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TH-3 Medium-Haul Application:

Protection Switching

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This paper describes the 300A and the auxiliary channel protection switching systems which provide continuity of service on TH-3 medium-haul radio systems. Both protection switching systems operate on a one-by-one frequency diversity basis. The 300A is a baseband-to-baseband system and protects the message circuit load. The auxiliary channel switching system protects the order-wire and alarm circuits and operates at both IF and baseband frequencies. System design considerations and circuits of special interest, including solid state switches and integrated circuit modules, are discussed in some detail.

I. INTRODUCTION

Protection switching systems providing continuity of message service are a necessary part of many radio communication systems. For long-haul applications, the TH-3 radio system uses the 100A IF-to-IF protection switching system for the radio portion of the system and the 200A IF-to-baseband and baseband-to-IF protection switching system for the FM terminal and entrance link portion of the system.[1] Two separate switching systems are required since switching sections are often connected in tandem and converging radio routes are often interconnected at IF frequencies. For medium-haul applications, the TH-3 system is generally comprised of a single switching section with FM terminals at each end. Therefore, baseband-to-baseband switching encompassing both the radio and baseband portions of the radio system is a more optimum arrangement. In addition, since the growth of service on most medium-haul installations is expected to be relatively slow, a single radio channel of the message capacity of TH-3 should be adequate for many years. Therefore, a system having one regular channel carrying service and one protection channel serving as a backup is appropriate. To meet these needs, the 300A, one-by-one, baseband-to-baseband, protection switching system was developed.

In this system, the two radio channels are permanently bridged at the transmitting end of the switching section and are switched at the receiving end of the system. The receiving end equipment includes a non-revertive switch, channel monitors, and control functions. A detailed description of the 300A system is given in Section II.

The auxiliary radio channel is part of the total message load carried by the TH-3 medium-haul system and has a protection switching system which is separate from the 300A system.[2] The auxiliary channel provides circuits for use within the switching section to carry order-wire, alarm, and control information. These circuits have appearances at each of the radio stations along the route. For reliability of service, the auxiliary channels are inserted on both the regular and protection channels of the radio system. The auxiliary channel protection switching equipment at the receiving main station determines whether the auxiliary channel demodulating equipment is connected to the regular or the protection channel. The repeater station protection switching is slaved to the main station equipment and operates in synchronism with it. The auxiliary channel switching system is described in Section III.

II. 300A PROTECTION SWITCHING SYSTEM

2.1 *System Considerations*

A one-way switching section utilizing the 300A system is shown in Fig. 1. The section includes one or more radio hops with FM terminals and wire line entrance links at each end. The entrance links may be connected external to the switching system if desired. The transmitting end of the 300A system feeds the baseband signal over both channels by means of a hybrid transformer. The hybrid also couples a continuity pilot oscillator to both channels. A switch provides access to the protection channel for emergency restoration or for other purposes. The function of the receiving end is to monitor the quality of the channels, perform the required logic and control functions, and to switch between the two channels.

An innovation of this system is that the channel monitors used to determine channel quality are located after the receiving switch. The advantage of this arrangement is that the switch in the 300A system is protected by the switching system. As a consequence of this arrangement, the channel monitors are not associated with a particular radio

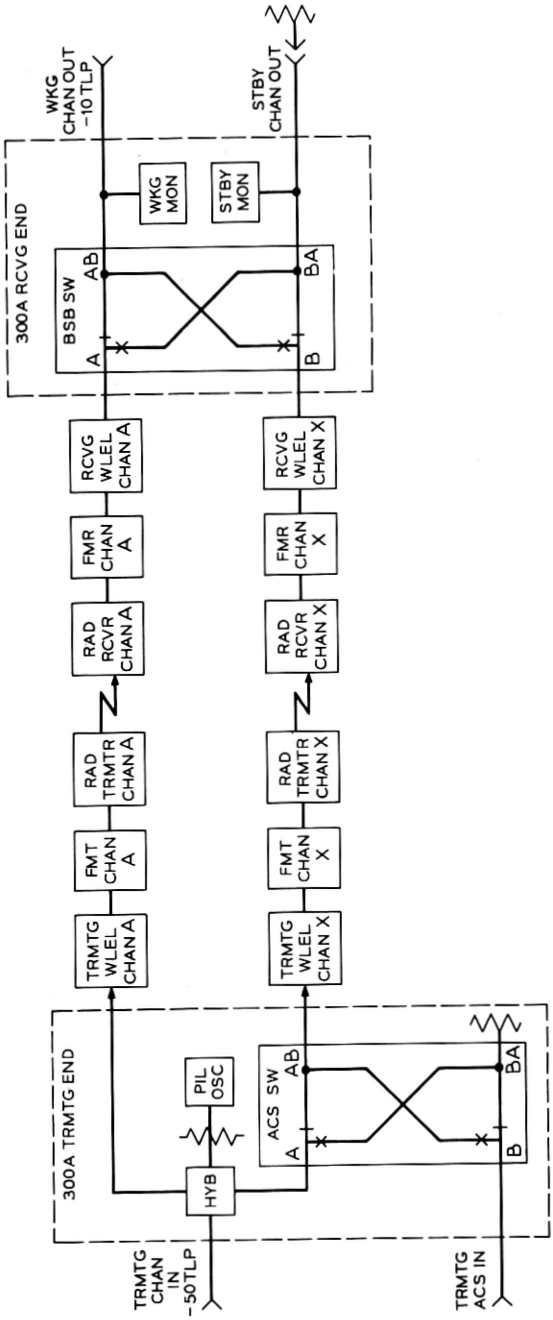


Fig. 1—Typical switching section block diagram.

channel, but may be connected to either one depending on the position of the switch. The working monitor is connected to the output of the system that is carrying service, and therefore will indicate failure every time service is lost. Of course, if the standby channel is available, the failure should not last longer than it takes to complete a switch, which is about one millisecond. The standby monitor is connected to the channel not carrying service.

Channel quality is determined on the basis of the presence or absence of the continuity pilot and on the level of noise in a slot located at 10.2 MHz. Either loss of pilot or excessive noise is considered a channel failure which, if emanating from the working monitor, will initiate a switch. Failures from the standby monitor will initiate alarms. The noise threshold at which a noise failure indication is given from the working channel monitor corresponds to a noise level of 55 dBrnc0 in the top message circuit. The standby monitor is set at a noise level of 53 dBrnc0 to insure positive switching action.

The continuity pilot frequency of 11.880229 MHz was chosen for the following reasons:

(*i*) It can be used on systems carrying video or digital signals whose transmission requirements preclude the use of low-frequency pilots.

(*ii*) The frequency spectrum in the vicinity of 11.88 MHz is clear of any interference from the radio system and a tone at that frequency does not cause interference into the radio system or into the 300A noise slot.

(*iii*) When frequency modulated on the radio carrier, the second-order sidebands of the 11.88-MHz pilot fall between mastergroups on the adjacent channel signal. This reduces the possibility of adjacent channel interference.

(*iv*) Modulation products related to the frequency difference between the pilot and the auxiliary channel carrier (11.384379 MHz) fall at a location which causes minimal interference.

The transmitted pilot level of −7 dBm0 corresponds to a frequency deviation of 69 kHz rms on the pre-emphasized TH-3 system, which is within CCIR recommendations for this type of pilot. This level was determined after consideration of several interrelated system characteristics and circuit limitations. It was desirable to insert the pilot at the lowest possible level to minimize interference and modulation problems and to load the message channel as little as possible. On the other hand, high pilot levels would allow wider pilot detector bandwidths for a required pilot-to-noise ratio, thereby enabling the detector to operate with greater speed. The above level was a compromise between these effects.

The pilot detector trip point (where the channel monitor indicates loss of pilot) was chosen to be −17 dBm0 or 10 dB below the level of the transmitted pilot. Allowing 5 dB for misalignment and for 11.88-MHz rolloff in the radio system, a minimum pilot-to-trip-point ratio of 5 dB remains. This margin is considered necessary for reliable detector operation.

A detector bandwidth of 1.2 kHz was chosen to insure that noise cannot simulate the pilot until a failure due to noise has occurred. This bandwidth is sufficiently wide to allow relatively loose requirements on the frequency stability of the pilot oscillator and on the selectivity of the pilot detector filter. With these characteristics, the pilot detector reacts to loss of pilot within one millisecond at noise levels exceeding 55 dBrnc0.

The noise slot is located at 10.2 MHz and has a bandwidth of 20 kHz. Considerations which led to this selection are as follows:

(*i*) This frequency is above the 10-MHz baseband and is below a potential source of interference from system tones at 10.55 MHz. It is also low enough to allow good correlation between noise in the slot and noise in the message circuits.

(*ii*) The bandwidth is as large as possible consistent with realistic selectivity requirements on the noise detector filter. The bandwidth is sufficiently wide to provide reasonable speed of recognition of high noise levels. Speed of recognition of excess noise is dependent upon the time constants of the detector circuit, the rate of change of noise level, and the actual noise level. With this bandwidth and the detector parameters chosen, the detector will indicate channel failure in about 10 milliseconds for a sudden change in noise level from no noise to noise 2 dB greater than the noise fail point. Since the fastest fades rarely exceed 1 dB per 10 milliseconds, this speed of response is adequate. It should be noted that equipment failures are detected much more rapidly by the continuity pilot detector.

The switching element used in the 300A system is a solid state baseband switch arranged in the configuration shown in Fig. 1. It functions as a make before break switch to insure continuity of service when a transfer between the regular and protection channels is made, provided that the two channels have been equalized for absolute delay.

The operate time of the switch is approximately one millisecond. The switch is controlled directly from the logic circuits.

One of the inherent properties of a solid state switch is that when power is lost, transmission through the switch is lost. To prevent transmission loss through the 300A switch, the switch is powered from two separate +24-volt feeders and the circuit is arranged to maintain transmission to the working channel output should one of the feeders fail.

The 300A system handles baseband message signals from 60 kHz to 12 MHz with the following transmission characteristics:

Receiving End

Insertion Loss—Less than 1 dB
Frequency Response—Within 0.3 dB, 60 kHz to 12 MHz
Within 0.1 dB, 300 kHz to 10 MHz
Return Loss—Greater than 26 dB
Isolation—Greater than 90 dB
Transfer Time—1 millisecond, make before break

Transmitting End

Insertion Loss—Less than 4 dB
Frequency Response—Within 0.3 dB, 60 kHz to 12 MHz
Return Loss—Greater than 26 dB

Integrated circuits are used exclusively to realize logic and control functions and are used to a limited extent in the linear circuits. The logic and control circuits use Western Electric's 4-volt RTL series of integrated circuits. Interfacing between the 4-volt and the 24-volt circuits is accomplished with relay driver integrated circuits. Integrated operational amplifiers are used as dc amplifiers and as modified Schmitt triggers. All integrated circuits used in the 300A system are standard hybrid integrated circuits. Each integrated circuit consists of a silicon chip mounted on a ceramic substrate having a lead frame to allow application to standard printed wiring boards. A typical printed board is shown in Fig. 2.

Field maintenance of the 300A system is accomplished with standard test equipment generally available in radio stations in conjunction with two oscillators and a split pad built into the 300A package. The two oscillators, one at 10.2 MHz and the other at 11.88 MHz, are used to adjust the noise and pilot trip points of the monitor units. Spare plug-in units are provided to allow quick repair of the 300A system.

Power sources of +24 volts and −24 volts are required by the 300A

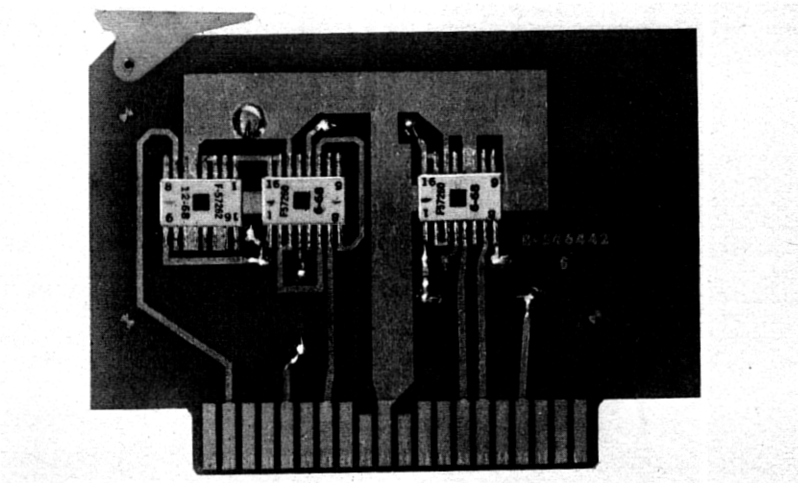


Fig. 2—Typical printed wiring board with integrated circuits.

system. The +24-volt source may be obtained from the −24-volt supply using dc-to-dc converters or directly from a battery plant. Suitable filtering of these supplies to reduce noise and transients is accomplished with power supply filters mounted in the same bay as the 300A equipment.

Additional voltages required for operation of the integrated circuits and for operation of units requiring regulated voltages are obtained with diode regulators associated with the individual units. These voltages include +4.3, +12, and −6.2 volts for the integrated circuits and +18 and −18 volts for the monitor units. Redundant power feeders are provided and fusing is arranged to preclude loss of transmission when a single fuse or feeder fails.

2.2 *Overall System Operation*

2.2.1 *Block Diagram of Receiving End*

An expanded block diagram of the receiving end of a 300A switching system is shown in Fig. 3. The "ON" and "OFF" gates in the diode switch are shown symbolically as "break" and "make" contacts, respectively. With the switch set as shown, channel A is the working channel and channel X is the standby channel. The working and standby pilot and noise monitors are connected to the respective channels through resistive bridging taps. These monitors supply the necessary information about the condition of both channels to the automatic logic, the pilot and noise fail indicating circuit, and the

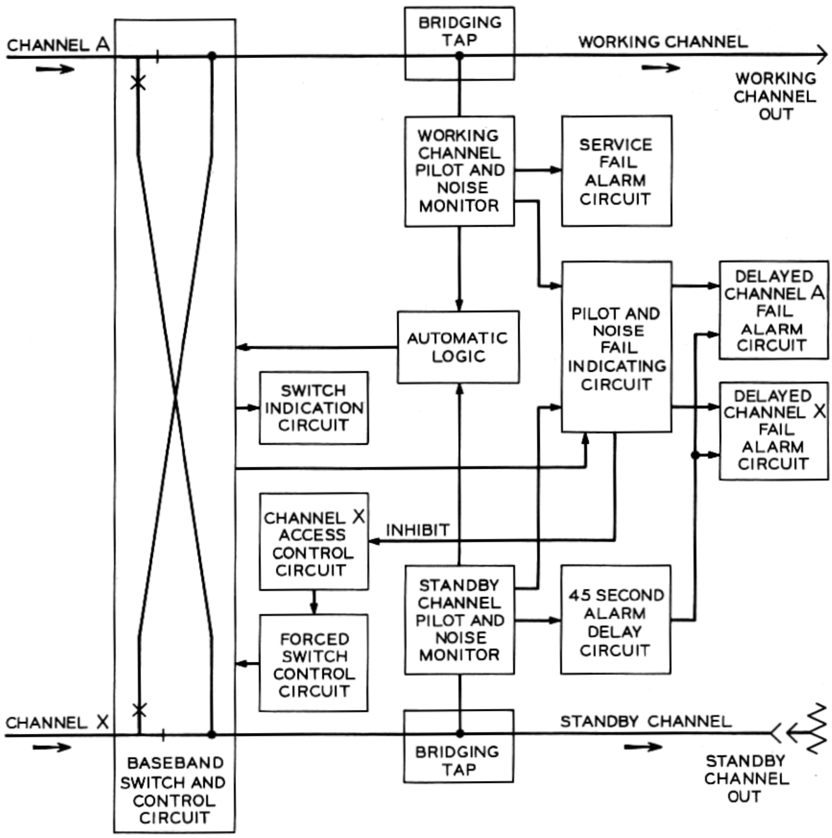


Fig. 3—Receiving end block diagram.

alarm circuits. Forced switch and channel X access controls are provided which operate directly into the baseband switch control circuit for manual control. The switch indication circuit identifies the working channel at all times.

2.2.2 *Automatic Switching*

With the control set for the automatic mode of operation, the baseband switch will operate whenever the working monitor indicates a failure while the standby monitor indicates good. Immediately following the switch operation the working monitor indicates good and the standby monitor indicates a failure.

For example, if channel A is the working channel and it fails while channel X is good, automatic operation of the switch immediately makes channel X the working channel and the failed channel A becomes the standby. If the failure was due to fading, channel A will recover as the fade clears out but the switch will not revert. Channel X will continue to be working channel and channel A the standby until X fails while A is good. Then the switch will automatically operate again to make A the working channel and X the standby.

2.2.3 *Manual Switching*

The receiving switch can be forced to make either of the channels the working channel by manual operation of the forced switch controls. When the forced switch controls are operated, the automatic logic loses control of the baseband switch. Automatic operation is resumed when the forced switch controls are reset to automatic.

2.2.4 *Access Switching*

A means of disassociating channels A and X so that channel A can carry the regular message service while channel X is being used for emergency restoration or some other special service is available as an optional feature. When it is furnished, operation of the access control at the transmitting end causes the transmitting access switch to operate. This disconnects channel X from the splitting hybrid and connects the access trunk through the switch to channel X. At the receiving end, operation of the access control forces the receiving switch to make A the working channel and X the standby channel, providing channel A is not failed at the time. A safety inhibit feature is provided which prevents the receiving access control circuit from operating if channel A is failed.

2.2.5 *Alarms*

A service failure alarm is generated whenever the working channel fails and cannot be made good immediately by automatic switch operation.

A delayed channel A or channel X failure alarm is generated whenever the standby channel fails and remains failed for 45 seconds. When the access controls are operated, an immediate service failure alarm is generated if either channel fails.

2.2.6 *Indications*

Front panel lamps are provided to indicate which channel is the working channel, whether channels A and X are failed due to noise or loss of pilot, and whether a channel failure is simply a prolonged failure of the standby channel or a more serious service failure. Lamps are also provided to indicate whether the system is operating in the automatic mode or whether one of the forced switch or access switch controls has been operated.

2.3 *Unit Descriptions*

2.3.1 *Baseband Switch*

This unit is comprised of four switching elements and a control circuit incorporated in one package. As shown in Fig. 1, it has two inputs (A and B) and two outputs (AB and BA). The switch is a bilateral device and the input and output designations are used for descriptive purposes only. In its normal state, the A input is connected to the AB output and the B input is connected to the BA output. In the switched state, the connections are reversed. Adjacent elements of the switch are always in opposite states, a characteristic which is taken advantage of in the design as described below.

Each switch element consists of two diodes, two transistors, and their associated components. As shown in Fig. 4, each element is identical. Operation of the element consisting of Q3, Q4, CR2, and CR3 will now be described.

To establish a low-loss connection between A and AB, transistor Q3 is turned on, and transistor Q4 is turned off, thereby forward biasing diodes CR2 and CR3. To open the connection between A and AB, transistor Q3 is turned off and Q4 is turned on. Diodes CR2 and CR3 are now reverse biased by the ground on the anode side provided by Q4 and by a positive voltage on the cathode sides provided by current from adjacent switch elements flowing through resistors R1 and R2. The two diodes and transistor Q4 form a controlled loss tee pad and transistor Q3 serves as a current valve to reduce the current drawn by the switch.

Simplified equivalent circuits of a switching element in the "ON" and "OFF" states are shown in Fig. 5. From Fig. 5, the insertion loss of an "ON" switching element is given by:

$$\text{I.L. (ON)} = 20 \text{ Log} \left[\frac{(R_o + R_f)(R_o + 2R_s)}{2R_oR_s} \right] \text{dB},$$

where

R_o = source impedance = 75 ohms,
R_f = diode forward impedance = 1 ohm, and
R_s = shunt impedance of biasing network = 3,000 ohms.

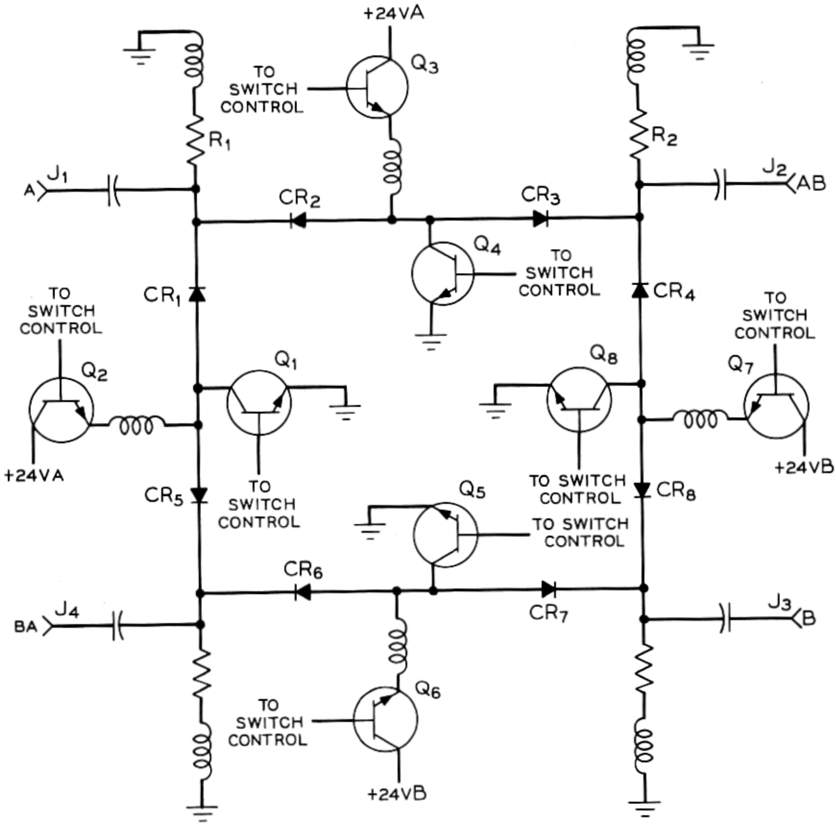


Fig. 4—Baseband switch schematic.

The impedance of the biasing network is designed to optimize the return loss of the switch for a particular diode impedance. The "ON" insertion loss is thereby controlled entirely by the diode impedance. With the above values, the insertion loss is 0.22 dB which is within the factory specified limits of from 0.1 to 0.3 dB. The insertion loss of an "OFF" switching element is given by:

$$\text{I.L. (OFF)} = 20 \text{ Log} \left[\frac{2}{R_o R_t (2\pi f C_r)^2} \right] \text{dB},$$

where

R_t = impedance of shunt transistor = 9 ohms,
f = frequency in Hz, and
C_r = reverse capacitance of the diode = 2.5 pF.

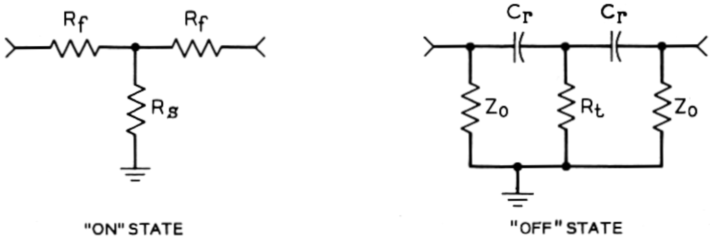


Fig. 5—Switching element equivalent circuits.

At a frequency of 10 MHz, using these nominal values, the "OFF" insertion loss is 101 dB. In practice, the insertion loss is about 95 dB, being limited by ground loops and by power supply coupling.

The operation of the switch elements is controlled to achieve a make before break type of operation. The switching action is also controlled to minimize the transient inherent in changing the bias of the diodes in the switching elements. The switching action is shown in Fig. 6. After the input control lead changes state, there is a delay of about

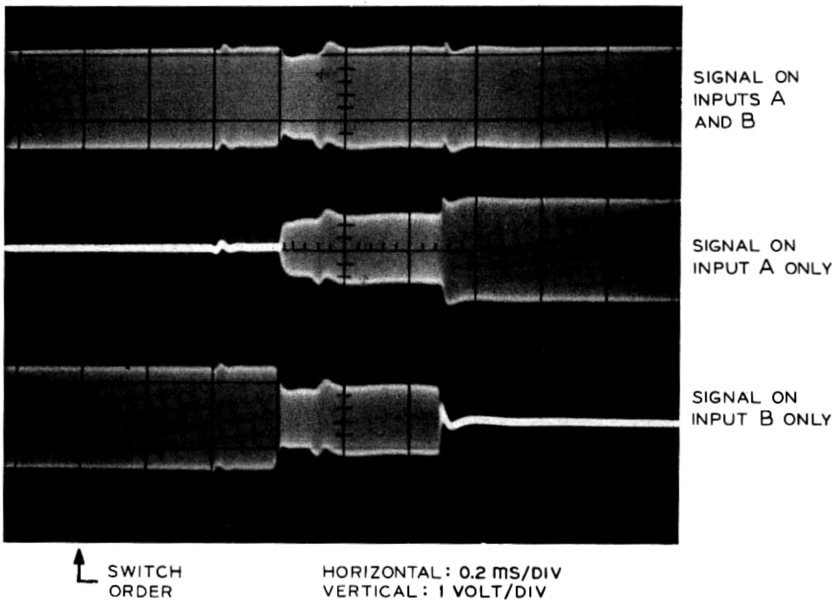


Fig. 6—283B switch transfer action as seen at output AB.

0.6 millisecond before the temporary period when both inputs are connected to the output. The double connection lasts for about 0.5 millisecond, after which the switch is completed. The switching transient has negligible energy above 60 kHz, and therefore does not affect signals carried by the 300A system.

The power handling capability of the switch is +20 dBm of sine wave power. This is the required capability for operation at a −10-dB transmission level point. When operated at this level, the switch contributes less than 5 dBrnc0 of noise.

A photograph of the switch, coded the 283B switch, is shown in Fig. 7. It is housed in a shielded unit with reduced size jacks used for signal connections and a 15-pin connector used for power and control leads. Its dimensions are 4.25 inches long, 3.8 inches wide, and 1.375 inches deep.

2.3.2 *Channel Monitor*

The channel monitor continuously monitors the quality and continuity of the working and standby channels by measuring noise in a

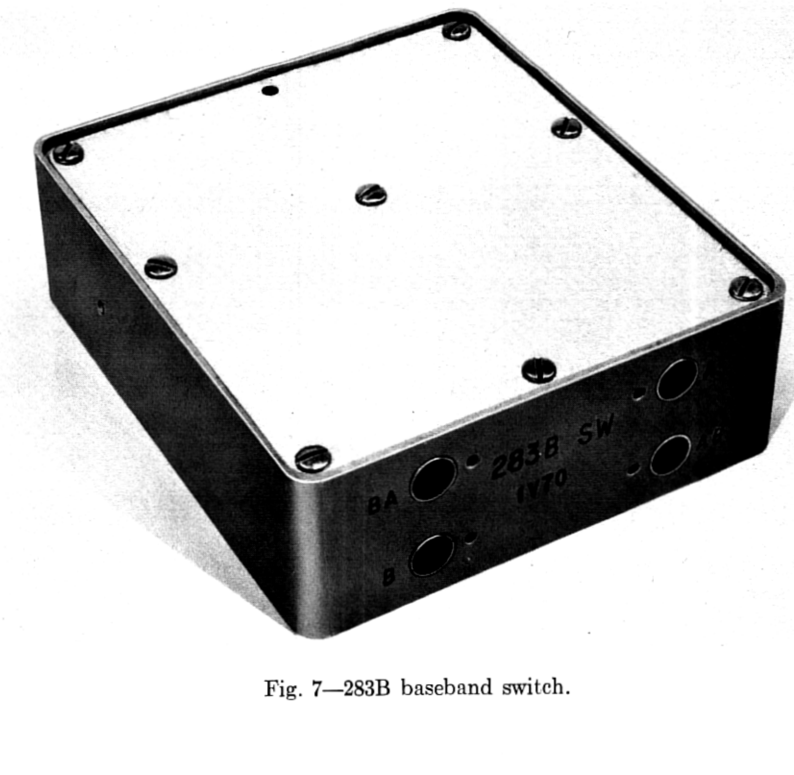


Fig. 7—283B baseband switch.

20-kHz slot centered at 10.2 MHz and by detecting the presence of a continuity pilot. A block diagram of the monitor circuit is shown in Fig. 8.

The sensitivity of the monitor is determined by the lowest level of pilot and noise which must be detected, which occurs when the entrance links are not included within the switching section. Under this condition, the BSB input of the monitor is a −64-dB TLP taking into account the 30-dB loss of the bridge tap. At this point, the pilot level at the trip point is −79 dBm and the power in the noise slot at the trip point is −88 dBm. Allowing a 10-dB margin, the sensitivity of the monitor must be sufficient to detect noise signals as low as −98 dBm. Since the detectors require signal levels of approximately 0 dBm, 98 dB of gain must be provided for the noise signal and 89 dB for the pilot signal. This gain is broken up into several blocks as shown in Fig. 8. Sufficient adjustment range is provided to enable the monitor to be used when the entrance links are included within the switching section.

Four filters provide the necessary selectivity in the monitor circuit. The first is a high-pass LC filter which attenuates the payload signal thereby preventing overloading of the following amplifier stages. Two monolithic crystal filters are used to separate the noise and pilot

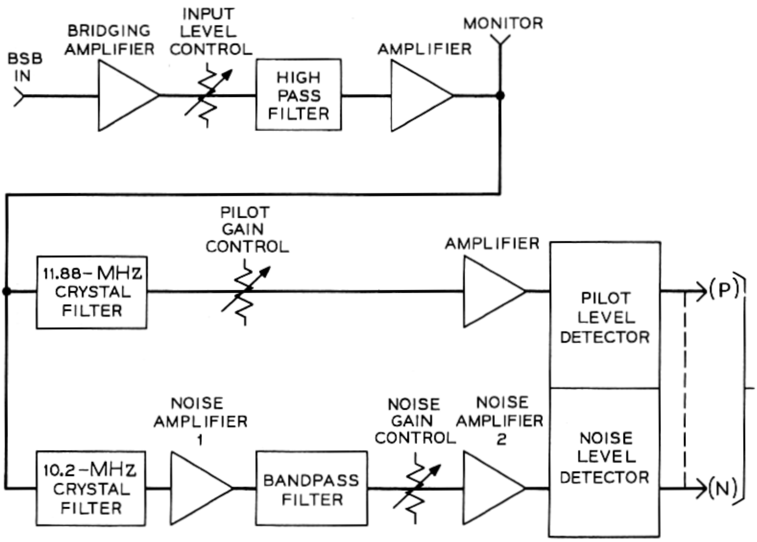


Fig. 8—Monitor circuit block diagram.

signals into two different paths. The selectivity of the crystal filter in the noise path is shown in Fig. 9. The pilot filter has a similar characteristic, but with reduced bandwidth. An additional bandpass LC filter is provided in the noise path to increase the selectivity, primarily to attenuate the auxiliary channel carrier located at 11.38 MHz.

Detection is accomplished with a pair of diodes followed by an integrated circuit operational amplifier as shown in Fig. 10. The operational amplifier functions as a Schmitt trigger to provide well defined switch and restore settings. It features a restore setting control which does not interact with the switch setting. With no noise present, the output of the OP AMP is held to −0.7 volt by the forward bias on diode CR1. A reference voltage of −0.6 volt on the non-inverting (NI) input of the OP AMP is provided by R4 and R5. Under these conditions, negligible current is drawn through the restore control R3, thereby preventing its setting from affecting the switch point. When the detected noise on the inverting (I) input reaches −0.6 volt, the output of the OP AMP becomes positive. Fast switching action is enhanced by positive feedback provided by resistor R2. The positive voltage at the output is limited to +4.3 volts by breakdown diode CR1. The voltage on the non-inverting input of the OP AMP becomes more positive and may be controlled by adjusting potentiometer R3. The setting of R3 will therefore determine the noise

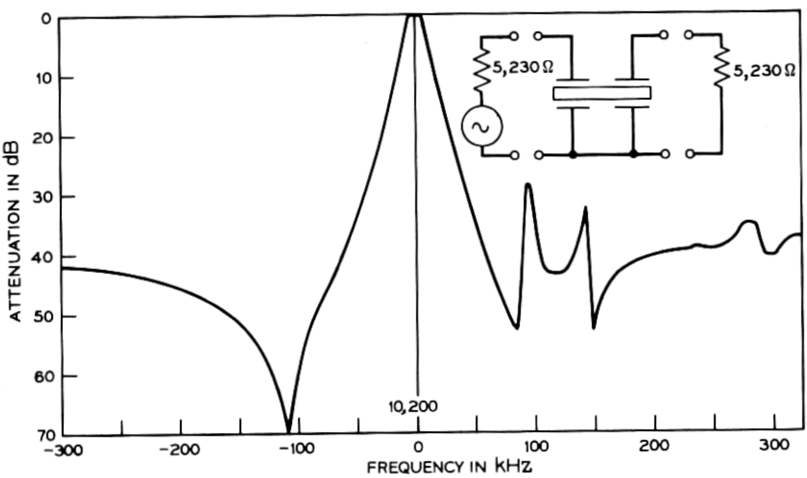


Fig. 9—Selectivity of noise crystal filter.

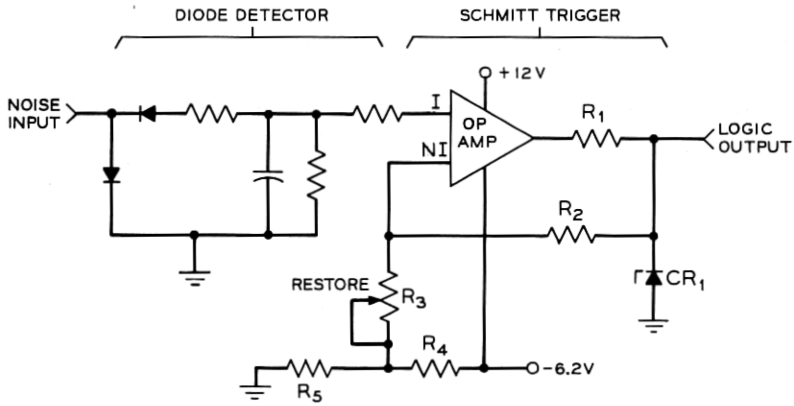


Fig. 10—Noise detecting circuit.

level at which the detector will restore to its no noise state. The pilot detection is done with a similar circuit except no restore adjustment is provided.

The monitor is housed as a shielded package as shown in Fig. 11. Its overall dimensions are 6.825 inches long, 3.75 inches wide, and 2.75 inches high.

2.3.3 *Automatic Logic*

The logic for automatic control of the system is shown as a single block in Fig. 3 and in more detail in Fig. 12. The logic levels shown on the interconnecting leads in Fig. 12 are the normal levels when the working and standby channels are both good, with channel A as the working channel, and the controls set for the automatic mode of operation.

The working and standby monitors each furnish two inputs to the automatic logic. Loss of pilot on the working channel causes a logic level change from 1 to 0 on the PW input. Failure of the working channel due to noise causes a logic level change on the NW input from 0 to 1. Either type of failure on the working channel causes the W input to the sequential logic to change from 1 to 0.

Similarly, a failure of the standby channel due to noise or loss of pilot causes the S input to the sequential logic to change from 1 to 0.

Whenever the working channel fails while the standby channel is good, the logic level on the T input to the flip-flop (FF) in the sequential logic changes from 1 to 0 causing the flip-flop to change

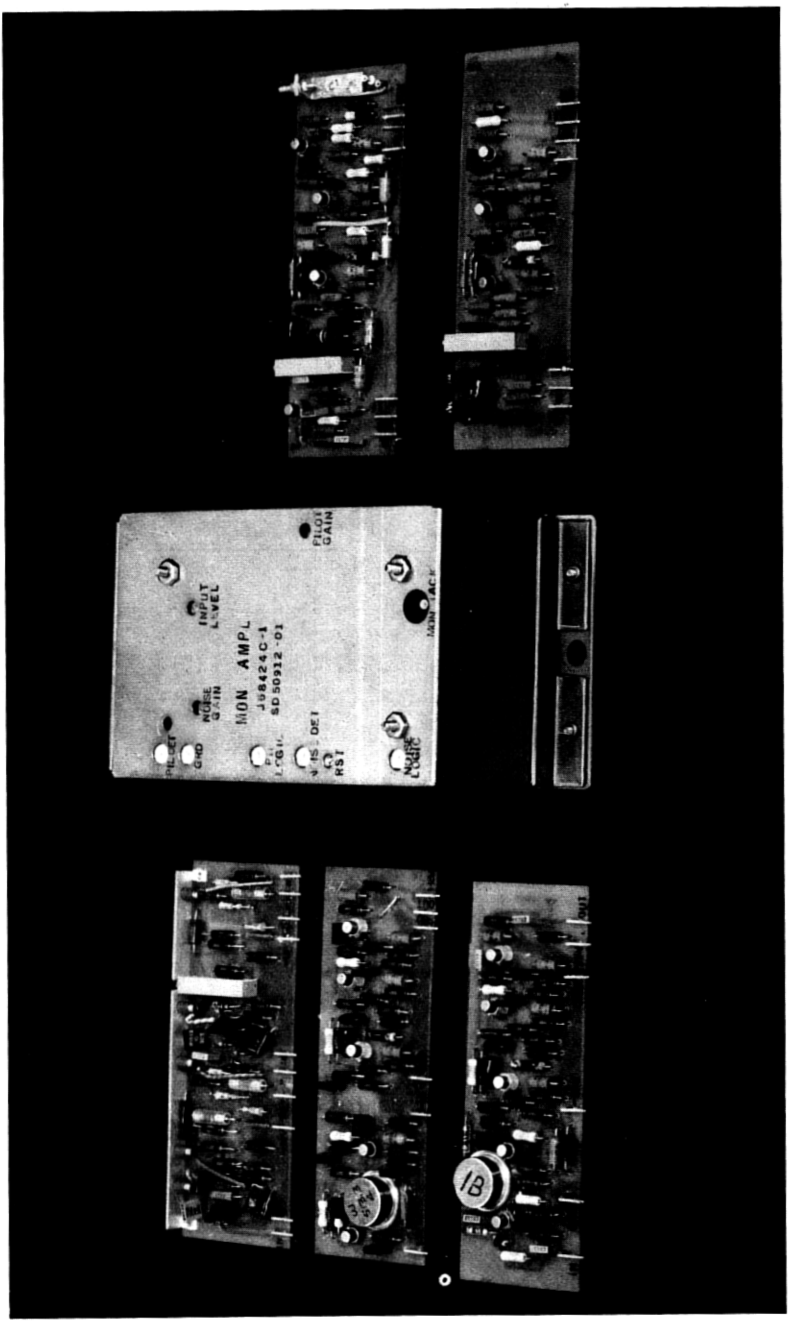
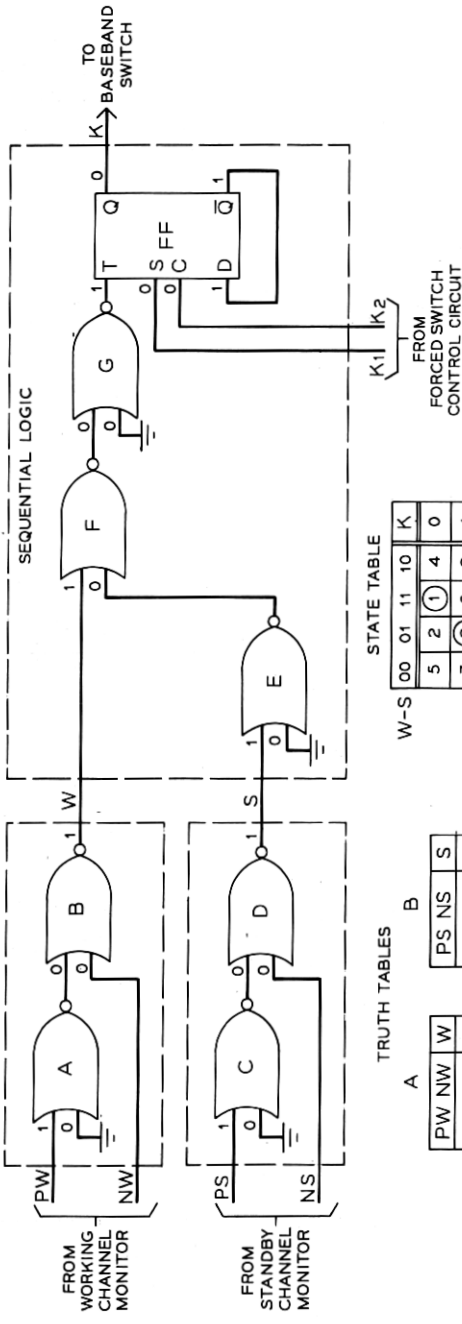


Fig. 11—Channel monitor.



TRUTH TABLES

A

PW	NW	W
0	0	0
0	1	0
1	0	1
1	1	0

B

PS	NS	S
0	0	0
0	1	0
1	0	1
1	1	0

STATE TABLE

W-S: 00	01	11	10	K
5	2	(1)	4	0
7	(2)	6	3	1
7	8	6	(3)	1
5	2	1	(4)	0
(5)	2	1	4	0
7	8	(6)	3	1
(7)	8	6	3	1
5	(8)	1	4	0

Fig. 12—Automatic logic circuit.

state. A change on the T input from 0 to 1 does not cause the flip-flop to change state.

The K output of the sequential logic controls the baseband switch. When K = 0, channel A is the working channel and channel X is the standby channel. When K = 1, channel X is the working channel and channel A is the standby channel.

Truth table A in Fig. 12 defines the input-output functions of gates A and B. Truth table B defines the input-output functions of gates C and D. The state table defines the input-output functions of the sequential logic composed of gates E, F, and G, and the flip-flop (FF).

The first stable (circled) state in the state table is taken as the condition when inputs W and S are both 1 and output K is 0. This means that the working and standby channels are both good and channel A is the working channel. If the working channel (A) fails while the standby (X) remains good, the inputs change from 11 to 01, causing the output to change from 0 to 1. This is the second stable (circled) state in the state table. When output K changes from 0 to 1, the baseband switch changes state reversing the roles of channels A and X, making X the working channel and A the standby channel. The working channel then becomes good again and the failed channel (A) becomes the standby channel. This changes the W and S inputs to the sequential circuit from 01 to 10 and the circuit assumes the third stable (circled) state, and the output K remains 1. If next the standby channel (A) becomes good while the working channel (X) is still good, the W and S inputs change from 10 to 11 and the circuit assumes stable state 6 (circled), with the output remaining at 1.

The next time the working channel (X) fails while the standby (A) remains good, the stable state changes will be from 6 to 8 to 4, with the output changing from 1 to 0. Subsequently, when the standby channel again becomes good, the inputs will again change from 10 to 11 and the circuit will return to stable state 1, holding the 0 output.

All other possible input-output changes are similarly defined by the state table.

There are two manual control inputs to the sequential logic (K1 and K2) that originate in the forced switch control circuit. These go to the set (S) and clear (C) inputs of the flip-flop. The forced switch control circuit operates directly into the baseband switch for manual control. The K output of the automatic logic is made to follow the forced switching operation by the K1 and K2 inputs. Otherwise an undesired automatic switch operation may take place just after the system is returned from manual control to automatic operation.

2.3.4 *Pilot and Test Oscillators*

Pilot, pilot test, and noise test oscillators are identical except for frequency. They are conventional solid state crystal-controlled oscillators designed for operation at either 10.2 or 11.88 MHz, followed by a two-stage amplifier and a low-pass output filter.

2.3.5 *Controls, Indications, and Alarms*

The controls, indications, and alarms circuit provides the sources required to generate alarms to the office and C1 or E-type alarm systems, and the operating keys and relays required to control the system locally or remotely.

The following features are provided:

(*i*) Local and remote indicating lamps to indicate the status of the system at all times

(*ii*) Local and remote alarm lamps to indicate the source of each alarm

(*iii*) Connections to office alarms, C1 or E-type alarm facilities, and aisle pilot lamps for alarms in the system

(*iv*) Operating keys and relays for making forced switches to either channel A or X or making an access switch to channel X

(*v*) An alarm cutoff (ACO) key to silence the audible alarm and to extinguish the appropriate aisle pilot lamps.

2.4 *Relay Interface and Wiring Considerations*

To protect the integrated circuits against noise and other voltage transients which might be coupled in from the office wiring, all alarm, indicating, and control connections between the 300A system and the office alarm system or remote alarm and control systems are made through interfacing relays. Integrated circuit relay drivers operate the relays which provide the outgoing alarms and indications. Incoming control orders operate relays in the 300A which in turn operate integrated circuit flip-flops to provide clean, non-bouncing inputs to the logic and control circuits. Diodes across each relay winding suppress the transients generated by the relays in the 300A. All wiring associated with relays and front panel lamps and controls is carefully segregated from the wiring associated with logic circuit interconnections.

2.5 *Equipment Features*

The 300A switch unit, shown in Fig. 13, contains the units for the receive end of a switching section for one direction of transmission

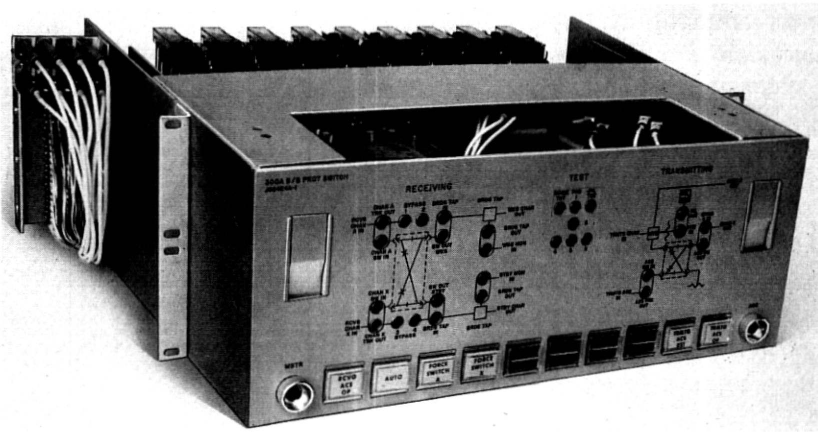


Fig. 13—300A switch unit.

and the units for the transmitting end of a switching section for the opposite direction of transmission. The test oscillators and split pad are also incorporated in the unit and have front panel jack appearances. The 300A unit occupies the space of four 1-3/4 inch mounting plates in a 19-inch bay. Its shipping weight is 42 pounds.

The unit consists of a drawer and drawer housing, which, when extended, allows access to all plug-in units and wiring. All active circuits are packaged as plug-in units for ease of maintenance and trouble shooting.

All controls and indications are mounted on the front panel and provision is made to multiple these functions to a remote control panel within the station. Connections for C-type or E-type alarm systems are also provided for control from distant alarm centers.

Access jacks are provided on the front panel for test purposes and to permit manual patches to be made during trouble conditions. As shown in Fig. 13, a simplified diagram of the transmission circuit is imprinted on the front panel jack field to indicate the function of each jack. Connections between the jacks are made by means of patch plugs. For normal operation the patch plugs are oriented in the vertical position, for test or trouble conditions the patch plugs are oriented in the horizontal position.

2.6 *Testing*

The 300A system is designed to be tested with the test oscillators provided in the 300A unit in conjunction with standard test equipment normally available in radio stations. Front panel jack appearances are provided to allow easy access to the pilot oscillator, baseband switches, and monitors. Special jack appearances are provided to allow patches to bypass service around the switch without interrupting service. The only adjustments required are the level and frequency of the pilot and test oscillators and the noise and pilot trip points of the monitors. Test points are provided within the 300A drawer for voltage measurements for use in trouble shooting procedures. When a trouble is located, it is generally repaired by replacing a defective plug-in unit with a spare unit.

III. AUXILIARY CHANNEL SWITCHING

3.1 *System Considerations*

The auxiliary channel carries the order-wire and alarm signals as well as providing additional voice channels for the TH-3 medium-haul system. Its signals are diplexed above the message load on the two radio channels in each direction of transmission, with modulating and demodulating equipment at each of the repeaters and main stations. It is a facility that is complete within itself and is independent of the 1800-message circuit load.

The auxiliary channel signal is inserted on and removed from the two radio channels within the protection switching system protecting the broadband message load, normally the 300A system. The auxiliary channel circuits receive no protection from, and are independent of the 300A system, except for the use of the 11.88-MHz pilot as described below. Protection is provided by the auxiliary channel switching system on a one-by-one basis.

Since the auxiliary channel circuits appear at each repeater, the switching system must operate switches at each repeater. As explained in Ref. 2, the main station and all repeater station switches must be operated in synchronism to either channel A or channel X. The control point of the auxiliary channel switching system is at the receiving main station of the switching section. Repeater station switches are controlled by the main station equipment by means of a voice-frequency control line operating over the auxiliary channel system in the opposite direction to that being protected, as shown in Fig. 14.

The main station portion of the auxiliary channel protection switching system is very similar in operation and physical make up to the 300A equipment. Therefore, the description of the main station equipment is limited to a discussion of its differences from the 300A equip-

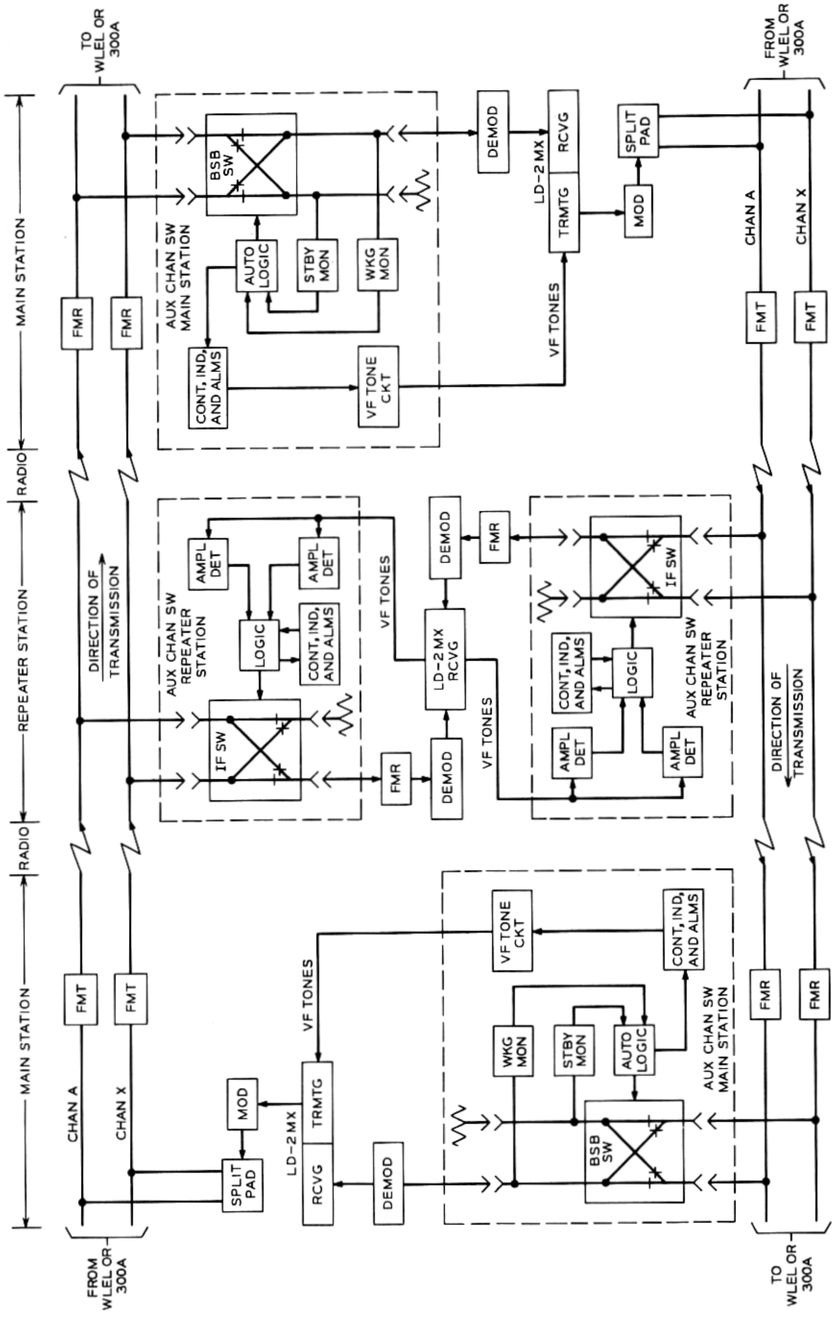


Fig. 14—Auxiliary channel switching system block diagram.

ment. The major differences are: no transmitting equipment is required for the auxiliary main station switch, the access feature is not provided, and a voice-frequency tone unit consisting of two tone oscillators is required for the main station unit. Other differences include a low-loss bridge tap and different monitor settings. These latter differences are required because the signal levels in the auxiliary main station switch are lower than in the 300A switch.

The repeater station equipment is bridged on both radio channels at IF, and connects one of the IF signals to the auxiliary channel FMR as shown in Fig. 14. The connection is made by a solid state IF switch similar to the 300A baseband switch. Operation of the switch is controlled by the tones being sent from the main station equipment. The tones are converted to a digital signal by bandpass filters and amplifier-detector circuits.

At both the main station and repeater station, controls, alarms, and indications are provided for use by station personnel. These functions can also be remotely monitored and controlled through connection to E-type alarm and status reporting systems.

The voice-frequency tone signaling code used to control the repeater station switches consists of two tones, one present and the other absent. With a 1615-Hz oscillator turned on, the switches are connected to channel A; with a 2295-Hz oscillator on, the switches are connected to channel X. If no tones or both tones are present at the repeater station, no switching takes place and an invalid code alarm is generated by the repeater station equipment.

As shown in Fig. 14, the control tones are carried to the repeater stations via the auxiliary channel in the opposite direction, which is in turn protected by its auxiliary channel protection switching system. This arrangement provides a reliable transmission path for the control tones. However, it is important that the repeater station be capable of recognizing the signaling tones in the presence of noise at least up to the switch point of the auxiliary channel. The tones are carried at a level of −25 dBm at 0 dB TLP which is sufficiently low to represent only a small portion of the auxiliary channel load handling capacity. The sensitivity of the repeater station switching equipment to noise on the control line is such that no false switching activity takes place until the noise level is about 70 dBrnc0, which is well above the critical point of 55 dBrnc0 where the channel is considered bad.

Power requirements for the main station equipment are approximately the same as for the 300A system. The repeater station units require +24 volts and −24 volts which is provided by the power supply for the auxiliary channel equipment.

3.2 *Repeater Station Unit Descriptions*

3.2.1 *IF Switch*

The IF switch, coded the 283A switch, is outwardly identical to the 283B baseband switch used in the 300A system (see Fig. 7). However, electrically it operates over the frequency range of 50 MHz to 100 MHz. This high frequency range, and a maximum signal power handling capability of +10 dBm, permit low diode bias current of about 5 milliamperes to be used in this switch compared to 40 milliamperes in the baseband switch. The high frequency of operation also allows the use of 10-microhenry instead of 1-millihenry chokes, thus permitting greater speed of operation.

The circuit of the switching elements is the same as that of the baseband switching elements (see Fig. 4), with the exception that the current limiting transistors (Q2, Q3, Q6, and Q7) are not required because of the low current levels in the IF switch. Low values of inductance and capacitance are used since the signal frequencies are in the IF range.

The switching action as seen at the output of the switch on an oscilloscope is shown in Fig. 15. The top line is with identical signals present on inputs A and B, the next line is with a signal on input A, and the last line is with a signal on input B. The transfer from A to B is completed within about 0.4 microsecond with no loss of transmission.

Other characteristics of the switch are:

Frequency Range—50 MHz to 100 MHz
Insertion Loss—"ON" State <0.3 dB
Insertion Loss—"OFF" State >90 dB
Return Loss—>30 dB
Power Supply—+24 volts at 60 mA.

3.2.2 *Logic and Control*

The logic and control for the repeater station IF switch is shown as single blocks in Fig. 14 and in more detail in Fig. 16. The logic levels shown on the interconnecting leads in Fig. 16 are the normal levels when: tone 1 is present, tone 2 is absent, the system is operating in the automatic mode, and the IF switch is set so that the FMR is connected to channel A.

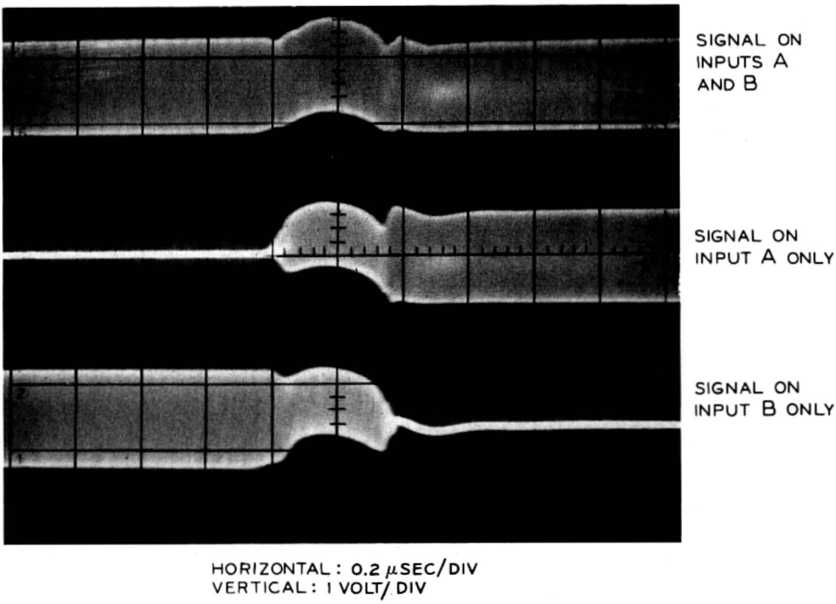


Fig. 15—283A switch transfer action as seen at output AB.

When an order is received to switch the FMR to channel X, tone 1 disappears and tone 2 becomes present, causing inputs T1 and T2 to change state (T1 = 0, T2 = 1). This causes the set-reset flip-flop (FF) to change state, and, after a 5-millisecond delay, the IF switch control lead (OP) changes to 1. A 1 on the IF switch control lead makes the IF switch change state thus switching the FMR to channel X. The 5-millisecond delay at the output of the automatic logic is bi-lateral, that is, the output to the OP lead is delayed 5 milliseconds for either a positive or a negative input transition. This prevents momentary operations of the IF switch if short transient input changes occur.

If the T1 and T2 inputs both become 1 or both become 0, the flip-flop (FF) will not change state. Either two ones or two zeros from the tone detectors is an invalid code. If the invalid code condition exists for more than 175 milliseconds, an invalid code alarm is generated by the invalid code logic circuitry.

Inputs A and B are used for manual control of the IF switch. When A and B are 1 and 0, respectively, the IF switch control lead (OP) is forced to become 0. When A and B are 0 and 1, respectively, the

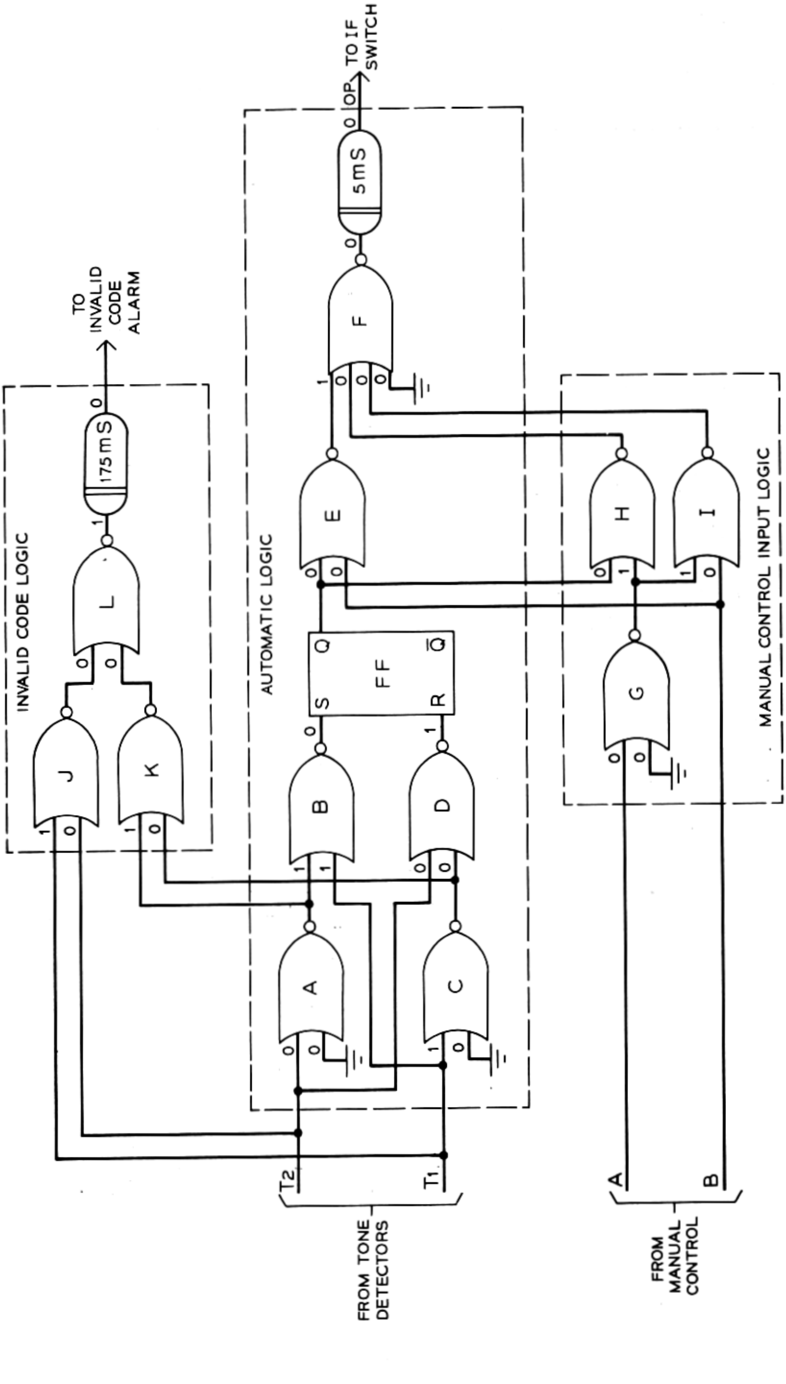


Fig. 16—Repeater station logic.

IF switch control lead is forced to become 1. When A and B are both 0, the circuit is under automatic control.

3.2.3 *Amplifier-Detector*

The amplifier-detector circuit detects the presence or absence of a VF tone that is originated at the main station switching equipment. There are two amplifier-detectors in each repeater station switch unit, one associated with the 1615-Hz tone and one associated with the 2295-Hz tone. The appropriate VF tone is picked off the VF line by a bandpass filter and applied to the amplifier-detector, which in turn supplies a logic signal to the logic circuit.

The amplifier detector is composed of two integrated circuit operational amplifiers and a diode detector. The first operational amplifier is used to amplify the VF tone and includes a gain control for setting the operate point. The tone is then detected by the diode detector and the resultant dc voltage is applied to the second operational amplifier. This operational amplifier functions as a Schmitt Trigger and is similar to the detector used in the monitor circuit (see Fig. 10). The Schmitt Trigger supplies the logic with a logic level 1 for tone present and a 0 for tone absent.

3.3 *Equipment Features*

The auxiliary channel main station switching unit consists of a 300A type drawer and a VF tone unit containing the two oscillator units. These units occupy the space of six 1-3/4 inch mounting plates in a 19-inch bay. The repeater station switch panel, shown in Fig. 17, contains the IF switch, two voice-frequency filters, two amplifier-detector units, logic, and control circuits. It occupies the space of one 1-3/4 inch mounting plate in a 19-inch bay.

IV. SUMMARY

Two independent switching systems have been described that provide automatic switching for the TH-3 medium-haul microwave radio system. The 300A system is a one-by-one baseband switching system that insures adequate reliability of the payload signal. The auxiliary channel switching system insures adequate reliability of the frequency-diplexed auxiliary channel circuits that carry order-wire and alarm information. Although protecting circuits that may be carried simultaneously on the TH-3 radio system, these two protection switching systems are functionally and physically independent. Considerable

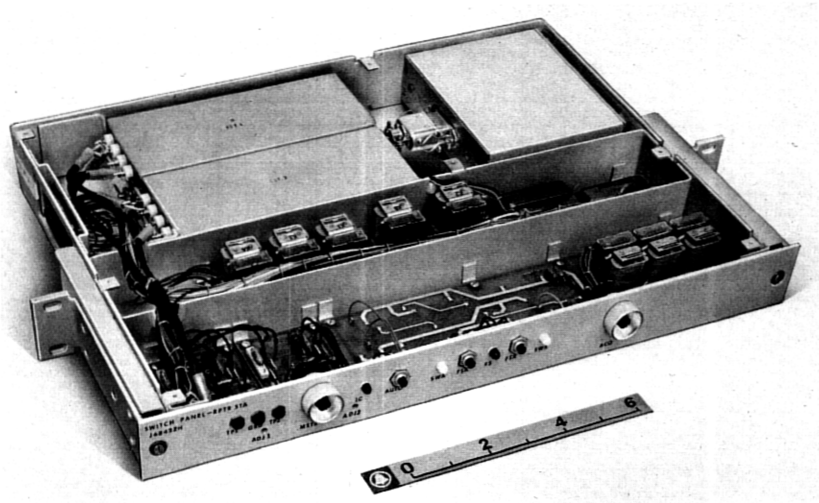


Fig. 17—Repeater station switch panel.

effort was taken to achieve high reliability, ease of maintenance, and simplicity of operation in both systems.

V. ACKNOWLEDGMENTS

Many members of the Radio Transmission Laboratory have contributed to the development of the TH-3 medium-haul protection switching systems. Among them the authors wish to mention R. O. Davidson, P. A. Pearson, and J. D. Wiidakas. The mechanical design was the responsibility of A. D. Boren, J. W. Sponsler, and L. F. Travis.

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