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RESPONSIBLE PUBLISHER: HUGO LINDBERG

EDITOR: SIGVARD EKLUND, DHS

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On cover: One of the large parabolic reflectors at Santa Elena, Colombia, 2,800 metres above mean sea level.

Long Distance Telephone Network in Colombia

E ANDERSEN, T BOHLIN, J ERIKSSON, E SAULEDA, TELEFONAKTIEBOLAGET L M ERICSSON, STOCKHOLM

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A comprehensive long distance telephone network with circuits between Colombia's most important cities has been built by the L M Ericsson Telephone Company for the Empresa Nacional de Telecomunicaciones. At the same time a large number of the long distance exchanges have been mechanized using L M Ericsson's crossbar switch systems. The country's telecommunications facilities have thereby been significantly improved, a factor which actively contributes to rapid economic development.

1. Radio and Carrier Equipment

General

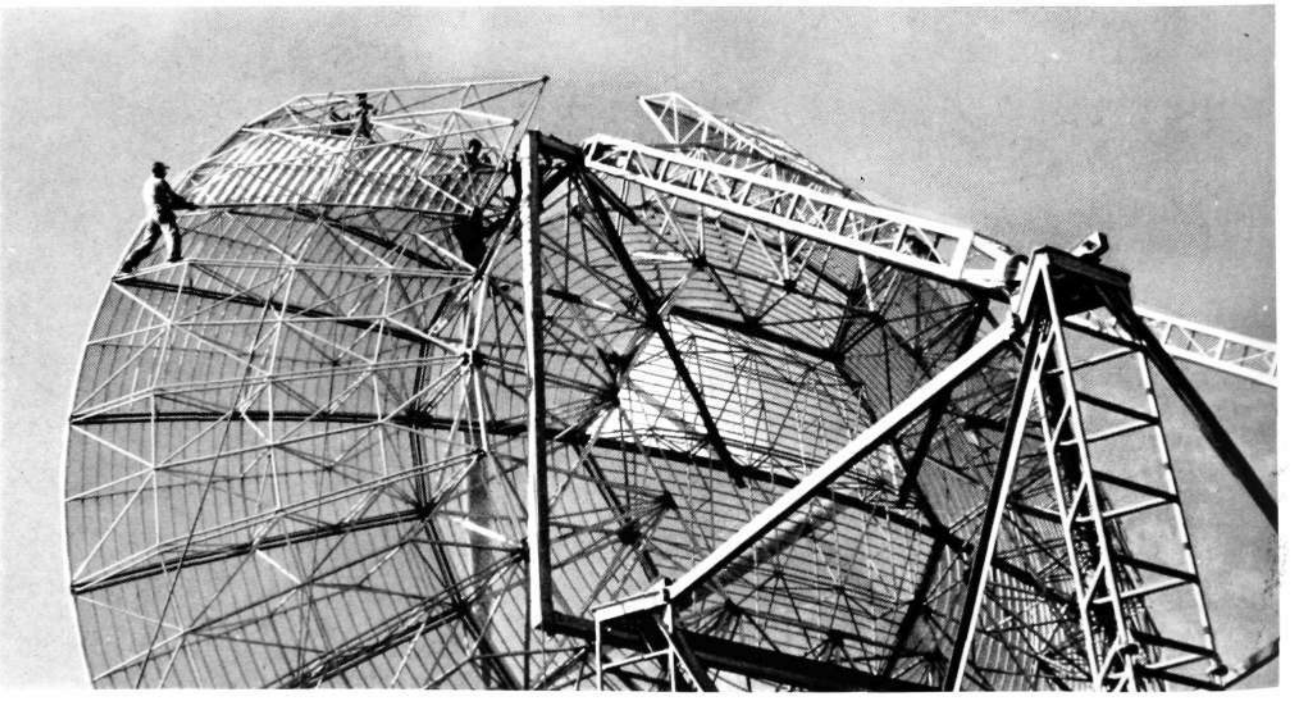
Starting already 1948, L M Ericsson had built the greater part of the Colombian long distance network i.e. the circuits between the country's most important cities. All these circuits use radio links in the VHF range as bearers, with associated multiplex equipment for up to 96 telephone circuits. Certain telephone channels are used for telegraphy.

The first VHF link was put into service in 1950 between Bogotá and Medellín and then Bogotá–Cali followed in 1954, Bogotá–Barranquilla in 1956, etc. All this work has been carried out under several contracts which over the course of years have been made between the Colombian State Telephone Administration (Empresa Nacional de Telecomunicaciones) and L M Ericsson.

The improvements in telecommunications facilities are appreciable. For example, it can be mentioned that before the commissioning of the radio link in 1956, the important route Bogotá–Barranquilla consisted of only two short-wave radio-telephone circuits, giving only moderate speech quality,

Fig. 1
Parabolic reflector

X 7896



which was to be expected of this type of circuit. Although the route today contains 60 high quality circuits there is a demand for an appreciable increase in number in the near future. The traffic demand on the other routes has also grown so rapidly that a transition from 96-circuit VHF links to 960-circuit SHF links is imminent on some of the most important ones.

The radio equipment installed by L M Ericsson was supplied by the Radio Corporation of America (RCA) and operates in the frequency range 235–300 Mc/s. The transmitter output power is 50 W. The equipment is duplicated and is provided with an automatic changeover facility from main to stand-by, a fault warning system and a service channel.

The multiplex equipment for telephony and v.f. telegraphy was supplied and installed by L M Ericsson. 96-circuit carrier systems are used for telephony and any telephone channel can carry 18 v.f. telegraph channels.

L M Ericsson has also installed the power supply equipment for the intermediate repeater stations of the radio links. This equipment was supplied by the Allmänna Svenska Elektriska AB (ASEA, Sweden) and is provided with flywheel generator sets with no-break changeover to the stand-by equipment. Most repeater stations, i.e. those not supplied from the public power supply mains, are provided with three diesel generator sets.

Some of the roads to the repeater stations have been built by L M Ericsson. This is also the case with some of the buildings for radio and power supply equipment.

In certain cases, cables have been used instead of radio links for the entrance arrangements to cities. These cables in which a frequency band of 300 kc/s is used have been installed by L M Ericsson.

All contracted guarantees concerning the technical performance of the equipment have been fulfilled with a good margin when making acceptance tests.

For the three longest circuits, the guarantee values of the signal-to-noise ratio were

Bogotá–Barranquilla, west route	51 db
Bogotá–Barranquilla, east route	54 db
Medellín–Barranquilla	56 db

According to the contract, these guarantee values were to apply at the acceptance tests for a period of three arbitrarily selected hours during each of seven consecutive days and be fulfilled for 99 % of the total time of 21 hours. The radio baseband was loaded with + 8 dbm0 white noise during these tests. According to the contract, the transmission tests were to be carried out during a period of 28 days and during this time the performance figures were to keep within the limits stipulated in the contract.

Among other gurantee values it can be mentioned that the maximum variation of circuit equivalent was not permitted to exceed ± 1.5 db including the variation due to changing over from any main radio equipment to its stand-by. As the circuits were provided with compandors, this meant that the variation of equivalent was not permitted to exceed ± 0.75 db.

Radio Equipment

The radio link network consists of different types of radio stations depending on whether these act as terminals or as repeaters with or without branching.

The radio system is composed of main and stand-by equipment for the respective directions. Each terminal station consists of three bays in a row.

The outer bays contain duplicated sending and receiving equipment with individual power supply. The middle bay contains equipment for automatic changeover between these two and further a fault warning system, a service channel and certain amplifier panels for patching the different speech directions.

The antennas used are of different designs depending on the hops to be covered. The types used vary from a simple Yagi to parabolic mirrors of up to 18 metres diameter, see fig. 1. The antennas are fed by an air-insulated coaxial cable having a low attenuation of about 0.02 db/metre. Transmitters and receivers have a common antenna and the system is therefore provided with directional filters. These filters are designed as cavity resonators in order to meet the high attenuation requirements placed on them due to the large difference in level between transmitter output and receiver input. The sending side is provided with a filter of band-pass type for the transmitted band and stop filter for the receiving frequency while the receiving side has only a stop filter for the sending frequency.

The multiplex baseband is sent directly to the transmitter frequency modulator. This modulator consists of two reactance tubes connected in parallel across the oscillator circuit so that one tube acts as an inductive reactance and the other as a capacitive reactance. The frequency modulated oscillator is provided with automatic frequency control governed by a reference crystal.

The modulated signal and therefore the frequency is multiplied 16 times during its passage through four doubler stages. It is then tripled, i.e. the original frequency is multiplied 48 times, before being applied to the output stage. The antenna absorbs 50 W output power in the VHF band.

The receiver, which transposes the signals from the VHF band to the baseband, consists of a low-noise RF amplifier followed by a crystal controlled mixer stage giving an intermediate frequency of 32 Mc/s. This is amplified and then limited using diodes. The baseband is finally obtained from a staggered discriminator. To compensate the changes of level which can occur with different reception conditions, the baseband level is maintained constant with the help of an automatic level regulator controlled by a 308 kc/s pilot frequency which is injected into the baseband. The regulator is followed by a baseband amplifier from which the multiplex terminal is fed.

At repeaters, the received signal is applied to the next transmitter at intermediate frequency, thereby avoiding demodulation to baseband. The discriminator and frequency modulator are, however, used for the service channel. At stations where no branching is expected, the frequency modulator is replaced by a crystal controlled phase modulated driver stage.

Changeover from main to stand-by equipment is carried out automatically when there is a fault on a transmitter or receiver and the action is remotely reported to the terminal station using an automatic code signal. In this way, the faulty repeater can be located directly at the terminal. In addition to the reports which come from the radio equipment itself, other information can be remotely reported, e.g. changeover of power supply, abnormal temperature rise etc.

The panels are provided with measuring instruments for checking tube cathode currents, incoming v.f. signals, power output to the antenna etc.

The frequency bands used in the system and the location of the antennas and their polarization have been studied in detail with regard to the interference which can occur between different links, especially at such places as El Ramo and El Picacho, where seven and six transmitters respectively operate simultaneously.

Carrier Equipment

The carrier plant of the long distance network consists of telephone equipment required for frequency translation between the speech band and the radio baseband, and also telegraph equipment for translation of d.c. pulses to v.f. pulses in the speech band. Trunk test boards with built-in measuring equipment and bays containing separating filters for splitting up the radio baseband and distribution in different directions are also included in the equipment. The required branching of the network has been obtained at quite low cost with the help of these filter bays.

A number of rearrangements of the existing equipment have been carried out in connexion with the installation of the carrier terminals, so that this equipment together with new equipment form a unified repeater station with centralized station alarm, trunks etc.

The carrier equipment is mounted on standardized frames and is designed in the form of plug-in units.

Each bay is provided with its own power supply unit which converts the mains supply voltage to the requisite bay voltages. These are distributed to the bay units via fuses in a current distribution panel. A blown fuse causes a bay and station alarm to be given, indicated by a bell and lamps. All tube currents can be read off on a meter situated in the current distribution panel.

The frequency translation between the speech band and the radio baseband normally occurs in four stages of modulation. The required carrier frequencies are derived from a crystal controlled master oscillator having a frequency stability better than 1 part in 10^6. The crystal is located in a thermostatically controlled oven, the temperature of which is maintained constant to within $\pm 1^\circ$ C. The carrier frequencies are generated in harmonic generators, separated in highly selective band-pass filters and amplified. A complete station is usually fed from a single oscillator equipment which if greater reliability is required is duplicated to give a regular and a stand-by set. When a fault occurs on the regular oscillator, automatic changeover to the stand-by is carried out and an alarm is given simultaneously. The changeover occurs rapidly and does not cause any interference to traffic in progress.

A signalling repeater is provided on the exchange side of each circuit. The circuits are normally built for four-wire operation. At certain small exchanges with manual operation, each signalling repeater is connected two-wire to the exchange.

The bays have been provided with level measuring equipment for measuring transmission, pilot and carrier levels, which covers the normal requirements of maintenance and operation. Voice frequency measurement is carried out using a test tone.

Talking, monitoring and signalling from any channel translating bay can be carried out with the help of a monitoring panel. Several trunk lines are included to permit interconnexion between bays and the trunk test board and also between rows of bays. The trunks are provided with lamps for denoting when they are engaged.

The telegraph equipment of the carrier network permits 18 frequency modulated telegraph channels to be accommodated in the band afforded by a telephone channel. The equipment is subdivided into three groups of six channels. Conversion of d.c. pulses to v.f. pulses occurs in the channel oscillator, the frequency of which is changed at $\pm$ 30 c/s in step with the impulsing, by using static relays. The equipment follows the CCITT recommendations and is intended for a normal teleprinter speed of 50 bauds, but can be used up to 80 bauds. Interference-free transmission is obtained as the frequency modulation permits amplitude limitation on the receiving side.

The telegraph currents can be read off on instruments in the bay and these currents can be adjusted to the prescribed values by using built-in potentiometers, therby obtaining at the same time the correct frequency shift on the sending side. A pulsing direct current is obtained from a generator which is also built into the bay, thereby permitting a rapid check of a telegraph channel to be carried out.

Power Supply Equipment

Eleven important junctions in the radio link network situated at heights varying from a few hundred metres up to 4,000 metres are so inaccessible that they cannot be supplied from a power line reasonably economically. They have therefore been provided with individual diesel electric generator sets. At each of these stations there are three identical sets, one of which supplies power continuously, one is on stand-by and the third can, if necessary, be undergoing maintenance. When it is not undergoing maintenance, it is also on stand-by and if due to a fault the first set stops or must be stopped, the other two sets start up and the first of these to reach the operating voltage takes over the load while the other stops again. In this way the power supply system is made very reliable.

Between the load (radio transmitters, etc.) and the three generator sets feeding a common three phase busbar there is a flywheel motor generator set. Because of its inertia and its rapid-acting, accurate voltage regulator, the flywheel set isolates the radio equipment from short-term disturbances on the generator side. Sufficient energy is also stored in the flywheel to bridge over the starting time of the diesel generator sets without any interruption, should there be a disturbance in the regular set leading to changeover to one of the stand-by sets. The flywheel set consists of a flywheel and axle running in two bearings. Connected to each end of the axle there is an armature rotating in a stator secured to the bedplate. One of the assemblies forms a 3-phase asynchronous motor operating from the motor generator busbars. The other assembly forms a single phase synchronous generator supplying power to the radio equipment. The flywheel is sufficiently large to supply full power to the radio equipment for 30 seconds should there be a changeover or fault on the diesel generators. During this time the voltage is maintained constant whereas the frequency falls continuously from 60 c/s down to 48 c/s.

There is no stand-by for this no-break power unit, but when compared with the diesel motors, it is extremely reliable and has very long operating time between overhauls. On the rare occasions when it has to be taken out of service, the radio equipment can be connected directly to the diesel generator busbars which also have sufficiently close voltage regulation, about $\pm 2\ \%$, for the purpose.

The whole power supply equipment including the no-break power set is completely automatic and provided with a comprehensive coarse regulating system which makes it practically foolproof.

Power plant has been installed by L M Ericsson at a few additional places where the radio link system is fed from the local supply mains. At these places there is only one diesel generator set as stand-by for the local mains, but otherwise the equipment is the same. When the diesel generator set, which of course is only the stand-by, has to undergo its periodic overhaul, it is replaced by a mobile set, thus ensuring a permanent stand-by.

All the stations are fully automatic. The voltage and frequency are controlled by sensitive regulators but are also supervised by special units to ensure that their values always lie within certain stated limits. In a well designed system, certain functions are checked so that when there are disturbances in the power system no values of frequency or voltage occur which can be dangerous for the flywheel generator set or radio equipment. It has therefore been arranged that any diesel generator is stopped immediately the permissible limits of frequency, r.p.m. or motor temperature are exceeded or if the oil pressure in the bearings falls below an acceptable value. Fault warnings are sent over the radio link to attended supervision points in the network. The sizes of the power plant vary from 6 kVA to 25 kVA. Having regard to the energy needed to reaccelerate the flywheel generator set after a fault and the frequently high operating altitude, however, the diesel motors must be made for considerably higher output powers. Thus, the nominal power of a diesel motor driving a 25 kVA flywheel set at 4,000 metres altitude is about 100 h.p.

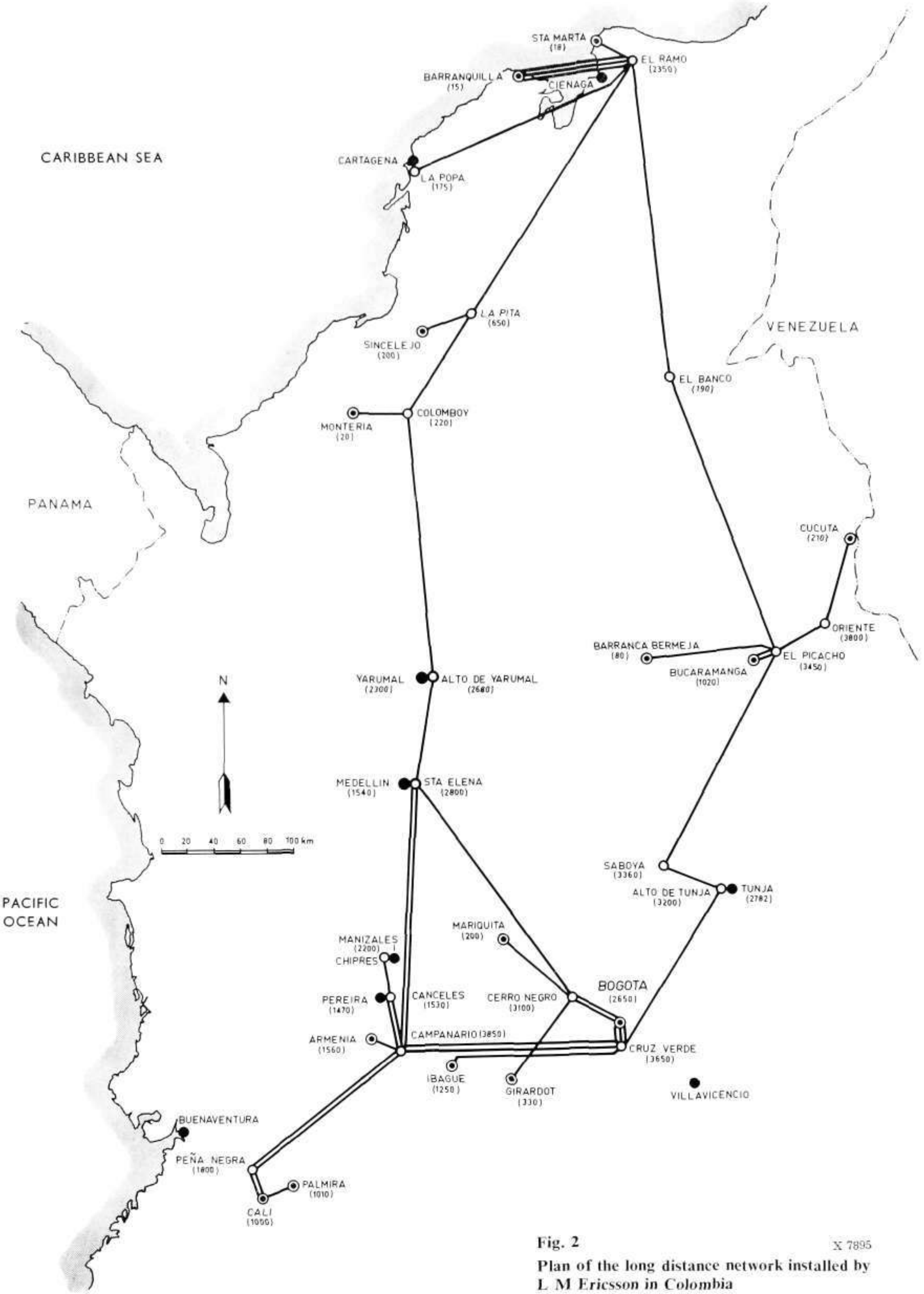


Fig. 2 X 7895

Plan of the long distance network installed by L M Ericsson in Colombia

—	Radio link
⊙	VHF radio and carrier terminal
O	*VHF radio repeater or terminal*
●	Carrier terminal
●O	Cable circuit
(18)	denotes height in metres above mean sea level

2. Automatization of the Long Distance Network

Introduction

A large part of the Colombian long distance network has been automatized in recent years. This was made possible both through the installation of the radio links and carrier equipments referred to in the first part of this article and through the acquisition by Empresa Nacional de Telecomunicaciones of a number of automatic trunk equipments for the larger and more important places in the country. The planning of the long distance network has been based on the traffic facilities offered by the automatic trunk exchanges.

Since 1961 a successive conversion has taken place from manual to outgoing semiautomatic service with automatic transit traffic on the more important trunks. Twenty-five of the largest towns had been linked up with the semiautomatic system by 1963.

Subscriber-dialled long distance traffic has also started and will be successively extended as new trunk circuits are installed and as the many local exchanges not belonging to Empresa Nacional de Telecomunicaciones are provided with the necessary circuits to the trunk exchanges and with trunk charging equipment.

The new trunk equipments have been supplied by L M Ericsson. They comprise automatic equipments of system *ARM 20* for places with large transit traffic and manual equipments of system *AFA 10* for areas with chiefly terminating traffic. The *AFA 10* exchanges are, however, equipped for automatic incoming and semiautomatic outgoing traffic.

Extent of the Automatic Network

System *ARM 20* automatic trunk exchanges have been installed in the following towns:

Bogotá	Switch	capacity	2,200	lines
Cali	»	»	1,200	»
Medellín	»	»	1,000	»
Barranquilla	»	»	1,000	»
Bucaramanga	»	»	400	»
Pereira	»	»	400	»
Armenia	»	»	400	»
Tunja	»	»	200	»

Trunk exchanges of system *AFA 10* have been supplied to 17 places as marked on the map in fig. 3.

The first step in the conversion is to semiautomatic operation. The reason why Empresa Nacional de Telecomunicaciones decided on this intermediate phase before going over to subscriber-dialled long distance traffic was chiefly that almost all local exchanges in the country belong to other administrations and that they require large numbers of junctions to the trunk exchanges as well as trunk charging equipment before subscriber-dialled operation can be introduced. An extensive alteration of the tariffs is also required.

The introduction of semiautomatic trunk traffic in the first stage requires only minor additions to the local equipments and allows the local administrations better time to procure the equipments needed for long distance subscriber dialling. At the same time better opportunities will be afforded for studying

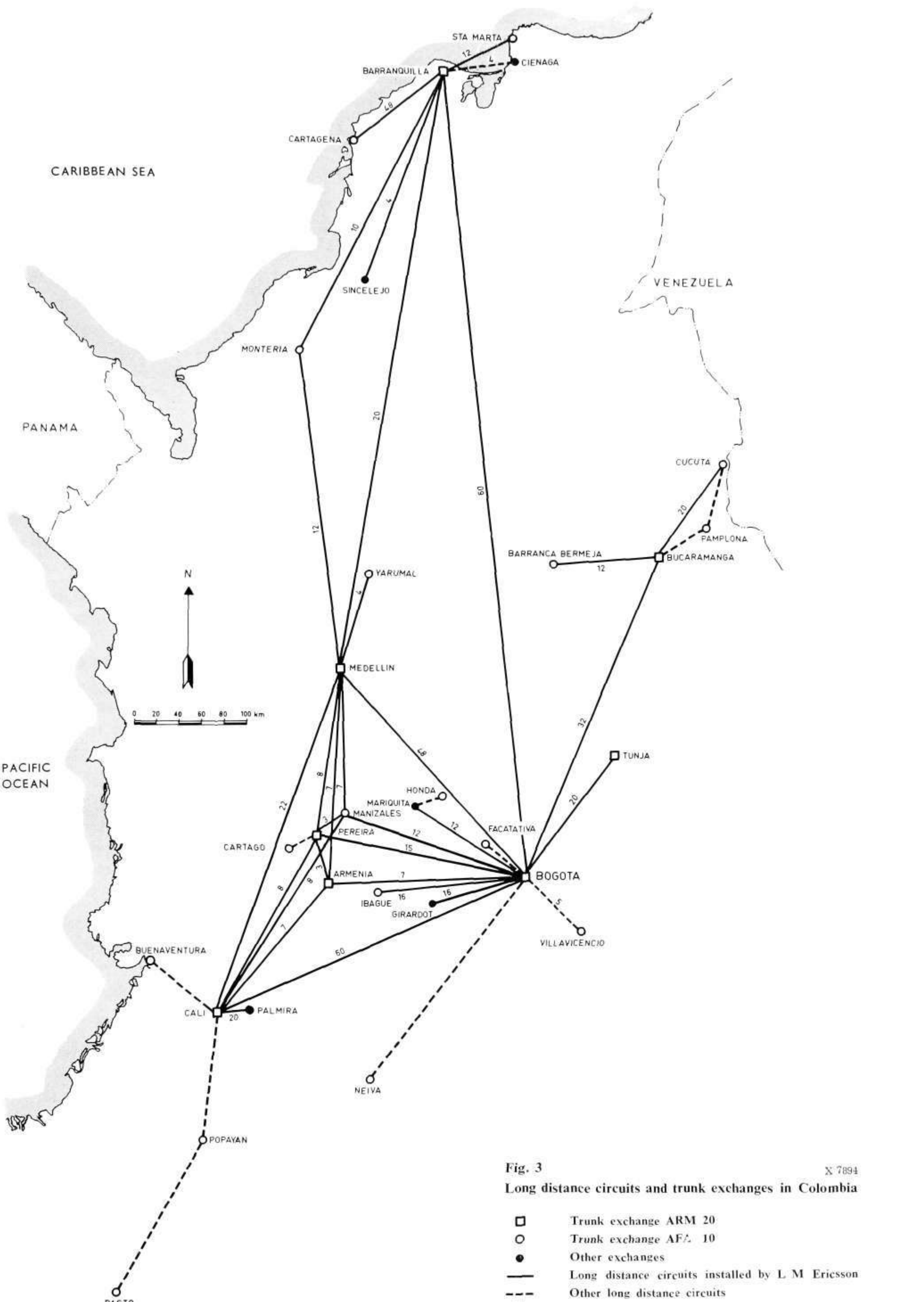


Fig. 3 X 7894

Long distance circuits and trunk exchanges in Colombia

- □ Trunk exchange ARM 20
- ○ Trunk exchange AFA 10
- ● Other exchanges
- —— Long distance circuits installed by L M Ericsson
- - - - Other long distance circuits
- 22 Number of telephone circuits

Fig. 4
The operators' positions at Bogotá

X 8455

the tariff questions and the methods of settlement between Empresa Nacional de Telecomunicaciones and the local administrations, as well as the traffic requirements of the long distance network.

The semiautomatic traffic will be handled on a demand basis on the record circuits insofar as the capacity of the trunk network allows, and verification of the calling subscriber will be used only for a small number of connections.

The *ARM 20* exchanges have cordless positions for all classes of traffic requiring an operator, i.e. outgoing semiautomatic long distance, manual long distance, and in Bogotá also the international traffic. All incoming traffic and the transit traffic from the semiautomatic trunk circuits will be handled on an automatic basis. The *ARM* exchanges are prepared for subscriber-dialled traffic and require only the addition of junction equipments which can receive numerical information from the local exchanges and send metering pulses to them.

The *AFA 10* exchanges have been installed at places with chiefly terminating traffic. They are equipped with cord positions. The incoming traffic is switched automatically to the local subscriber without operator assistance. The very small transit traffic that may occur at these places will be handled manually. This type of exchange as well can be supplemented for subscriber-dialled traffic.

As regards transmission and classification of trunk calls, numbering, metering and traffic questions, and to some extent administrative questions, the Colombian network is divided into regions, zones and group areas. The automatic trunk exchanges have been installed in the planned regional centres, and in some cases in zone centres with high transit traffic.

Technical Facilities of the Automatic Trunk Switching System ARM 20

Transit calls are switched automatically and always on a four-wire basis between two long distance circuits. All circuits are therefore connected on four wires to the exchange equipment. The existing two-wire physical circuits have hybrid repeaters and in some cases terminal repeaters.

Long distance calls are register-controlled and numerical information is sent on the trunk circuits in multifrequency code, 2 out of 6, between the registers. The originating long distance register is connected to the circuit during the entire switching time and sends the necessary information to the transit and terminal registers concerned, i.e. the area code is repeated to all transit points and the local subscriber's number is sent only after connection has been established with the remote terminal exchange.

For line signalling, i.e. the supervisory signals before and after setting up of the connection, discontinuous single-frequency signals are used in the speech band, but the exchange equipments also allow connection to systems with outband signalling.

A survey of the signal elements for line signalling at 2,400 c/s and of the register signalling frequencies is shown in fig. 5.

The trunk exchanges incorporate alternative routing. Apart from direct trunks, the system has facilities for selection of four other alternative routes in a predetermined order. The alternative routing has permitted an improved economic structure of the long distance network. Direct trunks can be introduced to a considerable extent and be designed for high utilization since the overflow traffic is directed to alternative routes common to several direct routes. The latter will thus be economical even for small groups of circuits. Alternative routing increases the total traffic capacity of the network since the traffic on the alternative routes is composed of the overflow traffic from a large number of direct routes; the traffic peaks on different routes, moreover, will probably not coincide even within coincident busy hours, and the busy hours on certain groups of routes occur at different times of the day. This means that the alternative routes need not be designed for the traffic peak of each single route. Should a breakdown occur on certain routes, the traffic should to a large extent flow normally by being automatically redirected to an alternative route.

Long distance connections can be switched over a number of circuits in series, and the system is therefore equipped with devices which prevent switching to and fro on the same route. The controlling register also checks that the predetermined maximum number of circuits of different classes is not exceeded.

The system has facilities for automatic switching in and out of pads, which permits the long distance network to be constructed on the VNL principle.

The trunk exchanges are so designed that, with low internal congestion, they provide full availability even with a large number of circuits on a route. This ensures the highest circuit utilization attainable in practice.

The switching stages are designed for two-way traffic, which means that a two-way circuit requires only one termination in the multiple.

The system provides for individual selection of all connected circuits. This facility is used both for order wire calls between operators within the same exchange and at different trunk exchanges, and for transit connections to manual trunks tied to a particular assistance operator. Above all, the individual selection facility permits connection of automatic test units for transmission measurements on all long distance circuits in the network that are accessible from the trunk exchange.

Incoming trunk circuits are switched automatically to the terminating subscriber's line. The registers at the terminating trunk exchange are equipped for sending the numerical information on the signalling principles required by the respective local exchanges. Conversion of the local exchange line signalling to the trunk signalling scheme is done in the junction relay sets at the trunk exchange. Colombia has different local exchange systems, and the trunk exchanges are designed to interwork with, among others, step-by-step, machine-driven and MFC register signalling systems. Modifications of the local systems could thus be limited and often avoided altogether.

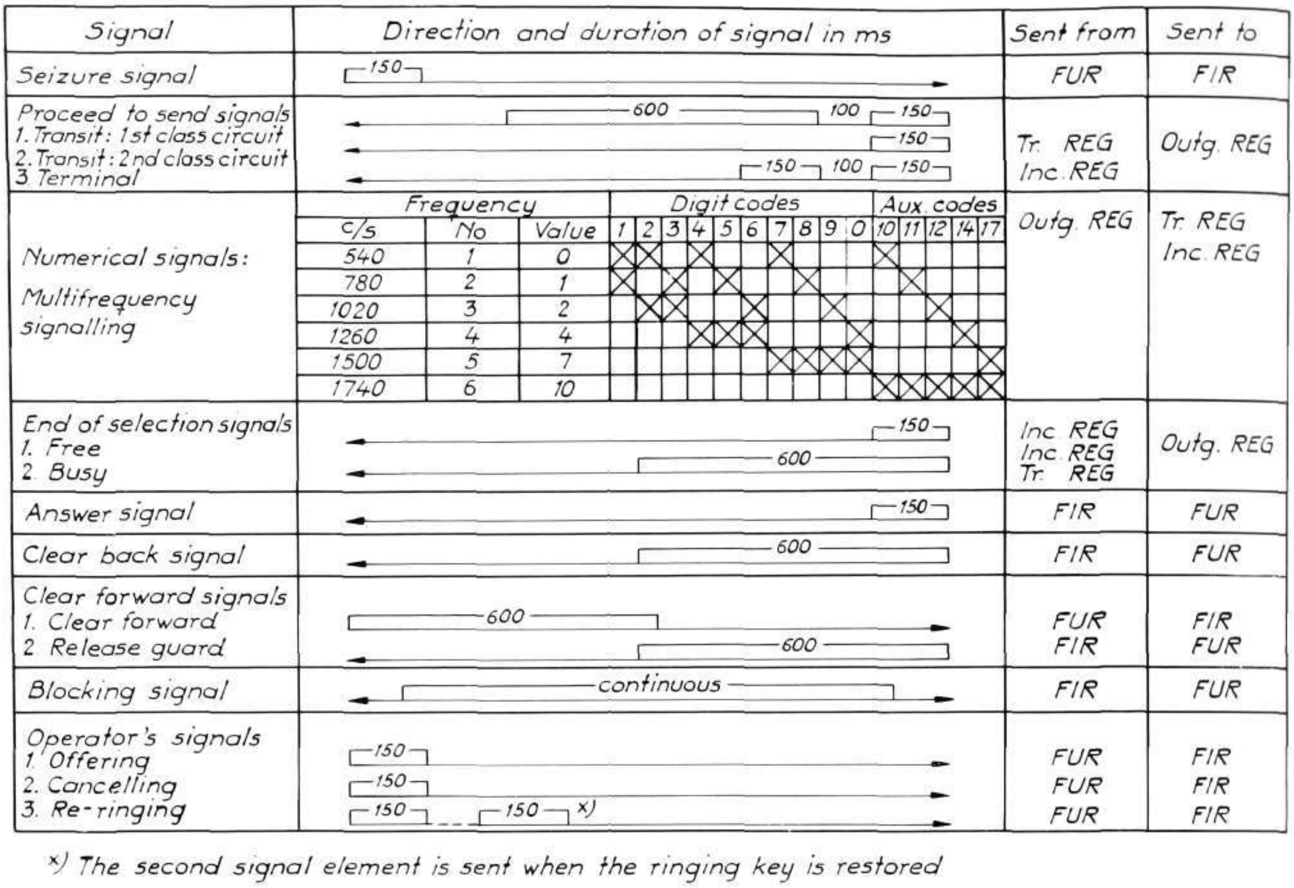


Fig. 5 X 7902
Signal codes for line and register signalling

The originating trunk traffic from the local exchanges is passed via record circuits connected to the trunk switching equipment. Connection of the caller to a free cord pair at a free operator's position is controlled by a queuing equipment.

The automatic trunk exchanges have equipment for service observation and traffic measurement. The service observation equipment indicates trouble in the system and locates the faults. The common control units are supervised by a Centralograph which records the identity of the faulty unit, the details of the units employed on the faulty connection, and how far the connection had advanced. The service alarm equipment indicates when the number of faults exceeds a predetermined level within a unit of time, and counters are used for counting switch occupations, switchings to alternative routes, measurement of congestion, etc. The traffic measuring equipment is used for erlang measurements in different switching groups. The measuring equipment is connected automatically during the busy hour of the exchange, as also are counters for measuring the traffic intensity and congestion. In view of the alternative routing, facilities are provided for measuring the traffic on separate routes and to the different terminating exchanges.

The conversion to subscriber-dialled long distance traffic requires that the trunk exchanges be equipped with junction circuits containing equipment for sending metering pulses to the local exchange, equipment for fee determination, and registers for receiving the numerical information from the local exchange. The local exchanges must also have equipment which can receive the metering pulses, and in some cases must be modified for sending on the pulses to the subscriber's meter.

For the subscriber-dialled traffic that is already operating, random time zone metering is employed, i.e. pulses are sent to the subscriber's meter during the conversation at a frequency corresponding to the tariff. Metering starts when the called subscriber's answer has been registered and ends when

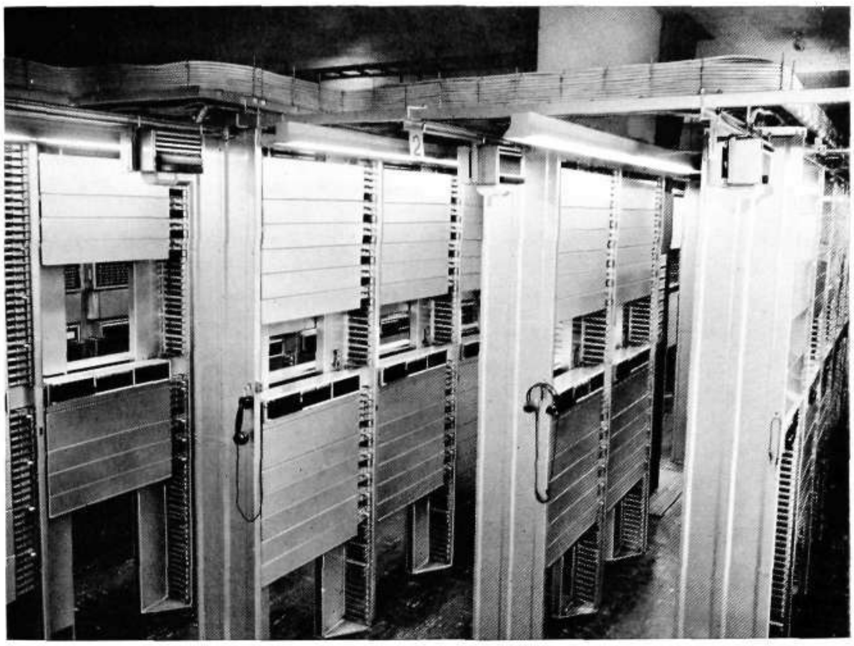


Fig. 6 X 8454
Part of the ARM 20 equipment at Bogotá

the caller replaces. Since the metering pulses are sent at random, the called subscriber's answer and the first metering pulse may not coincide.

For the semiautomatic trunk traffic two-digit codes are used for calling the trunk operator. Subscriber-dialled trunk numbers include a single-digit trunk access code, a usually three-digit group area code, and the directory number. All digits are dialled in one sequence without needing to wait for a new dial tone after obtaining a trunk line.

The operators' positions at the automatic trunk exchanges are of cordless type with keysets. The operators' position equipments and cord pairs terminate on the trunk switching equipment.

Outgoing trunk calls are usually handled at the demand position. The calls are switched automatically to a free cord pair at a free operator's position and the operator switches it to the trunk network via the same cord pair. Through-connection is not effected until the period counter has been switched into the circuit. The latter starts when the called subscriber answers and stops when the caller replaces his handset.

For demand service calls verification of the caller's number is adopted only for a limited number of connections by call-back to the subscriber. The operators' positions for non-delay working can be individually blocked against demand calls and used exclusively for delay traffic if required by the traffic conditions on certain trunks at certain times.

Some trunks, principally manual trunks, are not designed for automatic traffic. Calls on these routes are therefore handled at special delay and transit positions at the superior automatic trunk exchange. These positions have the same traffic facilities as the demand positions but are also equipped for tying of the manual circuits to specific cord pairs. This implies that the circuits are blocked against incoming automatic calls and are accessible only to the operator to whose position the circuits are tied. Connections of this kind can be established and cancelled form the operator's position, and a tied circuit can be loaned to another operator. When the tie-up is cancelled, calls on the route can be switched automatically.

The incoming traffic from the manual circuits requires an assistance operator at the automatic trunk exchange. A call on a manual trunk which is not tied to a particular operator is indicated at the delay and transit positions. Via a cord pair and the selector equipment any of these operators can connect to the line and extend the call. On a tied line a call is indicated on the cord pair to which the line is tied.

The international circuits in Bogotá, which at present are handled on a manual basis, terminate on separate positions with the same facilities as the national delay and transit positions.

All operators can enter an engaged circuit to offer a waiting trunk call. The switching system and the signalling scheme allow entry also via trunk circuits when so required and when the ordinary junction lines of the local exchange equipment possess this facility.

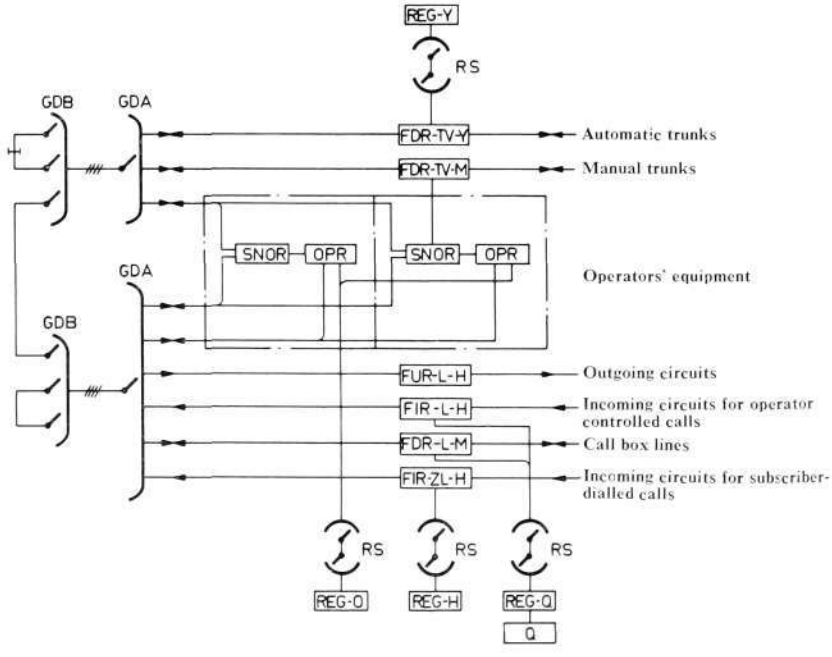
Order wire calls between operators within the same exchange or at different transit exchanges can be established from any cord pair at any position. Incoming operators' calls are signalled on the position equipment. The numbering of the order wire circuits is entirely independent of the subscriber numbering. Order wire calls are initiated by pressing a special key.

Traffic Routing in Trunk Exchanges ARM 20

Automatic transit exchanges *ARM 20* were described in Ericsson Review No. 2, 1960. The present account will therefore be confined mainly to the uses of these exchanges in the Colombian long distance network.

The trunking diagram of a typical *ARM 201* exchange is shown in fig. 7. The *GDA* and *GDB* stages are designed for two-way traffic and are divided into two groups. The trunk circuits terminate on one group, the upper in the diagram, and the junctions both for incoming and outgoing traffic with local exchanges terminate on the lower group. The cord pairs *SNOR* terminate on one side on the upper and on the other side on the lower switching group. Both sides of the cord pairs are designed for two-way traffic. The position equipments *OPR* terminate on the lower group; this switching path is intended chiefly for order wire calls.

All trunk circuits, one-way and two-way, are connected via junction equipments *FDR-TV* to the trunk exchange multiple. The junction equipments for automatic traffic, *FDR-TV-Y*, are connected via register finders *RS* to registers



X 8452

Fig. 7
Automatic trunk exchange
System ARM 201
Trunking diagram

REG-Y. On transit calls *REG-Y* controls the setting-up of the transit stage, and on incoming calls *REG-Y* also controls the operation of the switching stages in the local exchanges within the area. The junction equipments for manual trunks, *FDR-TV-M*, connect to cord pairs *SNOR* at positions for delay and transit traffic. This switching path permits tying of circuits to particular operators during peak traffic periods.

Local junction circuits for subscriber-dialled long distance calls are connected via the junction relay set *FIR-Z-H* to the transit exchange multiple. Via a register finder *RS*, *FIR-Z-H* has access to a register *REG-H*, the function of which is to receive the numerical information from the local exchanges, control the setting-up of the trunk stage and send the necessary information via the long distance network to all subsequent trunk exchanges on the route.

The record circuits from the local exchanges terminate on junction relay sets *FIR-L-H*. Via register finders *RS* the latter have access to registers *REG-Q*, which control the setting-up of the transit stage to a free cord pair *SNOR* at demand or delay positions. *REG-Q* is equipped with a queuing device which successively puts through waiting calls as operators in the desired group become free.

The junction lines *FUR-L-H* are used for all traffic to the local exchanges, i.e. subscriber-dialled, operator-controlled, operator traffic within the home trunk exchange for verification of the calling subscriber, call-back on delay calls, and incoming manual trunk calls.

Call box lines are connected to the transit centre via *FDR-L-M*. These are two-way circuits and can carry outgoing semiautomatic calls and all kinds of incoming traffic.

The trunk enquiry circuit terminates directly on the cordless enquiry positions.

The operators' equipments *OPR* connect to registers *REG-O* via register finders *RS*. The registers receive keyset pulses from the position equipment, control the setting-up of the trunk stage and send the necessary trunk information (cf. *REG-H*).

Outgoing subscriber-dialled calls pass through *FIR-Z-H*, *GD* in the lower and upper switching group and *FDR-TV-Y* to the long distance network. *REG-H* controls the entire long distance connection. Incoming automatic terminal traffic passes via *FDR-TV-Y*, *GD* in upper and lower switching group, and *FUR-L-H* to the local exchange. *REG-Y* controls the setting-up of the trunk and local switching equipment.

Transit calls between automatic trunks are passed via the upper switching group *GD*, which has special transit links with pads. The register which is connected to the incoming *FDR-TV-Y* controls only the setting-up of the trunk stage. All register information to subsequent trunk exchanges is passed through without repetition.

Transit calls from automatic to tied manual trunks are handled by an operator. A call on a tied route is signalled at the position to which the circuit is tied. If one of the desired circuits is free, the operator can operate a key to establish connection via *FDR-TV-Y*, *GV* in the upper switching group, and transit link to *FDR-TV-M*. Transit calls to manual circuits which are not tied to a particular operator can be switched automatically in the same way as between automatic trunks.

All incoming traffic from manual circuits is handled by an operator. A call from a tied circuit is signalled on the cord pair on which the circuit terminates, and connection is established without passing through the switching stages. The operator extends the call from the same cord pair via *GD* in the upper switching group to *FDR-TV*, if a transit connection, and via *GD* in the upper and lower groups to *FUR-L-H* if a terminal connection. Calls from manual circuits which are not tied to a particular operator are signalled at all free transit positions. When an operator answers the call with the key of a free cord pair, connection is established via *FDR-TV-M, GD* in the upper and lower switching groups to the cord pair *SNOR*. The subsequent procedure is as for tied circuits. The operator's register *REG-O* can control the connection on the long distance circuits and the setting-up of the local switching equipment.

Outgoing calls to the trunk operator are directed via *FIR-L-H, GD* in the upper and lower switching groups to a cord pair *SNOR* at a free position within the wanted group. The operator extends the call to the long distance network from the other side of the same *SNOR* via *GD* in the lower and upper switching groups to *FDR-TV*. The register *REG-Q* controls the setting-up of the call to the operator's position, and register *REG-O* the switching through the trunk stage and on through the remainder of the long distance circuit. Call-back to the local subscriber for verification or on a delay call is done from the same side of the cord pair as the call comes in and is extended via *GD* in the upper and lower switching groups to *FUR-L-H*.

Trunk Exchanges AFA 10

The *AFA 10* exchanges have registers *REG-Y(O)* which can receive the numerical information sent on the long distance network from other trunk exchanges and control the local exchange switching equipments. Incoming calls are extended automatically to the local subscriber without operator assistance. *REG-Y(O)* is also used for the semiautomatic outgoing trunk traffic and is therefore equipped to receive keyset pulsing from the operator's position and to control the setting-up of the trunk connections.

Register signalling and line signalling are exactly the same as for the automatic trunk exchanges and are shown in the signalling scheme in fig. 5.

Trunk exchanges *AFA 10* are not equipped with selector stages, any transit traffic that occurs being extended manually.

Subscriber-dialled traffic can be introduced under the same conditions as for the *ARM 20* exchanges with or without the addition of special switching equipment.

The operators' positions are equipped with ordinary cord pairs. Trunks, record and junction circuits to the local exchange, and internal order wires, terminate on the multiple of the manual board. Automatic trunks are also connected to incoming junctions in the local exchanges. The operators' positions have roughly the same facilities as the cordless boards at the automatic exchanges.

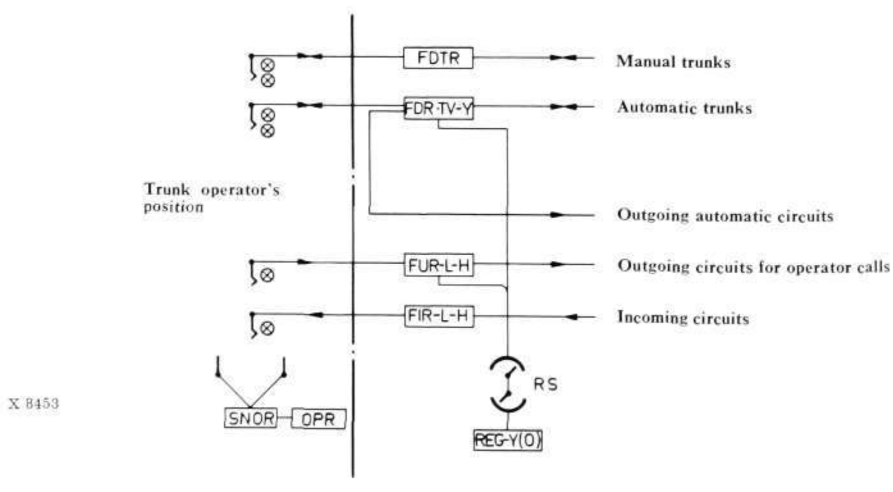


Fig. 8
Trunk exchange
System AFA 10
Trunking diagram

The trunking diagram for an *AFA 10* transit exchange is shown in fig. 8.

All traffic to the manual trunks *FDTR* is extended entirely on a manual basis.

The junction equipments *FDR-TV-Y* are two-way and are connected to the manual switchboard multiple, to incoming junctions in the local exchange and, via register finders *RS*, to registers *REG-Y(O)*. Incoming calls are routed automatically to the local exchange or to an operator according to the received area code. Outgoing trunk calls are also passed through *FDR-TV-Y* and are controlled by the register *REG-Y(O)*.

The record circuits from the local exchange are connected to the multiple of the manual positions via junction relay sets *FIR-L-H*. Verification of the calling subscriber's number, if required, is done by calling back via the junction lines *FUR-L-H*. These lines are also used for the terminating traffic from the manual trunk network.

Resumé

The automatization of the long distance network has brought a marked improvement in the handling of the traffic. After the change from manual to semiautomatic working the same number of trunks has carried a very much larger quantity of traffic. Automatization and the large increase in number of trunk circuits have resulted in an improved service for the public through quicker setting up of connections and better quality of transmission, and for the telephone administration a continuously growing traffic intensity with the attendant increase of revenue.

This first stage in the extension of the automatic trunk network has meant that Colombia now has a very advanced national trunk service and has created a sound basis for continued expansion to full automatization of the trunk network.

A new contract was signed with Empresa Nacional de Telecomunicaciones during 1963. It covers a new automatic trunk exchange at Cartagena and extension of the already installed trunk exchanges at Bogotá, Medellín, Bucaramanga, Tunja and Pereira by altogether 1,100 lines. These extensions permit an appreciable increase in the subscriber-dialled long distance traffic.

The Telephone User and the Switching Machine

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In a previous paper[1] presented at the "First Symposium on Human Factors in Telephony" at Cambridge in 1961, the author gave some aspects on a worldwide switching machine, mainly with respect to supervision and maintenance problems. In this paper similar problems are considered from the telephone users' point of view, with special attention to the performance during conversation. Possibilities of obtaining better matching between man and machine are discussed, which may be of importance in a future worldwide automatic telecommunication network.*

The Reactions of the Telephone Users

As the aim of supervision and maintenance efforts is to give the telephone users a satisfactory service at a reasonable cost, we have to look at the problems from the users' point of view. We then find:

- As long as nothing better is available, the telephone users are satisfied with the service given.
- The better service we can offer, the more the telephone facilities will be utilized.
- Competition and the increased demands for long distance switching will bring about the development of improved new systems and equipments, but already installed equipments of old design will still be in operation.
- The users can then compare the functioning of different types of equipment, and the result will be increasing demands for a better grade of service.

The consequence of this is that supervision and maintenance people have to increase their efforts in order to meet the increased demands. As 100 per cent reliability would be much too expensive, a certain fault rate must be tolerated. From the users' point of view, the unavoidable faults will appear more or less serious, and with respect to their inconvenience to users we can divide them into two main groups:

- Faults during switching, such as
  - no connexion
  - connexions to wrong numbers
- Faults during conversation, such as
  - poor transmission caused by too low speech level or too high noise level, distortion, inconvenient echo, short breaks etc., jeopardizing intelligibility or confusing the talker
  - double connexions or intelligible crosstalk, jeopardizing secrecy of conversation
  - breakdown of connexions

Faults of the first group seldom cause complaints if they are relatively few and are not repeated too often, as a calling subscriber can never be sure of not having made a mistake himself. He is satisfied if the next trial is successful.

* Revised version of papers prepared for the L M Ericsson Maintenance Conference in Stockholm, June 1962, and Second Symposium on Human Factors in Telephony at Copenhagen, September 1963.

The faults are mainly of the type "no go" and are not too difficult to trace by modern supervision and maintenance methods.

Faults of the second group are much more serious and will always annoy the users as they are considered as equipment failures. They are often difficult to trace, as they may be caused by a totality of minor irregularities in a number of parts of the equipment.

It is obvious that a plain summation of all types of faults will never give a true picture of the grade of service seen from the users' point of view. A small number of irregularities during conversation is much more annoying than a larger number during switching. AHLSTEDT[2] has therefore proposed the introduction of a fault scale, whereby the irregularities are weighted with respect to the inconvenience to users. For a telephone exchange or a group of exchanges, a figure of merit can be calculated and better related to the users' opinion than a fault figure based on plain summation.

Ahlstedt's ideas may be illustrated by two diagrams from his paper–fig. 1. In the upper one we have a plain summation of four fault classes, and the grade of service seems to be increasing with time. In the diagram below the fault classes have been weighted and the figure merit is deteriorating, which means that the maintenance efforts have not been directed to the most essential points.

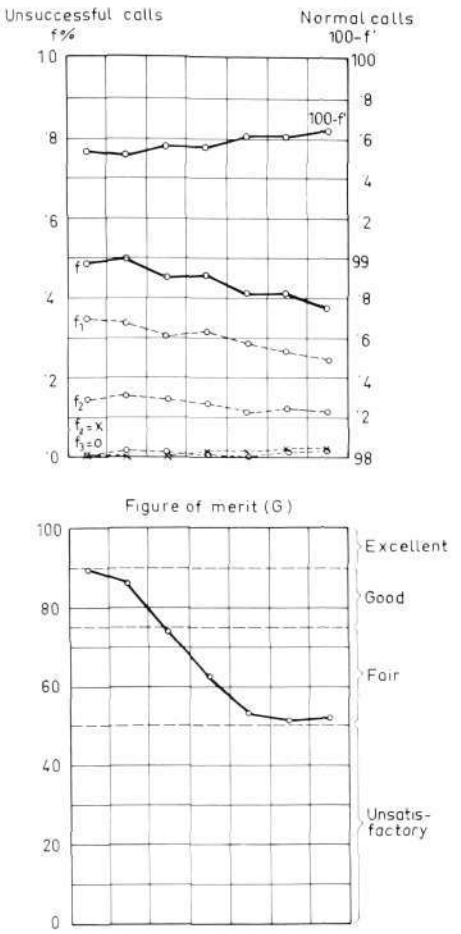


Fig. 1 X 2761

Evaluation of service reliability in automatic telephone traffic

$f' = f_1 + f_2 + f_3 + f_4$

f_1 Incomplete connection

f_2 Connection to wrong number

f_3 Speech transmission not possible

f_4 Speech cut-in on foreign connection

$G = 100 \times 1.2^{-f}$

$f = f_1 + 2f_2 + 20f_3 + 200f_4$

Proposed weighing factors

(Taken from a paper written by B. Ahlstedt)

The Importance of Deviations from Nominal Values

The quality of a call depends on the performance and reliability of all equipment parts such as subscriber sets and lines together with interconnected switching and transmission links chosen at random. By means of measurements the supervision people can determine the fault rate or performance of certain combinations of equipment such as a telephone exchange as a whole or the exchanges in a certain area together with interlinked trunks, or of a group of carrier circuits with or without the trunk exchanges at both ends. For the maintenance parties concerned, such statistics–showing the result of the maintenance efforts or the points at which they should be put in–are of great value. But we must remember that performance figures for certain parts of the equipment can never give the whole truth about the quality of calls passing through several groups of equipment maintained by different parties, as the risk of unsuccessful calls or of calls of too poor quality will increase with the amount of equipment used. This may be illustrated by two examples:

- Faults of the type "no" instead of "yes"–such as contact faults–where the total number of contact operations in switching a call will influence the risk of an unsuccessful call. If, for a local call, we only have 1,000 contact operations, a fault rate of 10^{-7} will give a negligible fault risk, but if on a complicated long distance call we need 100,000 contact operations, the risk will increase to one per cent, which is far from negligible.

- Faults due to gradual degradation causing too great deviations from mean properties, such as variations in line leakage, relay times, transmission loss, noise level, carrier frequency etc. The distribution of such deviations can be illustrated statistically by probability diagrams, which show the risk of deviations above given levels. When a number of parts are used together, we can calculate–according to statistical laws–the standard deviation for the whole by taking the square root of the square sum of the individual standard deviations. To simplify matters we can assume that all parts have the same deviation distribution, which means that we get the total standard deviation by multiplying the individual standard deviation by the square root of the number of parts. If we further assume that the distribution can be represented by straight lines, we get a diagram as in fig. 2. We again realize that the risk of faults–in this case caused by too great deviations–will increase with the number of interconnected parts on a call.

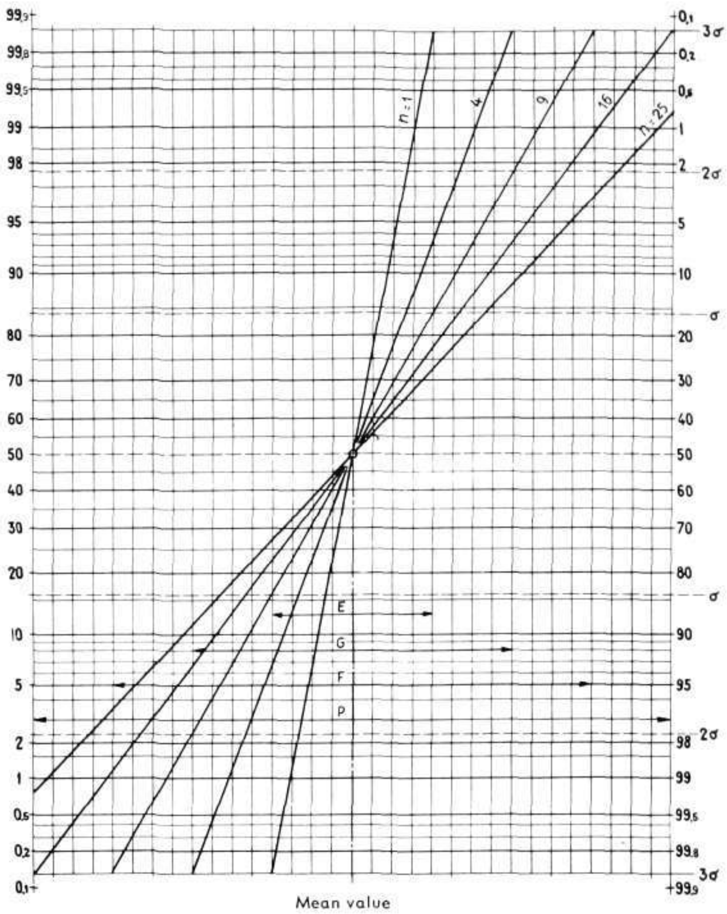


Fig. 2

Summation of deviations

"Opinion regions"
E = Excellent
G = Good
F = Fair
P = Poor

X 8462

From the point of view of the telephone public too great deviations mean inconvenience and, in respect of public opinion, we can classify the calls as

- Excellent (E)
- Good (G)
- Fair (F)
- Poor (P)
- Bad (B)

Every class can be given a maximum deviation value which can be illustrated by vertical "opinion regions"–E, G, F, P and B–in our diagram. The more equipment is involved in a call, the bigger the risk that the quality of the call will fall in a lower class and the bigger the risk of unsatisfactory connexions.

From the diagram we can draw some general conclusions:

- When many parts are engaged on a call, unlucky combinations even of small individual deviations can cause trouble, which cannot be traced without overall testing of individual calls. There is always the risk that serious faults in some parts, causing complaints, will be explained as unlucky combinations and therefore not be traced by the maintenance people.
- The greater the distance between the subscribers, the more equipment will be engaged on a call and the bigger the risk of degraded quality.
- These calls will be the most expensive ones, and we can predict that the public demands for performance especially during conversation will increase, as poor intelligibility will prolong the conversation time and increase the cost to the calling subscriber. In reality this means that the additional equipment needed for long distance calls should be free from faults and

deviations–which, however, is impossible–or that we have to increase the performance of local switching equipment which is engaged also on long distance calls, in order to meet future subscriber demands.

Speech Level and Noise

As an example we can study the influence of speech and noise levels on the quality of a call. On the basis of investigations carried out by many administrations, CCITT has made recommendations for the total reference equivalent and its distribution over the different parts of a telephone network in order to ensure a sufficient speech level for the listener.

We have also to consider, however, that noise can jeopardize intelligibility even if the speech level in itself is sufficient. For cheap local calls this may be of less importance, but becomes more so on expensive long distance calls. Room noise the subscribers themselves can get rid of, but the reduction of circuit noise–such as noise from relay contacts or switches, intelligible or unintelligible crosstalk, intermodulation or singing in carrier circuits, echo in 2- to 4-wire switching points–must be the task of the administrations.

For maintenance and supervision people it is essential to have an idea how a combination of speech and noise levels will influence the transmission. For that purpose we can use the isopreference contours–presented by KARLIN[3] fig. 3. On the coordinate axes the relative levels of speech and noise are expressed in decibels. In the coordinate plane are drawn a number of "isopreference contours" based on opinion tests. Every contour represents a combination of speech and noise levels for which the listeners have the same preference. The figures beside the contours express relative "preference levels" in db. It is said that a relative level of about 75 db corresponds to good performance, but 50 db will be too poor. As the opinion test was carried out with a restricted number of persons under specific conditions, one has to be careful in drawing conclusions, but in spite of that we may say that:

- ☐ A high preference level corresponds to better performance.
- ☐ All isopreference contours have maximum points, indicating maximum permissible noise level for a certain performance.
- ☐ A line through the maximum points, starting at 82 db speech level, splits the plane into two regions:

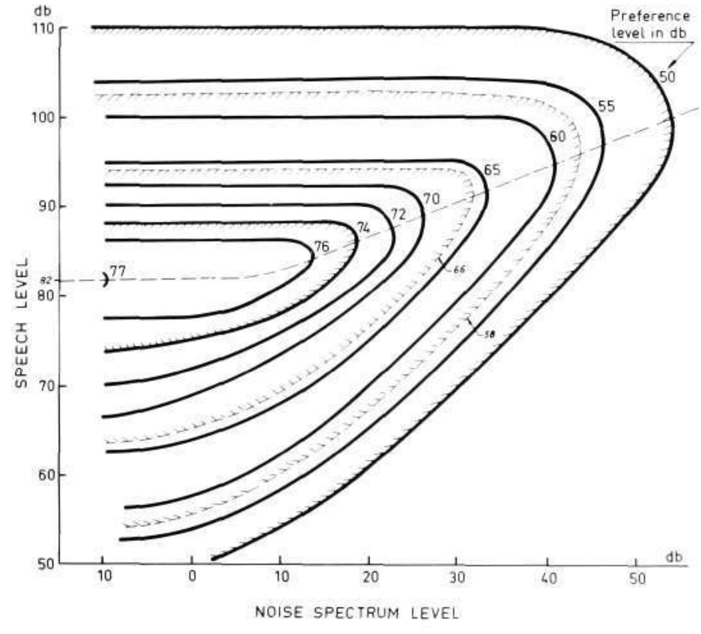


Fig. 3 X 8460

Isopreference diagram

for a 3000 c/s low pass circuit

The diagram is split in the following opinion regions:

Excellent	> 74 db
Good	74-66 db
Fair	66-58 db
Poor	58-50 db
Unsatisfactory	< 50 db

(Taken from a paper written by Munson & Karlin)

- In the upper region the performance deteriorates with increasing speech level because too high levels are painful to the listener. The horizontal shape of the contours indicates independence of noise level.
- In the lower region the opposite applies. Here performance deteriorates with decreasing speech level or increasing noise level, giving decreasing intelligibility.
- On every isopreference contour we have two points–one per region–giving the same preference, and the difference between the points shows the permissible speech level variations for a certain performance with decrease for increasing noise and increase when quality demands are reduced.

It should be noted, however, that prerecorded speech was used during the isopreference investigations, and the contours may give a wrong picture of the situation when we have natural speech between two subscribers. We can, however, compare the isopreference results with the opinion tests carried out on behalf of CCITT. MARKMAN[4], who took part in these investigations, has recalculated the CCITT results in order to get what we may call "isoopinion contours"–fig. 4–as described in the first part of Appendix 1. The contours are numbered with respect to the mean opinion score *Y*, and a table beside the diagram shows the risk of poor and bad calls for different *Y*-values, seen from the users' point of view.

As "electrical" scale parameters are used, the system reference equivalent SyRE is expressed in db and the noise level in dbmp. For purposes of comparison we have to change the "acoustical" scales re 2×10^{-4} dyne/cm² in fig. 3 into "electrical" scales.

☐ According to definition, an "acoustical" speech level of 65 db corresponds to SyRE of 34 db "at prescribed outgoing speech volume".

☐ Measurements at L M Ericsson show that acoustical noise level of 10 db corresponds to − 66 dbmp.

Observing that decreasing SyRE corresponds to increasing speech volume, we can introduce the acoustical scales beside the electrical ones in fig. 4 and show the isopreference contours from fig. 3 in the same diagram.

The CCITT investigations only cover the region below the splitting line, starting at 82 db in the acoustical scale corresponding to a SyRE of 17 db. The

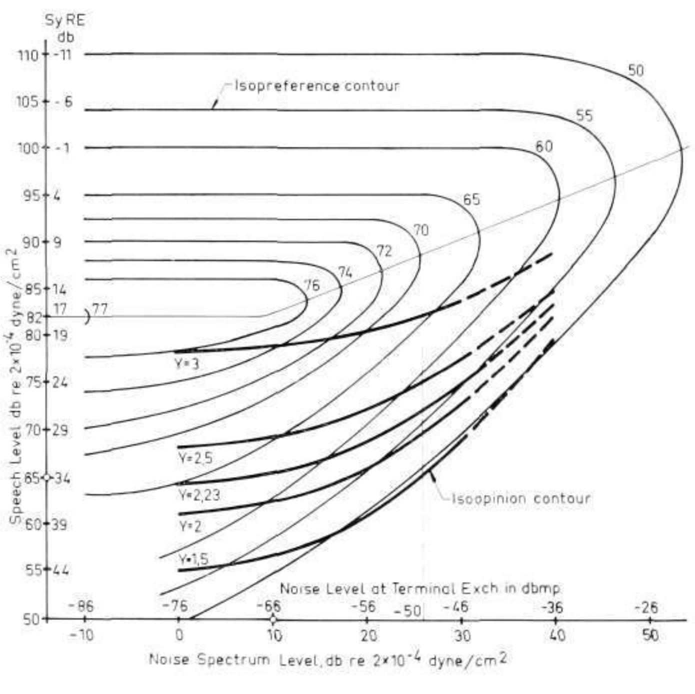


Fig. 4 X 8461

Isoopinion contours

calculated by F. Markman using CCITT opinion investigations

Y = Mean opinion score

Y	(Poor + Bad) %
3.00	0.75
2.50	7.2
2.23	15.7
2.00	25.8
1.50	52.7

trend of the isopreference and isoopinion contours is the same, but the slope of the latter is less for low noise levels. The explanation is that the talker during natural conversation adjusts his voice according to what he hears from the far end, as has been confirmed by investigations at L M Ericsson. From BOERYDS[5] investigations we have taken the diagram in fig. 5, showing the relation between SyRE and outgoing speech volume VU, when 50 db room noise but no circuit noise is present. It is interesting to note that VU has a minimum about 17 db, which is the starting point for the splitting line in fig. 4. We may therefore assume that the splitting line represents the most convenient system reference equivalents from the users' point of view. If the SyRE is too low, the users probably try to outtalk each other and raise their voices. If SyRE is higher than 17 db, the talker also raises his voice, thereby partly compensating for the SyRE increase. At a SyRE of 34 db we thus have a compensation of 4 db or about 25 % of the increase. We have here an example of a lucky interaction between man and machine. But it must be noted that the speaker does not react to his own speech but to what he hears from the far end. It is obvious that the desired adjustment of the voices will be jeopardized if the transmission conditions differ too much in the two directions, and this must be kept in mind when we later discuss long distance calls via a number of 4-wire links with repeaters.

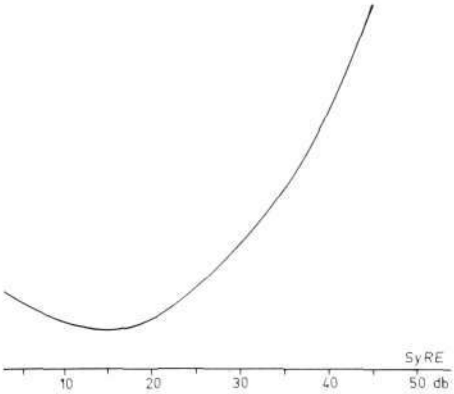


Fig. 5 X 2762

Speech volume (mean values) measured in the sending local exchange as a function of *the over all reference equivalents*

Participating persons: 240
(Diagram taken from a paper by A. Boeryd – fig. 1, curve 3)

From fig. 4 we may draw some conclusions from the isoopinion contours in the lower region and the isopreference contours in the upper:

☐ If we assume that isoopinion contour $Y = 2.23$–about 15 % risk of poor or bad calls–is the lower limit for satisfactory service, we may have SyRE = 35 db when no noise is present. On intercontinental calls CCITT permits a noise level of – 50 dbmp all the time, and we find that SyRE has to be reduced to 27 db if the same mean opinion score is to be maintained. It is obvious that supervision and maintenance people have to reduce the noise as far as possible and hunt for all noise sources, or we have to reduce the permissible SyRE, which has to be done in the 2-wire networks in order to ensure satisfactory transmission on long distance calls. A reduction of SyRE means increased investment costs in the local networks, and we have here a possibility of evaluating the inconvenience of circuit noise in terms of money.

☐ The isopreference contours in the upper region show that too high a level or too low a SyRE is also inconvenient to the listener. He can, however, protect himself by moving the telephone away from his ear, which one must do on a large number of calls between subscribers with short lines connected to the same exchange. If the user moves the receiver away from his ear, he moves the microphone away from his mouth and may develop unsound habits when he has to talk on long distance calls with poor transmission conditions. In fig. 3 we have approximately split the diagram into opinion regions, and if we assume that preference levels below 58 db should be considered as poor, we find that SyRE should never be better than – 4 db. Nowadays we have the technical means of attaining this, if we install modern telephone instruments with line equalizers at the subscribers' premises. It is, of course, not economical to replace all old instruments without line regulation, but a lot could be gained if this were done when subscribers complain about poor performance on long distance calls and if we teach them how to use the new instrument in the proper way and how to talk.

With respect to long propagation times and interlinked echo suppressors we have to inform our users–not being telephone experts–that they cannot intervene in each other's speech in the usual way on calls over very long distances but have to give the other party an opportunity to answer in order to avoid confusion, maybe resulting in "hallo"-calls and prolonged conversation time.

Loss Variations on Long Distance Calls

On a long distance call we have at both ends the telephone instruments connected to their 2-wire networks terminating in hybrids and between them a number of 4-wire links with repeaters. On successive calls between any two subscribers there will be rather small loss variations in the 2-wire sections, and the transmission conditions will be about the same in both directions if the transmitters and receivers of the instruments are properly maintained. Anyhow, in this part of the transmission path the variations from call to call will be negligible. In the 4-wire section we have another situation, as the transmission links are chosen at random. With alternative routing we do not know which switching points the call passes, and the number of tandem-switched links is unknown.

The links are chosen from batches for which nominal values of loss and noise can be stipulated. The individual links can, however, not be maintained exactly, but a certain deviation from the nominal batch value has to be permitted, which means loss and noise variation in the 4-wire network on different calls switched between the same distant subscribers. If we assume that all transmission links can be maintained at a standard loss variation of ± 1 db, we will have 2×1 per cent risk of a loss deviation of ± 2.33 db on one link and $\pm 2.33\sqrt{n}$ db on n tandem-switched links. For intercontinental calls, which are very expensive to the users, we may in rare cases have up to twelve 4-wire links. Using only 9 links, we shall have a total deviation of ± 7 db. In one per cent of the calls the difference between best and worst calls may be as high as 14 db, which is definitely noticeable to subscribers. If we furthermore consider that, for an intercontinental call, we have to permit a noise level of -50 dbmp, following isoopinion contour $Y = 2.23$ we find from the diagram in fig. 4 that we nominally have SyRE = 27 db, but for the best call 20 db, corresponding to a Y-value of about 2.9, and for the worst 34 db, corresponding to $Y = 1.5$. All the best calls will be considered as at least fair, but 52 % of the worst as poor or bad. Worst of all, the subscribers will note that good quality calls are possible and will therefore complain about calls with unlucky combinations of deviations.

But we must also consider that we may have different deviations in the two directions–maybe negative in one and positive in the other. The result will be that the talker with the best listening conditions has no reason to raise his voice, the more so as the other is probably shouting. This, too, will cause complaints–the reason for which is difficult to trace.

Then there is the fact that we cannot, with respect to stability and echo, switch the 4-wire paths without nominal loss. This is illustrated in fig. 6, where we have used the Bell System rules–see "Notes on Distance Dialing", section VI, according to which the nominal loss in a transmission path with n links ought to be

$$AN_0 = 2S + bn + \sum_{1}^{n} T_n \text{ db}$$

where

n is the number of tandem-switched links
S the hybrid loss
T_n a factor proportional to the propagation time of the links
b a constant

For an *actual* call we also have to take the loss deviations from the nominal values into account and introduce therefore a deviation term and get the expression

$$AN = 2S + bn \pm 2.33\,\sigma\sqrt{n} + \sum_{1}^{n} T_n \text{ db}$$

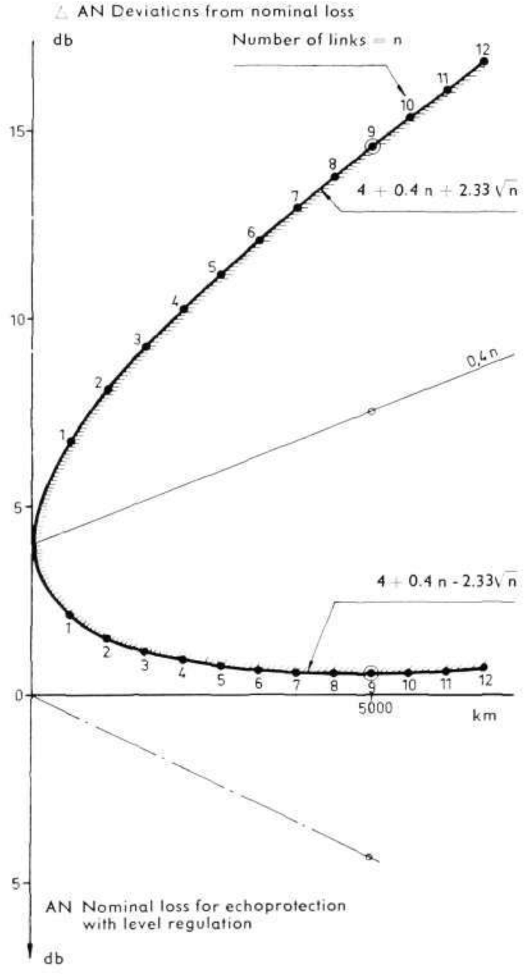


Fig. 6 X 8463

Loss variations with 1 % risk

on n tandem-switched 4-wire links each with $\pm$ 1 db standard deviation if AN with 98 % probability is to be within the deviation range $2 \times 2.33\, \sigma\, \sqrt{n}$. For the diagram in fig. 5 we have used the figures $S = 2$, $b = 0.4$ and $\sigma = 1$, giving the expression

$$AN = 4 + 0.4n \pm 2.33\sqrt{n} + \sum_{1}^{n} T_n \text{ db}$$

The last term is unknown, being dependent on the total propagation time, and therefore plotted below the zero line. The other terms are dependent solely on the number of links and are plotted above the zero line. It will be seen that the loss of $4 + 0.4\, n$ db has been inserted in order to compensate for negative loss deviations. If these loss deviations could be removed by technical means, we could maintain stability without introduction of extra loss, and all losses above the zero line could disappear. The losses below the zero line can be considered as nominal, giving echo protection when no echo suppressors are used. If the loss deviations are removed or essentially reduced, we should get:

- ☐ a reduction of nominal loss on LD calls, which means an increase in mean opinion score according to the diagram in fig. 4 and consequently in performance,
- ☐ a reduction of circuit noise influence, as the isoopinion contours for high mean opinion scores are flatter than for the lower ones, which means less dependence of circuit noise,
- ☐ the loss difference between expensive LD calls and cheap local calls will be reduced, and thereby the risk of users' complaints,
- ☐ certain users' complaints can no longer be explained unlucky combinations of deviations–so depriving the maintenance of an excuse for doing nothing.

The influence of loss deviations on the overall performance is discussed more in detail in the second part of Appendix 1.

There is, however, also another reason for reducing the number of calls with unsatisfactory transmission condition. In a future worldwide switching scheme we shall mostly have no operators to build up a call and thereby lose the possibility of operator-control of the transmission quality. The users have to judge themselves. But worldwide calls will have many digits and comparatively long switching times, and the risk of congestion is not negligible. The caller will seldom reject a call when he has got through but will complain after completion of the call if too poor transmission has prolonged the conversation time.

Elimination of Loss Variations on LD Calls

As the variations in the 2-wire network on successive calls between two subscribers are relatively small, we can confine our attention to the 4-wire part of the transmission path. The idea is illustrated in fig. 7. Two 2-wire networks are connected via hybrids to a chain of 4-wire links chosen at random in a number of 4-wire switching points. The links between two switching points are statistically controlled by automatic transmission testers in order to keep them within prescribed nominal values and standard deviations. The building up of a call can be compared to the industrial assembly of parts and components. There is, however, at present an essential difference. In industry we have a final test including rejection or adjustment of the assembled product before delivery, but in telephony we deliver all calls to the users without any final test.

It has therefore been proposed and CCITT is studying the problem of introducing a transmission test with adjustment of the total loss on all expensive

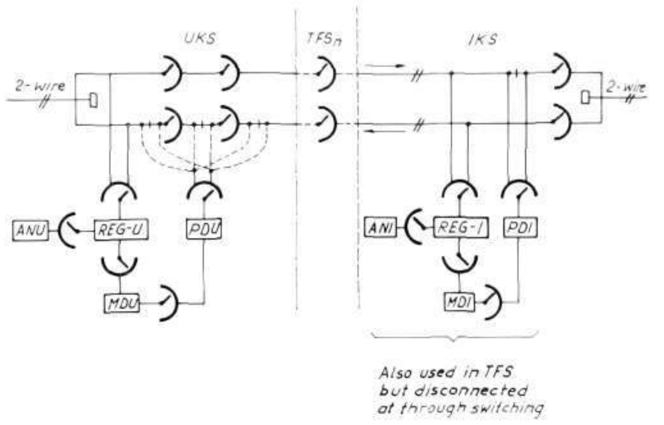
Fig. 7

Level control

on tandem-switched 4-wire circuits

UKS	Outgoing control point
TFS	Transit switching point
IKS	Incoming control point
REG	Register
AN	Analyser
MD	Level measuring device
PD	Level regulation device

X 8464



calls to a prescribed nominal value before conversation starts, when the risk of unacceptable loss variations is too great. One may assume that the transmission stability of the circuits involved is such that changes during actual conversation can be neglected and one can then confine the test to a short transmission check during a suitable phase of switching of the call. The prolongation in switching time must be small.

Such a method with end-to-end control of complex 4-wire circuits using only one measuring and one level regulator per transmission direction is roughly outlined in Appendix 2. This is on the presumption that we have a uniform signalling system in the 4-wire routes with successive through switching in intermediate switching points, as they are passed by a call in progress.

For international calls the method is not feasible as the through switching in the switching points giving access to the international network does not at present take place–because of signal translation–until the called party answers. We have thus no time for an end-to-end control. Another difficulty is that we must have uniform measuring methods throughout the world.

Both complications are removed if we split the complex 4-wire circuit for international calls into three sections, the originating and terminating national networks with interlinked international network. As we ought to have uniform signalling within the sections, we can have successive through switching in all intermediate switching points and use end-to-end control in sections where it is justified. In sections where it is possible to supervise and maintain a sufficiently low standard loss deviation–of the order of 0.5 db or less–level adjustment can be omitted, as the level variations on such sections will be comparatively small.

On an international call we shall thus have a maximum of 4 control points and three measurements with level regulators per transmission direction, and the complex circuit will be reduced to three tandem-switched multilinks. For each the level adjustment can be quite precise–standard loss deviation less than 0.5 db–giving a negligible adjustment variation. The nominal loss of every section, however, should be stipulated such that sufficient stability and echo protection is maintained in a combined complex circuit.

From the loss deviation curve in figure 6 it may be seen that the deviation influence per link decreases with the number of links. If some links are left uncontrolled between the national control switching points and the hybrids, our aim of reducing the nominal 4-wire loss and its variations will be jeopardized. All the more as the additional uncontrolled links come from a large number of small routes, which are more difficult to maintain than the big main routes with the risk that standard loss deviations will not be kept sufficiently small. In introducing level adjustment on expensive LD calls in a national network, therefore, one should choose the switching points with the hybrids to the 2-wire network as control points if economically justifiable.

From the supervision and maintenance points of view essential advantages are also gained:

- ☐ As the same 4-wire links are used for cheap as well as for expensive LD calls, the individual control of the latter also gives a statistical account of the quality of uncontrolled calls, and we can avoid loading the expensive LD network with special test calls.

- ☐ The control equipment is an objective judge of the transmission quality, and too poor transmission combinations can be locked for further investigations by the parties concerned. A lot of fruitless discussions between people in different maintenance areas will then disappear.

Inconvenience to the Telephone Users Caused by Irregularities

In the foregoing we have constantly referred to the "inconvenience to telephone users" caused by different kinds of irregularities. Attempts have been made to evaluate the inconvenience in terms of users' lost time or money, and the following authors should be mentioned:

- ☐ RAPP[6] considers the inconvenience of congestion and high reference equivalents, causing lost calls or poor intelligibility and prolonged conversation times. He suggests a method of weighting the inconvenience cost to the user against plant cost in order to arrive at a minimum.

- ☐ In a similar way CHRISTIANSEN and LIND[7] try to weight the inconvenience cost of technical faults against maintenance costs in order to find the most efficient maintenance methods.

Summary

- ☐ With time we have to foresee increasing performance demands from telephone users.

- ☐ All irregularities do not appear equally serious to users, and the introduction of a weighted fault scale would give supervision and maintenance people a proper picture of the inconvenience caused to users, so giving them means to direct their efforts to the most urgent points.

- ☐ The irregularities during conversation are the most serious ones, especially on expensive LD calls. On international calls we very often have language difficulties, as one or both users may not be using their own language. We can thus not count on the helpful redundance in human speech and should increase the intelligibility on international calls.

- ☐ We have therefore to reduce loss and noise as far as possible in order to give LD calls as near as possible the same quality as local calls in spite of the considerable extra equipment involved.

- ☐ It is essential to have about the same transmission conditions in both directions, so that the talkers can use their natural ability to regulate their voices in the proper way according to what they hear from the far end. This means better transmission conditions and a better interaction between man and machine.

- ☐ One way of reducing overall loss and avoiding loss variations caused by unavoidable loss deviations in tandem-switched 4-wire circuits is the introduction of a transmission check–before conversation starts–between an outgoing and incoming control switching point located as close to the hybrids as possible. The control of international calls may be split in national and international sections.

- ☐ With level regulation in the checking points the loss variations due to loss deviation combinations can be compensated for and only a loss for echo protection should remain.

- ☐ The echo protection loss in the 4-wire path can be reduced by normalizing the characteristics of the 2-wire circuits and telephone instruments to give a better matching with the 4-wire circuits.

- ☐ A transmission check on a worldwide basis, using only a relatively small number of actual LD calls as test calls, would give supervision and maintenance people in different areas and administrations a valuable help in tracing difficult transmission faults, as 4-wire connexions with too poor properties can, when desired, be automatically locked for investigation by the people concerned.

- ☐ As the control problems are worldwide, there will undoubtedly be a number of intricate problems to study and solve, which will take time. It would be advisable, however, to prepare new 4-wire switching points, so that control equipment can be introduced later on at a reasonable cost.

- ☐ The attempts to calculate and minimize the inconvenience to users from irregularities such as technical faults, congestion and too poor intelligibility are interesting, as planning, supervision and maintenance people will get a better picture of how to extend and maintain a plant economically having regard to the telephone users' demands.

- ☐ We have to teach the non-technical users to apply a certain conversation technique on very long distance calls with long propagation times and with interlinked echo suppressors, in order to prevent confusion and "hallo"-calls with the resulting prolongation of conversation time.

APPENDIX 1

Isoopinion Contours and Mean Opinion Score Deviations

In the calculation of the isoopinion contours MARKMAN[4] has used equation

$$Y = 3.35 + \beta(X + 2.5)^2 \tag{5}$$

where Y is the mean opinion score
X is the junction loss between terminal exchanges
β is a negative noise factor depending on circuit noise level as given in Markman's table 4.

In the CCITT investigations a loss of 6 db for subscribers' sets and lines was added to the junction loss. Hence we can put $X = \text{SyRE} - 6$ db and transform equation (5) into

$$\text{SyRE} = \sqrt{\frac{3.35 - Y}{-\beta}} + 3.5 \text{ db}$$

We get the isoopinion contours by keeping Y constant and inserting the β-values corresponding to different noise levels as given in Markman's table 4.

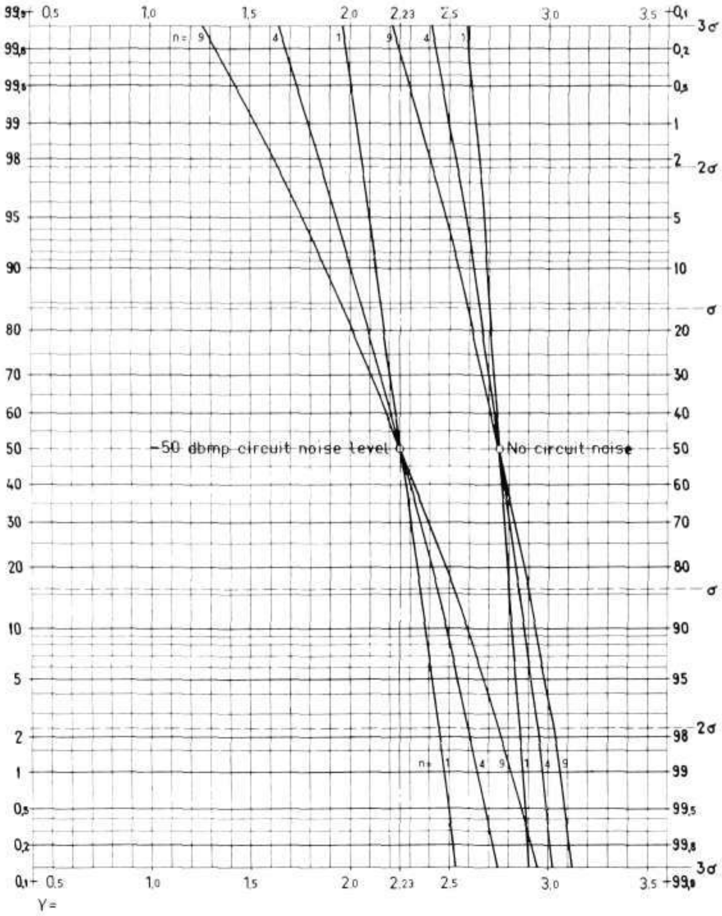


Fig. 8 X 8465

Mean opinion score distribution for n tandem-switched 4-wire links

Nominal SyRE = 27 db

From these curves we get only a rough picture of the trend in the mean opinion scores under various circuit conditions. We are, however, also interested in a more detailed study of the variations in mean opinion score, when we have loss variations on successive calls between two subscribers, as they will compare the worst calls with the best ones. Too big variations in mean opinion score will increase the risk of subscribers' complaints.

If we assume that the loss deviations in the 2-wire networks can be neglected on successive LD calls, we have only to consider the loss deviations in the complex 4-wire circuit. If in this circuit we have n links, each with a standard loss deviation of σ_x db with normal distribution, the loss distribution can be represented in a probability diagram by straight lines

$$X = X_0 - \lambda \cdot \sigma_x \cdot \sqrt{n}$$

where X is the nominal loss value and

λ is a linear vertical scale factor with $\lambda = \pm 1$, ± 2 etc. for the probability levels corresponding to $\pm \sigma$, $\pm 2\sigma$ etc.

Hence we get

$$Y = 3.35 + \beta(X_0 + 2.5 + \lambda \cdot \sigma_x \cdot \sqrt{n})^2 \qquad (5\ a)$$

The diagrams in fig. 8 show the distribution curves for Y for a nominal SyRE of 27 db, i.e. $X =$ SyRE - 6 = 21 db for 1, 4 and 9 links with a standard loss deviation of 1 db. Two curve groups are given–one for the noise level – 50 dbmp at the terminal exchange and the other when no noise is present. The curves have a slight clockwise bend but can with small error be substituted by straight lines.

This gives us a possibility to calculate a standard deviation of the mean opinion score in relation to the standard deviations of X and β. From equation (5) we get the differential mean opinion score

$$dY = (X + 2.5)^2 d\beta + 2\beta\ (X + 2.5) \cdot dX$$

By inserting the standard deviations $d\beta = \sigma_\beta$ and $dX = \sigma_x \cdot \sqrt{n}$ and observing that σ_β and σ_x are independent of each other, we get the standard deviation in the mean opinion score as the r.m.s. of the terms to the right

$$\sigma_y = (X + 2.5) \cdot \sqrt{[(X + 2.5)\sigma_\beta]^2 + (2\beta \cdot \sigma_x \cdot \sqrt{n})^2}$$

which can be transformed into

$$\sigma_y = 2\beta \cdot \sigma_x \cdot \sqrt{n}\,(X + 2.5) \cdot \sqrt{1 + \left[\frac{\sigma_\beta}{2\beta} \cdot \frac{X + 2.5}{\sigma_x \cdot \sqrt{n}}\right]^2}$$

An investigation using Markman's table 6 shows that the square term in the square root can be neglected as its influence on σ_y is only 10 to 15 % for the case we are interested in–many links and high loss values. Therefore, for further discussions we can neglect the noise variations and use the simplified equation

$$\sigma_y = 2\beta \cdot \sigma_x \cdot \sqrt{n}\ (X + 2.5)$$

or when $X =$ SyRE – 6 db

$$\sigma_y = 2\beta \cdot \sigma_x \cdot \sqrt{n}\ (\text{SyRE} - 3.5)$$

Considering an expensive LD call we find:

- ☐ On intercontinental calls CCITT recommendations permit a noise level of – 50 dbmp all the time, giving a β about twice as high as for noise-free calls.
- ☐ By reasonable maintenance and supervision efforts we can get a σ_x of about 1 db.
- ☐ The number of links depends on the routing plan, up to 12 links being permitted on intercontinental calls.
- ☐ SyRE is mainly dependent on the present situation in the 2-wire networks.

Our possibility of reducing σ_y is thus very restricted. If, however, we introduce the proposed level control with regulation before conversation starts and use the switching points to the 2-wire networks where we have the hybrids as control points, we gain the following:

- ☐ The whole complex circuit can be considered as one link regulated from the control points for an actual call.
- ☐ The standard loss deviation on such a regulated circuit is dependent on the measuring and regulation accuracy and can be kept very low–better than for the individual links.
- ☐ As the loss deviations in a regulated complex circuit are small, we can reduce the compensation for negative loss deviations. A reduction of 3 and 5 db for connexions with 4 and 9 links respectively, seems to be possible–compare fig. 6 in the main paper.

With level regulation we thus get

- ☐ an essential reduction of the standard deviation for the mean opinion score with decreased risk for subscriber complaints.
- ☐ a reduction of SyRE without changes in existing 2-wire networks, which means an increase in mean opinion score and a desirable raise in performance on expensive LD calls.

The table below shows the gain for some cases with $\sigma_x = 1$ db.

Level regulation	Noise level	None						— 50 dbmp					
	No. of links	4	9	4	9	4	9	4	9	4	9	4	9
without	SyRE db	20		27		34		20		27		34	
	M.O.S. Y	3.06		2.75		2.35		2.81		2.26		1.52	
	σ_y	0.07	0.11	0.10	0.15	0.13	0.20	0.13	0.20	0.19	0.27	0.24	0.36
	$p+$ %	0.3	0.2	1.7	1.3	7.7	6.1	1.1	0.7	8.5	6.5	38.4	32.0
	$p-$ %	0.8	1.0	4.2	5.0	16.5	18.9	3.7	4.9	22.4	26.3	64.0	69.7
with	Loss reduction db	3	5	3	5	3	5	3	5	3	5	3	5
	M.O.S. Y	3.15	3.20	2.90	2.98	2.53	2.65	2.99	3.09	2.52	2.68	1.86	2.07
	σ_y	0.03	0.03	0.04	0.04	0.06	0.06	0.06	0.05	0.08	0.07	0.11	0.10
	$p+$ %	0.2	0.2	1.1	0.7	5.2	3.3	0.6	0.3	5.0	2.8	27.3	18.1
	$p-$ %	0.4	0.3	1.6	1.1	8.0	5.2	1.5	0.6	8.8	4.8	39.0	27.3

In the table we have–using Markman's table 5–calculated the percentage poor and bad calls $p+$ and $p-$ corresponding to mean opinion scores $Y + \sigma_y$ and $Y - \sigma_y$ respectively. As σ_y is the standard deviation with respect to 4-wire loss deviations, it has to be noticed that about $2 \times 16\,\%$ of the calls will have a performance better or worse than shown in the table. Roughly the worst level regulated calls will be considered as good as the best unregulated ones by the users. The gain in performance is essential, when we have many 4-wire links, high circuit noise and high reference equivalents in existing 2-wire networks.

APPENDIX 2

End-to-end Control of Complex 4-wire Circuits

One way of introducing level control and loss adjustment of complex 4-wire circuits to prescribed nominal values is illustrated in fig. 7, where we have the following features:

- ☐ Outgoing and incoming control switching points–*UKS* and *IKS*–situated as near the hybrids as possible. Between them a number of transit switching points–*TFS*.
- ☐ In all switching points equipment–e.g. registers *REG*–which can receive sufficient numerical information in the form of code digits for country and area and, when needed, also the subscriber's local number.
- ☐ Analysers *AN* momentarily connected to the registers, which from the code digits determine:
  - In *UKS* whether an actual call needs a transmission check and whether echo suppressors need to be inserted.
  - Whether a *TFS* has to function as *IKS* or not.
- ☐ In *UKS* and *IKS* the registers must remain on the connexion until the transmission test and switching are completed. During switching automatic level regulators *PD* are connected to a suitable point in the switch train.
- ☐ No level regulation is needed in interlinked transit switching points, and the register is disconnected after through switching.
- ☐ In *UKS* and *IKS* level control units *MD* are connected between registers and level regulators *PD*.
- ☐ In *UKS* the *ANU* determines from the code digits the nominal loss value for the prospective call, which is stored in *MDU*.

The registers and analysers we already have in one or another form in modern switching systems with alternative routing, but they must have some new features added for the control. The *MD*'s and *PD*'s are new devices. In short the function will be as follows:

- ☐ *REGU* receives the code number, connects itself momentarily to an *ANU* and is informed whether level control–with or without echo suppressors–is wanted.

- ☐ If so, *MDU* is connected to the register and *ANU* transfers the nominal loss value to the *MDU*-memory.

- ☐ The call is switched through *UKS*, whereby *PDU* is connected to a suitable switching stage and also to *MDU*.

- ☐ The switching proceeds through all *TFS*, which are informed by their analysers that there is a more remote control point. With respect to alternative routing, this can be arranged dependent on the chosen route from the switching point. After through switching, the registers and analysers are disconnected.

- ☐ When the call reaches *IKS*, *ANI* directs *REGI* to switch in *MDI* and *PDI*.

In principle we can now make our measurements, as measuring and regulation outfits have been switched in at both control points, but we have to wait for a suitable moment in order not to disturb the ordinary digit transfer from *UKS* to *IKS*. If we were always able to determine from *UKS* the number of national digits in a remote area, the problem would be very simple, as we could start the measurement after the last digit and proceed with the switching in the remote area in the meantime, which would mean practically no prolongation of switching time. For areas with irregular numbering we cannot use this method, but we can always fix a minimum number of national digits, including the area code, and interrupt the sending of digits from *UKS* when these digits have been transmitted. After measuring, the remaining digits are sent. We actually save time as we can partly switch in the remote area during the measurement. Also *REGI* knows when digit sending is interrupted, and the following sequence can start:

- ☐ *REGI* sends a measuring signal in the backward direction at internationally determined level and frequency.

- ☐ The signal is received by *MDU* and the received level is compared with the loss value stored in the memory. *PDU* regulates the loss value in the backward direction to the prescribed nominal value.

- ☐ When *MDU* receives the measuring signal, it sends forward the determined reference level *increased* by the nominal loss value.

- ☐ *MDI* compares the received level with the reference level, and *PDI* regulates the loss in the forward direction to the prescribed nominal value.

- ☐ *MDI* disconnects the measuring signal, and *MDU* answers by disconnexion of its signal, whereafter both measuring devices are released and the transfer of the remaining digits can proceed.

The proposed method does not permit echo suppressors in the connexion during the transmission check, but we must be able to switch echo suppressors in or out for other reasons as well, and this can be arranged by signals from *REGU*.

On completion of switching, the two level regulators *PD* are the only additional equipment used for the call. As we have only one measurement for each talking direction of the whole 4-wire path, neither measuring nor regulation need to be too accurate, and a loss deviation of max $\pm$ 1.5 db corresponding to a standard loss deviation of 0.5 db ought to be possible with a level regulation of 1 db per step.

The nominal loss value which has to be introduced to avoid inconvenient echo when no echo suppressors are inserted should be determined with respect to the worst combination of link routes between two remote control points, giving the longest propagation time. In this way the telephone users will never note when different routes are chosen, and one reason for complaints disappears.

If the measured deviations are too large to be compensated by the level regulators, there is probably an undiscovered fault somewhere in the transmission path, but there may also be an unlucky combination of deviations. Such calls should be rejected, and as the whole digit information is stored in *REGU*, we can release the 4-wire network and build up a new path from *UKS* without disturbing the caller. In *UKS* the code numbers of all rejected calls should be registered for statistical purposes. The supervision people will then discover whether for certain code numbers there are too many rejected calls, and those numbers can be marked in *ANU*, so that the next rejected 4-wire connexion will be locked by the *PDU*-regulator. If this regulator is connected to another point in *UKS* than the incoming line from the 2-wire network, a new 4-wire path can automatically be given to the caller. The locked 4-wire path gives alarm and can be investigated by all maintenance parties concerned. In this way we give the maintenance and supervision people valuable means of discovering combination faults impossible to trace by other methods. During the transmission check we can also measure the noise level outside the narrow measuring frequency band. Calls with too high a noise level are rejected, as we cannot compensate for noise.

It is, of course, not necessary to check all LD calls. Less expensive national LD connexions not containing too many 4-wire links may be left unchecked. In this way only a relatively small number of LD calls–determined by *ANU* from the code numbers–need to be checked, which reduces the costs of the control equipment. This means, however, that in the national links we must insert sufficient loss for echo protection, which has to be compensated by the level regulators on transmission-controlled calls.

As only a small percentage of calls passing the terminating control point *IKS* has to be controlled, it is desirable to have a special forward signal from *UKS*, indicating that control is wanted in order to avoid unnecessary occupation of *MDI* and *PDI* units. Another way is to let *REGI* at a proper moment send a backward premeasuring signal, asking *REGU* for further instructions. Being dependent on the signalling possibilities in various switching systems, the problem of additional measuring signals has not been investigated in detail but should be included in a further study of level control.

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Overvoltage Protector NGC 31

B LINDGREN, TELEFONAKTIEBOLAGET LM ERICSSON, STOCKHOLM

UDC 621.316.93
LME 7392

For the past few years L M Ericsson has been making overvoltage protectors in the form of rare gas tubes. They are primarily intended to replace the older carbon arresters. The reliability, efficacy and loading capacity of the rare gas tubes have, however, made them usable also in applications for which the carbon arresters cannot be employed. Several types have been developed, with different properties as regards striking voltage, loading capacity and mechanical design.

The technical development is briefly described and the special demands on the manufacture of the tubes are touched upon.

The Function of Overvoltage Protectors

Disturbances may be induced into telephone lines as a result of atmospheric discharges or the vicinity of power lines. The former may appear in the form of travelling waves of very great amplitude.

The function of the overvoltage protector is to protect persons speaking on the telephone as well as the subscribers' and exchange equipment against induced atmospheric overvoltages and against overvoltages caused by contact between telephone and power lines provided that the current load does not permanently exceed 20 A. Consequently it does not protect against a stroke of lightning in the telephone line at the point of the stroke. But rare gas tube protectors on the line in the neighbourhood of this point reduce its destructive effect. The protectors are generally connected between each leg of the line and earth, but some protection is gained also if the protector is connected in parallel across the line.

What a Good Overvoltage Protector should do

A rare gas tube offers a very high resistance when the voltage across it is below its striking voltage. If the striking voltage is exceeded, a glow discharge takes place in the tube. The voltage across it then falls to the maintaining voltage of about 100 V. The glow discharge changes into an arc discharge if the current through the tube is greater than about 0.1 A. In such case the voltage across the tube falls to about 25 V. The protective action of the tube lies in the fact that the overvoltage is thereby discharged to earth.

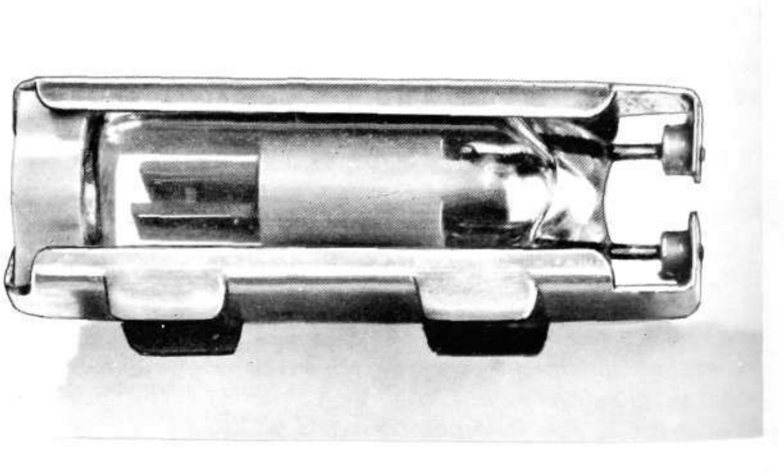


Fig. 1
Rare gas tube, NGC 313
Scale approx 2.5:1

X 8450

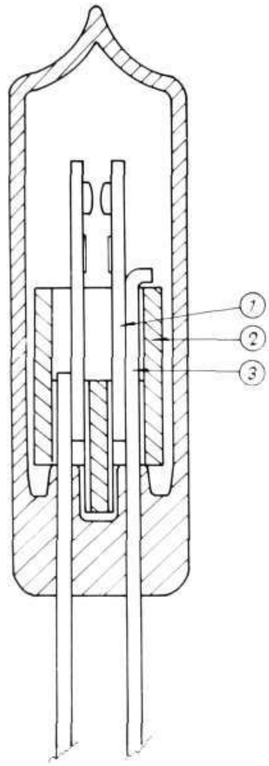


Fig. 2
Cross-section of rare gas tube type NGC 31

X 2753

Fig. 3
Discharge of shock wave 1/50 without and with a rare gas tube
T_1 = wave front time
T_2 = half peak value
Up = protection level
Ua = arc maintaining voltage

X 2754

It is, of course, vital that the overvoltage protector should function as rapidly as possible after the voltage has exceeded the permissible limit. In their original form rare gas tubes were not altogether ideal in this respect. They were subject to a statistically distributed time lag of between a few tenths of a microsecond and a matter of seconds. This was because the gas must be ionized to some extent for glow discharge to take place. Ionization may occur through the action of light, cosmic radiation or a strong electric field. The overvoltage protector must be so designed that the delay in striking is negligible.

The overvoltages induced by heavy atmospheric discharges may be of an order of 300 kV with a very steep wave front of 50 kV/µs. Fortunately they are very brief, generally of the order of 0.1–10 µs, but with a current intensity of thousands of amps. The overvoltage protector must therefore strike during these brief high-energy surges and discharge the energy to earth.

A good rare gas tube must therefore withstand repeated momentary currents of high amplitude without bursting of its glass envelope or destruction of its electrodes.

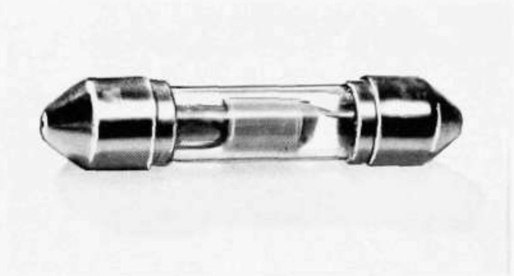
Construction and Properties of Overvoltage Protector NGC 31

The rare gas tube *NGC 31* is the final product in a long series. The experience of earlier designs has been utilized in the new tube. It consists of a diode in a glass envelope filled with rare gas. Its two electrodes are both cathode-activated and symmetrical, thus independent of the direction of the discharge current. The envelope has external mountings which fit into the carbon-arrester holder.

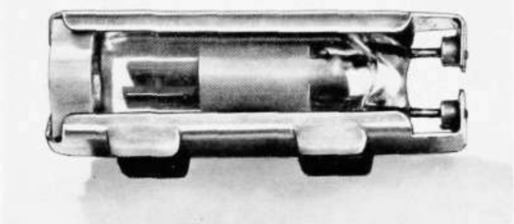
The construction will be seen from fig. 2. Two rectangular bimetallic strips (1), sized 15 × 4 × 0.65 mm, are fixed in a cylindrical ceramic body (2) with a short partition extending beyond the bottom of the cylinder. They have heavy duty contacts to avoid welding by an arc. Two fairly thick CC wires (3) through the glass stem connect the internal parts to the external mountings. CC wire is a copper-clad wire with iron core. The coefficients of expansion of the wire and of the glass into which it is fused are closely matched. This impedes leakage or too early bursting of the glass. To raise the limits for the permissible current load, the CC wire has been given a diameter as large as 0.8 mm. According to general opinion and practice in glass technique the maximum value was earlier about 0.5 mm. Through the increased diameter and special treatment of the CC wire a tight seal is obtained between copper and glass even at about three times as high a current as before.

A patented method has been used to ensure high speed of response of the protector. The method is simple and reliable. The glass-bulb is lightly powdered on the inside with a very fine-grained powder of light metal. Through the small weight of each grain the force of adhesion is sufficient to hold the powder to the glass. When a high voltage is applied to the tube, a number of micro spark discharges take place between the grains. The rare gas is then ionized and the delay in striking is reduced well below the required limit. The method is effective irrespective of the light conditions and within temperature limits of + 100 to − 78° C.

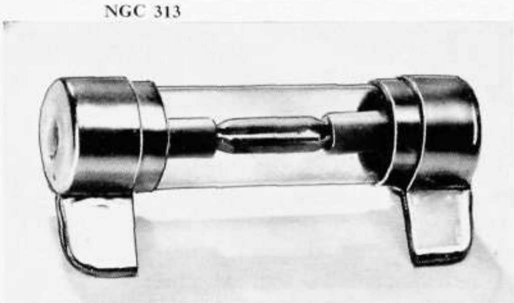
The rapidity of response of the rare gas tube is illustrated in fig. 3. For laboratory simulation of practical conditions and for testing purposes a standardized overvoltage wave has been created, known as wave form 1/50, 1 representing the wave front time and 50 the half peak value in µs. The high voltage to be impressed is optional. The *dashed* curve in fig. 3 shows the process without overvoltage protector, at an *arbitrarily* chosen peak voltage of 15 kV. The *continuous* curve shows the process when a rare gas tube is connected. The front voltage is cut off at a level slightly below 1 kV and in less than 0.1 µs. At the start there is a small tendency to oscillation which is followed by a rapid drop to arc maintaining voltage. During the first micro-



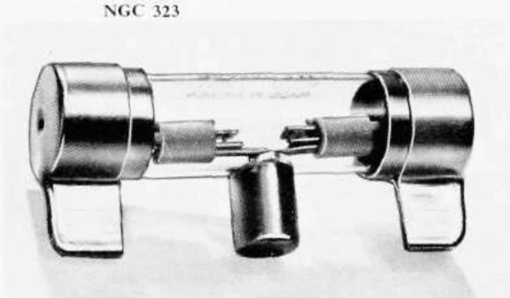
NGC 303



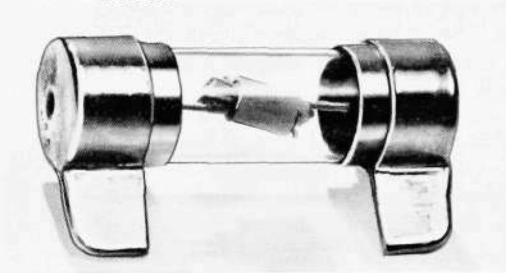
NGC 313



NGC 323



NGC 333



NGC 343

Fig. 4 X 2755—2759
Different types of rare gas tube

seconds the average residual voltage affords a level of protection of some 500 V, at which no damage can be incurred during so short a time. This result has been measured both with an oscillograph and with a specially constructed electronic, highly rapid peak-voltage meter which gives an indication of longer duration.

The electrodes, as noted, are bimetallic strips. During relatively lengthy discharges, which occur on permanent contact with power lines, the bimetallic strips are heated and come together to produce a short-circuit. On a powerful arc discharge through the tube the short-circuit is effected after about 0.5 second. It persists during the period of the disturbance and for a few seconds thereafter. The short-circuit also protects the cathode layers against gasification and greatly increases their life.

Data

Static striking voltage: Standard values are 250, 300, 350 and 400 V DC.

Shock striking voltages with wave form 1/50: (on tubes for up to 600 V DC static striking voltages) < 1,000 V.

Maintaining voltage on glow discharge: 75–150 V DC.

Maintaining voltage on arc discharge: 15–30 V DC (at > 100 mA).

Insulation: > 5,000 Mohms.

Time of arc before electrodes are short-circuited: 2–4 seconds at 5 A, 0.5–1.5 second at 20 A.

Electrode breaking time: after 5–10 seconds.

Rupture limit of glass base after 1-minute continuous current: > 20 A.

Rupture limit of glass base at 1.5 Coulomb: > 2,000 A.

Continuous current load (unlimited time): 15 A.

Cathode activation: Withstands current loads up to rupture limit of glass base.

The electrode system in *NGC 31* is used in several other types of tubes for 2-pole and 3-pole termination as shown in fig. 4. All these tubes are valuable and robust components in telephone networks.

Further information concerning the various types of tubes, their dimensions, electrical data, holders, etc. will be found in "*News from the Network Department*" *No. N 16e: Rare Gas Tubes.*

Ericsson LM NEWS *from All Quarters of the World*

New Brazilian Contract: Extension of Fortaleza Network

L M Ericsson has recently signed a contract with the Brazilian Municipality of Fortaleza for extension of its telephone installations. Fortaleza is capital city and an important administrative and commercial centre in the province of Ceará. It has at present four urban exchanges with a total capacity of 14 600 lines in operation – 10 000 of the 500-line selector system AGF and 4 600 crossbar ARF. The first of these exchanges was opened in 1937 and is still rendering admirable service. The new order involves an addition of 8 000 ARF lines.

The photograph above shows the signing of the contract by the chairman of the board of Ericsson do Brasil, General Juracy Magalhães, in the presence of (from left) the head of the Fortaleza telephone administration, Gerardo Maia, the president of Ericsson do Brasil, Ragnar Hellberg, the governor of Ceará, Colonel Virgílio Távora, and the mayor of Fortaleza, General Murillo Borges.

Another Large Order from Colombia

L M Ericsson has received orders from Colombia for telephone equipment to an amount of over 10 million kronor. They comprise mostly carrier and automatic switching equipment for extension of the long distance network, which was constructed by L M Ericsson.

Colombia is a large market for L M Ericsson, which has supplied a considerable part of the telephone installations in the country. The first Ericsson automatic exchanges were delivered in the early thirties.

Extension of the automatic exchanges of Bogotá and Medellín by some 40 000 lines was contracted last year.

First Automatic Exchange in Sumatra

The first automatic exchange in Sumatra, Indonesia, was opened recently. It is an Ericsson ARF 101 exchange with a capacity of 1 000 lines and is located at Tandjungkarang. In the photograph below the Resident of Lampung, Zainal Abidin, cuts the symbolical tape.

New Ericsson Factory near Dieppe

A new factory of Société des Téléphones Ericsson (STE) was recently opened at Saint-Nicolas outside Dieppe in the presence of high-ranking personages in French telephony. The photograph below was taken during a tour of the factory. The head of Société des Ateliers Vaucanson, M. Muel (left), demonstrates the plant to the P.T.T. Minister, M. Jacques Marette (right). In the centre is the president of STE, M. André Duprez.

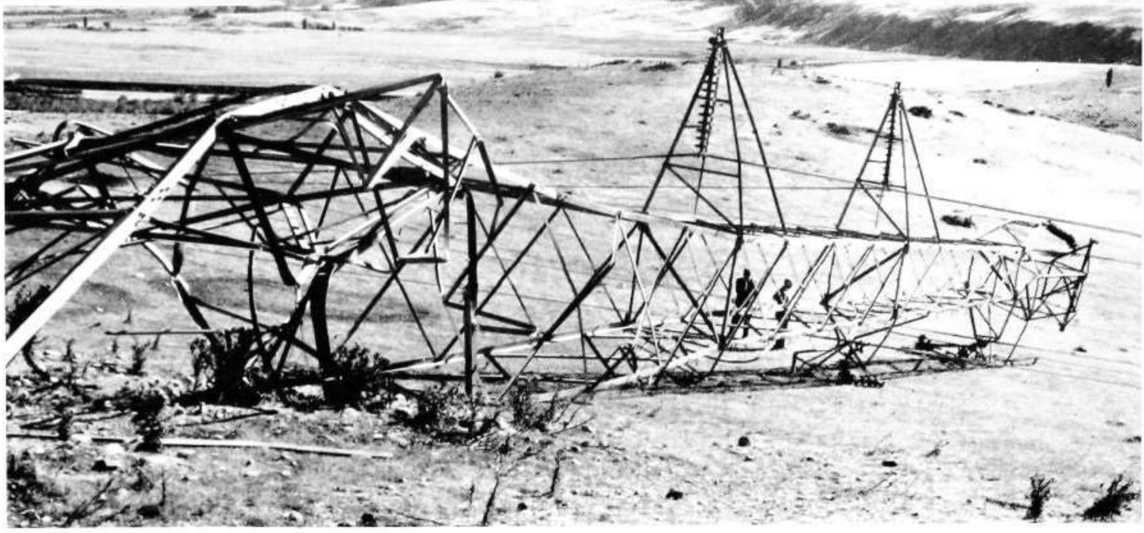
World's Largest Series Capacitor

On October 19, 1963, the Swedish Power Board put into operation the world's largest series capacitor. The bank is rated at 300 MVAr and consists of 6,000 units of Sieverts Kabelverk's type CRS 50. It is located at Djurmo in Dalecarlia on one of the 400 kV lines from Norrland. The capacitor raises the transmission capacity, by over 75 per cent, from 450 to 800 MW. The photo above shows (from right) Messrs. Gottschalk von Geijer and Gunnar Jancke of the Power Board and Mr. Kjell Hägglund of Sieverts Kabelverk in front of the new bank at the opening ceremony.

In October 1963 L M Ericsson's Dutch subsidiary opened its new sales offices at Voorburg near The Hague. During the official inauguration president Sven T. Åberg rang up the mayor of Voorburg, Mr. A. Feith (left in picture above), and asked him to officiate at the ceremony. The president of Ericsson Telefoon-Maatschappij, J. Badon Ghijben (centre), and the Director General of the Dutch P. T. T., Professor G. H. Bast (right) listened to the conversation which was relayed by loudspeakers throughout the building.

At the end of last year a study trip was arranged by the Swedish Agency for International Assistance for 21 African administrators, in the course of which they visited L M Ericsson at Midsommarkransen. Some of the group are seen in the photograph (left) in the Exhibition Room.

Ten large power line towers collapsed in a tempest in South Island, New Zealand, when the force of the gale was estimated at nearly 170 m. p. h. Although the poles were destroyed and several miles of the wires lay on the ground, this did not prevent the Ericsson carrier equipment from functioning satisfactorily. (Photo right)



(Photo left) The Jugoslavian ambassador Dušan Popović (left), with counsellor Vojislav Pekić on visit to Midsommarkransen.

The photo above shows a display window at Ericsson Telephone Sales Corporation AB, New Delhi, in which Ericsson time control equipment is effectively displayed.

The Thailand Ambassador to Sweden, Visutr Arthayukti, visited Midsommarkransen in December. (From left) The Ambassador, the Second Secretary Kanit Sricharoen, and L M Ericsson engineers L. Mjöberg and C. O. Morander.

Georg Olsson †

Georg Olsson, former president of Sieverts Kabelverk, has died at the age of 77.

After graduating from the Stockholm Technical College in 1905 he joined AEG as draughtsman and designer but soon transferred to Stockholms Allmänna Telefon AB and became head of its Installation Department in 1909. In 1915 he was appointed superintendent of its Maintenance Department and one year later head of the company's cable works at Älvsjö. There he remained until the cable works was taken over by Telefon AB L M Ericsson in 1921. In 1928 he became president of Sieverts Kabelverk, Sundbyberg, from which he retired on pension twelve years ago.

Ericsson Technics

Ericsson Technics No. 2, 1963, came out at the year end, so completing its nineteenth year of issue.

No. 1, 1963, issued last summer, opened with a paper by A. Dattner, "Experiments on Plasma Resonance". The author describes studies of resonance phenomena in plasma enclosed in a cylindrical waveguide under the influence of electromagnetic fields.

Thereafter follows "Magnetic Eddy Current Fields Calculated by Complex Successive Overrelaxation", in which J. Ehrenborg and J. E. Sigdell describe how vector fields which vary with time can be calculated by means of a complex overrelaxation factor. The method is employed for determining the field distribution in a magnetic conductor in the neighbourhood of an air gap.

In "Optimal DTL Circuits" Ø. Gjessvåg presents the general requirements for logic circuits in large logic systems and some points to be considered for their optimal design. A new type of diagram – the P-N diagram – is recommended as permitting better assessment of the properties of the digital circuit. A figure of merit for the DTL circuit is defined with reference to this diagram.

In "Cavity Method for Measuring Dielectric Constants at Microwave Frequencies" by P. Hedvall and J. Hägglund a circularly cylindrical cavity is used to measure the relative dielectric constant, ε, and the dissipation factor, tan δ, for a test rod placed axially in the resonator. Graphs and tables are presented for determination of ε and tan δ from measurements of the resonant frequency and Q value of the cavity. These are based on an exact calculation of the resonant frequency behaviour of the TM_{010} mode as a function of ε. The results hold good up to high values of ε, which is impossible with the commonly used perturbation methods.

In the concluding paper in No. 1, "Cavity Method for Measuring Plasma Properties", P. Hedvall has calculated the resonant frequency and Q value for a circularly cylindrical TM_{010} cavity containing an axially located plasma rod surrounded by a glass tube. In measurements of plasma properties by the microwave cavity method, the influence of the glass tube surrounding the plasma is often disregarded. The object of this study was to improve the cavity method by taking the glass tube into account. This improvement is of especial value when calculating the collision frequency of the plasma.

The main contents of Ericsson Technics No. 2, 1963, consist of a series of articles under the common heading "A Four-Wire Solid-State Switching System". They are concerned with a number of electronic switchboards supplied to the U.S. Air Force during 1962 by North Electric Co., L M Ericsson subsidiary, of Galion, Ohio. The switchboards form part of the 412-L air weapon control system for which General Electric was main contractor. The telephone system was designed in intimate co-operation with the Development Department of the parent company in Stockholm and is based on work on time division systems on which the Department has been engaged since the fifties. A laboratory model, EMAX I, was built on the time division principle in 1954. The series of papers on 412-L bears the following headings: "Application, Concept and Configuration", "Subscriber Instruments", "Common Control Equipment", "Numbering Plan and Signalling System", and "Time Division Switching Network". The following authors have contributed: C. Curran, C. G. Svala, A. A. Unseren, J. R. Siconolfi, C. B. Nennerfelt, A. Svensson, A. K. Bergmann, F. H. Haferd, E. Aro and S. L. Junker. The papers were previously published in conjunction with the Winter Session of I.E.E.E., New York, January 27–February 1, 1963.

This series is followed by "A Comparison between the Sensitivities of Radar Monopulse and Conical-Scan Systems" by T. Fjällbrant. With reflectors of the same diameter the systems can be made to have similar signal-to-noise ratios in the surveillance mode. In the tracking mode the monopulse system then has a 6 db better signal-to-noise ratio in the range channel and 3–6 db better in the angular error channel.

In "Excitation of Plasma Waveguides with Backward Wave Modes", finally, B. Agdur and B. Enander have studied the excitation of electromagnetic waves in a waveguide containing a cool isotropic plasma. Special attention is paid to cases in which backward waves exist. The influence of drift velocity of the plasma is investigated.

In November last year Ericsson Telefoon-Maatschappij N. V., Rijen, took part in "Europort", a large exhibition for ship's equipment in Rotterdam. Among other Ericsson exhibits were an entire range of equipment for ship's internal communications. (Photo left)

UDC 621.395.74
LME 808

ANDERSEN, E, BOHLIN, T, ERIKSSON, J & SAULEDA, E: *Long Distance Network in Colombia.* Ericsson Rev. *41*(1964): 1, pp. 2—17.

The first part of this article describes the comprehensive long distance telephone network of Colombia, that has been built by the L M Ericsson Telephone Company for the Empresa Nacional de Telecomunicaciones. The second part deals with the automatization of a large number of the long distance exchanges carried out at the same time using L M Ericsson's crossbar systems. The country's telecommunications facilities have thereby been significantly improved, a factor which actively contributes to rapid economic development.

UDC 621.3953
LME 830

ERICSSON, E A: *The Telephone User and the Switching Machine.* Ericsson Rev. *41*(1964): 1, pp. 18—33.

This article is a revised version of papers prepared for the L M Ericsson Maintenance Conference in Stockholm, June 1962, and the Second Symposium on Human Factors in Telephony at Copenhagen, September 1963. In a previous paper presented at the "First Symposium on Human Factors in Telephony" at Cambridge in 1961, the author gave some aspects on a worldwide switching machine, mainly with respect to supervision and maintenance problems. In this paper similar problems are considered from the telephone users' point of view, with special attention to the performance during conversation. Possibilities of obtaining better matching between man and machine are discussed, which may be of importance in a future worldwide automatic telecommunication network.

UDC 621.316.93
LME 7392

LINDGREN, B: *Overvoltage Protector NGC 31.* Ericsson Rev. *41*(1964): 1, pp. 34—36.

For the past few years L M Ericsson has been making overvoltage protectors in the form of rare gas tubes. They are primarily intended to replace the older carbon arresters. The reliability, efficacy and loading capacity of the rare gas tubes have, however, made them usable also in applications for which the carbon arresters cannot be employed. Several types have been developed, with different properties as regards striking voltage, loading capacity and mechanical design. The technical development is briefly described and the special demands on the manufacture of the tubes are touched upon.

The Ericsson Group

Associated and co-operating enterprises

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Telefon Fabrik Automatic A/S *København K*, Amaliegade 7, tel: C 5188, tgm: automatic

Dansk Signal Industri A/S *København F*, Finsensvej 78, tel: Fa 6767, tgm: signaler

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O/Y L M Ericsson A/B *Helsinki*, Fabianinkatu 6, tel: A8282, tgm: ericssons, telex: 57-12546

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Production Control (Ericsson) Ltd. *London, W. C. 1*, 329 High Holborn, tel: HOLborn 1092, tgm: productrol holb

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SIELTE, Soc. per Az. *Roma*, C. P. 4024 Appio, tel: 780221, tgm: sielte

FATME, Soc. per Az. *Roma*, C.P. 4025 Appio, tel: 780021, tgm: fatme

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AB Alpha *Sundbyberg*, tel: 282600, tgm: aktiealpha-stockholm

AB Ermi, *Karlskrona 1*, tel: 23010, tgm: ermibolag-karlskrona

AB Rifa *Bromma 11*, tel: 26 26 10, tgm: elrifa-stockholm

AB Svenska Elektronrör *Stockholm 20*, tel: 44 03 05, tgm: electronics

L M Ericssons Driftkontrollaktiebolag *Solna*, tel: 27 27 25, tgm: ericdata-stockholm

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LM Ericsson Telephone Co. (Pty.) Ltd. (Branch Office of LM Ericsson Telephone Co. Pty. Ltd. in Johannesburg) *Bulawayo, Southern Rhodesia*, P.O.B. 1974, tel: 64 704, tgm: ericsson

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Usam Sharif Company W.L.L. *Baghdad*, Sinak-Rashid Street, tel: 870 31, tgm: alhamra

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TECOMA Technical Consulting and Machinery Co. Ltd. *Khartoum*, P.O.B. 866, tel: 2224, ext. 35, tgm: sutecoma

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Tropical Commission Co. Ltd. *San José*, Apartado 661, tel: 3432, tgm: troco

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S. E. L. Maduro & Sons, Inc. *Curaçao*, P. O. B. 172, tel: 1200, tgm: madurosons-willemstad

Dominican Republic
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Guatemala
Nils Pira *Ciudad de Guatemala*, Apartado 36, tel: 62258, tgm: nilspira-guatemala

Honduras
Quinchón León y Cía *Tegucigalpa*, Apartado 85, tel: 1229, tgm: quinchon

Jar
Mo
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Nicaragua
Edmundo Tefel *Managua, D.N.*, Apartado Postal 24, tel: 3401, tgm: edfelco

Panama
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Paraguay
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Puerto Rico
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El Salvador
Dada-Dada & Co. *San Salvador*, Apartado 274, tel: 4860, tgm: dada

Surinam
C. Kersten & Co. N. V. *Paramaribo*, P. O. B. 1808, tel: 4444, tgm: kersten

Trinidad, W. I.
Leon J Aché Ltd. *Port-of-Spain*, 100 Frederick Street, tel: 32357, tgm: achegram

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Clark Walter Corporation *Newark 2, N. J.*, 744 Broad Street, tel: Mitchell 3-7333, tgm: wirewalter-newarknj. (For intercom)

State Labs. Inc. *New York 3, N. Y.*, 215 Park Avenue South, tel: Oregon 7-8400, tgm: statelabs (For electron tubes)

• AUSTRALIA & OCEANIA •

New Zealand
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