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This Issue in Brief

Mobile Telephone Terminal for 1 or 2 Radio Channels

The extension of the public telephone network to automobiles in which the mobile subscriber calls, talks, and listens exactly as with a conventional fixed subscriber set was formally initiated by the Bell System in a field installation in Harrisburg, Pennsylvania, in 1963.

Spaced at 30-kilohertz intervals are 11 channels at 152 megahertz for base-station transmission and a corresponding 11 channels at 158 megahertz for transmission from mobile stations.

Modulation at frequencies between 600 and 2150 hertz is used for both supervisory signaling and push-button calling. These frequencies are well within the limits of conventional telephone transmission.

For the independent telephone companies, a 1- or 2-channel base telephone switching system has been developed. The equipment described in this paper may be added to any conventional central office to interconnect the existing telephone network to the radio equipment operating with the mobile subscriber sets.

A New Stackable Carrier System for Open-Wire Lines

A stackable carrier system can be built up, channel by channel, on the same open-wire line if and when circuit requirements increase with time. It therefore has a special application in newly developing countries. Early systems were the Bell Type *P* System and the ITT *K 31/32* System.

Now modern circuit techniques, and miniaturization of components, have caused designers to look again at the stackable system and increase its facilities. In a new system, ten channels occupy the spectrum from 4 through 160 kilohertz. Speech information is transmitted by single sideband with added carrier. The frequency plan in the group mode makes it compatible with main-line systems whose pole routes it may share and 8 channels may be used over a route shared with both a CCITT 3-channel and 12-channel system.

Signaling is by frequency shift of the carrier to transmit the normally suppressed upper sideband. This allows signaling during speech without affecting quality. Since the channel can be used equally with signaling *on* or *off* a supervisory condition is possible. The mechanical construction will allow convenient and economical expansion of any initial installation.

Plastics Encapsulation of Components

Previously, encapsulation of electronic components with plastics has been limited to the low-cost limited-life market. Improvements in resins and application techniques now make plastics encapsulation suitable for more critical applications where absolute hermetic sealing is not required but performance must meet severe national and military specifications.

The degree of protection varies considerably with the type of resin and process employed. Resinous encapsulants now include epoxides, polyesters, silicones, polyurethanes, alkyds, and certain thermoplastics, that can be applied by techniques such as casting, liquid or powder dip-coating, use of resin preforms with molded cases, and various press-molding methods.

Specially formulated epoxide resins, termed Loex, have been developed for critical casting applications. Practical results on encapsulated silvered mica capacitors demonstrate the versatility of plastics encapsulation methods.

Loudness Rating of Telephone Subscribers' Sets by Subjective and Objective Methods

Although CCITT assumes the transmission bandwidth of the existing telephone network to be limited to the range 300 to 3400 hertz, yet loudness-rating methods recommended by it use a bandwidth of 100 to 8000 hertz for a subjective comparison and 200 to 4000 hertz for the objective system, OREM. It is possible for the loudness of a subset to be varied by as much as 6 decibels, due to the bandwidth difference.

A method of computing the bandwidth effect for any subset whose frequency response is known is based on the recommended methods of loudness calculation of ISO. For a steady signal of relatively wide bandwidth, such as speech, these methods are comparable in accuracy to the subjective or OREM rating and are therefore suitable as a basis for transfer from one rating assessment to another, and for estimating the modifying effects of different band-limiting frequencies.

SETED is a stable working standard which has been calibrated with reference to SFERT (in 1953) and to NOSFER (in 1966). Although these two master reference systems are alleged to give identical ratings the calibrations differ from SETED by 3·2 decibels for the send-end and by 1·7 decibels in the opposite sense for the receive-end. Even when full allowance has been made for confidence limits, there remains a probability that send- and receive-ends of SFERT and NOSFER differ in an opposite sense by amounts of the order of 2 ± 1 decibels.

The consequences of the reduced atmospheric pressure at altitudes of 500 meters (1650 feet) and higher are examined. If an altitude of 2000 meters (6600 feet) above sea level is taken as an example, it is found that the efficiency of a telephone connection is 4-decibels lower than at sea level due to a reduction in air density of 20 percent. A modified procedure is given for setting up an OREM or OBDM system so that ratings will be the same at any altitude. The equations, used for deriving the electrical output of a subset from its Reference Equivalent, must now include a factor to correct for reduced efficiency with increased altitude.

Direct-Coupled Waveguide Filters with Post Doublets

Waveguide small-bandwidth direct-coupled filters consist of a chain of resonant cavities formed by shunt susceptances created by post pairs spaced approximately a guide half-wavelength apart. Available theoretical and experimental data for the filters suggest the use of posts that have diameters so small as to make their manufacture difficult and increase filter losses. New formulas are now derived for the susceptance of pairs of posts in a waveguide which are valid over a much greater range of post diameters. These have been used to design a small-bandwidth direct-coupled waveguide filter and a comparison is made between its calculated and measured performance. This work was first published in August 1967 in the Proceedings of the Institution of Radio and Electronic Engineers, Australia, volume 28, page 269, and is now reproduced by kind permission of the Institution.

ITT-411 Intercommunication System

A private automatic loudspeaking exchange (PALX) reduces the demands made upon the PABX by handling the majority of internal calls. This is an important aid in large complexes like factories, chemical plants, hospitals, and similar organizations.

In addition the PALX includes many extra features such as loudspeaking sets, which it is claimed considerably reduce conversation time, direct selection using one-button calling, and a variety of subsets such as loudspeakers, loudspeakers with handsets, or handsets. Signaling, public address operation, and conference facilities can also be included.

The equipment is of modular design using 4-wire crossbar switching and is available in two non-extensible exchange sizes, 16 lines and 32 lines, and in three extensible exchange sizes, 20—100 lines, 100—600 lines and 100—2000 lines.

Voice-operated amplifiers in the control exchange and microphone amplifiers in the subsets operate in the transmission range 300 to 3600 hertz with an emphasis between 300 and 1000 hertz to improve speech intelligibility.

Vienna-Zollergasse HE-60L Trial Telephone Exchange

A second quasi-electronic trial office was put in operation in Vienna on 16 March 1966. Compared with the first trial office in Stuttgart, Germany, this installation offered a number of new features.

The Zollergasse Exchange handles up to 0·2 erlang of traffic per subscriber during busy hours, with less than 1 percent loss and has failure rates better than 0·15 failure per 100 lines per month, as well as substantially reduced maintenance requirements.

The trial installation also offers service features such as push-button selection, abbreviated dialing, routing in the local network, line identification, and subscriber- and operator-controlled switching to special services.

Technical Aspects of Telephone Network Planning

Many telephone administrations already have their own detailed specification for the transmission performance of the circuits within their national territories. Recommendations for general application are being prepared by the CCITT. To avoid forestalling these forthcoming recommendations no attempt is made in the present paper to indicate permissible limits. The paper shows by a number of examples the manner in which individual characteristics affect the overall transmission performance over long telephone connections and in particular to what extent these characteristics are relevant in the field of switching techniques. With the plans for extending subscriber dialing to connections beyond national boundaries, this aspect is becoming of increasing importance. Although the world-wide telephone network will in future serve mainly as a telephone system, it will also be used for data transmission. For this kind of traffic the characteristics discussed are also of significance. The use of separate data channels for signaling and the effect of pulse-code-modulation techniques are not discussed.

Television Transmitters for 470 to 860 Megahertz

A new series of television transmitters has been developed with improved operational reliability, reduced maintenance requirements, use of long-life components, higher output powers, and extended frequency ranges. The series consists of versatile basic modules and units which, by means of combination and modification, can be assembled into power output ranges from 10-kilowatts vision with 2-kilowatts sound, to 80-kilowatts vision with 16-kilowatts sound. The frequency range of these transmitters extends from 470 to 860 megahertz. Transmitter driver stages are transistorized and the low-level processing of the vision and sound signals is at a fixed intermediate frequency. The final vision and sound stages use modern high-power four-cavity klystrons. A combining unit for vision and sound signals is continuously tuneable and designed for a maximum of 50-kilowatts vision, 10-kilowatts sound, with automatic tuning correction. Parallel connection of complete transmitter chains at the output stages, as well as long-life components, mean that program failure is reduced to a minimum. The equipment, which is fitted with interlocks, is of a space-saving design.

Recent Developments in the Manufacture of Soft Ferrites used in Telephone Equipment

Modern telephone equipment demands precisely defined frequency-band filter circuits. The magnetic materials used in the filter inductances must have improved electrical properties to meet the demand. This improvement of the electrical and magnetic properties of commercial manganese-zinc ferrites is only possible with complete knowledge of the various parameters defining their manufacture.

This study presents an analysis of the phenomena involved in the preparation of ferrites and highlights the contributions made by various methods of investigation to the improvement of material properties.

Mobile Telephone Terminal for 1 or 2 Radio Channels

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1. Introduction

The improved mobile telephone system (IMTS) permits telephone subscriber sets to be installed in automobiles for interconnection with the conventional telephone network by radio through a fixed terminal station. By 1962 the concepts and design of what was termed the *MJ* system were completed by the Bell System. In this system the automobile set permits the subscriber to call, talk, and listen exactly as with a conventional fixed subscriber set.

Using a radio and switching terminal by International Telephone and Telegraph Corporation and mobile subscriber sets by Motorola Incorporated, a field trial was made in Harrisburg, Pennsylvania, in the last half of 1963 and a year later a full production system was cut over in Charleston, West Virginia. These were large systems, the latter providing for 480 mobile subscriber sets and 11 radio channels.

Later a small 2-channel system suitable for independent telephone companies was developed by International Telephone and Telegraph Corporation and the first system was put into service at Ritchie, West Virginia, early in 1965. Under contract with the Bell System, a 2-channel switching terminal compatible with the Bell *MJ* design was inaugurated at Dover, Delaware, in the summer of 1965.

2. General Requirements for all Systems

2.1 Channel and Signaling Frequencies

The radio frequencies for 11 two-way channels assigned by the Federal Communications Commission for base-station operation are given in Table 1.

Table 1 – Channel assignments for base stations

Channel designation	Frequencies in megahertz	
	Transmit	Receive
JL	152·51	157·77
YL	152·54	157·80
JP	152·57	157·83
YP	152·60	157·86
YJ	152·63	157·89
YK	152·66	157·92
JS	152·69	157·95
YS	152·72	157·98
YR	152·75	158·01
JK	152·78	158·04
JR	152·81	158·07

As can be seen the adjacent-channel separation is 30 kilohertz for both the transmit and receive channels with a 5·26-megahertz separation between the transmit and receive bands.

The audio signaling frequencies transmitted by the base and mobile stations are given in Table 2.

The audio frequencies chosen for signaling are well within the range of existing telephone equipment, thus making the signaling compatible with common telephone transmission mediums.

Table 2 – Signaling frequencies

Emitting station	Frequency in hertz	Designation	Application
Base	600	—	Manual operation
Base	1500	—	Manual operation
Base	1800	f_s	Seize tone
Base	2000	f_l	Idle tone
Mobile	1336	f_d	Disconnect
Mobile	1633	f_e	Connect
Mobile	2150	f_g	Guard

2.2 Numbering Plan

Early in the development of mobile systems it was decided that the scheme for assigning directory numbers to mobile installations would provide for only 10 000 mobile sets within any one telephone area code. This limitation simplified the switching terminal since any mobile could then be identified by 7 digits — the first 3 being the area code and the last 4 the basic station number. This number restriction implied that some central governing body in each telephone area must issue each number for a mobile installation.

Nonetheless, the mobile telephone is assigned the customary 10-digit number — 3 digits for the area code, 3 for the district-office code, and the last 4 for the station number. This scheme enables anyone anywhere on the North American continent to dial a mobile station just as if he were calling a residential phone. The office-code digits are absorbed by the toll telephone offices and discarded by the mobile system switching terminal.

2.3 Interface Requirements of the Switching Terminal

The switching terminal plays the major role in linking the mobile and conventional subscriber stations. The design of the terminal is unique as far as its interface with the nationwide telephone switching system is concerned. The terminal is arranged as an applique to the telephone central office and does not become integrally interwoven in the switching logic of the telephone office. This feature enables the terminal to be "tacked on" to any conventional type of central office. Clarification of this feature is best illustrated by an example.

When a conventional subscriber set dials a mobile subscriber set, the central office connects ringing current through any normal connector to 2 wires which, as far as it is concerned, may connect to a second conventional subscriber set. These 2 wires are tied to a special line circuit in the mobile terminal which detects the ringing but does not trip the ringing or answer the call. The terminal senses the demand, knows what mobile set is desired by the unique line circuit, turns on the transmitter, calls the mobile set, and waits. Meanwhile, the calling party is listening to what he thinks is a phone ringing. When the mobile unit answers, by the party lifting the handset, the calling person will recognize the answer by the end of ringing and the conventional clicks and circuit noises that occur when the party answers a normal call.

Using a 4-wire arrangement the switching terminal interfaces with both the radio transmitter and the radio receiver.

To the transmitter it provides:

— voice modulation maintained at a constant audio level through the action of a VOGAD (Voice-Operated Gain-Adjusting Device) circuit in the terminal (maximum output from terminal is 1 decibel referred to 1 milliwatt),

— direct current fed simplex to the transmitter to switch it to one of four modes: *off, low power, full power,* and *test converter on,*

— direct current loop fed from the transmitter to indicate if it is operating (below 3·2 milliamperes the transmitter is off and over 4·9 milliamperes the transmitter is on). This loop must be built out to 3500 ohms for proper operation of the line-current generator.

The terminal interfaces with a receiver over which:

— the audio output is coupled from the receiver,

— a direct current that is proportional to the signal-to-noise ratio for the particular receiver is fed from the receiver.

The terminal has strapping options to match line impedances of 150, 600, and 1350 ohms.

2.4 Tone Signaling in Calling

Figures 1 and 2 show the signaling sequences in making calls from the mobile station and from the base station. A parity check is made by the switching terminal on the identification of the mobile stations. As can be seen in Figure 1, the mobile sends out a guard tone (2150 Hz, f_g) after every *even* pulse regardless of how they are arranged in the transmission. The terminal, on receiving the f_g tone, checks to see that *even* pulses have been received. In this manner, there is a check to verify that some pulses have not been lost, possibly due to fading, et cetera.

2.5 Operation

Since most readers of this article are familiar with vehicular transmission and IMTS in general, such things as automatic base-station identification, voice handling, and automatic idle-channel mobile search will not be discussed.

From the view of switching flexibility, there are three unique features of the terminal:

— automatic handling in single-channel units of revertive calls, that is, calls to other mobile stations,

— use of party lines having circuit capabilities to accommodate harmonic, decimonic, synchromonic, coded, and superimposed ringing schemes, and

— availability of an auxiliary circuit that provides a metallic sleeve cut-through for automatic telephone number identifiers. This enables an independent telephone company to work mobile stations into automatic toll-ticketing equipment, or to allow direct distance dialing in small unattended offices.

2.5.1 Mobile-to-Base Call

The process of a call can best be followed from the block diagram of the base station shown in Figure 3. When a mobile handset is taken off hook to make a call, the mobile transmitter is turned on and transmits 350 mil-

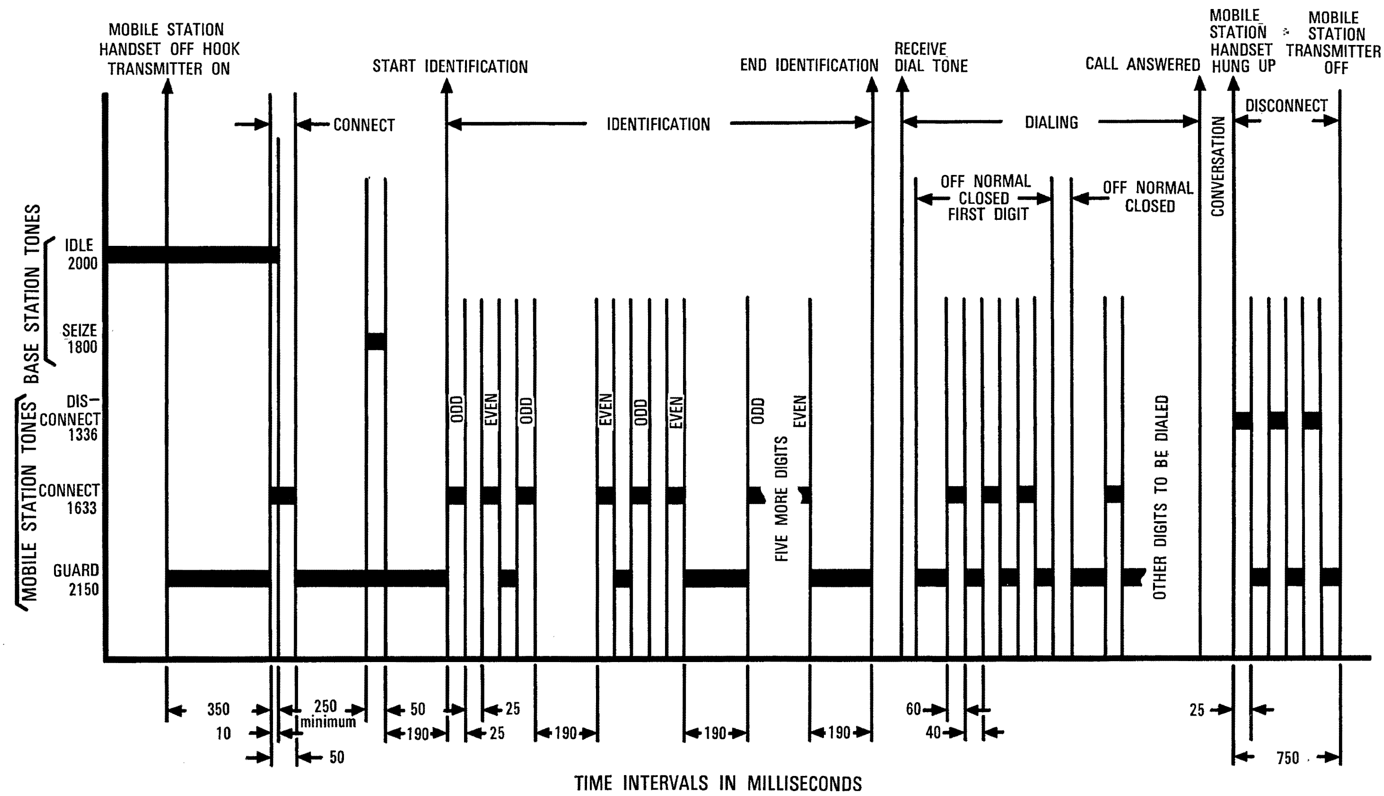

Figure 1 - Sequence of tone signals from mobile subscriber set to the base station.

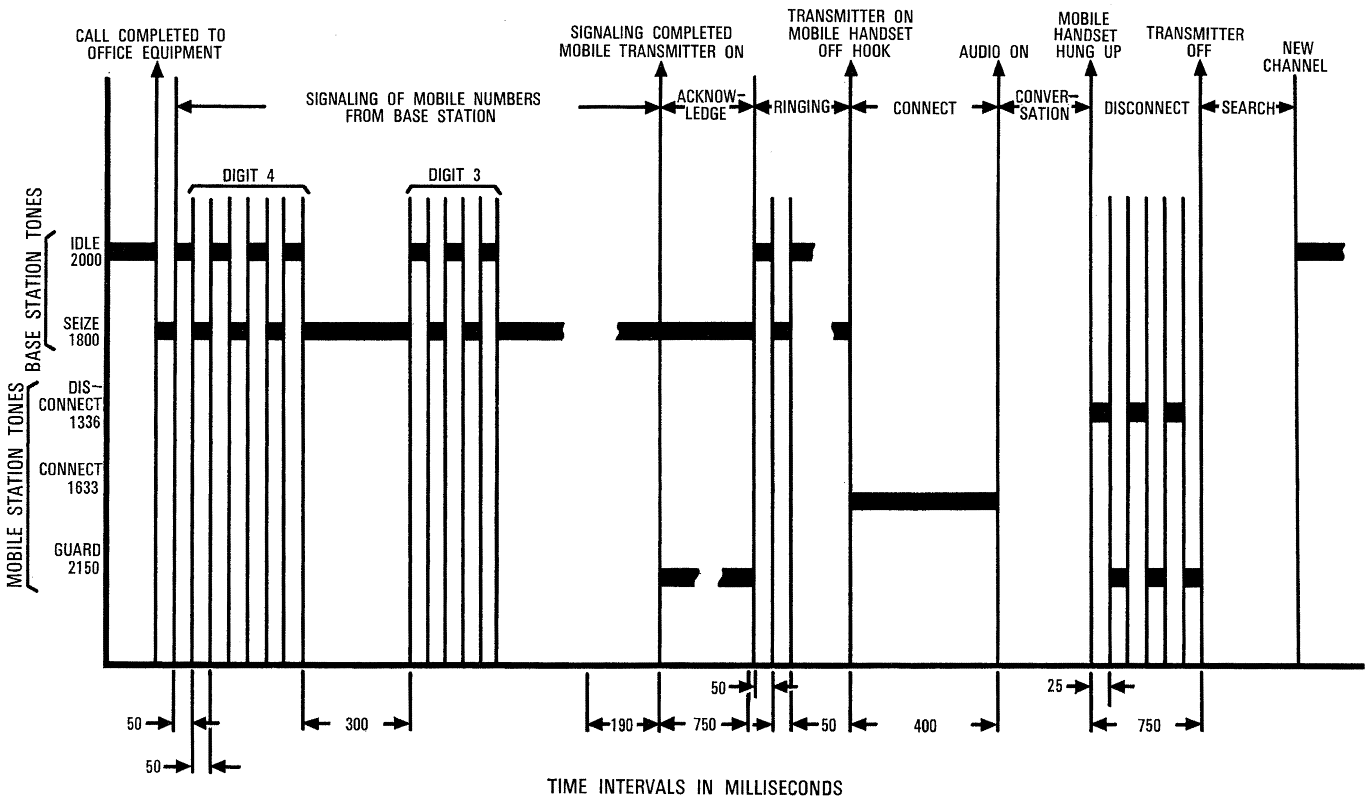

Figure 2 - Sequence of tone signals from base station to mobile subscriber set.

liseconds of f_g, which is received by one or more base-station receivers shown in the lower part of the figure. During this time the receiver with the best signal-to-noise ratio captures the call through the action of the receiver-selector circuit in the channel shelf. Then after some supervisory signaling (Figure 1) the mobile station automatically sends its 7 identification digits. The identification consists of a series of alternating tones (20 pulses per second), which are converted to direct-current pulses by the tone detector, passed through the link circuit, and stored in the register/sender.

The register is a serial-input circuit with later digit read out. It counts the number of pulses in each digit by means of a group of relays called the counting train. When the digit is complete and the 190-millisecond inter-digit pause is detected, the counting train presents the total in a 2-out-of-5 code to a 5-bit memory unit called a storage tank. The storage tanks have coded decimal read out. There are 4 storage tanks, which are used to verify the 7 identification digits. Hence, a store, presentation-for-check, test, and dump sequence is required for 3 of the storage tanks.

When the first 3 identification digits are received, the register marks the translator to determine whether the calling mobile station is a unit of that base station or one that requires special handling. The translator is unique in its function. The circuit uses "black boxes" that require the insertion of 4 small metal disks to program a mobile station's number. The black boxes are black plastic cross-point matrix packages (10 by 30 inputs) in which connection can be made from any of 10 vertical bars to any of the 30 horizontal bars by simply inserting a small round shorting disk. A very simplified version of the translator is shown in Figure 4. As the first 3 digits (area code) are being received, the register storage tanks remove the central-office battery voltages from one output bus in each number group depending on the digit stored. Our example indicates by the number on the *A*, *B* and *C* office-code decades that area code 312 has been received and is an acceptable area code. At the end of the 3 digits, the register relay *REG* operates and parallel feeds the translator (black box) matrix, connecting the storage tanks to the matrix. The metal disks in the matrix are not involved at this time. In the example it will be noted the leads *AH3*, *BT1*, and *CU2* will be the only register busses that will not have battery potential on them. The office code test relay *OC* operates. Due to the particular manner in which the terminals are connected in the strapping field we will note that only bus *H1* does not have central office battery on it, as compared to busses *H2*, *H3*, etc. That is, the three leads from *AH3*, *BT1*, and *CU2*, connected through the rectifiers in series with relay *H1*, do not have an electromotive force on them whereas all other H relays do. As shown, relay *H2* operates from *BT2* and *CU3*. When the *OC* relay operates, we will realize that the *H1* relay will be the only relay which will not operate in the *H*-relay complement at the extreme right. This complement then sends out a single relay-down mark (single relay not operated) which indicates a match and hence the call will be processed

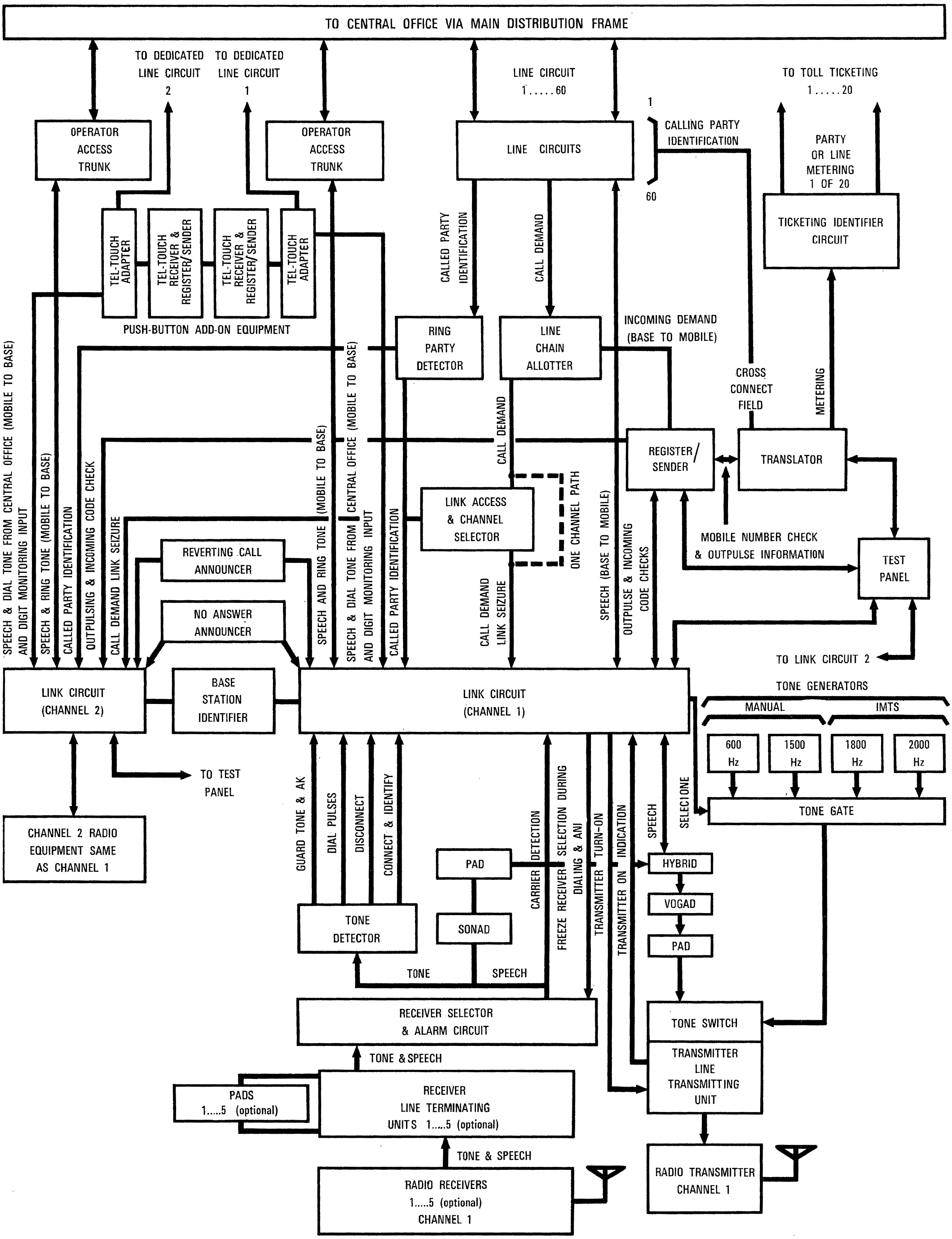

Figure 3 - Block diagram of base station. The Tel-Touch applique is in the upper left.

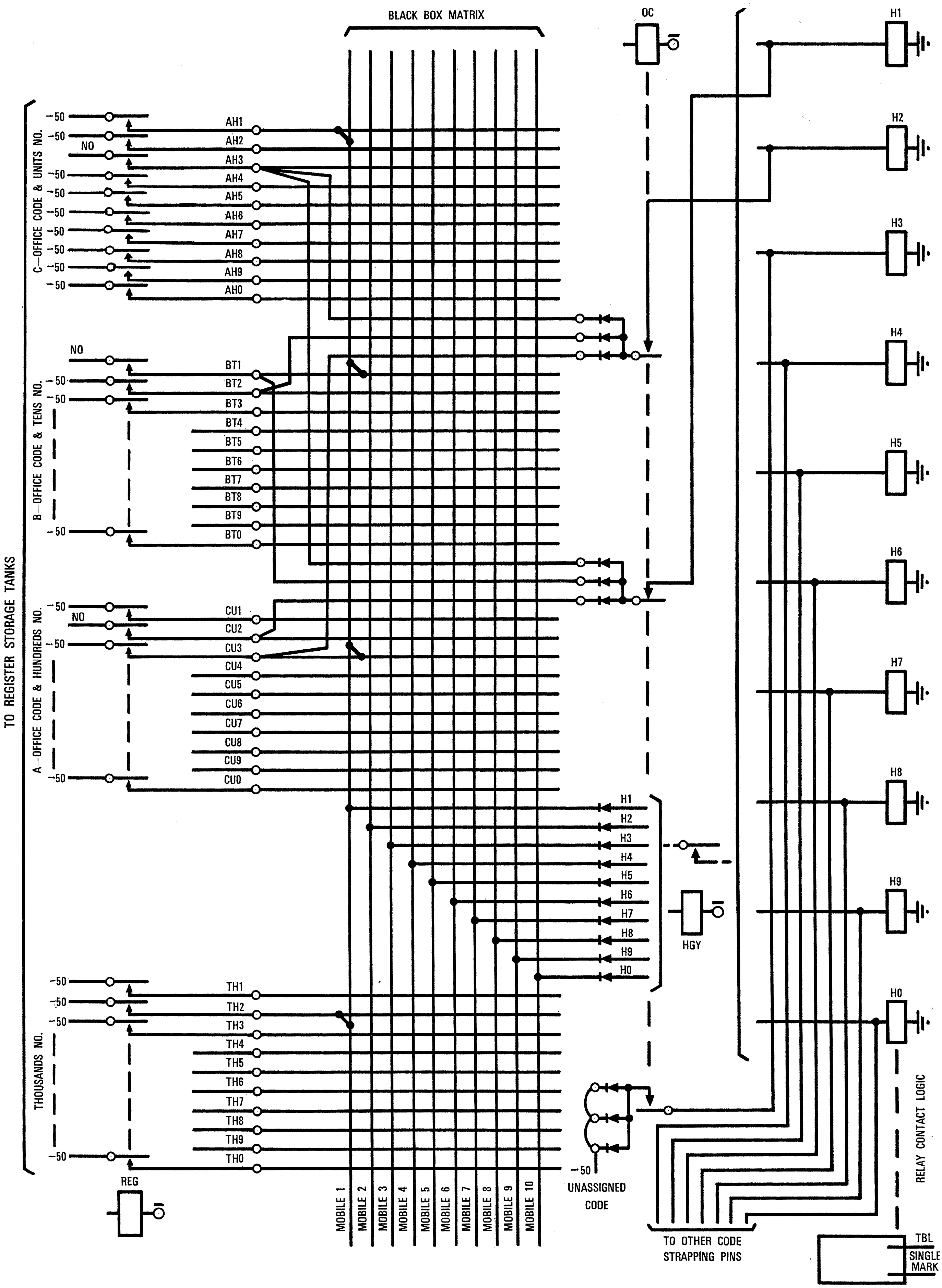

Figure 4 - Basic circuit of the translator.

further. If the number received had been 313, of course relay *H1* would have operated from *CU2* which would then have an electromotive force on it and all the *H* busses would have battery connected to them. An all-up signal (all relays operated) would be marked out and the call would have special handling.

If we assume a local area code has been sent by the mobile station, the translator will mark this condition and command the register to empty the three storage tanks. When the next 4 identification digits for a specific subscriber station in the local area have been received the register will once again extend the digit marks to the translator to determine whether it is a local mobile station or one which will require special handling. The procedure is similar to that used for checking the area code except that the *HGY* relay gates the marks through the metal disks to the vertical bars into the *H*-relay complement. Again a match is indicated by nonoperation of one of the *H* relays. If we now assume the called mobile station is a local one, the register once again empties the storage tanks and prepares to examine the digits dialed by the mobile subscriber.

To have the necessary data to process the call, the terminal does two simultaneous manipulations when it receives the numbers dialed by the mobile subscriber. First, it seizes an unlisted central-office circuit and repeats the dialed digits into the central-office switching equipment. Secondly, the digits are stored in the registers to be compared with the translator program.

When the mobile subscriber has finished dialing the first three digits, the register and translator check for a match just as for checking the identity of the mobile station. If a match does occur the call may be processed in three different ways depending on the digits dialed:

— common local call or free service,
— mobile-to-mobile call, or
— operator assisted call.

While examining the first 3 digits the translator is capable of determining whether the number dialed is an area code or an office code provided the number is programmed; hence depending on whether the call is to another area or office, or to the local office, the terminal may or may not continue storing and checking the rest of the digits. If the translator finds that the destination is another area or office the remaining digits are of use only to the distant office, hence it ignores them. If the translator finds that the call is within its own office then it must continue to monitor the digits to determine whether the call is to another mobile station or to a local subscriber.

If the call is to a local subscriber, the local office has already received the necessary digits. The mobile subscriber should hear ring-back tone or busy tone. If the call is to another mobile station, two options may be exercised.

— The calling mobile subscriber will hear a recorded message indicating he has called another mobile station and that he should depress either the *M* (manual) or *P* (party) button. By depressing either button the mobile's carrier is turned off. Absence of carrier informs the terminal to out-pulse the number stored in the register. The mobile subscriber would hear out-pulsing, the resultant ringing, and also when the called mobile subscriber answered. Subscribers must then use the manual or push-to-talk operation.
— The calling mobile station will hear a distinctive tone instead of the recorded message to indicate that the call is revertive and to revert to the manual mode.

If a nonlocal or restricted mobile station accessed the terminal the translator culls these calls by screening the identification of the mobile station as described above. An all-up condition exists in the *H*-relay complement which causes the terminal to either out-pulse a single digit — usually 0, or 3 digits — say *112*, depending on the optional strapping and the demands of the central-office switching equipment.

Since the base-to-mobile calls are processed in a straightforward manner and the basic technique is very simply described in an earlier section on basic interface requirements, this type of call will not be described. The choice of describing the mobile-to-base call was made due to the fact that it is this mode of operation that is affected by the addition of push-button calling to the system (see Section 5).

3. Mechanical Features

The smallest package that will accommodate a working switching terminal, consists of a single bay of equipment 108-inches high, 30·2 inches wide, and 13·6-inches deep (2740 by 770 by 350 millimeters). The equipment, with the exception of the test panel, is enclosed by easily removed covers.

The largest package that will house all the equipment for a full switching terminal will consist of two bays 108-inches high, 55·5-inches wide, and 13·6-inches deep (2740 by 1410 by 350 millimeters).

The smallest package is arranged for operation with a single radio channel and 5 lines. The 5 lines may accommodate 10 parties on each line. This package is arranged so that equipment can be easily added to build a full system capacity of 2 radio channels with options for single or dual transmitters per channel, up to 5 receivers per channel, and of 60 lines, half to serve up to 5 parties each and half for up to 10 parties each. The maximum number of mobile stations is restricted to 120 because of limitations in the number translators; hence, the line capacity for mobile stations is much greater than the translator can handle.

The system is basically electromechanical and uses telephone-type relays of the *4000* type. They require solder connections to both coils and springs. The electronic portion of the terminal is solid state, mounted on printed-circuit cards. The cards are equipped with gold-plated connectors and plug into a 2-deck shelf that makes up the channel shelf.

4. Smaller 1- or 2-Channel System

As mentioned earlier a smaller system was designed for the Bell System denoted as the *MJ(S)* system. The Bell System package is similar to the unit for the independent telephone companies but is mounted on 11-foot

(3·35-meter) racks. Its capacity is two channels with the ability to operate two transmitters per channel just as the independent unit. The main differences between the two units are given in Table 3.

Table 3 – Differences in two systems

Question?	MJ(S)	Independent
Number of lines	90 mobile	60 lines (120 mobile)
Multiparty working	no, single only	yes
Ringing detection	single frequency only	ring party detector
Automatic revertive call	no	yes
Remote test transmitter control	yes	no
Number of receivers per channel	8	5

5. Push-Button System

There are three basic design factors that must be considered for this system:

— the push-button terminal must be an add-on unit to the existing terminal because of design economies and the requirement for ultimately retrofitting the terminals in the field,

— there are two basic systems. The first involves central-office switching systems that are push-button oriented, such as our newer exchanges; and the second concerns central offices that must still receive dial pulses,

— the requirement in the mobile installation for a new control head that is fitted with the push-button mechanism.

If we refer to Figure 3, the sections at the top left show the push-button add-on equipment. As will be noted, this equipment is placed between the link and the central-office-dedicated line circuit. The push-button adapter is a relay circuit that is cut into operation when the mobile identification signals stop and monitors the audio as well as direct-current pulsing on the line. If the signals are multifrequency and can be detected by the receiver, the receiver will respond and mark out the digits that are being sent. If the first signal corresponds to a dial pulse, the adapter will respond and cut the receiver from the line and the call will be processed as a dial call.

Since the terminal has the ability to do some logic manipulations by means of its translator, the digits marked out by the push-button receiver are marked into the register via the link for storage and translation. The tones sent by the mobile station also go simultaneously to the central office to process the call if the central office is arranged to receive push-button calling. If the switching system is not so equipped, the receiver will mark a second register-sender unit as well as the register in the terminal. This second register-sender will convert the digit marking from the receiver to dial pulses and drive the central-office equipment.

Most of the manufacturers of telephone switching gear have, or are on the threshold of marketing, the push-button converter/receiver, which is necessary to convert existing dial offices to push-button calling; hence this package is not a new item to the telephone company.

The frequencies used in push-button dialing are listed in Table 4 and by reference to the chart we see that there appears to be a rather devastating clash between disconnect tone (1336 Hz) and the digits *2*, *5*, *8*, and *0*.

Table 4 – Push-button calling frequencies

Digit	Combination of frequencies in hertz
1	697 and 1209
2	697 and 1336
3	697 and 1477
4	770 and 1209
5	770 and 1336
6	770 and 1477
7	852 and 1209
8	852 and 1336
9	852 and 1477
0	941 and 1336

During early investigations it was felt that when sending any one of the four digits *2*, *5*, *8*, and *0* the channel shelf would detect the 1336 Hz as a signal for disconnect and terminate the call. To avoid this difficulty two basic changes were made:

— in the normal operation of the push buttons the higher frequency tones are set at higher output levels than the lower-band frequencies (697, 770, 852, and 941 Hz). This is necessary because the average subscriber telephone loop attenuates the higher frequencies more than the lower ones. The mobile installations are not similarly affected and all tones for them are adjusted to the same level,

— the original manual and automatic tones transmitted by the mobile sets normally go to the mobile transmitter limiter at a very high level to improve the signal-to-noise ratio. This precaution was felt necessary in a single-frequency detection system. However the push-button tones got to the mobile-transmitter limiter at a level below limiting. As a result of the low level of intermodulation products, the relatively low level of the signals, the high sensitivity of the push-button receiver, and the high reliability of the 2-tone system, the improved-mobile-telephone-system tone detectors do not detect the combination but the push-button receivers do.

An experimental push-button system was put into operation in a metropolitan area during the summer of 1966 with excellent results. Tests were made for fading and distance. The only critical consensus was that the existing control head was bulky and not in keeping with the modern styling of our automobile instrument panels. A repackaging of the control head is under consideration.

6. Conclusion

The program of the Improved Mobile Telephone System has an air of luxury to it and it is with some reservations that a telephone company looks at a proposed investment for such a project. Nevertheless, once it is installed, the system is profitable and extends the services offered by the telephone industry.

To the average independent telephone company, push-button selection is a luxury and its application to mobile systems is viewed with skepticism. Thus manufacturers must try to get into the push-button mobile-set field with as little initial investment as possible. Their research and development program will be tight and they will use as much of existing designs and hardware as is possible. Hence the first push-button systems will use dial units retrofitted with push-button adapters and converters. A very minimum amount of change is required in the existing base terminal and as far as the switching gear is concerned push-button dialing is available. The bulk of the conversion will involve the mobile units, especially the control head. Until this item is designed for large production, push-button mobile-station calling will remain as a possibility rather than a reality.

James L. Stepan was born in Hamilton, Canada in 1931. He received his BSc degree in electrical engineering (communications option) from Queen's University, Kingston, Canada, in 1955.

After graduation he was employed by Automatic Electric (Canada) Limited and Northern Electric Company Limited. In 1962 he joined ITT Telecommunications where he has served as project engineer for the improved mobile telephone system, for a special switching terminal for radio telephones on a rapid transit system, and for an electronic automatic telephone number identifier.

He is a member of the Association of Professional Engineers for the Province of Ontario, Canada.

A New Stackable Carrier System for Open-Wire Lines

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1. Introduction

A stackable carrier system can be built up, channel by channel, using the same line, as circuit requirements grow with time. Since each channel is self-contained, terminals need not be located at a common point, but may be used over differing or intermediate lengths of the line. Examples of earlier systems of this type in the field are the Bell type P system [1] and the ITT K 31/32 systems. A transistorized transmission system designed by Standard Telephones & Cables Limited [2] was also of this type. The advent of more-compact constructional techniques [3], etched circuits, further miniaturization of components, and the inherently higher reliability of silicon planar epitaxial transistors, made the opportunity to consider the redesign of the stackable system to take advantage of these developments with the ultimate aim of reducing cost, improving reliability, and giving increased facilities. This paper describes features and design aspects of such a new system.

2. System Facilities and Applications

As before, the new system is primarily for short-distance junctions, often on not-too-well transposed routes, and is particularly suitable for remote districts where power supply facilities are a problem. The system has to be compatible with existing main-line open-wire systems, whose pole routes it will often share. True stackability in the electrical and mechanical sense means that additional channels may be applied to the same pair at existing terminals, or at intermediate points along the line, with the minimum of change to common plant. An additional feature, not available in any earlier system, allows the transmission of metering impulses during conversations in the subscriber trunk dialing network. This additional feature also provides for circuit supervision even though the signaling scheme may not be fully out-of-band in the normally accepted sense. The system is also applicable to direct subscriber use by means of appropriate relay sets.

3. System Design

3.1 Constraints

The most obvious constraint in a system of this type was cost. The system had to have cost advantages over conventional main-line systems without too much loss of performance. Equipment common to a number of channels such as a carrier-supply scheme, common-pilot regulation, or line amplifiers was to be avoided and the channels were to be as self-contained as possible. Because of the requirement for frequency compatibility with main-line systems, it was necessary to provide for two sets of sending and receiving frequencies, namely "stacked" or "grouped" arrangements. This resulted in the need for separate send and receive functional units. To avoid high-stability crystal-controlled oscillators at both sending and receiving ends, two approaches were possible, namely, a transmitted carrier for each channel, or a transmitted pilot tone for carrier regeneration. To avoid common equipment which could unfavorably load the "first-in" cost of a small system the latter scheme was rejected and the transmitted-carrier system was used.

Study of typical applications and climatic changes in line loss showed that a suitable maximum attenuation should be about 29 decibels, with a variation of ± 6 decibels for regulation. The band of frequencies available extended from just above the voice band to the region of 160 kilohertz.

The following table indicates how this available spectrum might be used, showing channel spacing, number of channels and relative filter complexity for single- or double-sideband approaches, based upon the maximum planned line attenuation stated above.

Table 1 – Relative filter complexity

Channel spacing (kHz)	Number of channels available	Single sideband		Double sideband	
		Number of resonators	Target Q factor	Number of resonators	Target Q factor
6	12	7	500	—	—
8	10	5	250	6	330
10	8	{ 5	130	6	140
		{ 4	300	5	250
12	6	4	140	5	130

Table 1 refers to the receiving-channel band filter since this filter has the most severe requirement for discrimination against the adjacent channel carrier. This overrides the more usual sideband rejection requirement, but even this tends to be more severe in this type of system owing to the level differences between adjacent channels.

A further important constraint was power consumption. Remote terminals of up to three channel-ends must be capable of feeding from air-depolarizing dry cells or thermo-electric generators of small size [4]. Two watts per channel-end gave an output level to line sufficiently high to avoid the necessity for compandors on every channel. The basic system concept did not assume the use of compandors although undoubtedly in some applications the higher-frequency channels would require them. Omission of the compandor did not increase the filtering complexity as the major filtering problem is the rejection of the adjacent carrier at the receiver.

3.2 Filters and Frequency Plan

From Table 1 it was concluded that an 8-kilohertz spacing of channels would be the most suitable. At this spacing significant assistance from filters on the voice-

Table 2 – Relative levels

	Transmit amplifier output		Line		Detector input	
	Level	Modulation depth	Level	Modulation depth	Level	Modulation depth
Carrier	+ 9 dBm	—	+ 7 dBm	—	0 dB	—
Peak sideband	+ 5·5 dBm	68 percent	+ 4·5 dBm	75 percent	0 dB	100 percent
Relative test level	− 2 dBm	28 percent	− 3 dBm	32 percent	− 7·5 dB	42 percent

frequency sides of modulators and detectors could be obtained, since the carrier spacing is more than twice the voice bandwidth.

A series of harmonically related carriers based on 8-kilohertz was the best compromise regarding interference with main-line systems although there is no ideal arrangement in this respect. Several factors dictated the ultimate choice of single-sideband transmission, for example, easier filter design, better noise performance, and the proposed signaling system, although the latter required the development of a high-quality square-law detector. Figure 1 shows the frequency plans for a stacked system, and a grouped system. Many other arrangements are possible, provided that adjacent channels are either transmitted in the same direction or belong to the same exchange circuit.

Because of the possible 35-decibel level difference between transmitted and received sidebands and the higher level of the transmitted carrier, the intermodulation requirement for sending and receiving filters at the common junction ends was necessarily of a high order, particularly for products of the type 2A ± B. The necessary performance was achieved by using graded cores, those at the line junction being 35-millimeter diameter low-permeability ferrites.

3.3 Transmission Levels

In a single-sideband modulator 100-percent modulation occurs when the side-frequency vector has the same magnitude as the carrier-frequency vector. Some will regard this as 200 percent but since customer specifications are formulated without regard to the modulation system, it is best to identify 100 percent with peak modulation.

Since various forms of discrimination in favor of the sideband and against the carrier occur through the system filters, this maximum modulation depth will be obtained at the detector input under peak channel loading conditions. Under these conditions the modulator output corresponds to a lower depth of modulation. The relative test level of the channel was set at 7·5 decibels below peak modulation at the detector input. Table 2 shows relative carrier- and side-frequency levels at important points in the transmission path with the corresponding percentage modulation.

To avoid overloading the detector the modulator could not be used as a limiter so a pair of reverse-connected silicon diodes was used instead at the channel input before the low-pass filter. Peak loading of the transmitting amplifier corresponds to voltage addition of a + 9-dBm carrier and two + 5·5-dBm sidebands, namely + 16·4 dBm. However, to reduce this loading, part of the sideband selection was carried out prior to amplification.

3.4 Gain Regulation

The target of ± 6-decibels receiving-gain regulation was achieved by means of a thermistor-controlled pad, the regulating detector being exposed to the bulk channel signal, namely carrier plus sideband. A mean detector circuit is used for this function to minimize changes in gain due to the fluctuating sideband signal, although this is smoothed by the relatively long time constant of the thermistor.

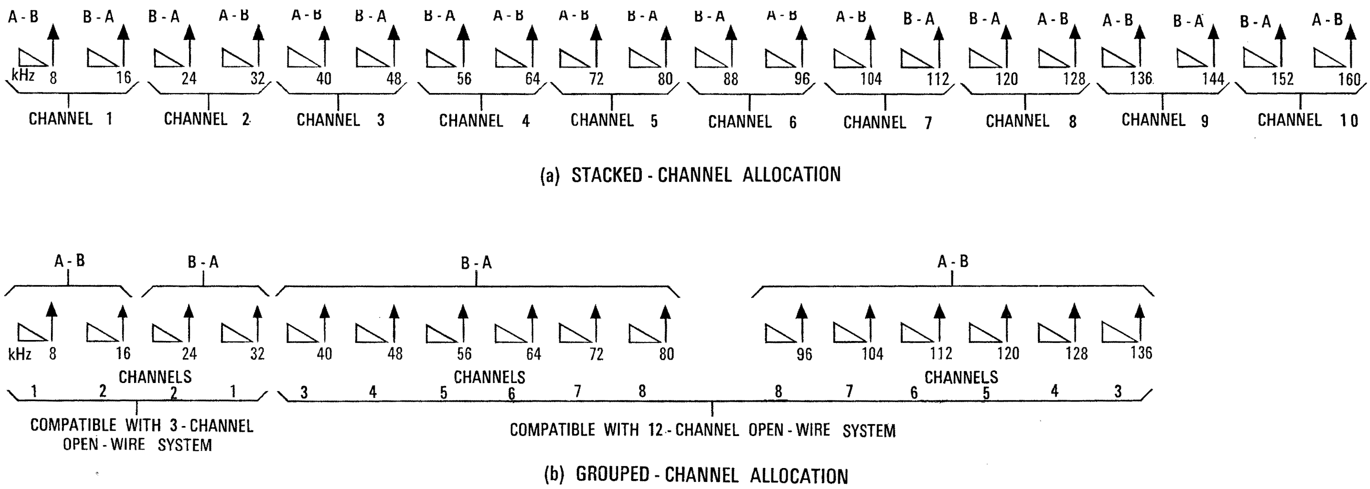


Figure 1 - Frequency allocation plans for stacked and grouped systems.

3.5 *Compandor*

The system was designed to work on lower-grade routes and should not require special line treatment such as transpositions for far-end crosstalk reduction. The system may also work on pairs paralleling main trunk systems. Since these pairs will not, in general, have transpositions applied to the same standard as the main trunk pairs, the transmission levels of the stackable system were designed so as not to degrade the main systems. In fact the new system is more likely itself to be degraded by the main system. It was therefore considered that in many applications a compandor would be desirable. Adoption of a compandor for all channels could have brought about a marginal simplification of some of the filters but, as mentioned above, it was felt that, since particularly in the lower-frequency channels a compandor could be avoided, this slight additional complexity would be justified. The compandor adopted for the system has a 2:1 compression ratio and is of syllabic type. This can give a noise advantage of up to 20 decibels.

3.6 *Signaling*

The earlier system used carrier interruption and so no signaling information could be passed during a conversation. Carrier-shifting methods need close tolerances in discriminator circuits unless this shift is of the order of 1 percent, which at 160 kilohertz is excessive from the point of view of channel degradation.

The arrangement finally adopted was to shift the carrier so that the upper sideband is transmitted during the signaling period, instead of the lower, that is, a 4-kilohertz downward shift. This made the discriminator circuit very simple and, as there is virtually no loss of performance, the channel could be used equally with signaling on or off, allowing a supervisory condition to be applied.

3.7 *Line Plant*

A fundamental difference between a stackable system and a main-line trunk system is that the line termination in the former is band-limited to the frequencies of the send and receive sides of the channels in use. It is this property which enables further channels to be added but it has the disadvantage of leaving the line open-circuit at frequencies not taken up at the point of termination. This causes an oscillating impedance variation in these unterminated frequency bands as one proceeds further along the line away from the terminal. Ideally, to overcome this problem we would require a wide range of specially tailored complementary networks, or alternatively, common buffer equipment which would consume power. In a practical system there must be some compromise.

This impedance variation is only of consequence when the frequency band in question is used over some intermediate part of the route, or where a spur route connected to the main line produces impedance irregularities.

In practice a line will always be required for normal service and will usually terminate on a switchboard. The voice termination will therefore vary widely with time according to whether the circuit is engaged or not, or paralleled to several telephones, as for example during unattended night service. Line filters, therefore, are unavoidable even though the carrier circuits may be well removed in frequency from the band of the voice circuit. Stackable channels may also be applied above the band of standard 3-circuit trunk systems.

The following types of line filter were developed to meet the end terminal requirements.

— A relatively simple impedance masking the line filter pair which can be used if the 4 to 8-kilohertz channel is not applied.

— A more complex line filter for use with the 4 to 8-kilohertz channel.

— A filter for combining stacked channels operating at carriers of 40 kilohertz and above with a standard 3-circuit system whose maximum line frequency is 31·11 kilohertz.

All these filters were designed to connect directly to an open-wire line without a line transformer and were appropriately rated. Line isolation is provided on the office side of the high-pass filter to protect the stacked channels.

Pole- and office-type autotransformers were designed for matching the standard types of entrance cables, the pole-mounted version having reactance correction for the low frequencies.

To insert or drop channels at intermediate points along the line a compromise termination at the ends of the line is required, the extent of this compromise depending upon the distance from the connection point to the end of the line. A network provided at the common point of the channel band filters enables a suitable combination of series and shunt resistors to be applied to smooth out any large impedance irregularities. The intermediate dropped channel is connected to the line via a 300-ohm transformer having negligible bridging loss outside the frequency band of its termination. It must be pointed out, however, that this method is applicable only if the length of the spur connection to the main route is small (below $\lambda/8$, top-channel frequency). If a long spur is unavoidable it is necessary to adopt a compromise termination at the end of the spur, that is to treat it like the main route although there are other, more complex, ways of dealing with this problem.

Finally the line filters were complemented by a special 6-terminal bridging filter allowing access to the physical circuit at an intermediate point.

With the line plant discussed a large number of system applications can be covered.

4. Circuit Description of New System

4.1 *Block Schematic*

Figure 2 shows a block schematic of the terminal cards. Separate send and receive cards are employed to allow changes according to system requirements. The hybrid-termination and ringdown units are disposed on these two cards. The 4-wire points are brought out to card terminals to permit the compandor to be included if required.

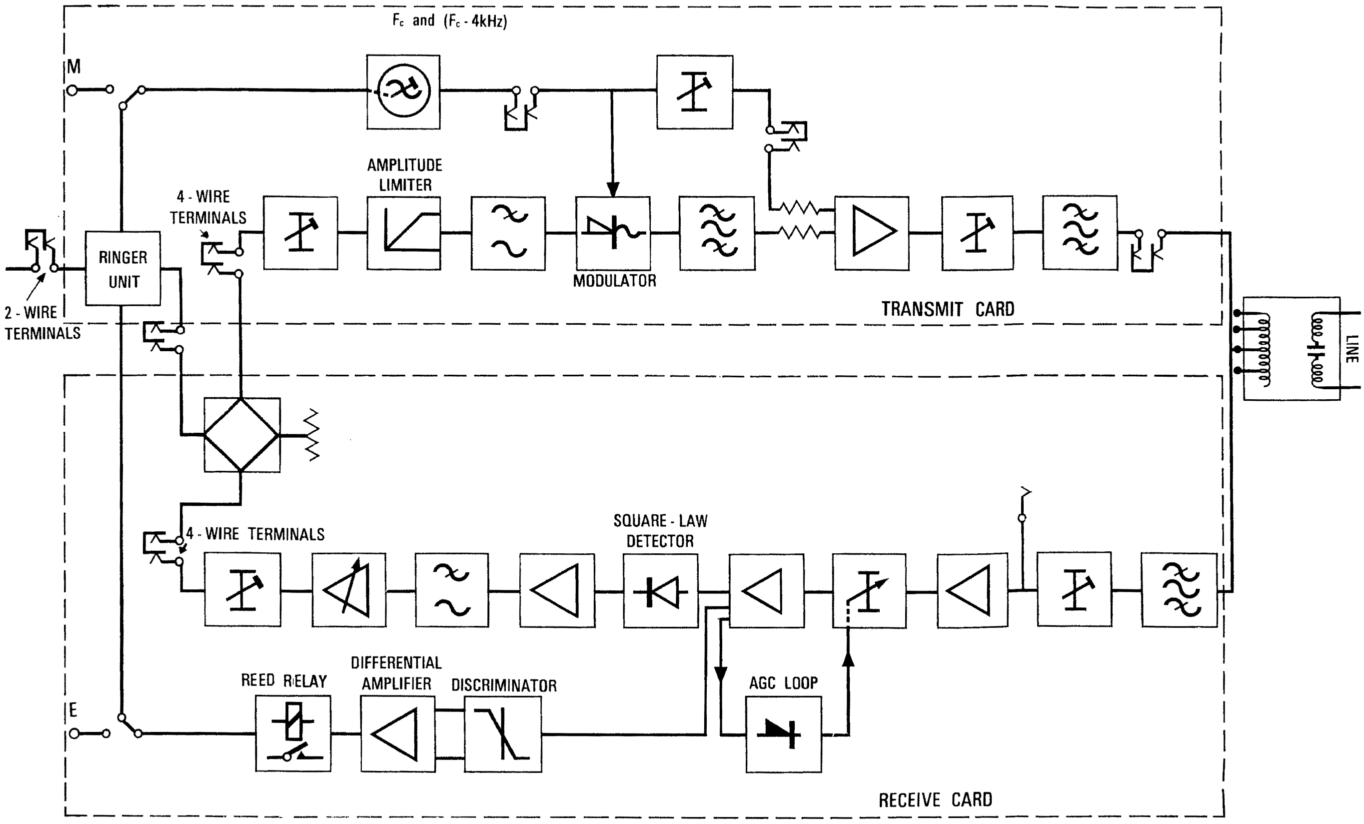


Figure 2 - Block schematic of receive and transmit terminal cards.

4.2 Transmit Path

At the output of the strappable span pads a diode limiter prevents peak signals from overloading the subsequent modulator. The low-pass filter (insertion-loss design) cuts off at 3·4 kilohertz and plays an important part in the channel-separation process as well as assisting the signaling. The modulator is the symmetrical transistor version of the Cowan circuit which suppresses the carrier supplied from the self-contained oscillator. The unwanted sideband, namely the upper during the signaling-off condition, is almost eliminated by the first sideband rejection filter preceding the zero-impedance transmitting amplifier. At this point the carrier is re-injected at a controllable level. The amplifier is transformerless, class *AB* push-pull, with an overload point of greater than 8 dBm0. The necessary frequency-attenuation characteristics in a transmitted-carrier single-sideband system depend on effective suppression of the unwanted sideband. Sharing the channel band-limiting function between two filters, one placed at the input and the other at the output of the amplifier enables the system requirement of −100-dBm0 intermodulation to be achieved in the most economical manner using small-volume cores for the filters. At the same time it relieves the amplifier of some of the unwanted-sideband loading. Pads are provided at the amplifier output for adjustment of line level.

Signaling is achieved by shifting the carrier by half the channel carrier spacing, namely 4 kilohertz. This alters the transmitted sideband from lower to upper. The signaling input condition is obtained by earthing the *M* wire to modify the oscillator tank circuit as shown in Figure 3.

4.3 Receive Path

The appropriate frequency band is selected by the receive-channel filter. Due to the effect of high near end transmitted signals the choice of coil cores in the receiving filter is important in reaching the required crosstalk and intermodulation margins. However a progressive reduction in core volume moving away from the line terminals was found to be possible. Level-adjustment pads are provided before the conventional receiving amplifier, which is followed by a variable pad under the control of a thermistor. A further amplifier provides three outputs, one of which is mean rectified and passed to the thermistor. A second output from the splitting amplifier is taken to the square-law detector to recover the modulation. A fixed-gain amplifier, low-pass filter, adjustable-gain amplifier, and span pads complete the receive path. The third output from the splitting amplifier provides the input to the signaling discriminator which operates a sealed reed-relay via a differential amplifier.

The ringing and terminating options catered for without additional equipment are 17 hertz on the 2-wire line, direct-current loop, or *E*- and *M*-wire earths. Generator-start contacts are provided to operate a 17-hertz generator which may be located with the channel equipment.

Table 3 – Temperature coefficients

Coil type	Frequency range (kHz)	Temperature coefficient in parts per million per degree Celsius				Ratio C_a/C_b
		Coil	C_a	C_b	Total	
A	4 to 48	+160 ± 160	−150 ± 90	+ 30 ± 30	+ 10 ± 250	1 : 0
B	52 to 100	+ 60 ± 60	−150 ± 90	+ 30 ± 30	0 ± 120	1 : 1
C	104 to 160	+ 30 ± 30	−150 ± 90	+ 30 ± 30	0 ± 80	1 : 2

5. Performance

5.1 Frequency Stability

One of the first investigations carried out during the design was the determination of the frequency stability with conventional components. The final oscillator circuit is shown in Figure 3 with biasing and matching details omitted. For use over the complete frequency range, 4 to 160 kilohertz, three different types of coil core are necessary. Since the temperature coefficients of the three classes differ, the types of capacitor used for C_a and C_b had to be chosen to give a zero change of nominal frequency over the temperature range 0 to 50 degrees Celsius.

Table 3 relates the spread of temperature coefficients of the three tank-circuit components, the total temperature coefficient and the capacitance ratio. Capacitors C_a and C_b are polystyrene and mica, respectively.

All oscillators were adjusted at mid temperature, namely + 25 degrees Celsius, and for a variation of ± 25 degrees Celsius a worst case frequency change of ± 160 hertz was expected. Tests on 10 different oscillators over this range, and with relative humidity from 10 to 90 percent, produced frequency errors all lying within the expected spread. Frequency changes due to supply-voltage change are minor by comparison, the worst case being ± 25 hertz for ± 5 volts on a nominal 20 volts.

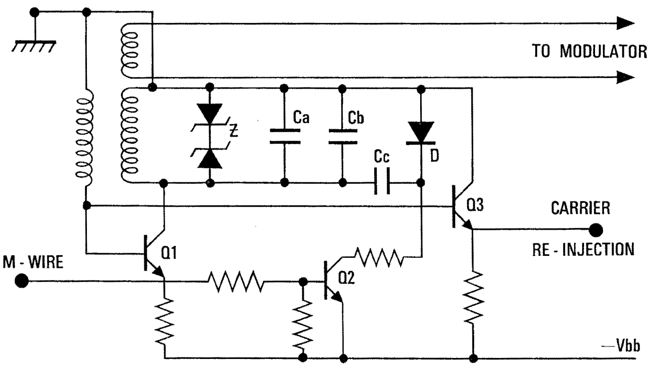


Figure 3 - Final oscillator circuit without biasing and matching details.

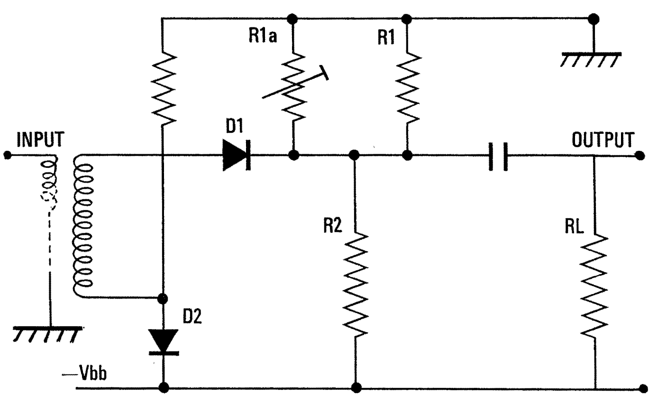


Figure 4 - Square-law detector with a suitably modified characteristic to reduce forward-voltage drop and maintain correct characteristic over working temperature range.

5.2 Square-law Detector

A linear detector used in a single-sideband transmitted carrier system produces unacceptable distortion unless the ratio of carrier to sideband amplitudes is high. Satisfactory harmonic performance therefore requires the use of a square-law detector.

A normal germanium point-contact diode exhibits a square-law current/voltage characteristic for small amplitude signals but was found to be too temperature sensitive. A silicon planar diode was therefore chosen using a circuit which suitably modifies its characteristics. The silicon diode alone is unsuitable because of its high forward-voltage drop V_f and its current/voltage characteristic which approaches a fourth-power law.

Table 4 – Harmonic performance with modulation depth

Carrier level	0	0	0	0	dBm
Side frequency level	–17	–7	–3	0	dBm
Modulation depth	14	45	71	100	percent
2nd Harmonic margin*	60	48	43	33	dB
3rd Harmonic margin*	60	39	31	26	dB

* With reference to the fundamental demodulated output.

Table 5 – Harmonic performance with temperature (at 45 percent modulation depth)

Temperature, degrees Celsius	–5	10	24	50	55
2nd Harmonic margin*	44	47	49	49	48 dB
3rd Harmonic margin*	39	39	40	40	40 dB

* With reference to the fundamental demodulated output.

Table 6 – Typical variation for 30-baud signals

Line loss	Nominal	Nominal +10 dB	Nominal −10 dB
Distortion milliseconds	−1·5	−1·0	−2·0

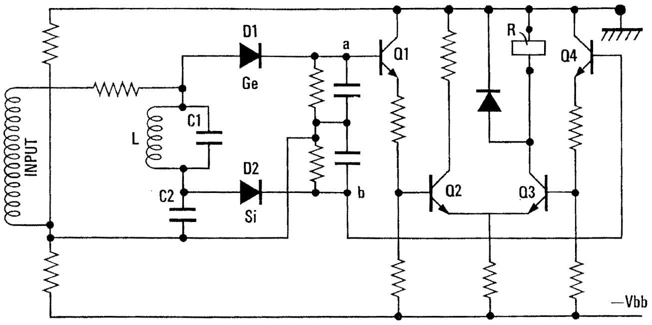


Figure 5 - Signaling receiver and discriminator circuit.

In the modifying circuit, shown in Figure 4, forward biasing is used to reduce V_f and the power law is changed by introducing series resistance. Diode *D2* and the potential divider formed by *R1* and *R2* serves to reduce V_f to zero. Since *D2* has the same temperature coefficient as *D1* this reduction is maintained over the working temperature range. Resistors *R1* and *R2* in parallel form the series resistance to modify the *D1* characteristic. In practice the optimum is established by adjustment of *R1a* while measuring the second harmonic output of a test signal. Tables 4 and 5 illustrate the detection performance.

To maintain the supply voltage to the detector constant with temperature, a 5·1-volt zener diode, having a nominally zero temperature coefficient, is used to establish *Vbb*.

5.3 Discriminator and Signaling Circuit

A schematic of the signaling receiver with the discriminator is shown in Figure 5. The network, consisting of *L*, C_1 and C_2, is arranged to have a pole at the normally transmitted carrier frequency f_1 and a zero at the transmitted carrier frequency corresponding to the signaling-*on* condition, $f_1 - 4$-kHz. With f_1 transmitted point *a* is more positive, and with $f_1 - 4$-kHz transmitted point *b* is more positive. Relay *R* is operated in the latter condition. In the absence of any signal the relay is held in the unoperated condition by the difference in the forward-voltage drop between the germanium and silicon diodes.

The signaling receiver tends to be self-protecting against voice operation in either the non-operated or operated condition since speech energy is always concentrated near the carrier frequency and thus supports the carrier.

Table 6 shows a typical variation of signaling distortion for 30-baud signals.

Adjustment on the signaling receiver was not considered necessary and is not provided.

5.4 Automatic Gain Control

A high resistance feeds the bulk channel signal to a diode bridge forming a mean rectifier circuit whose output is compared with a reference zener diode.

Mean detection of the signal was chosen for the function since this results in least change in the regulated level due to speech superimposed on the channel carrier, thus avoiding the need for filtering the carrier. It should be noted, however, that since the channel signal is ultimately recovered in a square-law detector the demodulated output suffers a doubling-in-level change due to the residual inaccuracy of the automatic-gain-control system. The relatively long time constant of a thermistor-controlled system avoids syllabic variations in this respect. The range of control is ± 6 decibels for a mean maximum line loss of 29 decibels. The residual error resulting from a 6-decibel loss change is 0·6 decibel after doubling by the square-law detector.

5.5 Overall Characteristics

Figure 6 shows the overall frequency-attenuation characteristics, obtained in a back-to-back test, for bottom, middle-range and top channels. Interchannel crosstalk is better than −65 dBm0 with 90 percent of adjacent combinations better than −70 dBm0. Adjacent channel inter-

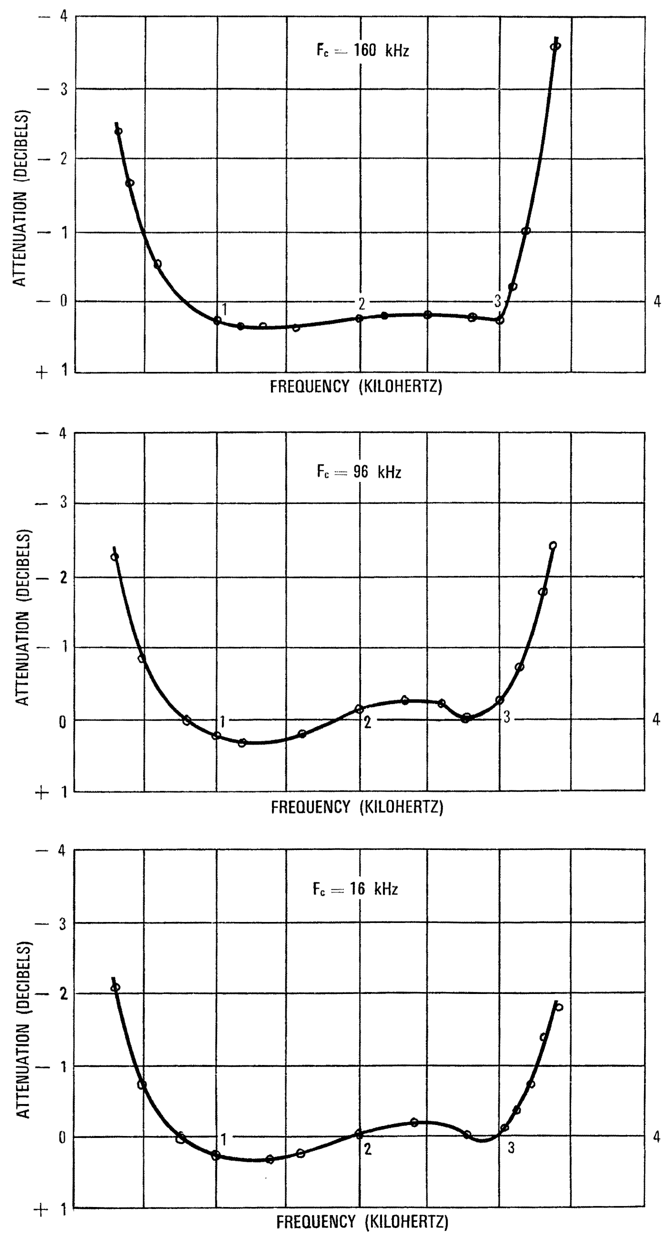
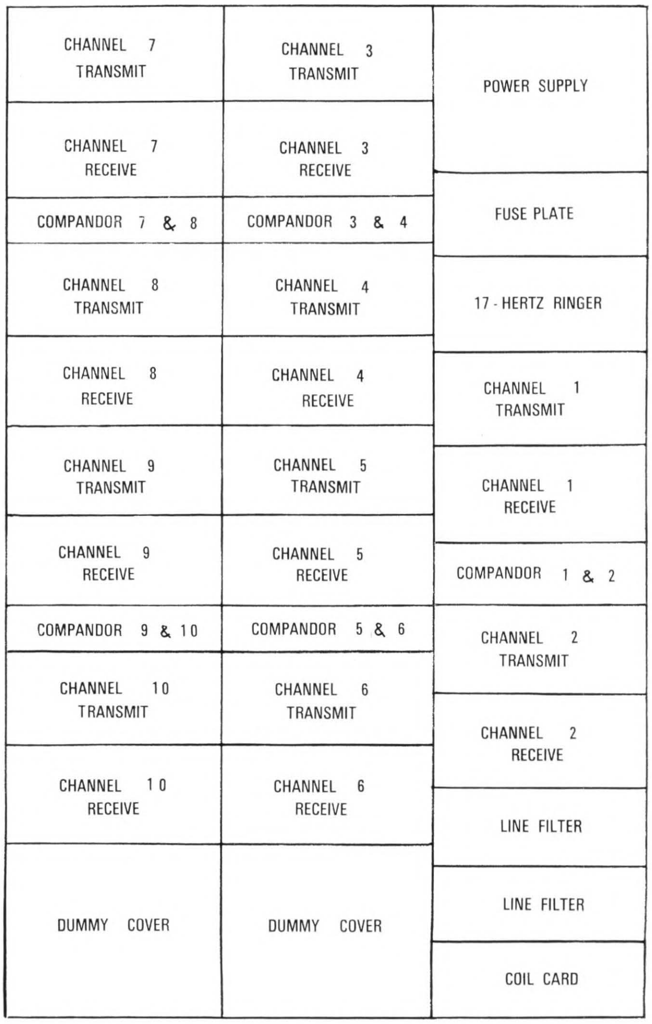


Figure 6 - Overall frequency-attenuation characteristic obtained in a back-to-back test for bottom, middle-range, and top channels.



◀ Figure 7 - Arrangement of a 10-channel terminal.

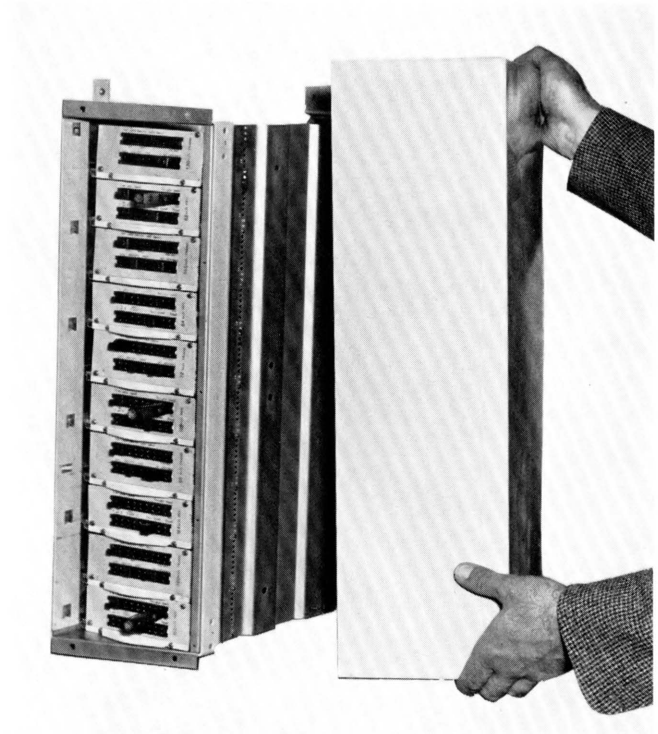
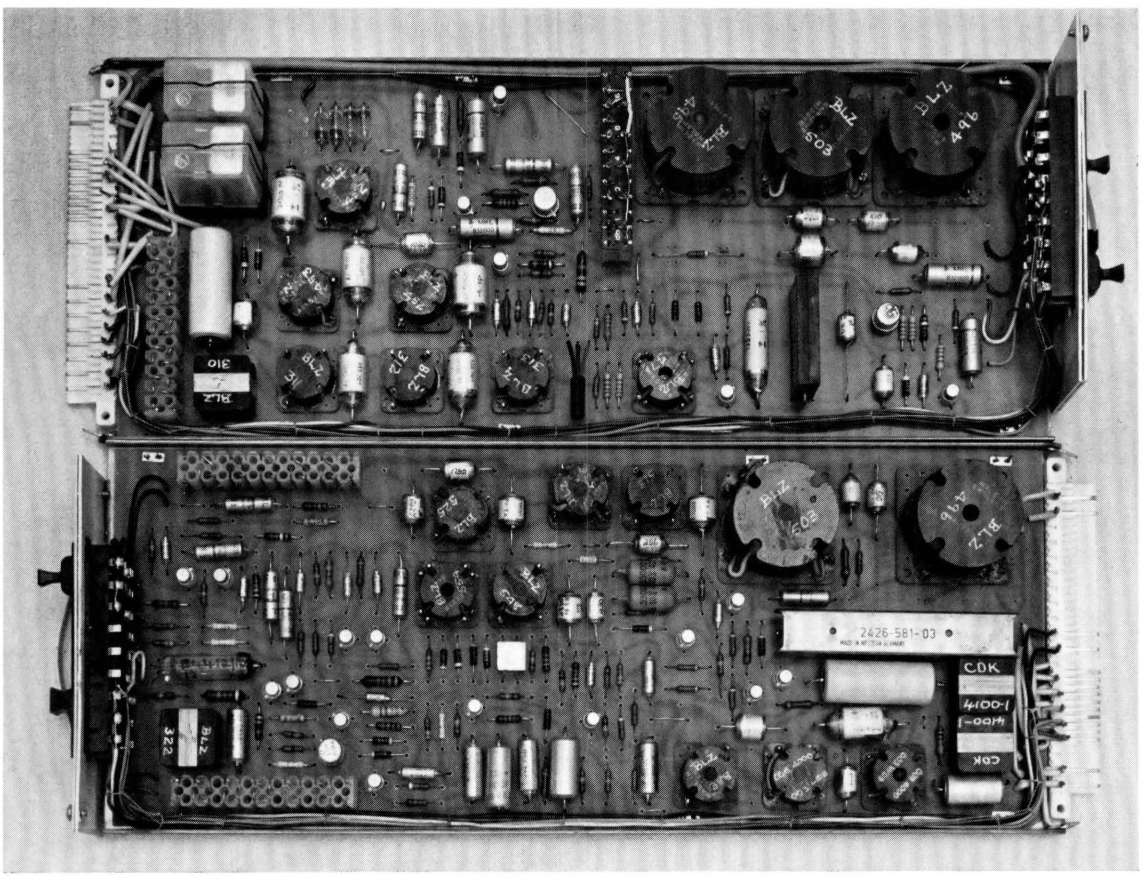


Figure 8 - Wall-mounted shelf for small stations.



▼ Figure 9 - Typical send (top) and receive (bottom) cards.

ference with shaped white-noise loading is better than 300 microvolts psophometrically weighted at zero relative level whilst send-to-receive within-channel crosstalk has a worst value of −45 dBm0. All results refer to uncompandored channels.

6. Mechanical Layout

Figure 7 shows the arrangement in which three shelves in deep-rack construction accommodate 10 channel-ends with power supply, compandors (if required), line filter and line coil. The first shelf may be used alone to provide the first-in equipment for up to two channels with common plant. A wall-mounted version of this shelf has been engineered and is shown in Figure 8. Two other shelves each accommodate 4 channel ends.

Typical send and receive channel cards are illustrated in Figure 9.

7. Acknowledgments

The authors wish to record the assistance received from their colleagues in Standard Telephones and Cables (SA) (Pty) Limited and Standard Telephones and Cables Limited, London.

References

[1] R. C. Boyd, J. D. Howard Jr. & L. D. Pedersen, "A New Carrier System for Rural Service (P1 Carrier)" BSTJ volume 36, March 1957 no. 2, pp. 349—390.

[2] N. J. Paola & R. B. McAinsh, "New Open Wire Carrier Telephone Systems in the frequency range up to 300 kilocycles per second". Transactions of the SAIEE, volume 55, part 9, September 1964.

[3] M. E. Collier, "Transistor Carrier Multiplex Equipments", part 2 - Deep Rack Construction (Mark 6 Multiplex). Electrical Communication, volume 40, no. 1, 1965, pp. 48—73.

[4] C. F. Boyce, "Open-Wire Carrier Telephone Transmission". MacDonald & Evans, London, 1962.

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Plastics Encapsulation of Components

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1. Introduction

Component encapsulation is normally required for protection against environmental agents such as moisture, chemicals, heat, and molds, and against general mechanical damage including vibration. The use of plastics for encapsulation has resulted from the increasing complexity of modern electronic equipment and the keenness of competition in this industry, which have necessitated the investigation of all possible ways of reducing the cost of the extensive range of components now required. Initially, plastics encapsulation was introduced for the very low-cost limited-life market, but in the light of experience gained in this application, and with a more thorough evaluation of the properties obtainable from the materials and processing techniques, it became apparent that plastics encapsulation might be suitable for more critical applications.

For many years, it had been considered that moisture protection for components required the use of hermetically-sealed metal cases. Such encapsulation, if properly executed, is truly hermetic, but in fact the several national and military specifications which define the performance requirements for such electrical components do not, in general, ask for *absolute* hermetic sealing. These specifications call for preservation of the essential electrical characteristics of the component during a prescribed period of days of exposure to a specified relative humidity and temperature.

Such requirements for the encapsulating medium permit the use of organic resin systems, such as polyesters, alkyds, epoxides, and silicones as simultaneous moisture barriers and mechanical strengtheners for components. In general, the most costly resin systems provide the greater degree of moisture protection, and there is a great variety of ways of applying the encapsulant to the component, as discussed later in this paper. Resin systems generally provide cheaper encapsulation than is possible with hermetic sealing.

When deciding the most suitable process and material for a particular component encapsulation, the following are the principal factors which must be taken into account,

— volume of production,
— permissible capital expenditure on plant,
— acceptable cost of encapsulation,
— degree of moisture protection required; this often determines the thickness of encapsulant,
— mechanical protection required,
— service temperature range, including resistance to wide temperature excursions (sub-zero to elevated),
— electrical requirements in encapsulant,
— possible effect of encapsulant on component, for example, due to chemical interaction, or to stresses set up during cure and/or thermal excursions, and
— heat dissipation requirements.

The variety of materials and processes now available are briefly discussed in the next sections.

2. Materials

Bearing in mind the wide range of techniques now in use for component encapsulation and protection (see Section 3), the main resinous materials used for this purpose are listed in Table 1, together with an indication of the principal forms in which they are commonly available.

The more-important characteristics of these various resin types are briefly commented on below.

2.1 Epoxides

The most commonly used epoxide resins are condensation products of epichlorhydrin and diphenylolpropane (bisphenol A), but resins based on cycloaliphatic diepoxides, epoxy-novalacs, epoxidised polyolefines, et cetera, are now commercially available for special applications. The bisphenol A resins are available in solid and liquid form, and can be cured over a wide range of conditions of temperature and time using a variety of curing

Table 1 – Main resinous materials

Type of resin	Liquid resin	Solid resin	Liquid rubber	Molding* compound	Powder	Coating solution	Foaming compound
Epoxide	+	+		+	+	+	+
Polyester	+			+			
Silicone			+	+		+	+
Polyurethane	+		+				+
Alkyd				+			
Thermoplastics for example, polypropylene				+	+		
Hot melts		+					

* Covers granular transfer molding compounds and also dough compounds.

agents such as aliphatic amines, aromatic amines, polyamides and acid anhydrides. They can be modified through the addition of plasticizers, reactive diluents, flexibilizers, fillers, and so on, and thus provide an extremely versatile group of materials.

Epoxides are characterized by low curing shrinkage, good adhesion properties, low water absorption and transmission, and good mechanical and electrical properties.

2.2 Polyesters

Polyesters were the first casting and potting resins widely used for component encapsulation. Liquid resins, comprising an unsaturated polyester and a reactive monomer, are converted to the solid form, usually by means of organic peroxide curing agents, with or without accelerators. The resin composition can be varied to give a range of flexibility or rigidity in the cured products, and fillers can be incorporated.

Although having generally good mechanical and electrical properties, polyesters suffer from a high shrinkage during cure, which often leads to cracking in castings and is probably an important factor responsible for their apparently inferior adhesion properties compared with epoxides. They are, however, relatively low-cost resins.

2.3 Silicones

Silicone resins, based on silicon-oxygen chain structures, have superior heat resistance to the other encapsulants listed in Table 1. They are generally suitable for continuous service at temperatures up to about 250 degrees Celsius, have good electrical properties, moisture resistance, and low-temperature properties, and are unique in providing a range of rubbery-type coatings and encapsulation compounds in addition to rigid types. They are still, however, expensive materials. Typical compounds include,

— two-component room-temperature vulcanizing *RTV* silicone rubbers in a range of viscosities,
— one-component rubbers curing at room temperatures by reaction with atmospheric moisture,
— transparent two-component rubbers curing at room or elevated temperatures,
— two-component dielectric gels,
— solventless silicones curing to hard tough products, and
— silicone varnishes, including high-purity grades for semiconductor device coating.

2.4 Polyurethanes

Reaction of diisocyanates with selected polyesters, polyethers, polyols, et cetera, gives casting and coating compounds which cure to rubbery solids at room or elevated temperatures. The reaction can be carried out in a one-shot system in which the complete reaction is carried out by the user, or with a pre-polymer system in which the reactants are partially reacted before use, and curing is effected in the presence of a catalyst or chain extender.

The resins can be formulated over a wide range of hardness, and provide a valuable combination of flexibility and resistance to shock and impact (high mechanical damping), with good electrical properties. Polyurethane liquid rubbers can be blended and co-reacted with liquid epoxide resins to impart flexibility and impact resistance to these materials.

2.5 Molding Compounds

Transfer molding compounds for component encapsulation are usually based on epoxide or silicone resins with either mineral powder or glass-fiber fillers. Unsaturated polyesters, which are also known as alkyd resins and include diallyl phthalate or *DAP* resins, are also available as granular transfer molding compounds; in addition, they can be compounded with suitable catalysts and fillers to give doughs or putties which can be applied to components by low-pressure methods. The injection molding of glass-filled *DAP* resins has been reported, using a cool-nozzle/hot-mold technique. The embeddment of components in thermoplastic materials such as polypropylene by injection molding requires special techniques to avoid damage to the component.

2.6 Foams

Light-weight and low-cost encapsulants are provided by foamed resins, produced by two main methods,

— gas evolution as part of the chemical reaction producing the resin; rigid and flexible polyurethane foams are produced in this way, and
— evolution of gas from blowing agents added to the resin; epoxide and silicone foams are typical of this class.

Low-density compounds (or syntactic foams) are produced by incorporating low-density fillers such as phenolic resin or glass microballoons in a suitable resin.

2.7 Hot Melts

Hot melts, based on special waxes or thermoplastics such as ethyl cellulose or cellulose acetate butyrate, are included for the sake of completeness although not widely used in component encapsulation.

2.8 Inorganic Compounds

Operation of electronic equipment at temperatures in excess of about 300 degrees Celsius has required the development of inorganic encapsulants based, for example, on dispersions of low-melting point glasses or inorganic binder/filler type of cements. These materials still present problems in processing, and there are certain deficiencies in their properties in the cured state.

3. Techniques

It will already be apparent that there is a wide variety of processes available for the plastics encapsulation of components; the principal ones are listed below.

— Casting techniques (molding, potting, sealing, et cetera).
— Dip-coating using solventless liquid resin compositions.

— Powder-coating by fluidized bed techniques.
— Solution-coating.
— Resin preform/molded case technique, for example, Ciba *E-PAK* system.
— Transfer molding.
— Dough molding.
— Injection molding.

It is not possible within the scope of this paper to consider these various processes in detail, but a critical analysis of their more important features is given. The ultimate choice of method for a particular component will depend on the factors listed earlier.

3.1 Casting Techniques

These are particularly suitable for production, involving a wide range of components in small or moderately large quantities. This scale of production can be achieved with relatively cheap and simple equipment, but may involve handling problems, and lead to variability in the products.

The technique can be mechanized for large-scale production through the use of automatic metering, mixing, dispensing, and casting equipment.

Molds can be constructed from a variety of materials, ranging from cheap plastics or silicone rubber to more expensive metal, the ultimate choice depending very much on the output required.

Casting is the principal process for potting in cans or molded cases, applying end-seals, and for impregnation of fine windings or intricate parts. The quality of protection obtained ranges from minimal to that necessary to meet the most severe requirements for plastics encapsulation. A wide range of casting resins is available. However, the processing of certain resins, hardeners, and fillers, involves toxic hazards requiring the provision of appropriate protection equipment.

3.2 Dip-coating

This technique requires simple and inexpensive processing equipment (no molds required) and the process can be adapted to automation. It is suitable for applying only relatively thin layers of encapsulant, but thickness can be built up by repeated dipping. The protective coatings are generally suitable only for less-severe humidity-exposure conditions.

There are still problems to be solved in formulation of dip-coating compounds with optimum flow properties which will give adequate coverage of components (reproducibility of thixotropic systems can still be troublesome).

3.3 Powder-Coating, Fluidized Bed

This technique can give a good coat in one dip, with virtually no material wastage even on complex shapes, without the use of solvents or liquid resins. The necessary plant ranges from simple fluidizing tanks to automatic machines incorporating ultrasonic cleaning, induction heating, fluidized-bed immersion, and oven curing. No molds are required, but masking is needed. The coating is difficult to apply to small components of low thermal capacity, but components can be preheated by induction heating.

A wide range of powders is now available including thermosets such as epoxides, and thermoplastics such as polyethylene, nylon, and cellulose acetate butyrate, but epoxides are usually preferred. The application temperatures tend to be too high for many components (120 to 200 degrees Celsius for epoxides, usually upwards of 200 degrees Celsius for thermoplastics). The technique is suitable for components requiring a relatively thin layer of encapsulant.

3.4 Solution-Coating

This method is limited in its use for component protection. In general, it is only suitable for the application of thin coatings owing to limitations imposed by the presence of a solvent. Typical examples are silicone dipping and impregnating varnishes, and silicone resistor coating cements. Possible applications are for pre-coating devices with, for example, a resilient layer, prior to encapsulation by conventional techniques.

3.5 Resin Preform/Molded Case Technique (Ciba E-PAK system)

This technique utilizes molded plastic cases or sleeves, and preformed resin pellets (usually uncured or partially cured epoxide). Only a small capital outlay is required for plant — mainly jigs and curing ovens — and production costs are generally low. No mixing and handling of liquid resins, hardeners, and fillers is necessary and no cleaning of molds is required. There is also no wastage of resin.

Finished products are of consistently good appearance and uniform size. The method is applicable to various forms of component protection, such as, encapsulation, sealing, end-sealing, and embedding in metal cans. A range of formulated epoxide pellets is now available, for example, Araldite *E*-form pellets, for specific applications. Epoxide pellets are sensitive to heat and moisture so that careful storage is necessary for reasonable shelf life.

Molded cases and sleeves, particularly thermosets such as epoxide and diallyl phthalate, are relatively expensive, and standardization of sizes is essential. Injection-molded thermoplastic cases and sleeves are generally cheaper but problems of resin-to-case adhesion occur with some materials like polypropylene.

3.6 Transfer Molding

This is readily adaptable to high-volume automated production using multicavity molds. No handling of liquid resin, hardeners, and fillers is necessary so toxic hazards are minimal. Good appearance and dimensional accuracy can be expected in encapsulated components.

A wide range of epoxide and silicone transfer compounds is now commercially available. Diallyl phthalates are also coming into use. Transfer pressures can be as low as 50 lb/in^2 depending on grade, which is advantegeous for delicate components. Rapid cure cycles of the order of 1 to 2 minutes can be achieved.

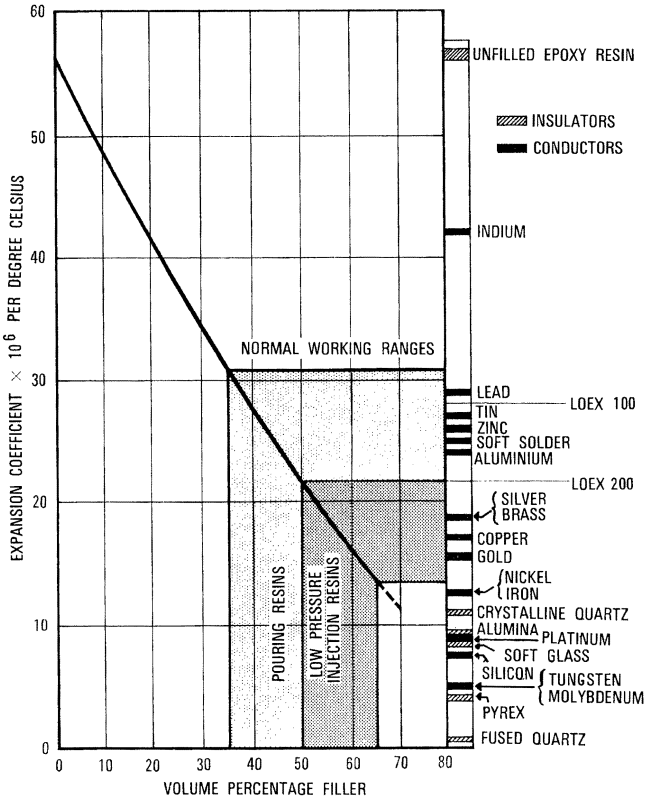

Figure 1 - Casting resins with matched thermal expansion.

The process involves substantial capital outlay for plant; molding presses and multicavity molds are expensive. The high cost of molds generally restricts the process to high-volume production components. Postcuring is frequently necessary to develop the full properties of the encapsulant.

Moisture protection afforded by transfer molding is still considered inferior to that achieved by casting, probably due to the influence of added mold-release agent. A fairly high wastage of material occurs in runners and transfer pot (30 to 40 percent).

3.7 Dough Molding

This process offers many of the advantages of transfer molding but with a reduced capital outlay for plant; presses and molds are generally simpler and less expensive (low molding pressures).

Polyester, alkyd and epoxide doughs are commercially available but many do not seem suitable for component encapsulation. Fast cure cycles are achieved with alkyds and polyesters, but the present epoxide doughs cure slower than transfer-molding epoxides, and have shorter shelf life.

Moisture protection is generally inferior to that obtained by best casting techniques. This process is potentially a cheap method of encapsulation using alkyd or polyester doughs for high-volume production components requiring moderate moisture protection.

3.8 Injection Molding

Limited experience has been obtained to date in the application of this technique to component encapsulation. Attractive features include possible use of cheap thermoplastic encapsulants in conjunction with fast-molding cycles.

Special molding techniques are probably necessary to minimize effect on components of the high injection pressure normally used. High thermal shrinkage and poor adhesion to lead-out wires can adversely affect moisture protection.

Recent developments are screw injection and cold plunger injection of thermosets; both use relatively cool injection cylinder and nozzle, and hot molds.

4. Applications

Two practical aspects of component encapsulation will be considered in some detail: the development and applications of *Loex*® (low expansion) casting resins, and investigations on the encapsulation of silvered mica capacitors.

4.1 Loex Casting Resins

The work carried out at Standard Telecommunication Laboratories, Harlow, England, on component encapsulation has been particularly concerned with the development of improved casting compositions based on filled epoxide resins. These have proved to have certain advantages over commercially available materials.

The following favorable processing properties were required in the basic epoxide system,

— low initial viscosity to facilitate handling, particularly degassing and the incorporation of a high loading of filler,
— reasonable pot life at temperatures up to 80 degrees Celsius,
— rapid gelation at the cure temperature to permit quick mold turn round,
— cure temperature not exceeding the upper limit of component rating,
— no excessive exotherm development during cure, and
— low toxicity.

In developing these compositions, particular attention has been paid to the following requirements in the cured products.

— Control of thermal expansion through the use of a high loading of carefully selected filler; this property can be sufficiently matched to that of conventional component materials (see Figure 1) so as to permit relatively large temperature excursions without setting up significant stresses either in the component or encapsulant.
— Reduction in curing shrinkage in order to minimize internal stresses and the shrinkage of resin away from an outer case; this again is achieved through the use of a high filler loading.
— Low moisture absorption through the incorporation of carefully selected and treated fillers, and the presence of hydrophobic additives.
— Low moisture vapor permeability using the same approach as for sorption: with epoxide resins we have

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Table 2 – Properties of *Loex* compositions

	Loex 200	*Loex* 100
HDT (ASTM D648)	137 degrees Celsius	70 degrees Celsius
Density	1·74 g/cm^3	1·76 g/cm^3
Linear thermal expansion (*ASTM* D696)	22 $\times$ 10^{-6}/degC	27–29 $\times$ 10^{-6}/degC
Curing shrinkage (volumetric)	about 1 percent	about 1 percent
Thermal conductivity	0·0013 cal/cm.s.degC	about 0·0011 cal/cm.s.degC
Water absorption (BS 2782 method 502F):		
24-hours immersion	6 mg	2 mg
1-week immersion	13 mg	5 mg
13-weeks immersion	24 mg	17 mg
Water vapor transmission (Patra cup method, 1-mm thick disks, 40 °C, 90 percent RH)	0·63 $\times$ 10^{-8} g/cm.h.mmHg	0·17 $\times$ 10^{-8} g/cm.h.mmHg
Flexural strength (BS 2782, method 304B)	15000 lb/in^2	15800 lb/in^2
Flexural modulus (BS 2782, method 304B)	1·6 $\times$ 10^6 lb/in^2	1·7 $\times$ 10^6 lb/in^2
Electric strength (BS 2782, method 201G)	approx. 300 V/mil over temperature range 20–150 degrees Celsius	approx. 250 V/mil over temperature range 20–150 degrees Celsius
Permittivity (BS 2067):		
1 MHz	4·31	4·00
80 MHz	4·23	4·04
Power factor (BS 2067):		
1 MHz	0·0075	0·0033
80 MHz	0·0085	0·0044
Insulation resistance (BS 2782, method 204A)	$>$ 2 $\times$ 10^{13} ohms	$>$ 2 $\times$ 10^{13} ohms
Volume resistivity (BS 2783, method 202A)	$>$ 10^{15} ohm.cm.	$>$ 10^{15} ohm.cm.

found that sorption and permeability respond in a similar way to changes in composition.

— High heat-deflection temperature *HDT*, particularly where stability of the properties of the encapsulant at elevated temperatures is important.

— Good thermal stability; the basic *Loex* resin system is characterized by high *HDT* thermal stability.

— Increased thermal conductivity for applications where heat dissipation in encapsulated components is important, particularly with the trend towards miniaturization; this is achieved through the incorporation of a high loading of selected fillers.

It should be emphasized that optimization of all the above properties cannot normally be achieved in a single composition, and two *Loex* compositions have been standardized for general use.

— *Loex* 200, for applications requiring minimum thermal expansion and high *HDT*, and

— *Loex* 100, for applications requiring minimum moisture absorption and transmission, but where some sacrifice in thermal expansion and *HDT* can be accepted.

Detailed properties of these two resins are given in Table 2.

A further composition for applications requiring maximum thermal conductivity is under development; this work has reached the stage of achieving an approximate 9-fold increase in thermal conductivity over that of the unfilled resin.

Some typical applications of *Loex* resins, requiring special properties in the encapsulant, are given in Table 3.

4.2 Encapsulation of Silvered Mica Capacitors

We present here test results on silvered mica capacitors encapsulated in several specially formulated epoxide casting resins, by a fluidized-bed epoxide coating, by compression molding in alkyd doughs, and by transfer molding in epoxide powder.

In the case of professional mica capacitors the resin coverage is very thin (0·03 to 0·05 inch or 0·76 to 1·27 millimeters), and it is desired to achieve one of the following levels of protection:

No. of days exposure to 90-percent *RH* at 40 degrees Celsius	21	56
Maximum permissible percentage change in capacitance	0·5	0·5
Maximum permissible loss angle, *tan δ*	0·0029	0·0029
* Minimum insulation resistance, megohms at 125 volts direct current	1·0 $\times$ 10^4	2·5 $\times$ 10^4

* It will be noted that the insulation resistance requirement is much more severe for 56-day test. These are separate specifications, 21-day and 56-day.

4.2.1 Cast Units

The results given in Table 4 are for mica capacitors cast in various epoxide resin systems using split thermoplastic molds for casting. With capacitors, first signs of failure due to moisture penetration are observed as a drop in insulation resistance. Prolonged exposure results in deterioration in loss angle and significant change in capacitance.

The results for a simple anhydride-cured-resin system (Resin 1), Table 4, show that it will not provide moisture protection even for a period of 21 days, because of the restricted resin thickness permitted on this type of capacitor.

The addition of a special liquid water-repellent additive gives notable improvement (Resin 2), although not all the units tested satisfy the 21-day exposure test.

Table 3 – Typical applications of *Loex* resins

Component	Special features or requirements	Resin used
Silvered mica capacitor	Maximum resistance to moisture to meet *H6* classification of *DEF 5011.*	*Loex* 100
Thin-film circuits	Protection against moisture and mechanical damage; latter requires low-expansion resin.	*Loex* 100
Microwave tunnel diode	Mechanical protection of fragile junction requires low-expansion resin to minimize effects of thermal cycling; also good moisture protection.	*Loex* 200
High-voltage silicon diodes	Good electrical breakdown characteristics in small device. Maintenance of high-reverse-voltage under humid conditions.	*Loex* 200 with reduced filler content
Antenna-base casting for aircraft and satellites	Resistance to thermal cycling, for example −40 to +70 degrees Celsius, in casting with substantial metal insert, requires matched expansion coefficient. Also radiation resistance for satellite antennas.	*Loex* 200
Ferrodot® recorder head	Requires matched expansion resin for impregnation of fine-wire/coil assembly, with no mechanical damage due to curing or thermal shrinkage.	*Loex* 200

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Table 4 – Long-term damp heat. Results on silvered mica capacitors (220–250 pF) encapsulated in cast epoxide resins

Resin system	Percentage failures		Average insulation resistance in megohms	
	After 21 days	After 56 days	After 21 days	After 56 days
1) Unfilled epoxide resin (anhydride cured)	100	—	$< 1{\cdot}0 \times 10^4$	$< 0{\cdot}5 \times 10^4$
2) Unfilled epoxide resin plus liquid water-resisting additive (amine cured)	20	100	$3{\cdot}9 \times 10^4$	$< 2{\cdot}5 \times 10^4$
3) Resin system as 2) plus 200 parts-per-hundred-of-resin filler	17	100	$3{\cdot}2 \times 10^4$	$< 2{\cdot}5 \times 10^4$
4) Anhydride-cured resin, containing water-resisting additive, 340 parts-per-hundred-of-resin filler and agent for wetting out surface of filler (*Loex* 100)	0	0	$> 5{\cdot}7 \times 10^6$	$1{\cdot}96 \times 10^6$

The addition of an inert impervious filler to Resin 2 did not noticeably change its moisture-protection properties (Resin 3).

The performance of a filled-resin system can also be significantly improved by the addition of a chemical agent which ensures complete wetting of the filler by the resin (Resin 4). This treatment ensures that moisture diffusing through the resin cannot find an easy diffusion path along the surface of a badly wetted filler.

4.2.2 Molded Units

Press-molded encapsulation offers a rapid production procedure with reduced labor cost and very attractive component appearance compared with cast units. Data have, therefore, been collected to determine the moisture protection provided by this type of encapsulation, bearing in mind that molding materials must have a built-in mold release agent, which will, however, reduce the adhesion of the resin to the component termination wires. This lack of adhesion could provide a path for moisture access to the component.

The data collected in Table 5 are for mica capacitors encapsulated in two commercial alkyd molding doughs. Dough *A* essentially meets the 4-day protection requirement, and nearly half the units pass the 21-day exposure test. Tests with a penetrant-dye solution show that failure is due to penetration of moisture between the resin and termination wires; this can occur because of the fairly high shrinkage of these resins on curing. In the case of Dough *B* the less satisfactory performance results from the presence of glass fibers in the dough which, unless properly wetted-out by resin, provide a path for penetration of water vapor through the resin.

A more sophisticated but more expensive encapsulation can be achieved by transfer molding the components in epoxide resin. In this case, cure shrinkage is lower than for alkyd doughs, and it is seen from Table 6 that 21-day protection is readily achieved with a wide range of Hysol transfer molding compounds. None, however, can provide 56-day protection with the limited resin thickness permitted on these capacitors. Failure to meet the 56-day requirement is probably due to presence of mold release agent in these resins.

4.2.3 Fluidized-Bed Coating

Where a lesser degree of moisture protection is required the simple technique of fluidized-bed coating of the component with an epoxide resin powder can provide

Table 5 – Long-term damp heat. Results on silvered mica capacitors (4000 to 4300 pF) with compression-molded alkyd encapsulation

Commercial alkyd dough	Initial parameters		After 4 days damp heat			After 21 days damp heat		
	Loss angle	Insulation resistance megohms	Percentage capacitance change	Loss angle	Insulation resistance megohms	Percentage capacitance change	Loss angle	Insulation resistance megohms
Dough *A*	1·0′	$6{\cdot}9 \times 10^{5}$	0·0	1·3′	$4{\cdot}0 \times 10^{5}$	+ 1·4	30·2′	<12·5
	0·6′	$6{\cdot}2 \times 10^{5}$	+ 0·9	25·0′	$5{\cdot}0 \times 10^{2}$	+ 7·7	> 47·0′	<12·5
	1·0′	$4{\cdot}5 \times 10^{5}$	< + 0·1	1·2′	$2{\cdot}5 \times 10^{5}$	+ 1·2	28·8′	$2{\cdot}8 \times 10^{2}$
	0·7′	$5{\cdot}7 \times 10^{5}$	< + 0·1	0·9′	$3{\cdot}1 \times 10^{5}$	+ 0·14	1·1′	$3{\cdot}1 \times 10^{5}$
	1·1′	$8{\cdot}3 \times 10^{5}$	+ 0·12	1·2′	$3{\cdot}1 \times 10^{5}$	+ 0·22	3·0′	$1{\cdot}8 \times 10^{4}$
	0·7′	$8{\cdot}3 \times 10^{5}$	< + 0·1	0·9′	$3{\cdot}1 \times 10^{5}$	+ 0·14	1·1′	$1{\cdot}2 \times 10^{5}$
	0·8′	$7{\cdot}4 \times 10^{5}$	< + 0·1	1·0′	$4{\cdot}0 \times 10^{5}$	< + 0·1	1·5′	$5{\cdot}0 \times 10^{4}$
	1·3′	$8{\cdot}9 \times 10^{5}$	< + 0·1	1·3′	$3{\cdot}1 \times 10^{5}$	+ 0·14	3·4′	$1{\cdot}7 \times 10^{4}$
	0·6′	$6{\cdot}9 \times 10^{5}$	+ 0·19	3·7′	$2{\cdot}5 \times 10^{3}$	+ 5·4	47·0′	52
Dough *B*	1·1′	$4{\cdot}3 \times 10^{5}$	+ 0·19	4·3′	$2{\cdot}1 \times 10^{3}$	—	—	—
	0·5′	$4{\cdot}5 \times 10^{5}$	+ 0·30	6·0′	$3{\cdot}1 \times 10^{5}$	+ 4·2	> 47′	45
	0·7′	$4{\cdot}6 \times 10^{5}$	+ 1·2	33′	$1{\cdot}25 \times 10^{2}$	—	—	—
	0·4′	$5{\cdot}0 \times 10^{5}$	+ 3·5	>47′	<12.5	—	—	—
	1·8′	$5{\cdot}0 \times 10^{5}$	+ 1·43	34′	$1{\cdot}8 \times 10^{2}$	—	—	—
	1·1′	$4{\cdot}5 \times 10^{5}$	+ 1·75	>47′	40	—	—	—
	0·8′	$4{\cdot}5 \times 10^{5}$	+ 2·75	>47′	31	—	—	—
Limiting values to DEF 5132 & 5011	—	—	0·5 percent maximum change	10′ maximum	$1{\cdot}0 \times 10^{4}$ minimum	0·5 percent minimum change	10′ maximum	$1{\cdot}0 \times 10^{4}$ minimum

Table 6 – Long-term damp heat. Results on silvered mica capacitors (50 pF) transfer-encapsulated in several Hysol epoxide molding compounds

Hysol resin designation	Initial values			After 21 days			After 56 days		
	Capacitance (pF)	Loss angle	Insulation resistance megohms	Percentage capacity change	Loss angle	Insulation resistance megohms	Percentage capacity change	Loss angle	Insulation resistance megohms
MG 4-01	51·28	1·8′	$> 6 \times 10^{6}$	+ 0·23	2·1′	$9{\cdot}4 \times 10^{5}$	+ 0·70	7·8′	$1{\cdot}3 \times 10^{3}$
	52·07	2·4′	$> 6 \times 10^{6}$	+ 0·17	2·65′	$3{\cdot}0 \times 10^{6}$	+ 0·38	8·3′	$2{\cdot}0 \times 10^{3}$
	51·52	2·1′	$> 6 \times 10^{6}$	+ 0·27	2·1′	$6{\cdot}0 \times 10^{6}$	+ 0·70	4·8′	$1{\cdot}0 \times 10^{4}$
	51·70	1·8′	$> 6 \times 10^{6}$	+ 0·15	1·8′	$5{\cdot}0 \times 10^{6}$	+ 0·93	7·6′	$3{\cdot}5 \times 10^{3}$
	51·70	2·1′	$> 6 \times 10^{6}$	+ 0·29	2·54′	$> 6{\cdot}0 \times 10^{6}$	+ 0·68	4·0′	$1{\cdot}25 \times 10^{4}$
MG 5F	51·84	2·36′	$> 6 \times 10^{6}$	+ 0·04	3·3′	$> 6{\cdot}0 \times 10^{6}$	+ 1·7	13·8′	$1{\cdot}2 \times 10^{3}$
	51·33	1·36′	$> 6 \times 10^{6}$	+ 0·64	2·3′	$> 6{\cdot}0 \times 10^{6}$	+ 1·4	9·1′	$1{\cdot}05 \times 10^{4}$
	51·13	2·04′	$> 6 \times 10^{6}$	+ 0·29	2·75′	40	+ 1·0	8·7′	47
	52·06	2·00′	$> 6 \times 10^{6}$	− 0·12	2·85′	$6{\cdot}0 \times 10^{6}$	+ 0·61	8·8′	$1{\cdot}0 \times 10^{4}$
	51·25	1·78′	$> 6 \times 10^{6}$	+ 0·23	3·1′	$> 6{\cdot}0 \times 10^{6}$	+ 1·0	9·1′	$6{\cdot}8 \times 10^{3}$
MG 6	51·78	2·06′	$> 6 \times 10^{6}$	− 0·04	3·07′	$4{\cdot}3 \times 10^{6}$	+ 0·62	8·0′	$5{\cdot}7 \times 10^{3}$
	51·34	1·88′	$> 6 \times 10^{6}$	+ 0·20	2·44′	$> 6{\cdot}0 \times 10^{6}$	+ 0·62	3·5′	$4{\cdot}6 \times 10^{4}$
	51·81	1·86′	$> 6 \times 10^{6}$	− 0·08	2·44′	$> 6{\cdot}0 \times 10^{6}$	+ 0·44	4·4′	$1{\cdot}8 \times 10^{4}$
	50·79	1·63′	$> 6 \times 10^{6}$	+ 0·10	2·1′	$> 6{\cdot}0 \times 10^{6}$	+ 0·73	3·9′	$2{\cdot}1 \times 10^{4}$
	51·55	1·60′	$> 6 \times 10^{6}$	+ 0·19	2·3′	$> 6{\cdot}0 \times 10^{6}$	+ 0·83	5·2′	$1{\cdot}1 \times 10^{4}$
XMG 4-D976	51·48	1·59′	$> 6 \times 10^{6}$	0·00	1·8′	$> 6{\cdot}0 \times 10^{6}$	+ 0·35	4·1′	$1{\cdot}1 \times 10^{4}$
	51·78	1·60′	$> 6 \times 10^{6}$	− 0·04	2·0′	$4{\cdot}3 \times 10^{6}$	+ 0·10	5·1′	$7{\cdot}3 \times 10^{3}$
	52·18	1·97′	$> 6 \times 10^{6}$	− 0·04	2·5′	$5{\cdot}0 \times 10^{6}$	+ 0·27	6·0′	$1{\cdot}95 \times 10^{3}$
	51·52	2·14′	$> 6 \times 10^{6}$	− 0·12	2·65′	$4{\cdot}0 \times 10^{6}$	+ 1·5	3·0′	85
	51·56	1·54′	$> 6 \times 10^{6}$	+ 0·43	2·1′	$> 6{\cdot}0 \times 10^{6}$	+ 0·25	3·7′	$1{\cdot}4 \times 10^{4}$
Acceptance limits to DEF 5011 & 5132	—	—	—	0·5 percent maximum change	maximum 10′	$1{\cdot}0 \times 10^{4}$ minimum	0·5 percent maximum change	10′ maximum	$2{\cdot}5 \times 10^{4}$ minimum

Table 7 – Long-term damp heat. Results on silvered mica capacitors (800 pF) encapsulated in epoxide resin by fluidized bed process

Thickness of resin in inches	Initial parameters		Parameters after 4 days	
	Tan δ	Leakage current (μA)	Tan δ	Leakage current (μA)
0·020 (0·51 millimeters)	0·0001	0·000 28	0·0001	0·001 54
	0·0002	0·000 24	0·0000*	0·001 47
	0·0007	0·000 31	0·0008	0·002 97
	0·0001	0·000 29	0·0003	0·001 55
	0·0000	0·000 33	0·0010	0·024 46
	0·0005	0·000 28	0·0006	0·000 85
0·030 (0·76 millimeters)	0·0002	0·000 30	0·0002	0·000 27*
	0·0000	0·000 32	0·0001	0·000 40
	0·0000	0·000 27	0·0000	0·000 43
	0·0002	0·000 30	0·0002	0·000 45
	0·0001	0·000 29	0·0001	0·000 33
	0·0003	0·000 27	0·0003	0·000 45
0·040 (1·02 millimeters)	0·0001	0·000 33	0·0000*	0·001 18
	0·0001	0·000 32	0·0001	0·000 40
	0·0001	0·000 42	0·0001	0·000 52
	0·0001	0·000 25	0·0001	0·000 26
	0·0001	0·000 29	0·0002	0·002 75
	0·0001	0·000 26	0·0002	0·000 30
Limiting values to DEF. 5011 & 5132	—	—	0·0029	0·0120

* Improvement due to heat curing in perfectly seated component.

an attractive production procedure. By its very nature the coating tends to be porous and does not therefore provide a very efficient moisture barrier.

The results in Table 7 show the degree of protection provided for several different resin thicknesses. Even the smallest thickness used (0·02 inch or 5 millimeters) provides moisture protection for 4 days which was all that was required for this particular form of component.

5. Future Trends

The rapid growth in the use of plastics for component encapsulation is largely due to a combination of economic and technical factors. Plastics encapsulation is economically very attractive in comparison with hermetic sealing, and advances made during the last few years in encapsulation resins and processes have now extended the range of application into the field of high-quality components.

It is envisaged that a major future trend will be towards cheaper encapsulation processes (including materials) which can be adapted to automated high-volume production. Dipping type processes can probably be developed to meet both these requirements in the case of low-cost components requiring minimal protection. For high quality components, having more stringent protection requirements, press-molding techniques (transfer, injection, or dough molding) look very promising, and offer good prospects of meeting the cost/productivity conditions. There are still, however, certain outstanding problems to be solved before these molding processes can be fully exploited. Casting techniques, using specially formulated liquid resin compositions, will probably still hold their own where maximum protection is needed or special conditions or requirements are encountered, and considerable progress is being made in adapting these techniques to high-volume production. In the field of encapsulation resins, an increasing demand is foreseen for more heat-stable materials which will withstand service temperatures in the range 200 to 250 degrees Celsius.

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Loudness Rating of Telephone Subscribers' Sets by Subjective and Objective Methods

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1. Introduction

A preceding article [1] dealt with the corrections to be applied to OREM-A ratings of subsets whose response lies within the working range of OREM-A, 200 to 4000 Hz, so that NOSFER and OREM-A ratings could be seen to be substantially equal when differences of the zero reference datum are taken into account. Now we will deal with two other aspects: the effect of bandwidth and altitude on loudness rating.

2. Effect of Bandwidth on Loudness Rating

When a subset has a significant part of its response outside the band 200 to 4000 Hz, the extra loudness contributions from those parts of its response below 200 Hz and above 4000 Hz are not included in the OREM-A rating. To establish corrections for all subsets a method is needed for estimating the loudness contributions of those parts of the response which lie outside the measuring band of an objective-rating instrument.

There is another aspect of the Reference Equivalent rating which must also be considered. The loudness rating of a subset is a statement of its electroacoustic efficiency relative to a master reference system whose sensitivity is known, so that when an average voice-level is specified the electrical output of a subset can be calculated. This information is needed when planning the national telephone network so that a subscriber can have a satisfactory signal level and no part of the network is electrically overloaded.

There is a CCITT recommendation, G 223, which gives limits for the maximum-allowable power levels at a "transmission reference" point, namely, where speech circuits are multiplexed and band-limited to within 300 to 3400 Hz. To make sure that these very important limits are not exceeded the planner needs to know the power the subset will supply to the line within this band, and the loudness efficiency within the same band at the receiving end.

Three bandwidths have now been mentioned, 100 to 8000 Hz for NOSFER, 200 to 4000 Hz for OREM-A, and 300 to 3400 Hz for multiplexed telephone circuits. It is evident that it would be useful to have a method for translating the loudness rating for any one of these bands into a rating appropriate to any other band.

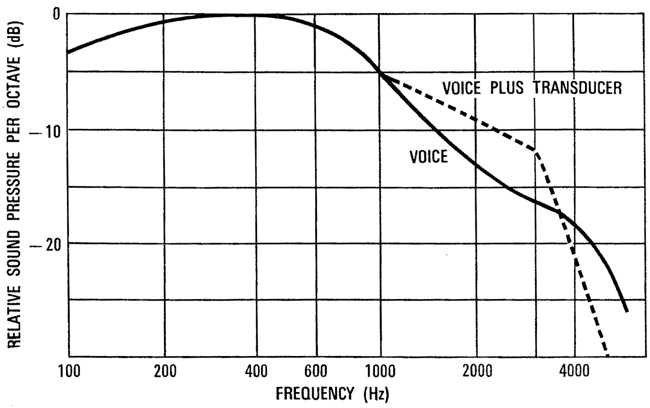

Figure 1 - Speech spectrum over a relatively long time period.

Two methods of calculating loudness are described in ISO Recommendation R 532 and, if the frequency response of the subset is known, either of these methods can be used to estimate the loudness contribution from those fringe portions of the response that extend beyond the narrower band but are within the wider band. The basic loudness is measured either objectively or subjectively and the estimating method is used only to add or subtract a relatively small loudness correction.

The methods A and B of ISO R 532 are based on the work of S. S. Stevens and E. Zwicker, and have been applied to many forms of noise by Urbanek [2], who shows that a signal with a wide-band smooth spectrum is the type of noise that gives best agreement between the two methods. A telephone speech signal falls within the range of this definition and it is expected that either method, A or B, could be used with an agreement better than $\pm$ 0·5 dB with each other and with a subjective assessment.

In calculating the loudness difference between two channels of different bandwidth the procedure when using Method A of ISO R 532 is as follows.

a) The input to all systems is taken as the average of male and female speakers talking at a normal conversational level. The speech spectrum is then that of Figure 1 based on the many measured spectra given in [3 to 6].

b) An ideal response curve is assumed for a reference subset and a grid pattern of partial-loudness contributions will be built up so that any change in loudness due to departures from the ideal can be quickly assessed. Since the high-frequency response of the subset contributes very little to the total loudness, and since even quite wide differences in the electroacoustic efficiency above 1500 Hz have relatively little effect on loudness, an average response above 1500 Hz is assumed for all subsets, rising by 5 dB from 1500 to 3000 Hz and cutting-off at 3500 Hz. Below 1500 Hz the ideal is assumed to be flat down to 100 Hz. This is shown in Figure 2.

c) The received-sound pressure level in a 6-cm^3 ear volume is assumed to be the preferred listening-level of 85 dBr*, which corresponds to a sound pressure level of about 75 dBr for the $^1/_3$-octave band of maximum loudness.

d) Loudness of other $^1/_3$-octave bands are then obtained from a curve which is the sum of the average speech-spectrum and an ideal subset response, (voice plus transducer in Figure 1) by equating the zero on the relative-dB scale of Figure 1 to 75 dBr.

* Sound pressure level referred to the threshold of hearing, 0·0002 dyne/cm^2.

e) Total-loudness calculations for the ideal subset then follow the routine of Method *A* in ISO R 532.

f) The loudness calculations are repeated for a series of response curves degraded from the ideal by taking various levels of sensitivity and various frequencies of band cutting. From these results, sectioned diagrams such as Figures 3(a) and 3(b) can be built up showing the loudness contributions of small areas of speech energy.

g) The response curve of a subset under test is plotted on tracing paper and superimposed on Figure 3(a) or Figure 3(b) adjusting the curves to equality at 500 Hz. The change of loudness due to a change of transmission bandwidth is obtained by totaling the elements of loudness lying below the response curve of the subset and between the relevant frequency ordinates.

From these diagrams we can estimate the loudness increase to be expected when the measuring band is extended below 200 Hz, giving a correction for OREM-A ratings; or, conversely, the loudness decrease to be expected when band limiting at 300 Hz for use in correcting NOSFER Reference Equivalents to telephone band-limited conditions.

Examples of maximum loudness corrections due to variation of this bass cut are:

1·5 dB when OREM-A band is extended down to 100-Hz bass cut,

2·5 dB when OREM-A band is restricted to 300-Hz bass cut,

4 dB to restrict NOSFER Reference Equivalent to 300-Hz bass cut.

When applying the band limitation of 300 to 3400 Hz to a subset with a response extending not only down to 100 Hz but up to 6000 Hz, a maximum difference of 6 dB between the NOSFER and a band-limited rating is possible. This is representative of the maximum departure of NOSFER from a practical rating for a 300- to 3400-Hz band-limited channel.

3. SETED Calibrations Derived from SFERT and NOSFER

SETED is a working standard in accordance with a recommendation of the CCITT, [7].

The original SETED equipment was calibrated against SFERT in 1953 [7] and has remained in the CCITT laboratory in Geneva since that date. In the past year its electroacoustic gain has been rechecked objectively and found to be in exact agreement with its original performance. When remeasured subjectively against NOSFER in 1966, some important differences were noted from the original SFERT calibrations as shown in Table 1.

Table 1

Reference Equivalent of SETED in dB (with band-pass filter in circuit)			
Sending end*		Receiving end*	
1953	1966	1953	1966
3·2 louder than SFERT	0·1 louder than NOSFER	1·1 louder than SFERT	2·8 louder than NOSFER

* CCITT Rapport Technique no. 340 (1966).

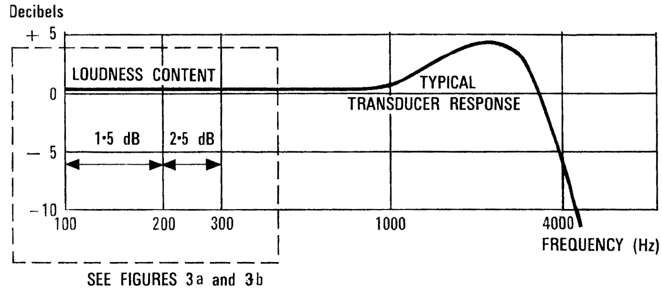

Figure 2 - Total loudness content of bass bands.

For the calibration of a working standard many replications are made and a 95-percent confidence limit for the limited population of the test team might be about 0·5 dB, in comparison to an external confidence limit of 0·8 to 1·0 dB.

When it is also noted that the differences between 1953 and 1966 calibrations for sending and receiving ends

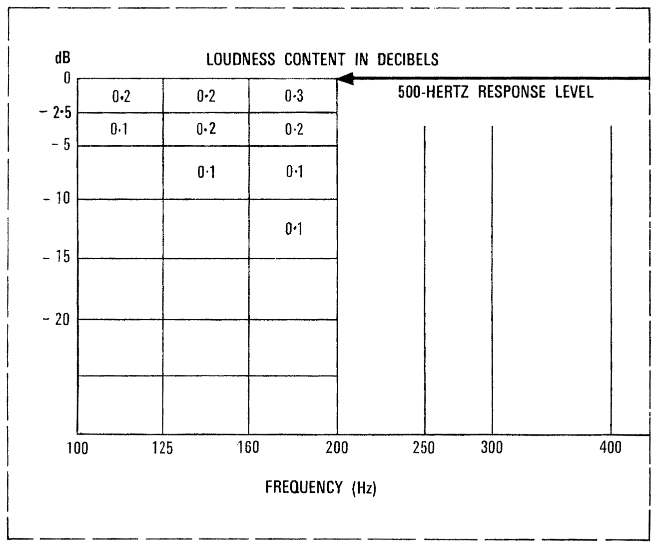

Figure 3(a) - Loudness content in decibels in the frequency range 100 to 200 hertz.

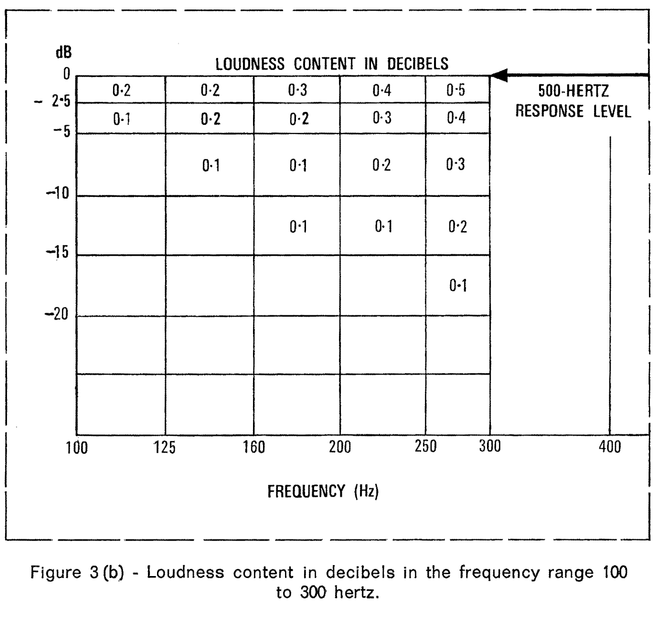

Figure 3(b) - Loudness content in decibels in the frequency range 100 to 300 hertz.

are in opposite senses, (a change of −3·1 dB for sending and +1·7 dB for receiving), the allowance of 2×1 dB for confidence limits still leaves a shift of 2·8 dB (4·8 minus 2 dB) unaccounted for.

This evidence arouses some element of doubt about the exact equivalence of NOSFER and SFERT ratings.

4. Effects of Altitude above Sea Level on Reference Equivalent

4.1 Subjective Reference Equivalents

NOSFER and SFERT are defined for electroacoustic air-to-air chains connecting a human speaker to a distant listener. When the atmospheric pressure changes due to altitude, the electroacoustic efficiency of each link in the chain will change. An altitude of 2000 meters (6600 feet) is chosen as an example because this gives an effect which cannot be ignored since it is an altitude at which many millions of the world's population live. The telephone receiver in any system will produce 2-dB reduced sound pressure in the ear at this altitude compared to the same receiver at sea level for the same electrical signal level.

This is a simple derivation from the gas equation:

$pv =$ constant (for constant temperature)

$p\delta v + v\delta p = 0$

$$\frac{\delta v}{v} + \frac{\delta p}{p} = 0.$$

If p represents the ambient atmospheric pressure and v is the volume of the ear cavity, then a change of volume δv caused by the movement of the receiver diaphragm will result in a change of pressure δp in the ear, and the ratio $\frac{\delta p}{p}$ will remain constant.

The sound produced by the human voice when using a constant muscular effort of the larynx will also suffer a similar reduction in pressure. The sound-pressure level of speech when speakers were subjected to ambient pressures corresponding to sea level and 10 000-meters (33 000-feet) altitude, was found to fall by about 10 dB, which is close to the expected change if the voice is assumed to be a simple mechano-acoustic machine [8]. If the muscular effort used in producing an airflow from the lungs and modulating it by the larynx is the same at sea level and 10 000 meters (33 000 feet) then the resulting sound pressure will be proportional to air density and be 10-dB lower at the higher altitude.

The level diagrams for the SFERT chain for altitudes of zero and 2000 meters (6600 feet) are as shown in Figures 4(a) and 4(b). For a constant speech effort from the speaker the listener will receive a signal level in his ear 4-dB lower at the higher altitude because the mouth produces 2-dB lower sound-pressure and the air in the cavity of the ear is 2-dB less efficient as a coupler between receiver and ear-drum.

On the other hand, if a telephone set is compared to SFERT, with both the set and reference system at sea level and then at the higher altitude, the same Reference Equivalents will be obtained in both locations. This is because both systems change their sensitivities by the same amount, and the relative difference is unchanged (see

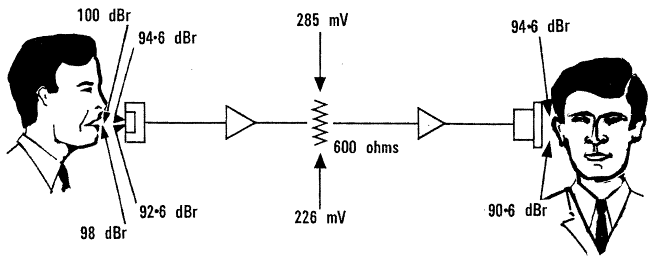

Figure 4 - Signal levels in SFERT chain.

Appendix for more detailed treatment). Thus the concept of Reference Equivalents is not a reliable basis from which to deduce the absolute levels in a telephone network, unless some corrections are introduced to adjust for altitude.

For the purpose of telephone network planning the important characteristic of a subscriber's set is the electrical output produced by a standard speaking-level. It is customary to derive this information from the Reference Equivalent, as expressed in the formulas applied to send- and receive-ends:

$V = -t + Ct$ for send-end

and $V = -r + Cr$ for receive-end

where $V =$ mean line volume, or electrical power in dBm0

$t =$ transmitting Reference Equivalent in dB

$r =$ receiving Reference Equivalent in dB

Ct and Cr are constants in dB.

These equations arise from an analogy between a telephone connection as in Figure 5, with SFERT as in Figure 4(a). But the Reference Equivalents, t and r, can only be connected with an absolute power level, V, by tacitly assuming the same lip pressure in Figure 5 as in Figure 4(a).

In this way, the mean speech-level and mean listening-level are uniquely connected to line signal-level, when effects of altitude are neglected.

To make these simple relationship universally applicable, the constants Ct and Cr must be modified by an altitude factor giving

$V = -t + (Ct - Ca)$

and

$V = -r + (Cr - Ca)$

where Ca is the factor obtained from Figure 6 for the altitude above sea level of the talker or listener.

4.2 Objective Reference Equivalent Systems

When objective-measuring equipments are operated at any altitude the same magnitudes of difference occur. For instance, if an OBDM system was calibrated at sea level and then raised to 2000 meters (6600 feet) without any circuit adjustment, the artificial mouth would produce 2-dB lower sound pressure and the meter would read +2 dB for a test set with zero OBDM send rating. Also for receive-end tests, the meter would read +2 dB for a set with a zero receive rating. The OREM equipment will show the same receive-end shift but its artificial mouth will react differently since the sound output is maintained constant by a servo loop. The reduced efficiency at the higher altitude will be counteracted by a rise in the electrical input. The consequently increased diaphragm excursion may be undesirable if it also increases the nonlinear distortion and this may be a limiting factor at low frequencies.

The OREM and OBDM instruments could be made to give results at 2000 meters (6600 feet) bearing the correct relationship to NOSFER (or SFERT) if the zero on the meter were made to correspond to 226 mV (or 285 mV reduced by 2 dB) and the sound pressure produced by the mouth were adjusted to 2 dB below the specified sea-level value.

This modified form of calibration is also consistent with the principle of making these objective equipments

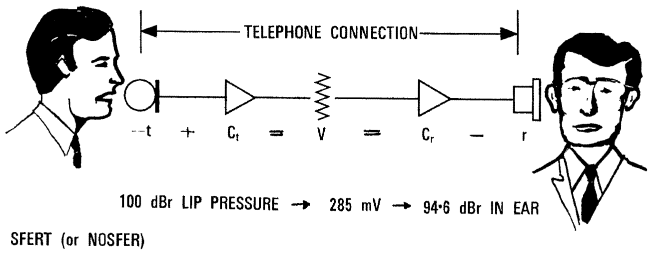

Figure 5 - Analogy of telephone circuit and SFERT.

replicas of SFERT, which at 2000 meters (6600 feet) takes on the levels shown in Figure 4(b).

The steps in the modified calibration procedure are then, for the OREM equipment:

- calibrate microphone as stated in handbook, using an indicated pressure correction for the pistonphone, which includes a change with altitude,
- calibrate sound pressure level on face of the microphone in the SFERT-replica mounting, to be less than 10·75 dyne/cm^2 (94·6 dBr) by the amount shown in Figure 6 for the altitude of the equipment.
- move the zero of the Reference Equivalent meter to correspond to 285 mV reduced by the correction factor of Figure 6, and
- the electrical signal injected in the line for receiving Reference Equivalent still remains 285 mV.

With this modified calibration, ratings will be the same as those obtained on the same type of equipment at sea level and will correspond to subjective Reference Equivalents when the corrections discussed in the preceding article [1] are applied. When used as a basis for network planning the altitude corrections, Ca, as described above will have to be used.

It should be noted that this modified method corrects for one acoustic transducer as in the sending or receiving end of a subscriber's set. It will be apparent from Figure 4 that when both the transmitting and receiving transducers are included, as in the overall or sidetone Reference Equivalent, a second altitude correction must be applied.

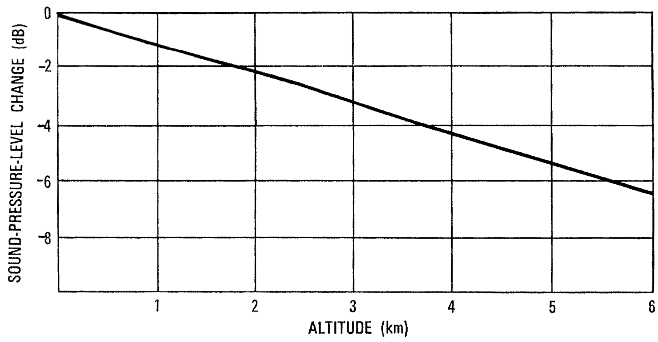

Figure 6 - Change in sound pressure level with altitude.

5. Conclusion

It has been shown how a method of calculating the loudness of speech signals of different bandwidths can be used to convert the Reference Equivalent of an assessment system to the equivalent of any other system.

There are two important applications of this technique, one to enable loudness ratings given by the objective system, OREM-A, to be brought into close agreement with a subjective assessment system such as NOSFER, and the second to derive from the ratings of either NOSFER or OREM-A a practical rating appropriate to a telephone system limited to the bandwidth 300 to 3400 Hz. The practical rating can be as much as 6-dB quieter than the NOSFER rating.

By using SETED as a stable link between SFERT (now no longer in use) and NOSFER, it has been possible to obtain a comparison between the old SFERT ratings and the modern NOSFER ratings. There seems to be a probability that sending-end and receiving-end ratings of SFERT and NOSFER differ in an opposite sense by amounts of the order of 2 ± 1 dB.

It has been pointed out that at reduced atmospheric pressure the human voice and a telephone receiver coupled to an ear are both working at a reduced efficiency. This results in a telephone system at 2000 meters (6600 feet) being 4-dB less efficient as a voice-to-ear transmission system than the same system at sea level.

Other results of the altitude effect are:

- a change in the calibration procedures of objective rating systems, such as OBDM and OREM,
- a need to correct sea-level sensitivities of reference systems such as NOSFER and SFERT when setting up at altitudes higher than 500 meters (1650 feet), and
- a need to add an altitude-correction factor when using Reference Equivalents as a basis for network planning.

Appendix: Effect of Reduced Atmospheric Pressure on Electroacoustic Systems

a) Transducers

For a given driving force the amplitude of movement of the diaphragm is proportional to the reciprocal of the mechanical impedance loading the diaphragm, and for all existing types of transducer the major controlling elements are either mechanical stiffness or acoustical resistance, both of which are unaffected by atmospheric pressure over the range from 0·02 to 50 atmospheres.

Electrostatic (capacitor) microphones are stiffness-controlled devices with the stiffness provided almost entirely by the mechanical properties of a stretched diaphragm. Change of sensitivity should be less than 0·2 dB for a reduction of atmospheric pressure from 760 mm Hg to 300 mm Hg, or a change of altitude from sea level to 7 kilometers (23 100 feet).

Electromagnetic transducers (rocking armature, ring armature, etc.) are basically mechanical-stiffness controlled, with some negative magnetic stiffness, again not affected by atmospheric pressure.

Dynamic, or moving-coil, transducers are acoustic-resistance controlled. Acoustic resistance is proportional to air viscosity, which is independent of air pressure and density over the range 0·02 to 50 atmospheres.

Carbon microphones are stiffness controlled by the mechanical stiffness of the diaphragm and the compression of carbon granules.

In general, the sensitivities of telephone transducers, as expressed by the relation between diaphragm movement and terminal voltage, are very little affected by the reduced atmospheric pressure up to 6-kilometers (19 800-feet) altitude since the major controlling impedance is independent of air pressure. The frequency response of some transducers is equalized at high frequencies by acoustical resonators, but since the mass and stiffness of acoustic elements change equally with pressure, the resonator frequency will remain constant; it is only the change in characteristic impedance of the resonator in relation to the mechanical controlling impedance that may reduce the magnitude of the equalizing effect. The response curve measured at a high altitude may be expected to differ from that measured at sea level at the high-frequency end of the range. The effect on loudness of speech transmission is not likely to exceed 0·2 dB.

b) Voice and ear

The human voice can be regarded as a mechanical pneumatic machine in which an air flow is modulated by the larynx vibrations. For constant muscular effort of lungs and larynx the sound output is approximately proportional to the air density (or atmospheric pressure). The sound pressure level of the voice then changes with altitude as shown in Figure 6 [8].

The sensitivity of the human ear is not affected by atmospheric pressure but the sound pressure produced in the volume of air enclosed between a telephone receiver and the head is reduced as the atmospheric pressure falls, by the amount shown in Figure 6.

References

[1] W. D. Cragg: Loudness Rating of Telephone Subscribers' Sets by Subjective and Objective Methods, Part 1, Electrical Communication, volume 43, no 1, pp 39—43, 1968.
[2] G. Urbanek: Rechnerischer Lautstärkevergleich Künstlicher Geräusche, Acustica, volume 17, no 6, 1966.
[3] H. K. Dunn and S. D. White: Physical Measurements on Conversational Speech, Journal of Acoustical Society of America, volume 11, p 278, January, 1940.
[4] K. Braun and H. Koschel: A Direct-Reading Insertion-Loss Measuring Set and its Application to the Improvement of Telephony, Fernmelde-Technische Zeitschrift, volume 5, no 10, pp 447—455, 1952.
[5] L. L. Beranek, Acoustic Measurements, John Wiley and Sons, New York, 1949.
[6] H. W. Rudmose et al: Voice Measurements and Audio Spectrometry, Journal of Acoustical Society of America, volume 20, no 4, pp 503—512, 1948.
[7] International Telegraph and Telephone Consultative Committee, Red Book, volume 5, pp 58—62, 1960.
[8] K. C. Clark et al: Effects of High Altitude on Speech, Journal of Acoustical Society of America, volume 20, pp 776—786, November, 1948.

W. D. Cragg was born on November 3rd, 1912, in Dewsbury, England. He took the Mechanical Sciences Tripos at Cambridge University, graduating in 1935. He joined Standard Telephones and Cables in 1938, and has worked in a wide field of electro-acoustic design and measurement, particularly high quality transducers, and room acoustics. He was transferred to Standard Telecommunication Laboratories in 1962, where his work has included the electroacoustics and measuring methods of telephone subscribers' sets.

Direct-Coupled Waveguide Filters with Post Doublets

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1. Introduction

Waveguide band-pass filters usually consist of a chain of resonant cavities formed by pairs of shunt susceptances spaced approximately a half-wavelength apart in the guide. In the direct-coupled filter, each susceptance except the end ones is common to two adjacent cavities, and its magnitude determines the coupling between them, while in the quarter-wave coupled filter the resonators are separated by coupling sections which are approximately one quarter (or three quarters) of a wavelength long.

In the past, the quarter-wave coupled filter has been favored, as the susceptances are smaller, and so less critical, than those of the direct-coupled design. The susceptances have been realized as inductive irises, single posts [1] or arrays of posts [2]; Craven and Lewin [3] have shown that an array of evenly spaced posts minimizes the higher-order mode interaction between adjacent resonators, thus permitting the use of quarter-wave coupling sections instead of the three-quarter-wave sections that had been previously necessary.

Nevertheless, the direct-coupled filter is to be preferred on account of its smaller size, provided a satisfactory mechanical design is available. The use of symmetrical irises, the susceptance of which varies rapidly with the width of the aperture, implies very strict manufacturing tolerances, while single posts must have excessively large diameters to give the required susceptance values. Multiple-post arrays have been found satisfactory, but the available theoretical [3], [4] and experimental [5] results for the susceptance of post doublets do not cover the range of values required for typical small-bandwidth designs, and so it has been necessary to use arrays of 4 or 5 posts, in which the post diameters are so small as to increase the filter loss significantly, and to lead to manufacturing difficulties.

Accordingly, new expressions have been derived for the susceptance of post doublets that are sufficiently accurate over the whole range of post diameters needed for filters of bandwidths 0·2 percent or larger. Two alternative formulas will be given, that show good mutual agreement, and which also agree with earlier results in the small-susceptance range.

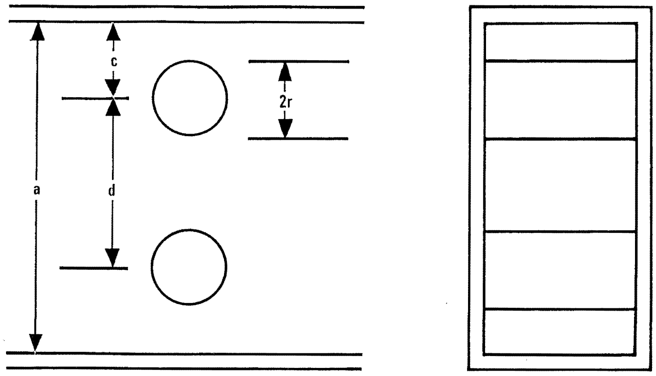

Figure 1 - Waveguide post doublets.

Since equal spacing gives no advantage in a direct-coupled filter, a spacing between posts of about half the guide width has been adopted; this gives relatively large post diameters, for which the losses are little more than those of symmetrical thin irises. For optimum performance, fine adjustment of the coupling can be carried out by means of small screws, centrally positioned between each pair of posts; these can compensate for manufacturing variations, and their correct adjustment does not present any major difficulty provided a swept-frequency alignment method is used.

2. Susceptance of a Post Doublet

For small diameters, the susceptance of a post doublet is best evaluated by the method of averaged boundary conditions, in which the waveguide electric field is expanded in an infinite series of orthogonal modes, and the resulting expression made to vanish at two or more positions round the periphery of each post. For arbitrary post spacing, the most accurate result of this type available is that of Gruenberg [6], whose expression for the reactance, with the notation of Figure 1, is

$$-X\frac{\lambda_g}{a} = 1 + \frac{1}{4}\operatorname{cosec}^2\left(\frac{\pi c}{a}\right)\left\{\ln\left(\frac{\pi r}{2a}\right) + \ln\cot\left(\frac{\pi c}{a}\right) - \left(\frac{2\cdot 8\,a}{\lambda}\right)^2 \sum_{m=3,5,\ldots}^{\infty}\frac{1}{m^2}\left(\frac{\pi r}{a}+\frac{1}{m}\right)\left(1+\frac{1\cdot 5}{m^2}\right)\sin^2\left(\frac{m\pi c}{a}\right)\exp\left(\frac{-m\pi r}{a}\right)\right\} \qquad (1)$$

where λ and λ_g are the free-space and guide wavelengths. This result is reasonably accurate for $r/a < 0{\cdot}05$, and can be improved by taking into account the series elements of the equivalent T-network [7], but it predicts an infinite susceptance for r/a near 0·1.

The method to be described is a semi-empirical one, insofar as no detailed evaluation is made of the field configuration in the neighborhood of the posts. We first suppose the round posts replaced by equivalent square ones, the sides t of which are given by [8]

$$\left.\begin{aligned} t &= 4r\,[E(k) - k'^2\,K(k)] \\ &= 1{\cdot}6944\,r \\ (k &= k' = 1/\sqrt{2}) \end{aligned}\right\} \qquad (2)$$

where E and K are complete elliptic integrals of modulus k. The square posts are now assumed equivalent to the thick iris shown in Figure 2 (a), with opening

$$w = d - 1{\cdot}6944\,r; \qquad (3)$$

this amounts to neglecting the coupling through the gaps between the posts and the side walls of the waveguide, which is evidently justified for large, well-separated posts, since the transverse field vanishes at the side walls, while the error incurred for small posts will be reduced by an artifice to be explained later.

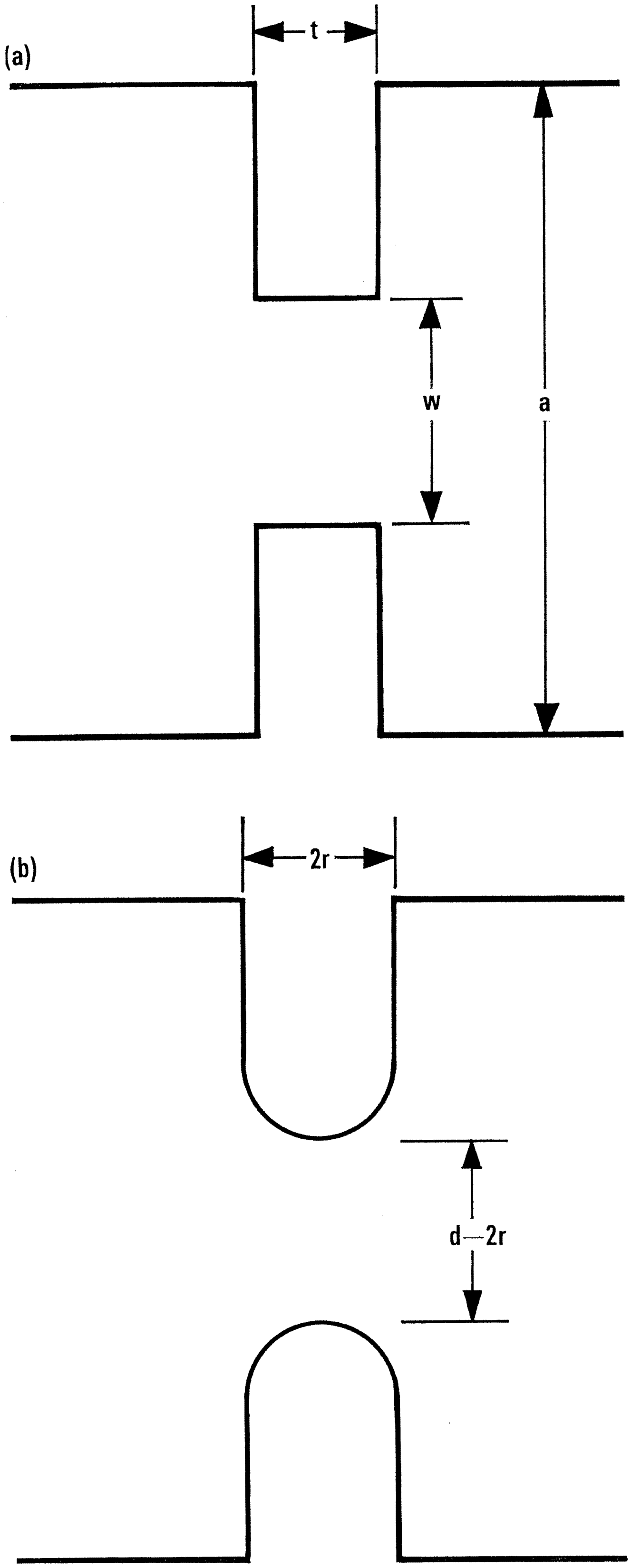

Figure 2 - Thick irises equivalent to a post doublet.

The susceptance of a thin iris of opening w is given approximately by [9]:

$$B/Y_0 = -(\lambda_g/a)\, cot^2\, (\pi w/2a) \qquad (4)$$

and the attenuation introduced by a shunt susceptance is [9]

$$L = 10 \log_{10} [1 + (B/2Y_0)^2] \text{ decibel}$$

$$= \frac{1}{2} \ln [1 + (B/2Y_0)^2] \quad \text{neper} \qquad (5a)$$

$$\simeq \ln |B/2Y_0| \quad \text{neper} \qquad (5b)$$

which in our case becomes

$$L_1 \simeq \ln [(\lambda_g/2a)\, cot^2\, (\pi w/2a)]. \qquad (6)$$

A thick iris introduces an additional attenuation [9]

$$L_2 = (27{\cdot}3\, t/w)\, [1 - (2w/\lambda)^2]^{1/2} \quad \text{decibel}$$

$$= (\pi t/w)\, [1 - (2w/\lambda)^2]^{1/2} \quad \text{neper}$$

$$\simeq \pi t/w \quad \text{neper} \qquad (7)$$

if $w \ll \lambda$, so that the total attenuation is

$$L = (\pi t/w) + \ln [(\lambda_g/2a)\, cot^2\, (\pi w/2a)] \text{ neper} \qquad (8)$$

and from (5a) this is equivalent to a shunt susceptance

$$\frac{B}{Y_0} = -2\, (e^{2L} - 1)^{1/2}$$

$$= -2 \left\{ \left(\frac{\lambda_g}{2a} \right)^2 \exp \left(\frac{2\pi t}{w} \right) cot^4 \left(\frac{\pi w}{2a} \right) - 1 \right\}^{1/2} \qquad (9)$$

where t and w are given by (2) and (3). We observe here that if $\lambda_g = 2a$, a typical value, and if the center-to-center spacing d between the posts is $\frac{1}{2} a$, then the limiting case of zero post radius, the structure of Figure 2(a) becomes a thin iris of opening $\frac{1}{2} a$, having from (4), a normalized susceptance 2. Equation (9), however, gives correctly $B = 0$ for this case, since approximation (5b) has been used to derive the attenuation L_1, and the exact expression (5a) for (9), whose accuracy is thereby improved for small post radii.

Figure 3 compares, for $d/a = \frac{1}{2}$, (9) with Gruenberg's result; it will be seen that there is good agreement for $0{\cdot}02 < r/a\ 0{\cdot}05$, justifying our neglect of the coupling through the side gaps. Equation (9) is not valid for equally spaced posts ($d/a = 1/3$), when the side gaps are responsible for about half the coupling. This case, and that of

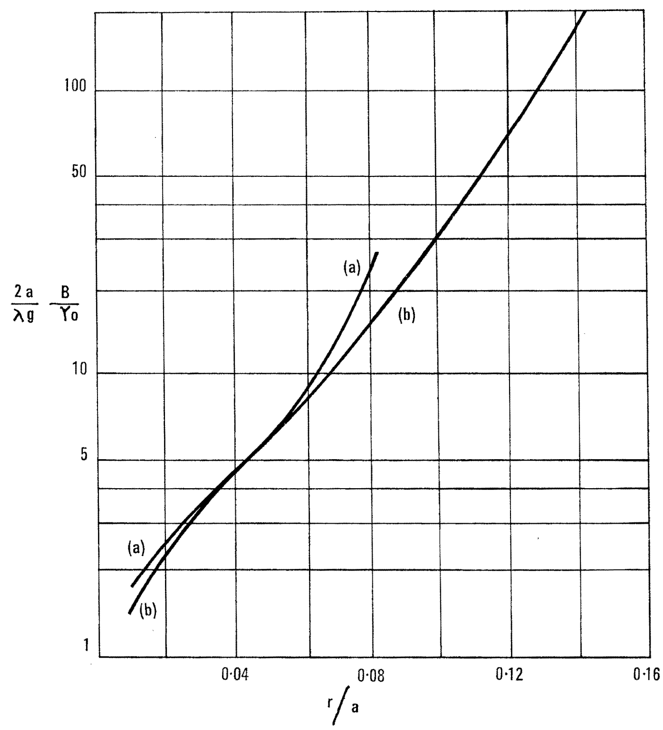

Figure 3 - Normalized susceptance of post doublets for $\lambda_g = 2a$ and $d = \frac{1}{2} a$, (a) from Gruenberg's formula and (b) from (9).

arrays of more than two posts, could be dealt with by regarding them as a combination of three or more thick irises, summing their separate contributions to the coupling, and inserting an empirical factor to represent the interaction between them.

A more accurate formula for large posts is obtainable by evaluating the attenuation of a thick iris with cylindrical opposing faces, as shown in Figure 2(b). Taking the z-axis along the guide with the origin in the symmetry plane of the obstacle, the width of the opening expressed as a function of z is $d-2\,(r^2-z^2)^{1/2}$ and the attenuation is

$$L_2 = 2\pi \int_0^r \frac{dz}{d-2\,(r^2-z^2)^{1/2}}$$

$$= 2\pi r \int_0^{\pi/2} \frac{\cos\Theta\, d\,\Theta}{d-2r\cos\Theta}$$

$$= \frac{2\pi d}{(d^2-4r^2)^{1/2}} \tan^{-1}\left(\frac{d+2r}{d-2r}\right)^{1/2} - \frac{\pi^2}{2}. \qquad (10)$$

As in (8), it is necessary to include a term $cot^4\,(\pi w/2a)$, where now w is chosen empirically to give the best fit to Gruenberg's result in its range of applicability. This leads to the formula

$$\frac{B}{Y_0} = -2\left\{\left(\frac{\lambda_g}{2a}\right)^2 \exp\left[\frac{4\pi d}{(d^2-4r^2)^{1/2}} \tan^{-1}\left(\frac{d+2r}{d-2r}\right)^{1/2} - \frac{1}{2}\pi^2\right] cot^4\left(\frac{\pi w}{2a}\right) - 1\right\}^{1/2} \qquad (11)$$

where $w = d - 1{\cdot}3r$.

When $d = \frac{1}{2}\,a$, the difference between (11) and the simpler (9) is very small for values of $r/a \leqslant 0{\cdot}15$, as will be seen from Table 1. For larger values of r/a, which however are unlikely to be required in filters, (11) should be used.

Table 1 – Comparison of the two susceptance formulas

r/a	$-B/Y_0$ from (9)	$-B/Y_0$ from (11)
0·02	2·38	2·34
0·04	4·61	4·52
0·06	8·30	8·09
0·08	15·36	14·96
0·10	30·6	29·7
0·12	68·1	66·5
0·14	177·8	177·6
0·16	584·7	621·3
0·18	2723	3399

The complete equivalent circuit of the post doublet is a shunt susceptance between two sections of transmission line. An expression for the lengths l of these line sections is [5]

$$l/a = -\frac{4\pi r^2 \sin^2(\pi c/a)}{a^2\,(1-r^2/4c^2)\,(1+11\pi^2 r^2/6a^2)};$$

this neglects interaction between posts but is in practice sufficiently accurate. The length of each resonator in a filter, measured between post centers, should exceed the value given by the usual design formula for filters with thin irises [10] by the sum of the lengths l for the bounding post doublets. In practice a further increase of about 0·015 inch will be made, and a screw provided for tuning each resonator.

3. Experimental Results and Conclusions

Accurate measurement of large susceptances in waveguide is a difficult and lengthy process [5], so it was decided to check the results of the preceding section by making a complete filter based on them.

This was a five-resonator filter in *waveguide 14* (1·372 × 0·622 inches or 3·5 × 1·55 centimeters) with a design frequency of 6·05 GHz. A Chebyshev pass-band shape was aimed for, with a voltage standing wave ratio not exceeding 1·04 over a 27·5 MHz band, and hence with a 3-dB bandwidth of 40 MHz. The required susceptance values were calculated in the usual way [5, 10] and are given in Table 2; the posts were made somewhat larger than the calculated sizes to allow for the effect of manufacturing errors in their diameters and positioning and to permit tuning the filter over a range of frequencies while maintaining a constant bandwidth.

A post spacing of $\frac{1}{2}\,a$ was chosen, and small screws were provided between each pair of posts to reduce the susceptances to the required values, as well as centrally positioned tuning screws in all cavities. The filter is shown in Figure 4. With $^1/_8$ inch insertion, the trimming screws reduced the susceptances by about 10 percent.

Table 2 – Parameters for the waveguide filter

k	g_k	$B_{k,\,k+1}/Y_0$	$2r_{k,\,k+1}$ calculated	$2r_{k,\,k+1}$ actual
0	0·0144	6·21	0·140 in	0·151 in
1	0·5848	57·21	0·318 „	0·331 „
2	1·169	87·57	0·344 „	0·359 „
3	1·369	87·57	0·344 „	0·359 „
4	1·169	57·21	0·318 „	0·331 „
5	0·5848	6·21	0·140 „	0·151 „
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Alignment was carried out using a swept-frequency signal generator and a Smith chart impedance plotter; starting with all resonators detuned, the first four were tuned successively for 180° shift of the center frequency marker on the display, and the fifth resonator for best match with a low voltage-standing-wave-ratio termination on the end of the filter, this procedure being equivalent to the well-known quarter-wave shift-of-minimum technique using a slotted line. Final alignment was then accomplished by suitably adjusting the coupling trimmers and readjusting the tuning to obtain the characteristic four-loop Chebyshev pattern shown in Figure 5.

Results of subsequent point-by-point checks of the voltage standing wave ratio (by slotted line) and insertion loss, shown in Figures 6 and 7, are in good agreement

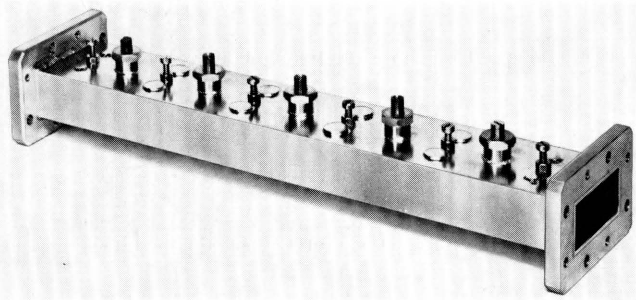

Figure 4 - Five-resonator direct-coupled waveguide filter.

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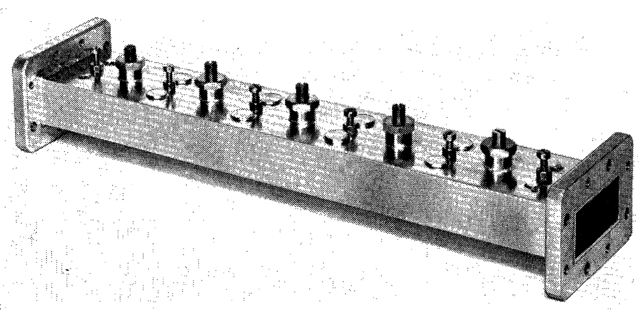

Figure 4 - Five-resonator direct-coupled waveguide filter.

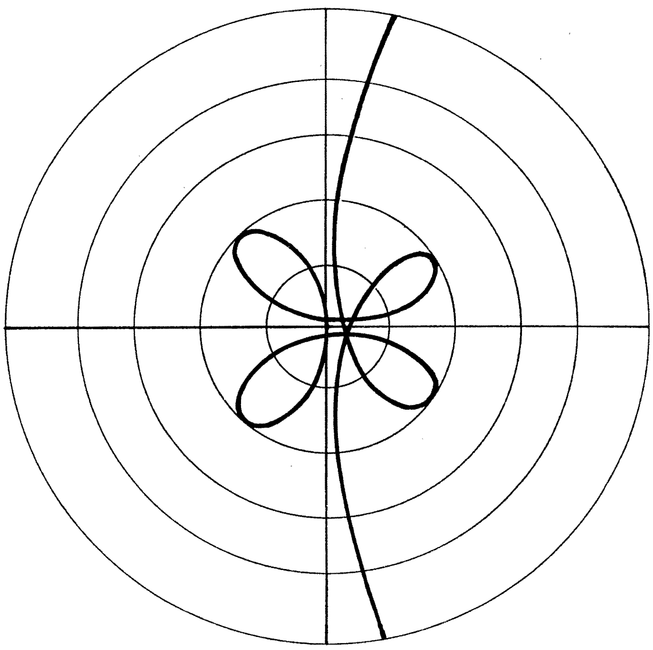

Figure 5 - Impedance plot for 5-resonator Chebyshev filter.

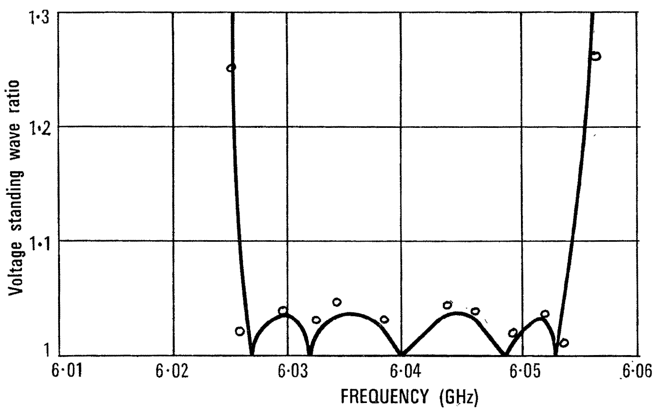

Figure 6 - Measured and calculated voltage standing wave ratio of filter (continuous curve is calculated voltage standing wave ratio).

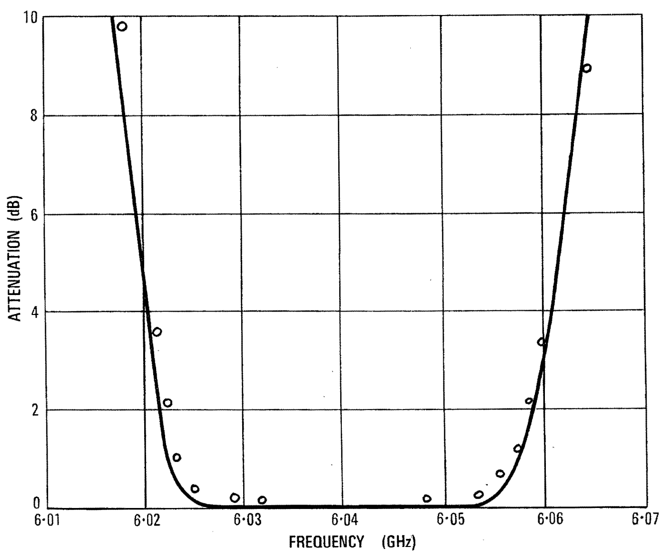

Figure 7 - Measured and calculated relative insertion loss of filter (continuous curve is calculated loss).

with the calculated performance. The insertion loss of the filter at the pass-band center was 0·8 dB; the theoretical unloaded Q (for silver) is 10000, which gives a theoretical loss of 0·45 dB, but since the loss of silver-plated waveguide is typically 50 percent in excess of the theoretical value [11], loss due to the post doublets and tuning screws is probably only about 0·1 dB.

An error in drilling the guide, which made the spacing between one pair of posts 0·014 inch (0·0355 centimeter) greater than nominal, provided an opportunity to check the accuracy of (9) and (11). The filter was in fact aligned without a trimming screw for this post doublet. Since, from Figure 7, the filter bandwidth was 3 percent below the design value, the central susceptances were actually 90·2. Calculations based on (9) and (11), taking the measured value of the post spacing d, give respectively 92·8 and 93·0, so the error in the formulas is about 3 percent in the susceptance, or only 0·0007 inch (0·0018 centimeter) in the post radius. A check measurement of the end susceptances, with the inner resonators detuned and trimming screws removed, gave results within about 2 percent of the calculated figures.

The formulas that have been obtained for the susceptance of post doublets in waveguide thus provide an adequate basis for the design of direct-coupled filters using post doublets. Such filters have the advantages of being simpler and cheaper to construct than similar filters with the usual symmetrical inductive irises, and smaller than quarter-wave coupled filters. The good agreement between the two formulas, for post radii up to 0·16 a, indicates that they are suitable for calculating filters with bandwidths down to about 0·2 percent.

References

[1] Mumford, W. W., Maximally-Flat Filters in Waveguide, Bell Syst. Techn. J., Vol. 27, No. 4, October 1948, p. 684.
[2] Simon, J. C. and Broussaud, G., Les filtres passe-band en hyperfréquence, Annales de Radioélect, Vol. 8, No. 1, January 1953, p. 3.
[3] Craven, G. and Lewin, L., Design of microwave filters with quarter-wave coupling, Proc. IEE, Vol. 103 B, No. 8, March 1956, p. 173.
[4] Model, A. M., Diffraction of the H_{10} mode by a multipost iris consisting of n evenly spaced posts, Telecommun, and Radio Engng., Vol. 18, Pt. 2, No. 4, 1963, p. 10.
[5] Whiting, K. B., Design of microwave filters with multiple post susceptances, Proc. IRE (Aust.), Vol. 24, No. 8, August 1963, p. 623.
[6] Gruenberg, H., Symmetrically placed inductive posts in rectangular waveguide, Canad. J. of Phys., Vol. 30, No. 3, May 1952, p. 211.
[7] Turner, R. J., Merlo, D., and Lovett, F. A. W., Development of Waveguide Filters for the Frequency Range 3.8 to 4.2 Gc/s using Triple-Post Cavities, Post Office Engng. Dept. Res. Report 20398, London, May, 1960.
[8] Marcuvitz, N., (Ed.) Waveguide Handbook, McGraw-Hill, New York, 1951, Chapter 5.
[9] Harvey, A. F., Microwave Engineering, Academic Press, London, 1963, Chapter 3.
[10] Matthaei, G. L., Young, L., and Jones, E. M. T., Microwave Filters, Impedance-Matching Networks and Coupling Structures, McGraw-Hill, New York, 1964, Chapter 8.
[11] Lending, R. D., New criteria for microwave component surfaces, Proc. Natl. Electronics Conf., Chicago, 11, 1955, p. 391.

S. W. Conning was born in Portsmouth, England, in 1923. He received the BSc degree in 1945 and the MSc degree in mathematics in 1952 from the University of London.

He worked at the Admiralty Signal and Radar Establishment on the development of infrared and radar equipment until 1949, and subsequently was employed at the Ministry of Power in London.

In 1954 he joined the Radio Transmission Division of Standard Telephones and Cables in Australia, where he has been engaged mainly in microwave development.

Mr. Conning is an Associate of the Institute of Physics and of the Australian Institute of Physics and a Member of the Institution of Radio and Electronic Engineers, Australia.

ITT-411 Intercommunication System

E. WIGREN
A. BOGESTAM
Standard Radio and Telefon AB, Barkarby, Sweden

1. Introduction

Large-size loudspeaking intercommunication systems can play an important role by increasing the efficient running of offices, hospitals, schools, factories and similar organizations. Initially, loudspeaking intercommunication meant only small and medium-sized installations designed for direct communication between a limited number of persons within a small department, or the like. Present PALX (Private Automatic Loudspeaking Exchange) systems are very often highly sophisticated installations. In addition to being used throughout the whole organization, they feature a number of extra facilities, including signaling, which can be integrated into the system.

Among the main advantages of present PALX systems, the following might be mentioned.

— Loudspeaking sets which permit handsfree operation and, it is claimed, considerably reduce the duration of conversations.
  The average length of conversation is 30 seconds as compared to approximately two minutes in an ordinary PAX.

— Push-button operation which shortens calling time. One-button calling and direct reception of calls can be included.

— The PALX also relieves the PABX from handling the majority of internal calls, thus leaving it free for outside calls. The rapid introduction of direct toll dialing on an international basis and also the introduction of direct in-dialing to subscribers within a PABX installation stresses the importance of keeping the external telephone system free from internal calls.

— A range of sets that incorporates a variety of special sets for use in various localities and for outdoor use, et cetera, permitting the user to reach all the areas within a complex.

2. PALX System

The ITT-411 PALX is a 4-wire crossbar system, with voice-operated amplifiers in the central exchange and microphone amplifiers in the sets.

At present the system consists of 16-line and 32-line nonextensible exchanges and extensible exchanges for 20 to 100 lines, for 100 to 600 lines and for 100 to more than 2000 lines. (See Figures 1, 2 and 3).

The extensible exchanges can be provided with a number of extra features including the following:

— *Direct selection;* one-button call to any of ten selected extensions.

— *Camp-on-busy;* for waiting on an occupied extension, and automatic connection when it becomes free.

— *Transfer;* for re-routing of calls from one set to any other set within the installation.

— *Staff location;* with visual or wireless paging. Paged person can reply from any master set in the installation.

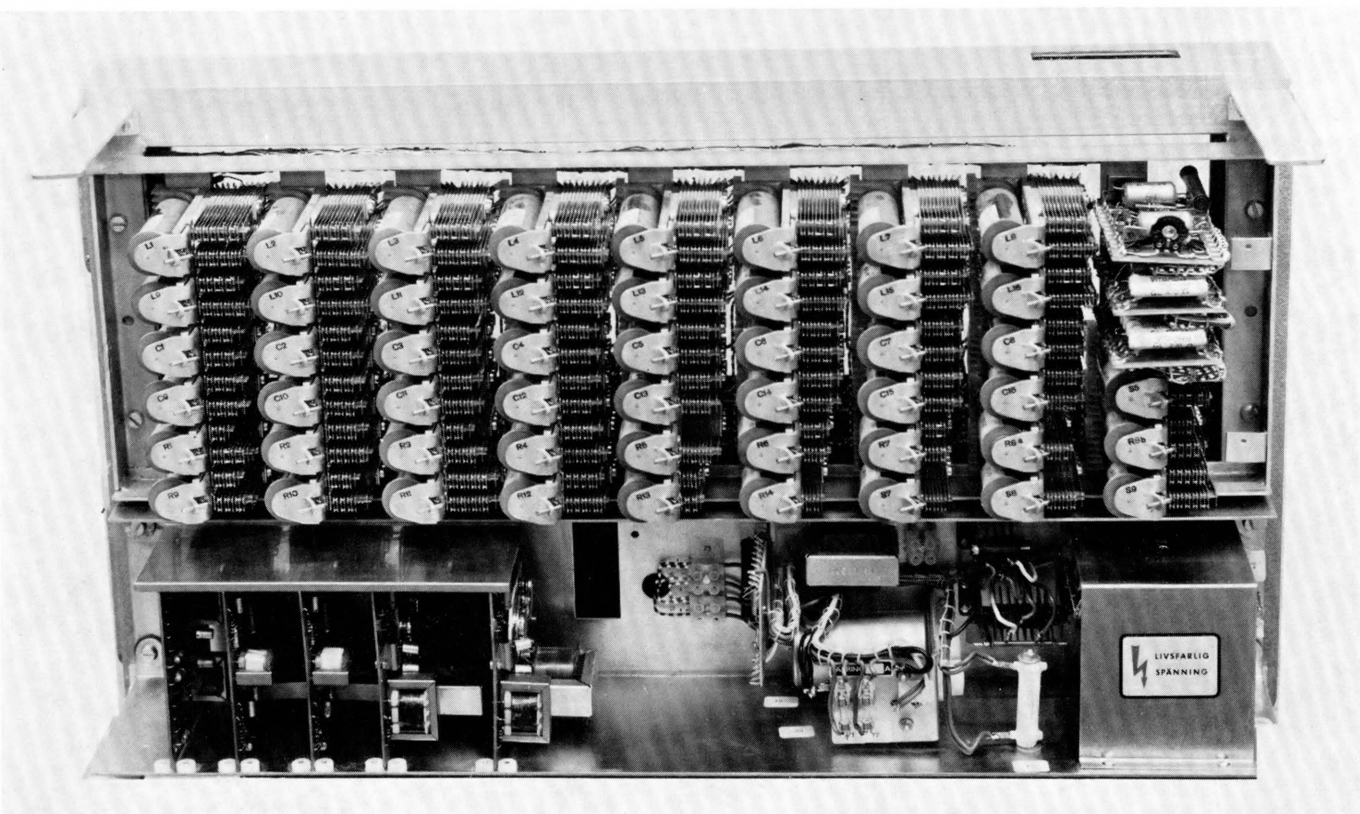

Figure 1 - A 16-line wall-mounted exchange with one cord circuit. Executive priority for one extension is included as a standard feature.

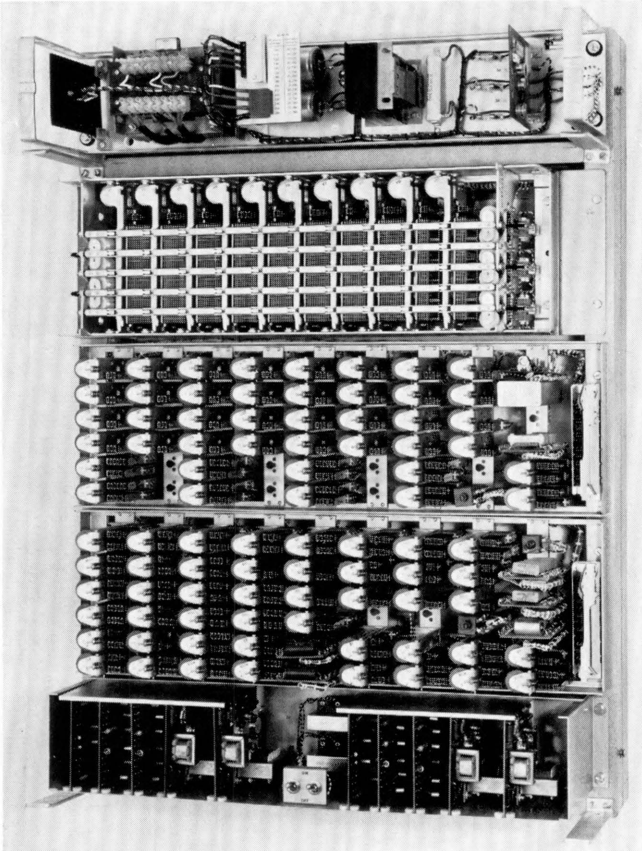

Figure 2 - A 32-line wall-mounted exchange with two cord circuits. Direct selection to 10 extensions and executive priority for one extension are included as standard features.

— *Group hunting;* hunting for the first idle extension in a group of optional extensions.
— *Group call* via ordinary sets.
— *Executive/Secretary* re-routing.
— *Conference* facilities.
— *Loudspeaker arrangements* for public-address operation.
— *Two-wire interworking* between different exchanges via tie-lines.

3. Choice of Sets

The choice of sets includes three main types of master set; loudspeaking, loudspeaking with handset, and non-loudspeaking sets. (Figures 4, 5 and 6.) A great variety of other sets is available, such as outdoor sets with separate loudspeakers, sets for panel, wall, and table mounting, and so on.

4. Signaling System

The push-button codes for the digits are transmitted as direct-current pulses on a 4-wire basis. When the first button is pressed, the calling station is identified and reception of the numerical information takes place in the register. The button must be kept in the depressed position until a free register is announced by the dial tone. The remaining digits may then be pressed in rapid sequence. By employing relays on release, an operating speed of up to 8 digits a second is possible.

4.1 Tone Signals

Audible and visual signals warn of incoming calls and so the system offers full privacy. Incoming calls can be answered either by pressing the call/answer button or by lifting the handset, or when the direct-in button on the set is in the actuated position, without any manual operation at all. The tone signals correspond to the signals used in ordinary telephone systems, except for transfer where the first ringing tone heard is a two-tone signal, indicating that the call has been re-routed.

4.2 Lamp Signals

A red pilot lamp is provided on each loudspeaking set to show when a speech connection has been established. It remains lit on participating sets as long as they are connected to other sets.

When a set is camping-on-busy or has been put on transfer the lamp shows a flashing light.

4.3 Keyboard

The keyboard for loudspeaking and non-loudspeaking sets has been designed to comply with international recommendations and standards for push-button-operated telephone sets. The twin contacts, provided for each individual function, assure reliable operation. All master sets are also equipped with special buttons for extra facilities, permitting their incorporation at any future time.

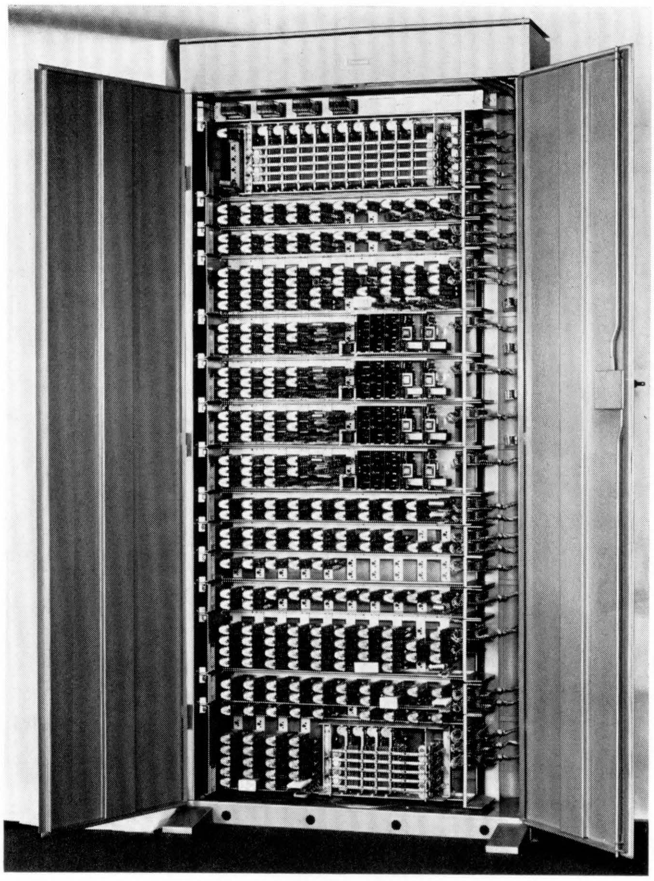

Figure 3 - Cabinet-mounted exchange extensible from 20 to 100 extensions with up to six cord circuits and complete facility program.

5. Transmission System

Figure 7 shows a block diagram of the transmission system. The transmission equipment contained in a loudspeaking set consists of a microphone, two loudspeakers and a three-stage microphone amplifier. The two loudspeakers are connected in parallel and the microphone capsule, of the electromagnetic type, is located equidistant from the two loudspeakers. The microphone amplifier is fed from the cord circuit. Both the loudspeakers and the microphone amplifier are matched to a 600-ohm line impedance.

Microphone sensitivity and loudspeaker volume can be adjusted to various room conditions and ambient noise levels by means of two three-position switches provided in all loudspeaking sets. The sets can be situated up to 2 km (6 500 ft) from the exchange if connected with lines of not less than 0·5-millimeter (0·2-inch) diameter.

The regulating and output amplifiers are located in the cord circuit of the exchange and are mounted on printed-circuit boards. The regulating amplifier has two identical channels and a voice-operated regulating circuit that controls speech direction. The output amplifier has a rating of 2 watts with 5 percent distortion.

Activation of a speech channel is initiated when the incoming signal reaches a level above normal room noise. At this level, the gain in the transmit direction is increased and at the same time the gain in the receive direction is reduced. Precautions have been taken to ensure that the decrease in gain of the receive channel is always greater than the increase in gain of the transmit channel, that is, the total gain in the overall transmission circuit is always kept below unity. This eliminates the risk of feedback.

A too-high noise level can make the use of the loudspeaker unsatisfactory. In this case, handset operation is recommended. However, in an occasionally noisy room, automatic voice-switching may be replaced by manual control using the call/answer button.

Figures 8 and 9 show the transmitting and receiving characteristics of the system. The transmission system has a range of 300 to 3600 hertz and, as is seen from Figure 8, an increasing transmitter gain between 300 to 1000 hertz is included to improve intelligibility. This frequency characteristic was chosen mainly to reduce the effect of room echo and background noise.

6. Traffic Layout

Figure 10 shows a traffic lay-out for a 20—100 line exchange. Identification of the calling extension is effected in the line-and-cutoff unit and the general-marker unit. The general-marker unit hunts for an idle cord-circuit unit and connects this to the calling extension via the line finder. At the same time, the register is connected to the cord-circuit unit. After registration of the digits and when the last digit button has been released, immediate connection to the called extension is effected by the final selector.

The finders are built up using crossbar switches with 10 verticals and 5 horizontal bars. Each 4-wire extension line is connected to a bar position in the verticals. As is seen from Figure 11, each vertical *V1–V2* is divided into two levels to which 20 extension lines are connected. A change-over contact *VR1–VR2* in the inlet and outlet of the cord circuit selects the correct level for connection to the transmission circuits. The bar positions *H1–H0* correspond to the unit digit in the extension number.

The basic equipment can be extended by additional crossbar switches to provide an exchange with up to 100 extensions.

Beyond 100 lines and up to 600 lines the crossbar switches are arranged in different switching stages, built up as link stages for the sake of economy.

Exchanges above 600 lines are divided into two basic extension groups identical in traffic layout with the 600-line exchange. Traffic between the two groups is arranged by interworking between group selector stages.

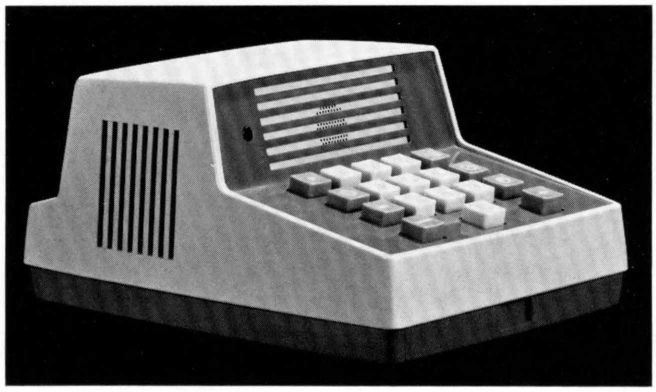

Figure 4 - Loudspeaking set. The keyboard is equipped with six special facility buttons.

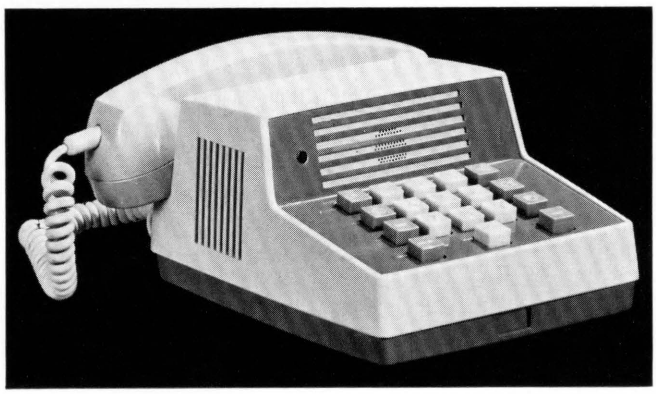

Figure 5 - Loudspeaking set with handset. Except for the hook switch arrangement, it is identical with the set in Figure 4.

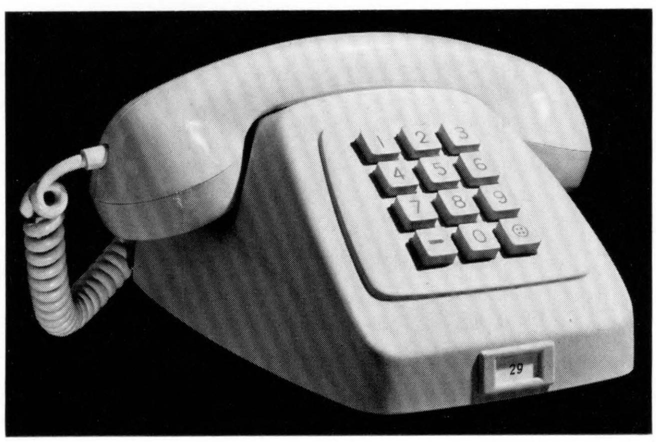

Figure 6 - Non-loudspeaking set equipped with one extra facility button.

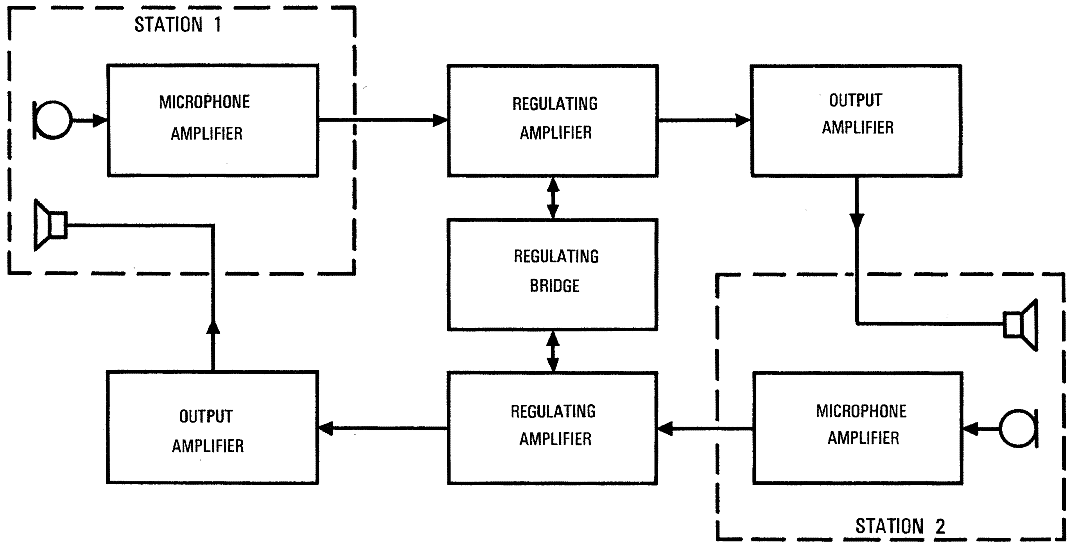

Figure 7 - Transmission system

7. Optional Facilities

7.1 Direct Selection

By the introduction of a direct selection unit (Figure 10) the digit buttons can also be used for single-digit calls. The grouping of the extensions is quite optional and direct selection may be made from any set to any one in a group of ten extensions.

7.2 Paging

A paging system, for example of the lamp-signal type, can easily be introduced by adding the staff-location unit and the cord-circuit marker unit to the exchange. All types of master set can both initiate and answer a paging call. Identification of the calling and sought extension number is carried out in the cord-circuit marker unit. This information is then transferred to the staff-location unit. The registration causes the paging combination of the desired extension to be illuminated on the lamp panels. At the same time the connection between the calling and the called extension is released. During the paging procedure no cord circuit is engaged.

By answering the paging, the number of the calling extension will be sent over from the staff-location unit to the general-marker unit, which sets up a connection between the two parties. As soon as the connection is established, the staff-location unit is released.

The same basic principles are applied in wireless paging which can also be included in the system.

7.3 Transfer

When the transfer facility is required, the transfer-marker, cord-circuit, and transfer units have to be incorporated in the exchange. If an incoming call is to be temporarily routed to another extension, its number is called. After pressing the transfer button, identification of calling and called extension takes place in the cord-circuit and transfer-marker units. An idle transfer unit will also be selected and connected. The transfer unit then registers both the calling and the called subscriber number and releases the connection.

Before a register sets up a call, a test in the transfer unit will be made to ascertain whether or not the called number has been transfer-registered. In the latter case, the register is disconnected and the re-routed number is set up from the transfer unit.

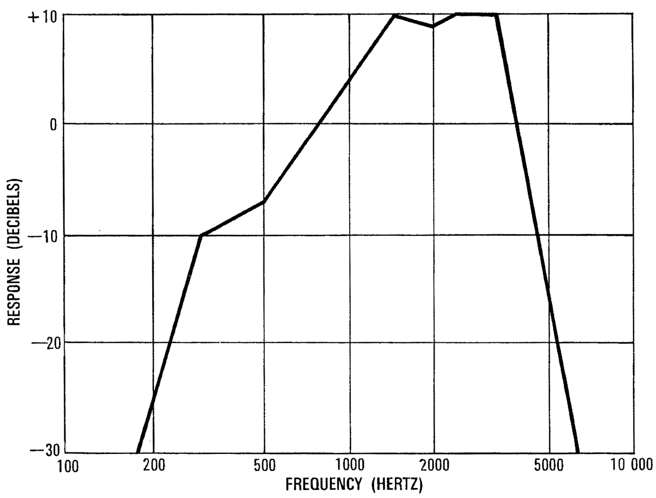

Figure 8 - Transmitting characteristic.

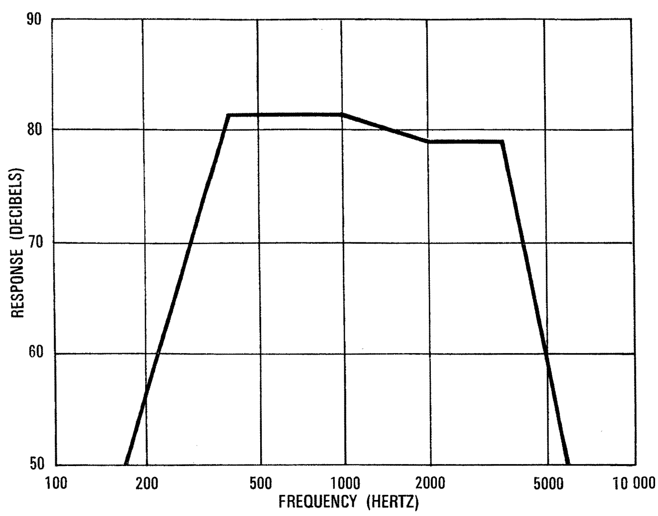

Figure 9 - Receiving characteristic.

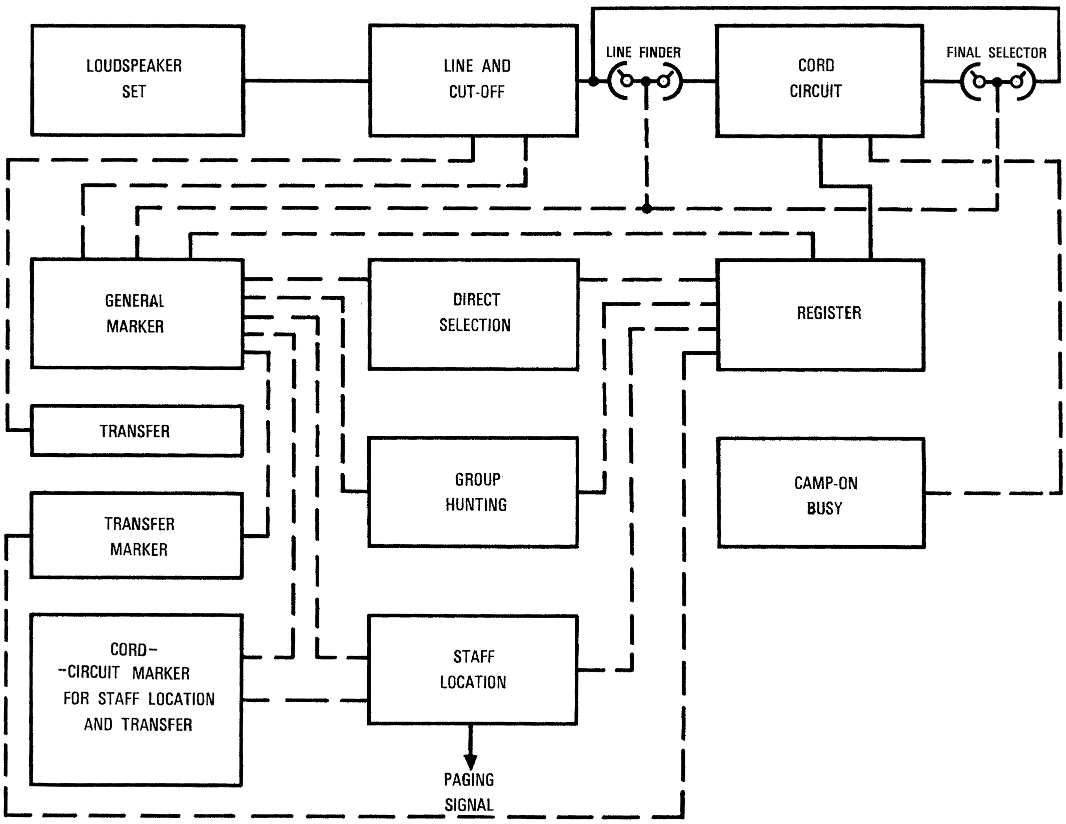

Figure 10 - Traffic lay-out 20—100 line exchange.

7.4 Camp-on-busy

By the introduction of the camp-on-busy unit, a call to a busy extension can be placed in waiting position. When the busy extension becomes free, the calling set is automatically connected. Instead of camp-on-busy, an optional set may be equipped with executive priority, that is, the ability to break in on a busy connection after a special warning tone has been sent.

8. Installation

The extensible exchange equipment is housed in lockable and dust-proof cabinets. All components are mounted on handy plug-in frames that are connected to the rack cable. When more than one cabinet is included in the exchange the cabinets are placed side by side against a wall, or back to back, which makes it possible to install an exchange of several hundred lines in a very small space. Main distribution jacks for the connection of extension lines are mounted on the top of the cabinet. The operating direct current for switching units and amplifiers is derived from a separately mounted power supply unit.

The arrangement of the cable network is similar to that used in ordinary private telephone installations. However, each extension line consists of two twisted pairs, one for the transmit and one for the receive channel. Plastics insulated cables are used for preference.

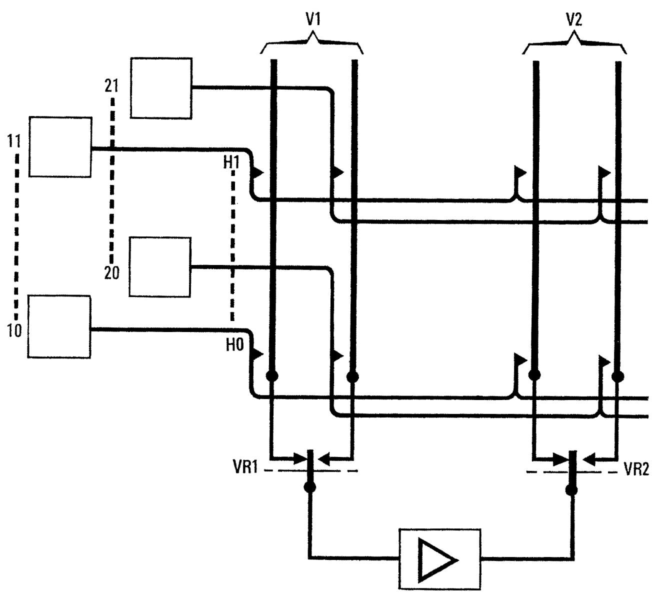

Figure 11 - Use of verticals in the crossbar switch unit.

9. Applications

The normal subset connected to the PABX does not provide the variety of facilities needed in a large and complex organization. Previously these extra facilities have been provided in part by small intercommunication systems between a few offices. The ITT-411 is the logical answer to this need since it reduces the demand on the PABX, provides a wide variety of facilities, and offers them to the complete organization. It will be useful within industrial, administrative, public health, and similar complexes.

Arne Bogestam was born in Karlshamn, Sweden, in 1925. He received an electrical engineering degree in 1945. After ten years at the LME Company, where he was employed in the laboratories on crossbar systems, he joined the Sinus Company, where he was in charge of the switching laboratory for loudspeaking private

communications systems. He joined SRT in 1961 as a member of the switching engineering staff, and in 1965 was transferred to the marketing group, where he now acts as product leader for intercommunication systems.

Ebbe Wigren was born in Malmö, Sweden, in 1922. He graduated from Västerås Technical College in 1945.

After positions as a construction and liaison engineer at the Swedish PTT, as a supervisor for marine telephone switching at the Swedish Naval Material Administration, and at Svenska Relä-fabriken, where he was responsible for the patent office, licencee sales, and general coordination, he joined SRT in 1960. Since 1963, he has been the product line manager for switching and audio communications.

Vienna-Zollergasse HE-60 L Trial Telephone Exchange

H. EBENBERGER
Standard Telephon und Telegraphen, AG, Vienna

1. Introduction

The second quasi-electronic telephone switching installation operating on the *HE-60 L* principle has been cut over in Vienna, Zollergasse (Figure 1). Its operation will be critically appraised from three aspects; operation, the subscriber, and the manufacturer.

1.1 Operating Organization

The Austrian PTT demands the following conditions from the Vienna-Zollergasse *HE-60 L* trial office:
— full compatibility with the existing telephone network,
— operation by available PTT staff upon appropriate training,
— operational and maintenance requirements not to exceed those of existing modern systems, and
— failure rates below the present lowest average of 0·14 failure per 100 subscribers per month (Crossbar System *48 HK*).

1.2 Telephone Subscriber

The subscriber takes his service and convenience features for granted. In Austria these include immediate ringing tone upon completion of selection on local calls, and rapid call establishment for toll calls. Consequently both toll and local traffic periodic-pulse call metering, and the variety of services which it makes possible, are accepted as normal.

The *HE-60 L* provides the following additional features:
— push-button or dial selection as desired, without modifications in the central office,
— abbreviated dialing (Figure 2).

1.3 Manufacturer

The manufacturer is interested in observing the results of concentrated application of new components such as Herkon® dry-reed relays; the effects of high traffic loads in a new and realistic environment; the reactions of an Administration which is known to impose stringent requirements; and the behavior of customers.

Figure 1 - Quasi-electronic trial office, Vienna-Zollergasse.

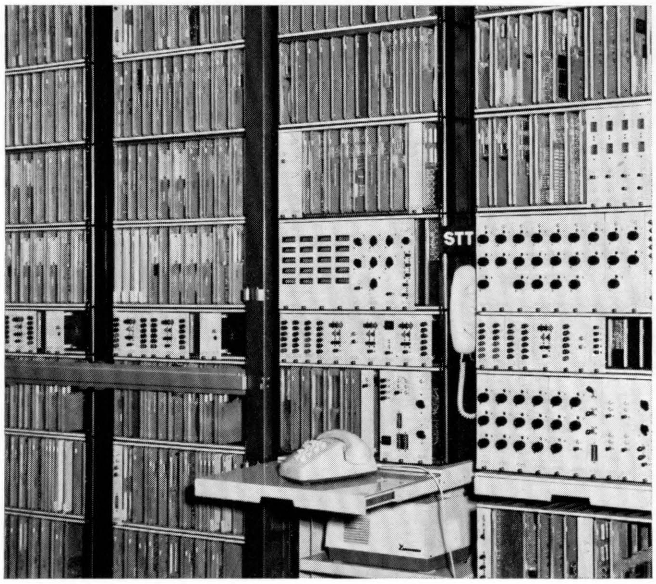

Figure 2 - Partial view of the quasi-electronic trial office; lower left, abbreviated-dialing translator units; push-button set.

2. Conditions

The Vienna-Zollergasse trial office is one of a series of developments which have left the laboratory to make tests under practical field conditions.

A report on the experiences in the public telephone network must include a comparison of the predicted or expected performance with the actual performance under normal field conditions over a certain period of time. To define the conditions, the system features of the *HE-60 L* trial office should be outlined and differences from the Stuttgart-Blumenstrasse installation pointed out [2 to 8].

2.1 System Features

The Vienna-Zollergasse trial office has the following principal features similar to the Stuttgart-Blumenstrasse installation [1, 9 to 11].
— Quasi-electronic register system and exclusive use of Herkon dry-reed relays and electronic components.
— Space-division multi-stage link system using 4-contact crosspoints; the individual stages are not associated with any particular digits of the directory number.
— Path finding on the guide-wire principle.
— Subdivision of the system into groups, each group having its own speech and control network, semi-centralized control functions, and duplicated markers.
— Routing control in the local network (second choice and overflow routes).

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— Classification of subscriber lines and service conditions in a class-of-service translator.
— Push-button or dial telephone sets, as desired by the subscriber.
— Two-digit abbreviated dialing of directory numbers comprising up to 15 digits.
— Integrated path testing during each call-establishing process.
— Forming of PBX groups without need for consecutive numbering; in-dialing to PABX.
— Recording of data from units involved in a disturbed connection.
— Application of the ITT Standard Equipment Practice (ISEP); use of plug-in units and wire-wrapping techniques instead of soldered wiring.

The trial office, Vienna-Zollergasse, has the following additional features which are different from the Stuttgart installation.

— All units for internal traffic as well as for incoming and outgoing external traffic are combined into one common group.
— Simplified switching network to save crosspoints and allow easier adaptation to traffic requirements.
— Provision of a call detector which identifies outgoing call requests and, for international calls, transmits the directory number of the calling subscriber to special outgoing trunk groups for charge printing. Subscriber-line identification may also be used for intercepting malicious calls or detecting unnecessary seizures of line circuits.
— Modified path-finding method (offering signal from the call destination, accepting signal from the call origination point).
— Provision of a special PBX group marker.
— Omission of the centralized stage markers and assignment of their duties to the decentralized control circuits of the switching grids and the central group marker.
— Performance of *D* group functions (outgoing traffic) by the *A* groups.
— Series-to-parallel, instead of parallel, information transfer in the marker, data, and testing networks.
— Extensive testing and monitoring facilities.
— Additional standardization of functional units, basic circuits, and components (for example, only two switching-matrix types are used).
— Exclusive use of printed-circuit plug-in units (except switching matrices).
— Separate rectified mains supply units for each rack.

This list of features should also include those service features which are readily available but, on request of the Austrian PTT Administration, have not been used in Vienna-Zollergasse [10] such as,

— subscriber-controlled switching to special services, for example, absentee and answering service,
— operator-controlled admittance to different classes of services,
— remote-controlled restriction of long-distance traffic by the operator in the event of excessive traffic loads or cable failures,
— an electrical lock on a telephone set which bars outgoing long-distance calls but allows outgoing local traffic and all incoming traffic to continue without restriction.

2.2 Switching Environment

The *HE-60 L* trial office is connected to the 10 000-line group 93 of the Vienna main junction centre 9. Since Zollergasse is in the immediate vicinity of Mariahilferstrasse, one of the business centers of Vienna, this choice of switching environment made it possible to field-test the installation under extreme traffic load conditions. Traffic measurements, carried out prior to the installation of the trial office, revealed a traffic volume seldom encountered in practice. Individual subscriber lines had 290 to 490 call minutes of traffic within 12 hours (measured on three working days between 0800 and 1200 hours), which corresponds to 0·4- to 0·7-erlang traffic per line.

To have a sufficiently large traffic load available for the trial office on the date of its commissioning, connection of subscriber lines to a 500-line group of the existing crossbar installation *Zo 93*, which operates on the *48 HK* principles, was started very early. On 16 March, 1966, it took only one minute to switch over to the *HE-60 L* trial office, 182 individual lines (13 of them with push-button stations), 39 *PBX* lines, and 81 party lines serving a total of 196 subscribers, without having to change any directory numbers. The standby equipment provided by the Austrian PTT was removed after four months so a changeover to conventional equipment was possible during this time, but the need did not arise. It should be mentioned that the manufacturing company had not requested standby or changeover facilities.

Each party line serves up to 4 subscribers (outside Vienna up to 8), each of which can be selected by dial operation, full secrecy of conversation being maintained. This sharing is primarily an economic solution, but it imposes on the *HE-60 L* installation additional requirements, for example, an additional digit must be processed to distinguish between party-line subscribers. On the other hand, in-dialing in Austria is a general requirement since PABX of all sizes are equipped with the corresponding facilities.

On 1 November, 1967, a total of 182 individual lines (25 of them with push-button selection, and 15 of these with abbreviated dialing service), 57 PBX lines, and 91 party lines with 293 subscribers were connected to the trial office, which has a capacity of 500 lines. The traffic load, measured over a period of 4 weeks, is shown in Table 1.

Even during busy hours, the 1-percent-loss limit is not exceeded.

The interaction between the *HE-60 L* trial office and the existing telephone network will now be briefly outlined.

The existing dialing system *48 HK* is of the decade type and, consequently, concentrates the incoming traffic of 1000 lines in the 3rd group-selector stage. The ultimate capacity of the trial installation being only 500 lines (800 subscribers), incoming traffic must be split into traffic to the quasi-electronic and traffic to the conven-

Table 1 – Traffic load over 4 weeks

Lines	Period	Traffic load in erlangs		
		Outgoing	Incoming	Total
Total traffic offered, 335 lines (182 individual lines, 63 PBX lines, 90 party lines serving 252 subscribers)	24 hours, all days	6·0	9·5	15·5
	Monday to Friday, 0800 to 1800 hours	19·0	28·0	47·0
	Busy hours	25·0	40·0	65·0
per line	24 hours, all days	0·018	0·028	0·046
	Monday to Friday, 0800 to 1800 hours	0·057	0·084	0·141
	Busy hours	0·075	0·119	0·194

tional equipment. The last three digits of the dialed number are, therefore, forwarded by the 3rd group selector via the *C* junctors of the *HE-60 L* office to the *C* register where they are stored; the directional (routing) marker is then able to determine which one of the two 500-line groups contains the desired party.

Outgoing traffic to the conventional equipment of the junction center, to other local junction centers of the Vienna network, to special services, and to the long-distance center, Schillerplatz, is passed by the *D* junctors to the "1st/2nd group selector/long distance", as illustrated in the Appendix. Traffic to the two adjacent junction centers, Krugerstrasse (*Kr* 52), and Neutorgasse (*Ne* 63) is handled, for each of these directions, by five special *D* junctors which forward calls to the 3rd group selector of these junction centers. *Kr* 52 and *Ne* 63 operate on the motor-selector principle. The relatively small groups of trunks carry very high traffic loads, the substantial amount of "loss" being handled as overflow into the normal call processing path (1st or 2nd group selector/long distance). In this manner, routing in the local network is efficiently realized.

3. Performance Results of Trial Office

The performance results of the first quasi-electronic trial office installed by ITT have been discussed elsewhere [13], [14]; they correspond, in all essential points, with those of the Vienna trial office. Hence, only the significant differences and any new features need be discussed.

3.1 Integration in Existing Switching Environment

For the public service field trial, the Austrian PTT demanded full compatibility of the quasi-electronic system with the existing telephone network. So far, not a single case of incompatibility has been recorded. Neither the sudden high traffic load on the date of commissioning, nor the irregular and extreme distribution of traffic have exceeded the capabilities of the trial office. The problem of adapting the installation to the special types of party lines and to in-dialing has also been solved satisfactorily.

From the very beginning, the trial office met all requirements for the economic handling of traffic over second-choice routes comprising small and heavily loaded trunk groups, and with respect to the efficiency of the *C* and *D* junctors, or the units performing their duties.

3.2 Review of Important Features

From the viewpoint of practical operation, the design approach in most cases has resulted in simplification and improvement of operation. Some of the features, however, should be investigated more critically under separate headings.

- *Routing in the local network* proved to be a valuable tool for achieving economy and flexibility of operation. In the future, this feature should be provided for large and growing local networks.
- *Integrated path testing* is a salient new feature of future telephone switching systems. The Vienna trial office is part of a crossbar junction center and has to interwork with conventional equipment. As a result, shortcomings and irregularities detected in the conventional equipment and the line network have also been recorded, so that there are relatively many "fault reports" which are only of interest for statistical analysis.
- *Flexibility* of the *HE-60 L* system was demonstrated by the fact that the in-dialing requirement, that is, selection of PABX extension numbers of any length, and calling of party line subscribers, could easily be met.
- *Display of data* from all the units involved in a disturbed connection on a fault display panel (Figure 3) proved to be a genuine step forward, especially since the display method has been further perfected and simplified. Fault detection and location procedures were of especial interest to the PTT.
- *Identification of the directory number* of a calling line is also of interest outside Austria. The identified number may, for example, be passed via special facilities to a ticket printer for automatic international-traffic charge accounting.
- *Modified path-finding process* (guide-wire principle) extends only to those parts of the switching network used for the connection. This meant a reduction of crosspoints and offering-signal regenerators.
- *Series-to-parallel transfer of information* in the marker, data, and testing network results not only in a reduced

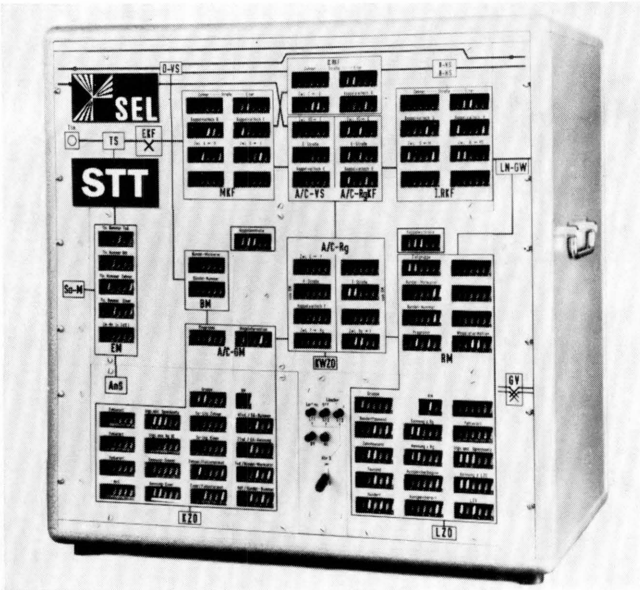

Figure 3 - Panel of memory for fault detection.

number of information lines but also permits substantial reduction in the number of relays.

— *Testing and monitoring facilities,* to detect and locate a variety of irregularities, have reached the costing limit tolerable for a trial office. Further expansion and improvement of these facilities may perhaps be justified in a future quasi-electronic network environment. However, provision must be made to allow quick and simple evaluation of the test results by the operating staff.

3.3 Maintenance and Operating Costs

During the development of the *HE-60 L* switching system, efforts were made to insure that quasi-electronic installations could be operated by the available qualified personnel. In the trial office, Zollergasse, the operating staff soon became familiar with the new technical environment.

Considering that in ten years of continuing development the number of telephone subscribers will double, development engineers too often fail to pay sufficient attention to the need for further trained personnel for the operation and maintenance of installations. The high cost of qualified personnel and the difficulties in finding such personnel is one of the principal motivations for the application of electronics to telephone switching.

The operating and maintenance cost of the trial office is below the level of even the crossbar system. One aspect of this is of interest. For installations such as the Zollergasse trial office, where personnel are available around the clock to deal with customer requests (connection and disconnection of lines, transfers, testing of meters et cetera) or perform administrative work (interception et cetera), the reduction of maintenance requirements below a certain level has not led to manpower savings because personnel do not become sufficiently familiar with the installation soon enough to be able to act quickly and correctly in the event of trouble. This problem, also observed in the Zollergasse trial office, should be taken into account in the future.

In view of the fact that the centralized units of the trial office (control circuits, registers, switching network,

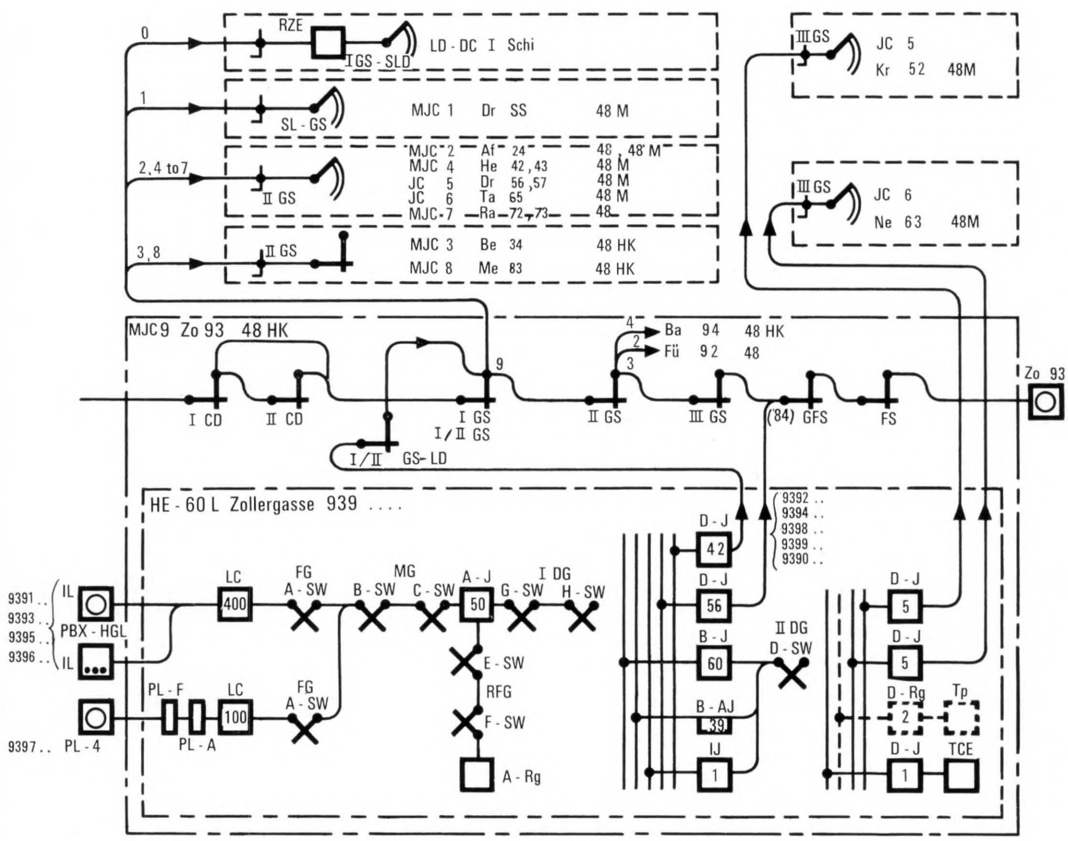

Figure 4 - System *HE-60 L*, Vienna-Zollergasse. Outgoing traffic (without internal traffic).

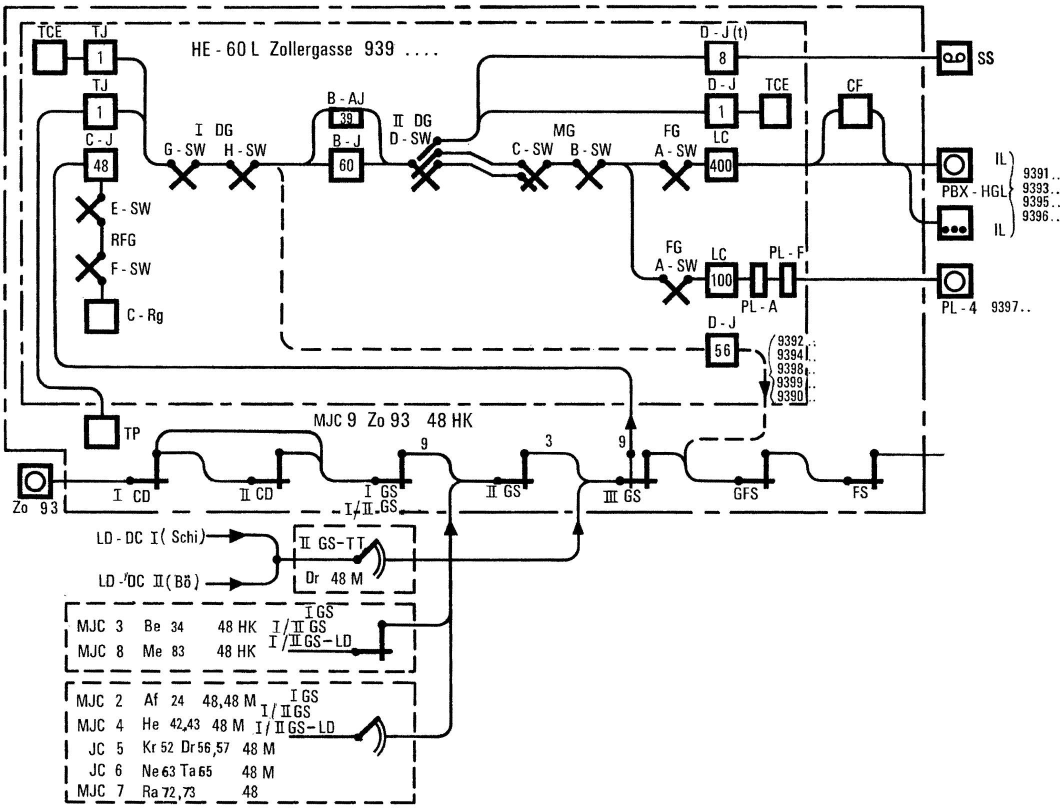

Figure 5 - System *HE-60 L*, Vienna-Zollergasse. Incoming traffic (without internal traffic).

Legend for Figures 4 and 5

A-SW	Switching Stage *A*
Af	Afrikanergasse (main junction center)
A-Rg	*A* register
A-J	*A* junctor
Be	Berggasse (main junction center)
B-AJ	Auxiliary *B* junctor
B-SW	Börseplatz (long-distance center II, Vienna)
Bö	Switching Stage *B*
B-J	*B* junctor
Ba	Baumgarten (main junction center)
C-SW	Switching Stage *C*
C-Rg	*C* register
C-J	*C* junctor
CF	Charge facility
CD	Call detector
D-SW	Switching stage *D*
Dr	Dreihufeisengasse (junction center)
D-Rg	*D* register
D-J	*D* junctor
D-J (t)	*D* junctor (tape recorder or subscriber)
DG	Directional grid
E-SW	Switching stage *E*
F-SW	Switching stage *F*
Fü	Fünfhaus (local center)
FG	Final grid
FS	Final selector
G-SW	Switching stage *G*
GFS	Group final selector
GS	Group selector
GS-LD	Group selector/long distance
GS-SLD	Group selector of secondary long-distance center
GS-TT	Group selector for terminating toll calls
H-SW	Switching Stage *H*
He	Hebragasse (main junction center)
IL	Individual line
IJ	Interceptor junctor
JC	Junction center
Kr	Krugerstrasse (junction center)
LD-DC	Long-distance dialing center
LC	Line circuit
Me	Meidling (main junction center)
MG	Mixing grid
MJC	Main junction center
Ne	Neutorgasse (junction center)
PL-4	4-party line
PL-F	Party line facility
PL-A	Party line adaptation
PBX-HGL	*PBX* — hunting group line
Ra	Rasumofskygasse (main junction center)
RFG	Register finder grid
RZE	Routing and zoning equipment
Schi	Schillerplatz (long-distance center I, Vienna)
SS	Special services
SL-GS	Service-line group selector
TP	Test position
TCE	Test connection equipment
TJ	Test junctor
Ta	Taubstummengasse (junction center)
Tp	Ticket printer
Zo	Zollergasse (main junction center)

System Designations

48	Dial System *48* (two-motion selector)
48 M	Dial System *48 M* (motor selector)
48 HK	Dial System *48 HK* (hundreds crossbar switch)
HE-60 L	Dial System *HE-60 L* (Herkon-electronic system with guide-wire path finding)

Numbers inside boxes on figures denote the number of units. Other numbers alongside boxes and lines denote directory-number allocation or direction.

etc.) are dimensioned for an essentially larger number of subscriber lines and that the number of subscribers connected to the *HE-60 L* installation is relatively small, the recorded failures do not allow final conclusions. The failure rate of the Zollergasse installation closely agrees with the failure rates observed over an extended period of time in the Stuttgart-Blumenstrasse installation [13]. Extrapolated for 2000 lines, the mean failure rate is 0·13 failure per 100 lines per month (as in Stuttgart).

Considering the fact that all disturbances are positively detected during the call-establishing process, and that the installation handles a very high traffic load, this low failure rate is very impressive.

3.4 Extra Facilities

A telephone customer given the opportunity to test push-button selection will soon recognize the advantages. Since the beginning of automatic telephony about half-a-century ago this is the first advance almost exclusively for the benefit of the telephone user. The reproachful — though expected — question, "why wasn't the dial set replaced earlier?", is a clear indication of the acceptance of push-button selection. Telephone customers provided with push-button selection sets — even if only for a short time — do not want to lose this feature. People who in the beginning were very skeptical about push-button dialing, very soon became convinced advocates. This explains its unusually rapid progress in the United States. At the end of 1967, there were more than 2·5 million push-button sets in use in the USA, 1·7 million of them installed in that year.

Abbreviated dialing, which for call-charging reasons could be provided only for certain subscriber lines, will surely also become a standard feature in future telephone switching systems.

4. Conclusions

In the continuous world-wide striving for economic and up-to-date telephone switching solutions, the Vienna-Zollergasse trial office, represents a significant step forward. By deciding to carry out this public service field test, the Austrian PTT has made an important contribution to international telephone technology. All requirements have been met by application of the quasi-electronic principle, for example, path finding by the guide-wire method, use of a register system associated with routing translators, and subdivision into groups with semi-centralized control functions and duplicated central units. The *HE-60 L* system permits easy realization of all the service features offered by modern switching installations, such as push-button selection, abbreviated dialing, subscriber- and operator-controlled switching to special services, routing in the local network, and subscriber identification.

Telephone switching technology nowadays faces a multitude of problems; some of them may have been answered by the Zollergasse trial office.

Appendix

Within the Vienna local telephone switching network, the quasi-electronic trial office at Zollergasse is part of the 9th 1000-line group of the main junction center *Zo 93*. Some of the traffic interrelations with the existing plant are, therefore, noteworthy. Disregarding a few installations of the so-called "Vienna System" (developed by G. H. Dietl) which are being replaced these days, the switching installations are designed on the Austrian *Dial System 48* which has been applied in three versions since 1949. The three versions are distinguished primarily by the component they use for through-switching:

— *Dial System 48* : Quadrangle selector (two-motion selector 27)

— *Dial System 48 M* : Albis or *WSW-type* motor selector of the Wiener Schwachstromwerke (Siemens)

— *Dial System 48 HK*: Crossbar switch *KS 55 f* of ITT.

The other components as well as internal signaling system *48 HK* and service features are identical in the three versions [15].

The integration of the quasi-electronic trial installation into the existing telephone switching environment is illustrated by Figures 4 and 5.

Figure 4 shows the flow of traffic originated by the individual lines, *PBX* hunting group lines with and without push-button selection facility, and the four-party lines. The calls proceed from the *HE-60 L* equipment via the *D* junctors to the 1st/2nd group selector/long-distance relay sets or via the *D* junctors to the final-selector stage in the remaining part of the 1000-line group. These *D* junctors are accessible via the 1st directional grid, while a second directional grid offers access via other *D* junctors to the previously mentioned small trunk groups leading to the relay sets of the 3rd group selector in the local junction centers *Ne 63* and *Kr 52*.

Intermeshing of the junction centers and access to the long-distance network (handling predominantly automatic and, to a minor extent, manual traffic) as well as to special services is apparent from the various outlet directions of the crossbar main exchange 9; similarly, the access from the 2nd group selector to its own local centers *Ba 94* and *Fü 92*.

As shown in Figure 5, traffic arriving from the long-distance center via the 2nd long-distance group selector or from the main junction centers via the 1st or 1st/2nd group selectors, or from the 1st/2nd group selectors/long-distance to the 9th 1000-line group is directed to the main junction center 9, Zollergasse, 2nd group selector, and arrives together with the orginating traffic via the 9th level of the 3rd group selector at the *C* junctors. Upon evaluation of the hundreds digit dialed by the calling subscriber, a decision is made as to whether the wanted connection must be set up in the *HE-60 L* system or in the "other" 500-line group of the crossbar exchange. In the latter case, the connection is switched through to the group line selector stage via *D* junctors following the 1st directional grid. The access of test connection sets and the connection of special *D* junctors is also indicated in the figure.

References

[1] Themenheft: Elektronische Telephonzentrale, Wien-Zollergasse, Technische Mitteilungen STT, volume 13 (1966), no 22.

[2] H. Schönemeyer, Quasielektronisches Fernsprechamt, Elektrowelt, volume 5 (1960), pp 174—175.

[3] Themenheft: Quasi-elektronisches Fernsprech-Vermittlungssystem HE-60, SEL-Nachrichten, volume 11 (1963), no 3.

[4] H. Willrett: Erste Fernsprech-Ortsvermittlungsstelle der DBP mit Tastwahlmöglichkeit, Ing. DBP, volume 12 (1963), no 4, p 124.

[5] H. Schönemeyer: Quasi-electronic telephone switching system HE-60, Electrical Communication, volume 39 (1964), no. 2, pp. 244—259.

[6] H. Schönemeyer, H. Siegel: Das quasi-elektronische Fernsprechvermittlungssystem HE-60, Ing. DBP, volume 13 (1964), no 2, pp 39—42.

[7] H. Schönemeyer: Neue Wege in der Vermittlungstechnik. Das quasielektronische Vermittlungssystem HE-60, Nachrichten Technische Zeitschrift, volume 18 (1965), no 1, pp 49—52.

[8] H. Schönemeyer, W. Hackenberg: A quasi electronic telephone exchange, Systems and Communications (1966), no 2, pp 26—34.

[9] H. Rensch: Characteristics and applications of reed contacts, Electrical Communication, volume 40 (1965), no. 3, pp. 385—397, also VDI-Zeitschrift, volume 107 (1965), no. 4, pp. 160—167.

[10] W. Hackenberg: Wien-Zollergasse, eine zweite Versuchsvermittlungs-

stelle des quasi-elektronischen Fernsprech-Vermittlungssystems HE-60 L, SEL-Nachrichten, volume 14 (1966), no 4, pp 177—189.
[11] H. Haslinger: Der internationale Stand der elektronischen Vermittlungstechnik, E und M. volume 83 (1966), no 5, pp 311—340 and also Technische Mitteilungen STT, volume 14 (1967), no 23, pp 3—36.
[12] O. Baade, L. Gasser: Behavior of telephone subscribers using pushbutton selection, Electrical Communication, volume 42 (1967), no. 2, pp. 236—246 and NTZ, volume 20 (1967), no. 2, pp. 96—105.
[13] H. Schönemeyer: Quasi-elektronische Fernsprechvermittlungsstelle Stuttgart-Blumenstraße zwei Jahre in Betrieb, Nachrichten Technische Zeitschrift, volume 19 (1966), no 6, pp 331—334.
[14] W. Rauscher: Experience with Trial Office HE-60L Stuttgart-Blumenstraße, Electrical Communication, volume 43 (1968), no. 1, pp. 14—19.
[15] F. Wolfgang: Das Fernsprechwählsystem 48, E und M, volume 78 (1961), nos 1/2, pp 41—52.

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Technical Aspects of Telephone Network Planning

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1. Introduction

The technical aspects of network planning here discussed include transmission-path characteristics between two subscribers in so far as they effect the transmission performance of a complete connection. This complete connection may include local, national, and international circuits.

The CCITT recommendations so far available mainly concern Reference Equivalents applied to line-transmission quality, carrier-frequency systems and radio links [3, 4]. With the increasing practice of subscriber dialing over long-distance lines it would be advantageous to have corresponding recommendations for all the equipment forming a complete connection. The reason for this is twofold. First, additional equipment is required for automatic switching, and second, the possibility of controlling the transmission quality of a circuit by an operator no longer exists.

Study Group XI of the CCITT has been entrusted with the task of drafting a recommendation for the technical characteristics of international automatic switching points (Questions 4, 5, and 8 of Study Group XI 1964/1968). Moreover, a Manual on National Telephone Networks for the Automatic Service has been prepared by the CCITT Special Autonomous Working Party 1 (GAS-1). This manual is intended to assist the rapidly developing countries, and Chapter V deals specifically with transmission problems of the type here considered.

A corresponding manual on local networks is being prepared by CCITT Special Autonomous Working Party 2 (GAS-2) and will be published after the CCITT Plenary Assembly in September 1968. (The first draft of the relevant Chapter V of this manual is available as documents GAS-2 *45* and *51*, 1964/68).

Section 2 of the present paper discusses the various characteristics which influence the transmission performance of telephone networks. Section 3 deals with the basic design problems of a transmission plan.

The use of separate data channels for signaling between switching centers is not taken into account here. If this were the case there would be a reduction in attenuation distortion and noise because some signaling equipment would be redundant. The introduction of pulse-code-modulation transmission and switching techniques would also alter many of the conditions discussed in the paper.

2. Relevant Characteristics

2.1 Attenuation and Attenuation Distortion

The losses due to switching equipment are measured like those in other parts of a telephone connection as net insertion loss between terminations of 600 ohms. At transit switching points of repeatered long-distance systems it is possible to keep these losses negligible. This may be achieved by adjustment of the attenuators used for regulating the system levels. The loss at the terminal non-repeatered 2-wire switching point should be conveniently small, say, around 0·1 neper or 0·87 decibel, or less. The effects of the end switching points on the overall loss of a connection is, however, not so great as the cumulative effect produced by the transit switching points, of which there could be 10 in a world-wide chain of 12 circuits.

More important is the attenuation distortion caused by the switching equipment. The CCITT recommends as an objective for a world-wide chain of 12 circuits that the distortion should not be greater than indicated by the stepped curve shown on page 28 of the CCITT Blue Book, volume III. According to this recommendation the permissible distortion referred to the attenuation measured at 800 hertz is,

+ 1·0 neper (8·7 decibels) for frequencies between 300 and 3400 hertz,

+ 0·5 neper (4·35 decibels) for frequencies between 400 and 3000 hertz,

and

+ 0·25 neper (2·2 decibels) for frequencies between 600 and 2400 hertz.

Over the whole of the voice-frequency band a variation of −0·25 neper is admissible.

The stepped curve has hitherto been applied only to long-distance transmission systems where, in the case of 10 amplified circuits for instance, the value applicable to one channel modulator would be 1/20 of the values given above. When, however, automatic-switching equipments are introduced in such a chain of circuits and with it a further source of distortion, it is appropriate to reduce these figures. This subject is being studied by the CCITT study groups concerned and the result of the study will in due course be incorporated in the above-mentioned draft recommendation of Study Group XI. It appears that this group, which is entrusted with the study of problems concerning switching equipment for international circuits generally, considers that the distortion caused by a transit switching point should not be greater than + 0·5 decibel (0·06 neper) from 300 to 400 hertz, + 0·3 decibel (0·035 neper) from 400 to 3400 hertz, and −0·2 decibel (0·023 neper) from 300 to 3400 hertz.

2.2 Balance to Earth

The balance to earth of switching equipment has an important bearing on the noise performance of a system and on the facilities a system offers for signaling. With the steady growth of networks of high-tension lines and electrification of railways, telephone cables are increasingly exposed to the effects of induction and earth currents. The switching equipment is earthed for signaling purposes by an impedance which, with the capacitance to earth of the two conductors of a cable pair, constitutes a bridge circuit. When this circuit is not balanced and a longitudinal voltage is induced on the cable conductors from outside, a difference voltage is produced across the cable conductors.

The degree of balance to earth of any piece of equipment is conventionally measured by applying a voltage between its earth terminal and the midpoint of a balanced 600-ohm resistance connected in shunt across the equipment terminals. The voltage then measured across the equipment terminals gives, when related to the applied voltage, the unbalance factor of the equipment as a percentage. The logarithm of the inverse value expresses the unbalance factor in nepers or decibels.

An example may illustrate the effect of induction from a power installation on the noise performance of a telephone circuit. A six-phase rectifier operated at 50 hertz may induce on the cable conductors an electromotive force of 45 volts; the harmonic of 300 hertz may be 1 percent or 450 millivolts. With a favorable unbalance factor of 0·5 percent (5·3 nepers or 46 decibels) the voltage across the circuit would be 3 millivolts which corresponds to a psophometric electromotive force of 1 millivolt, the weighting factor at 300 hertz being around 3, or 1·1 nepers (9·6 decibels) [5].

Since the CCITT considers that 1 millivolt is the maximum psophometric electromotive force that is permissible in the worst case of a world-wide connection (Recommendation G 123, [5]) and since Study Group XI suggests in their above-mentioned draft recommendation that the noise performance of an international transit-switching point should be less than 350 microvolts, it is evident how much the quality of transmission depends upon the balance to earth.

2.3 Crosstalk

Crosstalk arising within switching equipments is mainly due to capacitance unbalances between different circuits. It may be unintelligible or intelligible.

When unintelligible it must be ascribed to switching operations in neighboring circuits. This noise must be added to the noise produced by other sources in order to evaluate the total noise performance of the system.

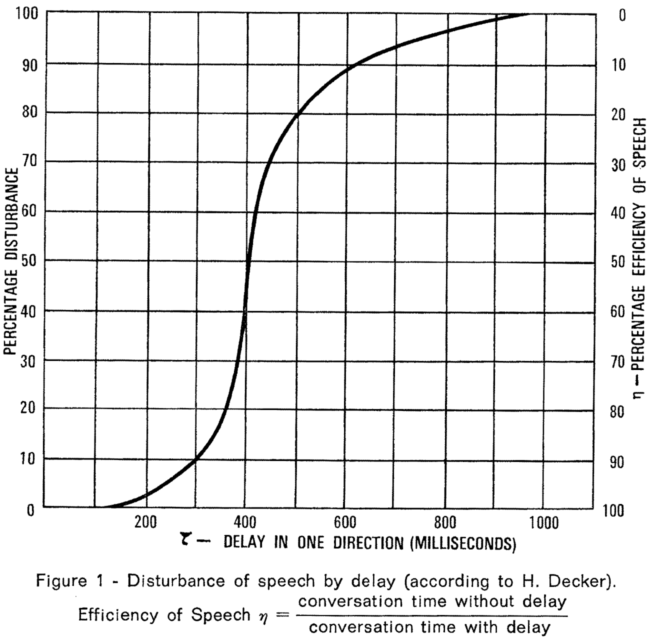

Figure 1 - Disturbance of speech by delay (according to H. Decker).

$$\text{Efficiency of Speech } \eta = \frac{\text{conversation time without delay}}{\text{conversation time with delay}}$$

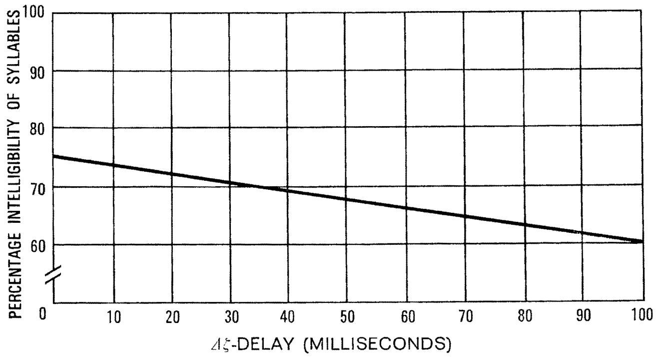

Figure 2 - Decrease in intelligibility with delay distortion (according to Lüschen, Küpfmüller). The reduction of intelligibility at point $\Delta\tau = 0$ is caused by measuring equipment.

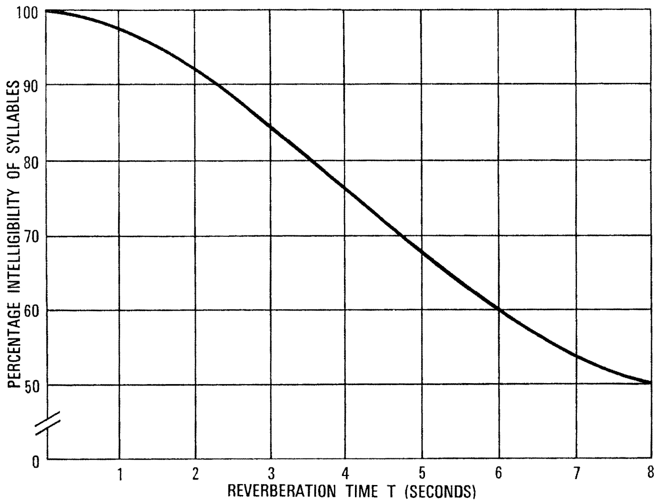

Figure 3 - Decrease of intelligibility with reverberation time T (according to Rint).

Intelligible crosstalk on the other hand arises from electro-magnetic couplings between two distinct speech circuits. The level which is permissible for this kind of crosstalk is determined by the condition of secrecy. Normally a syllable intelligibility not exceeding 3 percent should be sufficient to meet this condition. This rate of syllable intelligibility corresponds to a sentence intelligibility of 10 percent. In cases where the crosstalk attenuation exceeds 9 nepers or 78 decibels, this sentence intelligibility can generally be guaranteed.

The figures stated depend to some extent on the frequency response and the noise performance of a circuit exposed to interference from power installations. Since noise reduces the intelligibility it has a beneficial effect upon the tolerable crosstalk level.

In evaluating the crosstalk, account must be taken of the mean speech levels of both the inducing and the induced circuits. Unequal levels may improve the crosstalk level or make it worse. If worse, it may be necessary to accommodate the circuits in separate cables. Level differences occur mainly on subscribers' lines where they are due to the different sensitivities of the receiver and transmitter capsules.

The draft recommendation of Study Group XI includes a crosstalk requirement of 9·2 nepers or 78·5 decibels for international switching centers. However, in view of the haphazard character of crosstalk it is suggested that the requirement will be applicable only to 98 percent of the cases encountered. A diagram showing the suggested crosstalk margins applicable to subscribers' lines as a function of the sensitivities of the transmitter and receiver capsules will be found in the Manual for Local Networks.

2.4 Matching

The input impedance of telephone equipment should as far as possible be matched to the conventional reference impedance of 600 ohms. Mismatches result in losses and interaction effects of multiple reflections (balance return loss).

Mismatch loss is defined as the ratio between the actually transmitted power and the possible optimum power. The difference becomes significant only in cases of relatively bad mismatches. For rough evaluation in cases where the mismatch involves a factor of 2, that is where the terminations are 1200 ohms or 300 ohms instead of 600 ohms, the mismatch loss can be taken as 0·06 neper or 0·5 decibel.

Whenever measurements are made on any part of the equipment it is essential that test-set terminations match this 600-ohm reference impedance.

A much more pronounced effect is caused by reflections. These may affect the stability of a repeatered 4-wire circuit and, moreover, degrade the transmission performance by echoes. Section 3 of this paper will show how account is taken of these effects in the design of a transmission plan. Here we can mention the noncritical case of a 4-wire switching point placed between the terminals of matching amplifiers so that reflections to the line are reduced. In this case Study Group XI consider a reflection loss with respect to mismatch loss of not less than 2·3 nepers or 20 decibels to be satisfactory.

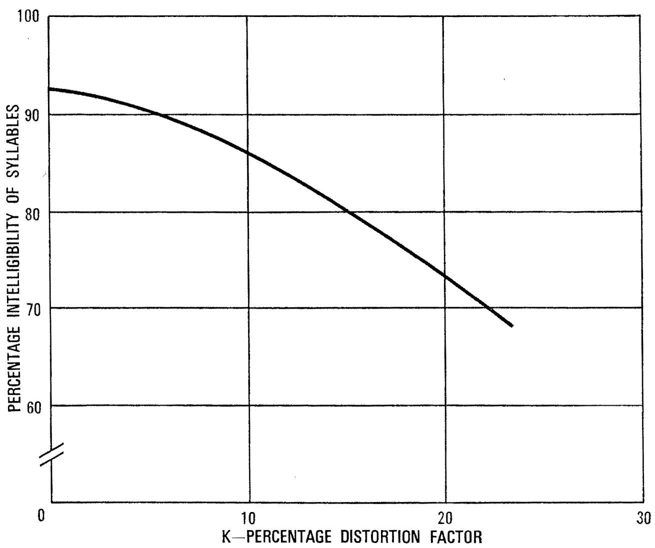

Figure 4 - Decrease of intelligibility with distortion factor k (according to K. Braun). The reduction of intelligibility at point $k = 0$ is caused by measuring equipment.

2.5 Noise Performance

2.5.1 Measurement

Noise is mostly permanent and thus amenable to measurement by the CCITT psophometer. Briefly, this instrument is a millivoltmeter whose input has a filter network attenuating the incoming noise in accordance with the combined frequency response of the human ear and a typical telephone receiver. The time constant of the instrument, around 200 milliseconds, simulates the time constant of the ear. The value measured is referred to as the weighted voltage.

The psophometer, however, does not lend itself to the measurement of clicks of the kind produced by some of the noise sources listed above. In the absence of a suitable instrument for objective measurements, an array of four click counters is being studied by the Study Group XI. The counters register all clicks of given duration which respectively exceed −10, −20, −30 and −40 dBm0. The total number of clicks and their distribution indicates their interfering effect on a given circuit. The measurement has a special relevance to data transmission.

2.5.2 Sources of Noise

There is a variety of sources generating noise. Induction from external power installations, unbalances to earth, and unintelligible crosstalk have already been mentioned. Other sources are

- ripple on direct-current power supplies used for feeding switching equipment,
- contacts,
- signaling processes, and
- electron tubes (white noise).

Induction from power installations occurs mainly on subscribers' lines. Generally, protective measures can be applied to both the inducing and the "induced" systems. On induced systems, for instance, the cable reduction factor may be increased to give better magnetic screening. Alternatively, isolating transformers may be inserted into the circuit, necessitating the adoption of alternating-current signaling methods. To decide on the measures to be taken in each particular case there is in Germany a permanent commission of experts drawn from the communication and power fields. The measures in each case are chosen to fit the particular local conditions. The Commission also apportions the costs of the protective measures amongst the various parties involved.

Noise arising from unintelligible crosstalk may be reduced by physically separating the speech circuits from the signaling circuits. Use may also be made of methods of compensating capacitance unbalances in cables. This however is economically justified only on lines carrying heavy traffic.

Ripple on the direct current used for feeding switching equipment may reach the cable conductors not only from the feeding bridge but by other paths. These paths should therefore present a high impedance to voice-frequency currents. The relays, or coils, which have hitherto been provided meet this requirement very well. If it is planned to replace these devices in the feeding bridges of quasi-

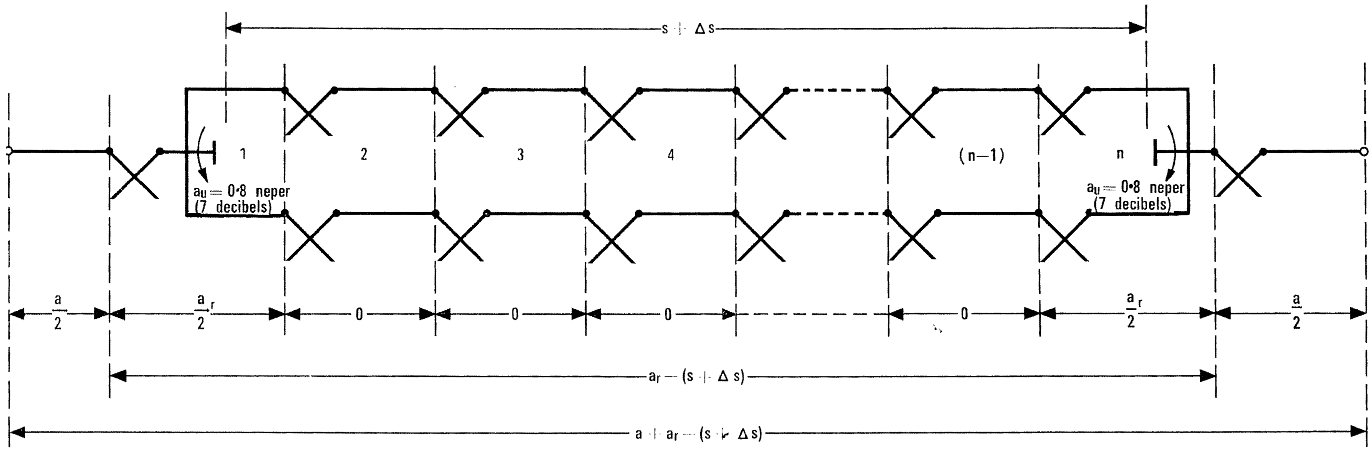

Figure 5 - 4-wire switching of a long-distance connection.

electronic installations by resistances it may be necessary to impose more stringent requirements on the ripple content of the feeding current. Feeding bridges consisting of relays show a noise attenuation of about 2·3 nepers or 20 decibels. To ensure therefore that the noise objective of 200 microvolts (usually produced on the conductors by the feeding bridge) is not exceeded, attention must be given to see that the weighted noise on the power-feeding circuit does not exceed about 2 millivolts. This relationship should be checked where other kinds of feeding bridges are planned to be used.

Contact noises are produced by the modulation of direct currents passing through contacts in voice-frequency circuits. The best known example of this kind of noise is the selector noise. Modulation takes place where a contact resistance fluctuates due to external influences as, for instance, mechanical vibrations. The currents modulated are either the feeding currents in subscriber circuits or so-called "wetting" currents. The latter may be several milliamperes. Their use is to prevent high contact resistance with consequent initiation of fading. Although they suppress fading they do not eliminate fluctuations of contact resistance altogether. With the future use of sealed contacts, fading as well as noise from contacts may be expected to be negligible.

Apart from noise induced in a circuit by signaling currents in other circuits, there is the noise due to signaling currents in the circuit itself. In modern systems the signaling equipment is often connected to the circuit by means of diodes with direct-current reverse potentials. The reverse direct-current resistance of these contacts must be high enough to prevent interference between the signaling and the speech circuits.

It is usual for a circuit to simultaneously serve for both the transmission of speech and signaling currents; for instance, there may be metering pulses of 16 kilohertz, 25 hertz, or direct current. With the increase in subscriber dialing a more rapid rate of impulsing must be expected with a consequent increase in noise.

With impulse intervals of more than 4 to 5 seconds, relatively high-level clicks may be tolerated. With intervals of only 0·5 second — as for instance for traffic between Europe and the USA — users may find these clicks disturbing.

Investigations have indicated that the noise introduced by metering pulses should not exceed about 300 microvolts. Consideration of this type of noise should, therefore, be given at an early stage of the design of a transmission plan, even when initially the impulse interval can be assumed to be relatively long. Modifications required at a later date to compensate for shorter impulse intervals are likely to be costly.

White noise from amplifiers rarely appears in switching equipment. In the context of this article white noise is the sum of all noise from any source and cannot be ignored since the total permissible noise voltage must

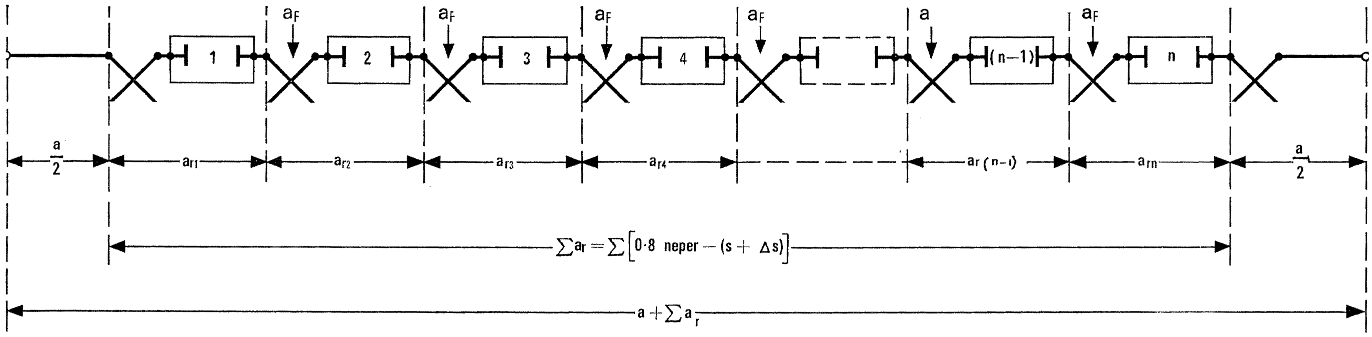

Figure 6 - 2-wire switching of a long-distance connection.

not exceed a figure needed for good transmission quality. Because of a random distribution of frequency and phase, individual noise components should be added on a root-mean-square basis.

2.6 Nonlinear Distortions and Propagation Time

Each of these characteristics may have a considerable effect on transmission performance. Nonlinear distortions reduce the intelligibility and interfere with voice-frequency signaling. Propagation time and distortions of the propagation time may greatly inconvenience telephone users and lead to difficulties in the voice-frequency signaling. (Figures 1 through 4). The contribution made by switching equipments to these distortions is generally negligible compared with that from the transmission sections. In future electronic exchanges it could well be that we will no longer be able to disregard the effects of switching equipment in this respect.

3. Designing of Transmission Plans

3.1 Reference Equivalents

The Reference Equivalent of a connection is a measure of the loudness of the received signal and forms the basis of every overall transmission plan. It is defined as the ratio of the loudness of the signal received over the connection and the loudness received over a reference system; it is expressed in nepers or decibels. A positive value indicates that the loudness on the evaluated system is lower than that in the reference system, a negative value that it is higher. The reference system of the CCITT, known as NOSFER, is set up at Geneva. Different Reference Equivalents apply to the sending- and receiving-end system.

The Reference Equivalent of each part of a complete connection in a telephone network is fixed so that for the majority of the possible connections the overall Reference Equivalent is as far as possible the same. For the remaining possible connections the Reference Equivalent should not exceed an admissible maximum value. Best intelligibility is achieved with an overall Reference Equivalent of 0·7 to 1·5 nepers (6 to 13 decibels). This approximates to the case of two talkers facing each other across a table. Departure from this optimum to higher or lower values reduces the intelligibility.

Reference Equivalents vary in practice with length and kind of circuit, switching equipments, network structure, and subscribers' sets. The ultimate design of any specific system is a compromise between the technically desirable and the economically achievable, the overriding condition being satisfactory loudness for all possible connections without the need for supervision by operators. In planning a national system, provision must also be made for connection to the international system. For this purpose the CCITT recommends that the Reference Equivalent of the sending-end system between the subscriber and the first international circuit should not exceed 2·4 nepers (20·8 decibels) and that the Reference Equivalent of the receiving-end system between the same two points should not exceed 1·4 nepers (12·2 decibels) [3].

3.2 Stability

In apportioning the admissible losses to the various parts of a telephone network it would be advantageous to assign zero loss to the longer repeatered circuits, then the whole of the permissible overall loss would be available for distribution amongst the extensions. Unfortunately this ideal plan cannot be realized, a certain amount of net loss being needed in 4-wire repeatered circuits to ensure that the chain will not oscillate between the terminating sets, even under the worst conditions. The loss to be provided in each repeatered circuit depends upon the switching equipment (for 4-wire or 2-wire transit connection) and on the operating conditions of the repeatered circuits (fluctuations in repeater gains, type of termination). Two cases arise which may be discussed.

3.2.1 4-Wire Transit Connections

Since all international lines are planned as repeatered 4-wire circuits by a CCITT recommendation, it follows that national lines in a complete connection must always terminate in a 4-wire circuit (Figure 5). The stability of this circuit depends, apart from its net loss and fluctuations of repeater gains, on the transhybrid loss at the terminating sets. If, at the 2-wire inputs of the terminating sets, account has to be taken of the presence of 2-wire selectors it will be necessary to fix the circuit net loss so that the expected minimum of 0·8-neper (7-decibel) transhybrid loss across the terminating set, together with possible variations with time of the circuit net loss meet the stability requirement of the circuit. This gives the conditions,

$$2 \times 0{\cdot}8 - 2\,(s + \varDelta s) \geqslant \varDelta a,$$

where s is the one-way amplification of the circuit,
$\varDelta s$ is its variation with time, and
$\varDelta a$ is the safety-margin-against-oscillation factor.

If, on the other hand, the 2-wire extension circuits are connected directly to the terminating sets, higher transhybrid losses a_u should be achievable by the insertion of individual balance networks adjusted according to the characteristics of the 2-wire circuit. In this case the expression changes to

$$2 \times a_u - 2\,(s + \varDelta s) \geqslant \varDelta a,$$

and the higher transhybrid loss will allow a higher amplification.

3.2.2 2-Wire Transit Connections

In this case each repeatered 4-wire circuit in a chain of circuits must be considered individually from the point of view of singing and the circuit net loss determined accordingly (Figure 6). To reduce the risk of interaction between amplified circuits, good balance networks are needed for their terminating sets when interconnected at 2-wire switching points. Reflection factors of less than 2 percent, corresponding to a return loss of more than 3·9 nepers (34 decibels) are generally required to ensure that the net losses of individual circuits are sufficiently small. The evaluation of the stability of each repeatered circuit may then be carried out as indicated above for a single, amplified circuit at a 4-wire transit connection.

4. Echoes

Speech currents in telephone circuits may be reflected at points of irregularities such as switching points, terminating sets, and interconnections of unmatched cable circuits. The reflected currents appear as echoes to the talker and as reverberations to the listener. The effect on the users depends on the propagation time and the attenuation of the connection. The greater the interval between the arrival of the signal and its reverberation, or between the sending of the signal and the arrival of its echo, the greater the annoyance to the users, unless the reverberation or the echo has been attenuated so as to become imperceptible. In very extended networks the propagation time may require that the net loss of individual sections of the circuit be increased beyond the value necessary to achieve stability. Another way of reducing the effects of these phenomena is to introduce echo suppressors. These devices, activated by the signal propagated in one direction of transmission, effectively bar or reduce transmission in the opposite direction. The use of suppressors, however, cannot be unlimited because they may interfere with the smooth exchange between talkers, and with some types of signaling.

References

[1] G. Rahmig: Einige Betrachtungen zum Dämpfungsplan von Fernsprechnetzen, Der Ing. der DBP, volume 13, no 1, pp 18—22, 1964.

[2] G. Rahmig: Dämpfungsplanung für ein Fernwahlnetz, SEL-Nachrichten, volume 10, no 4, pp 187—193, 1962.

[3] CCITT, Blue Book, volume III, part I, Recommendation G. 101, The New Transmisson Plan, 1964.

[4] CCITT, Blue Book, volume V, 1964.

[5] CCITT, Red Book, volume V, Recommendation, p 53, 1960.

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In 1946 he joined Standard Elektrik Lorenz, working as a technician while at college. On graduation, he was assigned to the engineering development of new telephone sets. He is now deputy chief of the laboratory for audio-frequency transmission.

Television Transmitters for 470 to 860 Megahertz

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1. Introduction

In 1952 work was resumed in the television field with the development and production of transmitters in Band III [1] (175 to 230 megahertz) and from 1960 onwards for Bands IV and V (470 to 790 megahertz).

These transmitters were designed [2] for vision output powers from 2 to 20 kilowatts (sound output powers from 0·4 to 4 kilowatts) and are tunable to every channel within the frequency band. Instead of final-stage modulation, used hitherto, the vision signal [3] is processed on a fixed intermediate frequency of 38·9 megahertz and converted to the transmitter output frequency by a mixer [4].

To accord with the state-of-art at that time, the transmitters used thermionic tubes throughout. The output power amplifiers operated with air-cooled ceramic high-power tetrodes of 10 kilowatts [5] or water-cooled four-cavity klystrons of 10 kilowatts. In the switching equipment, electro-mechanical relays operated the contactors. These transmitters are still manufactured and supplied and are suitable for color transmission [6].

Modern telecommunications practice has, however, influenced the development of high-power transmitters. Technical progress in the development of components and the demands of international markets have created a new set of characteristics which may be outlined as follows.

- Very low maintenance requirements and increased operational reliability.
- Remote control and remote monitoring of unmanned transmitters.
- Reduced-space requirements because the increase in the number of programs requires several transmitters to be housed in a common building.
- Improved electrical safety measures to IEC regulations for protection of operating personnel.
- Increase of the vision transmitter output power to 40 kilowatts and above.
- Extension of the transmission frequency range to 860 megahertz.
- The need to adapt to the various television standards.

These demands can largely be met with present-day components.

2. Characteristics of the New Transmitter Series

To achieve these requirements the following techniques were adopted in the development of the new transmitter series.

In the low-power-level processing circuits of the driver stages the thermionic tubes are replaced by silicon semiconductor components, such as diodes, transistors, and varactors [7].

Modern velocity-modulated tubes with high amplification factors (30 to 40 decibels), such as traveling-wave tubes and four-cavity klystrons, replace the medium and high-power tetrodes.

In switching, interlocking, and automatic equipment, open-contact relays have been replaced by switching-type semiconductor components, thyristors and reed relays for controlling the contactors (which at present cannot be replaced).

The IEC requirements have also been complied with. Transmitter operating personnel are protected by mechanical interlocks to prevent access to parts of the equipment which carry high voltages.

The intermediate-frequency modulation principle, previously used only in the vision transmitter, is also incorporated in the processing circuits of the sound transmitter. This has resulted in space-saving with vision and sound signal processing in a common, transistorized driver-stage unit.

The design of the high-power vision and sound stages is unified by the use of identical types of klystrons for the vision and sound output amplifiers, fed from a common space-saving high-voltage source.

The first and the two last-mentioned features have resulted in a reduction of the frontal length of the transmitter.

3. Description of the New Transmitters

Multi-purpose sub-units and basic units in standard racks become building-block modules from which it is

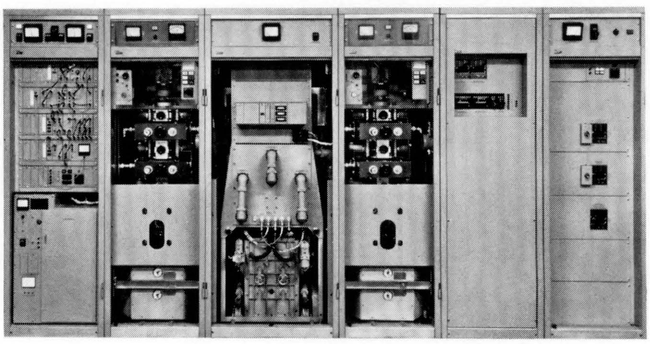

Figure 1 - Design of the 10/2-kilowatt television transmitter (from left to right): vision/sound driver stage, klystron vision amplifier, combining unit, klystron sound amplifier, high-voltage unit, and cable distribution rack.

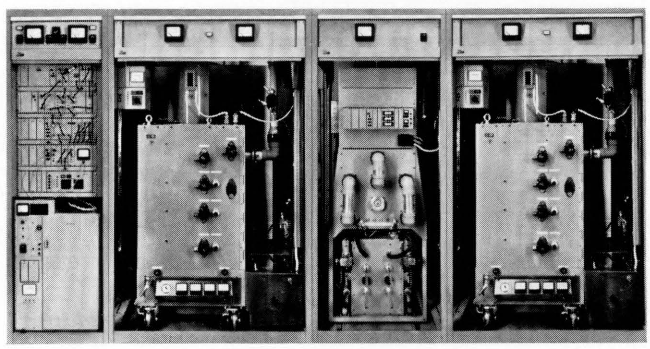

Figure 2 - The 40/8-kilowatt television transmitter (front row only — from left to right): vision/sound driver stage, klystron vision amplifier, combining unit, and klystron sound amplifier.

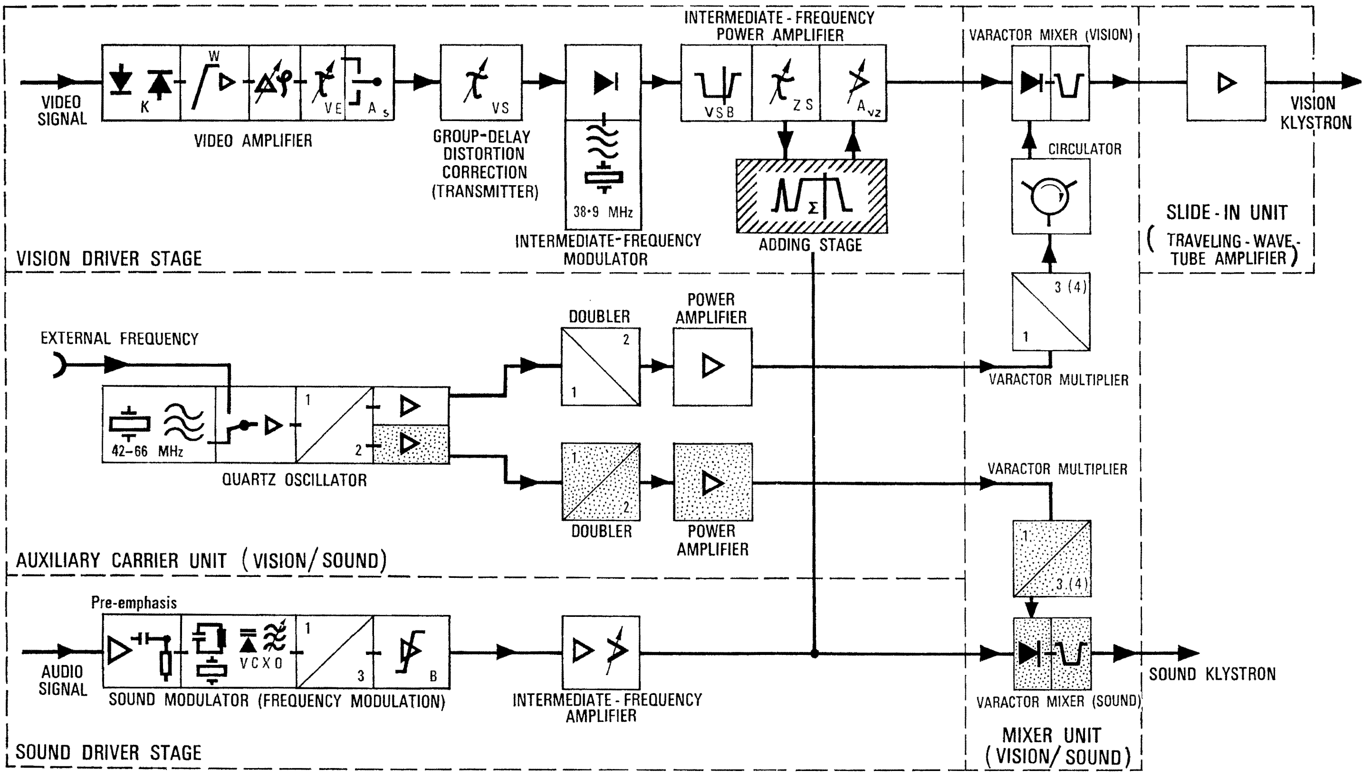

Figure 3 - Block diagram of the vision/sound driver stage.

possible to assemble different types of transmitters. As an example, a brief description is given of two Band-IV and -V (470 to 860 megahertz) transmitters for 10- and 40-kilowatt vision output, corresponding to 2- and 8-kilowatt sound output (10/2-kilowatt and 40/8-kilowatt types).

3.1 Design

The transmitters consist of the following basic units.

- Vision/sound driver stage.
- Klystron vision amplifier.
- Combining unit.
- Klystron sound amplifier.
- High-voltage unit (common for vision and sound klystrons).
- Cable distribution rack (feed and distribution of the mains supply to the individual basic units).

Figure 1 shows the design of the 10/2-kilowatt transmitter and Figure 2 gives a general view of the arrangement of the high-frequency part of the 40/8-kilowatt transmitter.

3.1.1 10/2-kilowatt Transmitter

The air-cooled 10-kilowatt klystron amplifiers (identical for vision and sound) are fitted with four-cavity klystrons Type *YK 1001*. The klystrons, designed for permanent-magnet focusing, are operated in the "depressed-collector" mode for improved electrical efficiency.

The equipment, including the combining unit and the 10-kilowatt power-supply, is designed for forced-air cooling. Pressure and ventilator fans are separate from the transmitter. The entire frontal length of the complete 10/2-kilowatt equipment is 4·1 meters (13·5 feet) with a rack height of 2·15 meters (7 feet). The mains supply is designed for three-phase operation and the mains power consumption of the equipment is approximately 45 kVA.

3.1.2 40/8-kilowatt Transmitter

The 40/8-kilowatt transmitter (see Figure 2) uses two-row installation because of the dimensions of the high-voltage equipment supplying the klystrons. The cable distribution rack and the high-voltage supply are accommodated behind the actual transmitter. Apart from these two units the general layout is similar to that of the 10/2-kilowatt transmitter.

Vapor-cooled 40-kilowatt klystron amplifiers (identical for vision and sound) and four-cavity klystrons (Type *3017*) are used. Focusing is by electro-magnetic means.

Air, vapor, or water cooling is provided for the entire equipment; the vision and sound klystrons have a common cooling-water circuit. The power cavities of the klystron (third and fourth cavities) and the 40-kilowatt combining unit are air cooled. The cooling equipment (fan and heat exchanger for condensing the water vapor) is separate from the transmitter.

The frontal length of the high-frequency part of the 40/8-kilowatt transmitter is 4·06 meters (13 feet), that of the high-voltage supply, including the cable distributor rack (back row), is 3·6 meters (11·8 feet). The power consumption of the entire equipment is approximately 200 kVA.

4. Essential Components and Their Effect on Layout

The basic components of the vision and sound driver stages and the combining unit have a decisive influence on the general layout of the equipment. They permit a reduction in the overall size, simplification of design and production, and an increase in the operational reliability.

4.1 Vision/Sound Driver Stage

The vision/sound driver stage is the heart of the new transmitter development. Vision and sound signals are processed on the intermediate-frequency principle corresponding to the specified television standard. After conversion to the output frequency, amplification increases the signal amplitude to the level necessary for driving the klystrons.

The intermediate-frequency modulation principle uses semiconductors for both vision and sound equipment. This produces a small, versatile unit with a wide field of applications.

The individual functional parts of the unit are housed in cassettes fitted to ISEP slide-in chassis carriers. These functional parts, shown in the simplified diagram Figure 3, are described below.

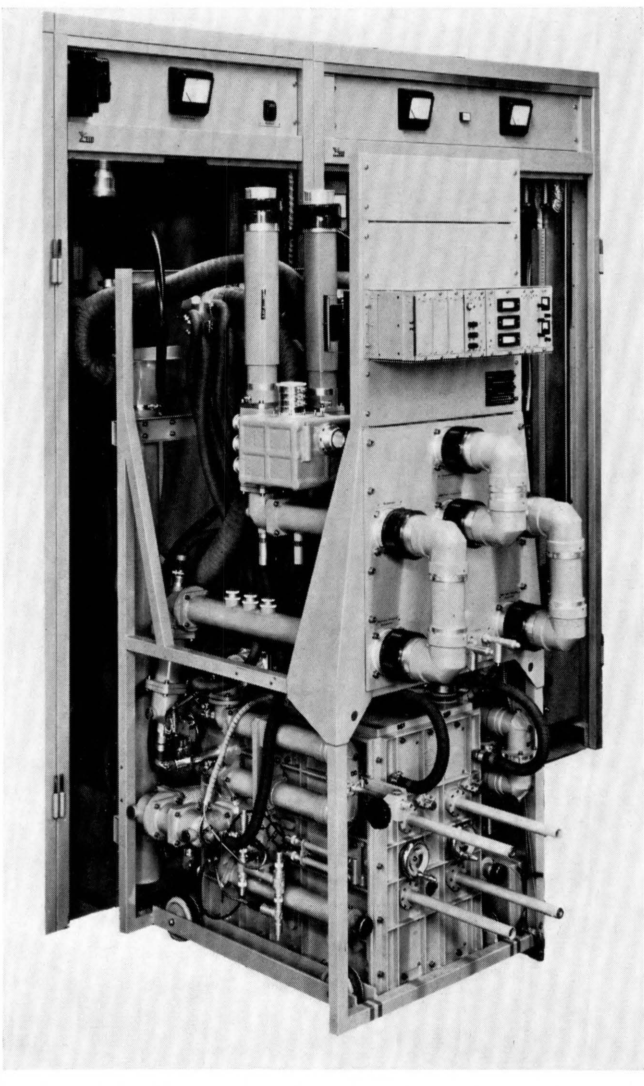

Figure 4 - 40/8-kilowatt combining unit.

4.1.1 Vision Driver Stage

The vision driver stage contains all the equipment required for processing the video signal, such as the amplifier, group-delay correction unit, phase-and-amplitude-correction unit, modulators for frequency conversion, sideband limiters, and so on.

Depending on the actual requirements, signal processing takes place partly at the video frequency, and partly at the intermediate-frequency level.

The video signal to the transmitter input undergoes the following consecutive processes in the vision driver stage.

In the video-amplifier cassette:

- black level definition by clamping K of the back porch of the video signal without affecting the "burst" signal,
- white limitation W to prevent excessive picture-content levels for frequencies below 500 kilohertz (prevention of noise in the audio channel) and also to indicate when signals drop below the threshold value,
- adjustable correction $\Delta\varphi$ of the differential phase to compensate for phase changes which mainly occur in the klystron amplifier and are amplitude-dependent (correction of color transmission errors within the transmitter),
- switched group-delay distortion τ_{VE} to compensate for receiver group-delay distortion, and
- automatic switching A_S of the vision transmitter to the black level to determine the transmitter output power and to maintain sound transmission in the event of insufficient video signal.

The transmitter group-delay-distortion correction cassette provides:

- group-delay distortion correction τ_{VS} for compensating any group-delay distortions originating in the transmitter.

The vision intermediate-frequency-modulator cassette provides:

- formation of the modulated intermediate frequency by a ring modulator via the intermediate frequency auxiliary carrier; the latter is provided by a high-stability quartz oscillator with electronic temperature control better than 1 part in 10^7 per month from 10 to 40 degrees Celsius.

The intermediate-frequency power amplifier provides:

- standardized vestigial-sideband band limitation at intermediate frequency using a passive vestigial-sideband filter,
- group-delay distortion correction τ_{ZS} at intermediate frequency for the individual sidebands within the range of double-sideband transmission, and
- amplitude compensation A_{VZ} at intermediate frequency to correct the non-linear amplification of subsequent output-frequency amplifiers, in particular the klystrons.

4.1.2 Sound Driver Stage

The sound driver stage contains all the equipment for processing the audio signal, such as amplifiers, frequency modulator, frequency multiplier, amplitude limiter, and so on.

Processing the audio signal at the intermediate frequency has the advantage, similar to the processing of the video signal, that the units and adjustments in the sound chain (transition from audio to intermediate frequency) do not have to be adjusted when the transmitter output frequency is altered.

The audio-frequency signal fed to the transmitter chain undergoes the following consecutive processes in the sound chain (Figure 3).

In the sound modulator cassette:

— amplification and matching of the symmetrical input signal to the subsequent asymmetrical circuit and preemphasis,
— conversion of the audio signal into a frequency-modulated signal by means of a voltage-controlled quartz oscillator *VCXO* at 11·13 megahertz (frequency stability better than 1 part in 10^5 per month at temperatures between 10 and 40 degrees Celsius),
— frequency tripling to the sound intermediate-frequency carrier of 33·4 megahertz,
— amplitude limitation *B*.

In the intermediate frequency cassette:

— level adjustment of the frequency-modulated sound intermediate-frequency signal for controlling the final-stage sound mixer in the vision/sound mixer unit.

4.1.3 Auxiliary Vision/Sound Carrier Unit

In the auxiliary vision/sound carrier unit the auxiliary carrier undergoes frequency multiplication, starting from an overtone quartz crystal of 42 to 66 megahertz with electronic temperature control. With the aid of this auxiliary carrier, which is identical for the vision and sound chains, the final output frequencies of the vision and sound transmitters are formed via the vision or sound mixer (see Figure 3).

To change the transmitter output frequency, only the unmodulated auxiliary carrier frequency has to be altered. This is done by changing the quartz crystal and retuning the first doubler and subsequent amplifier. The second doubler and power amplifier are continuously tunable over the auxiliary carrier frequency range, 500 to 900 megahertz. The intermediate-frequency units and their associated functions that determine the form and quality of the signal remain unchanged. Thus we see the advantage of using the intermediate-frequency principle.

A radio-frequency socket in the quartz-oscillator cassette between the quartz crystal and the amplifier is a feed in for an external frequency. When an external feed is used, the quartz oscillator is switched off.

Processing of the auxiliary carrier takes place, as shown in Figure 3, in the following sequence.

The quartz oscillator cassette provides:

— generation of 42 to 66 megahertz with a frequency stability equal to 1 part in 10^7 per month from 10 to 40 degrees Celsius,
— quartz-crystal changing facilities for changing transmitter output frequency,
— amplification of the generated oscillator voltage and if necessary feed in of an external frequency,
— frequency doubling and provision for driving two separate amplifiers, and

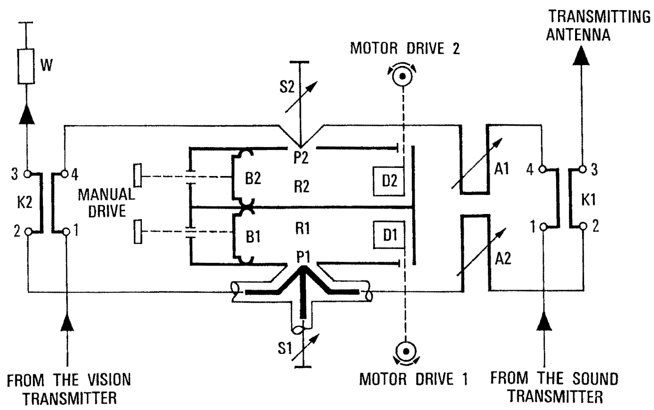

Figure 5 - Schematic of vision/sound combining unit.

— retuning when changing the transmitter output frequency.

The doubler cassette provides:

— further frequency doubling for the two subsequent amplifier chains, and
— retuning facilities for changing the transmitter output frequency.

The power amplifier provides:

— amplification to a level of approximately 15 watts for separate modulation of the varactor multipliers in the vision/sound mixer unit, and
— retuning facilities for changing the transmitter output frequency.

4.1.4 Vision/Sound Mixer Unit

In the vision/sound mixer unit the vision- or sound-modulated intermediate frequencies of 38·9 or 33·4 megahertz respectively, create, by subtractive mixing in two identical push-pull varactor mixers with the auxiliary carrier output frequency, the final vision or sound frequencies. A band-pass filter is provided at the output of each mixer to filter out the transmitter output frequencies.

The vision and sound output frequencies are produced in the following cassettes of the mixer unit.

For the vision chain:

— varactor multiplier,
— circulator, and
— varactor mixer, vision.

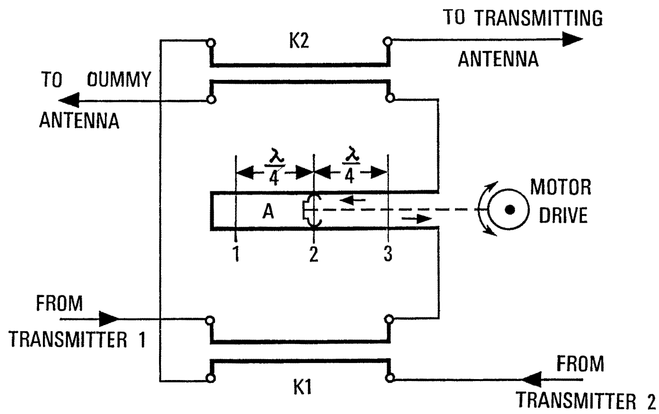

Figure 6 - Schematic of parallel transmitter operation.

And for the sound chain:
- varactor multiplier, and
- varactor mixer, sound.

4.1.5 Traveling-Wave-Tube Amplifier

A traveling-wave-tube amplifier is connected between the vision-mixer output and the vision-klystron input, and is an air-cooled permanent-magnet-focused tube (Type *YH 1020*).

The tube and associated power supply are combined in one unit and can be withdrawn from the vision/sound-driver-stage rack. The power supply is covered by a mechanical interlock.

4.1.6 Mechanical Construction

The individual assemblies are accommodated in slide-in chassis (ISEP design) which are arranged one below the other in a standard rack in the following order:

— auxiliary carrier unit — mixer unit — vision driver stage unit — sound driver stage unit	comprising interchangeable cassettes of solid-state design
— control panel	for separate switching of vision and sound signals
— traveling-wave-amplifier unit	for amplifying the vision signal to the level required for driving the vision klystron

All cassettes concerned with the processing of the signals, including the low-voltage supply units (also in cassette form), are located in individual rows of the ISEP slide-in chassis. The alternating-current mains voltage is fed to these units as a 40-volt single-phase supply. The supply to the individual cassettes (alternating or direct current) takes place via ISEP knife-blade contact strips.

4.2 Combining Unit

Among the newly developed basic components the combining unit is of importance. A typical unit is shown in Figure 4. The purpose of the unit is to feed output power from the vision and sound transmitters to a common antenna whilst isolating the sound and vision transmitters from each other. This unit was designed for outputs of 50/10-kilowatts, and a continuously tunable frequency range from 470 to 860 megahertz with automatic trimming correction. The resonators and coaxial power lines of the combining unit are forced-air cooled.

4.2.1 Electrical Design and Operation

The vision/sound combining unit comprises basically the following radio-frequency components (Figure 5):
- two 3-decibel couplers *K 1* and *K 2* at the vision and sound inputs,
- two stub lines *S 1* and *S 2*,
- two line stretchers *A 1* and *A 2*,
- two tunable waveguide resonators *R 1* and *R 2* combined into one block, and
- one resistive load *W*.

To achieve the shortest possible lengths of lines and the smallest possible size of equipment, the first four units are arranged closely around the resonator block whilst the load *W* is fitted at the rear of the frame rack.

The sound transmitter energy, fed in at *1* on the 3-decibel coupler *K 1*, is divided into two equal-energy paths which have their exits at *2* and *4* connected by line stretchers *A 1* and *A 2* to *P 1* and *P 2*, respectively. At these points *P 1* and *P 2* there is virtual total reflection because the resonators *R 1* and *R 2*, tuned to the sound frequency, represent a short-circuit at that point. If the lengths of the line stretchers are correctly adjusted, the energy leaves at *3* on the 3-decibel coupler *K 1* and passes through the control board to the antenna. A small, unreflected proportion of the energy passes via the 3-decibel coupler *K 2* into the load *W*.

Likewise the vision-transmitter energy fed in at *1* of coupler *K 2* is divided and flows virtually without losses (the resonators are detuned for the vision frequency) via the 3-decibel coupler *K 1* to the antenna. Any reflected energy being absorbed in *W*.

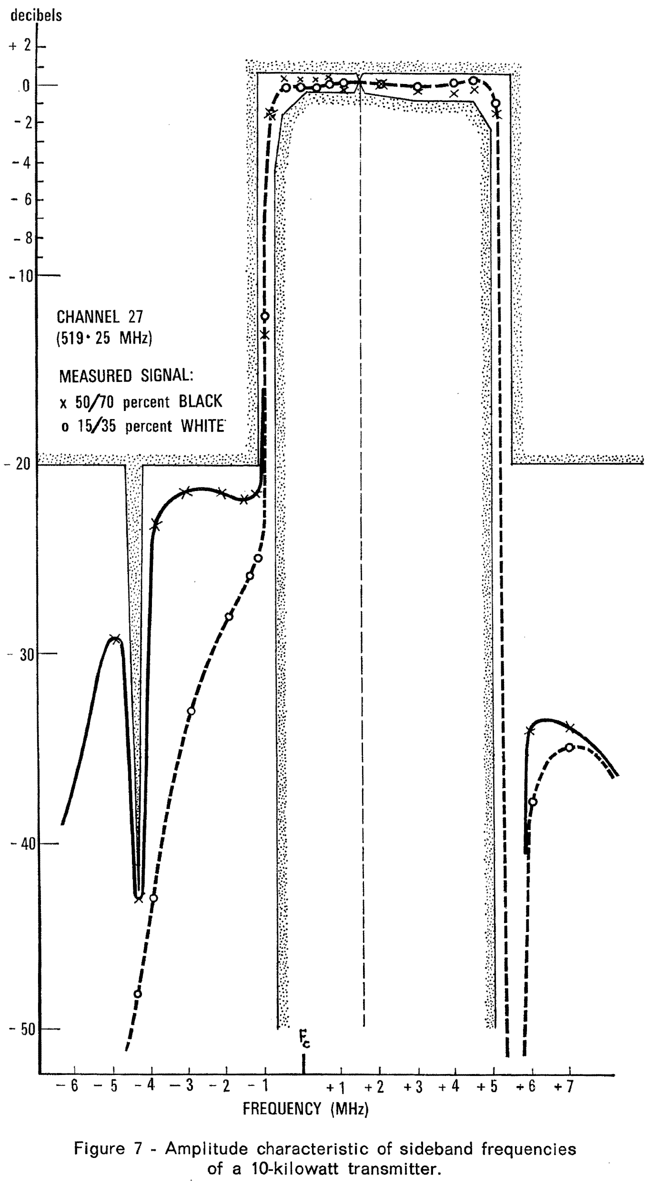

Figure 7 - Amplitude characteristic of sideband frequencies of a 10-kilowatt transmitter.

The stub lines $S\,1$ and $S\,2$ are provided for matching the input of the coupler $K\,1$.

The resonators are short-circuited, rectangular waveguides, coarse-tuned by manually shifting the walls $B\,1$ and $B\,2$ with the aid of spindles.

The fine tuning, or the automatic retuning of the resonators when their temperature rises, is accomplished by dielectric tuning. Rotating the rectangular ceramic plates $D\,1$ and $D\,2$ in the electric field affects the frequency of the resonators. The shafts of the plates are rotated by slow-running indexing motors controlled automatically by a discriminator circuit.

The resonators are coupled to the coaxial lines at $P\,1$ and $P\,2$ by a hole in the outer wall of the resonators through which the inner core of the coaxial line protrudes into the hollow space of the resonator.

Due to their very high Q (approximately 20 000), reactive powers of up to 10^6 volt-amperes can occur in the resonators during operation.

The 40/8-kilowatt combining unit differs from the 10/2-kilowatt design only in the cross section of the coaxial lines.

5. Further Transmitter Types

The versatility of design of the 10- and 40-kilowatt transmitters make it possible to assemble special types to meet other market requirements.

If, at some point in the transmitter chain (at a non-critical point in the intermediate-frequency chain of the vision/sound driver stage), the vision and sound channels are combined so that the subsequent stages operate as combined amplifiers, a combining unit will not be required.

5.1 Miniature Transmitter, 10/2 or 50/10 watts

In Figure 3 the vision intermediate frequency at the output of the vestigial-sideband filter is shown combined with the sound intermediate frequency in a special cassette known as the adding stage. In this semiconductor stage the two channels are added and further amplified in the linear amplifier A_{vz}. In the adjacent mixer both channels are converted to the output frequency (2-channel operation).

The mixer and the subsequent traveling-wave-tube amplifier operate as a combined amplifier. With this system the number of cassettes in the vision/sound driver stage can be reduced by the functional units shown shaded in the diagram.

5.2 2/0·4-kilowatt Transmitter

By adding a 10-kilowatt klystron amplifier and the appropriate power supply we obtain, from the modified unit described in Section 5.1, a three-rack 2/0·4-kilowatt transmitter.

5.3 Further Combinations Using Parallel Operation

In contrast to previous operational practice there is now a trend towards operating complete transmitter chains in passive standby or, with the exception of the driver stage, in parallel. In the latter case the driver stage operates as a passive standby.

With this latter method, the transmitters, designed for the full rated power, are operated with half the output power by reducing the high voltage (a comparatively easy matter in the case of klystron amplifiers). For example, the rated power of 10/2 kilowatts is obtained by adding the power of two transmitter chains having an output of 5/1 kilowatts each operating in parallel. The high-voltage supplies can be switched over within a very short time from reduced power to full power, and vice versa, without affecting transmission.

This method of operation offers the following advantages.

- Avoidance of breaks caused by the switching off or switching back of amplifier stages.
- Prolongation of the working life of the final stage amplifiers now working at half power.
- Continuation of program even in the event of failure of one transmitter chain.
- Achievement of the full-rated output in the event of failure of one transmitter chain by switching to full high voltage on the functioning transmitter within the shortest possible time. The faulty transmitter chain can then be repaired in safety while the program continues on the other.

In view of the fact that both transmitter chains permit full operation at the rated power, it is of course possible to obtain output powers of 20/4 kilowatts and 80/16 kilowatts with this combination if required on special occasions.

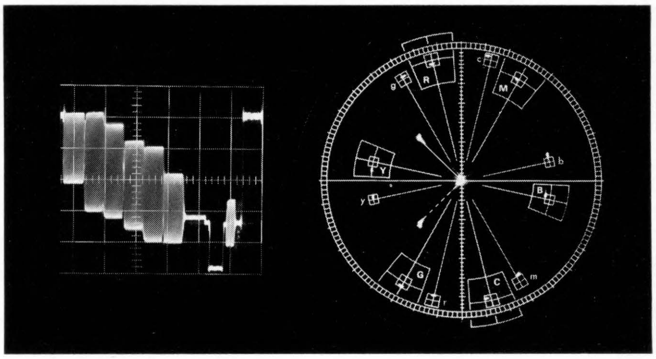

Figure 8 - Composite video with chrominance signal at the transmitter input.

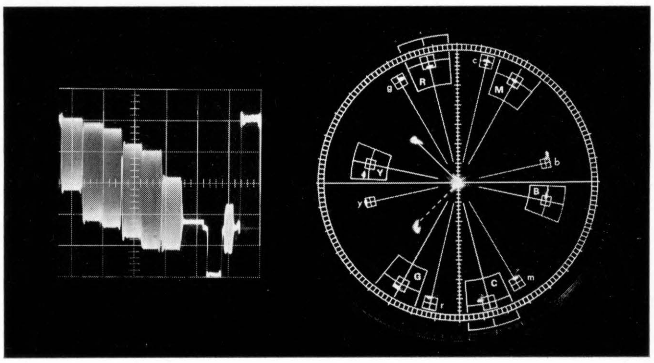

Figure 9 - Composite video with chrominance signal at the transmitter output.

The parallel connection method is accomplished by means of a network whose basic circuit is shown in Figure 6. This contains two 3-decibel couplers $K\,1$ and $K\,2$ and one line stretcher A.

Both transmitters work into the operating antenna on the adjustment of line A to position 2, or only one transmitter works into an operating antenna and the other into a dummy antenna for positions *1* or *3*, respectively.

If the transmitters radiate different powers, for example, due to different aging rates of the output amplifier tubes, the line stretcher can be adjusted so that all the available power is fed into the antenna. The line stretcher can be either manually or automatically operated.

6. Transmission Properties

The transmission characteristics of a television transmitter depend on the fulfilment of a large number of measurement and test requirements which are laid down in the transmitter specifications.

Figure 7 shows the amplitude characteristic of the sideband frequencies (transmission characteristic) when the transmitter is fully modulated for *white* and *black*, measured at the output of the vision transmitter.

Figures 8 and 9 show oscillographs of the composite video with chrominance signals at the transmitter input and transmitter output. The pictures were taken with a vectorscope.

The hues of the individual colors are virtually unchanged in the course of transmission. Minute phase deviations of the color vectors with the color burst (zero phase) remain within the permissible tolerance range.

7. Conclusion

By using modern circuit techniques and components the design concept for television transmitters has been up-dated. A new range of equipment based on a "building block" concept provides a flexible range of equipment suitable for different power outputs, for both monochrome and color operation, and for differing international standards.

The new range of transmitters will operate more reliably with reduced and safer maintenance procedures.

References

[1] E. Heinecke and H. Hornung: The Feldberg (Taunus) 10 kW Television Transmitter Installation A. Picture and Sound Transmitter, SEG Nachrichten, volume 1 (1953) no 4, pp 3—4.

[2] Deutsche Bundespost (German Post Office) Specification for television transmitter installations, frequency range 470—790 MHz with over 0·2 kW power. Edition 3, Dezember 1960: Edition 4 of 1964. Specifications of the Association of German Broadcasting Institutions.

No. 5/1 UKW FM Radio Transmitter, Edition 1 of 1st December 1956.

No. 5/21 Television Picture Transmitter, Edition 1 of May 1958.

No. 5/22 Television Picture Transmitter Monitoring Equipment, Edition 1 of May 1958.

No. 5/3 Television Sound Transmitter in Bands I and III, Edition 2 of 1st December 1956, supplement of October 1959.

[3] A. Kolarz and A. Schweisthahl: High-power Television Transmitter for Bands IV/V (Haardtkopf), Rundfunktechn. Mitt. no 3 (1959), volume 1, pp 29—39.

E. Heinecke and H. Hornung: Television Transmitter for Band IV/V with Modulation at Fixed Intermediate Frequency, SEL Nachrichten 9 (1961), volume 1, pp 1—5.

[4] H. Hornung and H. Wagenlehner: Television Transmitter for the 470 to 790 MHz Frequency Range with Modulation at Fixed Intermediate Frequency using Tetrodes, SEL Nachrichten 10 (1962), volume 2, pp 61—69.

K. Burwick, H. Gehrke and W. Nagel: Intermediate Frequency Processing and Monitoring in Television Transmitters with Modulation at Fixed Intermediate Frequency, SEL Nachrichten 10 (1962), volume 2, pp 77—85.

P. Klopf: Modulation of Television Transmitters in the Intermediate Frequency Range, Rundfunktechn. Mitt. no 5 (1961), volume 2, pp 79—87.

[5] H. Neumann and H. Wagenlehner: RF Output Stages for Telecommunication Transmitters in the 470—790 MHz Frequency Range, SEL Nachrichten 10 (1962), volume 2, pp 85—91.

[6] H. Gehrke: Television Transmitters for Black-and-White and Color Transmission, Elektro-Jahrbuch 1965, pp 149—155. AG für Verlag und Druckerei (Publishing and Printing Company), CH-9403 Goldach.

[7] W. Dahlke, R. Maurer and J. Schubert: Theory of Diode-Reactance Amplifier with Parallel Circuits, AEÜ 13 (1959), volume 8, pp 321—340.

100 typical circuits with semiconductor components published by ITT Intermetall (semiconductor works of German ITT Industries GmbH, 1967 Edition).

Heinrich Hornung was born in 1903 in Feuchtwangen (MFr.). From 1922 onwards he studied physics in Munich, Wurzburg and Erlangen, obtaining his doctorate in science in 1928. In the same year he joined C. Lorenz AG as a development engineer on high-power transmitters. In 1951 Dr. Hornung was appointed head of the high-power transmitter laboratory in Berlin. He has held the position of head of the Berlin laboratories for radio equipment since 1966.

Gotthard Müller was born in Berlin in 1905. During 1924—1930 he studied communication engineering at the Berlin technical university where he obtained a Dipl. Ing. degree. He continued working there as an assistant, gaining his doctorate in 1933. Dr. Müller joined the AEG research laboratories in Berlin and in May 1935, the navigation laboratory of C. Lorenz AG. From 1938 he was in charge of development of ground-radar equipment and in January 1955 he rejoined the high-power transmitter laboratory in Berlin as a development engineer. He has been head of the development for radio equipment in Berlin since 1963.

Recent Developments in the Manufacture of Soft Ferrites used in Telephone Equipment

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1. Introduction

Modern telephone equipment demands filter circuits with precisely defined frequency bands to allow an increasing number of telephone channels without risk of overlap. For this reason the filter circuits must use inductances that can be precisely adjusted, show high stability in any likely environment, and are repeatable in quantity production. The magnetic materials used for these inductances must satisfy the same criteria. Research must, for a given initial permeability, have regard to these objectives:

— high degree of manufacturing reproducibility for material characteristics,
— improved determination and reduced dispersion of the coefficient of variation of permeability with temperature,
— reduced variation of permeability with time,
— smaller tangent of loss angle, and
— reduced hysteresis loss.

To keep up with developments in the telecommunications industry, existing materials must be improved and new ones created with the same reliability over wider temperature and frequency ranges.

Evolution is towards smaller components. The heat created by smaller components in a compact assembly will mean a higher operating temperature. So as not to curtail the power handling capacity of telephone equipment the qualities of miniaturized components must improve.

The electrical properties of ferrite materials used for this type of application are generally defined by five fundamental properties.

— Initial permeability μ_i measured in a weak magnetic field at a predetermined frequency (usually 100 kHz).
— Figure of merit μQ representing the electrical loss of the material. Q is the inverse of the tangent of the electric-loss angle δ_{r+e} comprising the residual and eddy-current losses.
— Coefficient of hysteresis losses $h\mu^{-2}$.
— Temperature factor TF determined by the variation of permeability between two temperatures T_1 and T_2 where

$$TF = \frac{\Delta\mu}{\mu^2 \Delta T}.$$

— Disaccommodation factor DF determined by the variation of permeability with time t after demagnetization, where

$$DF = \frac{\Delta\mu}{\mu^2 \log \frac{t_2}{t_1}}.$$

Whilst any improvement in electrical quality or stability is welcomed by the circuit designer, provided it is not accompanied by increased cost, it would be of particular value if the material properties could be improved to a degree whereby a given core may be substituted by the next smallest in a standard series, such as the IEC range, without loss of performance. The improvement needed for such a substitution is shown in Table 1.

Table 1 – Material properties.

Material property	Standard condition of measurement	Value of material property: IEC 18 mm pot core existing material	IEC 14 mm pot core target material
μ_i nominal	23° C, 100 kHz, 5 gauss	2250	2250
$\mu_i Q$ min.	23 °C, 100 kHz, 5 gauss	200 000	515 000
TF	1 kHz, 23° –55 °C, 5 gauss	$1 \pm 0{\cdot}5 \times 10^{-6}$	$x \pm 0{\cdot}2 \times 10^{-6}$*
DF max.	1 kHz, 23 °C, 5 to 300 minutes	4×10^{-6}	$1{\cdot}6 \times 10^{-6}$
$h\mu^{-2}$ max.	23 °C, 5 to 25 gauss, 100 kHz	1000	155

* x depends on the compensation requirements and the effective permeability of the gapped core.

In order to attain this objective it is necessary to achieve better control of manufacturing parameters, and to know how variations in those parameters affect the properties of the final product. This is best done by a systematic method of optimizing a defined process, according to predetermined criteria of merit.

The theme of this paper is to describe in detail the scientific approach to this problem and to report on the progress achieved towards this objective.

2. Principal stages in the Manufacture of Manganese Zinc Ferrites

The process shown in Figure 1 is similar to many published processes [1, 2, 3]. Table 2 summarizes the principal stages, their roles, the principal adjustable parameters and methods of analysis used to optimize the process stage.

The relationships between the structural and electrical properties of ferrites have been studied by various authors [4, 5, 6, 7], in particular the variation of initial permeability with temperature and composition [8].

The final compositions sought in the system

$Zn_x Mn_y Fe^{2+}_{1-x-y} Fe^{3+}_{2+\delta} O_{4+\varepsilon}$

correspond to exact stoichiometry when $\delta = \varepsilon = 0$.

Typical compositions of ferrites with low-temperature factors suitable for use with mica or polystyrene capacitors respectively are given below [9].

$$Mn_{0 \cdot 542}\, Zn_{0 \cdot 374}\, Fe^{2+}_{0 \cdot 084}\, Fe^{3+}_{2}\, O_4 \quad (1)$$

$$Mn_{0 \cdot 549}\, Zn_{0 \cdot 395}\, Fe^{2+}_{0 \cdot 056}\, Fe^{3+}_{2}\, O_4 \quad (2)$$

These compositions yield initial permeabilities of 2000 to over 4000 depending on the microstructure and degree of doping of the materials. The stoichiometric compositions possess very small disaccommodation factors since the latter are dependent on the concentration of cation vacancies. The microstructure and the porosity of the specimens have a considerable effect on the properties. The initial permeability increases with the crystal dimensions [6] and hysteresis losses increase when intra-granular porosity is present.

The eddy-current losses depend not only on the microstructure but also, and principally, on the content of ferrous iron. To increase the resistivity of the ferrites, additives are introduced during the preparation, the purpose of which is either to insulate the crystals by diffusion to the grain boundaries during sintering (calcium), or to hinder electronic transitions between Fe^{2+} and Fe^{3+} in the system.

Chemical homogeneity of the ferrite is of prime importance. It has been shown [10, 12] that during sintering a partial volatilization of the zinc leads to a marked deterioration of the magnetic and electrical properties in the surface region of the specimens.

The physico-chemical objectives implied in optimizing the magnetic characteristics of commercial manganese zinc ferrites may be stated as:

— homogeneous stoichiometric composition throughout the specimen with a precise ferrous-iron content,

— crystal microstructure of uniform dimensions (of the order of 10 to 20 microns) with the lowest possible porosity localized at the grain boundaries.

3. Study and Selection of the Starting Products

3.1 *Generalities*

The starting materials must be as pure as possible, taking account of economic requirements, the silica content being particularly critical. Paulus [12] has shown that

Table 2 – Principle stages in manufacturing process

Process stage	Method	Adjustable parameter	Role or Objective	Method of analysis
Starting materials	Selection	Purity reactivity	Pure materials of suitable reactivity	Granulometry, chemical analysis, x-ray diffraction
Additives	Selection	Concentration	To reduce electrical losses (for example, effect of *Ca*)	As above
Weighing	—	Composition	To produce specific electrical properties such as μ_i, *TF*, *DF*	
Mixing	Vibratory milling or fluid - energy milling	Duration, solid/liquid ratio, et cetera	To produce chemical homogeneity	Electron-probe microanalysis, chemical analysis
Calcination	Static or rotary furnace	Temperature, atmosphere, and duration	Partial formation of the ferrite, pre-densification of the particles, homogeneity of the composition	X-ray diffraction, Mossbauer spectrometry, sintering rates
Milling	Vibratory milling	Duration, solid/liquid ratio, et cetera	To produce correct sintering activity	Specific surface by BET method
Granulation	Atomiser	Solid content of slurry, temperatures, air-flow, et cetera	To produce granules of uniform dimensions suitable for pressing	Optical microscopy
Sintering	Continuous or static furnace	Temperature/atmosphere schedule	To produce desired electrical and magnetic properties, density, homogeneous composition and suitable microstructure	Studies of sintering mechanism, electrical measurements, dilatometry, magneto-chemistry, microstructure, electron-probe microanalysis, x-ray fluorescence, neutron diffraction, diffusion studies and chemical analysis.

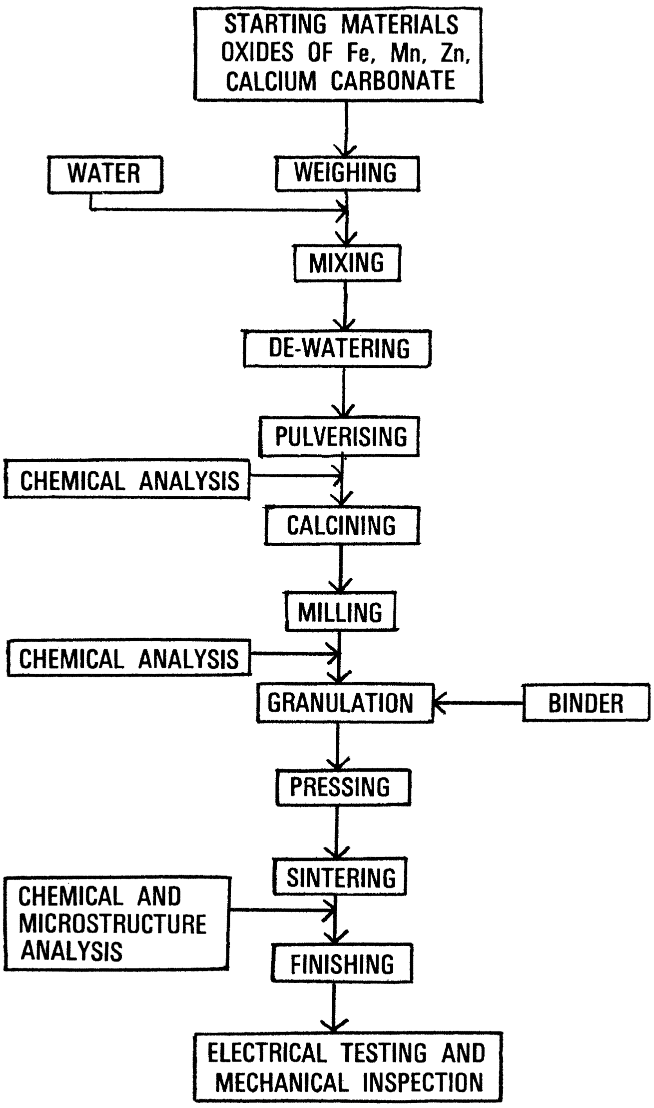

Figure 1 - Flow diagram showing the principal stages in the manufacture of manganese-zinc ferrite.

for silica contents greater than 0·04 percent the growth of the ferrite grains during sintering becomes discontinuous, giving very high hysteresis and eddy-current losses. Similarly, the presence of alkali or alkaline earth metals decreases the permeability considerably.

The shape of the particles, the granular distribution and the specific surface of the starting oxides, are no less important factors since they affect the milling, the reaction kinetics, and the homogeneity of the finished product. It is the totality of these factors which conditions the reactivity of a starting material.

To our knowledge there exists no single quantitative method of measuring this "reactivity" which we have chosen as one of the essential optimizing criteria. To determine it one is obliged to have recourse to the combination of several methods: x-ray diffraction and Mossbauer spectrometry, thermal dilatometry, et cetera.

3.2 *Mechanism of the Formation of Manganese Zinc Ferrite* [14, 15]

At low temperatures the formation of zinc ferrite is ob-

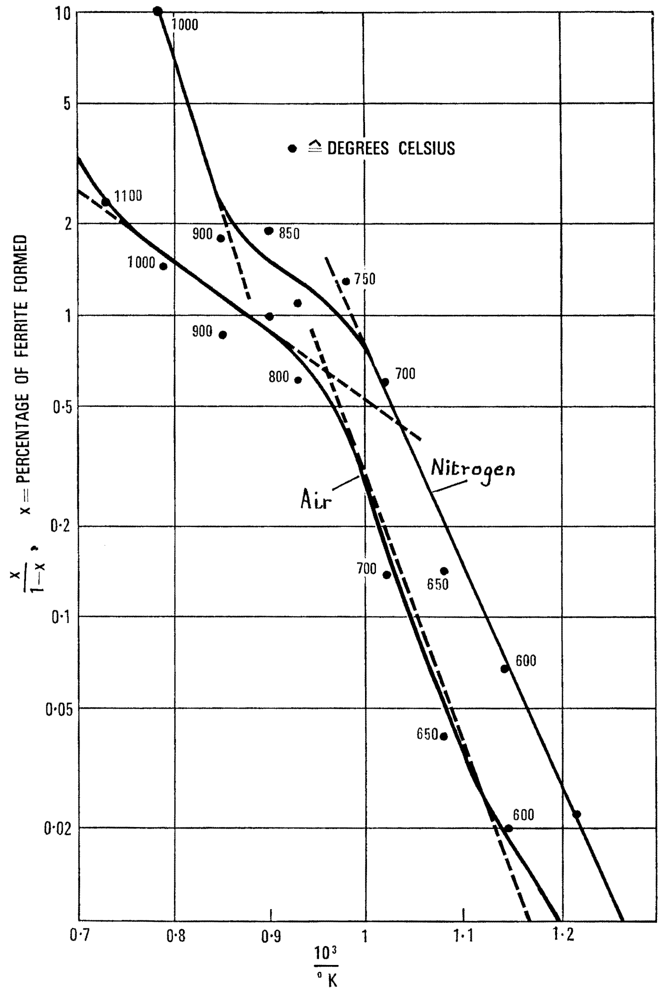

Figure 2 - Arrhenius' relationship between temperature and formed ferrite.

served. The initial temperature of formation of the spinel phase depends only on the oxide of iron chosen. It is 650 degrees Celsius for an oxide of small reactivity, less for an oxide with a large specific surface.

The diffraction spectrum of zinc oxide afterwards decreases progressively and disappears at 800 degrees Celsius. It must be considered that at this temperature the synthesis of zinc ferrite is practically completed. By using an Arrhenius' representation (see Figure 2) it is deduced that the reaction is controlled by a bimolecular process at the grain boundaries (linearity of the curve log $[x(1-x)^{-1}]$ as a function of T^{-1} up to 800 degrees Celsius).

In parallel, the phase Mn_3O_4 disappears progressively from 420 to about 620 degrees Celsius with the appearance of Mn_2O_3. The specific intensity of Mn_2O_3, maximum at 750 degrees Celsius, then decreases to disappear towards 850 degrees Celsius, that is, well before the normal reduction temperature of 920 degrees Celsius. This tends to prove that the oxide Mn_2O_3 enters into solid solution in the zinc ferrite formed initially.

This hypothesis has been confirmed by the study of the Mossbauer spectra of the specimens during synthesis [15]. Whilst zinc ferrite is paramagnetic, the spinel existing below 800 degrees Celsius shows a super-paramagnetic line with a maximum intensity at 900 degrees

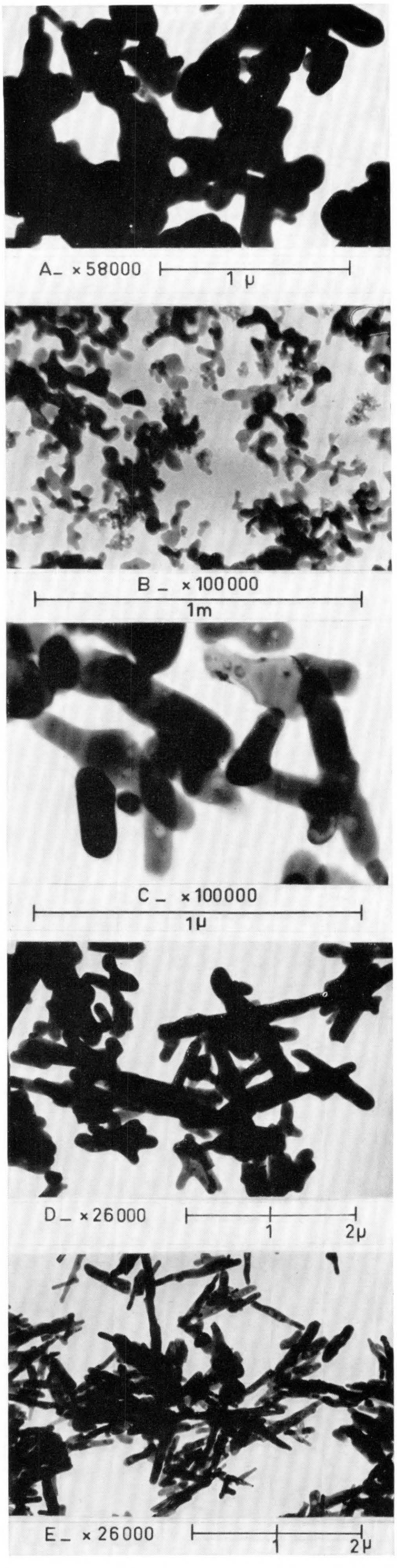

Figure 3 - Electron-microscope photographs showing iron oxides, *A*, *B*, *C*, *D* and *E* (see Table 3).

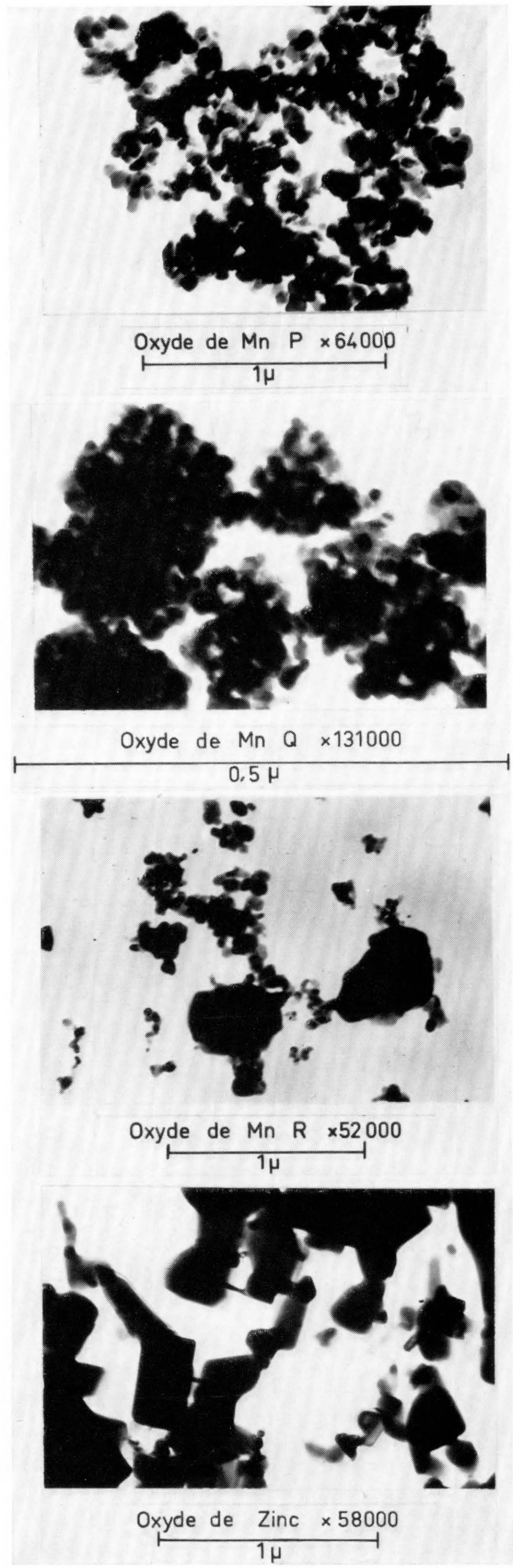

Figure 4 - Electron-microscope photographs showing manganese oxides, *P*, *Q*, and *R* (see Table 4), and zinc oxide.

Table 3 – Principal characteristics of the oxides of iron used

Characteristics	Type of oxide				
	A	*B*	*C*	*D*	*E*
Fe_2O_3 weight percentage	99·5	99·22	99·52	99·2	99·2
SiO_2 weight percentage	0·011	0·005	0·03	0·03	0·03
$Na_2O + K_2O$ weight percentage	0·019	0·0025		0·05	0·05
Particle shape	spherical	complex	rounded needles	needles	fine needles
Mean size of the particles (microns)	0·3	0·09	0·2×0·8	0·5×0·15	0·07×0·2
Specific surface $m^2 g^{-1}$	5·1	26·8	8	3·3	6·1

Celsius due to the short-distance interaction between the iron and manganese ions. Also the quadripolar effect at the level of the iron ions is much higher than in zinc ferrite. Between 850 and 1050 degrees Celsius the amount of ferrite present depends on the solubility of the manganese oxide in the zinc ferrite. Beyond 1050 degrees Celsius the reaction again evolves more rapidly and the Mossbauer spectra show the appearance of the ferrimagnetic phase.

This method allows a quantitive definition of the reactivity index of the oxides to be derived. For oxides of iron it is the temperature at which the spinel phase first appears and for manganese oxides the rates of dissolution in zinc ferrite at 1000 degrees Celsius may be used.

By way of example, we will compare the results obtained with 5 iron oxides and 3 manganese oxides. The characteristics of these oxides are given in Tables 3 and 4, and are complemented by photographs in Figures 3 and 4 taken with the electron microscope.

3.3 Selection of the Iron Oxides

A comparison of graphs showing the percentage of ferrite formed in air as a function of sintering temperature is given in Figure 5. The graphs have been obtained for mixtures of identical initial composition and based on manganese oxide of type *P*. They all show the same general behavior, with a change of slope around 800 degrees Celsius and confirm *a posteriori* the general characteristics previously described. Note the dispersion of the curves at low temperatures. The oxides *B*, *C*, *E* form ferrite below 650 degrees Celsius, but are not completely reacted at 1200 degrees Celsius. These oxides possess the largest specific surfaces and the smallest mean particle dimension. Because of this their reactivity is very high at low temperatures, but decreases above 1100 degrees Celsius since autosintering condenses them into particles less reactive than those found in oxides *A* and *D*.

The oxides which give the best results are those whose specific surface is of the order of 5 $m^2 g^{-1}$.

The essential difference between oxides *A* and *D*, of equivalent specific surface, resides in the shape of the particles. Oxide *A*, whose grains have a spherical shape, allows a better compacting than oxide *D*, whose grains are in the form of needles, and so the quantity of ferrite formed is always greater for oxide *A*.

Table 4 – Principal characteristics of the manganese oxides used

Characteristics	Type of Oxide		
	P	*Q*	*R*
Mn weight percentage	71	71	70·5
SiO_2 weight percentage	0·03	0·005	0·025
$Na_2O + K_2O$ weight percentage	0·004	0·025	0·05
Particle shape	spherical	spherical	spherical parallel-opipedal
Mean dimension (microns)	0·06	agglomerates of particles of 0·05	0·03 to 3
Specific surface $m^2 g^{-1}$	20	22	8

3.4 Selection of the Manganese Oxides

Using iron oxide *D*, the behavior of the manganese oxides *P*, *Q*, *R* has been compared. The results are shown in Figure 6. Up to 800 degrees Celsius manganese oxide does not take part in the formation of ferrite. Oxide *R*, resulting from the calcining of a carbonate at high temperature possesses small reactivity and dissolves to only a small extent in the zinc ferrite. This is shown on the graph by the presence of a level stretch between 800 and 1020 degrees Celsius and by a smaller percentage of mixed ferrite formed at 1200 degrees Celsius.

Oxides *P* and *Q* have substantially the same specific surface, 20 $m^2 g^{-1}$, but the second oxide is formed by agglomerates of particles limiting the breaking up of Mn_2O_3. A smaller intensity of spinel phase is observed up to 975 degrees Celsius. At higher temperatures the reactivities of the oxides are, however, sufficient to allow ferrite synthesis at 1200 degrees Celsius.

3.5 Selection of the Zinc Oxides

Most commercial products give similar chemical analyses and reactivities which do not need discussion here.

3.6 Electrical Properties of the Ferrites Obtained Starting from Selected Oxides

The selected oxides show a total impurity content

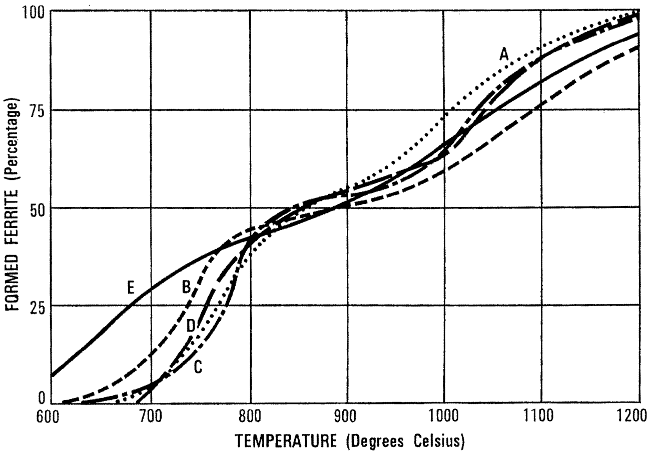

Figure 5 - Influence of iron oxide on the kinetics of formation for mixed manganese-zinc ferrites.

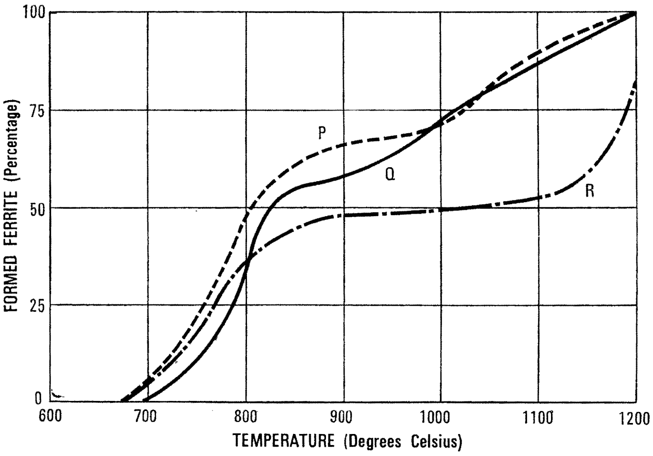

Figure 6 - Influence of manganese oxide on the kinetics of formation for mixed manganese-zinc ferrites.

which is sufficiently low and a high-enough reactivity to obtain a homogeneous product during presintering and sintering.

Typical results [9] obtained from selected materials are given in Table 5.

All compositions have an addition of CaO and correspond to Equation (2). The measurements were carried out on toroids of 35-millimeters external diameter.

Table 5 shows that by studying the physical and chemical properties of the starting materials good results can be obtained, and that it is possible to predict whether or not a new oxide will provide them.

Table 5 – Results from selected starting materials

Criteria and Conditions	μ_i 23 degrees Celsius, 5 gauss, 100 kHz	$\frac{h10^6}{\mu_i^2}$ 5 to 25 gauss, 100 kHz	$\frac{\tan\delta}{\mu_i}\cdot 10^6$ 5 gauss, 100 kHz	$\frac{\Delta\mu}{\mu_i^2}\cdot\frac{10^6}{\log\frac{t_2}{t_1}}$ 5 to 300 minutes
Target values	2250 nominal	< 1200	< 5	< 4
Mixture BP	2790	400	3·4	1·2
Mixture AP	2890	500	4·2	1·6
Mixture BQ	2780	490	4·8	1·1

4. Study of the Homogeneity of the Initial Mixture

To obtain good chemical homogeneity in the sintered ferrite, it is necessary to optimise the homogeneity of the mixtures from the initial stage of manufacture. To measure homogeneity quantitatively it is first necessary to define a precise criterion of homogeneity. To our knowledge this has not been done before.

The local concentrations of elements (Mn, Zn, $Fe\ldots$) have been determined using an electron-probe microanalyser, the resolution of which corresponds substantially to one cubic micron. The approximately gaussian distribution curves of the different elements making up the mixture can be determined, and the standard experimental deviations σ of composition deduced by scanning the specimen with an electron beam.

In addition, the standard deviation σ_0 for a perfectly homogeneous specimen can be calculated theoretically, knowing that there exists only a limited number of particles which can be analysed simultaneously by the microanalyser. Table 6 gives the calculated values of σ_0.

Table 6 – Calculated values of σ_0

Mixture	Code	Percentage metal in the mixture	Mean dimension of the particles in microns	σ_0
Fe_2O_3	B	47	0·09	1·22
MnO_x	P	13	0·06	0·75
ZnO	–	11	0·08	1·40

The efficiency of mixing, or criterion of homogeneity, is then defined by the ratio, σ_0/σ, which varies between 0 and 1, tending towards 1 as the mixture becomes perfectly homogeneous. Table 7 and Figure 7 compare the efficiencies of mixing of the principal elements, using on the one hand, a rotary ball mill, and on the other a vibratory ball mill.

Table 7 – $\frac{\sigma_0}{\sigma}$ as a function of the conditions of mixing

Mill type	Rotary ball mill	Vibratory ball mill				
duration (hours)	4	2	4	6	8	12
Fe	0·166	0·268	0·660	0·83	0·920	0·976
Mn	0·153	0·227	0·468	0·59	0·653	0·682
Zn	0·445	0·538	0·918	0·93	0·849	0·667

Mixtures obtained with a vibratory mill are more homogeneous than those obtained with a ball mill for a given milling time. Figure 7 shows that the homogeneous distribution of iron approaches the theoretical limit, whilst that of manganese improves more slowly. The distribution of zinc deteriorates after a duration of about 6 hours, the particles tending to reagglomerate. It is clear that the optimum duration of mixing is 6 hours in this case. The electrical properties resulting from an optimum mixture are improved, as shown in Table 8, which relates to a starting composition of 49·4 percent by weight Fe, 12·4 percent Mn, 10 percent Zn and a different vibratory mill for which the optimum mixing time was shown to be 4 hours.

Table 8 – Electrical properties for different mixing times

Electrical properties	Mixing time in hours				
	1	2	4	8	12
μ_i	2335	2545	2852	2677	2850
$\mu Q.10^{-3}$	338	347	437	374	189
$\frac{h}{\mu^2}\cdot 10^6$	324	260	177	665	1015
DF	1·45	0·71	1·08	1·62	0·37

It will be noted that the hysteresis and eddy-current losses are the most sensitive to the degree of homogeneity reached.

Elements added in small quantities like Ca, cannot have their distribution calculated according to the previously described method. X-ray images taken at the microanalyser have shown, however, that the distribution became uniform after about 8 hours of vibratory milling.

5. Presintering

This intermediate stage of manufacture aids granulation of the material and the automatic pressing of cores into complex shapes. It prevents excessive shrinkage and cracks in the course of the final sintering. Presintering should maximize the homogeneity of composition (a spinel phase instead of three oxide phases), and should finish before the grains have grown or hardened to an exaggerated extent. The reaction mechanisms of the presintering, whether carried out in air or nitrogen, are identical, as shown in Figure 2 by the parallelism between the two curves for the same activation energy.

A difference of the order of 100 degrees Celsius is, however, seen between the two types of treatment for the same percentage of spinel phase formed. To avoid the hardening and the growth of the grains, it is important that the percentage of ferrimagnetic phase should not have evolved too much at the expense of the intermediate phase in which the manganese ions are in the dissolved state. Here therefore is found the importance of the choice of atmosphere and of the oxides, MnO_x in particular, the best results being obtained for mixtures giving, at about 1000 degrees Celsius in air, the highest content in superparamagnetic spinel phase (mixture iron A, manganese P.

The presintered powder can be characterised by its density and its content in residual Fe_2O_3. It is then possible to determine the conditions of presintering leading to equivalent powders. Table 9 summarizes the characteristics obtained for two types of mixture of the same composition.

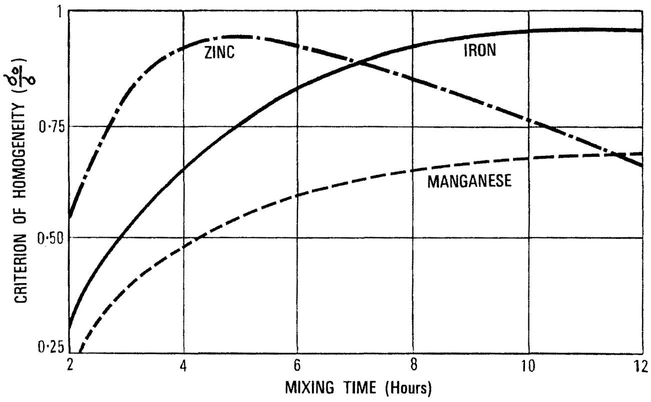

Figure 7 - Homogeneity as a function of time.

6. Sintering

6.1 Generalities

The search for optimum sintering conditions is complex because of the large number of parameters and the multitude of objectives to be realised.

The final ferrite should possess a precise and homogeneous content in ferrous iron, which requires operating under a controlled atmosphere, particularly during cooling. In parallel, the development of a correct microstructure imposes conditions of temperature, atmosphere, and the duration of the sintering. Moreover, to avoid a surface loss of zinc from the cores, it is necessary to operate under an atmosphere which is richer in oxygen as the temperature increases.

Lastly, a higher density is obtained as the percentage of oxygen is smaller at a given temperature and duration [18]. These somewhat contradictary requirements need the adoption of a compromise obtained on the basis of a systematic search covering the principal parameters [19].

The most fruitful methods of study for the optimization of sintering by systematic search for an optimum [19] are:

— thermogravimetric analysis (content of Fe^{2+} and determination of the oxide reduction rates),

— chemical analysis (proportions of the constituents),

— quantitative x-ray diffraction measurements (crystalline parameters, proportion of residual phases),

— x-ray fluorescence spectrometry (zinc losses),

— microanalysis (homogeneity of composition, distribution of the constituents and segregation at the grain boundaries),

— Mossbauer spectrometry (diffusion coefficients of the elements, magnetizations of the sublattices),

Table 9 – Characteristics for two types of mixture

Characteristic	Mixture iron B, manganese P presintered at 1020 degrees Celsius, 10 minutes	Mixture iron A, manganese P presintered		
		at 1050 degrees Celsius, 30 minutes	at 1070 degrees Celsius, 20 minutes	at 1100 degrees Celsius, 10 minutes
bulk density	1·68	1·7	1·72	1·72
pressed density	2·83	2·73	2·73	2·72
percentage of residual Fe_2O_3 (x-ray diffraction)	4	4·2	4·5	4·2

— neutron diffraction, the spectra of which are detectors of stoichiometry and allow the magnetic structure of the sublattices to be determined as well as the degree of inversion of the ferrite [25],

— optical micrography (granule and porosity measurement), and

— electrical measurement (μ_i, μQ, $h\mu^{-2}$, TF and DF).

6.2 Conditions for Obtaining a Stoichiometric Ferrous Ferrite

The required composition is achieved during the constant temperature stage of sintering or soak, for which the most important parameters are the temperature and the composition of the atmosphere. The same content of ferrous iron will be obtained at different temperatures, if the phase rule conditions established by J. M. Blank [20] and reviewed by E. D. Macklen [21] are realized. See Figure 8. That is,

$$\log P_{O_2} \sim k \frac{1}{T°K} + k',$$

where k and k' are constant for a given content of ferrous iron.

Along the same curve $P_{O_2} \sim \frac{1}{T°K}$ the mean dimensions of the crystals and thus the initial permeability are greater as the soak temperature increases. On the other hand the quality factor μQ shows an optimum, for at low temperature the permeability is low and the resistivity high, whilst at high temperature the permeability is high but the growth of the crystals increases the eddy-current losses. This optimum can be sought by arbitrarily fixing a soak time compatible with the use of industrial continuous furnaces.

The results of such an analysis, covering a number of experiments, are shown in Figure 9. It will be noted that the *iso*-μQ curves are substantially elliptical as a function of sintering temperature and of the degree of conversion of excess initial Fe_2O_3 into ferrous iron deduced from phase-rule curves (Figure 8).

6.3 Study of the microstructure

The realization of a correct chemical composition does not of itself allow ferrites with very low losses to be obtained. The microstructure must be regular and the porosity distributed in the grain boundaries. The rates of densification and of crystal growth depend essentially on the following parameters:

— rate of rise of temperature and atmosphere during rise of temperature,

— temperature, atmosphere, duration of the soak, and

— rate of cooling (the atmosphere during cooling is imposed by the conditions of stoichiometry realized at the soak).

With too rapid a rate of temperature increase uneven crystal growth occurs, trapping part of the porosity. A low density and high hysteresis losses result. A temperature rise of 100 degrees Celsius an hour is generally adopted as a compromise between a reasonable cycle duration and a correct growth of density. The soak duration t is dictated by the following requirements:

— maximum time available,

— minimum density to be reached, and

— dimension of the crystals compatible with a sufficient permeability and low losses.

In the absence of discontinuous grain growth created by impurities such as silicon, the mean dimension d of the crystals is given by,

$$d^2 \sim At\left(\exp - \frac{Q}{RT}\right),$$

where Q is the activation energy of migration of the crystal boundaries,

R the gas constant,

t the duration of the soak, and

A a factor dependent on the partial pressure of oxygen [22].

During most of the soak period the pores remain interconnected and the porosity P defined by,

$$P = 1 - \frac{\text{apparent density}}{\text{theoretical density}},$$

varies as $t^{-1/2}$, as can be demonstrated by the rate of density increase,

$$\frac{dP}{dt} = \frac{BD}{d^3T}, \text{ (see Coble [23])},$$

where B is a constant, and

D is the coefficient of diffusion of the vacancies.

Figure 10 shows the experimental confirmation of these results. In practice the optimization of the conditions of

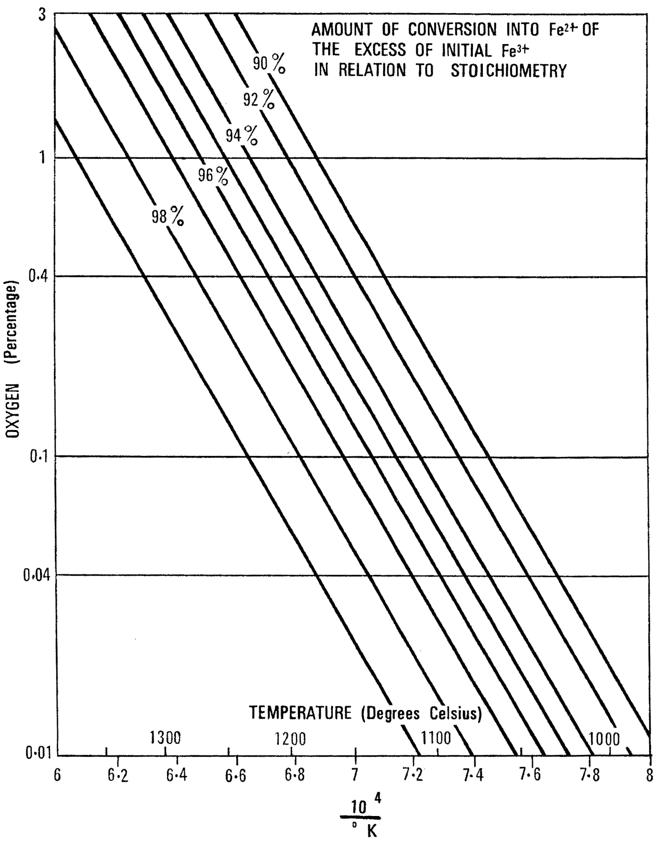

Figure 8 - Atmosphere/temperature curves showing the phase rule according to E. D. Macklen [21].

sintering during the soak will be governed by the following dicta.

— To obtain a given composition necessitates following the particular curve of Figure 8. For each point of this curve there corresponds a soak time leading to the desired crystal dimension.

— Among the various possibilities, the point of operation chosen will be that which leads to the highest final density.

These conditions fix the values of the three principal variables t, T, and percentage O_2 of the soak.

6.4 Homogeneity of Composition of Ferrite

6.4.1 Homogeneity of Distribution of Ferrous Iron

To maintain the state of equilibrium obtained at the soak the partial pressure of oxygen should vary during recooling in accordance with the phase-rule conditions. This requires achieving, and measuring in a precise manner, contents of oxygen which become very low at temperatures below 1100 degrees Celsius. Up to recent years apparatus for proportioning oxygen did not allow an optimum control to be obtained. To avoid too much oxidation the best method was to rapidly cool the specimens after sintering. However, this method has the disadvantage of creating strains which can cause cracks and decrease the permeability of the material. New methods of control of the oxygen content at temperatures as low as 700 degrees Celsius facilitate the maintenance of specimen stoichiometry and allow an amelioration of the cooling conditions. The results obtained by this process show a homogeneous distribution of ferrous iron up to the surface of the specimens.

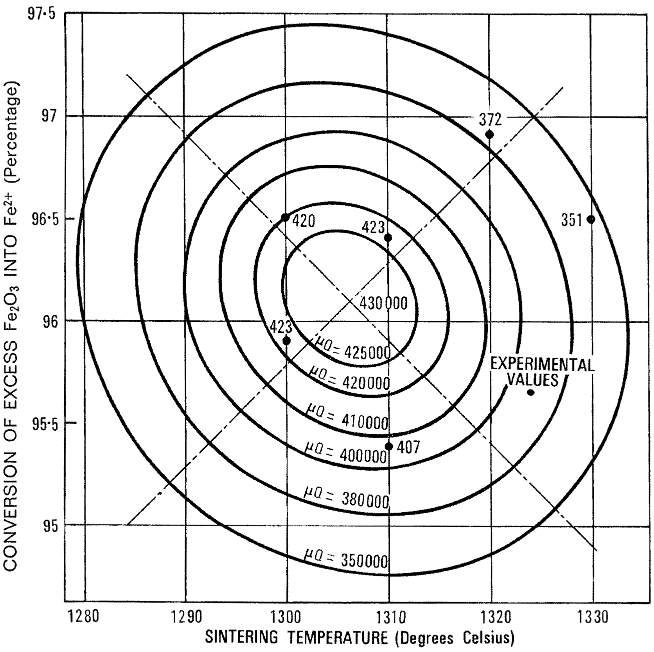

Figure 9 - Iso-μQ curves for various sintering temperatures.

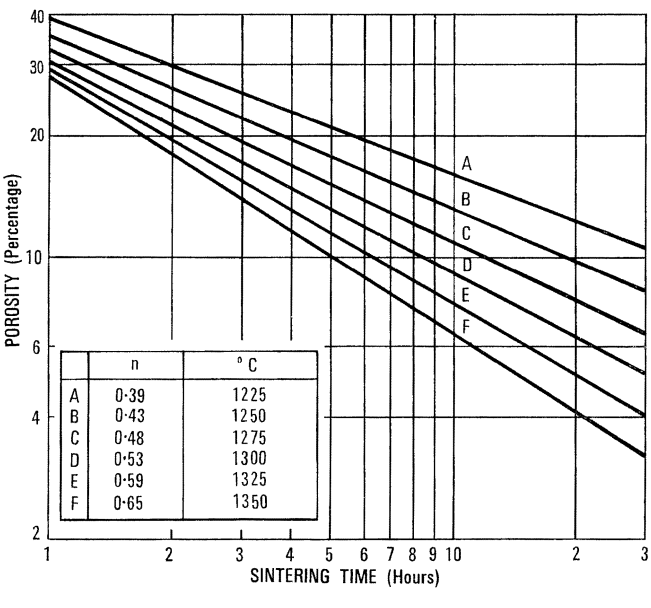

Figure 10 - Relationship between porosity and sintering duration at different temperatures and for a given amount of ferrous iron.

6.4.2 Homogeneity of the Distribution of Zinc

Realization of materials of high permeability ($\mu > 5000$) requires relatively high sintering temperatures ($>$ 1300 degrees Celsius) of long duration, under a reduced partial pressure of oxygen. These conditions favor volatilization of zinc at the surface [11]. A detailed analysis by x-ray fluorescence spectrometry and electron-probe microanalysis has shown that the contours of zinc concentration in the neighborhood of the surface follow the relationship,

$$\frac{C - C_1}{C_0 - C_1} = \Theta\left(\frac{d}{2\sqrt{Dt}}\right),$$

where Θ is the error function and

$$\Theta = \frac{2}{\sqrt{\pi}} \int_0^{\frac{d}{2\sqrt{Dt}}} e^{-V^2}\, dV,$$

given that

C_1 — limiting concentration at surface,
C — concentration at distance d from surface,
C_0 — initial concentration,
t — soak duration time, and
D — coefficient of diffusion of ion-controlling process of zinc loss.

It is then possible to calculate the quantity of zinc evaporated as a function of soak-sintering duration and atmosphere. The losses are inversely proportional to the oxygen content, and directly proportional to the temperature. This volatilization creates in the local neighborhood of the surface a vacancy concentration greater than that resulting from surface forces, causing a considerable decrease of permeability [10]. Moreover, it is no longer possible to obtain the same rate of oxidation in the interior and at the surface, even by modifying the partial pressure of oxygen. Flood and Hill [24] have shown that the ratio of ferric ions to ferrous ions depends on the number of vacancies and the partial pressure of oxygen. Spectrometry measurements carried out show the increase of the content of Fe^{2+} in the neighborhood of the surface in conformity with their results.

The specimen surface then possesses a higher electrical conductivity than the interior, thus lowering the quality factor.

A simple remedy for this deterioration of the electrical

Table 10 – Comparison of electrical results

Condition	μ_i	μQ	$\frac{h\,10^6}{\mu^2}$	$TF\,10^6$	$DF\,10^6$	Density
Laboratory furnace	2300	440 000	300	0·75	0·5	4·7
Industrial furnace	2250	400 000	450	0·70	1·6	4·7
Earlier period	2000	250 000	800	1·2	3·0	4·3

N. B. Standard conditions of measurement apply as for Table 1.

properties is to eliminate the surface zone by abrasion. Unfortunately this process is difficult to apply to complex-shaped cores. It is preferable to eliminate the zinc losses by modifying the composition of the atmosphere during the soak. An initial sintering in oxygen, or in air, permits the development of the desired microstructure whilst avoiding the evaporation of zinc. At the end of the sintering the atmosphere will be changed in accordance with the phase rule to obtain the desired FeO content.

A comparison of the electrical results obtained by the planned optimum method of sintering in a laboratory furnace, and the approximated conditions of sintering in an industrial continuous furnace is shown in Table 10. The samples used for the sinterings were identical in each case. For reference the typical properties of cores made at an earlier period are included to show the general improvement.

With regard to the nominal value of TF, this can be adjusted by predetermined changes in the precise ferrous-iron content of the ferrite and the manganese/zinc ratio, without degrading the other 4 fundamental parameters. The tolerance on TF depends on the uniformity of temperature and atmosphere conditions relevant to the ferrite undergoing sintering in the industrial furnace.

7. Conclusions

All the important process stages for the conventional method of ferrite manufacture have been examined in detail, using the best available analytical techniques. Criteria have been developed by which it has been demonstrated that process parameters can be optimized in terms not only of the physical measurements, but also in terms of the desired electrical properties of the final product.

The facility to change from one raw material to another with appropriate adjustment of process parameters, whilst maintaining the final product within its controlled performance specification, has been demonstrated. This facility provides the customer with a long-term assurance that his supply to a guaranteed performance will not be interrupted in the event of a raw material shortage.

The improvement in electrical properties arising from optimization of homogeneity at the earliest stage of the process has also been demonstrated.

The condition of the presintered powder in terms of physical parameters, together with the facility to adjust process parameters for different raw material combinations has been optimized and sintering schedules have been developed that result in a demonstrable improvement in electrical properties.

Comparison of Table 10, with the target properties shown in Table 1, demonstrates that significant progress has already been achieved towards the major objectives, particularly in respect of μQ, $h\mu^{-2}$ and DF.

8. Acknowledgments

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References

[1] C. S. Brown: Proceedings of the British Ceramic Society, no 2, December, 1964, pp 55—72.
[2] Y. Lescroel and A. Pierrot: Cables et Transmission, no 33, 1960.
[3] D. Swallow and A. K. Jordan: Proceedings of the British Ceramic Society, no 2, December 1964, pp 1—17.
[4] J. W. Proske: Thesis, Pennsylvania State University, 1964.
[5] Y. Shichijo: Transaction JIM, volume 2, 1961, pp 204—210.
[6] C. Guillaud: Proceedings of IEE, volume 104, B, supplement 5, 1957, pp 165—178.
[7] T. Akashi: NEC, Research and Development, no 8, October 1966, pp 89—106.
[8] E. Ross and E. Moser: Z. für angew. Physik, volume 13, 1961, no 5, pp 279—282.
[9] M. A. Strivens: IEE Conference on Magnetic Materials London, September 1967.
[10] M. Paulus and C. Guillaud: Bulletin Société Chimique de France, 1965, pp 1175—1185.
[11] A. Beer and J. Schwarz: IEEE Transactions on Magnetics, volume 2, no 3, September 1966, pp 470—472.
[12] P. Paulus: Physica Status Solidii, volume 2, 1962, pp 1325—1341.
[13] C. Guillaud, B. Zega and G. Villers: Comptes Rendus a l'Academie des Sciences 242, no 19, 1956, pp 2312—2315.
[14] G. Chol and F. Damay: Bulletin de la Société française de Ceramique, no 75, April-June, 1967, pp 61—77.
[15] G. Chol, Y. Gros and J. C. Pebay-Peyroula: Material Research Bulletin, volume 2, 1967, pp 753—764.
[16] K. R. Poole: Proceedings of the British Ceramic Society, no 3, September 1965, pp 43—48.
[17] G. Chol, F. Damay: Journal de Microscopie, to be published.
[18] E. D. Macklen and P. Johns: Proceedings of the British Ceramic Society, no 3, September 1965, pp 223—227.
[19] Wilde: Optimum-seeking methods — Prentice Hall, 1964.
[20] J. M. Blank: Journal of Applied Physics, volume 32, 1961, pp 378.
[21] E. D. Macklen: Journal of Applied Physics, volume 36, 1965, p 1022.
[22] M. Paulus: Physica Status Solidii, volume 2, 1962, pp 1181—1194.
[23] M. L. Coble and T. K. Gupta: Sintering and Related Phenomena, Gordon and Breach, 1967, pp 423—441, Editor, Kuczynski et al.
[24] H. Flood and D. C. Hill: Z. Elektrochem., volume 61, no 1, 1957, pp 18—24.
[25] U. König: Z. für angew. Physik, volume 22, 1966, pp 1—3.

Maurice Andrew Strivens was born in December 1922 in London, England. He received the degree of Bachelor of Science in chemistry from the Imperial College of Science and Technology, London, in 1943. During World War II he researched in barium titanate materials and ferrites with Philips Electrical Limited, England. He joined Standard Telecommunications Laboratories in 1950 as a senior research engineer, specialising in ceramic fabrication techniques. He is now Chief Engineer of Materials at the Magnetic Materials Division of Standard Telephones and Cables Limited.

Mr. Strivens is a member of the American Ceramic Society.

Gerard Chol was born in February 1940 in Paris, France. He received a Licence in Sciences Physiques and an engineering degree from the Ecole Supérieure de Physique et de Chimie Industrielles de Paris. After research work on infrared radiation at the Observatoire de Paris, he joined the Laboratoire Central de Télécommunications in 1963. He is now head of the magnetism group of Laboratoire Central de l'Eclairage.

Mr. Chol is a member of the Société Française de Physique and of the British Ceramic Society.

Francoise Damay was born in October 1936, in Paris, France. She received an engineering degree from the Ecole Polytechnique Feminine, and joined the Laboratoire Central de Télécommunications in 1958 where she participated in studies relating to semiconductors and laser materials. She is now in the magnetism group of the Laboratoire Central de l'Eclairage.

Jean-Pierre Auradon was born in September 1935, in Paris, France. He received an engineering degree from the Ecole Supérieure de Physique et de Chimie Industrielle in 1961. He joined the Laboratoire Central de Télécommunications in 1963 to work on the physics of magnetic thin films for fast memories. He is now in the magnetism group of the Laboratoire Central de l'Eclairage.

Mr. Auradon is a member of the Société Française de la Microscopie Electronique.

In Memoriam

Viktor Kühl, deputy member of the board of management of Standard Elektrik Lorenz AG, and general manager of its Components Division, died on 23 January, 1968, at the age of 60.

He was born at Nowawes near Potsdam, Germany, on 22 November 1907. In 1935, he graduated as Diplom-Ingenieur at the Technische Hochschule in Berlin. He joined Mix & Genest, Berlin, a predecessor company of SEL, in 1936. After the war he was appointed technical director of the Stuttgart plant. In 1950, he became manager of the Mix & Genest plant in Berlin. From 1956, he was general manager of the Components Division, Nuremberg, which grew to its present importance under his direction. In 1964, Viktor Kühl was appointed deputy member of the board of management of SEL.

Television Tubes to Smithsonian Institution · At the invitation of the Smithsonian Institution in Washington, Dr. Philo T. Farnsworth donated to it several 40-year-old television camera and picture tubes and all of his documents and laboratory notebooks of that time. Dr. Farnsworth has been called the "Father of Electronic Television" for inventions, some made before he was twenty years old, that later triumphed in the patent courts.

Victoria Lynch in the photograph holds the first cathode-ray tube equipped with internal deflection plates. On the table are, from the left, the first image dissector, first projection oscilloscope, a primitive image orthicon with electron multiplier, and the first oscilloscope tube with a flat screen.

International Telephone and Telegraph Corporation, United States of America

Victoria Lynch holds the first cathode-ray tube with internal deflection plates. On the table are four other original television tubes given to the Smithsonian Institution by Dr. Philo T. Farnsworth.

Pentaconta® Equipment for Kingston-upon-Hull · Kingston-upon-Hull, which runs the only privately owned telephone network in the United Kingdom, has placed an order for the supply and installation of a new Pentaconta crossbar telephone exchange to be known as the Bransholme Exchange. It will have an ultimate capacity of 1300 connections.

Standard Telephones and Cables, United Kingdom

Olympic Games Communication Facilities · The Xth Winter Olympic Games in Grenoble, France, required extensive temporary telecommunication facilities and we have received official congratulations for the successful operation of the following telephone installations.

There were installed at the new City Hall of Grenoble a Pentaconta telephone exchange with direct seizure and transfer facility to serve 32 public lines and 300 extension lines, a public-address equipment for the assembly hall of the Town Council, and a time display system.

At the annex of the City Hall a Pentaconta exchange with 100 extension lines was installed with a manual exchange giving these 100 extension lines access to the city network via 10 public lines.

The Olympic Games Organization Committee required a Pentaconta exchange with callback and transfer facility to which 9 public lines and 52 extension lines were connected, a duplex electronic interphone system for 19 stations, 5 interphone installations of the *Dirigent* type for 23 stations, and a *Villaphone* installation for the transport services.

For the aural and television broadcasting services, the French Administration required a Pentaconta exchange with a callback and transfer facility to which 54 public lines and 300 extension lines were connected, a local-battery semiautomatic exchange for 250 broadcasting and television program circuits, and 80 transportable multiline executive stations for the program and recording rooms. The American Broadcasting Corporation used a special manual exchange to which 15 public lines and 60 extension lines were connected, a manual switching device for the data teleprocess lines (3 desks), and 50 time-measurement stations.

Compagnie Générale de Constructions Téléphoniques, France

® Registered trademark

Oscillator and Frequency-Selective Level-Measuring Set · Two companion instruments, the *74308* oscillator and the *74309* frequency-selective level-measuring set, span the frequency range 250 hertz to 1620 kilohertz for use on audio, open-wire, balanced-pair, and coaxial systems handling up to 300 circuits. For operating convenience, the 5 frequency bands cover (1) audio and broadcast frequencies, (2) coaxial supergroup 1, (3) basic supergroup 2, and (4) and (5) small-core coaxial system frequencies. Output impedances of 75, 100, and 125 ohms cater for different systems.

When making loop measurements an automatic tracking signal from the oscillator removes the need for manual tuning of the level-measuring set. For end-to-end measurements, or when an external signal source is used, an automatic-frequency-control circuit in the level-measuring set can be activated to keep the set tuned to the signal for frequency drifts up to ± 300 hertz.

The frequency-selective level-measuring set can be used for wide-band measurements in addition to its normal highly selective in-channel tests. A facility for making return-loss measurements can be included.

The slow-motion-drive oscillator has a built-in checking circuit for frequency calibration and an off-cycles facility for accurately setting the frequency between calibration points.

Both instruments are portable, operating from either 230-volt 50-hertz mains, or an external direct-current supply of 19 to 21 volts.

The oscillator weighs 40 pounds (18 kilograms) and the selective-level measuring set 50 pounds (22·7 kilograms). Both instruments have the dimensions 22 by 15 by 8·75 inches (56 by 38 by 22 centimeters).

Standard Telephones and Cables, United Kingdom

Color-Television Distortion Tests · The *74252* distortion-measuring set will measure the differential-phase and -amplitude characteristics of a color-television link and display them on a meter. This simplifies the procedure and the only oscilloscope required is a low-grade model for locating the measured point on the waveform.

Measurements of differential phase can be made from ± 0·2 to ± 15 degrees in four ranges and of differential amplitude from ± 0·25 to ± 5 percent in three ranges. The instrument shown

Test equipment for making differential measurements of phase and amplitude of color-television links.

in the photo is available for either 625- or 525-line systems and uses plug-in circuit boards. It weighs 48 pounds (21·8 kilograms) and has the dimensions 22·5 by 9·5 by 16 inches (57 by 24 by 40 centimeters). It operates from a 230-volt 50-hertz mains supply.

Standard Telephones and Cables, United Kingdom

Pneumatic Tube System is Fully Automated · A pneumatic tube system type *NW 100* has been developed for installation in the Munich Clinic. It will have an initial capacity of four 8-line central control stations, 46 substations, and use approximately 4000 meters (13 000 feet) of tubing. A newly developed control system is capable of controlling the traffic to as many as 10 000 substations, which may have identification codes identical to their telephone extension numbers.

The pneumatic system will largely use horizontal central stations and, for the first time, unitized substation terminals. This system concept allows early installation of the machines, tubes, deflectors, and control equipment while the substations — which incorporate sensitive components — are assembled in the factory and installed shortly before the pneumatic tube system is put into operation.

Standard Elektrik Lorenz, Germany

X-ray Spectrometer · To meet requirements for increased resolution and reproduceability in the determination of soft x-ray spectra (wavelength greater than 5 angstrom units) a linear focusing spectrometer is designed to attach directly to a commercial electron-probe x-ray microanalyzer. Special attention has been paid to minimizing backlash and other errors. Thus an unusual 2:1 system is used for the counter arm. To avoid cyclic errors in gearing, a steel tape under spring tension transfers motion over pulleys of suitable radii. Tests with a full-size prototype have shown this to be a very reliable system.

A new type of x-ray proportional counter is used. It is a double counter: the front part uses flowed gas with an ultra-thin window, and the rear part is a beryllium-windowed xenon-filled sealed counter. This pillbox type of counter enables large window apertures to be used without appreciable deterioration in energy resolution.

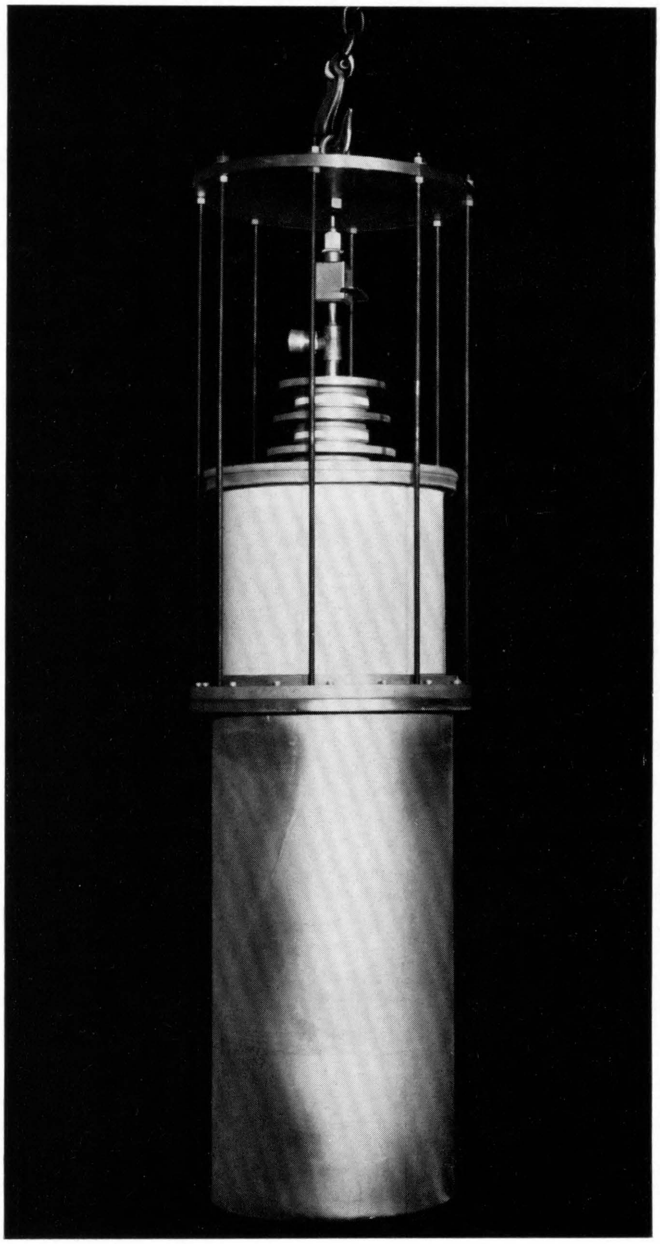
Standard Telecommunication Laboratories, United Kingdom

The *VM 10* mail presorting machine.

Triode Dissipates 390 Kilowatts · The world's most powerful conventional triode vacuum tube shown in the photo weighs more than 300 pounds (136 kilograms).

Capable of dissipating 390 kilowatts and with 30 kilowatts required by the filament alone, it will produce 90-megawatt pulses of 1-millisecond durations at 1-percent duty for such apparatus as particle accelerators.

ITT Electron Tube Division, United States of America



This powerful triode vacuum tube can dissipate 390 kilowatts in producing 90-megawatt pulses.

VM 10 **Mail Presorting Machine** · Under a contract awarded by the Deutsche Bundespost, a machine for presorting letters has been developed. It facilitates handling large volumes of mail and simplifies transportation to the distribution and letter-facing facilities.

The machine is designed for 4-digit postal area codes and uses luminescent indexing for identification of destinations. It is capable of processing 22 500 letters per hour. An edge-type conveyor carries the letters to a feeder-stacker that equalizes momentary variations in input quantities. From there, the letters are conveyed to the reading and distributing system.

Any one digit of the 4-digit postal area code may be used for sorting the mail into ten destinations. When required, several digits may be sent to a translator to control the sorting. Each destination unit holds five empty and three filled magazines, each with a capacity of 300 letters.

The *VM 10* presorting machine is of modular design, so that the individual units may be used with other facilities. It will be displayed at the 1968 Hanover Fair and then installed in a post office to gain experience with presorting.

Standard Elektrik Lorenz, Germany

Dutch Airport Re-equipped · Maastricht Airport reopened in February 1968 following a period of being closed for re-equipping. Among the new equipment is an instrument landing system that includes a single-channel *STAN 37* localizer, a single-channel *STAN 38* glide slope, a *STAN 39* outer-marker beacon, and a *STAN 39* middle-marker beacon. The localizer antenna has a reduced-height configuration to permit erection close to the runway. A special antenna array with quadrature-clearance is used for the glide slope to overcome siting problems due to rolling terrain in the foreground.

Standard Telephones and Cables, United Kingdom

Marine Radio Equipment for New Vessels · Among a dozen new ships we are supplying with radio communication and navigation equipment are five for American Mail Lines, five for States Steamship Company, and two survey ships for the United States Navy.

All installations will include standard marine radio transmitters and receivers, ultra-high-frequency radiotelephone systems, loran receivers, direction finders, and lifeboat radio sets. Alden facsimile equipment is also being provided for the ten commercial vessels.

ITT Mackay Marine, United States of America

Train-Describer Equipment · At a main signal box, 42 cathode-ray tubes having 1-inch diameter screens will provide a description of train locations on the British Railway's Lea Valley electrification scheme which covers 9 miles of track.

The system will use British Post Office *3000*-type relays for switching, storage, and transmission functions at the main Temple Mills West signal box and in smaller boxes at Cheshunt, Brimsdown, South Tottenham, and Hackney Downs. In these latter boxes, in-line digital indicators will be used for train describing.

Standard Telephones and Cables, United Kingdom

Radio Equipment for Oil Tankers · Three supertankers under construction for Esso Petroleum and the *Regent Westminster* being built for Regent Petroleum will be equipped with single-sideband high-frequency transmitters and receivers, *IMR 104* automatic direction finders, *SR 401* reserve receivers, and *IMR 113* 100-watt reserve transmitters which have radiotelephone facilities on the emergency channel of 2182 kilohertz.

The lifeboats of the three supertankers will be equipped with Solas II portable transceivers. The *Regent Westminster* installation will include loran navigation equipment.

We will train and supply radio officers for these vessels.

Standard Telephones and Cables, United Kingdom

Automatic Data Exchange Systems · An *ADX*® automatic computer-based data exchange will be installed at the London Heathrow Airport for Pan American Airways.

Replacing an existing message-switching system it will automate telegraph traffic among the offices of Pan American Airways throughout Europe, Africa, and India, with connections to its switching center in New York and to the world-wide network of the International Civil Aviation Organization. A total-system package will be supplied including computer programs for real-time working.

The *ADX* system is based on high-speed dual on-line stored-program digital computers. Magnetic disks provide storage for in-transit messages through the switching center, which, once switched enroute, are long-term filed on magnetic tape for future queries.

The system has a capacity of 100 incoming and outgoing telegraph channels operating at 50 to 75 bauds over either high-frequency radio links or land lines. Medium-speed data transmission up to 2400 bauds will also be accommodated. Automatic speed-and-format conversion will allow channels with differing transmission speeds and message structuring to interoperate.

The man-machine interface employs cathode-ray tubes and teleprinters to present operational and technical-status reports to a supervisor who can modify the day-to-day parameters from a control keyboard.

Reuters, the world-wide news-gathering agency, have also ordered an *ADX* system for their London Office in Fleet Street. Dual processors, one active and one standby, have been soft-

® Registered trademark

Control processor for *ADX* data switching equipment.

ware tailored to suit Reuter's special needs. The system will switch teleprinter messages at 50 to 75 bauds over radio links and land-line circuits. Special facilities include collection of traffic statistics on all channels, automatic frequency changing on outgoing radio channels, handling of omnibus and selector-code channels, and message-format conversion. Also there is a method of queue control to regulate the quantity and nature of traffic. It allows channels to be assigned to certain classes of traffic. This enables the controller to add or delete messages to these queues according to the news value of each message.

Standard Telephones and Cables, United Kingdom

Microwave Oven for Chinaware Industry · A microwave oven has been developed in cooperation with the Haviland factory at Limoges, France, for predrying china pieces. The predrying allows the china pieces to be taken off their molds very quickly, thus making substantial savings on molds, handling, and floor space. The equipment is capable of predrying 500 china cups per hour.

The pieces travel on a metal conveyor having a step-by-step motion. A heating cavity moves up and down above the belt. Three 1-kilowatt continuous-wave magnetrons are used to generate the microwave energy which is distributed uniformly inside the cavity.

Le Matériel Téléphonique, France

Microwave oven for rapid predrying of china dishes after molding.

Pentaconta Installations in India, Denmark, and Rumania · In India two 10 000-line Pentaconta 1000A exchanges were cut over on 11 November 1967 in Bombay and Kalbadevi. They are in the same building in which another 10 000-line exchange and an automatic toll center are being constructed. A 7000-line Pentaconta exchange was cut over in New Delhi on 24 February 1968. It is the first crossbar exchange in that city and the fourth in India. Two additional crossbar exchanges, one local and one toll, are being installed in Delhi.

A 900-trunk Pentaconta toll exchange was cut over on 2 September 1967 in Haderslev, Denmark. The Aabenraa exchange is due to be cut over in August, this year.

The first phase of a contract with Rumania signed in April 1965 was completed at ceremonies at which Vice-Minister Airinei of the telecommunications administration officiated at the acceptance of a 5000-line local, a 2023-junction tandem, and a 180-junction toll exchange in Bucharest and of four toll exchanges (425 junctions) in Brasov, Constanta, Eporie, and Mamaia. These events occurred on the 40th anniversary of our installation of the first 7A1 rotary exchange in Bucharest.

Bell Telephone Manufacturing Company, Belgium

Computer-Aided Line Equalization · A field engineer can telephone an equalization problem into the Computer-Aided Design (CADE) Center at Cockfosters, near London, and within 30 minutes receive a print-out of the component values and their juxtaposition to equalize the line he is working on. Equalization calculations using manual methods could take many days.

The field engineer finds the transmission loss in the usual way, making about 70 measurements which he telephones to a designer at the CADE center, where it is typed in at a graphics-display console. The loss characteristic is immediately shown on the screen, together with a number of equalization characteristics each corresponding to a specific equalization network. The CADE-center designer now carries out an iterative curve-fitting procedure using at each step a light-sensitive pen. First he selects from the equalization characteristics one that will equalize an aberration on the displayed loss characteristic. Then using the pen again he defines the center-position, width, and depth of the aberration against a fine-dot parameter grid on the display screen. The required equalization characteristic now appears superimposed on the loss characteristic and the designer modifies or accepts it. On pressing a key, equalization is immediately applied and the residual loss variations displayed.

The whole procedure can be repeated until all the aberrations have been reduced and the residual losses appear within the acceptable tolerance limits.

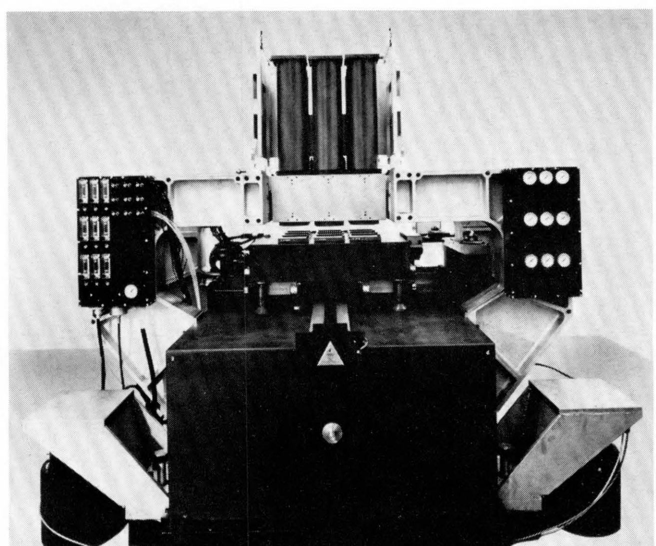
Finally, a print-out of component values and circuit configuration is produced and telephoned back to the field engineer within 30 minutes of his first call.

Standard Telephones and Cables, United Kingdom

Integrated Circuits Require Precision Mask-Making Engine · A laser-interferometer mask-making engine that is as accurate as a ruling engine makes masks for the processing of integrated circuits and transistors. As many as 9 masks, each corresponding to a manufacturing step, can be produced at one time. The masks are projection printed on glass photographic plates 4·5 inches (114 millimeters) square on which hundreds of square patterns of 0·04 inch (1 millimeter) size are produced by a step-and-repeat process.

The photographic plates to be exposed are placed on an optically smooth granite table that is guided along its X and Y axes on Pyrex ways affixed to a larger 9-ton (8000-kilogram) optically smooth granite table. Gas bearings assure smooth, effortless, precisely controlled motion.

The direction and amount of table movement are controlled by a digital computer. Interference fringes from helium-neon laser interferometers operating on the X and Y coordinates are counted by photodetectors to within a phase relationship of 1/8th of the laser wavelength or about 3 microinches (76 nanometers). The table can be placed and held in any dark or light fringe.



This machine for making masks for integrated circuits is operated from a computer. The XY coordinate positions of a stone table which carries the photographic plate that becomes the mask are measured by interferometers using laser beams.

A high-pressure xenon light source exposes the high-resolution photographic plates through 9 automatically focused lenses. Edge acuteness or pattern sharpness from maximum to minimum transmission of light has been measured at 1·5 microinches (38 nanometers). Minimum line widths and pattern spacings have been produced down to 40 microinches (1000 nanometers).

A library of about 100 punched tapes is available. Placed in the computer, a tape controls the direction and distance of travel of the granite table as well as the exposures. Servomotors drive the table to the positions determined by the tape. Once programmed for a pattern, that pattern can be stepped on 9 separate plates simultaneously with selected reduction ratios of 10, 5, 4, or 2 to 1.

ITT Semiconductors, United States of America

Conveyor System for Sterilizing Hospital Material · A special hospital conveyor system has been developed for the transportation of materials to be sterilized.

The materials to be sterilized are placed in containers having base dimensions of either 600 by 300 millimeters (24 by 12 inches) or 300 by 300 millimeters (12 by 12 inches). Since the system is used in wet sterilization areas, its enclosures are of high-quality steel and the conveyor belt is of plastics material.

The containers may be put on the conveyor in any desired order; they are assembled into groups and distributed to autoclaves or sterilizers. The conveyor chain includes indicators actuated by permanent magnets mounted in opposite corners to identify the size of the containers. The containers are then assembled by electromagnetically controlled distributors into lengths corresponding to the capacities of the autoclaves.

After a predetermined period of time, the distributor opens the autoclave, moves a group of containers into it, and closes it. The conveyor then proceeds with the assembling of a new group of containers.

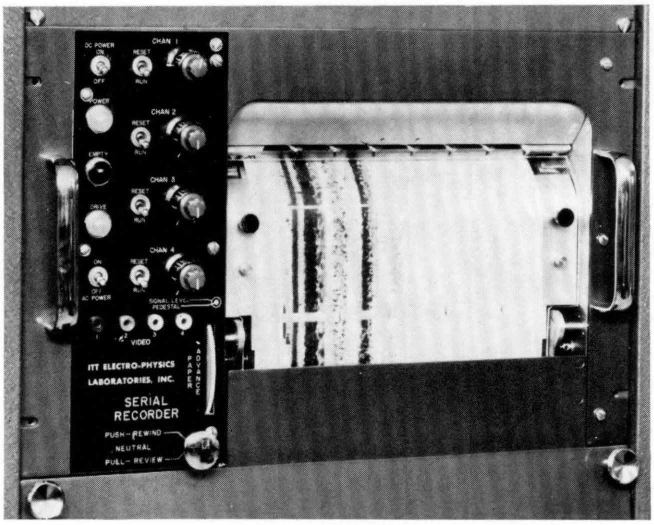
Standard Elektrik Lorenz, Germany

Conveyor system for moving containers of material into sterilizers.

Electrolytic Recorder · The paper recorder shown offers the utility of an oscilloscope with the permanence of facsimile. Up to 4 channels may be recorded simultaneously on 8-inch (20-centimeters) wide paper using electrolytic marking. Bandwidth is direct current up to 100 kilohertz with input to 6 volts.

Other features are adjustable feed rates of paper, electronic sweep, and selectable recording format. Both internal and external clocks can control recording sweeps. External synchronization can be applied. The recorder is particularly adapted to radar, side-looking sonar, and spectral analysis.

ITT Electro-Physics Laboratories, United States of America



Paper recording using electrolytic marking for four channels.

Diaphragm Relay · This relay derives its name from the characteristic geometry of the moving element. Housed in a conventional glass capsule, the contacts are attracted together by an external magnetic field operating on their ferrous backings. No intervening mechanism between operating force and contacts makes for a more efficient relay.

The operating-force magnetic circuit is of comparatively shorter length and increased area, thus providing the relay with a comparatively larger contact area and higher contact force.

Silver annular contacts avoid high spots at the contact-force center. Any high spots formed will be remote from each other and so give more area of contact. Silver contacts carried out 1·2 million operations at a load of 1 ampere at 60 volts and then gave an average contact resistance of 19 milliohms — the same figure obtained at the beginning of the test. There is no true contact bounce but a 0·5-millisecond period of high resistance occurs at low current/voltage levels.

For 37 ampere-turns the relay will provide a contact area of 5·6 square millimeters. This is more than ten times the figure for a conventional small reed relay requiring the same ampere-turns.

The relay is presently made in 1-, 2-, and 4-make types but variants are being designed. It is hermetically sealed in a glass envelope containing an inert gas. Compression glass-to-metal seals increase the bond between the metal/glass interface.

The relay has satisfied the British Armed Services DEF 5011 specification.

Standard Telephones and Cables, United Kingdom

Relay Handles 20 Kilowatts · The *RF 3* vacuum-type relay, only 2·25 inches (5·7 centimeters) long and weighing 1·75 ounces (50 grams), is capable of interrupting 20 kilowatts of direct-current power. It will carry 17 root-mean-square amperes and withstand 7500 peak volts at 16 megahertz. At 60 hertz it will withstand peak potentials of 12 000 volts. Its vibration rating is 10 *g* up to 500 hertz. Life expectancy is greater than a million operations.

Typical applications include switching in antenna, grid, and plate circuits, tapping of radio-frequency coils, and in controlling motors, machine tools, lighting systems, et cetera.

ITT Jennings, United States of America

Message Switching Center for French Land Forces · On 4 March 1968 an important electronic message switching center was inaugurated for the French Land Forces in the presence of the General, Central Director of Transmissions, and other dignitaries of the Army Headquarters Staff and of the Land Forces.

This *DS 66-3* electronic message switching center permits fully automatic routing of messages with the very highest reliability as the processing unit in service can be automatically replaced by a standby unit without loss of characters.

Similar centers have been operating since 1966 and 1967, respectively, at the main office of Air-France in Paris and at the Air Navigation Department at Orly Airport.

Compagnie Générale de Constructions Téléphoniques, France

Data Communication Systems · The *GH 210* data system uses integrated circuits for compactness and an error-correction technique for increased accuracy of transmission.

An installation has been ordered by the Ansett Australian National Airlines to increase by 6 times the rate of transmitting data over public telephone lines between Sydney and Melbourne. Information on flight schedules will take 1·5 minutes to transmit instead of 20 minutes as at present.

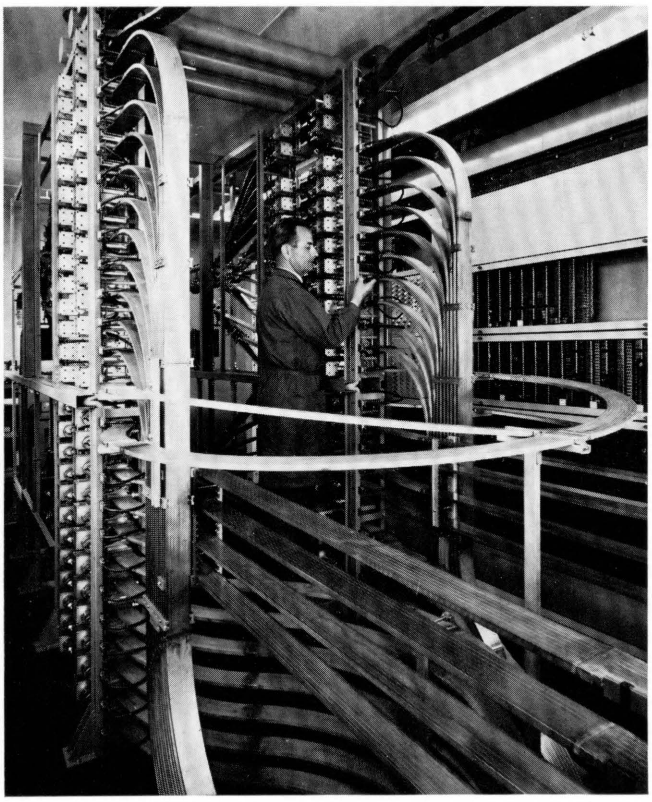
Associated British Foods of England have also ordered 12 of the *GH 210* terminals to be installed at bakeries in Bradford, Sheffield, Littleborough, Wakefield, York, and Newcastle. They will have access to a computer center at Stockport to assess daily orders, manufacturing requirements, and distribution loading.

Standard Telephones and Cables, United Kingdom

Pneumatic Tubes Distribute Toll Tickets · The Swiss telecommunications administration has put in service at its Zurich toll center an additional pneumatic-tube ticket distributor. It is designed for an ultimate capacity of 16 sending lines with 8 stations per line and of 13 receiving lines with 6 stations per line. Initially, 48 switches are in service. Each line is provided with an air lock. As many as 24 000 tickets are distributed daily.

There are now 7 such installations operating in Switzerland and another in Germany. These installations are equipped with from 11 to 145 stations and vary in length of pneumatic tubing from 185 to 2110 meters (600 to 6900 feet).

Standard Téléphone et Radio, Switzerland



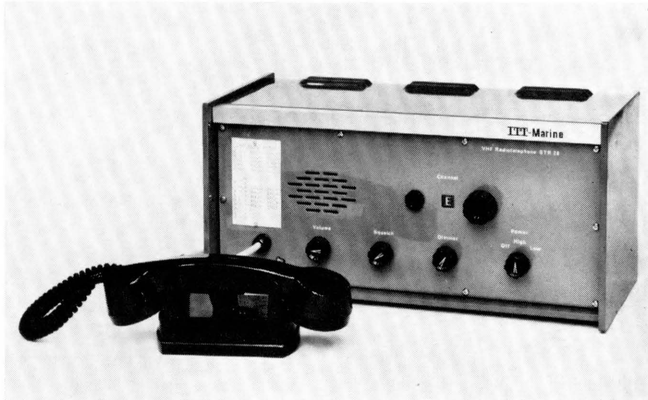
Switching facilities for pneumatic tube distributing system that handles toll tickets without carriers.

Marine Radiotelephone for Small Vessels · A 10-watt very-high-frequency transceiver has been developed for small vessels that are not required to work on all international marine channels. It provides for 8 simplex and 8 duplex channels. A very-high-frequency hybrid coupler is available to permit simultaneous transmitting and receiving on a single antenna on all duplex channels.

Direct-current drain from a 24-volt source is 100 milliamperes on standby for simplex reception, 0·5 ampere for reduced transmit power, and 1·5 amperes for full transmit power.

The use of Ministac modular construction gives a compact unit of 185 by 385 by 179 millimeters (7·3 by 15·2 by 7·1 inches).

Standard Electric, Denmark
International Marine Radio Company, United Kingdom



Marine very-high-frequency radiotelephone transceiver.

Intercommunication System for Broadcasting · A 4-wire intercommunication system has been installed for the Allgemeine Rundfunkanstalten Deutschlands (Radio and Television Broadcasting Companies of Germany). Leased from the Deutsche Bundespost, the lines of this network extend radially from the television control center at Frankfurt am Main to all stations of the broadcasting system as well as to the European network through the Eurovision Center in Brussels.

This new 4-wire system is flexible, very economical, and allows easy expansion. The lines can be used for speech, order-wire, control, and conferences. When expanded to its full capacity, it will provide for two conference circuits, each including as many as 15 radio and television stations. They, in turn, may add their own conference connections.

Facilities have been provided for adaptation to existing 2-wire local-battery and central-battery networks for speech communication. Transistor amplifiers compensate for all the losses occurring in the line network and ensure a uniform reference level at the transition points to the studio equipment. At the transition points between the broadcasting facilities and the public telephone equipment a so-called 4-wire audio-frequency terminal equipment ensures that the ringing, signaling, and speech transmission requirements of the telephone system are met.

Standard Elektrik Lorenz, Germany

X-Band Acoustic Delay Line · This delay line consists of a cadmium-sulfide evaporated thin-film transducer on a sapphire delay medium. The transducer is deposited onto a sputtered gold film on the heated sapphire substrate from separate cadmium and sulfur sources. The resulting high-resistivity film is polycrystalline but with a preferred orientation of the *c* axis normal to the substrate. In this form it can be used as an acoustic transducer for longitudinal waves. At 1 gigahertz the acoustic attenuation in sapphire is about 0·5 decibel per microsecond of delay and increases as the square of the frequency; thus at 10 gigahertz the loss would be 50 decibels per microsecond. So even though it is the lowest loss material commercially available it must be cooled to 77 degrees Kelvin to reduce the loss to 1 decibel per microsecond.

The line is mounted in a coaxial cavity using the same transducer as transmitter and receiver and the whole is suspended over a liquid nitrogen bath in a cryostat. For a rod

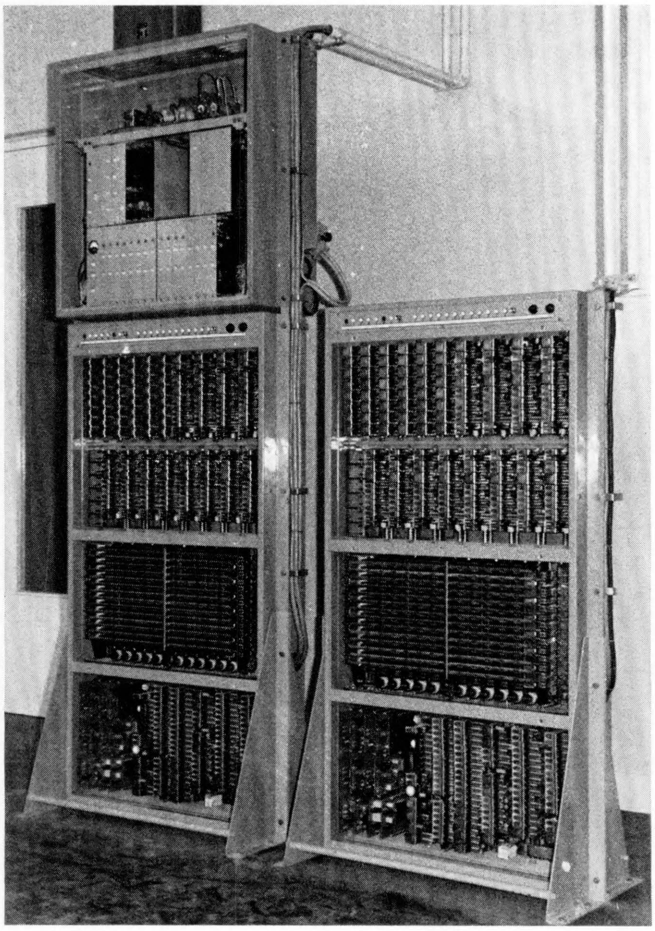
1·6 centimeter (0·63 inch) long with a delay of 3 microseconds the tuned transduction loss was 27 decibels at 10 gigahertz. For the first echo the total loss was 57 decibels. As many as 13 echoes could be measured, giving a total delay of 40 microseconds and a total loss of 94 decibels. Most of the transduction loss was due to electrical mismatch, which it is hoped can be improved.

When the transducer is untuned a bandwidth of 1 gigahertz is observed but the loss is very high. The low-loss bandwidth is limited by that of the tuner used, being about 100 megahertz in our case. By using the new delay media that are now emerging it should be possible to have *X*-band delay lines working at room temperature.

Standard Telecommunication Laboratories, United Kingdom

Concentrators in Paris Regional Network · A small village in the northern part of the regional public telephone network of Paris has been converted from manual service through a regional center to automatic service by the installation of 2 Pentaconta *CM 12* concentrators, and a 12-channel carrier system manufactured by Lignes Télégraphiques et Téléphoniques.

The remote units of the concentrators were installed in the Post Office of the village, in which 66 subscribers are located. These remote units are connected by the 12-channel carrier system over existing subscriber lines to the central-office units in a subcenter 6 kilometers (3·7 miles) away. The actual transmission path is about twice this length as it goes from the subcenter through the regional center to the village Post Office.



The two Pentaconta *CM 12* concentrators installed in the Paris regional telephone network.

Portable instrument for measuring 100 kilovolts.

The village is now included in the numbering zone of the subcenter, which has a lower tariff rate for calls to Paris than the regional center had.

Le Matériel Téléphonique, France

Voltmeter for 100 Kilovolts · The photograph shows a view of the *J-1005* portable voltmeter that will measure from 0 to 100 000 peak volts from 10 hertz to 20 megahertz within 3 percent. It also measures up to 40 kilovolts double-ended at 50 megahertz. The input capacitance is 4 picofarads for single-ended and 2 picofarads for double-ended operation. Shunt resistance is greater than 2 teraohms, the insulation resistance of the glass-enclosed vacuum voltage dividers that are the heart of the instrument.

A jack provides output to an oscilloscope to view waveshapes. A kit permits the input circuit to be at a different place than the indicating equipment. As shown the device is 16 inches (40 centimeters) high by 10 by 8 inches (25 by 20 centimeters) and weight is 12 pounds (5·4 kilograms).

ITT Jennings, United States of America

Response Tracer RT-1 · This equipment was developed for attenuation measurements on telephone channels, lines, voice-frequency filters, et cetera. It operates over the voice-frequency band from 200 to 3500 hertz and includes a signal generator and receiver with a common power supply. The amplitude-frequency response is displayed on the screen of a long-persistence cathode-ray tube in terms of attenuation versus frequency; the vertical attenuation scale is linear in decibels and the horizontal frequency scale is logarithmic in hertz.

The receiver recognizes both signal frequency and level so that no synchronization is required between the signal generator and the receiver. Independent equipments may be used at both ends of the channel under test.

The equipment will operate from either alternating current or batteries. Construction is in accordance with ITT Standard Equipment Practices and the weight is 10 kilograms (22 pounds).

ITT Laboratories of Spain, Spain

The World's Telephones - 1967†

The number of telephones in the world continued its rapid growth last year with an increase of 13·4 million. This was a gain of 6·9 percent and brought the total number of telephones in the world to 208·5 million at the beginning of 1967, twice the number in service only eleven years ago.

The volume of overseas calls is also continuing its rapid climb. During the year 1966, calls between the United States mainland and points overseas totaled 9·9 million, up by 22 percent over the preceding year. Underseas cable capacity is being boosted to handle the increasing traffic. The first transistorized underseas cable, capable of carrying 720 simultaneous conversations, is scheduled to be placed in service between the United States mainland and the Virgin Islands by mid-1968. Another cable, with 144-voice capacity, will connect the Virgin Islands and the Dominican Republic and will be linked to the United States-Virgin Islands cable. By contrast, when the first transatlantic cable was placed in 1956, it could carry only 36 simultaneous conversations; even improved terminal equipment now enables it to carry only 48.

A fifth transatlantic cable, from the United States to the Iberian Peninsula, has been proposed. This cable, also transistorized and with a capacity of 720 conversations, would make possible increased volume and higher quality service to many points in the Middle East and Africa.

In addition to the underseas cable networks, more than 230 satellite circuits are now being used to provide telephone service between the United States and places overseas. Use of increasing numbers of satellite circuits across the Atlantic and Pacific are planned as the volume of calling continues to grow.

Today a telephone user in the United States can reach more than 96 percent of the world's telephones. In 1967 connections were established with Brunei, Cayman Islands, Greenland, Qatar, and Spanish Sahara. Operator dialing of calls from the United States was extended to Norway, Spain, Sweden, Hong Kong, Malaysia, the Philippines, and Singapore.

The time is rapidly approaching, moreover, when many United States customers will be able to dial their overseas calls directly. A trial of customer dialing of calls from New York to London and Paris was made in 1967. The results showed that customer dialing to overseas points is feasible and that few problems were encountered.

Statistical data relating to continental areas, to individual countries, and to principal cities are contained in the

† An abridgment from the 1967 issue of "The World's Telephones-1967" published each year by the American Telephone and Telegraph Company, New York, New York.

Countries which have 500 000 or more telephones · Data are at January 1 — notes below

Country	Total telephones in service						Automatic	
	Number			Percent increase from		Per 100 population	Number	Percent of total
	1967	1966	1957	1966	1957			
Argentina	1 526 767	1 497 841	1 155 198	1·9	32·2	6·68	1 378 233	90·3
Australia[3]	2 978 336	2 810 833	1 704 000	6·0	74·8	25·81	2 533 886	85·1
Austria	1 087 007	1 008 693	540 524	7·8	101·1	14·88	1 045 576	96·2
Belgium	1 665 508	1 564 656	931 439	6·4	78·8	17·43	1 606 916	96·5
Brazil	1 431 653	1 344 717	847 868	6·5	68·9	1·67	1 216 811	85·0
Canada	7 880 471	7 445 071	4 499 325	5·8	75·1	38·91	7 621 047	96·7
Czechoslovakia	1 582 852	1 491 621	703 098	6·1	125·1	11·09	1 422 998	89·9
Denmark	1 411 040	1 363 988	922 881	3·4	52·9	29·09	1 034 274	73·3
Finland	892 300	835 682	486 193	6·8	83·5	19·19	797 220	89·3
France	6 554 441	6 116 700	3 313 426	7·2	97·8	13·19	5 748 610	87·7
Germany, East	1 723 814	1 658 817	1 066 582	3·9	61·6	10·09	1 723 614	100·0
Germany, West	9 532 417	8 802 166	4 323 225	8·3	120·5	15·89	9 532 417	100·0
Greece	579 076	508 262	136 835	13·9	323·2	6·69	553 457	95·6
Hungary	597 376	566 026	365 438	5·5	63·5	5·86	455 149	76·2
India[4]	961 063	881 407	314 885	9·0	205·2	0·19	691 191	71·9
Italy	6 467 597	5 980 702	2 609 127	8·1	147·9	12·44	6 417 264	99·2
Japan[4]	16 011 745	13 998 831	3 726 821	14·4	329·6	16·08	12 072 847	75·4
México	930 940	823 064	383 257	13·1	142·9	2·07	818 418	87·9
Netherlands	2 512 826	2 352 209	1 229 174	6·8	104·4	20·05	2 512 826	100·0
New Zealand[4]	1 087 133	1 025 084	568 339	6·1	91·3	39·87	894 272	82·3
Norway	945 573	907 919	631 524	4·1	49·7	25·09	749 899	79·3
Poland	1 411 481	1 294 046	561 100	9·1	151·6	4·44	1 174 094	83·2
Portugal	581 780	550 490	279 537	5·7	108·1	6·31	460 057	79·1
Rumania	510 000*	473 122	n. a.	7·8	n. a.	2·66	408 000	80·0
South Africa[4]	1 260 692	1 198 421	765 540	5·2	64·7	6·86	952 004	75·5
Spain	3 072 214	2 788 432	1 199 078	10·2	156·2	9·60	2 479 637	80·7
Sweden	3 757 495	3 572 630	2 312 223	5·2	62·5	47·90	3 711 234	98·8
Switzerland	2 395 123	2 259 077	1 293 743	6·0	85·1	39·25	2 395 123	100·0
USSR	8 400 000*	7 700 000	3 366 000	9·1	149·6	3·58	6 216 000	74·0
United Kingdom[4]	11 376 000	10 704 000	7 219 000	6·3	57·6	20·70	10 854 000	95·4
United States[5]	98 789 000	93 656 000	60 190 000	5·5	64·1	49·87	98 558 000	99·8

* estimated

accompanying tables. The list of countries with a half-million or more telephones increased to 31 at the beginning of 1967 with the addition of Rumania. The United States, which attained its hundred-millionth telephone during 1967, placed first in number of telephones with 98·8 million at the start of the year. Japan's system ranked second (as it has since 1963) with 16 million, followed by the United Kingdom, West Germany, the Union of Soviet Socialist Republics, Canada, France, and Italy.

In terms of relative telephone development, Sweden, with 47·9 telephones per 100 population, finished second to the United States (with 49·9), followed by New Zealand (39·9), Switzerland (39·3), Canada (38·9), and Denmark (29·1).

Not surprisingly, industrialized countries with comparatively low telephone densities per population show a greater percentage increase in the total number of telephones over the last ten years than countries with high telephone development. For example, Japan, with four telephones per 100 population in 1957, increased its telephones by 330 percent in the past decade. On the other hand, the United States, with 35 telephones per 100 population in 1957, showed a 64 percent increase. During that period, however, the United States added three telephones for every one that Japan added, and at the end of the period the United States had nearly fifty telephones per 100 persons as compared with sixteen in Japan.

In telephone talk, Canada retained its world title. Canadians averaged 664 conversations per person during 1966, up by 29 from the previous year. The United States' average of 648 (an increase of 28) continued it in second place.

Telephones by continental area · Data are at January 1 — notes below

Continent	Total in service			Privately operated[1]		Automatic		Total number of telephones in service 1966
	Number 1967	Percent of world	Per 100 population	Number 1967	Percent of total	Number 1967	Percent of total	
North America	106 329 000	51·0	48·8	104 939 000	98·7	105 837 000	99·5	100 779 000
Middle America	1 810 000	0·9	2·2	1 328 000	73·4	1 635 000	90·3	1 641 000
South America	4 469 000	2·1	2·6	2 237 000	50·1	3 999 000	89·5	4 242 000
Europe	66 976 000	32·1	10·6	11 825 000	17·7	61 275 000	91·5	62 432 000
Africa	2 618 000	1·3	0·8	23 000	0·9	2 034 000	77·7	2 474 000
Asia[2]	21 758 000	10·4	1·1	15 229 000	70·0	16 518 000	75·9	19 261 000
Oceania	4 540 000	2·2	24·4	345 000	7·6	3 878 000	85·4	4 271 000
World	208 500 000	100·0	6·2	135 926 000	65·2	195 176 000	93·6	195 100 000

Telephone conversations during the year 1966 · Number in thousands — notes below

Area	Local	Long distance	Total	Avg. per person
Argentina	4 144 071	56 931	4 201 002	185·1
Australia[3]	2 103 000	116 882	2 219 882	193·9
Belgium	843 215	211 742	1 054 957	110·7
Brazil	8 627 785	131 370	8 759 155	103·4
Canada	12 905 628	323 325	13 228 953	664·1
Colombia	1 738 661	15 063	1 753 724	94·0
Czechoslovakia	966 709	127 513	1 094 222	76·8
Denmark	1 314 113	380 753	1 694 866	353·3
France	1 826 082	918 098	2 744 180	55·5
Germany, East	839 760	274 040	1 113 800	65·3
Germany, West	4 860 600	2 042 341	6 902 941	115·7
Greece	1 155 775	43 402	1 199 177	139·2
India[4]	1 391 000	81 029	1 472 029	3·0
Italy	7 249 311	873 100[11]	8 122 411	156·6
Korea, Republic of	1 859 188	29 821	1 889 009	64·9
México	2 054 385	35 938	2 090 323	47·4
Netherlands	1 373 731	781 249	2 154 980	173·0
Philippines	1 811 534	1 633	1 813 167	54·2
South Africa[4]	1 705 722	108 792	1 814 514	99·6
Sweden[12]	3 948 000	641 300	4 589 300	585·1
Switzerland	853 337	940 447[11]	1 793 784	296·5
United Kingdom[4]	6 512 000	939 000	7 451 000	135·9
United States	122 467 000	5 196 000	127 663 000	648·0

Notes to tables

n. a. The abbreviation used for "data are not available".

[1] This applies to operation rather than ownership. Systems which are government-owned in whole or in part may be privately operated (e. g., Italy and Japan). The word "government" refers to nations, states or municipalities.

[2] These data include allowances for the Asiatic parts of Turkey and the USSR.

[3] Data are as of June 30th of the year preceding that indicated. For third table they are for the year ended on that date.

[4] Data are as of March 31st of the same year as that indicated. For third table they are for the year ended on that date.

[5] Data for Alaska and Hawaii are excluded for the year 1957, since, at that time, these Territories had not become States.

[11] Three-minute units.

[12] Data are for the year ended June 30, 1967.

Other Papers from International Telephone and Telegraph System Authors

This list includes papers published in other periodicals, and lectures presented at meetings. Some of these latter are also available in a written form, either printed in proceedings or edited internally. Where the publication is indicated, requests for reprints should be made directly to its editor, not to *Electrical Communication.* In the other cases, such requests should be made to the nearest editor of *Electrical Communication* or its associated language versions, as it may happen that a limited number of copies could be made available.

Standard Elektrik Lorenz AG

Articles

Haas, W., *Über den Entwicklungsfortschritt in der Trägerfrequenztechnik,* Übertragungstechnik I, volume 6, no 5.

Höfgen, G., *Ein elektronisches Goniometer,* Frequenz 22 (1968) 2, pp 32—34.

Kuhn, H., Müller, M., and Walter, G., *Rauscharmer Halbleiteroszillator für Richtfunkanlagen,* Nachrichtentechnische Zeitschrift 21 (1968) 1, pp 40—45.

Meifort, H., *Wärmeabführung bei freier Strömung und Konvektion,* Frequenz 22 (1968) 2, pp 58—62.

Nestel, S., *Die Entdeckung von bewegten Zielen durch Pulsdopplerradar,* Nachrichtentechnische Zeitschrift 21 (1968) 1, pp 15—23.

Oehlen, H., and Brust, G., *Spektrale Energie- und Leistungsdichte technisch interessanter Impulsformen und Impulsfolgen,* Archiv der Elektrischen Übertragung, 22 (1968) 2, pp 79—86.

Schmitz, W., *SEL-Beiträge zur Fortentwicklung der Eisenbahnsignaltechnik,* Signal und Draht, 50. Jubiläumsausgabe, 60 (1968) 1—2, pp 35—38.

Willrett, H., *Field Experience with Quasi-Electronic Telephone Switching Systems,* IEEE Transactions on Communication Technology, volume 15, no 6, December 1967, pp 730—735.

Lectures

Balkow, J., *Aktive nichtlineare Bauelemente der Elektronik II; Anzeigeelemente; Stromversorgungsgeräte für elektronische Steuerungen,* Lehrgang des Vereins Deutscher Ingenieure, Düsseldorf, 11—16 March 1968.

Carl, H., *Nachrichtenübertragung mit künstlichen Erdsatelliten. Verband Deutscher Eisenbahn-Ingenieure,* Nuremberg, 25 April 1968.

Comes, K., *Über ein Verfahren zur Approximation von Filtern mit vorgegebener Dämpfung,* Nachrichtentechnische Gesellschaft, Diskussionssitzung, Frankfurt-am-Main, 21—22 March 1968.

Dietrich, W., *Maschinen zum Lesen gedruckter Ziffern,* Verband Deutscher Elektrotechniker, Bezirksverein Nordbayern, Zweigstelle Erlangen, 29 February 1968.

Fendt, H., *Vakuumtechnik in der Fertigung von Elektronenröhren,* Verein Deutscher Ingenieure-Bildungswerk, Frankfurt-am-Main, 11—16 March 1968.

Fessler, D., *Teilelektronisches Fernwirksystem für Nachrichten-Übertragungs-Einrichtungen,* Elektrotechnischer Verein, Stuttgart, 14 March 1968.

Giese, W., *Funksprechgeräte für den öffentlichen und zivilen Bedarf,* Elektrotechnische Gesellschaft, Hanover, 2 April 1968.

Häberle, H., *Nachrichtenübertragung mit künstlichen Erdsatelliten,* Verband Deutscher Elektrotechniker, Frankfurt-am-Main, 19 March 1968.

Häberle, H., *Informationstheoretische Grundlagen der Digitaltechnik,* Verein Deutscher Ingenieure-Bildungswerk, Hanover, 25 March 1968.

Knauer, H. U., *Telefonieren ohne Handapparat: Grenzen und Möglichkeiten,* Verband Deutscher Elektrotechniker, Bezirksverein Köln, Stützpunkt Bonn, 20 February 1968.

Kramar, E., *Die Rolle (Aufgabe) der Funktechnik in der Luft- und Raumfahrt,* Verband Deutscher Elektrotechniker, Bezirksverein Oldenburg, 14 February 1968.

Lang, H., *Die Prüfung der Glas/Metall-Verschmelzung von Reedkontakten,* Nachrichtentechnische Gesellschaft, Diskussionssitzung, Frankfurt-am-Main, 19 March 1968.

Nestel, S., *Unterdrückung von Störsignalen bei Pulsdopplerradar,* Deutsche Gesellschaft für Ortung und Navigation, Düsseldorf, 23 April 1968.

Oden, H., *Wechselbeziehungen zwischen Koppelelement und Systemstruktur,* Nachrichtentechnische Gesellschaft, Frankfurt-am-Main, 19—20 March 1968.

Pogrzeba, H., *UKW-Funksprechtechnik und ihre Einsatzmöglichkeiten,* Verband Deutscher Elektrotechniker, Bezirksverein Frankfurt, Stützpunkt Mainz, 13 February 1968.

Raab, G., *Möglichkeiten der automatischen Verarbeitung von Pulsradarinformationen,* Deutsche Gesellschaft für Ortung und Navigation, Düsseldorf, 24—26 April 1968.

Reiner, H., *Überlegungen zur Bauweise zukünftiger Nachrichtengeräte,* Technische Akademie, Brunswick, 13 February 1968.

Rensch, H., *Die konstruktive Gestaltung von Reedkontakten und Reed-Relais,* Nachrichtentechnische Gesellschaft, Diskussionssitzung der Fachausschüsse 2 und 9, Frankfurt-am-Main, 19 and 20 March 1968.

Rötzel, D., *Sicherheit im Luftverkehr,* Verband Deutscher Elektrotechniker, Bezirksverein Düsseldorf, 18 April 1968.

Rupp, H., *Nachrichtensatellitentechnik als Ergänzung und zukünftige Konkurrenz der herkömmlichen Übertragungstechnik,* Technische Universität Stuttgart, 13 February 1968.

Schneider, M., *Planung von Fernmeldeanlagen,* Technische Universität Stuttgart, 31 January 1968.

Schwant, J., *Vergleich der verschiedenen Realisierungsverfahren von aktiven RC-Netzwerken,* Verband Deutscher Elektrotechniker, Munich, 19 February 1968.

Waitz, M., *Problems of and Solutions to Automatic Testing Equipment for Switching Installations,* IEEE-International Communications Conference, New York, 18 and 21 March 1968.

Wendel, W., *Das „Experimental Data Processor (E. D. P.) — System für die Eurocontrol Versuchszentrale“,* Verband Deutscher Flugleiter, Frankfurt-am-Main, 5 April 1968.

Bell Telephone Manufacturing Co.

Lectures

Goris, A., *Standpunt van een gebruiker van Elektroerosie machine* (Point of view of a User of Electroerosion Machines), Studyweek for special processing methods, Heverlee, 1—8 March 1968.

Provoost, R., *Organisatie van Arbeidsgeneeskundige Diensten* (Organisation of Services for Industrial Medicine), School for Social Health Care, Section Industrial Medicine, Université catholique de Louvain, 7 March 1968.

Scheldeman, C., *Informatie en Kommunikatie* (Information and Communication), Foundation Lod. De Raet, Heverlee, 6 February and 27 March 1968.

Sorber, S., *Personeelsbeleid in een groot Bedrijf* (Personnel Management in a large company), School for Social Health Care, Université catholique de Louvain, Louvain, 28 March 1968.

Stiévenart, J., *Opleidingsproblemen*(Training Problems) Post-graduation Course "Man in Industry", Industrial Training School, Hoboken, 27 March 1968.

Teirlinck, A., *Private Centrale P 1000 T, (P 1000 T* Private Exchange), Training School Telephone Administration, Brussels, 24 and 31 January, 7—14—21 and 28 February, 6—13 and 20 March 1968.

Van Overstraeten, J., *Samenwerking in het Bedrijf* (Collaboration in the Enterprise), Post-graduation Course "Man in Industry", Industrial Training School, Hoboken, 25 January 1968.

Van Overstraeten, J., *Informatie en Kommunikatie* (Information and Communication), Post-graduation Course "Man in Industry", Industrial Training School, Hoboken, 22 February 1968.

Van Overstraeten, J., *Opleidingsmethoden* (Training Methods), Post-graduation Course "Man in Industry", Industrial Training School, Hoboken, 27 March 1968.

ITT Laboratorios de España

Lectures

De Miguel, J. A.,*Futuros Systemas de Conmutación Telefónica,* (Telephone Switching Future Systems), Telecommunication Technical Engineers School, Madrid, 29 January 1968.

Gómez Solera, J. L., *Circuitos Básicos Lógicos,* (Basical Logic Circuitry), Telecommunication Engineers High School, Madrid, 26 March 1968.

Gómez Solera, J. L., *Memorias para Computadores,* (Computer Memories), Telecommunication Engineers High School, Madrid, 27 March 1968.

Santos, I., *Dispositivos de Hiperfrecuencias: Amplificadores paramétricos, Maser, Laser, etc.,* (Hyperfrequency Devices: Parametric Amplifiers, Masers, Lasers, etc.), Telecommunication Technical Engineers School, Madrid, 12 January 1968.

Santos, I., *Diseño de Filtros* (Filter Design), Physics Research Center L. Torres Quevedo, Madrid, 19 January 1968.

Compagnie Générale de Constructions Téléphoniques

Article

Duquesne, J., Le Gall, P., Benmussa, H., Marty, P., Rivet, C. P., and Verne M., *Un projet d'autocommutateur à microsélecteurs et à programme enregistré, étudié dans le cadre du système PERICLES,* Commutation et Électronique, no 20, January 1968.

Lecture

Girinsky, A., *Message Switching, ITT* Switching Symposium, Leningrad, January 1968.

Le Matériel Téléphonique

Articles

Belin, E., and Collet, B., *Constitution des centraux de Paris à l'aide d'unités de câblage,* Commutation et Électronique, no 20, January 1968.

Regnier, A., *Le réseau de connexion de l'autocommutateur Périclès - Michelet,* Commutation et Électronique, no 20, January 1968.

Lectures

The following lectures were given at the Symposium on Automatic Telephone Switching which was held at Leningrad in January 1968.

Canceill, B., *Computer aid for the telephone traffic problems.*

Deshays, M., *Pentaconta crossbar system in the extension and modernization of a telephone network.*

Le Strat, G., *Centralized charging in urban and toll central offices.*

Schultz, S., *Methods and devices for the maintenance of the Pentaconta system.*

Schultz, S., *Pentaconta toll switching systems.*

Trélut, J., *ARTEMIS-A central computer controlled electronic exchange.*

Laboratoire Central de Télécommunications

Article

De Dianous, P., *Application du traitement optique de l'information à la météorologie et à l'océanographie,* Nucleus, volume 8, no 6.

Lectures

Desauty, J., *Fiabilité en électronique,* Institut Supérieur d'Electronique du Nord, Lille, 22 February 1968.

Gaugain, E., *Le Système Crossbar No. 5,* Ve Séminaire Pentaconta, 25 March 1968.

Mornet, P., *PCM Integrated Telephone Switching and Transmission Systems,* Leningrad Symposium, 12 January 1968.

Standard Telecommunication Laboratories

Articles

Brewster, A. E., *A High-Speed Magnetic Printout System,* Electronics and Power, February 1968.

Brisbane, A. D., *A Pulsed Gas Laser and Its Application to Microcircuit Fabrication,* Electronic Components, January 1968.

Craven, C., *Relationship Between Direct-Coupled Waveguide Filters and Evanescent-Mode Filters,* IEE Electronics Letters, volume 4, no 3, pp 44—46, February 1968.

Franks, J., and Selway, P. R., *A GaAs Infrared Sensitive Diode Made by Diffusion of Chromium,* Brit. J. Appl. Phys. (J. Phys. D), series 2, volume 1, no 1, pp 25—28, 1968.

Heath, D. R., Selway, P. R., and Tooke, C. C., *Photoconductivity and Infrared Quenching in Chromium-Doped Semi-Insulating Gallium Arsenide,* Brit. J. Appl. Phys. (J. Phys. D), series 2, volume 1, no 1, pp 29—32, 1968.

Kao, C. K., and Williams, D., *Pulse Communication Along Glass Fibres,* Proc. IEEE, volume 56, no 2, pp 197—198, February 1968.

Lees, J., *Mobility Variation in GaAs/GaP Alloys,* Solid-State Communications, volume 6, pp 11—14, 1968.

Lewin, L., *Effect of Source Pattern on Wedge Diffraction,* IEE Electronics Letters, volume 4, no 5, pp 82—83, March 1968.

Mok, C. K., *Diaphragms in Evanescent Waveguides,* IEE Electronics Letters, volume 4, no 3, pp 43—44, 9 February 1968.

Toombs, P. A. B., *Thin Films of Barium Lanthanum Titanate,* Proc. Brit. Ceram. Soc., no 10, March 1968.

Lectures

Burrell, E. W., Waters, D. B., and Williams, D. A., *Choice and Performance of Codes for PCM Systems on Coaxial Cable including Line Regeneration,* IEE Colloquium on Pulse-Code-Modulation, 4 March 1968.

Butler, M. B. N., *High Resolution Studies of Electron-Phonon Domains in CdS,* Institute of Physics, Solid-State Conference, Manchester, 3—6 January 1968.

Cooke, R. E., *Performance of the Microstrip Transmission Line,* IEE Conference on Microwave Integrated Circuits, London, 22 January 1968.

Craven, G., *Evanescent Mode Waveguide Components,* IEE, Savoy Place, London, 9 February 1968.

Hartley, G. C., *Data and Digital Networks,* Research Institute of National Defence, Stockholm, March 1968.

Heath, D. R., *Photoconductivity Measurements in Chromium and Iron-Doped Gallium Arsenide,* Institute of Physics Solid-State Conference, Manchester, 3—6 January 1968.

Hochreutiner, R. M., *Asynchronous Digital Multiplexing for 6 and 25 Mb/s,* IEE Colloquium on Pulse Code Modulation, London, 4 March 1968.

Jessop, A., *High Capacity PCM Multiplexing and Code Translation,* IEE Colloquium on Pulse Code Modulation, London, 4 March 1968.

Lambourn, E. H., *The Digital Transmission of Music,* IEE Colloquium on Pulse Code Modulation, London, 4 March.

McNeilly, J. H., *A Single-Channel PCM Coder/Decoder for the Telephone Subset,* IEE Colloquium on Pulse Code Modulation, London, 4 March 1968.

Mash, D. H., *Varactors,* Imperial College, February 1968.

Mash, D. H., *Varactors,* Bath University, March 1968.

Mash, D. H., *P-N Junctions,* Edinburgh University, February 1968.

Pearson, K. W., *Satellite Multi-access Operation with PCM,* IEE Colloquium on Pulse Code Modulation, London, 4 March 1968.

Pitt, G. D., *High-Pressure Single-Crystal Hall Effect Measurements to 70 kb,* 6th European High-Pressure Meeting, Aix-en-Provence, 9 April 1968.

Reeves, A. H., *Telecommunications in A. D. 2000,* Presidential Address, West Ham College Engineering Society, 12 March 1968.

Reeves, A. H., *The Future of PCM,* (Closing Address), IEE Colloquium on Pulse Code Modulation, London, 4 March 1968.

Weir, D. A., *Electronic Switching — A Review,* ITT Symposium on Switching, Leningrad, 1—18 January 1968.

Standard Telephones and Cables Limited

Articles

Archibald, W. J., *Ultra-reliable Submerged Repeaters,* Electronic Equipment News, p 46, February 1968.

Boswell, D., *Hybrid Film Structure — A Growing Market Outlet,* Electronics Weekly, pp 28—29, 31 January 1968.

David, L. M., *Communications Today,* Factory Management, volume 37, no 4, p 6, April 1968.

Warren, S. W., *Properties and Performance of Basic Designs of Infrared Interference Filters,* Infra Red Physics, volume 8, pp 65—78. March 1968.

Lectures

Bennett, J. B. C., *Basildon Computer,* Basildon Engineering Society, March 1968.

Boswell, D., *Thick Film Technology in Europe,* Keystone address IEE/IERE/ISHM Conference on Thick-Film Technology, Imperial College, London, 8—9 April 1968.

Standard Telefon og Kabelfabrik A/S

Article

Thoresen, F., and Kroken, P., *Plastic insulated cables and wires for outdoor use,* Teknisk Ukeblad, Kjimi, Bergvesen, Metallurgi, volume 28, no 1, pp 8—11, 25 January 1968.

International Telephone and Telegraph Corporation

Lectures

Busignies, H. G., *Trends in Telecommunications,* presented at the Telecommunications Headquarters of the following countries: Austria, Denmark, France, Holland, Norway, Spain, Sweden and Switzerland.

Busignies, H. G., *Achievements and Trends in Telecommunications,* Switching Symposium, Leningrad, URSS, 10 January 1968.

ITT Avionics Division

Article

Dodington, S. H., *Ground-Based Aids to Radio Navigation,* Journal of the Institute of Navigation, Winter 1967—1968.

Lectures

Dodington, S. H., *A Fresh Look at Ground-Based Radio Navigation,* Aviation-Electronics Technical Symposium, organised by the U. S. Army Electronics Command, Fort Monmouth, New Jersey, 7 March 1968.

Rymer, R., *The Impact of Microelectronic Technology on Present and Future Communications Equipments,* Atlanta Chapter of the Armed Forces Communications and Electronics Association, Atlanta, Georgia, 12 March 1968.

ITT Defense Communications Division

Lecture

Glomb, W. L., *Design Considerations for Spaceborne Communication Equipment,* Institute of Electrical and Electronics Engineers International Convention, New York, 21 March 1968.

ITT Industrial Laboratories Division

Articles

Branchflower, G. A., Foote, R. H., and Figgins, D., *Applications Technology Satellite Image Dissector Camera Experiment,* National Aeronautics and Space Administration, NASA Technical Notes D-4186, pp 1—12, November 1967.

Crowe, K. R., and Gumnick, J. L., *Enhancement of Photoelectric Quantum Efficiency in the Near Infra-Red,* Applied Physics Letters, volume 11, no 8, pp 249—250, 15 October 1967.

Hirsch, R. L., *Inertial-Electrostatic Confinement of Ionized Fusion Gases,* Journal of Applied Physics, volume 38, pp 4522—4534, October 1967.

Hirsch, R. L., *Non-Thermal Getter Pump,* Journal of Vacuum Science & Technology, volume 5, no 2, pp 61—62, March—April 1968.

Lectures

Hirsch, R. L., *Experimental Studies of a Deep Negative, Electrostatic Potential Well in Spherical Geometry,* Division of Plasma Physics, American Physical Society Annual Meeting, Austin, Texas, 8—11 November 1967.

Hirsch, R. L., *Inertial-Electrostatic Containment of Ionized Gases, Status of the Research,* Fifth Symposium on Advanced Propulsion Concepts, Chicago, Illinois, 9 April 1968.

Hirsch, R. L., *Review of Inertial Containment Principles and a Beam-to-Spherical Discharge Experiment,* Division of Plasma Physics, American Physical Society Annual Meeting, Austin, Texas, 8—11 November 1967.

Book Review

Crossbar systems and Automatic Telephony — I. Pentaconta

(Les systèmes crossbar en téléphonie automatique I. Le Pentaconta)

R. Légaré and A. Delbouys

This book is part of the series "Cours professionnels des PTT" (PTT professional courses). Mr. André Blanchard contributed the preface. It comprises the following chapters:

— Introduction (brief history of automatic telephony).
— Equipment.
— Selection unit.
— Automatic exchanges.
— Standard switching circuits.
— Preselection.
— Group selection.
— Line selection.
— The register.
— The preselection coupler.
— The selection coupler.
— The translator.
— The feeding bridge.
— SOCOTEL multi-frequency code.

This book, of 16×25 centimeters (6·2×9·8 inches) format, comprises 172 pages, 77 figures and 11 folding figures including circuit diagrams. It can be obtained from "Editions Eyrolles", Paris at a cost of 39 F.

ITT Appointments

Ardeo Bertucci has been appointed managing director of FACE Standard, Milan, at a recent meeting of the company's board of directors. In 1966 he was appointed general manager. As managing director, Mr Bertucci succeeds Mr Carlo Roda, chairman of FACE's board of directors.

Edward L. Beyer has been elected a vice president of ITT Export Corporation. Mr Beyer, who continues as export sales manager, joined the ITT System in 1928 and has held several export sales management positions. A native of New York, N. Y., Mr Beyer was educated at New York University.

Francis T. Cassidy has been elected a vice president of ITT World Communications Inc. Mr Cassidy, a former assistant vice president, will continue as director of capital budgets and facilities planning. He has held several key technical and engineering positions since joining the ITT System as a engineer in 1953.

John Gilray Christy has been elected a vice president and treasurer of American Cable & Radio Corporation and vice president of ITT World Communications Inc. He will continue as treasurer of ITT Worldcom, a position he had held since 1966.

Albert E. Cookson, vice president of International Telephone and Telegraph Corporation, was recently promoted to general technical director of the ITT System. Mr Geneen stated that Mr Cookson is assuming the post previously held by Dr Henri Busignies, whose advancement to chief scientist of ITT was recently announced. In his new capacity, Mr Cookson will report to the Office of the President-Operations-ITT.

Stratton J. Georgoulis has been appointed general manager of the US operation of ITT Semiconductors. Mr Georgoulis will have charge of the division's operations in West Palm Beach, Florida, Lawrence, Massachusetts, and Palo Alto, California.

Paul C. Gordon has been named general manager of ITT Barton. ITT Barton is a major supplier of instruments employed in the measurement, recording and control of liquids and gases for the oil, gas, chemical, paper and other processing industries. Mr Gordon brings to his new post an extensive background in a variety of managerial assignments covering almost twelve years with ITT. He was most recently general manager of the ITT Advanced Mechanization Laboratory.

John W. Guilfoyle was recently appointed as group executive-Latin America for International Telephone and Telegraph Corporation. Mr Guilfoyle, who is a vice president, reports to Mr Geneen through the Office of the President-Operations-ITT. Before being appointed to the Latin American post Mr Guilfoyle served since July 1966 as group executive-Far East and Pacific. From June 1964 until the latter appointment he was group executive-U. S. Defense/Space Group. He also had served as president of American Cable & Radio Corporation and Federal Electric Corporation, both ITT subsidiaries.

Joseph Haber, formerly with the ITT Defense/Space Group, has been appointed director, Contract Administration ITT's Federal Electric Corporation.

Charles E. Haller, vice president of ITT Defense Communications Division, Nutley, N. J., has been appointed director-Operations. He had been serving as vice president and director-Engineering. In his new position, Mr Haller will have reporting to him the directors of Engineering, Manufacturing, Quality Assurance, Procurement and Operations Control.

Lyman C. Hamilton has been elected a vice president of International Telephone and Telegraph Corporation. Mr Hamilton, who also is treasurer of the Corporation, joined the ITT System in September 1962 as manager-financial planning in the treasurer's department. Later he served as director-financial programs, director-foreign operations in the same department, and as associate treasurer and director — treasury operations.

Robert Kirk has been elected a vice president of International Telephone and Telegraph Corporation. Mr Kirk, a native of Charleston, West Virginia, will also continue as product line manager-defense systems, avionics and electromechanical components for ITT. He came to ITT in April 1967 from Litton Industries in Washington where he had been vice president of the government products group since 1964.

Paul J. Marchesseault has been appointed director of sales at the Bobbs-Merrill Company, Inc. Mr Marchesseault comes to the Sams Company, a subsidiary of ITT, from Science Research Associate, Inc.

Edgar Park was recently appointed manager of switching engineering by ITT World Communications Inc. Mr Park, a former senior switching engineer, joined the Commercial Cable Company, an affiliate of ITT Worldcom, as station electrician at St. Johns, Newfoundland, in 1957. He was transferred to the New York headquarters as an engineer in 1962.

Stanley P. Pearson has been appointed director of service quality and manpower development of ITT World Communications Inc. A former manager, personnel resources and development, Mr Pearson has held key personnel administration posts with ITT System companies.

Claude J. Peay was recently elected vice president-Sales of ITT's Hamilton Management Corporation. Mr Peay was a registered pharmacist in Fort Collins, Colorado, before joining Hamilton as a sales representative in 1952. He became Hamilton's first million-dollar-a-year salesman, and in 1958 was promoted to manager of the North Platte, Nebraska, district, which eventually was enlarged to cover the entire state. Mr Peay moved to Denver as district manager in 1961.

Enrique de la Pedraja has been appointed the new managing director and general manager of "Marconi Espanola, S. A.". Previously he had been a member of the board of directors and assistant general manager of Standard Electrica S. A., to which company he belonged for 40 years. Here he helped develop the first Spanish telecommunications industry.

Robert C. Pittman, senior vice president and director of worldwide operations at ITT's Federal Electric Corporation, has been elected executive vice president by the FEC board of directors. During the years of his association with the ITT worldwide service organization, Mr Pittman has played an active part in all operations of Federal Electric. He has devoted prime attention to developing missile and space programs at the nation's test ranges, and to broadening Federal Electric's activities in support of the U.S. Air Force and the National Aeronautics and Space Administration's programs for the manned exploration of space.

James A. Purdy has been appointed group general manager-Far East and Pacific of International Telephone and Telegraph Corporation. In his new post, Mr Purdy will have responsibility for all ITT activities in the Far East and Pacific areas. These encompass manufacturing companies in New Zealand, Australia and Hong Kong; installations and service facilities in the Philippines; procurement, marketing and liaison activities in Japan, and the open country (where ITT does not have plants) marketing activities for ITT throughout the rest of the Far East and Asia.

Louis C. Reymond has been elected a vice president of ITT Export Corporation. Mr Reymond, who continues as comptroller-treasurer, joined ITT in 1953, working in various staff capacities in the ITT World Headquarters Comptroller's and Treasurer's Departments. A native of Brooklyn, Mr Reymond received a bachelor's degree in accounting from Long Island University and a master's degree in business administration from New York University Graduate School of Business.

James S. Rice has been elected a vice president of International Telephone and Telegraph Corporation. Mr Rice, who also is group executive, Commercial Telecommunications Group-North America joined ITT in 1966 and as director of the North American operations staff was responsible for the support of ITT's North American manufacturing research and sales activities.

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