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This Issue in Brief

Modern H. F. Point-to-Point Radio Equipment.

A new generation of remote-controlled automatically operated transmitters and receivers known as the STANFAST system has been designed to meet modern requirements for programmed operation.

In a large transmitter station, the operation of a single switch will find a free transmitter, connect it to the required antenna, and cause it to tune itself to the programmed frequency within twenty seconds. Should the transmitter become faulty it will be busied out of service and a spare will be selected automatically. The equipment is very compact, thus saving on building costs and where possible is transistorised, thus adding to the high reliability which is necessary for unattended stations.

The article describes a major step forward in the concept of overall system design. The previous concepts of individual transmitters, drive units, aerial switches and ancillaries, are now being considered at the design stage as integral parts of the station complex. It is this overall transmitting and receiving station design that the STANFAST system represents, and it is on this scale that modern communications engineering is being conceived.

Experience with Trial Office HE-60 L Stuttgart-Blumenstrasse.

Over the past few years, electronic telephone switching centers have been installed to an increasing extent. These switching centers serve primarily for gathering of technical and operating experience in an experimental application.

SEL has developed an electronically controlled switching system using reed relays in the switching network for the speech paths as well as for the connection of central devices to individual circuits. This system, which is known under the code designation HE-60 (Herkon* Electronic 1960), has been in operation in the Stuttgart local switching center 23 since July 1963. Compared with the conventional technique, the HE-60 system offers increased convenience to the subscriber and routing control in the local network.

The article reports on the use of the additional services and the results of a subscriber survey concerning the push-button telephone set.

The quality of the telephone service is primarily determined by the number of unsuccessful calls due to defects in the technical equipment. The failure rate is hence an important criterion for judging an equipment, by both the customer and the operating company. To determine the quality of the HE-60 system, a large number of test calls was routed between artificial subscribers in November 1965 and April 1967.

In addition, an evaluation of the fault history of the past four years provides valuable information on the reliability of the various functional groups, in particular that of the central devices. It also permits conclusions to be drawn on the time required for the elimination of faults.

Loaded "Wet" Submarine Cable.

Norway consists of rugged country broken up in a crisscross pattern by the water of fiords, lakes, and rivers. This water makes the planning of cable routes difficult. Both crossing the water and planning the route from each side is made expensive and hazardous by the sheer hills on the shores of the lakes and fiords.

Faced with this problem it is easier to lay an underwater cable following the route of the water, emerging only when the terrain is suitable. To do this without great expense a rugged and relatively inexpensive cable has been developed by STK in cooperation with the Norwegian Telecommunications Administration. This cable is called a "wet" submarine cable since it has no sheath and after laying water fills its interstices. When it is inserted in a loaded trunk route any length can be used because it is preloaded. Single coils are moulded into the polyethylene insulation and jointed into the cable before armouring.

This article describes the design of the cable and loading sections and discusses some of the projects where considerable saving has been made using this technique.

Geodetic Satellite.

In January of 1964, after four years of research and development, a U. S. Army Geodetic Satellite was orbited. The satellite and its associated ground stations provide a space-age tool for accurately determining relative locations of land masses separated by large bodies of water such as continents and islands.

The principle of the method is the following: Range and measuring ground stations are located at three known points and at the unknown point. All four stations measure range to the geodetic satellite simultaneously. The three range measurements from known points allow the satellite position to be determined vs time on several orbits. If three spacially separate satellite positions are calculated, the range measurement from the unknown point to these three positions will uniquely determine the location of the unknown point.

Range is measured as follows: Each ground station transmits an r-f carrier which is phase modulated by ranging side tones. The side tones are demodulated in the satellite transponder and used to remodulate another r-f carrier which is received by the ground station. Range is proportional to the phase shift of the transmitted modulating frequency and the received modulating frequency that is sufficient to measure.

ITT Aerospace supplied the original satellites as well as one of the transponders which were orbited and tested.

The satellite is approximately $9 \times 11 \times 13$ inches and weighs 40 pounds. It consists of solar cells, two turnstile antennas for operation at 420 MHz and 449 MHz (ranging frequency) and a single whip antenna for 136.8 MHz (telemetry).

The primary feature of the transponder is its high degree of phase stability, required for accurate ranging.

The system was tested over land distances of 500 and 1000 miles with the satellite in a 500-nautic-mile orbit. Results showed that the system ranging accuracy was approximately three to five meters and that the position of an unknown point could be located with an error of 16 and 34 meters over distances of 500 and 1000 miles respectively.

Submerged Repeater for the United Kingdom to Portugal 640-Circuit Cable.

The British Post Office requirement for a 640-circuit link between the United Kingdom and Portugal has led to the development of a 5-megahertz repeater using transistors.

The system requirements, which included a noise performance of 1 picowatt/kilometer under a channel load of -10 dBm0, are detailed.

Supervision of the repeaters is achieved using a pulsed-carrier supervisory system which enables gain and repeater noise to be monitored. Protection of the repeater from surges which arise due to cable faults is included in the design.

The repeater performance meets the specification requirements and also is sufficient for systems up to 3500 nautical miles in length.

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

The sensitivity of telephone sets is customarily described by loudness ratings which, by CCITT recommendation P 42, are obtained by subjective comparison with a master reference system, NOSFER, in the CCITT Laboratory in Geneva, or a working standard system which has been compared to NOSFER.

The subjective assessment of loudness is a complex function of the human voice, ear, and brain, and an exact objective

* Herkon = **her**metically sealed reed **con**tact

analogue would need a machine of the complexity of a medium sized computer. Fortunately, a usefully close approximation to human loudness assessment can be obtained by simplified replicas of voice, ear, and brain integration, if made according to principles which are now known to be suitable for rating sound spectra such as speech. These principles are built into measuring equipments, one of which is referred to for convenience as OREM-A.

An objective measurement of loudness has such great advantages of speed and versatility that the currently available OREM-A rating system is becoming widely used. However, much confusion is resulting from differences of up to 10 dB between some objective ratings and CCITT subjective ratings. These differences have now been shown to be due, largely, to three factors: the first, a comparatively recent improvement in acoustic calibration technique, the second, an improved understanding of the human appreciation of a frequency-band-limited signal, and the third, the lack of an artificial mouth which is a true replica of the human mouth and head.

Three correction factors are described which enable the maximum differences of 8 to 10 dB to be reduced to 2 or 3 dB. Some minor differences remain to be defined.

SELECTRONIC Stored-Program Supervisory System 702.

The purpose of the SELECTRONIC 702 is to collect data and alarms from remote stations into a central control station and to send control or numerical instructions from the central control station to any remote station. The central control station has complete control, the remote station sends data only requested by the master station.

The remote stations are continually scanned and the sequence of scanning is determined by a program stored in the ferrite store of the central control station. The program is written on a paper-tape, and transferred to the ferrite store by means of a paper-tape reader. The program has count and jump instructions so that a minimum number of instructions are stored. The data are displayed at the central control station on line diagrams with filament lamps, dial-type meters, and digital displays. A silicon-controlled-rectifier store is used for lamp drivers.

The data may be logged with an alpha-numeric print out. The format is flexible, this is also achieved with a stored program technique.

DIGITEL 1000 Remote-Control System.

The BTM Supervisory System DIGITEL 1000 is a combined interrogation system for remote control, remote indication, telemetering, and telecounting.

One master station controls several slave stations or collects data from them by sending instructions to all the slave stations. Only the slave station that recognizes in the instruction one of its addresses answers and returns the information requested or performs the control ordered.

The DIGITEL 1000 is intended for medium-capacity applications, e. g. 500 remote controls and 1500 data bits. The system consists of several wired-in interrogation and control programs:

— a cyclic scanning program,
— a priority scanning program,
— a manually initiated program, consisting of remote control, teleregulation, and interrogation on request,
— a telemetering logging program.

The instruction message contains 22 bits and the data message 19 bits. Both numbers include the 5-bits of the error control code, which protect both messages.

For utmost reliability, the remote controls and teleregulations are performed in three steps, with feedback from slave station to master station at each step.

The transmission speed ranges from 50 to 1200 bauds. The central logic of the system is implemented with silicon diode-transistor logic circuits. The peripheral circuits use relays. Both electronic circuits and relay circuits are mounted on printed circuit boards which are plugged into subracks.
All the equipment is ISEP.

European Color Television Standards — The PAL System.

Three European countries were introducing color television in the second half of 1967.

In the preceding years, European post administrations (responsible for the implementation) and the industry have been trying not to repeat the mistakes made in the early fifties when the aim was a common monochrome television standard. These efforts may now be called unsuccessful. At least two different color television standards will be operative in Europe after the long drawn-out discussions of the systems NTSC, SECAM, PAL and NIIR.

A description is given of the fundamentals common to any television system and of the special features characteristic of the PAL system.

Glow-Discharge Formation of Inorganic Films for Capacitors.

A new film-forming method has been used to make capacitors. The method relies on the ability of a low-energy, radio-frequency glow-discharge to excite a mixture of suitable gases and promote chemical reactions. This results in the formation of a solid film, without the use of heat. Many inorganic chemical systems can be exploited, but the work reported here refers specifically to the deposition of insulators, and particularly to silicon nitride.

Silicon nitride is a ceramic material which is normally made by direct combination of its elements. It is formed into shapes by powder pressing and sintering processes, but in this form it is not suitable as a capacitor dielectric. In view of the special conditions of purity and control which are inherent in this glow-discharge deposition method, the desirable dielectric properties of silicon nitride can now be exploited.

Silane (SiH_4) and ammonia (NH_3) gases are fed into a reaction chamber and subjected to a radio-frequency glow-discharge at a frequency of 1 MHz. The silicon nitride layer deposits on to suitably positioned substrates, and grows at about one micron per hour.

Experimental capacitors are made by using glass substrates furnished with evaporated aluminium electrodes. Results show that the dielectric properties of silicon nitride deposited by glow-discharge are somewhat similar to mica, but with a higher value of permittivity. These capacitors have been encapsulated in epoxy resin and heat treated, without any detrimental effect.

Economic, Operational, and Technical Aspects of Modern Global Communication Systems.

A brief history of the development of cable and satellite systems is traced, followed by an evaluation of their respective advantages and limitations.

This analysis together with recent developments indicates that both these international communications media will be able to co-exist in a complementary rather than competitive manner. A comparison of the parameters governing the employment of cables and satellites in the global network is developed, in which financial involvement, technical capabilities, reliability, quality and finally profitability are discussed.

It is concluded that, thanks to continuous technological advances, equal scope remains for cables and satellites in a progressively integrated global network capable of meeting all demands.

Electrical Communication in New Format

Electrical Communication is now available in four languages: English, French, German, and Spanish. The technical contents are the same in all languages.

To maintain a strong family resemblance among all four editions, they are now being printed in the same format, which requires an increase in the page size of the English language edition. This larger page provides additional flexibility in the presentation of large illustrations and long mathematical equations.

Readers who would prefer to receive one of the other language editions should write to International Telephone and Telegraph Corporation, Electrical Communication, 320 Park Avenue, New York, New York 10022.

Awards, Honors

Busignies Honored

Dr. Henri G. Busignies, General Technical Director of the International Telephone and Telegraph Corporation, has received the Certificate of Merit of the National Security Industrial Association in recognition of outstanding service to the defense of the United States of America through military-industry cooperation while serving as Chairman of the Research and Development Advisory Committee, 1965—1967.

Awards to Engineers of Standard Telecommunication Laboratories

The Institution of Electronic and Radio Engineers recently bestowed on Messrs. C. P. Sandbank, R. W. Harcourt, and J. Froom the Lord Rutherford Award for their paper entitled "Acoustic Amplification in Semiconductors".

The citation reads as follows: "This paper was considered to be the most outstanding on electronics associated with atomic physics published in the Institution's Journal during 1966".

The Institution of Electrical Engineers awarded their Electronics Division Premium to K. C. Kao and G. A. Hockman for their paper entitled "Dielectric Fibre Surface Waveguide for Optical Frequencies", which appeared in the Proc. IEE, Vol. 113, N° 7, p. 1151, July 1966.

Berlin Senate Honors Horst Ludwig Stein

The senate of Berlin awarded to Horst Ludwig Stein, manager of SEL's Central Publicity Department and Chairman of the Exhibition Committee for the 25th Great German Radio and TV Exhibition, a Silver Medal in recognition of his accomplishments.

The 25th Great German Radio and TV Exhibition, which took place from 25 August to 3 September 1967, met with worldwide response. With more than 500000 visitors and an unexpectedly large number of radio and TV dealers over a ten-day period, this exhibition contributed essentially to speeding up business in the entertainment sector.

Horst Ludwig Stein has been active in the Exhibition Committee for almost two decades, serving as its chairman during the past ten years. He holds offices in various other publicity, advertising, and press organizations.

Modern H. F. Point-to-Point Radio Equipment

L. J. HEATON-ARMSTRONG
B. S. JACKSON
Standard Telephones and Cables Limited, London

1. Introduction

High-frequency radio communication is continuing to play a major role in world communications. Radio telegraph and telex services, military communications, ship-shore services and meteorological broadcasts take advantage of every modern facility in this field.

The advent of satellite and submarine cable communication has opened up new feeder-route services and has created additional demands for circuits on new routes. High-frequency radio is complementary to these communication systems.

Modern equipment uses independent-sideband emission. This is a technique whereby a carrier is fed into two separate channels and each channel is modulated by a different source of intelligence to produce two double-sideband emissions. The upper sideband is selected from one channel and the lower sideband from the other and these are then combined to produce what is known as an independent-sideband emission, because each sideband contains intelligence which is independent of that in the other sideband.

This system makes available two audio channels, each nearly 6 kHz wide, into which four speech channels can be inserted. Alternatively sixteen voice-frequency telegraph circuits can be carried instead of one of the speech channels or a mixture of speech and telegraph channels may also be used.

This is a considerable increase in the information flow carried by the high-frequency link and in consequence a much higher standard of reliability is required. In the event of failure the circuit must be rapidly restored by switching in spare equipment. Furthermore it is necessary to change frequency three to four times during each twenty-four hours, due to changes in the ionosphere. Under earlier procedures this was achieved by resetting rapidly to the next frequency or by having spare equipment already working on the next frequency and making an almost instantaneous changeover on the terminal equipment.

However, automatically-tuned transmitters and receivers combined with automatic monitoring and switching systems provide these facilities with minimum manpower requirements. The small size of modern equipment also allows buildings to be smaller. These reductions in manpower and building size are vital to the economic operation of high-frequency radio links, and it is this concept of automatically-controlled radio stations that has been called STANFAST.

2. Transmitter-Station Equipment

2.1 General

The simple system of transmitters, each attached to signal input circuit and antenna output circuit, still meets the requirements of many small transmitter stations. There is little flexibility in this arrangement and a more common approach is to provide switching at the input and output to enable the transmitter to be used for other services or replaced if faulty.

Control of this type of system is usually concentrated at a central console or rack, each transmitter having its control panel with additional panels providing control of input and output switching.

For large transmitter stations the whole process of setting up a signal path may be automated from a single action by the operator, that of putting the service switch to the required position. This action initiates a search for a free transmitter by the control system and when one is found it is connected to the required input signal and aerial system. The transmitter is given frequency information and then run up, tuned, tested and put to traffic without further intervention by the operator. During traffic the equipment is continuously monitored for correct output level and failure of the transmitter would automatically switch in a free equipment.

To prevent a break in traffic when changing from a failing frequency to its replacement a period of dualling on both frequencies may be employed and here again the automated system improves the equipment utilization by the ease with which equipment can be brought into use for the changeover period.

2.2 Signal Path

A STANFAST system can range from a single modulator/transmitter combination to a full automated group. The latter is indicated in Figure 1. Line inputs carry either speech or voice-frequency-telegraphy circuits to the i. s. b. (independant-sideband) modulator equipment or direct current keying signals to the f. s. k. (frequency-shift-keying) modulator equipment. The output of the modulator equipment is at 100 kHz and is duplicated for the dualling requirement. A crossbar switch interconnects the modulator outputs to the transmitter inputs and a further crossbar switch connects the transmitter outputs to the aerial feeders, which lead to matching transformers and aerials. The transmitter consists of two parts, not necessarily co-located, the first part is the high-frequency exciter which synthesises a frequency and modulates it with the input signals to produce the required output frequency signal, and the second part is the high-frequency amplifier which raises the power level to that required for transmission.

2.3 Control Systems

Where the transmitter system is large enough and particularly with the modern automatic equipment, control and monitoring facilities are concentrated at a central point. Each transmitter has its own panel at which the normal functions of switching on or off, selecting frequency and indicating state of equipment are available. Other panels provide antenna switching, input patching and monitoring.

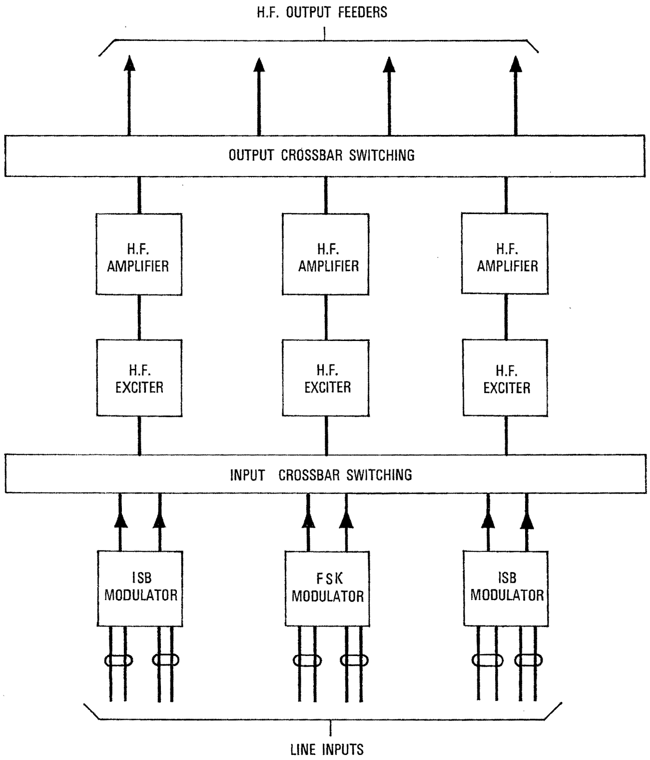

Figure 1 - Transmitter station, signal path.

This type of control is made over d.c. lines which can be extended for a few miles if necessary. Beyond this distance a remote control system using voice-frequency signaling over a single pair of lines, with suitable interface circuits each end, is used.

For the BPO (British Post Office) contract for Ongar radio station a fully automated system based on service requirement, and not on transmitter equipment, is being supplied. This system is similar to that installed by the BPO at Leafield [1, 2]. At Ongar each service has its own control panel with one or two frequency-selection switches, the number depending on whether the service is to be dualled or not. When a frequency is selected the control system selectors search for a free transmitter, when found it is connected to the modulator and antenna associated with the service chosen. It is then busied to the system to prevent reselection. All frequencies in use by the station are stored in a register to which the high-frequency exciter, that is part of the transmitter, is now connected for a few seconds in order to set to the frequency chosen. The normal traffic signal from the modulator to the high-frequency exciter is replaced by a tuning signal, which is a single frequency at a level of −6 dB with reference to full power condition. The transmitter is switched to "on" and "tune". When the control system finds that tuning is complete the tune signal condition is changed to give either full power for f. s. k. drive or two tones for full peak envelope power for i. s. b. drive. The monitoring system is now brought into operation and checks for correct output level; if correct, traffic signals are restored. If not correct, the transmitter may be rejected and the process repeated with a new transmitter.

This system, based on service selection, can also be remotely controlled and is less complex for equivalent station size as the initial control action is very simple.

2.4 Drive Equipment

With the steady introduction of cable circuits giving high-quality speech without fading or other effects associated with a high-frequency communication channel, telephony traffic has declined and the predominant traffic is telegraphy on high-frequency circuits. This is handled by frequency-shift keying (F1) of the carrier for low-capacity circuits or by multi-channel v. f. t. (voice frequency telegraphy) circuits (A7b) carried on i. s. b. emission. Tone-shift keying (t. s. k.) is also employed and is a single channel v. f. t. with the carrier fully suppressed.

These types of emission (A7b, F1) and other types of emission required, are produced by f. s. k. and i. s. b. modulators. This equipment is fully transistorized in present-day practice and is highly reliable. In the STANFAST system it is classified as line equipment and is permanently attached to the incoming line and in general set for the type of emission required. Remote selection of different emissions is available where changes are required in day-to-day operation.

The output of the equipment has been made standard at 100 kHz, this being a convenient frequency for crystal filters and for switching by simple relays without excessive crosstalk or matching problems.

The f. s. k. equipment is based on a highly stable LC oscillator which is pulled by electronically switched capacitances across the oscillator circuit. The basic circuit is shown in Figure 2, which also shows the shaping circuits provided to ensure the bandwidth requirements of CCIR (Comité Consultatif International des Radiocommunications) are met.

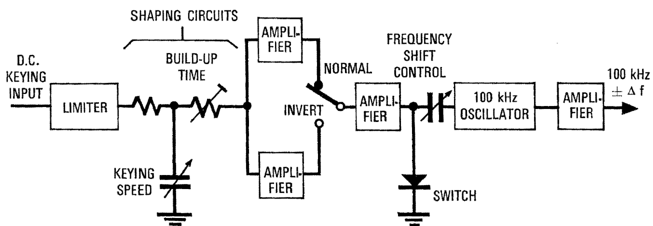

Figure 2 - Frequency-shift-keying modulator block diagram.

In addition to single-channel f. s. k. (F1), double channel (F6) and facsimile (F4) are provided and for occasional use, on-off keying (A1).

I. S. B. drive equipment provides two 6-kHz channels for speech or v. f. t. circuits. For stability of performance the standard balanced modulator/crystal filter system is used. The input circuits provide for a range of input levels and limiters are provided to avoid overload conditions. The output circuits are similar to those provided for the f. s. k. equipment.

Both these equipments provide line-up and test facilities to set up the overall system and then check for correct operation before traffic commences.

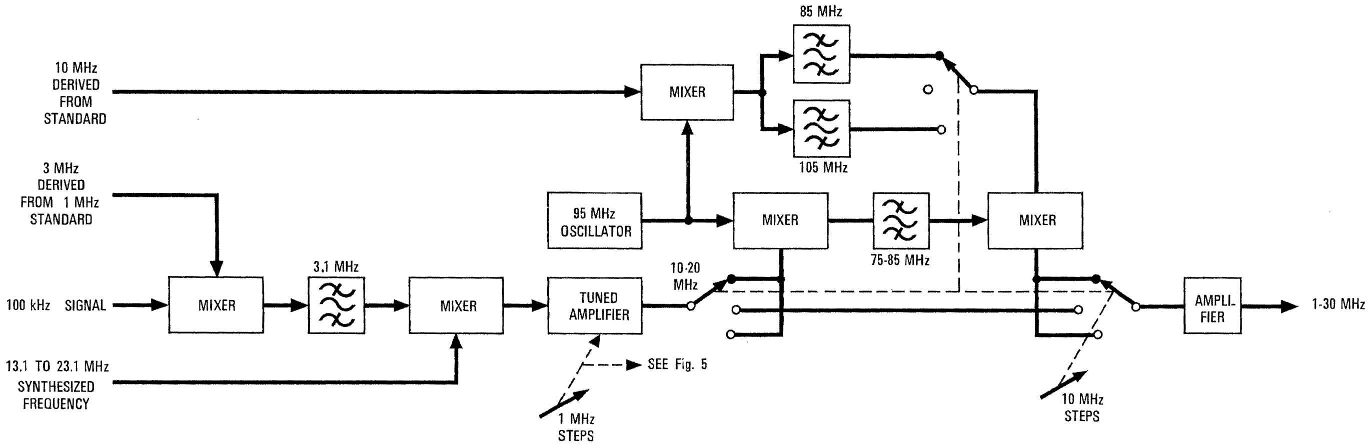

Figure 3 - High-frequency exciter, modulated signal path block diagram.

2.5 *High-Frequency Exciter*

There are several methods of producing the low-level signal at final output frequency from the fixed-frequency drive signal. In the STANFAST exciter (Figure 3) the 100-kHz signal is modulated with a 3-MHz signal and the 3.1-MHz sideband selected. This signal is again modulated with a frequency in the band 13.1 to 23.1 MHz and the lower sideband is selected, so that the signal now lies between 10 and 20 MHz.

The signal is used directly for output frequencies in this band but to cover the range 1 to 30 MHz it is modulated with 95 MHz into the 75—85-MHz band and then demodulated with either 85 or 105 MHz to give the 0—10-MHz or 20—30-MHz bands, the 10-MHz difference between the modulating and demodulating frequencies being referenced to a basic standard frequency source.

Frequencies between 13.1 and 23.1 MHz are produced from a series of frequencies lying between 1.7 and 3 MHz which are derived from a 1-MHz standard source (Figure 4). A series of dividers and mixers are used to produce the 100-Hz steps from the original 100-kHz steps.

Figure 5 gives details of the mixing and phase-locking process whereby the signal at 1.9—2.9 MHz (in 100-Hz steps) is mixed with the oscillator covering 16—25 MHz (in steps of 1 MHz) to produce the signal from 13.1—23.1 MHz in 100-Hz steps.

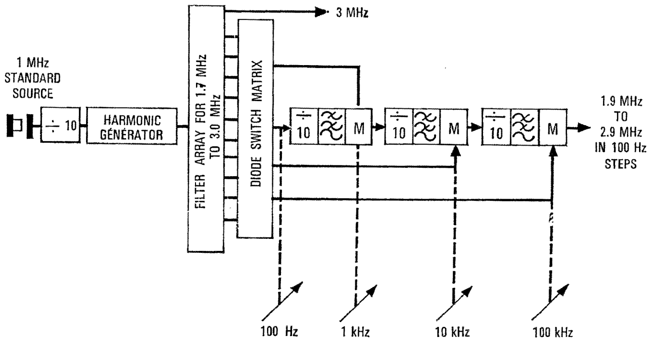

Figure 4 - High-frequency exciter, frequency synthesis, first stage.

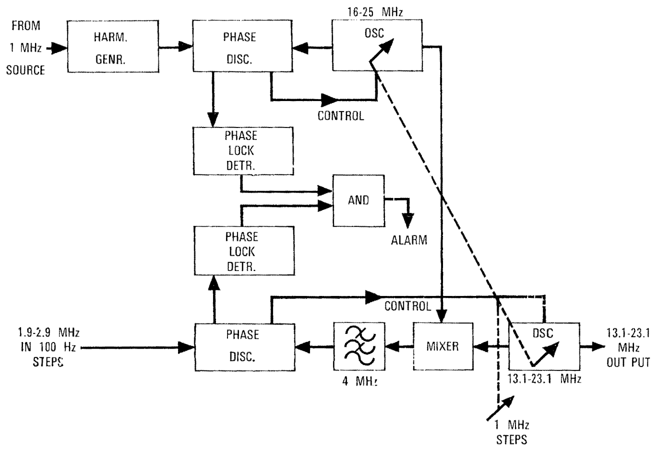

Figure 5 - High-frequency exciter, frequency synthesis, second stage.

2.6 *High-Frequency Amplifiers*

The modern high-frequency amplifier comprises the minimum of tuned circuits and moving parts, and the maximum of solid-state components. The power switching and tuning control systems consist of a series of logic modules sequencing and timing the various functions. All the high-tension supplies are provided by silicon rectifiers. Only the radio-frequency stages are valved and the trend is to change to transistors wherever possible, the main limitation being the linearity requirements and the power-handling capability of existing transistors.

Power outputs of 3, 10, and 30 kW are the generally accepted levels for short, medium, and long distance communication, these are provided in the STANFAST range by amplifiers designated QT2, QT3, and QT8. These are all very similar in design, the main difference is the size that is associated with power output rating. The 30 kW (QT8) is shown in Figure 6 and its block diagram in Figure 7.

The radio-frequency stages consist of three low-power, wideband stages, followed by a tuned penultimate stage and the tuned final amplifier. All stages are either tetrode

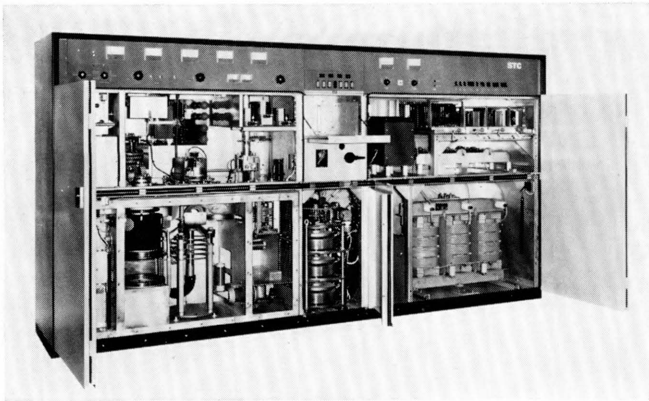

Figure 6 - High-frequency amplifier type QT8.

or pentode valved giving high stage gains with low drive power requirements. Negative feedback is applied over the amplifier to improve linearity and gain stability, and the circuit design is such that the feedback system does not require adjustment.

The amplifier is fully automatic in its tuning, loading, and gain setting and sets to the frequency of the high-frequency exciter. This is achieved by coarse position discriminators that roughly position the circuits according to frequency and then by phase discriminators that set the tuned circuits. Level discriminators set the loading and gain controls.

The block diagram of the 30 kW, QT8 shows the simple radio-frequency amplifier chain where the power is of the order of 30 mW at the penultimate grid, increasing to 200 watts at the final stage grid and then increasing to 30 kW in the output feeder. The spur amplifier chain provides a radio-frequency signal to drive the coarse position discriminators and is biased off except when in use. The radio-frequency feedback loop is shown and as it is across only two effective tuned circuits, since the penultimate grid circuit has very low Q, the phase change round the loop can never give positive feedback at any frequency at which the loop gain exceeds unity. An important item in the control and monitoring of the amplifier is the s. w. r. (standing-wave ratio) monitor unit. From this is derived the information to control the loading of the amplifier [3], to trip the equipment if excessive s. w. r. occurs on the output feeder and to indicate the power output and s. w. r. at any instant. The output power indication is also used in conjunction with a sample of the final valve cathode current to provide a protection system against excessive anode dissipation on the valve. This feature is used first to cut back the drive level to a safe condition and should this not be achieved and the dissipation continues to increase, a trip circuit is activated.

Control of the tuning and loading circuits is by the discriminator output operating the servo motor through its servo amplifier. The output of each discriminator is a direct-current voltage of polarity that determines direction of travel and having a null at the correct tuning or loading setting. This is converted to alternating current at the input of the servo amplifier by a ring modulator switching at mains supply frequency. The output of the modulator is amplified and applied to the control windings of the servo motor which drives the associated circuit to its correct setting. Direction of travel is determined by phase relation of the motor control winding to the reference winding voltages. As in most servo systems feedback is provided by a tacho-generator on the motor to ensure stability around the loop.

2.7 Switching

Two sets of switches are involved in connecting the transmitter to a system, the input 100-kHz switching and the output high-frequency power switches. Both are in crossbar form but are very different in concept.

The input crossbar is in the form of a double-sided printed-circuit board with reed switches making the required connection at the cross-points. Unused portions of the track, although in the form of stubs, do not cause difficulty nor does slight mismatch, as the frequency is only 100 kHz, but as all frequencies on the board are 100 kHz, crosstalk is the main problem and low capacity switches are used to obtain at least −80 dB crosstalk. The whole assembly is quite small and may be rack mounted.

The output crossbar-switch exchange is, however, a major item of equipment. As frequencies up to 30 MHz are

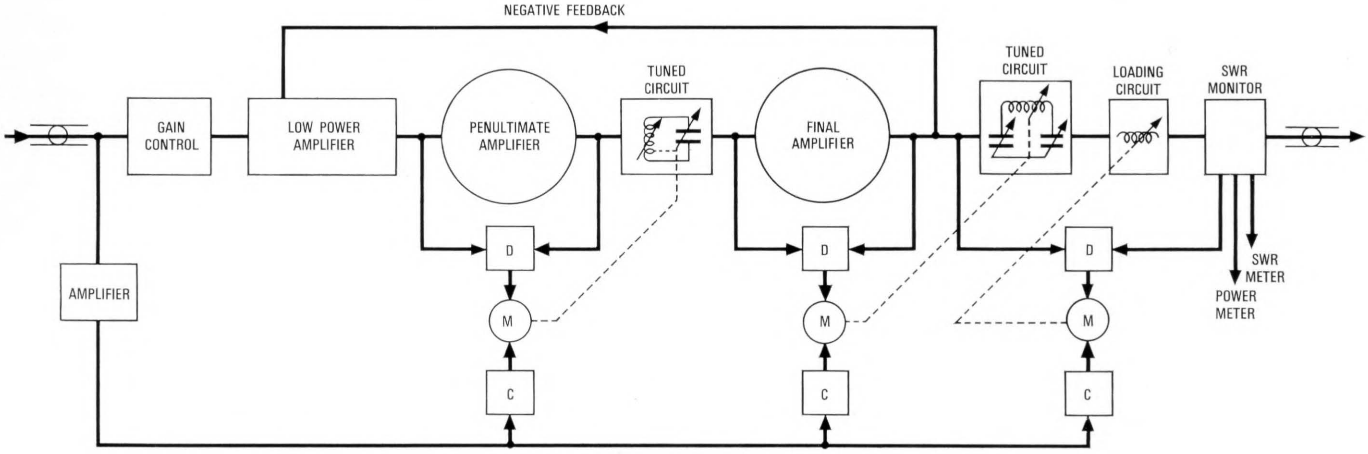

Figure 7 - High-frequency amplifier type QT8 block diagram.
D – phase or level discriminator. C – coarse position discriminator. M – motor.

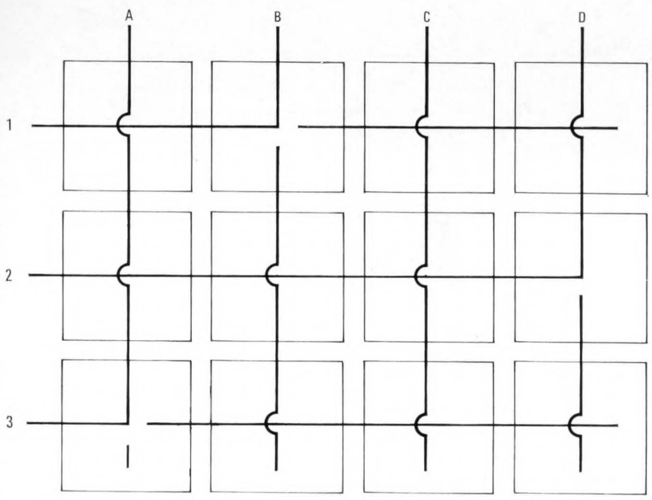

Figure 8 - Output crossbar switch, diagram.

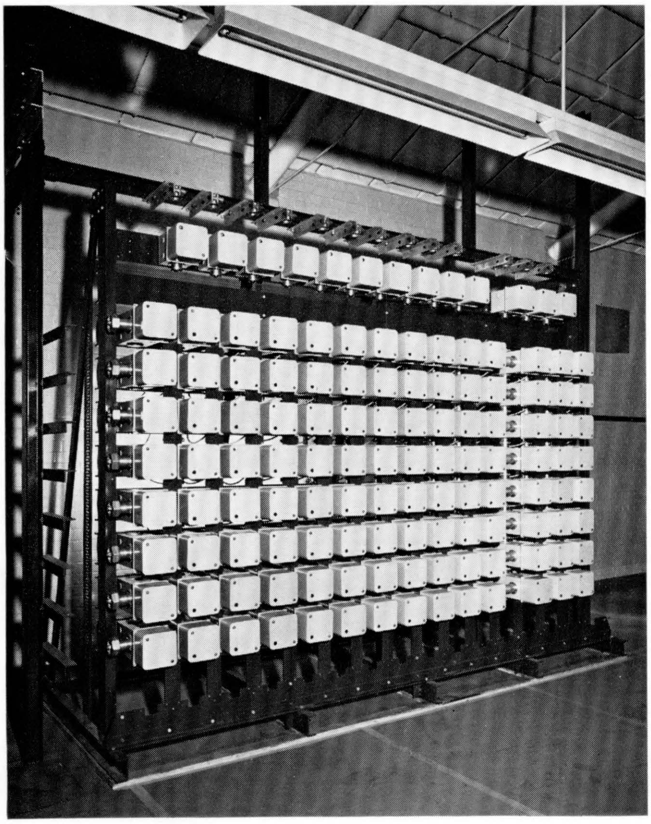

Figure 9 - Output crossbar switch, photograph.

to be carried through the exchange, unused stubs cannot be allowed. The power handled may be up to 30 kW, with a load s.w.r. of 2:1, giving in effect a power rating of 60 kW at any switch. Further to this, the path through an exchange could pass through twenty switches and the effect of cumulative s.w.r. from the switches could be serious, hence a very low s.w.r. is necessary for each switch. The switching method adopted is shown in Figure 8 where switches A3, B1 and D2 are operated to give paths through the exchange. Figure 9 shows a crossbar exchange in process of erection. The left-hand vertical and top horizontal lines are isolator switches, the rest being crossbar switches. Any switch can be withdrawn from the exchange for servicing without disturbance to adjacent switches. Each switch has its own motor drive and interlocks. These interlocks repeat the radio-frequency path through the exchange and act as protection for the transmitters. Transmitters are connected to the left-hand side of the exchange and antenna feeders are connected along the top. Exchanges can in theory be of any size, but in practice greater than 10×15 (150) switches is unwieldy and uneconomic. It is more convenient to have two small exchanges of 6×8 (96 total switches) with the cross connection allowing transfer of a transmitter from one group to the other.

2.8 Baluns and Feeder System

Most new equipment now works on the basis of 51-ohm coaxial feeders inside and in the near vicinity of the transmitting station, with transformers then converting to 600- or 300-ohm balanced lines for the long distances to the antenna feeders. In some cases however the coaxial feeder is run all the way to the aerial. Two basic types of coaxial feeder are available, the rigid copper tube type and the flexible type. In the larger sizes of flexible coaxial, the flexibility is restricted by its minimum bending radius which is quite large. When an intricate network of feeders is required inside the station the rigid feeder has many advantages with its sharp bends and piece-by-piece assembly. For the long runs without tight bends and particularly when run across fields to the aerial the flexible type is to be preferred.

To convert from coaxial to balanced feeder or antenna input, a balun transformer is used. The most usual type of transformer used is the ferrite-cored, oil-cooled, double-wound transformer. Apart from matching and balance difficulties, due to the wide frequency band required, the problem of handling many kilowatts of radio-frequency power is very great. Losses in the ferrite block may raise its temperature above the Curie point with the consequent destruction of the ferrite. This is overcome by providing oil-cooling channels in the ferrite, the use of extremely fine oil, 2 centistoke being used if necessary, and by choice of suitable ferrite material. An alternative type of transformer which is used for high-power operation is the transmission-line balun [4]. By suitable connection and choice of line length coaxial lines can convert from unbalance to balance and change impedance. With matching stubs the transformer can be made to cover a 7:1 frequency range. The main disadvantage of this type of balun is its size, which is of the order of 15 feet long and 3 feet wide for 4 to 28 MHz. Even this can only be achieved by folding the various sections back on one another.

2.9 Antennas

For the operational requirements of the station a wide-band antenna of good power gain and reliability is essential. These requirements are met by rhombic and logarithmic periodic antennas; the former having better power gain due to its narrower beam and the latter having the greater frequency range and wider beam width, which is often needed if working shipping or several receiving stations on a similar bearing.

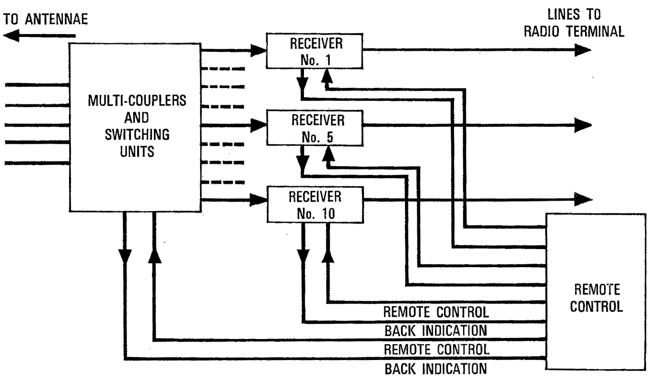

Figure 10 - Receiver station, block diagram.

Occasionally omnidirectional transmissions are required, this requirement being met by monocone or logarithmic spiral antennas which also have a wide frequency range.

A typical transmitter station will have its antenna complement made up largely from the rhombic and logarithmic periodic types with one or two omnidirectional types for standby or emergency purposes.

3. Receiver Station Equipment

3.1 General

The STANFAST receiving system has been designed with the objective of symplifying the operation of receiving stations and reducing the operating costs.

This is attained by using automatically controlled equipment which can be operated from a remote position by one man. Figure 10 shows a block schematic of a typical installation which consists of: antennas, multicouplers and switching, radio receivers and remote control equipment.

3.2 Antennas

For point-to-point working the antennas should be as directive as possible in order to reduce interference (Article 14.695 ITU Radio Regulations, Geneva 1959). Rhombic antennas are very suitable and cover a wide frequency band.

For reception from a particular area, a log-periodic antenna will probably be used and can be designed to cover a wide frequency band.

3.3 Antenna Multicouplers and Switching

A multicoupler is used in order to connect a number of receivers to a common antenna. The multicoupler accepts signals over a wide frequency band and if interference from intermodulation products is to be avoided it is essential to have highly linear amplitude response to signals up to several volts amplitude. A good noise factor is also necessary. These requirements can be met with transistorized equipment using negative feedback.

3.4 Radio Receiver

The RX 11 radio receiver forms an important part of the STANFAST system. The receiver is of modular construction and is available in a number of types to cover various requirements. The equipment is fully transistorized. The receiving frequency is selected by operating six decadic dials on a frequency synthesiser. The radio-fre-

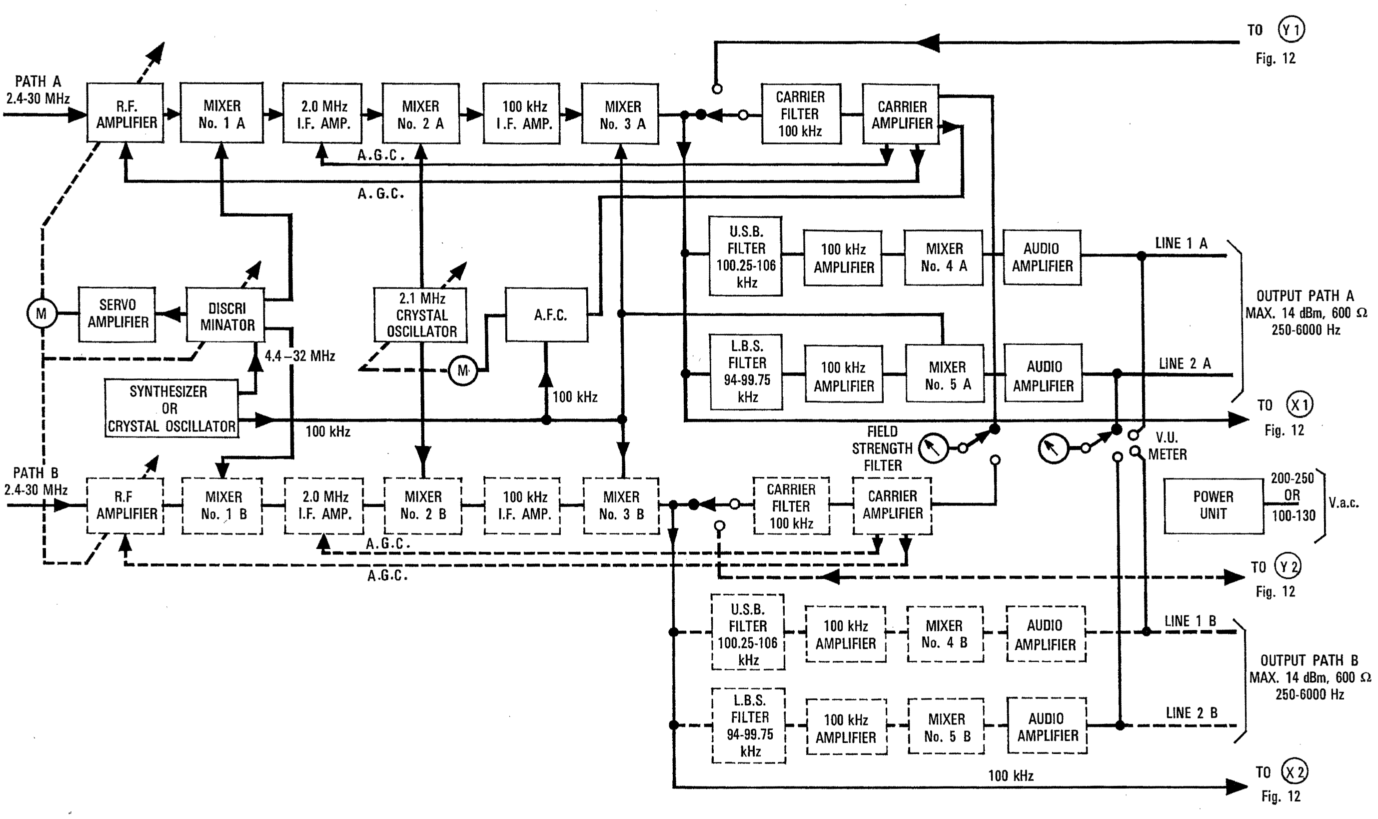

Figure 11 - RX 11 independant side-band receiver, block diagram.

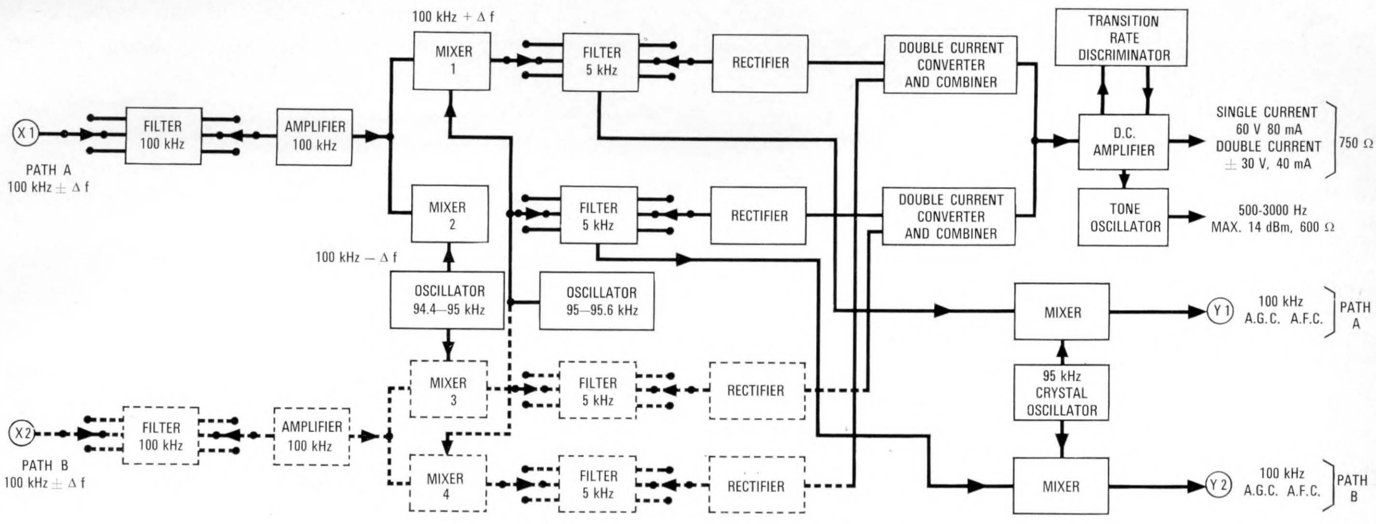

Figure 12 - RX 11 receiver, telegraph equipment, block diagram.

quency stages of the receiver automatically tune to the receiving frequency from information obtained from the synthesiser.

Figure 11 shows a block schematic of the receiver for reception of speech (A3, A3A, A3B) and multi-channel voice-frequency telegraphy (A7A). For reception of telegraphy (A1 or F1) and facsimile (F4) an extra unit is added, see Figure 12. A photograph of a dual-diversity receiver for i. s. b. and telegraph reception is shown in Figure 13. The top unit is the synthesiser, the next is the remote control; this is followed by the main receiver unit and then by the telegraph unit. The power unit is mounted below the blank panel.

Referring to Figure 11, the solid-line diagram shows the single-path receiver normally used for A 3, A3A, and A3B. The dotted lines show the second path added to form a dual-diversity receiver which is normally used for A7A, A1, F1, and F4.

The radio-frequency amplifier covers the frequency range 2.4 to 30 MHz in five bands. Separate two-stage amplifiers with 50-ohm coaxial input and output lines are provided for each band. Band selection is done entirely by switching the 50-ohm lines, thus avoiding contacts in tuned circuits, which are often a source of trouble.

The incoming signal is converted to 2 MHz in mixer 1A which is also fed from a synthesiser, the output of which is 2 MHz above the frequency of the incoming signal. The output from the synthesiser is fed to the mixer via a frequency discriminator which includes a tuned circuit similar to those used in the radio-frequency amplifier and ganged to them but tuned to a frequency 2 MHz higher. The servo system tunes automatically to the discriminator frequency and thus tunes the radio-frequency circuits to the incoming signal. The discriminator circuit acts as a "clean up" filter for the synthesiser output before it is fed to the mixer.

Figure 13 - RX 11 receiver.

The requirements of the synthesiser are close frequency tolerance, low noise and freedom from spurious outputs. These requirements are met by phase locking an oscillator to a frequency standard. The oscillator is operated at the output frequency thereby avoiding mixers which can cause spurious outputs. The oscillator output is passed through a variable frequency divider to a comparator. The standard frequency source of 5 MHz is also divided down and applied to the comparator. Integrated circuits are used in the divider chains.

The signal passes through the receiver where it is separated into carrier, upper sideband and lower sideband by crystal filters. The carrier is selected in a filter of 40-Hz nominal band-width and passed to the a. f. c. unit (automatic frequency control) where it is compared with the 100-kHz source from the synthesiser.

If not within one cycle, the motor-controlled servo will operate a capacitor to pull the 2.1-MHz crystal-controlled oscillator to the correct frequency. The motor-controlled a. f. c. system has an advantage over electronic systems because it has an infinite memory and if the signal fades the frequency adjustment will remain at its last setting indefinitely.

Means are provided to ensure that noise does not operate the a. f. c. in the absence of signal, this is achieved by disabling the a. f. c. if the carrier-to-noise ratio falls below a pre-determinated value.

The a. f. c. will pull in if the wanted frequency is within $\pm$ 25 Hz of the frequency to which the receiver is tuned. Should it be outside this range the a. f. c. system can be made to search over a range of $\pm$ 200 Hz by a manually-controlled switch which is released when the carrier is received. Means are also provided for adjusting the 2.1-MHz oscillator to its nominal frequency by comparing with a frequency derived from the synthesiser. This ensures that the receiver can be set up to the frequency as indicated by the synthesiser dials. For reception of F1 the signal is passed to the telegraph unit, at a nominal frequency of 100 kHz, by the dual-diversity inputs X1 and X2 Figure 12. Band-pass filters of nominal band-widths of 500, 1000 and 2000 Hz are provided to cater for different values of frequency shift.

The mark and space frequencies of the signal are each converted to a frequency of 5 kHz in mixers 1, 2, 3, and 4 and passed through separate 5-kHz filters (each filter has three band-widths to cater for different keying speeds) and are then rectified and appear as single current signals. These four signals are then converted to double-current form and combined in proportion to the square of the signal/noise ratios. This method of combination has been shown by Kahn [5] to give optimum results.

The method of separating the upper and lower keying frequencies into separate circuits and converting the signals to double current is explained in references [6] and [7]. The method has the advantage over the limiter and discriminator system when selective fading is present, because satisfactory operation will be obtained as long as any one of the four signal paths is giving sufficient output. Another advantage of the system is that a virtually continuous signal is available at 5 kHz for a. f. c. and a. g. c. (automatic gain control) purposes. This signal is converted back to 100 kHz and fed to the a. f. c. system in the main unit via terminals Y1 and Y2.

The telegraph output signal is monitored by a transition-rate discriminator [8]. This monitor looks at the number of times the double-current keyed signals cross the zero-current axis. If the noise level is high enough the number of crossovers will increase and operate the monitor at a pre-determined error rate.

A tone oscillator is also provided for sending tone to line as an alternative to the double- or single-current signals which are produced by a solid-state relay.

3.5 Remote Control

The normal remote-control facilities provide for the selection of any one of ten pre-determined frequencies with automatic tuning of the radio-frequency amplifier stages. An alternative, more complex, system allows selection of any frequency within the band.

The following facilities are available by remote control, some or all of which may be used as required:

— selection of any one of the 276000 available frequencies of operation spaced at 100 Hz intervals;
— signal back of selected frequency;
— selection of one of six modes of operation, i. e. A1, A3, A3A, A3B, F1, and F6;
— signal back of mode selection;
— selection of frequency shift;
— signal back of frequency shift selected;
— selection of keying speed (filter of appropriate band-width);
— signal back of keying speed selected;
— selection of four modes of receiver adjustment, i. e. fine tune, a. f. c. on, a. f. c. off, and synchronization of 2.1-MHz oscillator;
— signal back of (a) Carrier tuned in
  (b) Carrier high
  (c) Carrier low
  (d) 2.1-MHz oscillator synchronization
— switching on/off;
— signal back of receiver on/off.

4. Conclusion

The trend of the last seven years toward automatically tuned transmitters and receivers has continued, with the manually tuned or spot-frequency type of equipment now very rarely specified by operators. The techniques described in this paper have led to considerable savings in manpower, thus increasing productivity, and are even more impressive when considered as communication channels per man, this factor having risen by fifty times in the last ten years.

The techniques are still improving, with the accent on better quality circuits, reduced interference with other transmissions, better reliability and improved safety for personnel and equipment.

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L. J. Heaton-Armstrong was born in 1905 in Limerick, Eire. He was educated at Bedford School and Imperial College of London University from where he obtained a bachelor of science degree and the Diploma of Imperial College in 1927.

He joined Standard Telephones and Cables in 1927 and worked on the original high-frequency transatlantic radio telephone system. From 1929 to 1933 he was assigned to the Paris Laboratories where he was concerned with the Madrid — Buenos Aires high-frequency radio telephone link. He returned to Standard Telephones and Cables in 1933 and later was in charge of Point-to-Point Communications and Broadcasting.

Mr. Heaton-Armstrong is now Chief Engineer of HF/VHF Systems. He is a Fellow of the Institute of Electrical Engineers, an Associate of the City and Guilds Institute of London and a Fellow of the Institute of Electrical and Electronic Engineers.

B. S. Jackson was born in London in 1925. He was educated at Hitchin Grammar School, Hertfordshire until 1940 when he joined Standard Telephones and Cables as a trainee. After a short period he joined the Radio Division laboratories and also studied at Northampton College from which he received a bachelor of science degree (engineering) in 1946.

He then continued working on various projects in the high-frequency transmitter field, including the first automatically tuned transmitters. He has also been associated with the design of equipment for the major British Post Office Radio Stations at Ongar and Leafield. He is now in charge of the high-frequency transmitter development group working on high power automatically tuned high-frequency amplifiers, independent sideband and frequency shift keying modulators and aerial feeder ancillaries.

Mr. Jackson is a chartered engineer and member of the Institution of Electrical Engineers.

Experience with Trial Office HE-60 L Stuttgart-Blumenstrasse

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1. Introduction

A modern telephone switching center represents a complex configuration of equipment units, all of which must interwork properly to achieve satisfactory telephone service. It is therefore obvious that electronics will have a great impact on the future development of telephone switching. In the Federal Republic of Germany, the evolution of telephony will be further characterized by the transition from step-by-step selection to conditional selection.

In the first phase of this evolution, the objective consists of developing and field-testing systems designed on new switching principles and characterized by the application of novel components. Trial operations under field conditions produce valuable information on the performance of new components and circuits. They further show to what extent control functions can be centralized without jeopardizing service security. Finally, they give an indication of the operating manpower required and the training necessary for maintenance personnel.

This article describes the experience gained with a quasi-electronic telephone switching office for 1900 lines, which was developed by Standard Elektrik Lorenz AG. The installation (cf. Electrical Communication, Vol. 39, 1964, Number 2, pp. 244—259) is at present operating within the Stuttgart local telephone network.

2. Grouping and Operation

The trial office consists of the switching network (including the final grids FG, mixing grids MG, and directional grids DG), and the control network (including the registers Rg and the markers GM, DM, and GMD). The subscriber lines are combined into 2000-line control groups. Although one control group would have been sufficient to serve the 1900 lines connected to the Stuttgart trial office, two groups were provided to make it possible to test group interworking: the A1 group for 1400 subscribers and the A2 group for 500 subscribers (Figure 1).

Incoming traffic from other switching centers is handled by the junctors C (JC), outgoing traffic to other switching centers by the junctors D (JD). The 1st and 2nd directional grids (DG) serve 11 outgoing directions totalling 235 trunks. The junctors C have access, via a register finder grid, to C-registers which are associated with a group marker C (GMC). The junctors C, the group marker C, and the C-registers are combined into a special control group designated as "C Group". Analogously, the junctors D and the group markers D are combined into "D Groups".

To set up a connection between two groups, the group connector links their marking networks for the duration of a marking process.

In conditional selection systems, service reliability is largely dependent on the duplication of common and centralized units. In the HE-60 system all equipment units serving more than 100 lines have, therefore, been duplicated.

This applies particularly to the

(A) *Group markers and directional markers.* These centralized units are dimensioned for 2000 subscriber lines. They operate alternately, but whenever one of them fails the duplicate carries the entire traffic load.

(B) *Routing translator* (RT) which is capable of serving 10 000 lines. Each of the two routing translators is able to handle the traffic of the entire trial office.

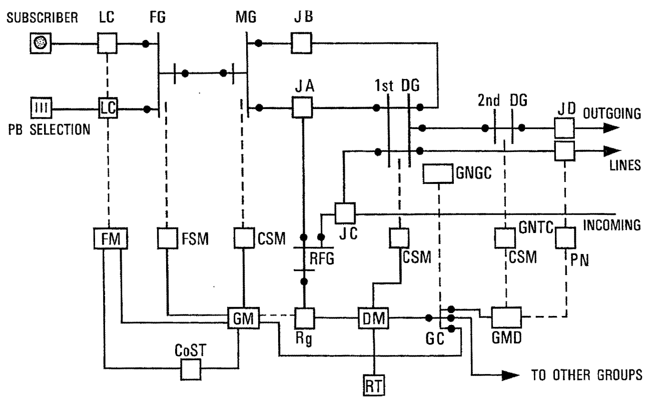
(C) *Centralized stage markers* (SCM). Each of the two centralized stage markers serves half of the switching matrices of the individual stages. In the event one of them fails, the other one handles the entire traffic, though with a higher loss probability.

The two final stage markers FSM act as stand-bys for each other, the subscribers being unable to notice when one of them fails.

The final markers have not been duplicated, since each of them is associated with only one 100-line group.

The two-stage switching grids are controlled by the so-called guide wire path-finding method, which ensures that even the last free and accessible link is found for a speech connection. The guide wire is run parallel to the speech and auxiliary wires (two speech wires, one metering wire, one holding wire) through the entire switching network, including register finder grid RFG. An offering signal applied to the guide wire fans out through the switching network and marks all links free and accessible for the desired connection. An accepting or "catching" signal is then applied in a direction opposite to that of the offering signal to switch through a definite path to the destination.

Only two marking steps are required to set up a call between any two subscribers of the HE 60 trial office:



CoST : CLASS-OF-SERVICE TRANSLATOR
CSM : CENTRALIZED STAGE MARKER
1st DG : FIRST DIRECTIONAL GRID
2nd DG : SECOND DIRECTIONAL GRID
DM : DIRECTIONAL MARKER
FG : FINAL GRID
FM : FINAL MARKER
FSM : FINAL STAGE MARKER
GC : GROUP CONNECTOR
GM : GROUP MARKER
GMD : GROUP MARKER D
GNGC : GUIDE NETWORK GROUP CONNECTOR
GNTC : GUIDE NETWORK TRUNK CONNECTOR
JA : JUNCTOR A
JB : JUNCTOR B
JC : JUNCTOR C
JD : JUNCTOR D
LC : LINE CIRCUIT
MG : MIXING GRID
PN : PILOT NETWORK
RFG : REGISTER FINDER
RG : REGISTER
RT : ROUTING TRANSLATOR

Figure 1 - Grouping of the HE-60 trial office.

1st step: In the line circuit of the calling subscriber, the offering signal is applied to the guide wire. This signal fans out from the final grid FG, through the mixing grid MG, the register finder grid RFG, and the A-registers to the group marker A. The group marker A selects one of the free A registers and returns the accepting signal to the line circuit. It is then available for the next call. The A-register transmits a dial tone to the calling subscriber to indicate that it is ready to receive dialing information.

2nd step: The A-register stores the dialing information, and after the sixth digit calls the directional marker A (DMA) and passes the dialing information to it. The directional marker obtains from the routing translator RT the destination group of the called subscriber and then actuates the guide network group connector (GNGC) to link the guide wires with the junctors B of the destination group. The third and fourth digits identify the final marker of the desired 100-line group, the 5th and 6th digit the desired subscriber.

Path selection to the desired subscriber is then initiated by applying to his line circuit an offering signal, which fans out, from stage to stage, to the group marker A. The accepting signal is then applied in the opposite direction to establish one of the many possible paths. Junctor B transmits the ringing tone and feeds the called line, while the calling line is fed by junctor A.

3. Special Convenience Features

A register-controlled telephone switching center makes it possible to introduce new service features. In the Stuttgart HE-60 trial office, the subscribers connected to the A2 "augmented-service group" are offered a number of new convenience services.

3.1 Push-button Selection

Push-button selection was especially welcomed by the telephone customers. It allows full use to be made of the inherent speed of the HE-60 system.

In November 1965, 52 users of push-button telephone sets were requested to answer a questionnaire containing 67 questions arranged in four groups. All these people stated that they preferred the push-button telephone set to the conventional rotary dial set. About four-fifths of them said that they were making more dialing errors with rotary dial sets than with push-button sets, while the remaining one-fifth said that they did not notice any difference. Other questions related to the external design of the push-button set, the key arrangement, key pressure, etc. All but one of the persons interviewed were in favor of retaining the present design.

The ringing delay had been noticed by only 42 of the people questioned, and only 12 of them considered it a disadvantage. They did not consider the keying noise (VF tone) significant: only one of them found it disturbing, 12 had not noticed it at all, and 40 found that it was not disturbing.

Many of the push-button users questioned, had not noticed the ringing delay and the keying noise until asked about them in the questionnaire. This permits us to conclude that telephone users pay little attention to minor details as long as they are offered a subset that is easy to handle.

3.2 Abbreviated Dialing

A limited number of customers can be given access to this special service feature, which makes it possible to reach 11 frequently called numbers of up to 15 digits by abbreviated dialing. In the Stuttgart trial office, 15 (out of a possible 16) customers have been admitted to this service.

3.3 Absentee and Answering Service

When a subscriber is switched to this service, his incoming calls are routed to an answering position. Switching to absentee service may be either subscriber- or operator-controlled. A special code is provided for subscriber-controlled switching to this service. In 1965 and 1966, the following use was made of the absentee and answering service:

	1965	1966
Operator-controlled transfer switching	114	85
Subscriber-controlled transfer switching	8	18

Although the subsribers had been advised in writing of this service, they failed to make extensive use of it.

4. Test Connections

Between 08:00 and 16:00 hours on weekdays, artificial traffic was generated in the trial office by means of a test connection set consisting of a main equipment, a connection unit, and a test number unit (Figure 2). The main equipment incorporates an automatic test number sender. It controls the automatic routine and evaluates test results by means of the test evaluation equipment. The connection unit engages 16 line circuits in cyclic sequence, while the test number unit contains 16 terminals which are called in sequence.

The test connection set indicates the following failure conditions (cf. Table 1).

In November 1965 and in April 1967, the trial office was tested with 6000 test connections each (test run without fault repair). The test run in November 1965 was performed with the pulse ratios, attenuation, and noise voltage values established for conventional systems.

(A) Pulse ratios (pulse: interval) 72:31 ms and 51:48 ms, alternating after each 500 tests connections.

(B) Attenuation $a_r = 0.6$ N (5.4 dB).

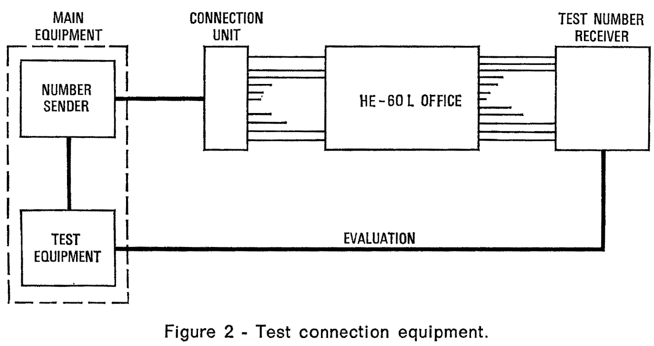


Figure 2 - Test connection equipment.

Table 1

Irregularity	Test Procedure	Indication
1. No dial tone	Check for 450 Hz	At $t > 2{,}800$ ms
2. All paths busy	Check for busy tone 450 Hz, morse code "e" during interdigital interval	Busy tone
3. Excessive impedance	Measurement during interdigital interval, 500 ms, 1100 Hz	Primarily during double connections (tested by HE-60 system)
4. No testing frequency signals	Ground as acknowledgment signal	Incomplete or wrong connection
5. No ringing	Check 10 s ringing current (upon seizure of test number)	Absence of ringing current
6. Subscriber does not answer	Application of 800 Hz in test number unit	Absence of 800 Hz
7. Excessive attenuation	Transmission of 800 Hz, duration 2000 ms	When set a_r value is exceeded
8. Noise limit exceeded	Measurement of noise voltage and time at A-filter	When set limits are exceeded
9. Premature metering	Registration of metering pulse **before** releasing connection	When metering pulse > 60 ms
10. No local call metering	Checking of metering pulse > 1 s **after** release	When pulse too short (< 1 s) or absent

(C) Noise voltage 100 mV, admissible noise duration 200 ms within 10 seconds. The duration of all noise bursts exceeding 100 mV is added up, and a fault indication initiated as soon as the sum value exceeds the permissible threshold (e. g. 200 ms). The noise may consist of several short bursts.

Out of 6000 connection attempts, 5998 were successful, the two failure indications involving an all-paths-busy and a subscriber-does-not-answer condition, both being due to work on the technical equipment.

This effectiveness may be ascribed to the functional and line tests performed with each marker opération in the HE-60 office. During each call establishing process, the a, b, c, and z wires are tested for continuity and foreign potentials.

In order to determine under which conditions there are noticeably more failure indications, more stringent testing conditions were applied in April 1967.

4.1 Dialing Reliability

In the Stuttgart telephone network, most of the telephone numbers consist of six digits. For 6000 connections, consequently, a total of 36 000 digits had to be dialed.

As can be seen (cf. Table 2), failures occurred only with unfavourable pulse ratios and very short interdigital intervals.

4.2 Excessive Attenuation (cf. Table 3)

The result can be summarized as follows:

500 test connections at $a_r = 0.4$ N (3.5 dB), no failure
3500 test connections at $a_r = 0.3$ N (2.6 dB), 1 failure
2000 test connections at $a_r = 0.2$ N (1.7 dB), 85 failures.

The overall system attenuation consists primarily of the supply circuit attenuation in junctors A and C, amounting to 0.08 N (0.63 dB) each, of the 16 kHz metering filters with 0.03 N (0.26 dB) and the wiring. Without the wiring,

Table 2

Test Connections	from to	0 1000	1001 2000	2001 2500	2501 3000	3001 3500	3501 3700	3701 5000	5001 5500	5501 6000
Pulse ratio	pulse ms / inter ms	72/31	51/48	51/39	59/31	51/39	35/65	75/35	51/48	72/31
Pulse + interval	ms	103	99	90	90	90	100	110	99	103
Interdigital interval	ms	1000	1000	500	500	500	500	500	500	500
Dialing disturbances		0	0	0	0	0	2	2	0	1

Table 3

Test Connections	from to	0 500	501 1000	1001 1500	1501 2000	2001 2500	2501 3000	3001 6000
Threshold set (N)		0.4	0.3	0.2	0.2	0.2	0.2	0.3
Indicated failures		0	1	16	24	16	29	0

it is 0.08 + 0.08 + 0.03 N = 0.19 N (1.65 dB). When further taking into account the tolerance of the test connection set, it its easy to understand the number of failures at 0.2 N (1.74 dB) threshold.

4.3 Noise

The test connections 1 to 3000, with the threshold values of 100 mV and 200 ms noise duration, showed no failure.

The result of the 3000 other test connections is illustrated in Figure 3.

As anticipated, failures occurred more frequently with extremely low noise voltage thresholds (1 mV). When the threshold was set to 5 mV, there were only 4 failures recorded for 1000 test connections. Compared to that of conventional telephone systems, this is a very low failure rate.

The telephone customers considered neither the insertion loss of 0.3 N (2.6 dB) nor the noise voltage of 5 mV a disturbance.

In addition to the above disturbances, the test connection set recorded 10 "no-dial-tone" failures. This means that only 0.16 percent of all test connections exceeded the waiting time limit of 2.8 seconds. It is further noteworthy that disturbances such as double connections and metering errors, which telephone customers consider particularly annoying, did not occur at all.

5. Analysis of Failure Statistics

The logbook of the trial office shows that a total of 852 disturbances had been reported between August 1963 and December 1966. Only 108 of these disturbances — i. e. 12.7 % — were attributable to the trial office, while the other 744 were due to failures of other switching centers and the cable network, and to subscriber behavior. Figure 4 shows the average failure rate per month, which varies between 1.66 and 3.1 failures. The mean value over 3½ years of operation is 2.63 failures per month. Figure 4 further shows for reference the average number of subscriber lines connected to the trial office. Although the number of subscribers served has increased by the factor 2.5, the failure rate appears to have a downward trend. This indicates that neither the degree of capacity utilization nor the operating time of the installation has any effect on the failure rate. It is therefore senseless to compute from these figures the failures per 100 lines per month. A comparison with conventional systems would be impossible, anyhow, since only the number of line circuits, switching grids, and junctors increases with the number of subscriber lines in centralized systems.

The type and speed of failure detection is of great significance in dialing systems. The earlier a failure is detected and repaired, the fewer connections it will involve. Only the four most important types of failure report will be listed here:

(A) Failure indication by alarm, testing, and monitoring circuits incorporated in the system.

(B) Failure recognition by functional tests using manual testing equipment.

(C) Trouble reports received from other switching centers.

(D) Customer complaints, normally forwarded by the competent maintenance departments.

The manual functional tests, which are presently performed at intervals of six weeks, cover:

(A) Guide wire network tests.

(B) Testing of junctors A, B, and C (tone signals; metering, loss, and balance).

(C) A-registers (outstoring of dialing information and disconnection).

(D) C-registers (end-of-selection, all-paths-busy, and disconnection).

(E) Call metering.

Testing results have been so good that an extension of the time between test runs should be taken under consideration.

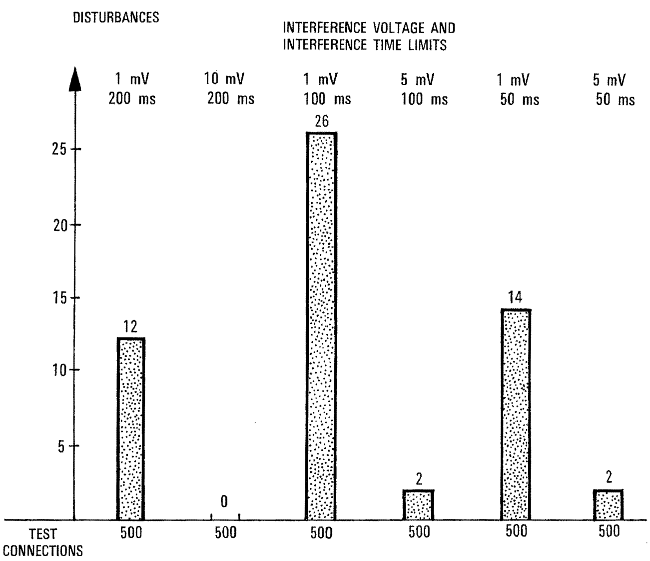


Figure 3 - Result of noise tests using the test connection equipment.

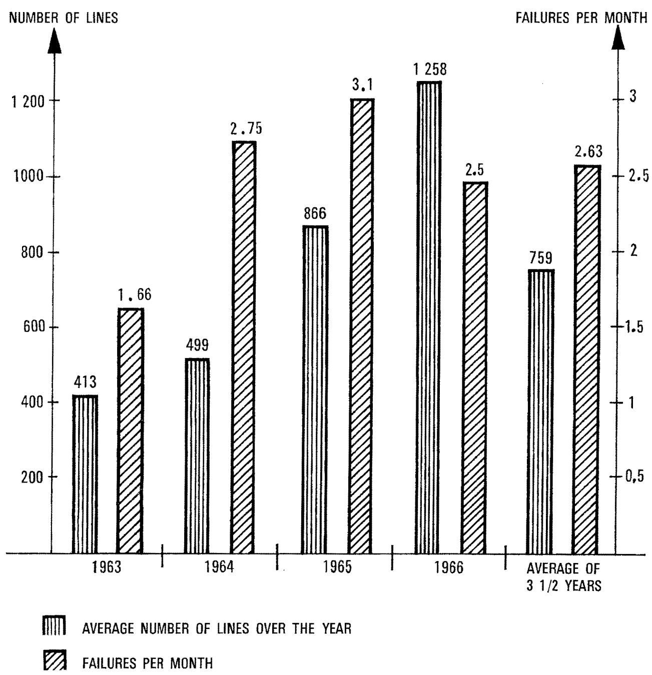


Figure 4 - Average number of subscriber lines and failures per month.

Figure 5 shows a breakdown of failure reports, by kind of report, received during 3½ years of operation.

The large percentage of failures detected by the system's testing and monitoring circuits is noteworthy. The number of connections disturbed by these failures is approximately equal to the number of failures, since failure occurrence and failure signaling coincide. Failures detected by other means sometimes require hours and days of failure location work. It is easy to estimate how many connections are disturbed by a failure existing over any extended period of time. The inherent advantage of the failure detecting facilities incorporated in the system is that they limit failure duration.

In Figure 6, the 108 failures recorded for the system are broken down by location; in Figure 7, the breakdown is by their effect on service.

As can be seen, 36 % of the failures did not affect traffic at all, and 23.2 % affected only individual lines.

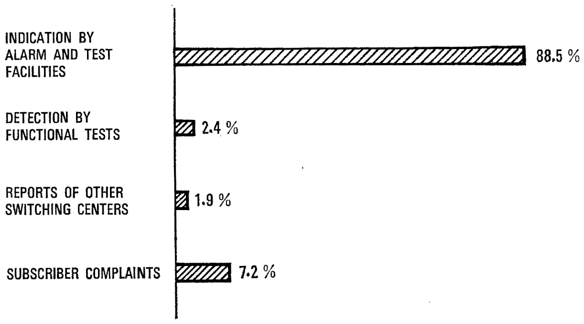


Figure 5 - Breakdown of failure reports.

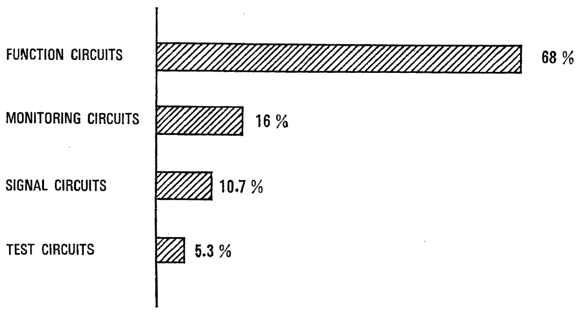


Figure 6 - Breakdown of failures by system parts.

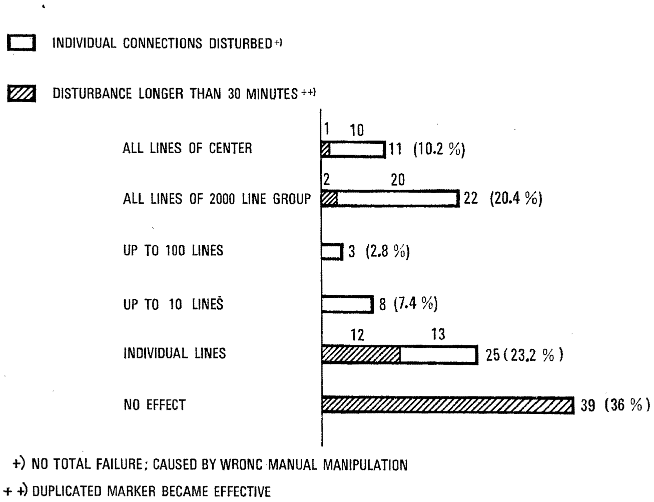


Figure 7 - Breakdown of failures by effect.

6. Component Failures

In any field trial, interest centers primarily on the majority components, which in the case of the HE-60 system are HERKON dry-reed switches, diodes, and transistors. The service reliability of the entire installation depends largely on their reliability.

During the observation period, i. e. in 26 280 hours of operation (Δt), the following numbers of components were replaced:

- 15 dry-reed contacts (of a total of 335 000 contacts)
- 5 diodes (of a total of 150 000 diodes)
- 3 transistors (of a total of 12 000 transistors)

From these figures we derive the component failure rate per hour $\lambda = \frac{1}{N} \times \frac{\Delta N}{\Delta t}$, where N is the total number of a specific component type and ΔN is the number replaced.

The component failure rate is for

Dry-reed contacts $\lambda = \frac{1}{335\,000} \times \frac{15}{26\,280} = 1.7 \times 10^{-9}\,[\mathrm{h}^{-1}]$,

Diodes $\lambda = \frac{1}{150\,000} \times \frac{5}{26\,280} = 1.27 \times 10^{-9}\,[\mathrm{h}^{-1}]$,

Transistors $\lambda = \frac{1}{12\,000} \times \frac{3}{26\,280} = 9.5 \times 10^{-9}\,[\mathrm{h}^{-1}]$.

The reciprocal of the failure rate is the mean time between failures $m = \frac{1}{\lambda}$. We obtain for

Dry-reed contacts $m = \frac{1}{1.7 \times 10^{-9}} = 5.9 \times 10^{8}$ hours or 67 500 years,

Diodes $m = \frac{1}{1.27 \times 10^{-9}} = 7.9 \times 10^{8}$ hours or 90 000 years,

Transistors $m = \frac{1}{9.5 \times 10^{-9}} = 1.05 \times 10^{8}$ hours or 12 000 years.

Taking into consideration the number of components used, this means that on the average, a dry-reed contact must be replaced once every 2.4 months, a diode every 7.2 months, and a transistor every 12 months.

Hermetically-sealed dry-reed contacts have in consequence proven to be capable of meeting the requirements of long life.

In conclusion, it should be mentioned that the trial office has not been provided with air-conditioning equipment, and that the ambient temperature varies between 20 and 32° C and the relative air humidity between 4 g/m³ and 18 g/m³.

W. Rauscher was born in Rommelsbach, Germany, in 1905. From 1927 to 1930, he studied at the Staatliche Ingenieurschule in Esslingen, where he graduated as an electrical engineer. In 1930, he joined the Deutsche Bundespost (German Post Office), and has since worked on the planning, design, and operation of telephone switching centers. In 1963, he became telephone switching adviser to the Post Office Administration in Stuttgart.

Book Review

INTERMETALL Data Manuals 1967/1968

In the series of INTERMETALL Data Manuals, the third manual, "Transistors", was published recently. The other two manuals, "Rectifiers/Thyristors" and "Diodes/Zener Diodes", appeared a few months ago.

Alphabetical type indexes, technical explanations, quality information, detailed technical data, dimensional drawings, and characteristics will make these manuals valuable aids to the design engineer.

This new series of data manuals supersedes all former data books, such as the SEL Data Manual "Transistors, Diodes 1966" and the INTERMETALL Manual "Transistors, Diodes 1965/1966".

All three data manuals are available to industrial enterprises free of charge and to private individuals at the price of DM 2.– each, upon request to INTERMETALL, Freiburg.

Book: ISEP — ITT Standard Equipment Practice

ISEP, the ITT Standard Equipment Practice, has proved its great value for the construction of electronic equipment and systems. ISEP parts can be used for building electronic equipment of any required size, ranging from plug-in cards with components through subracks, racks without enclosure, racks with hinged side walls and doors, up to fully enclosed racks.

Connection between printed-circuit boards and subracks is established by ISEP connectors. All system parts conform to international and national standards and may be combined with existing systems.

The book entitled "ISEP — ITT Standard Equipment Practice", published by SEL, explains with the aid of illustrations and examples the flexibility of the ISEP system. Dimensional drawings in the ordering section will serve the equipment designer as a planning basis.

The booklet will be distributed to industrial enterprises free of charge, and is also available to private individuals at the price of DM 4.– upon request to Standard Elektrik Lorenz AG, Nuremberg.

Handbook of Electronic Instruments and Measurement Techniques

Harry E. Thomas and Carole A. Clarke, now consulting engineers after retirement from International Telephone and Telegraph Corporation, are the authors of a recently published "Handbook of Electronic Instruments and Measurement Techniques". It is divided into 14 chapters as follows:

1. Instrumentation — The System Approach
2. Indicating Meters, Measuring Techniques
3. Bridge Circuits and their Application in Measurement
4. Bridge Design, Construction, and Operation
5. Oscilloscope and Pulse Instrumentation
6. Data Display and Digital Instrumentation
7. Frequency, Phase, and Time Measuring Instruments
8. Transducers and their Instrumentation
9. Electronic Voltmeters and Instruments for Direct Component Measurement
10. Instrumentation for Vacuum Tubes
11. Instrumentation for Transistors and Diodes
12. Instruments for Receiver Testing
13. Transmitter Measuring Instruments
14. Microwave and Radar Equipment and Measurement

There are 22 appendixes giving glossaries of terms; units, constants, symbols, abbreviations, and conversion factors; calibration of standards; multipliers, shunts, and fusing of instruments; measurements of radio-frequency power and standing-wave ratios; and description of potentiometers, digital voltmeters, spectrum analyzers, Q meters, transducers, X–Y recorders, grid-dip meters, sampling recorders, and recording oscillographs.

The book is 9.75 by 7 inches (25 by 18 centimeters) and contains 389 pages plus an 8-page index. It is published by Prentice-Hall, Inc. Englewood Cliffs, New Jersey 07632 at $16.00 per copy.

Loaded "Wet" Submarine Cable

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G. TIDEMANN
Standard Telefon og Kabelfabrik A/S, Oslo, Norway

1. Introduction

Norway, like many other countries in the world, is criss-crossed with water in the form of fiords, lakes, and rivers. In Norway fiords can reach as far as 160 km inland from the coastal line, and narrow lakes can fill the bottom of the valleys along dozens of kilometers.

Wherever these waters block a cable route, they have to be crossed by a suitable cable. In many cases the land on both sides of the fiord or lake consists of sheer mountain sides, plunging straight down into the water. In such places, the digging of cable ditches alongside the water is expensive and can in many places, because of landslides, be very risky. Under these circumstances it may often pay to put the cable in the water, provided suitable cables can be found. As an example, it can be pointed out that the main cable between Oslo and Bergen was laid in the Hardangerfjord with land-based repeaters. This was a 25 mm-solid-polyethylene-insulated-coaxial cable. When it came to multi-conductor cables, the situation was not so simple. Lead or aluminium-sheathed paper-insulated cables need strengthening members to support the sheath when the cables are to be laid below certain water depths. These strengthening members, consisting normally of one or more steel spirals, add considerably to the complexity and cost of the cable. If a sheath fault occurs on such cable, the whole cable will break down, and repair — for instance, in inland lakes — is not possible over many months of the year. The laying of multiconductor cables in water was therefore avoided wherever possible until a more suitable type of cable could be found. When plastics began to be used in the cable industry, a new type of cable called "wet" submarine cable was introduced. This type of cable, to be described in greater detail later, derives its name from the fact that there is no sheath to keep the water out of the cable. It can be laid at any depth, and if a fault only should develop, it would in most cases affect a single circuit.

This robust and inexpensive type of cable first became very popular as a subscriber cable connecting the many inhabited islands with the mainland. Later on, when it was also used for intermediate links in paper-insulated trunk cable systems, its lengths were limited to that of a loading section. Since in many cases this was not sufficient to cross the water, and certainly not long enough to run along the fiords or lakes, the Norwegian Telecommunications Administration requested STK to develop cables with built-in loading coils preferably designed so that the cable plus loading sections could be laid by a normal cable ship without any special precautions.

2. Description of the Cable

Since the so-called "wet" submarine cable has no sheath, the water can penetrate directly to the conductor insulation and fill all the cable interstices.

Subscriber cables of this type normally have 0.7-mm conductors. They have been made with the number of quads ranging from 10 to 100. Trunk cables usually have 0.9-mm conductors, but cables with 1.4-mm and 2.0-mm conductors have also been made. The number of quads in these cables has varied between 2 and 24. The insulation wall thickness has been approximately the same as that of the conductor diameters, giving a mutual capacitance in water of 55 to 60 nF/km.

The stranded-cable cores are protected by lappings of textile tapes, crepe paper, and jute rovings. The steel wires in the armoring have diameters of from 3.3 mm to 5.2 mm, depending on laying conditions. The armoring is normally protected by several layers of jute rovings and asphalt compound.

The electrical characteristics of this type of cable have been calculated from measured primary parameters (R, L, C, and G) and a typical set of curves is given in Figure 1. In the designing of new cables, the primary parameters can be precalculated fairly accurately if the screening and proximity effects of the armoring are taken into account.

When the problem arose of matching cables of this type to 37 nF/km paper-insulated trunk cables, it was at once obvious that it would not be economical to make the wet submarine cable with the same low-mutual capacitance. For the low-frequency loaded circuits the same impedance could be obtained by shortening the loading sections to yield the same mutual capacitance between loading coils as in the land cable system. The land cables normally contain 2 or 3 carrier frequency quads for 60 channel systems. To obtain impedance matching for these quads for the whole frequency range from 12 kHz to 252 kHz it was, as will be explained below, necessary to have a higher mutual capacitance on the wet submarine cable than on the land cables.

If the conductance G is disregarded, the numeric value of the impedance is given by:

$$z = \sqrt[4]{\left(\frac{R}{\omega C}\right)^2 + \left(\frac{L}{C}\right)^2} \tag{1}$$

At low frequencies only the $\frac{R}{\omega C}$ part is of importance and at high frequencies only the L/C part. If we can match the two cable types at one low-frequency point and one high-frequency point, the two impedance curves will follow each other sufficiently closely over the whole frequency range. Since the inductive permittivity of the two cables is the same while the dielectric permittivity of the wet submarine cable is much higher than that of the paper-insulated cable, it is obvious that the high-frequency part of the impedance can not have the same mutual capacitance C. If C were the same, the distance between the conductors and consequently the self-inductance L of the wet submarine cable would be much larger, giving

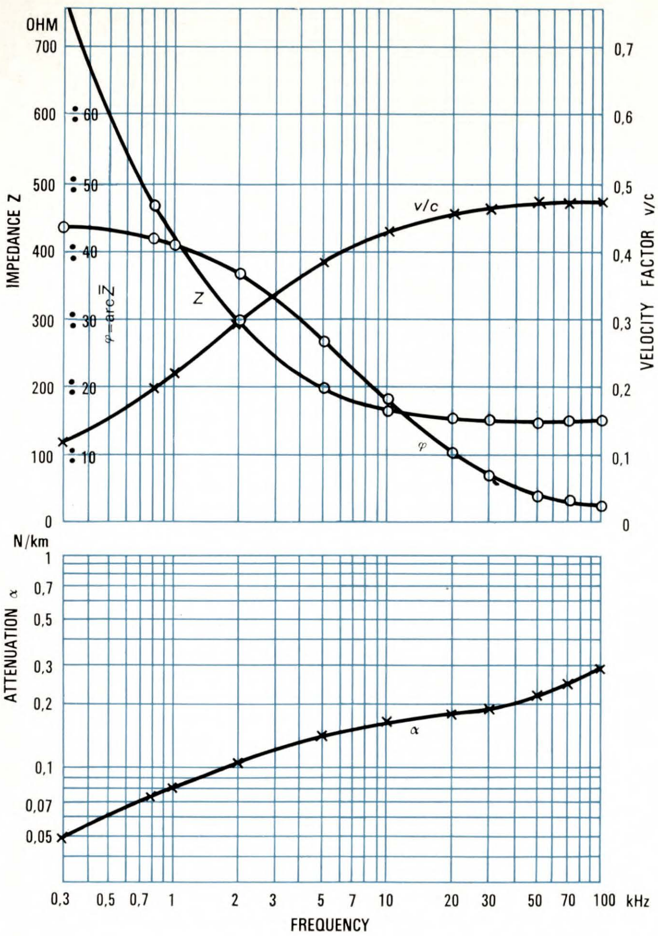


Figure 1 - Electrical characteristics of a typical "wet" submarine cable.

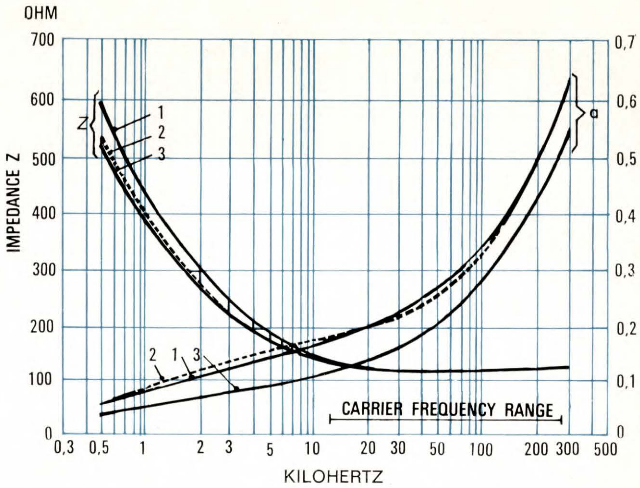


Figure 2 - Impedance and attenuation of land cables compared to those of "wet" submarine cables.
1 - 0.9 mm 4-quads wet cable with embedded quads
2 - 0.9 mm 12-quads wet cable
3 - 1.2 mm paper-insulated land cable

a higher impedance at high frequencies. On the other hand, if the self-inductance L were made the same, the wet submarine cable would have a much higher mutual capacitance C, giving the wet submarine cable the lowest impedance. Somewhere between these two extremes there is a design that would yield the same L/C ratio for the two types of cables, and this point fixes the ratio of insulation thickness to conductor diameter on the wet submarine cables. Since the mutual capacitance in this way is mack a higher value in the wet submarine cable than in the land cable, it remains only to reduce the conductor diameter to obtain the right R/C ratio for impedance matching at the low-frequency end of the range.

Impedance matching had to be obtained for the two standard types of paper-insulated trunk cables having 1.2 mm and 0.9-mm conductors, both with 37 nF/km mutual capacitance.This was obtained by wet submarine cables having respectively 0.9-mm conductors insulated with 0.95-mm PE to a mutual capacitance of approximately 56.5 nF/km, and 0.7-mm conductors insulated with 0.8-mm polyethylene to a mutual capacitance of 54 nF/km.

In Figure 2, the impedance and attenuation of the 0.9-mm wet submarine cable are compared with the corresponding curves for the 1.2-mm paper-insulated trunk cable. (Cables 2 and 3.)

In a wet submarine cable each insulated conductor is electrostatically screened from all the other conductors by the water. Because of this, there is no such thing as capacitive S–S unbalances or corresponding crosstalk. The S–E unbalances being directly the difference in coaxial capacitance between the two conductors of the circuit, they can on the other hand be high. However, it should be taken into account that a cable in water is normally very well screened from any outside influence that could induce noise in the cable.

The situation is less happy when it comes to phantom circuits and the Ph–S unbalances. The Ph–S unbalances are given by

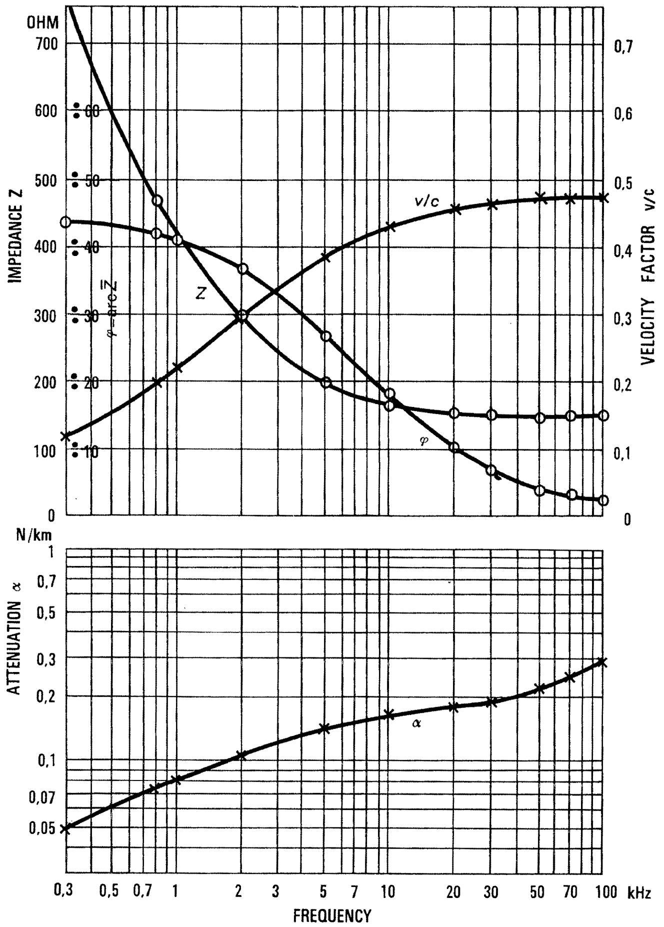
$$Ph-S_1 = \frac{1}{2}(C_1 - C_2)$$
$$Ph-S_2 = \frac{1}{2}(C_3 - C_4) \qquad (2)$$

C_1, C_2, C_3, and C_4 being the coaxial capacitance of each of the four conductors in the quad. $Ph-S$ unbalances are normally so high that the use of the phantom circuit on a normal wet submarine cable is precluded. The phantom-side unbalances can, however, be considerably improved by embedding each quad in a plastic sheath.

When this is done, the $Ph-S$ unbalances can be expressed with the well-known formula for paper-insulated cables:

$$Ph-S_1 = \frac{1}{2}(C_{10} - C_{20}) + (C_{13} + C_{14}) - (C_{23} + C_{24})$$
$$Ph-S_2 = \frac{1}{2}(C_{30} - C_{40}) + (C_{13} + C_{23}) - (C_{14} + C_{24}) \qquad (3)$$

As can be seen from Figure 3, a high C_{10} would normally lead to low C_{13} and C_{14} and vice versa, so that some degree of compensation will occur inside the quad. In addition, the C_{10} and C_{20}, etc., values are considerably smaller than the corresponding C_1 and C_2 values and would therefore yield smaller differences. Experience has shown that this is the case. The $Ph-S$ unbalances on this type of cable are normally less than one-third of those obtained on a truly wet submarine cable. On the other hand, $S-S$ unbalances occur on the embedded type, but these



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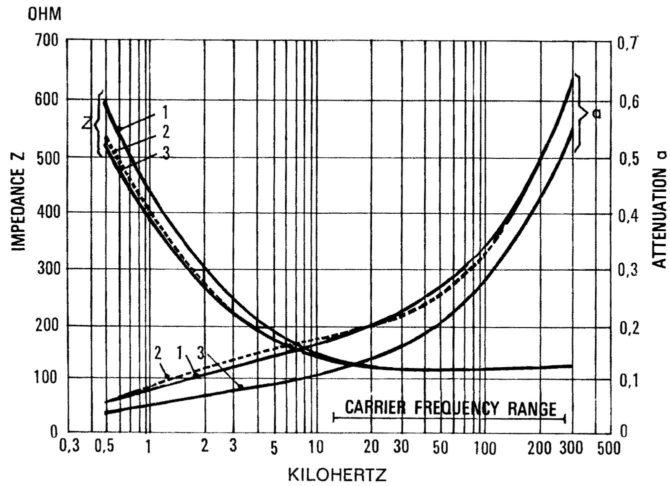

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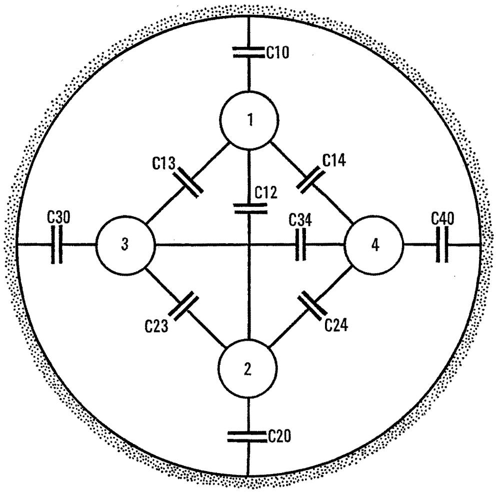

Figure 3 - Partial capacitances in a telephone cable star quad.

unbalances can be kept low by strict control of manufacturing processes.

When it comes to matching cables with embedded quads to the paper-insulated land cable, the picture is a little more complicated. The side circuits on carrier frequency quads can be matched and this is normally sufficient, since the phantom circuit is very rarely carrier-frequency operated. In the impedance matching of the side circuits, the diameter of the quad sheaths adds another variable parameter, so that the problem has several possible solutions. Of these, the one giving the smallest quad sheath diameter would obviously be the most economic.

For the loading of this type of cable it is important to obtain the same ratio between mutual capacitance for the phantom circuit and mutual capacitance for the side circuits as for the land cable. This ratio C_{Ph}/C_S for the different types of cable is as follows:

— Star quad paper-insulated cable: 2.7
— DM quad paper-insulated cable: 1.6
— Wet submarine cable : 2.0
— Star quad embedded in plastic : 2.75

The last value can be varied within limits, and a matching to a star quad paper-insulated cable should be possible. However, cables with embedded quads will in most cases be jointed to DM paper-insulated land cables, and to obtain the same C_{Ph}/C_S ratio as on these cables is considered impractical. This means that the length of the loading section on the submarine cable would be different for the phantom and the side circuits. On the submarine cable one would get phantom loading points closer to and separate from the side-circuit loading points. Certain difficulties can arise in trying to get the loading coils in step again when the system continues on the other side of the water-crossing.

3. Development of Loading Elements

It was clear from the start that, to ensure flexible construction, each individual coil had to be embedded in polyethylene and so shaped that a number of coils could be laid together to form both a flexible and strong snake-type construction. The polyethylene covering on the coils would have to continue as the conductor insulation on the connecting leads. The connecting leads would have to be sufficiently long so that staggered joints to the adjoining cables could be made. This jointing would have to be done in the factory prior to armoring so that a continuous and strong armoring could be obtained. In cases where this was not so important (shallow-water cables), the "snake" with connecting leads could be delivered to the customer who could, either on site or in his warehouse, joint in the loading assembly between two cables and from both sides lay and bind the armoring across the loading point.

The first problem is to make the coils insensitive to outside water pressure. Experiments have shown that coils embedded only in plastic suffered an average reduction in inductance of approximately 0.1 % for each kp/cm^2 increase in pressure. This was not acceptable for coils that could be laid at any depth up to 1000 m. By putting the coils into a strong brass casing prior to molding, the effect of water pressure was eliminated.

In mounting the coil inside the molding, care had to be taken to ensure that any pull exerted on the connecting leads was not transmitted to the thin winding wire of the coil, but was taken up by the molding itself. As shown in Figure 4, this was obtained by strapping the connecting leads along the end faces of the coil casing and anchoring them in a U-shaped piece of nylon. The winding wire was soft-soldered to the connecting leads at the anchoring points.

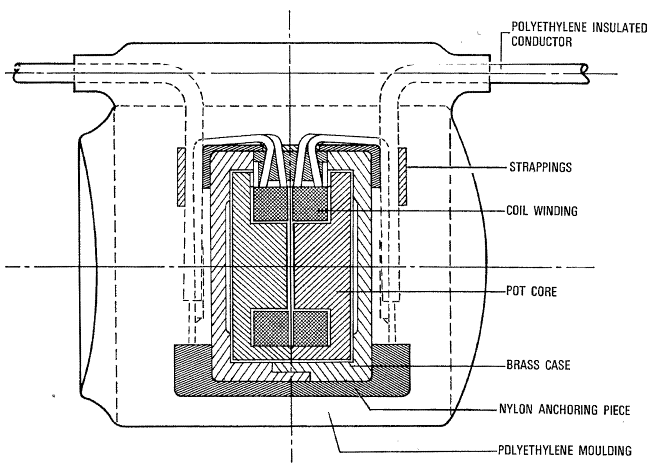

Figure 4 - Design of loading element.

The outside shape of the loading element is also shown in Figure 4. The concave end-face on the left end has a larger curvature radius than the convex end-face on the right. This gives good bendability and stability inside the snake formation as shown in Figure 5. The ridges protect the bends in the connecting wires and secure the angular position of the loading elements with relation to one another. The assembly of these loading elements with the connecting wires covering more or less of the cylindrical surface of the elements resembles the combination of vertebras and sinews in the human spine. At the end of the assembly 60-mm long conical pieces of polyethylene case the transition between the "snake" and the cable.

Since there are four joints for every loaded circuit at each loading point, it is very important to develop both a time saving and a reliable jointing technique. In the beginning, the same technique as that previously applied on wet submarine cables was adapted. This consisted of silver soldering of the conductor ends and molding of the polyethylene insulation in temperature-controlled molds fed from hand-driven screw-operated ram extruders. Although joints made by carefully-trained operators were highly reliable, they were also timeconsuming and therefore expensive. After careful testing and evaluation, the use of double, irradiated polyethylene sleeves placed over the joint and shrunk onto the insulation was adopted. This has considerably reduced the cost of jointing.

When the cable is fed through the armoring machine, the snake assembly is given extra protection in the form of plastic tape lappings covered by a soft steel tape lapping to support the armoring wires. Over the part of the snake assembly that has a larger diameter than the rest of the cable, the armoring wires were tied down by means of $\frac{1}{2}$ inch (1,27 cm) wide stainless steel tapes.

Prior to production of the first cable of this kind, a test length containing a snake assembly consisting of real and dummy loading elements was made and subjected to severe mechanical testing. The part containing the snake assembly was rolled forwards and backwards over a 1.5 m drum barrel under 4 tons stress. Electrical tests and visual inspection revealed no damage either to the loading coil assembly or to the cable.

4. Some Typical Installations

The first project was for a rather shallow inland lake in Telemark, Norway. The cable route followed the road along the lake. Over a stretch of about 1.5 km, the narrow road was cut into the steep hillside. Minor landslides frequently occur along this part. It was therefore considered a safer solution to lay the cable in the water. For this purpose, a 1400 m, 12-quad wet submarine cable was ordered. Three of the quads were carrier operated, and to match the impedance of the 1.2-mm paper-insulated land cable a 0.9-mm submarine cable with 0.95-mm polyethylene insulation was designed. This cable has a mutual capacitance in water of 56.5 nF/km, which gives a distance between loading points of 1132 m to match land cables having 37 nF/km and loading points at 1730 m intervals. To bridge the water, it was therefore necessary to introduce a loading point approximately in the middle of the cable. The sections on either side of the loading point consist partly of submarine cables and partly of land cables.

Since this was a typical shallow-water cable, the snake assembly was jointed in between two previously armored cable lengths and the armoring was jointed across the loading point afterwards. The cable core was made in one length, measured and cut at the right location for the loading point. In jointing in the snake assembly, conductors were crossed to reduce $S-E$ capacitance unbalance values.

The finished cable was shipped on the loading area of a large truck and pulled out on the ice by means of a weasel and a Land Rover. The cable was left on the ice to await the thaw.

The second task was to cross a 1200 m wide fiord in the north of Norway connecting two previously installed 19 quad 1.2-mm paper-insulated DM land cables. These cables carried 48 ordinary low-frequency telephone circuits on 16 of the quads utilizing both side circuits and phantom circuits. These quads were loaded with 77/48 mH at 1716 m distance. One quad carried three program circuits loaded with 16/10 mH at 858 m distance. The last two quads were carrier-operated on side circuits only.

In order to utilize the phantom circuits it was, as explained earlier, necessary to use plastic-embedded quads. This reduced the mutual capacitance sufficiently to make it possible to cross the water without loading the low-frequency side circuits. But since, as stated earlier, the phantom-mutual capacitance on the submarine cable is relatively much higher than on the DM land cable, it was necessary to load the phantom circuits of the low-frequency quads. A loading point consisting of 16 phantom coils was therefore arranged 810 m from one end of the cable.

To get away with only loading point in the program quad, its diameter was increased so that the mutual capacitance was sufficiently reduced. This quad was placed in the center of the cable and loaded in the middle by a unit consisting of two 16 mH side coils and one 10 mH phantom coil.

To obtain impedance matching to the two carrier-operated quads, embedded quads with a slightly smaller diameter and higher mutual capacitance had to be produced. As can be seen from Figure 6, a sufficiently good match was obtained over the carrier frequency range.

The loading assemblies were first completed and then jointed into the cable core prior to armoring. The cable diameter was 62 mm and the diameter over the snake assemblies 92 mm. The cable was laid by the cable ship of the Norwegian Telecommunications Administration without any difficulties or special precautions.

The largest project to date was carried out when the outer harbor of the city of Bergen was crossed by a 3500-m 37-quad cable with two loading points, each containing 68 side-circuit loading coils. This crossing had proved to be a difficult one. The first paper-insulated lead-covered cable placed in relatively shallow water had been damaged by anchoring. The second cable laid in deeper water had collapsed, since the water pressure had proved too much for the double-steel-spiral reinforced-lead sheath. These cables had not been loaded, they had to be connected to the loaded land cables by means of transformers. With this solution the attenuation was critical, and the submarine cables had to be made with 1.2-mm conductors. In this case, the impedance matching 0.9 mm wet submarine cables with built-in loading points provided both a cheaper and a technically more satisfactory solution.

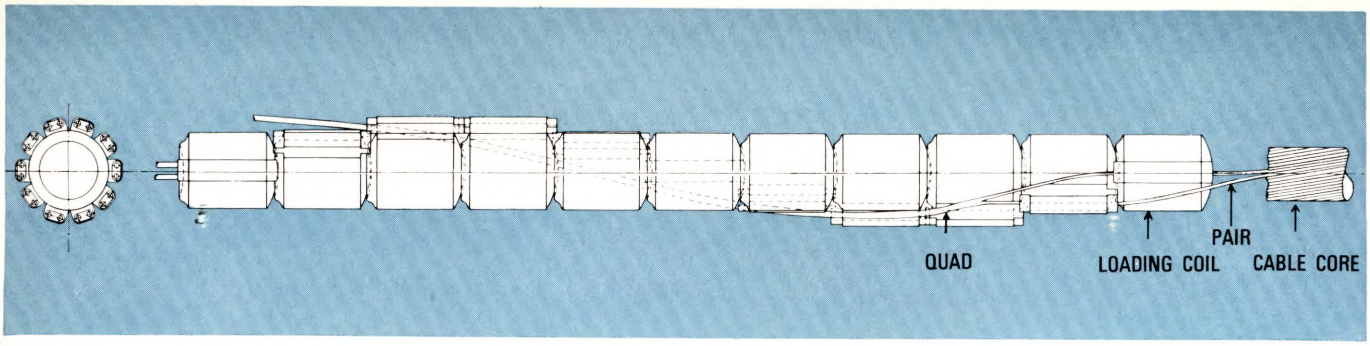

Figure 5 - Assembly of loading elements.

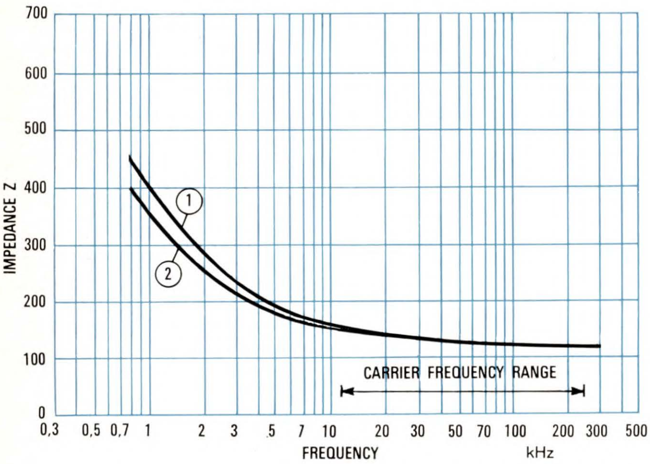

Figure 6 - Impedance matching of embedded "wet" submarine quad to DM land cable.
1 - CF-quads in wet submarine cable
2 - Paper-insulated DM cable

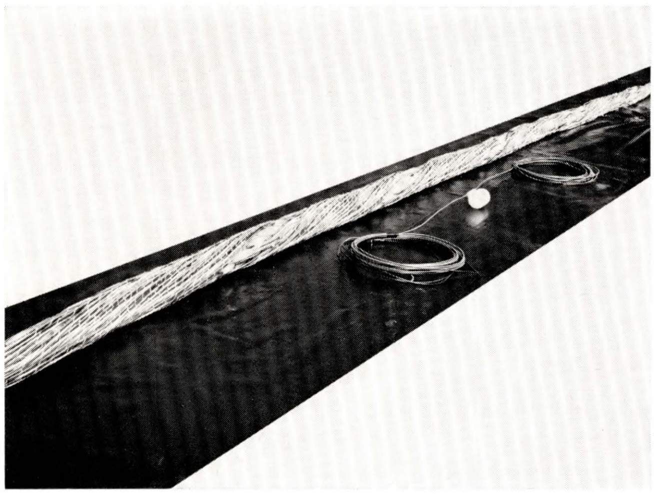

Figure 7 - Loading assembly containing 68 side circuit coils.

For this job, quads of the same design as in the first project were used. The nominal loading section in water is 1132 m. To bridge the water with only two loading points, this was stretched to 1165 m and to maintain the impedance the coil inductance was increased from 77 mH to 79 mH.

Also in this case, the loading assemblies were made ready prior to jointing into the cable core. The armoring was laid on continuously. The cable diameter was 71 mm, and the diameter over the 4 m long loading points was approximately 95 mm.

Figure 7 shows the jointing in loading assembly prior to armoring.

Since completion of the development, a number of orders have been received and executed. The following is a short description of the cables supplied.

For a fiord crossing in the north of Norway, a 3400-m long 0.9-mm 19-quad cable with two loading points each containing 34 side-circuit coils has been completed and laid.

Last year, a 4900-m 7-quad cable with four loading points each containing 10 side-circuit loading coils was produced. In production at the moment is a 5000 m long 19-quad cable with four loading points, each comprising 34 side-circuit loading coils. Both cables are to be laid along an inland lake where the surrounding country is highly unsuitable for installation of buried cables.

Work has also started on a 7000-m long 19-quad cable to cross a fiord in the north of Norway. The cable is to be connected to phantom-operated DM land cables and must therefore have quads embedded in plastic sheaths. To eliminate the scattering of loading coils all along the cable, compromises have been accepted on the loading of the phantom circuits. The loading on the land cables was 77/48 mH, while the submarine cable has 4 loading points each consisting of thirty-two 77 mH side-circuit coils and sixteen 28 mH phantom coils. The cable also contains a program quad, and the latter has 9 loading points, each containing two 16 mH side-circuit coils and one 6.5 mH phantom coil.

5. Conclusions

The finished product should prove technically satisfactory in every respect. The loaded low-frequency circuits have the same characteristics as the corresponding circuits in the land cable. The unloaded carrier frequency circuits have the same impedance versus frequency curves as the carrier quads in the land cable. To obtain this, it was necessary to reduce the length of the loading sections and increase the attenuation per unit length of cable both for the loaded and the unloaded circuits. The loading coil assembly is robust and the loaded cable can be laid and recovered as easily as an unloaded cable.

However, to be a success it must also compete economically with alternative solutions. When the object is to cross a stretch of water wider than a loading section, the loaded wet submarine cable is obviously the cheapest solution. Because of the reduced conductor diameter the loaded submarine cable costs about the same as a wet submarine cable with the same conductor diameters as the land cable. Estimates show that a 0.9-mm loaded cable generally is cheaper than the corresponding unloaded 1.2-mm cable, while a 0.7-mm loaded cable is more expensive on the average than the corresponding 0.9-mm unloaded cable. (Cu basis: $ 700 pr. metric ton). Alternatives would be either to detour the water by land cables or to suffer the technical degradation of the system by having a mismatching cable connected via transformers. The attenuation of the unloaded cables will also be considerably higher and more frequency dependent than on the loaded submarine cables.

In the cases in which the cable is laid along the water the conclusion is not always so obvious. Since, because of the difference in conductor diameters, the submarine cable costs about the same as the paper-insulated, lead or aluminium-covered, steel-tape-armored cable, the cost of the loading points in the submarine cable must be weighed against the cost of the ditch and the ordinary buried loading coil cases. In this comparison, the loaded submarine cable normally comes out the cheapest. However, if it is possible to use an unloaded submarine cable and put all the loading points on shore, this would in some cases be the cheapest alternative. Such cases are rather rare, and it can be argued that the landing points increase the chances of damage to cables by ice, landslides, anchoring, or other hazards. This alternative would also require more cables than a straight route. In any case, if a loaded trunk cable route has to cross a stretch of water or run alongside water, it is certainly worth while to consider the use of loaded wet submarine cables.

Walther Danielsen was born in Trondheim, Norway in 1907. He graduated from Trondheim Technical College in 1928. For six years he worked as a designer in Norsk Dynamoverksted and Norsk Ventilatorfabrikk. In 1934 he joined Standard Telefon og Kabelfabrik A/S and worked as foreman in the cable factory until 1947, when he joined the technical department for telephone cables.

Arve Rambøl was born in Eidskog, Norway, in 1919. He graduated from The Norwegian Technical University in Trondheim in 1945. After a short period of study in England, he joined The Norwegian Defense Research Establishment in 1946. Except for one year of study in the USA, he worked in this establishment until 1954, mainly on problems in connection with antennas and radio wave propagation. He joined Standard Telefon og Kabelfabrik A/S in 1954 as head of the technical department for telephone cables. In 1964, he was promoted to Chief Engineer Telephone Cables and in 1966, to Technical Director for STK.

Gunnar Tidemann was born in Meløy Norway in 1926. He graduated from The Norwegian Technical University in Trondheim in 1955. For two years he worked as an assistant to the professor in electrical communication. In 1957 he joined Standard Telefon og Kabelfabrik A/S as a member of the technical department for telephone cables. In 1966 he was promoted to Chief Engineer, Telephone Cables.

Geodetic Satellite

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ITT Federal Laboratories; San Fernando, California, USA

1. Introduction

In January of 1964, after four years of research and development, a U. S. Army Geodetic Satellite was orbited. The satellite and its associated ground stations provide a space-age tool which can be utilized for accurately determining relative locations of land masses separated by large bodies of water such as continents and islands.

It is the purpose of this paper to describe the US Army Geodetic Satellite system, its underlying theory, mode of operation; and in particular the geodetic satellite which was designed and developed by ITT Federal Laboratories.

2. Geodetic Measurement Theory

There are at least two modes of measurement which can be used to determine the location of an unknown point on the Earth's surface utilizing the Army Geodetic Satellite system. Both modes utilize four ground stations; three at known points and one at the unknown point. Each ground station makes accurate slant range measurements to the satellite by measuring the delay of an electromagnetic wave. The two modes are shown in Figures 1 and 2 (see p. 28) and will be described below.

a) Simultaneous Mode — This mode is used when the satellite is simultaneously within sight of all four ground stations. All four stations make essentially simultaneous range measurements to the satellites. The location coordinates of the known stations plus the range measurements at those stations uniquely determines the satellite position in space. Three such satellite positions and the corresponding range measurements to the unknown station uniquely determine the location of the unknown station. The solution to obtain the unknown point (as well as the satellite location) from three known points utilizing range measurements is essentially the intersection of three given arc lengths.

To reduce the geometric dilution (error in unknown point location) the satellite position is obtained in at least two orbits. This causes the range arcs to intersect at larger angles thereby decreasing the location error due to range measurement errors.

b) Orbital Mode — This mode is utilized where the satellite can be simultaneously viewed from the three known points and shortly after or before by the unknown point on the same satellite orbital pass. The known stations accurately determine the satellite orbit. The satellite orbital position is then extrapolated to coincide with the range measurement made by the unknown position. Three extrapolated positions and the corresponding ranges to the unknown station uniquely determine the location of the unknown position.

3. Theory of Ranging

The slant range between a ground station and the satellite is determined by measuring the phase shift of a propagated electromagnetic wave which is proportional to distance traveled. This is simply illustrated in Figure 3. The difference in phase between the transmitted signal and received signal is given by

$$\Theta = 2\pi n$$

where n = number of wavelengths λ of the signal in the distance $2r$.

$$n = \frac{2r}{\lambda},$$

therefore $$\Theta = \frac{4\pi}{\lambda} r$$

or $$r = \frac{\lambda}{4\pi} \Theta.$$

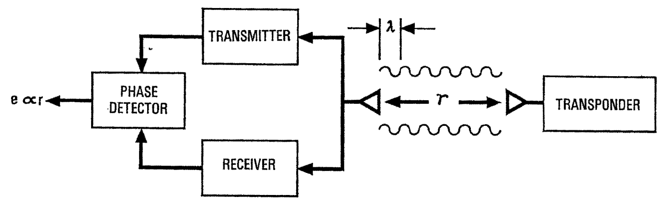

Figure 3 - Theory of range measurements.

The error in range due to an error in phase measurement is directly proportional to λ. Therefore to minimize the range error, the signal wavelength should be shortened. However if $\lambda < 2r$ the phase measurement will be ambiguous since the phase angle is greater than 2π radians.

The problem is overcome by modulating the RF carrier with a group of overlapping ranging frequencies which eliminate the ambiguity to the maximum range. These frequencies are shown in the Table 1. The highest frequency determines the ranging accuracy.

All the frequencies are phase coherent and multiples of a common crystal oscillator.

Table 1 – Ranging Frequencies

Ranging Frequency (nominal)	Total Wavelength (Nautical Miles)	Nonambiguous Range (Nautical Miles)
585 kHz	0.27	0.14
36 kHz	4.4	2.2
2 kHz	70	35
0.2 kHz	560	280
20 Hz*	4050	2025

* Extended range pulse

4. Simplified System Block Diagram

A simplified block diagram of the geodetic satellite system is shown in Figure 4. A frequency synthesizer generates the required ranging frequencies which are utilized to modulate the nominally 420-MHz transmitter. The transmitted signal is beamed to the satellite transponder where the ranging frequencies are demodulated. The demodulated ranging tones are used to phase modulate two receiver frequencies nominally at 225 MHz and 450 MHz and are returned to the ground station receivers. At the receivers the ranging tones are demodulated again and compared in phase to the transmitted tones. The phase difference is continually measured by the electronic servos and recorded on magnetic tape in digital form for later processing. Accurate time is obtained from a clock synchronized to a WWV transmitter via the VLF receiver.

The transponder is time shared among the four ground stations; each station transmitting for 10 milliseconds within a 50 millisecond interrogation cycle. A 2.5 millisecond guard band isolates the transmissions. This is shown in Figure 5.

The timing is achieved by designating one of the ground stations as the master station. This station transmits a master timing signal which is received by the slave stations via the satellite. The slave station also receives its own transmitted 10 millisecond pulse via the satellite. Each slave station then delays or advances its time of transmission to insure that its signal pulse arrives at the satellite at the assigned time with respect to master station pulse by monitoring the received pulses.

The satellite transmits two radio frequencies so as to correct for range errors caused by the ionospheric index of refraction. The ionosphere causes a change in the velocity or propagation from that of free space. The velocity in the ionosphere is inversely proportional to the index of refraction which in turn is inversely proportional to the square of frequency of propagation. With R_{HF} and R_{LF} as the higher and lower frequency measurements:

$$R_{\mathrm{true}} = R_{\mathrm{HF}}\,(\text{measured}) - \Delta R_{\mathrm{HF}}\,(\text{error in measurement}). \tag{1}$$

$$R_{\mathrm{true}} = R_{\mathrm{LF}}\,(\text{measured}) - \Delta R_{\mathrm{LF}}\,(\text{error in measurement}). \tag{2}$$

$$R_{\mathrm{LF}} - R_{\mathrm{HF}} = R_{\mathrm{LF}} - \Delta R_{\mathrm{HF}}. \tag{3}$$

$$\text{or } \Delta R_{\mathrm{HF}} \left(\frac{\Delta R_{\mathrm{LF}}}{\Delta R_{\mathrm{HF}}} - 1 \right) = R_{\mathrm{LF}} - R_{\mathrm{HF}} \tag{4}$$

$$\text{but } \Delta R \propto \frac{1}{f^2} \tag{5}$$

$$\therefore \Delta R_{\mathrm{HF}} \left(\frac{f^2_{\mathrm{HF}}}{f^2_{\mathrm{LF}}} - 1 \right) = R_{\mathrm{LF}} - R_{\mathrm{HF}} \tag{6}$$

$$\text{for } f_{\mathrm{LF}} = \frac{1}{2} f_{\mathrm{HF}} \tag{7}$$

$$\Delta R_{\mathrm{H}} = \frac{1}{3} (R_{\mathrm{LF}} - R_{\mathrm{HF}}) \tag{8}$$

Substituting equation (8) into (1):

$$R_{\mathrm{true}} = R_{\mathrm{HF}} - \frac{1}{3} (R_{\mathrm{LF}} - R_{\mathrm{HF}}) \tag{9}$$

Thus the true range is equal to

$$R_{\mathrm{true}} = R_{\mathrm{HF}} - K\ (R_{\mathrm{LF}} - R_{\mathrm{HF}}) \tag{10}$$

$$\text{where } K = \left(\frac{f^2_{\mathrm{L}}}{f^2_{\mathrm{H}} - f^2_{\mathrm{L}}} \right) = \frac{1}{3} \text{ for } f_{\mathrm{H}} = 2 f_{\mathrm{L}}$$

and R_{HF} and R_{LF} are the high- and low-frequency measurements.

The ground stations utilize a separate antenna and receiver for reception of the 136 MHz satellite telemetry data.

5. Ground Station Description

A photo of a typical ground station is shown in Figure 6 and a line drawing is shown in Figure 7. The station consists of an RF shelter, a data handling shelter, a storage and maintenance shelter and a diesel power supply. The telemetry equipment is not shown. Note that two 10-foot (3-meter) parabolic antennas mounted side-by-side are utilized. One antenna is used for transmission and reception of the higher frequency signal and the other for reception of the lower frequency. The pertinent ground station parameters are given in Table 2.

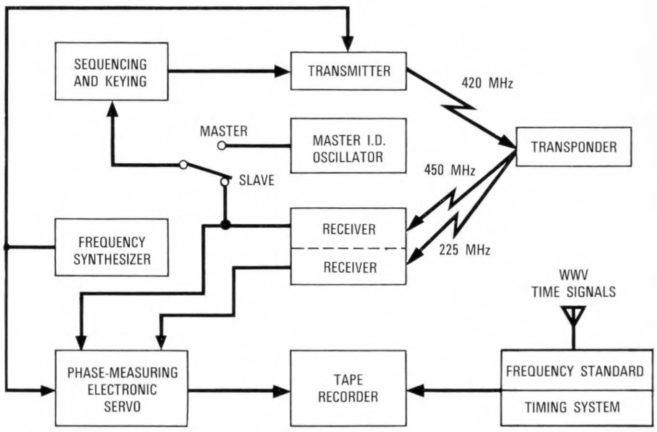

Figure 4 - Simplified block diagram of geodetic satellite system.

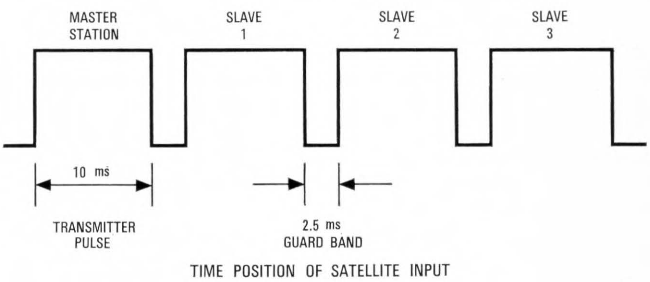

Figure 5 - Satellite interrogation cycle.

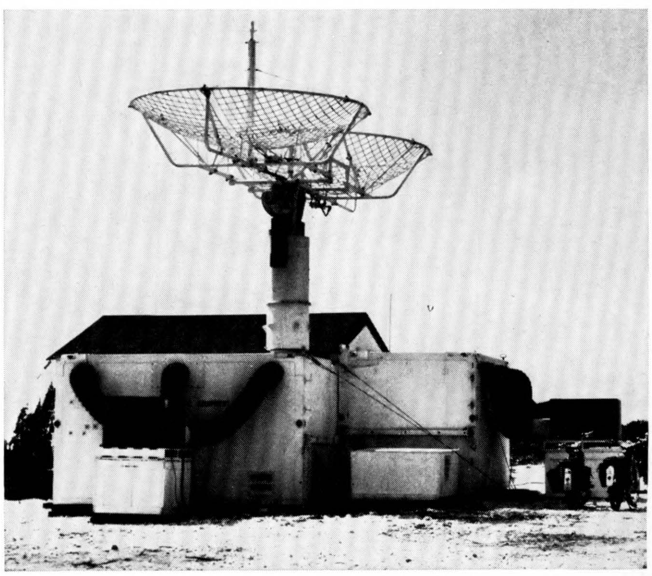

Figure 6 - Geodetic satellite ground station.

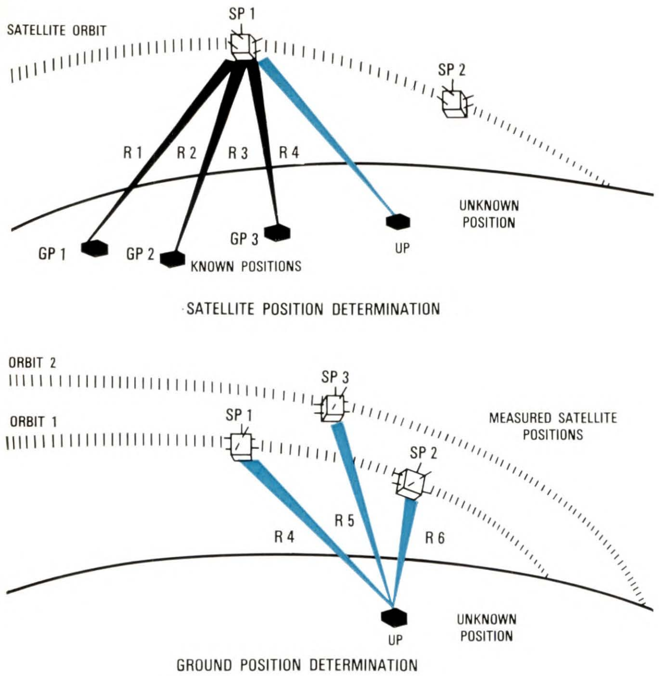

Figure 1 - Simultaneous mode.

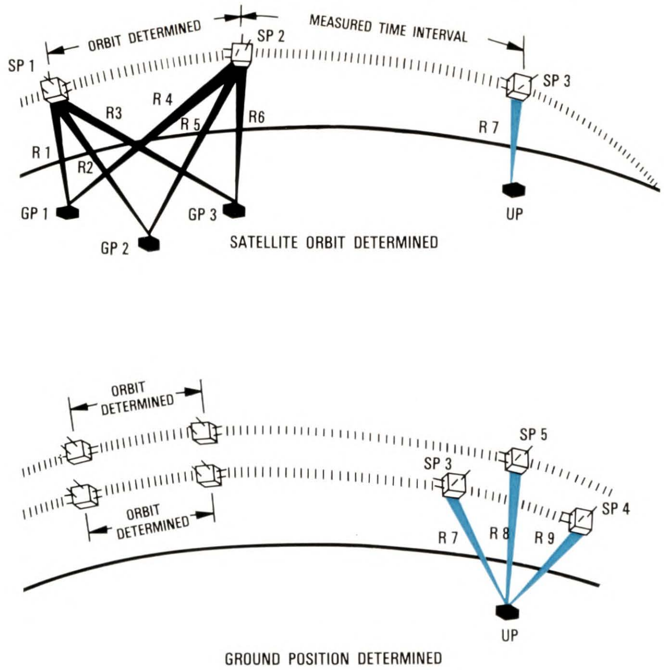

Figure 2 - Orbital mode.

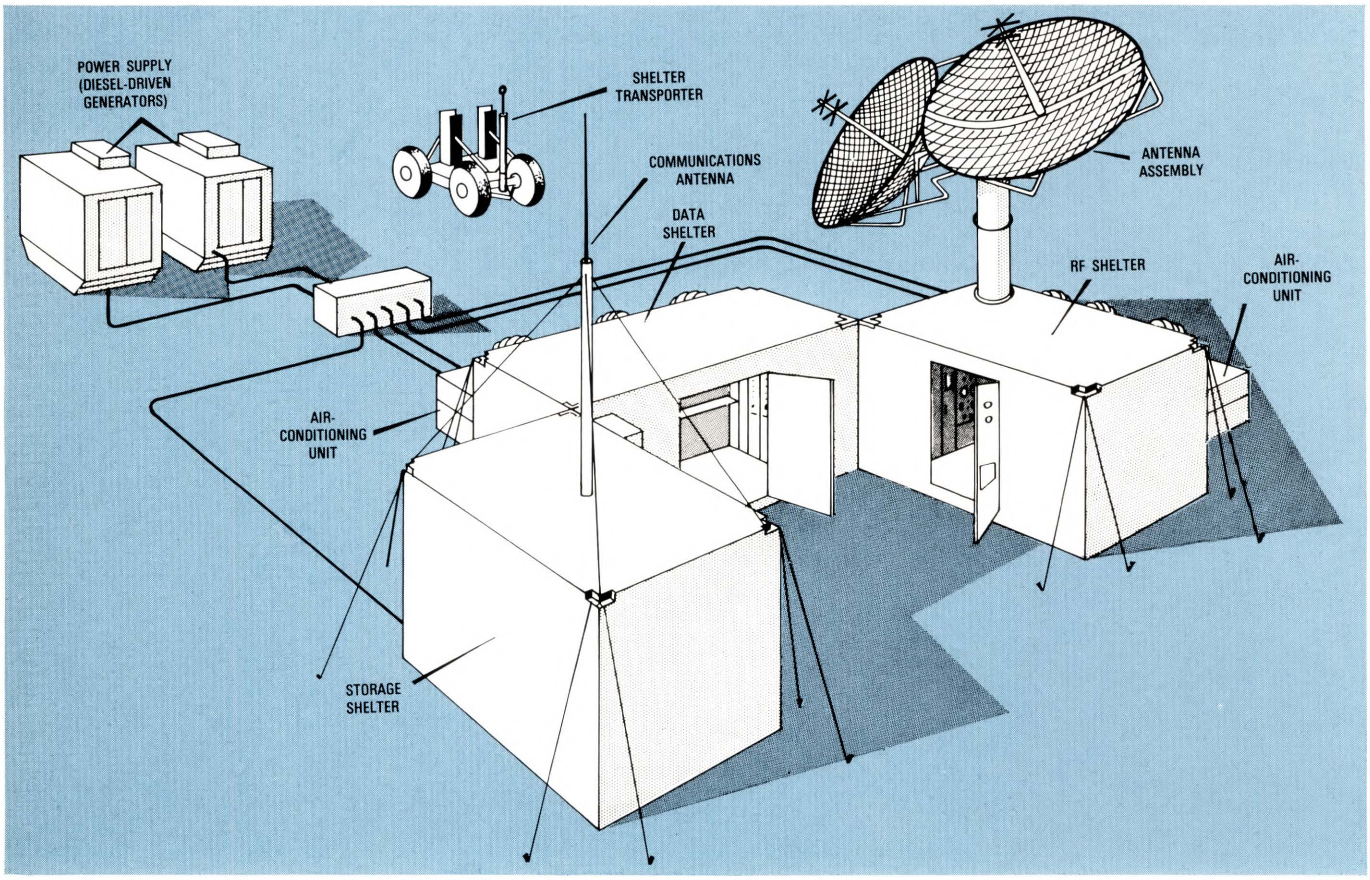

Figure 7 - Geodetic satellite ground station.

6. Satellite Description

The present Type II Satellite was developed and built under Army contracts:
DA 44-009-AMC-176 (X) and
DA-44-009-AMC-866 (X).

Three satellites were furnished under each contract. In the first contract S/N 1 satellite was designated the prototype, while S/N 2 and 3 were flight models. In each of these satellites, a government-furnished TR-27 transponder was incorporated.

Table 2 – Ground station parameters

Transmitter	
Frequency (nominal)	420 MHz
Transmitter Power	1 kW
Antenna Gain (10 ft.)	18 dB
Antenna Beamwidth	16 degrees
Phase Modulation Index	0.7 rad/subcarrier
Receiver	
Frequency (nominal)	
Higher	450 MHz
Lower	225 MHz
Antenna Gain	
Higher	18 dB
Lower	12 dB
Antenna Beamwidth	
Higher	16 degrees
Lower	30 degrees
Noise Figure	
Higher	6 dB
Lower	5 dB
Coherent Detection Bandwidth	1–4 Hz

In the second contract, all three were flight models. A TR-27 transponder was incorporated into S/N 4 and 6 satellites. The S/N 5 satellite incorporated an ITT Model C-101 transponder.

Only minor differences exist between the two groups of satellites.

The Type II Geodetic Satellite is the second generation design in the Geodetic SECOR (Sequential Collation of Range Satellite) Satellite Program. This satellite was designed to take advantage of the multiple launch techniques now available and its size and shape were dictated by the allocated space in the launch vehicle. The satellite was constructed so that the transponder occupied approximately one-half of the interior volume, while the supporting subsystems occupied the other half. This makes it possible to interchange transponders with relatively little redesign while retaining the supporting subsystems in tact.

6.1 Construction

The satellite is a rectangular parallelepiped of approximately $9 \times 11 \times 13$ inches ($230 \times 280 \times 330$ millimeters) and weighs approximately 40 pounds (18 kilograms) (see Figures 8 and 9). It is assembled on an aluminium baseplate to which are bolted the center structure, the transponder, and the outside case. The center structure is a dip-brazed aluminium frame with provisions for mounting the batteries and the telemetry subsystems. The outside case is also of dip-brazed aluminium to which are mounted the antennas and the solar cells and their associated cabling.

6.2 Telemetry

Housekeeping telemetry is provided by a fully transistorized PAM/FM/PM system operating in accordance with NASA Minitrack Specifications. The transmitter operates in the 136.8 MHz region with a power output of 100 milliwatts. Six data channels and two calibration channels are time-multiplexed onto a VCO with a center frequency of 730 Hz. The 730 $\pm$ 50 Hz output phase modulates the 136.8 MHz carrier. The six channels telemeter data on the battery voltage, power supply voltage, transponder power output, skin temperature, transponder temperature, and battery temperature. A command system is incorporated to turn the telemetry system on and off as desired.

6.3 Antenna System

Two turnstile antenna systems are provided for the transponder; one for operation at the 420 to 449 MHz frequencies, and the other for the 224.5 MHz frequency. A whip antenna was designed at 136.8 MHz for the telemetry system.

Each antenna element resembles a flexible carpenter's rule and is folded under the satellite during the launch phase. It erects automatically when the satellite separates from the launch vehicle.

6.4 Power Supply System

The power supply system consists of solar cells, rechargeable batteries, and a voltage regulator. The solar cells are silicon N-on-P cells and are designed for proper voltage and current matching, and adequate conversion efficiency. They are mounted on all external surfaces of the satellite and each surface is isolated with a diode. Each cell has a blue filter and a quarz filter 0.060-inch (1.5-millimeter) thick.

The storage battery consists of a single string of sealed nickel-cadmium cells designed for satellite applications. They are potted in two compartments with an insulating foam. The depth of discharge is held to a minimum, consistent with the battery lifetime requirements. The voltage regulator consists of a series transistor referenced from a zener diode. This regulator provides constant 12 volts

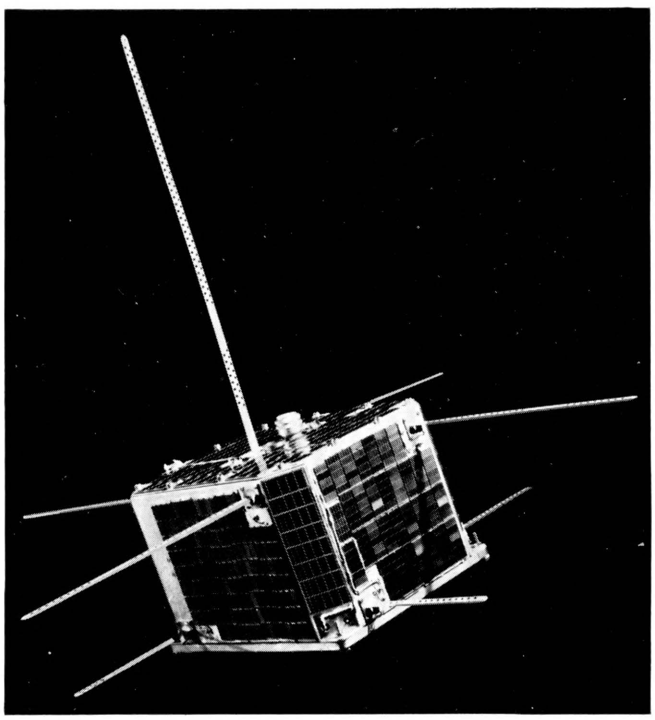

Figure 8 - ITT type II satellite.

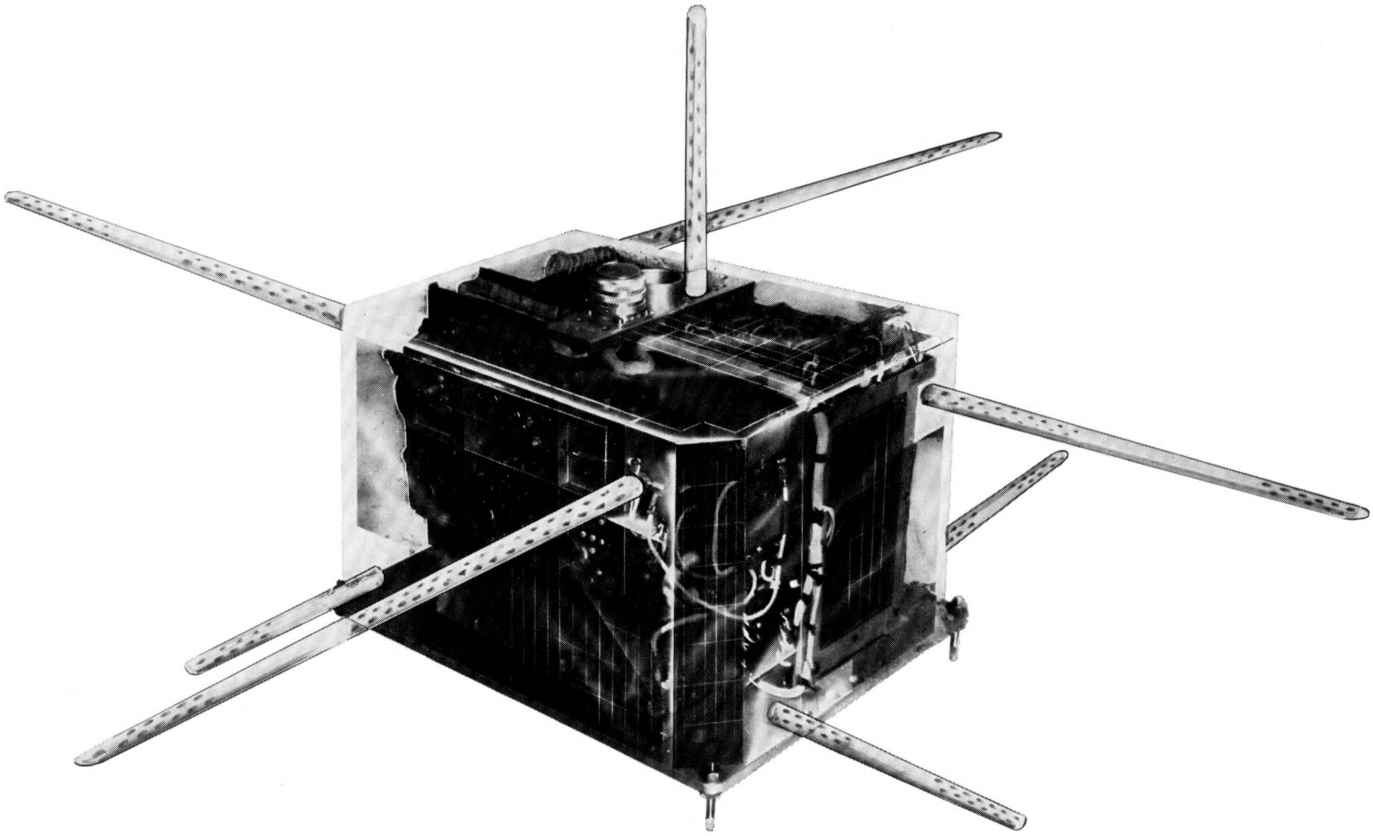

Figure 9 - Phantom view - ITT type II satellite.

to the electronics equipment regardless of the voltage swings of the solar cell-battery combination.

6.5 Satellite Orientation

The satellite is magnetically oriented by a magnet fastened to the center structure plus magnetic damping rods located on the case. This magnet causes the satellite to align itself with the Earth's magnetic line of force and assures that a constant relationship is maintained between the antenna patterns and the surface of the Earth. The damping rods minimize satellite oscillations and spin.

7. Type 101 Transponder

The Type 101 Transponder was designed and developed for the US Army under contract DA-49-018-eng-2624 to operate as a satellite-borne unit for the Army's Geodetic Satellite system. The transponder employs all solid-state components and is designed to operate over the temperature range of -20 to $+70$ degrees C. The primary feature of the Type 101 Transponder is its high degree of phase stability over a wide range of operating environmental conditions. This phase stability is necessary for the precision measurement of the ground station to satellite range.

The transponder consists of five separate chassis contained in two packages. The power supply and all receiver circuits plus the diplexer are contained in the receiver package while the transmitter occupies a separate package.

A photo of the transponder is shown in Figure 10. The total weight is less than 8 pounds (3.6 kilograms) and the power drain is approximately 28 watts during transmission.

The Type 101 Transponder block diagram is shown in Figure 11. The ground transmitted 420-MHz signal (which has been modulated by the ranging subcarriers) is received

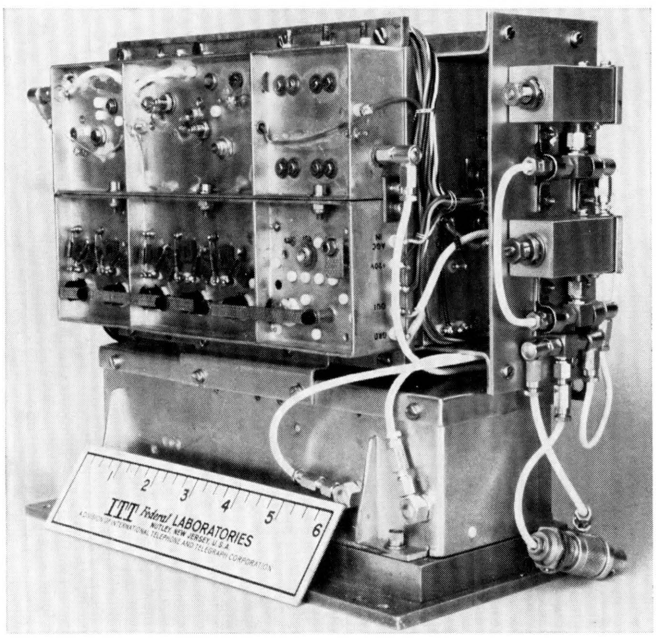

Figure 10 - The transponder.

via the higher-frequency antenna and sent to the mixer via the diplexer preselector. The signal is heterodyned to 28 MHz by the local-oscillator signal obtained from a crystal oscillator and a multiplier chain. The 28-MHz signal is amplified by the IF amplifier and demodulated by the discriminator to produce the composite ranging subcarrier signal. The IF gain is controlled by a carrier AGC circuit.

The ranging subcarriers are individually filtered in narrow-band crystal filters to improve the signal-to-noise ratio. They are then recombined and used to phase modulate the transmitter crystal oscillator signals. The phase modulator output is multiplied by three and amplified to approximately 5 watts at 112 MHz. The power amplifier output is doubled to 224 MHz and sent to the ground stations via the lower-frequency antenna. The 224 MHz is also doubled and transmitted via the higher-frequency antenna. The lower-frequency and higher-frequency signal power levels are 1.4 and 1 watt, respectively.

To conserve battery power, the transmitter does not function until a "select call" signal is received by the transponder.

The pertinent transponder specifications are shown in Table 3.

8. Satellite Launch Results

The results of four Type II Satellite launches is shown in Table 4. Of the four launches two were successful and two were not. Note that the first two launches resulted in nearly circular orbits at about 500 nautical miles (926 kilometers). The inclination for both was approximately 70 degrees.

The third launch had an ejection malfunction and the fourth, an electronic malfunction. Both of these were in essentially polar orbits.

Table 3 – Type 101 transponder specifications

Receiver Frequency	420.9 MHz
Transmitter Frequencies	449 MHz 224.5 MHz
Select Call Sensitivity	$\geqslant -100$ dBm
Ranging Sensitivity	$\geqslant -92$ dBm
Power Output	
224 MHz	$\geqslant 1.4$ watts
449 MHz	$\geqslant 1.0$ watt
Phase Stability	$\leqslant 2$ degrees (-54 dBm to -85 dBm)
Data Bandwidth	Rise Time < 1 ms Fall Time < 1.5 ms
Modulation Index	0.7 radians ± 10 %
Power Drain	
Standby	< 1 watt
Operate	28 watts

9. Geodetic Satellite Test Results

To determine the accuracy of the Geodetic Satellite system, two ground-station configurations were located within the United States as shown in Figure 12. The 500 mile (800 kilometer) quad consisted of:

Austin, Texas
Las Cruces, New Mexico
Fort Carson, Colorado
Stillwater, Oklahoma

Distances between stations are approximately 500 miles (800 kilometers). After test on the 500-mile quad, the stations distances were expanded to a 1000-mile quad with stations located at:

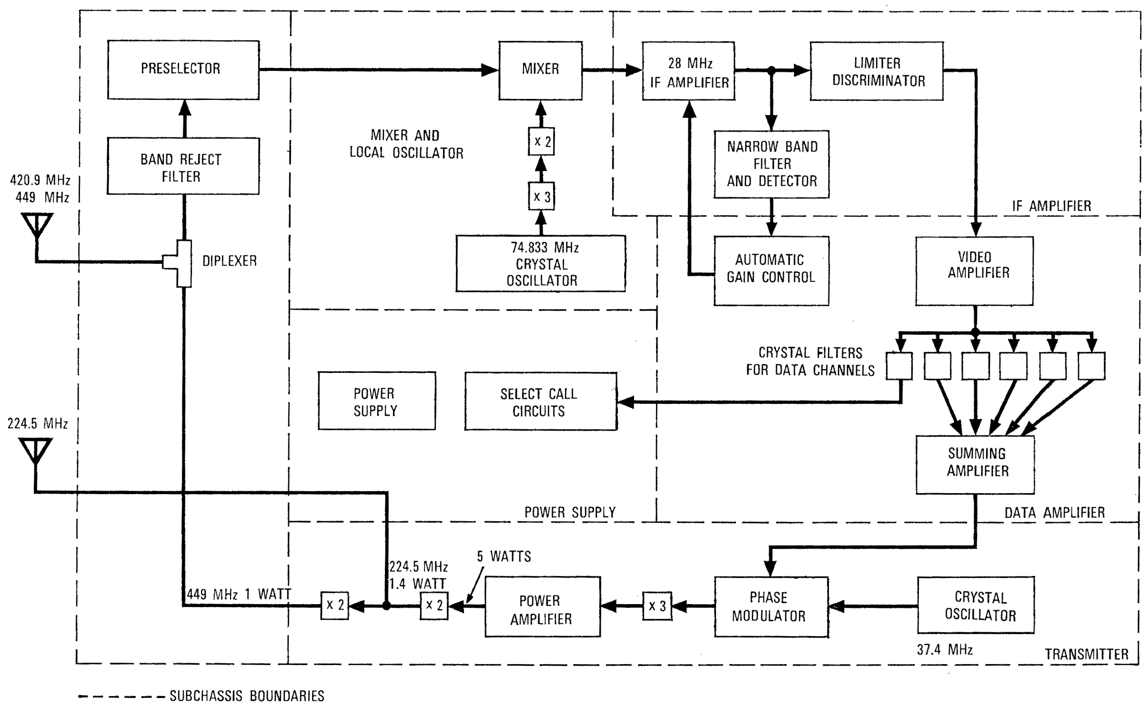

Figure 11 - Solid-state transponder model 102, block diagram.

Table 4 – Type II Satellite Launch Results

Type II Satellite	Launch Date	Parameters				Remarks
		Inclination	Period	Apogee	Perigee	
S/N II	11 Jan 1964	69.93°	103.4 M	938 km	907 km	Failed 1 Sept 1965 after 8400 passes*
S/N I	9 Mar 1965	70.10°	103.5 M	941 km	907 km	Pass 3000 11 Oct 1965 Pass 4000 21 Dec 1965
S/N III	11 Mar 1965	89.98°	97.5 M	995 km	284 km	Not Operational Ejection Malfunction
S/N V	3 Apr 1965	90.22°	111.4 M	1321 km	1268 km	Not Operational Electronic Malfunction

* Traveled approximately 250 000 000 miles (400 000 000 kilometers)

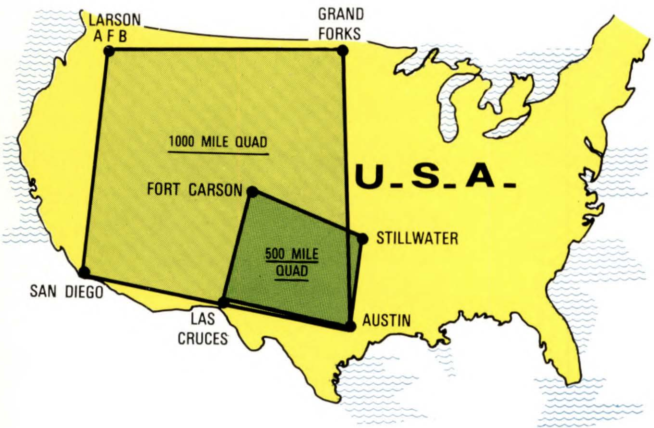

Figure 12 - Ground station test quads.

Austin, Texas
Grand Forks, North Dakota
Larson AFB, Washington
San Diego, California

The location of all the sites selected was obtained from the first-order US Coast and Geodetic Surveys in their respective areas. These positions were then used as the standard to check the system.

Tests were conducted under the direction of GIMRADA (Geodesy, Intelligence and Mapping Research and Developments Agency), US Army Corps of Engineers early in 1964. The ITT Type II satellite in a nearly circular orbit of 500-nautical mile (926-kilometer) altitude and 70 degree inclination was utilized.

In the 500-mile (800-kilometer) quad, Fort Carson was considered the unknown location and Larson Air Force Base was the unknown location of the 1000 mile quad. The results of the simultaneous mode of operation are shown in Table 5. The results were obtained from hundreds of solutions made with the system.

The results show that mean RSS (root sum squared) differences from the first-order survey are 14.8 and 33.4 meters for the 500-mile and 1000-mile quads. The standard deviation is 6.0 meters for both.

Table 5 – Simultaneous mode tests

Fort Carson Solution – 500-Mile Quad

	Lat. m	Long. m	Height m	RSS m
Mean Difference	−0.70	7.1	5.7	14.8
Standard Deviation	3.5	3.9	2.4	6.0
Total RSS				16.5

Larson AFB Solution – 1000-Mile Quad

	Lat. m	Long. m	Height m	RSS m
Mean Difference	−14.4	10.6	9.2	33.4
Standard Deviation	3.3	2.7	4.0	6.0
Total RSS				34.5

10. Distribution of System Errors

To determine the various factors which entered into the survey system errors, a simulation study was contracted by GIMRADA. The study assumed several error models and the actual satellite orbits and geometries on which measurements had been made. The theoretical errors were propagated through the solutions and the results compared to the solutions obtained from actual measurements. The results and error models are shown in Table 6.

It is seen that in the 500-mile quad, the actual deviation from the standard is bracketed by the two theoretical values. Also the actual deviation is much smaller than theoretical in the 1000-mile quad solution.

Assuming that the error models are valid it can be inferred that the system ranging accuracy is in the order of 3 to 5 meters.

The system is now being used operationally by the USA Corps of Engineers in the Pacific. Also development and testing is continuing on the system to further improve its performance.

Table 6
Comparison of Actual and Theoretical Solutions

	Test Measurements RSS (m)	Theoretical Model ≠ 1 RSS (m)	Theoretical Model ≠ 2 RSS (m)
500-Mile Quad	16.5	14.5	19.4
1000-Mile Quad	34.0	75.7	85.6

Theoretical Error Models

	System (m)	Troposphere Refraction	Ionosphere Refraction	Scale Factor	Site Survey
Model 1	2.8	5 % of Correction	5 % of Correction	1 ppm	4 ppm
Model 2	4.5	5 % of Correction	5 % of Correction	1 ppm	4 ppm

References:

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[2] T. J. Hayes, Brig. Gen., U. S. Army: SECOR for Satellite Geodesy, Paper delivered to 10th Congress International Society of Photogrammetry Congress International Society of Photogrammetry, held in Lisbon, Portugal, 7—19 September, 1964.

[3] Combined Engineer and Service Test, Geodetic SECOR System, USAEGIMRADA Task 4A623501D85304, 1 July 1964.

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He joined ITT Federal Laboratories in 1952, where he was concerned with the design and development of advanced pulse-position-modulation and delta-modulation systems. His activities have included technical as well as management work on radar, missile guidance, and satellite communication systems. He is presently Director of the Aerospace Systems Laboratory at the ITT Federal Laboratories Aerospace facilitiy in San Fernando, California. Mr. Albanese taught course in electrical engineering for six years at Newark College of Engineering. He has been granted four patents.

Submerged Repeater for the United Kingdom to Portugal 640-Circuit Cable

J. F. TILLY
Standard Telephones and Cables Limited, London

1. Introduction

The development of highly reliable transistors suitable for use in submerged repeaters [1] has made possible the design and development of repeaters with a bandwidth larger than that previously achieved by valve repeaters. This paper describes a transistor repeater designed to meet the requirements of a 640-telephone-channel system to link the United Kingdom and Portugal, which is due to be installed in 1969.

2. System Requirements

The system requirements were laid down by the British Post Office specification RC. 1862 of which those relevant to the submerged repeaters are detailed below.

2.1 Transmission Requirements

The specification called for the two-wire transmission of 640 3-kilohertz telephone channels between the United Kingdom and Portugal. A loading of −10 dbm0 per channel, which is the normal standard for deep-water submerged systems, was specified and with this load applied to all channels the system noise, averaged over all the channels in each direction, should not exceed 1 picowatt/kilometer per channel. In addition the maximum system noise in any channel should not be greater than 3 picowatts/kilometer, the standard recommended by the International Telegraph and Telephone Consultative Committee.

The noise performance was to be achieved over the life of the system, taken to be 25 years, and the design was to be such as to cater for annual temperature variations which affect the attenuation of the cable, and for the addition of an extra nautical mile of cable in the shallow water sections of the route, where repairs can be expected due to cable faults produced by trawling activities.

The length of cable to be laid is of the order of 1000 nautical miles (1852 kilometers) and of this length some 400 nautical miles (741 kilometers) is to be in armored cable to help reduce cable faults due to trawler fishing.

2.2 Supervisory System

The repeaters were required to have a supervisory system that permitted loop transmission measurements to be made from one of the terminal stations. In addition the noise and intermodulation performance of each repeater should be capable of measurement from the terminal. The supervisory design should also be such as to permit the replacement of a repeater by any of the spare repeaters to be supplied.

As with previous repeaters, the supervisory circuits should not degrade the main transmission paths and in the event of the failure of a component in the supervisory circuits, communication via the main transmission paths should not be lost.

2.3 Submerged Repeaters

The submerged repeaters were required to use components and techniques already approved for use in deep-water submerged systems or, where new components were employed, the reliability of such components had to be demonstrated.

Protection of the repeaters against current or voltage surges which could arise due to cable faults had to be achieved. This requirement, which existed on previous repeaters using valves, was accentuated by the vulnerability of transistors to such surges and a considerable part of the development of the repeaters was in this area.

3. Frequency Spectrum

The frequency bands for the high- and low-frequency directions of transmission were laid down in the system specification. In addition, frequency allocations had to be made for system pilots, for the bands used by frequencies employed in the supervisory circuits of the repeater and for speaker circuits for engineering use. These are as shown in Figure 1.

4. Repeater Circuitry

4.1 Transmission and Power Feeding Paths

A block schematic of the repeater is shown in Figure 2 where heavy lines indicate the main transmission paths. The power-separating filters separate the direct current transmitted along the inner conductor of the sea cable from the transmission frequencies within the repeater. This direct current, of the order of 150 milliamperes, is fed from the "A" end power-separating filter to the "B" end power-separating filter via the d. c. supply terminals of the line amplifier. This results in a drop of 23 volts across these terminals and from this voltage the line amplifier and the amplifiers of the supervisory circuits are energised.

The main transmission paths in the repeater use the principle of a common amplifier for both directions of transmission. The amplifier and the directional filters necessary for separating the two directional bands are connected in a figure-of-eight configuration with the amplifier in the common cross-over path. The equaliser, necessary to produce a repeater gain characteristic equal to the loss characteristic of a cable section, is also common to both directions of transmission.

Design of the directional filters is based on a conventional ring of Zobel high-pass and low-pass filters with susceptance-annulling networks at the common junctions. The loop-loss of the directional filter rings is considerably improved by the addition of a phase-reversing transformer of 1:1 ratio in the low-frequency side of one of the directional filters. This transformer is included in the equaliser circuitry.

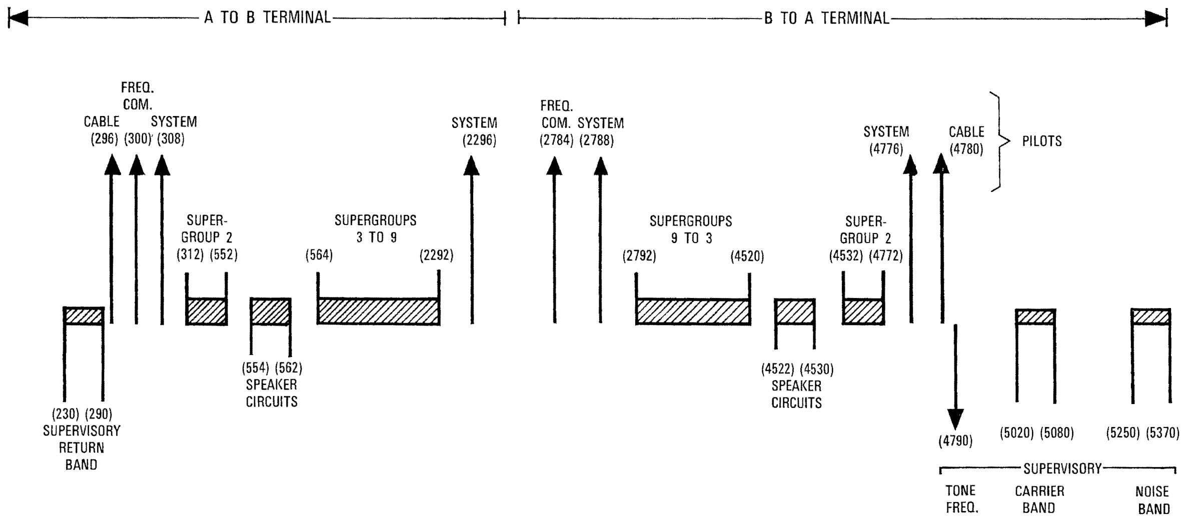

Figure 1 - System frequency spectrum (frequencies in kilohertz are given in parentheses).

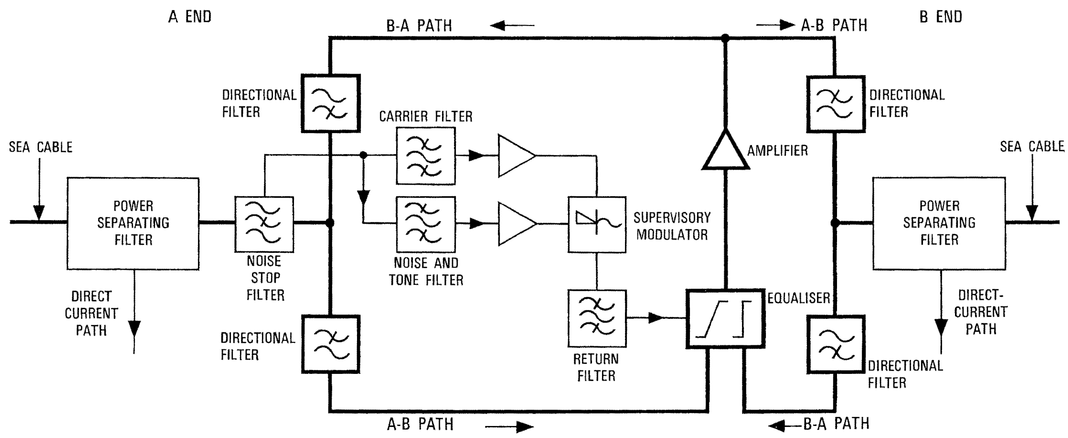

Figure 2 - Block schematic of repeater.

The amplifier, of which a simplified schematic is shown in Figure 3, is a three-stage amplifier employing bridge feedback through both the input and output transformers.

Unlike previous submerged-repeater amplifiers this amplifier does not use parallel 3-stage amplifiers since the reliability expected from the transistors (BPO type 4A2), is such as to remove the necessity for redundant circuitry. The gain characteristic of the amplifier is shown in Figure 4 and partly equalises the loss characteristic of a cable section. The transmission characteristic around the feedback loop is shown in Figure 5.

4.2 Supervisory Circuits

4.2.1 Loop Gain Measurement

To measure loop gain, pulses of 5050 kilohertz with a pulse-length of 50 microseconds and a pulse-repetition rate of 50 times a second together with a continuous tone

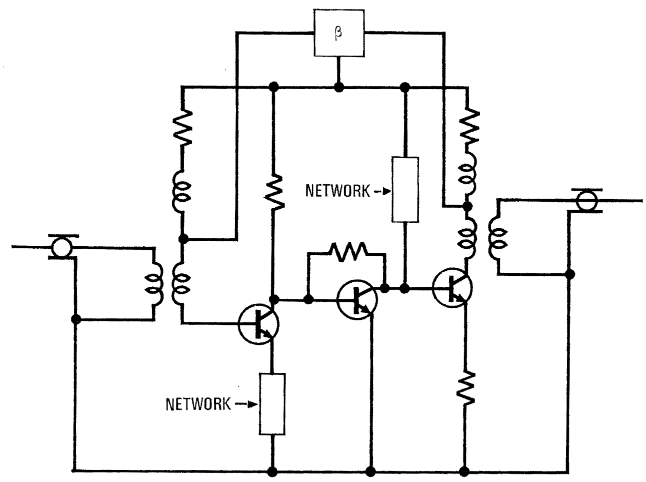

Figure 3 - Simplified amplifier schematic.

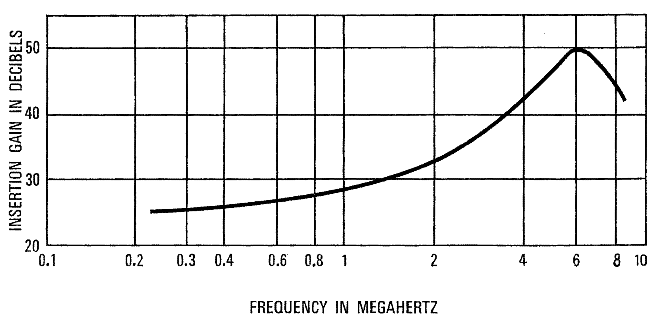

Figure 4 - Gain characteristic of repeater amplifier.

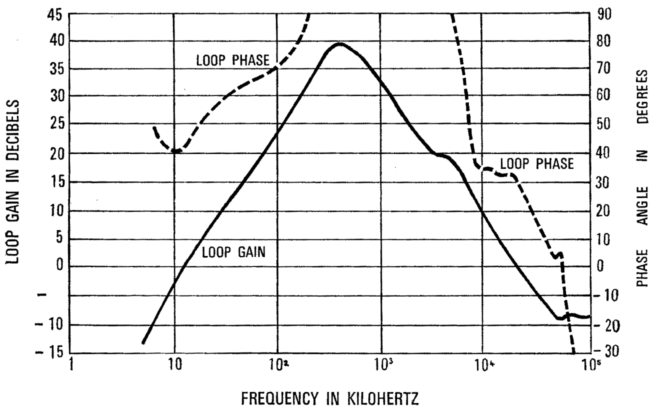

Figure 5 - Amplifier feedback loop characteristic.

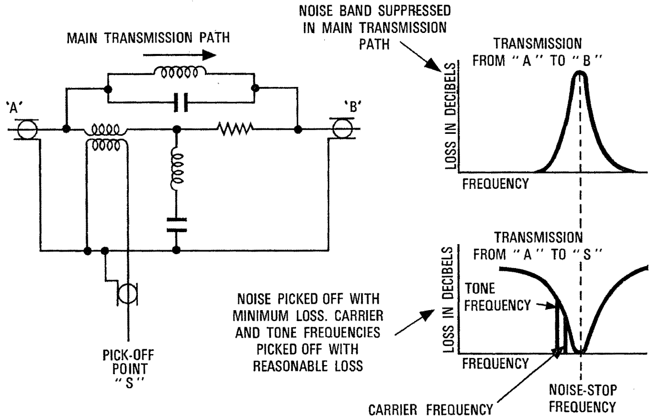

Figure 6 - Diagram illustrating supervisory pick-off method.

of 4790 kilohertz are transmitted from the "B" terminal. At the repeater the pulses are picked-off at the carrier filter, amplified by the carrier amplifier, and fed to the supervisory modulator. The continuous tone is also picked off at the repeater using a tone filter and fed through an amplifier to the signal terminals of the supervisory modulator. Modulation occurs and the resulting sideband, consisting of pulses of 260 kHz, is returned through the return-filter to the repeater amplifier input where it is transmitted back to the "B" terminal. Returned pulses from successive repeaters arrive at successive times at the "B" terminal and the magnitude of the pulses gives a loop-gain measurement, each repeater being separated from its neighbor on a time basis.

4.2.2 Noise Measurement

If no tone is transmitted from the „B" terminal then no continuous tone will be present in the repeater supervisory modulator, but noise from the repeater amplifier, which is picked off at the noise filter, will be present in the modulator and returned pulses of noise will be transmitted back to the "B" terminal, thus enabling repeater noise to be monitored. The noise-stop filter prevents the noise from one repeater, in the range of frequencies accepted by the supervisory noise filter, being transmitted to the next repeater.

4.2.3 Supervisory Circuits

The noise-stop filter is a bridged-T filter in which the pick-off for the carrier pulses, tone frequencies, and noise frequencies is also incorporated. This method of pick-off gives the required pick-off characteristic for the supervisory signals and good protection against faults in the supervisory circuits. Its operation is illustrated in Figure 6 and is fully explained elsewhere [2].

A crystal filter is used for the tone filter but the remaining supervisory filters are conventional coil and capacitor units. The tone and noise amplifier is a single-stage transistor amplifier, whereas the carrier amplifier uses two stages to give sufficient amplification to the carrier signals to produce satisfactory operation of the conventional ring modulator. The ring modulator uses silicon diodes specially developed for submerged-repeater applications.

Injection of the returned pulses uses the same principle as that used in the noise filter pick off but here a bridged-T circuit in the repeater equaliser is utilised.

4.3 Protection Circuits

The protection circuits used in the repeater have been evaluated with an artificial line simulating a system length in excess of that required for the UK—Portugal link. On this system the d.c. voltage applied between the inner and outer conductors of the cable can rise to 3.6 kV if the system is fed from one terminal only. A short-circuit cable fault could result in the transmission of a fault current of the order of 100 amperes and protection against such an occurence has to be provided.

The protection takes several forms. To prevent large voltages occuring across the d.c. supply terminals of the line amplifier a series chain of 5 zener diodes, each capable of withstanding surges of 200 amperes, is connected. This limits the voltage across the amplifier during a fault surge and gives redundancy to cover the possibility of a short-circuit fault in one of the diodes.

Surge voltages across power-separating filter coils are kept to a tolerable level by the use of gas discharge tubes. However, these tubes are not fast enough to prevent large, fast surges being transmitted by the transmission paths of the repeater to the input and output terminals of the line amplifier. To prevent these surges damaging transistors in the amplifier small-signal diodes are used. These are unbiased at the amplifier input but in order not to impair the linearity of the repeater they are back-biased at the amplifier output.

5. Repeater Performance

5.1 Main Transmission Path

The equalisation error of the repeater against the target characteristic for 7.5 nautical miles (13.9 kilometers) of BPO 0.99-inch Mk. II cable is shown in Figure 7. To ease the problems of designing a fixed equaliser for block equalisation, the repeater has excess gain rather than excess loss, particularly at the lowest frequencies.

The repeater characteristic for second and third harmonic distortion for a fundamental frequency of 1.6 MHz

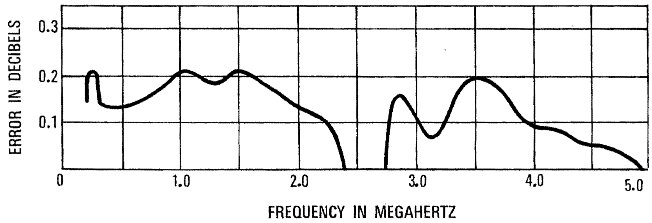

Figure 7 - Equalisation error of repeater compared to target gain.

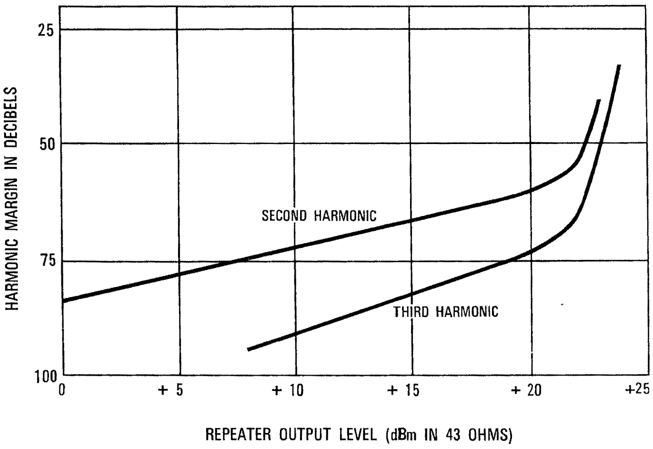

Figure 8 - Harmonic margins of repeater against fundamental output level.

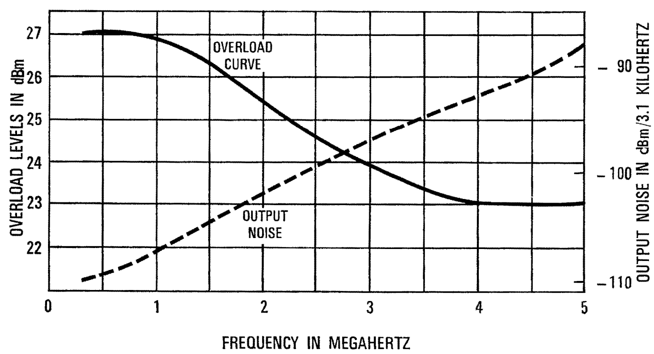

Figure 9 - Repeater output noise and overload level.

is shown in Figure 8. Variation of repeater noise level and overload level at the repeater output is shown in Figure 9.

The input and output impedances of the repeater in the working bands are such that the following relationship holds at all frequencies:

Return loss at repeater input in dB
+ Return loss at repeater output in dB
+ 2 × Cable attenuation in dB > 50

This ensures that mismatch losses, which may add from repeater section to repeater section, are kept to a tolerable level.

5.2 *Supervisory Circuits*

Using a pulsed carrier with a peak amplitude corresponding to a power level of + 8.5 dBm0, the returned noise pulse has an amplitude corresponding to a power level of −41 dBm0. This is 7 dB above the system noise in the return channel for a 1000-nautical-mile (1852-kilometer) system so that individual repeater noise can be identified on such a system.

With the addition of a supervisory tone at a level of −15 dBm0, a returned pulse with amplitude corresponding to a power level of −21 dBm0 is achieved. This level gives a 26 dB margin against the returned noise from the supervisory system and enables loop gain measurements to be made to each repeater.

The pulse width used enables repeaters to be separated on a time basis and is sufficiently narrow to cater for the reduction in repeater spacing due to the inclusion of submersible equalisers in the system.

The supervisory modulator gives satisfactory conversion loss figures for carrier-level variation of ± 8 dB from nominal. This ensures that any normal variations in the carrier level (due to system misalignment, temperature swing or cable repair) will not affect the supervisory measurements.

6. System Planning

6.1 *Thermal Noise Considerations*

With a repeater gain of 43 dB at 4772 kHz, a 1000-nautical-mile (1852-kilometer) system using 0.99-inch BPO Mk. II cable with a submersible equaliser for each block of 12 repeaters will require 133 repeaters.

Allowing 2 dB for intermodulation noise and for variations in cable attenuation due to shallow-water temperature variations, the minimum repeater output levels required to achieve a weighted noise of 1 picowatt/kilometre on a 1000-nautical-mile (1852-kilometer) system can be established. These levels, and their derivation, are shown in Table 1.

6.2 *Overload Considerations*

The system load is 1280 channels of 3 kHz each with a long-term mean level of −10 dBm0. This gives a mean load of 21.1 dBm0 with a peak power level of 34.1 dBm0 [3]. With the application of linear pre-emphasis having a 16 dB range from the bottom to the top traffic channels, all channels are not at the same level and the system peak overload needs only to be greater than 29.6 dBm0 since the pre-emphasis gives a 4.5 dB advantage over flat levels [4].

Taking the repeater r. m. s. overload figure as 23 dBm (see Figure 9) i. e. 26 dBm peak, then the maximum repeater output levels with a pre-emphasis of 16 dB can be established. These levels are shown in Table 1.

6.3 *Repeater Levels and System Noise*

Repeater output levels have been set as shown in the final column of Table 1. This gives a margin against overload necessary to accommodate changes in system levels due to misalignment caused by equalisation errors and cable attenuation changes due to temperature variations. There is also a margin against a system noise of 1 picowatt/kilometer per channel. Detailed calculations of the intermodulation contribution to the system noise show that it is small enough to ensure that the system noise requirement is met.

Table 1 Minimum, Maximum, and Proposed Repeater Output Levels

Frequency kHz	Repeater Output Noise (See Figure 9) dBm per 3,1 kHz	Minimum Output Levels for Repeater Thermal Noise of −78,5 dBm0p in 3 kHz Channel dBr	Minimum Output Levels with a 2 dB Allowance for Intermodulation and Misalignment dBr	Maximum Output Levels dBr	Proposed Output Levels dBr
300	−110	−34	−32	−19,6	−26,0
500	−109,6	−33,6	−31,6	−17,0	−23,4
700	−108,9	−32,9	−30,9	−15,0	−21,4
1000	−107,4	−31,4	−29,4	−12,9	−19,3
1500	−104,6	−28,6	−26,6	−10,8	−17,2
2000	−102,0	−26,6	−24,6	−9,0	−15,4
2500	−99,7	−23,7	−21,7	−7,9	−14,3
3000	−96,6	−20,6	−18,6	−6,6	−13,0
3500	−95,1	−19,1	−17,1	−5,6	−12,0
4000	−92,9	−16,9	−14,9	−4,8	−11,2
4500	−90,6	−14,6	−12,6	−4,2	−10,6
4800	−89,3	−13,3	−11,3	−3,6	−10

7. Conclusions

A 5 MHz repeater has been developed which meets the requirements for the UK — Portugal project.

The performance of the repeater is such that system lengths in excess of 1000 nautical miles (1852 kilometres), which applies to the UK — Portugal project, can be achieved. In practice, the maximum system length will be governed by the voltage rating of the high-voltage capacitors used in the power-separating filters of the repeaters. With the present capacitor rating of 6.25 kilovolts and taking into account only the voltage drop in the cable and the repeaters, the maximum length for a system using BPO 0.99 inch Mk. II cable and double-end power feeding would be 3500 nautical miles (6500 kilometer).

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[2] British Patent Specification Number 1,021,418: "Improvements in or Relating to Carrier Current Communication Systems Incorporating Repeaters".

[3] H. Williams: "Overall Survey of Transmission Performance Planning", Proceedings of the Institute of Electrical Engineers, vol. III, number 4, pages 727—743, April 1964.

[4] H. L. Bakker: "The Output Power of Line Amplifiers in Carrier Telephone Systems Employing Pre-emphasis", Philips Telecommunication Review, Vol. 26, N° 1, July 1965.

J. F. Tilly was born in England in 1930. He was educated at St. Catharine's College, Cambridge, and graduated in 1953 with a BA degree in mathematics.

In 1953 he joined the transmission division of Standard Telephones and Cables at North Woolwich. He became a member of the design group of the Submerged Repeater Systems Division in 1963.

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

(Comparative Results using SFERT, NOSFER and OREM-A)

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Definitions

SFERT is the abbreviation for *Système Fondamental Européen de Référence pour la Transmission Téléphonique.* This was the master reference system for subjective ratings until 1962.

NOSFER is the abbreviation for *Nouveau Système Fondamental pour la Détermination des Équivalents de Référence,* and replaces SFERT as subjective master.

OBDM is the abbreviation of *Objectiv Bezugsdaempfung-Messplatz,* an objective reference equivalent equipment.

OREM is the abbreviation for *Objective Reference Equivalent Measurement,* based on OBDM and calibrated to have the same nominal sensitivity as SFERT; used for objective ratings.

SETED is *Système Étalon de Travail Électro-Dynamique.*

1. Introduction

The loudness rating of a telephone connection between two subscribers is a measure of the overall loss from speaker to listener, and there are several rating systems in use based on different definitions of speaker-to-listener loss.

The systems compared herein are those subjective methods based on the reference-equivalent method specified by the CCITT (International Telegraph and Telephone Consultative Committee) [1] and those objective methods, such as OBDM and OREM-A, intended to simulate the reference-equivalent method. It should be noted that other systems using different reference datum or other methods exist but are not included in this comparison.

Ratings from both subjective and objective systems based on the CCITT reference-equivalent concept should give closely similar results. It is a primary objective of this article to explain some large differences that have been reported.

By international agreement*, telephone subscribers' sets are rated by a loudness comparison method carried out by the laboratory of the CCITT in Geneva. The system to be tested is compared with a standard reference system, NOSFER, is defined in the CCITT Red Book [1]. This system replaced the original master reference system, SFERT, in 1962 when new components for the latter became impossible to obtain.

The loudness ratings obtained subjectively in comparison to NOSFER are called reference equivalents. Ratings are, by convention, positive when quieter than NOSFER, and negative when louder. Transmitting Reference Equivalents are only determined when the speaking distance from the microphone is defined by the "Volume" modal gauge. (ref. CCITT Red Book, Vol. V, p. 149).

The subject of loudness rating for noises in general is also being studied by the International Organisation for Standardization (ISO) and the International Electrotechnical Commission (IEC) [2, 3] and the state of knowledge on this subject is sufficiently advanced to enable loudness ratings of a transmission chain to be measured by objective and subjective methods and also to be calculated with close agreement among all three methods, within ± 2 dB, for signals such as speech.

In seeking answers to the problem stated below, it has therefore been assumed from the start that objective and subjective rating methods should agree within 2 dB, and any differences greater than this should be explicable by simple reasons, such as incorrect gain in some amplification link or incorrect calibration. The method of calculating loudness described in reference [2] has been of great use in identifying possible sources of difference, in particular, the effects on loudness rating of bandwidth restriction, the use of male or female speakers and change in listening level.

2. Statement of the Problem

The subjective rating, reference equivalents (RE), determined by the CCITT Laboratory in Geneva is, by international agreement, the only legal rating but objective rating machines are being used in increasing numbers.

For those administrations who are prepared to use these machines simply as a stable means of comparison with their acceptance standards, and who are often only concerned with one type of handset, their performance is adequate, since it provides a quick measure of relative efficiency. However, there is a general confusion among manufacturers and telephone network planning groups, who have to deal with handsets of many different shapes and sizes, that a machine, which is called an objective reference equivalent measuring set, should give results between 4 and 8 dB different from the reference equivalent supplied by the CCITT Laboratory.

The magnitude of this difference is shown in Figures 1a and 1b, where OREM-A and SETED (NOSFER) results are compared, using results obtained in this laboratory. It is seen that for transmitting RE there is a displacement of 7-dB average, with a spread of 6 dB. Even if a correction of 7 dB were recommended the remaining spread of 6 dB would be quite unsatisfactory for this type of measurement, and a correction cannot be applied with confidence if the underlying reasons and limitations are not

* The expression "international agreement" in the present context is limited to those recommendations contained in documents and publications of the CCITT.

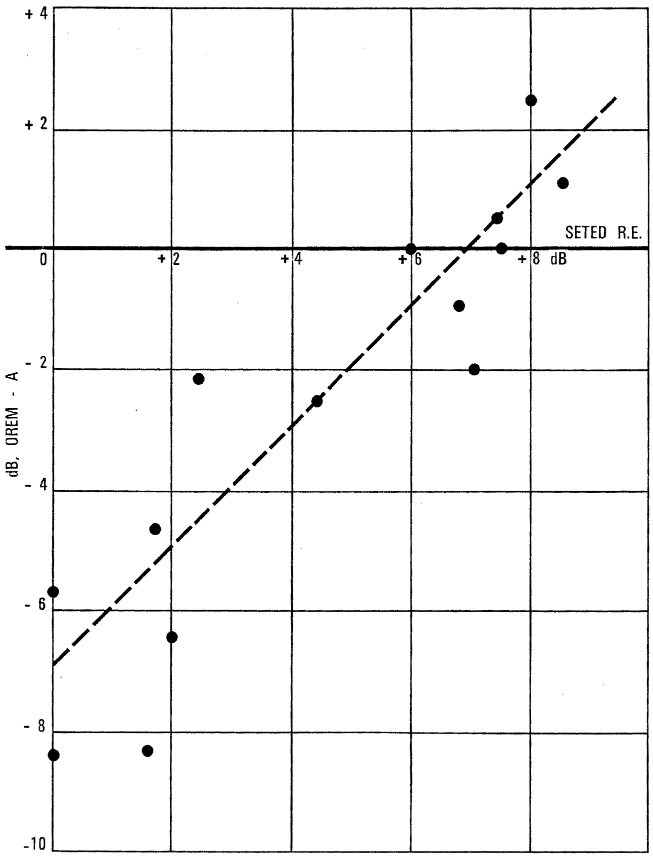
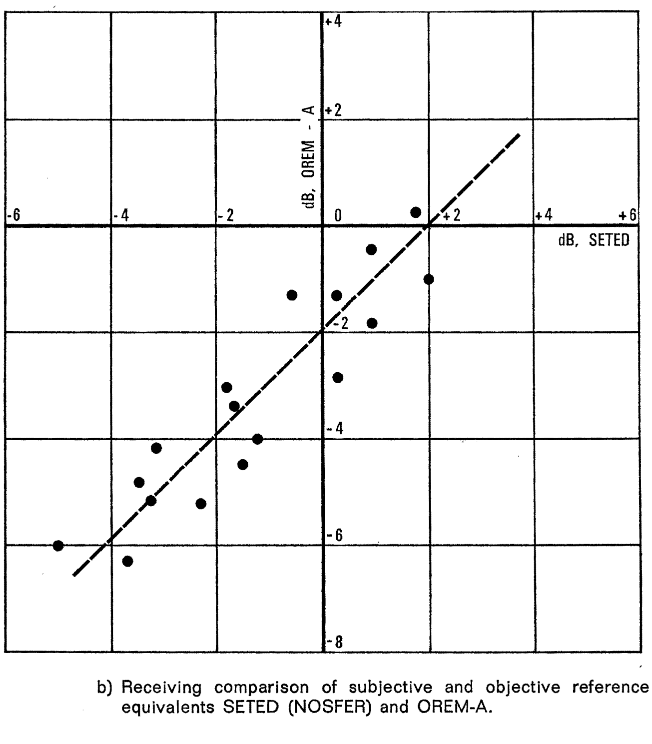


Figure 1 - a) Transmitting comparison of subjective and objective reference equivalents SETED (NOSFER) and OREM-A.



b) Receiving comparison of subjective and objective reference equivalents SETED (NOSFER) and OREM-A.

known. Similar differences are found between OBDM in the CCITT Laboratory, and NOSFER [10].

Agreement for receiving reference equivalent is much better, but even here there is a distinct average difference of 2 dB.

This question has now been studied at Standard Telecommunication Laboratories over a period of 18 months, and a logical set of correlating factors is outlined below. Since a subjective test team using a SETED reference system calibrated against NOSFER, and an OREM equipment are situated alongside each other, almost simultaneous measurements have been made on a large number of telephone sets of many different types.

The SETED system has been described in the CCITT Red Book, Vol. V [4] and is a reference system for subjective comparison, similar to SFERT in that it uses a close-speaking microphone.

The Bruël and Kjaer type 3350 system, Electroacoustic Transmission Measuring System, is described in a CCITT document [5] and is a modern version of the OBDM which is an objective rating system based on the work of K. Braun [6], to whose original articles the reader is referred for a description of the basic principles. It is sufficient to note here that the B & K system uses the internationally agreed relationship between loudness and sound pressure, and the sound power spectrum generated by the artificial mouth is similar to that of average speech. The loudness indicated should therefore be linearly related to a subjective loudness rating for one specified listening level.

The B & K system will be referred to below as OREM-A, which is specifically the B & K 3350 system using a 6-cubic-centimetre artificial ear (NBS 9 A) and the B & K artificial mouth type 4216.

The SFERT system (in Figure 2a) has a wide frequency band and unity air-to-air gain, when the receiver is coupled

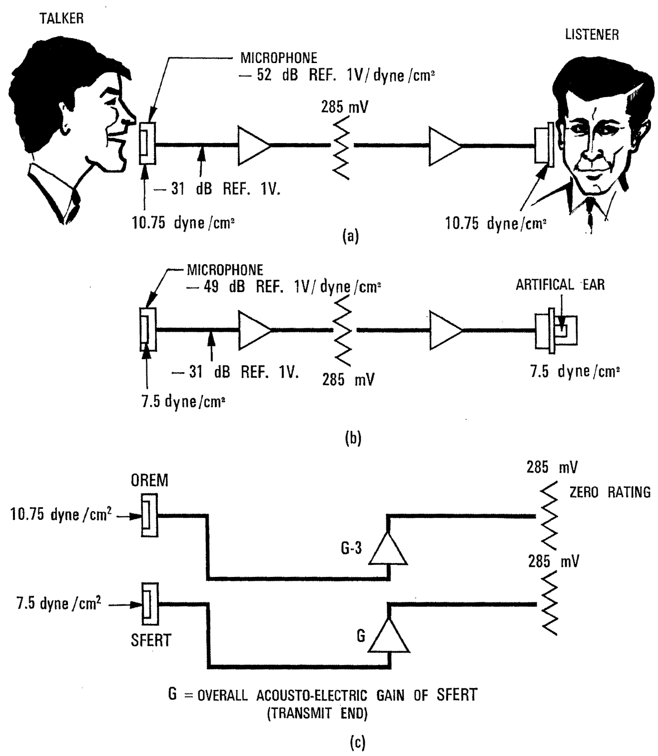


Figure 2 - a) SFERT - Thermophone calibration.
b) SFERT - Reciprocity calibration.
c) OREM and SFERT (Transmit ends): Reciprocity calibration.

to a human ear*. The conversion efficiency of 10.75 dynes/cm^2 giving 285 mV at the termination of the send end corresponds to the SFERT sensitivity given in the CCIF Green Book, Vol. IV, of −31.6 dB referred to 1 volt per dyne per centimetre squared.

The OREM-A equipment has nominally been given the identical sensitivity of SFERT, in that a sound pressure level of 10.75 dynes/cm^2 on the diaphragm of the input microphone produces 285 mV at the termination of the send-end, and the meter is adjusted to read zero for this voltage.

However, it was stated in CCITT Technical Report RT 294 that the sensitivity of the microphone used in SFERT was calibrated by the thermophone method, and when calibrated by other methods (for example, reciprocity now in common use) the sensitivity is 3 dB higher, that is, −52 dB ref 1 V/dyne/cm^2 for thermophone calibration and −49 dB ref 1 V/dyne/cm^2 for reciprocity calibration. This has caused some confusion in understanding how the OREM equipment using reciprocity calibrations, can have the same sensitivity as the original SFERT which used thermophone calibrations. But in a recent CCITT document (ref. [5], p. 3., footnote) is is stated that the zero reading on the OREM meter is 3 dB higher than that of SFERT.

To avoid further confusion, it may be useful to show diagrammatically how this has happened. In the original SFERT reference chain an average talking level was found to give 301 mV at the termination of the "send" section. This voltage has been rounded off to 285 mV to correspond to 1 neper below 0.775 V, (or 1 mW in 600 ohms), and sound pressure levels have been reduced in the same ratio to leave electro-acoustic sensitivity unchanged. To produce this 285 mV, a sound pressure at the SFERT microphone diaphragm was calibrated as being 10.75 dynes/cm^2, using the thermophone method of calibration and a microphone sensitivity of −52 dB ref 1 V/dyne/cm^2. When the same microphone was calibrated by reciprocity (now accepted as a more accurate method), it was found that the sensitivity was −49 dB ref 1 V/dyne/cm^2, and the talking pressure was then 3 dB low at 7.5 dynes/cm^2 (= 10.75 dynes/cm^2 −3 dB), (see Figure 2a and 2b). Thus, if the objective replica is set up using a 10.75 dyne/cm^2 sound pressure (determined by reciprocity calibration) the gain necessary to produce 285 mV will have to be 3 dB lower than the gain of SFERT. (Figure 2c).

If a separate transmission link with the same (wide-band) overall acousto-electric gain, *G*, (as in SFERT of Figure 2) were compared, at a mid-band frequency (500 Hz), to SFERT and OREM, it would be given an equal (or zero) rating in comparison to SFERT, but would be rated 3 dB louder than OREM zero.

3. Bandwidth Limitation

The objective replica of SFERT does, however, introduce a basic operational difference. Instead of covering the SFERT bandwidth of 100 Hz to 8000 Hz it uses a frequency sweep restricted to 200 Hz to 4000 Hz.

If a subset is constructed to have a send-end gain *G*, the same as SFERT in Figure 2c, but includes a band-pass filter cutting sharply at 200 Hz and 4000 Hz it will, when subjectively compared to the wide-band SFERT, be rated as transmitting less speech energy than SFERT and be estimated as being quieter by 3 to 4 dB (see Figure 3a). The reduction of loudness due to limiting a wide-band speech signal by a band-pass filter of width 200 Hz to 4000 Hz can be calculated by the method of reference [2] to be 3 dB. The CCITT Laboratory have also done some subjective assessments of band-limiting effects and have given a loudness reduction of 4 dB for this type of band-pass filter [7].

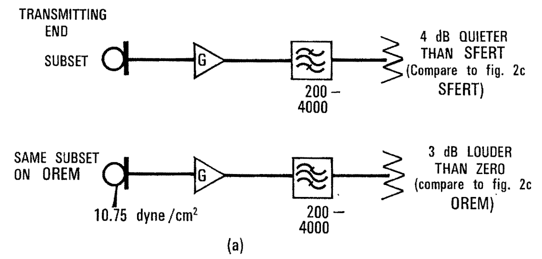


Figure 3 - a) Subset with gain "G" and band-pass filter.

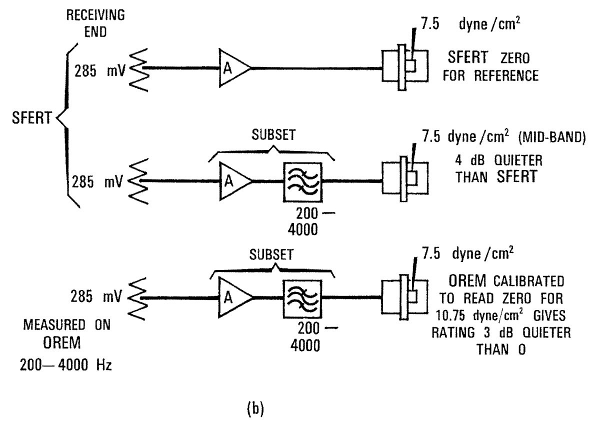


Figure 3 - b) Subset with gain "A" and band-pass filter.

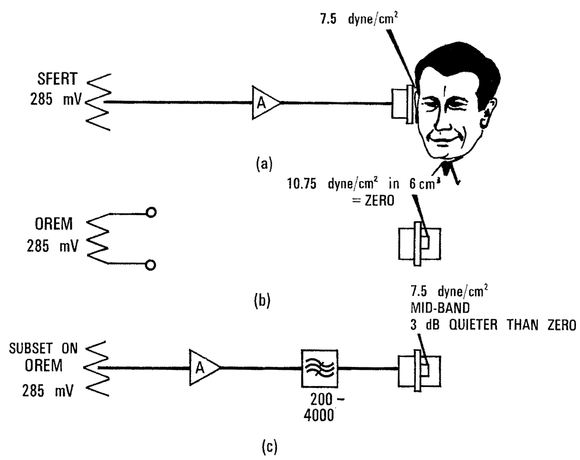


Figure 4 - a) SFERT - Receive end.
b) OREM-A - Receive end.
c) OREM-A - Receive end with subset.

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* **Note** — Overall gain of SFERT is given as −7.3 dB in CCIF Green Book, vol. IV, when using an ear volume of 29.8 cm^3. According to DIN E 44011 the SFERT receiver on a real ear encloses a volume of 13 cm^3. This gives a pressure increase of 29.8/13 or 7.2 dB, making overall gain 0 dB.

When measured on the OREM equipment, which only sweeps from 200 Hz to 4000 Hz, the presence of the band-pass filter will not affect the power integration and the mid-band gain G will alone determine the meter reading. Since gain G is 3 dB higher than OREM gain (G-3 in Figure 2c) the subset will be given a rating 3 dB higher than OREM zero. This set will then be given a Reference Equivalent of $+4$ dB by the SFERT comparison and -3 dB on the OREM equipment, (Fig. 3a and 3b).

This equals the 7-dB difference between subjective and objective ratings, given above as the average.

The receive-end difference can be treated in the same way. In Figures 4a, b, and c are shown respectively the SFERT receive-end, the OREM circuit arrangement for receive-end measurement, and an ideal subset with receive-end electro-acoustic efficiency the same as SFERT, with mid-band gain A but band-limited at 200 Hz and 4000 Hz.

The subset on OREM will produce 7.5 dynes/cm^2 in the 6-cm^3 artificial ear, which compared to the OREM "zero" of 10.75 dynes/cm^2 will register as 3 dB quieter than zero. But listening in comparison to SFERT, the human ear will appreciate the loss in sound energy cut off by the band-pass filter, and will rate the set as 4 dB quieter than SFERT, [7]. Thus the OREM rating will be about 1 dB louder than the SFERT rating, which is very close to the average difference given above in Figure 1b.

The use of a band-pass filter to simulate an ideal subset is permissible as an illustration of the great majority of subsets, which cut sharply at about 3500 Hz, and for practical reasons are given a sharply falling response curve below 300 Hz. The above argument applies to any subset with a narrower pass band than 200 to 4000 Hz.

Thus the basic corrections are established:

— send-end: add $+7$ dB to OREM-A readings
— reveice-end: add $+1$ dB to OREM-A readings

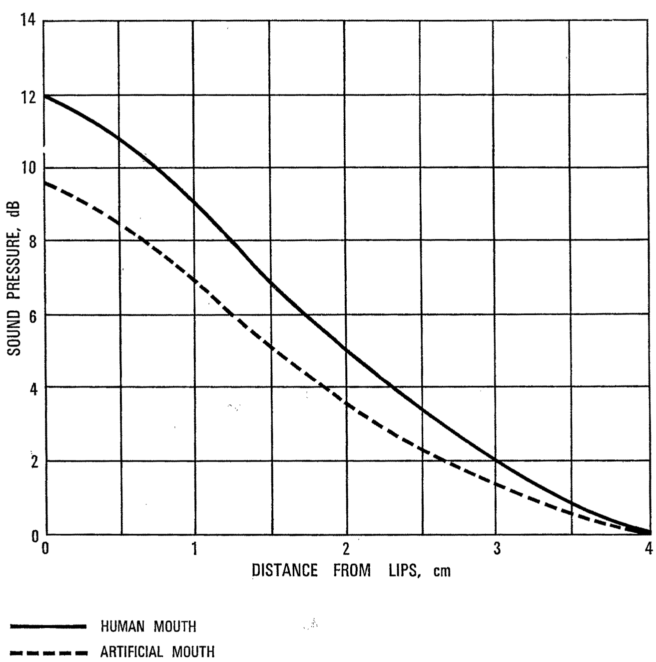

Figure 5 - Sound pressure at mid-band frequency on axis of mouth for B & K 4216 artificial mouth and human mouth. Relative to pressure at 4 cm from human lips.

4. A Correction for Short Hand-sets

The OREM equipment is calibrated to give the specified sound level on the diaphragm of a microphone at 4.35 cm from the lip position.

The above corrections apply for handsets which locate their microphones at this distance, or greater, from the lip gauge.

But the gradient of sound pressure decay, as the distance from the lips is increased from zero, is not the same for the B & K type 4216 artificial mouth and the human mouth. This is illustrated in Figure 5, where the curves for human and artificial mouths diverge from equality at 4 cm to a separation of over 2 dB at 1 cm and less. These curves are based on information given by H. S. Leman [8] and by Bruël and Kjaer [9].

The recommended modal gauge for volume measurement of telephone microphones places the face of mouthpieces of some modern handsets at less than 1 cm from the lips (and in some cases, inside the lips). For example, the measured and estimated correction for this deviation is about 2.5 dB for both the BPO (British Post Office) type 700 set and the WE (Western Electric) type 500 set, both using the volume gauge spacing as recommended for reference equivalent. It is seen from Figure 5 that the pressure with the artificial mouth may be up to 2.5 dB lower than for the human mouth and corrections can be read off the diagram and applied as additions to the basic corrections given above. For, say, a 1-cm spacing, the OREM reading should be made louder by 2 dB, that

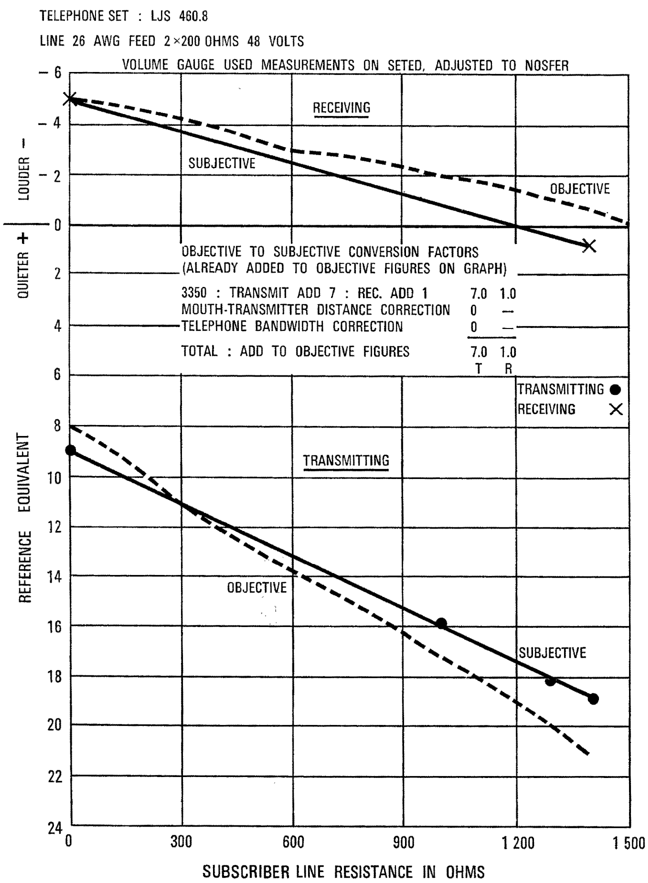

Figure 6 - Corrected objective/subjective reference equivalent comparison sheet.

is, an additional factor of −2 dB is added to the reading of the OREM meter.

5. Practical Example

The above are the major corrections which have been applied to the results of many types of subset, and for a large percentage of sets the gap between subjective and objective ratings has been narrowed to 2 dB or less.

One example of corrected OREM-A ratings and subjective ratings is shown in Figure 6, and it is immediately obvious that the basic corrections will need some minor factors to be taken into consideration. For instance, the effect of line length introduces a small difference between subjective and objective loudness integration.

6. Sidetone

The measurement of sidetone is well known to be subject to wider variations than either send or receive Reference Equivalent, but even for this rating and average correction can be deduced from existing information.

The thermophone-reciprocity calibration difference does not apply, since sidetone is an air-to-air measurement. But the band limitation effect of 4 dB is still relevant and an additional factor due to higher listening level in subjective assessment of sidetone introduces a correction of between 2 and 3 dB, making a total basic correction of about +6.5 dB to be added to OREM-A readings. This subject is still being studied.

7. Conclusions

It has become evident that objective loudness ratings of telephone sets can be in good agreement with subjective ratings if the modern theories of loudness integration are complied with. The Objective Reference Machine described in reference [5] contains most of the essential elements for indicating the loudness performance of telephone sets, and its objective ratings would show better agreement with subjective Reference Equivalents if the following corrections are applied.

— Transmitting rating:
— Receiving rating:
— Sidetone rating:

Handset length, add between 0 and −2.5 dB to OREM-A reading as spacing between center of microphone face and OREM lip gauge ranges between 4 cm and 1 cm respectively.

References

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[2] ISO Recommendation R 532. Method for calculating loudness levels, 1966.
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[4] CCITT Red Book, Vol. V, pp. 58—62.
[5] CCITT Com. XII 1964/68, No. 30.
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[9] B & K Artificial Mouth, Type 4216 (Handbook).
[10] CCITT Com. XII, 1964/68, No. 81.

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SELECTRONIC Stored-Program Supervisory System 702

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1. Introduction

Remote control and data gathering systems are used in many industries. The electrical industry uses them to monitor and control the generation and distribution of electricity. The oil, gas and water industries use them to monitor and control flow through pipe lines.

In all these cases the general requirement is very similar. There is one control or master station and a number of remote stations or outstations. The number of outstations varies from one to several hundred.

The outstations are from a few miles to several hundred from the master station. The communication between an outstation and the master station may be with radio links, microwave links, or by private or post office voice-frequency lines. The interconnection may be a separate connection from each outstation to the master station: this is called a radial system. The interconnection may be a single connection to the first outstation with subsequent outstations connected in series: this is called an omnibus system. Some systems are a hybrid of radial and omnibus techniques (Figure 1 shows a radial interconnection system). The SELECTRONIC System 702* is so flexible that it can meet all these requirements.

The type of data collected by an outstation in the 702 system consists of

(A) Readings from transducers, e. g. temperature from thermocouples, output from current transformers, flow from impulse meters. The number of transducer readings generally varies between 4 and 60 at each outstation.

(B) Alarm indications from contacts, e. g. an alarm contact closes when a current or temperature exceeds a preset limit. The number of alarms generally varies between 10 and 100 at each outstation.

(C) Single- or double-point indications from contacts, e. g. two contacts indicate the position for a circuit breaker or valve. The number of indications generally varies between 10 and 50 at each outstation.

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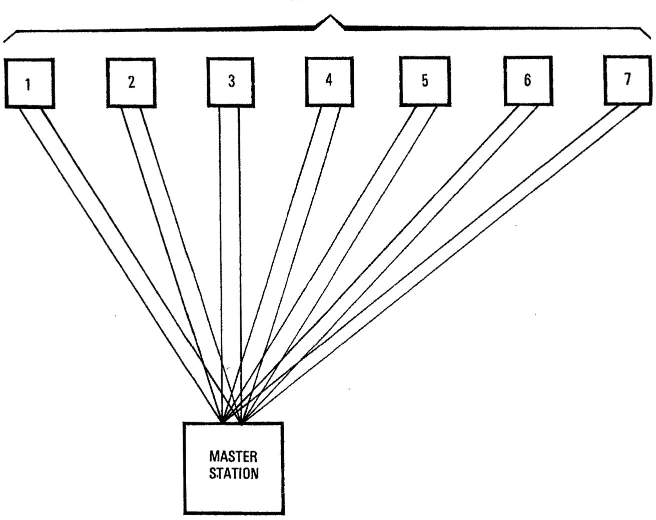

Figure 1 - radial system.

The following types of control or command instructions are sent by the master station to the outstations.

(A) A two-way control, which may be used to open or close a circuit breaker or valve. The number of two-way controls generally varies between 4 and 60 at one outstation.

(B) A decimal number of 1, 2, or 3 digits, which may be used to select a transformer tap position or the speed of a motor. These are called numerical instructions. The number of numerical instructions generally varies between 1 and 10 at each outstation.

The data gathered by the master station may be displayed to the operator in several forms. The alarms and indications are displayed with filament lamps. The lamps generally flash at 2 Hz when the item changes. The operator has "accept" switches associated with alarms or indications, which he presses to acknowledge a change. The flash conditions are removed when the accept key is pressed.

The lamps may be mounted on one large diagram that shows the geographic layout of the complete electrical network or pipeline. The lamps show the position of each valve, circuit breaker, alarm, etc. This type of diagram has several thousand lamps for a large system. If the outstations are similar a common diagram is often used. The common diagram shows the data for one outstation. The outstation is selected with switches by the operator. There is a single lamp per outstation that indicates any alarm or indication change at the outstation. The common diagram has several hundred lamps.

The transducer readings are displayed on pointer instruments or digital indicators. Filament-lamp digital indicators are used when the highest accuracy is required and because of their superior all-round visibility. The transducer readings may be multiplied by a number at the master station so as to be converted into the correct units. This is called "scaling", and the number is called the scale factor. The number of indicators is reduced by using a common diagram. The operator selects the reading with switches.

A paper record of data is frequently required and two printers are then usually provided. The printers have alpha-numerical characters, including the decimal point. There is complete flexibility of format, and red or black printing. This flexibility is achieved with stored-program techniques.

The first printer provides a printed record of transducer readings. These may be printed at preset time intervals or on request by the operator. The second printer provides a printed record of alarms, indications, or controls. This is called the "operational" or "event" logger. When an alarm or indication changes, the state of all the alarms and indications for the outstation is printed. The item that has changed is printed in red. When a control is operated the control is recorded by printing in red.

A control is selected by switches at the master station. These are mounted on the diagram or operator's console. The control is selected in two stages. The first stage selects the outstation, the number of the control, and open or close. The second stage, which is called "execute", initiates the control. This two-stage selection is provided for increased reliability.

The common diagram uses one set of control switches, which is shared between outstations by means of the outstation select switch.

Numerical instructions have a similar two stage selection.

2. Cyclic Scanning and Word Format

The most flexible and economic scanning technique for this type of system is "cyclic scanning", as used in the SELECTRONIC system 702. In a cyclic scanning system the master station sends an instruction requesting data or a control to be performed. The instruction is received by all outstations, but only the outstation that recognizes its address sends data to the master station or performs a control. The system, entirely under the control of the master station, is "half-duplex".

The transmission word from the master station consists of 19 bits made up of one start bit, 5 bits for the outstation address, 5 bits for the unit address, 4 bits for the function, and 4 bits for the parity.

The start bit is required for word synchronizing. It triggers the outstation time base to strobe the incoming word.

Outstation address 0 is not used, and the system may comprises up to 31 outstations since the code is binary. The unit address specifies the particular controls or group of data within the outstation in binary code. There may be up to 32 controls or groups of data at one outstation.

One bit of the unit address may be transferred to the outstation address bits as an option. In this case the number of unit addresses is reduced to 16 and the number of outstation addresses is increased to 62.

Similarly, an outstation address bit may be transferred to the unit address bits. The number of unit addresses is then increased to 64 and the number of outstations is reduced to 15. In this way, there are in effect 3 outstation sizes and the master station can address a system that includes a mixture of the 3 types.

The 4 bits for the function specify the type of data, controls, or numerical instructions, and the 4 parity bits are for avoiding errors in transmission.

Table 1 shows an instruction word from the master station requesting meter reading 8 from outstation 21.

The word length for data from the outstation is also 19 bits. This consists of a start bit, 14 bits for data, and 4 parity bits. Transducer readings are converted to binary-coded decimal (BCD) notation at the outstation. One data word from an outstation can therefore contain 14 alarms, or 7 double-point indications, or 3 digits with sign in BCD for a transducer reading.

These are shown in Table 1.

A 6-bit interword period is provided to allow switching time at the master station or the outstation. Assuming that the system uses voice-frequency lines, there is a delay through the send voice-frequency modulators and filters and the receive voice-frequency demodulators and filters. (These are called send and receive modems.) In addition to this, there is the line delay, and therefore the total time for sending an instruction from the master station to the outstation and for the outstation to send data to the master station is:

19 send bits from master station

+ 6 interword bits

+ send modem delay at master station

Table 1

INSTRUCTION WORD FROM MASTER STATION

1 BIT START	5 BITS OUTSTATION ADDRESS	5 BITS QUANTUM ADDRESS	4 BITS FUNCTION	4 BITS PARITY
1	OUTSTATION 21 1 0 1 0 1	METER READING 2 0 1 0 0 0	METER 0 0 0 0	0 0 0 0

DATA WORD FROM OUTSTATION

1 BIT START	14 PERSISTANT ALARMS	4 BITS PARITY

1 BIT START	14 FLEETING ALARMS	4 BITS PARITY

1 BIT START	7 DOUBLE-POINT INDICATIONS	4 BITS PARITY

1 BIT START	DIGIT 1 B.C.D.	DIGIT 2 B.C.D.	DIGIT 3 B.C.D.	SIGN BIT		4 BITS PARITY
1	9 1 0 0 1	2 0 1 0 0	7 1 1 1 0	-VE 1	0	1 0 0 0

+ line delay
+ receive modem delay at outstation
+ 19 send bits from outstation
+ 6 interword bits
+ send modem delay at outstation
+ line delay
+ receive modem delay at master station
= 50 bits $+ 2 \times$ line delay $+ 4 \times$ modem delay.

Assuming a transmission speed of 600 bauds, a line length of approximately 70 miles, and a modem delay of 2 ms this gives a total of

$$= 83.7 + 10 + 8 \text{ ms} = 101.7 \text{ ms}.$$

In a large system, a 1000 such instructions may be required to scan the whole system. If all the instructions are in sequence the maximum time for detecting an item that has changed, assuming there are no other changes or parity, is 101.8 s. This may be too long for alarms and certain indications. The 702 system therefore has two facilities to overcome this problem.

The first facility gives complete flexibility in the sequence of instructions from the master station. Also, the master station can jump to another sequence by a manual interruption, or automatically when a particular alarm or indication condition occurs. This is achieved with the stored-program techniques. With this facility, events that have to be detected very quickly are scanned at a much higher frequency than the less important items.

In the example given, 100 instructions may be very important. Assume these are interlaced with other groups of 100 instructions and there is only one change and no parity error.

The maximum access time for the 100 important instructions is 20.34 s. The maximum access time for the other 900 instructions is 183.16 s.

Hence this facility enables the access time of the important items to be reduced at the expense of the less important items. The example shown is a simple one with two levels of priority; in practice, several levels of priority with time interruptions may be required. The flexibility of the 702 system permits this. Another facility uses an outstation with an additional capability. This outstation has one quantum that indicates if any alarm or indication has changed since the last interrogation from the master station. The master station sends one instruction to each outstation in turn requesting this quantum. If the master station detects a change in this quantum, it jumps to a sequence of instructions that scans all the alarms and indications of this outstation.

In the example given, assuming 20 outstations and 5 quanta of alarms and indications at each outstation, the maximum access time for a single alarm or indication change is

$$(41 \times 101.8 + 11 \times 101.8) \text{ ms} \simeq 5.29 \text{ s}.$$

This also assumes that the scan sequence is 20 instructions to detect a change followed by 20 instructions of the 900 less-important items followed by the 20 instructions to detect a change again, followed by the next group of the 20 instructions of the 900 less-important items. This sequence is carried out until all the 900 items are scanned, and then starts again.

3. Error Detection in Transmission

The data and the instructions for the data are protected against noise in the transmission links in two ways.

The first way uses 4 redundant bits in every transmission word; these are called the parity bits.

The 14 information bits in the word are arranged in two groups of 3 bits and two groups of 4 bits, a parity bit being allocated to each group. The parity bit is a "one" if the information bits in its group contain an odd number of ones. The overall parity per group is thus made even. The 4-bit parity is generated by the send station and is regenerated from the received information at the outstation. If the received and regenerated parity patterns are different, an error has occurred, and the message is rejected. Some noise patterns can alter the message and still give correct parity. The parity protection described above gives a statistical improvement of detecting errors of 10^3 with the type of noise expected in British Post Office lines. The parity protection by itself is thus not adequate for noisy transmission conditions, and in addition to the parity protection, the 702 system uses retransmission if data have changed.

All the data from the outstations are stored at the master station. Each time data are sent from the outstation, they are compared with the data stored at the master station. If they are the same, the master station jumps to the next instruction. If they are different, the changed data from the outstation are held in a separate temporary store and the main data store is unchanged. The master station then repeats the instruction. On the second interrogation the master station compares the repeated data from the outstation with those in the temporary store from the first interrogation. If they are same, the data are changed in the main data store of the master station. This means that an error not detected by the 4-bit parity has to be repeated because of the data comparison. If the noise distorts the word so that it is the same on two interrogations in succession, it will produce an undetected error. The probability of this occurring is extremely small. This gives a further reduction of the undetected error rate by a factor of 10^{-10} on the type of noise expected in British Post Office lines.

The transmission security for control and numerical instructions is increased by two-stage selection at the outstations. The master station sends the instruction for a control or numerical instruction to the outstations, the selected outstation does a first-stage selection and sends the complete instruction back to the master station. The master station confirms the instruction. If it is correct, the master station sends an execute instruction and the outstation does the second-stage selection which initiates the control or numerical instructions. If it is not correct, the master station repeats the first-stage selection.

There is a delay circuit at the master station that is triggered each time an instruction is sent to an outstation. This delay is one-and-a-half the anticipated time for an answer from the outstation. If this delay expires without a response from the outstation, the master station jumps to the next instruction.

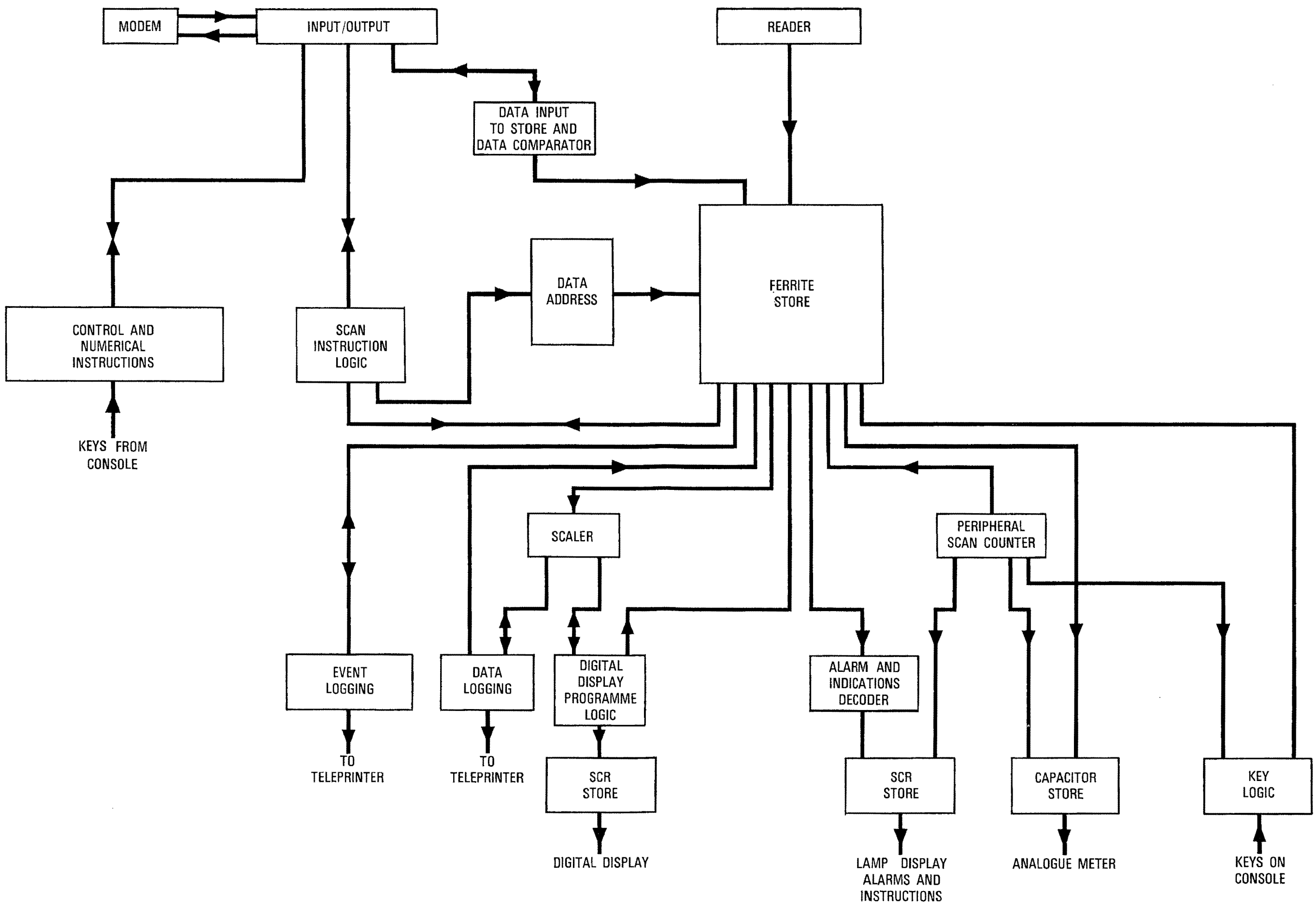

Figure 2 - 702 master station.

4. Master Station

Figure 2 shows a block diagram of the master station.

The data to or from the line are via the modem. The modem frequency modulates the digital data so that the latter can be transmitted over the communication link. It also converts the frequency-modulated data from an outstation to digital data, which feed into the 702 master station.

The input/output block contains a 14-bit register that transmits the instructions serially to the outstations and also receives the data from the outstations. This logic contains the pulse generator that strobes the data from an outstation and defines the bit time for transmission to an outstation. It also contains the logic that generates and checks the 4-bit parity.

The scan instructions, which are stored in the ferrite store, are used by the "scan instruction logic" to define the sequence of instruction words sent to the outstations requesting data.

There are six different types of instructions.

These include count and jump instructions, which ensure that the minimum number of instruction words need be stored. The stored instructions achieve complete flexibility for the sequence of scanning outstations.

A manual interrupt facility enables the system to change to another scanning programme from a clock, operator keys, or alarm conditions.

The data input to store and data comparator block codes the data to be written in the ferrite store. It also compares data received from an outstation with the data in the ferrite store, and determines whether a retransmission is required.

The control and numerical instruction logic converts the control or numerical key contacts into the instructions to be sent to the outstation. The logic is designed to ensure that a single hardware failure does not cause a false control. The master station changes to a "flip-back cycle" when the execute instruction is confirmed. The flip-back cycle consists of one quantum of meter readings, one quantum of persistent alarms, and one quantum of indications. These quanta are associated with the device that the control changes and that the "operator" sees on the diagram when the device has changed.

The scanning, logging, and digital display instructions are stored in the ferrite store. These are written on paper-tape and read into the ferrite store by means of a paper-tape reader.

The reader block organizes the data read from the paper tape into 14 bits, which are written into the ferrite store. This applies to all the instructions required for scanning, logging, and digital display into the ferrite store.

The peripheral scan counter (PSC) runs continuously. This is used for addressing the ferrite store, the silicon controlled rectifier (SCR) store, and the capacitor stores.

The data stored in the ferrite store for alarms and indications are read in sequence, and by means of the PSC each word is decoded. The decoder specifies the condition of the lamps. The lamps are driven by SCR's. The SCR's are arranged in rows of 28 SCR's and each row is selected by the PSC and therefore the condition of the SCR's is continuously updated from the ferrite store.

The digital-display-program logic reads from the store the transducer readings that are required for the digital display, and specifies the address of the scaling factor that is in the store for each reading. The readings from the store or the scaler are in BCD and are converted to decimal to drive the SCR store, which in turn drives the lamps of the digital indicators.

The scaler multiplies a 2-digit "scaling factor" by a 3-digit transducer reading to provide the correct unit. The scaler is time-shared between the digital display and the data logging.

The data logging prints out selected transducer readings on a selected format. The selection of readings and format is stored in the ferrite store, and the 11 types of instructions available provide a completely flexible alpha-numeric print out.

The event logger prints out the alarms, indications, or controls for an outstation when a change is detected in the outstation. The instructions for the format are stored in the ferrite store.

The key logic examines the keys associated with alarms or indications on the diagram and modifies the data in the store if a key is operated.

The capacitor store stores the analog transducer readings. This is continually updated from the ferrite store, and the BCD is converted to analog values with a digital-to-analog converter (DAC). This technique achieves a time-sharing of the DAC such that 256 readings are converted with one DAC.

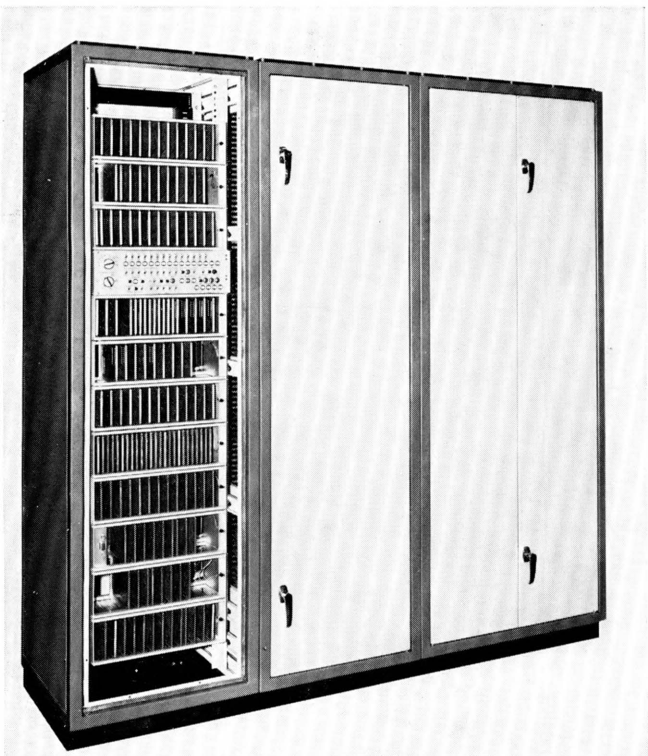

Figure 3 - Front view of master station.

5. Master Station Ferrite Store

The heart of the master station is the ferrite store, which is used to store both the program and the data received. Since the read/write cycle time is 13 μs., which is fast compared with the transmission rate and the update time required for the display and printers, it is time shared to perform all its functions. The ferrite store word is 15 bits, one bit being used for parity. The parity bit is generated and checked in every read/write cycle and the design ensures that the information in the store will not be destroyed in the event of a power failure.

The ferrite store is divided into six sections. One section stores all the data for alarms, another stores all the data for indications, another stores all the transducer readings, another stores the scan instructions, another stores the format instructions for the printers, and still another stores the instructions for the digital display.

The data stored in the first three sections are the data received from the outstations and the keys on the diagram or console. They are coded in a form to drive the different lamp conditions on the diagram.

The instructions for the last three sections are prepared on paper tape and entered into the ferrite store with a slow-speed paper-tape reader.

The scan instructions, printer instructions, and digital display instructions are written on a separate tape, a parity bit being allocated to each character on the paper tape. The number of instructions is kept to a minimum by stored-program techniques, which enable the system to optimize the number of instructions required and system operation changes.

The storing of instructions in the ferrite store is such that system requirement changes can be performed by software without tedious wiring changes.

6. Outstation

The outstation receives instructions from the master station. The outstation that recognizes its address sends the requested data back to the master station or operates the selected control or numerical instruction.

Transducer readings are converted to binary-coded decimal by an analog-to-digital converter (ADC). The selected transducer is connected to the input of the ADC with double-reed relays. The ADC has high common rejection and isolation. The alarm and indication contacts are arranged in groups of 14 to form the quanta. Each alarm or indication contact feeds into a filter, so that noise from the contacts does not cause a false operation.

A control has a two-stage selection. The first-stage selection causes a reed relay contact to close for the selected control. The second-stage selection causes a reed relay contact to close, and this is shared with all controls. The two-reed-relay contacts are in series and therefore both contacts must be closed before the device is operated. The outstation checks whether any reed-relay contact in the first or second stage is closed before a control is selected, and if any is closed, an alarm is initiated and operation of a control inhibited.

The outstation also checks whether more than one reed relay contact is closed on the first-stage selection. If so, an alarm is initiated and the second stage is inhibited. This hardware security on controls prevents a single component failure from causing a false operation of a control. Numerical instructions have a security system similar to that of controls.

7. Technology

The master station uses discrete and component transistor-resistor digital circuits for the low-speed logic, and diode-transistor integrated circuits for the high-speed logic. The semiconductors are entirely silicon planar, except for the power transistors in the SCR-row selection circuit.

The ferrite store uses lithium cores, allowing a wide operating-temperature range.

SCR's have been used instead of relays to drive the diagram and have been found to provide higher reliability.

Reed relays are used only for selecting the transducers to the ADC and for the outputs of controls and numerical instructions.

The digital logic at the outstation is available in diode-transistor integrated circuits.

8. Conclusions

The SELECTRONIC 702 system has complete flexibility of scanning outstations, logging of transducer readings, and digital display, using stored-program techniques. The software is simple and cheap compared with a general purpose computer. No use is made of wired programs, which are tedious to change and are not flexible.

The ferrite-core store in the 702 system, with its fast access time, allows peripheral devices to be connected freely without affecting the operation of the system. This makes access to a separate data processor simple as compared with that of other supervisory systems equipped with relay stores, which are bulky, expensive, and have extremely slow access time.

SCR's are used to drive the diagram to provide increased reliability and considerable saving in space, other supervisory systems use relays.

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DIGITEL 1000 Remote-Control System

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1. Introduction

In order to appreciate the place of the DIGTEL 1000* system among the existing types of digital supervisory systems, a short review will be given of the main types. On the basis of the number of functions that they perform, supervisory systems can be divided into:

— single function systems,
  e. g. a system for telemetering;
— multifunction or combined systems,
  e. g. a system for remote control, remote indication, and telemetering.

Combined systems for larger capacities usually have different information-scanning and remote-control programs, and some means of treating the information gathered.

The DIGITEL 1000 is a combined system.

Further distinctions can be made between:

— Point-to-point systems and multipoint systems.
  In the former, one outstation is connected to one master station. In the latter, several outstations are connected to the same master station.
  The DIGITEL 1000 is a multipoint system.
— Cyclic systems and start-on-change systems.
  In the former, the information in the outstation is continuously transmitted to the master station in a cyclic manner. In the latter, the information is transmitted only after a change in its state.
  The DIGITEL 1000 contains a cyclic scanning program.
— Spontaneous systems and interrogation systems.
  In a spontaneous systems the outstation delivers its information to the master station without waiting for a request from this latter, while in an interrogation system the outstation transmits bits of information only after a request is received from the master station.
  The DIGITEL 1000 is an interrogation system.

2. Principle of Operation

The DIGITEL 1000 is a combined interrogation system for teleindication, telemetering, telecounting, and remote control, intended for medium capacity applications. A system consists of one master station with several slave stations linked to it. When the master station sends an interrogation message, which is received by all the slave stations, only the slave station that recognizes the interrogation message as one of its addresses will return an answer. The answer contains the information corresponding to the interrogated address.

The master station interrogates each slave station according to a wired-in programmed sequence. All the data request codes, or instructions, have the same composition, whether they are for control, indication, or metering purposes.

The information returned by the slave station, called the data telegram, also always has the same standard format. At the master station the received data word is first checked, and the data are then transferred into individual memories for display or further processing.

The system comprises the following programs:

(A) The cyclic scanning program, which is the program that performs the periodic scanning of the indication, telemetering, and telecounting data in the slave station.
(B) One or more priority scanning programs. These deal with the items that are scanned at fixed time intervals. The program is started through an external or internal time signal, and performs one complete run of its instructions.
(C) The manually initiated program, consisting of remote control, teleregulation, and interrogation on request.
(D) Telemetering logging program. This deals with all the meter readings that are to be recorded in digital form.

The programs have a decreasing order of priority, as follows: manual program, priority scanning program, meter logging, and cyclic program, the latter being on when no other program is called for.

3. General Description

3.1 Telegram Composition. (See Figure 1.)

3.1.1 Instruction Telegram

This consists of 22 bits:
- 1 start bit
- 4 function bits
- 12 address bits
- 5 error-control bits

3.1.2 Data Telegram

This consists of 19 bits:
- 1 start bit
- 13 information bits
- 5 error-control bits

3.2 Programs

3.2.1 Manually Initiated Program

The manual program consists of the remote control and teleregulation, and the interrogation on request. The remote control offers the possibility of single or double controls (on-off). For three-position devices, triple controls can be provided (e. g.: on, off, stop).

By means of the teleregulation, up to 1000 different controlled positions are possible.

For greater security, the remote controls and teleregulations are performed in three steps. First, the address is sent to the slave station, thereby determining which device will be controlled.

The slave returns the inverse of this address to the master station for comparison. When the comparison yields no error, a second message is sent to the slave station, which in the case of a remote control contains a special code representing the on, off, or stop order, and in the case of a teleregulation contains a number between 0 and 999. This telegram is again returned to the master station and compared.

If the comparison is successful, a third telegram is sent from the master station to the slave station, which contains an execution code, called the OK code. The control

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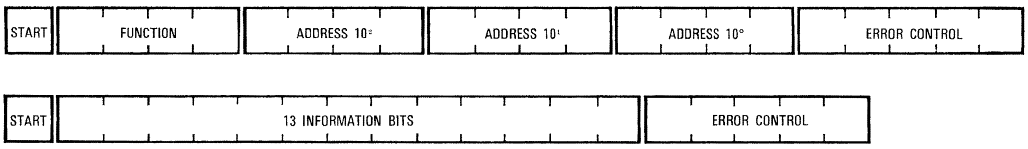

Figure 1 - Composition of instruction telegram and data telegram.

is performed and the OK code is returned to the master station for comparison.

Thus, each telegram in the control cycle is protected by the normal error-control bits, and also by the feedback from slave station to master station.

The interrogation on request, or on-demand function, permits the interrogation of a manually selected data word once every eight interrogations. Thus, the normal cyclic program proceeds, but after every seven instructions it is interrupted for the interrogation of the selected word.

To have the indication of the position of a controlled device without too much delay when a control is performed, the interrogation on request of the remote indication will be done automatically after the third control step. This automatic on-demand interrogation proceeds until the device has changed its state or until the control is reset.

3.2.2 Priority Scanning Program

Information that must be monitored at a higher rate, or that can be monitored at a lower rate than the information contained in the normal cyclic program, can be programmed in one or more priority scanning programs. This is also used for information that must be read at fixed time intervals.

The start for this program is given by an external signal (time base), and the program has priority of execution over the cyclic program, the latter being blocked during the corresponding time interval.

3.2.3 Metering Logging Program

It contains all the meter indications that are to be printed out or recorded in digital form. The program is started by a signal from a time base, manually or by the metering alarm circuits.

A serial printer is provided as a standard output device. First the time (hours, minutes) is printed out. Then the cyclic program is stopped and the first meter reading to be logged is interrogated. The received information is transferred into a buffer memory and printed out while the cyclic program is resumed.

The second meter reading is then interrogated, etc., until all the addresses of the logging program have been scanned. Thus, the normal cyclic interrogation is not blocked during the logging, but only slowed down a little.

3.2.4 Cyclic Program

This program includes all the normal information, such as meter readings, indications, and telecountings. Reserve addresses may be provided in the slave stations to allow for any future extension. These reserve addresses are not scanned and thus the cycle time is not increased.

When the cycle time becomes lengthy it is possible to bypass those groups of addresses under surveillance which indicate no change. The first data word of an interrogation group contains a bit that indicates whether there is any change. If a change has occured, then the group is interrogated; if not, it is by-passed. During each cycle one group is interrogated even if no change has occurred. In the following cycle another group is, and so on.

3.3 System Capacity

The 12 address bits in the instruction message offer the possibility of having, in binary-coded decimal, 3 decades or 1000 addresses.

Of the 4 function bits, the first 2 are effectively used as follows:

01: Remote control address.

11: Control message second step.

00: Control message third step.

10: All other address messages.

The 2 other bits can be used for the extension of the number of addresses.

Thus, the system can handle 1000 different addresses for remote indication, telemetering, and telecounting. These 1000 addresses must be distributed between the normal cyclic program, the priority scanning program, and the logging program.

The capacity of the manual program is also 1000 addresses, the distinction between the manual program instructions and the instructions of the other programs being made by the first 2 function bits. If the 2 other function bits are used, the capacity increases up to 4000 addresses for the manual program and 4000 for the other programs.

The information capacity of the data telegram is 13 bits, 12 of which are normally used. The 13th bit is used for special purposes only, such as the sign for the meterings.

One data word can thus contain 12 single indications or alarms, or 6 double indications or alarms. If the data word is used for metering, it can contain one metering to 1% with polarity or one metering to 0.1% with polarity, both in binary-coded decimal.

For telecounting, 3 digits in binary-coded decimal can be transmitted per telegram.

3.4 Transmission

Normally, transmission is via FM-telegraph channel, in reversible one-way operation, using 4 or 2 wires depending on operating conditions. Transmission speed ranges from 50 bauds up to 1200 bauds.

3.5 Telegram Duration and Cycle Time

3.5.1 Telegram Duration for Indication or Telecounting

Depending upon transmission speed, the time for a complete exchange of information between the master station and a slave station is:

$$T = 22\,p + t + 19\,p + 4\,p + d$$

wherein: p: duration of clock period,
$22\,p$: duration for instruction message,
t: interval between the end of the instruction message and the beginning of the data message in the slave station. $t = 7.5$ milliseconds for indication and telecounting,
$19\,p$: duration of data message,
$4\,p$: interval between data and instruction messages in the master station,
d: total transmission delay.

If voice-frequency lines are used:

$$d = 2\,d_l + 4\,d_m,$$

wherein: d_l: line delay,
d_m: modem delay, i. e. the delay interval in the send and receive channels.

Thus:

at 200 bds: $T = 45 \times 5 \quad + 7.5 + d = 233$ milliseconds $+ d$
at 600 bds: $T = 45 \times 1.67 + 7.5 + d = 83$ milliseconds $+ d$
at 1200 bds: $T = 45 \times 0.83 + 7.5 + d = 45$ milliseconds $+ d$.

3.5.2 Telegram Duration for a Metering

The time for a metering, using 20 milliseconds for analog-to-digital conversion is:

$$T = 45\,p + t + 20 + d.$$

With $t = 7.5$ milliseconds,

at 200 bds: $T = 45 \times 5 \quad + 7.5 + 20 + d$
$= 253$ milliseconds $+ d$
at 600 bds: $T = 45 \times 1.67 + 7.5 + 20 + d$
$= 103$ milliseconds $+ d$
at 1200 bds: $T = 45 \times 0.83 + 7.5 + 20 + d$
$= 65$ milliseconds $+ d$.

3.5.3 Telegram Duration for Remote Control or Teleregulation

The total time for a remote control or a teleregulation, between the start of the first message and the start of the control in the slave station, is:

$$T = 45\,p + t + 45\,p + t + 22\,p + 2.5\,d$$
$$= 112\,p + 2\,t + 2.5\,d.$$

With $t = 30$ milliseconds,

at 200 bds: $T = 112 \times 5 \quad + 2 \times 30 + 2.5\,d$
$= 620$ milliseconds $+ 2.5\,d$
at 600 bds: $T = 112 \times 1.67 + 2 \times 30 + 2.5\,d$
$= 250$ milliseconds $+ 2.5\,d$
at 1200 bds: $T = 112 \times 0.83 + 2 \times 30 + 2.5\,d$
$= 155$ milliseconds $+ 2.5\,d$.

3.5.4 Cycle Time

The cycle time for the cyclic program is equal to the time interval between two successive interrogations of the same address. In the DIGITEL 1000 the actual cycle time is not constant, since the cyclic program may be interrupted by another program. The minimum cycle time is equal to the number of instructions multiplied by the telegram time.

The cycle time can be reduced by the addition of an interrogation-on-change circuit, that permits the by-passing of unchanged indication information, as explained in section 3.2.4.

3.6 Security of Operation

The security of operation of the system depends on protection against transmission errors and protection against circuit failures.

3.6.1 Protection Against Transmission Errors

Each telegram is protected by a 5-bit error control code. It is a cyclic code, which is generated by thinking of the binary digits of the message as the coefficients of a polynomial and by dividing this polynomial by a generator polynomial. The remainder forms the error control code.

At the receiving terminal the error code is again generated from the received information and compared with the received error control code for error detection.

The code is implemented via a shift register with feedback connections. The generator polynomial used is:

$$1 + X^2 + X^5.$$

This code detects:

— all single errors,
— all double errors,
— all single error bursts of 5 bits or less,
— 93.8 % of all the single bursts of 6,
— 96,9 % of all the single bursts longer than 6.

(Ref.: Cyclic Codes for Error Detection, by W. W. Peterson and D. T. Brown, PIRE. Jan., 1961).

For transmission systems that satisfy CCITT standards, the error probability due to random noise is 10^{-5} per bit. The improvement in error rate obtained with the error control code used is about 5×10^9.

For remote control and teleregulation, an additional protection is provided by the feedback from slave station to master station.

When an incoming message in the master station is rejected, the corresponding instruction will be repeated until a useful answer is received. However, if after four successive interrogations of the same item no useful answer has been received, an alarm is given and the program will step to the next instruction.

If an interrogation message is rejected in the slave station that station does not answer. And after a time interval the master automatically repeats the interrogation message, up to 4 times.

3.6.2 Protection Against Circuit Failures

Circuit failures are first minimized by using in the central part of the system a worst-case calculated silicon diode-transistor logic with high-quality components.

In the peripheral circuits high-quality mercury-wetted and dry-reed relays are used. Non-hermetic relays are used only for individual functions.

A second protection against circuit failures is provided by built-in error-detection circuits.

The cyclic program includes one test instruction per slave station, which automatically checks the correct operation of the central parts of the master station and the slave station.

Circuits that detect faulty operation are also included for the power supplies and the address counters of the programs.

To prevent false controls or faulty information transfers, circuits are designed to detect that only one address is decoded. A hardware failure could cause the decoding of two or more addresses.

4. Circuit Description

4.1 Circuit Description of the Master Station

The block diagram is shown in Figure 2. The general operation is as follows.

The address of the item to be interrogated is given by the position of the address counter of the program that is on, or by the input circuits of the manual program, if this program is on. This address is transferred in parallel into the 16-bit transmit shift register, together with the function, which is given by the programer.

The shift register is shifted out serially to modulate the transmit channel. At the same time the shifted-out bits are sent into the error control circuit, which forms the redundancy bits. The redundancy bits are transmitted immediately after the last bit of the instruction has been shifted out. The foregoing operations are controlled by a position counter, which in turn is driven by a logic clock.

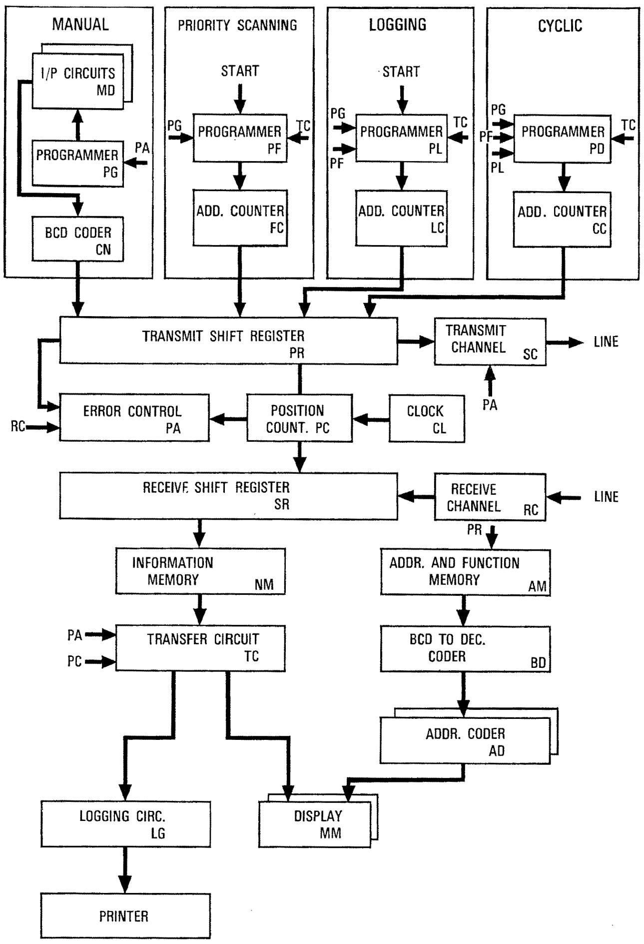

Figure 2 - Master station - Block diagram.

In the slave station, the instruction is decoded, and the requested information is sent back in the information telegram. The start bit of this telegram resets with its positive edge the clock and the position counter, so as to synchronize the master station with the transmitting slave station during the reception of the telegram. The information telegram is serially shifted in to the receive shift register. At the same time the information is entered into the error control circuit, where the redundancy bits corresponding to the received information are formed. After the information has been received, the error control circuit compares the received error control bits and the redundancy bits that have been derived from the received information. If no transmission error has occurred, the received bits and the derived bits must be identical. The information and the address and function are transferred in parallel into buffer memories. The address and function are decoded, and operate an address relay.

The information is then transferred to the electromechanical display memory, or to the logging circuits, by means of the transfer circuit, if the proper conditions are satisfied. These conditions are the following:

(A) A start bit must have been received.

(B) The error control check must be satisfied.

(C) Only one address is operated.

The programing circuits of the three scanning programs consist of a programer circuit and an address counter. The programer circuits contain the logic for switching the program on or off. The address counters give the sequence of addresses for the interrogation.

The cyclic scanning programer also contains the logic for the repetition of the interrogation in the case of a rejected answer or no answer. The cyclic program address counter is able to jump positions in order to permit the bypassing of addresses that are not used, or to bypass groups of addresses that have no information changes.

The circuits proper to the manual program include the input circuits for remote control, teleregulation and interrogation on-demand, the programer, and a binary-coded-decimal coder.

The input for remote control contains the turn-and-push semaphore or push-button control keys, with the additional individual relays, used to form the addresses of the control and the corresponding remote indication, and to memorize the discrepancy between the ordered position and the actual position of the controlled device. The input for teleregulation consists of a start push-button and two decade-switches, one of which is used to set the numerical information to be transmitted to the slave station, and the other to form the address of the regulated device.

The input for the interrogation-on-demand function is merely a start push-button, since the same address decade switch is used as for the teleregulation.

The manual programer consists of the logic for performing the four steps of a control or teleregulation: address, numerical information, execution order, and interrogation of the corresponding indication address. It performs the comparison with the feedback from the slave station for the first three steps. It also contains time interval circuits for resetting the program if it is not completed because of four rejected answers from the slave station. The programer gives an alarm if the control is not executed.

For the interrogation on-demand, the programer contains a counter with 8 positions, to permit the interrogation of the selected data once every eight instructions.

The binary-coded-decimal coder is needed to transform the decimal outputs of the manual program input circuits to the proper binary-coded decimal code for transferring into the transmit shift register.

The logic clock is a crystal-controlled oscillator followed by a frequency divider, which is a binary counter. The clock is synchronized by resetting the counter flip-flops.

The position counter is a 64-position binary counter. It is synchronized to the slave station position counter by resetting the flip-flops on the positive edge of the start bit of the received message.

The error control circuit is a five-bit shift register with feedback connections, as shown in Figure 3.

During the transmission of the instruction message, the bits are applied in series to the input of the generator. Gates G1 and G2 are open. At the end of the instruction message, the five bits of the generator shift register constitute the error control code. With G1 and G2 closed, the five bits are shifted out and added to the instruction message.

During the reception of the data message from the slave station, the incoming bits are applied to the input of the generator with G1 and G2 open. When the information part of the message has been received, G1 and G2 are closed, and the generator content is shifted out and compared bit by bit with the error-control bits of the incoming message.

The information memory and the address and function memory are constituted by set-reset flip-flops. The memories are needed to store the information and address during the transfer into an electromagnetic display memory.

The three decades of the address in the address memory are first decoded from binary coded decimal into decimal, and then applied to the address coder, together with the function bits. The address coder is arranged in matrix form, with the ten units of the address numbers as the vertical lines and the up to one hundred combinations of ten and hundred digits of the address numbers as the horizontal lines of the matrix. The intersections are formed by the address relays.

The transfer circuit is also a matrix with the address relays as the rows, and the 13 information bits from the information memory as the vertical lines. At the intersections are the memory relays. The memory relays have two coils, one for holding and one connected to the transfer circuit.

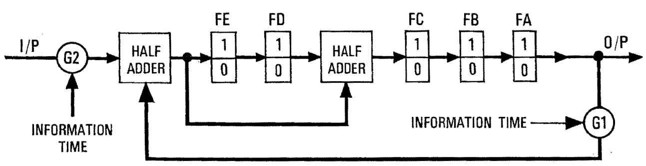

Figure 3 - Error control bits generator corresponding to $1 + X^2 + X^5$

For the remote indication display, various display programs are standardized:
— dark panel for single and double indications,
— illuminated panel for single, double and fleeting indications,
— illuminated panel for single and double non-fleeting alarms,
— illuminated panel for single and double fleeting alarms.

The metering display program offers the possibility of analog display, numeric display, and logging. The analog output has an accuracy of 1 % maximum.

For the numeric display and the logging of the meterings, scaling and zero correction can be provided, so as to display or print the real value of the quantity. A further optional function that can be provided is the detection of meterings that exceed preset upper or lower levels. An alarm signal is given, which can be used to start a cycle of the metering logging program.

4.2 Circuit Description of the Slave Station

The block diagram is shown in Figure 4. The general operation is as follows.

The instruction telegram is received in the receive channel and shifted into the 16-bit shift register, and at the same time entered into the error control circuit. The comparison is made between the received error-control bits and the error-control bits formed in the error-control circuit. If the comparison indicates no error, and if the received address belongs to the slave station, an address relay in the address memory is operated through the operate circuit.

The addressed telecounting, indications, or metering information is transferred in parallel into the shift register,

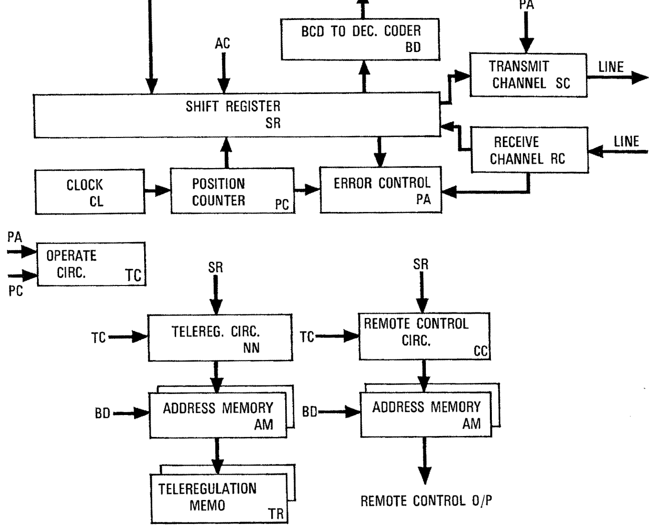

Figure 4 - Slave station - Block diagram.

shifted out serially and transmitted through the transmit channel. The error control circuit accepts the bits of the information message as they are shifted out, and at the end the error control bits are in their turn shifted out of the error control circuit and added to the data message.

For the three steps of the remote control and teleregulation operations, the answer of the slave station is the feedback for the comparison in the master station with the transmitted message.

In remote control, the first step selects an address in the address memory. An address relay is locked. After the return message has been compared in the master station, the second message from the master station sets the "on" or "off" flip-flop in the remote control circuit. An "off" or "on" relay is operated. The message to be returned to the master station is transferred into the slave station shift register directly through the operated "on" or "off" relay, and compared in the master station. If the comparison shows no error, the third message is transmitted by the master station, comprising the execution or OK code. The OK flip-flop in the remote control circuit is set and in its turn this flip-flop operates the OK relay.

The control circuit is now closed, and the control pulse to the device starts. The end of the control pulse is brought about either by the disappearance of the discordance between the state of the device and the ordered state, or by a time base, the duration of which is selected by the control address relay. In the latter case, the device has not reached its ordered position in the preset time interval, and an alarm is given.

The time base is located in the remote-control circuit, and consists of an astable multivibrator that drives a counting chain, the reset of which is adjustable and selected by the control address relays. If the reset of the counter is reached before the controlled device has completed its change of position, the control is reset and an alarm is given and transmitted to the master station. The reset of the alarm is done by a special remote control from the master station.

The amplitude of the output pulse is of 100 VA maximum with a maximum of 2 A and 500 V. Up to 16 different pulse durations can be selected.

For the teleregulation in the second step a number between 0 and 999 is transmitted from the master station and memorized in the teleregulation circuit. The return message to the master station is transferred in parallel into the slave station shift register directly from the operated memory relays in the teleregulation circuit. After the execution order has been received and checked in the slave station, the memorized number is transferred into the individual teleregulation memory, selected by the operated address relay in the address memory.

Any analog-to-digital converter (ADC) may be used with the DIGITEL 1000, provided that no more than 13 output bits are required (sign bit included), and that the logic levels of the output are adequate. Of course, the conversion time must be taken into account. Normally, the system allows a conversion time of 20 milliseconds maximum.

Scaling and zero suppression can be applied.

The indication input requires one make contact for the single indications, and one change-over contact for the double indications, to operate the interposing relays.

5. Equipment Practice

The central logic of the system is implemented with a worst-case calculated 100 kHz silicon diode-transistor logic. The logic circuits are mounted on plug-in printed circuit boards, the dimensions of which are: height, 160 mm; depth, 178 mm (6.3 by 7 inches).

The printed circuit boards are plugged into subracks. One subrack contains up to 27 printed-circuit boards. The subracks are mounted in 19-inch frames or cubicles. The peripheral relay circuits are also mounted on printed-circuit boards with the same dimensions as the boards for the electronic circuits.

All printed-circuit boards are provided with one or two 25-point plugs. ISEP (International Standard Equipment Practice) standards are applied throughout the system. Figure 5 gives a general view of the master station.

6. Maintenance Facilities

If a breakdown occurs, the outage time is minimized by quick location of the error and by rapid replacement of the faulty circuit. To aid in the detecting and locating of errors, the following facilities have been provided:

The master station is provided with a control system that contains alarms and displays for verifying the proper operation of the various circuits of the system.

The slave station is provided with normally empty subrack space, which is wired to accommodate printed-circuit boards for testing the proper operation of the slave station circuits.

Each subrack of the central parts of both master station and slave station has a free position into which a printed-circuit board can be plugged to bring out test points at the front side of the racks.

The on-demand function permits the exclusive transmission of selected information only.

Ease of replacement of a faulty circuit is afforded by the plug-in printed-circuit boards. A spare set of printed-circuit boards can be provided.

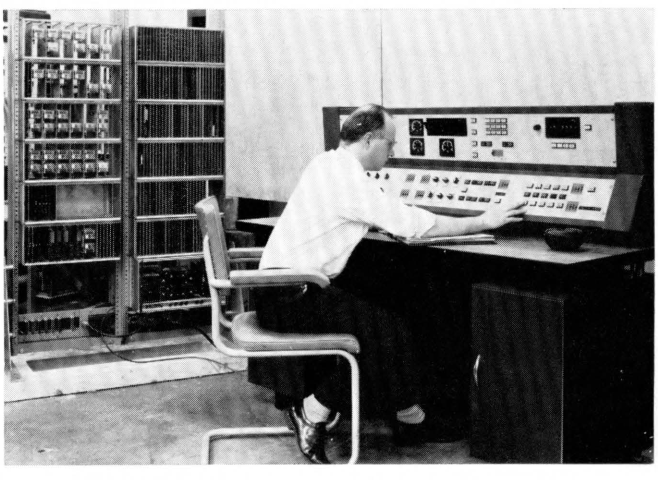

Figure 5 - General view on master station with control desk.

7. Application

A typical application of the DIGITEL 1000 is the remote-control system for the vehicular traffic tunnels at Brussels, Belgium.

The system consists of one master station to control all the traffic tunnels, each of them constituting a slave station. There are presently 12 tunnels for immediate operation, but the supervisory system is to be provided with extension capacities for up to 100 tunnels.

The electromechanical installations to be controlled in each traffic tunnel are: high and low voltage supplies, lighting program, ventilation, automatic cleaning of the walls, pumping, traffic signals, and general utilities such as the heating and ventilation of auxiliary buildings. The telecounting of the number of vehicles is also important.

The transmission program of a tunnel presently contains about 50 remote controls and 100 remote indications but it will be extended to include also four 1% telemeterings and eight telecountings of 6 decades.

Special features required by the customer are:

- transmission: two wires for every 20 tunnels;
- the information is displayed at the master station on a common panel for all slave stations. The slave station that is displayed is selected manually by the operator;
- the slave station in which a change of state occurs is automatically pointed out at the master station. This invites the operator to select the slave station concerned;
- each change in the state of the indications must be printed out;
- certain controlled functions, such as ventilation and pumping, can be regulated by both remote control and local automatic control;
- the information for controlling the lighting of the tunnels is obtained from a photoelectric sensor in the master station, which causes the automatic transmission of the corresponding instruction to all the slave stations simultaneously.

The DIGITEL 1000 supervisory system is particularly suited for this application, which requires a medium capacity system and the facilities of a combined interrogation system.

J. M. Lauriks was born in Boom, Belgium, in 1931. In 1953 he received an engineering degree in electricity and mechanics from the Hoger Instituut De Nayer, Mechelen, Belgium. The same year, he joined the Bell Telephone Manufacturing Co. and was assigned to the Apparatus Division. In 1961, he entered the Industrial Control Division and is now concerned with the development of remote control systems.

European Color Television Standards - The PAL System

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1. Introduction

When the problem of introducing color television in Europe arose, the American NTSC (National Television System Committee) system had a great influence on all considerations. The later methods, developed in Europe, have truly been called variants and improvements of the NTSC system in fair recognition of the pioneer work done in this field in the United States since 1950, when the development of an all-electronic, compatible color TV system was virtually complete. This included the color picture tube.

In 1954, regular color TV transmissions were introduced in the United States after the NTSC standard had been approved by the Federal Communications Commission on December 17th, 1953.

This standard, proposed by the NTSC, was the result of an intense research on the fundamentals, especially by the industry. It is being used in its original form even today. In 1960, it was introduced into Japan.

The European situation is best illustrated by the development of monochrome TV. The United Kingdom had introduced public television with a 405-line standard in 1937. One year later, France followed with a 455-line standard. Germany started with 441 lines in 1938.

After World War II, almost all the European countries adopted a monochrome system with 625 lines and 50 fields per second, very similar to the US system with its 525 lines and 60 fields. The United Kingdom retained its original 405-line system and France introduced a new standard with an uncommon number of lines: 819. The British and French situations became even more complex when second programs in the UHF range with 625 lines was started.

To summarize: television across European national borders has not been possible for monochrome and will not be possible for color TV for very similar reasons.

2. The Common Basis of All Color Television Systems

All the European color TV systems are based on certain important features of monochrome TV which will be retained and are therefore pointed out first.

At the transmitting end, the brightness values of a scene are converted, line by line, into voltages with the aid of photocells. The first vertical scan of the scene comprises $312 + 1/2$ lines, the second starts by completing the remaining half line and ends with the 625th line in interlaced relation, thus obtaining the two fields of a frame. The horizontal sweep frequency is an integral multiple of one-half of the frame frequency.

In the receiver, the scene is recreated by the beam writing the lines at the same frequencies. To obtain this result, two kinds of signals have to be transmitted: the brightness associated with every picture element and a synchronizing signal to ensure that the receiver tube-screen raster is built up in synchronism with the transmitter operation. The sync signal occupies the range between 75 and 100 % of the composite TV signal amplitude while the video signal varies between 10 and 75 %.

Whatever the color TV system to be developed, these two monochrome data had to be taken into account so as to meet compatibility standards which require that any monochrome TV receiver, regardless of its design and age, should be capable of receiving color TV signals and of reproducing a monochrome picture, and that in addition any color receiver should be able to reproduce a monochrome picture from a monochrome transmitter. This requirements had been postulated as a "condition sine qua non" in the forties by the American industry. In Europe, the agreement on a common color TV standard was difficult to reach because of the different standards used for monochrome in a geographically limited area and because basically different solutions for improving on the NTSC system had been found in France and in Germany.

However, there are principles of color manipulation that have to be incorporated in any color system. These should be recalled before a discrete European color TV system is reviewed.

2.1 Colorimetric Principles

One such principle important for color TV is that almost any natural color and the white tone can be simulated by the additive mixture of three primary colors.

The primary colors are those that cannot be generated by additive mixture. It can be shown by experiment that these primaries are red, green, and blue.

This principle permits color TV to be based on the mixing of these three primaries in the scanning and reproduction of a scene.

2.2 Scene Pickup

The pickup of picture elements and their conversion into electric signals may be seen by reference to the color-slide scanner in Figure 1.

A white raster is written on the pickup-tube screen and projected onto the transparent slide, the picture elements of which modulate the flying spot of light. In monochrome operation, this modulated light is directly converted by photocell action into the video voltage. For color TV, the primaries are filtered out, for instance, with dichroic mir-

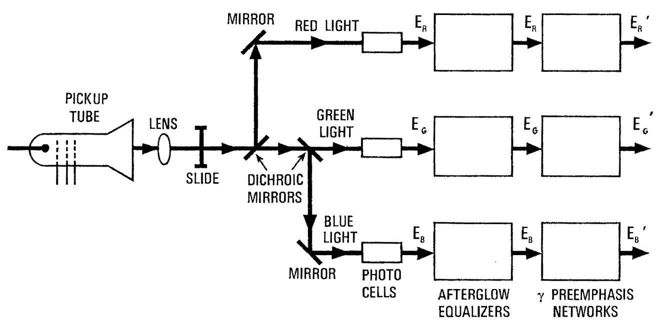

Figure 1 - Color Slide scanning (Schematic).

rors that are capable of transmitting certain parts of the spectrum and of reflecting other parts. The first dichroic mirror reflects the red light to the top in Figure 1, the second reflects blue light downwards, but both mirrors are transparent for green light. Thus three photocells are needed for the primary-color signals.

2.3 Luminance and Color Difference Signals

2.3.1 The Luminance Signal

For the further processing of these three signals E_R, E_G, and E_B, parts of them have to be combined to form the luminance signal, the only one to which a monochrome receiver will respond. Let us assume that the scene consists of nothing but three bars in the primary colors as shown in Figure 2. The blue channel will then transmit the

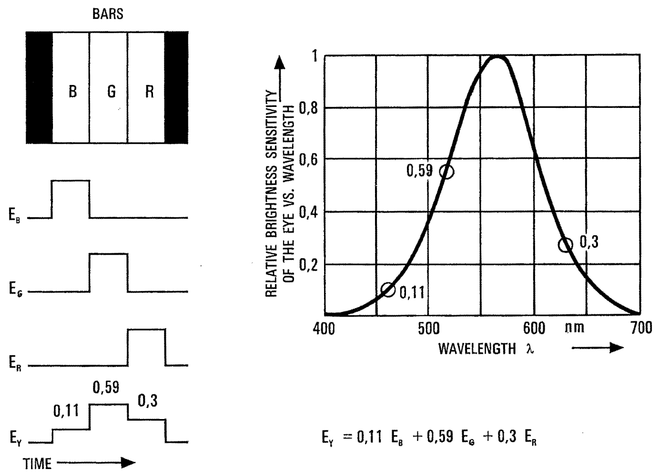

Figure 2 - Generating the luminance signal E_Y.

pulse E_B, as shown, of a duration corresponding to the width of bar B. Similar square-wave pulses will appear as E_G and E_R in the green and red channels, respectively.

If we simply added these three signals to obtain the luminance signal, the result would be a square-wave pulse of triple duration. A monochrome receiver would reproduce the three bars with equal brightness and it would be impossible to see three different objects.

Actually, however, the brightness perception of the human eye depends on the hue as plotted in Figure 2. Therefore, to cause the monochrome receiver to reproduce the hues with the proper brightness weight, the primary color signal voltages are multiplied by the factors derived from the sensitivity curve: 0.11, 0.59, and 0.3 for blue, green, and red, respectively.

The luminance signal E_Y is thus obtained as the sum of these three voltages. The equation:
$E_Y = 0.11\,E_B + 0.59\,E_G + 0.30\,E_R$ applies to any color TV system; it is a first condition for meeting the compatibility requirement.

2.3.2 The Color Difference Signals

The method of adding the color information to the luminance signal is also the same for all color TV systems: so-called difference signals are formed by a procedure similar to that in stereophonics. There are

the blue difference signal $E_{DB} = E_B - E_Y$
and the red difference signal $E_{DR} = E_R - E_Y$.

These difference signals have an important property for color TV. They disappear where the picture content is colorless. Each of the primary color signals is then equal to the other two; the signal voltages E_B, E_G, and E_R have the same amplitudes and the standardized maximum value of 1 for white. From this amount 1, only percentages are taken to form the luminance signal as described above, i.e. 11% of the blue voltage, 59% of the green, and 30% of the red voltage. In accordance with the equation for E_Y, the sum is again 1.

To form the blue difference signal, the value 1 of the luminance signal is subtracted from the value 1 for blue. The result is 0. The same is true of the red difference signal.

Another feature common to all color TV systems is the use of a subcarrier for the transmission of both difference signals. The subcarrier with its harmonic spectrum is added to the frequency band already occupied by the luminance signal.

2.4 Modulation

The next step is to combine the difference signals carrying the color information with the luminance signal into a composite signal. Because of the required compatibility, all data indispensable for monochrome transmission have to be retained. The nominal bandwidth for monochrome must not be exceeded although chrominance must additionally be transmitted.

The major difference between the various color TV systems is actually confined to the type of subcarrier modulation. Basically, there are only two: quadrature-amplitude modulation and frequency modulation, the former being used in NTSC and PAL (Phase Alternate Line), the latter in the French SECAM (Sequential with Memory) system. The NTSC system is the basis for the PAL system; therefore, its salient features are summarized in the next section.

3. NTSC as a Basis for PAL

The preceding sections showed how a luminance signal is obtained from three chroma signals and how the two color difference signals are derived. The general use of a color subcarrier in all color TV systems has been pointed out. The subcarrier modulation with the two chroma signals will now be described.

To solve this problem, the following conditions were stipulated in the development of the NTSC system:

a) the carrier should be capable of being modulated simultaneously with both chrominance signals E_{DR} and E_{DB};

b) for colorless picture elements, the subcarrier amplitude should be 0.

3.1 NTSC Modulation

To meet these conditions, a type of modulation was chosen in which both the phase and the amplitude of the subcarrier are simultaneously modulated. This modulation is obtained by splitting the subcarrier into two components in quadrature to one another and amplitude-modulating these components with E_{DR} and E_{DB}. Each of the two difference signals E_{DR} and E_{DB} can assume independently any positive or negative value between zero and a maximum. In other words, the resulting vector F of the subcarrier frequency (shown in Figure 3) may appear in any one of the four quadrants.

This type of modulation is best understood with reference to Figure 4. Here A is the mean value of the unmodulated subcarrier amplitude, m is the depth of modulation, Ω the carrier frequency, (in our case, the subcarrier frequency), ω the modulating frequency which is in the range from 0 to 1.5 MHz.

In Figure 4a, the carrier vector rotates at subcarrier frequency while the sideband vectors rotate, in the opposite direction, around the carrier vector. When the carrier is suppressed as in Figure 4b, the sideband vectors remain with a resultant which disappears when $m = 0$. This resultant always has the phase of the original carrier.

If this procedure is carried out in two modulators and the carriers fed to both are in quadrature, we obtain two resultants S_1 and S_2 (Figure 3), or their sum, the subcarrier F containing the color information.

The relationships between the phase angle φ_F and amplitude A_F of the modulated subcarrier can be derived from the vector diagram of Figure 5 showing the vectors associated with the standardized colors.

Figure 6 is the block diagram of a modulator based on NTSC principles. Its units are the color matrix where the luminance signal E_Y and the chrominance signals E_{DR}, E_{DB} are derived from the primary color signals; the two modulators to which the color carrier is fed from its generator in phase and in quadrature; and the adder, in which both chrominance signals and the sync signal are combined into the composite color TV signal.

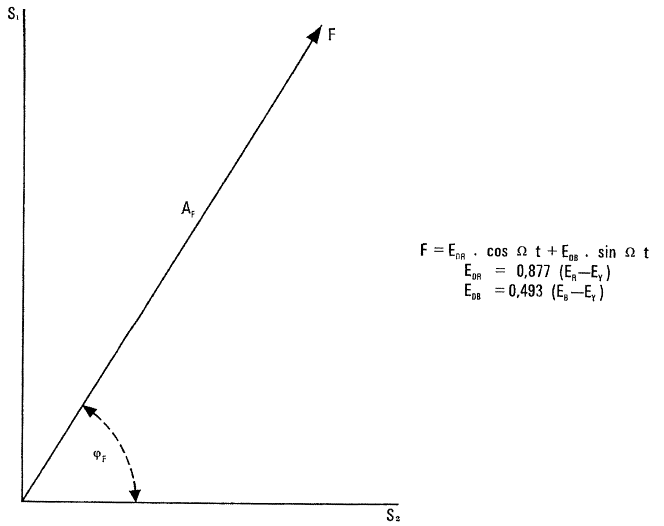

Figure 3 - Vector diagram of the modulated subcarrier.

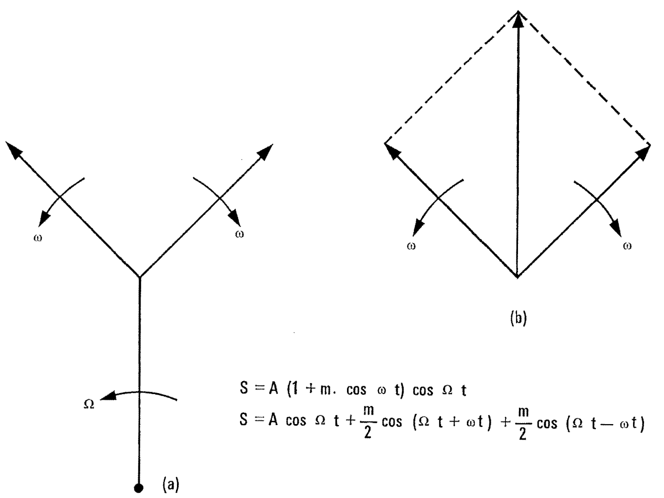

Figure 4 - Amplitude modulation.
a) Without and
b) With carrier elimination

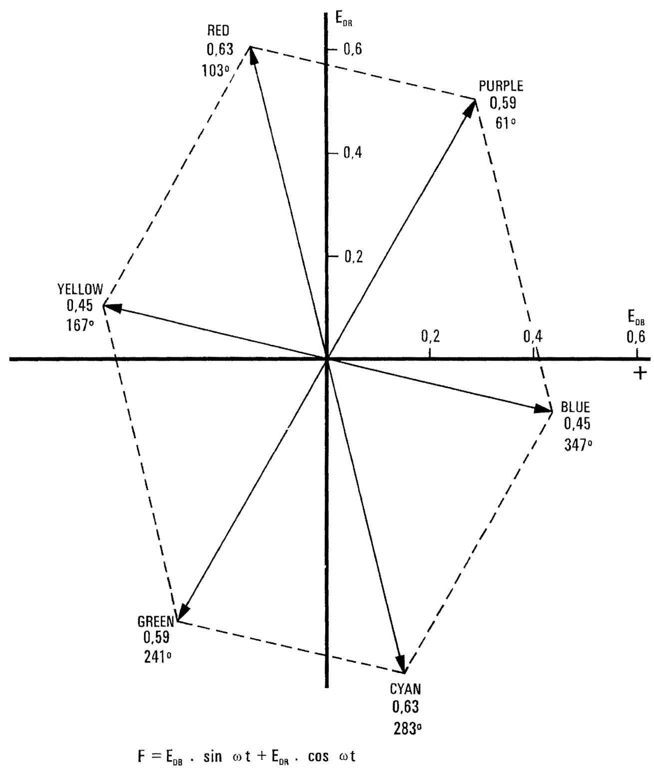

Figure 5 - Phase relations of subcarrier components.

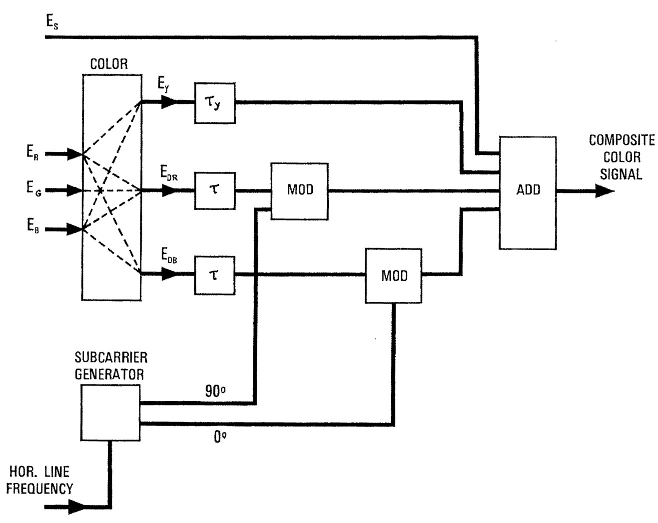

Figure 6 - NTSC — Modulator.

3.2 NTSC Demodulation

The chroma signals are recovered in the receiver with the decoder (Figure 7), which obtains the composite signal with a bandwith of 5 MHz from a video demodulator, as in monochrome receivers.

The modulated color signal corresponding to the equation

$$F = E_{DR} \cos \Omega t + E_{DB} \sin \Omega t$$

can become zero because E_{DR} and E_{DB} are zero for colorless picture elements or picture areas.

Demodulation requires the unmodulated carrier; this is generated in the subcarrier generator of the receiver and applied to the demodulators in phase and in quadrature. In the demodulator E_{DR}, the color signal is multiplied by the cosine oscillation of the subcarrier, which results in the difference signal $E_{DR}/2$ and two other components at double the frequency which can readily be filtered out. Similarly, $E_{DB}/2$ is obtained in the second demodulator. The luminance signal and the two color-difference signals are fed to the decoding matrix which supplies the primary color signals E_R, E_G, E_B after linear addition and subtraction operations similar to those of the transmit matrix.

3.3 Disadvantages of the NTSC Method

The NTSC method in itself may be called ideal. However, the transmission paths are not ideal, and this fact is reflected in the NTSC receiver. Since the important chrominance information is transmitted by a phase-modulated carrier, any undesired phase shift of this carrier with respect to the color burst must necessarily result in hue distortion.

It was this practical weakness in the modulation method that caused European television engineers to examine this problem and to find better solutions.

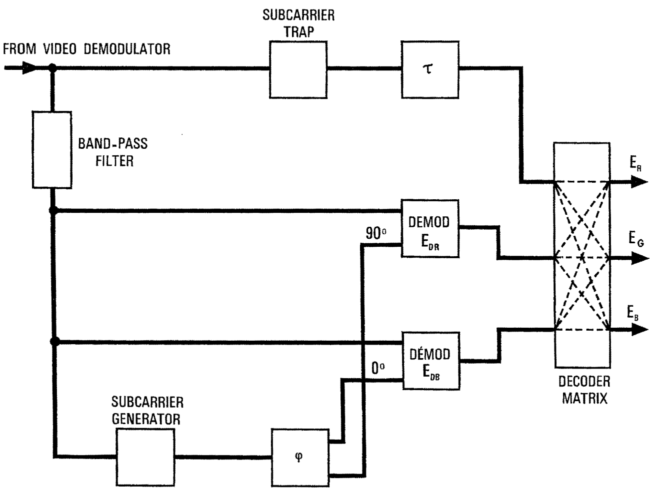

Figure 7 - NTSC — Decoder.

4. The PAL System

The PAL system may be described as the NTSC system plus additional circuits that eliminate phase errors introduced by the transmission path.

Figure 8 is the vectorial presentation of a chrominance signal F. In the NTSC system, the in-phase and the quadrature components of the carrier are in the same phase relation (0 and 90 degrees) at all times.

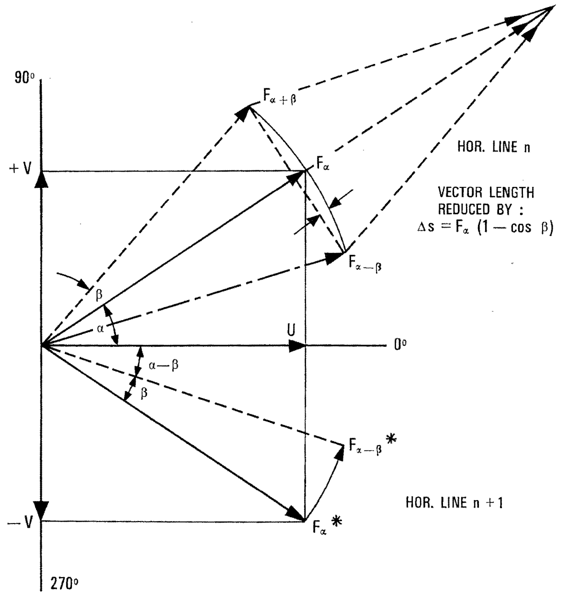

Figure 8 - PAL alternate line-switching principal (vectorial presentation).

In the PAL system, one of the two components (called U and V components) is alternatingly switched between 90° and 270° from line to line. In Figure 8, a constant primary color is assumed to be transmitted. The resultant vector of the V component will therefore change its position between F_α and $F_{\alpha*}$ from line to line.

Assume now a phase distortion causing the vector F_α to be shifted by the angle β in the direction $F_{\alpha+\beta}$. Since the V component of the transmitter is alternatingly switched by 180°, the resultant vector for the next horizontal line will appear as shown in $F_{\alpha-\beta*}$ that is, also shifted by the angle β and shifted in the same direction.

When the polarity of the V component is now alternately switched in the receiver, too, then $F_{\alpha-\beta*}$ will appear, in mirror symmetry to the U axis, in the first quadrant as $F_{\alpha-\beta}$.

This reversing of polarity requires that both carrier components U and V be individually accessible in the receiver. The vector F_α will then change, from line to line, between $F_{\alpha+\beta}$ and $F_{\alpha-\beta}$, that is, with the phase error β alternating between a positive and negative error; however, the alternating vectors will appear in the first quadrant.

To cancel this phase error, only one condition is necessary; both vectors $F_{\alpha+\beta}$ and $F_{\alpha-\beta}$ must appear at the same time. This is accomplished with a delay line. The vectors can now be added to obtain their mean value at angle α, that is, no longer containing the error β, but somewhat shorter than twice the length of F_α, depending on the magnitude of the eliminated error. This shortening of the vector by Δs is all that is left of the original phase error; it has the effect of reducing the color saturation, but by an amount so small as to be hardly perceptible.

4.1 PAL Modulation

The PAL modulator differs from NTSC only by the additional function of constant changeover of one subcarrier component by 180 degrees. The additional units are enclosed in broken lines in Figure 9.

The signals from the three primary-color channels are used in the matrix to form the color-difference signals, while the luminance signal E_Y is formed as the sum of the weighted primary-color signals. A subcarrier generator supplies the three components 0, 90, and 270 degrees. The 0° component is mixed with the difference signal E_{DB} in the U modulator, and the other two components are fed to the V modulator in an alternating sequence as controlled by switch S. The switching voltage is provided by a bistable generator synchronized with the horizontal (line) frequency. Finally, the composite color TV signal is produced in the adder, just as in NTSC.

4.2 PAL Demodulation

From the video demodulator in the receiver, the color signal is applied — as in NTSC — via a bandpass filter to Point A in Figure 10. It is then fed to adder V with a phase shift at 180° and to adder U directly and to both adders through a delay line which introduces a delay equal to one line sweep time.

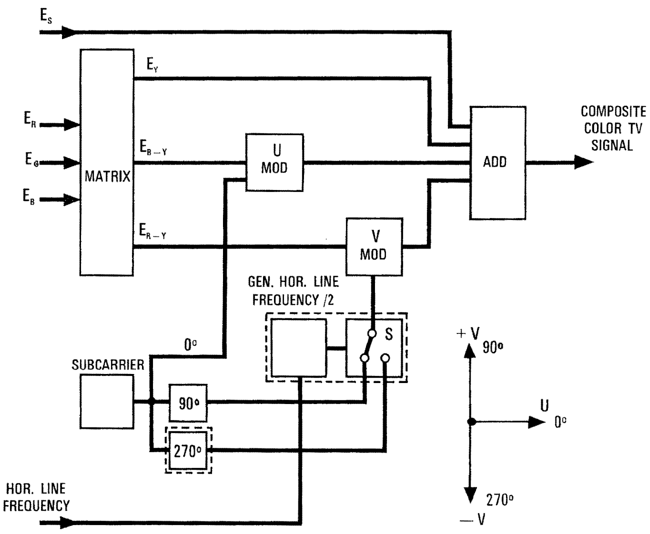

Figure 9 - PAL — Modulator.

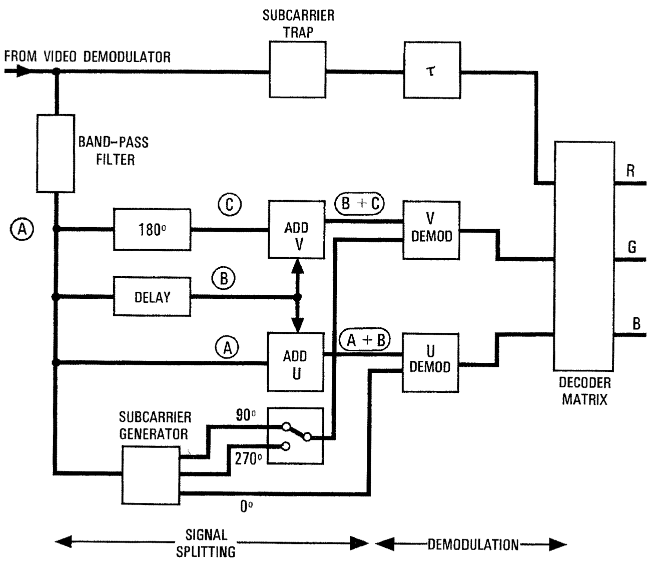

Figure 10 - PAL — Decoder.

Figure 11 shows the sequence of the signals appearing at points A, B, and C of Figure 10 and behind the U and V adders ($A+B$ and $A+C$) occupying four horizontal lines. The upper row A in Fig. 11 is the incoming signal sequence; the second row is the same row A delayed by one line while the third row is again row A with the polarity reversed by the 180° phase shifter.

The additions $A+B$ and $A+C$ as well as $A-B$ comprising two lines in tandem (lines 2 and 3) are illustrated in Figure 12, assuming that the hue of the scene remains unchanged during these two lines. The delayed signal F_1 of line 1 and the signal F_2 are simultaneously fed to the adder U. Addition of F_1 and F_2 results in the 0° vector of the magnitude $2\,U$ corresponding to the color difference signal E_{DB}.

At the same time, F_1 appears at terminal B and $-F_2$ at terminal C of the V adder. Their addition results in the 90° component of the color subcarrier with the magnitude $+2\,V$.

During line 3, F_3 at terminal A is in the first quadrant (because of the reversal of the 90° component) and the signal F_2, as for the preceding line, in the fourth quadrant. The sum of both is again $2U$, i.e. the 0° component. The addition of the signals at B and C, however, results in a component $-2V$ in the V adder because F_2 and $-F_3$ point downwards. Thus both subcarrier components are recov-

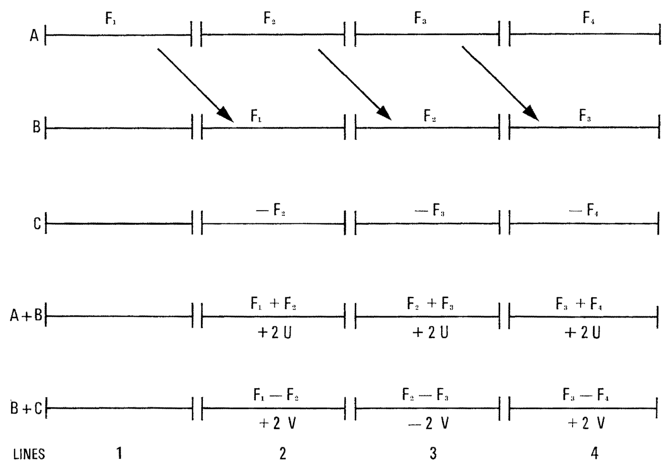

Figure 11 - Signal sequence in PAL — Decoder.

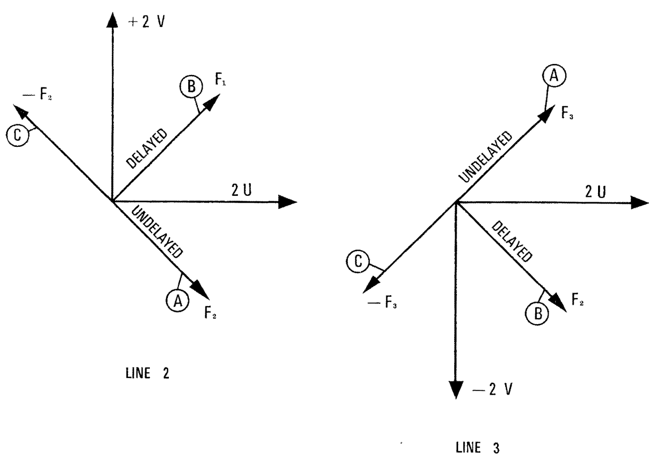

Figure 12 - PAL — Signal splitting.

ered in 0° and 90° positions, but the V component changes its polarity from line to line.

As in NTSC, each component is rectified in a synchronous demodulator. In the U demodulator, the reinserted carrier has the phase positions 0°.

Through the intermediary of demodulator V, the phase of the superimposed triggering signal jumps from 90° to 270° and vice versa from one line to the other. In this manner, the polarity reversal of signal V from one line to the other is compensated.

The PAL receiver demodulator has the following four additional functions as compared with the NTSC receiver:
(1) delay of the subcarrier by the duration of one line so that the information of two lines is constantly available;
(2) splitting of the incoming amplitude-modulated and phase-modulated color signal into the original components U and V, which amounts to a reversal of the analog process in the transmitter;
(3) alternate switching of the V component by 180° from line to line;
(4) derivation of sync pulses from the subcarrier for phase locking of switching mechanism in (3).

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Glow-Discharge Formation of Inorganic Films for Capacitors

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1. Introduction

Film-forming processes have always been needed in the manufacture of components for electrical communication. Examples of the use of films are to be found throughout the industry, from the insulation of wires and the formation of dielectric or metallic films, to the very specialized techniques used in present-day microelectronics. Liquid-phase methods previously used for depositing films, for example, those using paints and varnishes and electroplating, are now being supplemented by techniques of deposition from a vapour or gas, and considerable work is being carried out in this expanding field at the present time.

The coating of substrates with metallic films by evaporation or by sputtering in vacuum is well known. Chemical vapour deposition processes, though less familiar, are also being used increasingly. In such processes a suitable gas or vapour flows over a heated substrate where chemical reduction or decomposition occurs, the deposited film or layer then grows from the atoms which are liberated by the thermally initiated chemical reaction.

It has been found recently that radio-frequency energy can be used instead of heat to cause film-forming reactions to take place in a gas environment [1, 2]. The method and its application in capacitor manufacture is described in this article.

2. Vapor Deposition Methods

With the variety of deposition methods that are available, it is possible to choose the one most suited to the material itself and its substrate. Figure 1 illustrates the broad divisions between various gas-phase processes. Generally the evaporation and sputtering methods are applicable to metals having suitable vapor pressure, whereas vapor plating and the newer glow-discharge coating technique have a wider application in the deposition of metals, insulators, and refractory materials. For example, the evaporation of aluminium (used commercially in the manufacture of capacitors) is a relatively easy procedure. Aluminium evaporates easily and can be condensed as a film on to, say, a plastic-film substrate. Because it is an element, no problems of composition change arise. In the case of tantalum, the vapor pressure is so low that sputtering, with its high-energy ion bombardment, must be used to transfer material.

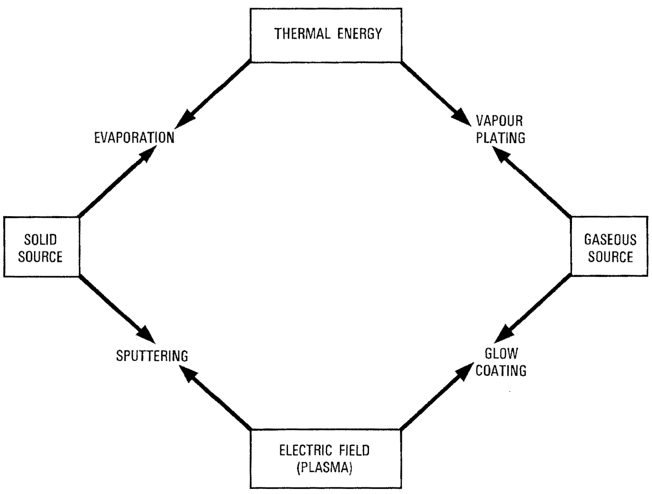

Figure 1 - Relationships of gas-phase deposition processes.

Some insulating materials have desirable dielectric properties and would be very suitable for capacitor manufacture if they could be made in thin-film form, but the processes of evaporation and sputtering are not always suitable for the satisfactory deposition of insulating materials, since departures from the correct composition can occur. However, if suitable source gases are subjected to a radio-frequency glow discharge at low pressure, a variety of dielectric films can be deposited quite successfully with close control of composition.

3. Chemical Reactions in Gas Discharges

Various forms of electrical breakdown in a gas have been investigated for many years. The differing conduction mechanisms which occur depend on such factors as the frequency and voltage of the applied field, the gas composition, and its pressure and temperature. Generally, spark or corona discharges take place at atmospheric pressure, whilst glow discharges occur at pressures below 1 torr. When direct-current or low-frequency alternating-current fields are used, it is usual to mount electrodes in physical contact with the gas. At radio frequencies, however, glow-type phenomena can be induced in the gas by means of an externally placed radiating system. This is usually in the form of an inductance or capacitance surrounding the tube containing the gas.

It has long been known that chemical reactions can occur in gases which are subjected to electrical stresses. Many investigators deliberately chose the inert gases like argon and neon for their electrical experiments to overcome unwanted electrode corrosion and peculiar black deposits which darkened the glass tubes. Other scientists exploited this ability of gas discharges to promote chemical reactions, and one of the earliest commercial uses was the application of a high-voltage corona discharge in oxygen to form ozone. The apparatus was termed an "ozonizer" and usually operated at or near atmospheric pressure. This type of application has recently been termed "corona chemistry".

At lower gas pressures and lower voltages, a glow-type discharge can be initiated in a gas that is stimulated by a radio-frequency field. This electrode-less discharge is silent, occurs at relatively low power, and results in a special kind of luminosity. It is not localized or fiery in appearance like the crackling corona and spark discharges.

This form of stimulation associated with the silent glow discharge has been found most suitable for producing chemical reactions which result in the formation of insulating films. From the point of view of chemical reaction and the deposition of a film, the emission of light may be regarded as a secondary mechanism merely incidental to the process. In our experiments, it has been noted that chemical reaction can be sustained in the radio-frequency field below the glow threshold, and films have been grown with no attendant visible glow. In these glow-discharge chemical reactions, existing chemical bonds in the gas molecules are broken to create simpler molecules, free radicals, or atoms with some ionization of these species. Thermally speaking, the gas is cold, but the energy derived from the radio-frequency field is sufficiently high for there to be appreciable excitation among the gas molecules. New bonds and therefore new molecules form in this cold gas, and where the synthesis results in the formation of compounds which normally exist in the solid phase, a film is deposited on to a suitably placed substrate.

4. Experimental Techniques For Film Deposition

The first experimental apparatus used for the formation of films by glow discharge is shown schematically in Figure 2 and pictorially in Figure 3. It is basically simple and consists of a reaction tube fitted with gas inlets and a vacuum pump. Radio-frequency energy is inductively or capacitively coupled to the reaction chamber from a 500-watt 1-megahertz oscillator which was specially designed for this work by Stanelco Industrial Services Ltd.; the gases to be reacted are separately metered and fed into the reaction zone, where a suitable substrate is located. The rotary vacuum pump is controlled by means of a throttle-valve to give operating pressures near 0.1 torr. After some minutes to allow for stabilization of the gas flow conditions, the radio-frequency field is applied and deposition commences.

One of the simplest examples of film growth is the deposition of silicon from silane gas. This gas SiH_4 is analogous to methane CH_4 and can be decomposed by heating to give its elements, silicon and hydrogen gas. This pyrolysis is conveniently carried out at 1000 degrees Celsius, when the crystalline semiconducting form of silicon is produced. In contrast, films of armorphous insulating silicon can be deposited cold from silane in a radio-frequency discharge using the apparatus previously described. Sheet Mylar or other similar plastic material can be used as a substrate and because deposition takes place at or near room temperature no degradation of the substrate occurs. Electron diffraction analysis has proved that the silicon deposit has an amorphous or glassy nature and electrical measurements of resistivity give a value of 10^{11} ohm-centimeters, compared with 10^3 ohm-centimeters for thermally produced ultra-pure crystalline silicon.

The main impact of the work on glow deposition has been directed towards the deposition of insulating compounds of silicon, like silicon dioxide or silica (SiO_2) and silicon nitride (Si_3N_4). These materials generally occur as glasses or ceramics and normally need a temperature above 1000 degrees Celsius for their formation.

The cold synthesis of these materials can be carried out easily in a glow discharge. Silane is mixed with another gas at the point of entry to the reaction chamber, and the corresponding compound is deposited on to a substrate. For example, nitrous oxide (N_2O) liberates oxygen in the glow discharge which then combines with silane to deposit a film of silica. These films are hard, glassy, and transparent, in fact similar to those produced at high temperatures by more conventional thermal techniques. The molecular nitrogen (N_2) liberated during this reaction does not combine with silicon under these conditions. However, if ammonia (NH_3) and silane (SiH_4) are reacted in a glow discharge in the absence of oxygen, nitrogen combines with silicon to form a film of silicon nitride. In the same way, titanium dioxide can be deposited from titanium tetrachloride vapour ($TiCl_4$) and carbon dioxide gas (CO_2). It is certain that the use of radio-frequency energy as a chemical catalyst will apply to a large number of similar reactions.

5. Pin Holes

In any film forming process, the number of pin holes per unit area should be as low as possible, and this is especially true of films destined for use as capacitor dielectrics. Films formed by glow-coating methods are particularly free from holes, and it is thought that a mechanism operates whereby an incipient pin hole is removed by an increase of electron activity at that particular point. Certainly, when glow discharges are used to clean up vacuum systems, microscopic particles of dust on a surface can sometimes be seen to scintillate and disappear. This mechanism should continue to operate throughout the growth process. Another favorable aspect of the method is that at the relatively high pressures used (100 microns of mercury) material will arrive at the substrate surface from all directions. This is in contrast to the evaporation of metals in high vacuum where particles of dust which fall on the surface of the growing film cast shadows and

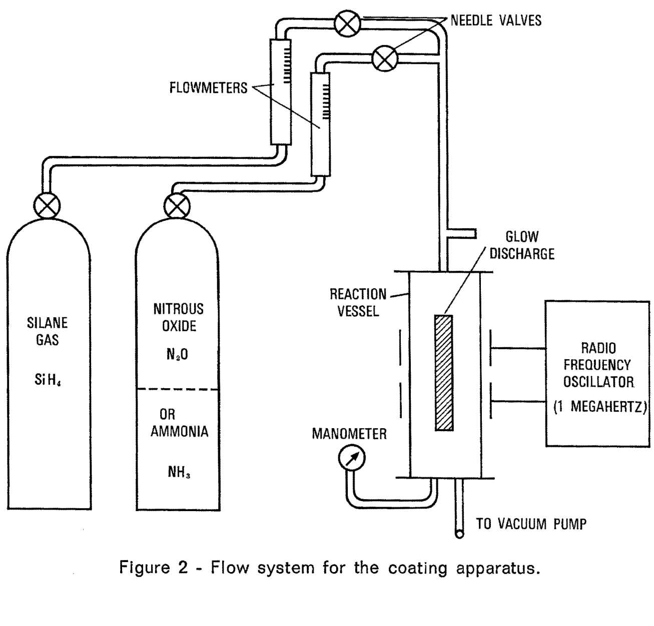

Figure 2 - Flow system for the coating apparatus.

give rise to tiny areas where deposition is absent or restricted.

6. Silicon Nitride — A Capacitor Dielectric

In view of the suitability of this new method for the deposition of insulators and dielectrics it was decided to try out the technique for the fabrication of experimental capacitors. The first material chosen for this investigation was silicon nitride because of its inherent stability and favourable electrical properties.

Silicon nitride is normally made in polycrystalline form by direct combination of the elements, nitrogen and silicon, at high temperature. The resulting powdered product is compacted by pressure in a suitable mould and sintered at high temperature. It has a relatively high dielectric constant of between 7 and 9, an electrical breakdown strength of near 10^7 volts per centimeter and, when pure, has an excellent power factor. In this bulk form, however, it is not really suitable for capacitor manufacture. Comparison of its dielectric properties with some other materials is given in Table 1.

Table 1
Dielectric Properties

Material	Dielectric Constant	Loss Angle at 1 Kilohertz	Dielectric Strength in Volts Per Centimeter
Silicon nitride	8	0.0002	5×10^6
Mica	6.8	0.0001	5×10^6
Fused silica	3.8	0.0002	1×10^6
Paraffin wax	2.2	0.0001	5×10^6
Polycarbonate (organic cast films)	2.8	0.002	1.8×10^6

7. Silicon Nitride Films

In the first experiments, on depositing thin films of silicon nitride from ammonia and silane, an excitation frequency of 1 megahertz was used associated with an external inductance/capacitance system coupled to the reaction tube. During deposition, a faint glow could be seen. The hard and glassy film deposited at a rate of approximately one micron (10 000 angstrom units) per hour on to the glass substrate and showed changing interference colours as it grew. A range of substrate temperatures was studied. Even when the films were deposited cold (25 degrees Celsius), they showed excellent dielectric properties. Infra-red absorption spectroscopy shows the presence of N–H groups in layers deposited cold, but these groups are progressively removed as the temperature of the substrate is increased, and appear to be absent from films deposited at a few hundred degrees Celsius. An important feature of the method is that the proportions of the gaseous reactants may be changed to give silicon nitride films of different composition. Properties which are composition dependent can, therefore, be optimized. Figure 4 shows the variation of dielectric constant with gas composition.

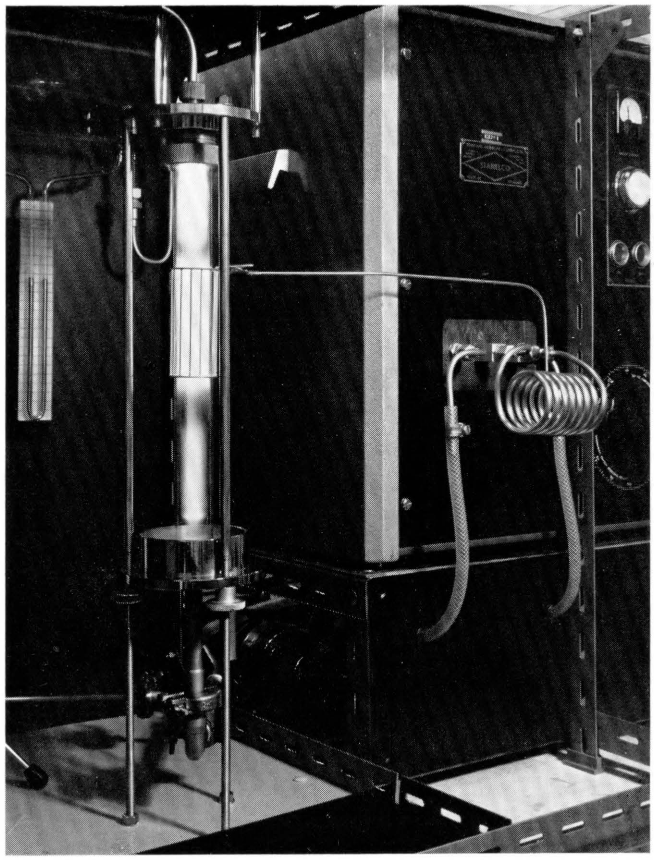

Figure 3 - Experimental apparatus for the formation of films by glow discharge.

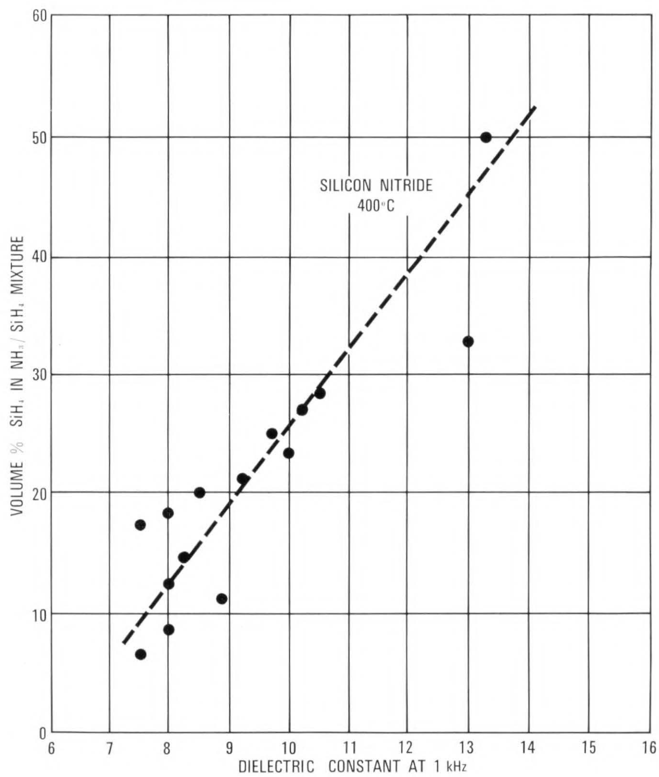

Figure 4 - Variation with gas composition of dielectric constant of silicon nitride deposited at 400 degrees Celsius.

8. Capacitor Fabrication

To assess the overall behavior of silicon nitride as a dielectric material, a deposition unit specifically for silicon nitride was built in the Capacitor Division of Standard Telephones and Cables. The integration of the deposition unit with a system for the formation of complete capacitors enabled electrical and environmental studies to be carried out on encapsulated capacitors. By this means it was also possible to evaluate the reproducibility and efficiency of the deposition technique on a plant of basically simple design.

Although this new plant was modeled on the one successfully used at Standard Telecommunication Laboratories, it was necessary to incorporate certain modifications. Some flexibility in the design was necessary to cater for such factors as an anticipated increase in the deposition rate, a greater handling capacity, and similar features of commercial importance. The central part of the deposition unit is shown pictorially in Figure 5.

Silicon nitride layers have been produced with the above system at various growth rates from 0.1 to 1 micron per hour, and with both good control and uniformity of film thickness over areas in excess of 10 square centimeters. The achievement of capacitors with good electrical behavior following various processing treatments demonstrated the inherent chemical stability of the amorphous nitride films even when subjected to various degrees of thermal, mechanical, and physical stress associated with the deposition of the electrode and the curing of the encapsulation material.

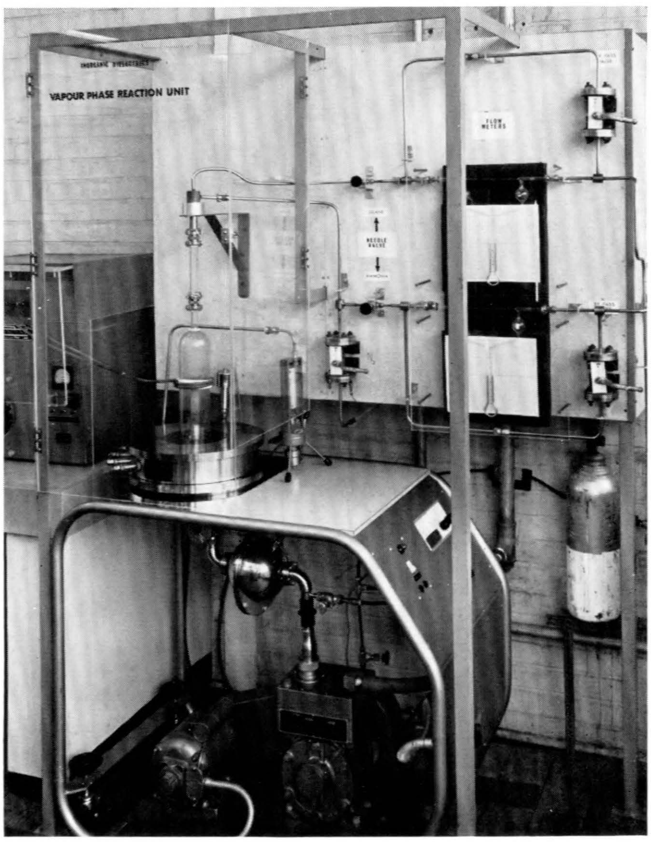

Figure 5 - Silicon nitride deposition plant.

8.1 *Apparatus*

During the construction of the deposition plant, due regard was paid to safety in handling the raw materials, silane and anhydrous ammonia. Corrosion-resistant materials were incorporated where necessary to reduce contamination to a minimum. For example, the gas supply lines, the electrode chamber, and the vacuum-pumping unit were constructed in stainless steel, while the deposition chamber was made from a specially shaped thick-walled transparent silica tube. Where possible, argon arc-welded joints were used so that the number of potential leaks was reduced and the complete system was leak tested prior to use at both low and high gas pressures. Perspex screens and electrostatic screening were employed to improve safety during plant operation, with full facilities to flush the complete system with an inactive gas, such as dry nitrogen, if a malfunction occurred.

During the operation of the system, gas flow rates are accurately controlled by stainless-steel needle valves and measured by means of specially designed differential flow-meters. Provision is made for the deposition pressure to be continuously monitored with a Pirani gauge, and checked with a permanently fitted McLeod gauge. The pressure is controlled by balancing of the total gas input rate against the throttled vacuum pumping speed.

Ancillary equipment includes a vacuum evaporation unit that was fitted with magnetic workholders and film-growth monitors for the controlled formation of metal electrodes on the substrate wafers before and after the nitride deposition. During processing, all materials are stored in a dust-free chamber at a relative humidity maintained below 4 percent by molecular sieve pumping.

8.2 *Design and Preparation of Test Capacitors*

For the preliminary examination a simple planar electrode design was adopted having an effective dielectric area in the range 0.04 to 4 square centimeters. Although in single-layer form the planar construction yields a low space-factor efficiency, an improvement can be achieved by alternately depositing metal and dielectric layers in the form of a multilayer system of capacitors connected in parallel on a single substrate wafer.

Various electrode materials, including copper, silver, gold, nickel, and aluminium were used during the initial experimental program, but aluminium was chosen for the completed capacitor evaluation because it can be used in a "burn-out" process to isolate, if necessary, flaws or pin holes in the dielectric films.

However, capacitors have been successfully produced free from the necessity for any burn-out behavior under a direct-voltage stress, thus supplying further evidence to suggest that these amorphous films of silicon nitride are free of pin holes.

In these test capacitors, microsheet glass substrates were used. It is pointed out that in the fabrication of commercial capacitors it is essential to use a low-cost substrate material whose bulk is only a small part of the overall volume of the finished component. Certain materials suggest themselves, for example, ceramics, organic films, or metal foils.

One of the main problems in the fabrication of an encapsulated electronic component is in the formation of a reliable bond between the external lead wires and the primary electrode areas of the basic component. It must be of low electrical resistance and have good mechanical strength. There are difficulties associated with the bonding of conductors to aluminium films, particularly in view of the ever-present oxide film.

The following bonding techniques have been used in this investigation, and the electrical results reported here apply to capacitors made with either of the methods outlined below.

(A) Electrode wires soldered to evaporated chromium-gold land areas connected to the aluminium electrode layers. This technique is suitable for maximum working temperatures between 150 and 200 degrees Celsius.

(B) Direct wire attachment to the aluminium surface using a silver conducting resin suitable for limited operating life at a maximum of 200 degrees Celsius. Alternative methods, such as flame-sprayed land areas suitable for soldering or microwelding are being examined.

A wide variety of encapsulation materials are currently available to meet the specialized requirements of the rapidly expanding field of electronic components. Such materials as silicone varnish, epoxy resin, and polytetrafluoro-ethylene, have been successfully used without any deleterious effect on the electrical performance of the silicon nitride film. In some samples, a protective layer of silicon nitride was deposited on the basic electrode/dielectric sandwich followed by a resin bath dip. Most of the samples employed for the electrical valuation were encapsulated in a silica-filled epoxy resin. This material provides a combination of desirable characteristics, those of low thermal expansion and low curing shrinkage coupled with good thermal stability and low water vapor absorption.

During processing, these encapsulated silicon nitride capacitors have withstood sustained temperatures of 200 degrees Celsius for more than 300 hours and thermal shock excursions of greater than 30 degrees Celsius per minute with no deterioration in their electrical properties.

9. Electrical Evaluation of Development Capacitors

The following electrical results were obtained on completed capacitors and are related to the behavior of commercially important capacitor dielectrics. Films having thicknesses of between 2000 and 6000 angstrom units were examined and gave a capacitance yield of from 0.035–0.012 microfarad per square centimeter respectively. Within this thickness range, all capacitors exhibited the same electrical sensitivity to changes in temperature, voltage, and frequency. During deposition of the silicon nitride, the film growth rate was monitored by the interference color of the film viewed perpendicularly in white light and checked during subsequent processing with a Michelson interferometer. In this way the growth rate was calibrated for a given set of deposition conditions and enabled film thicknesses to be controlled to within ± 3 percent.

9.1 Capacitance Measurements

Capacitance measurement data indicate that the dielectric constant obtained in our silicon nitride films is approximately 8. This is a considerable improvement over such materials as mica and the organic dielectrics.

In Figure 6 the change in capacitance with temperature over the normal operating range of a capacitor is compared with mica and ceramic (high-Q) capacitors. The mean temperature coefficient of capacitance over the full range from -50 to $+150$ degrees Celsius is 25 parts per million, that is, well within the limits of all commercially available capacitors. These measurements were obtained on several samples plotted continuously on an automated capacitance/temperature cycling bridge.

The capacitance is also very stable to changes in applied frequency, as shown in Figure 7, for measurements at 1-volt root mean square.

Both the temperature and frequency characteristics reflect the molecular and electronic stability of silicon nitride as deposited by the vapor-phase technique. For example, many dielectric materials exhibit a non-linear capacitance/temperature function at specific temperatures, which may be due to such factors as a change in composition or a re-orientation of lattice symmetry.

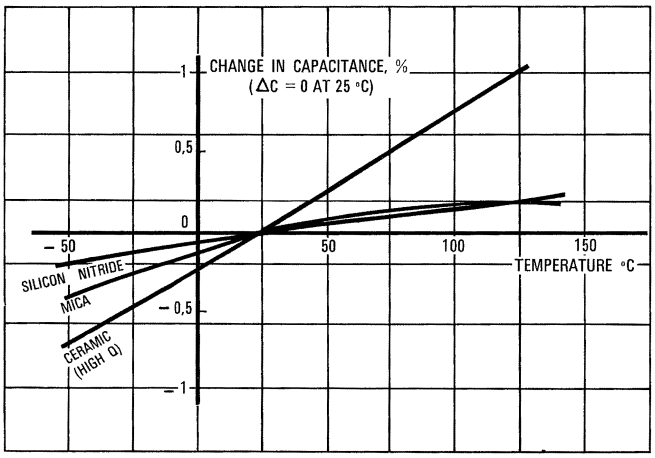

Figure 6 - Percent capacitance change with temperature from the capacitance value at 25 degrees Celsius.

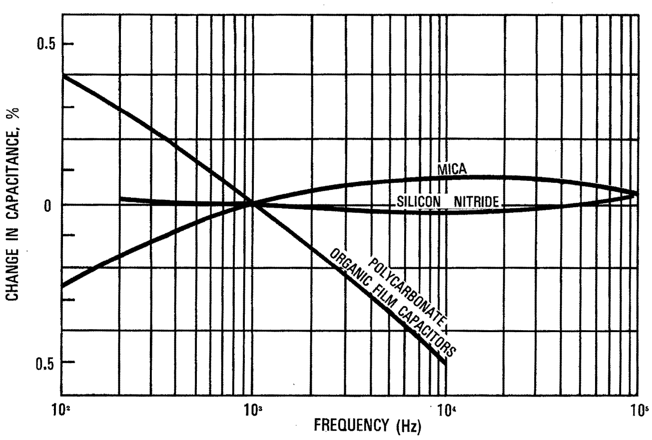

Figure 7 - Capacitance change with frequency.

The capacitance values are only slightly modified by the application of a direct-current field stress. For example, an increase in voltage from 10 to 50 percent of the breakdown voltage for a given silicon nitride layer decreases the capacitance by less than 0.5 percent.

9.2 Dissipation Factor

The measurement of the dissipation factor gives good indication of both the quality of the dielectric material and the electrode efficiency. Excellent values are obtained comparable with those of mica and polystyrene. Encapsulated capacitors have typical values of loss angle (tan δ) in the range 0.0002 and 0.0008 at 1-volt root mean square and a frequency of 10^3 hertz. As shown in Figure 8, minimum values are observed at around 4×10^4 hertz.

These values are satisfactory for practically all circuit applications.

A slight increase in dissipation factor occurs with rise in temperature, but this may occur as a result of surface strain introduced by expansion of the electrode and encapsulation material rather than due to a change in fundamental behavior of nitride layers.

The dissipation factor of silicon nitride is particularly low in comparison with anodic oxide and high-*K* ceramic materials which have values greater than 0.01. It is also low compared with glass dielectrics, where values of 0.0005 or greater are normal.

9.3 Insulation Resistance

Capacitors with a dielectric thickness of between 3000 and 4500 angstrom units were encapsulated and baked for 24 hours at 150 degrees Celsius to cure the resin encapsulant. Direct-current resistance measurements carried out at 50 volts showed a silicon-nitride resistivity of 10^{16} ohm-centimeters at room temperature. An increase in temperature of 100 degrees Celsius resulted in a resistivity decrease to 10^{14} ohm-centimeters.

The general behavior and stability of the direct-current resistance to changes in temperature indicates that, with suitable electrode, substrate, and encapsulation materials, a capacitor with a working temperature of 200 degrees Celsius is feasible.

The direct-current resistance of 0.01 microfarad silicon nitride capacitors is 10^{10} ohms at an applied voltage of 20 percent of the breakdown voltage. In the absence of burn-out regions in the dielectric layer, the silicon nitride capacitors are non-polar.

9.4 Breakdown Voltage

Capacitors tested to the irreversible breakdown voltage level indicated that the dielectric strength of silicon nitride $> 5 \times 10^6$ volts per centimeter. Minimum breakdown voltages for silicon nitride capacitors of various thicknesses are therefore as given in Table 2.

In realizing a high working voltage of at least 20 per cent of the breakdown voltage with such thin films it is obviously essential that at the critical stage of the electrode/dielectric formation the films be adequately protected from dust and other forms of impurity contamination.

Table 2
Capacitance and Breakdown Voltage of Silicon Nitride Layers

Silicon Nitride Thickness in Angstrom Units	Minimum Breakdown Voltage	Capacitance Yield in Microfarads Per Square Centimeter
3000	150	0.023
4000	200	0.017
5000	250	0.014
6000	300	0.011

9.5 Life Assurance Evaluation

Capacitors have been placed on a long-term aging test at various temperatures up to 200 degrees Celsius and at different direct-voltage levels. Preliminary results after several hundred hours show extremely little change in dielectric behavior; for example, a capacitance drift of less than −0.2 percent has been recorded.

10. Conclusion

It has been shown that films of inorganic insulators deposited from suitable gases in an electrodeless glow discharge can be used to make excellent capacitors. The ability to control the composition of these films within wide limits offers definite advantages over the sputtering and pyrolytic methods of deposition. Pin-hole-free films deposited at reasonable growth rates and under conditions of control are essential to meet the present and future demands of the electronic industry. This radio-frequency method of chemical reaction, which has been described, provides silicon nitride capacitors which meet these requirements well.

In addition, the films have very good stability to changes in temperature, voltage stress, and frequency.

In highlighting the main features of the silicon nitride capacitor, its ability to retain satisfactory electrical properties to a temperature of at least 200 degrees Celsius should be stressed. The potential high space factor obtained by the combination of a high dielectric constant and a thin film is also of considerable importance.

The current technological progress being made in plasma deposition processes should lead to the realization of capacitor manufacture on a continuous flow basis, with multi-layer units being fabricated at low cost in a single deposition unit.

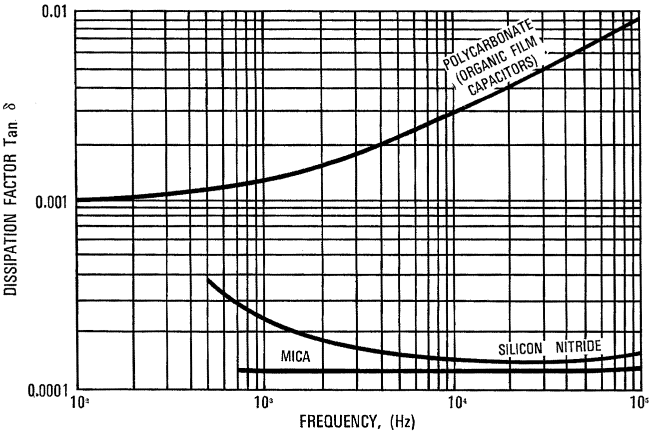

Figure 8 - Dissipation factor as a function of frequency.

References

[1] H. F. Sterling and R. C. G. Swann, "Chemical Vapour Deposition Promoted by R. F. Discharge", Solid State Electronics, volume 8, pages 653—654; August 1965.

[2] H. F. Sterling, J. H. Alexander and R. J. Joyce, "Deposition of Adherent Coating of Insulants in a Radio Frequency Glow Discharge", Le Vide, pages 80—94; October 1966.

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From 1960 to 1963 he was engaged on semiconductor research. In 1963 he joined the Capacitor Division of Standard Telephones and Cables to develop ceramic capacitors. Since 1965 he has been responsible for a study of plasma anodization and is presently engaged on developing deposition methods for the formation of inorganic dielectric capacitors.

H. F. Sterling was born in London, England, in October 1919. He joined the Yorkshire Dyeware Company in 1936. He served from 1939 to 1946 with the Royal Air Force on radar.

In 1946, he joined the Materials Division of Standard Telecommunication Laboratories. During recent years he has been concerned with the materials aspects of semiconductors, particularly silicon.

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Economic, Operational, and Technical Aspects of Modern Global Communication Systems

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1. Introduction

The growth of intercontinental communications rapidly reached an almost explosive level after laying the first 36-channel transatlantic submarine cable in 1956.

The availability of high quality instantaneous communication channels has set off a chain reaction in which satisfaction of present needs creates still further demand, so providing a powerful stimulus for increasing development of transoceanic communication networks. The means now available to satisfy this increasing demand are discussed in this paper by evaluating satellite and cable technologies within the framework of their capabilities, costs and relative advantages.

2. Historical Development of Cable and Satellite Systems

2.1 Early Beginnings

Communications, as we understand the term today, has its roots in the Industrial Revolution, from whence the tempo of life rapidly increased. The electrical telegraph, a wonder of its age, rapidly became established and it was not long before its bounds were extended beyond national limits. By the end of the 19th century a maze of telegraph cables traversed the ocean bed.

It was another quarter century, however, before transoceanic telephony became a reality, and as thermionic devices became more efficient, so a web of high-frequency radio circuits was woven round the globe, providing much of the basic network in service today.

Again, twenty-five years on, the first application of repeatered cables for transoceanic telephony was successfully demonstrated, and this medium has rapidly gone from strength to strength, supplemented in recent years by a new concept — satellites.

2.2 Transoceanic Telephone Cable Systems

Initially, most development effort concentrated upon improving communications over submarine cables, and as experience was gained, so wider bandwidths were exploited resulting in a generation of submarine systems from 36, through 80 and 160 to 360 channels capacity being evolved in the United Kingdom [1]. These systems relied upon valve techniques, since at that time the state of the semiconductor art was such that long-term proven reliability of solid-state devices was still being explored.

As it became clear that improved solid-state devices were able to fulfil the stringent requirements of reliability and long life demanded for submarine systems, designers and engineers were quick to seize upon these new techniques resulting in a second generation of wider-bandwidth, solid-state systems of 640-circuit capacity and development of systems of 1520-circuit capacity for applications in the early 1970's.

So, too, parallel development has taken place in the United States, resulting in successful valve systems of 36- and 128-circuit capacity, and newer solid-state systems employing wider bandwidths capable of accommodating 720 circuits. Research is proceeding into systems with capacities of over 2500 circuits for the mid-seventies.

In the ten years since the success of the first long-haul transoceanic cable link was demonstrated, a wide range of cable systems has been evolved, capable of satisfying the corresponding range of traffic demand over major world routes.

Figure 1 pictorially represents developments in transoceanic cable capacity.

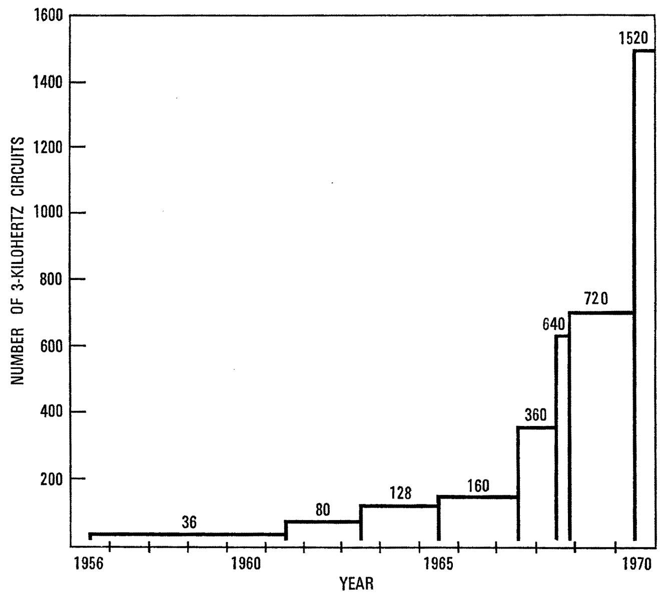

Figure 1 - Growth in available cable system capacity in circuits for transoceanic routes.

2.3 Satellite Communications

Success in the United States with early passive devices rapidly stimulated the concept of active communications satellites, with design parameters such as to allow for circuit capacities to be at least equal to those of existing cable systems. The success of the Telstar and Relay low orbit projects, through Syncom to Early Bird synchronous schemes has demonstrated the commercial viability of communications satellites, to the extent that the International Telecommunications Satellite Consortium (Intelsat) has now embarked upon the first phases of a global satellite system of the synchronous type which on completion in 1968, could make access and coverage available to most of the world's national networks.

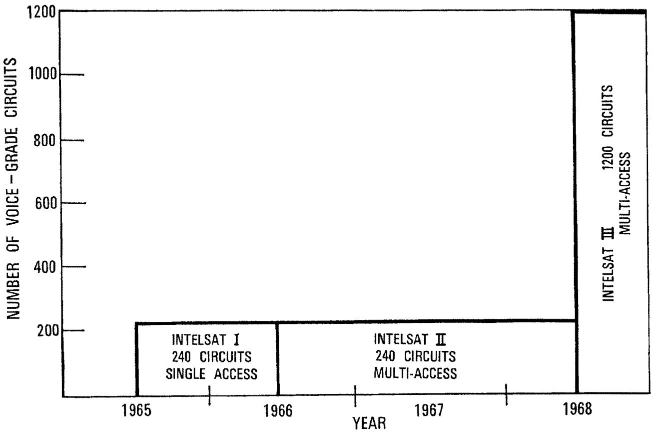

Figure 2 - Growth in available circuit capacity in satcom vehicles.

At present circuit capacity is limited, though adequate, by exploitation of 240 circuits; but successive phases of the Intelsat program, as shown in Figure 2, envisage circuit capacities of up to 1200 with multiple-access facilities in late 1968 [2].

2.4 *Integrated Systems*

Activity in each medium of communication has inevitably produced a highly competitive situation, in which merits and limitations of both cable and satellite systems can be argued at great length.

In the United States particularly, this competitive situation has been highlighted by the volume of argument and counter-argument brought before the Federal Communications Commission (FCC). Events have shown, however, that both media can co-exist, and, with reasoned thinking prevailing, recognition is now given to the fact that cables and satellites can each fulfill a specific role in provision of global communications.

Their complementary nature could be compared with a well established practice in countries with highly developed telecommunications where coaxial cable and microwave links are used to fulfill their specific role in an integrated internal network, each offering their advantages regarding economics versus required system capacity; ease of installation in difficult terrain and sensitivity to the congested frequency spectrum.

Whereas cable systems are expected for some time to cater for the more-orthodox and long-established modes of communications, satellites can find an application in supplementing these services, particularly in the more-sophisticated wide-band fields of television, networked computers and other data systems, or providing facilities for a relatively small number of circuits over very long intercontinental distances.

In the same way, designers of both systems can learn one from the other about the future application of integrated-circuit technology, digital-transmission techniques, and so on. These techniques, rather than narrowing the field, open up broader vistas for an integrated global communications network in which the cable and satellite media both play a balanced part.

3. Satellite Achievements and Limitations

3.1 *Success and Life Expectancy*

Any excursion into new sciences is bound to have its setbacks. Communication satellites are no exception, and valuable experience has been gained the hard way. With the rapid rate of technological advance that has been made in the satellite field in so few years, the margin of failure has been considerably narrowed, but disappointments have not yet been entirely eliminated.

The early low-altitude Telstar and Relay satellites performed a valuable function for the evaluation of system characteristics in a space environment and in practical demonstrations of transoceanic television transmission, but both satellites were short-lived.

The Syncom II and III vehicles presented no difficulties in attaining their prescribed positions. These two satellites enabled consolidation of previous experimental findings and demonstrated the commercial potential of communication satellites by United States Government Agencies, leading to the successful launch and commissioning of Early Bird.

Operated by the Communication Satellite Corporation (Comsat), the Early Bird satellite provided the first commercial 240-circuit space communication system in which a large number of nations (60 at the time of writing) have become active participants.

At the moment, Intelsat is building on foundations of experience gained with the Syncom and Early Bird satellites to study the problems of multiple access and other factors unique to the satellite mode of communication, backed up by a National Aeronautics and Space Agency (NASA) experimental program being conducted by means of Applications Technology Satellites (ATS), in which evaluation of antenna types, frequency spectra for specialised services, and kindred problems are forming a major part of the program. The data obtained will be of value in the determination of the basic space vehicle parameters embodied in later generations of Intelsats.

Comsat have already shown their confidence in the increasing longevity of satellites as Table 1 will show, the mean time to failure (MTTF) having been extended from 18 months to 5 years over 3 successive generations of Intelsat vehicles.

Table 1 – Life and success probability of Intelsat synchronous satellites: after Comsat [2]

Satellite designation	Circuit capacity (Bothway)	Life (MTTF) years	Launch & operational success probability	Failure rate for successful launches
Intelsat I (Early Bird)	240	1.5	—	—
Intelsat II (Lani Bird etc.)	240	3	0.75	0.25
Intelsat II (Squinted antenna)	240	3	0.75	0.25
Intelsat III	1200	5	0.75	0.25

It is worth remarking that some schools of thought have predicted a 0.95 probability of launch success for later generation satellites.

3.2 Subjective Reactions to Satellite Circuits

Without question, the success of the Intelsat program so far has made considerable impact upon the whole concept of transoceanic communication, but the fruits of success are beginning to become marred by a number of limitations.

Paramount among these are the questions of transmission delay and echo. To the tutored ear of the communication engineer, these effects may seem of little significance when weighed against the overall advantages of the satellite system, but what is the end-user reaction? The public as a whole is not prepared to accept an abstruse explanation when calls, say, from New York to London, "don't sound right somehow"!

Two series of subjective tests on both sides of the Atlantic in 1964 (using simulated delay) and 1965 (via Early Bird) have shown that there is a marked end-user reaction to long-delay-time circuits [3].

With the facilities of Early Bird available for the second series of tests, comparison was made between satellite circuits and random cable circuits using Time Assignment Speech Interpolation (TASI) and non-TASI techniques.

Results showed that there was little statistical significance between the amount of difficulty experience on either type of cable circuit, but there was considerable significance in the differences between cable and satellite circuits. This is evident from Table 2 which gives results of the experiment for a sample without any special precautions being taken [3].

Table 2 – Subjective result of sample end-user opinion of transatlantic circuits

Transmission quality	End-user rating	Cable circuits	Satellite circuits
Satisfactory	Excellent/ Good	87 %	77 %
Unsatisfactory	Fair/Poor	13 %	23 %
Total number of samples		1294	1335

Introduction of echo suppressors on both types of circuit led to the conclusion that the transmission quality over such circuits decreases with increasing delay. Different types and combinations of suppressors used in the tests produced similar results.

It was also shown that end-users tended to disregard previous experience of satellite circuit calls, opinion being based upon circuit conditions prevailing at the time of the sampling.

These tests provided a useful insight into the end-user's likes and dislikes, and tend to indicate that the public will only accept a decrease in transmission quality of up to a certain degree, which could make satellite circuits marginally unpopular.

3.3 Emerging Limitations

A number of factors can be quoted to illustrate the present limitations of the satellite medium.

a) The first live television transmission from Australia to the UK relied upon cable facilities for the sound channel since only limited bandwidth was available at the Carnarvon ground station. Therefore to cater for multi-purpose traffic, wide-band transponders are an essential element of the satellite ground terminals.

b) With the present tariff rates, European Broadcasting Administrations find it less costly to record transatlantic television programs by slow-scan techniques over cable circuits, though "hot" news can be transmitted live by satellite.

c) Arising from b), it is noteworthy that from commissioning to end 1966, Early Bird had only carried about 250 hours of actual television program time [4].

d) Preliminary reports indicate that to reduce the delay and echo problems, a United States domestic satellite network may provide only a "go" path, the "return" path being accommodated in a terrestrial system.

e) As microwave networks expand, it is becoming evident that signaling difficulties are being experienced, (and satellites *are* microwave devices) which could give rise to concept of "bypath" signaling channels via alternative media.

f) Since satellite systems share the same frequency allocation as the terrestrial microwave networks, special precautions are necessary in selecting a suitable location for the ground terminal to minimise mutual interference. This often results in the building of the ground station some distance from the main traffic centers, and the necessity for specially engineered land tail systems for interconnection of the ground terminal with the existing trunk network.

g) Perhaps the most important limitation of space communications as planned today is the need to abandon existing satellites and replace them with larger bandwidth satellites long before the end of their projected life span. Such premature obsolecence due to technological advance is likely to considerably increase the total investment in the space segment, which in turn must be reflected in the levels of satellite utilisation charges.

4. Cable Systems: Achievements and Limitations

4.1 Cables Lead Trend in Global Traffic

The last decade has witnessed a massive upsurge in the demand for communication facilities. Commencing within national networks, the rapid increase in demand soon spread to international level, resulting in what is popularly termed the "communications explosion".

Under pressure of demand for international facilities, existing high-frequency links became inadequate on major transoceanic routes, and it was the timely advent of repeatered submarine systems which pointed the way of future trends.

The first transatlantic cables, considered of adequate capacity at the time of planning, stimulated, rather than satisfied, the public demand so that facilities were saturated within twelve months of becoming operational.

This pattern has been repeated throughout the world, wherever cables have been provided. The reduction of channel bandwidth from 4 kilohertz to 3 kilohertz and the application of TASI has, in many cases, proved to be a palliative but not a solution.

Increasing annual traffic growth rates have been recorded, and the average duration of the call considerably increased.

Table 3 clearly demonstrates the effect that cables have made upon international traffic.

Table 3 – Growth in international telephone traffic

Country	Annual percentage increase in international traffic					
	1960/1	1961/2	1962/3	1963/4	1964/5	1965/6
United Kingdom	3.5	11.3	12.8	11.3	22.7 (2)	21.4
United States	25.6 (1)	11.8	18.7	16.2	20.3 (2)	26.0 (3)
Japan	9.0	8.0	10.0	13.8	48.0 (4)	38.1
Australia	7.7	1.5	36.3 (5)	48.1	73.9 (6)	33.2
New Zealand	24.5	11.8	85.0 (5)	76.7	55.7 (6)	29.5

(1) TAT-2 to European Mainland in Service
(2) TAT-3 to U. K. in Service
(3) TAT-4 to European Mainland in Service
(4) TRANSPAC Japan—USA in Service
(5) COMPAC Australia—New Zealand in Service
(6) COMPAC New Zealand—Canada in Service

4.2 Present and Forward Planning

The achievements in submarine-systems technology are already widely known, and are comprehensively documented throughout the world. It is sufficient to say, therefore, that although in the time scale submarine systems have not made the spectacular impact on the world as have satellites, their usefulness in knitting countries closer together in commerce and political understanding continues to proceed in a quiet, though relentless, way.

Designers and engineers, by applying modern component techniques, have already extended multifold the capacity of the submarine cable systems.

The British Post Office, together with British industry, are moving ahead in the development of solid-state systems of 12-megahertz bandwidth for the late sixties [5]. Such a system will be capable of accommodating 1520 channels over route lengths up to 4000 nautical miles.

Thinking in the United States is already directed towards systems with 20-megahertz bandwidth capable of accommodating some 2500 channels to be available in the mid-seventies.

Beyond these bandwidths, however, economic factors may dictate a transition from the traditional frequency-division-multiplex techniques to digital transmission. Land systems of 224-megabit capacity have already been shown to be feasible, and with the rapid advance in digital technology, it would be relatively easy for the submarine-systems designers to adapt the art to their particular field.

Whatever is the final mode of transmission, still wider-bandwidth systems will be planned when demand for such facilities are identified.

So, in this way, the versatility of submarine cables could increase, rather than diminish as pessimists predicted at the dawn of the satellite era.

4.3 Limiting Factors

A clear distinction must be drawn between the application of submarine-cable systems and their satellite counterparts.

Essentially, submarine-cable systems can only, in the first instance, provide a point-to-point transoceanic link; reliance being placed upon the adequacy of interconnecting tail facilities to extend multi-destination service. On the other hand, satellite systems possess the capacity for multi-point-access as an inbuilt characteristic of their design; though the provision of small bundles of circuits may prove expensive by this means.

Because of differing methods of investment in the two media, as discussed in Section 5 of this paper, the provision of cable systems necessitates a larger initial capital outlay than do satellites.

It is therefore important that manufacturers provide cable systems at an attractive cost level per mile, taking account of the two interdependent factors forming the principal limitations for transoceanic submarine cables, namely hardware cost and system topography.

Cost, naturally, can vary quite widely depending upon route length and system capacity, and this aspect will be discussed later. In examining the limiting factors for cable systems however, this final cost aspect is germane to this present discussion, since it is governed, in the main, by technical considerations.

As the capacity of cable systems increases, so a number of basic factors become increasingly important, viz:

a) repeater spacing
b) system equalisation
c) cable parameters
d) power supply.

Factors a), b) and c) are all interdependent, and are direct functions of the system capacity.

Increasing bandwidth necessitates shorter repeater sections, so increasing both the number of submerged repeaters and equalisers required. There is a limit to which one can go before the system becomes uneconomic on account of the shortness of repeater-section length.

It follows then that, for wide-band cable systems above, say, 600 circuits, attention must be paid to the design of the cable, since the attenuation per unit becomes an increasingly important factor.

At the present time, the British-designed 0.99-inch (25.2-millimeter) lightweight cables are, in general, suitable for all deep-water applications up to 640 circuits, but for systems of greater bandwidth, designs of cable of lower attenuation per unit length, and hence larger diameter, are necessary [5].

A design of 1.5-inch (38.1-millimeter) cable is now available for the new generations of systems with capacities in excess of 640 circuits.

Unlike satellites, cable systems cannot rely upon solar power as a supply source. Inevitably, at the present state of the art, repeaters require power to be fed over the cable from the shore terminals.

The constant-current feed methods at present in use often require voltages of several kilovolts to be applied at the terminal ends, and introduce the problems of surge protection for the repeaters under open-circuit cable-fault conditions. In order to keep both the applied voltage and surge risk at a manageable level, limits have, of necessity, to be applied to the route length and intermediate landing points are normally chosen, should the terminal stations be more than about 4000 nautical miles apart.

The lower-current requirements for a transistor system help with this problem, although complex transistor-protective circuits are required in the repeaters to ensure long life span of the transistors.

5. Comparative Evaluation of Satellite and Cable Communication Media

5.1 System Economics

One of the most difficult areas of comparative evaluation of satellite and cable systems is the field of system cost. The cost parameters are well defined in the case of submarine-cable systems, but need a considerable degree of qualification and an appreciation of the different entities involved in the ownership of the satellite system.

5.1.1 Capital Involvement in Satellite Communication Investment

With the progress in development of operational satellite communication systems, it is becoming somewhat easier to determine the pattern of capital costs, and the areas of capital investment and ownership of the satellite systems.

Early cost analysis tended to project a simplified, and often misleading, picture through concentration on cost of either the space segment or ground terminal part of the system.

It is essential to recognise the interests involved in the ownership and operation of the present satellite system within the framework of Intelsat.

The ownership of the space segment, i. e., satellites as placed in their correct orbit, resides in an international consortium of 60 nations known as Intelsat.

At present, Comsat owns 52 % of Intelsat and is its manager. In addition, Comsat owns 50 % of United States ground terminal stations, the other 50 % being shared by United States Common Carriers in accordance with an agreed formula based upon the present and future traffic needs of a given Common Carrier.

Administrations outside the United States have to contribute their share of the Intelsat capital expenditure in addition to the investment connected with the provision of their local ground terminals.

Also, all Common Carriers or Administrations have to lease the space segment facilities from Intelsat on rental based on the number of circuits used.

Thus, the capital costs involved in establishing satellite communication links are made up of two basic parts:

— a pro rata payment to Intelsat proportional to the participating Administrations shareholding and varying in sympathy with Intelsat capital investment.

— the capital cost of ground terminal(s).

5.1.1.1 Space Segment Costs

Limiting our considerations to an international satellite system of Intelsat type only, the present anticipated total capital expenditure over 1966—1971 period, as given in Comsat report [2], is shown in Table 4.

Table 4 – Planned Intelsat investment in thousands of dollars

Year	Total annual investment
1966	39 595
1967	40 251
1968	60 386
1969	35 937
1970	9 266
1971	1 459
	Total 186 894

The above investment projection through 1971 does not include further capital investment arising from the planned Intelsat IV programme, which will be in the order of a further $100 million.

The total Intelsat investment will be shared by the International Consortium of the participating member organisations who, in turn, will derive financial benefits arising from exploitation of the space segment through leasing of the satellite channels.

5.1.1.2 Ground Station Costs

A typical cost for a ground station equipped with an 85-foot (26-meter) antenna capable of ultimately handling up to 600 voice-grade circuits is at present in the order of $6 million [2].

This capital cost is made up by:

— buildings and equipment 92 %
— land 3½ %
— precommissioning interest 4½ %

Simpler stations, employing antennas of 42- to 45-foot (13- to 14-meter) diameter, and capable of handling up to 240 voice-grade circuits are also available either as fixed or transportable units.

Typical costs for such stations are:

— fixed $3.0 million
— transportable $1.9 million

Whilst offering a lower capital outlay, this type of station possesses the inherent disadvantage of lower antenna gain and limited capability which, in turn, has a direct effect upon operating costs.

A 42-foot (13-meter) ground-station antenna requires an effective satellite power 6.5 times that of a standard 85-foot (26-meter) station and, in consequence, a similar increase is made to the payment to Intelsat for the use of the space segment per voice channel operated through a smaller ground terminal.

5.1.1.3 Overall Capital Involvement

An example of overall capital investment can be drawn from Comsat estimates [2] as given in Table 5.

Table 5 – Planned Comsat capital investment in satellite systems for 1966—71

Expense details	$ Millions
Cumulative annual capital payments in space segment to Intelsat	95
Capital investment in ground station construction and improvement	37
System development and research and development costs	40
Miscellaneous plant and buildings	5
Total investment	177

Similarly, capital investment by any other Administration can be evaluated taking into consideration its shareholding in Intelsat and its plans for ground terminals.

5.1.2 Capital Involvement in Cable Investment

Submerged repeater cable technology is over twenty years old and cost parameters are, by now, very well defined.

By the very nature of cable systems, the capital costs vary directly with system capacity and route length.

In applying typical values, it is convenient to express the installed capital cost in terms of either system miles or circuit miles.

Table 6 shows some typical costs for modern long-haul systems taken between terminal stations terminating at supergroup distribution frames, while Figure 3 presents the same data pictorially.

Table 6 – Typical installed costs for long cable systems (over 2000 nautical miles)

Approximate system bandwidth in megahertz:	1	3	5	12
System capacity (3-kilohertz circuits)	160	360	640	1 520
Cost per system nautical mile in dollars	8 800	12 250	16 000	19 750
Cost per circuit nautical mile in dollars	55	35	25	13

Unlike the satellite approach, once a cable system has been installed and commissioned, no further capital outlay for the system is involved. (Any additional capital cost of multiplexing equipment in order to augment service would fall into the category of tail costs, equally applicable to either cable or satellite media).

It can be seen from Table 6 that a transatlantic 5-megahertz cable system providing 640 voice-grade channels would, in fact, involve some 5 times more capital investment than the provision of two ground stations for operation with a satellite system providing 600 circuits.

To the advocates of cable systems this fact, on first sight, appears daunting, but seen in broader context, as illustrated by the following analysis of operational costs and long term financial benefits, it is clear that cable systems are more than competitive.

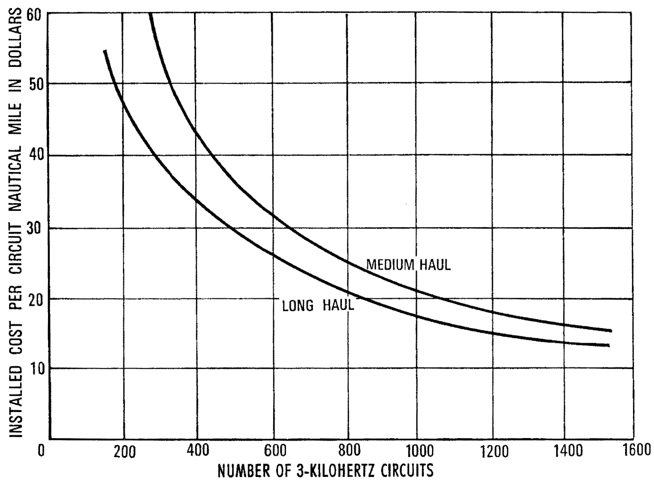

Figure 3 - Typical installed costs/circuit nautical mile for cable systems.

5.1.3 Evaluation of Capital Investment for Each Medium

As indicated in the preceding sections, a different form of capital investment is required for submarine cable and satellite systems, coupled with the direct share in the ownership of the communication facilities.

In the case of submarine cable systems, the operating agencies are also owners of the facilities, and, having contributed initial capital outlay, they enjoy complete control of the communication medium together with all the resulting revenues arising from the exploitation of that medium.

On the other hand, participation in the satellite communication link, although normally involving smaller capital contribution, places the operating agency in the position of an agent who has to deal via a principal entity (Intelsat in this case) to provide the overall communication facilities. Because of the intermediate entity involved, considerable expense is associated with hiring facilities owned by Intelsat, and therefore the financial returns are correspondingly reduced.

Thus, the comparison of the capital investment does not provide any meaningful information regarding relative economics of the two alternative communication methods unless operation and maintenance costs are also involved in the evaluation.

5.2 Operational Aspects

5.2.1 Derivation of Operating Costs

The annual operating costs for transoceanic links may readily be assessed in terms of the capital cost of the system.

Typical values are computed in Table 7 with assumed 10-year time scale for ground stations and 20 years for cable systems.

Participants in a satellite system would also pay a recurrent annual charge for the use of the space segment, designated as x in Table 7. This payment is a direct multiple of the number of circuits operated, expressed as units of satellite utilization.

Table 7 – Annual operating cost mix for transoceanic systems as percentage of capital cost

Item	Cable system	Ground stations
System operation & maintenance	3 %*	10 %
Depreciation	5 %	10 %
General & administration	1 %	1 %
Interest	6 %	6 %
Charge for use of communication medium	—	x
Total	15 %	27 % + x

* On long transoceanic cables this figure is somewhat lower. While recently published figures for TAT-1 to TAT-4 costs were 2.8%, the estimated maintenance costs of the projected TAT-5 wideband system is only 1.2%.

The proposed annual rates payable by the ground terminal operating agency to Intelsat per unit of satellite utilization have been tabled as [2]:

	1967	1971
Standard 85-foot (26-meter) ground station	\$ 20 000	\$ 9 000
42-foot (13-meter) ground station	\$ 130 000	\$ 58 500

It is anticipated that the above charges will be further reduced in succeeding years; though the actual extent of these reductions will be critically dependent upon future Intelsat capital involvement in the establishment of new systems such as the Intelsat IV network.

From the foregoing, it is clear that in the case where only a small bundle of circuits is required in a satellite system, the basic ground station operating costs would far outweigh fees for use of space segment. This is illustrated in Table 8, while Figure 4 shows a plot over the complete range.

Table 8 – Ground station contribution to satellite system operating cost (85-foot antenna – 600 units of satellite utilization maximum capacity)

Basic parameters: Capital cost of station (A) \$ 6 million
Annual operating cost (Table 7) 27 % A.
Payments to Intelsat \$8000 per unit of satellite utilization

Number of units of satellite utilization:	40	100	300	600
Annual operating cost of station (\$ Million)	1.62	1.62	1.62	1.62
Annual payments for space segment (\$ Million)	0.32	0.80	2.40	4.80
Total (\$ Million)	1.94	2.42	4.02	6.42
Percent contribution by ground station	84 %	67 %	46 %	25 %

Typical operating costs per system nautical mile of terrestrial distance may be derived for both cables and satellite links from assembly of the data in Tables 6 to 8.

These costs are set out in Tables 9 and 10.

The costs may also be readily expressed in terms of operating costs per circuit nautical mile and Figures 5 and 6 set forth comparisons between the two media on this basis, taking the space-segment charge currently in force (\$20000 per unit of satellite utilization), and a projected mean-future value of \$8000 per unit of satellite utilization respectively.

Figures 5 and 6 also indicate the effect of the space-segment charge upon the annualized costs and demon-

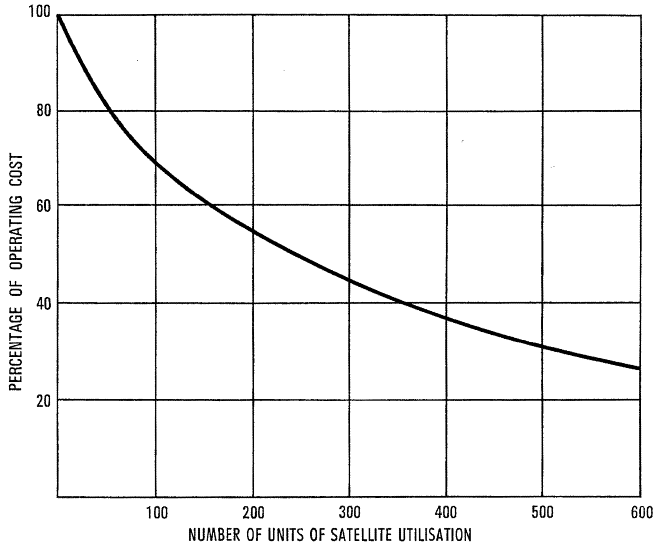

Figure 4 - Contribution by ground station to operating cost of satellite system (85-foot [26-meter] antenna — 600 units of Satellite utilization capacity).

Table 9 – Typical operating costs for cable systems

System bandwidth (MHz):	1.0	3.0	5.0	12.0
Circuit capacity (3 kHz)	160	360	640	1 520
Installed cost per system nautical mile in dollars	8 800	12 250	16 000	19 750
Annual operating cost per system nautical mile in dollars (at 15 % of installed, Table 7)	1 320	1 840	2 400	2 960

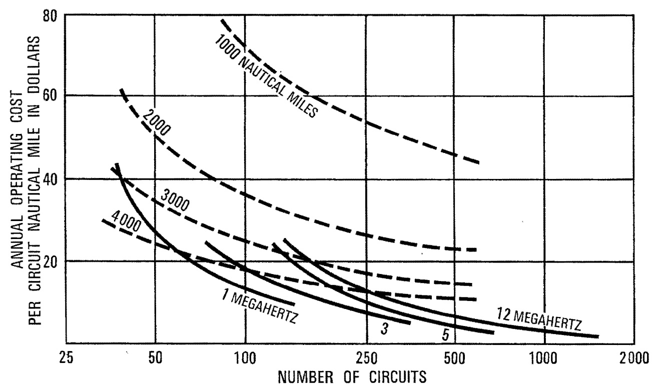

Figure 5 - Annual operating cost/circuit nautical mile. (based on present Intelsat utilisation charges). Solid line is for cable by system bandwidth Broken line is for satellite by terrestrial distance at \$20000 per unit of satellite utilization for this space segment.

Table 10 – Typical operating costs for satellite systems

Number of units of satellite utilization:	40		100		300		600	
Annual operating cost for 2 ground stations ($ Million)	3.24		3.24		3.24		3.24	
Payments to Intelsat ($ Million)	Current	Future	Current	Future	Current	Future	Current	Future
Up-link at $20000 per unit of satellite utilization (1967)	0.80	—	2.0	—	6.0	—	12.0	—
Up-link at $8000 per unit of satellite utilization (future)	—	0.32	—	0.80	—	2.40	—	4.80
Down-link at $20000 per unit of satellite utilization (1967)	0.80	—	2.0	—	6.0	—	12.0	—
Down-link at $8000 per unit of satellite utilization (future)	—	0.32	—	0.80	—	2.40	—	4.80
Total annual costs	4.84	3.88	7.24	4.84	15.24	8.04	27.24	12.84
Cost per system nautical mile in dollars when terrestrial distance is:								
1000 N. M.	4840	3880	7240	4840	15240	8040	27240	12840
2000 N. M.	2420	1940	3620	2420	7620	4020	13620	6420
3000 N. M.	1610	1290	2410	1610	5080	2680	9080	4280
4000 N. M.	1210	970	1810	1210	3810	2010	6810	3210

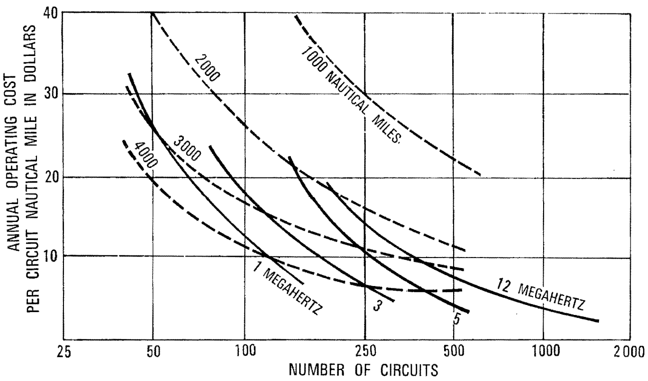

Figure 6 - Annual operating cost/circuit nautical mile.
(based on projected future utilization charges).
Solid line is for cable by system bandwidth Broken line is for satellite by terrestrial distance at $8000 per unit of satellite utilization for this space segment.

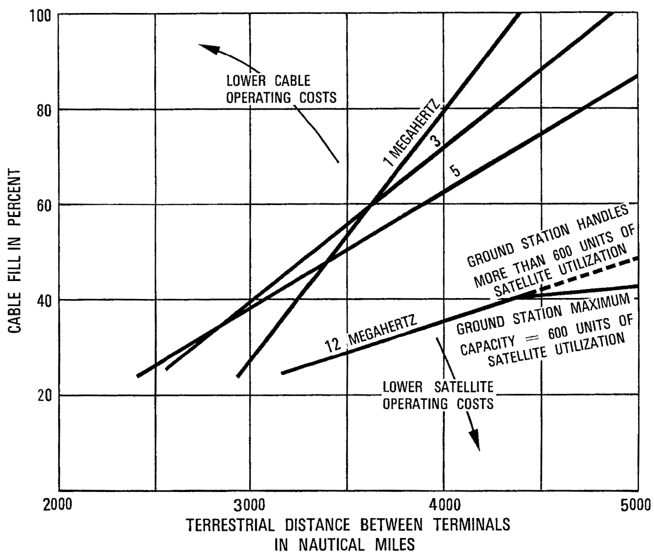

Figure 7 - Cable-fill requirement for equal cable/satellite operating costs based on future Intelsat charges for the space segment.

strate that, in general, cable systems would show better profitability over a wide range of point-to-point terrestrial distances.

5.2.2 Cost Equations by System Fill

Equating the costs given in the preceding Tables will enable a formula to be obtained which will give the practical cable fill factor necessary to provide a balance between the cost of operating a cable or a satellite system.

Figure 7 shows this equation in terms of cable fill versus terrestrial distance between terminals, and clearly demonstrates the economic advantages to be enjoyed from the operation of wide-band cable systems on long-haul routes of typical transoceanic length, even at relatively low factors of cable capacity fill.

5.2.3 Personnel and Training

Apart from the installation of the sea path of a cable system, the commissioning and subsequent management of the system require no specialised expertise beyond the basic principles of running any conventional transmission network.

Consequently, personnel trained in the maintenance skills particular to a land-based communications network can readily adapt to another branch of the same basic subject, and training of personnel becomes a simple, inexpensive exercise of extending an existing curriculum within the framework of the administration's training program. The same cannot be said for satellite techniques, which would almost certainly require start-up of a complete new wing within a training organization with the attendant high expense incurred in hiring expert personnel and the purchase of costly equipment.

An operating administration embarking upon a satellite solution for international access could find itself faced with a massive array of problems, so wide is the range of technical knowledge and skills required. Developing countries, whose reserves of indigenous expertise are limited may find their resources strained beyond the limit by the demands imposed by provision and management of the ground station. In these areas, a nucleus of external consultants and advisers, skilled in their respective arts, could provide assistance but such a scheme is normally very costly.

5.3 Technical

The rapid advance in the state-of-art of both cable and satellite systems has already been described. At this present time then, what has each to offer?

5.3.1 Satellite System — Parameters and Facilities

The establishment of the global satellite network from the initial Early Bird launch embraces three successive generations of satellites. Table 11 summarises the principal design parameters.

The transmitters in the orbiting vehicle have so far been relatively low power travelling-wave amplifier devices, in order to maintain an economic repeater efficiency/weight ratio, though the Soviet Union claim to have had a 40-watt transmitter operational in their Molnya type repeaters [6].

5.3.2 Terrestrial Hardware

Since the repeaters, of necessity, handle low level signals, a great deal of sophistication is built into the ground stations [7]. High transmitter power is essential, as is low noise temperature for the receiver. Large mechanical antenna structures are needed to optimize signal power ratios and give reasonable noise immunities. The ground terminal, therefore, consists of a considerable volume of apparatus essential to the working of the communication system itself, but not part of the physical communication path, viz:

a) sophisticated liquified-gas cooling of parametric amplifiers/masers;

b) electronic "look-on" control of antenna;

c) occasional weatherproofing of antenna system (pressurizing and heating of radomes);

d) special power supply arrangements;

e) complex control center;

all of which add significantly to the overall cost and maintenance complexity.

Present technology limitations imply the use of very large antenna structures of between 85-foot (26-meter) and 100-foot (30-meter) diameter. Smaller ground terminals are technically feasible, and are being used in the early global system, but operation of such terminals is considerably penalized as regards the charges for the use of the space segment (Section 5.2.1).

Because of this penalty all future major ground terminals are likely to embody the larger-diameter antennas. Also, to provide a degree of operational flexibility, adjustable antennas capable of working in East and West directions are likely to be specified in the future.

5.3.3 Cable System Parameters and Facilities

Modern wide-band cable systems, although essentially point-to-point links, provide all the facilities demanded by the communication carriers. Table 12 summarizes the principal parameters of modern cable systems, where it is seen that systems of 1500 to 2500 voice-channel capacity are currently under development and will be available for transoceanic-route application in the early 1970's.

Such large-bandwidth systems could accommodate, if required, redundancy-free video signals and will provide very large bandwidths for high-speed data transmission in addition to numerous voice circuits of excellent quality.

5.3.4 Reliability and Secrecy

Deep water cable systems have an excellent reliability record. Shallow water areas near the shore ends are subject to cable cuts by trawlers, but such breaks are easily repaired. In addition, new development by Bell Laboratories of a special plough to bury the shore ends of transoceanic cables has recently been announced, and this will remove the major cause of cable-circuit interruptions. The expected cable-system lifetime of 20 years may be surpassed in many cases.

Satellite system reliability is directly related to the satellite lifetime, and operational maintainability of the associated ground terminal equipment [4]. Present life expectancy for Intelsat III synchronous satellites is five years. Improvement on this figure is expected in the future.

Reliability of the satellite circuits can be provided at a cost by having redundant satellites in space. There is evidence that this solution is being accepted by Intelsat. While it provides security of communication facility, it is only attained at considerable additional capital investment in the space segment. Similarly, redundancy sub-systems are being introduced into the design of the critical ground

Table 11 – Developments in synchronous satellites

Designation	HS 303- "Early Bird"	F 1, 2, 3 "Lani Bird" etc.	Under construction
Intelsat No.	I	II	III
Manufacturer	Hughes	Hughes	TRW
Channel capacity	240 single access	240 multi access	1200 multi access
Amplifier	Linear IF 4–6 GHz	Linear IF 4–6 GHz	Linear IF 4–6 GHz
Bandwidth (Bothway)	50 MHz	125 MHz	500 MHz
Antenna system	Spin stabilised toroidal horn	4-Element biconical horn	Phased array
Antenna gain (min)	6 dB	6 dB	16 dB
Min E. R. P. (Effective Radiated Power)	+ 8 dBW	+ 14 dBW	+ 24 dBW

terminal equipment to secure high operational reliability of the overall communications links.

Finally, cable systems do not cause interference nor, in general, can they be interfered with. Since both satellite and terrestrial microwave systems utilise common frequency spectra, the question of mutual (or deliberate) interference and associated difficulties with selection of a suitable terminal site could arise. The problem of mutual interference can be overcome by suitable precautions [8], but with the present limitations of allocated frequency bands restraints on the use of microwave transmission facilities for land or space communications must be expected. Other forms of jamming fall within the scope of international law.

Whilst the legal aspects of the use of either medium fall outside the scope of this paper, it is worth mentioning that they are frequently reviewed by various international bodies [9] so that freedom of communication should not be impaired.

However, overall expansion of satellite communications will be limited unless an international agreement is concluded to allocate new and exclusive frequency bands in a range above 10 gigahertz.

5.4 Annual System Costs

Following a discussion of the capital investment, operational and technical aspects for the two modes of communication, an attempt is made to summarize the overall economic picture associated with ownership, operation and exploitation of the satellite and cable system.

This is done through an estimate of annual costs for an equivalent point-to-point communication facility based on "heavy" and "light" trunk routes of 600, and 80 voice-circuit capacity respectively.

The related annual costs for satellite systems are presented in Table 13.

Corresponding annual costs for submarine cable systems are given in Table 14. A comparison of the annual system expenditure is graphically shown for "light" trunk routes on Figure 8 and for "heavy" trunk routes on Figure 9.

Figures 8 and 9 clearly indicate the different basic mix of the capital and expense portions of the annual expenditure accounts, and dramatically indicate that a large proportion of the total annual cost in the case of Satcom system is the expense account payments to Intelsat.

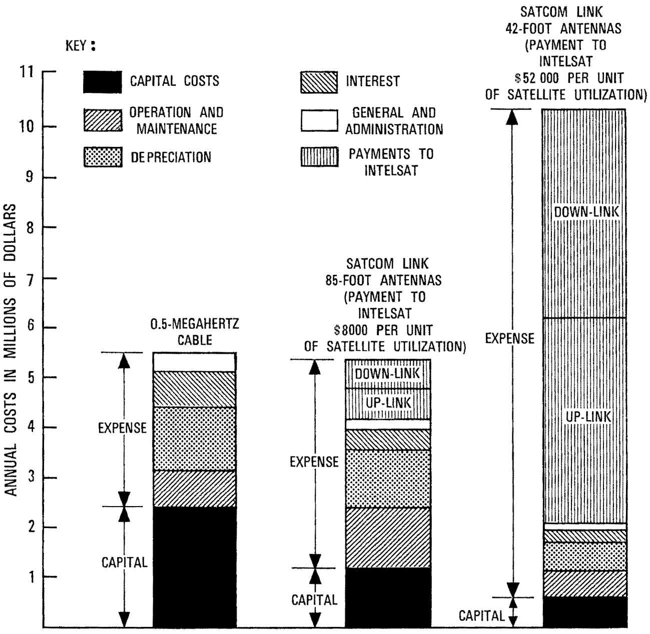

Figure 8 - Comparative annual cost mix for "light" transoceanic trunk route (2500 nautical mile).

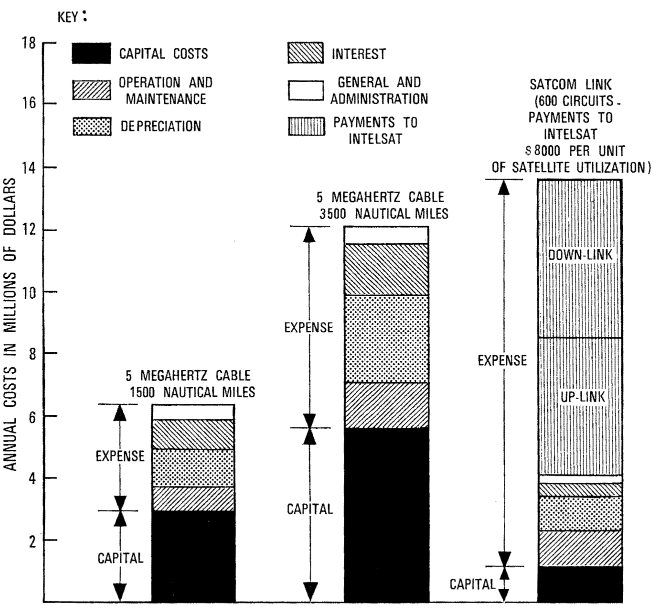

Figure 9 - Comparative annual cost mix for "heavy" transoceanic trunk routes (medium and long haul).

Table 12 – Modern oceanic submarine cable systems

System capacity (3-kilohertz voice circuits)	First used Year	First used Route	Cable diameter (inches)	Max. frequency (kHz)	Repeaters Gain (dB)	Repeaters Spacing (NM)	Line current (mA)	Repeater voltage
128	1963	TAT-3	1.00	1052	50	20	389	45
160	1965	Pencan	0.99	1164	50	17.3	415	86
360	1966	Atlantic test range	1.00	2964	40	9.5	500	55
640	1969	UK-Lisbon	0.99	4772	43	7.5	150	25
720	1968	Florida-Virgin Is.	1.50	5884	40	10	145	16
1520	Being Developed		1.50	12000	NA	7	NA	NA
2500	Being developed		1.50	20000	NA	5	NA	NA

NA = Information not available at time of writing.

Additionally, these diagrams clearly demonstrate the competitive standing of submarine cable links, when compared in the equivalent financial environment.

Because of the complex financial interplay involved with the satellite system, it is essential that all aspects of this structure are considered before a meaningful evaluation of the relative economics associated with cable and satellite systems is attempted. If this is undertaken, then results indicate that often there is very little difference between the economics of using cable or satellite circuits over routes of some 3000 to 4000 nautical miles length [10] although there are distinct and specific operational ownership and profitability advantages offered by the cable alternative.

6. The Present and Future Global Network

During the first eleven years of repeatered transoceanic submarine systems operation (1956—1966), the global network has grown from its first beginnings to the impressive total of:

65 000 route miles, inclusive of —
3 040 laid repeaters, and providing —
6 100 000 circuit miles.

Table 13 – Annual cost for Satcom system in $ million

	"Heavy" (600-circuit) trunk route (85-foot antenna)	"Light" (80-circuit) trunk route	
		(85-foot antenna)	(42-foot antenna)
Capital Account			
Capital cost of 2 ground stations	1.20	1.20	0.60
Modifications and improvements	0.01	0.01	0.01
Capital subscription to Intelsat (pro-rata to shareholding)	x	y	y
Expense Account			
Operating Costs:			
Operation: maintenance (10 %)	1.20	1.20	0.60
Depreciation (10 %)	1.20	1.20	0.60
Interest at 3 % average	0.36	0.36	0.18
General & administration (1 %)	0.12	0.12	0.06
Payments to Intelsat			
Up-link: 85-foot station, $ 8 000 per u. s. u.*	4.80	0.64	—
42-foot station, $ 52 000 per u. s. u.	—	—	4.16
Down-link: 85-foot station, $ 8 000 per u. s. u.	4.80	0.64	—
42-foot station, $ 52 000 per u. s. u.	—	—	4.16
Total annual costs	$13.69 + x$	$5.37 + y$	$10.37 + y$

* u. s. u. = unit of satellite utilization

Table 14 – Annual cost for cable system in $ million

	"Heavy" (640-circuit) trunk route		"Light" (80-circuit trunk route 2500 NM*
	1500 NM*	3500 NM*	
Capital Account			
Capital cost of system			
640 circuits, 1500 NM* $30 per circuit NM	2.41	—	—
640 circuits, 3500 NM $25 per circuit NM	—	4.82	—
80 circuits, 2500 NM $125 per circuit NM	—	—	2.16
Expense Account			
Operating costs:			
Operation & maintenance (3 %)	0.72	1.45	0.65
Depreciation (5 %)	1.20	2.41	1.08
Interest at 3 % average	0.72	1.45	0.65
General & administration (1 %)	0.24	0.48	0.22
Total annual costs	5.29	10.61	4.76

* NM = Nautical Mile

This vast global cable complex represents some \$700 million investment.

Through the employment of modern wide-band transistorized systems, this cable complex (Figure 10) will expand further as is dramatically illustrated by projects planned for the period 1967 through 1969:

	1966	Additional through 1969	Total	% Increase
Route miles	65 000	15 000	80 000	24
Circuit miles	6 100 000	5 900 000	12 000 000	96

The planned network additions represent a further \$75 to 80 million investment during the period 1967 to 1969.

Similarly, from the launch of Early Bird in 1965, the global coverage by satellite is growing rapidly until, in 1969, a network of six synchronous satellites will be available to provide the basis of a wide-band system accessible to most nations throughout the world.

The provision of the space segment of this network alone represents investment of some \$135 million before account is taken of the terrestrial equipment necessary to complete the link [2]. Further \$250 to 300 million will be invested in ground station facilities throughout the globe.

The growth of the global network can best be illustrated by summarizing the availability of international and intercontinental circuits in cable and satellite systems. Figure 11 develops this growth from the inception of the first transatlantic cable system in 1956 (when the extent of global network was some 1200 circuits) until end 1969, at which time known plans will provide capacity in excess of 20 000 circuits.

Looking further to the future, the year 1975 could see an integrated global network in excess of 70 000 circuits capacity, of which some 25% could be major intercontinental circuits.

Although forecasts for future traffic show wide variation, a general estimate for intercontinental circuits based

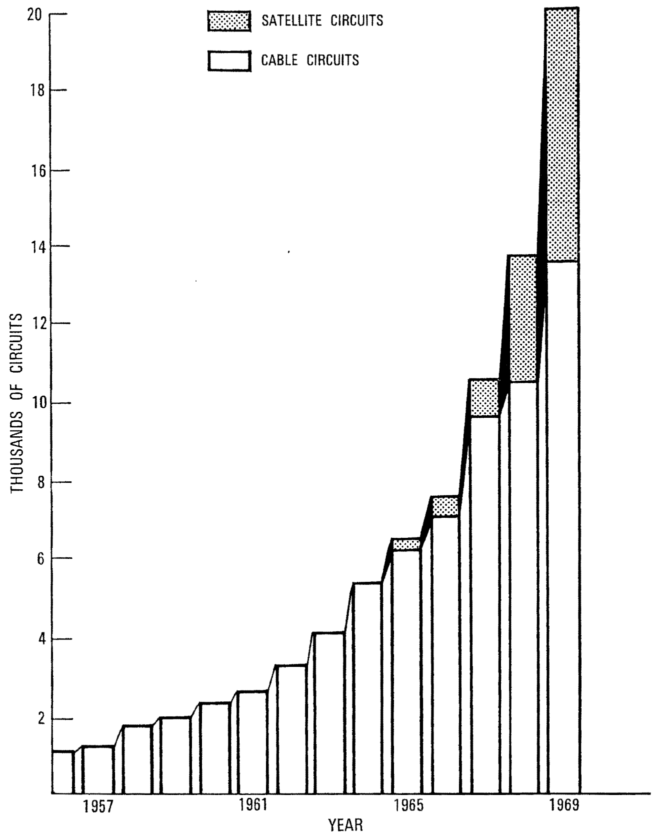

Figure 11 - Availability of voice-grade circuits in the global network.

upon our own work and current forecasts by a number of carriers and other bodies [11] is illustrated in Figure 12.

Requirements for facilities with a capacity of between 500 and 2000-plus voice circuits are identified over a complex crosspattern interconnecting major parts of the globe. To meet this large circuit demand while providing the accepted standard of high quality service at an economical level, all the development efforts in the field of cable and satellite technology will be needed, for both communications means will be used not only to satisfy currently identified demands, but also to stimulate further

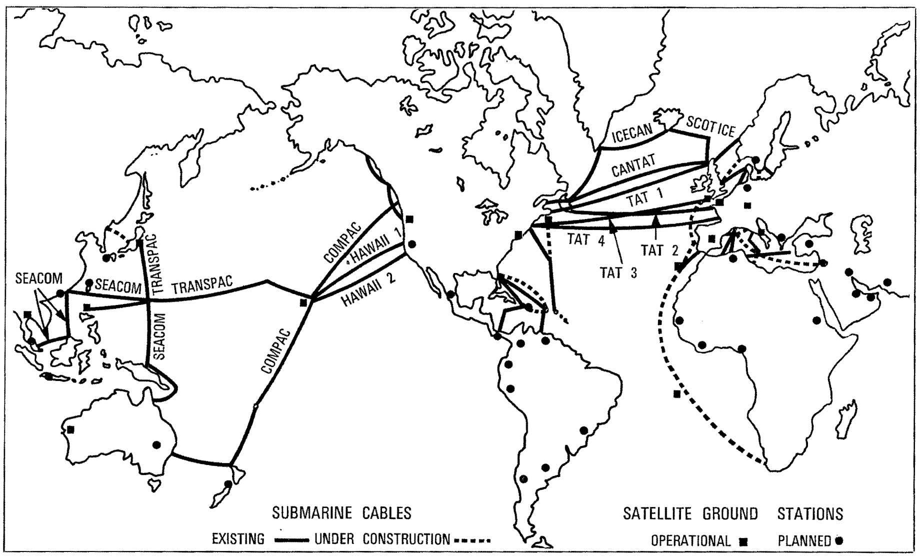

Figure 10 - Global submarine cable network and satellite ground stations.

growth in the increasingly flexible communications environment so created.

7. Conclusions

Just as in national networks, where both cable and microwave systems have been inter-married to form an integrated scheme, so events show that equal scope remains for cable and satellite systems in a progressively integrated global communication network.

Contrary to earlier thinking, the two media become more-and-more complementary in the operational, technical, and economic sense, rather than fiercely competitive, a fact recognized and borne out by recent statements of the Federal Communications Commission and independent bodies in the United States [10].

Technological advances will be equally reflected in future cable and satellite system design, and such systems will provide communication facilities to meet the expanding pattern of demand each with its particular area of application at economic cost levels, with resulting attractive profitability prospects.

The future, with its foundations for a comprehensive global network already laid, presents a unique challenge to all involved in the communications field. Great strides were made in the first half of the twentieth century. Even greater strides have already been made, and will continue to be made in the second, to ensure that the increasing demands for the communication facilities are satisfied, and that the new patterns of communications usage are developed to provide the most efficient communication facility — an essential and integral element of the overall progress of mankind.

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At present he is responsible for technical and economic studies of the international communication facilities and for evaluation of the requirements of future submarine-cable systems.

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He joined Transmission Group Market Research of Standard Telephones & Cables, London, in 1966. At present he is responsible for special studies in Submarine Systems Market Development Department, covering traffic, tariff and project studies, and system economic evaluations.

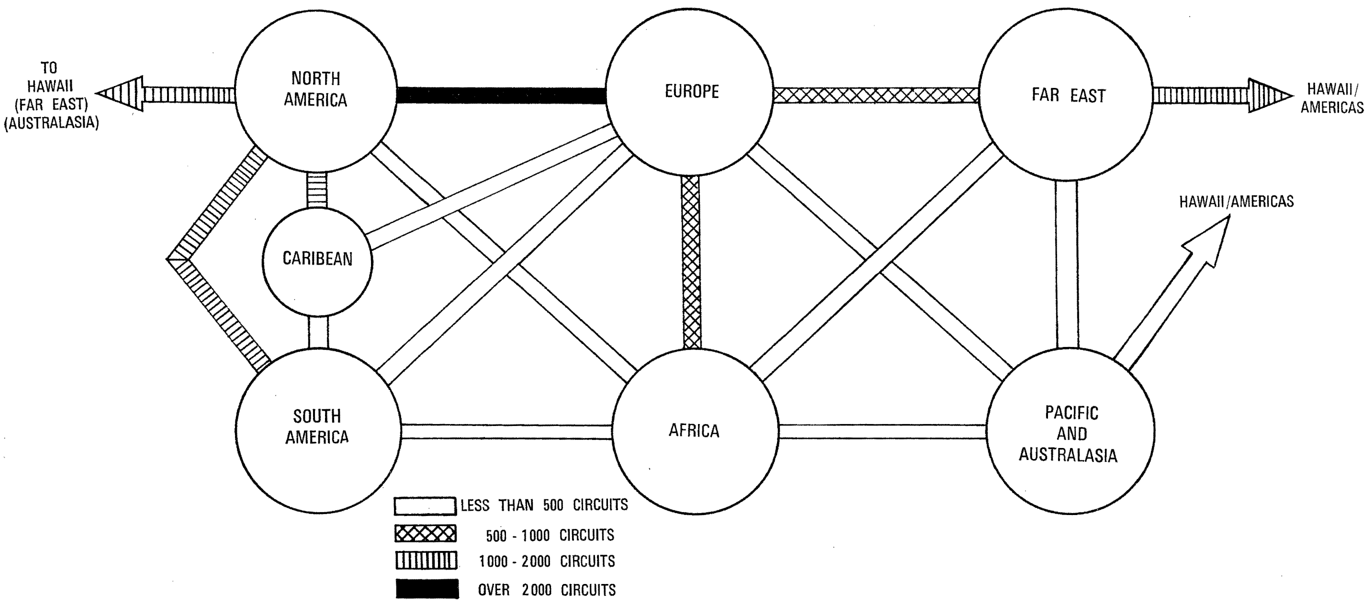

Figure 12 - Estimated extent of global network — 1975. (Intercontinental circuits).

United States Patents Issued to International Telephone and Telegraph System: November 1966 — January 1967

Between 1 November 1966 and 31 January 1967, the United States Patent Office issued 75 patents to the International System. The names of the inventors, company affiliations, subjects, and patent numbers are listed below.

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R. Bayer, Standard Telephon und Telegraphen (Vienna), *Circuit Arrangement for Loudspeaking Intercommunication Systems,* 3 283 077.

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F. A. Bekaert, Bell Telephone Manufacturing Company (Antwerp), *Call Transmitter,* 3 301 966.

W. Bergholtz and B. Krause, Standard Elektrik Lorenz (Stuttgart), *Trunk Group Supervision,* 3 294 921.

J. Bernutz and G. Sobel, Standard Elektrik Lorenz (Stuttgart), *Switching Arrangement for Contact Spring Strips,* 3 284 604.

E. Beyerle, Mix & Genest (Stuttgart), *Signal Evaluation Circuits,* 3 299 216.

J. N. L. Bezaguet and A. J. Judeinstein, Laboratoire Central de Télécommunications (Paris), *Data Storage System,* 3 300 624.

H. P. Birkemeier, ITT Bell & Gossett, *Pressure Relief Valve Having Means to Insure Full Opening Upon Failure of the Diaphragm,* 3 294 114.

M. Bohm, Standard Elektrik Lorenz (Stuttgart), *Method and Device for Distance Measuring with the Aid of Electric Waves,* 3 298 024.

T. L. Bowers, ITT Kellogg, *Expandable Printed Circuit Crosspoint Switching Network,* 3 291 914.

W. G. Brown, ITT Federal Laboratories, *Pulse Generator Employing Cascaded Counters and Coincidence Circuitry for Producing Plural Frequency Outputs,* 3 295 065.

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R. H. Clayton, ITT Industrial Laboratories, *Image Dissector with Field Mesh Near Photocathode,* 3 295 010.

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Non-Linear Decoder
3 298 017
M. L. Avignon and A. Y. Le Maout

A digital-to-analog decoder-expander has a non-linear characteristic derived by use of graded resistors forming the elements of a ladder attenuator. Constant-current generators are connected to given points on the attenuator. The decoded summation signal depends only on the precision of the resistors of the attenuator and not on the voltage supplied.

Expandable Printed-Circuit Crosspoint Switching Network
3 291 914
T. L. Bowers

A switching network is packaged to provide a minimum number of crosspoints regardless of the size of the network. The crosspoints are distributed over printed circuit cards. Each card, which has an inlet, is also provided with all the network components required to serve that inlet. Intercard cabling extends between cards in such a manner that all matrix components are brought together electrically, eliminating all intrastage cabling and large proportions of the interstage cabling.

Bonded Contacts for Gold-Impregnated Semiconductor Devices
3 300 340
N. A. Calandrello, J. Hill, and J. Royan

A semiconductor unit in which areas of a silicon dioxide protective layer are removed and a dopant is diffused into the body; Over this area is plated a noble metal, a second layer of nickel, and a third layer of solder. Contacts are then fused to the solder providing a rugged connection that can be mass produced.

Cylindrical Electro-Magnet
3 284 745
W. Grobe

A cylindrical magnetic core is provided with a meandering winding having conductors forming loops. The conductors are embedded in magnetic material extending parallel to the axis of the cylinder. The cross connections extend circularly concentric with the cylinder walls. Such magnets have a particular use in the control of a plurality of magnetic reed relays arranged circumferentially of the core.

Gas Separation Pump for Liquid Circulating Systems
3 290 864
J. H. Harker and J. Keyes

A pump, particularly for circulating hot water in a heating system, is provided in which separation of entrained gases to reduce noise of operation is effected in an improved manner. The detrained gas is guided into the static collection chamber of the pump so that the separation of the entrained gases takes place at the suction side rather than the discharge side of the pump.

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Caruthers, R. S., *Coordination of Product Goals and Research on the ITT System,* Semi-annual Meeting of Industrial Research Institute, Quebec, Province of Quebec, Canada, 9-11 October 1967.

ITT Industrial Laboratories Division

Article

Eberhardt, E. H. and Barr, F. H., *On the Elimination of the Lumen from the Responsivity Calibration of Photodetectors,* Applied Optics, volume 6, number 9, pp. 1575—1576, September 1967.

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Davis J. A., *Recent Developments in Cathode-Ray-Tube Display Techniques,* Seminar on Recent Advances in Display Media, National Aeronautics and Space Administration, 19 September 1967.

Gumnick, J. L. and Growe, K. R., *Enhancement of Photoelectric Quantum Efficiency on the Near Infra-Red,* Conference on Photoelectric and Secondary Electron Emission, University of Minnesota, 30 August 1967.

ITT Avionics Division

Article

Trolsen, G. H., *Macrocircuit Facility at ITT Federal Laboratories,* Solid State Technology, Volume 10, Number 7, pp. 54—56, July 1967.

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Dodington, S. H., *Mission and Traffic Control Systems,* University of California, Los Angeles, 18 September 1967.

Finocchi, A. J., *Panel Discussion on Microelectronics Reliability: Fact or Myth,* Symposium on Microelectronics Applications, Group on Aerospace and Electronics Systems, Institute of Electrical and Electronics Engineers, Garden City, New York, 21 September 1967.

Recent Achievements

More than 1 Million Lines in Crossbar — The number of telephone lines in crossbar for public exchanges and PABX's either installed by SEL or on order, exceeds one million. Thus, crossbar switching has proved satisfactory in the telephone installations of commercial and industrial enterprises as well as in those of governmental authorities in Germany and abroad, and in the German railway and post offices.

Standard Elektrik Lorenz AG, German Federal Republic

Television Transmitters for Sweden and West Germany — Sweden has ordered 10 transmitters for its second television network in Broadcast Bands IV and V. A nominal power rating of 40/8 kilowatts (vision/sound) is required of 8 installations and of 120 kilowatts for two transmitters. The Westdeutsche Rundfunk has ordered a 20/2 kilowatt transmitter. All these transmitters are of a new design.

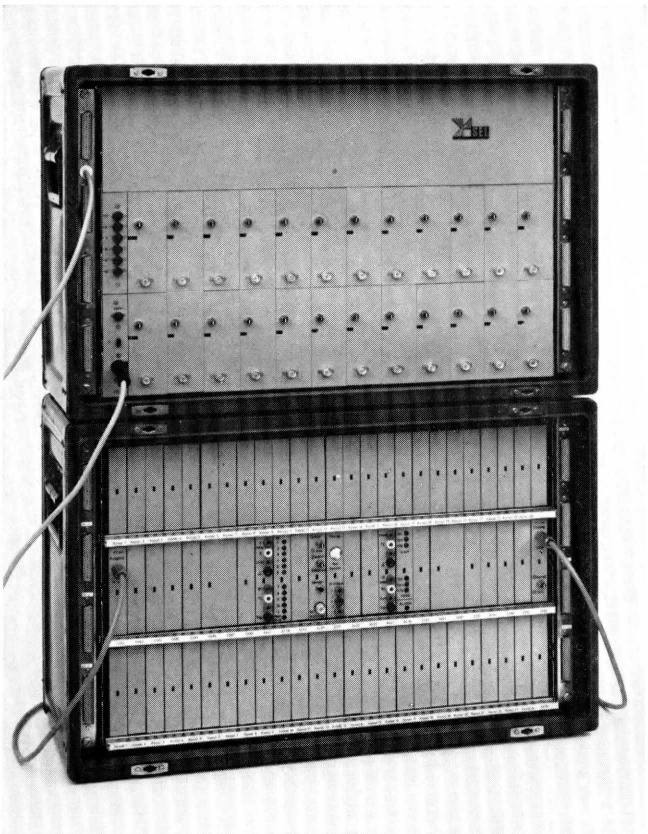
Standard Elektrik Lorenz, German Federal Republic

Pulse Code Modulation Provides Telephone Junction Circuits — In 1960 Standard Elektrik Lorenz was the first German company to complete an 11-channel mobile pulse-code-modulation system. It again enjoys this position with regard to a field trial in the Stuttgart local telephone network of a 24-channel pulse-code-modulation junction-cable transmission system.

Speech is transmitted over 24 time slots with a 25th time slot allocated to synchronizing signals. Non-linear encoding provides a companding gain of 24 decibels with a companding curve of 13 segments. The logic is made up of integrated circuits. Thin-film techniques are also used.

As shown in the Figure, the equipment is housed in portable boxes in the modular International Standard Equipment Practice. The upper box contains the power supply, relay sets, and hybrid circuits. The channel units of the transmit and receive sides are in the first and third subracks of the lower box respectively. The second subrack contains, from left to right, common units for transmit, alarm and test units, and common units for receive.

Standard Elektrik Lorenz, German Federal Republic



24-channel PCM junction carrier system.

Tantalum Capacitors Type TAG — The TAG solid-electrolyte tantalum capacitor was introduced in January 1965 with a capacitance range from 0.1 to 50 microfarads over a voltage range from 3 to 35 volts. Recent improvements have lowered the impedance, increased stability, reduced size, and permit capacitances up to 100 microfarads in the older size. The new rating is 300 microcoulombs.

Designed for radio and television receivers, its resin-dip encapsalution and radial terminal wires make it suitable for printed circuits. Its reliability has found it a place in measurement, control, and communication equipment. It is substantially smaller than an aluminium capacitor of equal rating.

Standard Elektrik Lorenz, German Federal Republic

ITT Data Service Opens in Stuttgart — In August 1967 a new company, ITT Data Service, opened a computing center in Stuttgart. It offers both computer time and programing services to business, technical, and scientific organizations. It operates 4 large and 2 small computers with the usual array of peripheral equipment. It is already handling data processing for Standard Elektrik Lorenz. Expansion to other cities in Germany is planned.

Deutsche ITT Industries, Freiberg, German Federal Republic

Receiver Featuring Solid-State TV Novel Circuit Techniques — At the 25th 1967 Great German Radio and TV Exhibition in Berlin, SEL presented a model of a black-and-white TV receiver which — with the exception of a 59-cm SELBOND® picture tube — uses only semiconductor devices as active components.

Of special interest is the VHF/UHF tuner, which is tuned by silicon capacitor diodes. A special circuit, which is amenable to integrated-circuit techniques, is used for the sound section. The horizontal deflection output stage is equipped with the thyristor BT 103 supplied by ITT Semiconductors-Intermetall. The power-supply section produces the 110 V set supply for the horizontal-deflection output stage, using a thyristor-controlled circuit without mains transformer.

Standard Elektrik Lorenz AG, German Federal Republic

German Research Satellite "Azur" — The purpose of this first German satellite is to study the inner Van Allen belt and the auroral zone, to measure changes in the emission spectrum of sun particles during solar eruptions, and to investigate the terrestrial magnetosphere.

The satellite consists of a cylindrical body with conical tips, and is provided with solar cells. It is in addition equipped with four antennas and a magnetometer, this latter being brought out at the lower axis. This space vehicle has a weight of approximately 100 kg (220 lbs) and uses a passive magnetic positioning system. Its target life is one year. It will be put into a high eccentric orbit (perigee: 300 km; apogee: 3400 km).

A number of large German companies are contributing to this project. Standard Elektrik Lorenz AG will supply electronic equipment for processing of digital scientific data during the planned experiments and for housekeeping measurements, as well as the low-frequency portion of the telemetry and command system.

Standard Elektrik Lorenz AG, German Federal Republic

Pentaconta® 32 Telephone System in Mexico — The Pentaconta 32 telephone system is built in units of 32 lines from the smallest size for 32 subscribers up to a maximum capacity of 3000 to 3500 subscribers, depending on traffic. The construction is 100 % plug-in; even the cabling is prefabricated and equipped with plugs. The equipment is mounted on small frames, built according to a module system, thus making it possible to choose for each circuit the most suitable size of frame. The frames are mounted in cabinets of a very rigid construction and equipped with protection against dust.

Because of the construction in small units and the extensive use of plug-in techniques, the installation time for the system is very short, about 2 to 3 hours per subscriber. For the same reason, the system is very flexible as regards number of lines, traffic capacity, and facilities, and it is possible to plan each exchange to conform with any specific requirements.

The first Pentaconta 32 exchanges have been in service in Mexico since the beginning of 1967 notably the 500-line exchange in San Miguel Allende, which is interworking with an existing exchange using multi-frequency code signaling.

Bell Telephone Manufacturing Company, Belgium

Miniaturized Main Distributing Frame delivered — The first miniaturized main distributing frame (MDF) has been installed in the Mechelen II exchange forming part of the Belgian RTT network. This exchange has a 10 000-line end capacity, and a frame module 3 m in length was therefore provided, equipped with 5000 test keys and 16 000 cable-pair connections. The cut over took place on 19 December 1967.

This equipment replaces an MDF of the former type 10 m in length, which was originally planned for this exchange. The installation took much less time than for the previous type of MDF. This was mainly due to the simplified cabling methods and the reduced number of hardware pieceparts used in the construction of the framework.

The RTT personnel have connected 10 400 cable pairs on the incoming side of the MDF and 5000 lines are connected as the starting capacity. It was the first time that the wire-wrapping method had been used for this work on both the cable side and the exchange side. The operators adapted themselves easily to the new jumpering rules.

The construction made it possible to meet all the unforeseen requirements, such as, for instance, the extra run of 4000 jumpers between cable pairs (Mechelen I and Mechelen II).

Bell Telephone Manufacturing Company, Belgium

Power Supply System for the ESRO I Scientific Satellite — A power supply system has been developed by Bell Telephone Manufacturing Company for the ESRO I scientific satellite of the European Space Research Organization. The flight units were delivered on 15 June 1967, for integration into the spacecraft by the prime contractor, Laboratoire Central de Télécommunications, Paris. They had undergone complete flight clearance testing at BTM and ESTeC (European Space Technology Center) at Noordwijk, Holland.

The development involved the design of the solar generator configuration, the design of a battery pack, and the development and manufacture of the hardware for a battery-charging control system and for the power conditioning. The launching phase and the space environment had to be taken into account during the development with regard to vibration, acceleration, radiation, micrometeorites, and high vacuum. The above mentioned flight clearance tests thus included sinusoidal and random vibration, linear acceleration, low-temperature operation, high-temperature operation, thermal vacuum, and also, for qualification, low-and-high temperature storage tests, and a humidity test.

The 7000 N-on-P silicon solar-cell generator and the 16-cell hermetically-sealed 3 ampere-hour battery pack were sub-contracted.

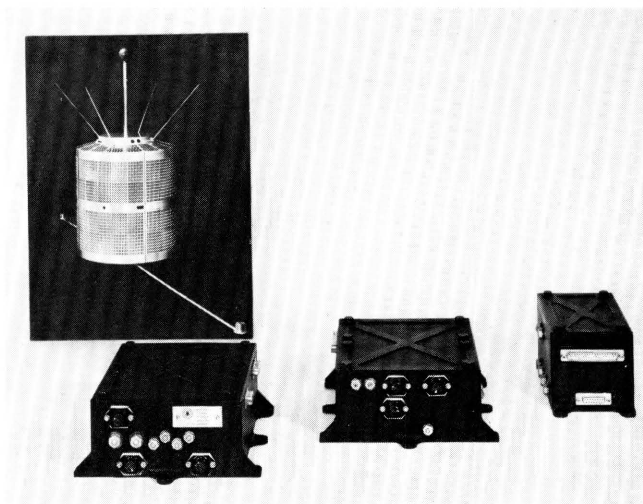
The photo shows the electronic sub units RL 1446-A, -B and -C. The two larger units, A and B, contain all the power-supply circuits to provide regulated voltages of +16, +12, +6, +3 and −6 volts and an unregulated voltage of +3.7 volts. The overall output power is 12 watts with a peak capability of 18 watts.

The weights of the units are respectively: 6.2 pounds (2.8 kilograms) and 7.3 pounds (3.3 kilograms). The dimensions are 8.6 by 7.5 by 3.16 inches (22 by 19 by 8 centimeters). The smaller unit C contains the control circuits for the battery charging. The weight of the unit is 3.75 pounds (1.7 kilograms). The dimensions are 7.5 by 3.6 by 3.45 inches (19 by 9 by 8.7 centimeters).

Reliability is obtained in all electronic units by component and circuit redundancy, which allows a failure, short- or open-circuit of any component, without impairing for the system operation.

All the circuits are encapsulated in polyurethane foam.

Mechelen II miniaturized MDF.



ESRO I Satellite and its electronic subunits RL 1446 A, B, and C.

Detailed checks have been performed to determine appropriate methods of operation by cycling a battery, battery-charge control, and regulator under electrical inputs and loads simulating the actual conditions to be expected in orbit.

Bell Telephone Manufacturing Company, Belgium

Miniaturized Voice-Frequency Telegraph System — The application of new design principles has resulted in an appreciable reduction of the quantity and complexity of the coils and transformers used in telegraph channel modems. The subsequent reduction in cost and size of the latter has permitted the design of a new series of equipments featuring increased flexibility and additional facilities at highly competitive prices. The channel capacity of these equipments grouped under the name "MTT" (MTT stands for Miniaturized Telegraph System) ranges from 6 (small cabinet) to 96 (rack of standard height).

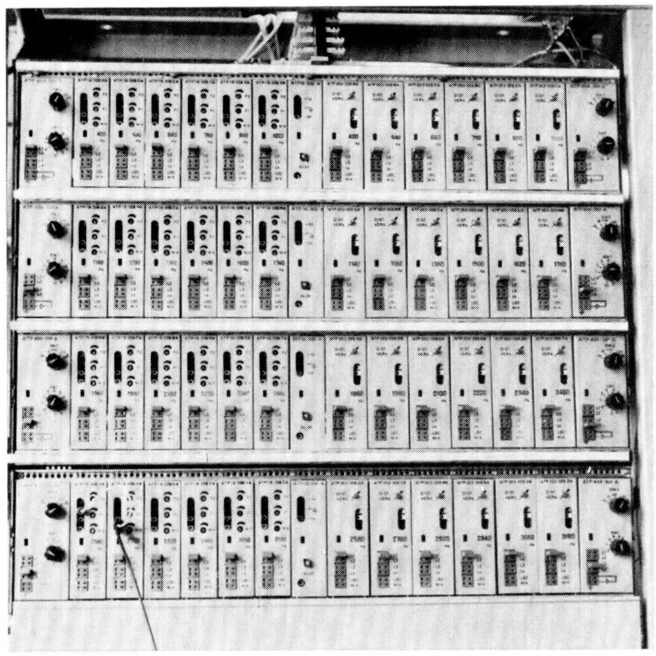
Each modem consists of two plug-in units: a VF (voice-frequency) transmitter and a VF receiver. These units can be supplied for all CCITT-recommended frequency spacings and they are all mechanically interchangeable. In parallel with the redesign of the channel modem, the common and auxiliary circuits have been updated.

The power supply comprises a d. c./d. c. convertor operating at 25 kHz; its volume is less than one third of the earlier design.

Integrated circuits have been used wherever economically justified. They permitted an extreme simplification of the test signal generator and the incorporation of a frequency counter.

Throughout the development of this system, special attention has been paid to reliability; for example, only silicon epitaxial transistors are used; tantalum electrolytic capacitors are avoided. The equipments of the MTT system operate satisfactorily in up to 55 °C ambient temperature.

Bell Telephone Manufacturing Company, Belgium



Subrack mounting of a 24-channel group. Each level comprises: a transmit line unit, 6 VF transmitters, a local voltage stabilizer, 6 VF receivers, and a receive line unit.

Direct Trunking Belgium – USA — On 1 September 1967, the Belgian Administration (RTT) put into service the first semi-automatic telephone links for direct traffic between Brussels and New York.

This was the first application in Europe of the CCITT N° 5 signaling system used on these both-way intercontinental lines.

The switching network that was developed and installed in the outgoing international center is shown on the Figure. It comprises essentially two combined selection stages, with Herkon reed relays as crosspoints. The final capacity of the switching network was calculated for a total outgoing traffic up to 450 erlangs.

The both-way intercontinental lines are connected individually to the A selectors, and access to the outgoing trunks with CCITT N° 4 signaling system to London, Frankfurt-transit, and Paris-transit are provided via the B selectors. These latter lines treat the overall automatic subscriber traffic for the whole country in the directions mentioned.

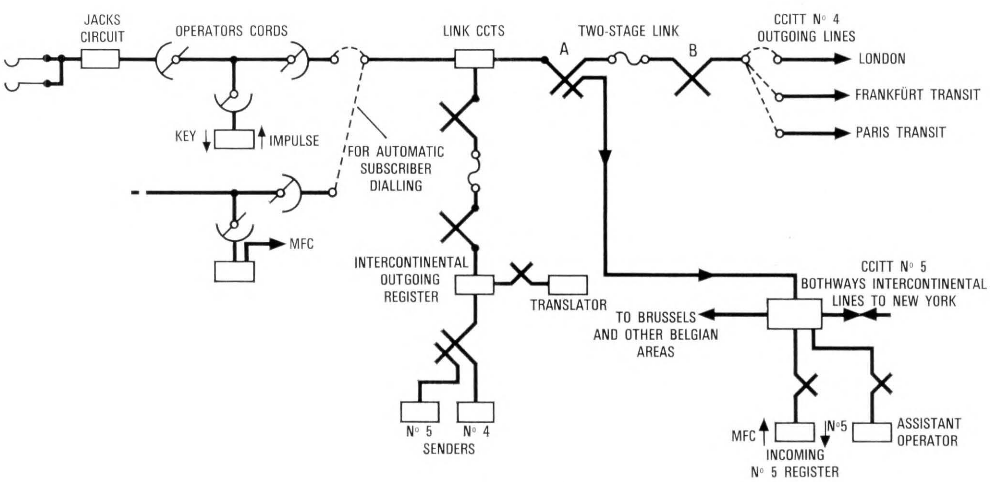
In a first stage, the intercontinental circuits are exclusively under the control of the extra-European desk operators, although fully automatic subscriber dialing has been provided for.

In the case of total occupation of the direct lines, the intercontinental calls are handled in overflow via Frankfurt.

The outgoing registers are arranged for impulse as well as European MFC (multi-frequency code) signaling on the reception side; they make use of code senders for CCITT N°4 and N°5 signaling systems. Routing control is performed by means of relay translators.

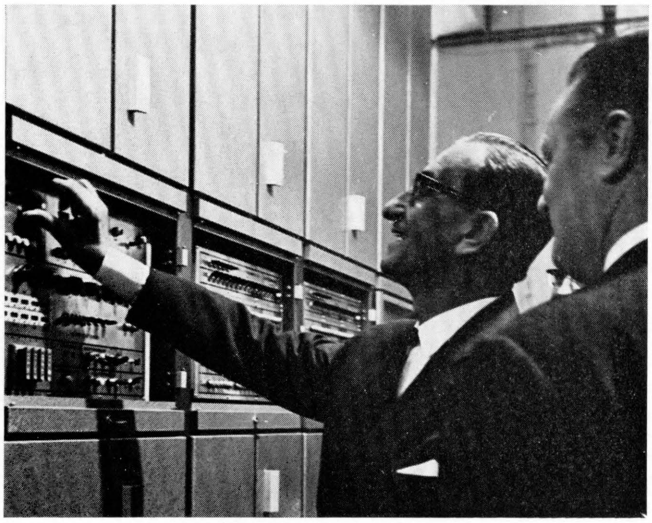
The incoming intercontinental calls over the both-way lines are automatically directed to all the subscribers of the Belgian network under the control of incoming registers. These latter are arranged for reception of the CCITT N° 5 signaling system, and the European MFC signaling system is used on the national side.

Bell Telephone Manufacturing Company, Belgium



Brussels International outgoing center for N° 4 and N° 5 CCITT signaling system.

First Stored-Program Controlled 10-C Terminal Exchange Delivered to the Belgian Administration — The first 1000-line 10-C terminal telephone exchange installed at Wilrijk, near Antwerp, was delivered to the Belgian administration on September 25, 1967. The official ceremony was attended by distinguished officials, including Mr. W. de Clercq, Vice Prime Minister of Belgium; Mr. H. Maisse, Minister and Secretary of State for Telecommunications; Mr. M. Lambiotte, General Manager of the RTT; Mr. F. J. Dunleavy, President ITT Europe; Mr. J. V. Lester, Executive Vice President ITT Europe; and Mr. J. Bourgeois, Vice President ITT Europe.



Mr. Maisse officially putting the 10-C exchange in operation.

After pressing the key that loaded the exchange program into the central processor's memory, Mr. Maisse called his colleague, Mr. Grootjans, via the new exchange, then formally accepted the equipment. After Mr. F. Pepermans, President Managing Director of BTM, had thanked the administration for its stimulating collaboration during the development period, Mr. M. Lambiotte expressed his confidence in the 10-C system. Finally, Mr. E. A. Van Dyck, Manager of the BTM switching systems division, described the 10-C system and summarized its principal advantages from the operational standpoint, including a space saving of over 60 %, reduced maintenance, etc.

After the addresses, the guests had an opportunity to test the system, particularly the new subscriber facilities such as abbreviated and push-button dialing, automatic absentee service, automatic call transfer, etc.

Bell Telephone Manufacturing Company, Belgium

Toll Board 2003 P — The 2003 P toll board is an equivalent of the existing 2003 A, B, and C toll boards, but it utilizes Pentaconta components. It is shown in Figure 1. It will be used for manual interconnection of local exchange subscribers of all known systems with rural, toll, and international trunks.

The 2003 P cord and positional circuits are arranged for sleeve wire (third wire) operation and supervision.

This recently developed equipment is composed of pieceparts (see Figure 2), which will be shipped in loose parts, packed in two kits, one for complete ironwork and one for the complete woodwork. This is in order to meet the requirements of the administrations who, for economic reasons, wish local labour to be used as much as possible.

During 1967 and 1968, nine manual toll exchanges using 2003 P toll boards will be cut over in Mexico.

Bell Telephone Manufacturing Company, Belgium

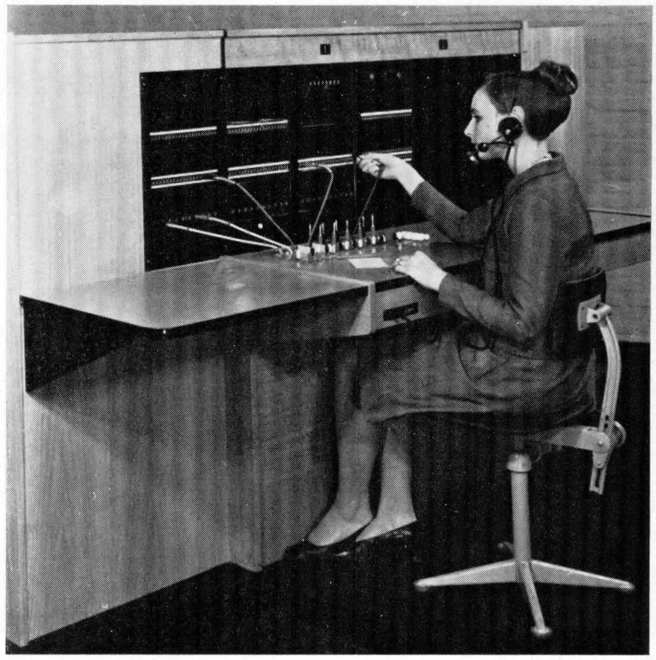


Figure 1 - Front view of the 2003 P toll board.

Figure 2 - Loose parts for building up a 2003 P toll board.

Cut-and-Strip Wire Guns — The Bell Telephone Mfg. Co in Antwerp have recently introduced on the market a new tool that will yield considerable savings in all operations dealing with the cutting and stripping of wires and cables.

Application of this tool in the production shops at BTM show a time reduction of 5 to 1 in comparison with conventional equipment and pay-back within two months.

The cut-and-strip wire gun is a pneumatic hand tool for fast and clean cutting and stripping, in one operation, of up to 5 PVC (polyvinyl chloride) insulated wires at a time. It is especially handy for fast and precise cutting and stripping on handmade cables forms, etc., in assembly operations. Some typical characteristics are given here below:

— weight less than 2 lbs (900 g);
— with ordinary telephone wire or similar wire, some 3000 wires can be cut and stripped in one hour (i. e., 600 operations on 5 wires);
— the gun operates with compressed air at 85—100 lb. in^2 (6—8 kg/cm^2);
— it is suitable for stripping almost all plastic and rubber insulations;
— in order to ensure accurate as well as nick-free wire stripping,

Bell Cut-and-Strip Wire Gun.

the wire-size can be pre-set according to the customer's specifications, thus eliminating potential mistakes by the operator;
- standard sizes 21 to 25 SWG (0.5 to 0.8 mm);
- standard stripping lengths are: $^1/_8$ inch (3 mm) — Model 724 001 A and $1^1/_3$ inches (34 mm) — Model 724 000 B;
- special intermediate lengths can be supplied;
- by plugging the appropriate distance fork into the gun, the operator automatically obtains the right cutting length; the standard accessories of each gun comprise 6 forks of different lengths, ranging from $1^1/_2$ to 7 inches (3.75 to 17.50 cm). Other lengths can be supplied at request.

Bell Telephone Manufacturing Company, Belgium

Expansion of the Pentaconta Switching System over the World — The public exchange in Alajueja, Costa Rica, was officially cut over on 1 August 1967.

This is the first in a series of 18 Pentaconta public exchanges to be supplied to Costa Rica and installed there by the Compagnie Générale de Constructions Téléphoniques (CGCT), inventors of the Pentaconta crossbar automatic telephone switching system.

This cutover is an important step in the carrying out of the project for development and modernization of the Costa Rican telephone network, undertaken by the "Instituto Costarricense de Electricidad", which is planning 30 000 additional telephone lines plus inter-urban automatic switching throughout the country. CGCT has received new orders for Pentaconta exchanges from various countries:

France: The French P & T administration has ordered a 5000-line telephone exchange for the town of Clermont-Ferrand, and the extension of the Paris-Rameau (2000 lines) and Melun (1000) exchanges.

Polynesia: The Post Office has ordered a 3500-line Pentaconta exchange to serve the 20,200 inhabitants of Papeete.

The districts of Punaauia and Mahina, located 8 kilometers (5 miles) from Papeete, will also receive 500 and 300-line Pentaconta exchanges, respectively.

CGCT has already installed a Pentaconta exchange on Raietea Island, 232 kilometers from Papeete.

Mexico: three new Pentaconta public telephone exchanges for Mexico were recently added to the 29 previously ordered by Telefonos de Mexico; these three exchanges are:
- Mante, 1600 lines, at Ciudad Mante, province of Tampico;
- Sur, 4000 lines, at Guadalajara, province of Jalisco;
- Chapalita, 6000 lines, also at Guadalajara.

In addition, the exchanges at Irapuato, Queretaro, Reynosa, Morelos, Bandera, Tecnológico, and Acero will be extended by a total of 5,600 lines.

With this last order, the 32 exchanges will total 88 950 lines. Since 1965, CGCT has been installing the exchanges with the help of the personnel of the associated company Industria de Telecomunicación, S. A., of Mexico.

Compagnie Générale de Constructions Téléphoniques, France

Universal Pentaconta Test Device — Assemblies like the equipped frames and bays used in automatic telephone switching systems are so complex that they must be checked in the plant for technical specification data, as soon as they are equipped.

Automatic devices are used to make checking more reliable. Such devices often have specific designs according to the type of assembly that is chosen among those most frequently mounted.

However, for those that are not usual enough to justify the use of a special costly device, LMT has developed a universal test device designed primarily for testing Pentaconta telephone assemblies. This universal test device features special electronic means and high-connection capacities affording great flexibility in utilization.

This flexibility has already been demonstrated in testing assemblies other than Pentaconta units, such as the electronic crosspoint matrices used in the LMT electronic PBX Artemis.

Le Matériel Téléphonique, France

Temperature-Compensated Crystal Oscillators — A contract for the supply of 10 prototype temperature-compensated crystal oscillators (TCXO), of frequencies ranging from 2 to 70 MHz, was awarded to Le Matériel Téléphonique by the technical department of the "Navigation Aérienne", in December 1966. Prototypes were built and customer approval was obtained during the first half of 1967. The frequency stability of these oscillators is better than 2 parts per million for temperature variations from $-20\ ^\circ C$ to $+70\ ^\circ C$, and better than 5 parts per million if the variations of the supply voltage and of the load resistance, and the aging during five years are taken into account. The drift of the quartz oscillator is compensated for by a corrective network that consists of an adjustable capacitance diode, thermistors and precision resistors. The entire oscillator is made in the form of a miniaturized sealed plug-in unit.

Universal Pentaconta Test Device.

The development work was carried out jointly by LMT for the manufacture of the quartz crystal, the oscillators and the tests, and by the Laboratoire Central de Télécommunications for the computation of the corrective networks and its processing on a computer.

Le Matériel Téléphonique
Laboratoire Central de Télécommunication, France

Color TV Test and Maintenance Instruments — Métrix products have captured 50 to 100 % of the French market for multimeters, TV wobbulators, signal generators, tube and semiconductor test sets, etc.

Recent color TV applications are:
— two signal generators or "color patterns" for the PAL system types GX 970 and GX 972), and one for the SECAM system (type GX 951);
— a transistorized two-gun oscilloscope, 0–15 MHz (type OX 701);
— a video wobbulator-generator (type WX 501).

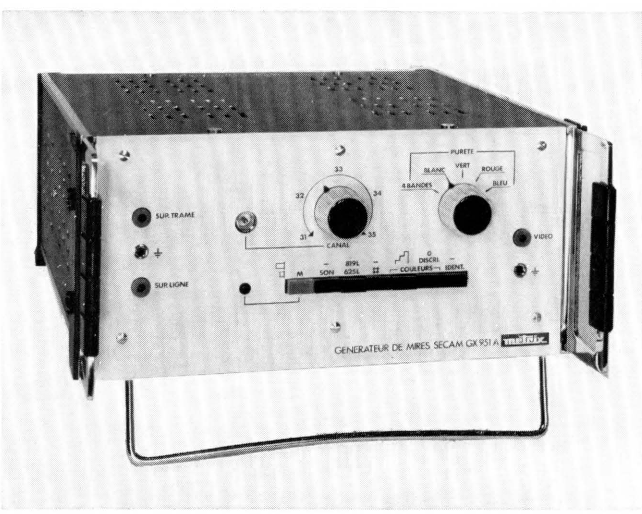
The elapsed time between the official adoption of the optimized SECAM III b system by the French government (20 January 1967) and the first broadcasting of color TV programmes (1 October 1967) was quite short for the transition from the prototype stage to normal production. But early preparation, use of advanced techniques (integrated circuits), and close cooperation with TV-set manufacturers and their association (SCART) enabled Métrix to have 300 GX 951 equipments put quickly into service, this figure having reached 850 on 1 November 1967. This instrument has proved to be both of a high technical standard and of great simplicity in use. Despite many fears, the maintenance of color-TV sets does not require specialized care, but can be ensured by the same servicemen working with black-and-white. After its official demonstration in April 1967, it is thought that about 2000 units will have been ordered by mid-1968.

On 2 October 1967, Métrix received a delegation of visitors representing the SCART, the French radio and TV-set manufacturers, and the radio and TV technical press.

Compagnie Générale de Métrologie – Métrix, France

Installation Begins on PCM Equipment — Installation has begun on London's first PCM junction telephone systems. Two routes from city exchanges to the subscribers are having existing cables converted to PCM carrier systems. In the first phase of this scheme, 40 PCM systems are being used, employing 960 dependent repeaters installed in existing manholes and footway boxes. The whole operation is being controlled by STC and the BPO, using critical path methods, and installation began exactly on schedule.

Standard Telephone and Cables Limited, United Kingdom



Pattern generator GX 951 A for the SECAM system.

Engineers from STC's Installation and Maintenance Service Division, Balsildon, at work on the first PCM installation in London's Waterloo Road.

Microminiature Data Communication System — The GH 210 data communication system is constructed in silicon planar integrated-circuits on a modular basis using plug-in boards. It is capable

General view of the GH 210 system.

of speeds of up to 4800 bits per second. A cyclic code method of error detection is used and any 4, 5, 6, 7, or 8 level code can be handled to give a distant terminal output replica of the input.

The two controls are designed for simplicity; the first determines the mode of operation, either to receive or transmit data at one of two speeds under local supervision, or for automatic reception and transmission under the control of a remote terminal. The other determines the system function and has three positions: "wait", "data", and "speech".

The "wait" position allows either terminal operator to suspend the data flow without loss of data while changing tape supply, and so on. The "data" position is used for the transmission of data and the "speech" position enables the operator to intervene without any loss of data.

The system will operate unattended on a 24-hour basis.

Standard Telephones and Cables Limited, United Kingdom

Pot Cores to IEC Recommendations — A range of ferrite pot cores to IEC (International Electrotechnical Commission) dimensions has been added to the range of products of the Magnetic Materials Division of Standard Telephone and Cables Limited. At present, four sizes (14 mm, 18 mm, 22 mm, and 26 mm) of core, with specific inductance values to the R5 series of numbers, are available in five grades of high-permeability ferrite material. Adjustable and unadjustable cores can be supplied, the adjustable cores being fitted with an adjuster that is contained wholly within the core. This patented adjuster mechanism is manufactured to close tolerances on dimensions and concentricity that ensure a smooth, kink-free adjustment curve. With the recommended adjuster setting, accuracies of 0.01 per cent can be achieved with an adjustment range of between 8% and 16%. Alternative adjusters can be supplied to provide even closer setting accuracies of wider adjustment ranges. Bobbins and mounting systems can be supplied with all cores.

Correctly assembled cores are stable over a temperature range of −20 °C to +70 °C and will withstand vibration and shock to specification DEF 5011 severity V2 and section 5.3, respectively.

The cores are manufactured with high-permeability, low-loss ferrite materials produced under stringent quality control methods. Of the five materials, two are used for unadjustable transformer cores. These are SA500T and SA601, and are suitable for use up to 10 MHz. SA601 has a very high permeability, which often enables a smaller size of core to be used.

The three materials for adjustable inductor cores are SA500L, SA502, and SA503, and are suitable for application up to 300 kHz.

SA500L is a general-purpose inductor material with a controlled positive temperature coefficient, low losses, and a low hysteresis constant. It is particularly suitable for use in tuned circuits with polystyrene capacitors.

SA502 and SA503 have lower losses, hysteresis constants, and disaccommodation factors than SA500L. SA502 has a zero temperature factor, which makes it particularly suitable for use with mica capacitors. SA503 has the same temperature factor as SA500L.

Standard Telephones and Cables Limited, United Kingdom

Microwave System for the Virgin Islands — The RL4H, 4 GHz solid-state equipment (cf. Electrical Communication, Vol. 42, N°4) will provide a 960-circuit link between San Juan and Magens Bay. The link, which is 80 miles long, will be done in two "hops": the first from San Juan to El Yunge, Puerto Rico, a distance of 20 miles, and the second over 60 miles of water between El Yunge and Magens Bay on St. Thomas Island. For the water hop, space-diversity techniques will be employed.

Standard Telephones and Cables Limited, United Kingdom

Multispeed Modem For BPO — A large order has been received from the British Post Office for modem equipment for the DATEL services to be cut over this year. The equipment operates at a speed of 2400 bits par second with a fall-back to 1200 and 600 bits per second, and with an optional supervisory (return channel) speed of 75 bits per second. The equipment is the first of its kind to combine so many operating speeds within one unit.

The high speeds of transmission will be used over private telephone circuits with fall-back on to the public switched networks at the lower speeds.

The BPO will use the equipment in their DATEL 2400 service to meet demands of business organizations to transmit digital data for computer use over telephone lines.

Standard Telephones and Cables Limited, United Kingdom

Telephone System in the New UK Liner, Queen Elizabeth II — A private automatic branch exchange employing a cord-type manual switchboard will connect 1000 passenger and 350 crew extensions in the new Q 4 liner launched on 20 September 1967. In port, there will be 46 exchange circuits for ship-shore connections, eight circuits will be available for the ship's radio channels, and thirty circuits for special services such as laundry, shops, and so on.

A dialing system for crew connection will use a 3-digit scheme. Passengers will obtain connection to other passengers through a manual switchboard but can dial ship's service direct.

Over 100 000 pair-yards (92 000 pair-meters) of cables are involved in the installation, which uses a new multi-unit type of cable having a small-diameter stranded construction not previously used aboard ship. Special cable harnesses, assembled in the factory, are used to connect the cabins and exchange without breaks in the cable or junction boxes.

Standard Telephones and Cables Limited, United Kingdom

Microwave Communication Link for Electricity Authority — The Central Electricity Generating Board is installing a microwave system between two power stations and a substation in Yorkshire which will use the 1500 MHz RM 15 A equipment manufactured by Standard Telephones and Cables Limited. The system will provide 4 speech circuits with engineers order wire and alarm facilities. The equipment is solid state and includes in a 6-foot rack a 1500 MHz duplicated radio terminal and from one to 24 channels of STC mark 6 multiplex.

Standard Telephones and Cables Limited, United Kingdom

Thin-Film Microphone Amplifiers — Three modular amplifiers 021 BA E, F, and N, using thin-film circuitry, have a response that is substantially flat from 400 Hz to 20 kHz. They are designed for the amplification of signals from all types of microphone. They are 19.3 × 10 × 5.1 mm (0.76 × 0.39 × 0.2 in) in size and weigh 1.5 g (0.05 oz) and may be mounted close to the microphone eliminating electrical unbalance because of long leads. The power consumption is low and type F requires 12 to 22.5 Vdc, E, 22.5 to 30 Vdc and N, 12 to 30 Vdc.

Standard Telephones and Cables Limited, United Kingdom

GH 305 Ultra-High-Speed Data Communication Equipment — Exhibited at the 1967 Business Efficiency Exhibition in London, the GH 305 equipment can transmit data at speeds up to 840 kilobits a second over unloaded telephone cable. It has been designed to link a data source and computer several miles apart and many have applications in computer links on rocket or aero-engine test sites, between master and slave computers in research organizations or on industrial sites.

The equipment is to be used by the United Kingdom Atomic Energy Authority at their research establishment in Harwell on links ranging from a few hundred yards to 1½ miles in length.

Standard Telephones and Cables Limited, United Kingdom

Mediterranean and Baltic Undersea Cable Orders — Very large orders have been received for four undersea cable systems which will include 1,000 miles of undersea cable and 114 submerged repeaters, together with land-based equipment and spares. The repeaters are transistorized and will allow 480 simultaneous two-way telephone conversations.

Two of the systems will terminate in continental Italy, one connecting Pisa and Barcelona (418 nautical miles of 0.99 inch cable with 56 repeaters), and the other Civitavecchia, near Rome, with Olbia, in Sardinia (135 nautical miles of 0.99 inch cable with 18 repeaters). A third system will connect Germany with Sweden across the Baltic (121 nautical miles of 0.935 inch cable with 15 repeaters), and the fourth will be laid from Agrigento in Sicily to Tripoli in Libya (304 nautical miles of 0.62 inch cable and 24 repeaters). This latter system will provide 120 circuits and the remainder 480 circuits.

Standard Telephones and Cables Limited, United Kingdom

New Teleprinter First of Kind in the World — A newly developed teleprinter known as the Envoy Dataprinter, combines features that have never before been available in one machine. These are the ability to operate on an 8-unit basis (i. e., to use the more-complex codes suitable for data processing) applications; a print out of 96 characters, which includes upper- and lower-case letters; and the use of electronic components to increase reliability and flexibility.

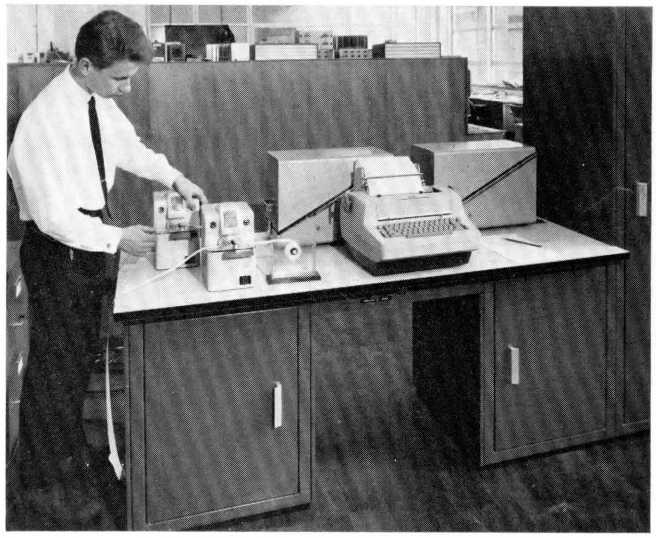
The Envoy electronic dataprinter.

Because of its suitability for use in computer and data processing applications the Envoy will carry the name "dataprinter" rather than "teleprinter". The result of four years' research and development, it represents a considerable advance in data communication techniques, and made its debut at the 1967 Business Efficiency Exhibition at Olympia, London.

The Envoy operates at speeds up to 10 characters per second and can be used both for on-link work (e.g. transmission and reception of data to and from a remote computer) and for off-line tape editing work (e.g. the punching, interpretation, and duplication of 8-track tapes).

The use of high-reliability integrated-circuit electronics has lead to the elimination of the complex mechanical units found in conventional equipment of this type. Altogether, more than 70 % of the parts found in comparable mechanical machines have been replaced by electronics in the Envoy. The result is an increase in reliability, simplified maintenance, and a reduction in maintenance time.

Creed and Company Limited, United Kingdom



The dependable data processor.

Dependable Data Processor — There is a need in several fields, for example process control and telephone switching, for a data processor with a higher degree of reliability than those presently available. Such a processor has now been produced at Standard Telecommunication Laboratories. It employs several types of redundancy, and the intention is that the machine will diagnose any single fault that occurs within itself and indicate its location, while continuing to operate normally. Provided the fault is repaired before another occurs in the same area, the machine will not fail. Since most faults will be on equipment cards, repair is just a question of changing a card, without the need to stop the machine.

The types of redundancy used are:

a) Information redundancy, or the use of error detecting and correcting codes in order to protect information storage and transfer against a single digit fault. The 18-bit word needs an additional 5 check bits and 1 overall parity bit. The size of storage is therefore increased by only $^1/_3$ over a non-redundant machine.

b) Triplication and majority voting, as used in the control and arithmetic units. Failure of the majority voters is guarded against by the redundancy in other areas.

c) Duplication plus error detecting/correcting codes, as used in the peripheral area. The presence of the codes provides a means of deciding which of 2 channels is correct if they disagree.

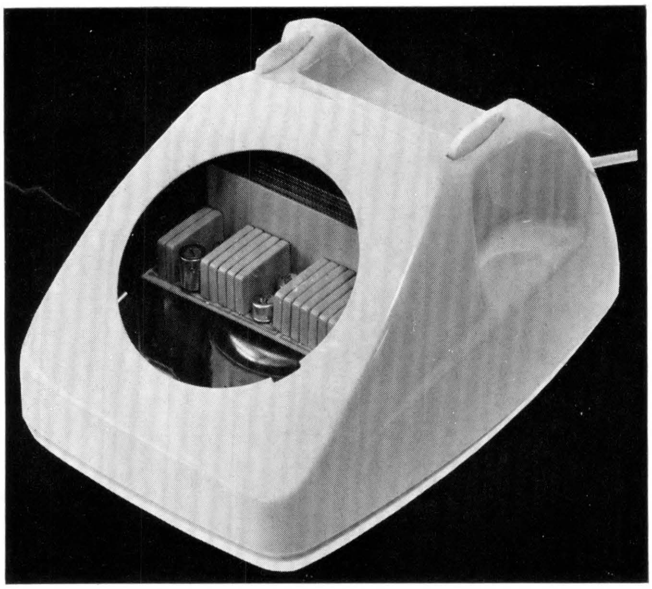
d) Time redundancy, or the use of a routine program to test normally redundant parts of the machine where a fault would remain hidden until those parts are required to operate because of a fault elsewhere.

The processor uses about twice the equipment of a similar, but non-redundant, machine. It must be considered, however, that the model described has only a small store (4096 $\times$ 24 bits), while a machine with a larger store would compare more favorably owing to the relatively small increase in storage size.

Standard Telecommunication Laboratories, United Kingdom

Single-Channel PCM Coder-Decoder for a Telephone Subset — A model of a single-channel companding PCM coder-decoder, small enough to fit inside a conventional telephone subset, has been designed and constructed at Standard Telecommunication Laboratories. It is shown in the figure. The coder operates on a time-counting principle in order to permit the maximum use of digital integrated circuitry, which gives improved reliability and small size.

Coding and compression are carried out by using amplitude-modulated speech samples to shock-excite a damped tuned circuit, and then counting the number of cycles that exceed a pre-



A telephone subset fitted with a model of a PCM coder-decoder.

determined threshold level. By making the threshold level time-dependent by a simple RC circuit, a smooth inverse sinh compression law is obtained, giving the normal 25 dB companding improvement.

At the decoder, the incoming PCM is first converted to pulse-width modulation, using only digital circuitry. The resulting pulses are then applied to a CR network whose response, sampled at a fixed time just greater than the maximum possible duration of the applied pulse, gives the expanded analog output.

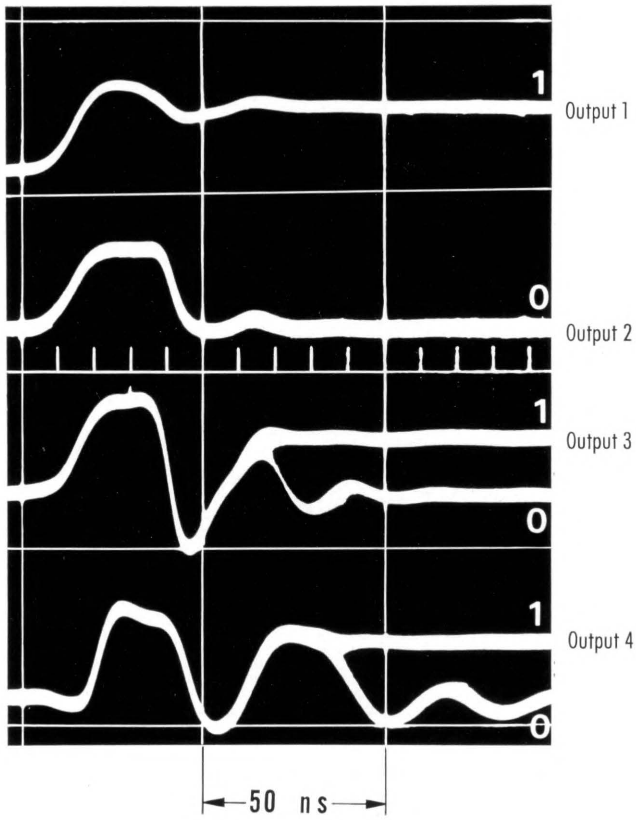
Using thin-film techniques for the analog circuits and flat-pack integrated-logic-circuit units, a complete coder-decoder has been constructed with a volume of about 4 cubic inches (66 cm^3), and a power dissipation of just under 0.5 watt.

Standard Telecommunication Laboratories, United Kingdom

Slow Devices in Fast Circuits Using the Equilibrium Principle — A 6-digit PCM coder has been built which, without extra complexity, can operate much faster than a serial coder, using devices with the same speed capabilities. The entire circuit uses general-purpose switching transistors with an f_T of 200 MHz; the coding time per sample is 140 ns, allowing 7 MHz sampling rate. This is $3\frac{1}{2}$ times the limiting speed of a serial coder using the same transistors. In the figure, a coding time of 90 ns for the first 4 digits is apparent; a further 50 ns is required for the two least significant digits.

The equilibrium method, used in this coder, implies an initial state of balance in the circuit which is upset by an input signal, causing each bistable digit to move towards its final equilibrium state (the output code) at a rate determined by its own inertia, and not by any external clock source. This coding process requires a number of binary decisions to be made, each corresponding to one bit of the binary-coded output. The autonomous operation of an equilibrium coder allows the switching actions following these decisions to overlap. This is in contrast to a serial technique, where each digit is completely established before the next one is set up.

Standard Telecommunication Laboratories, United Kingdom



A typical switching process by which the 4 most significant digits of the equilibrium coder reach their correct output state. The ranges of samples giving rise to the outputs 1001 and 1010 are 38 to 40 and 40 to 42 quantum step units, respectively.

Cold-Cathode Electron-Emitter Optical Display — An experimental metal-insulator-metal thin film device, which acts as a cold-cathode electron emitter, has been used in conjunction with a phosphor screen to provide an optical display panel.

Figure 1 shows an exploded view of a 25-element array of such devices, each of approximately 0.1 cm^2 area, which can produce

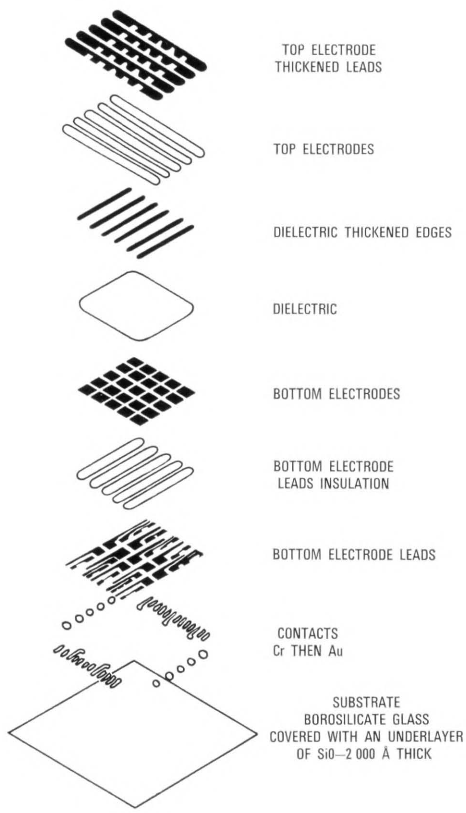


Figure 1 - Exploded view of 25-element array.

an optical display showing simple alpha-numeric characters as depicted in Figure 2.

The thin films are laid on glass substrates by vacuum deposition. The substrate is fixed opposite a flat phosphor screen in a vacuum, and after an electro-forming process, the current-voltage characteristic of the device shows a low resistance region, a voltage-controlled negative-resistance region, and a high resistance region. A similar characteristic is obtained for both positive and negative bias potentials. In the high resistance region, with the top metal electrode biased positively, electrons are emitted and accelerated onto the phosphor screen by means of a voltage of about 1000 volts connected between it and the top electrode, causing a glow that is readily seen under normal lighting conditions.

Standard Telecommunication Laboratories, United Kingdom

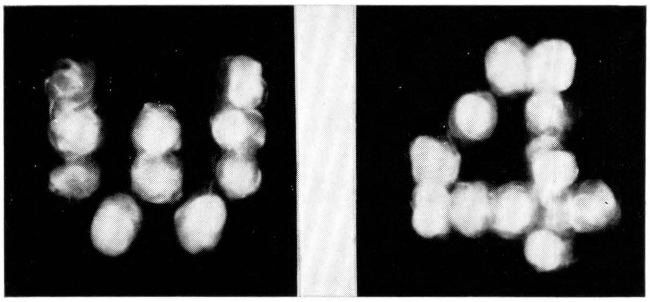


Figure 2 - Optical displays obtained from a 25-element array; the letter W and the numeral 4.

Thin-Film and Printed Circuits — A new technique for the "writing in" of patterns on a thin-film substrate that will directly produce interconnections and resistors has been developed by Standard Telecommunication Laboratories, and is being evaluated for production at the STC Film Circuit Unit at Paignton, in connection with their new fast-turn-round prototype facility.

The technique completely eliminates all the photo-lithography normally associated with printed wiring and thin-film circuits and enables a typical circuit to be written on a substrate in a matter of minutes by unskilled personnel. It makes use of a micro-positioning table and a specially developed stylus with fluids that are etch-resistant after hardening. The stylus is held stationary, and the table on which the substrate is mounted moves under it in response to coordinated instructions from a punched paper tape, which can be prepared using a computer fed with basic design information. Figure 1 shows the table and its controls.

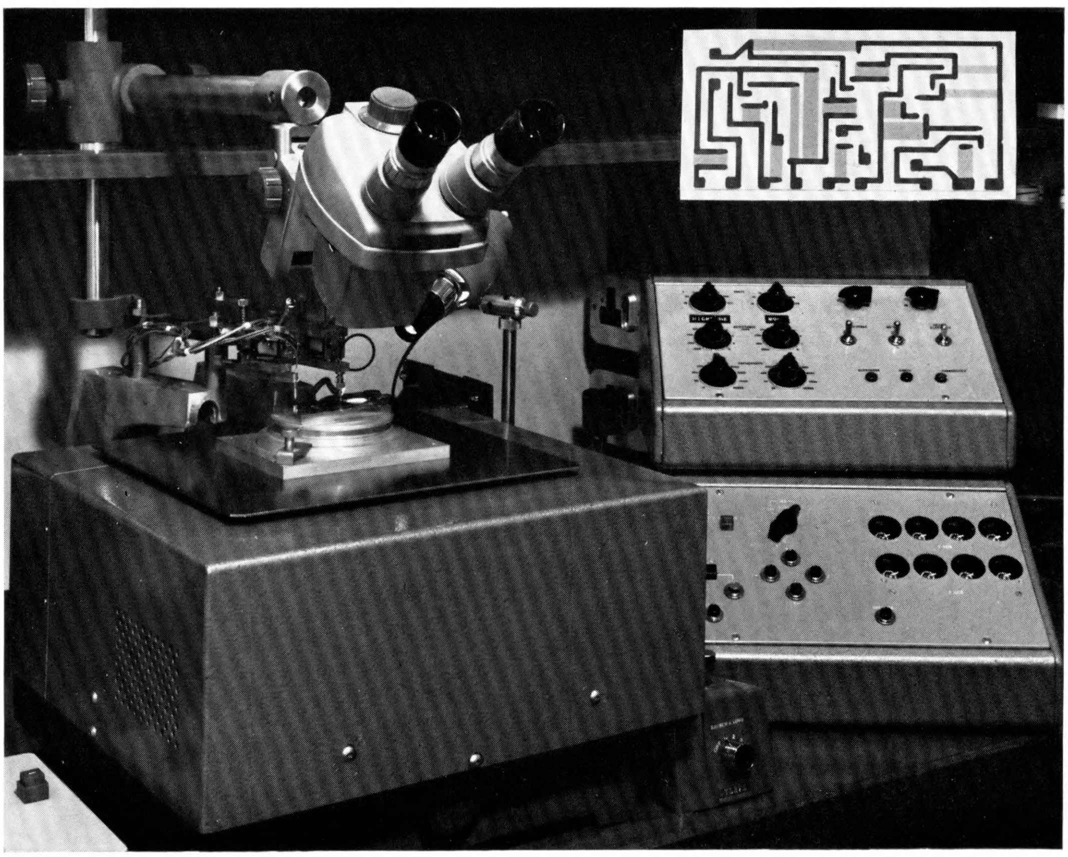
For film circuits, the starting point is typically a substrate comprising a sheet of $1 \times \frac{1}{2}$ inch (2.5×1.25 cm) glass having a deposited layer of, for example, nichrome under a thicker layer of gold. In the first "writing in" process, the interconnection pattern is traced out in etch-resistant fluid on the upper layer of gold. The fluid is hardened, and the substrate is then etched selectively so as to remove the gold not coated with resist, but leaving the underlying nichrome unaffected. The resist is then removed leaving the gold interconnection pattern.

A second writing operation next places an etch-resistant pattern on the exposed nichrome. The substrate is now selectively etched to remove uncoated nichrome only (leaving the gold connector pattern unaffected). In this way, nichrome resistors are formed. Line widths down to 75 microns have been produced. A tolerance of $\pm 5\%$ is typical for the major range of resistor values.

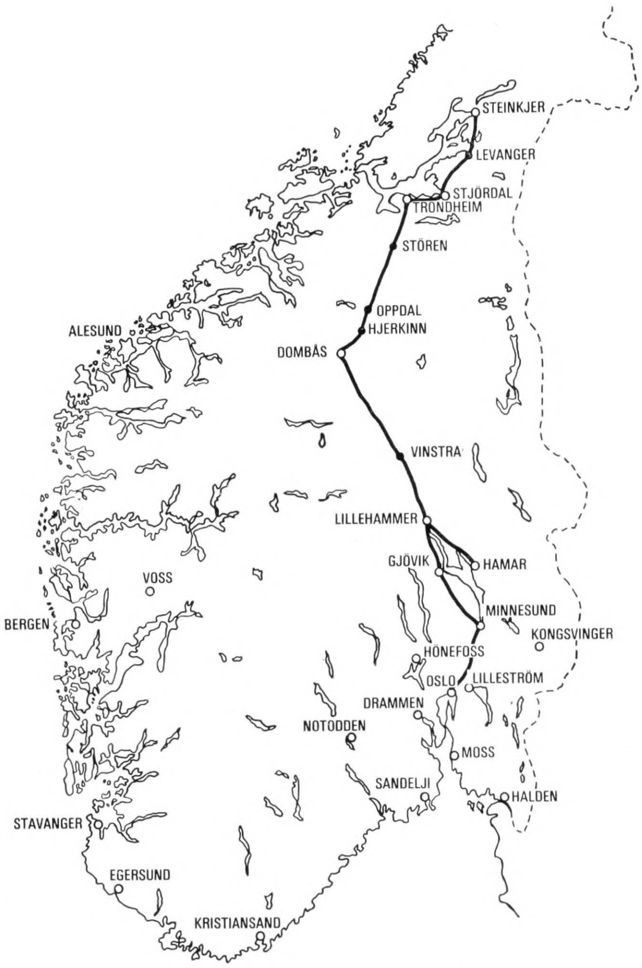
For printed circuit wiring, the starting point is a normal copper-clad plastic laminate, and in this case all the copper is etched away, except for that laying under the "written in" circuit pattern. Line widths up to 0.15 inch (3.8 mm) can be produced.

Standard Telecommunication Laboratories, United Kingdom

Coaxial Cable System in Norway — Standard Telefon og Kabelfabrik A/S, Oslo, has recently delivered the last coaxial cables for the cable system Oslo—Trondheim—Steinkjer, connecting two of the most densely populated districts of Norway. The cable route (see map) leads from Oslo through Gjøvik, Lillehammer, and Dombås to Trondheim, and further through Stjørdal to



"Writing in" equipment for tape-controlled thin-film circuit, fabrication, with (inset) a typical thin-film resistor and interconnection pattern produced on a $1 \times \frac{1}{2}$ inch (2.5×1.25 cm) substrate.



The Norwegian coaxial cable network.

Steinkjer. The system also includes a spur cable from Lillehammer to Hamar, and a submarine coaxial cable between Gjøvik and Hamar.

The mountain crossing between Dombås and Oppdal brings the cable route up to a little above 1000 m altitude in the neighborhood of Hjerkinn.

The cable contains two coaxial pairs 2.6/9.5 mm (0.104/0.375 inch) of CCITT-recommended type. The two pairs together with auxiliary quads form the center of the cable, surrounded by a layer of paper-insulated toll quads. The cable is lead sheathed between Oslo and Lillehammer, and aluminium sheathed for the remainder of the route. Except for a few thousand meters of duct cable in Oslo and Trondheim, all cables are steel tape armored for direct burial.

Between Dombås and Hjerkinn, a section of 33 km, two small coaxial pairs 1.2/4.4 mm (0.047/0.174 inch) are included in the cable. The pairs replace 4 of the auxiliarly quads. The small pairs, also of CCITT-recommended type, will handle the local traffic demand.

Between Oslo and Gjøvik there are two identical coaxial cables. One is for the Oslo — Bergen route, which was completed in 1957, the other for Oslo — Trondheim. STK has delivered a total of 886 km of coaxial cable for the system, 142 km of which are for the Oslo — Bergen connection.

The Norwegian Telegraph Administration has also included in the system a quantity of toll cables for district connections. STK has delivered in total 746 km of toll cable of various sizes.

The Norwegian State Railways, during the same period, laid parallel toll cables on the Hamar — Lillehammer — Trondheim section, and one cable from Trondheim to Stjørdal. Along the greater part of the route, these cables were laid in the same trench as the coaxial cable. For this railway cable system, STK has delivered 907 km of toll cable.

On the Oslo — Gjøvik — Vinstra and Støren — Trondheim sections transmission equipment of ITT manufacture has been installed, with 4 MHz repeaters and 9 km repeater distance. The maximum possible capacity is 960 telephone channels. No transmission equipment has yet been installed in the remaining sections, but it has just been decided to order 12-MHz equipment from Siemens for the Vinstra — Trondheim — Steinkjer section. The 4-MHz repeaters from Støren to Trondheim will then be installed elsewhere. This equipment allows for a maximum of 2700 telephone channels. The repeater spacing is halved to 4.5 km.

Since part of the cable sections had already been installed with the objective of 9 km repeater distance, it was necessary to investigate impedance mismatches in the neighborhood of the new repeater sites. The quality of the coaxial pairs, however, was such that only a couple of doubtful mismatches were encountered.

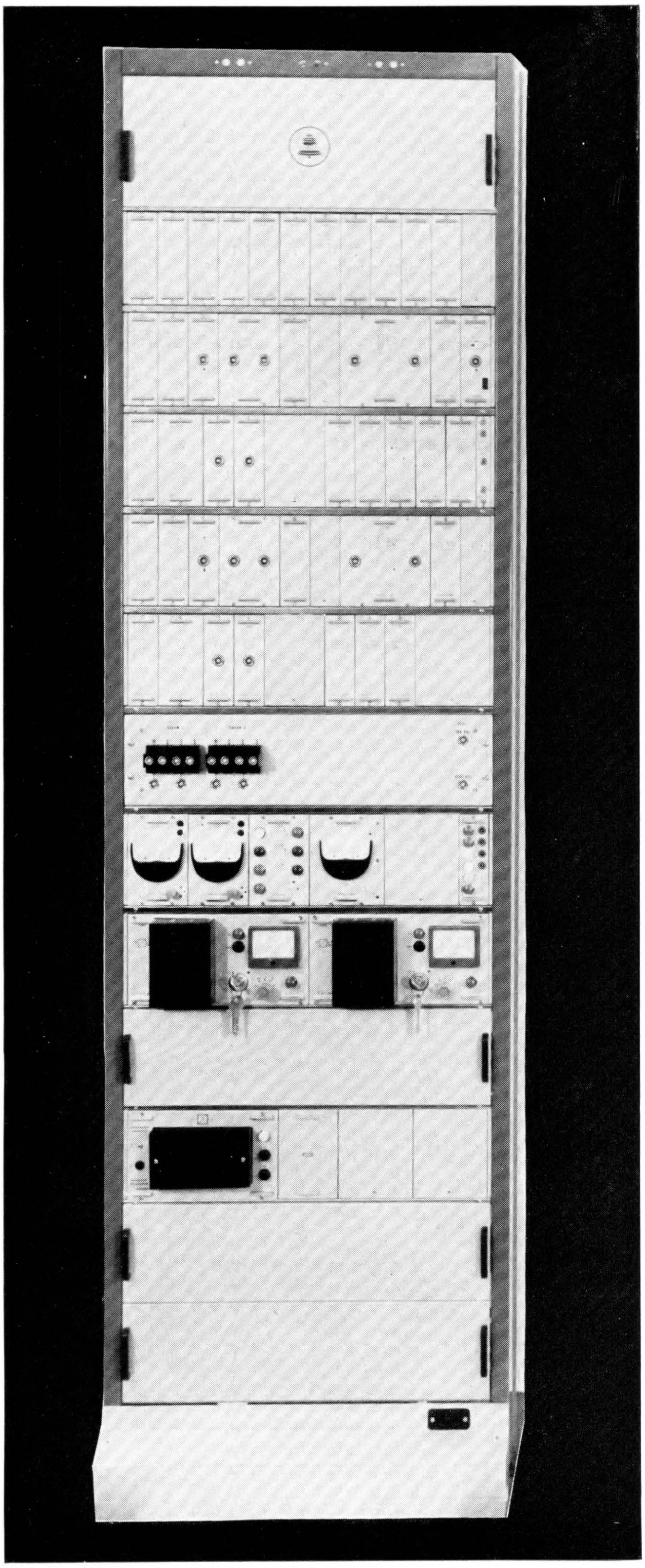
Standard Telefon og Kabelfabrik A/S, Norway

Stockholm—Arlanda ATC-center delivered by SRT in 1964.

Air-Traffic-Control (ATC) Data Displays — Eurocontrol — the central European multinational organization for control of the air traffic in the upper air space — has placed an order for an experimental ATC Data Processing System for its Brétigny test center with a European Consortium headed by Marconi, UK.

The data display system included in the project consists of 26 viewing units (11 $\times$ 24 inch), control devices (rolling balls, light pens, keyboards, etc.), display back-up system (digital logics, memories, character generators, etc.) and operator consoles, which will be supplied by Standard Elektrik Lorenz AG, Germany, with Standard Radio & Telefon AB, Sweden, as the main subcontractor. The delivery will be based on SRT's recent design of display systems, fully microminiaturized, which are still more advanced than the already widely well-known systems delivered for installations, such as the Stockholm-Arlanda, Oslo, and Copenhagen ATC centers.

Standard Radio & Telefon AB, Sweden



1260-channel equipment - Terminal equipment of the trial section.

1260-Channel Line Equipment for Small-Diameter Coaxial Cable System — This fully transistorized equipment, developed by Standard Téléphone et Radio S. A. (see Electrical Communication, Vol. 41 [1966], n° 3, pp. 313—319), operates with buried telecontrolled repeaters at the nominal interval of 2.97 km. The maximum number of repeaters between two terminals is 26 to 30, so that it is possible to utilize dependent repeaters over a distance of 81 km.

These repeaters are temperature compensated. Over longer distances, pilot-regulated repeaters are introduced. In case the pilot fails, power over-regulation is avoided by connecting each pilot-regulator (thermistor) to an emergency heating voltage supply.

A trial section, 47.7 km in length, was installed in Spring, 1967, and subsequently tested. All measured characteristics; frequency response, noise, cross-talk, etc., met all expectations. On the same occasion, cable attenuation and temperature variations of the ground and manholes were measured. Temperature recording has been continued for a longer period.

The test results are as follows:

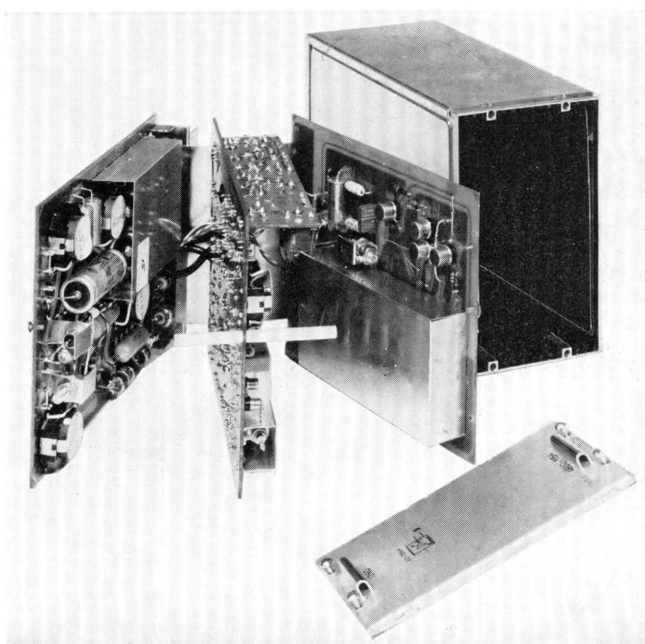
— the residual distortion of attenuation for the whole frequency band is less than $\pm$ 0.04 Np;

— the near-to-distant cross-talk difference for the whole frequency band is greater than 11.5 Np;

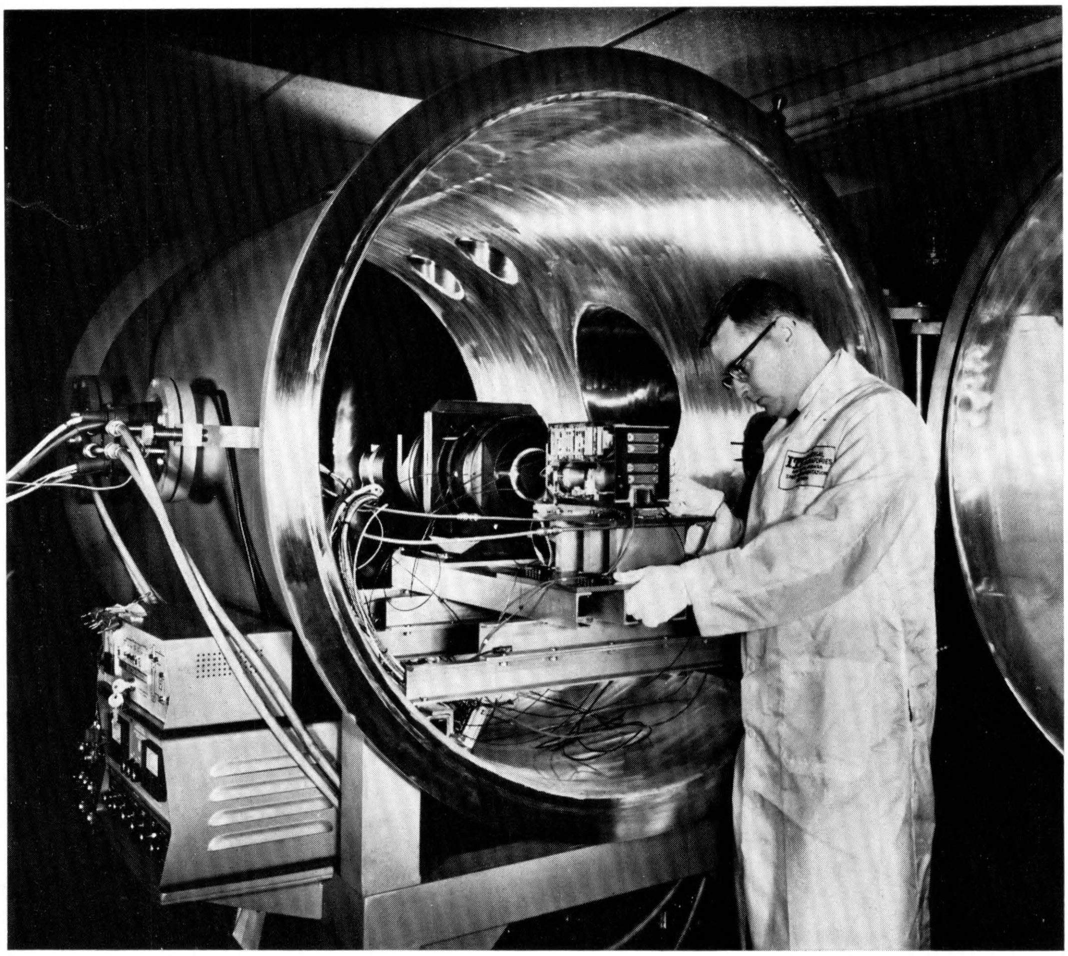
— with a $+$ 1.85 NpmO white noise load, the worst-case total noise is 1.5 pW/km.

Standard Téléphone et Radio S. A., Switzerland

Satellite Space Camera Program — The National Aeronautics and Space Administration has ordered an additional flight model of a daytime space camera system for the Nimbus-D satellite to be launched early in 1970. A unit under test is shown in the photo. It will be similar to that now being developed for the Nimbus-B satellite scheduled for launch early in 1968. Both systems rely on our Vidissector camera tube, the "eye" of the system.



1260-channel equipment - 6 MHz bandwidth line amplifier with pilot-regulator and supply separator filter.



Daytime camera system for the Nimbus-D satellite being tested under conditions of outer space.

While the daytime camera on Nimbus-D records global cloud cover and weather patterns in visible light, a filter-wedge spectrometer will measure and analyze vertical distribution of water vapor in the atmosphere of the earth.

Our total of nine satellite space systems includes two cameras aboard weather satellites Nimbus I and Nimbus II, launched in 1964 and 1966, two photoelectric cameras on Orbiting Geophysical Observatory satellites also launched in those years, and five cameras or instruments for Nimbus-B and Nimbus-D. In addition the moon-mapping Lunar Orbiters I through IV were all guided from earth to the moon with the aid of our photomultiplier tubes.

ITT Industrial Laboratories, United States of America

Underwater Tracking Range of Hawaii — In the Kaulakahi Channel between Niihau and Kauai, the Hawaiian Islands, is the Barking Sands Tactical Underwater Range recently completed for the United States Navy. This unique tracking facility enables evaluation of tactical performance of antisubmarine weapon systems under actual sea conditions over distances of more than 50 miles (80 kilometers) and depths from 400 to 1000 fathoms (730 to 1800 meters).

Hydrophones, projectors, and associated in-water electronic equipment must withstand the pressure of deep water for many years. Acoustic signals received by the instruments are transmitted to shore over more than 400 miles (640 kilometers) of cable.

On-shore equipment includes both analog and digital processors, timers, underwater and surface communication systems, consoles, displays, and two digital computers. It provides for real-time tracking and control of tactical maneuvers.

Pre-acceptance tests using Navy vessels and weapons systems demonstrated the operational capabilities of the range.

ITT Avionics Division, United States of America

Navigation-Satellite Shipboard Sets — The United States Navy has placed an order for the design and manufacture of radio navigation sets for use with navigaton satellites. The Navy designation is AN/SRN-9 and commercial version will be called "Sea-way" (Model 4007 AB).

Navigation satellites (P. C. Sandretto, "Terrestrial Navigation by Artificial Satellites", Electrical Communication, volume 39, number 1, pages 155—167; 1964) transmit signals to earth on two frequencies, modulated to give the position of the satellite and the exact time. This information and the Doppler shift due to the motion of the satellite with respect to the receiver are recorded and processed in a relatively small computer to give the position of the receiving station. Transmission on two frequencies permits correction for variations in the refractive index of the transmission path. These navigation fixes are independent of weather and are useful not only at sea but on land for geodetic surveys.

ITT Federal Laboratories, United States of America

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