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This Issue in Brief

Pentaconta Telegraph Switching System—The Pentaconta equipment designed for telephone switching is readily adapted to telegraph (telex) switching systems. The long history of these components assures their reliability and their use avoids the cost of unnecessary new designs.

In Europe, the average time charged for telex calls is 2.3 minutes and a quarter of the calls are for less than 1 minute. The further fact that 80 percent of the traffic is long distance makes rapid switching necessary as charges are earned only after the called station answers.

There will be at least one international center in each country and it will be equipped with registers, translators, and signalling circuits for interworking with the signals used in other countries. It will also handle national calls as well as serving local subscribers.

Main centers are designed to work with their own national exchanges and thus are not equipped for working directly with foreign international centers.

Secondary centers are designed for economy in capacities between 40 and 200 lines and they work with main centers.

Satellites are basically concentrators located remotely from the main center to which they are connected. They use the registers in the main centers.

Microminiature Radio Altimeter—The *STR 70-P* radio altimeter is a solid-state equipment using frequency-modulated continuous waves. It has an accuracy of ± 2.5 feet (0.75 meter) ± 3 percent and 1 foot (0.3 meter) at touchdown with a maximum indication of 5000 feet (1500 meters).

The transmitter oscillator works at about 290 megahertz and through a varactor multiplier produces 500 milliwatts at 4300 megahertz. This is frequency modulated at 100 megahertz for altitudes from 0 to 500 feet (150 meters) and is gradually reduced to 10 megahertz between 500 and 5000 feet (150 and 1500 meters). The frequency sweep occurs at a modulation rate of 300 hertz. Some power from the oscillator goes to a temperature-stable linear discriminator to produce a signal proportional to the oscillator frequency sweep. This is fed back to a varactor to control the oscillator frequency.

The receiver uses standard off-the-shelf semiconductor integrated circuits in flat-pack form and discrete add-on components selected for their high reliability. The whole set is separated into 6 replaceable and repairable modules divided to require a minimum number of connectors to reduce that source of unreliability. One small interchangeable module provides an interface to adapt the altimeter to the needs of the particular installation in either military or civil aircraft.

Silicon Planar Transistors and Diodes for Deep-Water Submarine Cable Repeaters—The methods used for the production and evaluation of high-reliability silicon planar transistors and diodes for the first major use of such components in deep-water submarine repeaters are described.

The production methods were essentially those used for commercial devices, which had themselves undergone a series of reliability improvement exercises since manufacture started in 1961. The diodes were encapsulated in a conventional metal transistor can. Especially high reliability was achieved by meticulous control of piece parts, processes, and subassemblies and by very careful screening of the finished devices.

A 20-year life was required for the devices with no more than 1 transistor failure in 1200 and 1 diode failure in 2400 every 4 years.

Assurance of this high reliability was obtained by: (A) performing accelerated tests in the temperature range from 240 to 280 degrees Celsius; (B) subjecting 2642 transistors and 4793 diodes to a severe mechanical/thermal test; (C) subjecting similar numbers of devices to a 3-month operating life test using the electrical conditions of the repeater but with the device temperature raised so that the test was equivalent to the required life; and finally carrying out a radioactive-krypton hermeticity test to a limit of 5×10^{-12} atmosphere cubic centimeter per second.

No device failures were obtained in tests (B) and (C).

Coaxial Cable System for 2700 Circuits—Any new transistor system must be compatible with the existing network of 960-circuit valve systems, as it is the expansion of these systems that represents the principal market. The valve systems have repeaters in surface huts spaced 9.7 kilometers (6 miles) apart. It was found feasible to space the 2700-circuit transistor repeaters at nominally 4.5-kilometer (2.8-mile) intervals so that alternate repeaters are housed in underground sites and the remainder in existing huts.

Alternate line amplifiers are automatically regulated by a pilot regulator operating from a 12 435-kilohertz pilot. The dependent repeaters receive power remotely from the attended stations, using a very low value of constant direct current which is inherently safe, and no special precautions for the protection of maintenance personnel are necessary.

A system of 11 repeater sections has been installed for field trial. An overall noise performance of 1 picowatt per kilometer has been obtained and the measured distribution of intermodulation products was as predicted. The individual amplifiers and the route show a very high degree of gain stability with variation of power supply and temperature.

Microwave Radio RL4H in Slimrack Construction—Rapid developments in the microwave field and in semiconductors have now made possible the design of a highly reliable, compact, and easily maintained all-solid-state system operating in the 4-gigahertz band, to provide mainline long-distance service with full 960-channel telephony and color-television performance specified by the International Radio Consultative Committee.

A slimrack is the radio bay of this system. A terminal station would also include the aerial system and overhead waveguide, modem, protection switching and supervisory equipment, and possibly an auxiliary link. The radio slimrack can be used as either a one-way repeater or as a terminal transmitter/receiver.

Hitherto the super-high-frequency transmitting power was obtained from traveling-wave tubes requiring high voltages, but now it is possible to incorporate the latest high-frequency high-power transistors and varactors. These give much longer life with lower power consumption at low voltages.

The slimrack incorporates easily replaceable modules to enable quick return to service and maintenance at base. Cooling is by natural convection and particular attention has been paid to adequate heat-sinking of semiconductors for maximum reliability.

Security of Interlocking Systems for Railroad Track Switching—Interlocking systems assure that a track arrangement and its signals are consistent and that all required protection is provided to reserve a selected route for a given train. A review is given of the interlocking means used for mechanical, electromechanical, relay, and geographic track switching systems.

The track switching, signaling, and detecting equipment for the geographic system is controlled by standardized sets of relays that are adapted to each particular installation by the design of the interconnecting cables.

After outlining the basic interlocking circuits, a number of principles are presented that have been developed over the years through experience with all previous switching systems.

Pentaconta Telegraph Switching System

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1. General

Increased application of automatic telegraph switching systems and their extension to new countries have stimulated interest in problems that formerly had not justified immediate attention.

One of these problems is an economical design of small exchanges giving full service to the subscribers. Another concerns speed of switching. The average charged time per call in Europe has dropped to 2.3 minutes and about 25 percent of all calls are charged for less than 1 minute. As about 80 percent of the traffic is long distance, fast switching reduces setting-up time, which is not charged to the subscriber, and increases paid-for utilization of the network.

Pentaconta * apparatus and techniques developed for telephone switching are applicable to these problems. Administrations using the Pentaconta system for telex in addition to telephony need stock fewer spare parts and will invest less time in training maintenance personnel.

The Pentaconta telegraph and telephone systems are very similar in the selection stages and the register connections. The telegraph system has more-complicated connecting and register circuits and has different subscriber identification. It includes all features of a modern telegraph system, and certain additional features can be provided if needed.

Special attention has been given to preventive maintenance, which is considerably reduced with crossbar switches. The weakest elements in telegraph exchanges are the polarized relays. The introduction of the mercury-wetted polarized relay is an important improvement, especially as the high quality of transmission can be guaranteed over a long period without special precautions.

Table 1 gives a breakdown of kinds of traffic in countries having a high density of telex subscribers.

TABLE 1
TRAFFIC IN COUNTRIES HAVING HIGH DENSITY OF TELEX SUBSCRIBERS

Type of Traffic	Large Countries in Percent	Small Countries in Percent
International calls	16	70
National calls	80	26
Local calls	4	4

There is a slight tendency toward an increase in local traffic since the introduction in the larger exchanges of the printergram, a telegram sent by teleprinter to the telegraph office.

The small average number of subscribers per exchange, especially in new networks, permits use of very simple control equipment. However the practically nonexisting local traffic, if we exclude special-service traffic, and the extent of international traffic require more-complicated control equipment.

2. Network

The basic Pentaconta telegraph switching system uses keyboard selection. Dial selection is available as an alternative but it and all the other versions are simplifications and are not discussed here.

Only the special teleprinter switching characteristics will be described, as the principles of the Pentaconta system are already well known.*

2.1 International Center

Every country will have at least one international center, which will be equipped with special signal adapters to interwork with all known signalling systems.

The translator can be equipped to use the routing plan of the International Telegraph and Telephone Consultative Committee (CCITT)

* Trademark of International Telephone and Telegraph Corporation and its associated companies.

* F. Gohorel, "Pentaconta Dial Telephone Switching System," Electrical Communication, volume 31, number 2, pages 75–106; June 1954.

for telex and gentex calls or for any other similar plan. The system will take care of communication between national classes (up to 100) and international classes. Semiautomatic positions are also foreseen to handle calls to manual directions or to small groups of trunks for which automatic service is not justified. The semiautomatic position also has call-back and operator-assistance facilities. They will interwork with radio automatic error-correcting systems, will meter on effective 10- or 6-second pulses, and have loop and tape alarm indications. Every position can be equipped with a group of trunk-status boards.

Due to the high traffic per subscriber, which averages 0.08 erlang and may reach 0.12 erlang, the line element was designed for 500 subscribers instead of 1000 as in telephony.

2.1.1 *Call Originated in the International Center*

Referring to Figure 1 a call originated by a subscriber connected directly to the international exchange will be handled as follows.

The subscriber presses his calling key. The common line equipment detects the calling condition and puts a calling condition on the line element marker circuit. The marker will identify the line to a free register and the connection between the subscriber and the register will be established through a free connecting circuit.

The register sends the proceed-to-select signal to the calling subscriber. The subscriber sends FIGURE SHIFT followed by the national number or the international prefix, depending on the type of call, followed by the end-of-selection signal. For a call to a local subscriber a group selection is made to connect a free fifties selector in the right line element and then the line is selected in this line element. Before the called line is connected the classes of the calling and called party are compared. If the comparison permits the connection, the register sends the WHO ARE YOU? signal to the called subscriber.

Time and date can be sent to both subscribers before the WHO ARE YOU? signal. The register will give the through connection and disconnect

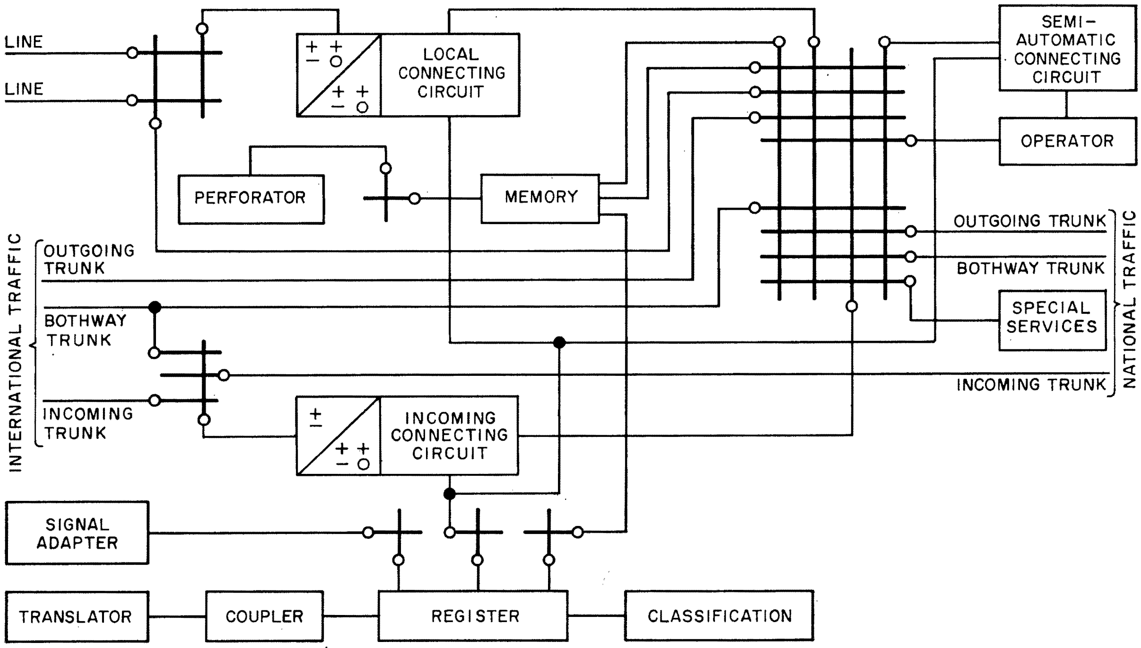

Figure 1—International center.

itself on the first element of the answer-back code of the called station. After making sure that the call is successful, metering signals on which charges are computed are started.

Only a group selection is necessary for calls to a special service. Normally all special services are connected to the group selection element. The call is handled exactly as for a local subscriber. However, if some operations should be omitted for some special services this will be taken care of by the register in accordance with the class of the special service.

If the call is for another national center a free trunk will be connected via the group selection element and a calling condition will be put on the forward path of the trunk. The distant exchange gives call confirmation followed by a proceed-to-select signal, whereupon the register in the originating exchange sends the selection information at maximum speed and disconnects itself.

The translator has all-trunks-busy relays per direction and if no free trunk is available in a certain direction alternative routing information, if any, is given without delay or supplementary information. When alternative routing is not to be used in the following exchange, the first character of the selection information, FIGURE SHIFT, is changed into ? (question mark) to inform the distant exchange that no overflow selection should be made.

When a call confirmation is not received within 2 seconds the trunk is considered to be out of order and the *DER* relay in the trunk circuit is operated by the register before the register starts a new selection. This operation will eventually be repeated up to 3 times. The *DER* relay will give a visible indication that a particular trunk is out of order. Optionally a sender circuit can be provided for testing trunks automatically. This common sender puts calling condition on the forward path for 500 milliseconds every 29.5 seconds. This sequence is repeated 5 times. If a call confirmation is received during one of the tests the trunk is automatically disconnected from the test equipment and is again available for normal traffic. The retest combined with automatic trunk testing is an improvement in maintenance practice as short interruptions in carrier systems are a well-known fact.

For a fully automatic international call only the prefix is sent. The register of the international center sends a second proceed-to-select signal to the calling subscriber. The subscriber sends the foreign subscriber's number preceded again by FIGURE SHIFT and followed by the end-of-selection signal.

For a call to an exchange using *B*-type signalling the register will connect a signal adapter circuit. When the selection information has to be sent in decimal pulses the register starts sending when sufficient information has been received to make the right selection (commonly after the first digit of the subscriber's number).

The signal adapter circuit is designed so that for calls to direct systems the moment at which a 200-millisecond stop polarity is received can be translated into letter codes such as *NC* and *OCC* to the calling subscriber and into *DER* when no pulse at all is received. For calls to register systems without code sending this is impossible as there is no control in the originating exchange on the setting-up time through the different exchanges.

The system is so designed that for calls to register systems using *B* signalling with code sending, the foreign code is transmitted to the calling subscriber without repetition.

When the call is going to a direct system the originating register will control the completion of the call, send WHO ARE YOU?, control the answer-back code, and send the time and date later.

When the foreign system is register controlled without code sending, the code *OCC* is sent for all unsuccessful calls.

Within a single network different codes, such as, *.NC* and *-NC* are used for rapid and simple reports.

For calls to systems using keyboard selection the register sends the selection information at maximum speed and disconnects itself. The call is then under the control of the foreign register.

For a call to a semiautomatic direction an operator position is selected and the register sends the received international prefix to the operator.

On receipt of the end-of-selection signal in the operator position a second proceed-to-select signal is sent automatically to the calling subscriber from the operator position. The subscriber sends the foreign subscriber number preceded by FIGURE SHIFT and followed by the end-of-selection signal. On receipt of this second end-of-selection signal the operator position circuit sends *MOM*. The operator starts handling the call when complete information is available and can set up the call immediately.

All calls to automatic systems will be controlled by the switching equipment and the operator will check only the exchange of answer-back codes and start the metering. This simplified method of operation permits operators to handle many more calls than do previous systems.

For calls to manual systems the switching equipment is used only to select a free trunk. The waiting time at the foreign office is generally too long to hold any common control equipment until the foreign operator answers the call.

The operator sends the selection information by keyboard to the foreign operator and supervises the establishment of the call.

2.1.2 *National Incoming Call*

The incoming trunk circuit receives the calling condition which it confirms immediately. The trunk-finder marker connects itself to a free register to which are transmitted the characteristics of the trunk (national or international trunk and type of service to be given). The register connects itself to the trunk through a free incoming connector and sends the proceed-to-select signal to the distant office by a 40-millisecond start polarity. The distant office sends the selection information followed by the class of the calling subscriber. The call is handled by the register as a call originated in its own exchange.

It should be mentioned that in case of an international call only the prefix is received from the distant register and the foreign subscriber number is sent immediately to the register of the international center. This not only saves time in transmitting selecting information but it reduces the storage capacity of the registers of the main centers to the national numbering and it standardizes subscriber operations throughout the country for international calls.

2.1.3 *International Incoming Call*

The procedures for international incoming calls are the same, except for classification. If the call has to be routed to a national subscriber, the international class of service must be translated into a national class of service. The class of the trunk circuit will indicate if the originating country is allowed to make international transit calls.

2.2 Main Center

The main center shown in Figure 2 differs from the international center by the absence of the semiautomatic operator positions and the corresponding semiautomatic connectors. The registers are designed to handle only national calls and have a limited storage capacity. The signal adapter is superfluous. The translator is simplified, as all the international prefixes need be translated into only one selection system. The capacity of a main center is practically unlimited and the same line elements are used as in the international center.

2.3 Secondary Center

The secondary center was developed in cooperation with the telex staff of Compagnie Générale de Constructions Téléphoniques. It is characterized by a special switching arrangement shown in Figure 3. This exchange is economical for capacities from 40 to 200 lines and provides all the facilities of the main center. This type of exchange is for large countries where the telex subscriber density is rather low. The register of the secondary center can be designed in another version to work as a satellite exchange. For a call originated in such a satellite the class of the calling subscriber is sent to the main office and then the register disconnects itself. For an incoming call only the two or three final digits and the class of the calling subscriber are sent.

2.4 Satellite

In countries with high or average telex subscriber density, the satellite exchanges reduce the price of the cable network by concentrating traffic. The arrangement is shown in Figure 4.

The satellite can be considered as a distant line element. For calls originated in a satellite, a trunk to the main center is immediately seized and, when the register in the main center is connected, the class of the calling subscriber is transmitted.

The register sends the proceed-to-select signal and the subscriber sends the selection information to the register in the main exchange. For a call to a subscriber connected to the satellite, the register sends the final 3 digits and the satellite sends the call-connect signal or one telegraph combination that will be converted into a normal code in the main exchange. Eventually time and date and the WHO ARE YOU? signals are sent by the register of the main exchange. No signal bypath is used in telex, as there is sufficient time before the motor is up to operating speed to send all the information via the normal transmission trunk.

The system is flexible enough to be introduced in all existing networks and can improve the efficiency of even the existing step-by-step systems using them as remote line elements or satellites.

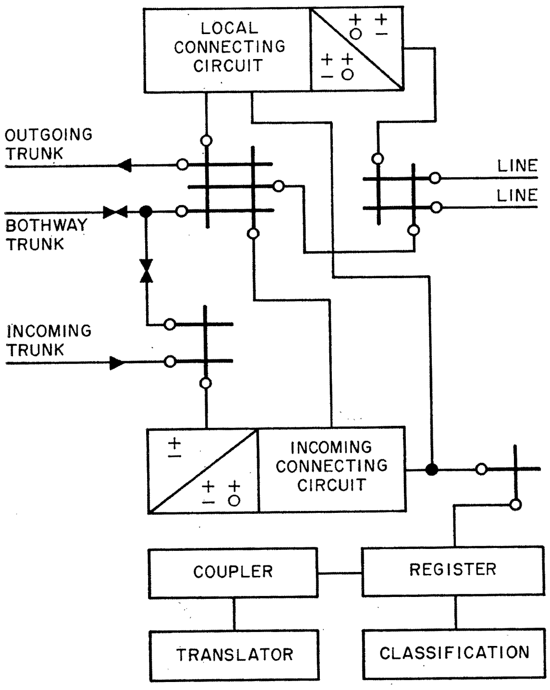

Figure 2—Main center.

3. Circuits and Main Features

3.1 Line Circuit

The line circuit is a 2-relay circuit and can be connected for either single or double current. The standard circuit works at 20 volts and 40

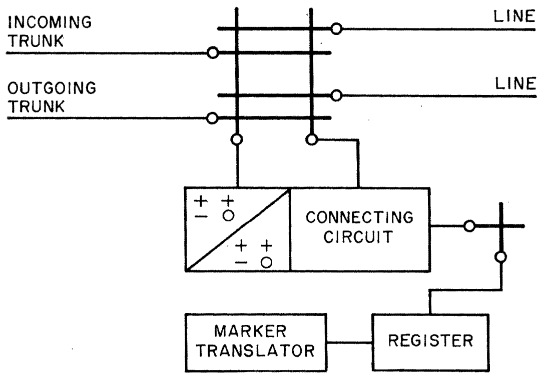

Figure 3—Secondary center.

milliamperes for single current or 20 milliamperes for double current. Other currents and voltages are possible. The line loop may have a maximum resistance of 2700 ohms, teleprinter included. In the rest condition there is no current on the line in the standard version but a 5-milliampere rest current is an optional feature.

3.2 Connecting Circuits

The connecting circuits were standardized to only three types. The semiautomatic connector without repeater is used for only the operator position in the international center.

The local and the incoming connectors are nearly the same, except for the metering relays in the local connector. Both circuits have a universal repeater, which for the incoming connector is always in double current at the incoming side.

3.3 Registers

As outlined in the network description, several types of registers are available. The register of the international center is certainly the most complicated, especially if several optional features such as time and date sending, various selection procedures depending on the class of the calling subscriber, special codes for observation of traffic, et cetera, are used. However, many elements of the three types of registers, and particularly the electronic circuits, have been standardized.

The main differences between the international and the other registers are as follows.

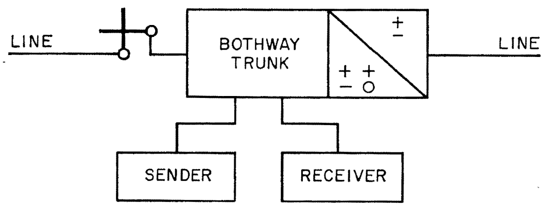

Figure 4—Satellite arrangements.

(A) Larger storage capacity (up to 15 digits).

(B) Connections to a signal adapter circuit for interworking with B-type signalling systems.

(C) Connections to a memory circuit are optional.

(D) Interworking with type-B keyboard systems is optional.

(E) Through connection and special signalling for start of metering if transmission is via radio channels.

The registers of a main and a secondary center differ because of the circuits with which they interconnect. As a maximum of 2 marker circuits are provided in the secondary center, the coupler circuit may be omitted and the translator and classification features integrated in the marker circuit. Another remarkable difference is the use of the register of a secondary center as the control element of a satellite.

3.4 Classification Circuit

Only one classification circuit is required even in large exchanges with several thousands of subscribers. It takes care of the class-of-service comparison between the calling and called subscriber. In international exchanges, it takes care of the transformation of classes for incoming calls. Although 100 different classes are foreseen, only 30 are intended to be compared with each other. The other classes are used in the register or in the translator or will be transformed before comparison. This high number of classes makes the system extremely flexible at practically no supplementary cost.

One important example can be given to underline this flexibility. The register can be wired so that on receipt of a certain class no supplementary selection information has to be sent by the subscriber. This means that special subscribers not having a normal 50-baud teleprinter can be connected via the normal, or even special, data channels to a special switchboard or to an automatic switching unit for special purposes. The telegraph switching equipment is used in this way as an inexpensive concentration equipment until a new service justifies additional investment.

3.5 Trunk Circuits

Three different types of trunk circuits are foreseen. The incoming trunk is the simplest and is very similar to the subscriber line circuit. The outgoing trunk has a special out-of-order relay, which will be blocked until the automatic retest circuit has found the line to be in good condition or until maintenance has been performed if the line was out of order.

The bothway trunk is more complicated than the incoming trunk as its operation as an incoming or outgoing trunk has to be well separated from the guard delay and the metering circuits. Some special precautions to avoid head-on collisions and retest are also foreseen, as well as the possibility of passing loop and tape alarm indications from *ARQ* systems to the switching system. The bothway trunk of the satellite differs from the other types in that some multiple relays are provided to store codes to be sent by a common sender to the main exchange. Another difference involves the interworking with markers and with send and receive circuits.

3.6 Metering for Tariff

The standard system of metering to determine charges for service foresees two different methods, one for national and one for international traffic.

The national traffic is registered on service meters with a minimum of 3 tariff units automatically registered at the start of each call. The number of tariff units is practically unlimited if an additional metering circuit is provided.

For international calls ticketing seems more applicable because of the great flexibility of the system. As subscriber identification is done on the answer-back code, or eventually on the digital part of the answer-back, the ticketing can be concentrated in the international center. Precautions are taken to prevent falsifying the answer-back code. All data are stored in the memory as long as the call is going on. At the end of the call, the information is perforated in telegraph code by a high-speed perforator. The tape can be handled by computers for billing the customers. An important optional item is to send the amount of the charges to the calling subscriber at the end of a call. This can be done for all calls or only on receipt of a special end-of-selection signal.

The choice of a tariff system depends on traffic distribution. Large countries have heavy national traffic and tariff variations among different zones are practically excluded. Therefore a large part of these low-cost calls can be registered on service meters. For international calls, where several new directions are added every year, it is much more economical to use ticketing as such changes have little influence on the program of the billing computer. In small countries, where up to 80 percent of calls are international, it may be more economical to have only ticketing.

Both solutions as well as only multimetering, even for international and intercontinental calls, are possible.

With ticketing, the time charged to a subscriber can easily be compared with the corresponding charges in the accounts between the administrations, as recently recommended by the International Telegraph and Telephone Consultative Committee (CCITT) at its meeting in Melbourne in 1966. This simplifies administrative work.

4. Operator Positions

There are two designs of operator positions available, one being a console having 2 receiving mechanisms and a single keyboard and the other a turret to be mounted on a standard table.

The console is equipped with *Lo 133* machines. This console cannot be adapted to all types of teleprinters because of high engineering cost. The turret was developed to connect all types of standard teleprinters and can be mounted on standard tables to comply with special requirements of customers.

The keyboard layout is practically the same and the features and manipulations are identical.

Both are cordless boards with a maximum of 6 cord circuits and 2 position circuits. The cord circuits may be underequipped and extended later as complete wiring is always installed.

To make full use of all the features of the position and switching equipment, the teleprinters must be arranged to provide a contact on the combinations upper-case *J* (bell) and upper-case *Z* (+).

Incoming calls are routed first to a free operator. If a free operator is not available, the call is routed to a busy operator, who connects it to a free teleprinter if at least one cord circuit is free. As soon as a cord circuit is seized it busies the position circuit for any other incoming call and determines which receiving teleprinter will be connected. The motor of the engaged teleprinter is started and an audible signal can be given.

The information is sent to the operator position by the register and the called subscriber as described for semiautomatic calls. The keyboard of the operator is disconnected until he pushes the corresponding send button.

To set up a call the operator seizes a normal register and sends the full selection information in one group of signals. The call-connected lamp will indicate when the call-connected signal was received in the switching equipment.

In case of ineffective calls, the trunk and switching equipment are immediately released from the outgoing end of the operator position. Extensive use is made of common automatic senders for all types of codes to simplify and limit the demands on the operator. Call-back facilities are provided to both the incoming and outgoing sides of the operator position to give greatest flexibility.

The metering is stopped automatically during operator intervention. Elapsed-time metering or metering with effective 10- or 6-second impulses from *ARQ* equipment is foreseen. In case of calls via *ARQ* channels, loop and tape alarm indications are given to the operator and, if necessary, the connection can be monitored.

The clearing signal can be originated by the caller, called subscriber, register, and operator. The caller may release the connection at any time except during setting up. The outgoing end will always be released as soon as one or both signals are given.

Conference and broadcast facilities can be arranged from special positions, which are also able to handle normal calls.

5. Equipment

The equipment is mounted in frames of two standard widths, 1.160 and 1.450 meters (45.7 and 57.1 inches). To simplify shipment and installation, these frames are assembled where they will be installed to form a bay between two uprights, the height of which can be 3.070 meters (121 inches) for 6 frames and 2.670 meters (105 inches) for 5 frames. The bays are mounted in rows, the length of which depends on the dimensions of the exchange room. Gangways between rows should give easy access to both front and back of the equipment.

Each bay has its own power-supply panel containing circuit fuses and signalling devices.

The supervision of the bay is aided by lamps in the supervision strip and by duplicate lamps at one end of each row as well as on the general exchange supervision panel. A remote general supervision panel can also be used.

The use of frames with well-fitted metal covers provides good protection against dust and shock. Figure 5 shows an international telex exchange in Lima, Peru, and Figure 6 displays the circuit-busy counters.

5.1 Line Unit

The line unit has 5 different types of frames as follows.

(A) Frames with line and cutoff relays. There are 50 lines per frame with adjustable resistors for controlling the line current and the compensation current for the repeater. Each line circuit can be wired as a single- or double-current line on an individual block.

(B) Frames with terminal selectors. Two types of frames are foreseen, one with 8 to 12 selectors and one with 12, 16, or 20 selectors. The number of vertical selectors is determined by the subscriber traffic. A fully equipped frame can handle up to 0.22 erlang bothway traffic per subscriber.

(C) Frames for line markers 1 and 2 with their associated distributing frame. Both markers of the same 500-line group are identical. The distributing frame consists of a certain number of terminal strip supports, each of which is connected by means of a connecting block to the marking relays of a hundreds group. The connections to the marking wires are made at the front side of the distributing frames by removable *U* links for a subscriber whose calling number corresponds with the equipment position terminal of the line and cutoff relay of the terminal selector frames or by jumper wires for other subscribers having a special allocation, for example, private-branch-exchange groups or for traffic equalization over the different fifties groups.

(D) Frames for call finders and fifties selectors. A primary section comprises all the call finders, fifties selectors, and mutual-aid selectors having a common multiple.

(E) Intermediate distributing frames.

5.2 Group Selection Unit of 4 or 5 Wires

The group selection may be in two different versions according to the initial capacity. Single-stage group selection is economical for up to 350 subscribers with average traffic. The 2-stage group selector for larger exchanges comprises the primary selector frames and the secondary selector frames controlled by a frame with 2 markers and 2 frames of marking relays. The maximum equipment for a single-group selection unit is 20 secondary selector frames which correspond to 1040 outlets.

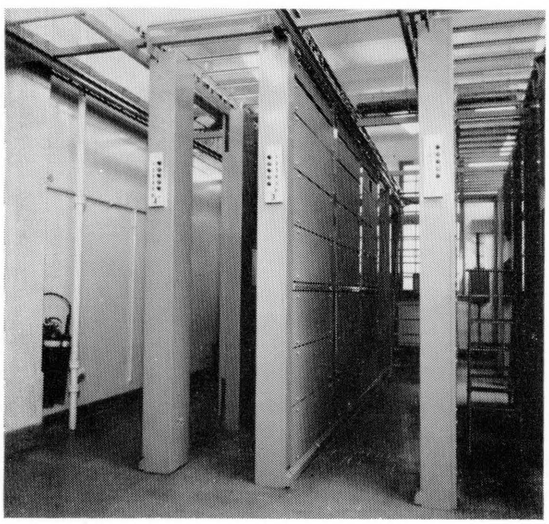

Figure 5—International transit exchange in Lima, Peru.

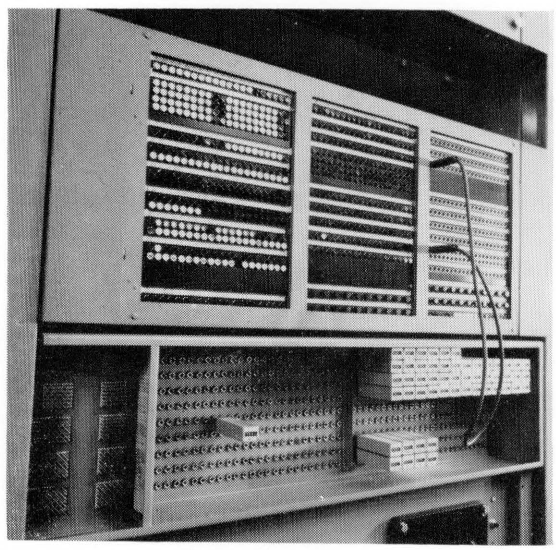

Figure 6—Display panel for all circuit-busy counters.

5.3 Group Selection Unit of 8 or 10 Wires

This group selection unit is always designed as a 2-stage unit. Normally, secondary frames of the small type with 12 secondary selectors are used. This type of group selection unit is used for the selection of trunks operating via *ARQ* equipment.

5.4 Trunk-Finder Element

An incoming call finder is a complete element capable of handling an incoming traffic of 55 erlangs. It consists of 3 sets of frames.

(A) There are 5 frames with trunk-finder sections.

(B) There is 1 frame for markers 1 and 2.

(C) There is 1 intermediate distributing frame.

5.5 Register and Coupler Bays

Depending on the type of exchange, the register is mounted in 1 or 2 frames. Large-type frames with reduced height are used to mount the coupler circuits. Depending on the line capacity of the exchange and the traffic to be handled,

TABLE 2

Equipment Required for Secondary Centers of Various Capacities

<table>
<tr><td colspan="7">150 lines with 4 primary sections or 200 lines</td></tr>
<tr><td colspan="6">150 lines with 2 primary sections</td><td rowspan="5"></td></tr>
<tr><td colspan="5">100 lines</td><td rowspan="4"></td></tr>
<tr><td colspan="3">50 lines</td><td rowspan="3"></td><td rowspan="3"></td></tr>
<tr><td colspan="2">20 lines</td><td rowspan="2"></td></tr>
<tr><td></td><td></td></tr>
<tr><td>Power panel</td><td>Power panel</td><td>Power panel</td><td>Power panel</td><td>Power panel</td><td>Power panel</td><td>Power panel</td></tr>
<tr><td>Intermediate distributing frame</td><td>Intermediate distributing frame and resistance lamps</td><td>Intermediate distributing frame and resistance lamps</td><td>Intermediate distributing frame</td><td>Intermediate distributing frame</td><td>Intermediate distributing frame</td><td>Intermediate distributing frame</td></tr>
<tr><td>Register finder</td><td>Marker 1</td><td>Marker 2</td><td>Line relays</td><td>Terminal selector</td><td>Line relays</td><td>Terminal selector</td></tr>
<tr><td>Register 1</td><td>Line relays</td><td>Terminal selector</td><td>Line relays</td><td>Terminal selector</td><td>Primary section 3</td><td>Primary section 3</td></tr>
<tr><td>Register 2</td><td>Primary section 1</td><td>Primary section 1</td><td>Primary section 2</td><td>Primary section 2</td><td>Primary section 4</td><td>Primary section 4</td></tr>
<tr><td>Supervisory panel</td><td>Supervisory panel</td><td>Supervisory panel</td><td>Supervisory panel</td><td>Supervisory panel</td><td>Supervisory panel</td><td>Supervisory panel</td></tr>
<tr><td>Register 3</td><td>Trunks (28 maximum)</td><td>Register 4</td><td>Register 5</td><td>Register 6</td><td>Register 7</td><td>Register 8</td></tr>
<tr><td>Pulse generator alarm circuit</td><td>Connectors (8)</td><td>Connectors (8)</td><td>Connectors (8)</td><td>Connectors (8)</td><td>Connectors (8)</td><td></td></tr>
<tr><td>Classification</td><td>Clock</td><td></td><td></td><td>Trunks (maximum 28)</td><td>Connectors (8)</td><td></td></tr>
</table>

1 frame with 2 couplers is equipped for 8, 10, or 12 registers.

6. Secondary Center

Table 2 shows an equipment layout for a secondary center. All selections are performed in one combined line-and-trunk selector. Special attention was given during the equipment design to make extensions from 20 lines up to 200 in the most-economical way. The different steps are indicated in the table. It is clear that such an equipment can be divided into 2 rows if this arrangement fits the available room better.

7. Satellite

For terminal satellite exchanges from 48 to 192 lines, a special design avoids the use of register circuits.

For an incoming call, the marker circuit of the satellite exchange receives the selection information from the register of the main exchange (2 or 3 digits and the class of service) and will indicate by a single telegraph signal if the call is successful or if some suitable code report should be sent to the calling subscriber.

For an outgoing call, the marker detects the calling condition and connects a free trunk. The class of the calling subscriber is stored on a multiple relay in the trunk circuit and is transmitted to the main exchange as soon as a register is connected. As soon as the selection information has been received, the register will send the tariff to be applied, if multimetering is used, to the satellite.

As this exchange does not require permanent maintenance personnel, alarms are automatically transferred to the main exchange. This type of exchange is designed for rapid and easy installation as the cabling is of the plug-in type.

These exchanges can be used in the initial plan in centers where a larger exchange will be justified later. The initial investment can be small while still giving good service to the telex subscribers.

Adriaan Melis was born in Antwerp, Belgium, on 28 August 1925.

He entered the services of Bell Telephone Manufacturing Company in 1947 in the circuit laboratory. He participated in the development of the *7E* telegraph switching system. He became head of the circuit design department in 1963.

Microminiature Radio Altimeter

W. L. GARFIELD

Standard Telephones and Cables Limited; London, England

1. Introduction

The radio altimeter *STR 70-P* was developed between 1963 and 1965 and entered production in 1966. This low-level radio altimeter has found wide application in a variety of aircraft from supersonic fighters to helicopters.

1.1 Specifications

In 1963 the future of the aircraft industries of Europe and the United States of America was problematical, both in the military and civil fields, particularly as to what types of aircraft would be designed. The one fact that seemed to be clear was that whatever aircraft emerged, there would be a need for low-level radio altimeters for one purpose or another.

The uses of such altimeters for civil aviation include: height indication, low approach, automatic landing, and terrain warning. For military aviation they also include terrain following, helicopter auto hover, and ancillary uses in weapons and reconnaissance.

From these many requirements a new altimeter would need flexibility of application. Equally important, and perhaps the main justification for a new development, would be improved reliability.

For these considerations the operational specification began to emerge and the main guidelines for the required characteristics were stated as follows.

(A) The maximum working range to be 5000 feet (1500 metres), the normal military requirement.

(B) From 0 to 500 feet (150 metres) it must have characteristics suitable for automatic landing.

(C) It must have characteristics suitable for automatic terrain following.

(D) It must be capable of driving up to 4 indicators.

(E) It must be capable of simple integration with one or more aircraft flight-control systems requiring a variety of outputs.

(F) It must be an order more reliable than previous equivalent equipments.

(G) It must be flexible and simple to install.

1.2 Operational Characteristics

The first decision to be made before development began was on the basic measurement techniques. It was decided that for a next-generation equipment, radio ranging of a well-established form should be used. The only question was should a pulse or a frequency-modulated continuous-wave technique be used. The latter was selected for several reasons.

(A) It is well established and is superior to pulse techniques for automatic landing because a pulse altimeter will detect the nearest object such as a fence or landing light whereas the continuous-wave system sees the total area of ground below.

(B) It was desired to produce an all-solid-state design and the generation of pulses of the required peak power for pulse operation are still beyond the present state of the semiconductor art.

(C) In all other applications there is no evidence that the frequency-modulated continuous-wave technique is in any way inferior to pulse techniques.

Extensive background experience established basic parameters known to be satisfactory for the landing function.

Frequency sweep	100 megahertz
Modulation frequency	300 hertz
Output time constant	0·25 second
Accuracy	± 2·5 feet (0·75 metre) ± 3 per cent and 1 foot (0·3 metre) at touchdown

From experience with *Mark 7* and *STR 43* radio altimeters, it was possible to establish the following characteristics for the range from 500 to 5000 feet (150 to 1500 metres).

Minimum sweep	10 megahertz
Transmitter power	500 milliwatts
Modulation frequency	300 hertz

In the *Mark 7* altimeter the ranges were switched, giving a 100-megahertz sweep from 0 to 500 feet (150 metres) and 10 megahertz from 200 to 5000 feet (60 to 1500 metres), while keeping all other parameters constant.

Accordingly, to provide a single continuous range for the new design, it was decided to make the sweep a constant 100 megahertz from 0 to 500 feet (150 metres) and then decrease gradually to 10 megahertz between 500 and 5000 feet (150 and 1500 metres). This procedure would give operational characteristics known to be satisfactory.

The modulation frequency could evidently be kept at 300 hertz for all purposes since by so doing it was known to produce a fast enough data rate to permit an output time constant of 0·1 second which, in turn, was known to be the minimum likely to be required in any application.

1.3 Interface Problem

The applications listed imply use of the altimeter with a variety of different aircraft systems with which it has to be interconnected. Undoubtedly these systems will have a variety of output requirements from the radio altimeter since, in most cases, they have been designed and developed with no reference to the altimeter output characteristics.

Accordingly, it was decided that there would be (A) a permanent indicator output capable of driving at least 4 indicators and (B) a small interchangeable module to provide flexibility of interface for various required outputs having different slopes and polarities. These latter would be installed as required by the users.

2. Constructional Techniques

The design of a frequency-modulated continuous-wave radio altimeter breaks down naturally into several parts determined by the frequency at which they operate. These are the transmitter, receiver, video and signal processing circuits, and power supply. The general division of circuit functions is shown in Figure 1.

2.1 Transmitter

The operational considerations above show that the transmitter should have the following characteristics.

Centre frequency	4300 megahertz
Maximum sweep	100 (± 50) megahertz
Output power	500 milliwatts
Linearity of triangular frequency sweep	better than 1 per cent
Modulation frequency	300 hertz

Since the transmitter was to be of semiconductor construction, it was evident that it would have to be of the varactor multiplier type because no transistor or other semiconductor oscillator was available having the required output power at 4300 megahertz.

The initial design in 1963 used a transistor oscillating at 67 megahertz and producing an output of 12 watts. This stage was followed by

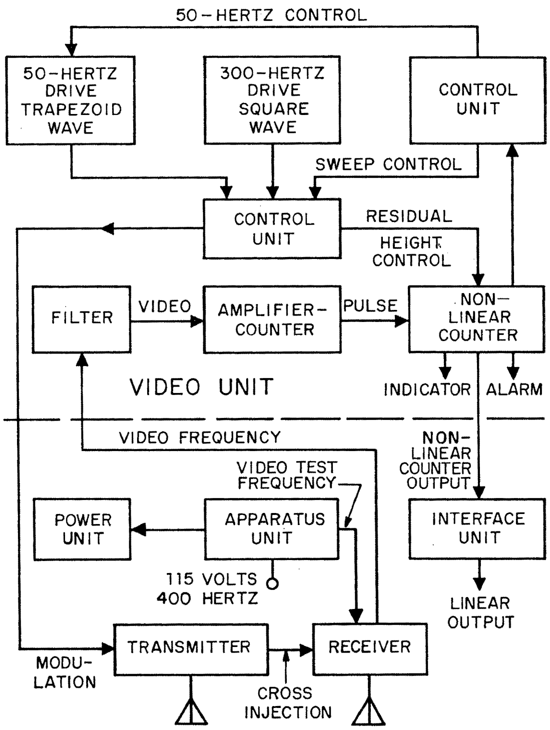

Figure 1—General division of functions in *STR 70-P* altimeter.

a varactor chain of multipliers which doubled the frequency in each stage to 4300 megahertz.

At the time of the initial design the available semiconductor devices made this the best line of attack though it was realized that advances in this art were being made so fast that higher-frequency higher-power transistors would soon be available. The idea was that as these became available, they could be fitted into the chain at higher frequencies, thus discarding more and more of the lower-frequency elements until the ultimate of an oscillator at 4300 megahertz was reached.

The transmitter in production at the time of writing uses a transistor oscillating at 287 megahertz producing an output of 4 watts.

One of the problems always present in the design of such frequency-modulated transmitters is that of stabilizing the centre frequency and ensuring linearity of sweep.

The oscillator must, of necessity, employ some form of electronic tuning, and the varactor is the only practicable solution. Unfortunately, varactors do not possess linear capacitance/voltage characteristics and even if they did it would be very difficult to design a circuit that had the necessary linearity of frequency/voltage law, especially over a large temperature range.

There are two solutions to this problem. The modulation waveform may be modified before applying it to the tuning varactors, or a stable method of continuously measuring the sweep may produce feedback to ensure that what this measurement method sees is identical with the desired characteristic.

In the early models of the transmitter the first method, which is essentially an open loop system, was employed. However, it was evident that the second method had advantages and this has now been incorporated into the latest design of transmitter. In essence, the oscillator operating at 287 megahertz has a small amount of power (10 milliwatts) tapped from its output and fed to an extremely stable linear discriminator and produces a video signal proportional to the oscillator frequency sweep.

This waveform is fed back in antiphase to the varactor modulation input together with the modulation waveform, and the degree of negative feedback is adjusted to give the desired linearity of sweep with good margins. The whole system is stable and linear over the temperature range from -55 to $+90$ degrees Celsius. The transmitter complete with its discriminator and feedback system is packaged in a single module.

The transmitter also provides 10 milliwatts at 4300 megahertz to serve as the local-oscillator signal for the receiver. In addition, the main transmitter output at the 500-milliwatt level passes through a ferrite isolator to protect the output varactor in case of accidental disconnection of load and to prevent reflections from the far end of the transmitter aerial cable from re-entering the transmitter and causing any spurious altitude signals.

2.2 Receiver

There is less scope for fundamental changes of technique in the receiver, and improvements are chiefly in components.

Basically the receiver has not changed in concept. It is a hybrid ring mixer with balanced diodes; however, the following improvements have been made.

(A) The hybrid ring is now a form of printed circuit on high-quality dielectric material, thus reducing its physical dimensions.

(B) In place of the previously used silicon diodes, modern hot-carrier diodes are employed.

(C) The video preamplifier has been incorporated into the receiver package, and full use is made of modern low-noise input-stage devices.

Point **(B)** is worth expanding. The frequency-modulated continuous-wave altimeter is basically a zero-frequency intermediate-frequency system and the bandwidth employed in the video amplifier is in this case from 600 to

50 000 hertz. This means that we are only concerned with noise problems which arise in band.

Previously the main trouble has been low-frequency or "flicker" noise produced in the mixer crystals. This was alleviated by the development of crystals having low flicker noise for Doppler navigator systems—but useful in radio altimeters.

The other source of disturbance is low-frequency interference. This phenomenon is caused by any variation in amplitude of the local-oscillator signal over the swept band or mismatches in the mixer which give rise to a spurious signal at the modulation frequency. Because of this it is the normal practice to run the local-oscillator-signal crystal currents much lower than would be used for an amplitude-modulated system, that is, at a level of 100 microamperes where 1 milliampere would be normal.

When using hot-carrier diodes, which normally run at higher currents than silicon diodes, it is necessary to apply forward bias if weak local-signal injection is used, and by this means both low-frequency interference and low-frequency noise are minimized.

The other advantages of hot-carrier diodes are size, robustness, and high burnout level. These characteristics enable the diodes to be soldered directly into the hybrid ring thus eliminating crystal holders, which have long been a source of contact problems.

The entire receiver achieves a noise figure almost 6 decibels better than previous altimeter receivers and is packaged in a module size which contains an input ferrite isolator, mixer, and video preamplifier.

2.3 Video Circuits

The video circuits, which are the most complex parts of the altimeter, also break down naturally into sections by function as follows: video amplifier, frequency counter or counters, and supervisory or flag circuits.

The major decision was, of course, what type of circuit elements to use. From the performance point of view no difficult parameters are involved, the amplifier bandwidth being about 50 kilohertz maximum and the counter maximum counting rate for linear operation being of the same order.

In 1963 there were three principal types of circuit elements that could be considered: silicon transistors, thin-film circuits, and integrated solid circuits (monolithic).

It is difficult to realize now that in early 1963 linear monolithic circuits capable of useful gains at 50 kilohertz were not easily available. Thus, the choice lay between transistors and thin-film circuits.

It is necessary to consider the reasons why microelectronic circuits are desirable in an equipment such as this. The prime purpose is improvement of reliability and for this reason the relative techniques need careful consideration and comparison.

The thin-film circuit, in 1963, offered great flexibility of design, since it was possible to have specific circuits designed and manufactured for the particular altimeter development. This in turn means that, with careful rationalization, circuits could be produced which needed very few external conventional components to be associated with them. In addition, as at mid 1963, the frequency response obtainable with thin-film circuits was much wider than that with equivalent monolithic circuits.

Of course the thin-film circuit has to have the active silicon elements (transistors and diodes) applied to it and this introduces additional joints which, though undesirable, are also unavoidable.

However, it was decided to make a first model of the new-generation altimeter using thin-film video circuits. This was accomplished by the spring of 1964 and was packaged in an Arinc (Aeronautical Radio, Incorporated) standard box of $\frac{1}{4}$ short half-height size. It had no alternating-current power supply and operated from 28 volts direct current; it was designated *STR 70-G*.

Before proceeding to the next phase of development it is worth while looking at the new ideas in operational techniques which we were developing at this time in parallel with constructional methods.

The *STR 70-G* was of all-solid-state design using the first design of transmitter described above and with thin-film microcircuits, but in operational techniques it was a duplicate of a previous altimeter, the *STR 40*.

But the transmitter, being electronically modulated, offered a flexibility of modulation not available in previous altimeters using klystron or triode valves. These latter commonly employed mechanical modulation which nearly always produced sinusoidal sweep characteristics. This, in turn, resulted in a beat-frequency signal out of the receiver which, at any one altitude, contained a broad band of frequencies the maximum of which was 1·6 times the mean.

With electronic modulation a linear triangular waveform can be applied which more nearly approaches the optimum giving a constant-frequency beat tone over the sweep at a fixed altitude.

Furthermore, it now becomes possible to apply complex forms of modulation which bring important advantages. The latest altimeter, the *STR 70-P,* employs a complex modulation waveform which not only eliminates step error but ensures that interference cannot occur between altimeters in multiple systems whether on the same aircraft or adjacent.

New circuits for the production of controlled sweep amplitude (frequency excursion) had also been developed and the nature of these circuits was to have a bearing on the circuit elements chosen for the next phase of development.

By the end of 1964 it was evident that developments in linear monolithic circuits had caught up with thin-film circuits in the frequency range of interest. In particular, the balanced operational amplifier and some switching elements seemed to be suitable for this application.

In addition, monolithic circuits were now very much smaller than thin-film circuits and the problems of diffusing resistance and capacitance elements into silicon chips had been more successfully overcome than those of depositing active elements on thin films.

However, the advantages are not all one way. To have special monolithic circuits designed and manufactured for a specific equipment is prohibitively expensive, and they could not be made in sufficient quantities to guarantee effective quality control.

This meant the use of standard off-the-shelf elements which were made in large numbers and with adequate quality assurance programmes.

Since these circuit elements are not designed specifically for the radio altimeter, a fairly large number of conventional components must be associated with them.

However, miniature resistors of metal-oxide film type and miniature glass-encapsulated capacitors were available and reliable.

So it was decided that for the production form of the radio altimeter, maximum use would be made of monolithic circuits, accepting that a fair number of discrete components would also have to be used, but that these latter would be carefully selected from types of known reliability and in large-quantity production with adequate quality control.

Having made the decision to go over to monolithic circuits, the choice of package remained to be resolved. There were, at the time, two packs available, the transistor-case type and the flat pack.

For mechanical application, the transistor-case type has the advantages of proved mechanical design, no teething troubles, and no requirement to weld: but, with its peripheral attachment space, it was larger. It is nearly always attached by conventional soldering and represents an intermediate stage between the transistor and the flat pack.

To obtain the very best reliability from flat packs it is necessary to weld them into the circuit and this necessitated a detailed programme of microwelding research relating to production-line methods. A technique using a printed-circuit board of conventional type having a copper track, which is given a gold flash, was adopted. The flat packs were welded onto the track side of the board and the conventional components were placed on the opposite side with their wires passed through holes and soldered on the track side.

The welding process is continuously controlled in production and carried out in clean-room conditions as is in fact the entire altimeter assembly procedure.

Figure 2 shows the assembly of conventional components to a board which already has the flat packs welded on.

2.4 Package Form

It might have been difficult to decide the shape and size of the transmitter/receiver unit for this new altimeter against a general background of multipurpose requirements. However, the decision was literally made for us by the necessity of fitting to one particular aircraft.

Figure 2—Operator assembling conventional components to a printed-circuit board, which already has flat packs welded on to the opposite side. A complete *STR 70-P* unit with covers removed is in the lower right corner.

This is a very-high-performance supersonic fighter/bomber and the only available space for the radio altimeter dictated the package size and shape which the altimeter now has.

The important question once again was whether to modularize, how much in each module, how to interconnect, what should be repairable and what not, and all the usual problems.

Certain parts such as the transmitter, receiver head, and power supply became modules quite naturally. But the entire video system could be arranged almost any way.

Now it is well known that the biggest menace to reliability in any airborne equipment is connectors, particularly plugs and sockets. Yet if easily replaceable modules are the aim, they must be used.

The philosophy of construction was simply that of using the minimum number of interconnections among modules. This was aided by deciding that all modules are repairable and thus larger modules can be used than if they had to be throw-away items.

Finally 6 main modules were evolved and these are shown detached from the chassis in Figure 3. The video unit, extreme left, has two sections which are plugged and screwed together and either may be replaced or the entire video unit replaced as a whole.

The chassis contains no active part of the circuit and is merely an interconnection and support means.

2.5 Alternative Packaging

It will be evident that circumstances have dictated that the package form of the first design of this altimeter is military orientated.

It is also clear that the modules lend themselves to packaging in different shapes of case and alternative designs are already under way.

For military purposes the original configuration is satisfactory and no difficulty has been encountered in fitting it in seven different types of aircraft; this is of logistic importance to the Armed Services.

However, civil aircraft users are less flexible in their requirements because of the cost of deviating from international packaging specifications, and it is this class of user for whom the same modules can be repackaged.

3. Conclusion

It is too rare in the art of electronics that the pursuance of a technique for its own sake brings beneficial side results. In this case however, the adoption of solid-state microwave techniques together with microcircuits in the search for high reliability results in an equipment that is substantially smaller and lighter than its predecessors, has lower power requirements, and is more rugged.

In addition, the flexibility which these new circuit elements give results in greater operational margins by permitting new circuit techniques to be applied. Figure 4 shows the complete altimeter system with one type of antenna and indicator.

What, then, is the next step? Gunn effect devices, together with multielement silicon chip devices, and many other new techniques are becoming available, so perhaps the next generation of radio altimeters will find the transmitter-receiver box eliminated, with the radio-frequency system integrated into the antennas and the signal processing circuits built into the indicator. It depends upon how reliable we can make the system, and to this the component manufacturers largely hold the key.

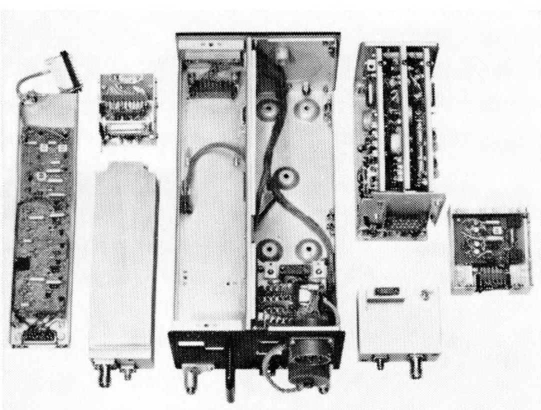

Figure 3—Modular construction of *STR 70-P*. From the left are the video unit, transmitter (front) and apparatus unit, chassis that has no active circuits but serves only for support and interconnecting, receiver (front) and power unit, and at extreme right the interface unit. The 3 units at the right are accommodated in the right half of the chassis unit.

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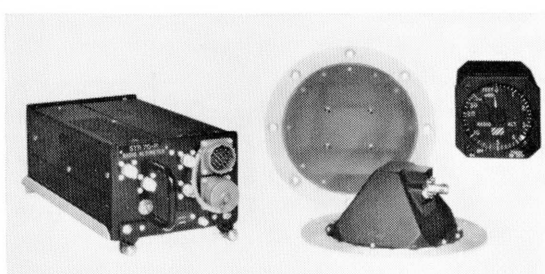

Figure 4—The complete *STR 70-P* equipment showing one type of antenna and indicator.

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6. W. L. Garfield and F. T. Norbury, "Instrument Low-Approach System and Radio Altimeter for All-Weather Landings," *Electrical Communication,* volume 41, number 2, pages 196–214; 1966.

William L. Garfield was born in 1916 and received his education at St. Paul's School of London and Northampton Polytechnic. He was initially trained as a classics scholar, but a keen early interest in engineering caused him to join Standard Telephones and Cables in 1940 as a junior member of the engineering inspection department.

Mr. Garfield is now chief engineer of the Navigational Systems Group in the Radio Division. He has many patents and has contributed many articles to the technical press.

Alexander Receives Wire Association Medal

D. C. Alexander, Vice President of Engineering of ITT Wire and Cable Division, received the medal award of the Wire Association for his paper "Impulse Dielectric Testing Applied to Insulated Wire."

The paper was presented at the Los Angeles Regional Meeting of the Wire Association on 17–18 February 1966. The award was conferred at the meeting of the Electrical Conductor and Non-Ferrous Wire Division in Buffalo, New York, on 12–13 April 1967.

Predicted Air-Traffic-Control System Realized

Over two decades ago there appeared in Electrical Communication a survey paper outlining a co-ordinated system of radio aids to air navigation and traffic control. This comprehensive system was designed to be adopted in stages because any abrupt change from the several uncoordinated systems then in use would not have been economically feasible. One of the last elements of the proposed system to be put in service was installed in 1967 and a report on this achievement is reprinted below together with the corresponding discussion in Electrical Communication.

New System Sends Altitude of Aircraft to L. I. Control Unit

(Reprinted in part from the New York Times of 14 February 1967.)

The $2 million installation in the Federal Aviation Agency's New York air traffic control center here enables any aircraft that has the necessary equipment to transmit its identity and altitude for display directly on the center's radar screens.

The information, beamed to a radar antenna as coded pulses, is processed by a computer in the center. It shows up on the screens used by air traffic controllers as a rectangular "tag" next to the plane's image. As the image moves, the tag moves with it.

Without such a tag a controller has no way of discerning from his screen the altitudes of the respective planes he is concerned with.

Pulses Transmitted to Ground

Heretofore, the only way the controller had of knowing a plane's altitude was to call the pilot by radio and ask him.

With the new device the controller need only refer to the screen. Once a pilot turns on his transmitting "beacon" the pulses to ground operate continuously and automatically. Any deviation in altitude of 100 feet or more is instantly recorded on the ground.

Several advantages are cited by the F.A.A. Among them are the following:

It will enable the controller to see for himself the plane's actual altitude at all times, not just when the pilot tells him.

It will reduce the chances of error caused by misunderstanding between pilot and controller.

It will help reduce the clutter on already overladen communications frequencies between air and ground. One controller estimated that half such clutter is controller altitude requests and pilot responses.

It permits the controller to dispense with plastic markers he now places alongside planes to identify them, and which he must move manually to keep next to images of the planes they refer to.

It eliminates the possibility that a plastic marker may accidentally be placed next to the wrong plane.

The FAA system is called NYCBAN (pronounced NICKban) for New York Center Beacon Alpha Numerics. The term "alpha numerics" refers to the use of alphabetical letters and numbers on the radar screen.

Aerial Navigation and Traffic Control with Navaglobe, Navar, Navaglide, and Navascreen

(Reprinted in part from a paper by H. Busignies, P. R. Adams, and R. I. Colin, then of Federal Telecommunication Laboratories, published in Electrical Communication, volume 23, number 2, pages 113–143; June 1946).

It is clear that the ultimate goal envisaged should involve considerably more complete service than the mere provision of beacon-assisted radar displays on the ground, and distance and azimuth indications in the airplane. A series of additional functions beginning to be recognized as ultimately desirable, is the automatic reporting of such data as identity and altitude to supplement the plan-position information provided by the responder-assisted surveillance radars on the ground.

There is general agreement that some sort of identification must be given. There is somewhat less agreement with respect to the extent of identification information which should be given; also, with respect to the question of whether altitude information could be given by responder beacons or be determined by height finders on the ground. Federal's position on this question is that the identification information should be given in a form capable of handling a very large number of different identification codes so that each airplane may have a permanently assigned identification code.

In respect to altitude information, it is felt that the desirable accuracies of altitude determination are of the order of 100 feet or so and, therefore, ultimately satisfactory control cannot be achieved at reasonable distances by unassisted height-finder techniques. It is accordingly believed to be necessary, ultimately, to provide some sort of altitude information by responder action.

In addition to providing the ground with the above-mentioned extra information, with respect to altitude and identity, it is believed that the ultimate goal should also include some means for producing a single integrated pictorial display. In such a display the plan-position information from the plan-position-indicator (PPI) scopes, and the altitude and identification information transmitted by the responder beacons, are combined in a simple readily readable form. This information should additionally be made available for controlling, computing, recording, tabulating, and predicting mechanisms of various types not yet clearly foreseen. Hence, it appears desirable to add the requirement that the information on the ground should not only be displayed in an integrated pictorial form, but should also be translated into the form of positive "tele-control" signals such as telegraph or selsyn signals which are readily adaptable for remote transmission and for controlling electromagnetic mechanisms.

Silicon Planar Transistors and Diodes for Deep-Water Submarine Cable Repeaters

J. M. GROOCOCK
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1. Introduction

For many years the manufacture of electronic components for use in submarine repeaters has been a specialized activity of a small number of firms. The very serious disruption of important communication links, loss in revenue, and high cost of repair caused by any failure of a submarine repeater necessitate an extremely high level of reliability for the repeaters themselves and for the components used therein.

Virtually all the commercial submarine repeaters presently operating use electronic valves, not transistors. To a considerable extent this has been because transistors, despite their claimed high reliability, have been regarded as new unproved devices by the submarine repeater makers, and it is certainly true that the several decades of reliable valve operation cannot be matched by transistors. In this paper the methods used to manufacture silicon planar transistors for the first major application of such components in deep-water submarine repeaters, together with the associated semiconductor diodes, are described, and also the methods used to give the required reliability assurance.

These semiconductor devices have been supplied for use in the submarine repeaters of a number of cables to be manufactured and installed by Standard Telephones and Cables, including that to be laid between the United Kingdom and Portugal. This cable will have 480 two-way 4-kilohertz circuits with a total bandwidth of 5 megahertz and it is due to be operational by the spring of 1969.

2. Electrical Specification of the Transistors and Diodes

The transistors and diodes were for use in the supervisory circuits of the repeaters. The basic requirements were for an *n-p-n* silicon planar transistor in the *TO5* encapsulation with a minimum f_T of 300 megahertz and a 25-volt V_{CE} rating and for a silicon planar diode with a 4-nanosecond reverse recovery time and 100-volt reverse breakdown. Summaries of the two specifications are given in Tables 1 and 2.

3. Reliability Requirements

The Submerged Repeater Division of Standard Telephones and Cables required for reliability for submarine cable repeater service that on test there be no more than 1 transistor failure in 1200 during 4 years of operation, and no more than 1 diode failure in 2400 during 4 years of operation. Finally, a 20-year life was required for the devices and the failure rate must not rise during this period.

4. General Principles of Production and Test

In supplying these transistors and diodes for submarine repeater use there were two reliability problems: (A) to make devices having the required reliability and (B) to obtain satisfactory assurance that this reliability level had been achieved.

The techniques currently used by S.T.C. Semiconductors for making standard silicon planar devices for civil and military applications, which have been successively upgraded by a series of reliability improvement exercises since manufacture started in 1961, were basically quite capable of providing the required reliability. It was therefore decided that no departure should be made from these methods. Especially high reliability would be achieved by meticulous control of pieceparts, processes, and sub-assemblies and by very careful screening of the finished devices. It was believed that this approach was much more sound than the alternative of introducing new processes and techniques, however attractive these might appear, which had not been proved by a long period of mass production.

The same principle was adopted with regard to the assembly operations. These were carried out by a small number of the normal production operatives, selected because they were known to produce work of particularly high quality and consistency. The alternative of recruiting and training special operators was not adopted. Reliance was placed upon repeated and careful 100-per-cent inspections under the supervision of the development and quality-control engineers, by precise record keeping, and also by ensuring that the total process time was kept to a minimum so that sub-assemblies were not held at any stage longer than necessary.

One other major decision was taken for reasons of reliability. This was to encapsulate the diode in a standard *TO18* metal transistor can using transistor techniques. There is no difficulty at all in doing this. Conventional transistor assembly methods are equally applicable to diodes; they are not normally used for reasons of cost and size, neither of which was of major importance in this case. The advantages of the metal-can approach were that essentially only one encapsulation technique had to be controlled to the high level of quality required rather than two, and in addition it is probable that it is more difficult to achieve very high reliability using the conventional glass diode encapsulation (*D07*) than the transistor encapsulation. This is because in the former both pressure and solder contacts are used for internal bonding, whereas in the latter all joints are made by either alloying or thermocompression bonding. In addition it is extremely difficult to control the atmosphere within the glass envelope of a conventional diode.

For the reliability assurance, separate procedures were carried out to cover the electrical reliability and the mechanical reliability, for

TABLE 1

ELECTRICAL SPECIFICATION OF *n-p-n* SILICON PLANAR TRANSISTORS

All Characteristics at 25 Degrees Celsius

Characteristic	Symbol	Test Conditions	Limits		Unit
			Minimum	Maximum	
Collector-base cut-off current	I_{CB0}	$V_{CB}=30$ volts $I_E = 0$	—	10	nanoampere
Collector-base breakdown voltage	$V_{BR(CB0)}$	$I_C = 10$ microamperes $I_E = 0$	45	—	volt
Emitter-base breakdown voltage	$V_{BR(EB0)}$	$I_E = 10$ microamperes $I_C = 0$	5	—	volt
Collector-emitter sustaining voltage	$V_{BR(sust)(CE0)}$	$I_C = 10$ milliamperes (pulsed) $I_B = 0$	25	—	volt
Large-signal current gain	h_{FE}	$V_{CE} = 1$ volt $I_C = 10$ milliamperes	50	200	—
Collector-emitter saturation voltage	$V_{CE(sat)}$	$I_C = 10$ milliamperes $I_B = 1$ milliampere	—	0·5	volt
Base-emitter saturation voltage	$V_{BE(sat)}$	$I_C = 10$ milliamperes $I_B = 1$milliampere	—	0·9	volt
Small-signal forward-current transfer ratio	h_{fe}	$I_C = 10$ milliamperes $V_{CE} = 15$ volts $f = 100$ megahertz	3	—	
Output capacitance	C_{ob}	$V_{CB} = 5$ volts $I_E = 0$ $f = 100$ kilohertz	—	6	picofarad
Emitter transition capacitance	C_{TE}	$V_{EB} = 0{\cdot}5$ volt $I_C = 0$ $f = 100$ kilohertz	—	10	picofarad
$r_{bb'}C_c$ product	$r_{bb'}C_c$	$I_C = 10$ milliamperes $V_{CB} = 10$ volts $f = 40$ megahertz	—	300	picosecond

example, to eliminate the possibility of failure due to internal bonds breaking. In both cases considerable use was made of overstress methods. The final mechanical test (see Section 6) and the long-term electrical burn-in (see Section 7) were essential parts of the reliability assurance procedure. They were intended to give proof of the achievement of the reliability levels specified in Section 3. More failures than the acceptable number would have indicated that the required reliability had not been achieved and would have failed the entire lot. Although these tests were applied to the devices for actual installation in the repeaters, it was *not* assumed that the tests provided effective screens and that failed devices could be rejected leaving a reliable residue.

For both the mechanical test and the burn-in, sample sizes were used which were sufficiently high to give statistical assurance of the failure proportion required. It was not, of course, possible to apply 4 years of testing. The equivalent of testing for 4 years was obtained for the mechanical test by using a very extreme mechanical/thermal overstress, and for the burn-in by carrying out 3 months of testing using the actual operation conditions of the submarine repeater, but raising the case temperature sufficiently to give an acceleration of 16 times (ratio of 4 years to 3 months).

Because the actual devices for use in the repeaters were subjected to these tests, unless the failure rate in the actual 4 years of operation was higher than that revealed in the equivalent of 4 years of testing, the reliability requirements would be met. It is almost universal experience that failure rates for semiconductor devices fall rather than increase. In addition tests carried out on samples (not for use) at much higher overstress levels, which provided the information on the acceleration factor needed for the burn-in, also showed that no significant part of the life of the devices was used up in the burn-in and that no wear-out failure mechanisms were induced (see Section 8).

5. Production Methods

For the manufacture of the high-reliability transistor there are a total of 78 different process and inspection operations involving 124 detail specifications covering the stages from the silicon slice input to the completion of assembly and encapsulation. No attempt will be made to summarize these operations. An account will merely be given of some of the

TABLE 2
ELECTRICAL SPECIFICATION OF SILICON PLANAR DIODE
All Characteristics at 25 Degrees Celsius

Characteristic	Symbol	Test Conditions	Limits		Unit
			Minimum	Maximum	
Reverse leakage current	I_R	$V_R = -20$ volts	—	25	nanoampere
Reverse leakage current	I_R	$V_R = -75$ volts	—	5	microampere
Reverse voltage	V_R	$I_R = 100$ microamperes	−100	—	volt
Forward voltage	V_F	$I_F = 10$ milliamperes	—	1	volt
Capacitance	C	$V_R = 0$ $f = 100$ kilohertz	—	2·2	picofarad
Reverse recovery time	t_{rr}	$I_F = 10$ milliamperes to $I_F = 1$ milliampere, $V_R = 6$ volts, $R_L = 1000$ ohms	—	4	nanosecond
Forward recovery peak voltage	V_{fr}	$I_F =$ 50-milliampere square wave, pulse width = 140 nanoseconds, rise time = 10 ± 0·5 nanoseconds, repetition rate = 90 kilohertz	—	2·5	volt

inspection procedures used especially for high-reliability purposes and of the results obtained. A complete record was kept of the movement of each slice through the various diffusion stages and similarly of each sub-lot through the various assembly stages. All rejected devices were labelled and routed to the Engineering Department for retention. An example of the sheet used for recording the assembly stages is given in Table 3.

Each inspection was described in a detailed specification. For example, the engineering inspection after thermocompression bonding is performed at a magnification of 50 times. The specification calls for examination in turn of each post bond, the aluminium wires themselves, each die bond, the die, and finally the header. On this one specification 24 detailed inspection features are covered.

6. Testing of Encapsulated Devices

On completion of the assembly the devices were subjected to a series of 100-per-cent tests. First they were tested electrically to the specifications given in Tables 1 and 2. The devices meeting the specification were then subjected to 5 temperature cycles between −55 and +150 degrees Celsius using the standard United Kingdom military temperature cycling procedure (Specification *K1007*—Method *5.5*). They were then subjected to 20 drops on a tumble test which imparted shocks of greater than 10 000 *g* [1]. This procedure has been found to be most effective in detecting weak bonds in high-frequency

TABLE 3

ASSEMBLY BATCH ROUTE CARD

Type TED 1163 | Slice Number 595/9, Header TO5 | Batch Number 6, Can Embossed | * Process Information Deleted

Process Description	Date in (1965)	Device Quantity In	Device Quantity Out	Device Quantity Failed	Date out (1965)	Operator Clock Number	Reason Failed	Temperature	Time	Inspection Level in Per Cent
Dice clean	17 Nov	—	—	—	17 Nov	—	—	—	—	—
Friction alloy	18 Nov	100	100	0	18 Nov	11226	—	*	—	—
Inspect	18 Nov	100	100	0	18 Nov	11285	—	—	—	10
Thermocompression bond	19 Nov	100	99	1	19 Nov	11229	—	—	—	—
Inspect	19 Nov	99	99	0	19 Nov	11286	—	—	—	10
Engineering inspection	19 Nov	99	80	19	19 Nov	12013	2 damaged wires 5 aluminium over junction 4 spread bonds 2 broken bonds 2 chipped dice 4 reject dice	—	—	100
Quality assurance inspection	22 Nov	80	80	0	22 Nov	10010	—	—	—	20
Process*	22 Nov	80	80	0	24 Nov	11270	—	*	*	—
Inspect	24 Nov	80	80	0	24 Nov	12013	—	—	—	20
Quality assurance inspection	24 Nov	80	76	4	24 Nov	10010	2 defective process 1 broken bond 1 spread aluminium	—	—	100
Encapsulate	24 Nov	76	76	0	24 Nov	11221	—	—	—	—
Engineering inspection	25 Nov	76	76	0	25 Nov	ERM	—	—	—	100
Wash	25 Nov	76	76	0	25 Nov	11700	—	—	—	—
To Engineering	25 Nov	76								

TABLE 4
RESULTS OF THERMAL/MECHANICAL TEST ON TRANSISTORS AND DIODES

Device	Number Tested	Number of Device Failures	Failure Proportion	
			90-Per-Cent Confidence	60-Per-Cent Confidence
Transistor	2642	0	0·087 per cent (1/1150)	0·035 per cent (1/2800)
Diode	4793	0	0·048 per cent (1/2070)	0·019 per cent (1/5150)
All devices	7435	0	0·031 per cent (1/3200)	0·012 per cent (1/8000)

silicon planar transistors and is considerably more searching than any other mechanical test (for example, centrifuging) or thermal test done separately. The results obtained are summarized in Table 4.

The diode, as noted above, was mounted on a transistor header. Advantage was taken of this to make separate connections to the "emitter" and "base" leads so that redundancy was introduced into the internal connections. In fact, on one diode one of these connections failed during test. This did not cause a device failure and would not, of course, have produced any malfunction of the repeater in actual use. Nonetheless the device was excluded.

The devices were then tested 100 per cent for hermeticity. A helium mass spectrometer unit was used applying a limit of 5×10^{-7} atmosphere cubic centimetre per second. This was a true screening test, defective devices being screened out and the assumption being made that devices passing the test would remain hermetic subsequently. This assumption was checked when a much finer test, using the radio-active-krypton method, was performed immediately prior to shipping the devices (see Section 9).

The results of the helium mass spectrometer test are given in Table 5.

TABLE 5
RESULTS OF HELIUM HERMETICITY TEST (TO LIMIT OF 5×10^{-7} ATMOSPHERE CUBIC CENTIMETRE PER SECOND)

Device	Transistor	Diode
Number tested	2642	4793
Number failed	1	7

7. Burn-In

A few of the transistors and diodes passing the helium hermeticity test were used for small sample evaluations and the rest were measured 100 per cent for I_{CBO}, $V_{CE(\text{sat})}$, $V_{BE(\text{sat})}$, and h_{FE} for the transistors and V_F, V_R, and I_R for the diodes, at the conditions given in Tables 1 and 2 respectively. Automatic measuring equipment contained in a room maintained at 25 ± 1 degrees Celsius was used. So that there could be no doubt about the correctness of the measurements, each characteristic was measured three times.

Then 2557 transistors and 4743 diodes were soldered into the burn-in rack shown in Figure 1. This rack applied the submarine repeater operating conditions of $V_{CB} = 9$ volts, $I_C = 0{\cdot}5$ milliampere to the transistors, and $I_F = 1$ milliampere to the diodes. The power was supplied from lead-acid storage batteries, which were physically disconnected from the semiconductor devices during charging. There was therefore no chance of voltage spikes being applied to the devices.

The burn-in was continued for 3 months and for this to be equivalent to the required 4 years of operation an acceleration factor of 16 times was obtained by raising the ambient temperature to 70 degrees Celsius. This was achieved by circulating thermostatically controlled heated air through a closed loop within the burn-in rack. The condition of the devices during the burn-in was monitored from time-to-time by switching off the power supply and applying very-low-energy probes to each device in turn. These probes measured the gain of the transistors at a current of 25 microamperes and the forward current of the diodes at a V_F of 350 millivolts. At the completion of the burn-in the devices were checked in the same manner for failures. The results obtained are given in Table 6.

The reliability requirement specified in Section 3 is again satisfied. The equivalent failure rates given in Table 6 are the maximum failure rates (at the specified confidence level) which are expected to be possible for operation of the devices in the submarine repeaters.

On removal from the racks all the devices were remeasured for the characteristics measured before burn-in. Again the measurements were repeated twice. Although the actual usage of the devices in the submarine repeaters was insensitive to changes in characteristics, it is of interest to record some of the results obtained.

For the first 1000 devices measured, Table 7 gives a grouped frequency table of the percentage change of gain produced by the burn-in. This gives a clear indication of the character-

Figure 1—Life test rack on which 2557 transistors and 4743 diodes were burnt-in for three months, without any failures. The rack applies the submarine repeater operation conditions with an elevated device case temperature.

TABLE 6

RESULTS OF 3 MONTHS BURN-IN (EQUIVALENT TO 4 YEARS OPERATION) ON TRANSISTORS AND DIODES

Device		Transistor	Diode	All Devices
Number Tested		2557	4743	7300
Number of failures		0	0	0
Failure proportion in per cent	90-per-cent confidence	0·090	0·049	0·032
	60-per-cent confidence	0·036	0·020	0·013
Equivalent failure rate in per cent per 1000 hours	90-per-cent confidence	0·0026	0·0014	0·00091
	60-per-cent confidence	0·0010	0·00057	0·00037

TABLE 7

PERCENTAGE CHANGE OF GAIN PRODUCED BY BURN-IN

Range of Change in Per Cent	Number of Devices: Gain Decreased	Number of Devices: Gain Increased
0–1	124	446
1–2	9	299
2–3	3	103
>3	2	—
3–4	—	10
4–5	—	2
5–6	—	1
>6	—	1

istic stability of the devices. A probability-paper plot of the actual results (not reproduced here) showed that the distribution of gain changes was normal from the 0·5th to the 99th percentile. Other characteristics had similar stability.

8. Overstress Tests

As noted in the last section the burn-in was carried out under a condition more extreme than the actual usage so that the 3-months burn-in was equivalent to a much longer period of operation. A series of severe overstress tests was carried out with the intention of determining the acceleration factors involved.

Several years reliability testing experience of commercial devices made by essentially the same technology had indicated that catastrophic failure could be best revealed by testing at temperatures in the range from 200 to 280 degrees Celsius. Accordingly samples, each of 50, of the submarine repeater transistors and diodes were tested at 240 and 280 degrees Celsius. However, these devices had such high reliability that even after over 6 months testing (4900 hours) there had been no catastrophic failures and the characteristics showed little change. Changes in collector-emitter saturation voltage are possibly the best indication of incipient catastrophic failure in these transistors. In this experiment after 4900 hours at 240 degrees Celsius only 2 of the 50 transistors showed saturation voltage changes of greater than 5 millivolts (15 millivolts and 17 millivolts), and for these 2 devices the changes had occurred early in life and the saturation voltages had then become stable. Similarly at 280 degrees Celsius there were 4 devices showing changes greater than 5 millivolts (7 millivolts, 12 millivolts, 21 millivolts).

Table 8 gives a grouped frequency table of the percentage change in gain produced by the 4900 hours at 280 degrees Celsius. Very similar changes were produced by storage at 240 degrees Celsius.

While these results give valuable qualitative evidence for the reliability of the submarine repeater devices they do not enable quantitative acceleration factors to be calculated. The actual acceleration factors used had therefore to be based upon experience with commercial devices made with an essentially similar technology.

TABLE 8
PERCENTAGE CHANGE OF GAIN PRODUCED BY 4900 HOURS AT 280 DEGREES CELSIUS

Change in Gain in Per Cent	Number of Devices	
	Gain Decreased	Gain Increased
0	1	—
1	1	4
2	1	5
3	—	9
4	—	8
5	1	5
6	—	1
7	—	3
8	—	4
9	1	2
10	—	2
11	—	1
18	—	1

In a typical series of experiments carried out on these commercial devices, samples of 200 were taken from a series of 5 lots. Each sample was carefully randomized and half stored at 275 degrees Celsius and the other half at 300 degrees Celsius. Measurements were made at 0, 720, and 934 hours on devices stored at 275 degrees Celsius and at 0, 72, and 144 hours on those stored at 300 degrees Celsius. Using a failure criterion of an increase of collector-emitter saturation voltage (at $I_C = 10$ milliamperes, $I_B = 0{\cdot}3$ milliampere) from less than 300 millivolts to greater than 400 millivolts the results given in Table 9 were obtained.

The results show that a change of temperature from 300 to 275 degrees Celsius increases the time for a given proportion of failures by a factor of 3·8. By assuming that the Arrhenius equation applies, the activation energy for the failure mechanism was found to be 38 kilocalories per mole [2]. This in turn was used to calculate the temperature at which the failure rate is reduced by a factor of 16 relative to the

TABLE 9

RESULTS OF STORAGE TESTS AT 275 AND 300 DEGREES CELSIUS ON COMMERICAL TRANSISTORS

	Number	Percentage
Tested at 275 degrees Celsius (5 lots)	489	—
Failed at 720 hours	207	42·4
Failed at 934 hours	256	52·5
Tested at 300 degrees Celsius (5 lots)	476	—
Failed at 72 hours	59	12·4
Failed at 144 hours	156	32·8

burn-in temperature of 70 degrees Celsius. The value thus obtained was 54 degrees Celsius. Other experiments have given lower values of the activation energy down to 25 kilocalories per mole (1·1 electron-volts per atom). For this latter value the limiting temperature is 46 degrees Celsius.

In fact the repeaters themselves will operate in an ambient at a maximum temperature of 10 degrees Celsius and the temperature rise within the repeater will be 20 degrees Celsius, giving an anticipated maximum transistor case temperature of 30 degrees Celsius. With either of the applied activation energies, there is therefore a considerable safety factor.

The 20-year life requirement (see Section 3) is also covered by these results. The high overstress tests described at the beginning of this section indicate that there is no wear-out mechanism. The failure rate must therefore be expected to fall rather than rise with time. Achievement of the 4-year requirement therefore assures achievement of the 20-year requirement.

An alternative approach is to express the reliability requirement of Section 3 as: (A) no more than 5 transistor failures in 1200 in 20 years of operation and (B) no more than 5 diode failures in 2400 in 20 years of operation. For the 3-months operation to be equivalent to 20 years requires an acceleration factor of 80 times. For this factor an activation energy of 38 kilocalories per mole gives a limiting temperature of 45 degrees Celsius and an activation energy of 25 kilocalories per mole gives a limiting temperature of 33 degrees Celsius. Both are higher than the anticipated maximum transistor case temperature of 30 degrees Celsius. Use of an acceleration factor as high as 80 is undesirable. However, this is more than compensated for by the fact that the burn-in (see Table 6) gave zero transistor failures and zero diode failures, whereas for the quantities tested the reliability requirement would have been met if as many as 10 failures of each had occurred.

9. Hermeticity Testing by the Radio-active-Krypton Method

As a final screening test after the completion of the burn-in and the post-test measurements, all of the devices were measured for hermeticity using radio-active krypton.

The method which is about 1000 times more sensitive than the helium mass spectrometer method depends upon pressurizing the devices for a period of time in a gas containing a proportion of radio-active krypton. The gas enters any devices having leaks and after removal from the pressure vessel the devices are tested in a scintillation counter. The radio-active krypton gives off radiation which penetrates the device encapsulation. The method, unlike that using the mass spectrometer, is not therefore dependent upon the tracer gas leaking out of the device under test. For highest accuracy, precautions must be taken to prevent or remove tracer gas absorbed on the surface of the devices. In addition it is possible to correct for such absorbed gas by monitoring separately the non-penetrative radiation which is also given off by the radio-active krypton.

Because of safety and cost considerations it is not possible to use a simple chamber for the pressurization of the devices. The equipment actually used (Figure 2) was developed by S.T.C. Semiconductors following earlier joint work with the United Kingdom Atomic Energy Authority. The krypton is contained in a closed system and is pumped between the storage chamber and the test chamber by either heating the appropriate section or by cooling with liquid nitrogen. The various control valves are operated pneumatically by high-pressure nitrogen gas.

The pressure within the test chamber was dependent upon how much of the chamber was occupied by devices and inert filler blocks and varied from 23 to 42 pounds per square inch (16 170 to 29 500 kilograms per square metre) for different tests. Soaking times were adjusted in the range 48 to 140 hours. The activity of the gas was 12·9 millicuries per milliliter.

So far 1600 of the devices which have completed burn-in have been tested. Of these 1591 gave count rates corresponding to leak rates of 3 ($\pm$ 2) $\times 10^{-12}$ atmosphere cubic centimetre per second. The correction for background radioactivity and the surface count of the devices had a similar range of values, so this represented the effective zero value of the method as used. Only 8 devices gave count rates higher than this but all less than the rate corresponding to 20×10^{-12} atmosphere cubic centimetre per second. Usually the surface count was high also, so there was no clear evidence that these devices were in fact leaking, even at this fantastically low level. It is also most unlikely that this number of devices would all have almost the same leak rate while only 1 other device was within the rest of the vast range of possible leak sizes. Nonetheless these 8 devices were rejected for submarine repeater use.

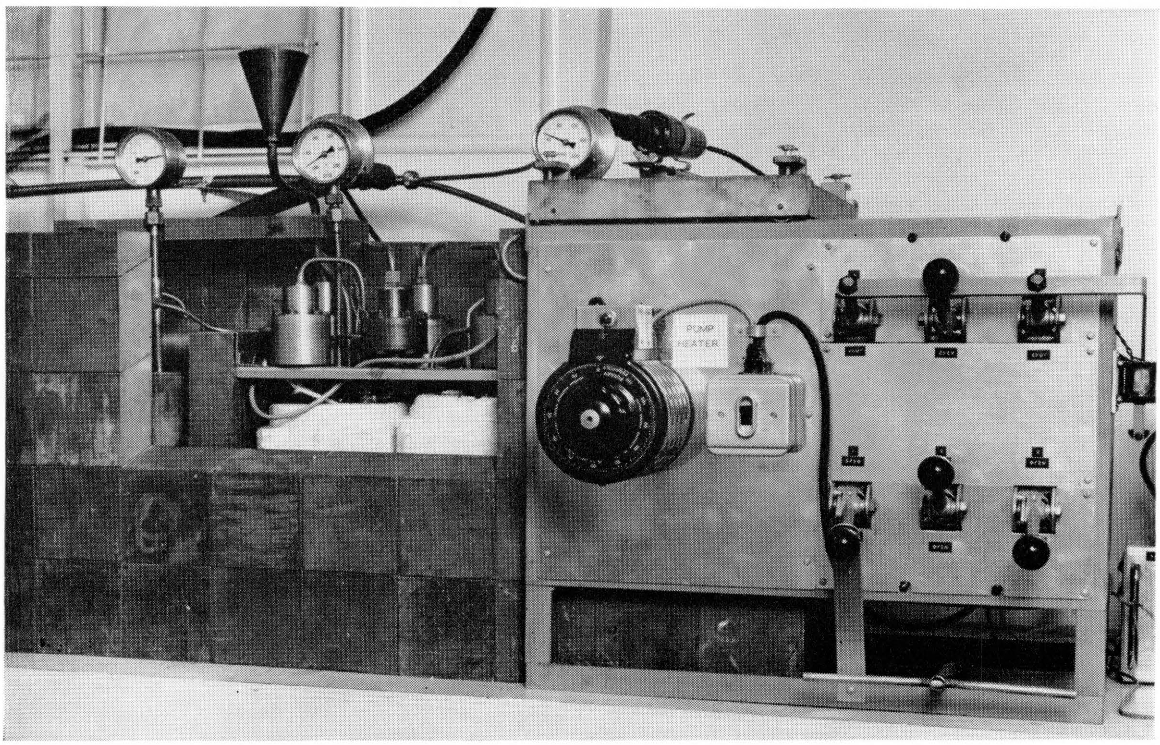

Figure 2—S.T.C. Semiconductors designed this equipment for pressurizing semiconductor devices in radio-active krypton to obtain ultra-fine leak measurements. Some of the lead bricks used for screening have been removed to reveal the test chambers.

Finally 1 device had a leak rate of $7 \cdot 3 \times 10^{-10}$ atmosphere cubic centimetre per second and this was, of course, excluded also.

10. Conclusions

This paper has described the methods used by S.T.C. Semiconductors to obtain transistors and diodes of the reliability needed for deep-water submarine repeater applications and also the methods used to give assurance of the achievement of that reliability. For making the devices the silicon planar techniques, of which the company has long experience, were utilized. No major modifications were made to standard processes but meticulous care was taken in production, inspection, and screening procedures.

For the reliability assurance the basic suitability of the designs were checked by overstress tests and then the mechanical reliability, the electrical reliability, and the hermeticity of the devices were checked successively on all the devices by a severe mechanical/thermal test, a 3-months operational burn-in, and by radio-active-krypton hermeticity testing. The mechanical test and the burn-in also constituted an acceptance test and the numbers of devices tested were adequate to give statistical assurance of the required reliability.

Both the transistors and diodes successfully passed all their tests and they are currently being built into deep-water submarine repeaters.

11. Acknowledgments

The successful completion of the exercise described in this paper was a result of the skilled and conscientious efforts of a large number of people. Those particularly concerned with the planning and execution of the work were Dr. G. B. Thomas, Dr. E. R. Monks, Mr. A. C. Brown, and Mr. J. Bickley.

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J. M. Groocock was born on 29 April 1929. He obtained an honours degree in chemistry in 1949 from the Imperial College of Science and Technology, London University, and then in 1953 a Ph.D. degree for research in physical chemistry.

From 1951 to 1958 he worked for the Ministry of Supply heading a team doing research on the physical chemistry of solid explosives.

In 1958 he joined the Transistor Division of Standard Telephones and Cables and shortly afterwards became head of the transistor design section. In 1961 he became head of the newly formed Quality Assurance Department and later, on the formation of S.T.C. Semiconductors, he became responsible for quality assurance in both the Harlow and Footscray factories.

He was involved in the very active work on the reliability of semiconductor devices carried out at Footscray. He is a member of the British Standards Institution Committee on Electronic Reliability and has represented the United Kingdom at meetings of the International Electrotechnical Commission.

Since early in 1967 Dr. Groocock has been Company Quality Assurance Manager of Standard Telephones and Cables. He represents the company as a whole in the quality and reliability fields and is also responsible for coordinating the work of the quality managers throughout its 25 divisions.

Coaxial Cable System for 2700 Circuits

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1. Introduction

An assessment of the market had shown increasing need for a 12-megahertz 2700-circuit transmission system on coaxial cable of 2·6/9·5 millimetres (0·375-inch diameter). Although a valve system was available to meet this demand, it was realized that a transistor system would have very significant advantages both in first cost and maintenance charges.

Much work had to be done on the evaluation of transistors for this requirement and several alternative solutions were considered. Thus one development was for an amplifier at 3-kilometre (2-mile) spacing. By increasing the power dissipation to about 7·5 watts per amplifier it was found possible to raise the signal levels to line so that a spacing of about 4·5 kilometres (2·8 miles) between amplifiers could be achieved. However, with the advent of better types of silicon epitaxial planar transistors and further development of the amplifier configuration it was found possible to achieve this result with a power consumption of only 0·64 watt. The final circuit gives a noise performance of 1 picowatt per kilometre (1·6 picowatts per mile) and excellent gain stability with variations of power and temperature.

2. Line Amplifier

The line amplifier is of course the heart of the system and is worth discussing in some detail. Considerable development effort was expended in its realization, as the choice of transistor types and circuit configuration have a profound effect on repeater spacing and power requirements. A performance to enable a system noise of 1 picowatt per kilometre (1·6 picowatts per mile) to be achieved was set as a design target. This gives a good margin for any deterioration due to equalization errors, in order to guarantee the requirement of 3 picowatts per kilometre (4·8 picowatts per mile) for the hypothetical reference circuit of 2500 kilometres (1500 miles) under all conditions of service set by the International Telegraph and Telephone Consultative Committee (CCITT).

2.1 Desirable Properties

The most important properties may be listed as follows:

(A) Good input and output return losses to minimize reflections and gain errors.

(B) Low noise figure.

(C) Low intermodulation noise.

(D) Good overload margin.

(E) Low power consumption.

(F) Gain-frequency characteristic accurately shaped to match the cable, and good stability of gain with variations in power supply and ambient temperature.

(G) Accurate control of gain to compensate for changes in cable loss with temperature and to cater for repeater spacing tolerances.

(H) Circuit flexibility to enable minor changes to be made easily in both the mean and the adjustable gain-frequency characteristics. Then amplifier variants for use with older types of coaxial cable, which have slightly different characteristics, can be conveniently designed.

(I) Long life and high reliability.

(J) Ability to withstand induced power and lightning surges.

The requirements of low intermodulation noise and good overload margin conflict with low power consumption, and a compromise is necessary here. A major factor in the design has been the aim to restrict the power supply current fed along the cable inner conductors to the dependent repeaters to a maximum of 50 milliamperes at a maximum of about 300 volts relative to earth (250 volts for the British Post Office). This is considered to be safe for maintenance personnel [1, 2]. Work on the cable route is then possible without provision of the expensive safety precautions that were necessary on the earlier designs of coaxial systems using valves.

Thus the amplifier power consumption is severely limited, if a reasonable number are to be fed remotely from widely spaced points along the route. The remarkably low figure of 0·64 watt (13 volts and 49 milliamperes) has been achieved, allowing 13 dependent repeaters to be fed in each direction from a power feeding station when 300–0–300 volts is used, giving a maximum distance between power feeding points of 121·5 kilometres (75·5 miles) (10 repeaters with 250–0–250 volts, a distance of 94·5 kilometres (58·7 miles)). Other benefits arise from this low power consumption: low junction temperatures of the transistors (only 75 degrees Celsius above ambient in the output transistor) and low rise in ambient temperature of the amplifier components (about 2 degrees Celsius). These are conducive to long life and high reliability.

2.2 Configuration

The line amplifier circuit configuration is shown in Figure 1. It is a feedback triple of silicon planar transistors, with hybrid circuits at input and output to provide good return losses against the cable, together with low noise figure and good output-stage efficiency. The mean forward gain-frequency characteristic is shaped mainly by the impedances $R_2 + Z_p$ and Z_0 together with an input pre-equalizer (not shown). The pre-equalizer loss is small in the higher-frequency portion of the band to permit maximum slope of the system pre-emphasis characteristic in this region and so optimize thermal and intermodulation noise and overload performance [3].

The gain may be adjusted to compensate for change in cable loss with temperature and for repeater spacing tolerance by means of the adjustable equalizer in the feedback path. It is a well-known type described by Bode [4] and employs the symmetrical constant-resistance equalizer (characteristic impedance R_0) terminated in the adjustable resistance xR_0. This is either a thermistor automatically controlled by a 12 435-kilohertz pilot regulator at regulated repeaters, or a fixed resistor at unregulated repeaters. The loss-frequency characteristic of the equalizer R_0 governs the adjustable gain-frequency shape of the amplifier.

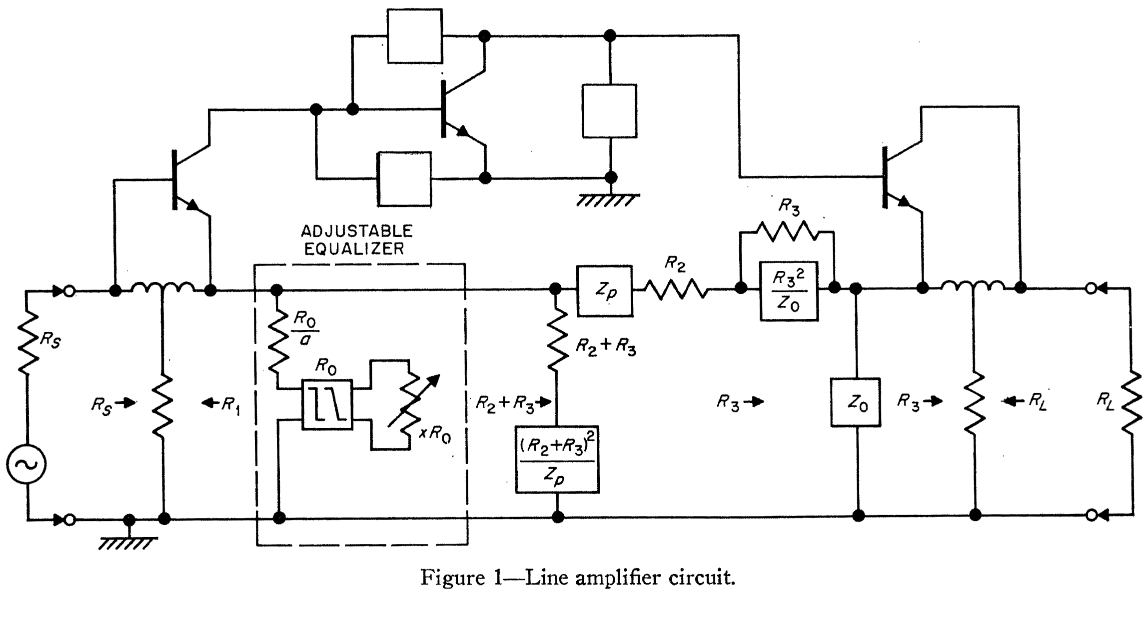


Figure 1—Line amplifier circuit.

To satisfy the requirements of the adjustable equalizer

$$\frac{R_1(R_2 + R_3)}{R_1 + R_2 + R_3} = \left(\frac{a^2 - 1}{a}\right) R_0$$

where a is a design constant, and R_1 and $R_2 + R_3$ are resistive impedances presented by the rest of the circuit.

The circuit provides the substantial amount of forward gain variation of ± 6 decibels at 12·5 megahertz, and the configuration is notable in that this is achieved without appreciable variation in the overall loop gain. This is a valuable feature, because it is important to have as much overall feedback as possible to minimize intermodulation and to get good gain accuracy. The more usual way of changing the gain of a feedback amplifier is to change the amount of overall feedback. Sufficient amplitude and phase margin must be obtained at minimum gain (maximum feedback) to ensure freedom from oscillation. Thus at maximum gain (minimum feedback), the amount of feedback may not be sufficient for good intermodulation or gain accuracy. However, this circuit is not subject to this limitation. A way of looking at it is to say that change of the adjustable equalizer varies the local feedback on the first stage and not the overall feedback.

Similarly Z_0 may be changed to alter the forward gain without appreciably changing the overall feedback. Instead the local feedback on the output stage is changed. This can be useful in shaping the forward gain of the amplifier without affecting the overall loop gain, giving considerable freedom in the design. Minor changes in mean gain-frequency and adjustable gain-frequency shapes to cater for various cable types may readily be made.

2.3 Amplifier Performance

To prove the design, 15 models of the line amplifier, shown in Figure 2, were constructed. Transistors taken at random from three different manufacturers were used. Some of the test results on the models are shown below. These results, together with results of the system field trial using the same model amplifiers (given in Section 7) illustrate the adequacy of their characteristics.

Noise Figure at 12·5 *Megahertz:* (Including the pre-equalizer) Maximum 5·3, minimum 4·3, and mean 4·6 decibels.

Overload at 12·5 *Megahertz:* Maximum +21·5, minimum +20·3, and mean +20·8 decibels referred to 1 milliwatt.

Harmonic and Intermodulation Margins: Only products indicative of those producing most noise are given—in general they involve the highest possible fundamental frequencies. Power at each fundamental output was +10 decibels referred to 1 milliwatt.

2A–B $(2 \times 11 - 9{\cdot}5 = 12{\cdot}5$ megahertz). Maximum margin 70·0, minimum 66·5, and mean 68·3 decibels.

2A $(2 \times 6 = 12$ megahertz). Maximum 58·0, minimum 53·0, and mean 56·2 decibels.

A–B $(12{\cdot}4 - 12{\cdot}1 = 0{\cdot}3$ megahertz). Maximum 79·0, minimum 71·0, and mean 76·3 decibels.

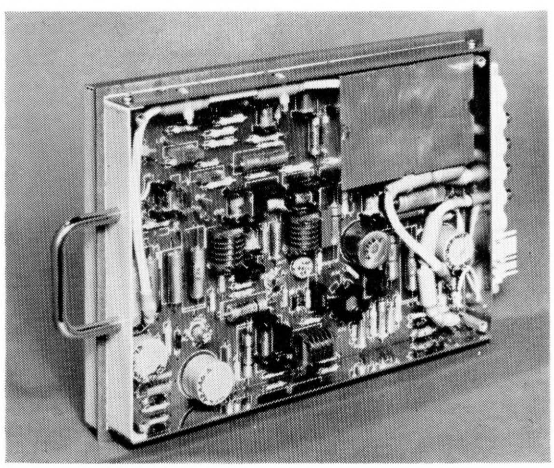


Figure 2—Line amplifier.

Return Loss:

	Input		
Frequency in megahertz	0·3	4	12·5
Maximum in decibels	59	29	30
Minimum in decibels	40	27	19

	Output		
Frequency in megahertz	0·3	4	12·5
Maximum in decibels	30	40	30
Minimum in decibels	25	32	24

Temperature Coefficient: Figure 3 shows the change in gain for a rise of 40 degrees Celsius above room temperature. (Average of 4 amplifiers.)

3. Repeater Spacing

It was clear that with a transistor repeater the equipment could be best housed in underground footway boxes, et cetera, as had been successfully done on the new 1·2/4·4-millimetre (0·174-inch diameter) coaxial cable systems [5, 6]. However, the immediate need was to equip spare coaxial cores in existing cables and later to replace the old valve systems on these cables. Now these valve systems were installed in surface huts nominally spaced at 9·6 kilometres (6 miles). Thus for maximum utilization of existing plant and cable terminations, new systems should be spaced on a submultiple of 9·6 kilometres (6 miles). At first sight this imposed a nominal repeater spacing of 4·8 kilometres (3 miles) but an analysis of actual routes showed that because of siting difficulties, huts were typically spaced at shorter distances. This is illustrated in Figure 4, which gives an analysis of 30 valve routes in the United Kingdom. It will be seen that 75 per cent of repeater huts are spaced at 9 kilometres (5·6 miles) or less. The new repeater was therefore designed for 4·5-kilometre (2·8-mile) spacing but provision was made for coping with occasional long sections. (See Section 5.)

4. System Noise

A digital computer was used to establish the optimum pre-emphasis characteristic for the system, using measured amplifier thermal noise and intermodulation performance. Figure 5 gives the calculated noise for a 280-kilometre (175-mile) homogeneous section with the conventional power level of −15 decibels referred to 1 milliwatt reference zero level per channel as required by the International Telegraph and Telephone Consultative Committee (CCITT). This includes the effects of transmit and receive terminals and two main repeaters, which employ additional flat amplifiers to overcome equalizer losses. This calculation does not include penalties due to equalization errors, but ample margin compared with the international recommendation of 3 picowatts per kilometre (4·8 picowatts per mile) is obtained.

5. Regulation

The decisions to use existing huts also affected the techniques for automatic level regulation. As wide departures from nominal length were to be expected, it was advantageous for the adjustable gain of each repeater to have suf-

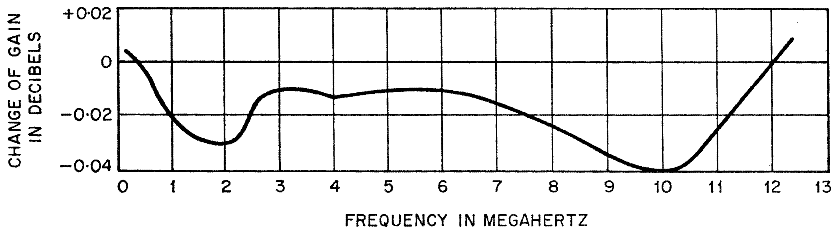


Figure 3—Change in gain for a 40-degree Celsius rise as a function of frequency.

icient range to compensate for both length and able-temperature variations. Large ambient emperature changes were to be expected in the urface huts, and remote sensors would be leeded to operate a system dependent on ground emperature. It was therefore decided to use backward-acting pilot regulators—a technique that we had operated very successfully on earlier systems.

The International Telegraph and Telephone Consultative Committee (CCITT) had recommended three line control pilots at 308, 4287, and 12 435 kilohertz for the 12-megahertz valve system. Because it was thought that valve ageing and other variables would be greatest at the highest-frequency end of the band, 4287 kilohertz had been selected as the principal regulating pilot. With the transistor amplifier however, it was not expected that variations of this kind would occur and 12 435 kilohertz was nominated as the main regulating pilot. As changes in cable attenuation as a function of temperature increase with frequency, the accuracy of correction is improved.

It was found feasible to obtain ±4 decibels of automatic regulation range and this, coupled with the excellent amplifier noise performance, permitted regulation at alternate amplifiers only. At the fixed-gain amplifier the control network can be used over its full ±6-decibel range to compensate for excessive length errors. This means that sections of up to 5·25 kilometres (3·26 miles) can be tolerated.

On any given route the degree of stretching is usually such that the resultant increase in random noise is tolerable and a total noise within 3 picowatts per kilometre (4·8 picowatts per mile) can be expected.

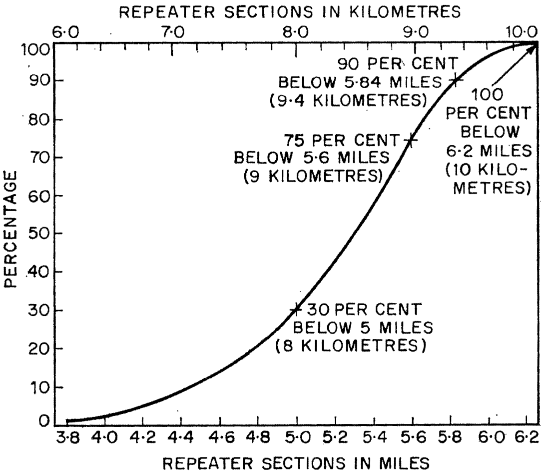


Figure 4—Percentage of repeater sections below the stated lengths for 30 routes of 4-megahertz 960-channel systems.

6. Fault Location

Closely allied to the regulation philosophy is the method of supervision used, so that staff at attended terminal stations can identify a faulty repeater. A pilot regulator of the type described can provide, at relatively little extra cost, a second output for driving an alarm circuit. A differential direct-current amplifier is used to drive a relay which puts a loop across an interstitial pair when the pilot error at the line amplifier output is greater than ±2 decibels. The range of the regulator is such that only alternate amplifiers need to be regulated. To monitor the unregulated amplifiers a simple output pilot level detector is used, and to keep this circuit as simple and cheap as possible it is operated from the 308-kilohertz pilot.

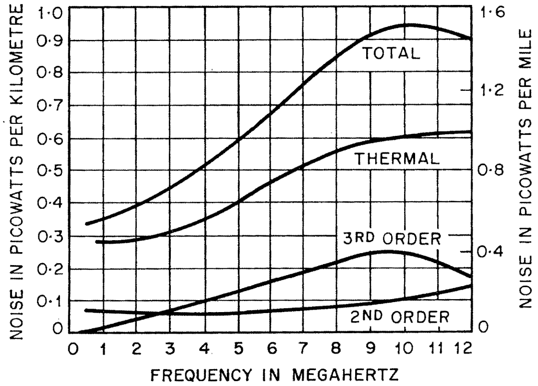


Figure 5—Computed system noise for a 280-kilometre (175-mile) route.

If a cable breaks, current stops flowing round the power feeding loop and pilot alarms are given from all stations. A combination of a series and a shunt connected relay is used to give a unique power alarm from the station immediately before the break.

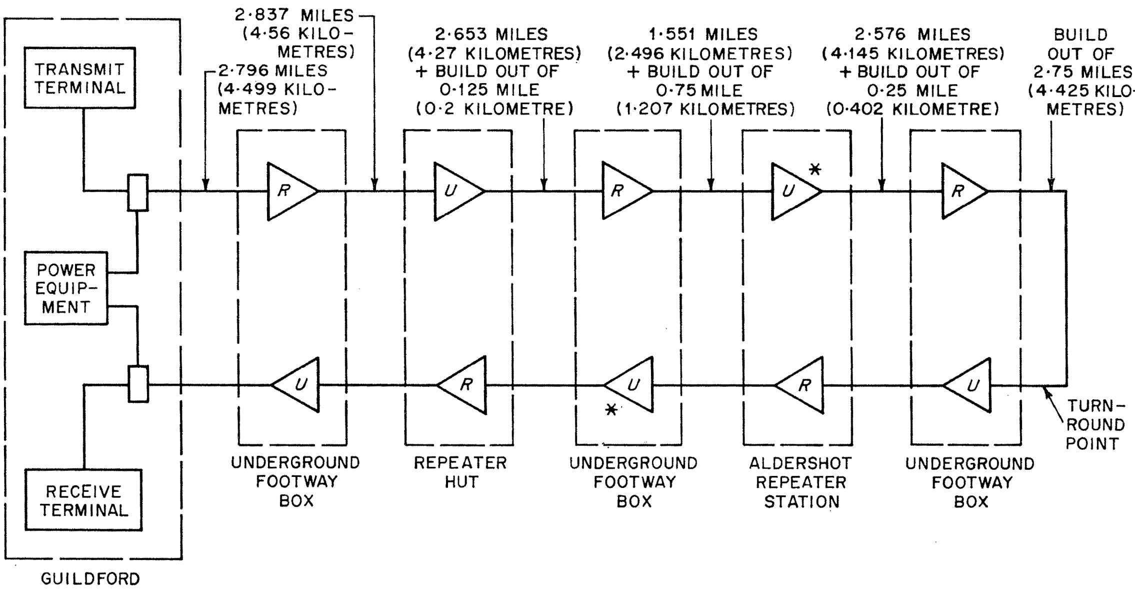
These large-core coaxial cables are normally well supplied with interstitial pairs which can be used for extending the alarm conditions from the repeaters to the terminal as direct-current loops. Thus three alarm pairs are needed. At the terminal, after the presence of the loop has been detected, its resistance is measured and the distance away is proportional to the value obtained. If a fourth interstitial pair is used as a reference arm of the Wheatstone bridge, operation is independent of temperature variation.

A differential direct-current amplifier is used in the bridge to obtain a uniform performance over the operating range. The sensitivity is such that accurate discrimination is achieved on routes of up to 100 stations. An advantage of this scheme is that very long routes can be supervised from a single attended station.

7. Field Trial

7.1 Route Description

A trial system has been installed with the co-operation of the British Post Office on part of the coaxial cable route between Guildford and Reading. This is a typical 6-core cable installation with one pair of cores already equipped with a 960-circuit valve system installed in huts spaced at nominally 10 kilometres (6 miles). The additional intermediate repeaters were installed in underground footway boxes as shown on the route schematic in Figure 6. By looping back the high-frequency path at the fifth repeater through line-simulating networks, a 48-kilometre (29·8-mile) one-way link was obtained. The terminal repeater, which is fully transistorized, is constructed in Mark 6 Equipment Practice [7] and is shown in Figure 7. A typical repeater installation is shown in Figure 8.



* indicates amplifiers with 6-decibel offset.

Figure 6—Route of field trial installation having a total looped length including build-out sections of 48 kilometres (29·8 miles). R indicates regulated line amplifier and U is for fixed-gain amplifiers.

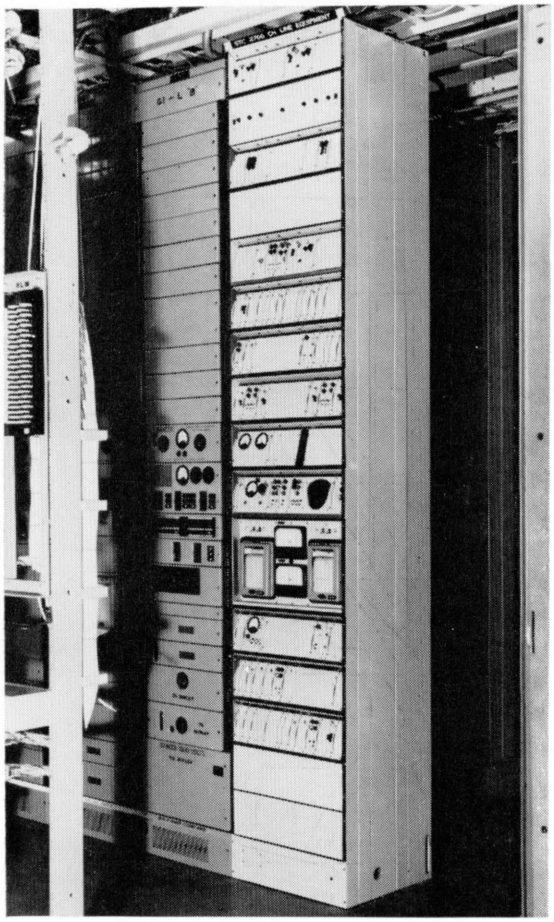


Figure 7—Terminal repeater.

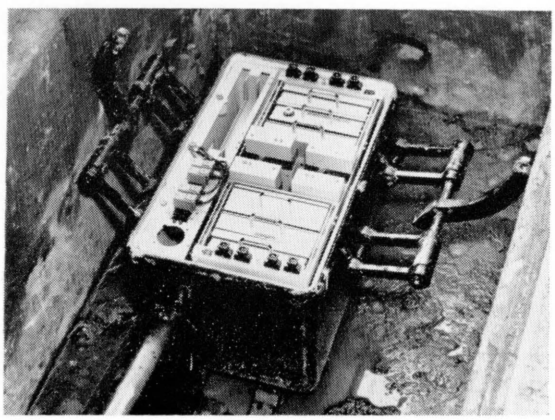


Figure 8—Typical unattended repeater.

7.2 Results

The gain-frequency characteristic is shown in Figure 9; the overall spread over the frequency band was limited to 0·55 decibel. Changes have since been made to the amplifier that will reduce the spread per repeater section to approximately 0·2 decibel before residual equalization.

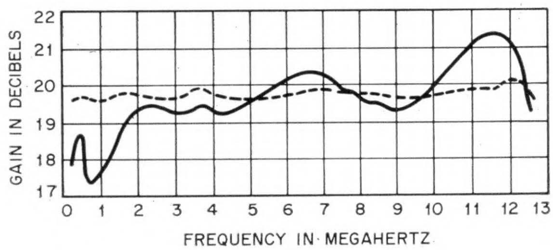


Figure 9—Gain-frequency characteristic over the trial route. The solid curve is before and the broken-line curve is after mop-up equalization, which limited the final spread to 0·55 decibel.

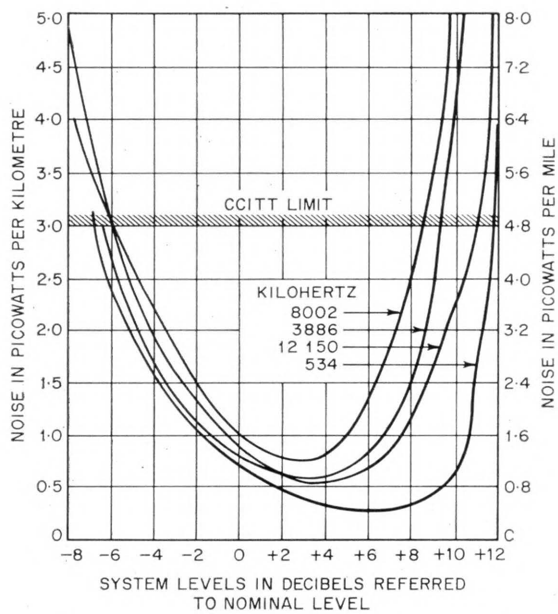


Figure 10—Performance of the trial route when loaded with white noise. The limit of 3 picowatts per kilometre (4·8 picowatts per mile) set by the International Telegraph and Telephone Consultative Committee (CCITT) is indicated.

Figure 10 shows the performance of the trial route when loaded with white noise. Zero loading corresponds to the conventional power level of −15 decibels referred to 1 milliwatt reference zero level per channel. It will be seen that the noise falling in each frequency slot is not more than 1 picowatt per kilometre (1·6 picowatts per mile). As the loading is increased the signal-to-noise ratio at first improves, indicating that random noise is dominant. As the loading is increased still further, intermodulation noise increases but nevertheless there is a margin of 8 decibels before the recommended maximum of 3 picowatts per kilometre (4·8 picowatts per mile) is exceeded, which demonstrates that good overload margins have been obtained.

The accumulation of certain distortion products along the route is shown in Figures 11 and 12. The repeater section phase shift used in the calculated curves was obtained by adding a measured repeater phase characteristic to the calculated phase shift of 4·5 kilometres (2·8 miles) of cable. The close correlation between

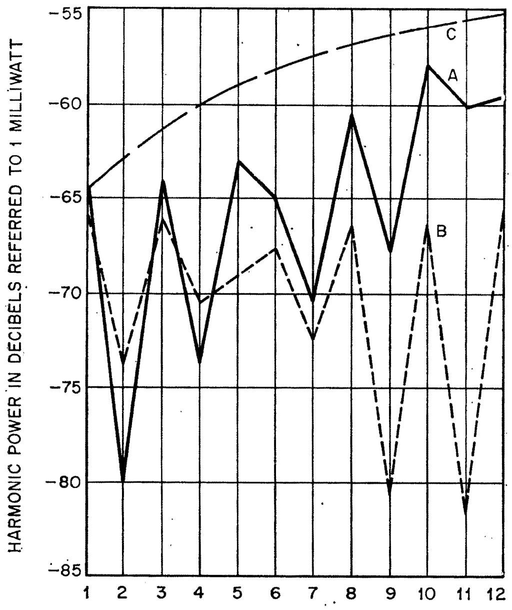


Figure 11—Second-harmonic distortion over the trial route for a fundamental of 6·25 megahertz at 0 decibels referred to 1 milliwatt at the transmit terminal output. A is measured, B is calculated allowing for section phase shift, and C is calculated assuming power addition.

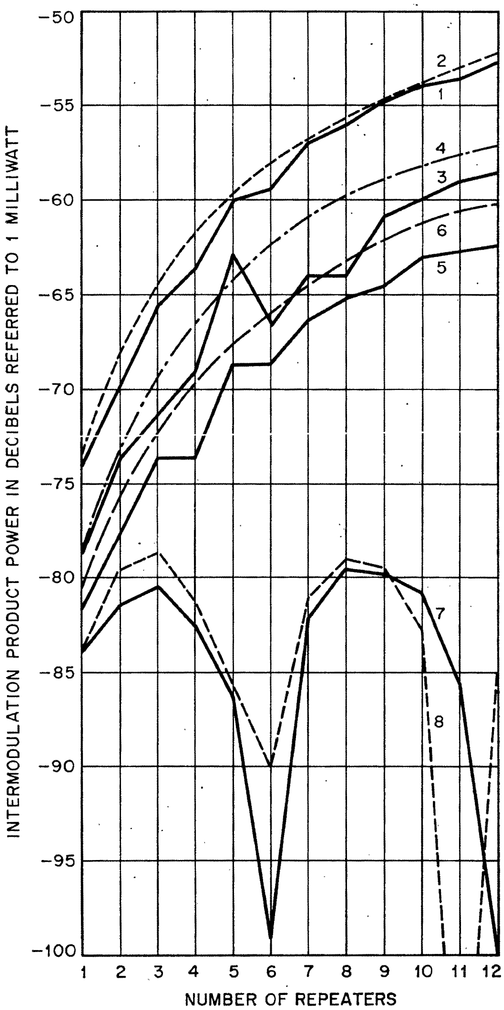


Figure 12—Third-order intermodulation distortion $2A$–B with fundamental frequencies having an output of +5 decibels referred to 1 milliwatt at the transmit terminal output. The solid-line curves are measured and the broken-line curves 2, 4, and 6 are calculated assuming voltage addition. Curve 8 is calculated allowing for section phase shift. Frequencies are as follows: $2 \times 11 - 9{\cdot}5 = 12{\cdot}5$ megahertz for curves 1 and 2; $2 \times 10{\cdot}2 - 12{\cdot}4 = 8$ megahertz for curves 3 and 4; $2 \times 8{\cdot}2 - 12{\cdot}4 = 4$ megahertz for curves 5 and 6; and $2 \times 6{\cdot}3 - 12{\cdot}3 = 0{\cdot}3$ megahertz for curves 7 and 8.

the calculated and measured results support the theory used when evaluating the performance of the system on long routes.

The power-feeding current of 49 milliamperes is normally controlled to better than ±1 milliampere (±2 per cent). Thus from Figure 13 it can be estimated that variation of gain due to this cause on a route length of 280 kilometres (175 miles) would be less than ±0·3 decibel even if the power to all the repeaters changed by this amount simultaneously, a most-unlikely event.

Figure 14 shows the near-end crosstalk measured at the terminal when the high-frequency loop back was disconnected and the line terminated at the last repeater. The crosstalk was measured at close frequency intervals, using a detector of 200-hertz bandwidth. The crosstalk maxima and minima at frequencies near the top of the band are shown on the graph. These ripples, due to different crosstalk paths along the line, continue over the whole frequency band, but the general level of crosstalk decreases with decreasing frequency.

The field trial route gain-frequency stability measured over a period of six months is shown in Figure 15. The error characteristics closely agree with those expected from the line amplifier variable gain-frequency characteristic design

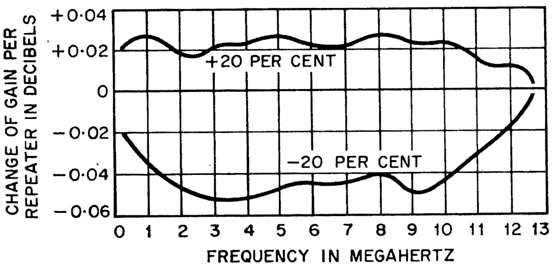


Figure 13—Variation of gain per amplifier with changes of 20 per cent in power-feeding currents.

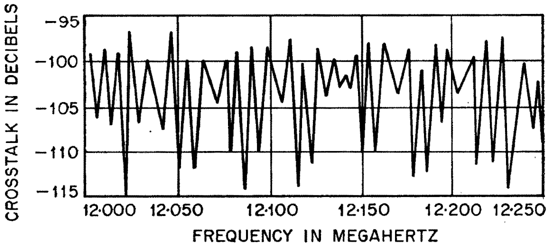


Figure 14—Crosstalk measured at close frequency intervals for the trial installation.

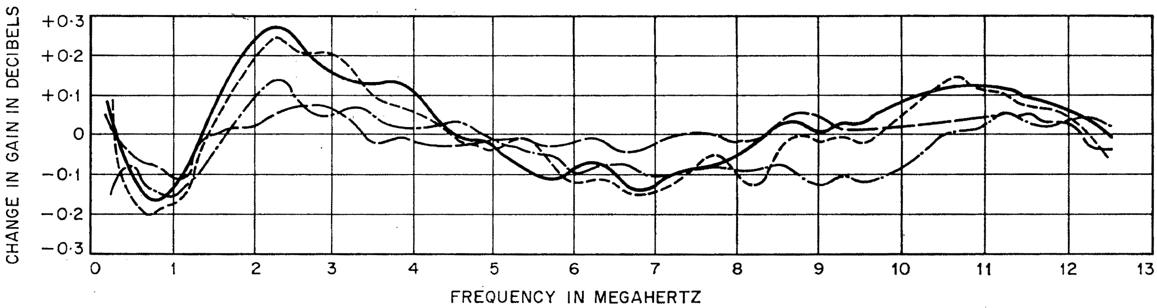


Figure 15—Variations of gain of the trial installation relative to values measured on 7 April 1966 with a cable temperature of 5·5 degrees Celsius.

	Date	Cable Temperature in Degrees Celsius
— — —	24 May 1966	10·0
—·—·	15 June 1966	13·3
- - - - -	12 July 1966	18·3
———	29 September 1966	18·0

error and changes in cable temperature. Further measurements on the route stability with time are continuing.

8. Conclusion

These and many other measurements have established that the design aims have been met and that the relevant recommendations of the International Telegraph and Telephone Consultative Committee (CCITT) and of appropriate British Post Office specifications are satisfied with adequate working margins.

The new system provides an economic means of greatly increasing the circuit capacity of existing cables and, because repeater stations can now be buried, new cable routes can be installed more cheaply than hitherto.

9. Acknowledgments

The authors wish to thank the British Post Office for permission to publish the graph in Figure 4 and the photographs of the equipment in the field. They also wish to record their appreciation of the efforts of their colleagues at Standard Telephones and Cables Limited, Basildon, without which this development would not have been possible.

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Microwave Radio *RL4H* in Slimrack Construction

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Standard Telephones and Cables Limited; London, England

1. History

Until recently, microwave radio transmitters have used travelling-wave amplifiers to produce power in the range of 1 to 10 watts. These required a power supply of about 3000 volts and had an estimated life of about 10 000 hours. These equipments had an all-solid-state local oscillator, which gave 50 milliwatts output at super-high frequencies.

The all-solid-state *RL4H* equipment has dispensed with the travelling-wave tube by the incorporation of the latest high-frequency high-power transistors and varactors. These give a 4-gigahertz output of 2·5 watts from the transmit local oscillator, which feeds a varactor up-converter to give 1 watt of transmitter output. The life of this source is planned to be 100 000 hours.

In addition, a much lower noise figure is obtained in the receiver.

The feasibility models of the transmit local oscillator and up-converter were developed and built by Standard Telecommunication Laboratories in Harlow and formed the basis for further development and engineering for manufacture by Standard Telephones and Cables.

2. General Description

2.1 Purpose

The *RL4H* slimrack unit is designed to work either as a repeater or as a terminal bay in the all-solid-state *RL4H* radio system. The system can use up to 5 + 1 or 4 + 2 radio channels in accordance with the frequency recommendations of the International Radio Consultative Committee for the 4-gigahertz band.

Each radio channel will accept a baseband of 960 telephone channels or television video (monochrome or colour) plus a super-video sound channel.

The 6 receive and 6 transmit radio channels may use a common bipolar feeder and Cassegrain aerial.

The *RL4H* radio slimracks are planned to work in conjunction with the auxiliary link radio equipment produced by Bell Telephone Manufacturing Company (Belgium).

2.2 Function

When operated as a terminal bay, the slimrack equipment comprises a separate transmitter and receiver with separate power supply units.

The transmitter accepts a frequency-modulated intermediate-frequency signal at 70 megahertz and 0·3 volt from the modulator panel of the modem bay and converts this to 1 watt at 4 gigahertz.

The receiver accepts a super-high-frequency input in the range −30 to −65 decibels referred to 1 milliwatt and converts this to a 70-megahertz output of 0·5 volt, which is fed to the demodulator of the modem bay.

When used as a repeater, the intermediate-frequency output of the receiver is connected to the transmitter power-amplifier panel. There is one common power supply unit in this case.

The slimrack requires a 24-volt direct-current power supply and consumes approximately 120 watts.

2.3 Block Schematic

The waveguide used for all the super-high-frequency components is size *12A*, code *M(F) 45*, of the International Electrotechnical Commission, having internal dimensions of 2·000 by 0·667 inches (50·8 by 16·9 millimetres).

As shown in Figure 1, the receive input frequency from the channel branching circulator is selected by a 6-section signal filter, which has a maximally flat bandwidth of ±20 megahertz. The other channel frequencies are reflected back from this filter to be directed by the circulator to the other receivers.

On the receive side of the channel branching circulator is a short-circuiting shutter, which when inserted reflects the other receive channels to their particular bays and permits the flexible waveguide to be removed for making noise-figure measurements on the receiver.

The received signal passes through the signal filter to be directed via a circulator to the local-oscillator filter, from which it reflects back into the input mixer at a nominal level of −30 decibels referred to 1 milliwatt.

The receive local-oscillator frequency is derived from a crystal source at about 125 megahertz, the output of which is amplified and doubled in frequency before finally being multiplied ($\times 16$) by a step-recovery diode to 4 gigahertz. This local-oscillator output frequency is selected by the 3-section waveguide filter having a bandwidth of ± 8 megahertz and is fed through the circulator into the mixer.

The other circulator in the receive path has a termination on its third port and is included to reduce the leak of unwanted receiver products, such as local-oscillator frequency, into other receivers. It thus acts as an isolator.

The input mixer and pre-amplifier unit has a noise figure below 8 decibels.

The pre-amplifier output is fed to the main intermediate-frequency amplifier. This provides an automatic-gain-control loop back to the pre-amplifier to give a constant output of 0 decibels referred to 1 milliwatt for a variation in super-high-frequency input between −25 and −65 decibels referred to 1 milliwatt.

An adjustable group-delay equalizer is provided to balance the group-delay characteristic of the hop—principally that of the far-transmitter power amplifier, up-converter and filter, receive filter, and receive intermediate-frequency

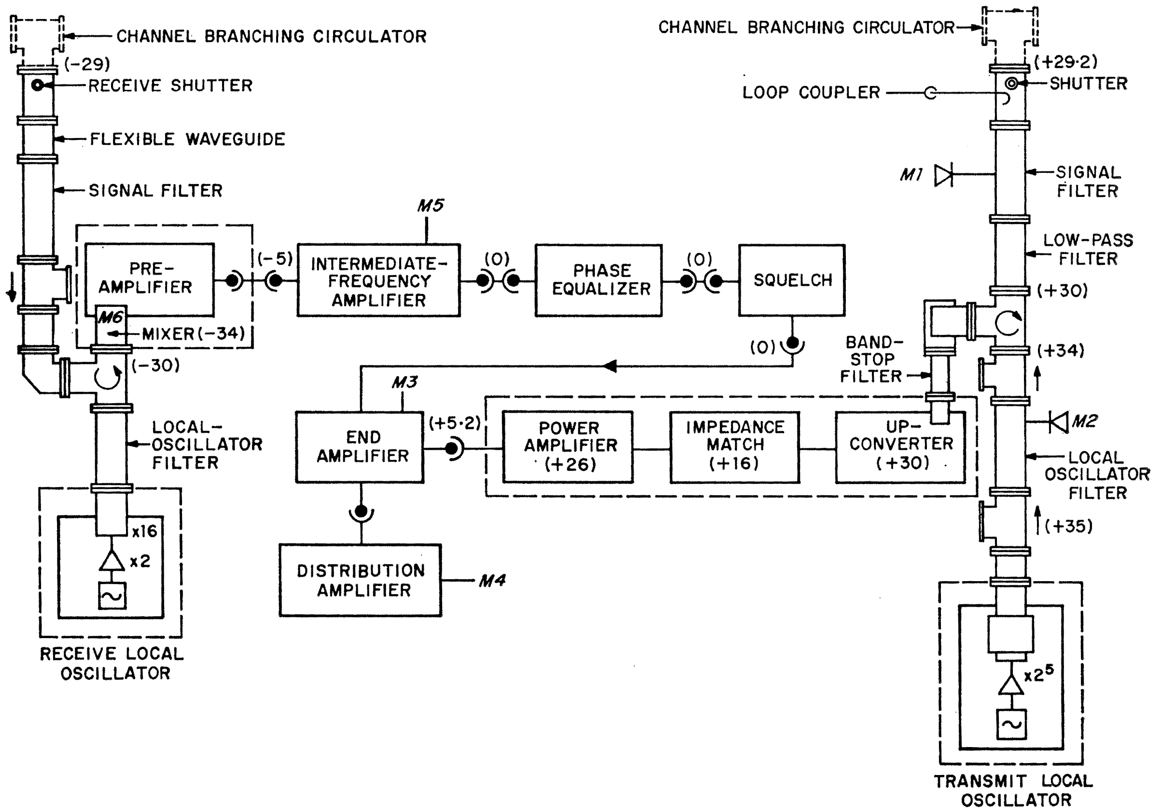


Figure 1—Block diagram. Nominal power levels are shown in parentheses in decibels referred to 1 milliwatt (dBm).

amplifier—to within 2 nanoseconds at ± 10 megahertz.

The squelch panel is set to operate when the input signal level falls to -69 decibels referred to 1 milliwatt. An electronic switch disconnects the through signal path and energizes a 70-megahertz oscillator to feed into the end amplifier. This squelch signal acts as a temporary carrier to subsequent repeaters, holding them at approximately normal gain and thus preventing the transmission of a broad-band noise signal. The squelch panel operates as a 0-gain panel for higher signal levels.

The end amplifier provides two separate outlets of 0·5 volt. If three such outlets are needed, a further distribution amplifier may be provided.

On the repeater bay, the end-amplifier output is coupled into the power amplifier. This panel feeds the two varactor diodes of the up-converter. The up-converter is supplied with 2·5 watts at 4 gigahertz from the transmit local oscillator, which acts as the pump frequency.

At the output flange of the up-converter is a band-stop filter that reflects back the unwanted lower sideband ($f_{LO} - 70$ megahertz) to be reconverted by the up-converter to give about 0·5 decibel less conversion loss at the wanted upper sideband ($f_{LO} + 70$ megahertz).

The 1-watt output at the upper sideband passes through a low-pass filter, which suppresses the second and higher harmonics of 4 gigahertz, to the transmit signal filter. This filter is similar to the receive signal filter apart from a coupling loop and monitor diode. This diode is coupled to one of the centre cavities of the signal filters such that it monitors the signal output of the bay and operates the bay alarm if the output drops 4 decibels. If the diode were not within the filter it would also rectify the local-oscillator frequency or the transmit frequencies of adjacent bays.

At the output of the signal filter a loop coupler is provided for output power measurement to calibrate the diode in the filter. This also would normally couple the transmit power of the adjacent bays. This is overcome by inserting a transmit shutter to short-circuit the waveguide output. This permits the other bays to function normally whilst the output power is measured.

Normally the shutter is in the out position to permit the transmit output to pass to the channel branching circulator.

2.4 Mechanical Features

The slimrack framework, excluding the overhead waveguide assembly, is 200 millimetres wide, 225 millimetres deep, and 2065 millimetres high (7·9 by 8·8 by 82·3 inches). The waveguide receive and transmit runs are mainly vertical and are housed between the two sides of the bay as will be seen in Figure 2.

As is evident from the front view given in Figure 3, the panels protrude forwards from the front edge of this framework. Apart from the meter and alarm panel, the panels are nearly identical to those used on the *RL6* system. These panels plug on to a plate containing the 70-megahertz connectors type 1·5/5·6. Locating pins and retaining clips are provided.

The power supplies for these panels are connected via short wire lengths that are wire wrapped at each end to give both extra reliability over the use of plugs and cost reduction. Adjustment to these panels is made by using a hook-on type of tray immediately beneath the panels. The tray is supplied as a testing tool and is not a permanent part of the bay. This enables the wrapped wire joints to remain unbroken whilst the panels are laid horizontally on the tray. Short cords are provided to connect the intermediate-frequency panels to the sockets in the mounting plate.

The two multiplier panels, the pre-amplifier, and the power amplifier are all rigidly bolted to their associated waveguide components. To facilitate their easy removal, the waveguide flanges are held by quick-release clamps. The waveguide shims are held captive by screwed dowel pins.

Figure 2—Rear view of the slimrack showing vertical waveguide runs.

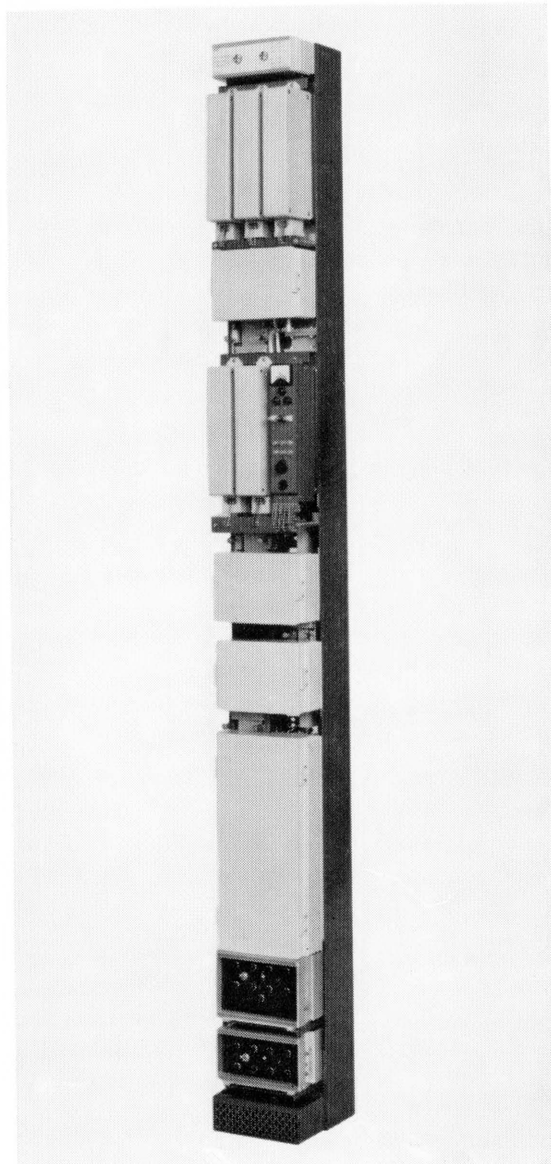


Figure 3—Front view of the slimrack. At the top is the alarm indicator while the 3 panels immediately below are the squelch, end amplifier, and distribution amplifier. The pre-amplifier is next and beneath it are the equalizer, intermediate-frequency amplifier, and meter panel. The next three units are the receive local oscillator, power amplifier, and transmit local oscillator. At the bottom are the transmit and receive power units.

These four panels have cast aluminium boxes which include cooling fins where necessary. Their lids have a thick neoprene sheet covered with silver-plated foil which clamps around the edges and partitions of the panel to give the required radiation suppression of 75 decibels.

At the top of the slimrack, two star flag indicators are provided to indicate ALARM ON and ALARM OFF conditions.

Cooling of the slimrack is by natural convection. Air enters the grill at the bottom, passes both through and at the sides of the power units, and then passes around the cooling fins of the transmit local-oscillator panel and power amplifier.

In this way, the temperature of these panels is maintained to within 15 degrees Celsius of the ambient temperature. This in turn enables the semiconductor junction temperatures to be kept as low as possible for greatest reliability.

The other panels suffer a negligible rise in temperature.

The bay is adjusted in height and levelled by adjusting screws at the base and then screwed to a base plate. At the top of the bay, a locating section ties the bays to one another and acts as a support for the overhead waveguide. The provision of flexible waveguide in both waveguide connections minimizes strain on the bay waveguide.

The slimrack has been designed to accept a 24-volt direct-current busbar at the top of the bay.

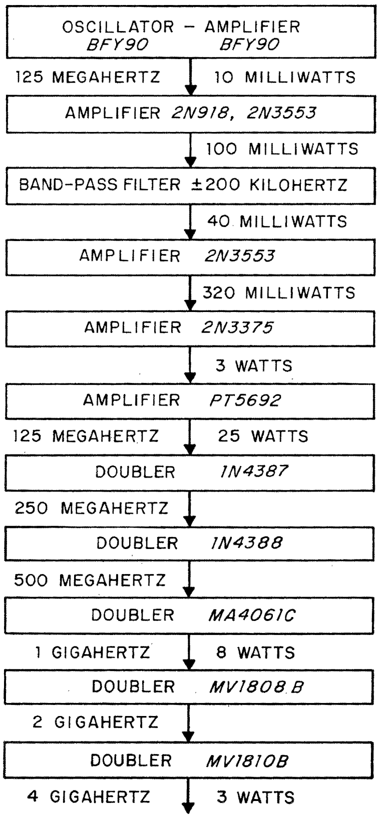


Figure 4—Transmit local-oscillator chain.

3. Transmit Local Oscillator

The transmit local oscillator arrangement shown in Figure 4 employs a 125-megahertz crystal-controlled oscillator unit, which separately plugs on to a driver-multiplier panel. The latter is rigidly bolted to the final two doubler stages of coaxial line and waveguide.

3.1 Oscillator Unit

The crystal-oscillator stage used a *BFY90* transistor with the common-base configuration for stability. The oscillator operates in class *A* on the series resonance of the crystal. The feedback circuit is via two impedance transformers. A step-up transformation ratio of the first requires a higher load impedance. A step-down transformation ratio of the second lowers the required load impedance but also lowers the selectivity of the feedback loop.

A compromise is made so that the load impedance is low enough to minimize variations in transistor output impedance for a feedback loop selectivity of about a quarter of the crystal selectivity.

Allowing for the crystal dissipation, the output is 6 milliwatts. This level is sufficiently high to permit adequate buffering between the oscillator and the following amplifier. The latter (*BFY-90*) also operates in common-base connection and produces a 10-milliwatt output in 50 ohms. The return loss is 25 decibels.

The oscillator is housed in an oven at 60 degrees Celsius. The oven heating element is a transistor controlled by a thermistor via a proportional transistor control circuit.

3.2 Transmit Driver and Multiplier

The 10-milliwatt input at 50 ohms from the oscillator panel is fed to two successive class-*A* amplifiers using *2N918* and *2N3553* transistors with common-emitter connection respectively to give a nominal output of 100 milliwatts at 50 ohms, which is taken to the helical line filter.

The voltage from a diode coupled to the mid cavity of the 4-gigahertz local-oscillator output filter is fed back between the two stages of the amplifier. This can be used to adjust the gain of the amplifier by ±3 decibels to allow for changes in output of the rest of the multiplier panel, for example, due to temperature variation.

The helical-line filter is used to suppress the noise output of the oscillator and amplifiers at the higher baseband frequencies. It has two helical-line sections of fixed coupling, which are tuned with silver-plated brass tuning slugs. The 3-decibel-down bandwidth is ±200 kilohertz and the midband loss is 4 decibels. The temperature coefficient has been compensated by using copper coils in an aluminium box.

The filter is followed by three further stages of amplification operating in class *C* and in common-emitter configuration. The first stage employs a *2N3553* and the second a *2N3375* transistor. The 3-watt output of the stage can be measured at the test point provided.

The final driver stage uses a *PT5692* transistor to give a 25-watt output to drive the successive doubler stages.

The first three doubler stages use *1N4387*, *1N4388*, and *MA4061C* varactors respectively and are built in lumped-circuit techniques.

The third stage produces an 8-watt output, which is coupled to the coaxial-to-waveguide unit that is bolted to the panel. The fourth coaxial doubler employs an *MV1808B* that drives the final waveguide doubler using two *MV1810B* varactors. These couple to a crossbar in the waveguide.

The waveguide output goes through a terminated circulator to a 3-section local-oscillator filter with feedback loop.

The final output is 2·5 watts at the output of this filter.

The noise output of the transmit local oscillator is a maximum of 5 picowatts with respect to the 200-kilohertz root-mean-square deviation for 960-channel loading, for the range from 10 kilohertz to 6 megahertz. This range is wider than the telephony band from 60 kilohertz to 4·2 megahertz and is to cater for television.

As mentioned earlier, great care has been taken in the heat sinking of the semiconductors in this panel to reduce the junction temperatures for maximum reliability; the target is 1-percent failure per 1000 hours for this panel.

4. Receive Local Oscillator

The same 125-megahertz crystal-controlled oscillator described in Section 3.1 is used for the transmit and receive local oscillators. It plugs on to the driver-multiplier unit.

4.1 Driver-Multiplier

As shown in Figure 5 the 10-milliwatt 50-ohm input to the driver is amplified by a common-emitter *2N3553* in class *A*. The output goes to a single-section helical line filter having a 3-decibel-down bandwidth of ±300 kilohertz, which is used to suppress the higher baseband noise from the oscillator and amplifiers.

The filter is followed by a further class-*A* amplifier, a common-emitter-connected *2N3553*.

This is followed by a *2N3553* transistor doubler (common base), which provides an output of 200 milliwatts at 250 megahertz.

The output goes to a step-recovery multiplier. This (×16) multiplier has a printed-circuit input with no idlers. It couples through a double quarter-wave choke, to suppress radiation at 4 gigahertz, to the step-recovery diode (*HPA0251*). A waveguide piston and impedance-compensating screws are used to optimize the output of the 16th harmonic (4 gigahertz), which is selected by the 3-section local-oscillator filter described in Section 7.2.

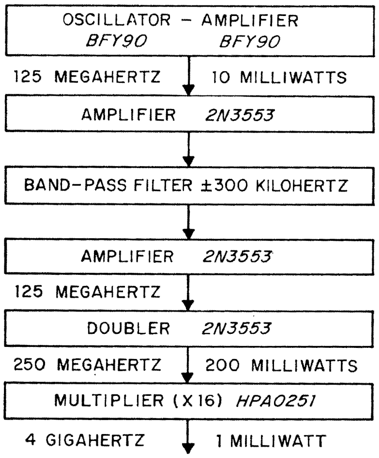


Figure 5—Receive local oscillator.

The output required is −2 decibels referred to 1 milliwatt and the baseband noise output is similar to the transmit local oscillator, namely 5 picowatts maximum in the range from 10 kilohertz to 6 megahertz.

5. Power Amplifier—Up-Converter

This unit accepts a 0·3-volt modulated intermediate-frequency input and up-converts this to 4 gigahertz with 1-watt output. A level diagram is given in Figure 6.

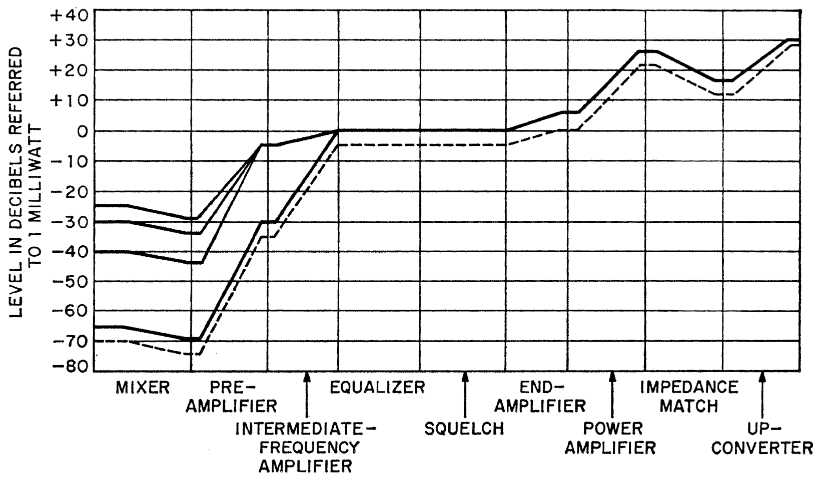
5.1 Power Amplifier

The intermediate-frequency input to the panel is 0·3 volt (minimum) at a terminal station and 0·5 volt at a repeater. To allow for this, a 4-decibel pad can be strapped in or out of circuit in the input of the panel.

The pad is followed by a matching circuit and then by 5 amplifying stages all using common-base connections. The first 2 stages use *2N918* transistors, followed by *2N3137, 2N2950,* and *2N3375* transistor stages.

A 3:1 matching transformer is used between the second and third stages. Harmonic traps are used in the collector loads of the second and third stages.

Figure 6—Level diagram for repeater bay.



The final stage provides an available 400 milliwatts at 70 megahertz to act as the signal for the up-converter.

5.2 Up-Converter

The *upper* sideband up-converter has been chosen for use since it has positive resistance at all ports and is unconditionally stable. A *lower* sideband up-converter is effectively a negative-resistance parametric amplifier and is thus inherently unstable and theoretically would also have decreased efficiency.

Hence the transmit local-oscillator frequency is necessarily always lower than the transmit signal frequency.

The three ports of the up-converter at the pump (local-oscillator) frequency, output signal frequency (upper sideband), and input signal frequency (intermediate frequency) must be matched for optimum efficiency. This is achieved for the two 4-gigahertz cases by the design of the crossbar waveguide transition. A waveguide piston is adjusted behind the crossbar and impedance-compensating screws can be adjusted to give additional correction.

However for the intermediate-frequency case the problem is much more difficult. The Manley-Rowe [1] equations predict that the ratio of the output signal power to the intermediate-frequency power should be in the ratio of their frequencies, that is, 4000:70 (megahertz). Thus the output power of 1 watt could be achieved with 17·5 milliwatts of intermediate-frequency input if the efficiency were 100 per cent. Since an efficiency of about 45 per cent is to be expected, about 40 milliwatts is necessary at the intermediate-frequency input.

The input impedance of the up-converter however is principally reactive and presents a difficult matching problem. This has been overcome only by resistively loading the input circuit. Of the available 400 milliwatts, about 40 milliwatts is applied to the two varactor diodes (*MV1810B*). The bandwidth achieved in this way is flat in amplitude to within 0·25 decibel at ±10 megahertz.

The partial saturation of the varactor diodes produces a 3:1 limiting action from intermediate to super-high frequency.

As mentioned in Section 7.3, a band-stop filter at the lower-sideband frequency is positioned by some two wavelengths from the up-converter crossbar to increase the up-converter efficiency by about 0·5 decibel. The final output power inclusive of circulator losses is 1 watt at the input flange of the transmit signal filter, with a 2·5-watt pump input.

6. Input Mixer and Pre-Amplifier

The combined input mixer and pre-amplifier is required to give an intermediate-frequency output of −5 decibels referred to 1 milliwatt to the main intermediate-frequency amplifier in response to a super-high-frequency input in the range −25 to −40 decibels referred to 1 milliwatt, the latter half of the panel being within the automatic-gain-control loop. The level diagram from mixer to up-converter is given in Figure 6. The unit has an intermediate-frequency response flat to within 0·2 decibel for the range 60 to 80 megahertz. The noise figure of the unit including the main intermediate-frequency amplifier is required to be below 8 decibels. The unit has a radiation margin of 75 decibels at 70 megahertz and 100 decibels at 4 gigahertz.

6.1 Input Mixer

The waveguide input is coupled at 4 gigahertz to the mixer diode *AAY39* by a crossbar-type transformer. The waveguide back plate is fixed and combines with the crossbar to give with an average diode a broad-band match (3·8 to 4·2 gigahertz) to the low-level signal in the presence of the local oscillator.

The 70-megahertz output is fed orthogonally from the crossbar to the pre-amplifier through two quarter-wave chokes, which suppress the 4-gigahertz signal by 80 decibels. A further

20-decibel loss in the 4-gigahertz band is produced by two dust cores to give an overall 100-decibel radiation margin. At 8 gigahertz the chokes give little protection, but the dust cores provide 40 decibels of protection against radiation. The choke output at 70 megahertz is coupled to the input stage of the pre-amplifier within the panel.

The mixer diode connects to one side of the insulated crossbar with its outer end earthed. The diode is held in a mounting cap that contains an 8-gigahertz choke. This choke helps to minimize the level of sum frequency that is produced by the mixer. This frequency is the sum of the local oscillator and received frequency and, if allowed to pass into the adjacent waveguide circuits, could form resonances. The reflected sum frequency would then mix with the local-oscillator second harmonic to produce a further 70-megahertz signal with a possibly excessive group delay [5]. To give the required noise figure of under 8 decibels, the diode is biased with 0·15 volt. The local-oscillator level is required to be nominally −2 decibels referred to 1 milliwatt, which gives a diode current of about 1·5 milliamperes.

To allow for the variation of impedance between diodes, matching screws are provided to assist in obtaining the required characteristics at both super-high and intermediate frequencies.

6.2 Pre-Amplifier

The pre-amplifier is basically a 5-stage low-noise adjustable-gain amplifier using a *2N2415* followed by four *2N918* transistors.

The input from the *AAY39* mixer gives an intermediate-frequency source impedance of about 170 ohms. This input is coupled to the *2N2415* first stage, which is designed for a low collector current to give a noise figure of about 2·2 decibels. The first two stages are operated in the common-emitter configuration.

A band-pass filter is connected between the second and third stages. This provides 30-decibel rejection peaks at 40 megahertz and 100 megahertz, and a pass-band characteristic of 0·1 decibel at ±14 megahertz with an impedance of 150 ohms.

The third and fourth stages have a common-base configuration. The automatic-gain-control feedback voltage goes to a diode that shunts the output of the third stage. The variation of this diode impedance gives a 15-decibel variation in overall gain.

The fifth stage is a buffer amplifier with an output impedance of 75 ohms. The output level is −5 decibels referred to 1 milliwatt.

To facilitate alignment, an input 75-ohm test point having a reduced gain of 6 decibels is provided.

6.3 Other Intermediate-Frequency Panels

The other panels include the main intermediate-frequency amplifier, adjustable group-delay equalizer, squelch unit, and end amplifier. These panels are electrically almost identical to those used on the *RL6* system. They are generally described in Section 2.3.

6.4 Measurement Results

The characteristics shown in Figures 7 and 8 were measured from the intermediate-frequency input of the power amplifier through the transmit half, coupled through flat attenuators at super-high frequencies, to the receive half to simulate a single-hop system with no feeders. The amplitude characteristic was recorded for the nominal input level and for a 35-decibel fade.

The group-delay characteristics shown in Figures 9 and 10 were first measured for the same transmission path with no equalization. The group-delay equalizer was then set to balance the test path with normal receive level to the input mixer. The equalizer was left in the same condition when the 35-decibel fade was applied and the characteristic remeasured.

Receiver noise-figure measurements are shown in Figure 11. The rise in noise figure at higher input levels is due to the main intermediate-frequency amplifier.

7. Waveguide Filters

7.1 Signal Filters

The purpose of the signal filters is principally that of acting as the receive and transmit channel branching filters in conjunction with a 3-port circulator. See Figure 12.

The receive signal filter is required as protection against near-end products from transmitters which leak through the transmit-receive circulator, particularly in the neighbourhood of the image frequency, and also as protection against adjacent receive channels. It also gives a high suppression to local-oscillator leak.

The transmit signal filter is required to give adequate suppression against the local oscillator and unwanted sidebands. This filter also incorporates an output-level monitoring diode.

Both filters have to give minimum return loss at the adjacent channels (±58 megahertz) and also a minimum reflection group delay at these frequencies in their function of channel branching.

The group-delay characteristic is to be equalized on a hop basis but temperature variations of the order of 20 parts per million per degree Celsius using copper waveguide would have given too large a value of group-delay slope.

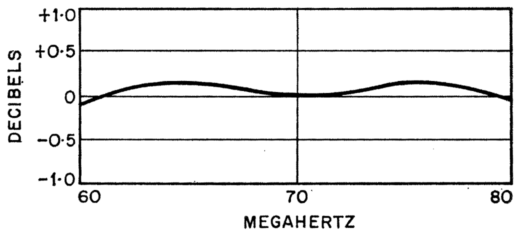


Figure 7—Transmitter-to-receiver response-frequency characteristic for a nominal input level of −30 decibels referred to 1 milliwatt.

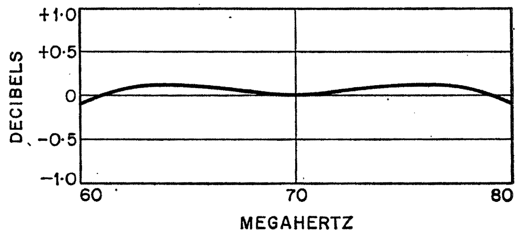


Figure 8—Transmitter-to-receiver response-frequency characteristic for an input level of −65 decibels referred to 1 milliwatt corresponding to a 35-decibel fade.

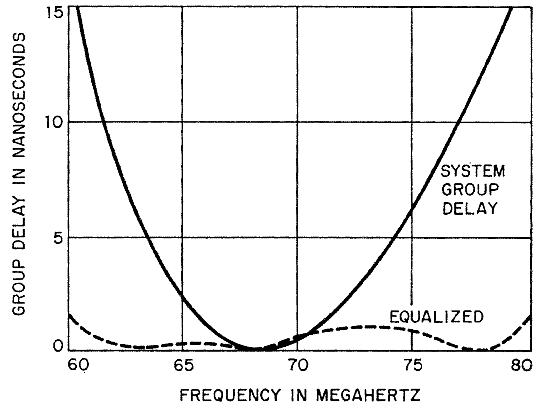


Figure 9—Group delay for a single hop at a super-high-frequency nominal input of −30 decibels referred to 1 milliwatt.

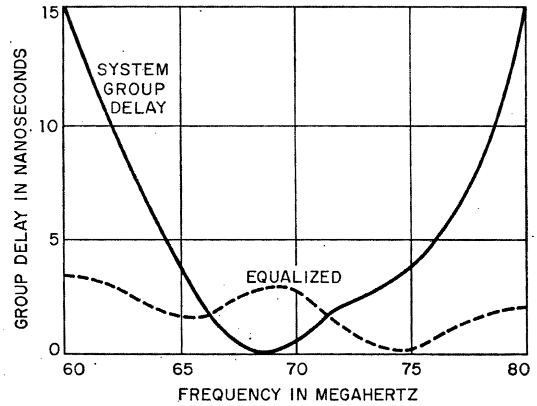


Figure 10—Group delay for a single hop at a super-high-frequency input of −65 decibels referred to 1 milliwatt corresponding to a 35-decibel fade.

Thus "Nilo" waveguide having only 2 parts per million per degree Celsius is used. It has to be silver plated.

The filters are of maximally flat characteristic and have a 3-decibel-down bandwidth of ±20 megahertz. There are 6 direct-coupled sections. The inductive obstacles used are symmetrical irises. These serve the double purpose of fixing the bandwidth of the adjacent cavities and acting as the coupling between cavities. The filter is required to be tunable over 200 megahertz, that is, two groups are required to cover 3·8 to 4·2 gigahertz. To obtain a constant bandwidth, a capacitive screw is adjusted on the centre line of the gap between the irises (in the same plane).

The cavities are tuned using capacitive screws at their centres. These are made in quartz to give minimum loss at the lowest frequencies and to eliminate contact problems.

Since there are 6 tuning screws and 7 iris screws to adjust, it is necessary to use a Smith chart plotter to indicate the swept reflection coefficient in magnitude and phase and also to display the transmission characteristic for alignment purposes.

7.2 Local-Oscillator Filters

These are required principally to suppress the unwanted sidebands of the multiplier chains used in the local oscillators. The receive local-oscillator filter is also used to reflect the signal frequency to the input mixer with a minimum of return loss and reflection group delay. The transmit local-oscillator filter incorporates a

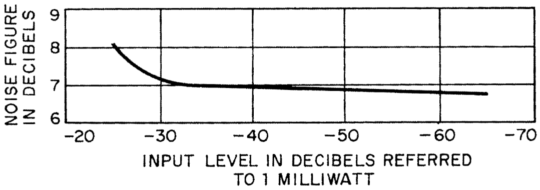


Figure 11—Receiver noise figure for super-high-frequency input.

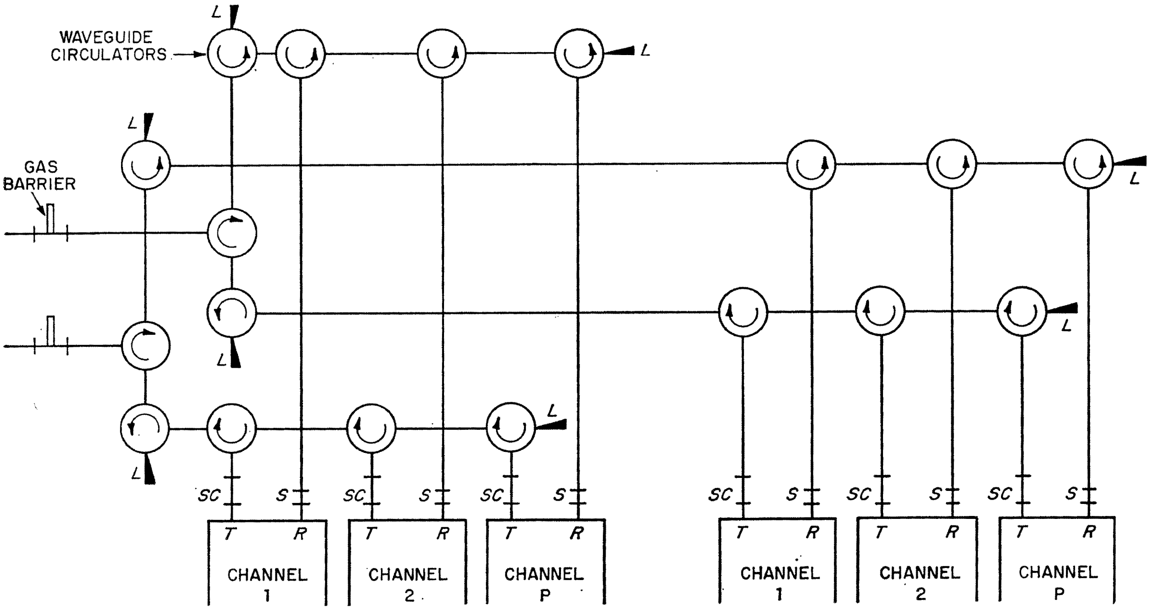


Figure 12—Channel branching scheme. S = waveguide shutter switch. SC = waveguide shutter switch with test point on transmitter side. L = waveguide load. T and R are transmit and receive halves of the indicated channels.

coupling diode used in the automatic-gain-control loop of the transmit multiplier panel.

The filters are of 3 sections with a 3-decibel-down bandwidth of ±8 megahertz and have a Chebishev characteristic. They are made in copper but otherwise are mechanically similar to the signal filters.

7.3 Band-Stop Filter

This filter is used in conjunction with the up-converter. It is required to reflect back the unwanted lower sideband to give about 0·5 decibel greater efficiency. The output amplitude and phase characteristics of the up-converter need to be left unimpaired.

The filter used is a 2-section ±25-megahertz maximally flat band-stop filter. The filter is designed as two main groups, which are used with different spacings from the up-converter.

The design used employs transverse resonant rods for each section, quarter-wave coupled. The bandwidth of each rod can be adjusted over a given range by a capacitive screw. A further capacitive screw, with fine trimmer, adjusts the centre frequency.

The filter is positioned at about 2 wavelengths from the up-converter crossbar to permit access to the quick-release clamp.

7.4 Low-Pass Filter

Although the signal filters have been designed to give a minimum of holes in the 8-gigahertz band, it is necessary to provide further suppression to reduce the harmonic output of the up-converter.

The low-pass filter used is of coaxial form. The design uses 6 sections incorporating alternate lengths of high- and low-impedance coaxial line. The coaxial circuit is housed in a solid block mounted on the waveguide.

The 50-ohm coaxial outlets couple via probes into the main waveguide at either end of the filter. Short-circuit plates are inserted into the waveguide to complete the two waveguide-to-coaxial transformers.

The small excess reflection coefficient is spot matched by waveguide impedance-compensating screws.

The filter cut-off frequency is 5·2 gigahertz and the suppression exceeds 50 decibels in the range 7·5 to 14·5 gigahertz, that is, the second and third harmonic bands are adequately suppressed.

The cut-off frequency of the first waveguide mode is 14·5 gigahertz, which could be passed by the coaxial low-pass filter.

8. Circulator

The 3-port circulator serves three functions.

(A) Coupling the local oscillator and signal frequencies at the mixers with the aid of filters.

(B) Channel branching.

(C) Isolating when fitted with a short absorbing block.

The same design is used for these three purposes.

A cylindrical block of yttrium-iron-garnet is used. It is positioned between two discs of polytetrafluoroethylene. This assembly is fitted symmetrically between triangular-shaped matching steps at the centre of the cast *Y*-shaped waveguide junction.

Matching screws are used to produce the final typical performance of 0·12-decibel forward loss and 40-decibel backward loss in the band 3·6 to 4·2 gigahertz. A field strength of about 1000 gauss is needed from the magnet.

9. Power Supply

In the terminal bay, the repeater power unit is replaced by separate receive and transmit units which are fed independently. These are of similar design and differ mainly in capacity.

9.1 Repeater Power Supply Requirements

The power unit is required to work from a primary direct-current supply of nominally 24 volts but with a possible range of 21·5 to 33 volts (either battery or rectified mains).

The outputs required are −19·5 volts at 900 milliamperes for the intermediate-frequency circuits, +28·5 volts at 1750 milliamperes for the local-oscillator circuits, and −22 volts at 400 milliamperes unstabilized for the crystal oven.

The power unit was required to be small, stable, of high efficiency, and of maximum reliability. Low impedance and low noise were also necessary.

9.2 Circuit Operation

This is outlined in the block schematic of Figure 13. The three basic circuits are:

(A) Pre-regulator, which provides regulation for input voltage variations.

(B) Invertor, which provides isolated output voltages of different amplitudes.

(C) Stabilizers, which provide stabilization against temperature, load variation, and low output impedance.

The battery or rectified mains supply goes to the direct-current-to-direct-current pre-regulator through an input filter that filters out the switching waveform generated in the power unit and prevents noise being generated on the battery terminals. The pre-regulator employs pulse-width modulation to compensate for the input voltage variation. The regulator consists of a control circuit, series transistor, and smoothing circuit. The control circuit under control of the output voltage varies the time during which the series transistor is saturated. The control circuit controls this against input voltage variation and load variation. The frequency of the pre-regulator is controlled by a synchronizing pulse from the invertor. The switching waveform is smoothed by a swinging-choke filter circuit, which has a good no-load characteristic.

The pre-regulator works at an efficiency of the order of 90–95 per cent over the range of operation of the power unit.

The output of the pre-regulator goes to the direct-current-to-direct-current invertor, which steps up the voltage at 2·5 kilohertz and provides semi-stabilized supplies for the two series stabilizers. The invertor is driven by a saturating-current driver transformer that determines the frequency of operation. The output is rectified and a smoothing circuit is incorporated to eliminate high-voltage high-frequency spikes.

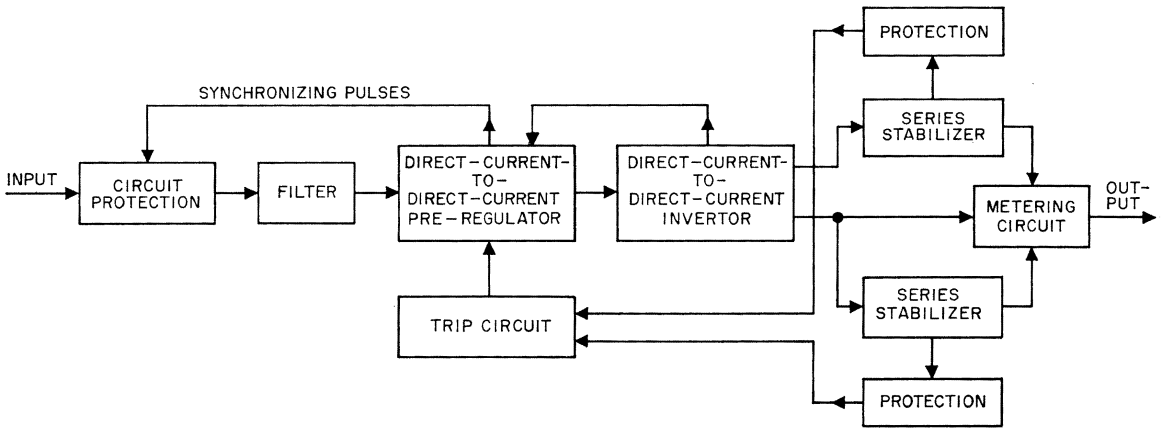


Figure 13—Power supply.

The series stabilizers provide low-noise low-impedance outputs that are temperature compensated to give variation of less than ± 1 per cent in the range 0–70 degrees Celsius. The output voltage is set to within ± 1 per cent by an 8-step control. The frequency response of the sensing and amplifier circuits gives a low output impedance up to 1 megahertz.

The outputs from the stabilizers go to the metering circuits, which provide for the monitoring of the currents and voltages. The currents to each major panel are shunted and by a switch on the power unit can be monitored on the meter panel.

9.3 Protection

All outputs are protected by an over-voltage trip circuit and a single over-current trip on each stabilizer. The outputs to units not directly in the transmission path are fused so that a fault on these panels cannot affect the transmission path.

The over-voltage and over-current protection circuits operate the trip circuit, which is a 3-coil double-reed relay that latches on and switches off the series transistor in the pre-regulator. The trip is reset by switching off the main supply for 30 seconds.

The power unit itself is protected from failure of the pre-regulator circuit by an over-voltage circuit in the pre-regulator which operates the protection circuit consisting of a silicon controlled rectifier in conjunction with a high-rupture-capacity fuse. The circuit is further protected by a diode that blows the input fuse should the input voltage polarity be reversed.

The power units have high efficiency, about 66 per cent, due to the incorporation of the switching-type pre-regulator. This also has the effect of giving an overall regulation with input voltage of better than 10 000:1. Noise is less than 1 millivolt root-mean-square up 10 megahertz.

10. Meter and Alarm

10.1 Function

The meter and alarm panel is used to indicate the monitored levels shown on the transmission schematic of Figure 1. It further indicates the correct voltages and currents of all the stabilized power supplies in conjunction with the power unit switch. Thirdly it contains the bay alarm circuit incorporating flag indicators at the top of the bay.

10.2 Level Indication

The various monitoring diodes are connected via potentiometers on the meter panel to the meter. These potentiometers are set such that for nominal operational levels the indication is central within a blue band, the ends of which represent the normal limits. A decibel scale is provided for the super-high-frequency input level.

10.3 Voltage and Current Indication

The power unit switch is employed for this purpose. Voltage indications should align with a red line in the centre of the blue band on the meter. Current indications should lie within the blue band.

10.4 Alarm Sequence

When the bay output level as indicated by *M1* in Figure 1 drops by 4 decibels, the ALARM ON flag indicator opens. The alarms would operate both in the local station and control station.

Manual switching of the meter panel key would indicate by a lamp whether the fault occurred in the receive or transmit section of the bay. Whilst this key is depressed the ALARM OFF flag will be open with the ALARM ON flag closed.

After the fault is remedied the alarm lamp will go off on the meter panel and the keys may be raised to restore normal conditions.

The same alarm procedure will be followed for a 4-decibel drop in power to the intermediate-frequency squelch panel when the squelch will operate and also when the intermediate-frequency gain is set to manual.

11. Maintenance

The slimrack has been designed with a reliability target corresponding to a failure rate of 3 per cent per 1000 hours. With this in mind, the maintenance philosophy is that of replacement modules. Thus all panels have been made easily removable. The four panel units with waveguide ports have quick-release flange connections.

Minor adjustments to the intermediate-frequency panels can be made if desired by using a "hook on" tray onto which the panels can be placed leaving the wire-wrapped joints unbroken.

12. Conclusion

The *RL4H* slimrack is of low cost and low power consumption. It has the advantage of requiring much less floor space than previous radio bays and, being all solid state, has high reliability.

13. Acknowledgment

The author wishes to acknowledge the valuable assistance of a number of colleagues engaged on the development of the *RL4H* slimrack.

14. References

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Security of Interlocking Systems for Railroad Track Switching

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A previous article * compared the geographic system with the relay technique hitherto known with regard to the three most important problems, namely: route search, flank protection, and signal aspect selection. Despite the ever-increasing application of the geographic system on world railroads, questions have been raised by experts as to the safety of the new system. Thus a comparative paper on the two most important interlocking systems might be of international interest at this time. The diagrams follow the rules of The Association of American Railroads.†

It is possible to establish the following natural conditions from the protection procedure.

(A) Establishment of route: Permissibility proving, points setting (individual setting, route setting).

(B) Route protection: Clear proving, flank protection, overlap, locking (route locking, individual locking).

(C) Signal control: Establishing normal position. Setting signal at STOP, release (route release, partial release, individual release), setting lock levers.

The various types of interlocking systems will now be considered in the light of these processes.

1. Interlocking Techniques

1.1 Mechanical Interlocking

In mechanical interlocking systems the points and signals are set directly and mechanically by the signalman. The relationships between the control levers are also determined by mechanical means (mechanical locking dogs).

1.1.1 *Establishing the Route*

Since the points are connected mechanically with their signal-box levers by rods or steel wires, it can be safely assumed that the points will follow the lever movement. In the standard interlocking of the Deutsche Bundesbahn the points are set by double wires. They rely on the points following the wire movement. A wire-breakage lock is incorporated in the points drive for protection against wire breaks. This blocks the drive, thus holding the point in its position.

To establish that all the points needed for the route are in the correct position, a slide, connected with the signal lever, permits the signal lever to be thrown only when the points levers have assumed the correct position. The points levers cannot be thrown if they are locked by the route slides of a route.

1.1.2 *Route Security*

By route locking, the route and signal slides in the locking frame are rendered mechanically immovable. The route is to be released only when the train has moved and the route cleared. For this reason the slide or lever is provided with an electrical lock, which is released automatically by the train or manually by a man who is observing the clearing of the route.

1.1.3 *Signal Control*

The route slide in the mechanical locking frame releases the signal levers.

As a rule only semaphore signals are used. In mechanical interlocking, light signals would usually be employed only when an entire section is uniformly equipped with light signals.

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* W. Schmitz, "Geographic Relay System for Railroad Interlocked Routing," *Electrical Communication,* volume 39, number 3, pages 383–402; 1964.

† "American Railway Signaling, Principles and Practices, Chapter XX, Interlocking Circuits," available from Association of American Railroads; George McCann, Secretary; 59 East Van Buren Street, Chicago, Illinois 60605, at $1.20 per copy; plus postage.

Since the signal box is designed for mechanical signal control, when light signals are used the levers must also be provided with suitable contacts and the signal box with relays.

1.1.4 *Establishing Normal Position*

The signals can be restored manually by pulling back the lever or are automatically brought to the STOP position by the train movement. All the exit signals on sections with block protection must be automatically set at STOP by the train movement, so that the train is protected from following movements on the same section. Semaphore signals are provided with a signal arm coupling, by means of which the rigid connection between signal arm and actuating wire can be electrically released.

After the train movement is completed, the signal and route levers must be restored by hand.

1.2 Electromechanical Interlocking System

The power for the electromechanical interlocking system was generally taken from batteries as security against failure of the power source. It is only in the past 20 years that the longer distances to be controlled brought about the use of alternating current, including polyphase systems, for control. The mechanical locking frame was retained.

1.2.1 *Establishing the Route*

The direct relation between the position of the points lever and the position of the points in mechanical interlocking is not inherent in electromechanical interlocking. The lever movement closes contacts through which electric power is sent via cable conductors to an electric actuator or electromotor that sets the points. This motor sets the points via rods through a coupling so that positive action is not assured. The coupling protects the motor from overload, and permits trailing of the points machine. Failure of contacts to close or the interruption of lines or cable wires would result in the motor not following the lever movement. The points movement therefore has to be detected and signalled back to the signal box. Thus, while in mechanical interlocking the position of the lever is the sole identification of the position of the points, in the case of electromechanical interlocking there must be an additional indication of position.

Route setting has been in common use in France for about 60 years. The reversal of a route lever closes contacts that convey control current to all the points machines concerned. This type of route setting is now considered to be essential. For permissibility proving by operating the route push buttons or route lever it is first of all possible to establish whether all the necessary points settings are permissible. Only then is control power applied to the machines. This method has the advantage over individual points setting in that no points reversal is performed unnecessarily if for any reason the route setting is not permissible.

Individual points setting is customary in German electromechanical interlocking systems. Conflicting routes are excluded by means of locking dogs in the locking frame. Clearance proving in the case of adjacent points is usually obtained visually by the signalman and for very distant points by electrical lever locks. The latter consist of an electromagnet operated from steady current via the points detector, their armatures locking the points levers in the dropped condition.

The points are generally set by direct-current-operated electromotors. The standard circuit for the German electromechanical interlocking system is discussed in [1].

1.2.2 *Route Security*

In the German type electromechanical interlocking system the route levers and the signal levers have been combined into a single route signal lever. When the route signal lever is thrown from 0 to 45 degrees it moves the track slide bar from a middle position to the right or left according to direction of rotation. When the lever reaches 45 degrees electrical locking is automatically applied and only then can the lever be moved to 90 degrees for the signal control. Since for electrical points setting not only the points lever position (mechanical) but also the points position (electrical) have to be checked, the route signal lever has, in addition to the locking magnet, a lever-locking magnet that is energized only when the detection magnets of the points belonging to the routes concerned are energized.

1.2.3 *Signal Control*

Modern German electromechanical interlocking is designed for the setting of semaphore and disc signals by motor mechanisms. For corresponding circuits see [2]. To improve visibility it was decided to introduce light signals [3], which were controlled by relays. The first light signals were operated with direct current, finally with double-filament 50/50-watt lamps. After the war, Germany changed over to alternating-current light signals. Three-contact double-filament 12-volt lamps are supplied from transformers with full voltage in daytime and reduced voltage at night. Both lamp filaments are used only for red signals.

For signal control the route signal lever must be thrown beyond 45 degrees. By mechanical blocking this is permitted only when the armature of the locking block has dropped in and thus the lever is blocked from going back from 45 degrees.

1.2.4 *Establishing Normal Position*

For automatic setting of the signals to indicate danger, contacts for the relay of the insulated rail are inserted in the signal control circuits. These relays, as will be seen later, are used for the route release.

The locking magnet that blocks the route signal lever from being moved backward from the 45-degree position is energized by relays in the track circuit, when the latter is cleared by the last train axle. The route signal lever is thereby released, so that it can be set back from the 45-degree position by hand. In the release circuit the signal control relays are checked for release. The stop position of the signal is often directly detected in the release circuit.

To establish the normal position, the route lever must be restored to normal so that the track slide bar again cancels the blocking of the conflicting levers.

1.3 Relay Interlocking System

This type of system has electrical interlocking between the control members by means of relay contacts, in addition to electrical points and signal control. The only mechanical interlocking still required is in the construction of the interlocking relays. In these devices two relays are mechanically coupled in such a way that one armature is always operated and the other released, the released armature holding the other operated. The use of such interlocking relays or magnetic locking relays is essential if a change of position of contacts is to be avoided in the event of a power failure.

1.3.1 *Establishing the Route*

Relay interlocking systems at the present time can be designed with the advantage of route setting, which is a simple matter. For each route, one latching relay is provided, which is designated as the allotted route. Since in relay interlocking the entrance-exit control predominates, the route relays are switched on by the push buttons assigned to the section and station tracks. The permissibility proving is effected by the contacts (inserted in the circuit of the route relay) of the conflicting route relay. To increase the protection from conductor faults, the contacts are arranged in duplicate. Contacts of the route relay connect the points setting relays. The locking circuit of the route relay replaces mechanical interlocking and also checks whether the reversal is permitted before a points control relay is energized. The proving of the clear condition should be carried out in the locking circuits of the route relays, so that the permissibility proving is complete. For this, contacts of the track circuits at the points must be switched into the circuits of the route relays. However, clear-proving is often effected only in the points circuit.

To control over long distances, the German Bundesbahn uses 3-phase-current points machines, which are controlled by an unearthed circuit using only 4-conductor cable. The 3-phase circuit is shown in Figure 1. The detection current is passed through all 4 conductors in the switch machine. The indication of a trailing condition is effected by a trailing relay *WTR*, the operation of which is checked automatically in service.

In the normal position detection relay *WK* is energized by current flow from *B* to *N*. If the point is to be thrown, then the push-button relay *PBR2* is energized and its contact *PBR2* breaks the detection circuit so that *WK* releases. Thereby in the relay circuit (not shown) the position relays *WPR1* and *WPR2* and the two control-current relays *WCR1* and *WCR2* are energized. Operating current then flows in the three phases via *WCR2, WCR1, WPR2,* and conductor *RW;* through *WCR1, WPR1,* and conductor *NW;* through *WCR2, WCR1,* and conductor *CW*. The latter flows via the transformer, so that the relay *WCK* is held

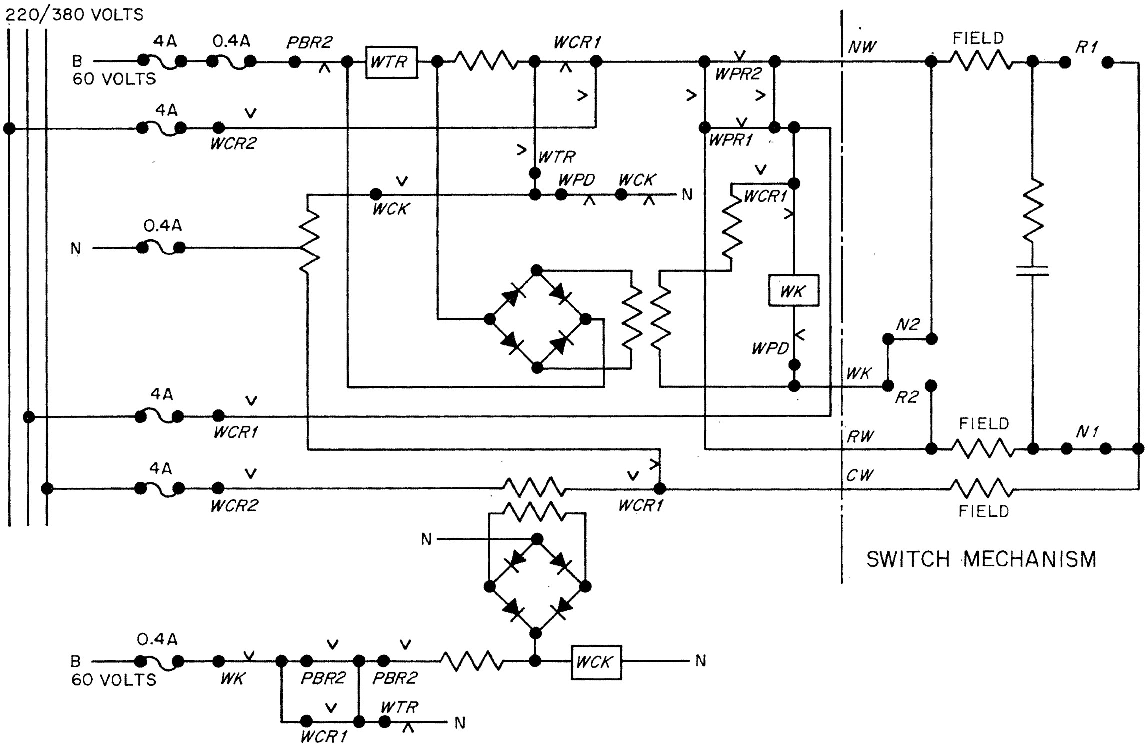

Figure 1—Switching machine is operated from 3-phase power supply.

PBR = push-button relay
WCK = relay for checking switch correspondence
WK = relay for indicating switch position
WPD = relay for detecting switch position
WPR = relay for changing switch position
WTR = relay for trailing switch.

energized via the rectifier as long as the operating current is flowing. To start the drive the current flows from conductor *NW* via field and capacitor with resistor. Then contacts *R1* short-circuit the capacitor. If the home position of the points is reached, the contacts *N2, R2* change over, and *N1* opens. The trailing magnet *WTR* is energized (to check its operation). Relay *WCR1* is cut off. The interruption of the control circuit causes *WCK* also to release, since the power supply via transformer and rectifier is cut off. The contacts *WCK* cut off the power supply from *WTR* via the transformer. *WK* now responds again to detect the opposite points position. In the case of trailing from the points position shown in Figure 1, contact *N2* opens and *R1* closes. The trailing relay *WTR* is energized via line *NW,* contact *R1,* and conductor *CW.* It establishes a locking circuit for itself via contacts *WPD* and *WCK.*

1.3.2 *Route Security*

Every route is provided with a route relay *RR* that effects the points control (see 1.3.1). When the points are in the correct position a locking relay *RL* is switched on for a group of routes, and in Figure 2 it is used for routes *A1* to *A3.* This can lock the whole route or only parts of it. In its circuit, for each point including flank protection, the points position is detected by *WKN* or *WKR,* the clear state by *TR,* and the locking by *WL.* All the locking relays must be latching relays so that there will be no inadvertent release of locking in the event of a power failure. For extensive track systems with a great many routes this circuit is so complicated that the route-setting contacts available when standard route relays are used no longer suffice, so that many kinds of contact-saving special circuits were introduced [4].

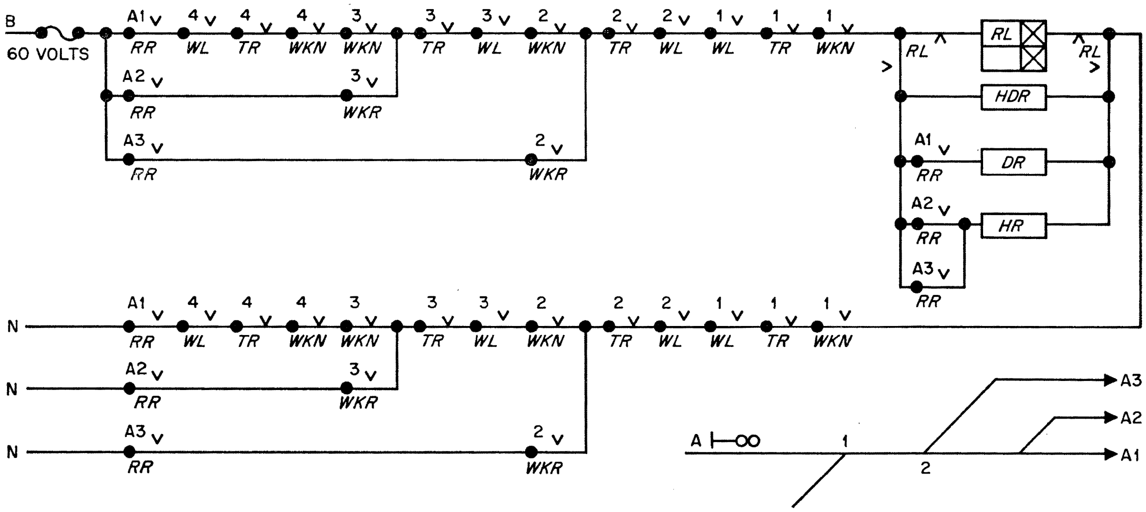

Figure 2—Signal control circuits with relay interlocking.

WL = point locking relay
WKN = normal switch indicating relay
WKR = reverse switch indicating relay
TR = track relay
RR = route relay
RL = route locking relay
HDR = approach and proceed relay
DR = proceed control relay
HR = approach control relay.

1.3.3 *Signal Control*

In relay interlocking systems in Germany, only alternating-current light signals are used. The light-signal circuit is similar in form to that later used in geographic interlocking systems. Since this type of system is dealt with in Section 1.4.3 there is no need to describe it here.

It is, however, worth noticing the connections of the signal setting relays *HDR, DR,* and *HR*. These are double connected as shown in Figure 2. By connecting the locking circuit and the signal control circuit the necessary proving contacts of the points can be used in common for both tasks. All these contacts, however, are doubled for protection from conductor faults. First of all the route-locking relay *RL* is switched over and then the same circuit passes through signal-control relays *HDR* and *DR* and *HR,* respectively.

1.3.4 *Establishing Normal Position*

In Germany relay interlocking systems are equipped with full track circuits to the extent that the permanent way permits. It is obvious to use for the release the existing individual track circuits of the points and track sections instead of the insulated rail with track contact.

The route is therefore released at the moment at which the last axle of the train clears a section, while another section is occupied. The cooperation of several sections is necessary to prevent the track relays from releasing when there is a mains failure.

Since all the contacts of the points relays had been doubled in the signal control relay circuits of Figure 2 to increase the security, the return to the stop positions of the signals accordingly become safer. The security is also further increased by the fact that all the track relay contacts of the route are included, so that in the exit movement all the *TR* contacts break in sequence. Since two signal control relays are cut off, it is impossible for both of them to fail to release.

1.4 Geographic System

1.4.1 *Route Establishment*

In the geographic system a route is made up of standard units assigned to the various functions such as signals, points, and track circuits. To obtain a relationship between the starting point and the destination point, the requisite condition is first determined (permissibility proving) and then established in a route search circuit for each point. The route search has already been dealt with in detail in an earlier article [5]. Figure 3 now reproduces the circuits including proving the points for availability. The two circuits begin by push-button contacts *PB* and end on relays *XR* and *NR,* respectively. Relays *N* and *R* are assigned to the points and each of these is connected from points to points; they determine the necessary points position. The push-button contacts *PB* are bridged by contacts of the end relays *XR* and *NR,* respectively, so that after the route push buttons are released, the desired route is maintained. If the depressed buttons are released before the route search circuit is completely switched through in both directions, the whole circuit returns to normal.

If we consider permissibility proving in detail, we recognize that conflicting routes are fully excluded by the contacts *N* and *R*. A circuit channel locked against all conflicts corresponds to the selected route. Through the effect of contact *WL,* in the case of route locking, there can be no route search beyond this point. This of course presumes that separate locking devices are used for route and flank-protection locking.

The clear proving of the points is an easy matter with the geographic technique, since a track relay contact *TR* is introduced into the route search circuit. For circuits that are also to be used for shunting routes that have not been proved clear, as shown in Figure 3 the contacts *TR* can be bridged by contacts *WPR* so that the route search circuit can be switched through when the points track circuit is occupied, only when the point is not to be moved.

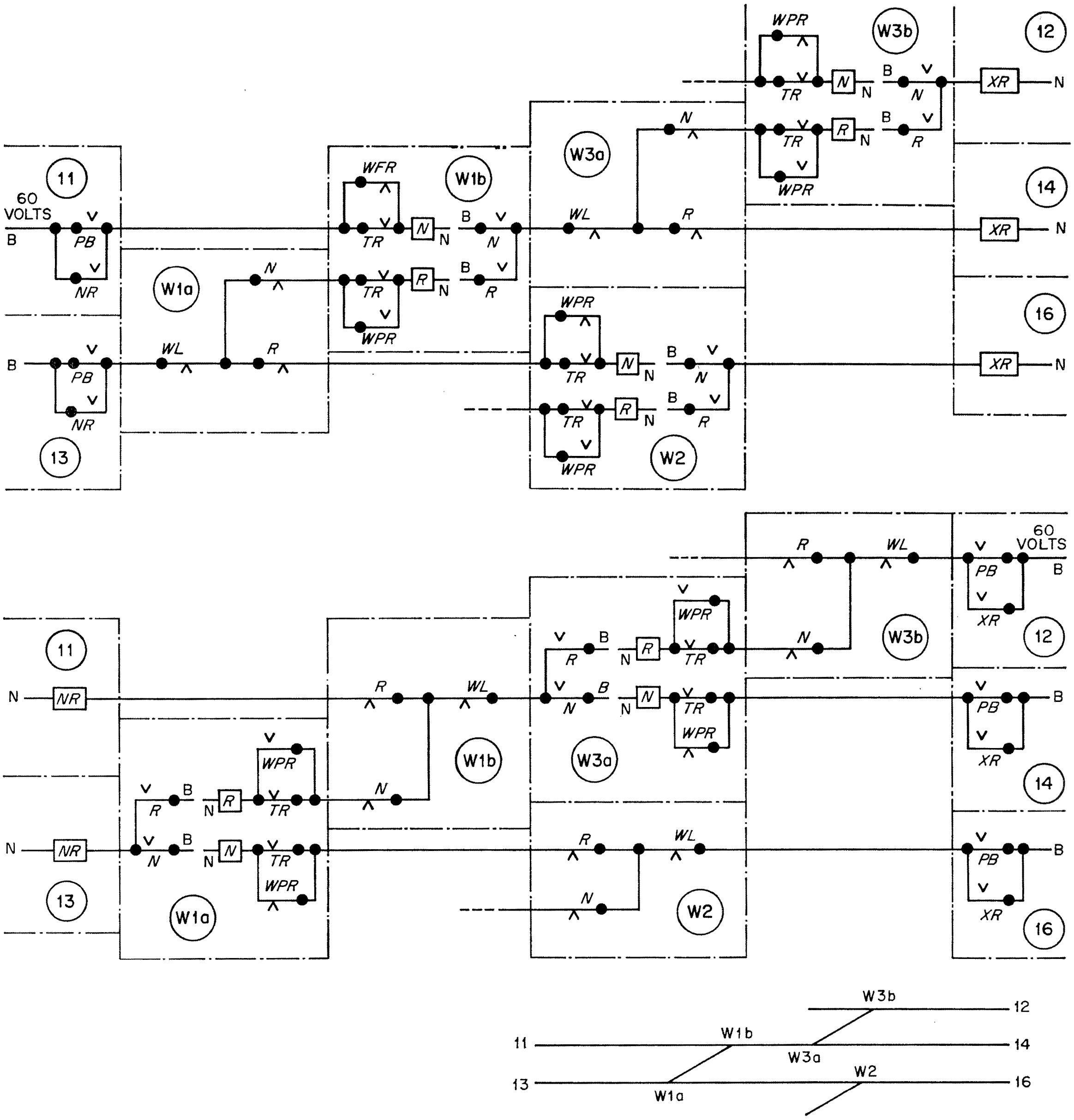

Figure 3—Route search.

N = normal relay
NR = entrance relay
R = reverse relay
TR = track relay
WPR = track position relay
WL = switch lock relay
XR = exit relay.

Only after the completion of the route search is the movement of the points initiated, as far as is necessary, in a further geographic circuit. According to Figure 4, by means of contacts of the end relay *XR* for the points, *WR* is connected when it is established by contacts *N, R,* and *WPR* that the point is to be moved. The points reversal is effected by contacts *WR* and *WPR*. The points circuit corresponds to the circuit of Figure 1 for relay interlocking.

1.4.2 *Route Security*

In the geographic technique, as we have already stated, every point has its own locking device which, when the points are in the correct position, is energized in another geographic circuit.

If a flank protection point is in a wrong position, it is brought into the correct position through the locking contact of the running point contact *WL1*. If the point is correctly set then a locking latching relay *WL2* is operated. Thus every point has two locking latched relays: *WL1* for locking in the route and *WL2* as flank protection.

1.4.3 *Signal Control*

Very extensive safety measures were introduced into the circuits of the signal operating relays in the geographic technique. The three operating magnets *HDR, DR,* and *HR* were retained, although the inadvertent depression of relay armatures had been precluded by the design. As shown in Figure 5, two bipolar

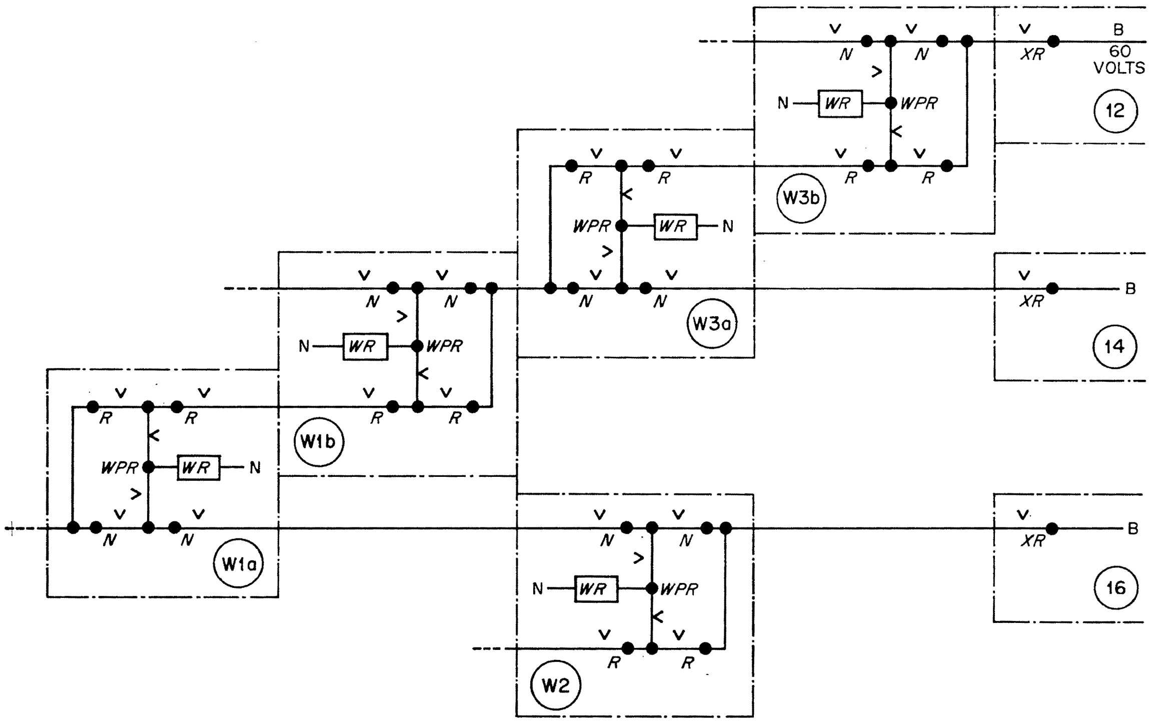

Figure 4—Initiation of control of switches.

N = normal relay
R = reverse relay
WPR = switch position relay
WR = switch control relay
XR = exit relay.

switching circuits are provided, one of which is used for the connection of relay *HDR*, the other for controlling the aspect relays, *DR* and *HR*. Furthermore, to produce similar effects at both ends of the route, auxiliary relays *FRX* and *FRN*, and *FIX* and *FIN*, are provided both at the entrance and at the exit. The light signal circuit of Figure 6 now contains, in addition to the known repeaters and the proving relays, *CDR* and *LOR*, an auxiliary relay *SCR* at the signal and the two relays *VR1* and *VR2* required for automatic train control.

For the signal control in Figure 5, the contact *NR* in the signal set closes a circuit via conductors 18, relay *FRX* in the destination set, conductors 38, to the relay *FRN* of the signal group. Then the control relay *HR* is energized, starting from contacts *FRX* via lines 19 and 39. Contacts of relays *FRN* and *HR* test the light signal circuit since in Figure 6 relay *CDR* is connected through contact *DR*, *G* transformer, contacts *HR*, *FRN*, resistor, and *FRN*. The control relay *HDR* is switched on by contact *CDR* via *HR* and *FRN*, which

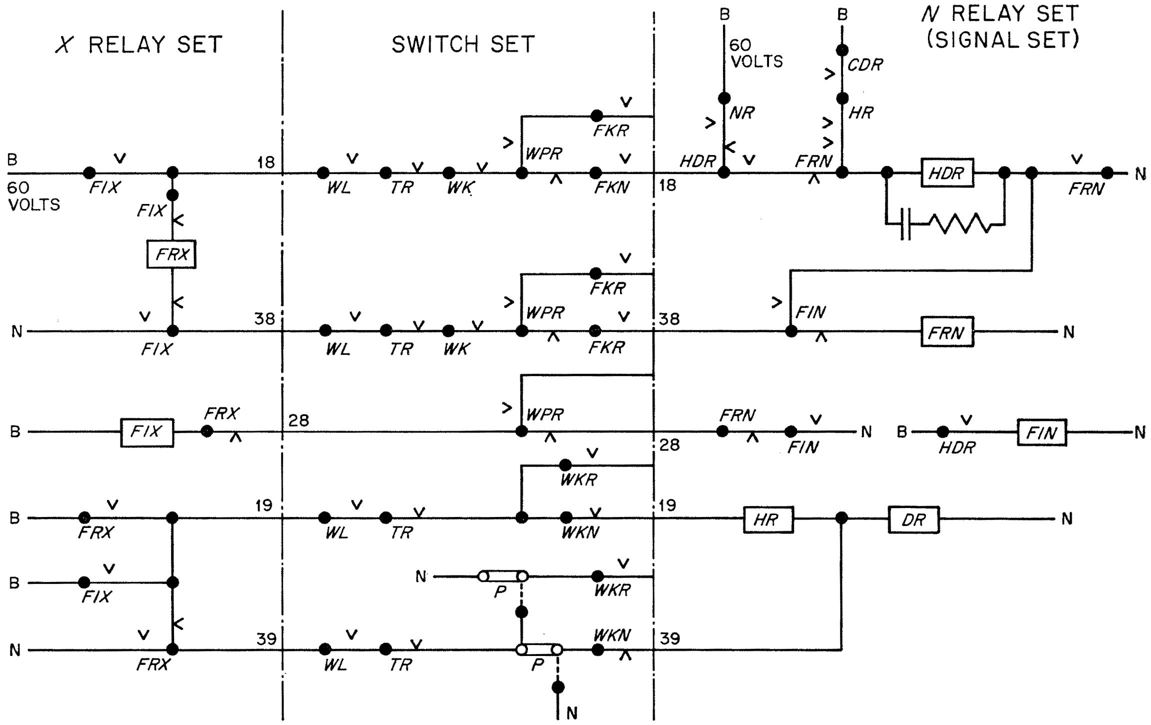

Figure 5—Signal control for geographic system.

CDR = cross-connection detection relay
DR = proceed relay
FIN = entrance traffic indication relay
FIX = exit traffic indication relay
FKN = normal flank indication relay
FKR = reverse flank indication relay
FRN = entrance traffic relay
FRX = exit traffic relay
HDR = approach and proceed relay
HR = approach control relay
NR = entrance relay
P = program plug
SCR = light changing relay
TR = track relay
WK = switch indicating relay
WKN = normal switch indicating relay
WKR = reverse switch indicating relay
WL = switch locking relay
WPR = switch position relay.

cuts off relays *FRX* and *FRN*. At each of the ends of the geographic circuit in Figure 5 a detection relay *FIX* and *FIN* is energized, whereupon *HRD* establishes a locking circuit for itself: *FIX,* 18, *WL, TR, WK, WPR, FKN,* 18, *HDR, FRN,* relay *HDR, FIN,* 38, *FKR, WPR, WK, TR, WL,* 38, and *FIX.* To bridge the switchover time the control relay *HDR* is retarded by 2 seconds (also required when there is a mains failure).

If we assume that the signal is to be set clear without speed restriction, relay *DR* will be connected and relay *HR* cut off. On the other hand, if "line clear for restricted speed" is to appear, *DR* is not energized and *HR* remains connected. This different effect is obtained by switching over program plug *P* in the points circuit. In Figure 5, the plug *P* is connected to negative feed in the left-hand points position, but to the "through" feed in the right-hand

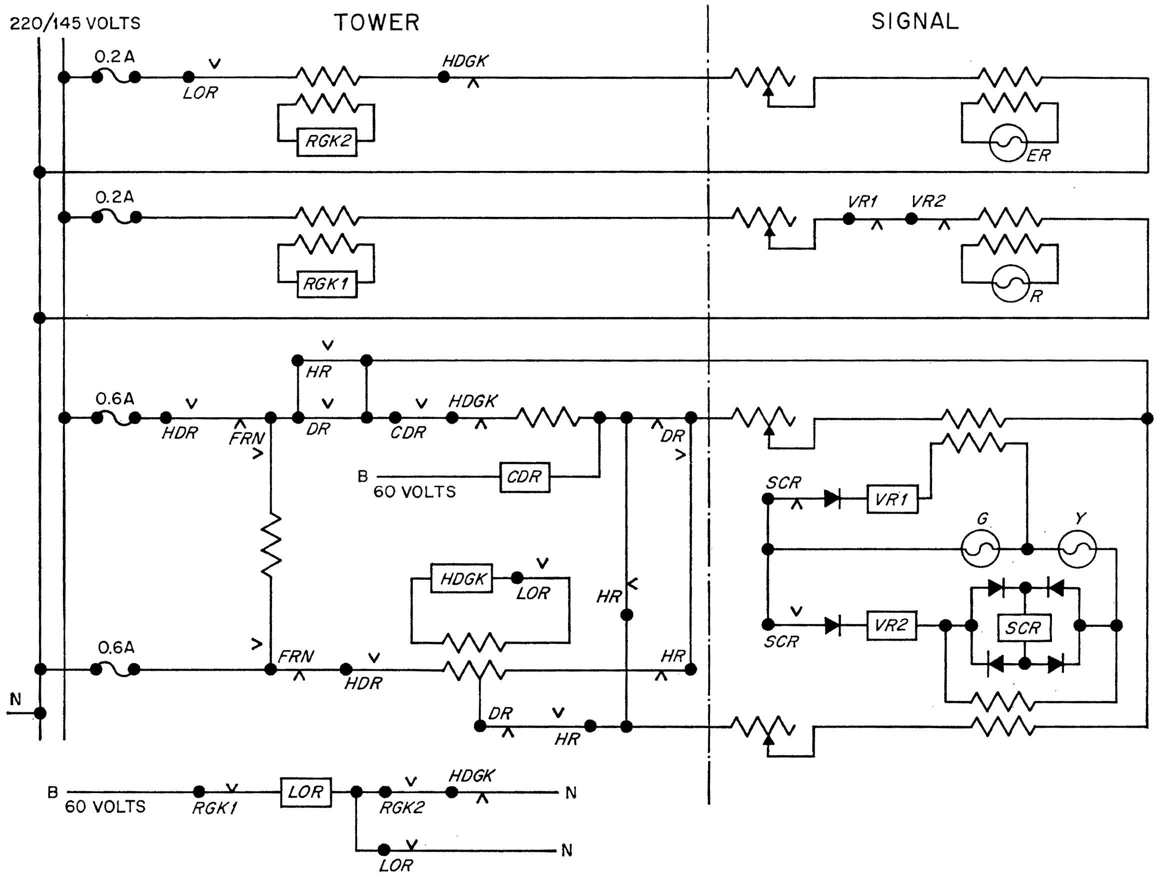

Figure 6—Light signal circuits.

CDR = cross-connection detection relay
DR = proceed control relay
ER = emergency red light
FRN = entrance traffic relay
G = green light
HDGK = approach and proceed indicator
HDR = approach and proceed relay
HR = approach control relay
LOR = light out relay
R = red light
RGK = stop indicator
SCR = light changing relay
VR = automatic train control relay
Y = yellow light.

position. Then *HR* is inserted in the left-hand and *DR* in the right-hand position.

In the green aspect lighting circuit of Figure 6, either green lamp *G* alone is connected by *HDR* with *DR,* or in series with yellow lamp *Y* through *HDR* with *HR*. In the first case the relay *VR1* is switched on, in the second case relay *SCR* is operated and then via its contact *G, Y,* and relay *VR2* are switched on. Contact *VR1* or *VR2* interrupts the red light circuit, whereby its detector *RGK1* releases. The latter cuts off *LOR* so that now the route detector *HDGK* responds. Relay *LOR* is thus proved for release every time a signal is cleared. Relays *VR1* and *VR2* are also used for switching on the train control (ATC = automatic train control).

1.4.4 *Establishing Normal Position*

The signal is set at stop by the track relay contacts in the signal setting circuits when the train moves. Since the track relay contacts in the control circuits of Figure 5 are arranged in duplicate in two different circuits, the protection of the stop condition is greatly increased, even beyond that of the relay interlocking system.

It is peculiar to the geographic system that it locks each individual point (and consequently releases each point) in accordance with the distribution of the route circuit on the individual points. In our geographic interlocking system the release is effected by the cooperation of the track circuit of the points to be released with the two adjacent track sections. The following conditions are electrically proved in this case: release of the point that had previously been run over, occupation and release again of its own section, and occupation of the next section.

Since the route push buttons return to normal after operation, no control operation is necessary at the time of release or afterwards.

An auxiliary relay is assigned to each points group for emergency manual route release. These auxiliary relays are connected to a geographic circuit, which for the auxiliary release is manually connected from the exit end. To ensure readiness for action for this purpose, a geographic circuit is used that also initiates the locking of the points, but now energized with 30 volts alternating current instead of 60 volts direct current. Since the release of a point depends on the release of the previous point being completed, the auxiliary release acts from the exit end even when a part of the route is ready to be released by the train movement. For this reason the release from the entrance end is not appropriate. It would require additional means for the auxiliary release of partially released routes.

2. Degree of Security

We will now investigate how safety is obtained in the four different systems. We shall begin by considering the circumstances that might impair safety and the steps taken to deal with such conditions.

2.1 Mechanical Interlocking

Lever reversal is prevented in the locking system by mechanical locking members. These members are subjected to heavy stresses and thus heavy wear. If frequent attempts are made to reverse locked points levers this wear becomes important. The interlocking system does not indicate wear, and the mechanical locking margin may be gradually reduced until there is no lock. The remedy is to inspect existing margins at certain time intervals and to replace the badly worn parts. The margins are reduced not only through wear on the locking edges and surfaces but also through wear in joints and bearings. The clear-proving of the state of points is nearly always done by visual inspection and is therefore subject to all the weaknesses due to external conditions (weather, night) and human error. Electric lever locks of the points controlled by direct-current circuits are rarely used because the displacement force exerted by hand permits only small areas of control. Lever locks of this kind have to be heavy because of the displacement forces. Even when these forces act only on the latches, the lever locks continue to be subject to heavy wear in the event of frequent attempts at reversal.

The security of the points setting is provided by the security of the points-throwing during the lever movement. Part of this security is provided by the wire-breakage lock. "The efficiency of the wire-breakage lock depends on the springs remaining permanently operated and the locking levers remaining easily rotatable on their shafts, that is, not corroded. It is a question of maintenance, of keeping all equipment efficient by frequent proving, and by lubricating the joints and slides." [6]

If the point is trailed, the lever trails, because the pulley is released from the coupling, this condition causes the tappet rod in the mechanical locking to be moved and a red fault sign appears on the lever. The coupling can be put into engagement again with a resetting lever. "The coupling spring is much more powerful than the latch spring. It is adjustable, so that the coupling force can be varied. If the spring were too powerfully strained, this might prevent the trailing in some circumstances, for which reason the coupling force is adjusted in the factory of the signal manufacturers to 85 kilograms (187 pounds) and the setscrew secured by rivetting." [6]

Penzlin [7] gives some information about maintenance and the cause of faults. "Renew the wiring when 4-millimeter wires are weakened by rust by 1 millimeter in diameter and 5-millimeter wires by 1.5 millimeters. Renew wire cables when the galvanizing is completely removed by weather and torn or rusted through more than 1/10... Cables heavily exposed to rust should be moderately greased in dry weather." There are detailed instructions as to what must be done if the points wires break. The following faults are emphasized: wire or cable breaks, wire twisting, foreign bodies getting into rollers, and equipment requiring more than normal force. The mechanical locking must be thoroughly inspected, tested, and cleaned once a year. Any worn lock parts and rollers must be renewed. The permissible wear must be determined by gauge. The points levers must be proved every three months. All the most important parts, such as springs, must be dismantled and dimensionally checked annually.

For the maintenance of the route locking, Penzlin considers that the following work should be done once a year: cleaning, removing waste oil, testing springs, determining backlash, friction, clamping, proving whether there is the regulation distance of 0.5 to 1 millimeter between latch and locking hook.

Check gauges have been designed to check all tolerances. For the block lock, multistage check gauges A to E were designed.

The electrical slot coupling is used for automatic signal replacement, together with the track contact, which also effects the route release. Penzlin checks the slot coupling by interrupting the coupling current. "In the case of signals with electrical slot coupling, oil the signal-arm brake every three months, take the air brake off once a year and thoroughly clean it. When the coupling current is interrupted the arm that is at clear must drop freely to $\frac{2}{3}$ of its stroke."

Generally speaking, circuit faults are not taken into consideration for the circuits in mechanical interlocking. Thus, the cable conductor to the coupling magnet is not protected from incident voltages or contact with other live cable conductors. Protection from wire breakage is provided by the natural circuit. Thus, the circuit of the insulated rail is protected from cable conductor breakage, but not, for example, from conductor contact. No safety measures are taken in the internal circuits.

2.2 Electromechanical Interlocking

Although the forces that may be exerted on the small points levers are much less in electromechanical interlocking than in mechanical interlocking, nevertheless the locking members and margins are also less. In the interlocking frame any important reduction of security can be prevented only by regular examination.

The various mechanical interlockings of the point levers (armature lock, battery switch, release magnet) and the route signal levers (lever locks with the two locking stages at 30 and 65 degrees and with the route lock at 45 degrees) require for perfect operation not only no wear but also exact adjustment to the lever contact arc. The operating tolerance of the lever contacts is usually only 5 degrees of lever movement. The points circuit was the first to be given very high grade circuit security in the German interlocking system. The first safety check was also set up for this circuit. The detection magnet permits the complete reversal of the points lever only when it has released. When the points lever is thrown over, at first only one negative feed is cut off by the battery switch contact, the detection magnet does not drop back if there is a faulty connection to negative. By lever locking when the detection magnet is in the operating state, the further throwing over of the lever and therefore points reversal are prevented. These mechanical relationships require careful maintenance. In addition to the regular proving of these interlockings, Penzlin [8] requires that the points levers be cleaned of dust and metal abrasion every three months and that all contact positions be checked. The control and detection fuses are to be checked by random tests for blowing. For the points machines, Penzlin requires monthly checking by hand cranks, and that the machines be taken apart completely, cleaned, and worn parts replaced once a year. The contacts in the machine must be examined every two weeks for signs of burning, and after 1000 operations the motor brushes should be cleaned and worn parts replaced. Penzlin also recommends the following for electrical proving; setting the route signal switch and interrupting all the contacts in the lever-blocking circuits to check that the circuit is correct.

The signal machines also require similar maintenance work. The most dangerous defect is the failure to return a signal to stop. If spurious current passes into the conductors to the coupling, the semaphore signal arm does not drop. A mechanical jamming in the electric coupling of the signal arm, however, which would prevent the signal from dropping to stop, is also to be reckoned with. This in turn will have resulted in sequential interlocking, by which the resetting of an arrival signal becomes dependent on the previous stop aspects of the exit signal.

If we look at the circuits we find that no precautions have been taken against circuit defects. The release circuit and the circuit of the insulated rail show no improvements over the corresponding circuits of the mechanical interlocking system, although the possible defects are considerably increased by the increased length of the circuits.

Circuit improvements for increasing safety began in the cable connections between signal box equipment and external plant, both in the circuits of the light signals and also particularly in the points circuit (owing to several serious risks).

The light signals are switched on by two relays. It was feared that a relay might be inadvertently operated by hand. As soon as extraneous voltage enters the connecting conductors of one of the operating relays, the relay responds, even when the lever has not been thrown over. The protection was increased by detecting the release of the relays in other circuits, for example in the release circuits. However, if extraneous voltage enters a lever conductor when the lever has been thrown, then if a points detection contact is interrupted, not only this lever but also the others will remain energized. Thus there are no effective precautions against conductor faults in the interlocking system. In the light signal circuit also provision is made only for protection from cable faults, preferably from conductor contacts of the route setting wires and incidence of voltage in one of the two conductors. Any contact between the return conductors would be unnoticed.

From the points circuit a safety indication was given in [1]. The following cable faults were taken into consideration: breakage, line contact in the various switching states even between two points, earthing shorts, spurious current (incidence of 34 or 136 volts direct current) in cable, and nonresponse and nonrelease of one of the three magnets. This relates only to the cable connection between lever mechanism and machine.

2.3 Relay Interlocking

Since in relay interlocking there is no mechanical safety interrelationship, much more care and expense have been applied to the safety of the switching means. The bipolar circuit commonly used can be endangered only by two particular faults, incidence of voltage on the left and wrong connection with negative on the right of the relay. One of these faults may continue until the danger condition occurs through the subsequent appearance of the second fault. The protection has thus become much more reliable as compared with the internal switching of electromechanical interlocking. The safety of the points circuit will be discussed in relation to the geographic technique, because this is already adjusted to their degree of safety.

The combination of route locking and signal lever connection also means bipolar circuits for the locking device, although it was introduced only to protect the signal lever. Here again the weakness of the bipolar circuit (we have already mentioned that not every fault becomes perceptible in a restrictive sense) means that there is not complete security. In addition, when there is locking due to failure, the signal levers are also switched on. Despite the contact-saving circuits, therefore, it would be better to arrange locking and signal levers in separate circuits.

2.4 Geographic System

Since the circuits of the geographic interlocking system were only designed once, without further adaptation to the various station layouts for any number of signal boxes, these circuits have been given much more care in the design stage. For each individual circuit an extensive safety index was established.

Although the route search circuits (Figure 3) represent only simple circuits for the interconnection of the operated entrance and exit push buttons, here again, because of the geographic arrangement, switching errors become perceptible by restricting operation.

The security of the points circuit is very important. Inadmissible movements of points can endanger the safety of a train. For the points circuit of Figure 1, as in the case of all the circuits of this system, an extensive safety check index was made, which was examined by the German Bundesbahn before the circuit was approved. The security check was expanded to cover the following errors. If they are not suitably protected, relays might be inadvertently operated by hand. Relays do not release or do not respond. Nonclosing of contacts in switching plant and in the machine. Interference voltages on the terminal strips of the relay groups. Disconnection or short-circuit in the case of resistors, diodes, transformers, and capacitors.

The proving of the nonrelease or nonresponse of relays is intended to prevent the successive relays from responding or releasing or the points setting circuit from being established. The other types of interference cause the repeat relays not to respond or even in rare cases not to release. In a few cases of trouble, usually the incursion of negative potential (in the case of earthed systems = earthing short), a fuse is destroyed.

The safety list for the points circuit contains 113 pages, showing in the form of tables the effects of 310 types of faults. Of these, only 15 cause the destruction of a fuse in the points circuit concerned; 4 others result in the destruction of the fuse in the source of the extraneous interference voltage. Of the faults considered, 15 are due to the nonrelease and 15 to the nonresponse of a relay. Consequently 280 of the faults investigated affect conductors and components other than relays.

The greatly increased safety of geographic (Spurplan) circuits is very clearly demonstrated in the signal-setting circuits (Figures 5 and 6). All the interlockings are in duplicate in two separate circuits. For this purpose the circuits are reversed in polarity so that any fault becomes immediately perceptible in restricted operation. There is also much greater security in the lamp signal circuit. The proving relay proves the clear circuit not only for short-circuits but also for spurious voltage. In every signal for clear setting a check is made of the readiness for operation of the emergency red. The extinction of the red lamp by the automatic train control relay ensures that the red lamp is actually switched off only by the clear lamp.

3. Comparison of Security

In the first 70 years of the development of railroad signalling systems, there was a gradual increase in the security obtained, due to the recognition of uncertainties or even accidents. In the 30 years that followed, effects were made (without neglecting security requirements) to put the emphasis on the speedier and more rational handling of the service, showing a clear trend from heavy to lighter construction. In this development, the following principles, **(A)** through **(J)**, have become clear.

The original idea of ensuring security by means of heavy structural parts was found to be impracticable. Heavy movable parts also mean correspondingly heavy wear on those parts. For this reason careful maintenance is essential. Checks on wear must be made at regular intervals to discover and replace worn parts before the unreliability margin is reached.

(A) The security of the mechanical interlocking system and of the mechanical interlocking of the electromechanical interlocking system is based on careful and timely maintenance.

The endeavour to rely less on the human element for safety is another trend in the design of interlocking systems. Instead of visual inspection to assure a clear track, automatic track repeater systems were devised. For route releasing and giving line clear, train participation was introduced instead of manual operation, and so on. The multiplicity of such measures and their simplification were achieved only after serious human failures.

(B) Security must not depend on the human factor but must be ensured by automatic means.

It is not justifiable to make security depend on the regularity of inspections and maintenance work.

(C).The interlocking equipment alone is intended to ensure security. Faults in this equipment are to result in failure of the intended operations (points or signals cannot be set) but no unsecured settings must be possible.

To keep the active forces and therefore the wear on equipment as low as possible, small levers are used (which became possible only when electromechanical interlocking was introduced), but at the same time the dimensions of the interlocking gear and therefore of the security margins were reduced to such an extent that the degree of safety of these mechanical devices was not greatly increased. As interlocking systems became larger, as in the case of the multirow interlocking system, in fact, safety was even reduced by further reduction in the interlock-gear margins.

Locking magnets are widely used in electromechanical interlocking systems and operation of these magnets depends on contacts in other equipment. Their armatures mechanically influence the interlocking system. Only after a great deal of experience had been collected and evaluated was the fear of nonrelease of de-energized magnets due to remanence replaced by attempts to provide protection by means of armature locking. When levers are thrown over, the energizing circuit for the magnet is cut off. The further throwing over of the lever is prevented by means of an armature senser that acts if the armature does not release. Moreover, in the earlier signal relays there was wear on the bearings and also sticking trouble.

(D) The old fear of nonresponse of electrically released relays as a result of remanence no longer exists, due to modern scientific relay techniques.

The interlocking system is connected via cable conductors to the external plant (points, signal machines, et cetera). These cables could be damaged in various ways when other work was being done near them. The damage chiefly consisted of broken wires and sometimes of crossed wires. For this reason steps were taken to provide unimpaired security if cables were damaged. The principle applied was that in the event of faults, the relays would be in the response or release condition and prevent operations.

(E) Checking relays for response or release is not now done to test the reliability of the relays but to check the circuit for conductor faults.

Safety measures such as bipolar circuits are rarely used in the internal wiring of electromechanical interlocking systems because of the expense. Conductor faults in the interlocking equipment are usually disregarded in security considerations, although they sometimes result in danger.

A reliable signal relay is essential for a relay interlocking system. To determine line faults in the event of faulty energization, the relay must now transmit this condition through another contact to a third circuit, which restricts the intended flow of operations. This requires that contacts of the two relay conditions (respond, release) must not be closed simultaneously. This property of the signal relay is known as compulsory control. This term does not mean common coupling of the contacts with the armature.

(F) Signal relays must be so designed that all the contacts of the opposite condition are open as long as one contact of the other relay condition is closed.

When relay interlocking systems were introduced, the circuits—even inside the system—became much safer. Bipolar circuits were usually employed. The degree of security of the various switching measures was systematically investigated [9]. Although the bipolar circuit was not entirely satisfactory from the security angle, it was extensively used because of its simplicity and despite the relatively high cost.

(G) The switching circuits in relay interlocking systems are additionally protected by security measures.

In the electromechanical interlocking system, for example, a considerable proportion of the safety interlocking devices is bridged, that is, disconnected by an unintentional cross-connection between the conductor and the lever locks. In relay interlocking such risks resulting from simple faults are avoided by the inclusion of safety circuits.

The geographical interlocking system is the most complete form of relay interlocking hitherto known. Its most obvious advantage from the point of view of security is the use of standard geographic cables prepared and proved in the factory. The entirely diagrammatic and uniform allocation of the wires to the functions to be performed eliminates the risk of any faults due to human error. It is well known, however, that conductor faults are most frequent when reconstruction work is being done on interlocking systems, if the latter have to be individually wired on the spot. Experience has shown that when a system is reconstructed faults may occur through the nonremoval of wires that are no longer needed, and these faults are often undetectable even by electrical proving of the new circuit. This cannot happen in geographic interlocking systems, since all the wires are removed when the old geographic cables are dismantled. The old connections must be removed before the new cables can be connected.

(H) Geographic interlocking offers absolute security from wrong interlocking connections, even when reconstruction work is done in interlocking systems.

Since the circuits of the geographic interlocking system are designed once and for all and can then be used for any number of signal boxes, much more care and expense is devoted to design and proving by the manufacturers and by the German Bundesbahn than would be possible or even economically practicable in the individually connected relay interlocking systems. A comparison of the respective types of circuits will confirm this. Since, moreover, the possible faults have a restrictive effect, this circuit may be said to have practically complete security.

(J) The geographic system has made it possible, by carefully calculated safety circuits of the highest quality, to increase security to an extent hitherto impossible.

As used in the signal control circuits of the geographic systems, the bipolar safety circuit in two separate and completely independent circuits, sometimes with reversal of polarity, provides a degree of safety hitherto unattained in interlocking systems. It may be mentioned that it was the geographic system that first made it possible to arrange the entire security system of the interlocking system in factory-wired-and-proved interchangeable relay sets, which prevents faulty wiring in these switching units.

As a result of the above investigation it can be confidently stated that the geographic interlocking system, apart from its known operational and economic advantages, is also the safest known type of interlocking system.

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Wilhelm Schmitz was born on 4 April 1902 in Honnef am Rhine, Germany. He received an engineering degree in 1926 from the Technische Hochschule in Aachen, and a doctorate in engineering in 1932 from the Technische Hochschule in Berlin-Charlottenburg. In 1939 Dr. Schmitz was appointed a university lecturer.

In 1927 he joined Siemens and Halske, where he worked on the design of railroad switching systems.

He joined Standard Elektrik Lorenz in 1949, and was head of the railroad signal development department until his retirement in May 1967.

Dr. Schmitz is the recipient of numerous patents.

Recent Achievements

Symposia in Europe—Four symposia* were organized by International Telephone and Telegraph Corporation in cooperation with the administrations and authorities of Portugal, Czechoslovakia, Hungary, and Romania.

A Telecommunication Symposium was held in Lisbon on 10–14 April 1967 with active participation of the Lisbon and Oporto Universities and of major customers of Standard Eléctrica. The symposium was opened by Portugal's Minister of Marine, Admiral Fernando Quintanilha de Mendonca Dias, and attended by key representatives of science and technology.

In Prague, a Transmission Symposium was held on 10–12 May 1967 and attended by some 100 specialists from the Telecommunication Administrations, Ministry of Transport, Ministry of Technology, government import agency Kovo, and the electronic industrial corporation Tesla. See Figure 1.

Hungarian transmission specialists from the Telecommunication Administrations, Elektroimpex and Budavox, participated in the Transmission Symposium in Budapest on 16–18 May 1967.

Approximately 200 top officials and engineers attended the Transmission Symposium in Bucharest on 6–8 June 1967. (Figure 2.) Participants represented the Telecommunication Administrations, Bucharest University, several state research institutes, and industry.

Leading engineers of the International Telephone and Telegraph System from Belgium, England, Germany, Italy, and Sweden presented a wide range of papers on telecommunication techniques and equipment, notably on pulse code modulation, one of our inventions.

International Telephone and Telegraph Corporation

* Papers are listed on pages 562–563.

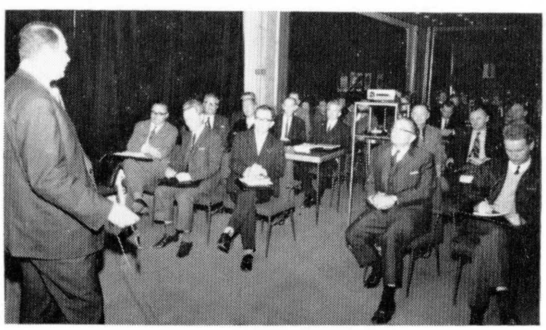

Figure 1—Prague Symposium with P. A. Hopfner of ITT Europe speaking.

Satellite Tracking Station Is Transportable—A trailer-mounted tracking and control equipment will monitor and guide in real time the first orbiting of an active satellite lofted by an Eldo launcher.

The earth station employs a short-base interferometer using 5 paraboloidal antennas, each 4.3 meters (14 feet) in diameter, and a master simultaneous-lobing tracking antenna for monitoring. Trailers house the tracking receivers, interferometer receivers, and associated digital-data handling and monitoring equipment. Angular position and rate, slant range, and range rate are measured with the cooperation of a continuous-wave coherent L-band transponder in the satellite.

Figure 2—Bucharest Symposium. From left to right: Messrs. Van de Velde, Bell Telephone Manufacturing Company; Varga, Standard Telephones and Cables; and Liekens, Bell Telephone Manufacturing Company.

Orly Airport Gets Electronic Message Switching Center—An electronic message switching center, *DS 66-3,* was inaugurated on 23 May 1967 at Orly Airport (Paris) for the Air Navigation Department. It is connected to the Aeronautical Fixed Telecommunication Network (AFTN) and replaces the Pentaconta semiautomatic center installed in 1960. Equipped for 100 duplex lines on cutover, the center immediately handled the daily average traffic of 31 000 messages. Operation conforms with the recommendations of the International Civil Aviation Organization (ICAO).

The high reliability exhibited over a full year by the initial installation of this type for Air France,* confirms the value of duplicate retransmission equipment with automatic switchover. New features include duplicated 300-line-per-minute teleprinters for permanent recording of daily traffic, a supervisory position adapted to the particular installation, enlargement of the capacity of the temporary magnetic-drum store to about equal the busy-hour traffic, and a simplified and faster message retrieval and retransmission system.

Compagnie Générale de Constructions Téléphoniques
France

Pentaconta Exchange in Como, Italy—A new Pentaconta telephone exchange in Como, Italy, will replace the 40-year old rotary *7A* exchange of 7800 subscribers to which had been added a *7D* unit of 5000 subscribers.

The new installation will have an initial capacity of 14 000 subscribers, 600 local junctions, and over 1000 toll junctions. The designed final capacity will be 30 000 subscribers and 3000 junctions.

Located in the center of town and connected to 2 urban exchanges totalling 8700 subscribers and to 9 rural exchanges totalling 2800 subscribers, the new equipment has to use the same rooms as the older rotary apparatus so there must be a gradual replacement of the old by the new.

Como, north of Milan, is well known as a resort area and also for its industry. It has 150 000 inhabitants.

Fabbrica Apparecchiature per
Comunicazioni Elettriche Standard
Italy

* "Telegraph Message Switching Assured by Synchronous Operation of Duplicate Equipment," Recent Achievements, *Electrical Communication,* volume 42, number 1, page 138; 1967.

Degassing Metals by Silver-Boat Technique—Further research on the silver-boat technique * has led to the development of methods for degassing and consolidating metals.

The silver boat can take the form of a canoe-shaped vessel made of one or several tubes as illustrated in Figure 7. Water passed through the tubes ensures that the boat remains cool. However, a metal charge in the boat can be melted by eddy-current heating induced by a radio-frequency field. Some levitation occurs at the molten zone, which ensures that the melt does not touch the cool boat, the two being

* "White-Hot Metal in a Cold Crucible," Recent Achievements, *Electrical Communication,* volume 39, number 1, pages 14–15; 1967.

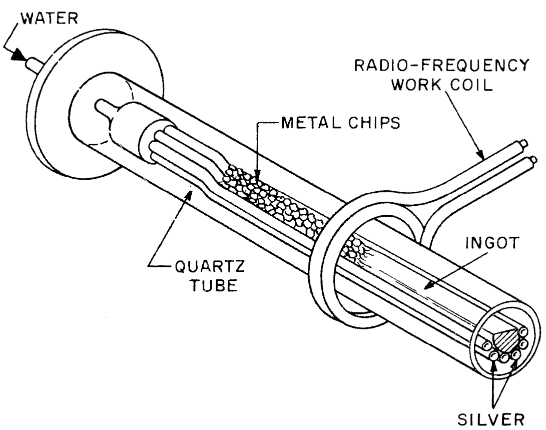

Figure 7—Consolidation of degassed metal chips in a silver boat.

Tracking data are in the form of 3 position and velocity vectors that are processed in real time by a computer to issue commands to the satellite launch vehicle to control thrust vectoring and terminating. The overall system accuracy is in the order of 50 meters (160 feet) in position and 5 meters (16 feet) per second in velocity for each measurement of a trajectory with a smoothing time in the order of 2 seconds.

The system is entirely original in concept and is the result of extensive cooperation of Bell Telephone Manufacturing Company and other Belgian organizations such as Manufacture Belge de Lampes et de Matériel Électronique and Ateliers de Constructions Électriques de Charleroi. The transportable station is fully operational on the Gove site in the Northern Territory of Australia and has been successfully operated for the *F6/1* suborbital trial preparatory to the first orbital launch in June 1968.

Bell Telephone Manufacturing Company
Belgium

Le Bourget International Air Show—The products of 8 associate companies of the International Telephone and Telegraph System were displayed at the 27th International Air Show from 26 May to 4 June 1967 at Le Bourget Airport near Paris. Figure 3 shows the 2000-square-foot (185-square-meter) display of the following products.

Bell Telephone Manufacturing Company, Belgium: European Satellite Research Organization *ESRO 1* satellite and phase-lock tracking receiver.

Claude Paz et Visseaux, France: Lights for marking obstructions to air navigation.

Fabbrica Apparecchiature per Comunicazioni Elettrische Standard, Italy: Ground beacon for distance measuring (DME).

Laboratoire Central de Télécommunications, France: Panel display of participation in *ESRO 1* and Intelsat 3 satellite programs.

Le Matériel Téléphonique, France: Tacan (beacon, airborne transmitter–receivers, and portable test set).

Figure 3—International System display at Le Bourget Air Show.

Standard Elektrik Lorenz, Germany: Instrument landing system (ILS) equipment, model of beacon for Doppler very-high-frequency omnidirectional range (DVOR), teleprinters, printed circuits for space equipment, and a model of Intelsat 3 satellite.

Standard Radio & Telefon, Sweden: Demonstration of communication with Dirigent equipment, mobile transceiver, rough model of the Kiruna satellite.

Standard Telephones and Cables, United Kingdom: Ground beacon for very-high-frequency omnidirectional range (VOR), *STR 70* altimeter, model of instrument landing system (ILS), very-high-frequency microminiature transmitter–receiver, model of ground beacon for distance-measuring equipment for very-high-frequency omnidirectional range (VOR-DME), combined very- and ultra-high-frequency equipment, and aircraft antennas.

Mobile transceivers developed jointly by Le Matériel Téléphonique and Standard Telephones and Cables, together with *ITT6* equipment, were also displayed.

In Figure 4 is another display of 1500 square feet (140 square meters) by Le Matériel Téléphonique in a hall reserved for members of the Syndicate of Professional Electronic and Radio-electric Equipment Manufacturers (SPER) in which the following equipment was exhibited.

Figure 4—Display of Le Matériel Téléphonique at Le Bourget Air Show.

Tacan (ground beacons, three generations of airborne transmitter–receivers, portable test set, and a demonstration of a course computer). A transponder for distance-measuring equipment (DME) that responds to interrogations from both Tacan and distance-measuring transmitters. Transponders for Interrogation, Friend or Foe (IFF) systems. Ultra-high-frequency mobile ground equipment. Single-sideband high-frequency equipment for helicopters. Model of a training simulator for the Concorde supersonic transport aircraft. Airborne computers made by Laboratoire Central de Télécommunications.

International Telephone and Telegraph Corporation

Submarine Cable for Telephony Between South Africa and Europe—Work is well under way on a submarine cable system over the following route.

	Nautical Miles	Kilometers
Capetown to Ascension Island	2 554	4 730
Ascension Island to Cape Verde Islands	1 723	3 191
Cape Verde Islands to Canary Islands	902	1 670
Canary Islands to Lisbon	762	1 411
Total	5 941	11 002

The cable will accommodate 360 simultaneous conversations over 3-kilohertz channels. Groups consist of 16 channels translated into a band from 60 to 108 kilohertz. Supergroups consist of 5 groups translated to the band from 312 to 552 kilohertz. For one direction of transmission 4.5 supergroups are translated to a band from 312 to 1428 kilohertz and for the reverse direction from 1848 to 2964 kilohertz.

Groups and supergroups may be routed without demodulation. Filters having sharp cutoff characteristics for the 60–108- and 312–552-kilohertz bands at the Canary Islands permit switching such bands into an existing cable to Spain.

Terminal equipment includes duplicate carrier supplies and translators for channels, groups, and supergroups.

Repeaters, one of which is partly shown in Figure 5, are placed at 9.5 nautical miles (17.6 kilometers). Power is supplied over the cable, shown in Figure 6, at Capetown, Ascension Island, and Canary Islands at voltages as high as 10 kilovolts from stabilized constant-current direct-current supplies. The system will require 623 repeaters and 50 equalizers.

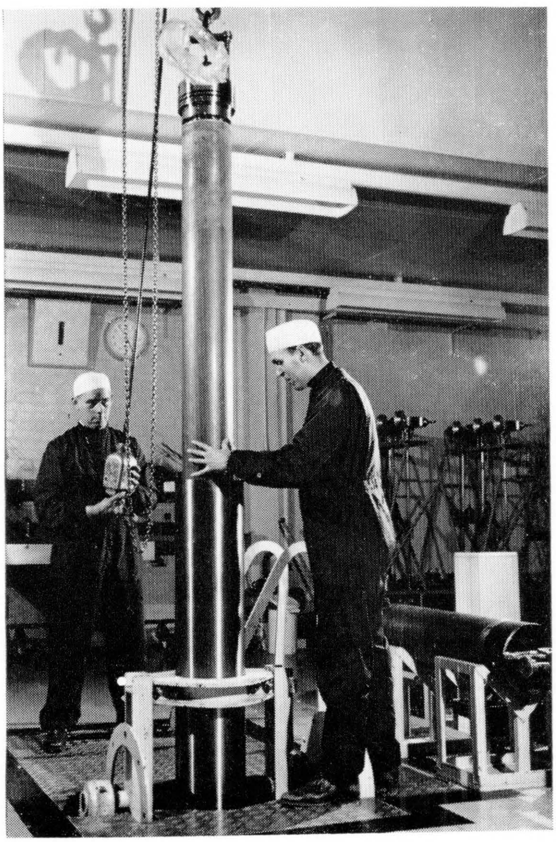

Figure 5—Telephone repeater capsule being lowered into the high-strength steel case that can withstand sea-bottom pressure preparatory to undergoing testing before being accepted for service.

The cable is being made at Southampton, the repeaters, equalizers, and power supplies at North Woolwich, and the terminal equipment at Newport, Basildon, and South Africa.

The system will be owned by a new South African company called South Atlantic Cable Company (Pty) Limited formed jointly by the Industrial Development Corporation of South Africa and the American Cable and Radio Corporation.

Standard Telephones and Cables
United Kingdom

Brazil Telephone Properties Sold—The International Telephone and Telegraph Corporation has completed the sale of all its domestic telephone holdings in Brazil for an estimated 12.2-million dollars. About half of this amount will be used for the continuing development of the production facilities of Standard Eléctrica, our communications manufacturing company in Brazil. Recently ordered equipment to add 150 000 telephones to the Rio de Janeiro area public telephone network is now being produced and installed by Standard Eléctrica.

The Brazilian states involved in the negotiations were Rio Grande do Sul and Paraná. The telephone properties in both states had been operated by our subsidiary, Companhia Telefônica Nacional (CTN).

International Telephone and Telegraph Corporation

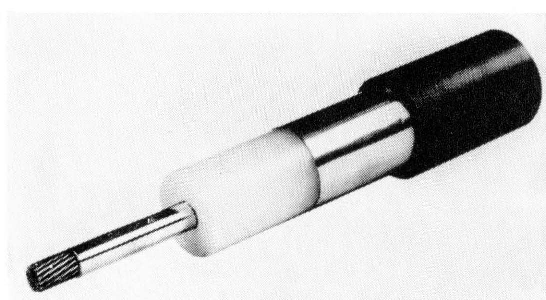

Figure 6—Deep-water 1-inch (25-millimeter) submarine cable having strength member at the center.

separated by a low-thermal-conductivity ambient gas film. Thus no contamination of the charge by the boat material can occur. Furthermore, the temperature that can be reached by the charge is not limited by the melting or softening point of the boat, and metals such as tungsten (melting point 3370 degrees Celsius) can be melted in the silver container whose melting point is only 961 degrees Celsius. The boat can be enclosed in a nonreactive envelope of glass or quartz, the ambient being any desired gas. It is thus possible to decarburize, deoxidize, and generally purify metal melts. Zone-refining passes can then be made to segregate certain metallic impurities.

An example is the preparation of a 0.1-percent zirconium–nickel alloy, special attention being paid to the removal of carbon from the nickel before addition of zirconium. When such an alloy is used as the cathode core material for thermionic valves, evolution of carbon monoxide during high-temperature operation is minimal. This has led to a spectacular increase in valve life by a factor of at least 3.

Standard Telecommunication Laboratories
United Kingdom

South Vietnam Inaugurates Automatic Telephone Switching System—Marshall Nguyen Cao Ky, prime minister of the Republic of South Vietnam, officially opened a new automatic telephone switching exchange in the Saigon suburb of Tan Son Nhut. The 2000-line exchange is part of an integrated network (Figure 8) that will provide the Vietnamese people with a modern nationwide telephone communications system. It is the first automatic crossbar switching system in South Vietnam for civil use.

Altogether, 8000 lines of Pentaconta crossbar equipment are being installed in 23 exchanges in the network, which stretches 700 miles from the delta area in the south to the northern boundary at the 17th parallel. This equipment is among the most advanced in the world and is presently operating in more than 70 countries.

The microwave network linking Saigon with 8 key cities (also shown in the figure) was supplied and installed by one of our companies.

ITT Caribbean Manufacturing
Puerto Rico

Pneumatic Tubes for Schiphol Airport—The new Schiphol Airport near Amsterdam was inaugurated late in April by Queen Juliana of the Netherlands.

To ensure rapid and reliable transportation of documents in this modern and large airport, a fully automatic pneumatic tube system serves 46 stations over 7000 meters (23 000 feet) of tubing and can accommodate up to 80 stations.

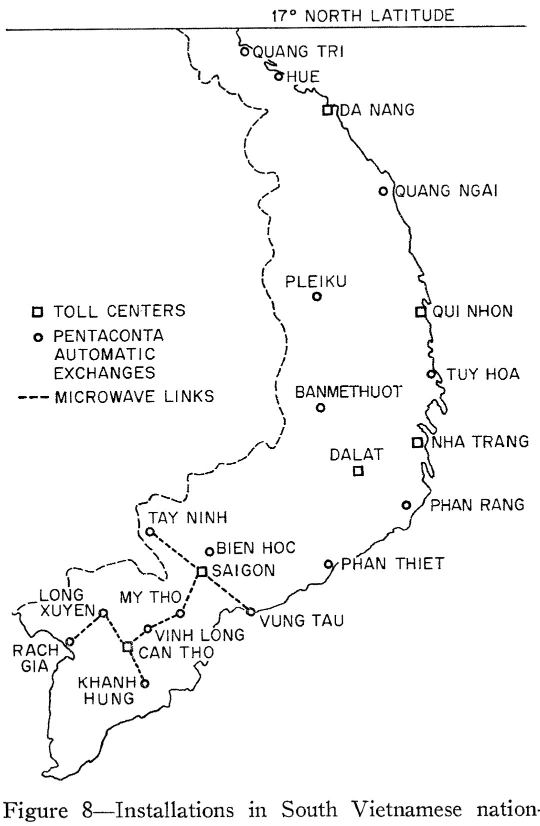

Figure 8—Installations in South Vietnamese nationwide telecommunication system.

Carriers are switched automatically using magnetic sensing of destination codings.

Figures 9 and 10 show the equipment, which was provided by Standard Elektrik Lorenz and installed by Nederlandsche Standard Electric Maatschappij.

Nederlandsche Standard Electric Maatschappij
Netherlands

Tank Simulator—The advantages of training air crews in simulators of the craft they are to operate has led to a contract for the engineering development of a prototype and five production training simulators for the new French military tank *AMX 30*.

The tank simulator will be equipped with a 1000-line closed-circuit television system enabling the trainee apparently to drive the vehicle over several miles of roads and countryside negotiating typical obstacles such as ditches, banks, houses, and other structures. The simulated hull is mounted on a hydraulically driven motion platform controlled by a computer that is informed of all the essential conditions of the immediate terrain by a sensor that feels its way across a 300:1-scale model of the training area accompanied by the eye of the television camera.

Le Matériel Téléphonique
France

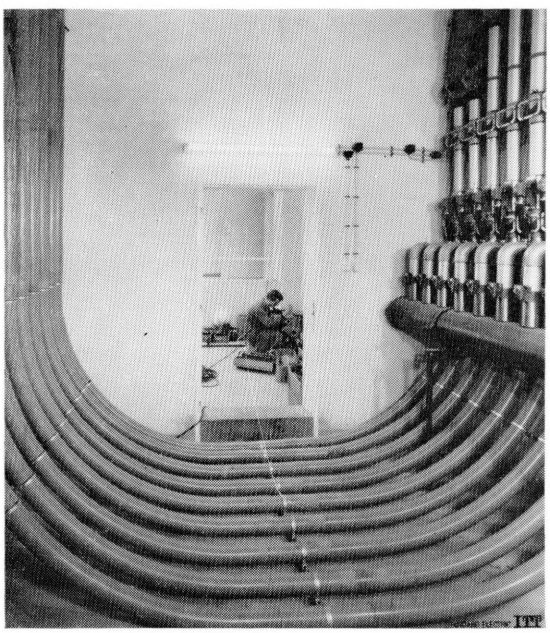

Figure 9—Receiving pneumatic tubes at Schiphol Airport.

Pentaconta Exchanges in Switzerland—Since the cutover of the first Pentaconta exchange at Regensdorf * on 9 September 1967 with an initial capacity of 6000 subscriber lines, four additional Pentaconta offices have been inaugurated: Bäumlihof/Basle with 10 000 subscriber lines, Magden/Aargau with 1000 lines, Richterswil/Zurich with 5000 lines, and Pfäffikon/Zurich with 5000 lines.

The new exchange at Pfäffikon includes an *STR-10* 23-channel radio link that serves as junctions with the rural main exchange at Zurich.

Standard Téléphone et Radio
Switzerland

* "Pentaconta Exchange Inaugurated in Switzerland," Recent Achievements, *Electrical Communication*, volume 42, number 1, pages 144–145; 1967.

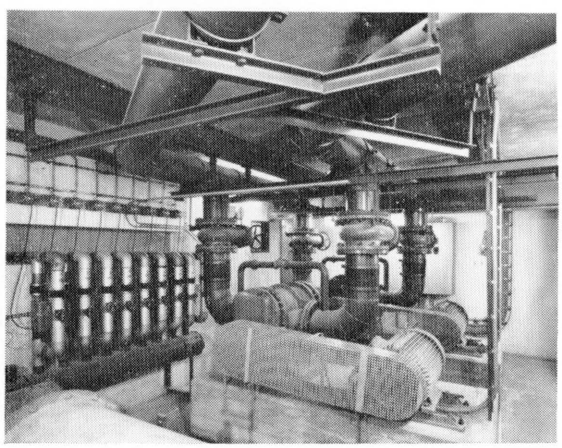

Figure 10—The blower room at Schiphol Airport.

Tuner Diodes for Television—Semiconductor diodes *BA 141* and *BA 142* can be used as voltage-adjustable capacitors at frequencies up to 1000 megahertz. For television receivers, a tuner for which is shown in Figure 11, tracking is within 3 percent and Q varies from 300 at 47 megahertz to a minimum of 75 at 800 megahertz.

Matched sets of *BA 141* diodes will cover television Broadcast Bands I and III combined, corresponding to frequencies in the ranges from 47 to 68 megahertz and from 174 to 223 megahertz, respectively. These diodes also cover Broadcast Bands IV and V combined, from 470 to 780 megahertz. Sets of *BA 142* diodes will tune individual Broadcast Bands I and III or the frequency-modulation broadcast bands from 87 to 105 megahertz. These diodes are now being marketed in the United Kingdom by S.T.C. Semiconductors.

ITT Semiconductors-Intermetall
Germany

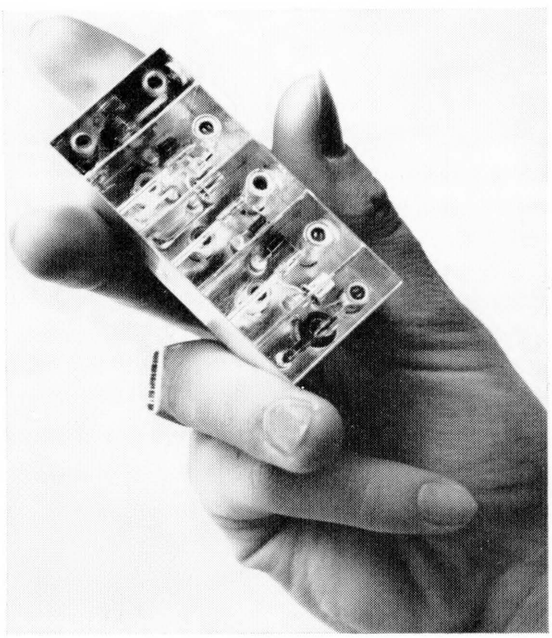

Figure 11—A television tuner using voltage-adjustable diode capacitors in *DO-7* glass mounts. The diodes may be seen in the centers of the three middle sections.

Printing Reperforator, Model *EPR*—The model *EPR* electronic printing reperforator shown in Figure 12 incorporates less than one-third of the mechanical components found in conventional equipment.

Although designed for operation as an on-line receiver, it is also suited for off-line applications whenever a printed and punched tape record is required. Standard 5-track 11/16-inch (17.5-millimeter) wide paper tape is used, the 1000-foot (305-meter) reel having a capacity of approximately 120 000 characters.

The *EPR* incorporates all the facilities of a conventional printing reperforator but requires less maintenance, as electronic units replace 70 percent of the mechanical parts of conventional printing reperforators. Periodic maintenance is required only once every 1000 hours of operation at 50 bauds or annually, whichever is earlier.

Normally the *EPR* operates at 50 or 75 bauds, but other standard speeds are possible. Speed change is effected by repositioning a connecting link in the electronic unit.

The *EPR* has no clutch, mechanical selector, or motor speed governor, which reduces the essential spares by 50 percent. The electronic unit

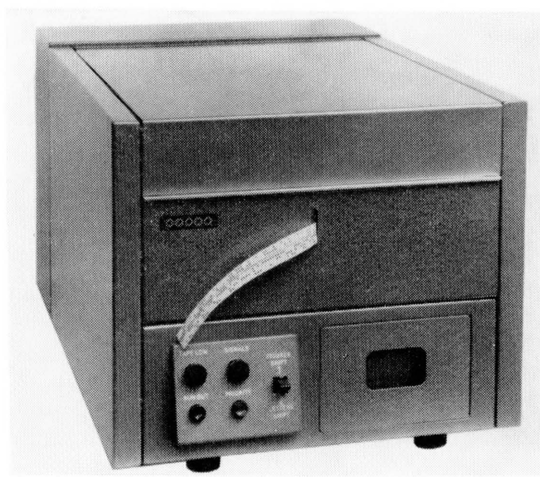

Figure 12—Electronic printing reperforator.

consists entirely of plug-in modules and printed-circuit boards, with strategically placed test points for rapid fault location.

Full compatibility with all existing electromechanical telegraph equipment is another feature of the *EPR,* and it is available either complete with an integral silencing cover or without a cover for tape relay console mounting. The absence of a speed governor and the use of an asynchronous induction driving motor has made it possible to enclose the whole drive unit for quiet operation. It requires 75 watts from the standard mains.

Creed & Company
United Kingdom

Racetrack Traffic Indicator—In May, Daimler Benz of Stuttgart put a new automobile test track in service. Built in the limited space of 1500 by 150 meters (5000 by 500 feet), it required sharp highly banked curves to permit cars to be driven at high speed on both the relatively short straight runs and the connecting bends. The limited view of the driver when in the curves has required the use of traffic indicators at the entrance and midpoint. An indicator is shown in Figure 13.

Electronic loop detectors are inserted in the track to detect the passage of a car. An electronic sum-and-difference counter of the type used in railroad safety equipment checks the triggered pulses. In addition to the track displays, a control tower also has a display on a true-to-scale simulated track.

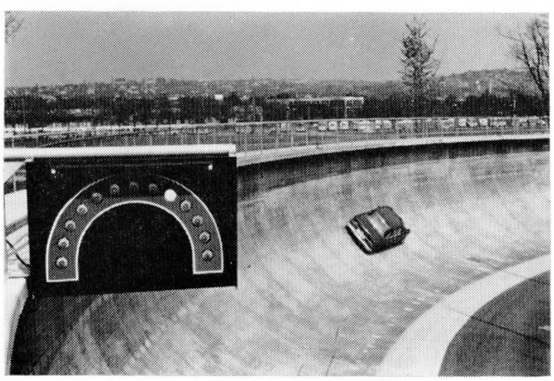

Figure 13—View of traffic indicator on the curve in the test track.

Standard Elektrik Lorenz
Germany

Crossbar 67 Telephone Exchange in Austria—The first of a new generation of crossbar telephone switching developed in Austria, Crossbar *67,* is now in service in Schwadorf, near Vienna. This central office has an ultimate capacity of 800 lines and incorporates such modern features as rapid push-button calling, identification of the calling subscriber, and economical maintenance. It is register controlled and employs *KS55f* crossbar switches, *ZM53* magnetic counters, and other components of long-established high reliability in new circuits. This design stems logically from our introduction of crossbar switching into Austria a decade ago.

Standard Telephon und Telegraphen
Austria

Photon Rate Meter—A highly sensitive photon rate meter has been produced that measures from 1×10^{-7} to 1×10^{-2} foot lambert brightness with an accuracy of $\pm$ 5 percent for a field of view of 1.8 degrees. Spectral sensitivity of the instrument is from 3200 to 5500 angstrom units. It is available for battery or alternating-current mains operation.

ITT Industrial Laboratories
United States of America

Peak Photometer—A prototype peak photometer has been delivered to the services of the Meteorologie Nationale. It is intended for the measurement of the brightness of flashes of lightning.

This small portable unit indicates the luminous energy coming directly from a flash of lightning to its photodiode. It also shows at what distance from the observer the lightning occurred. These two data permit the lightning flashes to be classified. The operator may adjust to 5 different sensitivities and information can be obtained on storms more than 50 kilometers (30 miles) away.

Laboratoire Central de Télécommunications
France

Ferrodot High-Speed Printer—An experimental alphanumeric printout machine capable of online printing at 10 000 characters per second, besides facsimile at equivalent speeds, with a definition of 160 dots per inch has been developed. Speeds of the order of 60 000 characters per second may ultimately be attained, to satisfy the needs of future computing and data transmission systems.

The basis of the system is shown in Figure 14. A single line of recording heads (160 per inch) is applied to a drum having its surface plated with high-remanence magnetic alloy. As the drum rotates, characters are recorded in the form of 9-by-15-dot matrices, each dot being recorded by a 20-nanosecond magnetic impulse derived from electronic logic circuits. Character size and font may be varied at will by including appropriate circuits; line justification and character spacing are also flexible. The surface of the drum then passes through a fluidized bed of minute resin-coated nickel–zinc ferrite particles that are attracted to the magnetized area. The drum then touches the moving roll of paper to which the magnetic powder adheres, and to which the latter is finally fixed by melting the resin with radiant heat. Unlimited copies may be obtained without re-recording, since successive re-applications of the powder do not destroy the magnetic pattern on the drum. There are no special requirements for the paper used, which may be thin and cheap.

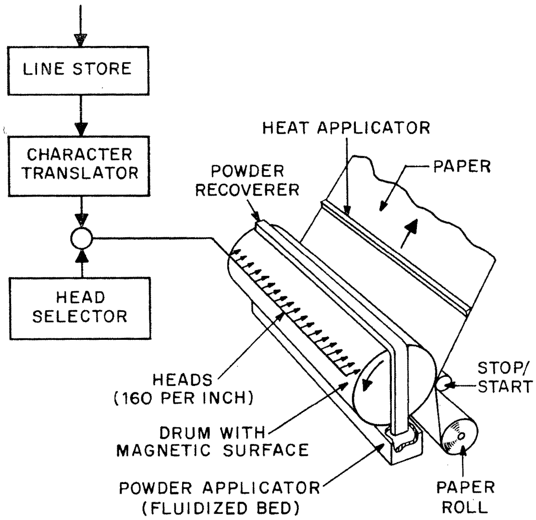

Figure 14—Arrangement of Ferrodot high-speed printer.

The printer can also be used in a display unit with computers or other data processing systems. The recorded image is used to attract a dark magnetic powder, thus making the pattern visible for either direct viewing or projection. Updating and modification are possible as with a conventional cathode-ray-tube system, except that, as repeated scanning is not required to maintain the display, computer storage capacity is saved.

Standard Telecommunication Laboratories
United Kingdom

Post Office Automation Continues—A letter-sorting equipment is being constructed for the Danish Postal Administration for a field trial in Copenhagen.

There will be 15 coding desks where destination codes are stamped on letters that are automatically fed to the operating positions. Following a coarse sorting, all letters for 100 destinations will be machine sorted into appropriate selection boxes. The sorting machine is of modular construction and can handle over 21 000 letters per hour. Another field trial of this type of equipment in Wiesbaden, Germany, is mentioned on page 444 of the immediately preceding issue of this magazine.

Standard Elektrik Lorenz
Germany

Radiotelescope for Belgium—A radiotelescope based on the interferometer principle is being installed for the Royal Observatory of Belgium at the Humain-Rochefort Radioastronomy Center. It uses 48 equatorially mounted paraboloidal antennas, some of which are shown in Figure 15. Each antenna is 5 meters (16 feet) in diameter, and they are arrayed along orthogonal asymmetric base lines to produce a pencil-beam pattern of 3 minutes arc width at the half-power values. An ultrasensitive receiver is connected to each antenna and the receiver outputs are combined.

There are two operating modes. In the scanning mode the surface of the sun, the diameter of which is about 30 minutes of arc, may be sequentially explored by the pencil-shaped beam. A signal processing system permits this radio picture to be produced on a television screen. The radio picture may be compared and correlated directly with an optical view taken with a camera. The drift mode is used for radio source mapping and intensity measurements.

Conceived by Professor Coutrez of the Royal Observatory of Belgium, the engineering and manufacturing were commissioned to Bell Telephone Manufacturing Company. The system will be placed in regular service late in 1967.

Bell Telephone Manufacturing Company
Belgium

Autotrack Receiver—An autotrack receiver has been delivered to the technical center in The Hague, Netherlands, of the Supreme Headquarters Allied Powers in Europe (SHAPE). It is intended to drive, in automatic tracking mode, the simultaneous-lobing antenna of the first satellite ground terminal of the North Atlantic Treaty Organization (NATO), which is to operate in conjunction with the United States Interim Defense communication satellite network.

The system will be used mostly for advanced research in the Lincoln Experimental Satellite (LES) series. It will provide outstanding lock-on and tracking capabilities for military research satellites in quasi-synchronous orbit. Advances in frequency search and acquisition

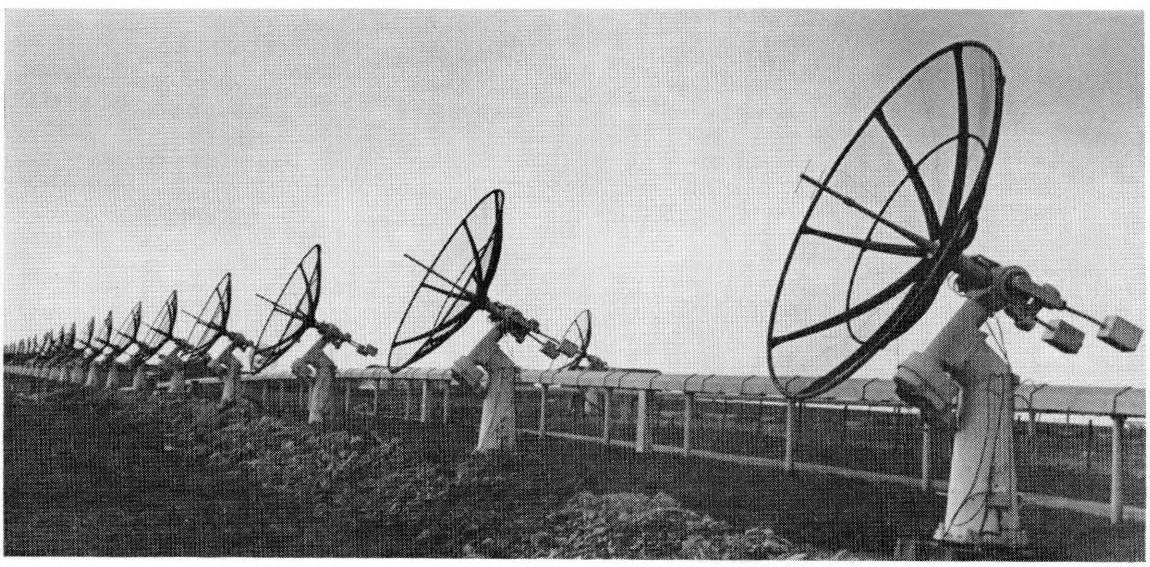

Figure 15—View of some of the 48 antennas making up an interferometer system for solar and galactic radioastronomy.

and in threshold extension techniques involving third-order phase-lock loops with narrow equivalent noise bandwidths have produced a powerful tool to explore the potentialities of satellite communication using low radiated power in orbit and moderate-size earth terminals.

Bell Telephone Manufacturing Company
Belgium

Doppler Radio Range for Aircraft—After a successful trial of several months, a very-high-frequency omnidirectional radio range has been placed in regular service at St. Pantaleon near Salzburg, Austria, by the Bundesamt für Zivilluftfahrt. It differs from conventional ranges in that it employs the Doppler principle to provide extraordinarily stable course indication despite very rough terrain including mountain ranges.

A 30-hertz signal frequency modulates a 9960-hertz subcarrier that is radiated on a very-high-frequency carrier. Figure 16 shows 39 antennas arranged in a circle 13 meters (43 feet) in diameter. These are successively and individually connected to the transmitter by an electronic switching device. This gives the effect of a moving radiator required by the Doppler principle.

Flight tests on both north-south and east-west routes showed substantial improvement over a conventional range at the same place. The Doppler installation makes it possible to fly on automatic pilot even over mountains. A similar system is being installed at Frankfurt-on-Main, Germany.

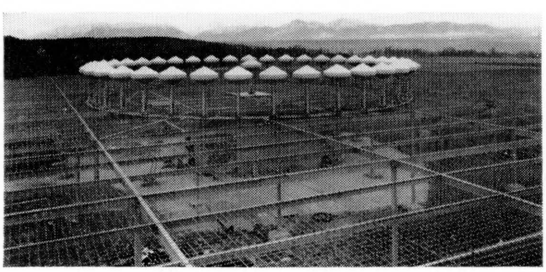

Figure 16—Circular array of 39 radiators for the Doppler very-high-frequency omnidirectional radio range near Salzburg, Austria.

Standard Elektrik Lorenz
Germany

Data Display System in Hospital—A data handling and display system has been installed at the Royal Caroline Hospital in Stockholm. As shown in Figure 17, it comprises a number of display terminals distributed in intensive-care rooms, operating theaters, X-ray department, doctors' offices, and laboratories. The terminals are controlled by a display processor that regenerates display data at a speed that produces a flicker-free picture. Data are inserted into the system or called out for display with a keyboard at the on-line display terminals.

The display processor has an autonomous data handling capability that permits the organization of a very flexible display system including such facilities as: automatic display in tabular form of input data received from the patient; automatic conversion of patient data into easily

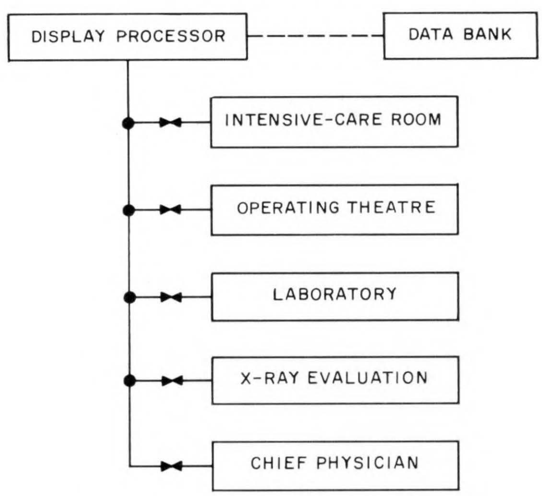

Figure 17—Hospital application of data display system. At each terminal there is a keyboard machine for inserting and requesting data and a console for visual display.

inspected graphs; conversion of time-scale of graphs; keys for display of a designated computer and programmed function; automatic alarm when input falls outside criteria limits; wide selection of categories of data for display; and visual intercommunication between terminals permitting instantaneous and safe ordering without error sources due to intermediaries.

The display processor includes a core store for administrative programs and for data being displayed. It also has a back-up store (magnetic tape or disc) to provide long-time recording and a wider selection of display data. Such a back-up store can also be part of a central computer system that contacts a general-purpose patient data bank. The central system is relieved of much input/output load thanks to the autonomous operation of the display system.

Standard Radio & Telefon
Sweden

Travelling-Wave Tube *W45B/5E*—Between 470 and 960 megahertz, the *W45B/5E* travelling-wave tube provides 200 watts for television transmitters in Broadcast Bands IV and V or 50 watts for common vision and sound transposers. They can also be used for pulsed operations producing 500 watts for a duty cycle of 10 percent. Two important features are simultaneous switch-on of all power supplies, including heaters, and a weak external magnetic field from the permanent magnet in the mount.

Standard Telephones and Cables
United Kingdom

Message Switching System for Irish Airport—On 15 May, Erskine H. Childers, Irish Minister for Transport, Power, Posts, and Telegraphs, officially cut over a computer-based message switching system for Aeronautical Fixed Telecommunications Network (AFTN) working at Shannon Aeradio Telecommunications Centre.

This dual *6300 ADX* system shown in Figure 18 switches aeronautical telegraph messages in the correct message format established by the International Civil Aviation Organization (ICAO), automatically at high speed in order of priorities to various local and international locations.

Standard Telephones and Cables
United Kingdom

Modem *GH-1101*—*GH-1101* is a new, compact, and highly reliable frequency-modulated modem for the rapid and accurate transmission of digital data over telephone-type circuits.

The equipment, which transmits binary data signals in serial mode, can be used for simultaneous two-way transmission over two-wire telephone-type connections at a data signalling rate of 200 bits per second.

An automatic answering circuit can be provided which automatically connects the modem to the line when a ringing signal is received. It also contains timing circuits for automatic disconnection of the line after the end of a transmission or when a data connection has not been established.

GH-1101 is an advanced development of our earlier modem equipments which have been used for these applications. It conforms with

Figure 18—The dual *6300 ADX* system at Ballygirreen near Shannon Airport.

the standard equipment practice of ITT Europe and with recommendations *V21* and *V24* of the International Telegraph and Telephone Consultative Committee (CCITT). The subrack can be placed in a special desk-top cabinet shown in Figure 19 or mounted on a 19-inch bay.

Orders from the Swedish Telecommunications Administration have been received as well as substantial export orders from Denmark and Australia.

Standard Radio & Telefon
Sweden

Television Transmitters for Broadcast Bands IV/V—New television transmitters have been designed for operation between 470 and 860 megahertz having output (picture/sound) powers of 2/0.4, 10/2, and 40/8 kilowatts. An initial order has been placed by the Swedish Board of Telecommunications.

The video transmitters will handle color using any of the three systems: Phase Alternation Line, Sequential with Memory, and National Television System Committee (PAL, SECAM, and NTSC). The use of silicon transistors and diodes for all but the output stages, which use travelling-wave tubes and klystrons, ensures high reliability and easy maintenance. Modular design permits extension of an installation by adding either active or passive units.

The equipments conform with the recommendations of the International Radio Consultative Committee (CCIR) and the International Electrotechnical Commission (IEC). They may be connected to a remote power supply and can be operated unattended.

Standard Elektrik Lorenz
Germany

Telecommunications for German Motorways—The first manually operated push-button-controlled crossbar switching system was installed in 1957 for the Federal Ministry of Transport of Germany for communication among motorway maintenance and emergency stations, supervisory offices, filling stations, and police stations. Increases in both traffic density and network size now require modernization and expansion of this system.

In collaboration with the Ministry, the system was expanded to include a medium-size crossbar private automatic branch exchange of the Citomat type having 2 trunks, 10 lines, and 2 links, a voice-operated communication circuit to the roadside telephone pillars along the motorway, as well as an ultra-high-frequency transmitting and receiving circuit. The switching equipment for all these circuits is built into a single desk shown in Figure 20.

Standard Elektrik Lorenz
Germany

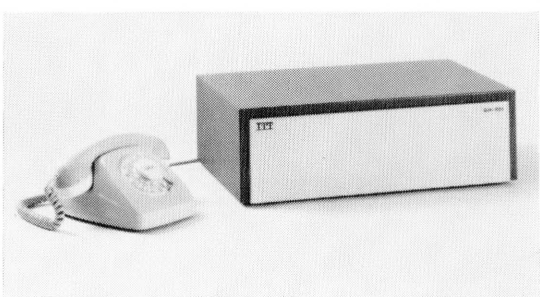

Figure 19—Modem equipment *GH-1101* housed in a desk-top cabinet.

Figure 20—Switching desk for the motorway telecommunication system.

Heat Sink Having Low Capacitance and High Resistance—The *4KC/160M* tetrode will operate at 500 megahertz with an anode dissipation of 250 watts when mounted on the heat sink shown with it in Figure 21. The mounting pedestal has a middle section of beryllia ceramic (*HS10A*), which has the electrical insulating qualities of high-grade alumina ceramics and the thermal conductivity of brass. The combination provides a low output capacitance of only 8 picofarads.

Standard Telephones and Cables
United Kingdom

Multiplex Equipment for 2700/1800-Channel Telephone Systems—The bayside shown in Figure 22 accommodates the multiplex equipment for master groups and supermaster groups including carrier supply for a complete 2700/1800-channel telephone system. Automatic gain control for reference pilots for the master and supermaster groups is incorporated in the respective translating subracks. Power and carrier supplies are duplicated with automatic changeover. Several 1800-channel systems have been delivered to Mexico.

Bell Telephone Manufacturing Company
Belgium

Colombia Expands Cali Telephone Network—Empresa Municipales de Cali (EMCALI) of Colombia has ordered step-by-step telephone switching equipment to extend 10 Cali exchanges at Cento, San Fernando, Versalles, Versalles Satellite, Limonar, and Guabito. This existing network serves 51 800 lines and will be increased to 73 900 lines.

Standard Telephones and Cables
United Kingdom

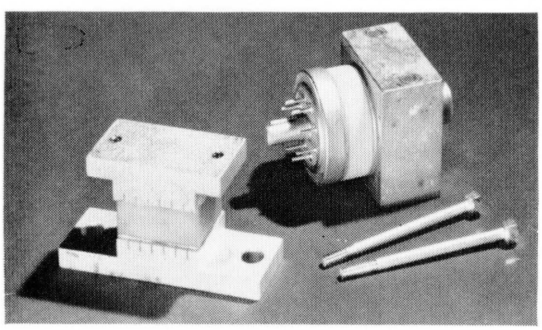

Figure 21—The *4KC/160M* ultra-high-frequency tetrode with its associated heat-sink mount.

Thick-Film Circuits—The initial production target at Paignton is 500 000 thick-film circuits per year. Basic passive components, resistors, capacitors, and inductors are being produced by

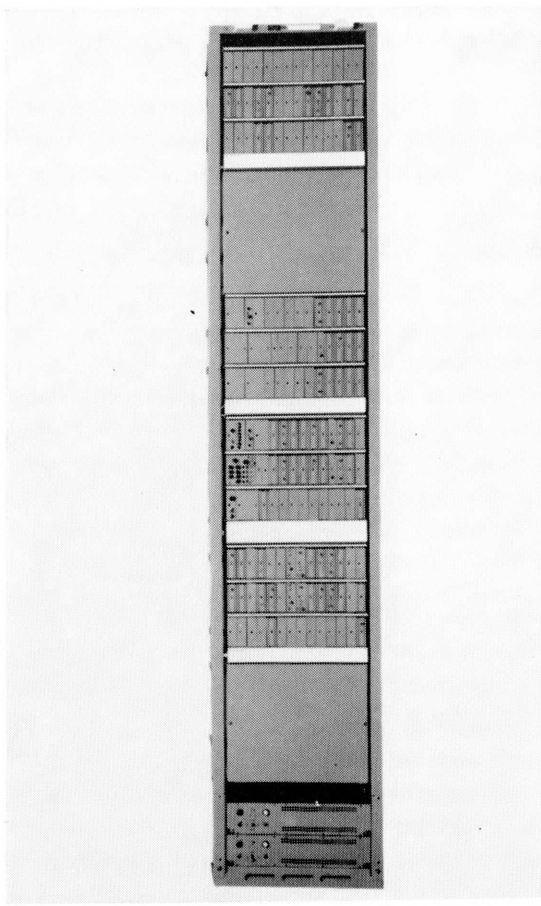

Figure 22—Master and supermaster groups for a 2700/1800-channel telephone system are mounted in this bay, which is 520 millimeters (21 inches) wide and 2750 millimeters (108 inches) tall. Design conforms with the standard equipment practice for ITT Europe.

sequential screen printing on ceramic substrates. The printing inks have conductive, resistive, or dielectric properties, and after printing the films are hardened by firing. A protective glaze is then used.

Component values can be adjusted to close tolerances by abrading with a fine high-pressure jet of alumina powder. Finally conductor areas are soldered for attaching lead wires.

Glaze finish is satisfactory for tropical applications but for military environments the circuits are also encapsulated. Selection plus-or-minus tolerances for resistors are either 1, 15, or 20 percent and for capacitors, 20 percent.

Standard Telephones and Cables
United Kingdom

Crossbar Private Automatic Branch Exchange in Austria—A large crossbar private automatic branch exchange having 80 city lines and 700 extensions was put in service in July 1967 for the United Nations Industrial Development Organization in Vienna. This modern installation is equipped for through dialing to the extensions.

Standard Telephon und Telegraphen
Austria

Radio Control for Cranes—Following an agreement with Dynascan Corporation of Chicago, we will market the Telemotive system for remote radio control of electric overhead travelling cranes. The system enables the crane to do without a cab operator and places control in the hands of a supervisor on the factory floor.

Standard Telephones and Cables
United Kingdom

British Post Office to Extend Subscriber Distance Dialling—The British Post Office has ordered Pentaconta telephone switching equipment as part of its plan to extend direct distance dialling by subscribers. Of the 40 transit centers planned for the United Kingdom in the next few years, immediate consideration is being given to those for Belfast, Bristol, Cambridge, Chester, Edinburgh, Glasgow, Inverness, and Sheffield.

Standard Telephones and Cables
United Kingdom

Thailand Radio Relay Network—A contract has been signed by the government of Thailand for the delivery and installation of two radio relay links having a total length of 1700 kilometers (1100 miles).

Modern solid-state 6-gigahertz equipment of the *FM 1800/TV-6000* type will link Chiengmai at the northern border via the capital, Bangkok, with Hat Yai in the vicinity of the Malaysian border. The new radio link will further connect Thailand via Singapore to the international communications network.

On completion of the project in 1969, Thailand will have a national telecommunications network of advanced technology that will permit the introduction of nationwide direct distance dialing.

At the same time, the Thailand National Telephone Organization issued a contract covering the installation of a radio relay link of the same technological design between Bangkok main post office and the satellite earth station in Tung-Sukla.

Standard Elektrik Lorenz
Germany

Pulse-Code-Modulation Telephone Equipment—Further orders for pulse-code-modulation equipment for the public telephone network have been placed by the British Post Office. They include 170 terminal equipments and 3200 intermediate regenerative repeaters. Each terminal equipment provides 24 both-way speech circuits and 24 telegraph channels over two pairs of wires in a voice-frequency junction cable.

Standard Telephones and Cables
United Kingdom

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Standard Telephones and Cables
United Kingdom

United States Patents Issued to International Telephone and Telegraph System: August–October 1966

Between 1 August 1966 and 31 October 1966, the United States Patent Office issued 85 patents to the International System. The names of the inventors, company affiliations, subjects, and patent numbers are listed below.

J. M. Abraham, ITT Industrial Laboratories, Method of Vapor Deposition, 3 276 902.

R. T. Adams and G. Raisbeck, ITT Federal Laboratories and Bell Telephone Laboratories, Apparatus for Reducing Spin of a Space Satellite, 3 270 983.

H. H. Adelaar, Bell Telephone Manufacturing Company (Antwerp), Four-Wire/Two-Wire Converter, 3 267 218.

M. Arditi, ITT Federal Laboratories, Optically Pumped Magnetometer Using Microwave Transitions, 3 281 663.

R. E. Arseneau, ITT Kellogg, Electronic Switching Telephone System, 3 268 667.

R. E. Arseneau, ITT Kellogg Communication Systems, Timer, 3 275 850.

E. A. Ash, E. A. F. Sell, T. M. Jackson, and L. A. Vinton, Standard Telecommunication Laboratories (London), Tunable Cavity Resonator, 3 273 085.

D. R. Barber, Standard Telecommunication Laboratories (London), Magnetic Core Pulse Circuit, 3 281 801.

H. Benmussa and M. J. Clerc, Compagnie Générale de Constructions Téléphoniques (Paris), Electronic Translator, 3 275 753.

H. Benmussa, P. R. L. Marty, and S. Kobus, Compagnie Générale de Constructions Téléphoniques (Paris), Pentaconta Semi-Electronic System, 3 270 139.

J. Bernutz, Standard Elektrik Lorenz (Stuttgart), Electrical Connectors Employing a Plug-In Contact Spring, 3 268 850.

J. Bernutz, Standard Elektrik Lorenz (Stuttgart), Printed Circuit Board Connector, 3 264 596.

J. Bernutz, Standard Elektrik Lorenz (Stuttgart), Supporting Frame for Printed Circuit Board, 3 278 714.

F. T. Bilek, ITT Kellogg, Hydraulic Pushbutton Assembly, 3 268 673.

A. E. Brewster, B. S. Mason, and G. R. Pearce, Standard Telephones and Cables (London), Clutch Apparatus, 3 280 947.

F. Buckwald and H. Kudritzki, Standard Elektrik Lorenz (Stuttgart), Arrangement for Controlled Dispatch of Stored Pneumatic Tube Carriers, 3 265 325.

C. F. Carlson, ITT Bell & Gossett Hydronics, Heating or Cooling Systems and Air Separating Devices Therefor, 3 276 188.

R. H. Clayton, ITT Industrial Laboratories, Display Storage Tube with Solenoidal Focus and Simultaneous Deflection of Writing and Flood Beams, 3 281 621.

R. H. Clayton, ITT Industrial Laboratories, Scan Conversion Tube Wherein the Flood Beam Passes Through the Storage Electrode and Is Scanned over an Image Dissector, 3 281 622.

R. W. Cotterman and W. H. Wright, ITT Telecommunications, Nuclear Blast Detector, 3 281 811.

R. Dahlberg, Intermetall (Freiburg), Method of Making Masks for Vapor Deposition of Electrodes, 3 271 488.

J. G. Dupieux, J. P. LeCorre, and P. Sénèque, Laboratoire Central de Télécommunications (Paris), Multiplex Switching Stage and its Associated Control Circuits, 3 281 537.

J. G. Dupieux and P. Sénèque, Laboratoire Central de Télécommunications (Paris), PCM Switching Stage and its Associated Circuits, 3 281 536.

C. W. Earp, Standard Telephones and Cables (London), Doppler VOR Beacon, 3 273 152.

M. Fleischer, Standard Elektrik Lorenz (Stuttgart), Step-by-Step Feed Device and Brake Means for Record Media, 3 279 668.

H. Fliegner and W. Hinz, Standard Elektrik Lorenz (Stuttgart), Pneumatic Apparatus for Individually Separating Flat Items, 3 279 786.

A. F. Giordano, ITT Federal Laboratories, Three-Dimensional-to-Planar Projection Display, 3 281 519.

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N. E. Hamilton and M. C. Welch, Purchased Invention, Crucible Seal, 3 279 896.

J. H. Harker and J. Keyes, ITT Bell & Gossett Hydronics, Gas Separation Pump for Liquid Circulating Systems, 3 276 187.

H. J. Hartmann, Standard Elektrik Lorenz (Stuttgart), Method of Producing Electrical Semiconductor Devices, 3 271 632.

J. S. Hawkins, Jennings Radio Manufacturing Corporation, Hermetically Sealed Relay Having High and Low Voltage Contact Assemblies in a Common Chamber, 3 275 775.

L. J. Heaton-Armstrong, Standard Telephones and Cables (London), Automatic Electrical Control System Having Plural Comparators and Automatic Disabling of Coarse Comparator, 3 277 378.

M. J. Herry, J. P. LeCorre, and G. R. Yelloz, Laboratoire Central de Télécommunications (Paris), Time Division Multiplex Transmission Systems, 3 274 339.

J. Hill, National Transistor Company, Article Handling Method, 3 279 143.

S. L. Hjertstrand, Standard Radio & Telefon (Barkarby), Magnetic Switch Contact Assembly, 3 268 840.

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K. Hubner, Purchased Invention, Four Layer Semiconductor Device, 3 277 352.

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F. Kupersmith, ITT Federal Laboratories, Frequency Modulator System Having a Temperature Compensating Amplifier Circuit in the AFC Loop, 3 277 397.

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H. Mach, Standard Elektrik Lorenz (Stuttgart), Central Branch-Off in Pneumatic Tube Systems, 3 265 327.

H. Mach and H. J. Peter, Standard Elektrik Lorenz (Stuttgart), Pneumatic Tube Systems, 3 265 324.

H. Mach and H. J. Peter, Standard Elektrik Lorenz (Stuttgart), Pneumatic Tube System Switching Points, 3 265 326.

J. F. McNulty, ITT General Controls, Electromagnetic Friction Braking Arrangement, 3 270 265.

R. Michel, Standard Elektrik Lorenz (Stuttgart), Apparatus and Method for Recording and Reproducing a Plurality of Timing Tracks, 3 277 453.

A. Midis, R. Czajkowski, and D. C. Sheldon, ITT Kellogg, Electrical Control Systems for Point-to-Point Transit Systems, 3 263 625.

B. D. Mills and R. F. Payne, Standard Telephones and Cables (London), Continuously Graded Electrode of Two Metals for Semiconductor Devices, 3 270 256.

J. J. Muller, Le Matériel Téléphonique (Paris), Compatible Single Sideband Radio Transmission System, 3 277 376.

J. E. Oeschger, Jennings Radio Manufacturing Corporation, Vacuum Variable Capacitor, 3 270 259.

R. K. Orthuber, C. V. Stanley, and T. P. Dixon, ITT Federal Laboratories, Method of and Apparatus for Character Recognition, 3 280 257.

D. P. Perry, ITT Federal Laboratories, Skew Elimination System Utilizing a Plurality of Buffer Shift Registers, 3 281 805.

D. I. Pomerantz, Purchased Invention, Planar Semiconductor Devices, 3 271 201.

S. M. Poole and G. L. H. Herondelle, Le Matériel Téléphonique (Paris), Flight Simulator, 3 269 030.

A. Prekeris and J. M. Barnett, American Cable and Radio Corporation, Telegraph System, 3 280 248.

H. Reiner, Standard Elektrik Lorenz (Stuttgart), Thin-Film Switching Circuit, 3 275 894.

G. W. Reznor, ITT Reznor, Surge Arrestor, 3 273 597.

H. Rossle and B. Schwarz, Standard Elektrik Lorenz (Stuttgart), Electrical Semiconductor Device, 3 280 390.

M. Scata, Fabbrica Apparecchiature per Comunicazioni Elettriche Standard (Milan), Electromechanical Adjustable Polarized Relay, 3 265 827.

O. Shames, Purchased Invention, Rapid Synchronous Time Interval Detector, 3 267 464.

J. B. Shevlin, ITT Cannon Electric, Electrical Connector Having Shrouded Pin Contacts, 3 277 422.

H. E. Snider, Jr., ITT Federal Laboratories, Movable Display Member Controlled by Impedance Element Mounted on Said Member, 3 281 820.

R. E. Solomon, ITT General Controls, Oven Control System, 3 281 074.

G. B. Speen, ITT Federal Laboratories, Combined Gyroscope and Accelerometer, 3 276 270.

R. H. Taplin, ITT Federal Laboratories, Miniature Sonobuoy and Cable, 3 281 765.

R. V. Tetz, Jennings Radio Manufacturing Corporation, Parallel Resistance-Capacitance Voltage Divider, 3 274 483.

M. F. Toohig and E. H. Eberhardt, ITT Federal Laboratories, Charge Storage Tube and Target Electrode Therefor, 3 277 334.

L. M. Vallese, ITT Federal Laboratories, Adjustable Input Impedance Amplifier, 3 271 528.

J. Van Eynde, V. Maggini, and H. Van Horan, Bell Telephone Manufacturing Company (Antwerp), Field Telephone System, 3 264 412.

H. Van Meines, Bell Telephone Manufacturing Company (Antwerp), Electrical Contact Arrangements, 3 277 316.

G. Vogel, H. Schönemeyer, and L. Gasser, Standard Elektrik Lorenz (Stuttgart), Dial Signal Receiving Facilities, 3 270 144.

J. Vroman, Bell Telephone Manufacturing Company (Antwerp), Anti-Coincidence Logic Circuits, 3 278 758.

M. Wagner and H. K. Stander, Standard Elektrik Lorenz (Stuttgart), Method of Producing a Solid Electrolytic Capacitor, 3 279 030.

M. W. Wallace, ITT Electron Tube Laboratories, Method of Making a Traveling Wave Tube Helix Mounting, 3 276 107.

G. Wessel, Standard Elektrik Lorenz (Stuttgart), Relay with Reed Contacts, 3 270 302.

R. G. Williams, M. F. Toohig, and R. W. Hunter, ITT Industrial Laboratories, Storage Tube System and Method, 3 277 333.

L. G. Wolfgang, ITT Industrial Laboratories, Printing Cathode Ray Tube Using Photoconductive Layer, 3 277 237.

Designs

J. S. Hawkins, Jennings Radio Manufacturing Corporation, High Voltage Capacitor Discharge Grounding Relay, Des. 205 454.

L. L. Lepoix, Standard Elektrik Lorenz (Stuttgart), Page Printer Cabinet, Des. 205 560.

Electrical Connectors Employing a Plug-In Contact Spring

3 268 850

J. Bernutz

An electrical connector having a contact spring insertable into a spring-strip housing from the end to which the wiring is connected and arranged for easy removal. The contact spring is provided with an elastic member which engages with a recess in the housing and which may be readily removed by a simple tool which releases the member from the recess.

Automatic Electrical Control System Having Plural Comparators and Automatic Disabling of Coarse Comparator

3 277 378

L. J. Heaton-Armstrong

A system to control the tuning of a tank circuit in a transmitter in which the input signal is applied to two comparator circuits. One comparator circuit is responsive to a difference in tuning between the tank circuit and the input signal above a given level. The other is responsive to said difference between the given level and acceptable tuning differences. Outputs from the comparators adjust the tank circuit tuning. Activation of the second comparator renders the first comparator inoperative.

Electrolytic Capacitor Seal

3 277 349

W. J. Hyland, R. A. Canty, and J. E. Doody

A sealing closure member for an electrolytic capacitor consisting of a resilient dielectric closure plug which is sealed to the outer container of the capacitor. The plug carries a metal cup-shaped member for contact with the inner element of the capacitor, the upper edge of the cup-shaped member being contained in a slot in the plug, and a terminal connector extending through the plug and soldered to the bottom of the cup-shaped member.

Compatible Single Sideband Radio Transmission System

3 277 376

J. J. Muller

A single-sideband radio transmitter in which the signal may be detected in a double-sideband amplitude receiver, provided with a circuit to separate out a single sideband and to modulate the carrier frequency with this sideband, and further with a circuit to separate out harmonics of the detected amplitude-modulated carrier and to modulate the selected sideband with the detected harmonics in reversed phase.

Adjustable Input Impedance Amplifier

3 271 528

L. M. Vallese

An amplifier having two amplifying stages in the form of transistors between input and output and a variable positive feedback circuit between said stages to provide a control to adjust the input impedance to a value between zero impedance and a negative impedance value.

Method of Producing a Solid Electrolytic Capacitor

3 279 030

M. Wagner and H. K. Stander

A process for manufacturing a capacitor having a solid sintered titanium body as one electrode, consisting of removing any titanium oxide film from the body surface, heating it to a temperature between 300 and 500 degrees Celsius until a bluish-violet titanium oxide film becomes visible, electrolytically forming an additional titanium oxide film on the first film, and then depositing a counter electrode on this outer film.

Other Papers from International Telephone and Telegraph System Authors

The following list includes papers published in other periodicals and, in some cases, presented at meetings and not yet published. Some unpublished papers may be available in limited quantities and requests should be directed to *Electrical Communication*. Requests for published papers should be made to the indicated publication and not to *Electrical Communication*. The affiliation of the author is given in parentheses.

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"Data Communication Equipment *GH-201*." (Standard Radio & Telefon, Sweden)

"Data Modems *GH-2002*." (Standard Radio & Telefon, Sweden)

"ISEP *MK 1* Telephone Multiplex Equipments." (Bell Telephone Manufacturing Company, Belgium)

"Landline Equipment for Carrier on Cables." (Bell Telephone Manufacturing Company, Belgium)

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"P.C.M. Multiplex Transmission on Junction Cables." (Standard Telephones and Cables, United Kingdom)

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