ERICSSON REVIEW

THE MOLLISON INTERNATIONAL SWITCHING CENTRE
LONG DISTANCE TRAFFIC IN MEXICO
INSTALLATION OF 12 MHz SYSTEM
MULTIPLEX AND RADIO-RELAY EQUIPMENT
WORLDWIDE NEWS

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Test consoles for measurements of the national and international circuits in the Mollison Switching Centre, London

The Mollison International Switching Centre

Rowland W. Button and Manfred Buchmayer

In April 1972 the United Kingdom Post Office awarded LM Ericsson the Contract for a large International Switching Centre (ISC) in London.
The Mollison International Switching Centre is one part of the Stag Lane International Telephone Service Centre multitask project to establish one of the largest switching centres for international telephone traffic in the world.
What made the Mollison project a special one to LM Ericsson was that with its 25,000 ARM 20 crossbar positions, a switching capacity of 8,000 Erlangs and a call handling capacity of well over 100,000 calls an hour, it is the largest single international exchange project LM Ericsson had ever undertaken.
Because the ARM 20 system with well over 600,000 lines in service by the end of 1973 is so well known, the system design will not be gone into in any great detail in this article. Instead, attention will be paid to the management of the project, the special facilities offered and to the integration of Mollison ISC into the UK national and international networks.

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The Mollison order

In September 1971, LM Ericsson, together with other manufacturers of telecommunication equipment, was invited by the United Kingdom Post Office to submit a tender for the design, manufacture and installation of an international 4-wire switching centre in London. Two switching units had to be provided, one for outgoing international traffic and one for incoming international traffic. The initial and final capacities of each of the units were specified to be 1,500 and 4,000 Erlangs respectively. Each of the units were to be equipped with an international maintenance centre. The Post Office planning strategy required the units to cater primarily for international subscriber-dialled traffic originating and terminating in the United Kingdom. On April 27, 1972, the contract, which later on came to be known as the Mollison Contract, was awarded to LM Ericsson.

The contract is divided into three phases. The contractual handover date for Phase I with a traffic capacity of 3,000 Erlangs was December 27, 1974. Phase II with a traffic capacity of 2,000 Erlangs and Phase III with one of 3,000 Erlangs should be ready for service on December 27, 1975 and December 27, 1976 respectively.

As mentioned above, the order comprised manufacture, design, delivery and installation of a 4-wire ARM 20 international switching centre with an initial capacity of 3,000 Erlangs and a contracted final capacity of 8,000 Erlangs. Within this framework two switching units had to be provided, one for outgoing international traffic and one for incoming international traffic. Each unit had to be served by an international maintenance centre comprising an International Transmission Maintenance Centre (ITMC) and an International Switching Maintenance Centre (ISMC). The equipment to be supplied had to be complete, i.e. to be supplied as a working entity including power plant and rack lighting.

Automatic transmission measuring equipment, service observation equipment, international accounting equipment using computer techniques and maintenance equipment were included in the order.

Three national line signalling systems, AC11, DC3 and LD4, were specified. The two first line signalling systems mentioned are associated with the Multi-Frequency inter-register signalling system MF2.

The third is a combined line and register signalling system with loop disconnect pulsing. These signalling systems are described in more detail under Register signalling and signalling systems.

Three international signalling systems were also specified, CCITT 4, CCITT 5 and CCITT R2.

A training package for PO engineering and maintenance staff, and provision of a complete training exchange were included in the order.

The international and national network configuration of Mollison ISC

Mollison ISC position and importance in the international network

Before phase I of the Mollison ISC was brought into service in October 1974, the Faraday and Wood Street ISCs had to carry all international traffic to and from the United Kingdom.

The total design capacity of these two CT1 "full facility" ISCs was then about 4,400 Erlangs. The term "full facility" is

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applied to any ISC offering all internationally agreed facilities.

By the end of 1974, International Subscriber Dialling (ISD) facilities were planned to be available for subscribers in 45 centres in the United Kingdom. At the same time approximately 65% of all international calls originating in the United Kingdom were directly dialled by the subscribers. By the end of 1979 ISD facilities will be available from most United Kingdom group switching centres (primary centres) generating international traffic of more than 0.25 Erlangs.

With the rapid increase of ISD, the traffic not requiring operator assistance is taking a bigger and bigger share of the total international telephone traffic. As a consequence there is a trend towards diverting the ISD traffic to big switching units handling automatic international traffic only. The Mollison ISC is such a unit and therefore operator assistance and transit facilities are not provided. It is termed a "limited facility" unit. Operators of distant administrations may dial through the unit provided no United Kingdom operator intervention is required.

The introduction of the Mollison ISC will affect the network functions of the Wood Street and Faraday ISCs. Much of the growth of ISD traffic will be diverted to the Mollison ISC and only traffic for which full facilities are essential will be connected to the UK ISCs offering such facilities.

The United Kingdom network

At present the United Kingdom national network is evolving from a 2-wire switched network based on fully interconnected zone-centres with subservient group-centres to a network based upon Group Switching Centres (GSC) interconnected via one or two links on a two-wire switched basis and backed by a 4-wire switched transit network for certain multilink traffic.

These changes follow from the introduction of Subscriber Trunk Dialling (STD) which also prepared the way for ISD by giving subscribers dialling access to distant centres via the trunk network. Each local exchange is connected to its GSC which is basically a two-wire switching unit. The GSC is linked to at least one secondary centre called a District Switching Centre

Fig. 1
The Mollison International Switching Centre equipped with crossbar switching system

(DSC) which is a 4-wire switching unit. In turn the DSC is connected to its Main Switching Centre (MSC), which has basically the same system design as the DSC, but is also fully connected to all other MSCs. The transmission standards are given in fig. 2. The Mollison ISC connexion to the basic network is shown in fig. 3.

The incoming and outgoing units

The network configurations of the incoming and outgoing units of the Mollison ISC are completely independent of each other. There are no bothway circuits of any description. No interconnection exists between the incoming and outgoing unit. The networks can therefore be described separately but there are a few facts common to both units which, in order to fully explain the network logic, will now be stated.

— Access on the international side has been limited to major traffic streams only. Initially this means access to European countries and four "intercontinental" destination countries. The European countries are France, Germany, Spain, Sweden, Norway, the Netherlands, Denmark, Italy, Belgium and Switzerland. There is also access to and from the USA, Canada, South Africa and Australia.

— As already stated there are no international assistance operator facilities provided. The units are primarily designed for calls directly dialled by subscribers or operators.

— No international automatic transit facilities are provided.

For the *incoming unit* the planned objective is to give access to all UK numbering groups. There are about 700 of these.

For the traffic terminal in London there are three basic modes of access. These are:

— via direct circuits using LD4 to exchanges within the central sector of London

— via sector switching centres serving the outer sectors of London. These routes employ AC11/MF2 as a general rule but DC3/MF2 is a possibility

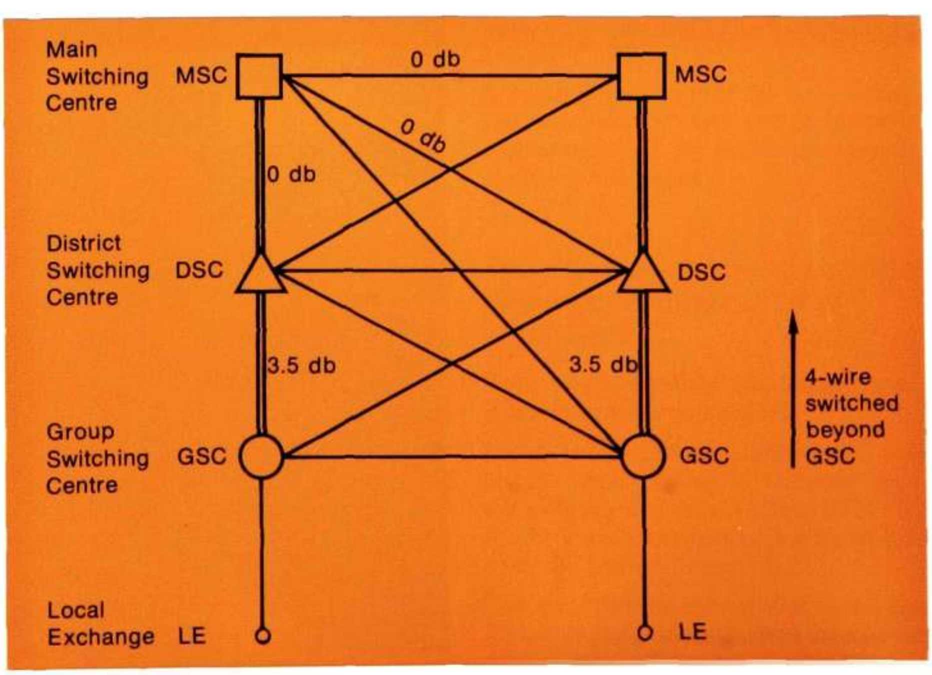


Fig. 2
UK transit network
Basic routes
Auxiliary routes

— via a trunk tandem exchange to which is connected all London exchanges. This will tend to be the second choice route and employs LD4 signalling techniques.

For the traffic terminal in the provinces, routes using AC11/MF2 are always specified and this policy permits direct routes (where traffic level justifies) to the group switching centres (primary centres) serving numbering groups. These routes may be high usage or fully provided. Alternatively, calls may be routed to terminal exchanges via the national transit network which comprises district (secondary) and main (tertiary) switching centres.

The international network will initially consist of CCITT 5 and CCITT 4 routes but already agreements have been reached to incorporate CCITT R2 into the circuit provisioning plans as well as augmenting the international network. Considerable re-configuration of the existing UK Post Office international network is also planned. Distant administrations have to "parcel" their traffic into the appropriate categories to ensure that the correct traffic facility is available at the incoming ISC in the UK. The planned network configuration for the incoming unit Phase I is given in fig. 4.

The *outgoing unit* is handling international subscriber-dialled traffic from the UK destined for countries with which the UK has major traffic streams (the same countries as listed for the incoming unit) originated in London and the provinces. The provision of outgoing ISD facilities at almost all of the UK group switching centres is planned. London and other major centres are already equipped and equipment provision programs for many cities and towns are in hand. All ISD traffic follows the same route as subscriber dialled national trunk traffic (STD) until the GSC is reached. At this point the destination country code is identified, the appropriate UK ISC selected and the process for call charging initiated.

ISD traffic originating in London will therefore be routed via London central switching units or via London sector switching centres. As with the incoming unit routes from central London units use LD4 signalling or sometimes DC3/MF2, routes from the outer sector switching centres in London use AC11/MF2.

ISD traffic from the provinces is routed via AC11/MF2 direct from GSCs or via the national transit network with the national transit network being the final choice in all cases. It may be useful to state that access to the major traffic streams is not confined to Mollison ISC and the trunking arrangements permit access to other UK ISCs for this class of traffic.

The network configuration for the outgoing unit is shown in fig. 5.

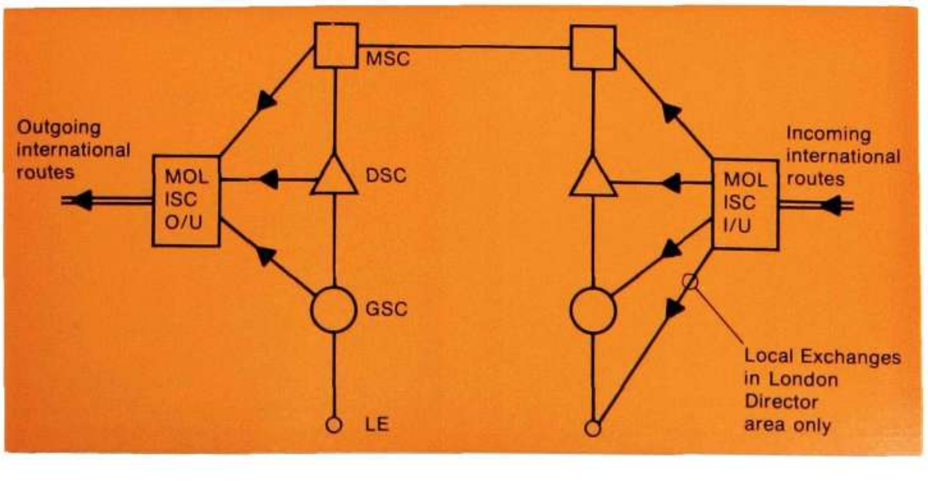


Fig. 3
Mollison ISC connexions to basic network

Linkup of Stag Lane ITSC with the national and international network

Stag Lane is located some 16 Km from central London. Since approx. 70% of all telephone traffic to and from the UK is terminated or originated within central London it is thus out of centre of the traffic density. To connect calls to and from London a large number of PCM systems are used to minimize cable needs.

To connect calls to and from the provinces HF systems are employed.

To interconnect the ISCs at Stag Lane with coast and earth stations, dedicated HF hypergroups are assigned for international services. The Stag Lane repeater station will be capable of providing terminations for about 17,000 international circuits which include all the international telephone circuits at Stag Lane plus in addition leased circuits and circuits for other special requirements. The ultimate line capacity for all purposes is expected to be provided by 70 hypergroups carried by 24 ×12 MHz line systems on 5 coaxial outlet cables and 550 24-channel PCM systems.

The LM Ericsson management of the project

Twelve departments in three LM Ericsson divisions, several United Kingdom subcontractors and Thorn-Ericsson, the LM Ericsson associated company in the United Kingdom, are involved in this project. A project manager with the overall technical and financial responsibility for the project was appointed. For each department a co-ordinator was appointed.

In the course of a project the management effort of the project leading team shifts between different areas. Whereas in the beginning most efforts have to be put into the design of the equipment specific for the project, the emphasis shifts at a later stage to monitor production, deliveries and installation activities.

To keep control of the project it was essential to establish one single communication channel between the project management at LM Ericsson and the counterpart at the Post Office. It was therefore agreed that all communication had to be channelled through those two project managers.

All meetings between representatives of the Post Office and LM Ericsson, even meetings of a purely technical nature, were attended by the Post Office and LM Ericsson project managers or their deputies since technical decisions cannot be made without considering the consequences on the time schedule and cost involved.

During the whole project the cooperation between all parties involved in both the Post Office and LM Ericsson has been excellent.

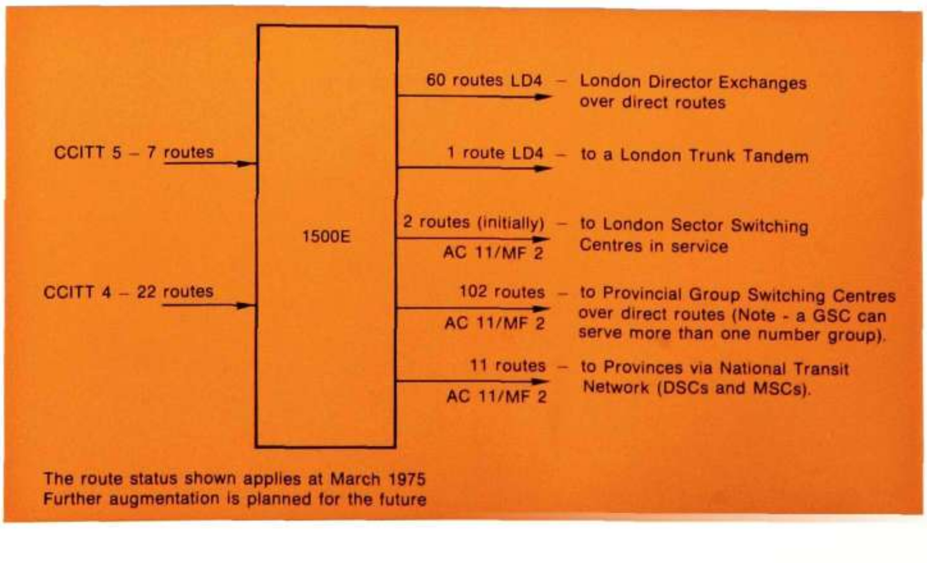


Fig. 4
Incoming unit phase 1. Outline network configuration

Not counting the project coordinators in the different LM Ericsson-departments, there were at the most 10 people involved in the project management team during the project.

Project schedule

A major project can be divided into several partly overlapping phases, each one of them important for acheiving overall success, but some more critical and vital than others:

- collection of information for design;
- design of floor plan lay-out;
- design of equipment specific for the project;
- verification of design;
- manufacture of equipment;
- production of installation documentation;
- installation and testing;
- final acceptance test.

Collection of information for design

For Mollison a very detailed specification of requirements of about 500 pages, which accompanied the Post Office tender specification, was the starting point upon which the design could be based. However, during the initial stages of the project numerous discussions were necessary between representatives of the Post Office and LM Ericsson to define details of the design. Due to the excellent assistance given by the Post Office engineering staff, the goal to have all detailed design specifications ready four months after order was achieved well ahead of schedule.

Design of floor plan lay-out

The final capacity and the phase in which the exchanges were to be extended from the initial capacity were known from the beginning of the project. This almost unique opportunity made it possible to give much consideration to minimizing the disturbances in traffic when extending the exchange and at the same time to optimize the floor lay-out from the maintenance point of view.

It was agreed between the Post Office and LM Ericsson that as far as possible all suites belonging to phase I should be fully installed to reduce extension work which would have to be done in a suite carrying traffic.

The equipment installed for phase I was confined to areas which in practice could be screened off, so as to prevent installation staff during installation of phase II and III interfering with equipment already in service.

To prevent congestion in the cable troughings, computer calculations of the main cable runways were made before the floor lay-out was presented to the Post Office for approval. At the same time calculations were made to define the average transmission loss and its distribution in the exchange.

Verification of design

The success of any project but particularly a project of the size of Mollison depends very much on designs being correct and that no, or very few,

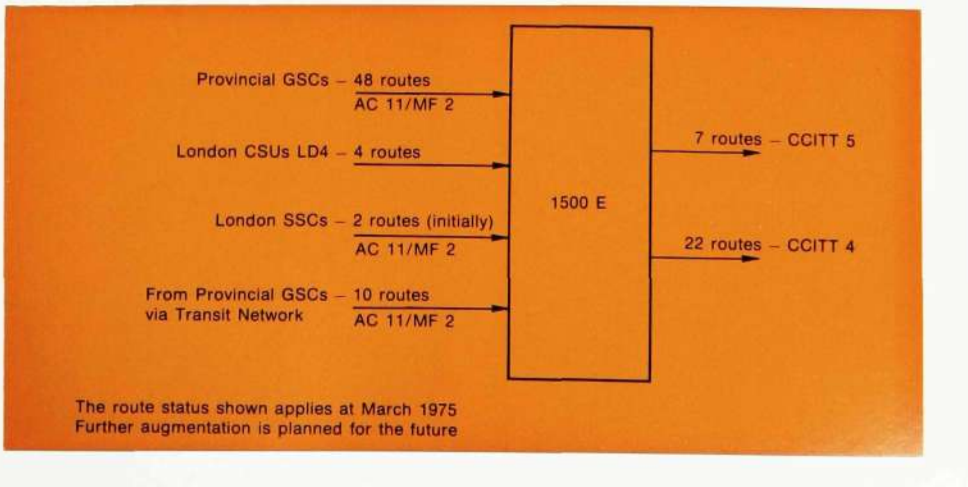


Fig. 5
Outgoing unit phase 1. Outline network configuration

modifications are carried out on the site. Therefore it was decided at a very early stage that a specially-assembled test model should be built to test the compatibility of the new designs with the UK network. It was not considered necessary to make similar compatibility tests with the international network since the design of the equipment for the international signalling systems employed was well known to LM Ericsson and proven in other markets. The model exchange consisted of five racks and contained factory-manufactured prototypes of all equipment necessary to interwork with the UK national network. The trunking diagram for the model exchange is shown in fig. 7.

Prior to and parallel with the compatibility tests at the model exchange in London, extensive laboratory tests and desk tests as well as subsystem tests were carried out at the LM Ericsson laboratories in Stockholm. Post Office engineers were actively involved particularly in the desk and the compatibility tests.

It should be noted that for the design test in the model exchange in London, only the quantity of equipment needed for the test model was at first ordered from the factory. This equipment was manufactured and factory-tested on line in LM Ericsson's production units in accordance with normal production routines.

The production of the equipment to be installed at Mollison was not ordered from the factory until the results of all tests were available and any necessary modifications had been made to the design and the production documentation.

Even though compatibility tests in a model exchange are by no means a guarantee that no faults in design will be detected later on, it is certainly an assurance for the project management that the design has been debugged to the largest possible extent and that the production documentation is correct.

The end result in the Mollison project was excellent. The modifications that had to be carried out on site before the equipment went into service were negligible.

Manufacture of equipment

Because of LM Ericsson equipment practice, in which practically all relay sets are fitted with plug-in units, the equipment can be manufactured in three phases:

Fig. 6
Intermediate distribution frame

1. iron and cable
2. racks
3. relay sets.

Iron, cable and racks are less dependent on the detailed project design and therefore to a large extent manufacturing can be carried out well in advance of the relay sets. The relay sets on the other hand are not needed on site until the start of the testing activities.

Production of installation documentation

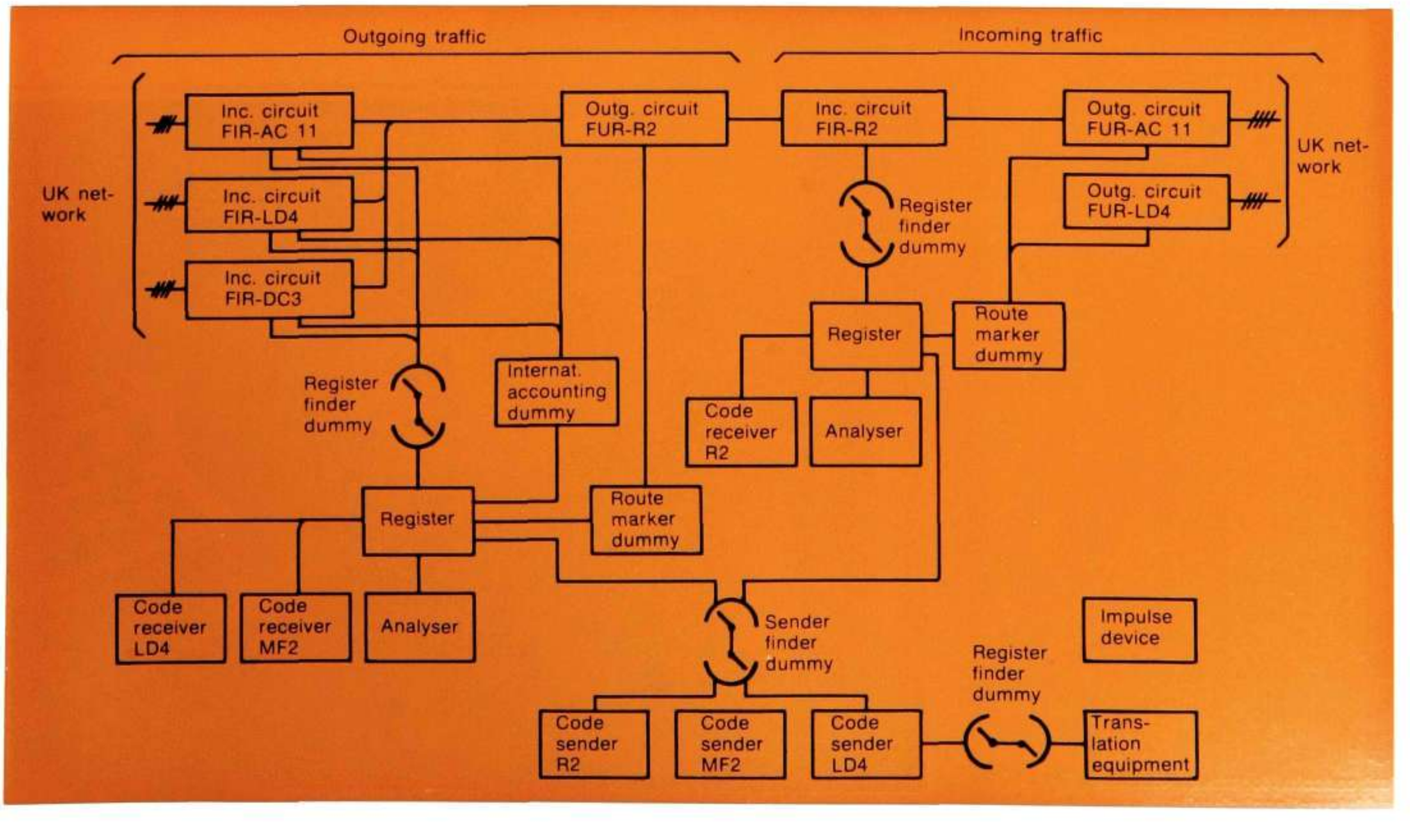
For this project more than 30,000 pages of installation documents were produced, two-thirds of which were produced with the aid of computers. Cable running list for 110,400 cables were automatically printed out. The cable length was calculated to be 2,875 km. Interconnection and grading documentation for approximately 4,300 racks was made up.

To minimize disturbances when extending the exchange, the group selector links were dimensioned from the beginning for ultimate traffic. No rearrangement will be necessary when extending the exchange. Register and code sender groups were graded for the contracted maximum size but equipped for the initial capacity only. This means of course that in the initial phase the grading design is not optimal and to compensate more equipment has to be provided initially. This slight disadvantage is more than offset by the reduction in disturbance of traffic flow during extension, an important factor very relevant to international networks.

Installation and testing

Most of the installation staff was locally employed for this contract. All the locally-employed staff had to be trained, as Mollison was the first public crossbar telephone exchange of LM Ericsson design installed in the UK. Each member of the installation staff had to go through a two-week intensive course at the locally-established training school before he or she was employed in actual installation work. This was necessary to achieve the high standard of installation set by LM Ericsson.

Fig. 7
Trunking diagram. Test model for Mollison project



The locally-employed testers were trained partly at the LM Ericsson international training centre in Stockholm and partly on site in London.

Final acceptance test

Procedures for the final acceptance test were agreed upon well in advance between representatives from the Post Office and LM Ericsson.

During the installation and testing of the exchange PO staff was continuously monitoring all the LM Ericsson activities.

Additionally the PO staff assigned to maintenance duties were actively involved in the functional testing of the exchange and thereby more able to familiarize themselves with equipment and documentation.

Prior to the start of the final acceptance test the PO staff had been satisfied that all the functional and compatibility tests had been carried out in accordance with LM Ericsson test instructions.

The final acceptance test, which was carried out jointly with the PO, has therefore to be seen as a final confirmation of the switching performance of the exchange.

During the final acceptance test for phase I about 270,000 calls were made through the switch blocks.

Technical characteristics of the Mollison ISC

The ARM 20 system, the register organization ANA 12 as well as the LM Ericsson design of the IMC have been described in previous LM Ericsson publications[1—7]. Therefore these designs will not be gone into in any great detail in this chapter.

THE SWITCHING SYSTEM

The switching systems for the two exchange units (incoming and outgoing) are completely separated. For simplified diagrams see fig. 9.

Both are of the ARM 20 crossbar type. The incoming unit has a 5-wire switching matrix whereas the outgoing unit has a 10-wire switching matrix.

Full availability exists from all 8,000 inlets to all 8,000 outlets within a unit.

Fig. 8
Test consoles for measurements of the national and international circuits

The control and supervision of switching through the exchange is vested in the route markers and markers which are called upon by a register as soon as sufficient digital information concerning the routing of the call has been received and stored. The register subsystem employed at Mollison is of the ANA 12 type.

Several different register signalling methods in the transmission and in the reception paths can be used from one and the same register.

The flexibility of the ANA 12 register subsystem is such that in Mollison only one type of register is used, i.e. the hardware is the same independent of whether the register is in the register group for signalling system CCITT No. 4 or any other register group. Only the "programming" of the registers as well as the code senders and receivers connected to it differ, depending on in which group it is employed.

REGISTER SIGNALLING AND SIGNALLING SYSTEMS

Five register signalling systems are used to meet the interface requirements of the exchange. Of these, three are international, CCITT No. 4, 5 and R2, and two national, LD4 and MF2.

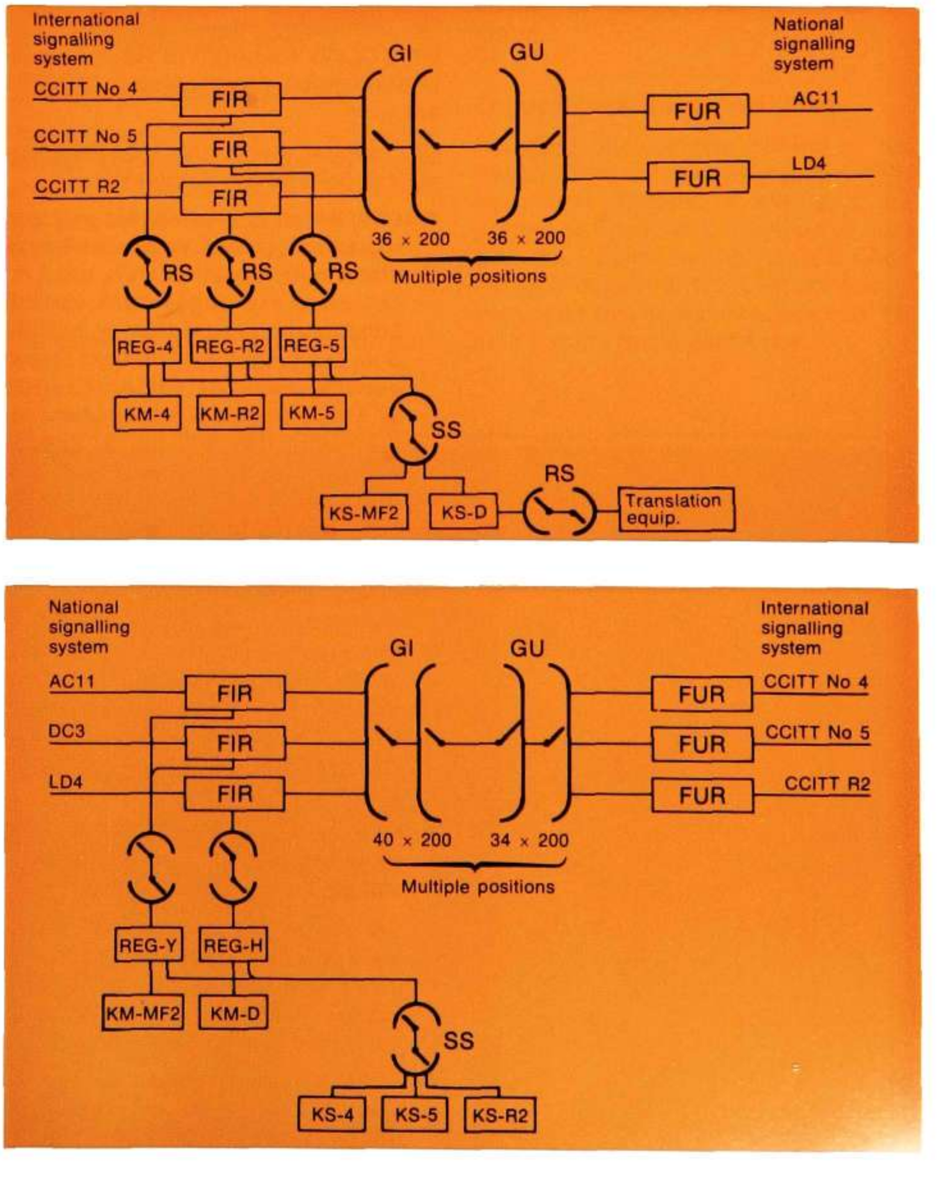


Fig. 9
Incoming unit (top) and outgoing unit. Simplified trunking diagrams

Each incoming and outgoing circuits is terminated on a line relay set (FIR or FUR) adapted to the particular signalling system used on the route. The incoming line relay sets are via register finders (RS) connected to a register group (REG) serving one or more signalling systems.

As shown in the trunking diagram in fig. 9 each register can connect itself to to the appropriate code sender (KS) for signalling on the forward transmission path.

The *international routes* to and from Mollison ISC can be divided into those serving European countries (continental) and those serving other parts of the world (intercontinental).

On continental routes signalling systems CCITT 4 and CCITT R2 and on intercontinental routes system CCITT 5 are used.

On *national routes* the following signalling systems are employed:

- LD4, which is a combined line and register signalling system with loop disconnect signalling. It is used on circuits to exchanges within central London and to and from trunk tandem exchanges serving the London director area. The circuit is seized by a loop phantom arrangement on the 4-wire line and digital signals are received by the register or sent to the line in loop disconnect pulses at the rate of ten per second.
- DC3 is a 4-wire phantom line signalling system used from London Group Switching Centres (GSC). It has a limited number of signals and is designed for use with the MF2 register signalling system. When used, it will be as an alternative to LD4, serving the London director area.
- MF2 is a multifrequency register signalling system. In this system signals are sent in 2 out of 6.

  On seizure of the register, backward guard is sent until a forward guard is received, and then there follows a compelled sequence of backward and forward signals.
- AC11 is a line signalling system used to and from the provincial transit network. The system uses 1-VF 2280 Hz line signals but digital and interregister signals are sent in the MF2 code.

The International Maintenance Centre (IMC)

The Mollison IMC consists of an International Transmission Maintenance Centre (ITMC) and an International Switching Maintenance Centre (ISMC).

International Transmission Maintenance Centre (ITMC)

The main function of the ITMC consists of circuit testing and fault reporting. The following equipment has been provided for the ITMC:

Supervision Consoles

On the supervision consoles an indication is given when a fault occurs on a circuit and the type of fault is identified.

Test Jack Frames (TJF)

All circuits are connected via the TJF to the line relay sets in the exchange. Circuits are easily accessible for maintenance purposes.

Access Selector (AS)

The AS, which has been specially designed for this project, gives automatic access from the test consoles in the ITMC to all line relay sets in the exchange. Three different access points can be selected for each circuit, i.e. line access, circuit access and parallel acess. The AS is also accessible from the automatic transmission measuring equipment (ATME 2).

The access selector is mainly used for:

— transmission measurement from test consoles
— functional tests of echo suppressors
— monitoring of circuits
— checking whether the line relay set is occupied or blocked
— recording of line signals
— blocking of circuits.

Test Consoles (TC)

Each of the 24 test consoles is provided with two control panels and two instrument panels. They are used for manual and semi-automatic measurements and tests of the national and international circuits connected to the exchange. Testing can also be performed with the aid of an automatic exchange tester connected to the test consoles. For automatic line access the access selector is used. A number of PABX circuits, omnibus circuits and international service circuits are connected to each test console.

International Switching Maintenance Centre (ISMC)

All common control equipment and the switch blocks are supervised in the ISMC. The following equipment has been provided for the ISMC:

Central Alarm Equipment (CLU)

The CLU signals visibly and audibly abnormal conditions in the exchange which are differentiated in three levels. Blocking of devices and circuits are signalled as supervisory alarms.

Service Alarm (DL)

The service quality of all common control equipment e.g. markers, group markers, registers and code senders is automatically supervised by the service alarm equipment. The supervision is carried out by comparing the number of occupations with the number of forced releases in each group of device. If the present permitted fault level is exceeded, alarm is given in the supervisory console of the ISMC.

Route Alarm (VL)

Each route is supervised and an alarm is given if the number of blocked circuits within the route surpasses a preset level. The alarm is signalled to CLU. Alarm is furthermore given in the observation console where it is also indicated which route has generated the alarm.

Centralograph Equipment (CPH)

Faults in the common control of the switch block are recorded on the CPH equipment. Details of the fault are printed out indicating the type of fault and the equipment connected when the fault occurred. The CPH printout is then used by the maintenance staff for fault tracing in the exchange.

Fig. 10
Installation work

AUXILIARY EQUIPMENT PROVIDED FOR THE PROJECT

Traffic Measuring Equipment

One electronic traffic measuring device of type MET2 has been provided for each unit. For a more detailed description of MET2, see the article in Ericsson Review No. 3, 1972[8].

Service Observation Equipment (SOE)

The service observation equipment which is connected to the incoming line relay sets is intended for supervision of live traffic. In the SOE register and line signals appearing during the setting up of a call are recorded. This information is displayed on the panel in the SOE. In the SOE the address digits are analysed so that, if desired, traffic to certain countries only can be supervised. The SOE is considered to be a very useful tool for statistical purposes.

POWER SUPPLIES

The exchange power plant provided for Mollison is of the LM Ericsson system BZB with an installed capacity of 8,800 A and a normal operating voltage of 48 V DC. Separate plants built up of the following main equipment units are provided for the outgoing and incoming units respectively.

- thyristor rectifiers
- control rack cabinet
- distribution rack cabinet
- battery rack cabinets.

The batteries are built up of high performance enclosed planté cells.

Cables are used to distribute the power from the power room to the switching equipment on the apparatus floor. For a more detailed description of the power supply system see Ericsson Review No. 4, 1968[9].

The computer part of the international accounting equipment is provided with an LM Ericsson no-break power supply consisting of solid-state single and three-phase inverters that are fed from the 48 V DC exchange power plant. The single-phase inverter is provided with a solid-state switch for uninterrupted changeover to the main supply.

INTERNATIONAL ACCOUNTING EQUIPMENT (AVR)

The international accounting equipment keeps record of the accumulated effective call duration time for all international traffic outgoing from the Mollison unit. This record is used for accounting purpose between administrations. The accounting is carried out separately for each route destination.

A route destination (R-D) is defined as the combination of the outgoing international route and the destination country. During the setting up of a call, all information about the R-D is available in the register organization of the ARM 20.

The answer signal (B-answer) and the clear-forward signal which are necessary to determine the effective call duration time are available in the incoming line relay set (FIR) in the outgoing unit. Therefore the accounting equipment has interface both to the register organization and to the incoming line relay sets.

The accounting system used at Mollison is designed to serve simultaneously a maximum of 8,000 incoming circuits and 198 route destinations. The number of outgoing circuits is not relevant. By scanning all incoming line relay sets at appropriate intervals the specified accounting accuracy is achieved.

Hardware system

The hardware of the accounting system comprises 3 main parts:

The switching equipment which consists of the accounting circuits in the exchange including switch matrixes common to groups of 1,000 incoming line relay sets and 198 R-D outlets.

The interface equipment which is physically located in the switching room. It consists basically of pulse generator and receiver units. Built in check-functions are continuously monitoring the interface equipment.

The computer equipment which is located in a computer room. It consists of 2 identical LM Ericsson UAC 1610 computer systems and two magnetic tape units.

A switch unit is provided by which any of the two or both magnetic tape units can be connected to the active computer, which handles the accounting. A panel facilitates monitoring of computer operation and manual switchover.

Software system

The software comprises 3 functional parts:

The on-line realtime system of the computer analyses all 8,000 incoming circuits. Scanning is performed at appropriate intervals. Information will then be stored on counters in a core store for one calender month in number of call periods to each route destination and divided in 3 different tariffs depending on the time of the day. (See fig. 11 for principles of scanning.) At the the end of the month the information will be recorded on magnetic tape and the information on the counters erased.

In addition for security reasons the information on the tariff counter is dumped daily to magnetic tape.

During normal operation the computer will perform routine checks of the equipment and maintain alarm frequency counters.

If the preset error limit should be exceeded, an alarm is given to the central alarm system in the exchange. Error printout can be obtained.

The service system handles all printouts, changes of route destinations, tariff pattern and various system constants.

All service functions normally need intervention at the computer console, typewriter or paper reader.

The maintenance system provides facilities for normal testing of the accounting function in all incoming line relay sets.

Reliability

To provide a high degree of reliability, the computer system is duplicated. One computer system is active and the other normally functions as passive

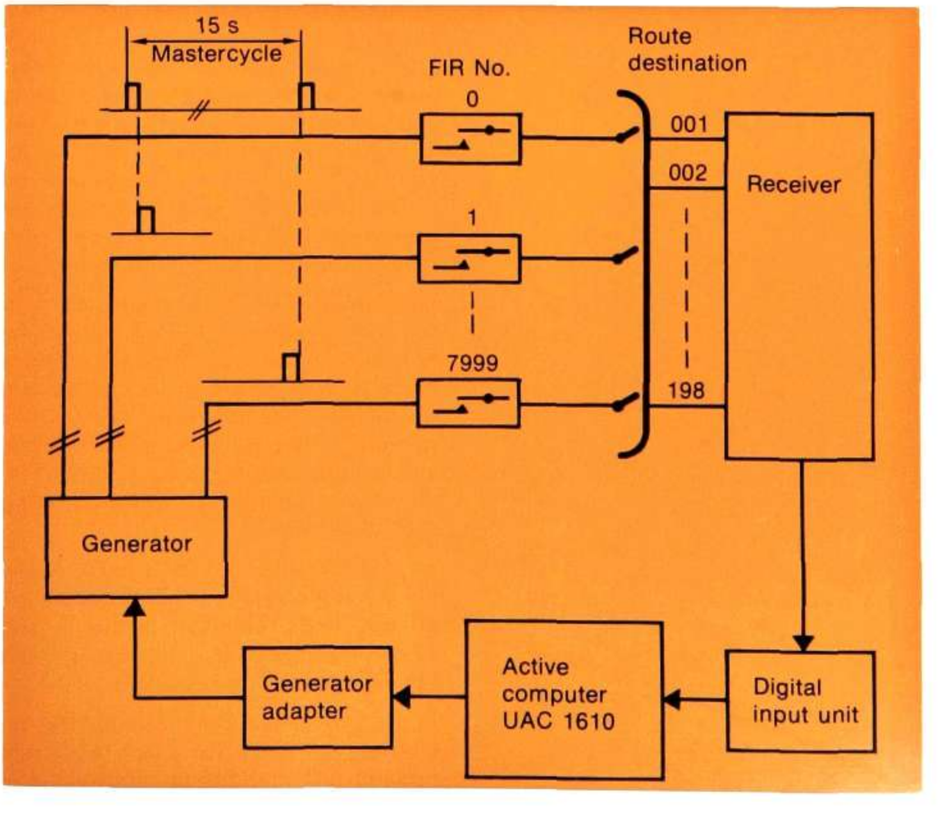


Fig. 11
Scanning principle for accounting equipment

stand-by. Both computers run a program for testing the hardware.

If, because of a defect in the active system, switchover is carried out, the interface equipment is switched to the stand-by computer which will be made active and perform the accounting.

Monthly processing of the record is done in an off line computer. This record consists of day-by-day accumulated data, recorded identically on the two magnetic tapes of which any can be used for processing. Normally the accumulated total for the month is read from the tape. If, however, switchover to the stand-by computer has occurred during the actual calender month the subtotals from both computers are added to obtain a monthly total for each accounting subject.

Conclusions

Phase I of the Mollison International Switching Centre which forms part of the Stag Lane International Telephone Service Centre situated 16 km from central London was successfully brought into service in October 1974.

In accordance with the Post Office planning strategy the exchange caters primarily for international subscriber dialled telephone traffic originating and terminating in the United Kingdom. At the end of 1974 approx. 65% of all international telephone calls originated in the United Kingdom were directly dialled by the subscribers and this class of tariff is rapidly increasing.

The introduction of Mollison ISC into the network affects the network function of the two existing ISCs since much of the growth in ISD traffic will be diverted via Mollison. Only traffic for which full facilities are essential will be directed to United Kingdom International Switching Centres offering such facilities.

With 25,000 ARM crossbar multiple positions, equivalent to 150,000 local exchange lines, Mollison is the largest single international exchange project LM Ericsson has undertaken.

In the contracted final capacity the exchange will comprise 4,300 racks and provide terminations for approximately 23,000 national and international telephone circuits.

A large international maintenance centre to supervise the performance of the transmission network and the switching equipment has been provided.

The success of this public crossbar exchange project — the first for LM Ericsson in the United Kingdom — has been a result of the joint effort of all those involved both within the United Kingdom Post Office and LM Ericsson.

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Long Distance Traffic in Mexico

Sune Lindblad and Bengt Johansson

The article deals with the development of the Mexican long distance traffic (LD), the network for which is to more than 80 % built up with LM Ericsson transit exchanges ARM 20, ARM 50 and AKE 13. These systems have been described earlier[1, 2], so that the emphasis in this article is laid on the development of the LD network and the adaptation of the exchanges to the conditions existing in Mexico.

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Mexico is a country with an ancient civilization with many relics from the Pre-Columbian epoch and from the Spanish colonial period. Since the beginning of the century the country has undergone a rapid development on all fronts.

A map of the country is shown in fig. 1. Mexico covers an area of about a quarter of that covered by the USA. Practically the whole of the country consists of a high plateau in which certain areas are devoted to large scale agriculture. Fruit, coffee and cocoa are also grown on the eastern and western coastal slopes. The population today is just over 50 million inhabitants.

A rapid industrialization has taken place. Mining, iron and steel works and the extraction of oil are some examples of today's multifarious industry. A vigorous workshop industry has also developed. For example, there are a number of car manufactury factories and the telecommunication factory Teleindustria Ericsson, S.A., which is partly owned by LM Ericsson.

In the heart of the country lies the capital city Mexico D.F. or Mexico City, the cultural and industrial centre of the country with 9.2 million inhabitants. Other important centres are the industrial towns of Guadalajara, Monterrey, Puebla and Veracruz.

In 1926 LM Ericsson's Mexican subsidiary company, Empresa de Teléfonos Ericsson, S.A., obtained a concession for the operation of the national and international trunk traffic in Mexico, a concession that the company retained and exploited until 1948. The operation of all telephone traffic was taken over by a company formed for the purpose, Teléfonos de México, S.A., in which LM Ericsson was one of the interested parties. In 1958 the company passed over completely to Mexican ownership.

Fig. 1
Map of Mexico

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Development of the telephone traffic

Mexico has a long telephone history. As long ago as 1883 the first international telephone call was exchanged between Mexico and Texas, USA. This was a manually connected call between the border towns of Tamaulipas and Brownsville, a distance of 3.5 km. Thus Mexico came into the picture very early on as regards international telephone connections. A brief resumé of developments since then is given below.

In 1914 manual traffic with Washington was introduced, and in 1927 with London and Canada. All LD traffic was handled manually until 1959, when the first ARM 20 exchange was taken into service in Puebla. ARM traffic was initially semi-automatic, but with the introduction of Toll Ticketing in 1965 the national traffic was gradually fully automatized. The LD network has been expanded very rapidly — 19% per year during the last five-year period. In 1970 fully automatic traffic, via an ARM 20 exchange in Toluca, was introduced with USA—CANADA, which constitutes a common automatization area. This was an extremely advanced and early step, since the traffic with Canada and the USA constitutes about 90% of the total Mexican international traffic.

A total of 21 ARM exchanges and one AKE 13 exchange, with together 65,680 multiple positions, have been in service since January 1st, 1975.

Network structure

The structure of the Mexican telephone network is shown in principle in figs. 2 and 3. The exchanges in the network are divided up into the following main types:

(1) Local exchanges OT, for a total of just over two million subscribers
(2) Primary centres, CZ, about 220
(3) Secondary centres, CA, about 60
(4) Tertiary centres, CR, a total of 15, of which three also handle international traffic to USA—CANADA
(5) The national centre, CN, in Mexico City

The long distance network is to a great extent built up of carrier systems over radio links or physical lines. The total number of channel kilometres now amounts to about 5,700,000 km.

When extending the telephone network, one of the most important goals, even during the semi-automatic phase, was to eliminate waiting times but nevertheless maintain good utilization. Today Mexico has a network with well developed alternative routing, full availability in the transit exchanges and limited single operator working, which has made it possible to eliminate waiting times in an economic way while maintaining good line utilization.

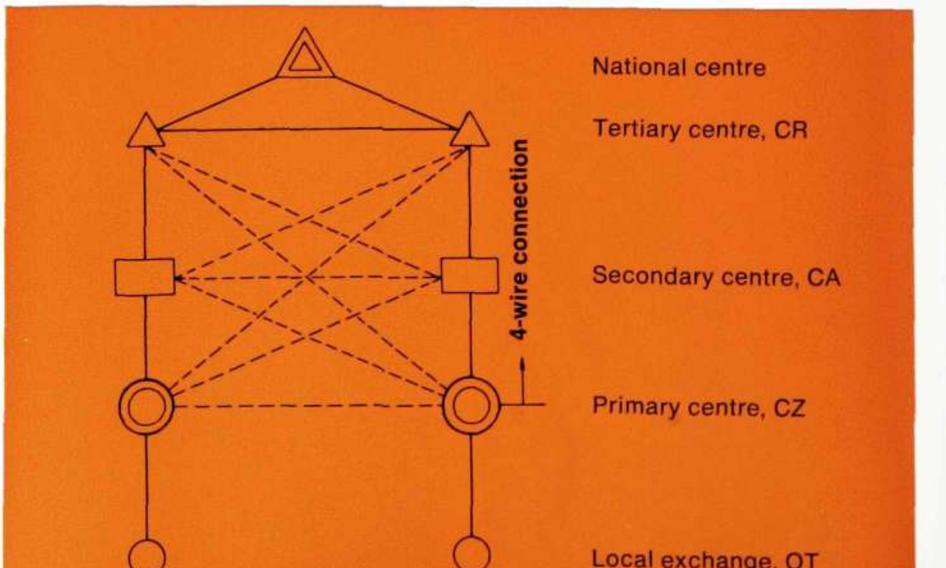


Fig. 2
Network structure in Mexico
——— Low-usage routes
– – – – – Normally high-usage routes

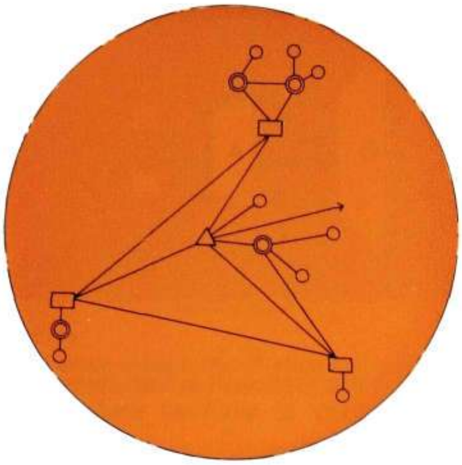


Fig. 3
Network structure within a tertiary area

- △ Tertiary centres CR, connected to each others and also to certain secondary centres in other regions
- ▭ Secondary centres CA, also connected to certain tertiary and secondary centres in other regions
- ◎ Primary centres CZ
- ○ Local exchanges OT

Transit exchanges ARM 20 and ARM 50

ARM exchanges handle national traffic, ARM 20 being used at all levels and ARM 50 only as primary centres in small primary groups. Three ARM 20 exchanges also handle international traffic to USA—Canada.

The ARM exchanges interwork with several types of LM Ericsson and ITT urban and rural exchanges and also with transit exchanges of ITT type PC-1000 and LM Ericsson type AKE 13 (SPC).

MFC signalling is mainly used for interworking with the local exchanges. When interworking with older types of local exchanges of both LM Ericsson and ITT design with other signalling systems, the conversion to MFC is normally arranged at the local exchange.

All automatic national LD traffic and all international traffic is charged on the basis of specified call information. Consequently the ARM exchanges are equipped with fully automatic, centralized toll ticketing equipment.

Stored Program Controlled transit exchange AKE 13

In the capital, Mexico City, the need for transit exchange equipment increases very rapidly and this makes great demands on the final capacity of the exchanges. It is for this reason that the Administration ordered an SPC exchange AKE 13. This exchange, the trunking diagram for which is shown in fig. 4, was connected in at San Juan, Mexico City, in 1973 and was the first SPC exchange to be brought into service in Latin America. Together with two existing ARM exchanges it constitutes the national centre in Mexico City and has lines to North, Central and South America and satellite connection with Europe and Japan. At present the SPC exchange contains 3,600 in-

Fig. 4
Trunking diagram for the AKE 13 exchange in San Juan

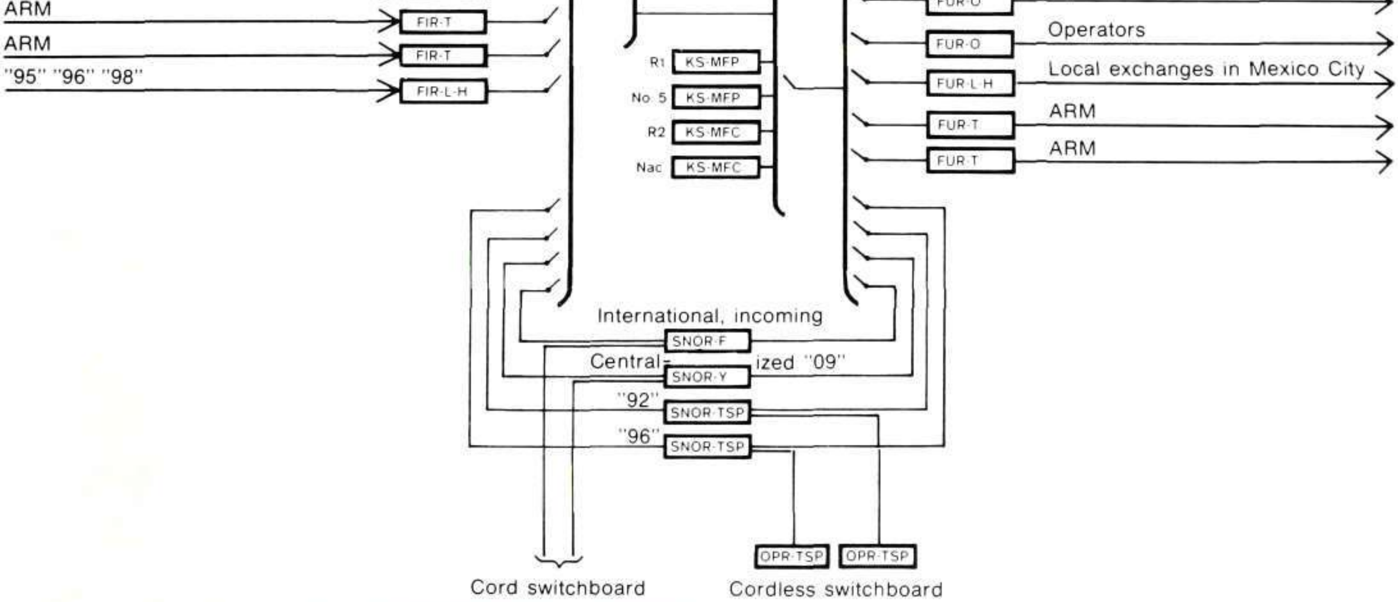
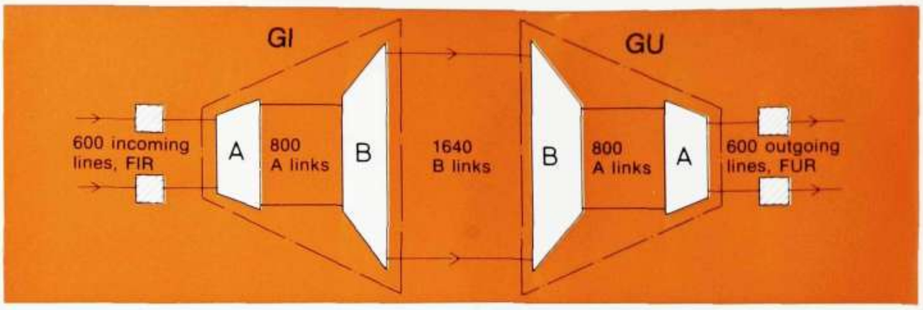


Fig. 6
Switching stages GI and GU interconnected by 1,640 B links



coming and 4,200 outgoing multiple positions and two duplicated processors which operate in a multiprocessor arrangement.

To a great extent it is on the administrative plane, especially as regards operation and maintenance functions, that AKE 13 offers a series of new and valuable facilities. Above all these consist of an automatization and centralization of the operation and maintenance functions and an effective supervision of the telephone plant and the associated network, for maintaining a thoroughly good service and transmission quality. For this purpose there is a control room with input and output devices for providing efficient communication between the operating and maintenance staff and the AKE equipment, in the form of electric typewriters, tape reader, tape punch and magnetic tape units, fig. 5.

The switching stages are one-way and are built up of partial stages for incoming traffic GI and outgoing traffic GU, which are interconnected with B links, fig. 6. Each partial stage has 600 inputs, 800 A links and 1,640 B links. The selector stage is dimensioned for high input load with a high degree of insensitivity to overload and uneven loading.

MFC signalling and CCITT signalling systems No. 5, R1 and R2 are all used in the exchange. One of the advantages of AKE 13 is that other signalling systems can easily be included if necessary.

As Toll Ticketing is used, the exchange is equipped with magnetic tape units for storing the required call charging information. Automatic transmission measuring equipment is also being introduced.

Long distance traffic in Mexico City

Mexico City constitutes the central point for the LD traffic. Owing to the size and geographical extent of the city, with about 85 local exchanges, the handling of the LD traffic has been divided up among several exchanges. The traffic routing applied provides good line utilization.

Mexico City has the following (1—8) exchange systems and other LD equip-

Fig. 5
Control room in San Juan with typewriter, for communication between service staff and the plant, and the control panel for the processors

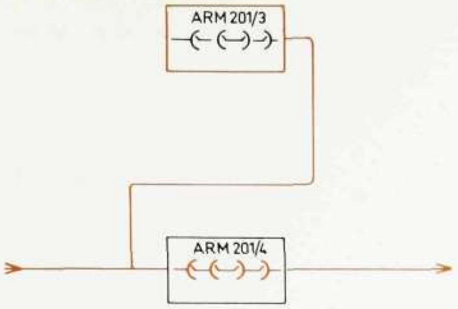


Fig. 7 a
Distribution of the traffic via expansion stage ARM 201/4 to the local exchanges in Mexico City

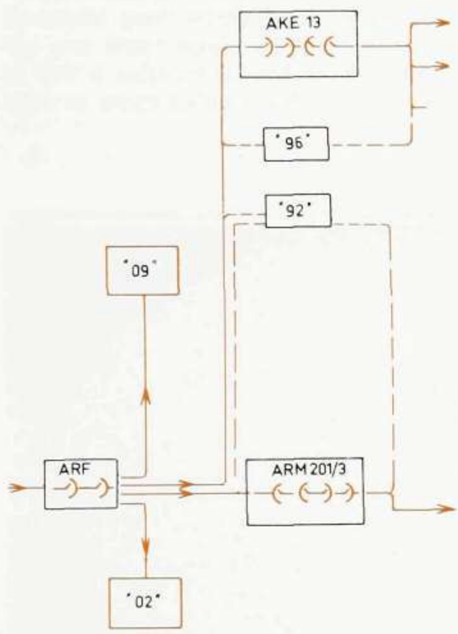


Fig. 7 b
Distribution of the traffic from the AGF exchanges and a number of ARF exchanges via distribution stage ARF

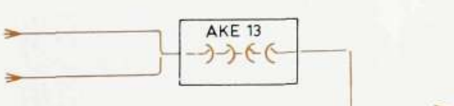


Fig. 7 c
Terminating national and international traffic from AKE 13 is distributed over direct routes to each local exchange

ment, see fig. 7. The equipment is installed in two buildings, the AKE 13 with the associated operator equipment in San Juan, fig. 8, and all other equipment in Victoria. The buildings are situated in the centre of the city at a distance of 1 km from each other.

(1) Transit exchange AKE 13 serves completely or partly a successively increasing number of national routes, and all international routes to and from North, Central and South America, Europe and Japan. There are also direct routes to all the local exchanges in Mexico City.
(2) Transit exchange ARM 201/3 serves completely or partly a certain number of national routes.
(3) Expansion stage ARM 201/4 serves terminating high-usage routes from the national network and also a route from transit stage ARM 201/3. The traffic is distributed via the expansion stage over outgoing direct routes to the approximately 85 local exchanges in the city, see fig. 7a.
(4) Distribution stage ARF, for the distribution of the outgoing traffic from AGF exchanges and a number of ARF exchanges in Mexico City. This unit distributes national traffic to ARM 201/3 and national and international traffic to AKE 13. In addition, telephone operator services (92 and 96) are requested and national (02) and international (69) positions are called via this distribution stage. The remaining exchanges in the city are directly connected to the AKE 13 unit without a distribution stage, see fig. 7b.
(5) Traffic service positions NAT-TSP "92". For automatic national calls these positions provide assistance in connection with personal calls and the reversing of call charges.
(6) Traffic service positions INT-TSP "96" provide the same service as in (5) but for automatic international calls to USA—Canada.
(7) Manual positions "02" for ordering and setting up national calls, primarily delay traffic and traffic to manual exchanges.

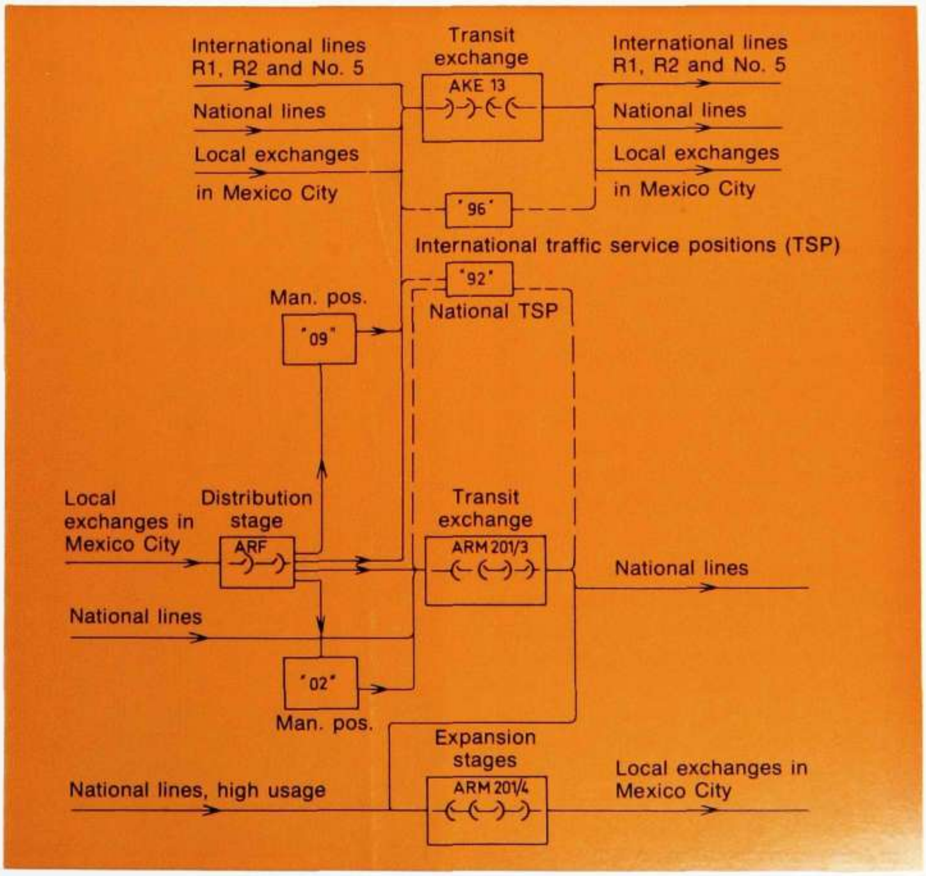


Fig. 7
The distribution, in principle, of the LD traffic in San Juan and Mexico City

(8) Manual positions "09" for ordering and setting up international calls.

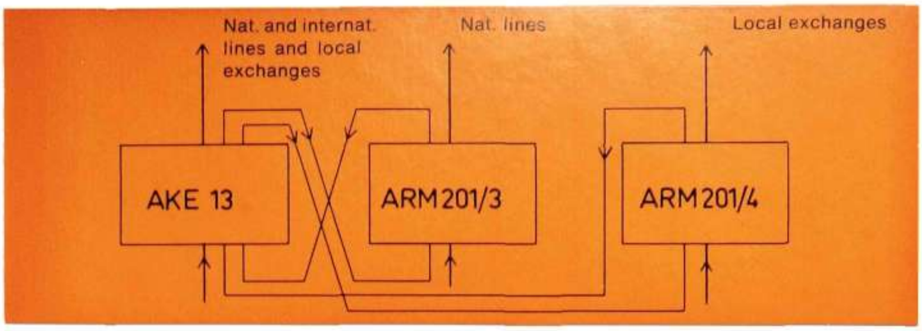
Terminating traffic from AKE 13 is distributed over outgoing direct routes to each local exchange in Mexico City, fig. 7c, in a corresponding way to that from the expansion stage ARM 201/4, see (3).

Overflow routes have been included between the stages in order to increase the utilization on both the national LD lines and the direct routes to the local exchanges, see fig. 9. Thus there are routes in both directions between AKE 13 and ARM 201/3. If, for example, all lines on a route are engaged in one of the stages, rerouting takes place via the overflow route to the other stages, where a search is made for a free line on the wanted route.

Alternative routing is also applied in order to achieve the best possible utilization of the national lines. When all lines on a high usage route are engaged, as a first alternative a line is selected on the wanted route to AKE 13.

Fig. 8
San Juan exchange in Mexico City

Fig. 9
Overflow routes between different stages



Long distance traffic in the rest of the country

The automatized local exchanges in the rest of the country are connected to transit exchanges, system ARM, or in some cases to another system for fully automatic LD traffic.

The LD network is so designed that subscribers connected to manual exchanges are also able to get the full benefit of automatization. Thus telephone operators at a place with manual operation are connected to the nearest automatic transit exchange, and with a push-button set they can connect in to the whole of the automatic network. An incoming LD call to a manual local exchange is also connected up automatically to the operator in that exchange, who then connects up the call to the wanted subscriber.

International traffic

There are four international exchanges in Mexico. Three of these are ARM 20 exchanges, which are installed in Monterrey, Chihuahua and Hermosillo. They are used only for automatic traffic with USA—Canada and are designated CT3 exchanges, in accordance with CCITT nomenclature. The fourth, the AKE 13 exchange at San Juan, which has already been discussed, handles the traffic with the whole world and is called a CT2 exchange. All four exchanges have international ordering and traffic service positions, but all other international operator services are centralized in the exchange at San Juan (fig. 8).

Numbering

Four to seven digits are used in Mexico for the subscriber numbers. These numbers are used alone when calling subscribers in the same numbering area, which usually coincides with the primary group.

When calling a subscriber not in the same numbering area there is always an additional trunk code, which consists of one to four digits. The numbering scheme is arranged so that the national or significant number, which is the combination of the subscriber number and the trunk code, always contains eight digits.

Trunk code	*Subscriber number*
A	BCDEFGH
AB	CDEFGH
ABC	DEFGH
ABCD	EFGH

Apart from these numbers there is an additional two-digit trunk prefix, so that altogether a subscriber has to dial ten digits. The first digit of the prefix is always 9, but the second digit, the traffic class digit, varies according to the traffic case. In this connection the prefix also differentiates between traffic cases for international and national traffic as is shown in the following list.

Trunk prefix	*Traffic case*
91	Fully automatic national traffic without TSP service
92	Ditto with TSP service
93	Spare
94	Spare
95	International traffic to USA—Canada without TSP service
96	Ditto with TSP service
97	Spare
98	International traffic to the rest of the world without TSP service
99	Spare
90	Spare

For traffic routing technical reasons the traffic class digit has been used to separate the traffic to USA—Canada from the traffic to the rest of the world. As has been mentioned before, the traffic to these two countries constitutes 90% of the total international traffic. The traffic with the rest of the world, on the other hand, is handled only by the AKE exchange in Mexico City.

The international number for traffic towards USA—Canada does not include a country code, since this traffic direction has been separated from the traffic to the rest of the world by a traffic class digit in accordance with the above list. When calling USA—Canada a subscriber dials 12 digits, two as the trunk prefix, three as the numbering area code in USA—Canada, three as the exchange code and four as the subscri-

ber number. For international traffic to other countries a subscriber must dial the trunk prefix + the country code + the national number.
Special services usually have a two-digit number beginning with 0, but there are certain services, such as the fire brigade, rescue service etc., that have normal subscriber numbers.

Transmission plan

In order to permit an economic transmission plan, 4-wire connections are used in the transit exchanges right down to the lowest level, i.e. the primary centres. The plan satisfies the requirements of CCITT Recommendation G121. This means that the maximum permissible reference equivalent in the national network up to the international exchange is 21 dB for sending (SRE) and 12 dB for receiving (RRE). A variant of the method with distributed loss, which is generally used, has been applied in Mexico. This variant is advantageous from the point of view of transmission loss. As may be seen from fig. 10, in Mexico the loss in the transit exchange where the changeover from 4-wire to 2-wire occurs is 0 dB instead of 2 dB, as in the case of the method normally used, on condition that the loss between this transit exchange and the subordinate local exchange is at least 2 dB. This allows a correspondingly higher loss in the 2-wire network up to the subscribers than would be possible with the method generally used. This extra loss can most suitably be allocated to the 2-wire trunk and subscriber network, which will thus be cheaper.

In order to be able to realize this transmission plan the 4-wire exchanges are provided with attenuators having higher attenuation than normal. When 4-wire and 2-wire lines are interconnected these attenuators are taken out of circuit and thus provide the extra contribution of 2 dB that is required according to the transmission plan.

The 4-wire transit exchanges are provided with facilities for individually balancing the hybrids, which are impedance matched and have sufficiently high balance attenuation. An extra 2 dB attenuator has also been included for lines where the transmission loss between the transit exchange and the subordinate local exchange is less than 2 dB. This enables the stability requirements of the transmission plan to be met.

Signalling

In 1964 the first ARF 10 exchange with LM Ericsson's compelled MFC register signalling system was introduced in Mexico. Since then MFC has gradually become the predominant signalling system both on the local and the LD plane. MFC signalling is also used for interworking with older local exchanges, the necessary signalling conversion taking place at the local exchange, as has been mentioned earlier. On the international plane CCITT signalling system R1 is used for traffic with USA—Canada, R2 for traffic with Central America and No. 5 for traffic with Europe and South America.

A discontinuous line signalling system is normally used, with a short element (150 ± 30 ms) and a long element (600 ± 120 ms).

Call charging

Local calls are charged on the basis of unit charge metering on call meters. This includes all calls where the distance as the crow flies does not exceed

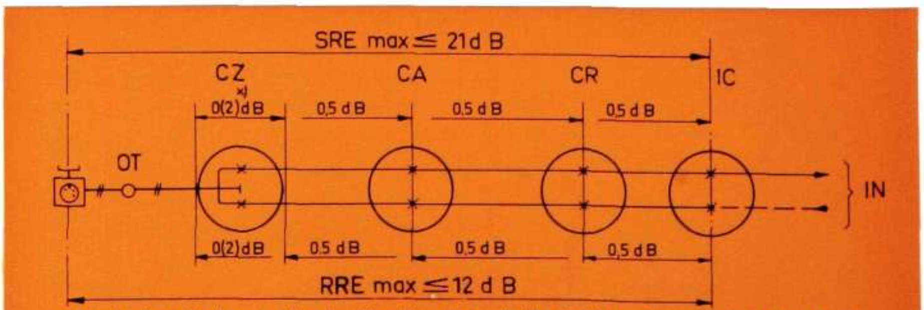


Fig. 10
Transmission plan for Mexico

OT Local exchange
CZ Primary centre
CA Secondary centre
CR Tertiary centre
IC International exchange
IN International network

12 km. In large local exchanges areas, where another method of charging would be complicated, unit charge metering is used also when the distance exceeds 12 km.

LD calls, i.e. all other calls than those mentioned above, are charged by means of Toll Ticketing (TT). For this purpose 29 different tariffs are used which are dependent on distance. For this reason the country is divided up to form a coordinate network. The positions of the subscribers in this network are determined by the first digits in their significant eight-digit number. When calls are charged using TT, the relevant distance and tariff are calculated by a computer. Higher tariffs are applied for traffic handled by a telephone operator and charging is done manually.

When the TT system is used for call charging, the identity of the calling subscriber (subscriber number + category) is transmitted to the charging transit exchange. The TT equipment also records the number of the called subscriber, the times at which the call commences and finishes, and in connection with output it calculates the length of the call. At large transit exchanges this information is fed direct on to magnetic tape in a magnetic tape unit, fig. 11, which contains two tape recorders. Normally both of these are in use and take it in turns to record calls. However, when a tape has to be changed or if one of the recorders develops a fault, the other recorder will record all the calls.

Small transit exchanges are not equipped with a complete TT equipment. Instead, they are connected to a terminal equipment, which transmits its information via a point-to-point data link to the appropriate TT equipment at the parent exchange. Several data links from exchanges with incomplete TT

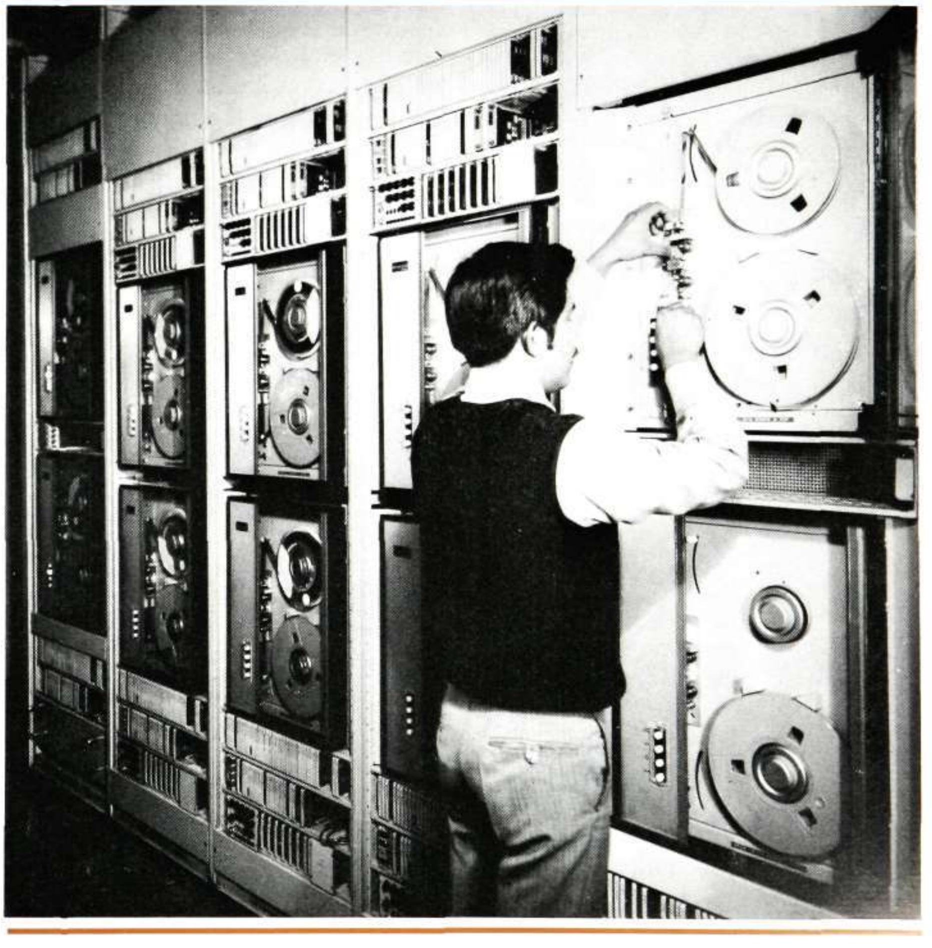


Fig. 11
Magnetic tape unit

equipment can be connected to the terminal equipment at the parent exchange.

Older exchanges which did not have equipment for identifying the calling subscriber, have since been provided with separate equipment for this purpose. This is connected in circuit by a special line signal from the transit exchange.

In order to avoid transporting the magnetic tapes from transit exchanges out in the country to Mexico City, the equipment permits the transmission of data from ARM exchanges with complete TT equipment to a magnetic tape unit in Mexico City. Such transmission is being applied to some extent on a data channel delivered by LM Ericsson, and when greater experience has been obtained, this type of data transmission may be extended.

Telephone operator traffic

Different forms of telephone operator service can be obtained in accordance with the following:

National calls to be set up by a telephone operator are ordered by dialling 02 (08 in certain cases in country districts), and the call is then set up by the operator direct to the called subscriber, when this subscriber is connected to the automatized network. International calls to be set up by the operator are ordered by dialling 09.

When a national or international call is set up automatically, a special service may be utilized by connecting in TSP telephone operators. When the prefix for this service is selected (see under Numbering) the operator is connected in automatically and provides the required service, which hitherto has consisted of personal calls and reversing the call charges. Having carried out the requested service the operator disconnects from the call.

The TSP operator who is connected to the TT equipment TT-TSP, see fig. 12, marks that the call is TSP controlled, and thereby causes the corresponding tariff to be connected in. The operator also controls the start point for charging.

Extension plans

The telephone network in Mexico is

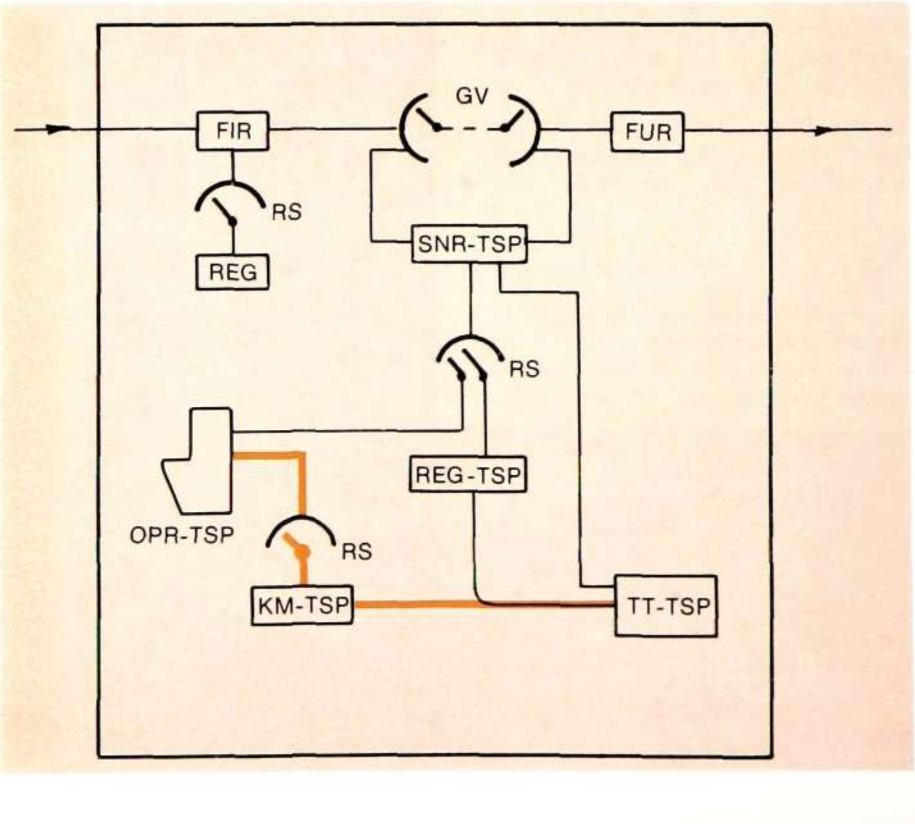


Fig. 12
The connection of the TSP telephone operator to the Toll Ticketing equipment TT-TSP

developing very rapidly and the number of telephone sets, which is now over 2.2 million (Jan. 1st, 1974), has almost doubled during the last five-year period. During the same period the long distance network has increased by about 170% and its combined length is in the region of 12,000 km.

This rapid expansion of the LD network is to continue. Thus, transit exchanges for, in all, 59,400 multiple positions have been ordered for taking into service during 1974—1975.

Domestic manufacture

In 1964 LM Ericsson bought the existing factory of Teleindustria S.A., which has since been merged in Teleindustria Ericsson S.A. (TIM), in order to be able to comply with the Mexican desire for domestic manufacture.

At first only the DIALOG type of telephone sets were manufactured. However, other products were successively introduced and the factory expanded considerably. For this reason a large building site was purchased at Tlalnepantla on the outskirts of Mexico City. A factory building of about 25,000 km^2 and also a large office building were erected on the site and were taken into use in 1970. The buildings were extended in 1974, the factory being increased by 8,300 m^2. This factory uses modern and efficient methods throughout. The total number of employees is now 1800, of which number 1150 are factory workers and 650 salaried staff.

The products manufactured comprise public and private telephone exchanges, intercom system (PAX, VOX, DYA), telephone sets, multiplex equipment for the long distance and trunk network, loading coils and power plants.

TIM is a subsidiary company of LM Ericsson, who own 70% of the company. The remaining 30% is Mexican owned.

Conclusion

Mexico is an advanced country in the field of telephony with an extremely modern technique and a rapid expansion rate. Toll Ticketing was introduced in 1965 and is now applied for all LD traffic. This has made possible the introduction of fully automatic traffic to USA—Canada, which accounts for about 90% of the total international traffic. The first SPC exchange in Latin America, an AKE 13 transit exchange, was taken into service at San Juan in 1973. Fully automatic traffic to Europe, Central America and Brazil has recently been introduced via this exchange.

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The First Installation of LM Ericsson's New 12 MHz System

Sture Lagerlund

The author discusses the test results from the installation testing of a prototype route equipped with LM Ericsson's new 12 MHz line equipment for small-core coaxial cable.

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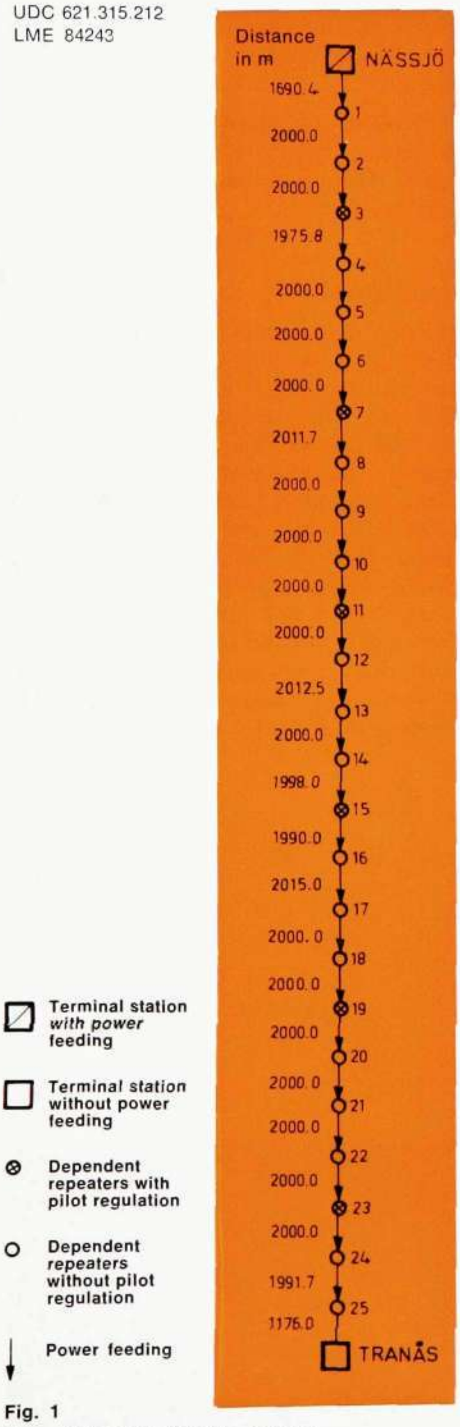

Fig. 1
Plan of the route Nässjö—Tranås

The small-core cable connection between Nässjö and Tranås, two towns in the south of Sweden, has been equipped with LM Ericsson's new 12 MHz line system ZAX 2700-4. The cable, which is 51 km long, passes through a varying countryside with woods, cultivated fields and pasture land. It contains four small-core coaxial tubes.

Twentyfive repeater housings are jointed into the cable, see fig. 1. Two systems have been installed on the route. Six of the housings are equipped with line amplifiers with pilot regulation and the remaining nineteen with fixed line amplifiers. The new housing Tvt 72, standardized by the Swedish Telecommunications Administration, has been used for the first time.

All the dependent repeater stations are fed with power from Nässjö.

Terminal rack

By using LM Ericsson's space-saving M4 mechanical construction with certain simplifications, it has been possible to mount the cable entry gland in the terminal rack instead of in a special rack.

The new cable entry gland, which is of the same type as that used in the repeater housings, is also being used for the first time. The entry gland is placed near the remote power feeding unit, which is advantageous from a protection point of view as it avoids power feeding over flexible cables between racks. The cable entry gland and the remote power feeding unit can be seen at the same time, which reduces the risk of incorrect connections.

Installation testing of the terminal rack

Installation testing was begun during August 1974. The measures taken at this stage included strapping the relevant units for the available station battery voltage of — 36 V and selecting the alarm outputs (urgent or non-urgent), measuring the transmission loss and adjusting the levels in the line terminating shelves, checking the frequency and level of the send regulation pilot, strapping in the necessary equalization to compensate for the attenuation distortion of the station cabling and connecting in the speaker circuit equipment.

Line repeaters

The line repeaters for one system were delivered towards the end of August 1974 and the work of putting them into operation began. The fixed repeaters were strapped for the correct gain taking into consideration the repeater spacing, see fig. 2. All the repeaters were equipped with their fault location crystals and were strapped to provide a suitable shunt resistance for the location of cable breaks. Each repeater was vibration tested using a dry joint tester. Amplifiers that were to be fitted at the send side of a short cable section (in this particular case the two end sections, see fig. 1) were equipped with line building-out networks. Finally, all repeaters were tested at the pilot frequency 12,435 kHz, the fixed repeaters at the nominal input level and the regulated repeaters also over the range ± 4 dB, and each fault location frequency was measured.

The cables required for connecting in the line repeaters were marked with the contact number, system number and direction. The work of preparing these cables took place at the same time that the line repeaters were being checked. Early in September 1974 all repeater housings had been equipped with their line repeaters and unequalized transmission loss curves had been measured between the terminal stations Nässjö and Tranås, fig. 3.

Phase inversion

In order to get some idea of the intermodulation characteristics of the new system at an early stage, noise loading measurements were carried out using a Wandel and Goltermann noise meas-

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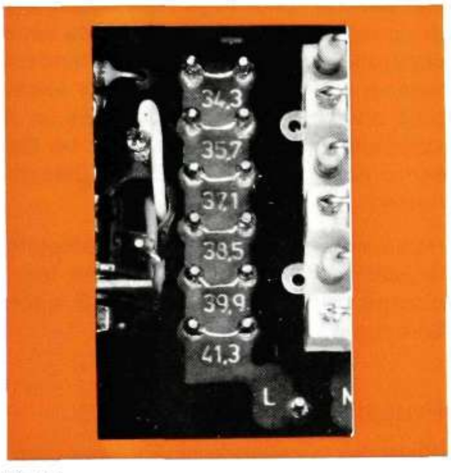


Fig. 2

The gain of an unregulated repeater can be set to any one of five values between 34.3 dB and 41.3 dB. When delivered, all straps are made. To obtain the required gain the unwanted straps are cut off

uring equipment RK-5. The noise measured was just over 5 pW/km at the nominal level, and measured in the worst measuring slot (11,700 kHz), or in other words very much greater than the 1.5 pW/km which was the highest expected value for this installation.

It was therefore decided to remove all the line repeaters and return them to LM Ericsson, where it was discovered that by mistake the outputs of the line amplifiers had not been phase inverted with respect to their inputs, which resulted in an unfavourable addition of certain intermodulation products.

Re-equipping the line repeaters

The mistake was soon rectified, and at the beginning of November 1974 it was possible to start again with the work of fitting the repeaters in the dependent repeater housings. In order to check that the phase inversion gave the desired result, a quick check was made using the noise measuring equipment. This time the measured values were less than 1.5 pW/km in the worst measuring slot, when measuring at the nominal level.

Connecting in the second system

The repeaters for the second system were delivered in the middle of November.

With the experience gained from the work of equipping the first system, the work on the second system took a very short time (about four days altogether, the 25 repeaters being fitted in one day).

Equalization

The new system can either be equipped with fixed equalizer networks or manual cosine equalizers, see fig. 4.

The line terminating shelves in the terminal racks at Nässjö and Tranås are equipped in accordance with the latter alternative.

The equalization procedure with the cosine equalizer is very simple and time saving but requires special test equipment, such as a sweep generator and a wideband double-detecting level meter. In less than 30 minutes per direction and system the spread was reduced to ± 0.3 dB (fig. 3).

Power feeding unit

The power feeding unit is equipped with special protection circuits, which in the event of a cable break reduce the voltage to zero. During the installation measurements it was observed

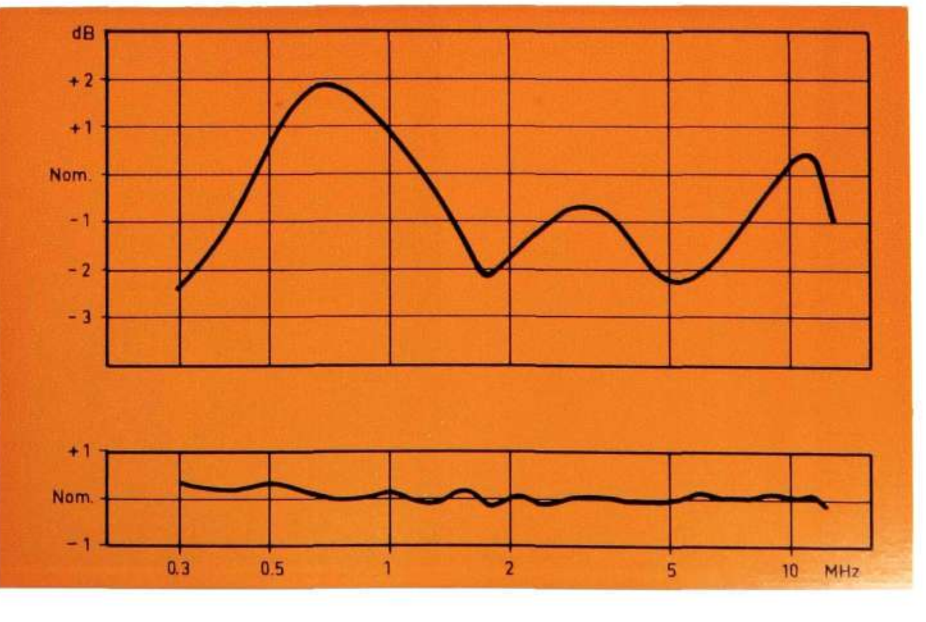


Fig. 3

Transmission loss curve. Deviation from the nominal level before and after equalization

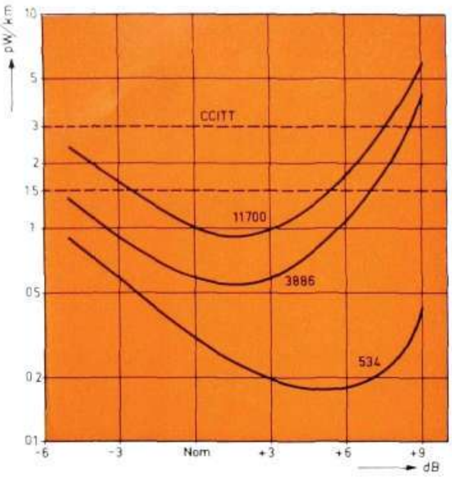


Fig. 5
Noise in a loaded system as a function of the level

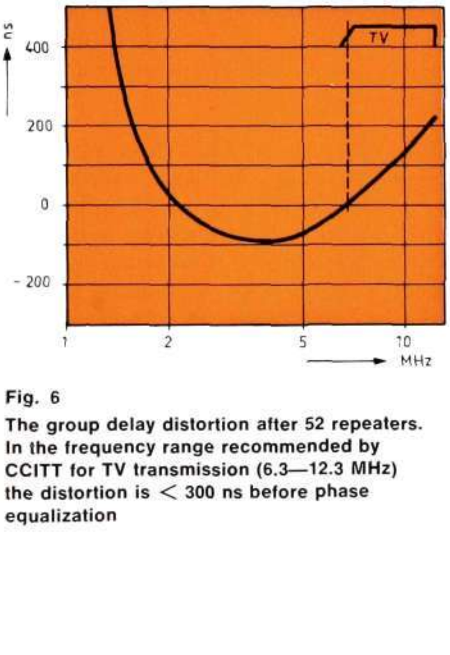


Fig. 6
The group delay distortion after 52 repeaters. In the frequency range recommended by CCITT for TV transmission (6.3—12.3 MHz) the distortion is $<$ 300 ns before phase equalization

that the time constants chosen for the protection circuit were unsuitable, and meant that at least 15 seconds must elapse before the power feeding units could be restarted.

Once this problem had been cleared it became possible to restart the power units immediately.

Level measurements at the dependent repeater stations

Since the pilot regulation must compensate for the temperature-dependent loss variations in the cable, the pilot level into a regulated repeater should not deviate by more than $\pm$ 4 dB from the nominal level at any time of the year. For this reason it is important that the gain settings for the fixed repeaters are suitably chosen with regard to the length of the cable sections.

In order to check the level settings for the route, the input and output levels were measured at the regulated dependent repeater stations at the pilot frequency, and also at the edges of the frequency band. The results of these measurements indicated that suitable gain settings had been selected for the fixed repeaters.

Regulation memory

The pilot-regulated line repeaters are equipped with a memory, which controls the thermistor in the pilot receiver if the pilot is interrupted. The memory function is designed so that the regulation is locked in gain positions at intervals of 0.5 dB.

As several pilot-regulated repeaters are connected in cascade, and as each separate memory is locked in a random manner to the nearest higher or lower gain position, the level changes on a complete pilot section will not be the same each time the pilot is disconnected.

However, repeated tests on a complete regulation section show that the level change keeps within $\pm$ 2.0 dB each time the pilot is disconnected.

Prototype measurements

When the installation testing was completed at the beginning of December 1974, a series of prototype tests were begun, which included measurement of

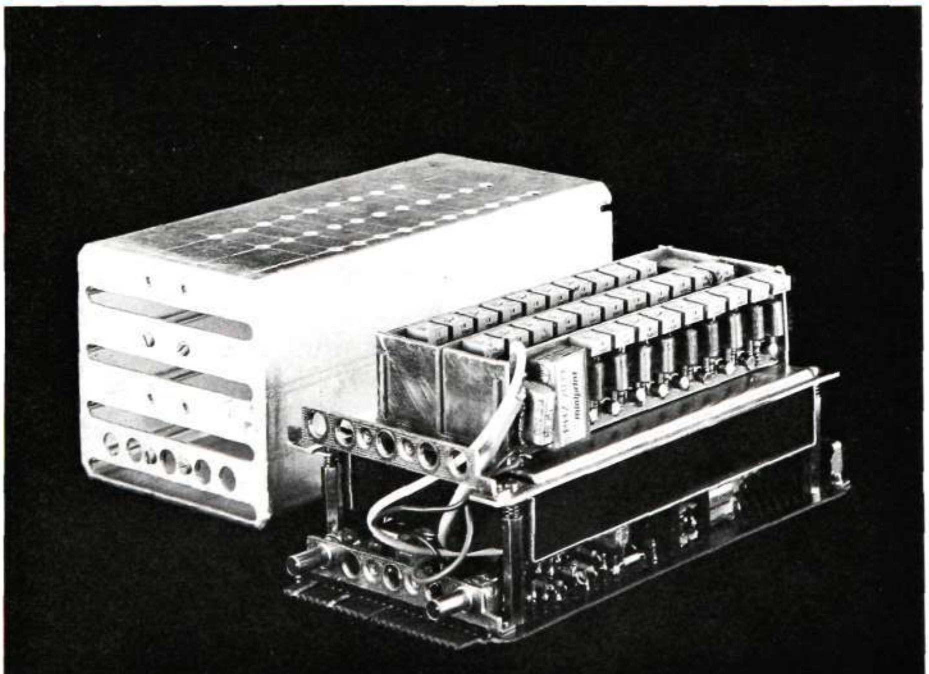
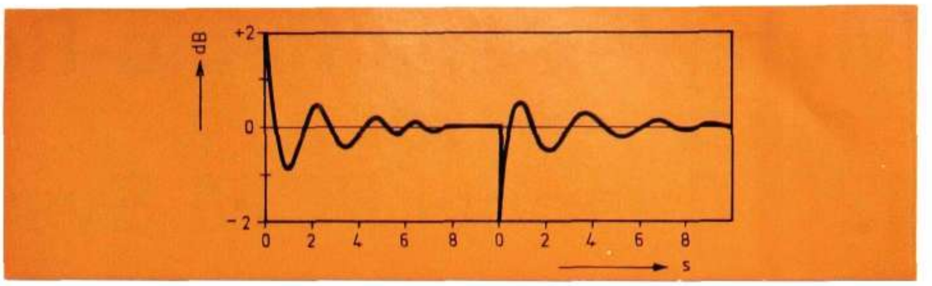


Fig. 4
Cosine equalizer

Fig. 7

Step response after 28 regulated repeaters. The first overshoot is less than 1 dB for a 2 dB change of the pilot level



crosstalk, group delay measurements, check of the envelope gain and step response and also comprehensive noise measurements, figs. 5—7. The worst measured values of crosstalk for the whole route were > 94 dB for near-end crosstalk attenuation and > 98 dB for far-end crosstalk attenuation. Noise loading measurements showed that the sum of the thermal noise and the intermodulation noise at nominal level was well under the guarantee value of 1.5 pW/km in all the measuring slots, and that the overload margin was good. These results may be considered as being very satisfactory.

Conclusion

A long-term test has been started in order to check the level stability of the new system. Experience from the installation testing shows that CCITT recommendations as well as the guarantee values are met very adequately.

Fig. 8

The terminal station at Nässjö. The newly installed rack is on the right. The racks to the left of this contain earlier generations of LM Ericsson 12 MHz and 1.3 MHz systems

Multiplex and Radio-Relay Equipment for a 120-Channel PCM System

Per Fremstad, Heinz Karl and Stig Karlsson

The digital multiplex equipment for 120 telephone-type channels which has the system designation ZAK 30/120, is a further development of PCM multiplex equipment for 30 channels. The equipment combines the signals from four different 30-channel primary multiplex equipments, each at a bit rate of 2.048 Mbit/s, into a single digital output signal at a bit rate of 8.448 Mbit/s. A radio-relay equipment suitable for this system has been developed by the Norwegian company NERA A/S. The radio-relay equipment, which has the system designation NERA 30-120/13G, operates in the 13 GHz band and the modulation principle is direct phase-shift modulation of the radio frequency with coherent demodulation in the receiver. The equipment is built together with the antenna to form a single unit.*

Apart from the multiplex and radio-relay equipments the authors describe a method developed by LM Ericsson for branching and feeding in groups of 30 channels at repeater stations.

* There is a version of this equipment for transmitting 30 PCM telephone-type channels.

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Within the framework of the cooperation agreement between the two companies LM Ericsson and NERA A/S a digital radio-relay equipment and associated multiplex equipment have been developed for transmitting 120 PCM telephone-type channels. The equipments offer economic and flexible system solutions for the increasing traffic in the rural and urban network[1]. Thus the radio-relay equipment has been designed for installing outdoors, which means that no station buildings are required for the radio-relay equipment. Remote power feeding over the baseband cable makes the radio link independent of access to electrical power at the installation site. The multiplex equipment, which in principle is a digital multiplexer, permits direct leak dropping in the system within one and the same modem shelf assembly. This means that investment in digital multiplexers at an early stage will be very advantageous economically in a long network, where the primary groups can be branched off at repeater stations, even if the capacity requirement is moderate initially. Multiplex equipment ZAK 30/120 (also called second order multiplex equipment) constitutes the second stage in LM Ericsson's multiplex hierarchy for PCM transmission equipments[2, 3]. On the send side the equipment combines the signals from four different primary multiplex equipments, each at a nominal bit rate of 2.048 Mbit/s, into a single digital output signal at a bit rate of 8.448 Mbit/s. On the receive side this signal is again divided up into four outgoing primary multiplex signals.

By exploiting the excess capacity in the second order multiplex signal and resorting to the pulse justification method in the signal processing, no synchronism is necessary between incoming signals and the digital multiplex equipment. The frame structure is in accordance with CCITT Recommendation G.742.

The equipment is built up as a shelf stack with its own power supply, fig. 1. The units included in the equipment are mainly digital. The components consist of integrated TTL circuits with ceramic encapsulation, which give

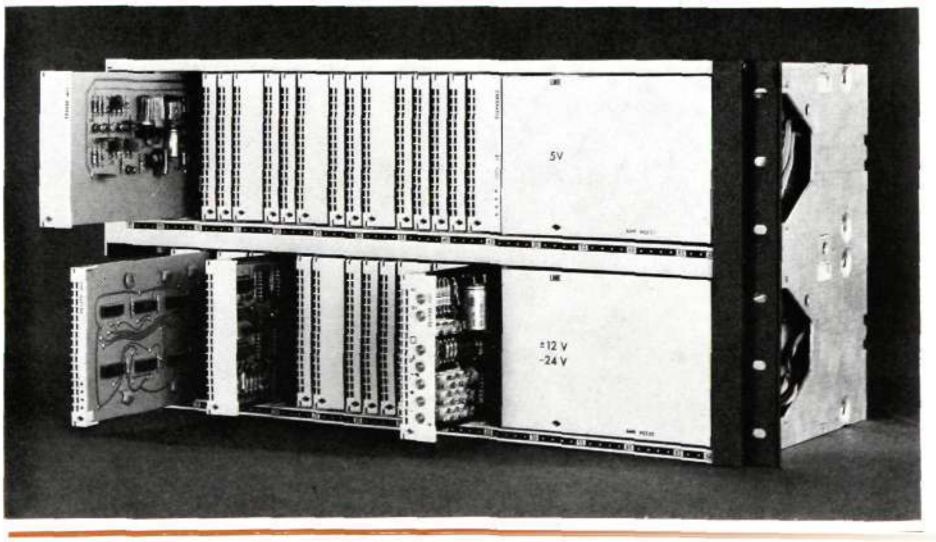

Fig. 1
LM Ericsson's second order multiplex equipment ZAK 30/120 for 120 PCM channels

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high reliability. The maintenance required has been reduced to a minimum. Test points, which are protected against short circuit, are provided on the fronts of the units, which enable measurements to be made without causing operational disturbances. All the units are built up as plug-in type printed board assemblies.

The radio-relay equipment is designed for transmission of digital signals at *radio frequencies (RF) in the band* 12.75—13.25 GHz. The digital baseband units are adapted for interworking with the PCM multiplex equipment. The digital signal modulates the radio frequency direct. The modulation principle used is two-phase-shift keying, where

— a digital 0 does not affect the phase of the radio wave

— a digital 1 shifts the phase of the radio wave by 180°.

On the receive side the equipment operates in accordance with the heterodyne principle, with 70 MHz as the intermediate frequency. The digital signal is recovered in a coherent demodulator.

Thanks to the use of the 13 GHz band, the radio frequency and the waveguide components are small. This, in combination with the digital building blocks for the baseband units, makes for an equipment that is mechanically extremely compact. The equipment is built together with the antenna to form a single unit designed for mounting on an antenna tower, see fig. 2. This has eliminated the waveguide attenuation, which would otherwise be in the region of 12 dB. (This assumes that with a normal system design, with the radio-relay equipment at ground level and the antenna mounted on a tower, about 40 metres of waveguide would be required on both the send and receive sides.) The elimination of the waveguide attenuation has made it possible to limit the diameter of the antenna *to 1 m and the output power to* 100 mW. (For certain applications the antenna diameter can be increased to 2 m.)

The radio-relay and multiplex equipments are connected together by a symmetrical cable (the baseband cable), which on the multiplex side is connected to a radio link terminating equipment which has almost the same function as in the case of cable equipments[4]. The terminating equipment also provides the power for the radio-relay equipment via the baseband cable. The distance between the terminating

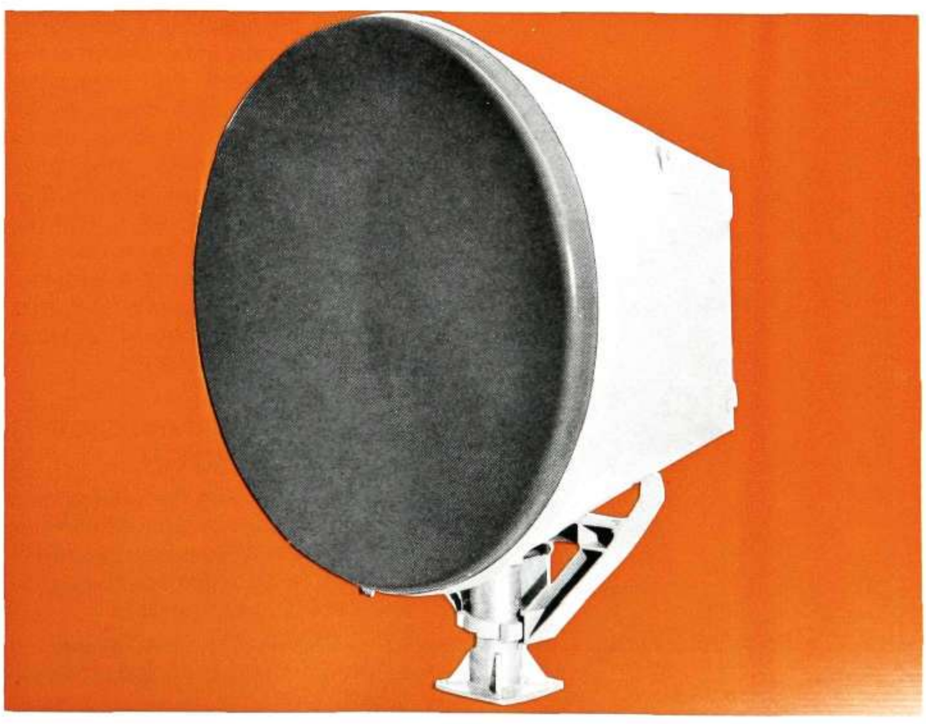


Fig. 2
NERA's radio-relay equipment 30-120/13G for 120 PCM channels

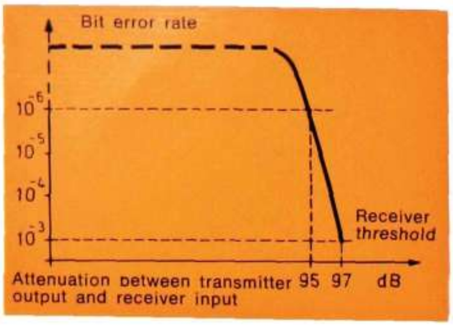
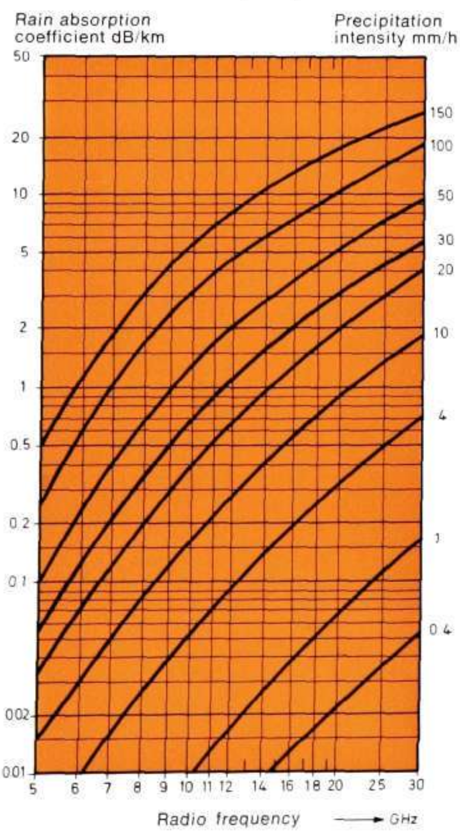


Fig. 3
Bit error rate for a digital radio-relay system

Fig. 4
Attenuation, caused by precipitation, as a function of the radio frequency



equipment and the radio-relay equipment can vary from a few metres to a number of kilometres.

The mast mounting and remote power feeding of the radio-relay system equipment provides great flexibility when planning the network, since the equipment may be installed at any selected site. Thus it is possible to take into consideration the radio wave propagation conditions as well as town planning (no high towers in the town etc.).

Quality requirements of digital radio-relay systems

The transmission quality of a radio-relay system for transmission of digital signals is determined primarily by the bit error rate. As these transmission systems are relatively new, there are no international recommendations for the transmission quality corresponding to CCIR Recommendations 393-2 and 395-1 for FDM-FM radio-relay systems, especially as regards bit errors as a function of time. However, in general it may be said that a bit error rate of $< 10^{-6}$ is indicative of good speech quality whereas a bit error rate of $\geq 10^{-3}$ corresponds to a break in the circuit.

A typical bit error rate curve for radio-relay system NERA 30-120/13G is shown in fig. 3. As may be seen from the diagram, the quality of a radio-relay circuit is practically independent of the attenuation between the transmitter and the receiver right down to the threshold value for the receiver, unlike in the case of FDM-FM radio links where the signal-to-noise ratio changes proportionally with the fading. On the other hand, as can be seen from the curve, the changeover from satisfactory quality (bit error rate $= 10^{-6}$) to a break (10^{-3}) is very abrupt, it takes place within a matter of 2 dB.

Propagation conditions for radio waves at 13 GHz

When comparing with the propagation conditions for conventional radio-relay systems (FDM-FM systems in the RF band 2—8 GHz) attention should be paid to the following points:

— at 13 GHz the attenuation caused by precipitation is no longer negligible

— digital radio-relay systems are less sensitive to interference than FDM-FM systems.

As may be seen from fig. 4[5], the rain absorption coefficient at 13 GHz, for a rain intensity of 30 mm/h, is about 1.3 dB/km, whereas at 7 GHz it is only 0.2 dB/km. This and the higher free space attenuation at 13 GHz — 16 dB higher than at 2 GHz and 5 dB higher than at 7 GHz — means that the lengths of the radio hops must be reduced compared with those normally used at 2 and 7 GHz. It is not a good solution to compensate for the higher free space attenuation with a higher antenna gain. A larger antenna would also have a greater directional effect, which would increase the stability requirement for the radio mast and thus make it more expensive. Hence the lengths of the hops should be limited to between 25 and 30 km.

Moreover shorter hop lengths have the advantage that the probability of fading derived from multi-path propagation is reduced, since the fading probability increases in accordance with the cube of the hop length but only linearly with the radio frequency. For practical planning this means that the fading margin may be lower than for radio links that have greater hop lengths than 30 km.

As regards the sensitivity to interference from other radio channels it is interesting to compare the following figures:

— an FDM-FM link requires that the level of an interference signal shall be 65 dB under the wanted signal if the interference signal is not to contribute more than 2 pWOp to the total noise power in a telephone channel

— for a digital radio link a discrimination of 20 dB between the interference signal and the wanted signal is all that is required in order to hold the bit error rate under the 10^{-6} value.

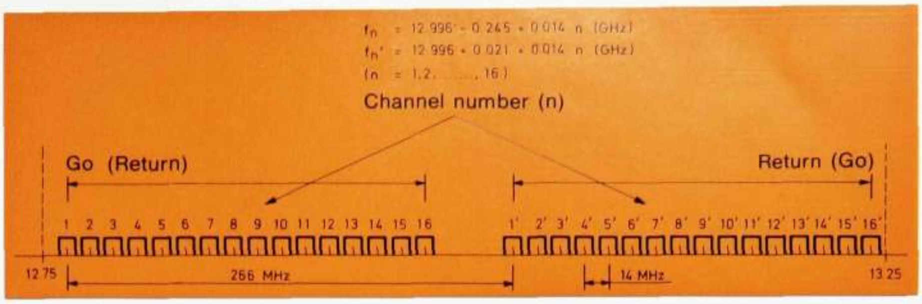
The low carrier-to-noise power ratio requirement of 20 dB may be exploited economically in various ways:

— the angular distance between different radio channels, which converge on the same network node, may be reduced, and hence the

Fig. 5

Radio-frequency channel arrangement for radio-relay systems in the 13 GHz band

Capacity: 300 FDM or 240 digital telephone circuits



number of radio channels per node can be increased compared with FDM-FM systems

— a less stringent side lobe attenuation requirement may be applied for the antennas

— radio hops that use the same radio frequency may be placed closer to each other

— two radio signals may be transmitted in parallel at the same radio frequency, on condition that the two radio waves are cross-polarized.

The latter facility is applicable primarily for parallel transmission of the same information over two radio channels, 1 + 1 operation.

Radio-relay equipment (RL)

RF channel arrangement

In Recommendation 479 CCIR has laid down a frequency plan for the RF band 12.75—13.25 GHz. NERA's 30-120/13G system uses the version of the frequency plan proposed by CCIR for 300 FDM or 240 digital telephone circuits, fig. 5, with a frequency spacing of 14 MHz between adjacent radio channels and 266 MHz between the transmitter and the associated receiver.

Modulation and demodulation

The equipment works with direct modulation of the radio wave, which is phase-shift modulated in the transmitter output circuit by means of a PIN diode. On the receive side a coherent demodulator is used to recover the digital information. The carrier is recovered using the remodulation principle.

Two-phase-shift keying (2-PSK) modulation with coherent demodulation is the best method of obtaining a low receiver threshold value and insensitivity to interference between adjacent radio channels. The digital signal transmitted by the radio link is also differentially coded. This is done because the coherent demodulator is unable to distinguish the absolute phases of the modulated signal, only the signal phase changes.

Another advantage of coherent demodulators is that a frequency modulated signal is always automatically demodulated. This simplifies the setting up of service channels between the radio link terminal and the radio link repeater stations.

Transmitter and receiver equipment

The transmitter output power is generated in a 2 GHz microstrip oscillator, which generates 1 W, fig. 7. This is followed by a wideband frequency multiplier (×3×2).

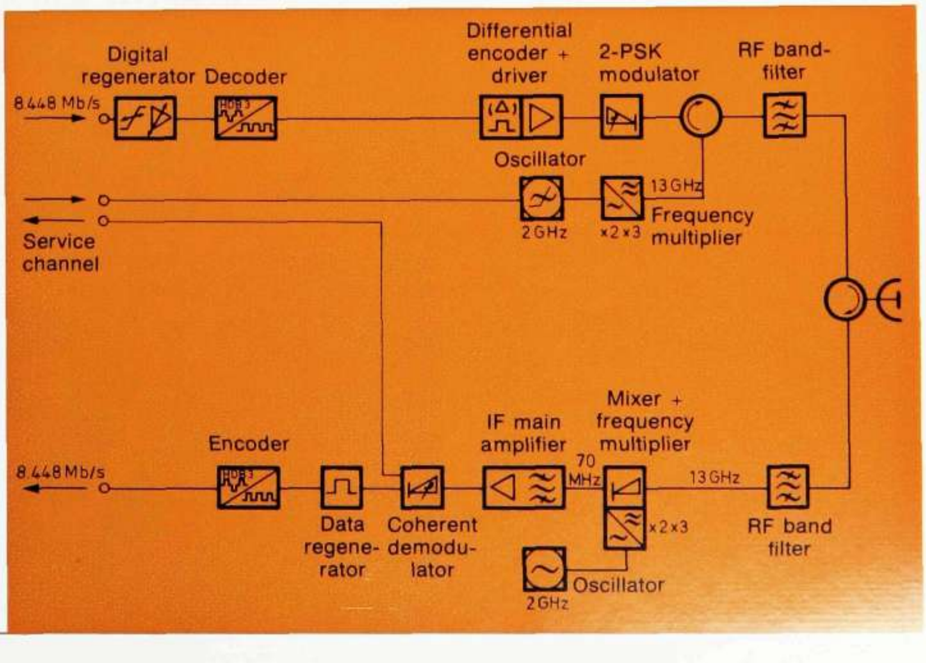


Fig. 6

Block diagram of radio-relay equipment NERA 30-120/13G

(The circuit symbols are explained in fig. 13)

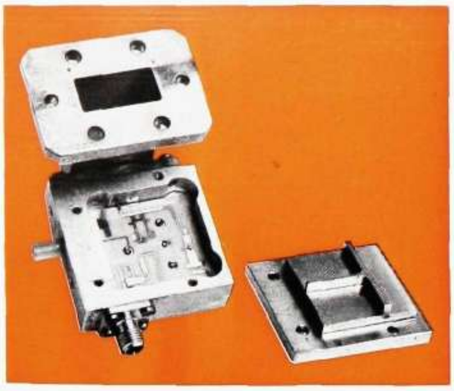


Fig. 8
Frequency multiplier and balanced mixer

The phase-shift modulator and RF oscillator chain are interconnected via a circulator.

The nominal power at the transmitter output is + 20 dBm.

The receiver operates in accordance with the heterodyne principle, the incoming radio frequency being transposed to an intermediate frequency of 70 MHz by a frequency generated locally in the receiver. The local oscillator is a 2 GHz oscillator of coaxial construction. The frequency multiplier that follows is built up together with the RF mixer on an alumina substrate to form a common wideband circuit, see fig. 8.

The variations of the receiver input signal, caused by the varying propagation conditions, are equalized by the IF amplifier, which operates with automatic gain control.

Baseband equipment

At the baseband input on the transmit side the bipolar digital line signal is regenerated in a digital amplifier, which provides automatic equalization for the attenuation of the cable between the terminating equipment and the radio-relay equipment. The HDB3 (or AMI) code, which cannot be transmitted over the radio link, is converted to a monopolar pulse train before being fed into the phase-shift modulator.

On the receive side the bipolar line signal is reconstructed with the aid of a regenerator and an HDB3 (or AMI) encoder.

Phase jitter on the demodulated pulse train, and/or the occurrence of more than 128 successive identical bits, is used as the switching criterium for switching to the protection channel. The reason for this choice is that there is an almost linear relationship between phase jitter and bit error rate and that it is improbable that an 8.448 Mbit/s line signal contains more than 128 successive identical bits.

Remote power feeding

The radio-relay equipment may be fed with power over the phantom circuit in the balanced baseband cable. The feeding voltage to the terminating equipment is usually — 48 V. The maxi-

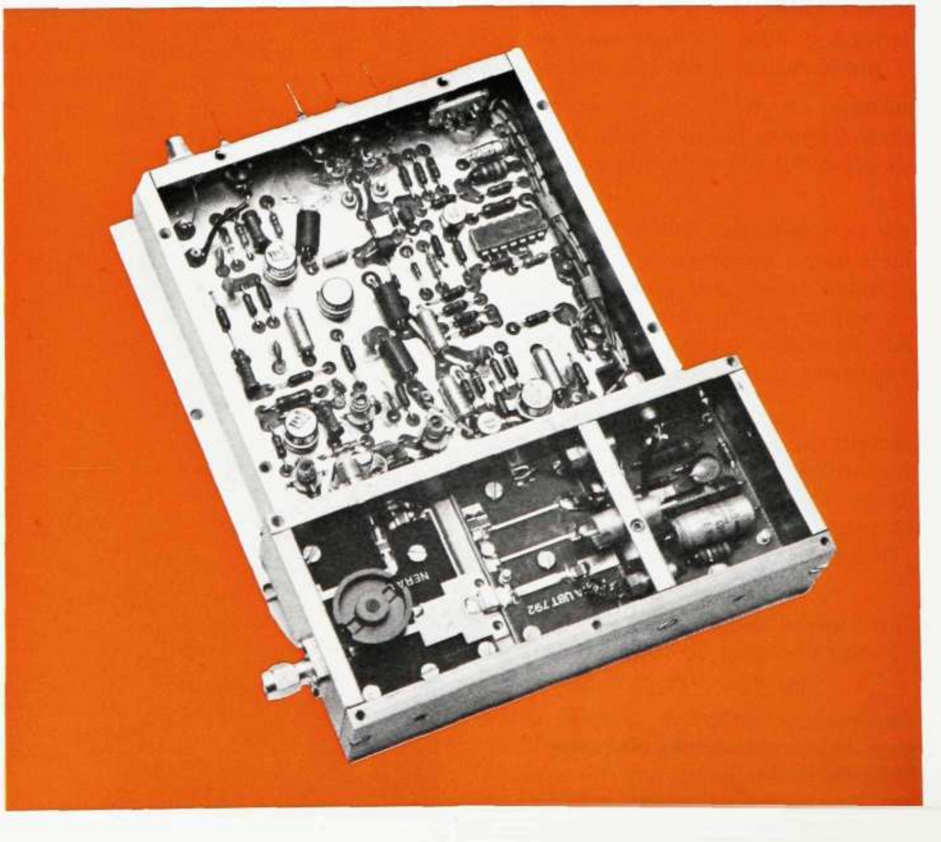


Fig. 7
2 GHz microstrip transistor oscillator

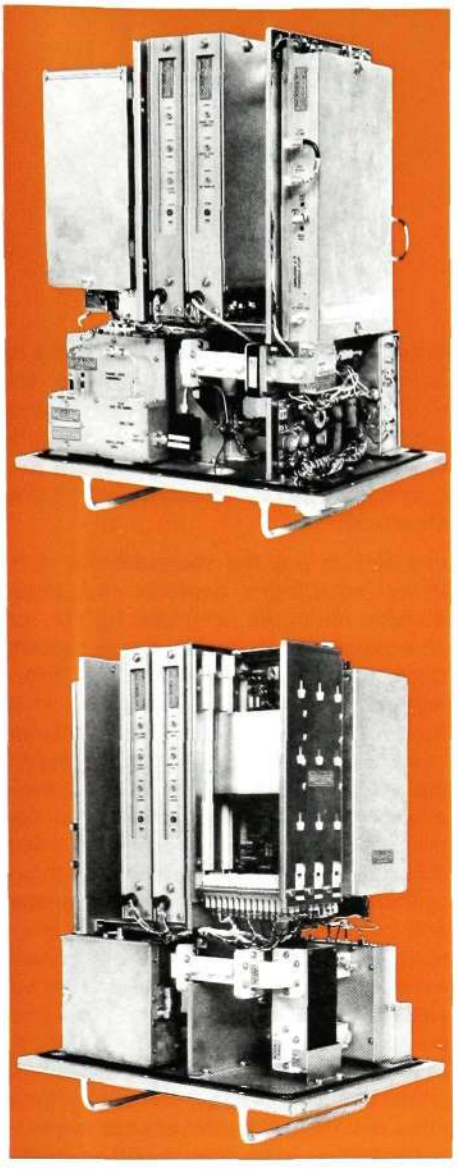


Fig. 10

The radio-relay equipment with the protective cover removed. The upper illustration shows the equipment from the front and the lower from the rear

mum permissible resistance in the feeding loop is about 25 ohms.

The power consumption for a radio-relay equipment is approximately 25 W.

Maintenance, alarm and supervision

A portable test equipment is available for carrying out maintenance tests on the radio-relay equipment. It can be connected in with a plug and socket.

The radio-relay equipment can be supervised remotely from the terminating equipment by means of alarm indications and remote measurements of the most important equipment parameters. The terminating equipment also has facilities for connecting in a service channel telephone. In addition, protection channel switching and local looping of the transmit and receive equipments can be remotely controlled from the terminating equipment.

Up to 20 indications per radio-relay station can be remotely transmitted over the service channel.

Mechanical construction

The radio-relay equipment is enclosed in a waterproof case, which is mounted in a frame on the rear of the antenna. Two radio-relay equipments can be mounted in the same frame, see fig. 9. The radio-relay equipments are protected against direct insolation and precipitation by a screen, which encloses the exterior of the antenna and the frame (fig. 2). The equipments are accessible through doors on the rear of the frame.

The waveguide output of the radio-relay equipment is connected to the antenna feeder horn by means of a quick-acting locking device which permits rapid conection and disconnection without tools. Consequently the whole radio-relay equipment can be replaced quite easily if a fault develops. Faulty units will be replaced indoors.

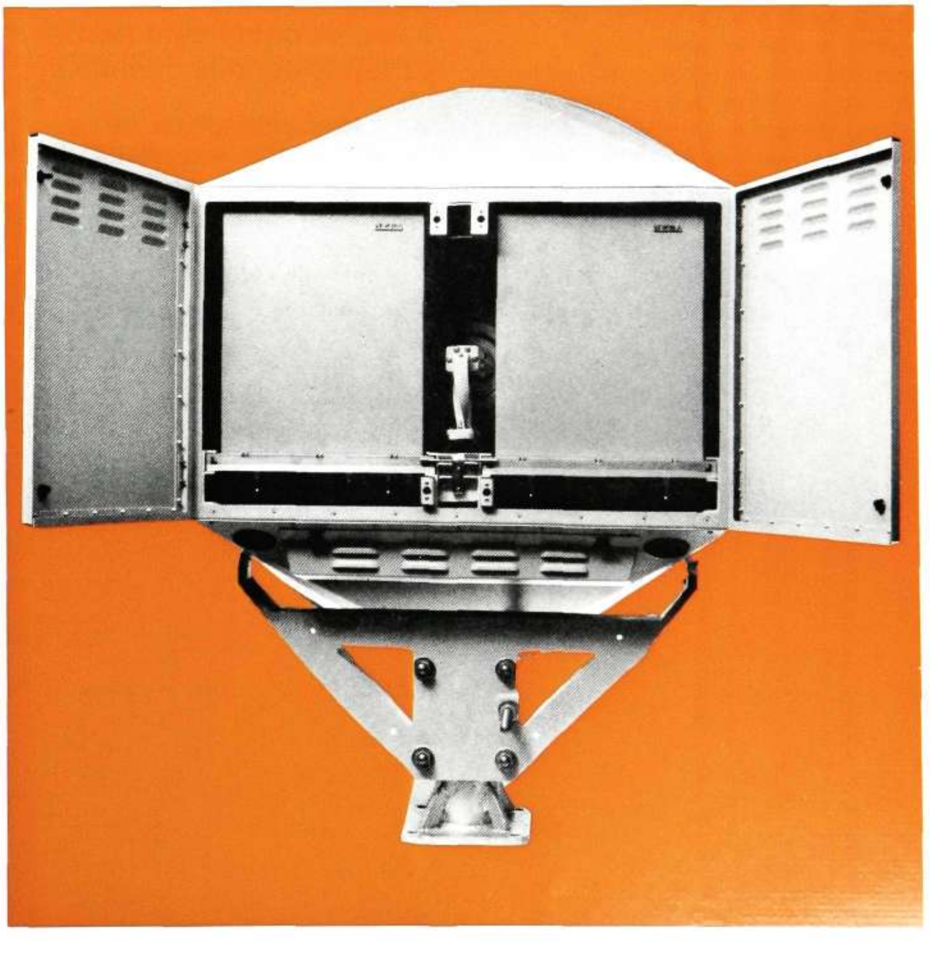


Fig. 9

The radio-relay equipment with the antenna, seen from the rear

Fig. 10 shows the mechanical design of the radio-relay equipment. Each unit is an electrical functional unit, and may be replaced in the field by a similar spare unit.

The baseband and auxiliary units are built up as printed board assemblies, which are mounted in screening boxes that can be swung out.

The transmitter and receiver oscillators, which have been described earlier, are also mounted in screening boxes, which are positioned in such a way that frequency adjustments or changes can be carried out without dismantling the equipment. The remaining RF units, of which a number are designed as microstrip circuits and others in a coaxial construction, and the IF units are also mechanically individual units placed in screening boxes. The signals between them are taken via waveguides or coaxial cables.

Multiplex equipment (MUX) for 120 telephone channels

THE BASIC PRINCIPLES OF SECOND ORDER MULTIPLEX EQUIPMENT

The primary multiplex equipment, the basic principles of which have been described previously in Ericsson Review[3], converts analog speech signals from 30 different telephone channels to digital signals. These are combined together with the frame alignment and signalling information to form a single time-divided digital bit stream in accordance with a standardized frame structure.

In a similar way the second order multiplex equipment exploits the time-division multiplex principle, fig. 11, for combining the incoming digital signals from four primary systems. The information must then be organized in a frame structure so that synchronism can be established between the sending and receiving ends of the transmission link. The problem is that the primary systems are controlled from different clocks. Hence the incoming primary bit streams differ both in phase and frequency. This problem can, however, be solved by introducing a certain excess capacity in the second order bit stream, and using a buffer memory and the justification method[8]. The justification method implies that the second order multiplex fills up the empty time slots resulting from the excess capacity by adding extra bits (positive justification).

The higher the bit rate of the primary system the lower will be the justification rate and vice versa. Justifying bits may only be included once in each frame of the second order bit stream, and then always in a particular bit position. Positive justification is signalled in advance in a separate justification

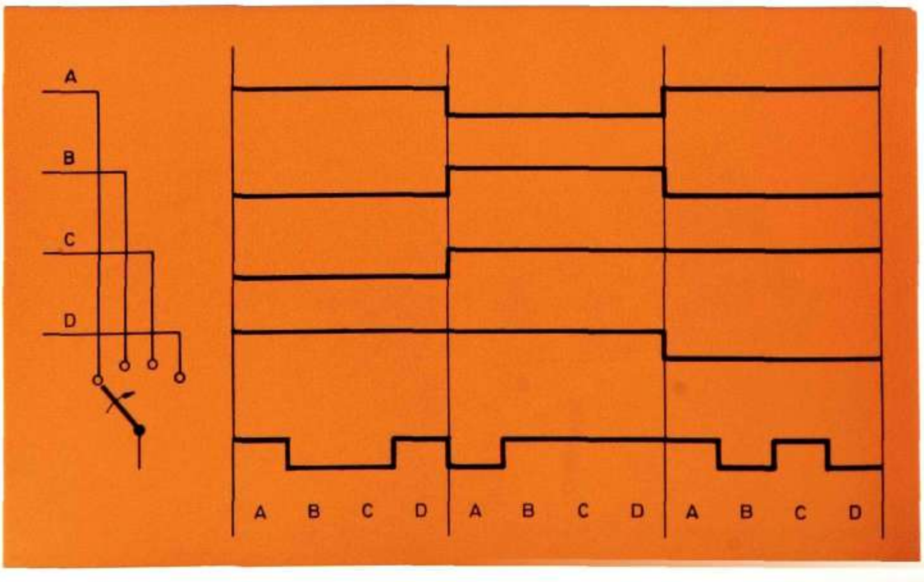


Fig. 11
Time-multiplex principle for four digital primary bit streams A—D

channel. This enables the receive logic to delete the inserted bits and to recover the original bit rate of the primary data.

The frame structure for an 8.448 Mbit/s digital multiplex equipment is laid down in CCITT Recommendation G.742. The basic frame structure is shown in fig. 12.

SYSTEM DESIGN FOR LM ERICSSON'S DIGITAL MULTIPLEX EQUIPMENT ZAK 30/120

The design and function of the digital multiplex equipment is illustrated in fig. 13. The primary group units are individual for each primary system included. The remainder of the units are common for the whole system.

The send side is controlled by pulses generated in the send logic adjustable oscillator 8.448 Mbit/s, which is normally oscillating freely. It can also be controlled by the received signal or an external signal via interface T2. This form of control is used in connection with branching or in future integrated networks.

The signals from the primary systems are each stored in their particular buffer memory. The send logic checks how many bits are stored in each memory. When the number of stored bits is less than a certain value a justification message is sent to the receiver. Read-out from the memory is then inhibited in the justifying bit position. The memory thus has time to fill up and is prevented from becoming empty.

After time-division multiplexing and addition of the frame alignment signal, the 8.448 Mbit/s signal is fed to the 8.448 Mbit/s digital line adapter, where the binary signal is converted to the bipolar line signal (HDB 3 or AMI code).

The function of the receive equipment is the inverse of that of the send equipment. The bipolar line signal is received in the 8.448 Mbit/s digital line adapter, where it is converted to binary form. It is then taken together with the timing signal to the receive justification and framing logic units where the receive side is synchronized with the send side and the justifying bits are removed. The signal information is then taken to the respective buffer memories. The primary information is fed out from the buffer memory with the aid of the controlled send clock 2.048 Mbit/s. The read-out bit rate is determined by the mean value of the number of bits stored in the buffer memory. If the number of bits in the memory tends to increase, the read-out rate is increased, and vice versa. The jitter is reduced considerably by means of an internal regulation loop.

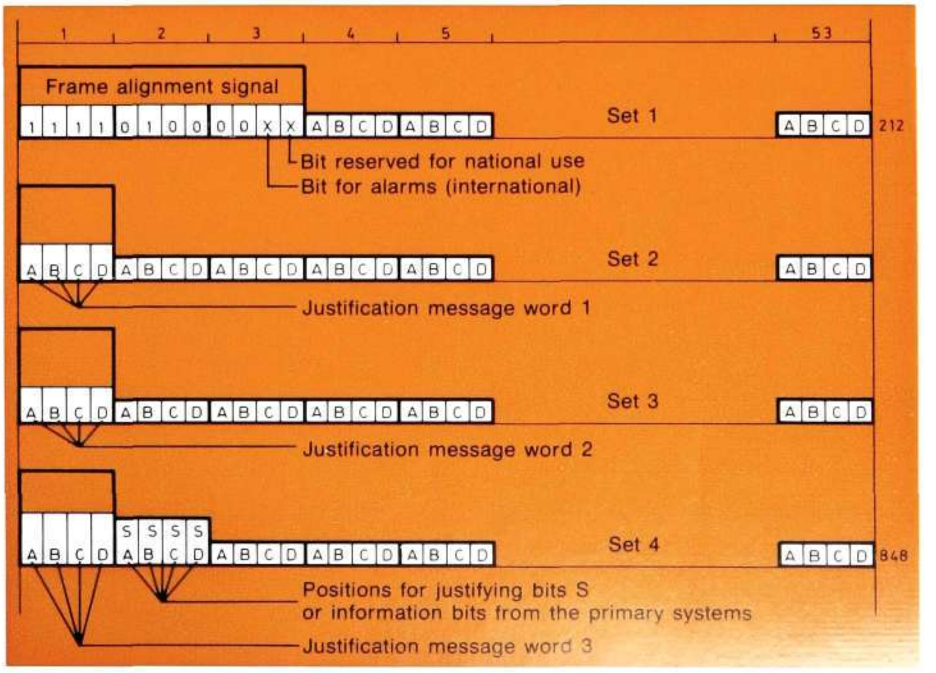


Fig. 12
Frame structure for the second order multiplex equipment

Interfaces

A high degree of flexibility has been achieved by the selection of suitable interfaces. All the data interfaces, D1, D2 and D2B, are bipolar and HDB 3 (or AMI) coded. Each of them is connected to 75 ohm coaxial cables, one for each direction of transmission. The extra 8 Mbit/s interface D2B is used in connection with branching.

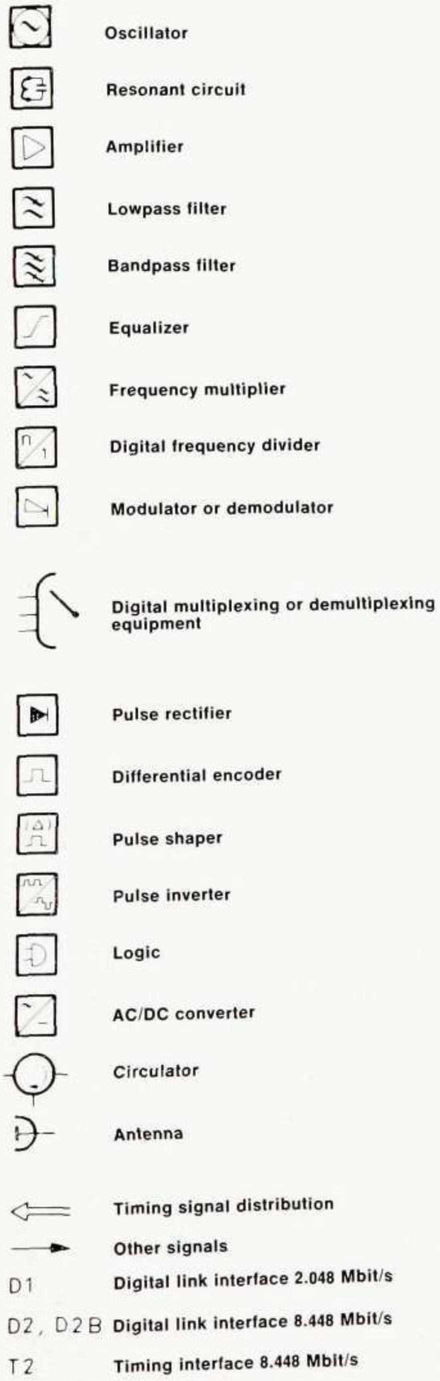
Fig. 14 shows how the second order multiplex equipment ZAK 30/120 can be connected via its various interfaces to different line equipments and to the nearest higher or lower order multiplex equipment.

Maintenance and alarms

The need for maintenance in the second order multiplex equipment has been reduced to a minimum. The frequency of the crystal controlled send clock 8.448 Mbit/s should be checked once a year in order to verify that the limits have not been exceeded. In other respects the system is supervised by built-in alarm circuits. The distant terminal transmits information regarding its operational state by means of two bits in the frame alignment signal.

Faults are combined in the alarm unit of the multiplex equipment to provide a sum alarm which after a delay of a few seconds is fed, in the form of an urgent or non-urgent alarm, to the rack alarm unit.

The alarm unit in the multiplex equipment has a number of alarm lamps that represent different types of faults and also outputs that can be connected to, for example, a common maintenance centre.



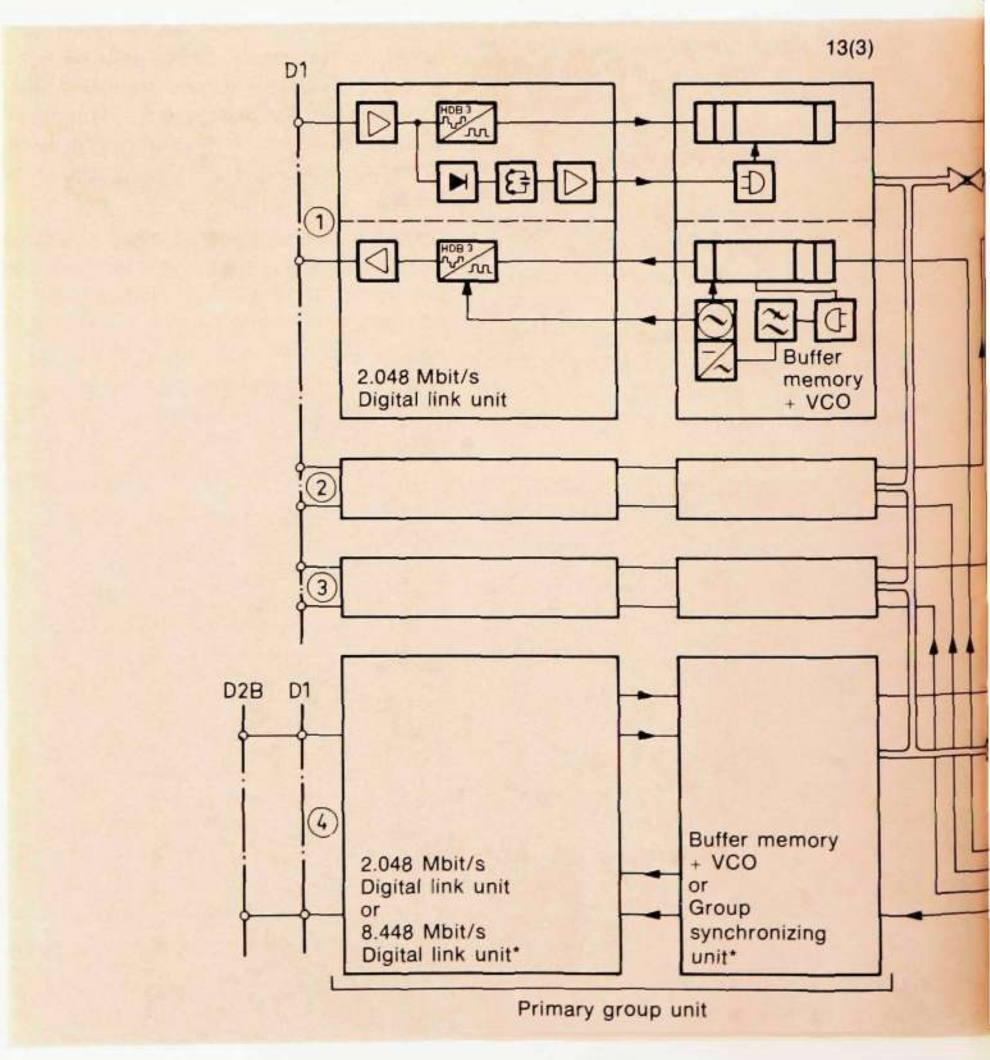
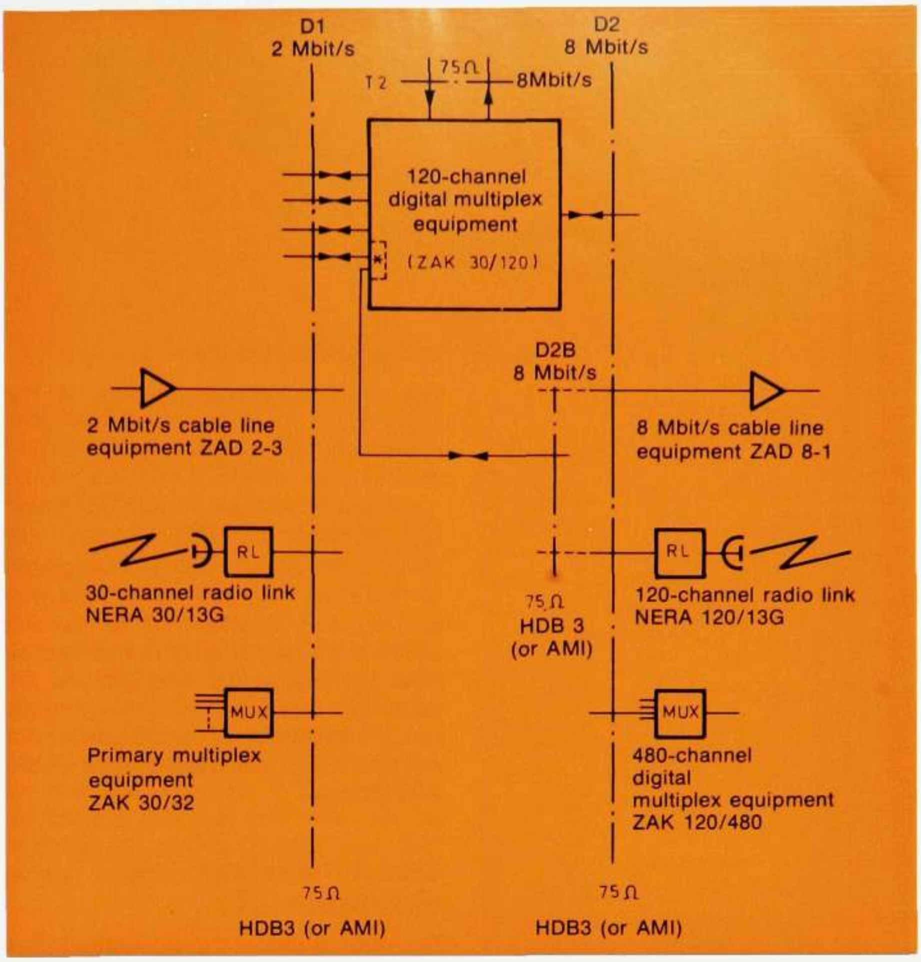
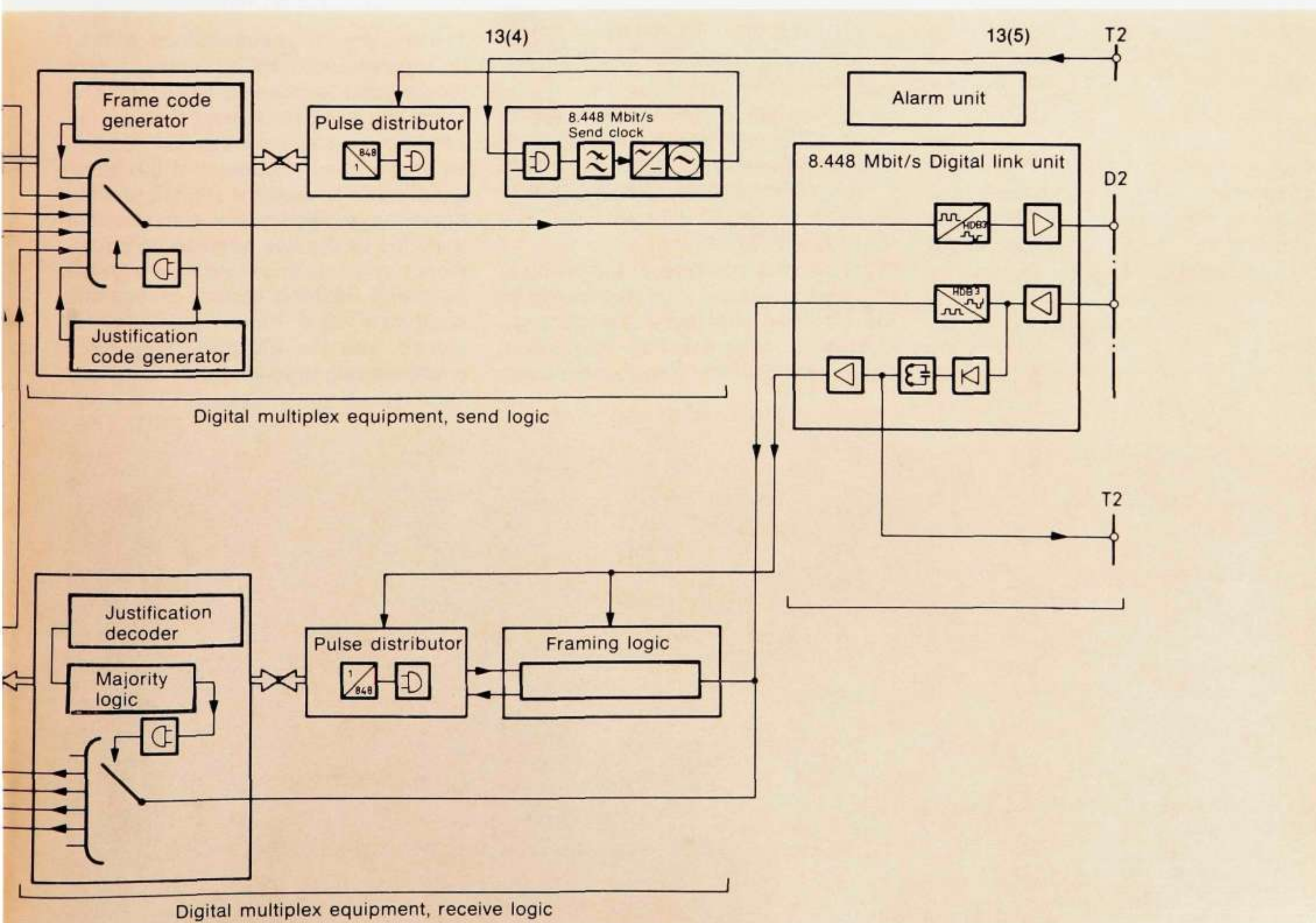


Fig. 13
Block diagram of second order multiplex equipment ZAK 30/120

Fig. 14

Connection of second order multiplex equipment to line system and other multiplex equipments





Mechanical construction

The mechanical construction is the same as for the PCM primary multiplex equipment ZAK 30/32. The unit and shelf design and the build-up of the racks are described in detail in Ericsson Review No. 2, 1972[3].

The second order multiplex equipment is contained in a shelf stack, the modem shelf stack shown in fig. 15, and consists of two shelves combined to form one mechanical unit with the addition of a ventilation unit. All the units with the exception of the DC converters are built up of standard printed board assemblies.

Line terminating equipment (LT)

The line terminating equipment has two functions, namely:

- adaptation of the digital line signal received from the multiplex equipment to the radio link baseband cable and vice versa
- termination of alarm signals, measuring the operational parameters of the radio-relay equipment, connection of the service channel and remote power feeding of the radio-relay equipment.

Different arrangements of the terminating equipment are used depending on the distance between the radio-relay equipment and the line terminating equipment and the type of cable used:

a) *The distance between the MUX and RL equipments is only a few metres.*

The line terminating equipment comprises a transformer unit, for impedance matching between MUX and the baseband cable to RL, and alarm and test units.

b) *The distance between the MUX and RL equipments is less than 2 to 3 km.*

The equipment in accordance with a) is supplemented by a digital repeater for the incoming signal and a connection unit, which contains overvoltage protection.

Tre radio-relay equipment is fed with power over the phantom circuit of the baseband cable.

c) *The distance between the MUX and RL equipments is more than 2 to 3 km. The baseband cable is equipped with one or more line repeaters.*

The equipment in accordance with b) is supplemented by a remote power feeding unit for the line repeaters. The radio link equipment must then be fed with power via separate cable pairs since the phantom circuit of the baseband cable is used for remote feeding of the line repeaters. It is also possible to divide up the line terminating equipment physically in accordance with the functions outlined above, so that the equipment for cable matching is placed with the multiplex equipment and the equipment for supervising and

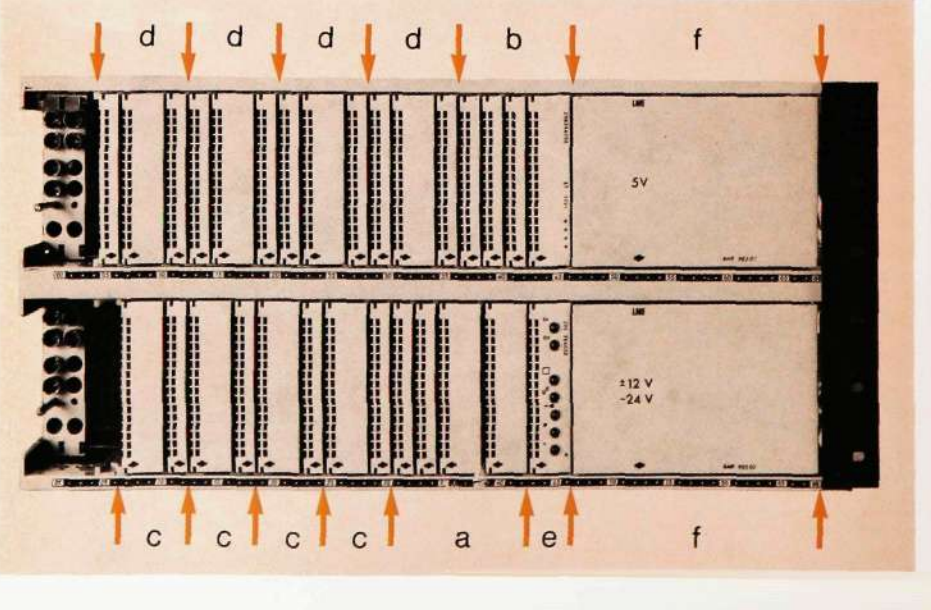


Fig. 15

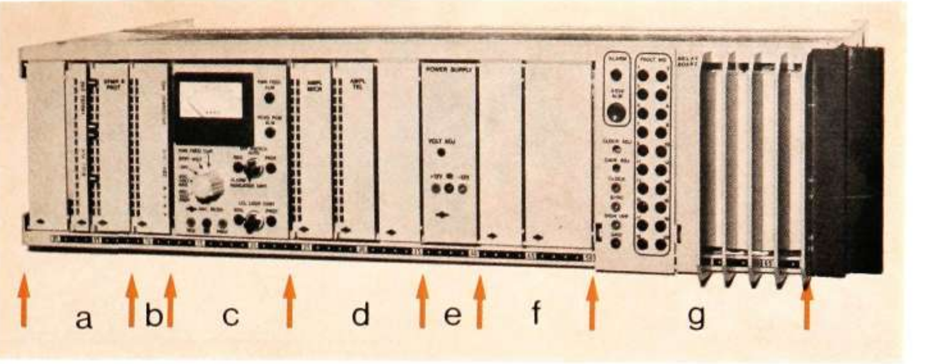
Mechanical construction of the second order multiplex equipment

a) Digital multiplexer, send logic
b) Digital multiplexer, receive logic
c) Primary group unit, send side
d) Primary group unit, receive side
e) Supervisory unit
f) DC converter +5 V and ±12 V

Fig. 16

Mechanical construction of the line terminating equipment

a) Cable connecting and matching units
b) Digital repeater
c) Alarm and test unit
d) Service channel units
e) Power supply for units a—d
f) Spare positions
g) Remote supervision units (including power supply)



feeding the radio-relay equipment is placed in its vicinity, if there is a suitable building available.

The mechanical design of the terminating equipment is the same as that for the multiplex equipment, that is to say, the functional units are built up as printed board assemblies that are placed in a shelf of standard size, fig. 16. The equipment in accordance with arrangements a) and b) is contained in one shelf. For arrangement c) two shelves are needed. The shelves may be mounted anywhere in the multiplex equipment rack but they can also be mounted separately in their own rack or wall-mounted frames.

Branching at repeater stations

The introduction of high order multiplexes in a digital network makes it essential to be able to branch off lower order bitstreams, for example when connecting together a number of exchanges along a common route, fig. 17. It may be a question of traffic between two adjacent exchanges (exchange 1 ⟷ exchange 2 in fig. 17) or/and traffic that goes to a superior exchange (exchange 2 → group centre in fig. 17). In digital networks both stop and leak dropping are used. As can be seen, this can be realized by using two digital multiplex equipments.

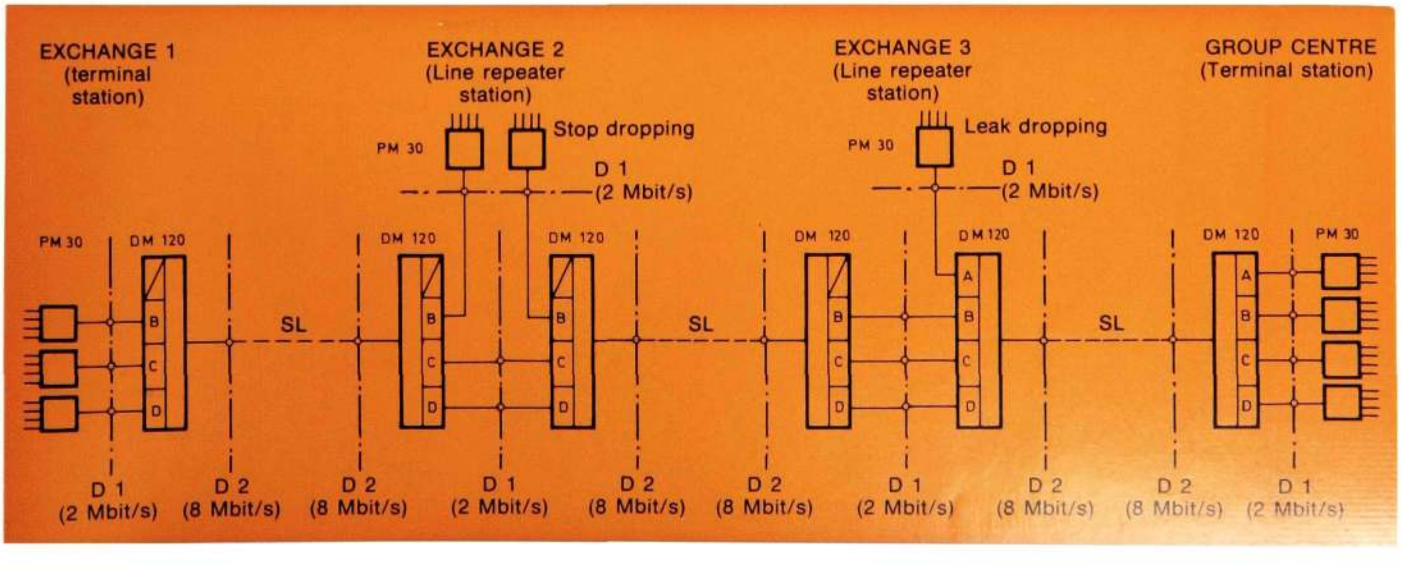
Studies of a number of networks show that leak dropping is often of value. In order to be able to offer a simple and economic solution, LM Ericsson have developed a method which permits leak dropping using only one digital multiplex equipment ZAK 30/120, fig. 18. This is achieved by utilizing the extra 8.448 Mbit/s interface D2B in the equipment, figs. 13 and 18. From a system point of view interface D2B has the same function as interface D1 for a primary system in the most distant exchange. In the 120-channel multiplexer at the exchange before this, a digital link adapter 2.048 Mbit/s is replaced by a digital link adapter 8.448 Mbit/s. Its interface D2B is connected to the 120-channel line system that connects this exchange with the one that follows. The associated buffer memory in the multiplex equipment is replaced by a special unit, the group synchronizing unit, which synchronizes the data flow coming into D2B with the data flow generated in the local multiplexer.

The combined pulse trains are taken via interface D2 to the next exchange. In fig. 18 the whole capacity is utilized up to the group centre, but this need not be the case. By introducing 120-channel digital multiplexers with associated line equipment at an early stage, the capacity can be increased successively as the traffic grows.

Fig. 17

Stop and leak dropping at repeater stations using two digital multiplex equipments

SL 8 Mbit/s line system
Radio link or cable
PM 30 PCM multiplex equipment for 30 telephone channels
DM 120 Digital multiplexer for 120 PCM telephone channels



Technical data

RADIO-RELAY EQUIPMENT

NERA 30-120/13G (RL)

System capacity	120 PCM telephone channels (8.448 Mbit/s)
Radio-frequency band	12.75—13.25 GHz
RF channel spacing	14 MHz
RF channel arrangement	CCIR Rec. 479
Modulation	2-PSK differential coding
Demodulation	Coherent

Interface between RL and baseband cable

Line code	HDB 3 or AMI
Impedance	120 Ω balanced
Pulse amplitude, RL output	± 3.0 V
Pulse amplitude, RL input	± 3.0 V
The RL input stage automatically equalizes a cable attenuation of related to 4.2 MHz	0—45 dB
Service channel	Frequency modulated

Transmitter

Nom. RF output power	+ 20 dBm
Frequency stability	$\pm 2 \cdot 10^{-5}$ over the temperature range — 40° C to + 55° C

Receiver

RF input level	— 20 to — 90 dBm
Bit error rate	$<10^{-3}$ at – 77 dBm $<10^{-6}$ at – 75 dBm
Noise factor	≤ 10 dB

Antenna

Type of antenna	Cassegrain, *dual polarised*
Antenna gain	1 m Ø: 39 dB 2 m Ø: 45 dB
Remote power feeding	
Voltage	— 48 V/— 60 V, + 20 % — 15 %
Current consumption	< 0.85 A
Power consumption	< 25 W
Weight	< 20 kg
Dimensions H × W × D	370 × 200 × 300 mm

LINE TERMINATING EQUIPMENT (LT)

Bit rate	8.448 Mbit/s $\pm 30 \cdot 10^{-6}$
Line code	HDB 3 or AMI

Interface between LT and MUX

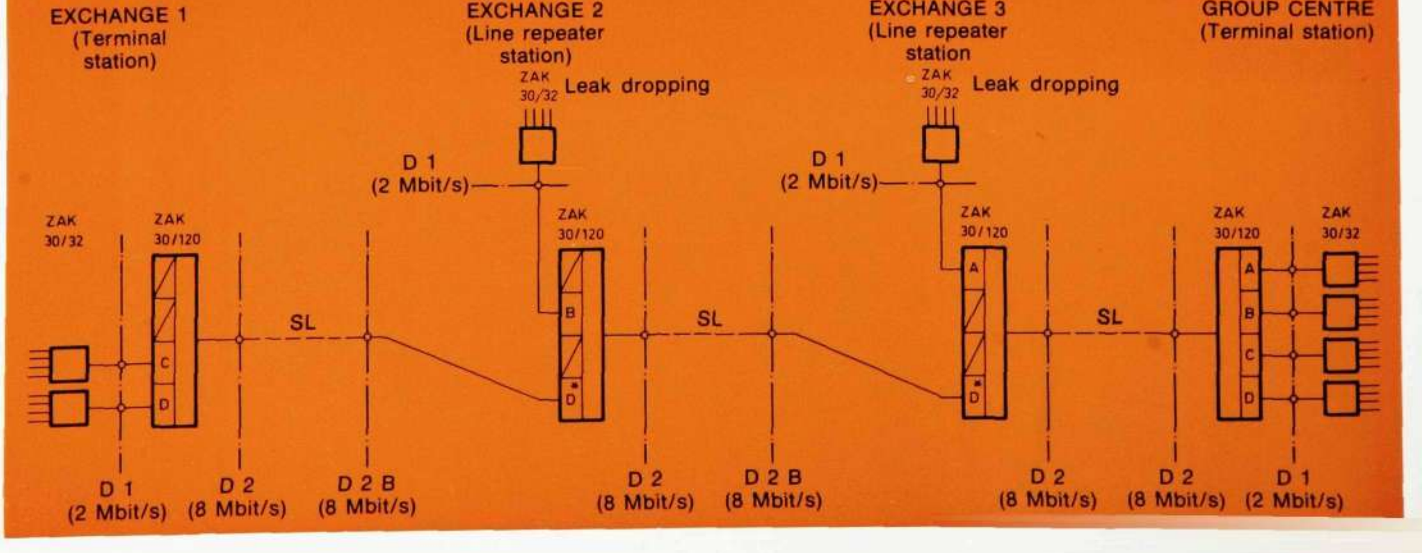
Pulse amplitude, LT output	± 2.37 V
Pulse amplitude, LT input	±1.19 . . . ±2.37 V
Impedance	75 Ω, unbal.

Interface between LT and baseband cable

Impedance	120 Ω balanced
Pulse amplitude, LT output	±3.0 V
Pulse amplitude, LT input without a digital repeater	±1.5 . . . ±3.0 V
with a digital repeater, nominal value	±3.0 V
The digital repeater automatically equalizes a cable attenuation of related to	0 . . . 45 dB 4.2 MHz

Fig. 18

Leak dropping at line repeater stations using LM Ericsson's digital multiplex equipments ZAK 30/120



DIGITAL MULTIPLEX EQUIPMENT MUX (including branching equipment)	
Primary systems that can be connected	4 × 30-channel systems in accordance with CCITT Rec. G.732
Mode of operation	Asynchronous with positive justification
Bit rate	8.448 Mbit/s ± 30 · 10^{-6}
Frame structure	CCITT Rec. G.742
Frame alignment strategy	CCITT Rec. G.742
Justification control	Single error correction of the justification message by means of majority decision
8 Mbit/s digital interfaces D2 and D2B	
Bit rate	8.448 Mbit/s ± 30 · 10^{-6}
Line code	HDB 3 or AMI
Pulse amplitude, input and output	± 2.37 V
Impedance	75 Ω, unbal.
Permissible attenuation of the input signal	0—6 dB
2 Mbit/s digital interface D1	
Bit rate	2.048 Mbit/s ± 50 · 10^{-6}
Remaining data as for D2	
Power supply	
Battery	— 24, — 36, — 48 or — 60 V
Mains connection to	110, 127 or 220 V a.c. (48—65 Hz)

Dimensions

The multiplex equipment consists of two shelves and one ventilation unit

H × W × D	280 × 480 × 326 mm

The multiplex equipment may be placed in the same rack as the primary multiplex equipment ZAK 30/32

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3. Lindquist, S., Frizlen, H.-J. and Carlsson, J. Å.: *PCM Multiplexing Equipment ZAK 30/32*. Ericsson Rev. *49* (1972): 2, pp. 34—46.
4. Arras, J. and Tarle, H.: *PCM Line Equipment ZAD 2*. Ericsson Rev. *49* (1972): 2, pp. 47—55.
5. CCIR — XIIIth Plenary Assembly (Geneva 1974), Vol. V (Study Group 5), Report 233—3.
6. CCIR — XIIIth Plenary Assembly (Geneva 1974), Vol. IX (Study Group 9), Report 610.
7. CCIR — XIIIth Plenary Assembly (Geneva 1974), Vol. IX (Study Group 9), Recommendation 497.
8. Bernemyr, R.: *Introduktion i PCM-transmissionsteknik*. TELE (1969) No. 3, pp. 4—10.

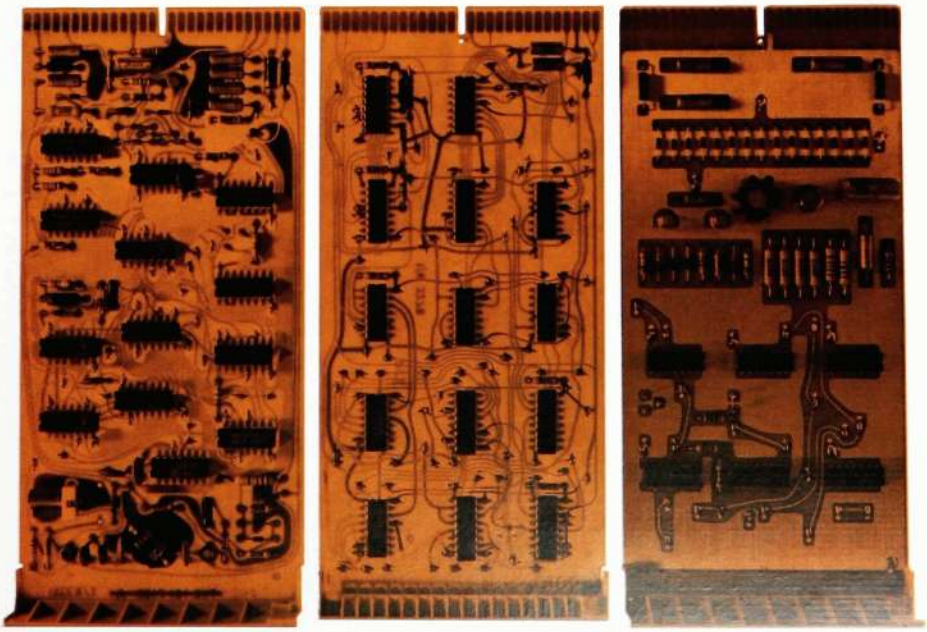


Fig. 19

Units for leak dropping, left to right: 8.448 Mbit/s digital link adapter, receive side; group synchronizing unit; 8.448 Mbit/s digital link adapter, send side

WORLDWIDE NEWS

From the Annual Report of the Ericsson Group:

Summary of the technical development during 1974

During 1974 LM Ericsson assigned a total of 410 MSKr for research and development. This corresponds to 7 % of the Group's sales. During recent years particularly large investments have been necessary within the field of automatic switching in connection with the development of the stored-program-controlled exchanges.

● Within the telephone exchange field several large computer-controlled automatic trunk exchanges were taken into service during 1974. The program volume was further increased to include new traffic cases.

● The first large installation with stored program control of an existing crossbar exchange was put into operation in Århus, Denmark, with very good results.

● Within ELLEMTEL work was continued on the development of a new computer-controlled local exchange system. The switching part of the system consists of a newly developed cross-point switch built up of small reed switches developed by RIFA. The system can alternatively be supplied with a digital group selector stage.

● In order to standardize the mechanical design of equipments of the future, ELLEMTEL have developed a new mechanical construction directly adapted to the requirements of modern telecommunication systems. With this construction plants can be built up on a modular basis with easily handled units.

● Within the field of traffic research may be mentioned studies concerning traffic supervision problems, optimization of the starting time for digit sending, methods for calculating the present value of replacement costs, investigation of telex traffic and analysis of data communication systems.

● Whithin the transmission field the parent company has developed a multiplex equipment that combines four 30-channel PCM systems to form a 120-channel system with a bit rate of 8.448 Mbit/s. The system is in accordance with CCITT recommendations and is primarily intended to work with radio links as the transmission medium.

In the Italian subsidiary company FATME the design was completed of a 24-channel carrier system for symmetrical cable pairs.

● During 1974 equipment was delivered to the Swedish Telecommunications Administration for a subscriber-controlled public data network that permits traffic between subscribers in Stockholm, Gothenburg and Malmö. The network is intended to provide experience for a future permanent subscriber-controlled data network. The major part of the equipment in the present network has been developed by ELLEMTEL.

● A valuable contribution to the many years of development work on picture telephones has been the field trials undertaken during the year, in which subscribers from the design, planning and production departments at the parent company's main plant have taken part. The trials demonstrated how picture telephones can be used to advantage in organizations and can save a considerable amount of time.

● Within the private branch exchange field the development of an electronically controlled private branch exchange ERITRONIC ASD 501 for 16 extensions was continued. The exchange, which requires no operators, was demonstrated as a prototype at the USITA exhibition in San Francisco, where it attracted great attention. The PABX is characterized by rapid installation and high operational reliability.

The development of a new central memory for the very largest types of private branch exchanges was completed, and the first prototype is to be delivered for field trials during 1975. The central memory provides the possibility of changing the number, class, night service, reference etc. of an extension from a terminal.

● During 1974 orders were received from the European space organization ESRO for over 10 MSKr for the development and manufacture of different units for the maritime communication satellite MAROTS and microwave antennas for another scientific satellite.

The LM Ericsson globe on the cover of the Annual Report exists in reality, in the form of large wall decorations at the airports of Stockholm, Malmö and Gothenburg

● The design work on a computer-controlled interlocking system continued in collaboration with the Swedish State Railways, SJ. The new system is to replace the existing relay interlocking system at large railway stations. In the railway signalling field the development of an ATC (automatic train control) system is in progress.

● Among the development projects in microcircuit technique at RIFA were the application of very thin epitaxial layers for obtaining high component density and the use of ion implantation for the production of high quality resistors in monolithic microcircuits.

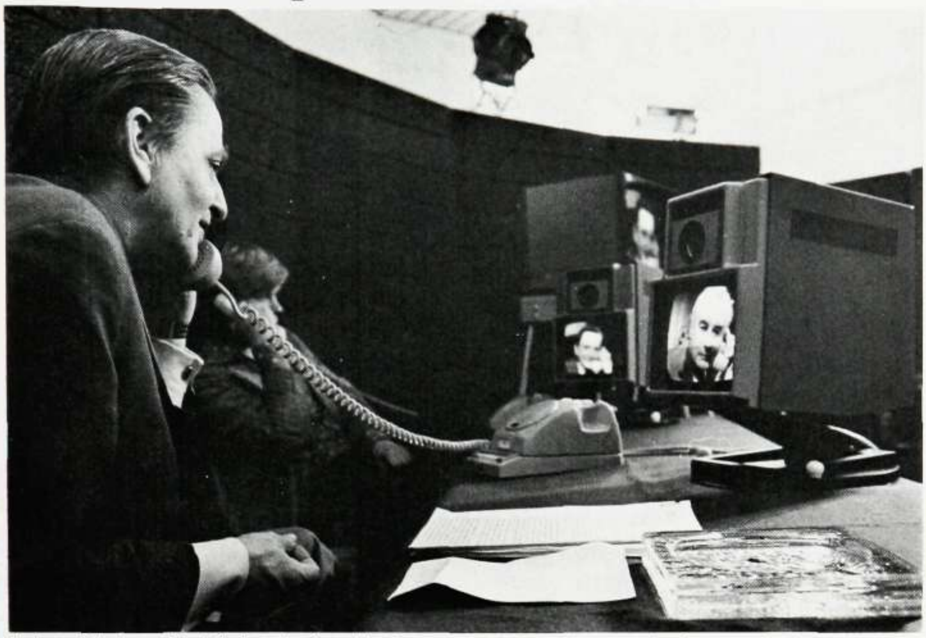
● Svenska Radio AB, SRA, concluded the development of a new mobile telephone for the manual public telephone network, which uses frequency synthesis and is switchable for up to 80 radio frequencies.

Marketing began of SRA's paging system ERICALL CONTACTOR.

● LM Ericsson Telematerial AB designed a new advanced fire alarm system, BRANDLARM 80.

A new alarm equipment for the safety supervision of large areas such as airports

Picture telephone call Stockholm—Melbourne opens technical week



Prime Minister Olof Palme in Stockholm converses via picture telephone with the Australian Prime Minister Gough Whitlam in Melbourne

A call was exchanged via an LM Ericsson picture telephone between the Swedish Prime Minister *Olof Palme*, in the new Parliament building in Stockholm, and the Australian Prime Minister *Gough Whitlam*, in Melbourne, to mark the opening of a Swedish technical week in Melbourne on the 26th of May. A number of Swedish companies, including LM Ericsson, took part. The visiting expert delegation was headed by the Swedish Minister of Labour *Ingemund Bengtsson*.

Addresses were delivered by Dr *Christian Jacobæus* of LM Ericsson Stockholm, "Some problems within the telecommunications field", *Göran Sundelöf* of LM Ericsson Stockholm, "The AXE telephone switching system — basic concept", *B. J. Mc Kay* LM Ericsson Australia, "Digital systems in telecommunication", and *P. B. Janson* LM Ericsson Telematerial AB Stockholm, "Intercom systems".

The picture telephone connection went via TV links between Sweden and Lille in France, over the English Channel to the ground station at Goonhilly, England, and then via satellite over the Indian Ocean to Australia and the earth station Ceduna near Adelaide. Then via APO links to Melbourne where the outside broadcast link of a TV company was used for the final stage of the connection.

Cont. from p. 90

was developed. The system is based on microwave technique.

- A new method of manufacturing vaseline-filled cables was developed on the basis of ideas that originated in the telephone cable division.
- The experimental resources of the Central Material Laboratory were augmented.

Modular component system for printed circuit boards

LM Ericsson have developed a component system, Modular Built Component System (MBC), for use particularly in printed board assemblies. The components are designed with the module M = 2.54 mm as the basic unit and are produced as single modules (4 × 3 M) and double modules (8 × 3 M) with a length of 6 M.

The system comprises test instruments, control and indicating devices. The components are built up on a graphite-coloured polyamide plastic base.

The securing method, with fixing pins for holding the components securely before soldering, is patented in most industrial countries. The tinned connecting wires are square-shaped to permit a number of different connecting methods, such as for example soldering or wrapping.

Network planning program delivered to ITU in Geneva

Development work in the field of network planning has been going on at LM Ericsson for many years and has to a great extent been carried out within the framework of a cooperation agreement in this field between the Swedish Telecommunications Administration and LM Ericsson. Theoretical studies by *Fried, Jacobæus, Rapp, Wallström* and others have provided models that have made possible correct dimensioning as well as optimization of exchanges and networks.

In the telephone traffic section at LM Ericsson a number of computer programs have been developed for studying different types of networks.

One of these programs, specially intended for the dimensioning of international networks, was prepared in connection with a study of the telephone and telex network in West Africa for ITU. This program has since been used for an ITU study of the Middle East and Mediterranean Telecommunication Network.

In order to simplify the work of ITU it was decided that this computer program should be entered on the ITU computer in Geneva. The program was formally handed over by LM Ericsson in connection with the first run.

The first computer results from the test run of the project "Middle East and Mediterranean Telecommunication Network" are studied at the ITU computer centre in Geneva by (from the left) T. Fried, ITU consultant (on leave of absence from LM Ericsson), M. Anderberg, LM Ericsson, R. Butler, Deputy Secretary-General of the ITU, C. Jacobæus, LM Ericsson, M. Mili, Secretary-General of the ITU, and L. Engvall, project leader at ITU. With his back to the camera I. Uygur, Head of the ITU Data Division

What happens when LM Ericsson celebrate their centenary?

Next year is centenary year for Telefonaktiebolaget LM Ericsson — the company is thus as old as the telephone. It was on April 1st, 1876 that Lars Magnus Ericsson set up a precision tool workshop in Stockholm, which was later to become the foundation on which the present parent company of the LM Ericsson Group was built up.

The various jubilee activities that are to take place to celebrate the centenary will to a great extent be directed towards the company's customers in different countries, with a view to strengthening even further the good personal relationships that already exist today.

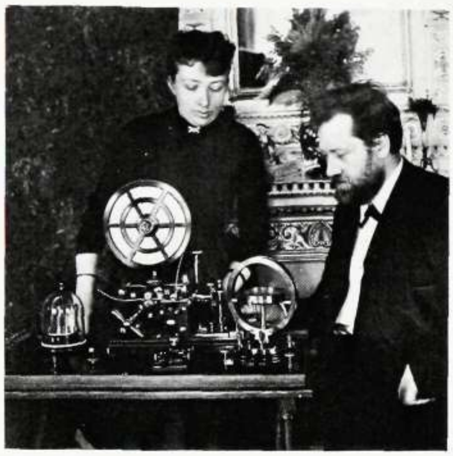
The main feature of the jubilee activities, with their "heavy" customer bias, is to be a symposium on telecommunication at which international experts will be the speakers. The symposium is to take place on the 4th and 5th of May.

Furthermore the international telecommunication prize, founded by LM Ericsson in connection with the centenary celebrations, is to be awarded for the first time. There is also to be a reinauguration of the LM Ericsson Memorial Room at the Technical Museum in Stockholm on May 5th, the birthday of Lars Magnus Ericsson.

On the same day a celebration dinner, to be attended by HM King Carl Gustaf of Sweden, is to be held at Stockholm Stadshus (Town Hall) for the symposium delegates, important customers and specially invited guests.

Among the more general activities during the jubilee year may be mentioned the publication of a book in three volumes entitled "LM Ericsson 100 Years". Two of the volumes are devoted to the company's economic and commercial activities and one volume to the technical development.

Two films are to have their premiére. One of these, with the title "On speaking terms", shows how LM Ericsson solve communication problems throughout the world. The other film is on historical, documentary lines and portrays the company's first 100 years against the background of world events during that period.



Lars Magnus Ericsson and his wife with a telegraph apparatus manufactured by the company

The jubilee year will also be reflected in Ericsson Review, among other things by the publication of a jubilee number containing papers read during the symposium and the speech of the winner of the LM Ericsson prize.

Other jubilee activities will be held specially for present and pensioned employees of the company. The form that these activities are to take is at present being investigated. The staff organizations are among those taking part in the investigation.

PABX to Alaska

LM Ericsson's French subsidiary company, Société Française des Telephones Ericsson, in collaboration with Ericsson Centrum Inc. in New York, have delivered a PABX of type CP 100 F for 1300 extensions to ALEYASKA PIPELINE SERVICE in Fairbanks. CP 100 F, which has a maximum capacity of 2400 extensions, is based on the crossbar switch technique and was developed and manufactured by the French company.

The exchange in Alaska has, among other features, 140 bothway junction lines for automatic traffic with 17 work camps engaged in the large pipeline project.

PABX to Poland

The largest private branch exchange that LM Ericsson have delivered to Poland hitherto, has been handed over to the state-owned iron works Huta Bieruta in the town of Czestochowa. The exchange was ordered by the Polish foreign trade organization ELEKTRIM.

The exchange is of the type AKD 791, which thus makes it debut on the Polish market. The plant in question comprises 2000 extensions and 94 exchange lines. The number of internal call possibilities is 142.

Only four operators are required to serve the 2000 extensions. This has been made possible by the fact that 30 of the incoming lines from the public network have been provided with direct in-dialling facilities, so that the extension numbers can be dialled direct without operator assistance.

New literature

Elementary Treatment of Reliability and Spare Parts Calculations is the title of a new compendium published by Telefonaktiebolaget LM Ericsson (No. T/S 7025-5 e). The language is English and the author Dr. *Branko Tigerman* of the Transmission Division in Stockholm.

The aim of the compendium is to explain in simple and elementary ways the more common reliability concepts. It is intended for all those who in their work require information and opinions in the fields of reliability and spares calculations, without being specialists in these fields.

In the main, the practical examples are taken from the transmission and carrier field.

Computer-controlled ARE 13 to Kuwait

LM Ericsson have received another large order from the Kuwait Ministry of Communications. The order is for a new stored-program-controlled, international transit exchange with crossbar switches, type ARE 13, for both fully automatic and manually handled traffic. The exchange includes equipment for 1400 international lines, mainly satellite circuits to all continents.

The order also includes a new processor-controlled toll ticketing system for both the fully automatic and manually handled traffic and modern operator consoles with display panels for the calling and called subscriber numbers etc.

The exchange is controlled by processors in the control equipment ANA 30, which belongs to the same family as the control equipment in the local exchange system ARE 11. ARE 13 also includes a new version for national traffic.

Since 1966 Kuwait has been an important market for LM Ericsson. During 1973 and 1974 the company received orders worth a total of 85 MSKr.

A traffic control processor in system ARE 13

The Ericsson Group

With associated companies and representatives

EUROPE

SWEDEN

Stockholm
1. Telefonaktiebolaget LM Ericsson
2. L M Ericsson Telemateriel AB
1. AB Rifa
1. Sieverts Kabelverk AB
1. Svenska Radio AB
5. ELLEMTEL Utvecklings AB
1. AB Transvertex
4. Svenska Elgrossist AB SELGA
1. Kabmatik AB
4. Holm & Ericsons Elektriska AB
4. Mellansvenska Elektriska AB
4. SELGA Mellansverige AB

Alingsås
3. Kabeldon AB

Gothenburg
4. SELGA Västsverige AB

Kungsbacka
3. Bofa Kabel AB

Malmö
3. Bjurhagens Fabrikers AB
4. SELGA Sydsverige AB

Norrköping
3. AB Norrköpings Kabelfabrik
4. SELGA Östsverige AB

Nyköping
1. Thorsman & Co AB

Sundsvall
4. SELGA Norrland AB

Uddevalla
4. Wamebolaget AB

EUROPE (excluding Sweden)

DENMARK

Copenhagen
2. L M Ericsson A/S
1. Dansk Signal Industri A/S
3. GNT AUTOMATIC A/S

FINLAND

Jorvas
1. Oy L M Ericsson Ab

FRANCE

Paris
1. Société Française des Téléphones Ericsson
2. Thorsmans S.A.R.L.

Boulogne sur Mer
1. RIFA S.A.

Lannione
6. Société Lannionaise d'Electronique SLE-CITEREL

Marseille
2. Etablissements Ferrer-Auran S.A.

IRELAND

Dublin
1. L M Ericsson Ltd.
2. Thorsman Ireland Ltd.

ITALY

Rome
1. FATME Soc. per Az.
5. SETEMER Soc. per Az.
2. SIELTE Soc. per Az.

NETHERLANDS

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1. *Ericsson Telefoonmaatschappij* B.V.

NORWAY

Oslo
3. A/S Elektrisk Bureau
2. SRA Radio A/S
4. A/S Telesystemer
4. A/S United Marine Electronics

Drammen
3. A/S Norsk Kabelfabrik

POLAND

Warszaw
[illegible]

PORTUGAL

Lisbon
2. Sociedade Ericsson de Portugal Lda

SPAIN

Madrid
1. Industrias de Telecomunicación S.A. (Intelsa)
1. L M Ericsson S.A.

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Zurich
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Horsham
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2. Swedish Ericsson Rentals Ltd.
5. Swedish Ericsson Company Ltd.

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3. Thorn-Ericsson Telecommunications (Mfg) Ltd.
6. Thorn-Ericsson Telecommunications Ltd.
4. United Marine Leasing Ltd.
4. United Marine Electronics (UK) Ltd.

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Hamburg
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Hanover
2. Ericsson Centrum GmbH

Lüdenscheid
2. Thorsman & Co GmbH

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Buenos Aires
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1. Sales company with manufacturing
2. Sales and installation company
3. Associated sales company with manufacturing
4. Associated company with sales and installation
5. Other company
6. Other associated company
7. Technical office

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