TH Radio System Equipment Aspects

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This article discusses the considerations governing the general over-all physical arrangements of the TH system, which lead to differing treatments for the radio equipment, FM terminals, and protection switching equipment. It describes the general mechanical features of these divisions, from the sliding-rack bay used for the radio equipment to the extensive use of plug-in units for protection switching.

I. FUNDAMENTAL EQUIPMENT PLANNING

It is the nature of systems such as TH radio that the problems associated with engineering station layouts, and with preparation of orders for production in the manufacturing shops, are of considerable magnitude. More obviously, the designer is concerned with arrangements for operation and maintenance, with manufacturing and installation problems, and with expenses involved in all of these. Reliability is also of particular importance in the TH system in view of the large message circuit capacity of a TH radio channel. The design of the TH equipment is based on satisfying the physical problems while retaining proper economic balance.

To reduce engineering and installation effort, the equipment is designed insofar as practical for assembly, wiring, and testing of complete bays in the manufacturing shop. These operations can be performed more efficiently there, and the amount of field installation and testing effort is thereby reduced. Engineering effort is also reduced by adherence to standardized floor-plan arrangements wherever possible.

For convenience and speed in the restoration of service in the event of failure, extensive use is made of plug-in connections and plug-in units. These are also used for efficient packaging and ease of installation as a system grows. Furthermore, the plug-in designs are consistent with the philosophy of repair procedures. Spare units are provided in each station or at nearby maintenance centers so that defective units can be readily replaced and sent to a maintenance center for repair. Some maintenance centers are equipped with a test bench and facilities for testing units and making repairs.

The design of bay equipment is directed toward arrangements which provide ready access for routine testing and replacement of units. Where possible, the transmission equipment is given preferential location on the bays to minimize the use of ladders during normal maintenance. Routine tests are made with integrated sets housed in rolling cabinets and with multipurpose meters which plug into metering connectors on the bays.

To assure reliability, great care has been used in the choice of components. This is particularly true in the case of capacitors, which are hermetically sealed designs wherever possible. All connectors are provided with goldplated contacts and have been rigorously tested. Reliability is also stressed in the power plants and, as will be discussed later, in the blower system for the microwave radio bays.

In addition to the topics discussed below, a number of miscellaneous items should be mentioned for the sake of completeness, since they will not be considered in detail. They are, however, important parts of the complete system, and include alarm and order wire equipment, so vital to operation and maintenance, and patching and testing jack arrangements.

II. TH STATION ARRANGEMENTS

There are two general types of TH radio stations: (a) main radio stations and (b) radio repeater stations.

Main stations are varied in their characteristics. They may be end points or intermediate points in the system where intermediate frequency (IF) signals are accepted from and delivered to terminal facilities. In addition, main stations provide points of flexibility in the system where provision is made for IF patching and monitoring, automatic protection switching, dropping or picking up of signals to and from local or spur radio facilities, and maintenance switching from regular to protection channels. Such stations also provide convenient locations for performing systems tests. These stations usually are fully or partially attended.

The radio repeater stations provide transmission gain and maintain line-of-sight paths. They comprise the majority of the stations in any large system and are normally unattended. Unlike main stations the repeater stations are more uniform in their makeup and are more adaptable to standardized floor plans and building construction.

The transmission equipment for the TH radio system falls into two somewhat different categories. One includes the microwave radio and associated microwave carrier supply equipment, which is common to all stations. A general view of this equipment is shown in Fig. 1. The other includes facilities such as protection switching and patching bays which are found in main stations only. The two categories are located in different but preferably adjacent areas in main stations, as indicated by the

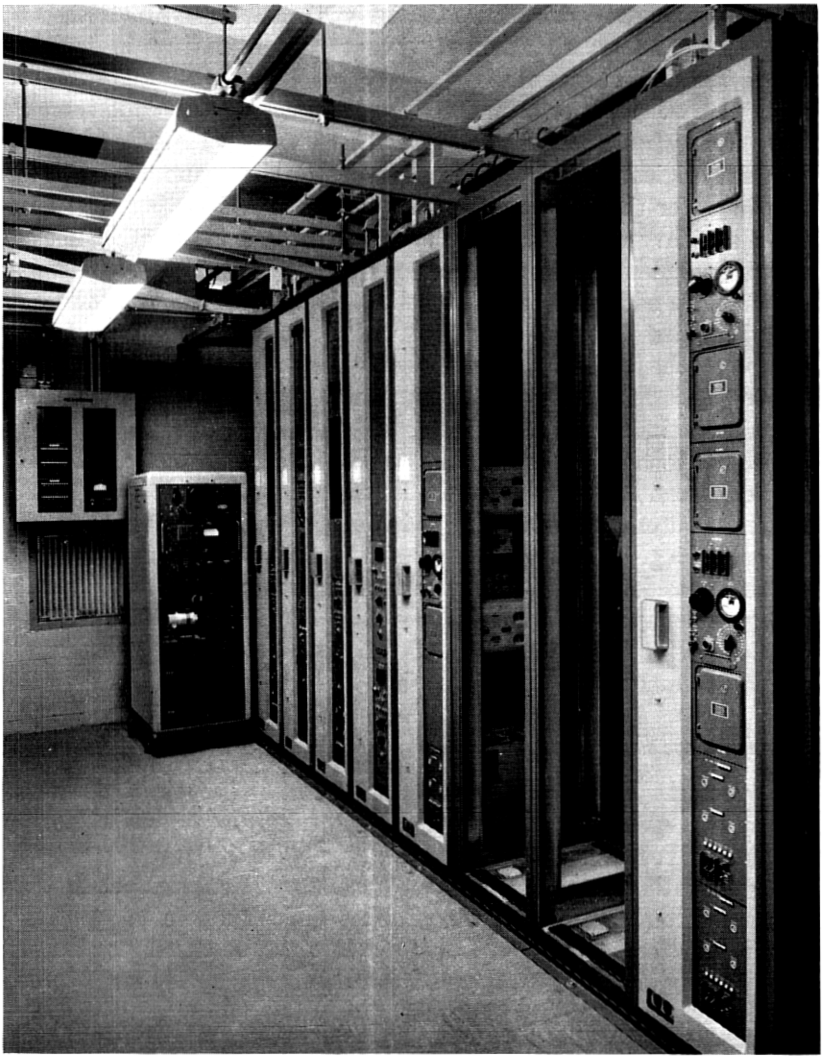

Fig. 1 — General view of the microwave radio equipment bays in a station lineup.

typical floor plan in Fig. 2. This is desirable because the requirements for the microwave equipment are determined by the number of radio channels provided, whereas the requirements for the other equipment are determined by the manner in which the radio channels are assigned and administered. Furthermore, there are unique requirements of the radio equipment which make standardization of the layouts desirable if not essential. Standardization of this type allows growth of the bay equipment in an orderly manner, with consequent savings in engineering and installation expense.

The plan adopted for the microwave bays is essentially the same for all stations, whether main or repeater. As shown on Fig. 2, each of the two lines originates with basic equipment for the group, one with the three bays for the microwave carrier supply and the other with three for the auxiliary radio channels. Beyond these basic bays, either line can grow independently as long as even-numbered channels are installed first and then odd-numbered channels. This is possible because the bays beyond the first three are associated with one side of the station for one line-up and the opposite side for the other line-up. Thus, orderly growth of a line-up is maintained even though the station may be temporarily a terminal point on the route.

The additional facilities provided at main stations vary to suit differing requirements for service and administration. These consist of FM terminals, automatic protection switching, equalization, and patching and monitoring. With the varying amounts and types of such equipment, practical considerations do not permit a high degree of standardization of floor-plan layouts. However, there are restrictions on transmission cable lengths and a preferential association of certain bays, which result in a limited amount of standardization.

2.1 *Microwave Equipment Floor Plan*

The factors which lead to standardized layouts of the radio equipment are the waveguide for microwave carrier supply distribution and for antenna connections, the tube-cooling air facilities, and the need for orderly growth. Of these factors, the waveguide facilities benefit most from standardization. Rigid waveguide is a difficult medium for ordinary field installation since the various pieces must be fitted precisely in place. Pre-engineering of waveguide parts is necessary if they are to be delivered on the job ready for installation.

The antenna waveguide runs, which originate at the broadband radio bays, are simple and direct in themselves; there are four waveguide

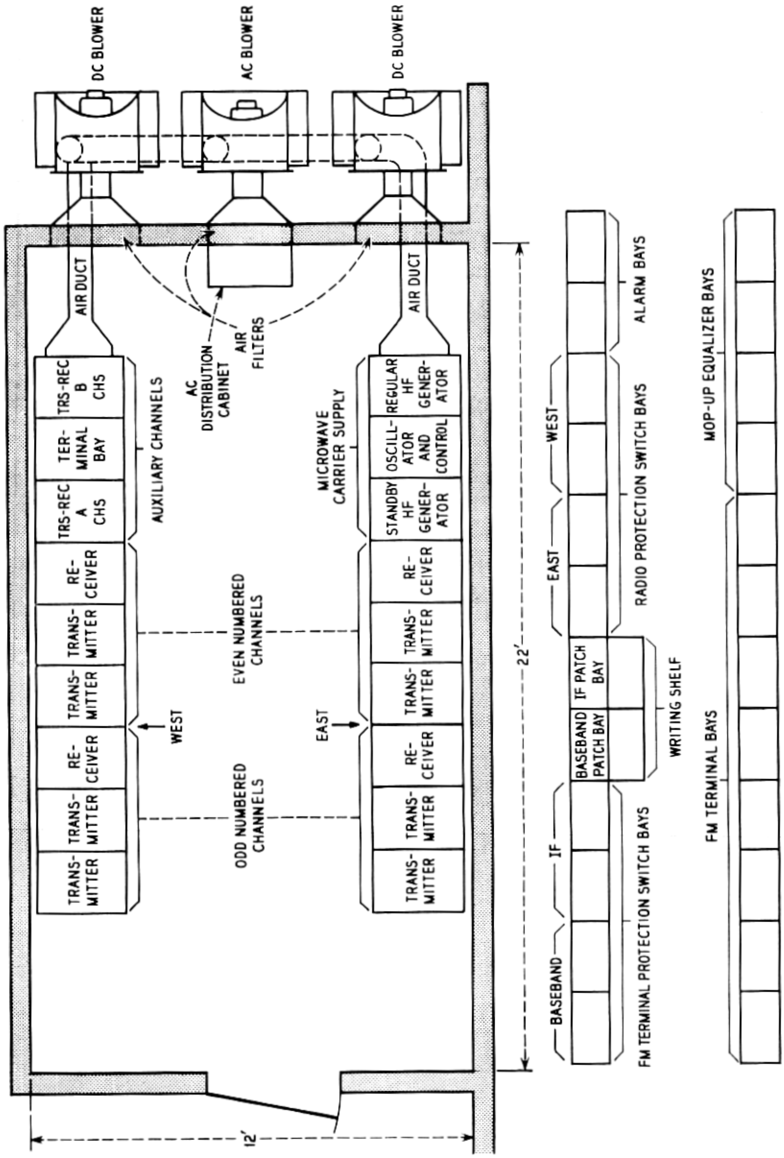

Fig. 2 — Typical floor plan of a main station, showing locations for two categories of equipment.

runs from each row of bays for a fully equipped station. However, these runs include the channel separation networks for the auxiliary channel transmitters and receivers. Careful planning in the location of the networks and in the running of the waveguide from the networks to the auxiliary channel radio bays is necessary to keep waveguide runs as short and simple as possible.

In the distribution of the carrier frequencies from the microwave carrier supply bays to the various transmitter and receiver bays, still more difficult problems arise. One of the two microwave carriers must be distributed to all the broadband radio transmitter bays (eight ultimate) and the other to all the broadband radio receiver bays (four ultimate), and both carriers to the auxiliary channel radio bays. This is accomplished by two "waveguide trees," one for each carrier. Utilizing waveguide junctions having one input and two output ports, plus waveguide spacers and bends, a single output at the microwave carrier supply bay is divided and subdivided. In the ultimate, twelve outputs are produced for the various bays containing transmitters and eight for those containing receivers. Still further splitting of the microwave carrier power takes place within the broadband transmitter and receiver bays.

The waveguide runs are located in the space above the radio bays and over the aisle between the two rows of bays. Fig. 3 shows the arrangement for a fully equipped two-way station. It is apparent that con-

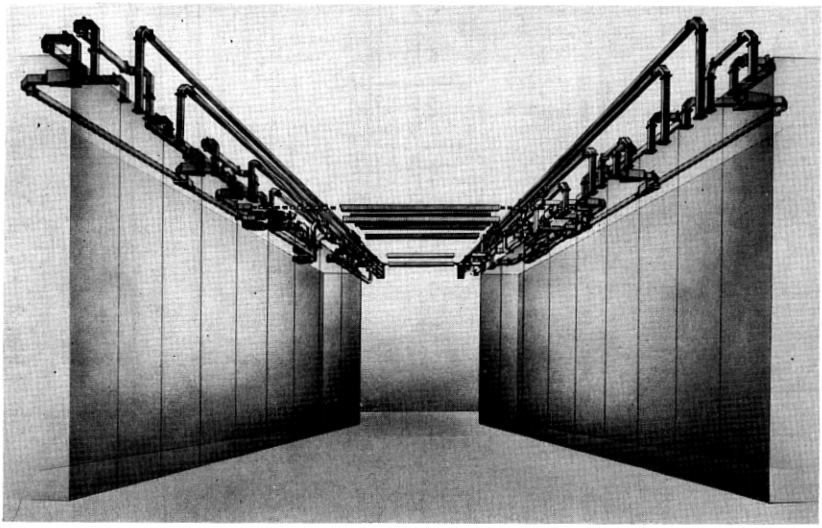

Fig. 3 — Waveguide connections for a fully equipped two-way station.

siderable reduction in engineering effort is realized if these waveguide arrangements are standardized for all stations. This has been done and standard floor plans have been prepared accordingly.

2.2 *Antenna Waveguide Connections*

Standardization of waveguide arrangements has been confined to the radio repeater room where control is practical. Beyond the radio room, the antenna waveguide runs cannot be confined to a fixed pattern because of varying job conditions. Specifically, the location of the weather seal, where the waveguide passes through the outer wall of the building, is determined by the position of the building relative to the antenna tower, and is chosen to provide the most direct run to the tower. Waveguide runs from the radio room to the weather plate must therefore be engineered to fit local conditions. This aspect of the job has been simplified by the introduction of flexible waveguide at the weather plate. The use of flexible waveguide at this point makes the mating of indoor waveguide runs to outdoor waveguide runs easier mechanically. In addition, the flexible waveguides are long enough so that any indoor waveguide in a group of eight may be connected to any outdoor waveguide in a corresponding group. This is important since the cross connections vary from station to station, as determined by many factors which are difficult to coordinate.

III. ANTENNA SYSTEM

At the weather seal in the outside wall of the radio station, the indoor waveguide runs from the radio room connect to pressure windows. At the outdoor end of the pressure windows, the pressurized waveguide runs begin; these connect to the antenna system. The horn-reflector antenna and systems combining networks of the antenna system have already been described.[1,2] Here note is made of the problems involved in the support of networks and waveguide on the towers and of waveguide runs into the buildings.

The discussion requires examination not solely of TH radio but of the total picture of TH combined with other systems. The horn-reflector antenna can transmit all three common carrier microwave systems developed for Bell System use. These are at 4 kmc (TD), 6 kmc (TH) and 11 kmc (TJ). As described in Ref. 2, systems combining networks permit coupling signals of any or all of the three systems with either horizontal or vertical polarization on a single antenna. Each such assignment requires a separate waveguide run to the pressure windows.

The number of antennas required for a given station depends on factors beyond the scope of this discussion but ranges from one to a usual maximum of eight. The usual practice is to place all antennas on a single tower, which may range in height from about 40 to 400 feet. Thus, at a station at the intersection of two routes with all three systems appearing and both polarizations used, there will be eight antennas. Each antenna will have connected to it the full array of systems combining networks, to each of which six rectangular waveguide runs will connect or an ultimate of 48 for the station. In contrast, a repeater station on a single route equipped only for TH radio need only have one combining network and two rectangular waveguide runs per antenna. The fully equipped stations with four antennas would have an ultimate of eight rectangular waveguide runs to the pressure windows.

Because of the wide variations possible in the provision of systems combining networks and the associated waveguide runs to the building, it is essential that the design of the supporting structures permit flexibility in engineering to meet local conditions. On the tower, this involves the positioning of restrainers and protective shields for the combining networks which are, in effect, an extension of the vertical run of circular waveguide from the antenna. Adjacent to each input or output derived in the systems combining networks, hangers are provided to support the rectangular waveguide extending to the base of the tower. These hangers must permit varying the position of the rectangular guide to accommodate orientations of the combining networks as determined by antenna orientation and network polarization in combination.

At the base of the tower, the rectangular waveguides are channeled into horizontal runs to the building. Where possible, the horizontally run waveguides are placed in a common supporting structure. However, the more usual condition is to provide for separate paths to the building for the different systems. This keeps the total length of waveguide required to reach the transmitters and receivers to a minimum, to achieve the lowest practical transmission loss.

IV. MICROWAVE RADIO EQUIPMENT

The microwave radio equipment, as distinguished from FM terminals and protection switching, comprises the common microwave carrier supply and the transmitters and receivers for both the broadband and auxiliary radio channels. Because of the problems involved in the maintenance of this equipment and considerations arising from use of traveling-wave tube (TWT) amplifiers in TH, a new type of bay framework has been designed. This new design is called a sliding-rack bay framework and is also used, for uniformity, for the multiplex terminals of the auxiliary radio channel.

4.1 *Sliding-Rack Bay*

The sliding-rack bay framework permits a closely coordinated association of the radio equipment bays, uses floor space more efficiently, and provides access to all equipment from one aisle. The design also simplifies the distribution of cooling air for electron tubes and permits location of the TWT amplifiers for convenient maintenance. The design provides a conventional type of rack structure on which the equipment is mounted. This equipment rack is in turn mounted in a basic framework on rollers, with the face of the rack at right angles to the front of the bay. When access to the equipment is required, the rack is pulled forward into the aisle space. In this position both sides are fully accessible for maintenance. The bays may be arranged side-by-side in rows, like books on a shelf; and because the slideout feature permits access to all equipment from the front aisle, the rows of bays may be installed back-to-back or against a wall.

The design is illustrated in Fig. 4. The basic framework is made up of top and bottom castings which are joined together by four corner posts. The same casting is used for both the top and the bottom and is designed to result in a trough across the top of a line of bays for the running of cable. At the bottom of the bay a cover plate is provided over the trough to form a duct which runs through the line-up of bays and is extended as bays are added. This duct is used for the distribution of cooling air to the bays in the line. The sliding rack is conventional except that the rear upright is extruded with a cross section which forms a duct from top to bottom of the rack. This duct is used for the distribution of cooling air to the equipment mounted on the rack. Air is supplied to this duct through a flexible hose connected to the main duct in the base of the bay. The rack is mounted in the basic framework on heavy-duty ball-bearing tracks. Sufficient travel is provided in the tracks to permit the bay to be fully exposed in the outboard position.

The bay is 19½ inches wide, 28 inches deep, and nine feet high over-all. All structural members of the basic framework and sliding rack are made of aluminum. The vertical members are extrusions and the top and bottom members of the basic framework, as stated earlier, are castings, also of aluminum.

To permit the sliding rack to be moved outward, the power, coaxial and miscellaneous connections are made to the rack in flexible cables which are positioned and formed to allow the required lateral movement

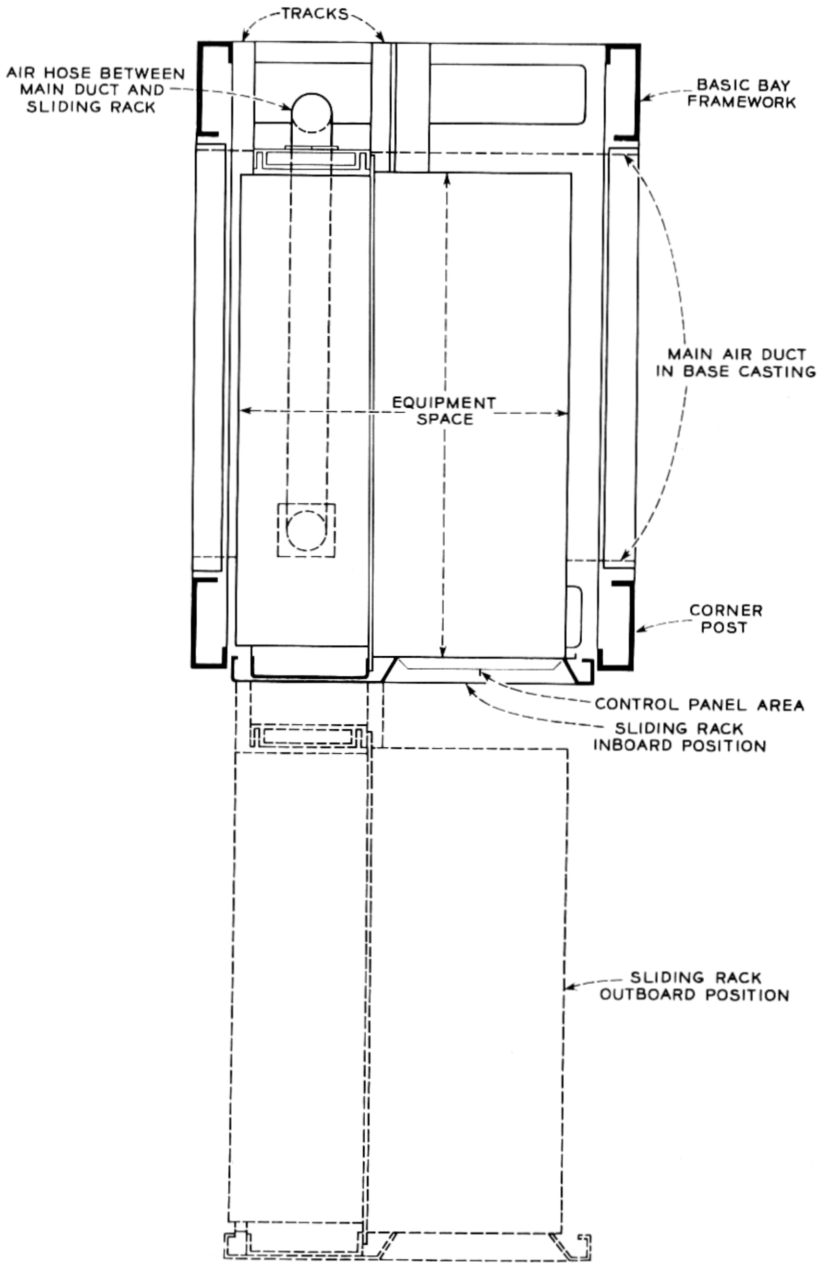

Fig. 4 — Plan view of sliding-rack bay framework.

without placing undue stress on the cable forms. Where waveguide connections are made, short pieces of flexible rectangular waveguide are provided in the waveguide runs to permit the waveguide to flex with the movement of the rack.

An area is provided on the front face of the sliding bay for operating and routine maintenance controls and for providing access to the electron tubes of the TWT amplifiers. Access to a traveling-wave tube is through a hinged door at the front end of the amplifier housing. Since the tube is approximately 12 inches long, sufficient clearance is provided in front of the door, to permit the tube to be inserted and withdrawn from the amplifier, by mounting the amplifier on the bay with the hinged access door facing the aisle. The controls and access doors are visible and accessible with the bay in the inboard position. This permits most routine maintenance checks to be made without pulling the bay to the outboard position.

Inter-unit wiring for the bay is in a local cable located at the rear upright. Connections from the sliding bay to external points, including waveguide, are attached at approximately the rear vertical center of the bay and follow an upward path (bay in closed position) to the underside of the top casting. Here, they turn forward to the front and through a slot in the top casting. All external connections terminate in this area — the waveguide in fixed flange, the coaxial cables in jacks, the power cables with sufficient length to reach the power distribution duct, and the miscellaneous signal and alarm leads on terminal strips. Thus, all installer connections are made at the top and external to the bay. No wiring or assembly functions are performed by the installer inside the bay except where equipment is added to partially equipped bays in the field.

4.2 *High-Frequency Generator Bay*

Typical of the application of the sliding-rack bay is the high-frequency generator bay shown in Fig. 5. This is one of two such bays used with an oscillator and control bay to comprise the common microwave carrier supply. The salient features of the bay design described above are illustrated in this photograph. In addition, the treatment of waveguide components and their interconnection on the mounting panel can be seen. In the upper portion of the bay are mounted panels containing the low-voltage rectifier units supplying heater voltage and the lower plate supply voltages to the electron tube circuits. At the bottom of the bay the high-voltage power supply for the TWT amplifiers appears. To protect personnel against the hazard of high voltages within this rectifier

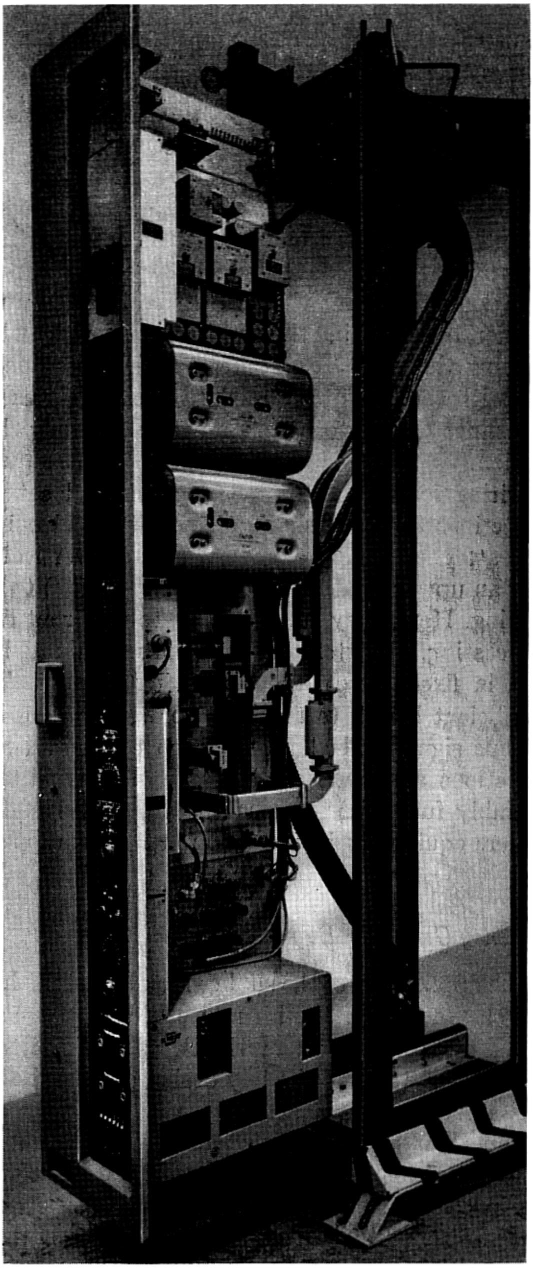

Fig. 5 — High-frequency generator bay, a typical application of the sliding-rack designs.

and the TWT amplifiers, the units are both electrically and mechanically interlocked. The electrical interlock is by means of switches released on opening of the TWT access door. The primary protection, however, is the mechanical interlock using keys which must be obtained from the high-voltage rectifier. The keys are seized in position on the rectifier until the main switch for the rectifier has been turned off.

4.3 *Radio Transmitter Bay*

Similar in general design to the high-frequency generator bay is the broadband transmitter bay illustrated by Fig. 6. Two transmitter panels and associated TWT power supplies are contained in the fully equipped bay. The low-voltage power supplies are mounted on the individual transmitter panels. Near the rear edge of the transmitter panel is seen the waveguide network (the channel separation network) which couples the transmitted microwave signal into the antenna run. Each such network is a series element of the waveguide run to the antenna. For the maximum of four broadband transmitters possible on one antenna waveguide run, two bays are needed, and the interconnection requires that the waveguide be looped through the first of the two bays to reach the second. For the fully equipped two-way station, one such pair of bays is required for the odd-numbered broadband channels and one for the even-numbered, for each direction.

4.4 *Radio Receiver Bay*

The broadband receiver bay appearing in Fig. 7 shows a somewhat different treatment of the panel design. Here the waveguide components are confined to the right side of the panel, while the left side is utilized for the IF main amplifier and equalizer. Again the channel separation network appears near the rear edge of the panel. Unlike the case of the broadband transmitter, four receivers can be mounted in the fully equipped bay, and looping of the antenna run through the bay is not necessary. Similarly, only half as many receiver bays are required for a station.

4.5 *Auxiliary Channel Radio Bay*

For the auxiliary radio channels, the transmitter and receiver for a send and receive pair to one side of a station are combined on a common panel, and two such panels are mounted in the same bay at a through station. The bay arrangement is shown in Fig. 8. Since the auxiliary channels comprise two pairs in each direction, representing four terminal

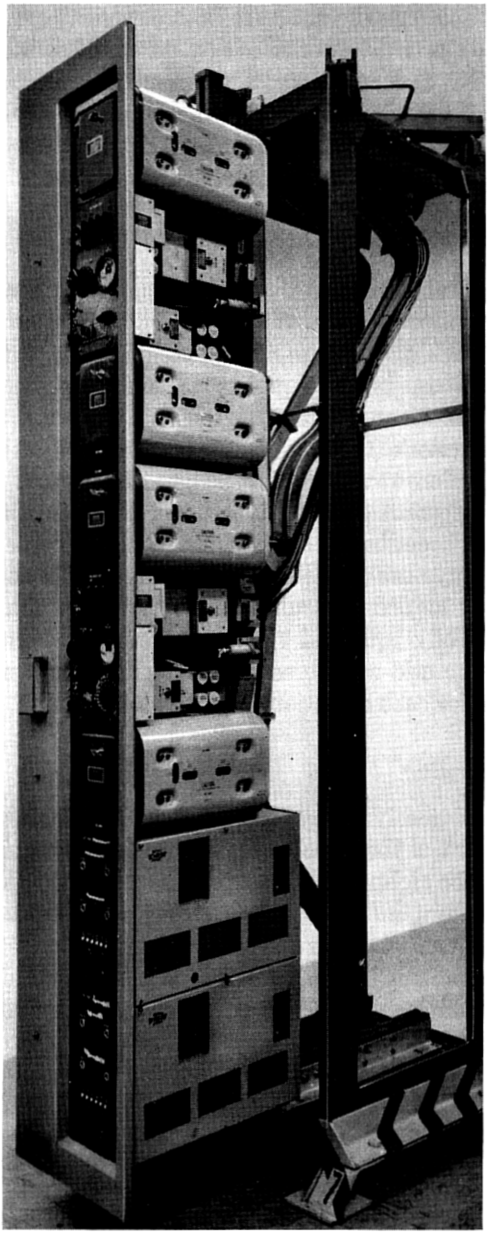

Fig. 6 — Broadband transmitter bay.

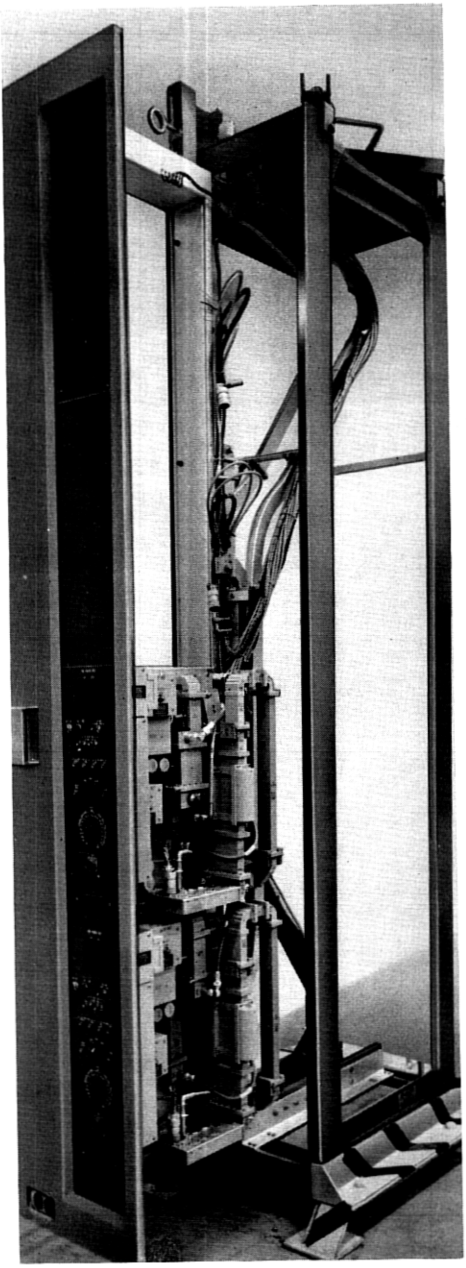

Fig. 7 — Broadband receiver bay.

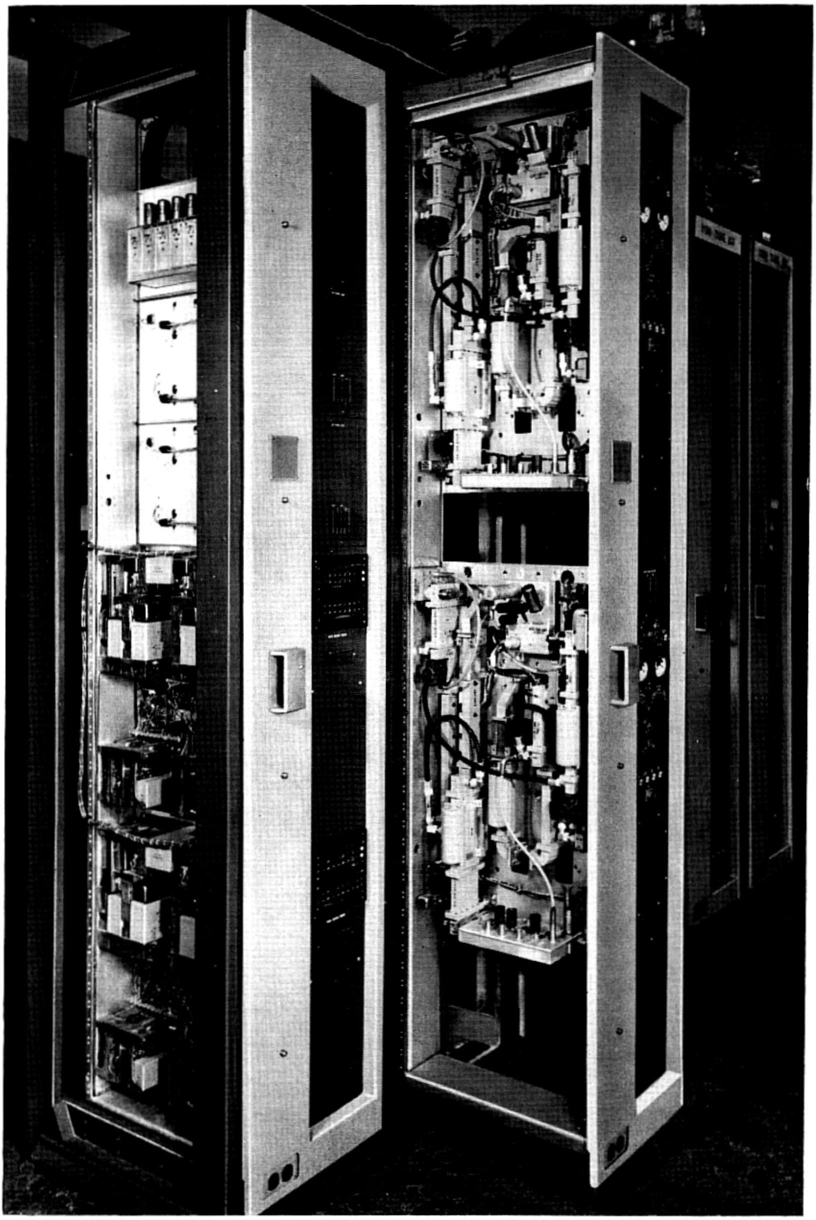

Fig. 8 — Bay arrangement for auxiliary radio channels.

pairs at an intermediate point, two bays of the type shown are required at such a station. When the station operates to one side only, two bays are required but are only half equipped. The channel separation networks for the auxiliary channels are not located on the panels but are placed in the horizontal waveguide runs in the space above the bays. Four waveguide connections serve two transmitters and two receivers in each bay. Since no more than four waveguide runs can be brought into one bay, the two microwave carrier supplies are brought in by minimum-length coaxial cables from transducers located immediately above the bay.

4.6 *Microwave Equipment Cooling*

In the radio transmitters and receivers and the microwave carrier supply, there are electron tubes requiring forced-air cooling to prevent overheating and subsequent shortening of tube life. The TWT amplifiers, in particular, must be provided with cooling air continuously. Loss of air on these tubes will result in severe damage to the tubes within a period of minutes and will disable the entire station. Accordingly, a

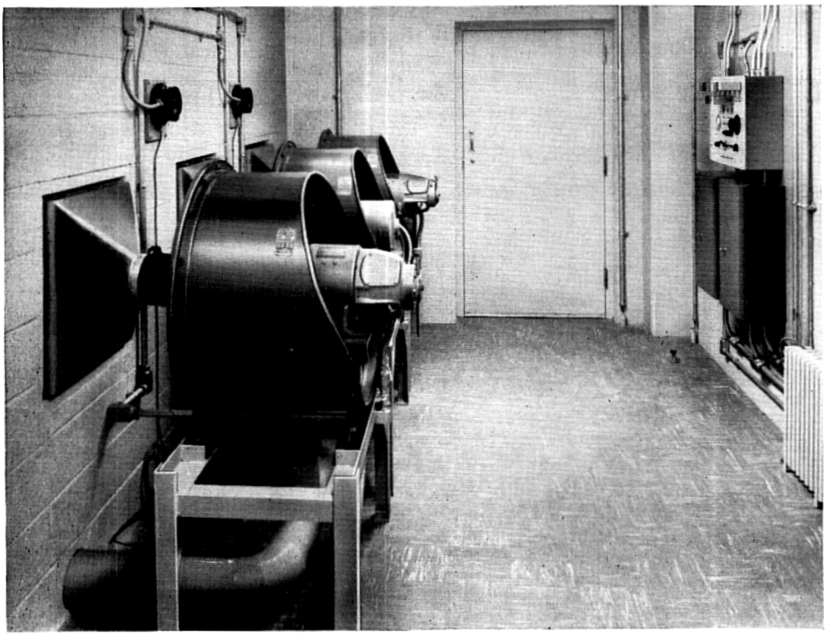

Fig. 9 — Typical blower system installation.

highly reliable central blower system supplies air to all of the transmitters and receivers and to the microwave carrier supply equipment for a full station of eight two-way channels. The capacity is adequate for maximum altitude and temperature conditions. As will be seen from Fig. 9, showing a typical blower system installation, three blowers are provided. These blowers are arranged to feed into a common duct assembly which, in turn, is connected to the duct provided in the base of the radio equipment bays. Since the spacing between the two radio bay line-ups has been standardized, a common blower duct assembly is used for all installations, thus realizing the economies inherent in the prefabrication of this assembly in the factory.

The use of three blowers and the power supply and control arrangements for these are the basis for the high reliability attained. In normal operation only one blower operates at a time, the back-flow through the idle blowers being blocked by automatic check valves in each blower output pipe. The primary blower is an ac powered machine which operates on the essential ac services supply for the TH station. The second and third blowers are dc machines which are driven, as ordered by the control circuits, from the 130V standby battery. The automatic control features perform the functions listed below.

Condition	Action
1. Loss of ac power	Immediately starts first dc blower and stops it on restoration of ac power.
2. Failure of ac blower for other than ac power failure	Senses reduction in air pressure and starts timing circuits associated with both dc blowers preparatory to starting. After approximately seven seconds starts first dc blower and halts timing for start of second dc blower.
3. Condition 2 plus failure of first dc blower	Completes timing sequence for second dc blower approximately 16 seconds after origin of condition 2 and starts second dc blower.

Alarms are reported for the conditions described above or for blower system failure. Only condition 1 is automatically reversible. Condition 2 or 3 locks the dc blower assigned in service until personnel can effect corrective action.

Since the air supply cannot be turned down after a station has been placed in service, special provisions have been made to permit the addition of bays to a line. Such additions are always at the end of a line away from the blower supply, and gaps in a line are not permitted. The duct through the base of the bays has a movable plug at its outer end. As each bay is added, the movable plug is unlatched and advanced by the increment of one bay. Since the sealing action of the movable plug is imperfect, a gasketed cap is placed over the duct on the last bay of the line to seal the opening.

Temperature control of the radio equipment is part of the effort which has been made in all parts of the TH system to improve transmission stability. To this end, the room ambient where the radio equipment is located is held within limits which will not allow the temperature of a waveguide filter or network to deviate more than ±10°F from the normal for that filter. The room ambient established is not necessarily critical, but it is expected that this will be within the range of 70° to 80°F. To meet this requirement, air conditioning is provided, in addition to the heating equipment normally furnished. Usually, the radio equipment is located in a separate room in order to reduce the air conditioning load requirements for the station. At stations where there is a need for air conditioning in the other areas, the radio equipment may be located in the same area with other equipment provided the temperature limits are satisfied.

V. FM TERMINALS

The FM terminals are designed for mounting on a conventional framework. This framework is the duct type which has been a Bell System standard for some years. The FM terminal with its power supplies on the 11-foot six-inch high bay framework is shown in Fig. 10. Also illustrated is the arrangement used for the plug-in units of the terminal. This general design is used for all active circuits of the terminal with the exception of the klystron oscillators in the transmitter. Insertion of the plug-in units automatically connects power and transmission leads and picks up cooling air when required.

The power supplies for both the transmitter and receiver are located at the top of the bay. Immediately below the power supplies is the FM transmitter, comprising six plug-in units and the klystron oscillator section. Jacks for access are located at the lower right of the transmitter. Below the transmitter appears a monitor and alarm control panel which serves as a mounting for the units monitoring the baseband amplifiers of both the transmitter and receiver. Provision is also made on this panel for alarm keys and lamps and appearances of test trunks.

The bottom portion of the bay is used for the FM receiver and a blower for cooling the equipment on the bay. The receiver requires three plug-in

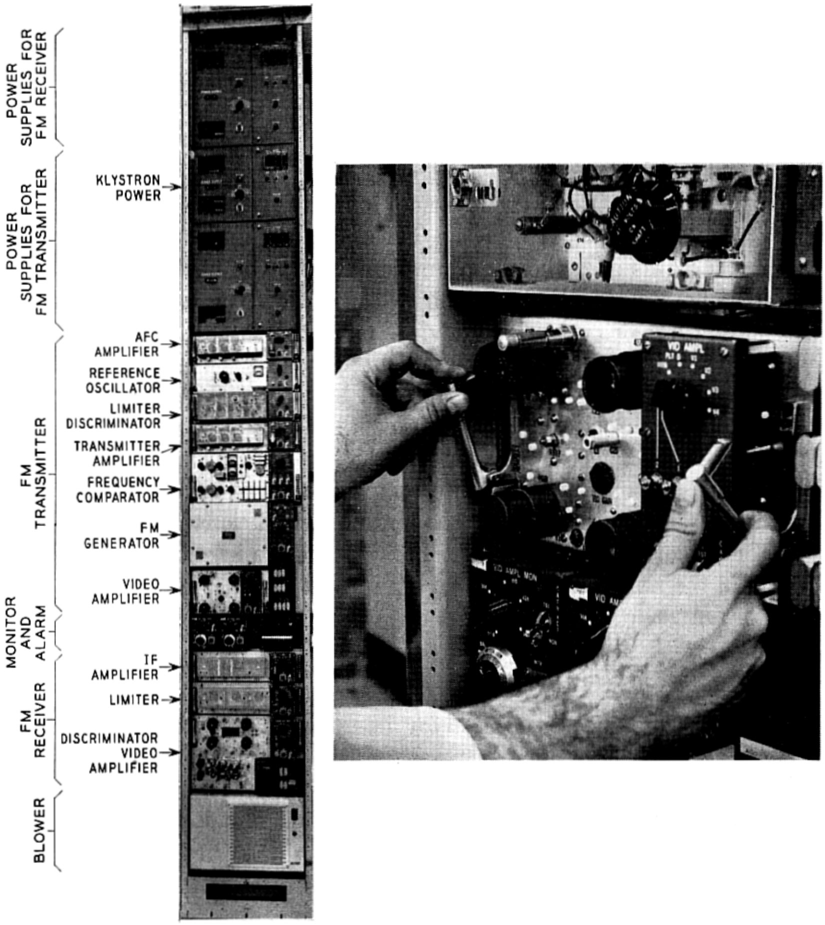

Fig. 10 — FM terminal bay; photo at right shows plug-in arrangement.

units, when fully equipped, and has provisions for access jacks similar to those on the transmitter.

The use of the blower unit for each bay is a marked difference from the tube-cooling system for the microwave equipment. Several factors entered into this choice, foremost being the flexibility desired in location of FM terminal bays and the difficulty of engineering and installing air-duct work for a common air supply. Also, the reliability needed in the air supply for the FM terminal is not so critical since loss of the air supply will not result in immediate damage. With the arrangement used, a supply pipe extends to the top of the bay from the blower unit. From this pipe, connections are made with plastic hose to the back of the units requiring cooling air.

VI. PROTECTION SWITCHING EQUIPMENT

Like the FM terminals, the protection switching equipment is mounted on 11-foot six-inch duct-type bay framework. Four types of bays are recognized, two of these being switching bays (baseband or IF) and the other two control bays (dc or tone control). The bays are always used in pairs consisting of one switching and one control bay, the manner of pairing being determined by the type of protection switching section

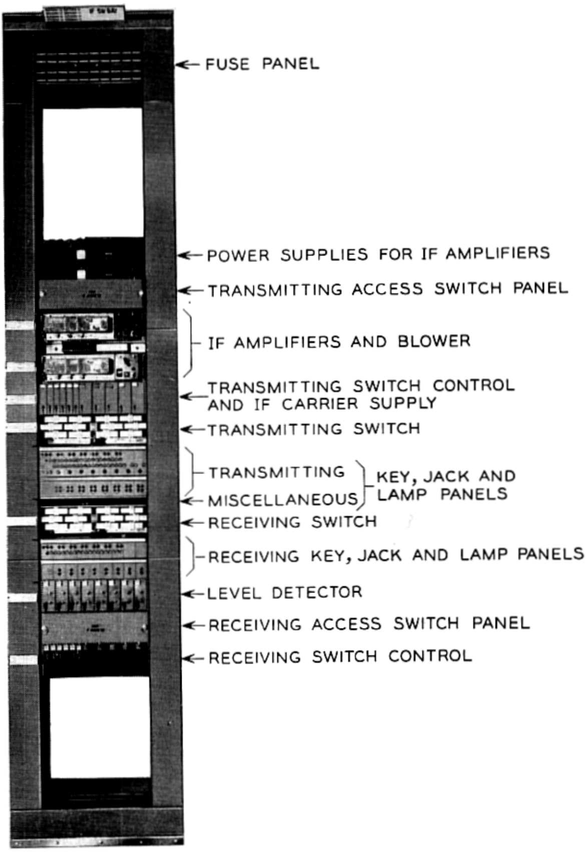

Fig. 11 — Intermediate-frequency protection switching bay.

to be served. Whatever the type of switching section, one pair of bays is required at each end and contains the equipment required to serve both directions of transmission within the section.

Four types of switching sections are possible, encompassing the allowable combinations of IF and baseband switching. Where FM terminals are involved, the choice of pairs of bays is dependent on whether the terminals are protected alone or in combination with radio links. This determines the method by which the ends of the switching sections communicate, one with the other. Where only FM terminals are protected, the switching section is baseband-to-IF (or IF-to-baseband), and both ends are located in the same building. Reports and orders between the ends are then provided by dc signals over station cabling. If radio links are included in the same switching section with FM terminals, the sec-

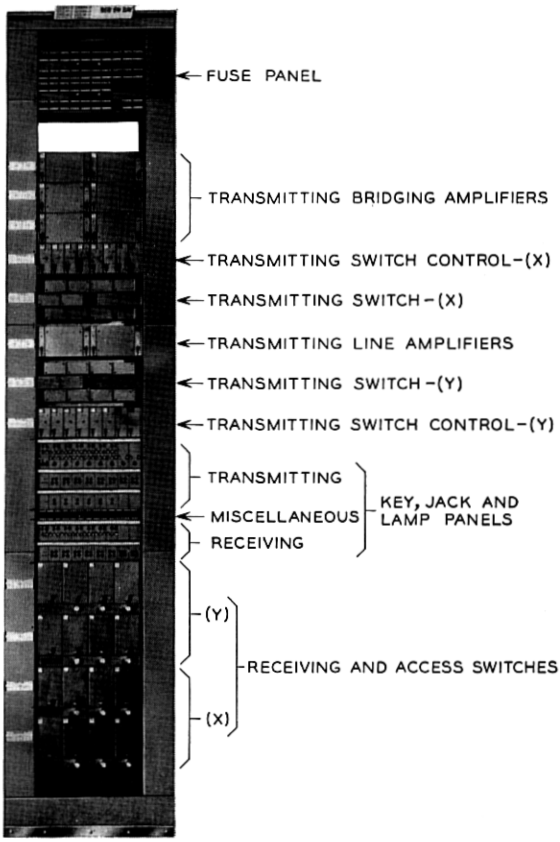

Fig. 12 — Baseband protection switching bay.

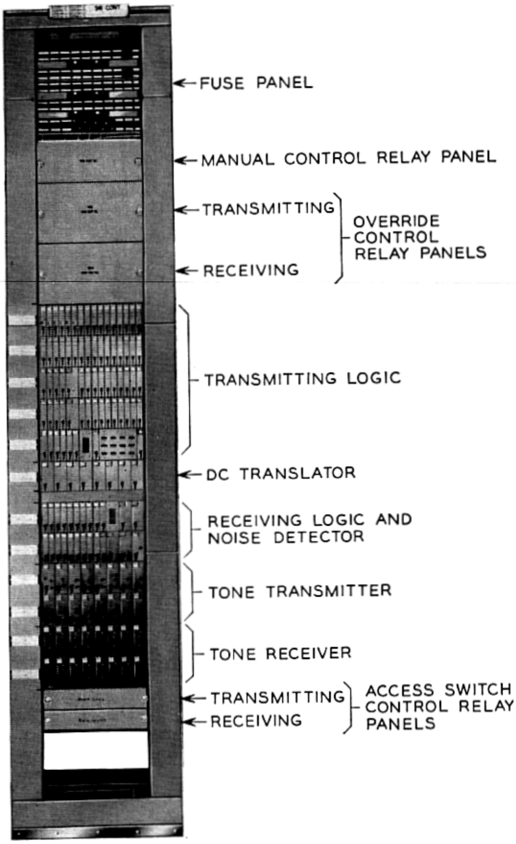

Fig. 13 — Protection switching control bay.

tion may be as above or it may include FM terminals at both ends with baseband-to-baseband switching. In either case, the communication between the ends is provided by a system of tones transmitted over the auxiliary radio channel. For protection of sections including radio links only, the same system of control tones is provided with IF switching equipment at both ends.

As implied above, the differences between the control bays lie in the equipment required for handling report and order signals and in the simplification of logic made possible with dc reporting. Thus, while the tone system requires a group of oscillators and detectors and a receive-end logic, the dc system employs dc reporter circuits, which can be wired directly to both ends of the section, and which reduce the receive-end logic to comparatively simple switch verification units.

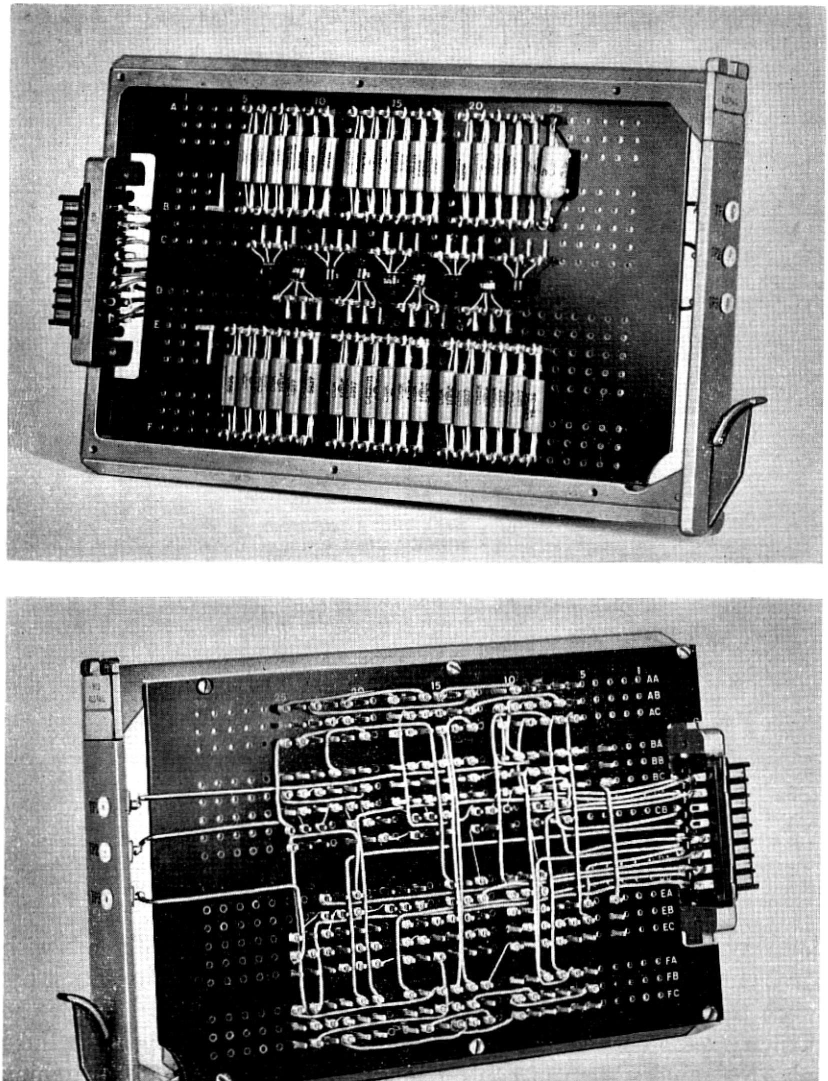

Fig. 14 — Views of a release-fail plug-in unit.

Three of the protection switching bays mentioned above are shown by Figs. 11, 12, and 13. The control bay for dc reporting is not shown since its general design is the same as that of its tone reporting counterpart. Examination of the bays reveals that there is a wide variation in the component units used in them. The more conventional are relay units and jack mountings. The IF switching bay also uses the same plug-in IF amplifier found in the FM terminal.

More than in any other equipment for the TH system, advantage has been taken of plug-in unit design for convenience in maintenance and additions. This is made possible by the extensive use of transistorized

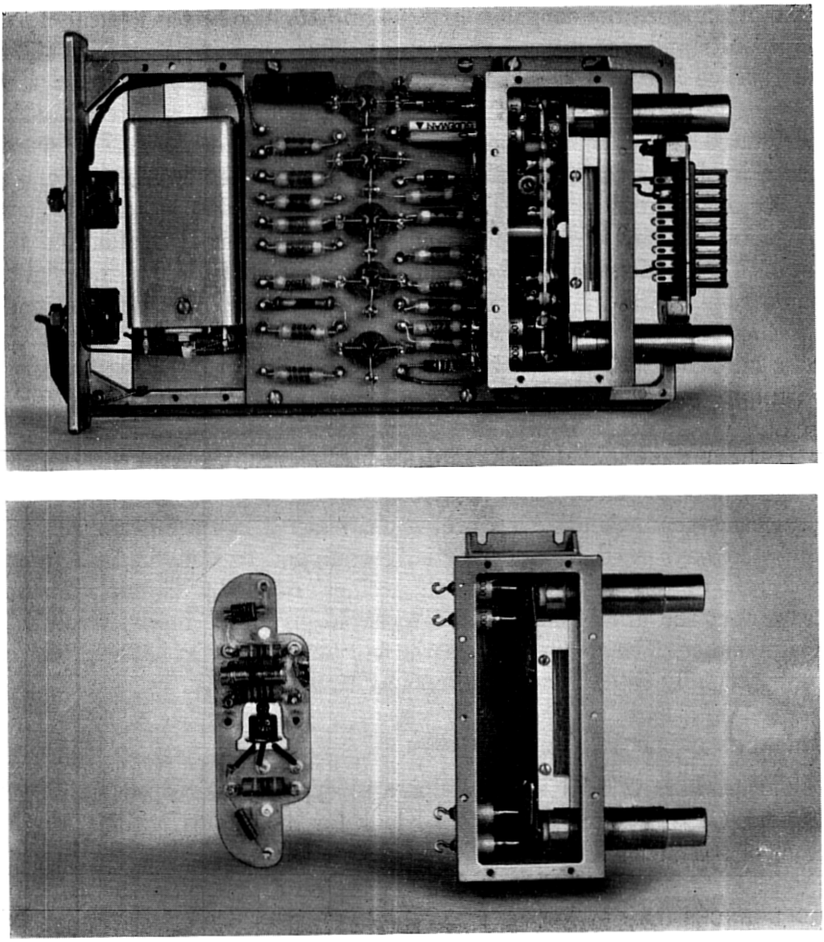

Fig. 15 — Views of an IF level detector unit.

circuits. For these, a basic design has been chosen which lends itself to a type of bookshelf mounting, wherein receptacles are affixed to the rear of the mounting compartment into which the units are plugged. The mountings are assembled such that the upper and lower members provide slider grooves at one-inch intervals horizontally and recesses into which latches on the units drop on insertion. The grooved parts are a single die-cast part which is used in all such applications.

The plug-in units are constructed on die-cast frames of which two basic sizes are used. The difference is in the face of the frames, which are available in nominal widths of one inch and two inches. Thus, one molding die with interchangeable slides for the face section can be used. Two of the units are shown in Figs. 14 and 15. The first is typical of the logic units and also several other units. The mounting board is a fiber part which is universally perforated to receive terminals designed specifically for the purpose. As many as 180 terminals can be inserted in the perforated grid. The components are mounted by their pigtail leads on one side of the board, and all wiring is placed on the opposite side.

The second unit is the IF level detector used in the IF switching bay (Fig. 15). In this design a two-inch face frame has been adapted for mounting circuitry involving a relay, as well as transistors and pigtail components. The unit also illustrates the introduction of coaxial connections to a unit while still maintaining the features of being completely plug-in. Other designs not shown make use of a pair of die-cast frames, with appropriate framework parts between, to build up units requiring greater volume than is provided by the two-inch face frame.

It should be noted that the bays illustrated are provided with all the plug-in units required for a complete protection group comprising two protection channels and six working channels. It is more often the case that the bays need be only partially equipped as delivered. In these cases, the unused positions of the mountings are filled with empty frames to protect the units installed and to avoid erroneous insertions during maintenance. The mountings on the bay are fully wired, and pairs of bays are fully interconnected for the ultimate growth.

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