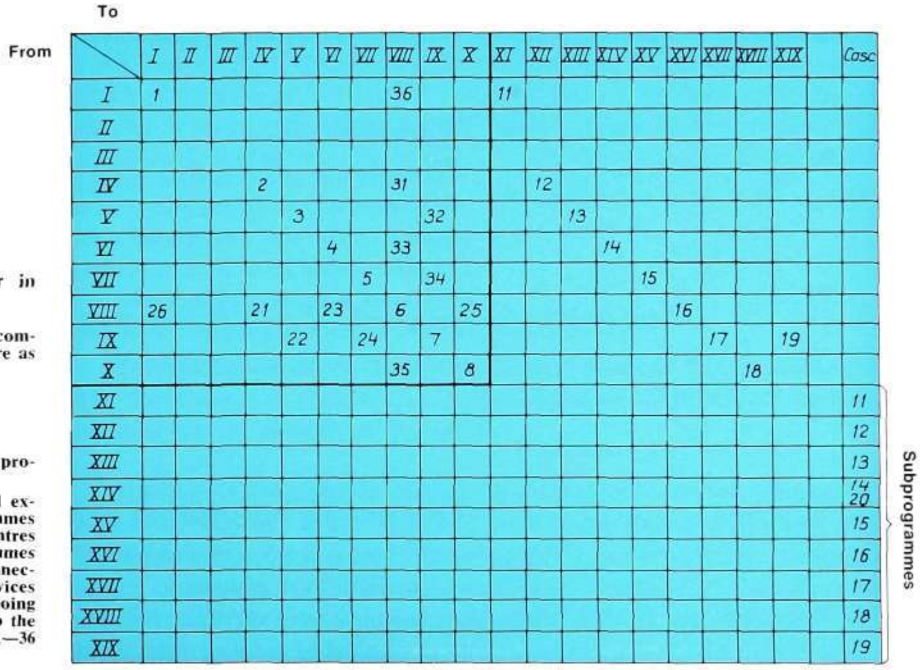


The test numbers in the Centar I and II local exchanges are directly connected to TVP, whereas the test numbers of the other ARF 50 exchanges are divided into five groups of 10 numbers each and connected to outlets from PVG.

Through the centralized traffic route testing a check is maintained both on the incoming and outgoing traffic and on the local traffic within the zone and group areas. TVP carries out the centralized traffic route testing in cooperation with corresponding code answering devices on normal traffic routes.

For generation of all types of traffic outside the local area there is a code answering device *CASC* which can set up secondary connections to all zone centres in the district and to all group centres in the Zagreb zone. The local exchanges in Zagreb, on the other hand, are equipped with code answering devices *CA*, which have answering functions alone (fig. 5).

Fig. 6 shows an example of the programming of traffic route tester TVP for all automatic telephone exchanges.



| | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII | XIII | XIV | XV | XVI | XVII | XVIII | XIX | | Casc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I | 1 | | | | | | | 36 | | | 11 | | | | | | | | | | |
| II | | | | | | | | | | | | | | | | | | | | | |
| III | | | | | | | | | | | | | | | | | | | | | |
| IV | | | | 2 | | | | 31 | | | | 12 | | | | | | | | | |
| V | | | | | 3 | | | | 32 | | | | 13 | | | | | | | | |
| VI | | | | | | 4 | | 33 | | | | | | 14 | | | | | | | |
| VII | | | | | | | 5 | | 34 | | | | | | 15 | | | | | | |
| VIII | 26 | | | 21 | | 23 | | 6 | | 25 | | | | | | 16 | | | | | |
| IX | | | | | 22 | | 24 | | 7 | | | | | | | | 17 | | 19 | | |
| X | | | | | | | | 35 | | 8 | | | | | | | | 18 | | | |
| XI | | | | | | | | | | | | | | | | | | | | | 11 |
| XII | | | | | | | | | | | | | | | | | | | | | 12 |
| XIII | | | | | | | | | | | | | | | | | | | | | 13 |
| XIV | | | | | | | | | | | | | | | | | | | | | 14<br>20 |
| XV | | | | | | | | | | | | | | | | | | | | | 15 |
| XVI | | | | | | | | | | | | | | | | | | | | | 16 |
| XVII | | | | | | | | | | | | | | | | | | | | | 17 |
| XVIII | | | | | | | | | | | | | | | | | | | | | 18 |
| XIX | | | | | | | | | | | | | | | | | | | | | 19 |

**Fig. 6**

**Programming of a traffic route tester in Zagreb**

**The groups marked with Roman numerals comprise at most 10 test numbers each. They are as follows:**

| | |
|---|---|
| **I—X** | **local exchanges** |
| **XI** | **group centres** |
| **XII—XIX** | **zone centres** |

**The Arabic numerals indicate the different programmes.**

**Programmes 1—8 carry out testing of local exchanges in the local Zagreb area. Programmes 11—20 test the traffic routes to the group centres in the Zagreb zone. With the subprogrammes 11—20 in column CASC, secondary test connections are set up from the code answering devices CASC. Programmes 21—26 generate outgoing traffic from the Centar II local exchange to the other local exchanges, and programmes 31—36 from these exchanges to Centar II.**

Particular attention was paid in the programming to the simultaneous working of all five traffic route testers. It was thus possible to arrange for the tests to comprise all test numbers or all types of traffic with one combination of programmes.

## Controlled Corrective Maintenance

Both large and small automatic telephone exchanges are able to deliver a large number of data for supervisory and recording purposes. So large a quantity of data may readily lead to such an accumulation of information as to delay its evaluation and render difficult the tracing of sources of disturbance. To ensure effective service supervision, a method is required which quickly and clearly indicates the failure rate and the source of failure automatically.

For this reason the principle recommended by L M Ericsson — controlled corrective maintenance which fulfils the aforesaid requirements — was introduced in all telephone exchanges. All central exchange equipments are continuously supervised by means of built-in circuits, and each operational failure is recorded on statistical counters. In addition a failure rate counter *DL* adds up the number of failures, while another counter adds up the number of occupations. When a present failure rate is exceeded, a service alarm is issued which indicates that the devices concerned must be tested and the faults remedied. As long as no service alarm is issued, no tests or preventive maintenance shall be carried out. An exception is the programmed testing with traffic route testers described in the preceding section.

### *Centralograph Equipment*

The Centralograph equipment is used for supervision of connections through the switching stages and for detailed recording of types of fault in the devices concerned. The centralograph equipment is one of the most important aids in a modern maintenance programme. Apart from the existing equipment at the Zagreb transit centre, Centralograph equipment has been installed also in the zone centres of type ARM 50 at Varazdin, Bjelovar and Karlovac.

### *Route Alarm*

The blocking alarm circuits in the outgoing junction relay sets associated with one route are brought together and connected to a route alarm relay set with a capacity of 10 routes. When the number of blocked junction relay sets reaches a predetermined level, a route alarm is issued. The corresponding alarm lamps are placed at the service supervision position or on a panel. Introduction of this type of alarm is in progress at all zone centres in the district and at all ARK 30 group centres in the Zagreb zone.

### *Transmission of Alarms to Maintenance Centre*

All important categories of alarm, such as service and route alarm, are transmitted from local exchanges, group and zone centres to a lamp panel in the maintenance centre. The alarm transmitter *FUR-LT* and alarm receiver *FIR-LT* are connected to ordinary junction circuits, which also carry traffic. The alarm

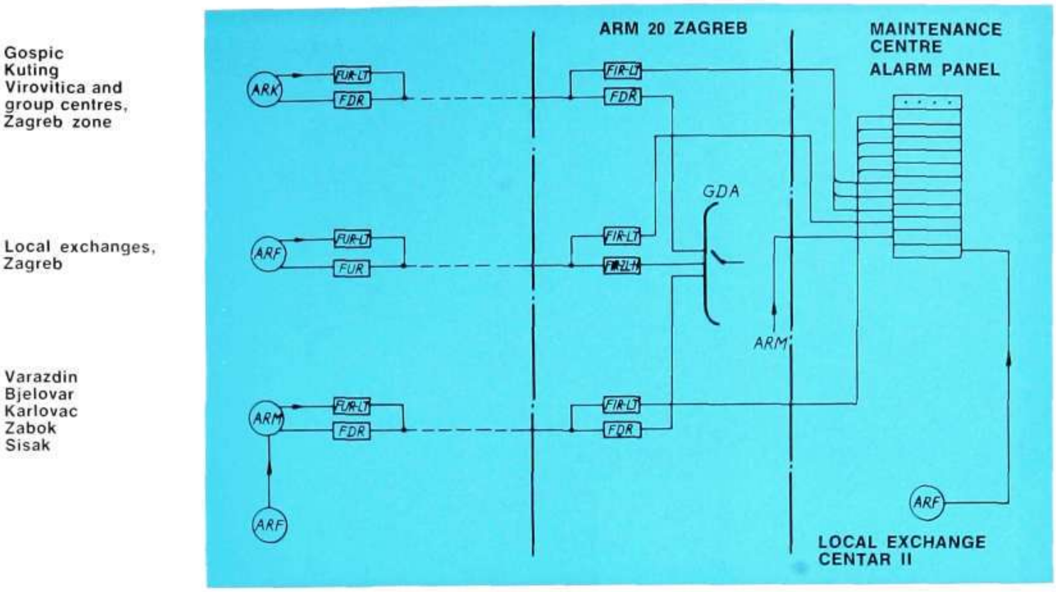


**Fig. 7**

**Principle for transmission of alarm via FUR-LT, FIR-LT**

transmission system is adaptable and can be used for circuits with DC or AC signalling and for carrier circuits. Conversations in progress are, of course, not disturbed by the transmission of alarm.

## *Centralized Remote Measurement of Subscriber Lines*

In the local Zagreb area the fault reporting system is centralized and all measurements of subscriber lines and telephone sets take place from a single exchange. The existing equipment, however, is not suited for measurement of subscriber lines on remote exchanges or on exchanges connected via radio links. In conjunction with the construction of a maintenance centre for Zagreb, L M Ericsson's new remote measuring equipment was introduced within the entire area. The equipment operates independently of distance and type of circuit between the exchanges, and of the type of exchange. The measuring equipment consists of an order transmitter and a result receiver *PR-A* and of a number of order receivers and result transmitters *PR-B*. Voltage measurement, check of tones, alarm etc. can be done in addition to measurement of subscriber lines.

*PR-A* is installed in the Center II local exchange, and every local exchange, group or zone centre has a *PR-B*. *PR-B* receives orders from *PR-A* on normal junction circuits and carries out the desired measurements, transmitting the results back via *PR-A* to the test desk, where the results are shown on a lamp panel.

## Results of the New Maintenance Method

The maintenance centre is designed to allow complete implementation of the new maintenance method in all crossbar exchanges in the Zagreb zone and in the zone centres throughout the district.

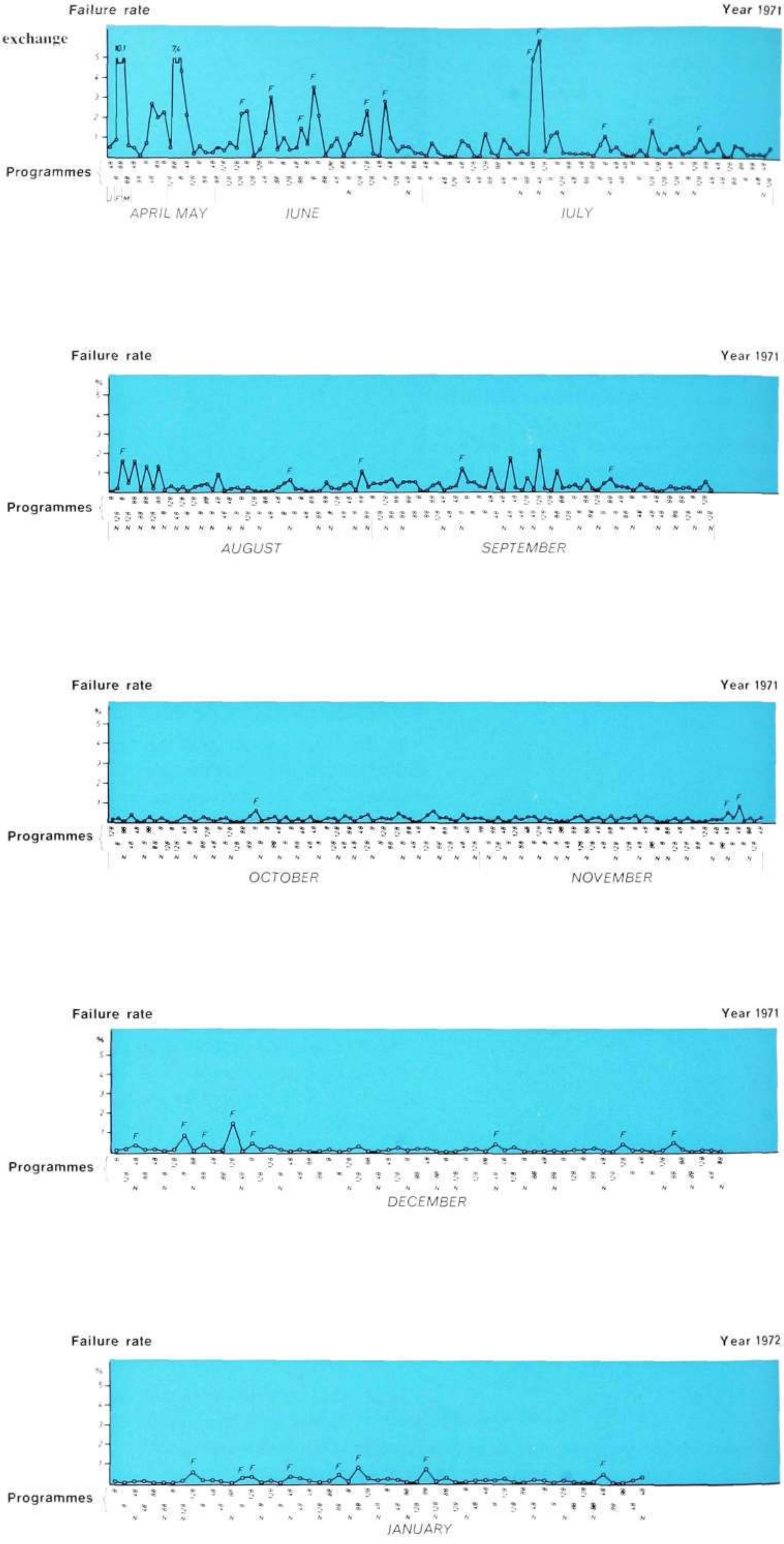
Experience hitherto shows that the new method has a great significance for the present maintenance organization. At some exchanges the number of working hours per connection during 1971 was reduced by about 25 % compared with 1970. Further improvements are expected in the coming years. The Zagreb staff can thus take over maintenance assignments also for the new ARF 102 exchanges.

Fig. 8

Quality of service at Trnsko local exchange

F = Faults repaired

N = Nighttime tests



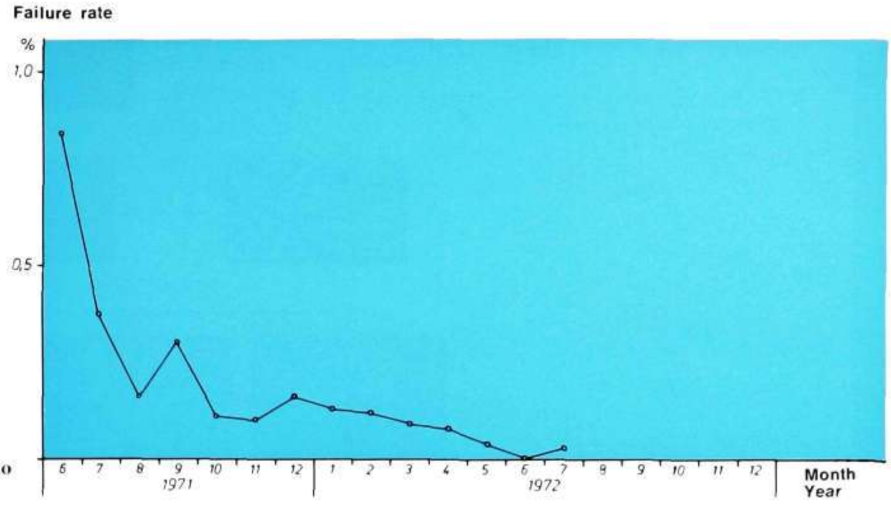


**Fig. 9**

**Monthly average failure rates at Trnsko local exchange**

In June 1971 the new maintenance method was introduced for the first time at the ARF 50 local exchange at Trnsko. The daily programmes with the traffic route tester were stopped when the daily rate exceeded 2 ‰; fault tracing was then started. The night programmes, on the other hand, were not interrupted, the results being evaluated on the following day. Fig. 8 shows the results of the quality of service tests. Fig. 9 shows the monthly mean failure rates. Through the adoption of the new method the improvement in quality of service was such that, shortly thereafter, it was decided to introduce the method also at the other crossbar exchanges in the local Zagreb area. There are already certain indications that similar results can be attained at these exchanges as well.

The operational reliability on the Zagreb-Varazdin route was investigated during April—December 1971 with an automatic traffic route tester at Zagreb. At the end of the year the reliability was found to have considerably improved. This is a consequence, in part, of the intense use of traffic route testers and, in part, of the use of the new test and supervisory equipment at Varazdin.

Apart from traffic route tests through the zone centres, similar tests are being made to the group centres of type ARK 30 in the Zagreb zone. The results show an improvement towards the end of 1971.

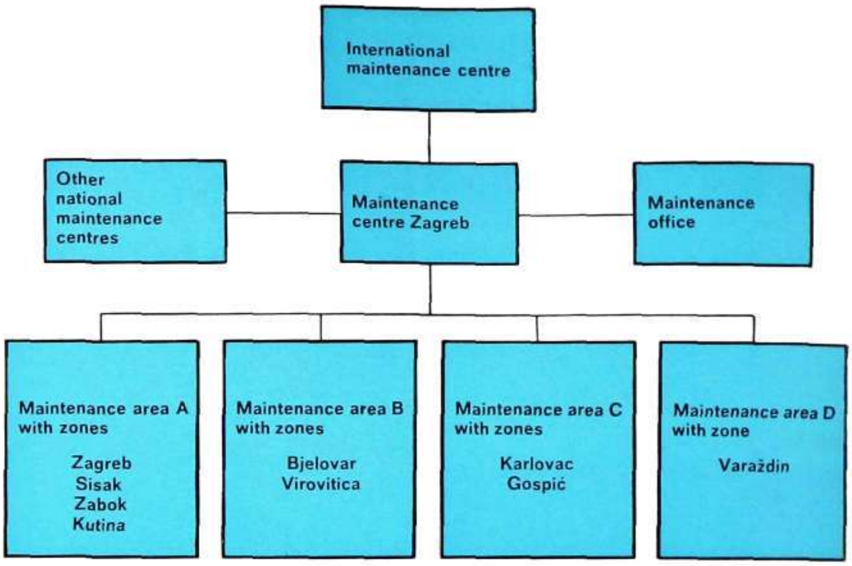
## New Maintenance Organization in Zagreb District

All existing local exchanges with 10,000 or more subscribers will continue to be attended, while future exchanges, which almost without exception are being built in new residential areas, will be unattended. These new ARF 102 exchanges will be maintained by the technician group in line with the experience gained from the maintenance centre. The group will also take over certain assignments in the ARF 50 exchanges in the Zagreb zone, as also in ARF exchanges in other zones of the district.

The extension of crossbar group centres in the Zagreb zone involves no increase in maintenance staff. Apart from regular inspections and routine tests of the exchanges, these staff have hitherto worked also on the M.D.F. and made measurements of subscriber lines and telephone sets. Since the introduction of the new maintenance method, on the other hand, the exchanges are visited only as required (TVP indication, alarm, subscriber's complaint or the like) as the *PR-A* and *PR-B* equipments permit centralized measurement of subscriber lines.

Fig. 10

**Future maintenance organization, Zagreb district**



This also results in a considerable reduction of travel time, which previously amounted to one-third of the total working time. In the future these technicians will also be assigned to work on complicated faults in exchanges in other zones.

In the other zone centres of the district, staff had already been trained in the new maintenance method and additional staff will be trained. The construction of additional maintenance centres, which will also cover the terminal exchanges, is also under preparation. Depending on size, traffic etc. each such centre will cover two to four zones. An international maintenance centre IMC is also planned for the new fully automatic international transit centre *(CT3)* of type ARM 202/4.

Fig. 9 shows the planned future maintenance organization for this purpose.

The existing maintenance centre in Zagreb, with the equipment described, serves the Zagreb, Sisak, Kutina and Zabok zones down as far as terminal exchanges within maintenance area A. Other functions are the checking and coordination of the incoming and outgoing traffic at the zone centres in the district, as also checking of the outgoing traffic to other district centres in the country.

The maintenance centre planned at Bjelovar will superwise all exchanges in the Bjelovar and Virovitica zones( maintenance area B), that at Karlovac will supervise all exchanges in the Karlovac and Gospic zones (maintenance area C), and that at Varazdin all exchanges in the Varazdin zone (maintenance area D).

These centres will be equipped with traffic route testers and will be supervised by the superior centre at Zagreb. Similar supervisory equipments will be provided at the group centres and terminal exchanges.

## Summary

The experience hitherto shows that very satisfactory results have been attained with centralized testing and supervision. The maintenance of a considerably larger number of lines has been carried out with the same number of staff, and also with considerably better results. A continued extension of centralized maintenance within the Zagreb district ist therefore planned.

## References

1. HAMERS, J. A.: *The Introduction of a New Maintenance Method into the Telephone Area of Rotterdam and Its Influence on the Maintenance Organization*, Ericsson Rev. *45*(1968): 2, pp. 46—60.
2. ERIKSSON, V.: *Equipments for Maintenance of ARF 102 Automatic Telephone Exchanges*, Ericsson Rev. *46*(1969): 2, pp. 30—48.
3. ERIKSSON, V.: *Equipment for Maintenance of ARM 20 and ARM 50 Automatic Telephone Exchanges*. Ericsson Rev. *47*(1970): 3, pp. 99—108.
4. WATTVIL, A.: *Equipments for Test Traffic in Multi-Exchange Networks*, Ericsson Rev. *47*(1970): 4, pp. 137—148.
5. SÖDERBERG, A.: *International Maintenance Centre, IMC*. Ericsson Rev. *48*(1971): 3, pp. 113—120.
6. HAMERS, J. A.: *Six Years of Controlled Corrective Maintenance (CCM) in the Rotterdam Telephone District*. Ericsson Rev. *49*(1972): 3, pp. 74—85.

# Field Trial of CCITT Signalling System No. 6 using AKE 13

J. D. HINWOOD, OVERSEAS TELECOMMUNICATIONS COMMISSION & D. W. CLARK, L M ERICSSON PTY. LTD., AUSTRALIA.

UDC 621.395.38
LME 8313
83022

*Eleven administrations are currently engaged in an international field trial of a new telephone signalling system under the supervision of the CCITT. This system, CCITT Signalling System No. 6, will be applicable to all types of international telephone circuits. Overseas Telecommunications Commission, Australia, OTC (A), which is one of the above administrations, is using L M Ericsson's stored program controlled transit exchange AKE 13 for its field trial equipment. The development work for this exchange was performed by a joint OTC-LME team of engineers and programmers and was based on design techniques previously developed by LME for the Rotterdam AKE 13 telephone exchange, which was installed by LME for the Netherlands PTT and placed in service during 1971. CCITT Signalling System No. 6 has been described in detail in publications listed among the references. This article is intended to describe the current status of the development of System No. 6 including the specification and the field trial.*

## Background to the Field Trial

During the period leading up to 1964 administrations and recognized private operating agencies around the world began to realise that existing international signalling systems would be inadequate to meet the future requirements of the world telephone network. Accordingly CCITT defined the basis for the study of a new signalling system, to be called CCITT Signalling System No. 6.

Stated briefly, System No. 6 was not only to be applicable to all types of international circuits (including TASI derived and satellite circuits), but was also to include all additional facilities which were seen as being desirable for the telephone networks of the future. Amongst these new facilities were:

- automatic repeat attempt;
- echo suppressor control;
- routing signals;
- signals to indicate congestion of equipment or groups of circuits, called-party line conditions and other causes of ineffective calls;
- signals to indicate the calling party's category, etc.;
- network management (administrative) signals;
- the ability to operate equally well in conjunction with en bloc and with overlap numerical signalling;
- the ability to operate with variable numbers of digits both for the country code and the national number without increase of post-dialling delay, due for example, to time-out;
- capacity for adding signals to cater for unknown future requirements.

To perform the study, CCITT set up Working Party XI/1 (Signalling System No. 6). The work carried out by this working party was issued as a specification by CCITT Study Group XI and presented as a contribution to the IVth Plenary Assembly of CCITT in 1968. The study was described at the Plenary as "a study without any doubt the broadest ever carried out by CCITT or its predecessors, the CCIF and the CCIT".

This specification of System No. 6 was approved and was published in the CCITT White Book, Volume VI. The IVth Plenary Assembly also adopted the proposal to perform field trials of this new system and established the "Joint Working Party of the Field Trials of System No. 6" (GM/FT6).

Administrations or recognized private operating agencies were then invited by CCITT to participate in the Field Trial and the following eleven are directly participating in these trials:

Australia — APO and OTC (A)
Belgium — RTT
France — PTT
Italy — PTT and Italcable
Japan — KDD
The Netherlands — PTT
Federal Republic of Germany — PTT
United Kingdom — POC
United States — AT & T

# Signalling System No. 6

## *General*

System No. 6 represents a considerable departure from the earlier principles of telephone signalling. Earlier signalling systems transferred their information over the speech circuit or over a special signalling channel provided in association with each speech circuit.

In System No. 6 all inter-exchange signalling is performed via separate circuits dedicated for signalling and no signalling is performed over the speech circuits. This departure from the normal technique introduced new problems, such as:

— If the signalling link becomes faulty then all speech circuits are out of service. Hence a very high degree of reliability is required on the signalling link(s).

— Because System No. 6 does not signal over the speech circuits there is no check that these are suitable for carrying conversation. Hence it has been judged necessary to introduce a special check of the continuity of the speech circuits.

The main advantages of System No. 6 are:

— The individual line relay sets associated with each speech circuit are simple as they do not send and receive line and register signals.

— The existence of signalling links between exchanges means that the information transferred on these links need not be restricted to information relating to a particular telephone call. The potential has been opened up for the economical introduction of the transfer of additional information relating to the management and statistical performance of the telephone network in addition to signals relating to particular telephone calls.

- The potential for additional signalling capacity also introduces the possibility of economically designing variants of System No. 6 for special applications (e.g. national or regional use) which are fully compatible with System No. 6.

It is interesting to note that the regional and national application of System No. 6 is being studied within CEPT, the European Post and Telecommunications Commission, and that, among other countries, the United States is in the process of designing a national system compatible with the revised international variant currently being specified as a result of the field trial.

## *Signalling Principles*

The introduction of System No. 6 requires the establishment of the two separate parts of the system, the signalling links and the speech circuits.

The signalling links are derived from individual circuits of 3 or 4 kHz nominal bandwidth to which 2,400 b/s data modems are attached at each end. The modems are controlled by signalling terminals which individually generate basic signal units (SUs) of 28 bits in length and consisting of 20 information bits and 8 check bits. All information sent over the link must be converted to this basic format before transmission.

The check-bits are used for error control. Error correction is performed by retransmission of signal messages found faulty.

Information messages can be either lone signal units (LSUs) in which all information is contained in 20 information bits or multi-unit messages (MUMs) in which the information is spread over a number of signal units. Typical LSU and MUM formats are shown in fig. 1.

**Fig. 1 a**

**Format of a lone signal unit (LSU)**

| | | | |
|---|---|---|---|
| XXXXX | XXXX | XXXXXXXXXXX | XXXXXXXX |
| 1—5 | 6—9 | 10—20 | 21—28 |
| heading | signal information | label (identity of the speech circuit) | check |

**Fig. 1 b**

**Format of an initial address message (IAM) with three signal units**

**ISU** **Initial Signal Unit**
**SSU** **Subsequent Signal Unit**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| ISU | 10000<br>address message code | | 0000<br>ISU code | XXXXXXXXXXX<br>label (identity of the speech circuit) | | | XXXXXXXX<br>check |
| 1st SSU | 00<br>* | XX<br>** | XXXXXXXXXXXXXXXX<br>other routing information | | | | XXXXXXXX<br>check |
| 2nd SSU | 00<br>* | XX<br>** | XXXX<br>1st address signal | XXXX<br>2nd address signal | XXXX<br>3rd address signal | XXXX<br>4th address signal | XXXXXXXX<br>check |

* SSU indicator
** length indicator

**Table 1**

**Design objectives for handling time ($T_h$) and cross-office transfer time ($T_c$)**

| Type of message | | Answer | Other one-unit messages | IAM of 5 SU |
|---|---|---|---|---|
| $T_h$ in ms | Average | 12 | 25 | 25 |
| | 95 % level | 25 | 60 | 60 |
| $T_c$ in ms | Average | 40 | 60 | 120 |
| | 95 % level | 70 | 140 | 200 |

## *Signalling Speed*

The No. 6 signalling system is intended to be faster than previous signalling systems and hence CCITT has specified in detail target requirements relating to allowable handling and cross-office transfer times at No. 6 exchanges. This has been done to reduce post-dialling delays, especially where many telephone links may be involved in a particular connection. The design objectives for the handling time $T_h$ and the cross-office transfer time $T_c$ are shown in Table 1.

## *Quasi-Associated Signalling Link Operation*

Because of the high-speed of System No. 6 it is possible to tolerate slight reductions in speed by introducing non-associated modes of working where advantageous. The quasi-associated mode of operation introduces a signal transfer point (STP) into a data link. It is most useful where signalling links are established between terminals A and C and between C and B handling System No. 6 traffic (see fig. 2). Using C as an STP, communication between A and B can be established without providing a separate A to B data link. This is done by reserving labels in the A to C and C to B signalling links for communication between A and B. These labels identify the A to B speech circuits.

For quasi-associated signalling between A and B it is not necessary to use exactly the same labels in the two signalling links A to C and C to B as the specification requires an STP to be capable of translating labels during transfer of messages.

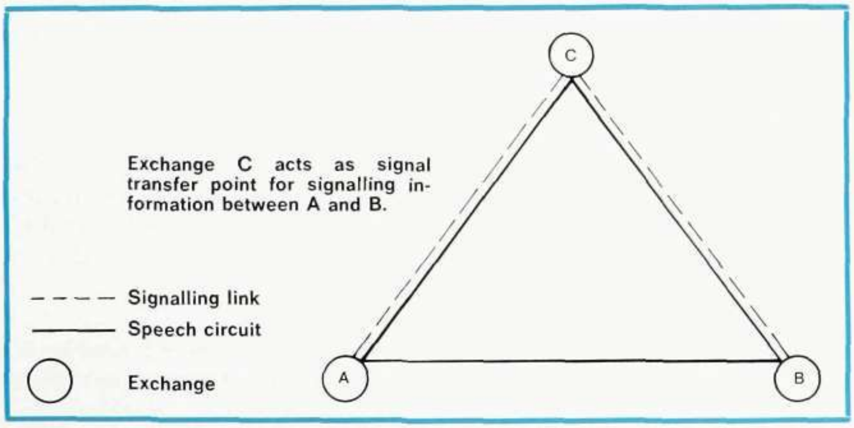


**Fig. 2**
**Quasi-associated signalling**

### *Security of the Signalling Link*

It is extremely important that signalling communication is secure when using System No. 6. This is achieved by providing reserve signalling facilities which are used when the regular signalling link becomes faulty or experiences excessive error rates. Since signalling links in System No. 6 are fully synchronous, monitoring of the error rate at each incoming end of the signalling link is used to determine when changeover to a reserve facility is necessary.

When, by means of the error-rate monitor, it has been determined that changeover should occur, changeover procedures are invoked. These procedures are complicated but are designed to ensure that during changover the integrity of the signalling link is maintained and that both ends of the link receive all necessary information to ensure that telephone calls are not lost or disturbed.

Should these changeover procedures not result in speedy re-establishment of communication (e.g. due to processor malfunction or multiple failure of regular and reserve signalling links) emergency restart procedures are invoked. These procedures are intended to re-stablish communication automatically as quickly as possible and to minimise the effect of an emergency situation. Should the emergency restart period be prolonged then all telephone speech circuits served by the failed links must be blocked to subscribers trying to establish telephone calls over these links.

### *System No. 6 Network Configurations*

The basic No. 6 network will consist of a network of data links together with a network of groups of speech circuits between exchanges. The speech circuit network will be conventional in concept and will consist of routes between exchanges dimensioned according to the community of interest for telephone traffic between the exchanges.

The signalling network will however be quite different and will be designed to make use of the high capacity of the individual signalling links. The ability to use quasi-associated operation (as described above) to provide both regular and reserve signalling facilities has created many possibilities for the minimization of the signalling network.

## CCITT Activities During the Field Trials

### *Organization of Joint Working Party GM/FT6*

GM/FT6 established its method of working at its first meeting and found it useful to follow the same method at all subsequent meetings. Three subgroups were established:

*Sub-Group 1* was entrusted to deal with the field trial timetable, the various polygons of routes to be included in trials and the general organization arrangements. At the 5th meeting of GM/FT6 this Sub-Group was also entrusted with the evaluation of the field trial results and the preparation of the Final Report of GM/FT6.

*Sub-Group 2* was entrusted to deal with the defining and specifying of the test methods and procedures to be used during the various phases and stages of the tests.

*Sub-Group 3* was entrusted to deal with the additions, deletions and modifications of the System No. 6 Specifications.

Since the IVth Plenary Assembly in 1968 both Study Group XI and Working Party GM/FT6 have held several meetings and have discussed and implemented many alterations to the System No. 6 Specification.

## *Activities of GM/FT6*

As stated above, Sub-Groups 1 and 2 are primarily concerned with the actual field trials whilst Sub-Group 3 is concerned with the System No. 6 Specification. Sub-Group 3 thus attracted a great deal of interest and many contributions have been presented to this group for consideration. These contributions have resulted mainly from difficulties encountered during the design of the field trial equipments and as a result of interworking difficulties arising from varying interpretations of the specification and its intention.

The discussions around these contributions have often been quite lengthy and there have been times when agreement has been difficult to reach. However, there is a genuine desire on the part of the participants to produce a final specification which is flexible and does not unduly restrict implementation techniques.

The most significant changes which have been made to the specification since 1968 are as follows:

- The security arrangements for maintaining communication between two terminals in the event of link failure have been changed considerably. In particular the criteria for determining when a signalling link is faulty have been tightened, automatic and manual changeover procedures have been revised, an emergency restart procedure has been introduced, and signals indicating when a signal transfer point fails have been introduced.

- The continuity check of each speech circuit has been revised to convert it from a backward direction check to a forward direction check and to take into account possible failure of the speech circuit within the switching network of a System No. 6 exchange. This cross-office continuity check may be performed either on a per call basis or by a statistical method.

- Call set-up procedures have been revised to enable more convenient interworking between System No. 6 and Signalling Systems R1, R2 and No. 5 Bis, all of which were approved at the same Plenary Assembly as System No. 6.

- Much greater consideration has been given to the handling of out-of-sequence and unreasonable signals from System No. 6 and the specification has been revised to define in much greater detail actions to be taken at the receiving end of a signalling link when such signals are detected.

- The specification now takes into account certain types of exchange malfunction and defines how such malfunction situations should be handled.
- The format of the System No. 6 signals has been revised to improve the utilization of the 20 information bits in the signal units.

Due to lack of time some of the agreed specification changes will not be tested during the field trials but will be included in the draft final specification. For this reason SG XI at its meeting in March 1972 decided to establish a special drafting group, which is autonomous from Joint Working Party GM/FT6. This drafting party is entrusted with the preparation of the final specification for System No. 6.

## AKE 13 in Sydney and Interworking Exchanges

### *AKE 13 as used in the Field Trial*

In the field trial in Sydney OTC (A) is using a L M Ericsson stored program controlled transit exchange AKE 13 equipped with 64 bothway circuits FDR-6 for signalling system No. 6 and a number of circuits for signalling system No. 5 for other international lines as well as MFC and dial pulse circuits for the national network, fig. 3.

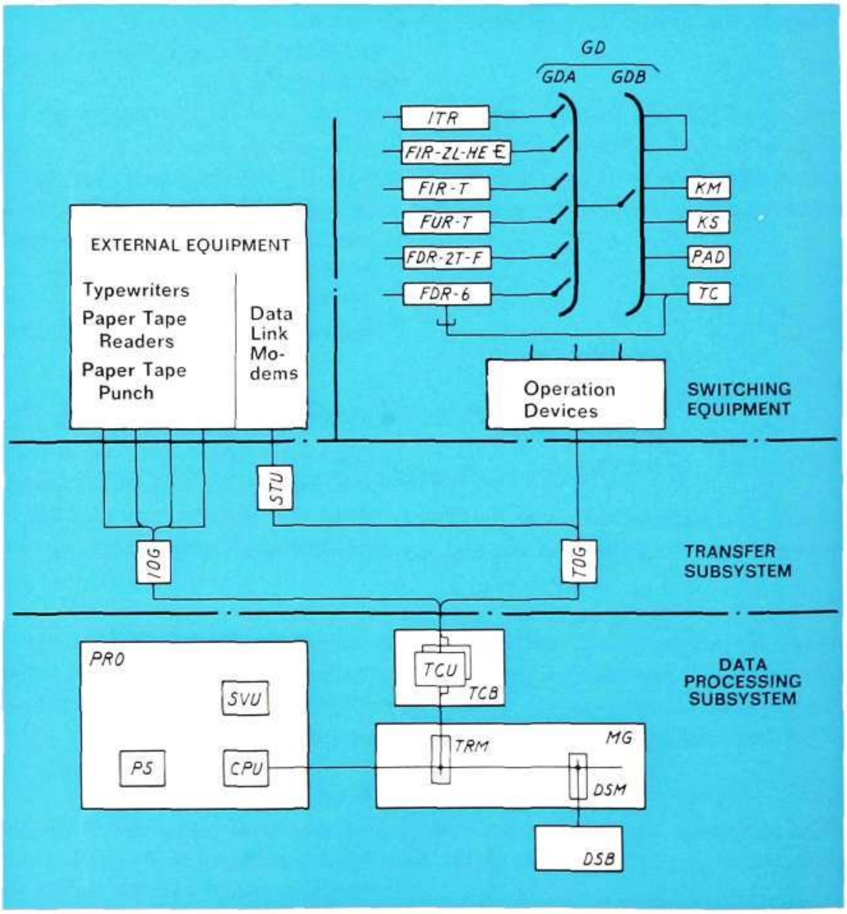


**Fig. 3**

**Block diagram of AKE 13 as used in the field trial**

| | |
|---|---|
| **GD** | **Switching stage** |
| **ITR** | **Connecting device of announcing machine** |
| **FIR-ZL-HE** | **2-wire DP-line (incoming)** |
| **FIR-T** | **4-wire MFC-line (incoming)** |
| **FUR-T** | **4-wire MFC-line (outgoing)** |
| **FDR-2T-F** | **4-wire No 5-line (both way)** |
| **FDR-6** | **4-wire No 6-line (both way)** |
| **KM** | **Code receiver** |
| **KS** | **Code sender** |
| **PAD** | **Pad** |
| **TC** | **Transfer control** |
| **IOG** | **Input output control** |
| **STU** | **Signalling terminal unit, No 6** |
| **TOG** | **Test and operation group** |
| **PRO** | **Processor** |
| **PS** | **Program store** |
| **CPU** | **Central processing unit** |
| **SVU** | **Supervisory unit** |
| **TCB** | **Transfer control block** |
| **TCU** | **Transfer control unit** |
| **DSB** | **Data store block** |
| **MG** | **Multiplexor group** |
| **TRM** | **Transfer multiplexor** |
| **DSM** | **Data store multiplexor** |

The AKE 13 system is divided into the following main parts:

- Switching Equipment
- Transfer Subsystem
- Data Processing System

*The switching equipment* is made up of code switches arranged for 4-wire switching, different types of trunk circuits, continuity check transceivers, pads for speech circuits of signalling system No. 6, code receivers etc. as well as operation and control devices for the operation of switches and relays.

*The transfer subsystem* converts the signals from the data processing system into signals suitable for controlling the operation of the switching and external equipment. It also includes No. 6 Signalling Terminal Unit, STU.

*The data processing system* contains a processor performing all logic functions necessary for switching the connections, a data store in which all of the exchange data are stored, a transfer control acting as intermediary between the data processing system and the transfer equipment as well as a multiplexor group connecting the data store and the transfer control to the processor.

## *Interworking using System No. 6 Signalling*

The AKE 13 equipment in Sydney is being used to interwork with equipment in UK, USA, Japan, Italy and the Australian Post Office (APO) Research Laboratories. General details of these processing equipments are given in Table 2.

## *Interworking using Existing Signalling Systems*

The Sydney AKE 13 exchange is programmed to handle System No. 5, Loop-disconnect and MFC-signalling (MFC is the national variant of System R2) in

**Table 2**

**General details of field trial processing equipment**

| Administration | OTC (A) (Sydney) | UK (London) | USA (Columbus) | JAPAN (Tokyo) | ITALY Italcable (Rome) | APO (Melbourne) |
|---|---|---|---|---|---|---|
| Manufacturer of Processing Equipment | L M Ericsson | GEC/AEI | Western Electric | Fujitsu | Bell (Antwerp) | Bell (Antwerp) |
| Word Size (bits) | 16 + 1 | 16 + 2 | 20 | 16 + 1 | 16 + 1 | 16 + 1 |
| Size of Core Store | 128 K | 32 K | 300 K | 64 K | 32 K | 16 K |
| Size of External Store | — | 144 K | — | — | — | — |
| Store Cycle Time, μs | 2.4 | 3—4 | 6.3 | .75 | 1 | 2 |

addition to the System No. 6. The provision of these other signalling schemes enables comparison of performance to be made and also facilitates the System No. 6 testing by connecting the AKE 13 to the national network (MFC signalling), the international network (No. 5 signalling) and to the OTC PABX and test telephones (loop-disconnect).

By using these interworking exchanges many different types of calls may be established and the operation of the AKE 13 system, as well as of the No. 6 signalling system, evaluated.

On completion of the international field trials as specified by the CCITT, national field trials between Melbourne (APO) and Sydney (OTC (A)) are envisaged. During these trials it is hoped to confirm that System No. 6 will satisfactorily interwork with Australian MFC and to examine the suitability of System No. 6 as a national signalling system.

## Field Trial Activities

### *Organization and Facilities*

The Field Trial participants co-operate with each other to form polygons. This means that each partner only interworks with 3 or 4 other administrations or recognized private operating agencies.

The aim of the field trials is to test in practice the recommendations of the preliminary specification and to amend these where necessary, so as to produce a thoroughly checked final specification.

Consequently, GM/FT6 divided the field trial into the following phases:

(a) *Preliminary Phase*

Pseudo-random bit error testing of the various types of voice frequency links which may be used as data links.

(b) *Phase A*

Signalling link tests were performed using a standard list of typical messages. These tests endeavoured to determine signalling link performance and reliability and to verify the security of System No. 6 against signalling link failure.

(c) *Phase B*

During this phase, test calls (both manual and automatic) were generated to test numbers in each of the field trial exchanges. These calls were established with varying background loads of simulated traffic to demonstrate the capability of System No. 6 to switch telephone calls and to interwork with other CCITT signalling systems.

(d) *Phase C*

To augment the tests of phases A and B a final phase was planned during which subscriber and operator originated paid traffic would be switched by the field trial exchanges. However, it became apparent that, due to various operational and time limitations, significant phase C testing would not be undertaken.

In addition to the System No. 6 exchange, the following facilities are typically required:

(a) *Interconnecting Circuits*

Included here are the System No. 6 signalling links and their associated speech circuits between the two System No. 6 exchanges, connection with the local network to terminate certain test calls and connection with telephones and special call generating equipment.

(b) *Call Generating and Answering Equipment*

These devices may be manual (ordinary telephone handsets) or automatic devices for establishing switched connections and verifying the connection. In addition to these devices that establish switched calls, special test programs are required to generate simulated calls and to verify the sequence of the messages received. Mutilatd or delayed messages provide an indication as to the operation of the System No. 6 under conditions of loading, not achievable by manual dialling.

This simulated traffic enables a load to be placed on the whole system to verify its proper functioning under normal and overload conditions.

(c) *Communications between Testing Centres*

The communications equipment involved here includes direct access to the international telephone network and the international telex network. Also full-time private circuits connecting to loudspeaking facilities are provided. Conferencing facilities are also required when performing tests involving more than two partners.

(d) *Transmission, Recording and Reporting of Results*

The transmission of results between partners is either by telex or by using the System No. 6 signalling link. This latter method, although not used by the majority of participants, saves considerable time as the data is already in the computer's memory. It also highlights the versatility and flexibility of System No. 6. In operation, a simple program extracts each value to be sent, codes it in binary or BCD as desired by the recipient, formulates it into a System No. 6 message with an illegal label and then transmits it to the partner. It is a System No. 6 requirement that all messages received with an illegal label be typed out (fig. 4). It took as long to write the program to send such messages as it did to prepare a telex of 1 day's results.

```
OTC/FT6 720726 0515 TW1
MESSAGE RECEIVED ON A VACANT LABEL 089030,0,00,02,0000-00
END

OTC/FT6 720726 0515 TW1
MESSAGE RECEIVED ON A VACANT LABEL 089045,0,00,02,0000-00
END
```

**Fig. 4**

**Example of printout received on exchange typewriter console on reception of an illegal message from No. 6 signalling link, showing details of time, link and message**

### *Progress*

The field trial has been under way since November 1970 and the AKE 13 equipment has been in operation since then. The first real telephone call between cooperating international partners was, however, not switched until more than one year later. During the intervening period the main field trial activities were:

- Performance of bit error rate tests on the various types of transmission media to be used.
- Establishment of signalling links and checking of synchronisation procedures.
- Exchange of information using traffic generated by test tapes (Test Tape Simulation, TTS, method).
- Measurement of queueing delays and retransmission characteristics in conjunction with controlled error injection and whilst transmitting TTS traffic at varying signalling link loads.
- Checking of all signalling link security procedures (change-over, change-back, emergency restart) and evaluation of performance of these during varying types of signalling link failure.
- Checking and evaluation of procedures for quasi-associated signalling link operation.

After the first period OTC (A) efforts have been associated mainly with evaluating the performance of the No. 6 System under conditions where real test calls are initiated and received. The method used in this connection has been to generate test calls from a special test call generator according to procedures defined by CCITT. Responder, No. 6 speech circuits and signalling links are used exactly as they will be used under real traffic conditions. End-to-end tests are performed by exchanging test tones before releasing connections.

Transit as well as originating and terminating No. 6 switching has been performed.

## Observations and Results

### *General*

At the time of writing (July 1972), the international field trials are still in progress and the national field trials have not yet commenced. It is therefore not possible to be definite on all aspects of the System No. 6. However, sufficient data have been obtained from tests on the operation of the System No. 6 signalling link to provide statistically significant results. In general it can be said that the No. 6 System has performed according to prediction and there has not been much occasion to interfere with the basic system. However, many specification ambiguities and errors have been uncovered and progressively corrected by CCITT during the field trial period.

### *Signalling Link Performance Tests*

These tests have revealed that the assumed bit error rate of less than 1 in $10^5$ is generally achievable and provides fully adequate operational conditions. Also tests carried out on data links having inferior performance (1 in $10^4$) provided acceptable results.

**Fig. 5**

**Example of messages received when a signalling link is taken out of service automatically and subsequently restored to traffic**

```
OTC/FT6 720726 0509 TW1
SIXLINK OVER
ROUTE NO TO TERMINAL/STATE FROM TERMINAL/STATE REASON
  +01         +03    +1          +02    +4      3
END

OTC/FT6 720726 0510 TW1
SIXLINK LOAD TRANSFER
ROUTE NO TO TERMINAL/STATE REASON
  +01         +02    +1     8
END
```

## *Signalling Link Security*

It has been demonstrated that, with the security arrangements as now specified, it is possible to ensure continuity of service for the speech circuits served by a signalling link in case of failure of that link (fig. 5). The delay to messages when changing over to a reserve signalling link depends on the loop delay of that link and whether it is normally synchronised. In most cases the delay to messages is less than 1 second and is therefore not noticeable to the subscribers using the system.

Should all signalling links fail simultaneously due to a number of transmission system failures, then clearly System No. 6 signalling cannot operate. Provision is made in the Specification of System No. 6 to re-commence signalling on the first link available. This emergency transfer (fig. 6) of the signalling traffic results in the minimum delay to telephone calls.

**Fig. 6**

**Example of messages received when all signalling links to a given destination fail simultaneously and traffic is subsequently restored on one of these**

```
OTC/FT6  720726  0511  TW1
SIXLINK EMERGENCY RESTART
LOCALLY INITIATED ON ROUTE 1
END

OTC/FT6  720726  0512  TW1
SIXLINK LOAD TRANSFER
ROUTE NO TO TERMINAL/STATE REASON
   +01         +02    +1     8
END
```

**Table 3**

**Call set-up times**

| Speech Circuit | Overlap Dialling | En bloc Dialling |
|---|---|---|
| No. 5 cable | not possible | 3.5 s |
| No. 5 satellite | not possible | 4.3 s |
| No. 6 | 1.0 s | 1.5 s |

## *Call Set-up Times*

Many thousands of calls have now been established and satisfactory switching performance and interworking with other signalling systems has been demonstrated.

It has also been demonstrated that, due to the fast signal transfer of System No. 6, reduced post-dialling delay can be achieved. This advantage may be negated, however, by other signalling systems in an overall connection.

Table 3 lists average call set-up times for a single link connection (Sydney-Tokyo) using No. 5 and No. 6 signalling. The System No. 6 calls used a cable data link which may control satellite as well as cable speech circuits. The System No. 5 calls used en bloc dialling over the existing intercontinental telephone network. All calls were to a 7-digit ordinary Tokyo subscriber.

## *Operational Facilities*

An SPC exchange is capable of performing much of the routine work presently performed by maintenance staff. This has been demonstrated during the field trials where automatic continuity testing of speech circuits is undertaken. Faulty circuits are withdrawn from operation and a repeat test performed. If this second test is successful the circuits are returned to service; if unsuccessful the maintenance staff is alerted.

Similarly, if unreasonable messages are received or if circuits are blocked too long, the maintenance staff is alerted (fig. 7).

```
OTC/FT6 720725 0148 TWO 367
UNACCEPTABLE MESSAGE IN THIS STATE 054540,0,01,67,3084-0135
END

OTC/FT6 720725 0148 TWO 368
FDR-6 DEVICE BLOCKED INCOMING 055175,0,00,01,3084-0135
END
```

**Fig. 7**

**Examples of printouts received when an out-of-sequence message is received relating to a particular telephone call and when a circuit is blocked by the remote end**

Whilst the facilities in a working exchange may differ from those provided in a field trial, the field trial environment is satisfactory to evaluate the requirements. In this regard the field trial experience has shown the desirability of having easily read print-outs. In the majority of cases the print-out would be complete and the need for reference to other documents eliminated.

## Future Plans

Australia's geographical remoteness from the majority of its communicating partners necessitates the extensive use of facilities such as TASI, satellite circuits and echo suppressors.

Many of the existing international signalling systems are unsuitable for operation with one or more of the above facilities. Hence, CCITT Signalling System No. 5 was chosen as the most suitable for the Australian application.

The rapid growth of international telephone traffic and the imminent introduction of international subscriber dialling on a large scale will require much tighter control of the network to be kept. To do this, it will be necessary to collect more information about the status of the network and the success rate and reasons for failure of telephone calls than is currently possible with System No. 5.

System No. 6 with its considerably increased range of signals and speed, and its spare capacity for additional signals, will enable these and other unknown requirements to be met.

It was with this in mind that OTC (A) called for tenders for a stored program controlled telephone exchange for its new terminal in Sydney. For this plant requiring System No. 6 signalling facilities L M Ericsson's transit exchange AKE 13 equipped for 2,400 circuits has been selected. This exchange is planned to be available for operation late in 1973. In designing this exchange extensive use has been made of experience gained during the field trial.

The implementation of a new signalling system cannot be undertaken unilaterally and so the proposed System No. 6 implementation dates of other countries are of major importance in determining the rate of penetration of System No. 6 in the world telephone network.

To date, a number of countries have indicated their intention to implement System No. 6 as listed below.

| | |
|---|---|
| Australia (OTC) | 1973 |
| Italy (ITC) | 1975 |
| Japan | 1976 |
| UK | 1973 |
| USA (AT & T) | 1976 |

The actual signalling routes that will be established using System No. 6 will depend on the amount of traffic between countries, the types and length of transmission media, the reliability and diversity of the transmission systems.

## Conclusion

From the commencement of the field trials in October 1970 weaknesses and defects in the original specification were detected and corrected at subsequent GM/FT6 meetings. The original specification has changed considerably during the field trials and it is believed that the present specification will result in a CCITT signalling system which is capable of being implemented into a wide variety of applications and of interworking with all existing telephone networks.

This signalling system has many new facilities and considerable spare capacity to cater for future requirements. Not only is the signalling system capable of controlling telephone connections but it also has an extensive range of signals available for administrative purposes. This system may therefore be used for communicating between exchanges and administrations but, most important, it is capable of carrying signals which are used for the supervision, management and control of the network.

Subject to the approval of this present specification by the CCITT Vth Plenary Assembly in December 1972, it is expected that System No. 6 will make a significant contribution to telephony signalling.*

## References

1. CCITT: *White Book, Volume VI. Specification of Signalling System No. 6.*
2. CCITT: *COM GM/FT6 — No. 77 Revised Signal Unit Formats and Codes.*
3. CCITT: *COM GM/FT6 — 101 Revised Issue No. 4 of the Specifications of Signalling System No. 6 for the Field Trials.*

---

* The CCITT Vth Plenary Assembly subsequently has approved the revised specification of Signalling System No. 6, which will be included in the new edition of the CCITT recommendations.

# Man and Telephony

E. A. ERICSSON, TELEFONAKTIEBOLAGET LM ERICSSON, STOCKHOLM

UDC 007.51:621.395.34
LME 1023
5811

*The quickly growing volume of telecommunication traffic has necessitated an increasingly wide automatization, and large parts of the international traffic have already been automated. All telecommunication networks in the world will in due course be interconnected to a global telecommunication machine, which will enable subscribers themselves to dial their local, national and international calls.*

*The public is not interested in the design of the machine, but is interested in the traffic facilities it offers and in the man-machine interaction that is required for the successful establishment of calls. Experience shows that subscribers have difficulties and often fail in their attemps to set up calls. Nationally and internationally (Working Party II/5 of CCITT, CEPT, and Human Factors Symposia) attempts are being made to chart the difficulties and to find ways to facilitate the use of the telephone.*

*This article should be considered as a personal contribution to the debate, in which some human problems are illustrated and indications are given of means to circumvent them. The aim is to stimulate among the parties concerned within administrations and industry an interest in finding suitable solutions, so that non-technical people can utilize the more and more complicated machine in the proper way to their own advantage. It should be possible, as far as telephony is concerned, to remove the fear that exists for technology in general.*

## Historical Review

The successive development of telephony has placed increasing demands on the actions to be performed by subscribers.

### *Manual Operation*

The subscriber merely had to call a specially trained operator, who set up the call for him. In the early days the name of the wanted person was sufficient, but with growing number of subscribers public telephone directories had to be published and the subscriber had to learn to search in the alphabetical lists and give the operator a telephone number instead of name.

### *Automatization of Big Cities*

In big cities the subscribers were connected to a number of exchanges, and manual interexchange switching was time-consuming and expensive. People complained about poor service and Strowger developed his automatic telephone system. Automatization of telephony in big cities was found to be profitable and various switching systems followed. For the public the conversion to automatic operation implied learning of dialling procedures and interpretation of tones. The traffic between cities was still handled manually and nobody thought of nationwide automatization. The big cities were considered as isolated islands and little attention was paid to standardization of the system properties which influenced the man-machine interaction. But this caused no difficulty as long as automatization was confined to local areas.

**Subscriber difficulties:**
- **Subscriber's number?**
- **Dialling?**
- **Interpretation of tones?**

**If one makes a mistake, the wrong person will be called and may be irritated.**

## *Nationwide Automatization*

The development of transmission technique made it possible to build long distance networks with improved grade of service and faster switching of calls over increasing distances. The rapidly growing long distance traffic has rendered automatization necessary and profitable, and some countries have already completed their national automatization.

In conjunction with long distance automatization the technicians have been forced to consider the properties of already installed equipment and to choose the most economical solutions. They were, however, aware that dialling procedures and tones had to be as similar as possible for a whole country.

For the public the nationwide automatization involved further problems, as countries were divided into numbering areas. On calls within an area only the subscriber number had to be dialled; but to other areas the number was preceded by an area code, and it is easy to make mistakes when passing an invisible borderline between numbering areas.

## *Worldwide Automatization*

The experience of nationwide automatization has been quite satisfactory and now the international traffic as well is being automatized on similar principles.

In the first stage international operators in the country of origin alone connect booked calls to the wanted party in the country of destination. The connection times are shortened, as only one operator is involved and the use of alternative routing improves the utilization and grade of service of the international network. The next step is to add equipment to the national network so that the subscribers can dial their own international calls, but this increases the difficulties:

- It may be difficult to find out which digits should be dialled, namely the country code followed by area code and subscriber number. For technical reasons CCITT has stipulated that for most countries the initial area code digit (0 or 9) shall not be dialled, which confuses many callers and causes mistakes.
- The complete number contains many digits and there is a great risk of digits being omitted or dialled in the wrong order. In some countries one must wait for a second dialling tone.
- After successful dialling the caller may misinterpret tones which deviate from those he is accustomed to.

Automatization over increasing distances thus places greater demands on those who wish to dial various kinds of calls themselves. As we approach full automatization of the global telecommunications network, we can now get a much better survey of the relation man-machine than was possible in earlier development stages.

We must also take into account that people have become much more mobile. For various reasons a movement of population is taking place; for instance people try to get better jobs at other places in their home country or abroad.

Fast and cheap communications bring about increased travel, and a rapid rise in long distance calls can be predicted. At present people dial relatively few calls from foreign places, but these calls will undoubtedly increase greatly with time. As there are essential differences in system properties in different parts of the global network, a foreign visitor must always find out how to dial a call. He has to follow different procedures than at home and it is no wonder that mistakes are made.

Much would undoubtedly have been different if the technicians of the past had been able to foresee coming developments and tried to standardize system properties which concern the public.

## Consequences of Unsuccessful and "Unnecessary" Calls

Through improved design and the introduction of rational corrective maintenance methods, high operational reliability at a reasonable cost is possible and will gradually increase as older and less reliable equipment is replaced. The rate of unsuccessful calls caused by technical faults and congestion can be reduced to a fraction of 1 per cent.

Mistakes made by the caller cause many more errors — according to Swedish operational statistics about 3.5 per cent in national and a much higher figure in international traffic. An interesting British article[1] gives the following estimation of yearly cost caused by unsuccessful or "unnecessary" calls from about 9 million British subscribers:

| | |
|---|---|
| ● No reply | £9.8 million |
| ● Wanted party engaged | £6.8 ,, |
| ● Technical faults and congestion | £2.9 ,, |
| ● Faults made by caller | £4.0 ,, |
| ● Booking of subscriber diallable calls | £2.3 ,, |
| ● Enquiries for numbers listed in own directory | £4.1 ,, |
| Total | £29.9 million |

Even if the estimate is unsure, it shows that high costs are involved and the situation is probably similar in all countries.

A reduction of these cost items is an operational interest, and by proper arrangement and utilization of operational statistics it should be possible to estimate various kinds of costs with sufficient accuracy, so that other parties within administrations and industry can be stimulated to analyse causes and effects and take steps to reduce operational costs. Through statistical follow-up the operations people can find out the efficiency of measures taken.

We may briefly consider chiefly three kinds of measures which influence subscriber behaviour, and thus the last three cost items listed above:

- Standardization and simplification of procedures
- Easily available, brief but intelligible information
- Special services which facilitate use of the telephone or satisfy new needs.

It should also be possible to reduce the first two of these cost items through technical arrangements which diminish the risk of repeated call attempts due to busy or no reply.

## Standardization and Simplification of Procedures

For economical reasons it is utopian to believe in essential changes of already installed equipment solely in order to simplify the task for the public, who furthermore might be irritated by apparently meaningless changes. But old equipment will become worn out and gradually replaced by a more modern technique. Through international agreements one should try to standardize certain system properties essential to the ordinary user, so that people will not need to follow a different procedure depending on the place from and to which a call is made in the global network. It should be possible at low cost to prepare new equipment for these standard properties, to be put into operation in due time. Some examples:

### *Standardized Tones*

- Dialling, ringing, busy, congestion and interception tones

**Confusing tones on international calls. What tone is that — ringing, busy or some other strange tone?**

Variations of tones in different countries are confusing on international calls and may lead to misinterpretation. Properly dialled calls may be prematurely released and tones difficult to interpret will increase occupation time, resulting in an unnecessary, unpaid but expensive extra load.

In Sweden it has been found profitable from the maintenance point of view to replace old signalling machines by electronic signalling devices adapted for CCITT signalling standard.

### *Dialling of Area Code on Local Calls*[2]

When using other people's telephones one must know from what numbering area one is calling. Area code and subscriber number should admittedly be marked on all telephone sets in the public network, but people often forget to look. If the area code is dialled when it should not be, the caller receives information to this effect and must start dialling again; and if the area code is forgotten, the wrong subscriber will be dialled.

Some administrations, however, have arranged that a local call is put through even if the area code is dialled, so as to avoid repeated calls. If the caller is unsure where he is, he can always begin with the area code. This admittedly involves dialling of some extra digits, but the inconvenience of calling a wrong number or beginning once again is avoided.

### *Retention of Initial Area Code Digit on International Calls*

A main cause of unsuccessful international calls is the difficulties callers have in discovering the proper digit sequence to dial. A serious obstacle is that the initial digit of the foreign area code (0 or 9) must at present be omitted for many countries. This permits the addition of one digit to subscriber numbers without troublesome alterations of local registers with limited digit capacity. Should the initial area code digit be dialled by mistake, one is informed accordingly and must dial again.

There are now, however, register designs (for example with tail-eating digit stores) with such a digit capacity that there is no need to omit any digit. In such a case the connection can be completed whether the initial area code digit is dialled or not. Compare dialling of area code on local calls! A main reason for unsuccessful international calls would then disappear. There is admittedly the inconvenience for travellers, who are accustomed to include the initial area code digit, on visits to places where that is not yet possible, but they will receive an announcement to that effect.

## *Second Dialling Tone*

In most countries there is only one dialling tone to indicate that dialling may begin, but in some countries — for technical reasons — one has to wait for a second tone during dialling, which confuses travellers. Those who are accustomed to the tone will wait in vain when it does not appear and will prolong the occupation time for expensive equipment. Those who do not wait for the tone where it is needed risk an unsuccessful call. As it has been found that the second dialling tone prolongs dialling time, it is likely to disappear in all countries.

## Subscriber Information

If a person is to be able to dial various types of call, he must know among other things: what digits to dial, how to dial, and how tones from various parts of the world should be interpreted. Every administration tries to give its users sufficient information based on the national situation, but the methods are far from uniform, which complicates the information search for foreigners. The problems are being studied nationally and internationally[3] with the aim to create global guidelines for the provision of easily available information, so that people will both try and can quickly find what they need. Some of the problems are touched upon below.

## Subscriber Listings in Public Telephone Directories

Traditionally a country is divided into numbering areas, each with an area code, and into directory areas, which may be parts of a big numbering area (as in North America) or include many numbering areas, each with its alphabetical listing (per place as in Germany and Holland or for several places as in Sweden). The differences are due to the different economic solutions adopted for automatization of a national network, which resulted in different principles for the planning of national networks and numbering schemes. The consequences for a future global telecommunications machine could not be foreseen.

Normally the subscribers receive only the public telephone directory of the area where they live. For information about people outside that area one needs more directories or must call an enquiries operator. To reduce this inconvenience, a directory area should have a certain geographical size, but there will still be borderline cases.

In big city areas with high telephone density the directories will be rather bulky and unmanageable. Many administrations try to avoid this by reducing subscriber data to a minimum — merely surname, Christian name or initials, and address. Only exceptionally occupation is listed. In this way there will be space for 400—500 subscribers per page and up to a million subscribers on some 1000 pages. A further reduction of the directory cost can be achieved through computerized typesetting, which affect also the subscriber data format.

**To find a number in a telephone directory is not always so easy.**

In big subscriber listings common surnames — maybe with various spellings — will appear in large numbers. The Stockholm numbering area has more than 10,000 Andersson and — to illustrate spelling variations — nearly as many Erichsson, Erickson, Ericksson, Ericson, Ericsson, Ericxson, Ericzon, Erikcohn, Eriksohn, Erikson, Ericksson, Erikzohn, Erixon, Erixson, Erixsson.

To be able to search for a subscriber one must know the search rules (which are not always self-explanatory) and have sufficient data about the wanted person to decide in which alphabetical directory one should look. The information offered can hardly be called easily available, and it is no wonder that number enquiries increase with telephone density and directory size, causing severe trouble for many administrations. Many subscribers cannot be bothered to search or cannot find information even in their own directory, and the cost of the enquiries service increases in spite of yearly expensive replacements of directories.

Even if far-reaching changes cannot be counted upon in existing automatic networks, having regard to the problems of developing countries an attempt should be made through studies of information search to find global guidelines for, e. g.:

- suitable size of directory areas and their division into numbering areas
- planning of numbering schemes including subscriber numbers, area codes, various prefixes, special service numbers etc.
- suitable borderlines for directory and numbering areas so as to minimize the number of borderline cases
- area boundary information such as maps and/or tabulated place names with reference to directory sections
- space-saving subscriber data for reduction of size of directories
- simple and non-confusing search rules
- listing of homonymous surnames with various spellings

The problems are complicated by the fact that one must take into account changes in the community whereby new administrative boundaries come into conflict with area boundaries in the telecommunications network that have been established for technical and economical reasons. In Sweden, for example, big local government areas are being formed the boundaries of which cross directory and numbering areas in a capricious way. The postal address will be a code number followed by the name of the local government area. If place names disappear, the search for subscriber numbers will be more difficult, as reference must be made to several alphabetical directories in each local government area.

## Other Sources for Number Information

Even if certain improvements can be made in public telephone directories, they nevertheless remain imperfect from the information point of view. Other ways must therefore be sought for reducing number enquiries, such as:

### *Classified Section of Public Directories*

The alphabetical listing for each trade and profession can be split up into smaller areas — city districts, suburbs etc. — so that the listings will not be so long and names can be found more easily.

### *Local Telephone Directories*

In areas with high population density the public directories are unfortunately unwieldy and provide poor local service. If smaller areas — a city district or small town with surroundings — are listed, one will get more manageable local telephone directories, often published on private initiative and bought by the public. Through the inclusion of trade advertisements, directories can be sold at a reasonable price. The initiative is praiseworthy, but some directories are difficult to use as the publisher is not a directory expert. An improvement would be gained if administration experts offer advice to private publishers or publish local directories themselves. With computerized directory production, extracts can easily be made from the big data files for the ordinary public directories, so lowering the cost of production of local directories.

In letterheads, advertisements etc. companies notify their telephone numbers, with area code where possible. Many companies also notify their international number and, when in-dialling facilities exist, the extension number to be dialled without invervention of the company operator.

### *Letter Head Information*

Unfortunately many companies dislike the recommended format for "combined" national and international telephone numbers as being too long, which should be considered in future studies.

It should be noted that the reason for "combined" numbers is the confusing omission of the initial trunk code digit on international dialling. If this omission could be avoided, everything would be much simpler, as one would merely have to dial the country code — to be found in a country table — followed by the complete national number taken, for example, from a letterhead. Combined numbers would become superfluous.

Private persons as well often issue information about their telephone numbers by word of mouth or in writing — especially when their number is changed.

### *Personal Telephone Directories*

**The "personal telephone directory" provides easily accessible information and one avoids the necessity of looking through bulky public telephone directories.**

Oral or written information is the easiest way to get a telephone number, as one avoids the search in bulky directories. A person can, however, only retain a few telephone numbers in his memory and there will be an increasing need for personal telephone directories in which telephone numbers can be listed systematically.

Many more administrations should use this idea and study the question of a suitable layout, and then, through propaganda, convince people of the advantage of personal telephone directories. These should also contain short instructions on dialling of various kinds of calls and interpretation of tones etc.

In this way people would have easily available information in their pockets and would more seldom have to search in bulky public directories or apply for enquiries assistance.

## Introductory Pages in Public Directories

### *Listing of Service Numbers*

If there is a common service numbering scheme for a whole country or a directory area, it can be tabulated on an introductory page of the public directory, so that numbers to service operators and other services, such as time, weather, news, alarm clock — sometimes in several languages — can easily be found. Some administrations illustrate the services with pictograms, but that is mostly considered unnecessary.

### *Dialling Instructions*

Too detailed instructions are difficult to follow and are therefore seldom read. Most subscribers have a fair knowledge of dialling, but sometimes need certain information, which should then be easy to find and intelligible.

Directory instructions should therefore be as brief as possible and should contain references to tables for area codes, country codes, call rates etc., and the procedure for dialling local, national and international calls together with explanation of tones etc.

For beginners such instructions may be too meagre and some administrations give detailed information in beginners' brochures. Tape recorders might also be utilized for detailed instructions or information concerning the interpretation of tones. Another way is to call an enquiries operator for more personal service with questions and answers.

### *Information to Foreigners*

The public telephone directory is mainly intended for the nationals of a country and can hardly be used by foreigners and immigrants with insufficient knowledge of the language. Some administrations (for example Finland and Sweden) have therefore introduced a special introductory page with brief instructions in English and one other language. Service numbers to enquiries operators speaking certain languages should also be indicated.

In multilingual countries (such as Belgium, Canada, Switzerland) ordinary dialling instructions are given in several languages.

Detailed information to foreigners can also be given in tourist brochures.

### *Directory Layout*

Even with an adequate linguistic knowledge it may be difficult to find information in foreign directories because of the difference of layouts. Certain items of information are printed somewhere on the introductory pages, others in the alphabetical sections. Much would be gained if the principles could be established for a standard directory layout with the national information arranged in a certain order so that it can be easily found. Instructions should also contain an explanation of symbols used in the directory and the principles used in the alphabetical sections. In the long run standardization would facilitate the finding of informtion, as the same search rules can be applied in many countries.

The dialling information important for all users could be followed by information of less immediate interest, for example, subscription terms, legal regulations, propaganda for special equipment and services.

## Other Information Channels

### *Special Instructions for International Calls*

With the introduction of subscriber-dialled international traffic, administrations publish special brochures containing instructions for dialling to various countries and tables containing area codes for important places abroad. These brochures, to which additions are made when automatic service is opened to new countries, are utilized as propaganda for the automatic international service and are distributed to switchboard operators of companies with international relations. Private people can ask for the brochures.

## *Information before Travelling Abroad*

Increasingly commonly before making a visit abroad, people ask the enquiries service for information about dialling in the foreign country and how calls can be made to their home country.

Unfortunately the operators lack sufficient information and cannot always give a proper reply. It would seem to be an important task for the CCITT Secretariat to collect for each country and to distribute to administrations essential information such as:

- area code tables for wholly or partly automatized national networks, or at least the planned trunk prefix
- existing or planned international prefix
- countries with which originating or terminating subscriber-dialled traffic is possible, and planned opening of new relations
- service numbers to enquiries operators with specification of usable languages.

The number of enquiries of this type might be reduced if the national brochure on international dialling also contains some short information on dialling procedures in other countries.

## Coin Box Telephone Instructions

Many types of coin box telephone are in use, working on many different principles, for example as regards the coins that can be used, and when and how shall they be inserted. Sometimes there are many types within a small area.

It is true that there are printed instructions in the telephone booths, but the operations statistics still show high error rates because people do not read or misinterpret the instructions.

For a foreigner a coin box telphone is often his first encounter with the telephone system of a foreign country and he is in difficulty if he cannot understand the instructions but must guess at the probable procedure.

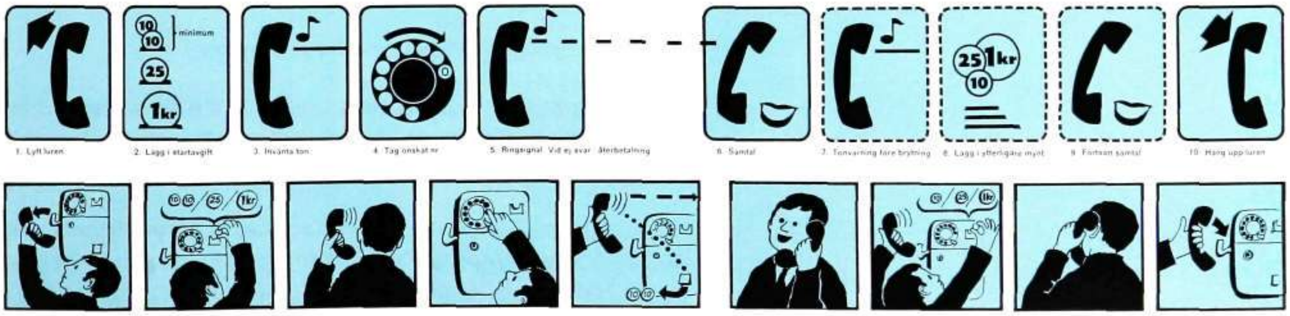
In the past the designers have considered mainly technique and economy, not human abilities and needs and the consequences of increased travel. Through electronic developments it has become possible to simplify the design of telephones and make them less vulnerable to misuse. The technicians should, of course, also try to make telephones more "human" and easier to use. Worldwide standardization of some features seems desirable — for example coin insertion procedures.

Intelligible instructions should, of course, still be provided in telephone booths, but instead of descriptive text it would be preferable to present the successive

**Attempt at intelligible instruction for the Swedish coin-box telephone:**

**— upper row: Symbols with a few explanatory words**

**— lower row: Illustrations without words**



operations in a sequence of self-explanatory pictograms (fig. on p. 147 shows an example). Some trials are under way, the aim being to present information so that people without knowledge of the language can easily and quickly see what to do in a given situation, for example when a mistake has been made.

Standardization of pictograms as such seems hardly to be necessary, but rather of the events which need to be illustrated and what additional information should be given about dialling of different types of call.

## *Propaganda in News Media*

Through advertisements in the press and short announcements on radio and TV, administrations notify the introduction of new telephone facilities and services. It would also be desirable to use news media to teach people to utilize the technique, but unfortunately the media show only a half-hearted interest. What can be done to change this attitude?

## *Subscriber Training*

In some countries excellent results have been obtained through training of children at school in the proper use of the telephone. They show a great interest and this seems to be a good way to foster efficient users. Schools are now also beginning to realize that a knowledge of telephoning should be included in the teaching of civics.

**In-dialling without intervention of company operator saves**
**— time and money for the caller**
**— operator costs for the company**

## Introduction of New Facilities

Modern telephone systems are equipped for new facilities aimed at simplifying the use of the telephone or at satisfying latent needs, for example

- push-button dialling makes dialling easier and faster
- abbreviated dialling to often called parties
- in-dialling to company extensions without intervention of a switch-board operator (fig. 5)
- various kinds of call transfer, for example follow-me calls; reswitching of calls to another telephone on encountering busy or no reply. A larger number of calls will result in a conversation which reduces unpaid unsuccessful calls and increases circuit availability
- automatic call-back when a busy subscriber becomes free, which reduces repeated call attempts
- signalling of waiting call during conversation
- enquiry, transfer and multiparty calls
- various kinds of line blocking and priority
- automatic alarm clock
- data transfer between ordinary telephones and computers

Many of these facilities have for a long time existed in PBXs, where the information problems are relatively simple, as only a limited number of people must learn the procedures.

It will be much more difficult to introduce new facilities in the public network, as they place a greater demand on people's ability to use the technique properly. Through experiments and field trials the attempt is made to investigate people's needs and reactions, but the introduction of new facilities in the public network implies modernization of existing equipment. What services can be offered depends, therefore, on the exchange to which subscribers are connected.

Most probably special subscriptions will be required for many of the services which will be used only by a limited number of subscribers, who should also be able to use the services without help, for example:

- *dialling procedures:* abbreviated dialling, initiation of call-back, automatic alarm clock
- *during conversation:* enquiry, transfer, multiparty calls.

For a number of services (change of abbreviated number, call transfer, priority, line blocking etc.) further investigation are needed to find out whether the user himself will be able to manage the procedures or whether service people should be called in.

Depending on the technical solutions and existing or future signalling facilities, the services will be restricted to the local exchange, local numbering area, home country etc. There will be a risk of faulty manipulation and the technique must be such that ordinary telephone traffic is not disturbed and that users are informed whether they have followed the correct procedure or not, which may require new types of tones.

As only certain supbscribers will apply for the special services, the public directory should merely list the services available, while giving complete information in separate brochures. Such brochures can hardly be published for each exchange but should be usable within big areas and preferably within the whole country. This necessitates national standardization of procedures, which should be so simple that instructions can be brief, yet easy to understand. This standardization of procedures and instructions should as far as possible be global, anyhow for services which are switched over the international network or are usable for foreigners.

For some services which will be popular for ordinary people and for foreigners, for example automatic alarm clock or call-back on busy, instructions should be given in the public directories.

## Summary

The worldwide automatic telecommunications machine under construction will be manipulated by ordinary people with a poor technical knowledge. An attempt has been made to illustrate some problems and difficulties encountered by people in trying to use a complicated technique, and it is obvious that the goal for further development must be the creation of a human technique with more consideration of man's ability and needs than has been the case in the past. Everything should be done to facilitate human control of the technique — some suggestions are given. Having regard to the rapidly increasing international traffic and increased travel, the problems should be considered not only from the national point of view but also from that of international coordination so as to bring about as far as possible:

- simple and preferably standardized procedures
- global methods for subscriber information.

The problems are rather complex and concern many fields — technique, economy, planning, information, operation etc. — which makes coordination difficult. Close cooperation between various parties within administrations and industry is needed so that the technique is adapted to and does not run away from man. The knowledge of human problems in complex cause-and-effect situations is often too poor and much would be gained if persons with a lively interest in such problems could be given time and resources to influence others so as to increase their understanding and stimulate them to participate in the desirable coordination of urgent measures.

Every activity involves a cost; and as long as there are no reliable methods for efficiency control, one can understand the hesitation and failure to act. The British estimate of the cost items, where big reductions seem possible, indicates however that an essential profit can be made by investment in measures such that:

*an increasing number of people dare and are able to use the technique properly to their own advantage.*

## References

1. RYAN, F. A. & JOHNSON, T. C.: *The cost of getting engaged.* Post Office Telecommunications journal *24*(1972): 1 pp. 2—3.
2. *COM II—No. 33 (CCITT 1968—72) Dialling of trunkcode or not within numbering area.*
3. *COM II—No. 15 (CCITT 1968—72) Instructions for users of the automatic service.*

# ADG 101 — Manual Electronic Cord Switchboard

W. PEGERT & R. WALTER, TELEFONAKTIEBOLAGET L M ERICSSON, STOCKHOLM

UDC 621.395.655.2
LME 8372

*Manual telephony still fills a great need. There are many sectors in which a PMBX has its given place, for example in hotels, small offices and the like with limited internal communication or where the cost aspects are decisive. In order to meet the rising demand for a modern PMBX, L M Ericsson have developed a product based on electronic components and cord winders. The design of the switchboard is suited to an office environment; the switchboard is easily extendable, extra facilities can be added, and it has small dimensions. ADG 101 offers all normal facilities demanded of a modern switchboard, such as automatic ringing, individual line supervision, subscriber metering, and secrecy of conversation.*

## Capacity and Mechanical Features

The PMBX *ADG 101* has a final capacity of 200 extensions, 16 exchange lines and 18 cord pairs. The system is built up on the modular principle with plug and jack connection, which allows stepwise extension in groups of 20 extension lines, 8 exchange lines and one cord pair. The switchboard is always wired for full capacity.

For a small number of lines only one line box (fig. 1) is required, in which case the capacity is 100 (80) extensions, 8 (16) exchange lines and 18 cord pairs. A second line box can easily be installed when the line requirement increases (fig. 2).

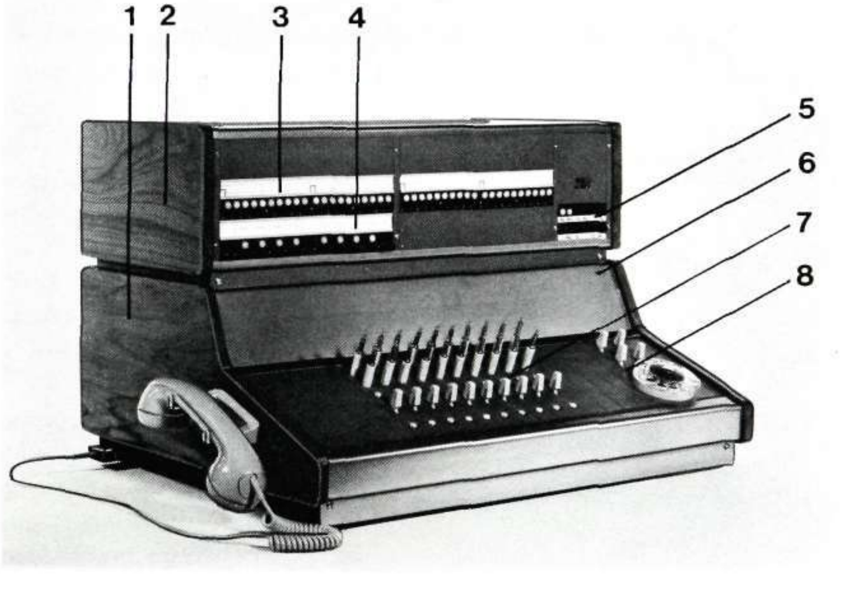


**Fig. 1**

**ADG 101 equipped for 40 extension lines, 8 exchange lines and 10 cord pairs.**

**1 Basic unit**
**2 Line box**
**3 Extension line unit**
**4 Exchange line unit**
**5 Control unit**
**6 Shelf for printed circuit boards with cover plate**
**7 Switching set**
**8 Position set**

Through the use of electronic components, reed relays, miniature relays, and cord winders instead of cord weights, the switchboard has very small dimensions. Its volume is only one-third of that for floor switchboards of present type. The switchboard can therefore be placed on a desk, counter or the like, and harmonizes well in different environments (see front cover). Operating devices and indicators have been placed, and the colouring selected, to enable the operator to attain optimal results.

ADG 101 can interwork with all types of manual and automatic public systems. By connection of alternative printed circuit boards it can be equipped for automatic or manual ringing.

All units and printed circuit boards are inserted from in front. The entire system of construction, with plugs and jacks and easily accessible wiring points, reduces the cost of installation, extension and maintenance to a minimum. No special tools are required for assembly and connecting up of the switchboard.

## Characteristics

The switchboard has been given all facilities required of a modern PMBX, viz.

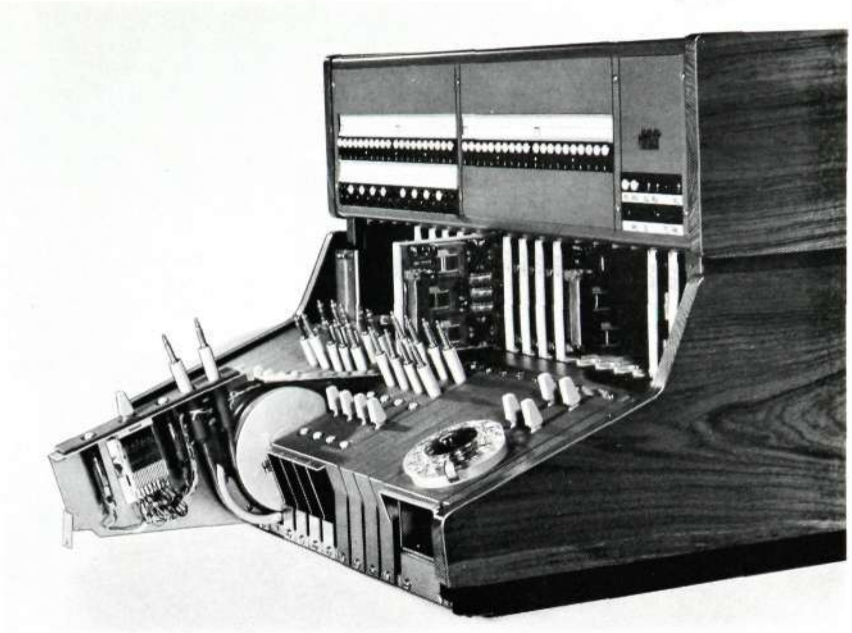
- *automatic intermittent ringing* as soon as the ringing cord is plugged into an extension jack
- *manual ringing signals* can be used, which is of value in hotels, hospitals or similar institutions where automatic ringing may be disturbing at certain times of the day or night
- *ringing* via the answering cord
- *automatic ring tripping* when the extension answers a call
- *ringing tone* to the calling party
- *ringing lamp* to indicate transmission of ringing signals
- *magneto exchange lines* can be installed
- *automatic holding* of exchange lines on incoming calls
- *direct dialling facility* allows an extension to dial a number to the public exchange without operator assistance
- *an exchange line is obtained* by dialling digit 9, whereupon the call lamp flashes
- *subscriber meters* can be installed on exchange and extension lines
- *privacy of conversation* is ensured by the issue of a warning tone to conversing parties when the operator enters a circuit
- *individual current feed* for the extension lines
- *individual supervisory lamps* for answering side and ringing side
- *pilot lamp* for call signals and supervisory signals
- *a discreet buzzer signal* is heard when the pilot lamp lights but is not repeated on new calling and supervisory signals until the operator has completed earlier connections
- *a continuous buzzer signal* can be obtained
- *waiting tone* is issued on a waiting exchange line
- *supervision* of an exchange line by the operator while she is handling other calls
- *a splitting key* enables the operator to speak to one party without the other being able to hear the conversation
- *an enquiry* can be made to the operator in the course of a conversation on an incoming exchange line
- *transfer* of exchange line call to another extension

**Fig. 2**

**ADG 101 with two line boxes equipped for 140 extension lines, 16 exchange lines and 14 cord pairs.**

**Fig. 3**

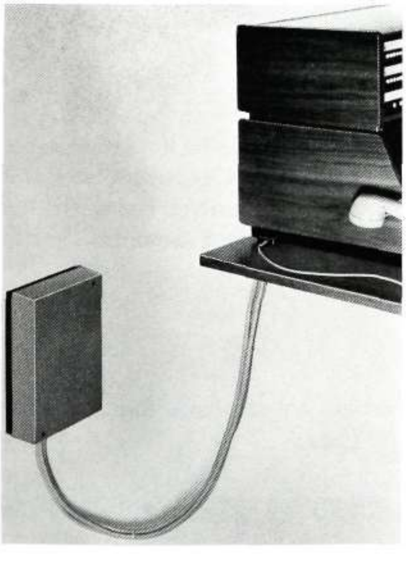
**ADG 101 with a switching set and associated printed circuit board partially withdrawn.**



- *a mains failure* does not cut off established calls on exchange lines
- *tests* of lamps and cords in the switching sets
- *a lamp test* can be made on the exchange line call lamps; the risk of lost calls as a result of lamp failures is thus eliminated
- *extra jack* for connection of handset for assistant operator
- *blown fuses* are indicated by a lamp signal and disconnectable buzzer signal
- *space* is provided for notes which the operator may need to make and to have readily accessible so as to be able to work efficiently
- *night switching* of exchange lines with ordinary cord pairs to optional extensions
- *no current consumption* when the switchboard is switched for night service

**Fig. 4**

**ADG 101 with incoming cable connected via a terminal box.**



# Mechanical Design

## *General*

From the constructional and functional aspects the switchboard is divided into two parts, the basic unit and line boxes. In the basic unit there is a shelf for printed circuit boards and a central wiring unit to which all wiring between the various equipment items is concentrated. Position set and switching sets are placed in the basic unit (fig. 3). The line boxes contain extension and exchange line units. In the first line box there is also a control unit.

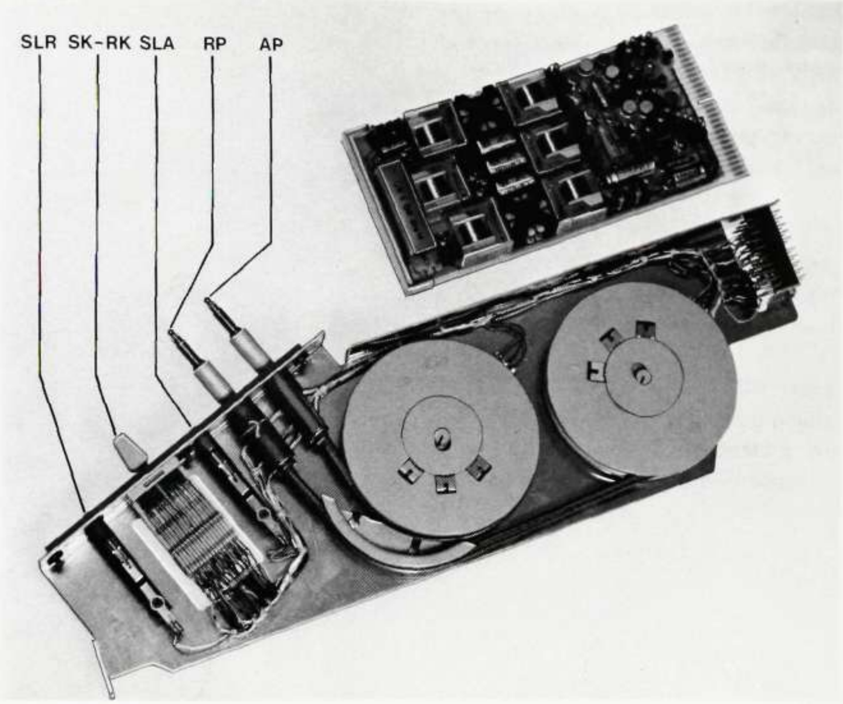
Incoming cable is terminated directly on the line boxes or via wall-mounted terminal boxes (fig. 4).

The sides of the switchboard consist of plastic-coated natural-coloured teak. Fixing plates for the line units and for the top and rear covers of the switchboard are of green-enamelled sheet steel. Switching sets and position sets are framed within anodized light metal sections. Vacant positions are covered with green plastic strips.

Fig. 5

**Switching set with printed circuit board.**

| | |
|---|---|
| **AP** | **Answering plug** |
| **RP** | **Ringing plug** |
| **SLA** | **Supervisory lamp, answering side** |
| **SK-RK** | **3-position key with speaking position SK and ringing position RK** |
| **SLR** | **Supervisory lamp, ringing side** |



## *Switching equipment*

The equipment for a cord pair consists of a switching set and a printed circuit board (fig. 5).

The switching set, the front of which is coated with green plastic, contains two cord winders with 3-pole cords and plugs. The plugs have a handle and a protective spiral of grey plastic which, in combination with the construction of the cord winder, greatly diminish the mechanical strain on the cord.

L M Ericsson possess long experience of the use of cord winders from the portable switchboard ABM 10, which has been subjected to very severe field tests. The cord winder is the cornerstone of the ADG switchboard and contributes greatly to its small space requirement. Fig. 6 shows a cord winder specially adapted to ADG 101.

The switching set includes a 3-position key and two supervisory lamps. The body and lever of the key, which is of small dimensions, are of grey plastic.

The printed circuit board contains current feed relays and electronic components and the usual operation and control circuits.

## *Line equipment*

The line units are of three types, one for ordinary extension lines (fig. 7), one for extension lines with subscriber's meter, and one for exchange lines. The line unit contains a jack strip and lamp strip and a printed circuit board with line components. The unit for normal extensions is wired for a subscriber's meter, which can easily be added if required at a later stage.

## *Position equipment*

The dial and other common operating devices are combined into a position set. The front is covered with a green plastic plate.

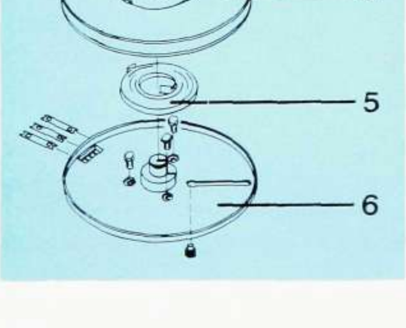
The position equipment also comprises two printed circuit boards placed on the shelf of the basic unit.

**Fig. 6**

**Cord winder.**

**1 Cover**
**2 Terminals**
**3 Helically wound ribbon cable with 3 conductors**
**4 Wheel**
**5 Return spring**
**6 Hub**

**The ribbon cable (3) connects the terminals (2) to the terminals on the fixed hub (6). The switchboard cord is wound up on the wheel (4) and connected to the terminal (2). When the cord is pulled out, the wheel rotates and the return spring (5) is tensioned. When the cord is released it is wound up on the wheel again by the force of the spring.**



## *Control equipment*

Lamps and jacks for complete supervision of operation and for control of cords etc. are placed in a control unit.

## Technical data

| | Basic unit + 1 line box | | | Basic unit + 2 line boxes | | |
|---|---|---|---|---|---|---|
| *Capacity* | | | | | | |
| Extension lines | 80 | 100 | 120 | 200 | 220 | 240 |
| Exchange lines | 16 | 8 | — | 16 | 8 | — |
| Cord pairs | 18 | 18 | 18 | 18 | 18 | 18 |
| *Dimensions* | | | | | | |
| Width | 62 cm | | | 62 cm | | |
| Height | 41 cm | | | 59 cm | | |
| Depth | 53 cm | | | 53 cm | | |
| *Weight* approx. | 50 kg | | | 60 kg | | |

The *operating voltage* is 24 V DC and may vary between 20 and 28 V.

*The line resistance* for an extension including telephone set may be up to 1,000 ohms, i.e. about 800 ohms for the line loop. The leakage resistance may not be below 15,000 ohms. The limits allowed by the public exchange must also be taken into account, however, as extensions on night service are directly connected as public exchange subscribers.

*Current feed* is delivered from the public exchange to night service extensions and also to the operator's speaking equipment when exchange line calls are answered. Local current feed is provided on other calls.

*The current consumption* is:

| | |
|---|---|
| internal calls | approx. 150 mA |
| call between operator and extension | approx. 75 mA |
| ringing to extension | approx. 320 mA |

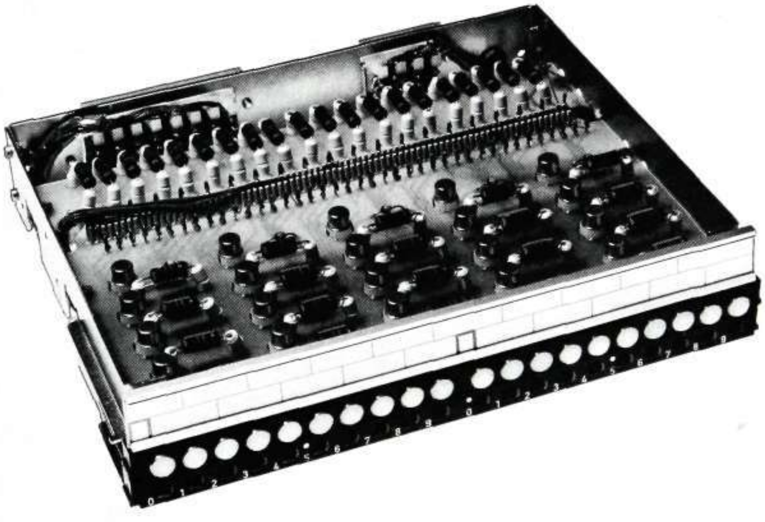


**Fig. 7**

**Line unit for 20 extensions. The lamps are controlled via transistorized call circuits.**

## Accessories

### *Power equipment*

The following equipment is recommended:

| Number of cord pairs | Alt. I | | Alt. II |
|---|---|---|---|
| | Battery | Automatic charger | Mains supply unit |
| —10 | c. 15 Ah | BMM 1831 | BMN 2121 |
| 11—18 | c. 30 Ah | BMM 1832 | BMN 2122 |

All units can be connected to mains voltages of 110/127/220 V, 50—60 Hz.

### *Terminal box*

Terminal box *NEF 442* is recommended for line termination. It has a black base plate and grey plastic cover and accommodates 80 pairs. Dimensions: 285 × 195 × 85 mm.

### *MDF*

A main distribution frame *NBA* is recommended for switchboards with more than 40 extensions. A MDF without line fuses can alternatively be arranged by duplicating the number of terminal boxes, half of the boxes being used for the line side and the other half for the switchboard side.

### *Telephone sets*

L M Ericsson's normal telephone sets with or without dial can be connected.

### *Subscriber meters*

ADG 101 is wired for connection of subscriber meters. Resettable meter units can be placed in the jack field beside the exchange line units. For the extension lines non-resettable meters are placed in a wall frame. Control equipment on separate racks is required in addition.

### *Magneto exchange lines*

The exchange line equipments can be adapted to a magneto system by the addition of separate equipment.

## Summary

L M Ericsson's manual cord switchboards of CB and magneto types were designed more than 20 years ago. Their satisfactory system properties combined with high quality and a flexible mechanical structure have ensured a wide market for these switchboards. There has been an increasing demand, however, for smaller and more compact units of modern external design, as also for new facilities. For this reason the CB type PMBX, ADG 101, has been designed as replacement for ADE 121, ADF 143, 144 and 162.

ADG 101 will soon be followed by a correspondingly built magneto switchboard, ABJ 101, in replacement of ABH 162 and ABK 205, 206.

# ERICSSON News

## from All Quarters of the World

## Ericsson Group Operations Nine Months, 1972

Order bookings during the first nine months of 1972 amounted to $ 757,500,000, an increase of 12.5 percent over bookings of $ 673,400,000 during the comparable period of 1971, it is notified in the Group's interim report.

The need for equipment for public networks continued to rise in many of the Group's major markets. In certain markets demand was affected by restrictions on capital expenditures, generally undertaken in order to check continuing inflation.

The market for telecommunications material used primarily in the private sector is more sensitive to economic conditions. Order bookings for internal communication systems, communication radio for vehicles and other equipment for this sector were thus affected by still depressed business conditions in many countries. Cautious tendencies in the building sector in some markets resulted in lower orders for cable and wire.

The increment of new subscribers of the Swedish Telecommunications Administration, as well as the increase in long distance telephone traffic, is currently very low. This circumstance, together with the fact that substantial production occurs in the Administration's own plants, resulted in reduced orders from this customer. Total order bookings from customers in Sweden were substantially lower than during the corresponding period a year earlier.

In the larger foreign markets the increase in order bookings was notably high in Norway, France, Italy and Brazil.

Of the total orders booked, Swedish customers accounted for 17 percent, those in Europe outside Sweden for 48 percent, Latin American customers for 27 percent and other markets for 8 percent.

Competitive conditions in the world market have not changed significantly. However, there now seems to be a certain stabilization of prices. The order backlog, which at year-end amounted to $ 852,200,000, increased to $ 1,010,300,000.

Group sales during the first nine months of 1972 totalled $ 599,440,000, an increase of 16 percent over sales of $ 517,261,000 during the corresponding period a year earlier. Sales in Sweden were somewhat lower, while foreign invoicing increased 23 percent.

Factory deliveries rose during the first nine months of the year. In the Swedish sector of the Group, employment was adjusted downward in conformity with order bookings, resulting in a decrease in the number of employees from 29,160 at the beginning

*(cont. p. 160)*

## Tunisia places $ 5.5 m. telecommunications order with Ericsson

The Ministry of Post and Telecommunications in Tunisia has placed an order worth over $ 5.5 m. with the L M Ericsson Telephone Company. The order comprises Ericsson crossbar equipment to be used both in new automatic exchanges and for extension of existing exchanges.

The contract, the largest yet received by Ericsson in Tunisia, is the fourth in a series of orders placed with Ericsson by the Tunisian telecommunications administration since the country achieved its independence.

*(cont. p. 158)*

## New $ 10 m. plant for L M Ericsson's Norwegian subsidiary

A/S Elektrisk Bureau, a member of the Ericsson Group, has recently moved into a new head office and factory building at Billingstad outside Oslo. The new building represents an investment of about $ 10 m. and houses 800 employees.

In addition to the new factory at Billingstad the Norwegian company has factories at three other locations in the country and employs 2,700 people. The company is expanding rapidly; its order bookings during the first six months of this year were 18 percent higher than the corresponding figures for last year and sales were up 23 percent.

**Crown Prince Harald of Norway on a tour of the new Billingstad plant with Eilif Björnstad (right), Administrative Director, and Kjell Kveim (left), Vice Administrative Director.**

## Large order for LME from Swedish Telecommunications Administration

L M Ericsson has received from the Swedish Telecommunications Administration an order for terminal equipmets for a new type of transmission system which can simultaneously transmit 10,800 telephone connections on line pair in a coaxial cable. The order totals around $ 4 m.

The first order for equipment of similar type was placed by the Administration in 1967, for the Västerås—Örebro route. This equipment has now been installed and forms part of the first commercial connection in the world with so high a capacity. The experience gained from this new system will now be used in the extension of the larger equipments in south and central Sweden.

## Large Zambia order to L M Ericsson

The government of the Republic of Zambia has signed a contract with the L M Ericsson Telephone Company for automatic telephone switching equipment. The value of the contract is $ 5.6 m. and includes delivery and installation of equipment for both local and long distance subscriber dialling.

The order is the biggest of its kind ever placed by the Zambian government. It will result in an extensive modernization and expansion of city networks as well as the country's subscriber trunk dialling network including automatization of rural areas.

Compared to other countries in Africa, Zambia has a high telephone density. The contract now awarded will considerably increase this density.

The contract was gained following international bidding, in which many of the world's leading manufacturers of telecommunications equipment participated. Delivery and installation of the equipment now ordered will commence towards the end of next year and be completed in 1976.

The equipment covered by the contract is of the Ericsson crossbar type. Ericsson has previously supplied Zambia with telephone switching equipment for about 5,000 subscriber lines.

## Ericsson to start factory in the Republic of Ireland

The L M Ericsson Telephone Company has reached an agreement with the Industrial Development Authority of the Republic of Ireland concerning the establishment of an Ericsson factory for production of telecommunications equipment in Ireland. The new factory will be located at Athlone about 60 miles from Dublin and, when in full production, will provide employment for about 500 people. Ericsson's investment in this new production facility is estimated at over $ 2 m.

Ericsson has been represented in Ireland since 1964 by a subsidiary marketing company and is currently employing about 200 people in that country. It has secured a large part of the market for telephone switching equipment. During the past two years order bookings have amounted to $ 8 m. annually. So far the equipment delivered and installed by Ericsson has been imported from Sweden, but the intention is that the new factory shall supply part of the equipment required for continued expansion of the Irish telephone network.

Ericsson has also concluded an agreement with the Irish Post Office for delivery during the next five years of equipment of the Ericsson crossbar type in quantities roughly equal to those during the last two years.

The Ericsson Group is already operating 36 production units of its own in Sweden and the new Irish factory will be the 33rd production unit outside Sweden.

## Substantial telephone equipment order from Lebanon to L M Ericsson

*The Telecommunications Administration* of Lebanon has placed an order worth over $ 5.5 million with the L M Ericsson Telephone Company for delivery and installation of equipment for automatic telephone exchanges. The installation will be carried out by LME's subsidiary in Lebanon, Société Libanaise des Téléphones Ericsson, which will also be responsible for maintenance, but the equipment will be manufactured by LME in Sweden. The deliveries are to be made over the course of the next two years.

The equipment ordered will be used for extension of existing national and international exchanges as well as for 14 new exchanges.

Since 1951, when L M Ericsson received its first order for equipment for automatic telephone exchanges from Lebanon, the company has delivered equipment serving over 200,000 Lebanese subscribers.

## Agreement in the long distance field between L M Ericsson and Norwegian company

The Norwegian company NERA BERGEN A/S and the L M Ericsson Telephone Company have concluded an agreement within the special sector of long distance telephony comprising radio links with associated carrier equipment. The agreement relates to development and marketing. NERA will be responsible for the further development of radio link equipment, which for several years has constituted an important part of NERA's production. L M Ericsson will undertake the further development of the carrier terminals which are used with radio link equipments.

NERA BERGEN A/S have some 400 employees. 80 % of the company's shares are owned by Bergens Industri-Investering A/S and 20 % by the Norwegian state.

---

### Tunisia places . . .

*(Cont. from p. 157)*

In connection with the signing of the new contract the Tunisian Minister of Post and Telecommunications, Habib Ben Cheik, expressed his great satisfaction with the equipment delivered hitherto and with the Swedish company's contribution in Tunisia, especially within the training field.

The award of the contract to Ericsson coincided with the opening on December 1 of a new automatic telephone exchange for local and trunk traffic in Kelibia in northeastern Tunisia. This inaugural ceremony took place exactly ten years after the first Ericsson-equipped exchanges were cut into service in Tunis.

In October this year Bertil Bjurel, Director General of the Swedish Telecommunications Administration (right) presided at the opening of a 60 MHz telephone connection between Västerås and Örebro. Among the visitors were Björn Lundvall (left), head of the Ericsson Group. To demonstrate the excellent transmission quality of the system, the telephone circuit they were using was arranged to pass no less than 20 times to and fro between Västerås and Örebro — a distance of 1125 miles!

The Board of L M Ericsson recently visited some of the factories in central Sweden. (Left) Ambassador Erik Boheman, Vice Chairman of the Board, and (right) Peter Wallenberg. In the background Lars-Olof Ekeberg (right) conversing with the head of the Ingelsta factory at Norrköping, Åke Bidö.

A new building on the Midsommarkransen site, with a total floor area of about 19,000 m², was ready for occupation in November. It contains laboratories and offices.

A study group from Albania has visited L M Ericsson. (From left) Deputy Director Gambeta, Exportalb, Director Mosho, Agroexport, Deputy Director Joanidhi, Albimport, Deputy Director Gjini, Foreign Trade Ministry, Anadolli, Commercial Counsellor, Albanian Embassy, C.-H. Ström, LME, Deputy Director Sheti, Foreign Trade Ministry, and J. Jahn, LME.

Some of the Swedish members of parliament who visited L M Ericsson in November at a model of the Midsommarkransen plant. To the left Jan-Gustaf Lundh, LME.

L M Ericsson was visited at the end of November by a delegation from Hungary for *discussion of questions of cooperation*. (From left) Andras Tóth, Departmental Manager of the Hungarian State Telephone Factory BHG, Denes Sellö, Director General of BHG, Fred Sundkvist, Vice President of L M Ericsson, István Kulcsár, Technical Secretary of BHG, Lászlo Horváth, Director General of the Hungarian Foreign Trade Company BUDAVOX, and Lajos Nágai, Hungarian Commercial Counsellor in Stockholm.

## Traffic signalling news

On the second of May this year central equipment was put into use for control and supervision of all street traffic signal installations in Copenhagen. The equipment was delivered and installed by Dansk Signal Industri A/S.

The central equipment controls and supervises the signals with the aid of 26 master controllers. The signals at up to 12 street crossings can be connected via local controllers to each master controller. There are five different signal control programmes. The morning traffic has one programme, the afternoon traffic another, and so on. The central equipment also supervises that the signal switching operations take place at the correct time. Should a fault occur, this is recorded at the police radio centre.

The MI Division Signal Department has installed in Gothenburg a computer for traffic control of an area consisting of 18 crossings. The CWIP (UAC 1605) computer used for this purpose is a processor developed by the Signal Department especially for the controll of railway and street traffic.

The computer controls the traffic signals on the basis of the information received from detectors in the carriageways. The numbers and speed of vehicles decide which among a number of signal programmes is most suited for use at a particular moment. The computer is also able, within the scope of a signal programme, to carry out minor variations under traffic control. It can for example, give one traffic stream at a crossing a longer green period at the cost of other traffic streams at that crossing. This permits very flexible control of the traffic.

The system used in Gothenburg has earlier been tested at 21 crossings within the Odenplan area in Stockholm. The result was that the waiting time for vehicles was reduced on an average 25 % and the number of stops on an average 19 % when the traffic was controlled by a computer instead of a conventional master controller.

The UAC 1605 computer also has a large statistical section which provides the traffic engineers with constant information not only concerning quantities of traffic, queues and mean speeds, but also concerning waiting times and number of stops for vehicles in the area.

## Personnel news

On September 15, 1972, Mr Ivar Hilfing, took over the assignments hitherto performed by Mr Ragnar Hellberg on the board of the Italian companies of the Ericsson Group, FATME and SIELTE. Mr Hilfing has been appointed vice chairman of these boards and member of the Management Committees of the two companies. Mr Arvid Westling remains for the time being vice chairman of SETEMER and member of its Management Committee.

From the same date Mr Hellberg has taken over Mr Ivar Hilfing's assignments on, and at the same time been appointed chairman of, the boards of Swedish Ericsson Telecommunications Ltd., Swedish Ericsson Rentals Ltd., and Production Control (Ericsson) Ltd., and managing director and member of the board of Swedish Ericsson Co. Ltd. Mr Hellberg's assignments in the French companies Société Française des Téléphones Ericsson and Rifa S.A. remain unchanged.

## Doctorate for member of Ericsson staff

On September 22, 1972,. Thomas Ericsson, of the Long Distance Division, defended his treatise "Unifilar sources and source approximation".

The treatise includes a study of mathematical models of information sources, especially of so-called discrete sources, sources which produce a sequence of signals from a finite alphabet. Telegraphy and data transmission are the practical applications of most immediate interest.

An attempt is made in the treatise to characterize mathematically the relation between model and reality. A study is made also of structural properties of certain classes of source models — so called unifilar models. Finally a study is made of the way in which different models — of different complexity — can be related to one another.

Dr Ericsson's treatise is published in Ericsson Technics No. 3.

---

**Ericsson Group Operations . . .**

*(Cont. from p. 157)*

of the year to 27,630. In the foreign sector the number of employees rose from 37,700 to 42,130. Recruitment was notably high in the subsidiaries in France, Italy and Brazil.

The margin of sales over production costs decreased by 2.1 percent compared with the first nine months of 1971 but was slightly more favourable than that prevailing during the second half of 1971.

Selling, administrative and research and development expenses increased by 5.8 percent, a significantly lower rate than the rise of approximately 16 percent recorded in the two preceding years.

The excess of interest expense over interest income increased by $ 4,200,000 compared with the same period of 1971.

Foreign exchange losses amounted to $ 4,000,000. For the full year such losses are estimated to reach $ 5,200,000. A significant part of these losses were incurred by Ericsson do Brasil (EDB) as a consequence of successive devaluations of the Brazilian currency.

Group income before special adjustments and taxes amounted to $ 64,124,000 (10.7 percent of sales), compared with $ 56,370,000 (10.9 percent of sales) for the first nine months of 1971.

Consistent with the method used in annual reporting, income after minority interests and taxes was $ 25,759,000, equal to $ 2.09 per share, compared with $ 23,187,000, equal to $ 1.88 per share in 1971, based on 12,304,094 shares outstanding in both years.

It is presently expected that total sales for the entire year 1972 will exceed those of 1971 by 11 to 12 percent. Income before special adjustments and taxes is estimated to be somewhat higher than for 1971.

Group investments in property, plant and equipment during the period amounted to $ 52,900,000 as against $ 55,300,000 during the same period a year earlier.

The Swedish sector of the Group accounted for $ 22,600,000, compared with $ 27,500,000, and the sector outside Sweden for $ 30,300,000, compared with $ 27,800,000 in the preceding year.

Current investments to expand or construct plants in France, Italy, Spain and Mexico to meet production requirements in these markets contributed to the increase in capital expenditures outside Sweden.

# The Ericsson Group

## *Subsidiaries, associated companies and technical offices*

## EUROPE

### DENMARK

**L M Ericsson A/S** *DK-2600 Glostrup*, Kirkebjerg Allé 86, tel: (01) 96 6133, tgm: ericsson københavn, telex: 19020 "ERICSSON KH"

**GNT AUTOMATIC A/S** *DK-2860 Søborg*, Telefonvej 6, tel: (01) 69 5188, tgm: nortelmatic, telex: 27064, "GNT AUTOMATIC KH"

**Dansk Signal Industri A/S** *DK-2650 Hvidovre*, Stamholmen 175, Avedøre Holme, tel: (01) 49 0333, tgm: signaler københavn, telex: 16503, "16503 DSI DK"

**ELMI A/S** *DK-600 Gentofte*, Kirkebjerg Allé 90, tel: (01) 45 42 11, tgm: elmiworks, telex: 16600, ''FOTEX DK'' att. ELMIWORKS

### FINLAND

**Oy L M Ericsson Ab** *SF-02420 Jorvas*, tel: (90) 2991, tgm: ericssons, telex: 12546, "LME SF"

### FRANCE

**Société Française des Téléphones Ericsson**
*F-92 Colombes*, 36, Boulevard de la Finlande, tel: Paris (1) 781 3535, tgm: ericsson colombes, telex: 62179, "ERICSSON CLOMB''

*F-75-Paris 17e*, 147, rue de Courcelles, tel: Paris (1) 227 9530, tgm: eric paris, telex: 29276, "ERICSSON PARIS''

**Etablissements Ferrer-Auran S.A.** *13 Marseille, (10ème)*, 88, Avenue de la Capelette, tel: (91) 47 4851, telex: 42579, ''RINGMA 42579 F''

**RIFA S/A**
*F-62206 Boulogne sur Mer*, B.P 146/3, tel: (21) 31 9206, telex: 11431, ''BORIFA 11431 F''

*F-92 Boulogne sur Seine*, 5, Rue Vauthier, tel: (1) 603 0640, telex: 20781, ''FARIFA 20781 F''

**Thorsmans S.a.r.l.**
*F-75018 Paris*, 3, Passage ruelle, tel: 607 6974

### GREAT BRITAIN

**Swedish Ericsson Company Ltd.** *Morden, Surrey*, Crown House, London Road, tel: (01) 542 1001, tgm: teleric, telex: 935979 ''SWEDERIC LDN''

**Swedish Ericsson Telecommunications Ltd.** *Horsham Sussex*, Viking House, Foundry Lane, tel: (0403) 641 66 tgm: teleric, telex: 877522, ''SWEDERIC HORSHAM''

**Production Control (Ericsson) Ltd.** *Horsham Sussex*, Viking House, Foundry Lane, tel: (0403) 641 66, tgm: productrol, telex: 877522, ''SWEDERIC HORSHAM''

**Swedish Ericsson Rentals Ltd.** *Horsham Sussex*, Viking House, Foundry Lane, tel: (0403) 641 66, tgm: celefon, telex: 877522, ''SWEDERIC HORSHAM''

**Thorsman & Co. Ltd.**
*Chorley Lancs, PR6 OLP*. Thor House, Yarrow Mill, tel: (02572) 4999

**E. B. Marine Communications Ltd.** *Morden, Surrey*, Crown House, London Road, tel: (01) 540 9595, telex: 935979 ''EBMAR LDN''

### IRELAND

**L M Ericsson Ltd.** *Dublin 2*, 32, Upper Mount Street, tel: (01) 619 31, tgm: ericsson, telex, 5310, "LMI EI''

### ITALY

**FATME, Soc. per Az.** *1-00100 Roma*, C. P. 4025 A. tel: (06) 4694, tgm, fatme, telex: 61327, "61327 FATME"

**SETEMER, Soc. per Az.** *1-00198 Roma*, Via G. Paisiello 43, tel: (06) 86 8854, tgm: setemer

**SIELTE, Soc. per Az.** *I-00100 Roma*, C.P. 5100, tel: (06) 577 8041, tgm: sielte, telex: 61225. "61225 SIELTE''

### NETHERLANDS

**Ericsson Telefoonmaatschappij N.V.** *Rijen (N.Br.)*, P. O. B. 8, tel: (01612) 3131, tgm: erictel, telex: 54114, ''ETM RIJ NL''

*Voorburg 2110*, P. O. B. 60, tel: (070) 81 4501. *tgm: erictel den haag*, telex: 31109, ''ETMVB NL''

### NORWAY

**A/S Elektrisk Bureau** *N-1360 Nesbru*, P.B. 98, tel: (02) 78 8060, tgm: teleb, telex: 11723, ''TELEB N''

**A/S Industrikontroll** *Oslo 6*, Grensevejen 86/88, 3. etg., tel: (02) 67 8394, tgm: indtroll

**A/S Norsk Kabelfabrik** *Drammen*, P.O.B. 369, tel: (02) 83 7650, tgm: kabel, telex: 18149, "KABEL N''.

**A/S Telesystemer** *Oslo 6*, Tvetenveien 32, Bryn, tel: (02) 68 7200, tgm: telesystemer, telex: 16900, "ALARM N''

### POLAND

**Telefonaktiebolaget L M Ericsson, Technical Office** *Warszawa*, Ul. Nowy Swiat 42, tel: 26 4926, tgm: tellme, telex: 813710, "813710 TELLME PL''

### PORTUGAL

**Sociedade Ericsson de Portugal Lda.** *Lisboa 1*, Rua Filipe Folque 7, 1°, tel: 56 3212, tgm: ericsson

### SPAIN

**Industrias de Telecomunicación, S.A.** *Getafe*, Paseo Felipe Calleja 6, tel: 295 2100, tgm: ericsson, telex: 22666, "ERIGE E''

**L M Ericsson, S.A.** *Madrid* 5, Bernadino Obregón 25, tel: 467 8700, tgm: ericofon, telex: 23333, "23333 LMESA E"

### SWEDEN

**Telefonaktiebolaget L M Ericsson,** *S-126 25 Stockholm*, tel: (08) 719 0000, tgm, telefonbolaget, telex: 17440, "LME S''

**ELLEMTEL Utvecklings Aktiebolag** *S-127 25 Skärholmen* Box 249, tel: (08) 97 0220

**Bjurhagens Fabrikers AB** *S-200 12 Malmö*, Fack, tel: (040) 93 4770, telex: 3123, "BJURHAG S"

**AB Rifa** *S-161 11 Bromma 11*, Fack, tel: (08) 26 2600, tgm: elrifa, telex: 10308, "ELRIFA STH''

**L M Ericsson Instruktionsteknik AB** *S-117 47 Stockholm 44*, tel: (08) 68 0870, tgm: instruktec

**L M Ericsson Telemateriel AB** *S-135 01 Stockholm-Tyresö 1*, Fack, tel: (08) 712 0000 tgm: ellem, telex: 10920, "10920 LMSBO/S"

**Sieverts Kabelverk AB** *S-172 87 Sundbyberg*, tel: (08) 28 2720, tgm: sievertsfabrik, telex: 1676, "SIEVKAB S"

**Svenska Radio AB** *S 102 20 Stockholm 12*, Fack, tel: (08) 22 31 40, tgm: svenskradio, telex: 10094 "SRA S"

**AB Thorsman & Co.** *S-611 01 Nyköping 1*, Box 149, tel: (0155) 810 00, tgm: thorsmanco

**AB Transvertex** *S-145 53 Norsborg*, Fittja industriområde, tel: (08) 710 0935

### SWITZERLAND

**Ericsson A.G.** *8061 Zurich*, Postfach, tel: (01) 41 6606, tgm: telericsson, telex: 52669, "ERIC CH''

### TURKEY

**Ericsson Türk Ticaret Ltd. Sirketi** *Ankara*, Rumeli Han, Ziya Gökalp Cad. tel: 12 3170, tgm: ellem

### WEST GERMANY

**Ericsson Centrum G.m.b.H.** *3 Hannover, Dornierstrasse 10*, Postfach 1809, tel: (0511) 63 1018, tgm: ericen, telex: 922913, ''922913 ERICE D''

**E B Marine Nachrichtentechnik GmbH,** *Hamburg 70*, Mühlenstieg 5. tel: (0411) 652 9831, telex: 212076

**Thorsman & Co GmbH,** *D-4796 Salzkotten*, Lange Strasse 4, Postfach 96, tel: (05258) 8450

## ASIA

### INDIA

**Ericsson India Limited**
*Calcutta*, P.O.B. 2319, tel: (032) 45 4494, tgm: inderic, telex: 7165, ''ERICCU CA 7165''

*New Delhi 24*, No. 15,Community Center, Suraj Parbat, tel: (011) 63 1637, tgm: inderic

### INDONESIA

**Ericsson Telephone Sales Corporation AB**
*Djakarta*, P.O.B. 2443, tel: (07) 463 97, tgm: javeric, telex: 4414 "JAVERIC DKT 4414''

*Bandung*, Djalan Ir. H. Djuanda 151, tel: (082) 820 94, tgm: javeric

### IRAQ

**Telefonaktiebolaget L M Ericsson, Iraq Branch** *Baghdad* P.O.B. 2388, Alwiyah, tel: 960 07, tgm: ellemco

### KUWAIT

**Telefonaktiebolaget L M Ericsson, Technical Office** *Kuwait, State of Kuwait*, P.O.B. SAFAT No. 5979, tel: 42 0074, tgm: erictel

### LEBANON

**Société Libanaise des Téléphones Ericsson** *Beyrouth* B.P. 8148, tel: 25 2627, tgm: ellem, telex: ELLEM 20876 LE

### MALAYSIA

**Ericsson Talipon SDN BHD** *Shah Alam, Selangor, Batu Tiga Industrial Estate*, P.O.B. 28, Tel: Kuala Lumpur (03) 36 1821, tgm: kuleric, telex: 265, ''ERICMAL KLTX 265''

**Telecommunication Manufacturers (Malaysia) SDN BHD** *Shah Alam, Selangor, Batu Tiga Industrial Estate*, P.O.B. 28, tel: Kuala Lumpur (03) 36 1821, tgm: kuleric, telex: 265, ''ERICMAL KLTX 265''

### PAKISTAN

**L M Ericsson Telephone Company, Technical Office** *Karachi*, P.O.B. 7398, tel: (90) 51 6112, tgm: ericsson

### THAILAND

**Ericsson Telephone Corp. Far East AB** *Bangkok*, P.O.B. 824, tel: (02) 51 8191, tgm: ericsson, telex: 2274, "THAIERIC''

## AFRICA

### A. R. EGYPT

**Telefonaktiebolaget L M Ericsson, Technical Office** Egypt Branch *Cairo* P.O.B. 2084, tel: (02) 465 83, tgm: *ericgypt*, telex: 2009, "ELLEME UN''

### ETHIOPIA

**Telefonaktiebolaget L M Ericsson, Technical Office** *Addis Ababa*, P.O.B. 3366, tel: (01) 492 60, tgm: ericsson, telex: 21090 "MOSFIRM ADDIS''

### MOROCCO

**Société Marocaine des Téléphones Ericsson** *Casablanca*, 87, Rue Karatchi, tel: 788 75, tgm: ericsson

### TUNISIA

**Telefonaktiebolaget L M Ericsson, Technical Office,** *Tunis*, Boite Postale 780, tel: (01) 24 0520, tgm: ericsson, telex: 695, "ERICSSON TUNIS''.

### ZAMBIA

**Ericsson Telephone Sales Corporation AB**
*Lusaka*, P.O.B. 2762, tel: (011) 744 42, tgm: ericofon

*Ndola*, P.O.B. 2256, tel: (026) 3885, tgm: ericofon

## AMERICA

### ARGENTINA

**Cia Ericsson S.A.C.I.** *Buenos Aires* Casilla de Correo 3550, tel: 33 2071, tgm: ericsson, telex: 0122196, "CATEL BA''

**Cia Argentina de Teléfonos** S.A. *Buenos Aires*, Belgrano 894, tel: 33 2076, tgm: catel, telex: 0122196, "CATEL BA''

**Cia Entrerriana de Teléfonos S.A.** *Buenos Aires*, Belgrano 894, tel: 33 2076, tgm: catel, telex: 0122196, "CATEL BA''

**Industrias Eléctricas de Quilmes S.A.** *Quilmes FNGR*, 12 de Octubre 1090, tel: 253 2775. tgm: indelqui buenosaires, telex: 0122196, "CATEL BA''

### BRAZIL

**Ericsson do Brasil Comércio e Indústria S.A.**
*BR-010 00 São Paulo*, Rua da Corda 500, tel: (011) 298 2322 tgm: ericsson, telex: 021817, ''ERICSSON SPO''

*Rio de Janeiro*, Caixa Postal 3601-ZC-00, tel: (021) 221 7477, tgm: ericsson, telex: 031839, "ERICSSON RIO"

**Fios e Cabos Plásticos do Brasil S.A. (FICAP)** *Rio de Janeiro*, caixa postal: 1828, tel: (021) 391 4550, tgm: ficap, telex: 031485, "FICAP RIO"

### CANADA

**L M Ericsson Limited** *Montreal 381, Quebec*, 2300 Laurentian Boulevard St. Laurent, tel: (514) 331 3310, tgm: caneric, telex: 05-267682, (TWX) 610-421-3311, "CANERIC MTL''

### CENTRAL AMERICA

**Telefonaktiebolaget L M Ericsson, Oficina Tecnica de Centroamérica** *San Salvador*, Apartado 188, tel: 21 7640, tgm: ericsson, telex: 20087, "ERICSAL 20087''

### CHILE

**Cia Ericsson de Chile S.A.** *Santiago*, Casilla 10143, tel: (04) 825 55, tgm: ericsson, telex: 40598, "40598 ERICH CL"

### COLOMBIA

**Ericsson de Colombia S.A.** *Bogotá*, Apartado Aéreo 4052, tel: (92) 41 1100, tgm: ericsson, telex: 044507, "ERICSSON BOG''

**Fábricas Colombianas de Materiales Eléctricos Fácomec S.A.** *Cali*, Apartado Aéreo 4534, tel: 42 1061, tgm: facomec, telex: 55673, "FACOMEC CLO''

### COSTA RICA

**Telefonaktiebolaget L M Ericsson, Technical Office** *San José*, Apartado 10073, tel: 21 1466, tgm: ericsson, telex: 283, "283 LME-CR"

### ECUADOR

**Teléfonos Ericsson C.A.**
*Quito*, Casilla 2138, tel: 52 4000, tgm: ericsson

*Guayaquil*, Casilla 376, tel: 30 0900 tgm: ericsson

*Cont. on next page*

## *Subsidiaries, associated companies and technical offices* *(Cont. from preceding page)*

MEXICO

**Teléfonos Ericsson S.A.** *Mexico D.F.*, Apartado Postal M-9958, tel: 566 8955 *tgm*: *coeric*, telex: 017234, "ERICSSON TLA" PARA COERIC

**Latinoamericana de Cables S.A. de C.V.** *Mexico 12 D.F.*, Apartado Postal 12737, tel: 549 0844 tgm: latincasa, telex: 017234, "ERICSSON TLA" PARA LATINCASA

**Teleindustria, S.A.** *Mexico 1, D.F.*, Apartado Postal 1062, tel: 565 7033 tgm: ericsson, telex: 017234 "ERICSSON TLA"

**Telemontaje, S.A. de C.V.** *Mexico 1, D.F.*, Apartado Postal 1062, tel: 576 4044, tgm: ericsson, telex: 017234, "ERICSSON TLA" PARA TELEMONTAJE

PANAMA

**Telefonaktiebolaget L M Ericsson, Oficina Técnica de Panamá** *Panama 5, R.P.* Apartado 4349, tel: 64 3600, tgm: ericsson, telex: 368674 "368674 SONITEL"

PERU

**Cia Ericsson S.A.** *Lima*, Apartado 2982, tel: 31 1005, tgm: ericsson, telex: 3540202, "ERICSSON 3540202"

**Soc. Telefónica del Perú, S. A.** *Arequipa*, Apartado 112-1012, tel: 6060 tgm: telefonica

EL SALVADOR

**Telefonaktiebolaget L M Ericsson, Technical Office** *San Salvador*, Apartado 188, tel: 21 7640, tgm: ericsson

URUGUAY

**Cia Ericsson S.A.** *Montevideo*, Casilla de Correo 575, tel: 91 2611, tgm: ericsson, telex: 398228, "ROULEMENT UY" PARA MELANDER

USA

**The Ericsson Corporation** *New York, N.Y. 10017*, 100 Park Avenue, tel: (212) 685 4030, tgm: erictel, telex: 620484, "ERICTEC 620484"

**Ericsson Centrum Inc.** *New York, N.Y. 10016*, 16, East 40th Street, tel: (212) 679 1000, tgm: erictel, telex: 620149, "ETELSAC 620149"

VENEZUELA

**Cia Anónima Ericsson** *Caracas*, Apartado 70516, tel: (02) 34 4661, tgm: ericsson, telex: 21530, "21530 ERIC VEN"

**Alambres y Cables Venezolanos C.A. (ALCAVE)** *Caracas*, Apartado del Este 62107, tel: (02) 33 9791, tgm: alcave, telex: 22845, "22845 ALCAVE VE"

### AUSTRALIA & OCEANIA

AUSTRALIA

**L M Ericsson Pty Ltd.**
*Broadmeadows, Victoria 3047*, P.O.B. 41, tel: (03) 309 2244, tgm: ericmel, telex: AA 30555, "ERICMEL"

*Rushcutters Bay N.S.W. 2011*, 134 Barcom Avenue, tel: (02) 31 0941, tgm: ericsyd, telex: AA 21358 "ERICSYD"

*Boroko, Papua New Guinea*, P.O.B. 5602, tel: Port Moresby 565 66, tgm: ericpor, telex: Port Moresby 153

**Teleric Pty. Ltd.**
*Broadmeadows, Victoria 3047*, P.O.B. 41, tel: (03) 309 2244, tgm: teleric, telex: AA 30555, "ERICMEL"

*Rushcutters Bay N.S.W. 2011*, 134 Barcom Avenue, tel: (02) 31 0941, tgm: teleric, telex: AA 21358, "ERICSYD"

**Conqueror Cables Pty. Limited** *Dee Why, N.S.W. 2099*, P.O.B. 69, tel: (02) 982 3344, tgm concab sydney, telex: 24305, "CONCAB AA 24305"

**A.E.E. Capacitors Pty. Ltd.** *Preston, Victoria 3072*, 202 Bell Street, P.O.B. 95, tel: (03) 480 1211, tgm: engiquip melbourne, telex: 31001, "AEEMELB AA 31001"

---

## *Representatives*

### EUROPE

AUSTRIA

**Electro-Diesel Handelsaktiengesellschaft, Abteilung Telecom** *1160 Wien*, Postfach 98, tel: (0222) 43 5956, tgm: teleric, telex: 75976, "75976 TELECOM A"

BELGIUM

**Allumage Lumière S.A.** *Bruxelles 7*, 128-130 Chaussée de Mons, tel: (02) 23 9425, tgm: allumalux, telex: 21582, "ALLUMALUX BRU"

GREECE

**Angelos Cotzias** *Athens, 18*, Omirou Street, tel: (021) 62 6031, tgm: cotziasan, telex: 215252, "215252 CTZS GR"

ICELAND

**Johan Rönning** *Reykjavik*, P.O.B. 5300, tel: 840 00, tgm: rönning, telex: 2040, "ROENNG IS"

CANARY ISLANDS

**TRANSA Transacciones Canarias S.A.**

*Las Palmas de Gran Canarias*, Tomas Morales 36, tel: 21 8304, tgm: transa, telex: 95052, "95052 CASTI E"

*Santa Cruz de Tenerife*, Tirso de Molina, 2 "Edificio Dulcinea", tel: 22 9240, tgm: transa

YUGOSLAVIA

**Merkantile Inozemna Zastupstva** *Zagreb* P.O.B. 02-1027, tel: (041) 41 6655, tgm: merkantile, telex: 21130, "21139 YU MERTIL"

*Beograd*, Gospodar Jevremova 46 tel: (011) 63 2878, tgm: merkantile, telex: 11263, "YU MERKAN"

### ASIA

BAHRAIN & UNITED ARAB EMIRATES

**Yusuf Bin Ahmed Kanoo** *Bahrain, Arabian Gulf*, tel: 40 8188, tgm: kanoo, telex: BHN 215

BURMA

**Myanma Export Import Corp., Agency Div.** *Rangoon*, P.O.B. 404, tel: 112 58, tgm: myanagent telex: UBMEIC BM 2005

CAMBODIA

**Comin Khmere S.A.** *Phnom-Penh*, P.O.B. 625, tel: 233 34, tgm: engineer

CYPRUS

**S.A. Petrides & Sons Ltd.** *Nicosia*, P.O.B. 4522, tel: 427 88, tgm: armature, telex: 2308, "ARMATURE"

HONG KONG AND MACAO

**Swedish Trading Co. Ltd.** *Hong-Kong*, P.O.B. 108, tel: 23 1091, tgm: swedetrade

IRAN

**Irano Swedish Company A. B.** *Teheran*, Khiabane Sevom Esfand 29, tel: 31 4161, tgm: iranoswede

JORDAN

**The Arab Trading & Development Co.** *Amman*, P.O.B. 6141, tel: 259 81, tgm: aradeve

KUWAIT

**Morad Yousuf Behbehani** *Kuwait, State of Kuwait*, P.O.B. 146, tel: 42 7071, tgm: barakat, telex: 2048, "BEHBEHANI KUWAIT"

LEBANON

**Swedish Levant Trading** *Beyrouth*, P.O.B. 931, tel: 23 1624, tgm: skefko

OMAN

**Muscat Trading Company** *Muscat* P.O. B. 127, tel. 458, tgm: tijarah, telex: MB 258 MUSTRAD

PAKISTAN

**Panasian Marketing Service Ltd.** *Karachi*, P.O.B. 3941, tel: (90) 51 2051, Ext. 53, tgm: panasian

PHILIPPINES

**Asia Industries Inc.** *Makati, Rizal*, M.C.C. Post Office 1322, tel: 87 7011, tgm: usi asia, telex: 7222233, "7222233 AII PH"

SAUDI ARABIA

**Engineering Projects & Products Co. Ltd. (Eppco)**

*Riyadh*, P.O.B. 987, tel: 222 22, tgm: eppcol

*Yeddah*, P.O.B. 1502, tel: 222 22, tgm: eppcol

*Dammam*, P.O.B. 450, tel: 222 22, tgm: eppcol

SYRIA

**Constantin Georgiades** *Damas*, P.O.B. 2398, tel: 266 73, tgm: georgiades

TAIWAN

**Trans-Eurasia Enterprise, Ltd.** *Taipei*, P.O.B. 3880, tel: 51 7038, tgm: esbtrading

REPUBLIC OF VIETNAM

**Vo Tuyen Dien-Thoai Vietnam** *Saigon*, P.O.B. 1049, tel: 226 60, tgm: telerad

**International Business Representative** *Saigon*, 26—28, Hai Ba Trung Street, tel: 226 60, *tgm*: *ibur*

### AFRICA

ETHIOPIA

**Mosvold Company (Ethiopia) Ltd.** *Addis Ababa*, P.O.B. 1371, tel: (01) 101 00, tgm: mosvold, telex: 21090, "MOSFIRM ADDIS"

KENYA, TANZANIA, UGANDA

**The Old East African Trading Co. Ltd.** *Nairobi, Kenya*, P.O.B. 30013, tel: 271 61, tgm: broche, telex: 22261, "OLDEAST NAIROBI"

LIBERIA

**Telecommunications Authority** *Monrovia*, P.O.B. 9039, tel: 222 22, tgm: radiolibe, telex: 4211 TLX BOOTH LIB

LIBYA

**ADECO African Development & Engineering Co***Tripoli*, P.O.B. 2390, tel: 339 06, tgm: adeco

MALAWI

**Business Machines Ltd.,** *Limbe*, P.O.B. 5557, tel: Blantyre 513 52, tgm: falt, telex: 342, "FALT LIMBE"

MOZAMBIQUE

**J. Martins Marques & Ca. Lda** *Lourenço Marques*, P.O.B. 2409, tel: 24953, tgm: marquesco

NIGERIA

**Communications Associates of Nigeria Ltd. (Comsac)**, *Ilupeju (Lagos)*, P.M.B. 1129, tel: 322 06 tgm: comdec lagos

SOUTH AFRICA
NAMIBIA

**Dryden Communications (Pty.) Ltd.** *Johannesburg, South Africa*. P.O.B. 2440, tel: 838 5454, tgm: qualsteels, telex: 430094, "430094 SA"

SUDAN

**El Rahad Trading Corporation** *Khartoum*, P.O.B. 866, tel: 776 95, tgm: suconto, telex: BHN 251

ZAIRE

**I.P.T.C. (Zaire) Ltd.** *Kinshasa*, P.O.B. 8922, tel: 253 45, tgm: induexpan, telex: 327, "IPTC KIN"

### AMERICA

BAHAMA ISLANDS

**Anglo American Electrical Company Ltd.** *Freeport, Grand Bahama*, P.O.B. 104

BOLIVIA

**Prat Ltda** *La Paz*, Casilla 4790, tel: 277 12, tgm: prat, telex: PRAT BX 5363

COSTA RICA

**Tropical Commission Co. Ltd.** *San José*, Apartado 661, tel: 22 5511, tgm: troco

DOMINICAN REPUBLIC

**Humberto Garcia, C. por A.** *Santo Domingo*, Apartado 771, tel. 682 3645, tgm: gartier

GUATEMALA

**Nils Pira** *Ciudad de Guatemala*, Apartado 36, tel: (021) 622 57, tgm: nilspira, telex: 4172, "PIRAGU"

GUYANA

**General Supplies Agency** *Georgetown*, tel: 638 38, P.O.B. 375, tgm: benwiks

HONDURAS

**Quinchón Leon y Cia** *Tegulcigalpa*, Apartado 85, tel: 251 71, tgm: quinchon

NETHERLANDS ANTILLES

**S.E.L. Maduro & Sons Inc. Merchandise Dept.** *Willemstad, Curaçao* P.O.B. 304, tel: 130 00, tgm: madurosons, telex: CU 92

NICARAGUA

**Roberto Teran G.** *Managua*, Apartado 689, tel: 224 00, tgm: roteran

PANAMA

**Sonitel, S.A.** *Panama 5, R.P.*, Apartado 4349, tel: 64 3600, tgm: sonitel, telex: 368674, "368674 SONITEL"

**Mr. Tore Korch** *Panama 5, R. P.*, Apartado 4349, tel: 64 36 00, tgm: sonitel, telex: 36 86 74, "36 86 74 SONITEL" FOR MR KORCH

PARAGUAY

**S.A. Comercial e Industrial H. Petersen** *Asunción*, Casilla 592, tel: 44 124, tgm: pargtrade

EL SALVADOR

**Dada-Dada & Co.** *San Salvador* Apartado 274, tel: 21 7940, tgm: dada

SURINAM

**W.E. van Romondt's Trading Company Ltd.** *Paramaribo*, P.O.B. 1837, tel: 728 31, tgm: vanromondt

TRINIDAD, W.I.

**Leon J. Aché Ltd.** *Port-of-Spain*, P.O.B. 276, tel: 323 57, tgm: achegram

### AUSTRALIA & OCEANIA

NEW ZEALAND

**ASEA Electric (NZ) Ltd.** *Wellington C. 1.*, P.O.B. 3239, tel: 706 14 tgm: asea, telex: 3431, "ASEAWELL NZ 3431"

SATHERLUND & KROOK