100A Protection Switching System

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(Manuscript received July 12, 1965)

The 100A Protection Switching System is intended to ensure continuity of service in TD Microwave Radio Relay Systems by transferring service from a failed working channel to a standby protection channel. Switching is done at IF on a switching section basis. A switching section may contain up to ten radio repeater stations, with the average section containing three to four repeaters. A fully equipped 100A system provides means to replace any one of ten regular channels with either of two protection channels. Two regular channels may be switched simultaneously to the two protection channels. The circuit interruption due to a fade initiated or a maintenance switch is less than 10 microseconds. The interruption due to an equipment failure is less than 35 milliseconds, a time short enough to prevent false operations in the telephone switching plant. The control information necessary to sequence the operation of the switches at the transmitting and receiving ends of the switching section consists of coded voice-frequency tones. These may be transmitted over any reliable voice-frequency facility having suitable transmission and delay characteristics. All of the active devices in the system are solid state. The system requires sources of both +24 and −24 volt power.

I. INTRODUCTION

The high reliability demanded of microwave radio relay systems requires that protection be provided against system outages that occur as a result of fading or equipment failures. This protection is obtained by frequency diversity through the use of standby protection channels and an automatic protection switching system. Each radio relay route is divided into a number of switching sections, each of which may contain up to ten radio repeaters. One or two of the total number of radio channels in the switching section are designated as protection channels. The automatic protection switching system uses the protection channels to replace failed regular channels by operating IF switches at the transmitting and receiving ends of the switching section. By manual operation of the IF switches, the protection channels may also serve as alternate facilities during an emergency or while maintenance is being performed on a regular channel.

The original protection switching system developed for use with the long haul TD-2 system has a capability of protecting any one of the five regular working channels with one protection channel.[1] It was first placed in service in 1953 and since that time has given consistently good performance. About 1960 the TD-2 system was expanded to 12 channels through the use of channels placed interstitially with the original 6, and many routes are now equipped with both the regular and the interstitial channels. A second one-for-five switching system is, therefore, required to provide protection for these interstitial channels. However, a much better over-all protection switching arrangement results if the regular and the interstitial channels are combined into a two protection and ten regular working channel system, i.e., a two-for-ten system. By selecting the protection channels with maximum frequency separation, the chance of having at least one protection channel available during periods of heavy fading is greatly increased. Also, while one of the protection channels is being used to carry service during the maintenance of a regular channel, the second protection channel is available to guard against a failure of one of the remaining regular channels or the first protection channel. The 100A Protection Switching System was developed to fill this need of a two-for-ten system. The 100A system will operate with both the existing TD-2 system and the TD-3 system.

II. SYSTEM CONSIDERATIONS

Since the 100A system is intended for use with existing installations of TD-2 as well as new routes, its design must be compatible with existing system arrangements. Therefore, like the earlier one-for-five system, switching is done at IF on a switching section basis, and all of the monitoring, switching, and control equipment is confined to the transmitting and receiving ends of the switching section. However, since on some new routes, the radio system initially may have only one working channel, the 100A system must also accommodate radio systems with as few as one protection and one regular channel.

The IF switch at the transmitting end of the switching section bridges the regular channel to the protection channel. The IF switch at the receiving end transfers the channel output from the regular channel to the protection channel. The two IF switches at the ends of the section must therefore operate in proper time sequence to minimize service interruptions. It also follows that if a regular channel fails suddenly, time will be required to recognize that the failure has taken place and time will be required to pass the control information between the transmitting and receiving ends to operate the IF switches in their proper sequence. The total interruption time for an equipment failure has a lower limit determined by the length of the switching section and the type of facility used to pass the control information. In any case, the interruption will be long enough to cause a hit in data transmission. For the 100A system, a limit of 35 milliseconds has been set. Typically, most switching sections have equipment failure interruption times of less than 30 milliseconds.

Circuit interruptions due to equipment type failures occur less frequently than those caused by fading or maintenance switching. The maximum fading rate experienced on working systems seldom exceeds 100 db per second. In about 35 milliseconds (time to complete a switch) the channel has faded at this maximum rate an additional 3.5 db. Thus, in the case of a switch which is fade initiated, the receiving end transfer is made between a slightly degraded regular channel and a good protection channel. In the case of a maintenance switch, the transfer will be made between two good channels. In both cases the interruption time is dependent only on the transfer time of the receiving end switch. Through the use of diode type switches this interruption time is held to less than 10 microseconds, a time sufficiently short to prevent a hit for moderate speed data transmission, if the transmission times of the radio channels are equalized.[2]

Channel quality at any time is determined by the signal-to-noise ratio of the recovered baseband signal. This can be monitored in a number of ways. In the TH Radio System, the received carrier power at each radio repeater is monitored through the automatic gain control circuits. When the carrier power falls to a predetermined value resulting in a definite signal-to-noise ratio, a relay removes a tone on an auxiliary radio channel which also passes through the repeater station. The absence of this tone at the receiving end of the auxiliary channel is the signal for the switching system to initiate a switch. In the one-for-five system for TD-2, channel quality is determined by monitoring the baseband noise in a slot at about 9 mc, a frequency well above the top message frequency. A sufficient increase in the noise results in a switch request. This method allows all of the monitoring equipment to be concentrated at the receiving end of the switching section and removes the need to connect the switch controls into the auxiliary radio channel at each repeater. However, the baseband response over the switching section must be good to 9 mc to ensure a reasonably constant relationship between noise at 9 mc and noise at the lower baseband frequencies. Carrier is also monitored at the receiving end of the switching section in TD-2. This is done to protect against an equipment failure which might occur in the last radio repeater at a point where a noise initiated switch would not be called for. The TD-2 approach was adopted for the 100A system for the following reasons: (*i*) it has worked well with the earlier system, (*ii*) no auxiliary channel is available, and (*iii*) considerable modification would be required to each TD-2 radio repeater to provide the monitoring facilities.

Reliability is a major consideration in the design of a switching system. Circuits in the 100A system are very conservatively designed and use only solid-state devices. Alarms and indications are provided to call attention to a system malfunction or a prolonged switching operation. However, since many of the circuits in the 100A system are trigger circuits, i.e., one transistor of a pair is on while the second is carrying no current, an actual operating test is the only effective way of checking for a quiet failure. To check for these quiet failures, the 100A system includes an automatic test circuit (referred to as an exerciser) which once daily, or on request, makes and restores switches from all regular channels to each of the protection channels. If a switch operation is not completed within a predetermined time, the channel at fault is identified and an alarm is initiated.

The continuity of transmission through the switching section, however, depends not only on the switching system to carrying out normal switching activities, but also making the right decision in the face of abnormal conditions. One such abnormal condition would be a failure of the control line connecting the receiving and transmitting end equipment. The failure could include an open circuit condition, high noise, or interfering tones. Unless precautions are taken, all of these conditions could result in false transmitting end switch operations since the logic and master control point is at the receiving end and the transmitting end is a slave unit. In the 100A system each switch order consists of a two-tone code combination. These tone combinations are decoded by the transmitting logic. If the tone combination is a valid one and remains uninterrupted for a predetermined interval, then and only then, will a switch operation proceed. To guard against a high random noise level from simulating a valid order, noise level sensing circuits are used on the tone control line. These circuits prevent a switch action when the line is noisy.

Safeguards must also be built into the receiving end equipment to guard against a control line failure. Each switch order that is originated must be timed. If the logic at the receiving end of the system does not obtain verification that a switch operation is completed within the timing interval, then a new switch order to the second protection channel must be originated. If the second protection channel is not available, an immediate alarm must be given to the operating personnel. Similarly, if an order to take down a switch is not carried out in the required timing interval, the receiving end switch must be held operated and maintenance personnel must be warned. Therefore, the receiving end equipment must time and check the sequence of all its signal inputs. Any abnormal sequence of events, whether due to the control line or other system failures, must be processed, identified and translated to a warning to the maintenance personnel.

III. OVER-ALL SYSTEM OPERATION

A simplified block diagram showing the important interconnections of a typical one-way switching section using the 100A system is shown in Fig. 1. Transmission is from main station P to main station Q, over the ten regular channels designated A through J, and the protection channels designated X and Y. At the auxiliary station S, one or more of the regular and both protection channels are branched to provide a side leg TV drop facility. The switching equipment is confined to the two main stations P and Q and the auxiliary station S. All of the switching in the section is done at the 70-mc IF by means of fast acting diode switches which are shown symbolically as single-pole, double-throw switches. The automatic switching is initiated and controlled by the receiving end equipment at station Q. Switching at the transmitting and auxiliary stations is coordinated with the receiving end by means of tones transmitted over the voice-frequency facility which may be independent of the radio route. One voice-frequency line is required for each protection channel. A similar arrangement is required to provide protection switching for the opposite direction of transmission in the same switching section.

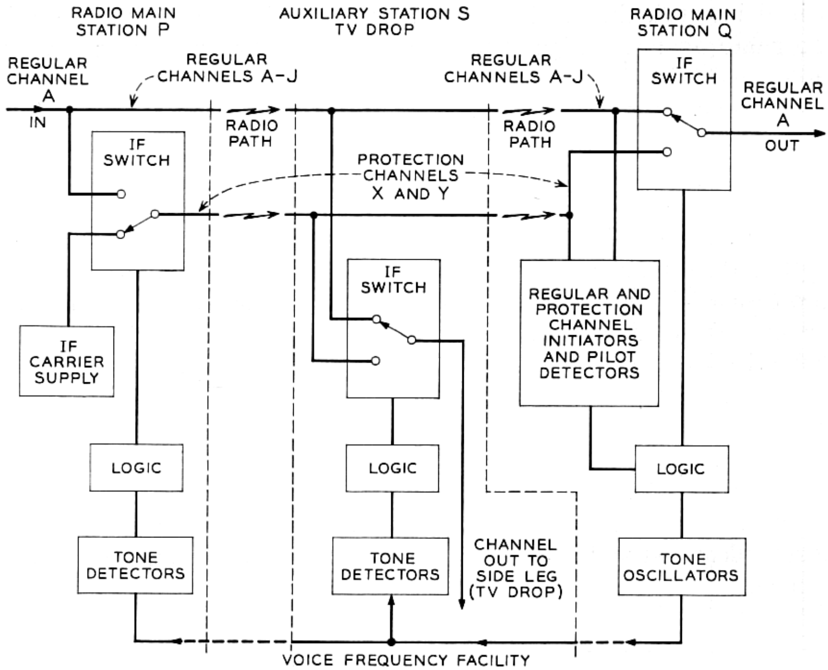

Fig. 1 — Switching section — simplified IF block diagram.

All the radio channels are monitored at IF at the receiving end of the switching section by initiators bridged to each of the channels. These initiators continuously measure the IF carrier level and the channel noise. If either should become unsatisfactory, a switch request is made if a regular channel is involved or a switch inhibiting order is originated if a protection channel is involved. If an initiator for a regular channel makes a switch request, the receiving end logic, in conjunction with the protection channel initiators and associated circuits, determines if a protection channel is available for service. If a protection channel is available, an order is sent by means of a coded group of order tones over the voice-frequency control line to the transmitting end. The transmitting end equipment decodes the order and bridges the failed regular channel to the selected protection channel. The auxiliary switching station also receives the order but no immediate action is taken.

The transmitting end bridge is made when the IF switch operates to provide transmission on both a regular and a protection channel simultaneously. Operation of the switch also removes the output of the IF carrier supply from the protection channel. The IF carrier supply provides the idle protection channel with IF carrier and a 7-mc pilot tone. The absence of the pilot tone, which is detected by the pilot detector associated with the protection channel initiator at the receiving end of the system, notifies the receiving end logic that the bridge at the transmitting end has been made. A receive end transfer is then made from the regular to the protection channel. After the transfer is made, a guard tone, which is normally present on the voice-frequency line, is removed. The absence of the guard tone tells the auxiliary switching station to complete the switch from the defective regular channel to the protection channel and provides an additional safeguard against accidental removal of the transmitting end bridge.

When the regular channel again becomes good, the receiving and transmitting end switches are restored. First, the receiving end switch is restored to its normal state. Then simultaneously, the switch order tones are removed and the guard tone is restored. This results in the removal of the bridge at the transmitting end, and the restoral of the transfer at the auxiliary switching station.

IV. SIMPLIFIED SWITCHING SYSTEM

A one-for-one protection switching system which does not require a voice-frequency control line is also provided as part of the 100A system. In this arrangement, a permanent bridge is made between the two channels at the transmitting end of the switching section. Switching between the regular and protection channels at the receiving end of the section is under the control of the two monitoring initiators and the receiving end logic. Switching and restoring is made without the delay caused by the transmission of the switching tones of the regular system. The simplified system may be expanded into a full ten regular two protection system by the addition of the voice-frequency facility and appropriate plug-in units.

V. RECEIVING END

Fig. 2 is a block diagram of the receiving end of the switching system. The regular and protection channels are taken from the IF interconnecting circuits through IF amplifiers to the IF receiving

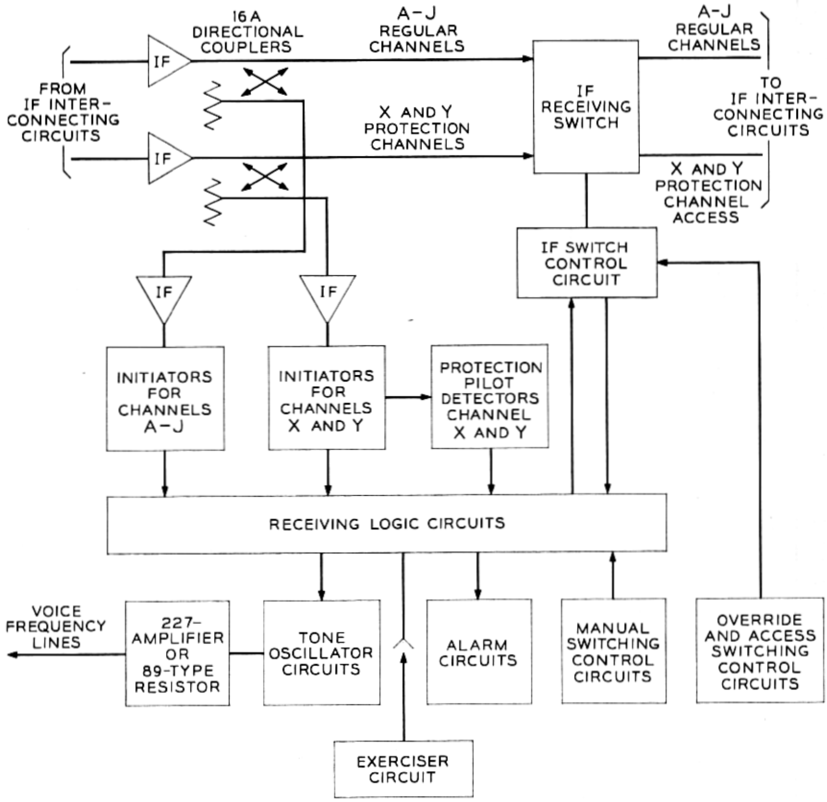

Fig. 2 — Receiving end block diagram.

switch. This switch acts as a transfer type switch allowing either the regular or the protection channel to be connected to the switch output. Also, provision is made in the switch to connect the output of the protection channel directly to external circuits, thus allowing access to the protection channel should it be required for emergency service.

The regular and protection channels are also connected to the initiators through directional couplers and level restoring IF amplifiers. The initiators monitor the channels for noise and carrier. The regular and protection channel initiators are identical, but are used at different sensitivities. The regular channel initiators are set to indicate that a channel is bad on noise corresponding to a 35-db fade in a nominal TD-2 radio repeater section. The protection channel initiators are set to indicate that a channel is bad on noise corresponding to a 33-db fade. Both regular and protection channel initiators indicate a bad channel on an 18-db drop in carrier. The difference in initiator channel noise settings helps to prevent unnecessary switching on previous section failures. When a previous section failure occurs, the regular channel initiators in succeeding sections may also indicate that the channel is bad and request protection. After the head end bridge is made in a succeeding section, the apparent simultaneous failure of both the regular and protection initiators is interpreted by the receiving logic as a previous section failure and no receiving end switch is ordered. It is important, therefore, that the protection channel initiator operate rapidly when a head end bridge is made to a noisy channel; this is obtained by setting the protection channel initiator to operate at a smaller depth of fade than a regular channel initiator.

Associated with each protection channel initiator is a pilot detector. This circuit monitors the 7-mc pilot tone normally present on the idle protection channel. The output signals from all the initiators and the pilot detectors are fed directly to the receiving logic circuit. These signals are used by the receiving logic to determine the operations of the switching system. The receiving logic controls the receiving IF switch through the IF switch control circuits. The switch control circuits in turn notify the receiving logic whether the receiving switch is operated or nonoperated. The receiving logic also controls the operation of the transmitting and auxiliary station switches by turning on the appropriate tone oscillators to produce the required order tone combinations.

The system may be controlled by the operating personnel directly through the manual switch control circuits or the override switch control circuits. The manual switch control circuits are located at the receiving end of the system only and control system operation by giving simulated channel good or bad indications to the receiving end logic. The override switch control circuits are located at both the transmitting and receiving ends of the system. They operate the IF switches directly by dc control voltages and override any of the normal logic and control. Manual switching is used to carry out all the normal maintenance switching. Override switching is used only when there is a voice-frequency control line malfunction or when the logic is being maintained.

The manual switch controls are on a per channel basis. To make a manual switch, the regular channel is made to look bad to the receiving logic independent of its actual condition. In addition to making and restoring switches, the manual switch control circuits may be used to inhibit switching to a channel by "locking" it out. "Lock-out" of a regular channel is accomplished by making it look permanently good to the receiving logic. Lock-out of a protection channel is accomplished by making it look permanently bad to the receiving logic. When a channel is locked out, no switching alarms are originated for that channel and, effectively, it is not a part of the switching system.

Like the manual switch controls, the override switch controls are on a per channel basis with the exception of a common control, the *status quo*. No override switch operation can be made until this control is operated. Operation of the status quo control at the receiving end of the system maintains the control voltages being applied to the IF switch control circuits by the receiving logic, disconnects the IF switch control circuits from the logic, and removes all tones from the voice-frequency line. Thus while *status quo* is operated, no automatic or manual switches can be made. Its operation, however, does not disturb any switches in effect. Subsequent operation of the override switch controls can make or restore switches from any regular channel to either protection channel, regardless of initial conditions. When it is desired to restore the system to automatic operation, the procedure depends on whether any override switches are in effect. If no override switches are in effect, it is only necessary to restore the *status quo* control. If override switches are in effect, then care must be taken to ensure that the same switches are being ordered by the receiving end logic. This can be obtained by use of the manual switch controls.

Override switching at the transmitting and receiving ends of the switching section are similar but completely independent. Therefore, to avoid circuit interruptions, override switch operations at the transmitting and receiving ends of the switching section must be properly coordinated by the operators.

The access switch control circuit provides a means of operating the IF switch so that a protection channel may be connected directly to the station IF interconnecting circuits for special uses. A protection channel must first be locked out through the manual switch controls before the access switch control circuits will function. Since a protection channel carrying service cannot be locked out, this interlocking circuitry prevents a service interruption caused by an inadvertent operation of the access controls on a busy protection channel. Operation of the access control also connects the initiator for the protection channel to the service failure alarm circuit. Thus, an immediate alarm is given should the protection channel fail while connected through the "access" terminals. The access controls at the receiving and transmitting ends are independent. Therefore, to complete the IF circuit through the switching section, access controls at the transmitting end of the system must also be operated.

The receiving logic initiates a number of alarms to warn maintenance personnel of abnormal situations. The most important of these is the service fail alarm. It is an immediate alarm and is given whenever:

(*i*) a regular channel requests a switch and a switch is not completed

(*ii*) a protection channel fails when it is protecting a regular channel and a second protection channel is not available

(*iii*) a protection channel fails while it is being used for special message or television service, i.e., protection channel access switches have been operated

(*iv*) the pilot returns to a protection channel when it is protecting a regular channel and a second protection channel is not available. The return of the pilot to the protection channel is an indication that the bridge between the regular and protection channel has been taken down, and the protection channel is no longer carrying service.

Other alarms are:

(*i*) a prolonged switch request alarm which is initiated if a regular channel has failed for longer than approximately 45 seconds

(*ii*) a prolonged protection channel failure alarm which is initiated if an idle protection channel fails due to excessive noise or loss of carrier, or the pilot disappears from the channel. The alarm is given after the trouble condition has been in effect for approximately 45 seconds

(*iii*) a switch release fail alarm which is initiated immediately if a switch cannot be restored.

The exerciser circuit performs a test routine once daily or on request. This test routine consists of checking the protection channel initiators and the normal automatic switching operations of the system, i.e., switching and restoring each regular channel to each protection channel. Initiation of the test switching operation is made by simulating noise and carrier failures in the regular and protection channel initiators. If a test sequence is not completed satisfactorily, an alarm is given and the exerciser disengages. Thus, the exerciser is able to minimize the possibility of a recurring system malfunction due to an undetected equipment failure which otherwise might exist for a long time.

VI. TRANSMITTING END STATION

Fig. 3 is a block diagram of the transmitting end IF switch and control circuits. Each regular channel connects through the low-loss arm of a 16A directional coupler. The high-loss arm of this coupler is connected to the transmitting IF switch. Operation of the IF switch will bridge a regular channel to one of the two protection channels. When a bridge is made, the protection carrier supply is disconnected from the protection channel. Access to the protection channels for special service is also gained through the IF switch. IF amplifiers are used in each of the protection channels to make up for the 20-db coupling loss of the 16A directional coupler and the loss of the IF switch.

Operation of the transmitting end IF switch is controlled by voice-frequency tone combinations generated at the receiving end and

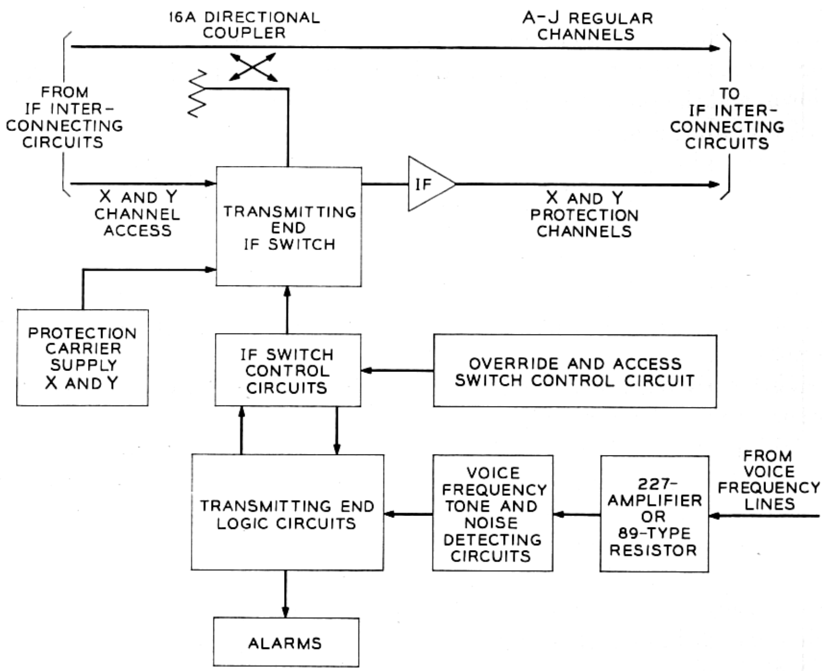

Fig. 3 — Transmitting end block diagram.

transmitted over voice-frequency lines, one for each protection channel. The tone combinations used on each voice-frequency line are identical. Six tones are used. One tone is used as a guard tone and is normally present when no switches are in effect. The other five tones are used in two-tone combinations to provide ten individual channel switch orders.

Detecting circuits determine the presence or absence of tones by voltage-sensitive circuits and frequency-selective networks. The outputs of the detectors are connected directly to the transmitting end logic where the order is decoded. A valid switch order consists of the combination of two and only two order tones and the presence of the guard tone. After the switch operation is completed, the guard tone is removed. A valid order for a switch restoral consists of the removal of the two order tones and the reinsertion of the guard tone. If the order is a valid one, the transmitting end logic operates the IF switch through the IF switch control circuits. These switch control circuits, which are identical to those at the receiving end, in turn, inform the transmitting logic of the completion of the bridging operation.

Also located at the transmitting end of the switching section are the noise detecting circuits. These circuits, one for each voice-frequency line, monitor the noise in an unused band. If the noise becomes excessive, the noise detectors send an inhibiting voltage to the transmitting end logic. Operation of the noise detector will prevent the system from either making or removing a bridge to the protection channel associated with the noisy voice-frequency line.

The transmitting end logic originates a number of alarms to indicate system malfunctions. Three of these alarms are associated with the voice-frequency line equipment:

(*i*) line failure alarm initiated by complete loss of tone

(*ii*) noise detector alarm initiated by an operation of the noise detector

(*iii*) invalid code alarm initiated by the receipt of an incorrect tone combination.

The remaining alarm which is associated with the IF switching is the transmitting prolonged bridge alarm. This alarm is initiated when a bridge has been in effect for longer than approximately 45 seconds.

VII. AUXILIARY STATION

The auxiliary switching station or TV drop switching equipment is a hybrid arrangement of the transmitting and receiving end equipments. The IF switch is a receiving type transfer switch and the logic circuits are almost identical to those at the transmitting end. The voice-frequency tone and noise detecting circuits are identical to those used at the transmitting end. Override switching controls are omitted. However, should it be necessary, the same function can be performed by IF patch cords between conveniently located jacks.

VIII. IF SWITCHES

The IF switches used at the receiving, transmitting, and auxiliary stations are almost identical both electrically and mechanically. Fig. 4 is a block schematic of the switch as connected for the receiving end of a switching section.

The basic switching unit used in the IF switch is the 8-type gate. The 8-type gate is essentially a single-pole, single-throw diode switch. In its ON state the gate has a through loss of less than 1.5 db. In its OFF state the gate has a through loss in excess of 85 db. Each of the regular channels is associated with a group of three gates. As seen in Fig. 4, the regular channel is connected directly to one of the gates. The other two gates are connected to networks associated with the two protection channels. Only one of the three gates is ON at a time. The outputs of the three gates are connected to a common output by means of a 499A network. This network maintains a good 75-ohm transmission path from the ON gate to the channel output.

Each protection channel connects directly to the common input of a "one-by-twelve" 4051A network. One 4051A network is used to serve each protection channel. Ten of the outputs of the network connect directly to associated gates of the regular channels. Of the two remaining outputs, one connects through a gate to a termination, the other through a gate to the protection channel access out jack. Only one of the twelve gates associated with each network may be ON at a time. Thus, the protection channel may be connected to one of the regular channel outputs, if it is being used for protection, or to the protection channel access if it is being used for special message service or to a termination if it is idle.

When a system is not fully equipped, i.e., not all 12 channels are used in the system, 509A terminations which simulate the impedance of an OFF gate are used at the unused ports of the 4051A and 499A networks. Like the 499A network, the 4051A network is a band-pass network which absorbs the stray impedances of 11 OFF gates while preserving a good 75-ohm transmission path from its input port to the ON gate.

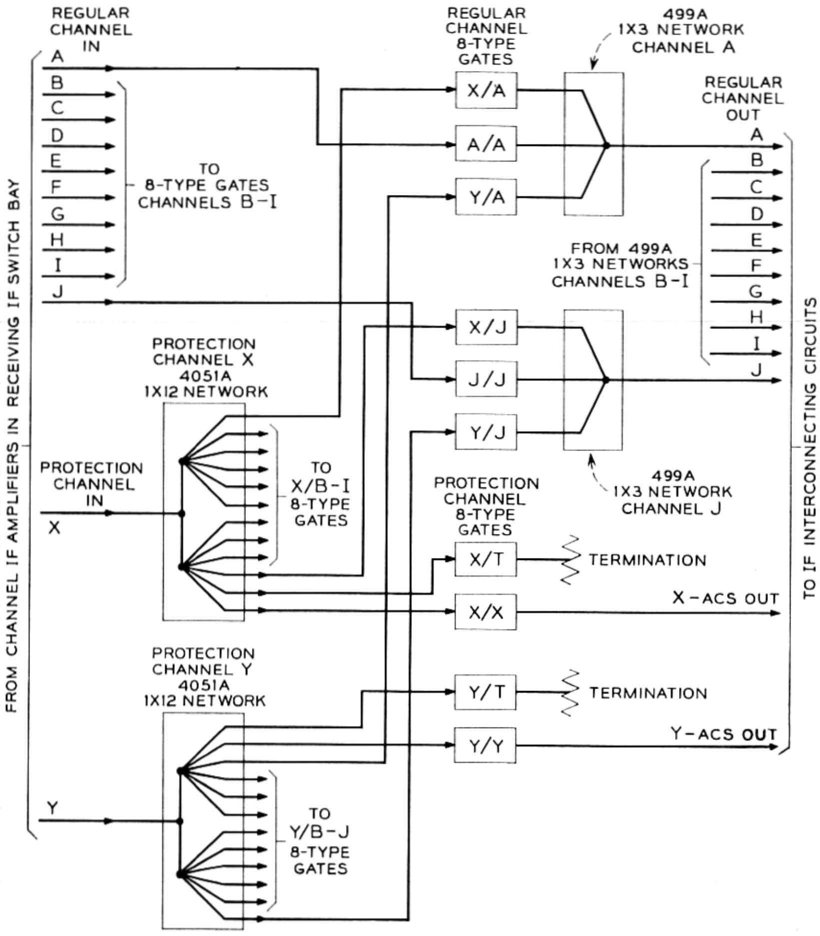

Fig. 4 — IF switch — receiving end.

The 8-type gate, 499A network, and 509A terminations were originally designed for use in the TH protection switching system. They are described in an earlier B.S.T.J. article describing that system.[2] The 4051A network, however, was specially developed for the 100A system. The electrical basis of its construction is simple and is an extension of the design of the 499A (1-by-3) network. However, in order to preserve symmetry, control the stray reactances, and provide a transmission deviation of less than 0.1 db over the 60- to 80-mc band, the mechanical arrangement of the components becomes much more critical. Fig. 5 is a photograph showing the internal construction of the network.

The IF switch at the transmitting end, which is shown in Fig. 6, is almost identical to that used at the receiving end. However, the direction of transmission through the switch is reversed. The high-loss arm of the directional couplers of the regular channel connect directly to the common port of the 499A networks. The common port of the 4051A network connects to the IF amplifiers of the protection channels.

Fig. 7 is a typical transmission characteristic for an IF switch. A photograph of a completely equipped IF switch is shown in Fig. 8.

IX. INITIATOR AND PILOT DETECTOR

A block diagram of the initiator and the pilot detector is shown in Fig. 9. The initiator is essentially an FM receiver with carrier and noise level sensing circuits. The pilot detector, which is used with the initiator on protection channels only, consists of a narrow-band 7-mc amplifier and level sensing circuit.

The input signal to the initiator is a sample of the 70-mc output of the final radio receiver of the switching section. The amplifier-limiter in the initiator suppresses any amplitude modulation present on the signal before applying it to the discriminator. The amplifier-limiter also provides additional automatic gain control to compensate for low limit gain IF amplifiers in the final TD radio receiver. Associated with

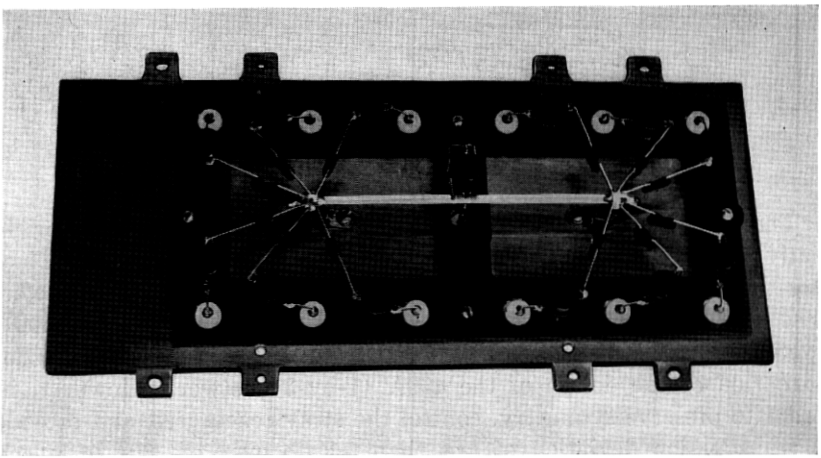

Fig. 5 — 4051A network.

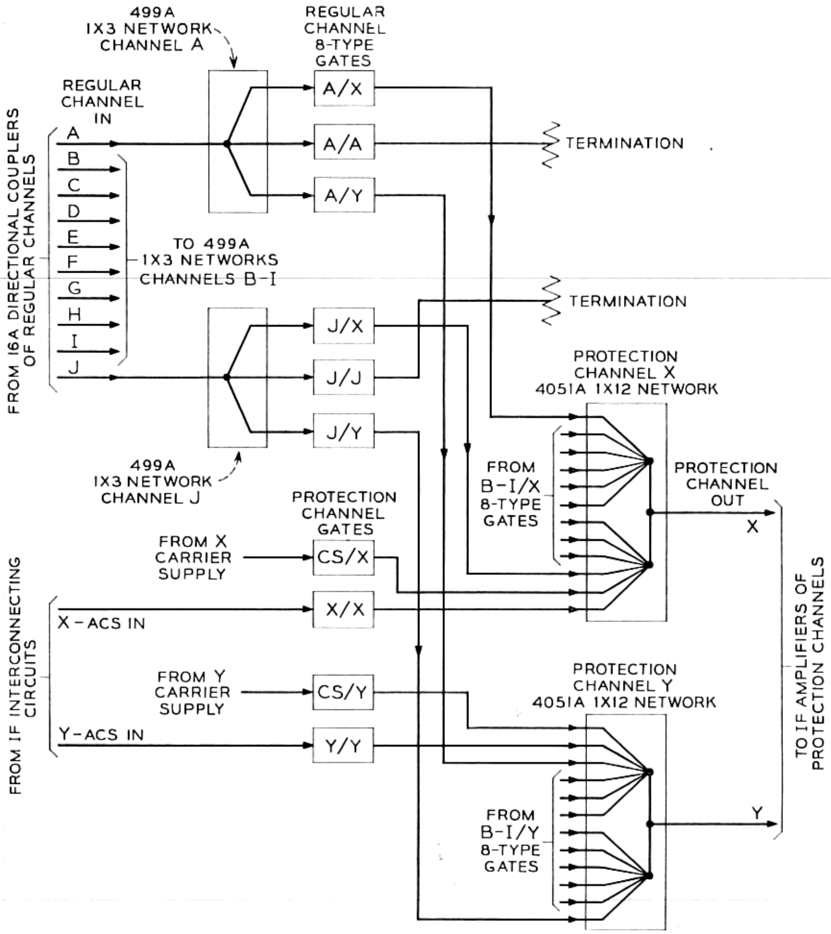

Fig. 6 — IF switch — transmitting end.

the amplifier is a narrow-band carrier detector whose output depends on the 70-mc input IF carrier power. The bandwidth of the carrier detector is so chosen that random noise will not simulate the presence of carrier.

The demodulated output of the discriminator is applied to both the pilot detector, which will be discussed later, and the noise amplifier detector portion of the initiator. The bandwidth of the noise amplifier is limited to about 100 kc at 9 mc by two similar band-pass filters. The output of the noise amplifier is applied to a noise detector. Its

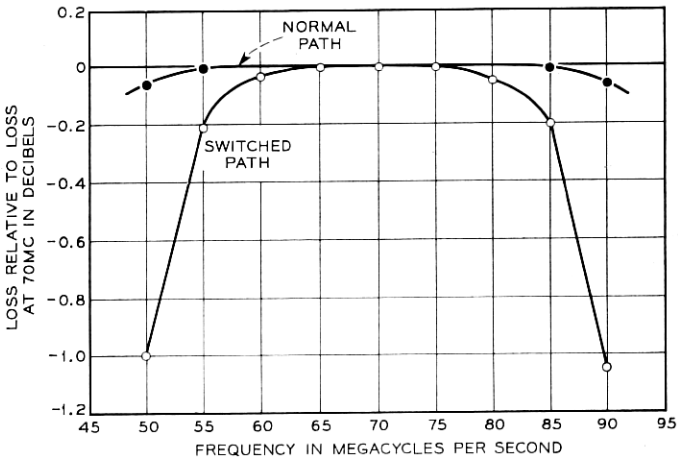

Fig. 7 — Typical transmission characteristic of the IF switch.

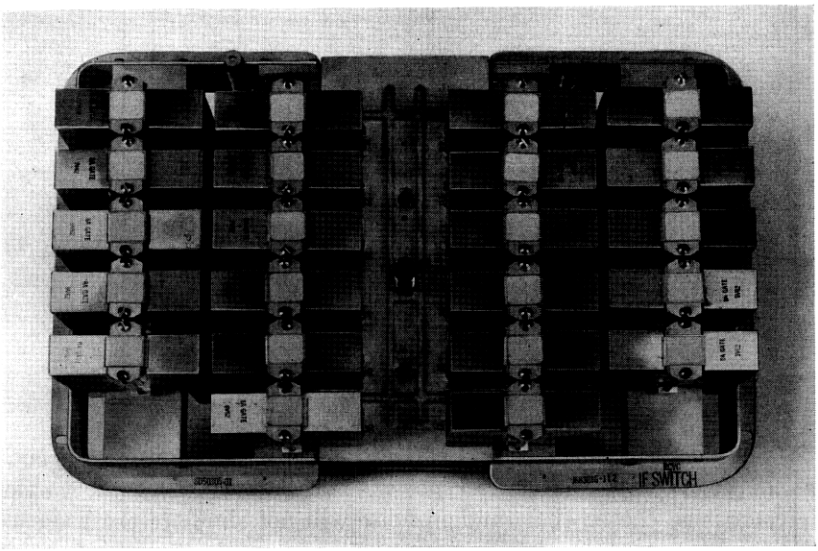

Fig. 8 — Typical IF switch.

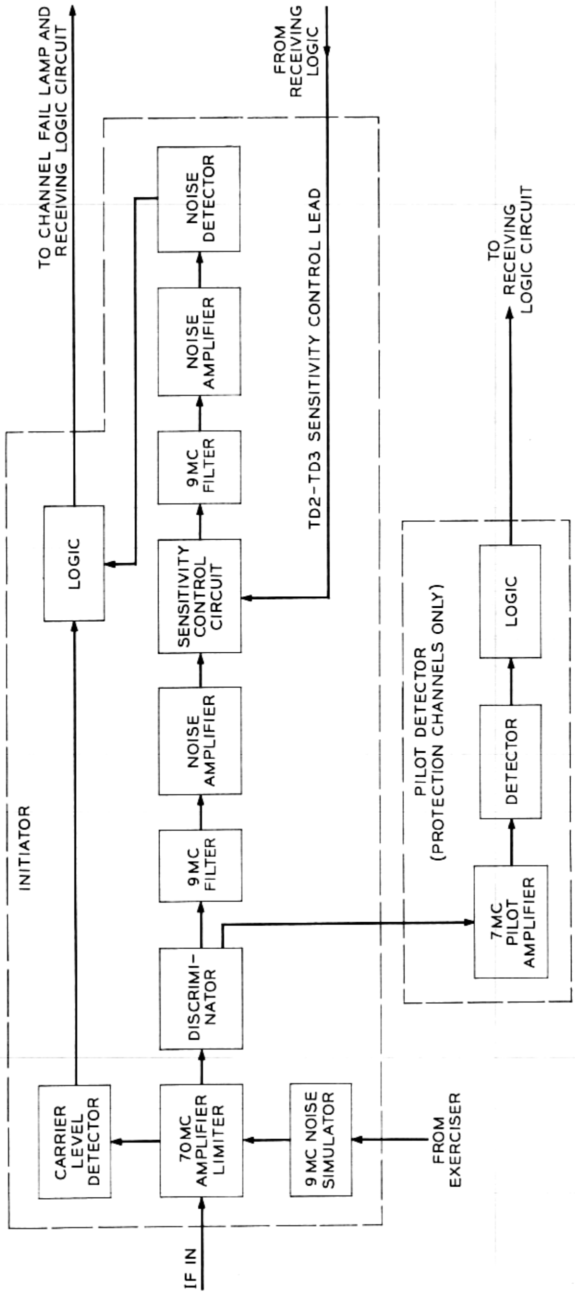

Fig. 9 — Initiator and pilot detector block diagram.

output, proportional to the noise at 9 mc on the radio channel, is applied to the initiator logic circuit. The initiator logic circuit provides a channel status signal to the receiving end logic circuit which is +8 volts when the carrier power is adequate and the noise level sufficiently low and 0 volt when the carrier power is low or the noise is high. Its output is also used to provide a channel fail lamp indication.

The amount of noise (at 9 mc) required to obtain a 0-volt output from the logic circuit is adjusted by means of the sensitivity control circuit. Since the initiator is intended for use with both the TD-2 and the TD-3 systems, separate adjustments and a TD-2 — TD-3 switch are provided. The sensitivity may also be changed automatically by the receiving logic. This is required when TD-2 and TD-3 radio channels are used in the same switching section. Since TD-3 will have a wider baseband spectrum and thus will carry more message channels, the protection channels must be comprised of TD-3 equipment. The sensitivity switch of the protection channel initiator must therefore be set to the TD-3 position since the TD-3 system has a lower thermal noise than TD-2. The lower thermal noise results from a lower receiver noise figure and higher transmitted output power. Should the protection channel be required to protect one of the TD-2 radio channels, the TD-2 sensitivity will be selected automatically. The necessary control voltage is provided by the receiving end logic when the switch is ordered.

The initiator also contains a 9-mc oscillator which is normally not operating. On a signal from the exerciser, the oscillator is turned on to simulate a noisy channel during a system test cycle.

Fig. 10 shows an initiator assembly. There are three parts containing the following circuitry. The right side contains the IF amplifier-limiter and discriminator; the left side contains the selective noise amplifier and detector; and the section in the middle contains the logic circuitry.

The protection pilot detector is also connected to the discriminator of the initiator, but is contained in a separate unit. It consists of a narrow-band (approximately 200 kc) 7-mc amplifier followed by a detector and logic circuit.

Table I gives a summary of the important operating parameters of the initiator and pilot detector.

X. IF AMPLIFIERS

The 100A system uses a solid-state IF amplifier design having a maximum gain of about 26 db. A manual gain control provides a

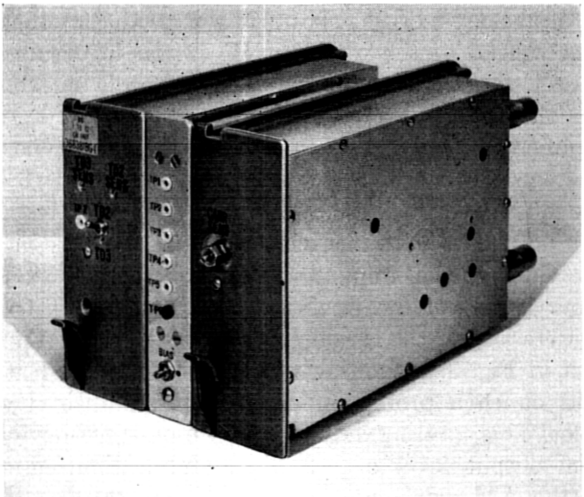

Fig. 10 — Initiator unit front end.

TABLE I — INITIATOR AND PILOT DETECTOR CHARACTERISTICS

Initiator Noise Detector	
Center frequency	9 mc
Bandwidth	140 kc at 3-db down points
Switch point (channel bad)	adjustable over 20- to 40-db fade TD-2 and TD-3 TD-2 position range: 30–50 db C/N* TD-3 position range: 45–65 db C/N*
Restore (channel good)	approx. 5 db from switch point
Initiator Carrier Detector	
Center frequency	70 mc
Bandwidth (nominal)	4 mc at 3-db down points
Switch point (carrier absent)	−3 dbm at initiator input†
Restore point (carrier present)	approx. 1 db above switch point
Pilot Detector	
Center frequency	7 mc
Bandwidth (nominal)	220 kc at 3-db down points
Nominal received pilot level	corresponds to 1.2-mc peak frequency deviation
Pilot absent point	14-db drop from normal pilot level

* Carrier-to-noise in 140-kc band.

† Corresponds to an 18-db drop in carrier level at the initiator 16-type directional coupler monitor. The IF amplifier used to compensate for coupler loss normally operates in compression.

gain range of at least 6 db. As shown in Fig. 2, an amplifier is used on each channel ahead of the receiving IF switch to ensure a fixed IF receiving level. An amplifier is used ahead of each initiator circuit to make up for the bridging loss of the couplers.

The amplifier has 7 grounded-base stages using 15-type transistors. Each interstage consists of a low-pass filter network which incorporates a broadband transformer.[3] The gain-frequency response of the amplifier is adjusted by means of variable resistances in two of the interstages. Gain of the amplifier is controlled by a variable resistance network in one of the interstages. A typical gain-frequency response characteristic of the IF amplifier is shown in Fig. 11.

As shown in Fig. 3, a limiting-type amplifier is used at the transmitting end on each protection channel to stabilize the protection channel pilot. This limiting amplifier is a nine-stage device providing a maximum output level of −2 dbm, and a limiting circuit that suppresses the AM sidebands by greater than 20 db. The nominal input level is −26 dbm. The output level is adjustable from −7 dbm to −2 dbm. The gain-frequency response is similar to that of the amplifier previously described.

XI. PROTECTION CARRIER SUPPLY

The protection carrier supply provides two frequencies differing by 7 mc, one at 70 mc and the other at 63 mc at a much lower level. By passing these signals through the limiter amplifier at the transmitting end, an FM signal is generated which is detected later by the initiator and its associated pilot detector at the receiving end.

A block diagram of the protection carrier supply is shown in Fig. 12. This unit is a plug-in assembly similar to the other IF units.

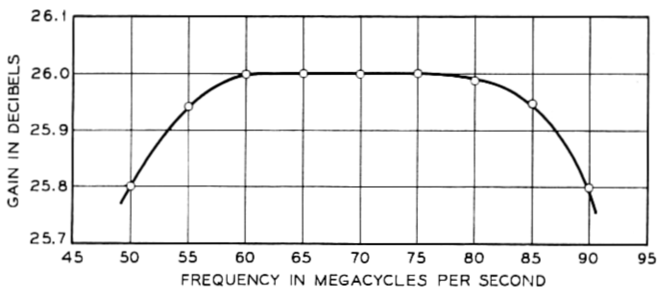

Fig. 11 — IF amplifier typical gain-frequency characteristic.

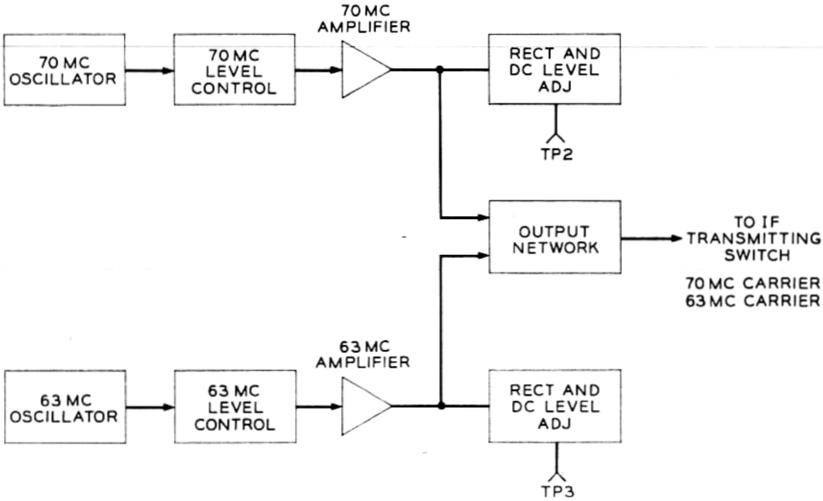

Fig. 12 — Protection carrier supply block diagram.

XII. RECEIVING LOGIC

The major portion of the logic and control circuits for the system is concentrated in the receiving logic. The receiving logic is made up of transistor resistor logic circuits, flip-flop storage or memory circuits, delay circuits, cross-connecting diode matrix circuits and gate circuits. These basic circuits are similar in design and operation to those used in the TH protection switching system.[2] For ease in servicing and maintenance, the circuit components are housed in plug-in units. There are twenty-eight types of plug-in units. A total of one hundred and ten plug-in units are required for a completely equipped receiving logic circuit serving a two-for-ten switching system.

XIII. ESTABLISHING A SWITCH

When a regular channel initiator indicates that a regular channel is not usable, its 0-volt output signal results in the operation of a status flip-flop memory circuit in the receiving logic. If a protection channel is available, a switch assignment is made by the receiving logic to that channel. The assignment circuits are so arranged that each regular channel prefers to be assigned to a particular protection channel. However, if the preferred channel is not available, the assignment will be made to the other protection channel. In the following description, it will be assumed that regular channel A has failed and has been assigned to protection channel X. At the time this assignment is made, a 50-millisecond switch initiation timing circuit is energized. For the duration of this 50-millisecond timing interval, a gate circuit opens the connection between the regular channel initiator and the status memory circuit. Also, for the duration of the interval, the protection channel X is marked "good" to those logic circuits involved in a normal A to X switch. Thus, once started, the switch is allowed time to complete. Also, at the time the assignment is made, an order is sent to encoding circuits to turn on two order-tone oscillators in the voice-frequency equipment. The arrival of the tones at the transmitting end of the system causes the transmitting logic to order an A to X bridge.

When the bridge is made at the transmitting end, the pilot on the X protection channel is removed. The loss of the protection pilot is detected by the X channel pilot detector at the receiving end. If the "no pilot" indication and the original A to X assignment order are both present, an order is sent to the receiving switch control circuits which, in turn, operate the receiving end IF switch to transfer service from channel A to channel X. When the switch control circuit operates, it generates a receiving switch verification signal which causes the X protection channel voice-frequency guard-tone oscillator to turn off. The removal of the guard tone provides an additional lock on the transmitting end bridge. The receiving switch verification signal also causes an A to X switch register and an X switch register to operate. These registers indicate the number of completed A to X switches and also the total number of switches to protection channel X.

The switch from A to X is now completely established. When the 50-millisecond time interval has elapsed, the regular channel initiator is reconnected to the channel A status memory circuit in the logic and the protection channel "mark good" voltage is removed. If channel A is still requesting a switch, the A to X switch is maintained by the receiving logic. The switching operation is now complete.

XIV. RELEASING A SWITCH

When the regular channel A recovers while switched to protection channel X, the output from the channel A initiator returns to its normal "good" voltage condition, the flip-flop memory circuit at the input to the receiving logic returns to its normal "no switch request" state, the switch assignment A to X is cancelled, and the receiving end switch control circuits are ordered to restore the receiving IF switch.

When the assignment is released, a 50-millisecond switch release timing circuit is started. For the duration of this 50-millisecond interval, the channel A initiator is disconnected from the input memory circuit of the receiving logic and the protection channel is marked "bad" to the logic circuits involved in a normal A to X switch. Thus, the switch is allowed time to release completely before the regular channel A can initiate a second switch request or before one of the other regular channels can initiate a switch to channel X.

When the switch control circuits operate, a signal is sent back to the receiving logic to verify that the receiving end switch has been restored to normal. If this verification signal and the X assignment release signal are both present, logic signals are generated which return all circuits to their normal "no switch request" state, turn off the two order-tone oscillators and turn on the guard-tone oscillator. This constitutes an order to release the transmitting end bridge and the auxiliary station switch.

When the transmitting end bridge has been released, the pilot is returned to channel X and the pilot detector at the receiving end so informs the receiving logic.

XV. FAILURE TO INITIATE A SWITCH

If a switch to a protection channel is initiated but for some reason the switch is not completed during the 50-millisecond switch initiation timing interval, the receiving logic will initiate a switch to the other protection channel. If the switch to the second protection channel also cannot be completed, a double switch initiation failure occurs. This results in the regular channel being automatically locked out, i.e., its switch request is not honored. However, at ten-second intervals, the lock out on the regular channel is removed and the receiving logic will again attempt to complete the switch. The process continues until the regular channel is locked out manually or the switch is completed. A more detailed description follows.

When an A to X switch is not completed at the end of the 50-millisecond timing interval, a 65-millisecond "switch initiation failure X" timing circuit is energized. For the duration of the 65-millisecond interval, channel X is marked bad to the logic and forces the assignment circuits to make an A to Y assignment. The A to X order is cancelled and an A to Y switch started in the normal manner. If, however, the A to Y switch is not completed at the end of the 50-millisecond switch initiation timing interval, then a 65-millisecond "switch initiation failure Y" timing circuit is energized. For the duration of its 65-millisecond interval, channel Y is marked bad. At this point, both protection channels are marked bad due to the overlap of the switch initiation failure intervals. The combination of the regular channel A status memory still requesting an assignment, and both the X and Y channels marked bad to the logic results in a "lock-up" in the assignment circuits. This lock-up prevents A from being assigned to either protection channel after the end of the switch initiation failure intervals. The locked-up state remains until an unlocking pulse is applied. This is generated by a circuit which provides a pulse once every ten seconds.

XVI. PREVIOUS SECTION FAILURES

When a regular channel fails or becomes excessively noisy, it may also appear failed in succeeding switching sections. The regular channel initiators will request a switch and the receiving end logic will order the head end bridge to be made. After the bridge is made, both the regular and protection channel will appear to be bad if the failure is in a preceding section. This apparent simultaneous failure is an indication to the receiving logic that the failure could be a previous section failure. The sequence followed by the logic under these circumstances depends upon the duration of the regular channel failure. If the channel recovers after the transmitting end is bridged, but before the end of the 50-millisecond switch initiation timing interval, the receiving logic performs the sequence for a temporary previous section failure. If the failure exists for more than 50 milliseconds, the receiving logic performs the sequence for a permanent previous section failure. In neither case is the receiving switch operated. However, one or both the protection channels will not be available for use while the receiving logic is carrying out these sequences.

16.1 *Temporary Previous Section Failure*

When the head end bridge is made, as the result of the previous section failure, the pilot detector will indicate removal of the pilot and the protection channel initiator will indicate a bad protection channel. Such a combination of signals in the receiving logic prevents the generation of a "no pilot" signal and the receiving end switch is not made. However, as soon as the regular channel recovers in the previous section, both the regular and protection channel initiators will indicate good channels. If the failure is of a temporary nature so that the channel recovers within the 50-millisecond switch initiation timing interval, the receiving end switch would complete were it not for an additional inhibiting circuit not normally used in the ordinary switching sequence. The inhibiting circuit used includes delay and sequence circuits. The delay is applied to the generation of the no pilot signal so that it cannot appear until about 3 milliseconds after the indication from the protection channel initiator is changed from bad to good. This ensures that the regular channel initiator output will always indicate "channel good" before the no pilot signal is generated. The output of the regular channel initiator and the no pilot signal are then combined in a sequence circuit. This sequence circuit provides a receiving switch inhibiting voltage when the regular channel becomes good before the no pilot signal is generated. Thus, a receiving end switch is prevented.

16.2 *Permanent Previous Section Failure*

A previous section failure, which lasts longer than 50 milliseconds, is interpreted by the logic as a failure to initiate a switch and the previously described sequence for failure to initiate a switch is carried out.

XVII. FAILURE OF PROTECTION CHANNEL

If the protection channel fails while not in use, it is not available for an assignment. However, if the protection channel fails while in use, the sequence followed by the receiving logic depends on whether it fails due to loss of carrier or excessive noise.

If the protection channel fails while in use due to loss of carrier, which will occur with equipment type failures, service will be transferred to the second protection channel. If the second protection channel is not available however, no action is taken. If the second protection channel is available, loss of the carrier results in the generation of an order to the assignment circuits to drop the original assignment and to make a new assignment to the second protection channel. The A to X receiving end switch is first released and then simultaneously the order to remove the A to X bridge and the order to establish the A to Y bridge is sent to the transmitting end of the system. Finally, when the transmitting end bridge is made and the protection pilot is removed, the new A to Y receiving end switch is made. It should be noted that during the switching sequence, the regular channel A was carrying service from the time the A to X receiving end switch was dropped until the A to Y receiving end switch was established. The degree of service interruption suffered will therefore depend upon the state of the regular channel. The maximum interruption time for the transfer from X to Y is the time taken to put up a normal switch which is approximately 30 milliseconds.

The receiving logic takes no action on a protection channel in use which fails due to noise. This design choice was made because of the undesirability of exchanging a slightly noisy channel for the circuit interruption involved in making the transfer to the second protection channel.

The return of the pilot to a protection channel while a switch is established to it is treated by the receiving logic as if the protection channel had failed due to loss of carrier, i.e., a transfer is made to the second protection channel. Return of the pilot may be caused by an equipment failure in the switching system or by the removal of the transmitting end bridge due to a false order from the voice-frequency facility. This false order, for instance, could be generated by the opening up of the voice-frequency line and the insertion of a test tone at the guard-tone frequency.

XVIII. TRANSMITTING END LOGIC

The transmitting end logic establishes and takes down bridges from regular to protection channels in response to signals received over the voice-frequency lines from the receiving end logic. A fully equipped transmitting end logic consists of a total of 19 plug-in units. The 19 plug-in units include five types of circuits, each of which is made up of combinations of gates, delay, and memory circuits. These individual circuits are similar to those used in the receiving end logic.

The transmitting end logic is made up of two similar groups of equipment, one controlling bridges to protection channel X, the other to protection channel Y. Each part receives its bridge orders from the tone detectors of the voice-frequency line associated with its respective protection channel. Both parts connect to the switch control circuits which, in turn, through the IF switches, set up the bridges between the regular and protection channels.

18.1 *Establishing a Bridge*

The outputs of the tone detectors connect directly to decoding and code validating circuits. An order for a bridge, for example from A to X, requires the presence of two order tones and the presence of the guard tone on the voice-frequency line serving channel X. The presence of this combination of tones results in an order at the output of the decoding circuits for an A to X bridge. However, the valid code circuit delays the order from proceeding to the switch control circuit for approximately 6 milliseconds. If the order remains without interruption for the full period, the valid code circuit allows it to proceed, otherwise an invalid code alarm is initiated and a bridge is not ordered.

When the A to X bridge is made by the IF switch, the channel X carrier supply is disconnected from the X protection channel and the IF switch control circuit sends a bridge verification signal back to the transmitting end logic. On receipt of the verification signal, a 30-millisecond timer is started in the transmitting end logic. The output of this timer circuit is coupled to the valid code circuit which, in turn, prevents any new order from proceeding to the switch control circuit during the timing interval, thus temporarily locking up the bridge. The removal of the pilot tone of carrier supply is an indication to the receiving end logic that the bridge has been made and the receiving logic then removes the X guard tone. When the absence of the X guard tone is detected at the transmitting end, an inhibiting voltage is generated, which locks up the bridge.

XIX. RELEASING A BRIDGE

Once a bridge is established, the two order tones must be removed and the guard tone must be restored in order to release the bridge. When the order tones are removed, the decoding circuits generate the order to release the bridge. However, as in the case of establishing a bridge, the valid code circuit prevents the order from proceeding for 6 milliseconds. At the same time, the return of the guard tone is detected by the bridge lock-up circuits. If the order to take down the bridge remains for the 6 milliseconds and the guard tone is still present, the order is allowed to pass to the IF switch control circuits. The IF switch then takes down the bridge and returns the carrier supply to the protection channel. Once the bridge is ordered released, the switch control sends a verification voltage to the transmitting logic and all circuits are returned to their normal state.

XX. VOICE-FREQUENCY EQUIPMENT

Table II lists the frequencies and the order-tone codes used to control the transmitting end bridges and the auxiliary station switch-

TABLE II—FREQUENCY AND ORDER TONE CODES

Tone Codes Required when Requesting a Switch Order

Noise Detector	Switch to X or Y	Code Tones					Guard Tone
	A	P	P	O	O	O	P
	B	P	O	P	O	O	P
	C	P	O	O	P	O	P
	D	P	O	O	O	P	P
	E	O	P	P	O	O	P
◀——▶	F	O	P	O	P	O	P
	G	O	P	O	O	P	P
	H	O	O	P	P	O	P
	I	O	O	P	O	P	P
	J	O	O	O	P	P	P
	No order	O	O	O	O	O	P
Freq. cps 900 1400		1615	1785	1955	2125	2295	2465

P designates presence of tone; O designates absence of tone.

ing. Two identical sets of six voice-frequency tones are used, one set for each of the voice-frequency lines. As discussed previously, one voice-frequency line is associated with each protection channel. When all of the radio circuits are normal, one of the tones, the guard tone, is present on each line. A two out of five selection of the remaining tones, the order tones, permits switch orders to be sent for any one of the ten working channels. The use of two tone combinations minimizes the possibility of setting up false bridges due to noise or interfering tones. However, false switch orders can occur if the noise becomes high enough in spite of the coding arrangement. For this reason, voice-frequency noise detecting circuits are used. These noise detecting circuits monitor the noise in a 500-cps band centered at 1150 cps. When the noise becomes excessive, the noise detector generates an inhibiting voltage. This voltage is applied to the logic circuits in such a way as to prevent any bridge or switch orders, false or real, from being acted upon at the transmitting or auxiliary station, respectively. At the same time an alarm is given. Thus, the noise detecting circuits guard the switching system against false signaling orders due to high noise on the voice-frequency line by maintaining the system in *status quo*. The noise detector inhibiting action is particularly valuable when a radio system is used to provide the voice-frequency circuits.

20.1 *Control Tone Source*

Six tone oscillators are required for each protection channel. Each tone oscillator circuit consists of a transistor oscillator, which is operated continuously, followed by a diode switch and a transistor amplifier. The switch which connects the output of the oscillator to the amplifier is under the control of the receiving logic. The output of the amplifier is connected by a resistive network to the other five circuits and to the voice-frequency line. A block diagram of the control tone source is shown in Fig. 13.

20.2 *Tone and Noise Detecting Circuits*

A block diagram of the tone and noise detecting circuits is shown in Fig. 14. A low-pass filter with a cutoff frequency above the highest tone frequency used provides protection against interference from any high frequency generated in the office where the detectors are located. Each tone detector is preceded by a voice-frequency amplifier and a band-pass filter which selects the desired tone. The outputs of the tone detectors are applied to the transmitting or auxiliary station logic circuits. The noise detecting circuit is similar to that used for tone detecting, except for the wider filter bandwidth. This wider bandwidth makes the response time of the noise detector less than that of the tone detectors. For this reason the noise detector will operate before tone detectors when a pulse of random noise is applied to the circuit.

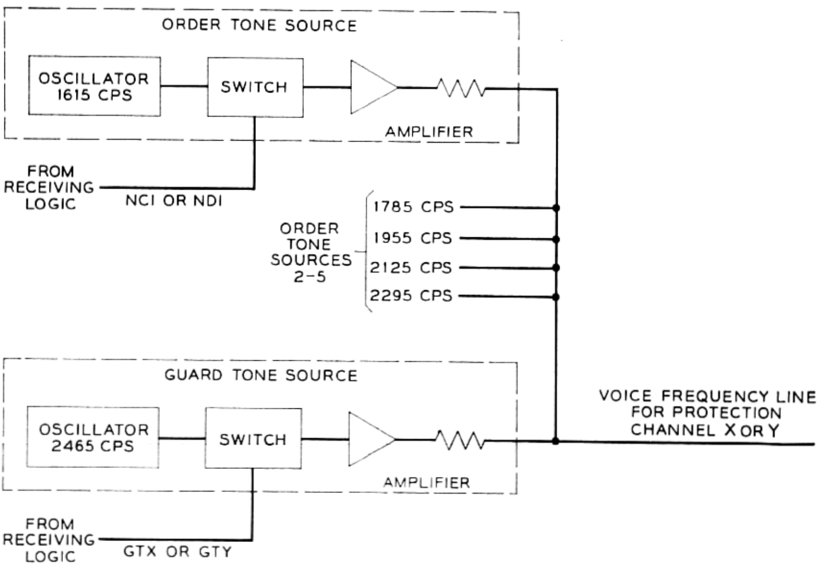

Fig. 13 — Control tone source block diagram.

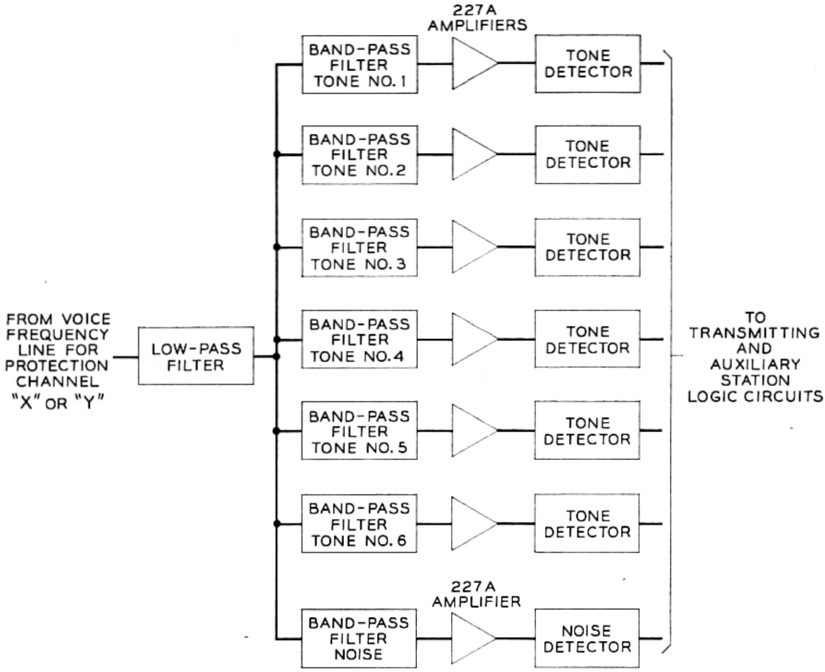

Fig. 14 — Tone and noise detecting circuits block diagram.

XXI. EXERCISER

The exerciser circuit performs test functions in the 100A Protection Switching System. A successful completion of its test routine indicates that when the initiator calls for a switch or a release that a satisfactory switch completion and switch release is made. An alarm is given by the exerciser if the test routine is not completed satisfactorily.

The test routine consists first of a check that the initiators on the protection channels are operating and indicating that the channels are good. A simulated carrier failure is then made on the first regular channel by applying a ground to the input stages of the initiator for that channel. By momentarily marking the "Y" protection channel bad in the receiving logic, the switching system is forced to provide protection by switching to the "X" protection channel. If evidence is provided by a verification signal from the receiving logic to the exerciser that the transmitting bridge and receiving switch were completed in the proper order, the switch is ordered to release. If the switch is released (also in the right sequence), the exerciser advances to the next channel. A similar procedure is followed for the remaining regular channels. Upon completion of this sequence, the exerciser then checks switches and switch releases to protection channel Y by simulating noisy regular channels. This is performed by turning on the 9-mc oscillator in the initiator of each regular channel in turn. The switches are forced to "Y" by momentarily marking the "X" channel bad in the receiving logic. An alarm is given if any switch or release cannot be made within a predetermined time interval or if a wrong sequence of operation occurs. For example, an alarm is given if a verification of a receiving end switch is received before a head end bridge is made. A visual indication shows which working channel and which protection channel are involved in the failure. The time taken for a test routine, if no source of trouble is encountered, is less than 5 seconds for a fully equipped system. The exerciser is arranged so that if a request for protection is made by a regular channel during the test routine, the exerciser will disengage in about 1 millisecond to permit normal operation of the system.

In addition to providing a test routine, the exerciser may be used to simulate a permanent failure of any one of the regular channel initiators on carrier or noise and so force a switch to protection. The exerciser may also be used to provide simulated channel failures repetitively. Both of these features are useful for system maintenance and troubleshooting.

The exerciser does not completely check out all of the operations the system is capable of performing. It will not check the procedure for previous section failures, transfer of a switch from one protection channel to the other should the first protection channel fail, etc. Tests to check these operations are performed during normal routine maintenance.

The exerciser uses a timing clock to start the automatic test routine. The clock may be set for one operation during a twenty-four hour period. The time selected for the automatic operation should be one at which minimum automatic switching is usually experienced. The exerciser assembly and its associated key and lamp mounting are shown in Figs. 15(a) and 15(b).

XXII. DESCRIPTION OF BAY EQUIPMENT

The protection switching equipment is mounted on bays which are completely shop wired and tested for ten regular and two protection channels. These bays may be partially equipped with plug-in units by the shop as specified on order by the customer. At the receiving end,

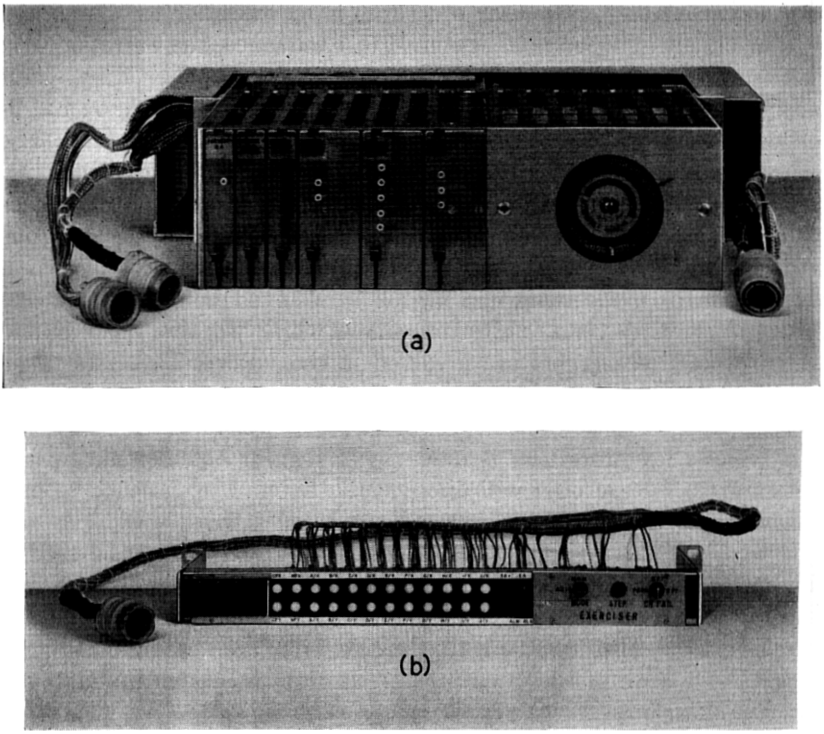

Fig. 15 — Exerciser: (a) assembly, (b) key and lamp panel.

two bays are required. The first is the receiving IF switch bay as shown in Fig. 16. This is a 9′-0″ duct type bay arranged to mount the IF switch and associated equipment together with initiators for the ten regular channels and two protection channels. The exerciser and its associated key and lamp panel are also mounted in this bay. The +24 volt and −24 volt supplies are obtained from a fuse panel which is mounted near the top of the bay. The fuse panel also distributes −20 volts which is a regulated voltage for operation of the IF plug-in units. The −20 volts is obtained from two pairs of voltage regulators mounted on this bay. An automatic transfer unit and a manual switch unit are provided with the regulators for maintaining a reliable regulated supply at all times. The second receiving end bay is the receiving control bay as shown in Fig. 17. This bay mounts the complete two-by-ten receiving end logic with its associated manual controls and tone oscillator facilities together with the voice-frequency line equipment associated with the transmission of these tones. Another fuse panel is

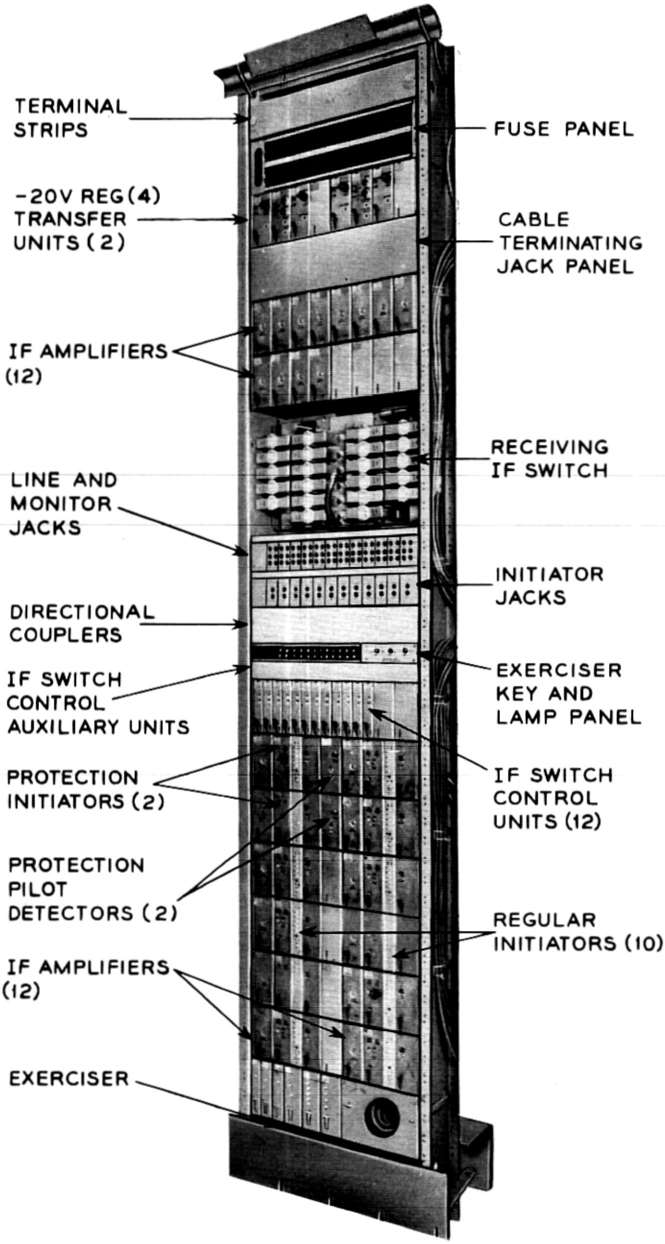

Fig. 16 — Receiving IF switch bay.

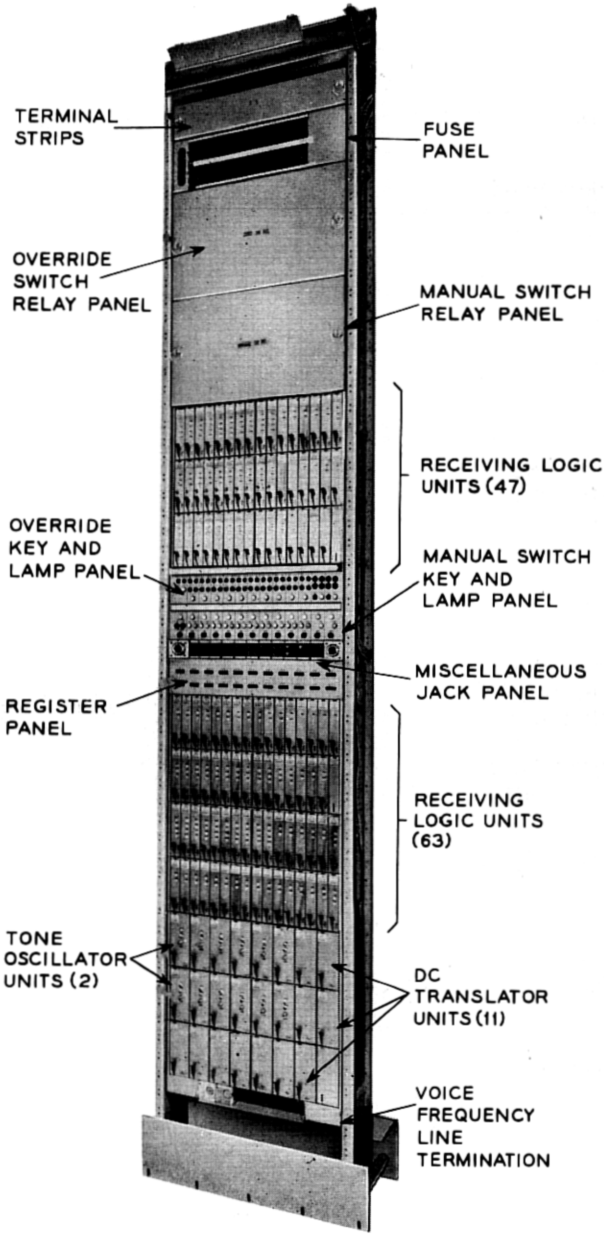

Fig. 17 — Receiving control bay.

provided for the distribution of the −24 volts and +24 volts required for the equipment in this bay. An override switch relay panel and a manual switch relay panel and their associated key and lamp panels are used to perform by manual operation the functions that are performed automatically by the logic circuitry. A register panel is used to record the number of switches that are made to the two protection channels. Dc translator plug-in units are used to provide sufficient current for lamp indications of alarms or failures detected by the transistorized plug-in units. A miscellaneous jack mounting is used to mount the alarm lamps and voice-frequency line jacks. Two test connectors are also provided on this mounting which provide a means of coupling the 100A test console to the receiving end logic circuitry for performing routine tests.

At the transmitting end, the transmitting IF switch and control bay shown in Fig. 18 mounts the IF transmitting switch and its associated IF switch control equipment. The plug-in units in this bay are the transmitting end logic, carrier supply, IF amplifiers, tone detectors, noise detectors, and dc translators. The voice-frequency line equipment for receiving the guard tones over the VF lines is also mounted here. An override switch relay panel and associated key and lamp panel are also provided for manual operation of the transmitting logic circuitry. A miscellaneous jack mounting contains the alarm lamps, voice-frequency line jacks and a test connector for performing routine circuitry tests.

The auxiliary station bay equipment is very similar to the arrangement for the transmitting IF swich and control bay with some minor differences. No override switch relay panel is furnished and the logic circuit uses an enabling and lock-up plug-in unit instead of a bridge lock-up unit. An auxiliary IF switch and control bay is required for each direction of transmission. Routine tests at an auxiliary station are fairly simple and are performed with a small plug-in test unit that checks out the logic functions.

XIII. DESCRIPTION OF UNITS AND PANELS

The major units in the 100A system are arranged as plug-in units. These units are primarily the ones containing active circuits that may require the most maintenance. In the event of a circuit failure, a failed unit can be readily replaced and thus reduce circuit outage time to a minimum. Other units are required that do not require as much maintenance and, therefore, can be permanently wired into the over-

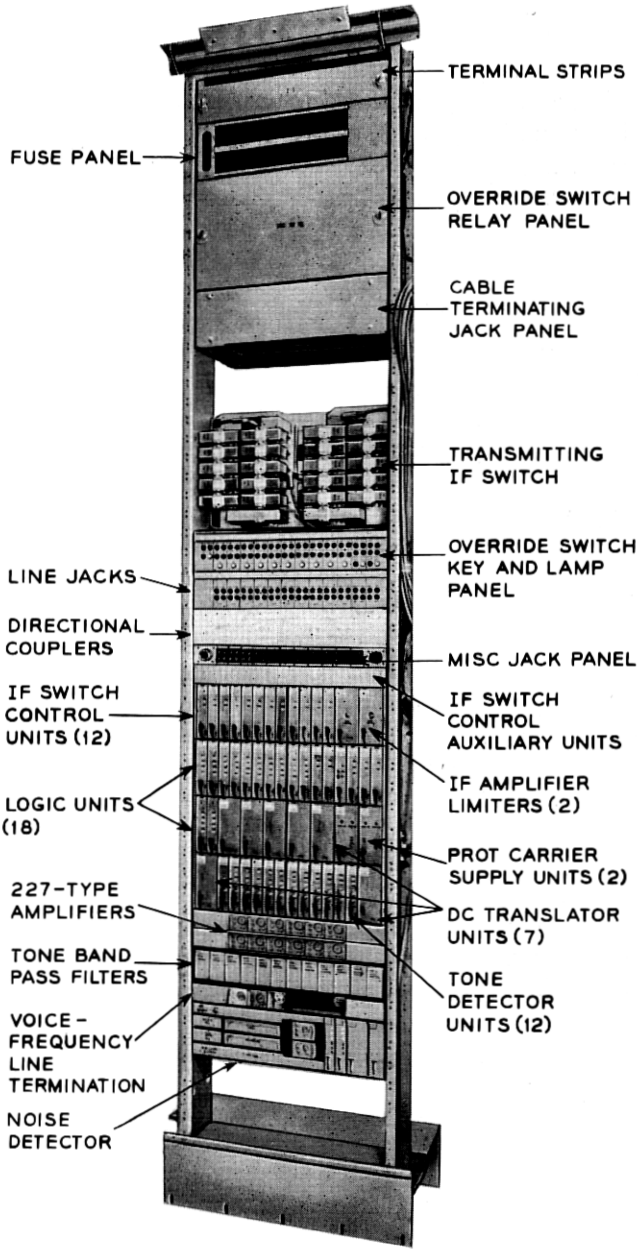

Fig. 18 — Transmitting IF switch and control bay.

all bay equipment. These units or panels are secured to the bay uprights and become part of the basic structure.

The 100A protection switching system plug-in units are of two types. The first is the open unshielded type which contains primarily dc circuits for logic, alarms, dc regulators, and transfer units as well as low-frequency tone oscillators and detectors. The second is the shielded type which contains all IF circuitry such as that required for amplifiers, carrier supplies, and other high-frequency circuits associated with the initiators.

Other units required in the bay arrangements are mountings for the plug-in units, VF line terminating equipment panels, fuse panels, jack and lamp panels, and relay panels for the override and manual circuitry.

XXIV. SWITCHING TEST SET

The switching test set which is used at the transmitting and receiving ends of the section incorporates most of the test equipment required for checking the operation of the 100A system and for testing its component parts. The equipment included in the test set is listed below.

(*i*) IF power meter
(*ii*) IF unit test panel
(*iii*) electronic counter with time interval counter
(*iv*) control unit test panel
(*v*) audio oscillator
(*vi*) electronic voltmeter
(*vii*) bay logic test panel
(*viii*) power supplies
(*ix*) dc voltmeter.

All units comprising the test set are mounted in the rolling console shown in Fig. 19. In addition to the test console, a high-frequency oscilloscope is required to perform certain tests.

24.1 *IF Testing*

The test set provides means to power the initiators, pilot detectors, carrier supply, and the IF amplifiers. The carrier supply oscillator frequencies may be checked with the counter, and the levels measured with the power meter. Initiator and pilot detector trip and restore points may also be checked. Transmission and return loss measurements of IF units are made using separate IF test sets generally available in the radio station while the IF units are being powered from the test set.

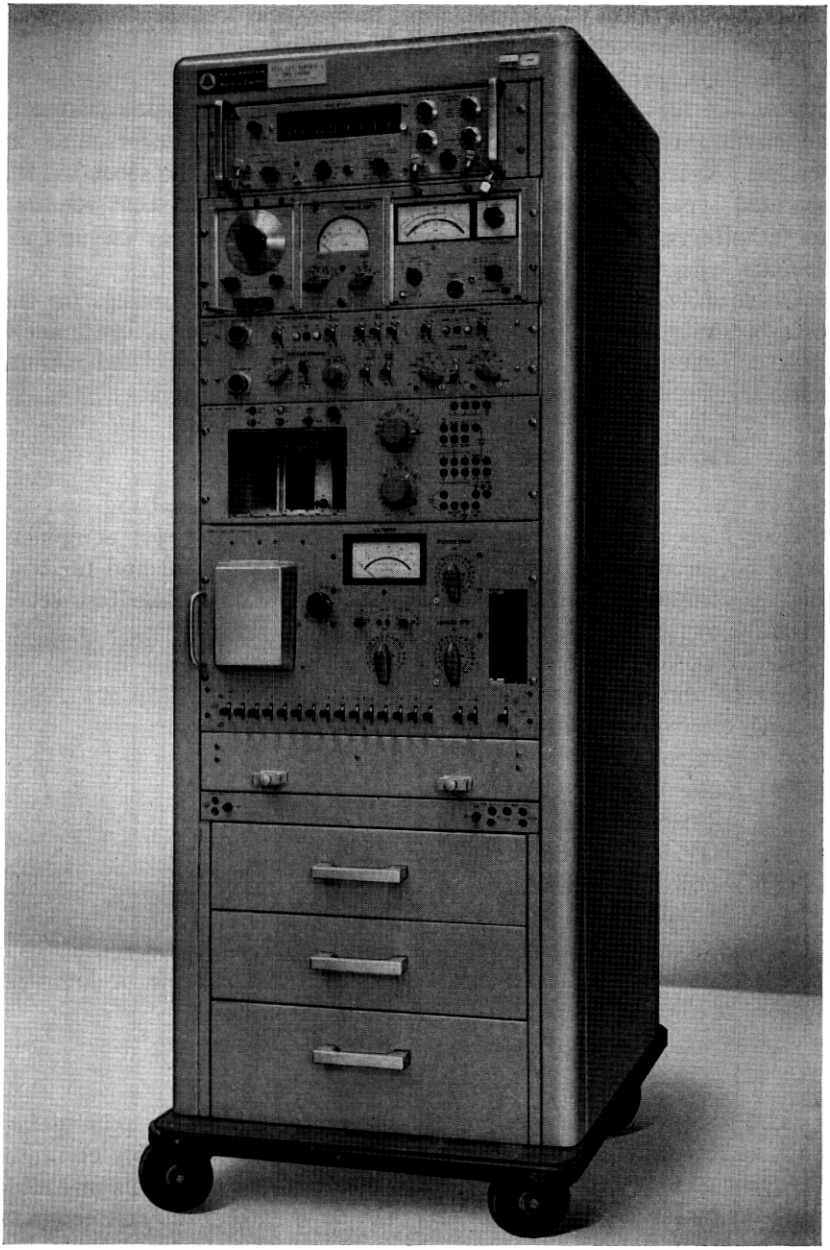

Fig. 19 — Test set console.

24.2 *Control Unit Test Panel*

The control unit test panel provides means to test all of the logic and control type units used in the 100A system. The unit under test is first inserted in a test slot. The proper input and output voltages for the unit under test are then set up automatically by a card reader and a perforated test card. Test keys are provided to change the test voltages in accordance with the required test sequences. Response of the unit may then be measured in terms of dc voltage, frequency or time interval by using the instruments in the test set.

24.3 *Bay Logic Panel*

The bay logic panel is used to check the operation of the transmitting and receiving end logic circuits. It is connected to the bay under test by means of a cable and test connectors mounted on the bay. The panel simulates the opposite end of the system to the bay under test, i.e., the transmitting end when the receiving end equipment is being tested and vice versa. By means of the operating controls, channel failures may be simulated on a manual or repetitive basis. The resulting operation of the logic may then be followed by means of the lamp display and the test oscilloscope. The switching system is always placed in *status quo* before the bay logic panel is connected, hence no actual system switching takes place during test.

At the auxiliary station, the testing of the logic circuitry is performed with a small plug-in unit which contains a set of switches for checking each channel individually. This arrangement is adequate due to the relative simplicity of the equipment.

24.4 *Voice-Frequency Tests*

The audio oscillator is used to provide tones to check the voice-frequency tone detectors, and the electronic voltmeter to measure received tone levels.

24.5 *Test Instructions*

A complete set of test instructions for each of the units, both logic and IF, are included in a file drawer in the test console.

XXV. POWER PLANTS

The 100A equipment requires sources of both +24 volts and −24 volts with battery reserve. Since the 100A system uses transistor-resistor logic circuits, the power source must be free of relay transients and excessive noise. In some stations −24 volt plants with adequate capacity are installed. These may be used providing the feed to the 100A is adequately filtered. Where −24 volts is not available, standard power plants may be used. A small +24 volt plant was developed specifically for the 100A application.

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