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# *The AR6A Single-Sideband Microwave Radio System:*

# Radio Transmitter-Receiver Units

By R. C. HEIDT,* E. F. COOK,* R. P. HECKEN,*
R. W. JUDKINS,* J. M. KIKER, Jr.,* F. J. PROVENZANO, Jr.,*
and H. C. WANG*

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This paper describes the essential features and the performance of the AR6A microwave transmitter and receiver. Subsystems that are major contributors to repeater noise are explained in detail. Design objectives for each of these units are given and compared to typical results obtained from measurements. Transmitter linearity was improved substantially through the use of predistortion. The thermal noise contribution of the receiver was reduced by use of a new low-noise microwave preamplifier.

## I. INTRODUCTION

The two basic portions of the AR6A† radio bay are the transmitter and receiver units. These units have a natural interface at the Intermediate Frequency (IF)‡ and are described in the next two sections.

In general, the receiver establishes the required noise figure, and provides the required frequency selectivity, automatic gain control,

* Bell Laboratories.

† Amplitude Modulation Radio at 6 GHz for the initial (A) version of the system.

‡ Acronyms and abbreviations used in the text and figures of this paper are defined at the back of this *Journal.*

and both dynamic and static equalization. The transmitter supplies microwave gain with low intermodulation distortion at the required output power.

The alarm and control system spans the entire bay. This system monitors the operation of the radio bay and provides remote switching capability to exercise important repeater functions to facilitate maintenance testing.

## II. THE AR6A RECEIVER

### 2.1 General

Figure 1 is a block diagram of the AR6A receiver equipped for the space-diversity application. The multichannel Radio Frequency (RF) signals from both the main antenna and diversity antenna (when implemented) are amplified by the optional waveguide microwave preamplifier in each waveguide run. The desired channel is then selected by channel-separation filters. The outputs of the separation filters are input to the space-diversity switch at a nominal full-load power level of −28.6 dBm. The output of the diversity switch is combined with the receive microwave carrier (local oscillator) signal in the receive microwave filter and applied to the Schottky diode single-ended down converter. Integral to the down converter is an IF preamplifier that boosts the signal level to about −4 dBm. In the case when the receiver is not equipped for space diversity, the waveguide from the diversity antenna and the associated channel-separation filter are omitted and the space-diversity switch is replaced by an isolator and a shutter monitor assembly.

The remaining elements of the receiver are located in the IF shelf. The filter portion of the filter/equalizer[1] provides the basic selectivity for the repeater, while the equalizer is used to compensate for static residual amplitude shape due to the various repeater components. At a repeater station the output of the filter/equalizer is applied to the Automatic Gain Control (AGC) amplifier, which provides flat gain with a dynamic range of 61 dB to compensate for fading. Correction is made for both up fades and down fades. The AGC is controlled by the receiver control unit, which maintains the average of the three detected radio pilot voltages constant. The radio pilots are fed to the pilot detector unit through an auxiliary output port of the AGC amplifier. The pilot detector unit filters and detects each of the radio pilots. The output level of each of the detectors is provided as the inputs to the receiver control unit. An IF monitoring point for the radio channel is accessible at the front panel of the pilot detector unit.

At main stations, a dynamic equalizer is used in conjunction with the AGC amplifier to provide up to 16 dB of linear slope or 8-dB

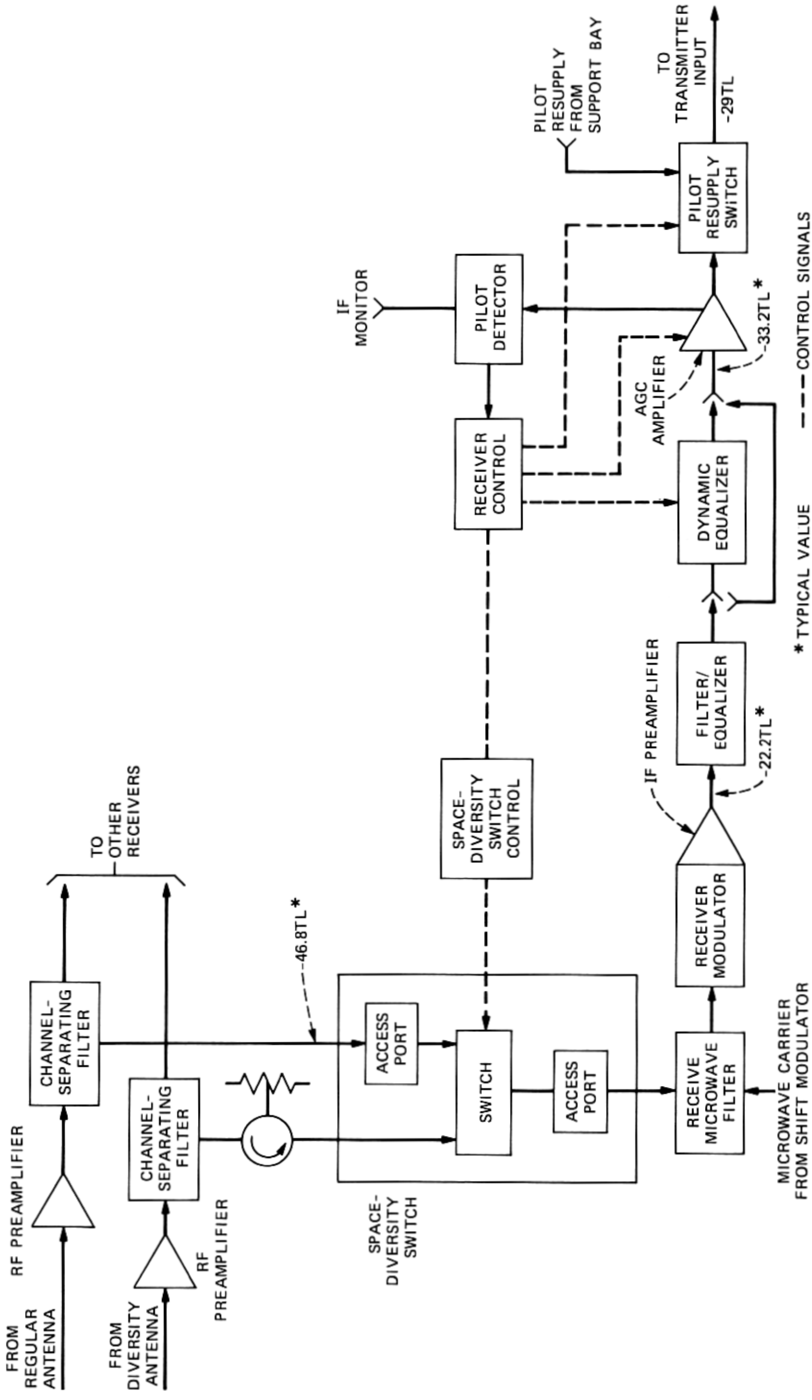


Fig. 1—Receiver portion of an AR6A TR bay.

parabolic amplitude shape to compensate for dispersive fades. The operation of the dynamic equalizer is also governed by the receiver control unit by monitoring the relative differences in level of the three radio pilots.

The output of the AGC amplifier is passed through the pilot resupply switch to the receiver output. Signal loss or signal overpower will cause the receiver control unit to actuate the pilot resupply switch. This action terminates the AGC amplifier output and connects another set of radio pilots from the AR6A support bay to the receiver output. The resupply pilots prevent following repeaters from going to full gain on loss of the channel load.

The receiver control unit also signals the switch request to the space-diversity switch control unit. This request is given when any radio has faded 36 dB or more below the normal received level on a nominal 27.1-mile hop length. This information is derived from the pilot detector signals and the control voltage outputs.

The equalization strategy and operation of the AGC amplifier, dynamic equalizer, receiver control unit, and pilot detector unit are described elsewhere.[2] Further details of the space-diversity switch and control circuit, the receiver modulator/IF preamplifier, pilot resupply switch, and the microwave preamplifier are presented in the following sections.

### 2.2 Circuit description

#### 2.2.1 Low-noise microwave preamplifier

An optional low-noise microwave preamplifier (656A) is used in the common waveguide run feeding TH-3, as well as AR6A, receivers on a given polarization. The signal on a TH-3 channel is 16 dB higher in power than the full-load AR6A signal; therefore, the amplifier must exhibit excellent linearity to prevent intermodulation "crosstalk" between radio channels. The 656A amplifier intermodulation distortion performance is good enough to allow this common waveguide amplifier to be used with a mix of TH-3 and AR6A on a given route.

The single-stage amplifier using a gallium arsenide (GaAs) field effect transistor (FET) (103B) was designed to operate over the band of 5.925 to 6.425 GHz. The average gain ranges from 8 to 10 dB, with a ±0.5 dB gain shape allowed over the frequency band. A maximum loss requirement of 10 dB is imposed on the amplifier when the transistor is unpowered. The maximum noise figure is 3 dB with typical values measured around 2.7 dB. Typically, the third-order intermodulation coefficient, $M_{A+B-C} = -45$ dB.

Mechanical construction of this amplifier is very similar to the 4-GHz amplifier previously designed for use in the TD Radio System.[3] The GaAs FET is mounted in a microstrip circuit module. Three circulators in air strip-line (Fig. 2) provide good return loss at the input and output waveguide ports as well as an effective passive bypass circuit in case the amplifier module fails. The amplifier has a return loss requirement of 30 dB minimum at both waveguide ports.

The dc operating point for the GaAs FET is a compromise between noise figure and linearity. A built-in regulator sets the gate voltage so that $I_D = 15$ mA at $V_{DS} = 4.8$ volts. The amplifier operates from a −24 volt supply drawing 60 mA. In case of transistor or power supply failure, a contact closure is provided for an alarm indication. At the same time, a visible green Light-Emitting Diode (LED) will be turned off.

### 2.2.2 Receiver modulator/IF preamplifier

The modulator mixes the received RF signal with the locally generated microwave carrier (LO), which is at a frequency 74.1 MHz above or below the center frequency of the received signal. The modulator, a direct use of an existing TH-3 FM radio design,[4] consists of a stepped waveguide transformer, a waffle-iron low-pass filter, and a diode-mount waveguide section. The basic arrangement of the circuit is shown in Fig. 3. The IF signal is fed through a coaxial low-pass filter to the IF preamplifier input. To obtain improved third-order intermodulation performance for AR6A applications, an LO level of +10 dBm is used instead of +6 dBm as for TH-3. An $M_{A+B-C}$ of about −21 dB is obtained for this LO drive level and optimized diode dc biasing.

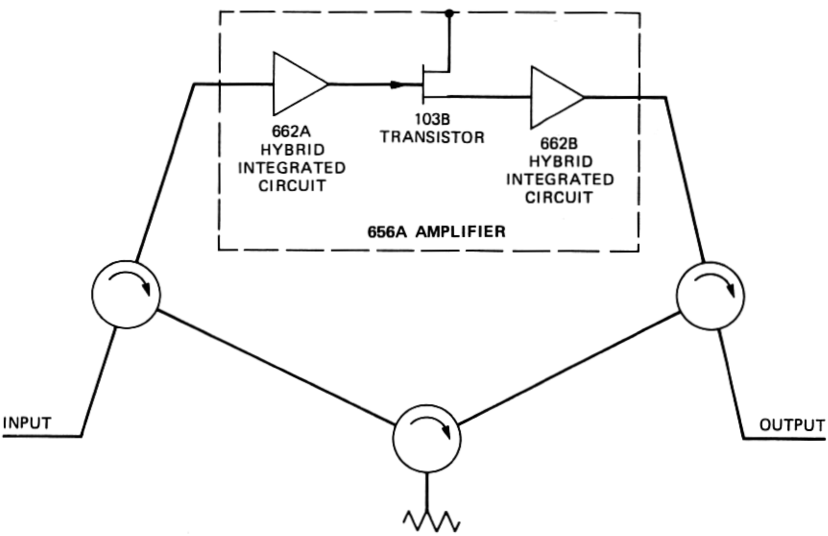


Fig. 2—RF preamplifier.

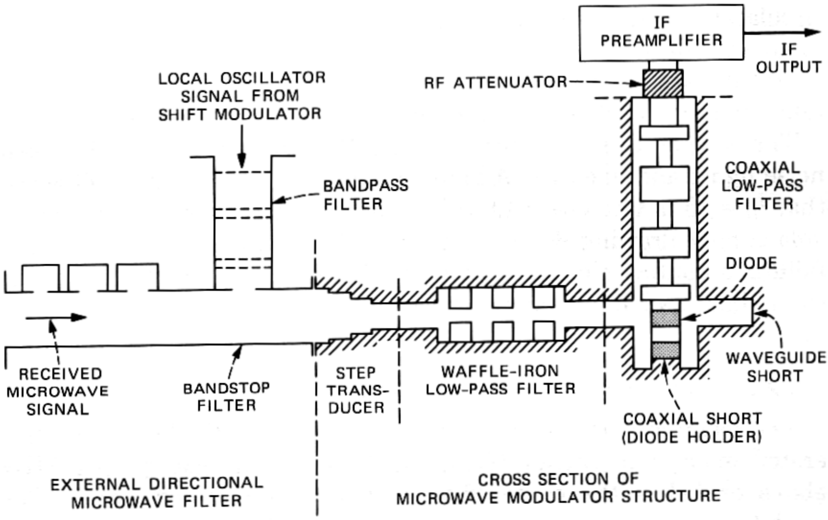


Fig. 3—Basic arrangement of receiver modulator and IF preamplifier assembly.

The 3-stage IF preamplifier has an overall gain of approximately 32 dB. A gain control allows a gain variation of ±3 dB. A slope control is used to achieve flat gain across the band, and two return loss controls are used to provide 30 dB or greater output return loss. The first stage is a low-noise common emitter configuration followed by two hybrid-feedback stages in the output. This configuration provides low-distortion and high-output return loss. The first-stage transistor is designed for low thermal noise performance, but a trade-off was made between best thermal noise and low intermodulation noise. With a dc bias current of about 25 mA and $V_{CE}$ of 3 volts, a gain of 17 dB is realized in this stage with a noise figure of 2.7 dB and an intermodulation coefficient $M_{A+B-C}$ of −45 dB. The following two stages are biased for high-linearity performance. With both transistors biased at an $I_c$ of 120 mA and $V_{CE}$ of 13 volts, the noise figure of the two stages combined is 8 dB with $M_{A+B-C}$ of −80 dB. The complete receiver modulator/preamplifier provides a nominal 28 dB of RF-to-IF gain at a full-load output level of −4 dBm with a noise figure of 8 dB and an overall $M_{A+B-C}$ of −75 dB.

### *2.2.3 Pilot resupply switch*

Figure 4 is a simplified block diagram of the pilot resupply switch circuit. The unit contains a 10-dB directional coupler, a wideband power detector, and an IF switch. The −10 dB port of the coupler is connected through an IF isolation amplifier and power detector. The signal path through the coupler is connected to the receiver-out port

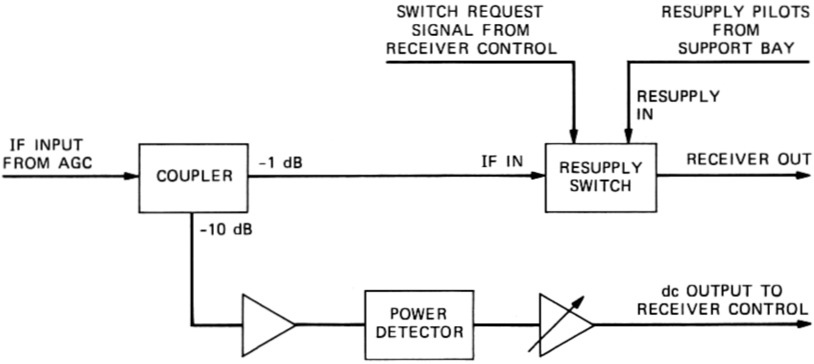


Fig. 4—AR6A resupply switch circuit.

through the normally closed contacts of the switch. The insertion loss through the pilot resupply switch unit is 1 dB. The local set of resupply pilots from the AR6A support bay is applied to the normally open contacts. In this condition, there is 90 dB or greater isolation between the resupply input port and the receiver output port.

The dc output from the power detector is buffered by a variable gain operational amplifier and connected to the receiver control unit. The gain of the amplifier is adjusted to achieve a prescribed output level for a corresponding reference IF power input. This circuit also provides an overpower monitoring feature. If the output exceeds a given threshold for a period of about 80 ms, the receiver control unit will initiate a pilot resupply switch request. The threshold corresponds to an overpower condition of about 12 dB. The receiver control will also initiate a switch request for an underpower condition and in response to a local or remote switch request.

Operation of the resupply switch is controlled by the receiver control unit. When the switch request is made, the IF input from the AGC amplifier is disconnected from the receiver output port and terminated internally in 75 ohms. At the same time the internal termination is disconnected from the local set of resupply pilots, which are then connected through to the receiver output port.

### *2.2.4 Space-diversity switch and control*

The 436A switch, shown in Fig. 5, provides switching between two input ports and a single waveguide output port. One input is WR159 waveguide and is connected to the channel-separation filter that is part of the common waveguide lineup connecting to the main (or preferred) antenna. The other input, an SMA-coaxial port, is connected to the channel-separation filter that connects to the diversity

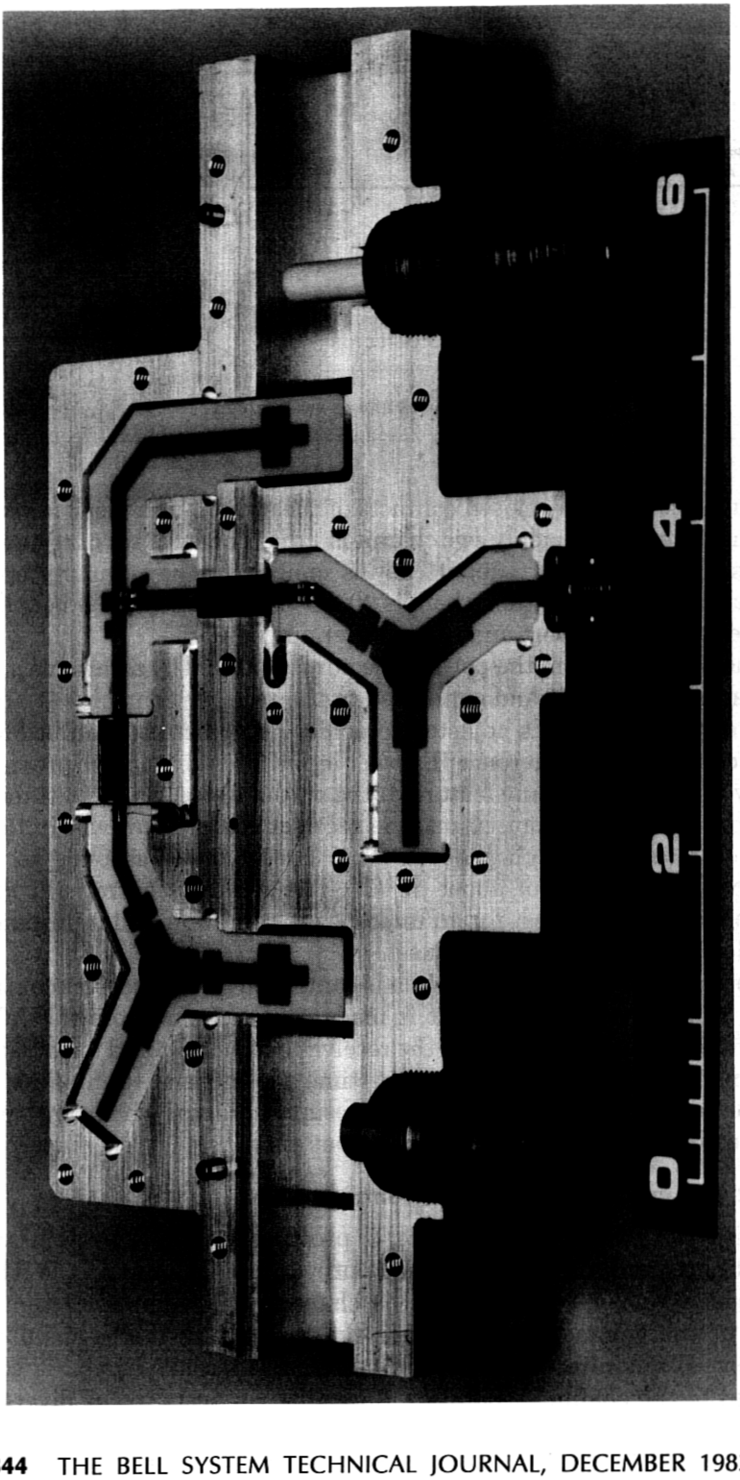


Fig. 5—Space-diversity switch.

antenna. Isolators are built into each port. They provide a [illegible] load to the channel-separation filters when either path of th[illegible] is in its open state. The return loss of the input waveguide [illegible] required to exceed 30 dB; the output waveguide port, 20 dB; a[illegible] input coaxial port 25 dB. The insertion loss is required to be les[illegible]an 1.75 dB. An air leakage path is provided between input and output waveguide ports to provide a path for air when used in a pressurized waveguide system. The switch is designed to fit into the space normally occupied by the 16B shutter monitor and 23A isolator in nonspace-diversity applications. Therefore, the switch is equipped with test access ports and shorting plates to perform the functions of a shutter monitor.

Diode modules in each of the input paths of the switch incorporate three p-i-n diodes. In the preferred signal path the diode module is zero biased to its low-loss (closed) state. In the nonpreferred signal path the diode module is forward biased to its high-loss (open) state. Isolation between input and output ports in the open state exceeds 70 dB.

The space-diversity switch control unit contains the control circuitry for the 436A switch. The circuit can be separated into an analog portion that delivers the driving current function for each p-i-n diode module and a digital portion that includes the fault and alarm circuitry, the reversion circuitry, the main switching circuitry, and the test circuitry.

The switch control panel contains three red LEDs for indicating fault conditions, two green LEDs for indicating which antenna is connected to the receiver, a momentary pushbutton switch for resetting fault conditions or manual antenna selection, and a mode select switch that allows manual or automatic operation.

Although there are no field adjustments, it is necessary to position two miniplugs for selecting various options. One of these user-selectable options allows either antenna to be designated as the preferred antenna and the other enables the automatic reversion option. Other miniplugs are for factory test purposes only.

In operation the main switching circuitry responds to a digital switch request signal generated in the receiver control unit. This switch request will be honored only if the control unit is in the automatic mode and has not switched in the previous 10 seconds. Two driving functions are employed to control the separate diode modules in the space-diversity switch. These driving functions are identical but 180 degrees out of phase and are overlapped to provide a make-before-break type of transition. The maximum rate of switching is limited to one transition every 10 seconds.

If the automatic reversion option was chosen and the receiver has been connected to the nonpreferred antenna for 30 minutes, the reversion circuitry will cause a switch back to the preferred antenna. If a switch request is received during the next 3 minutes, indicating that signal fading is still excessive on the preferred antenna, the control circuit will switch the receiver input back to the nonpreferred antenna and reinitiate the 30-minute timer. If a switch request had not been received during the 3-minute interval, the receiver would remain connected to the preferred antenna.

Any one of six fault conditions will result in a space-diversity switch alarm. Seizure faults are generated whenever either antenna is selected manually or whenever either test function is selected. A reversion fault occurs after 14 consecutive reversion attempts fail. The 15th attempt will cause a 7.5-hour timer to time out thereby inhibiting the operation of the reversion circuitry while allowing the rest of the control circuitry to function normally. A reversion fault is reset by depressing the EXCHANGE ANTENNA/RESET switch. A switch request fault is produced whenever a continual switch request is present for more than 85 minutes. The antenna in use is then seized and further operation of the control is blocked to prevent indefinite switching at a 10-second rate. This fault is reset when a low-to-high logic-level transition is received on the switch request input or the EXCHANGE ANTENNA/RESET switch is depressed.

All control unit input and output levels are Transistor-Transistor Logic (TTL) except the two analog signals driving the space-diversity switch. The ALARM output provides a signal to the alarm and control interface circuit. The output labeled SDS ACTIVITY provides a means of monitoring the space-diversity switch performance.

## III. THE AR6A TRANSMITTER

### *3.1 General*

Figure 6 shows the signal-carrying components of the transmitter, together with other ancillary units. The input signal to the transmitter is the 10-mastergroup IF spectrum and includes all pilot tones. This spectrum at a full-load power level of −10.8 dBm comes from either the 500A switch or the output of the preceding receiver and is first applied to the predistorter.[5] The predistorter adds a specific amount of third-order intermodulation distortion with the proper phase relative to the main signal to reduce the intermodulation distortion generated by the remainder of the transmitter. After the signal is predistorted, it enters the amplifier/transmitter modulator, which consists of an IF buffer amplifier, slope equalizer, and a single-ended up converter. The double-sideband RF signal out of the modulator, at a nominal full-load level of −16.7 dBm per sideband, is directed

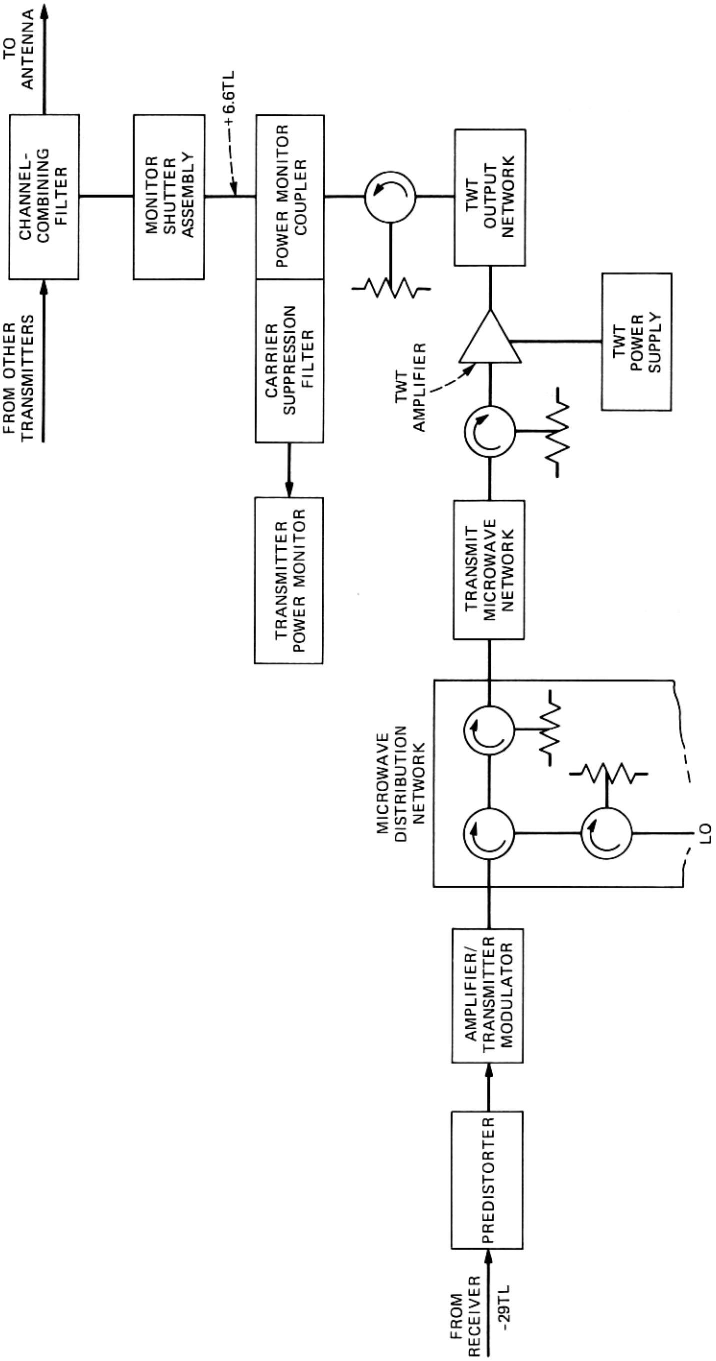


Fig. 6—Transmitter portion of an AR6A TR bay.

through the microwave distribution network to the transmit microwave network (1450 type), which is a bandpass filter with a 1-section delay equalizer. The bandpass filter selects the appropriate sideband and attenuates the carrier and unwanted sideband. More details are given in the next section of this chapter. From the transmit microwave network the signal passes through an isolator to the input of the TWT amplifier.[6] The traveling-wave tube has a typical gain of 44 dB, with gain plus noise figure ≤69.5 dB, and a third-order intermodulation coefficient $M_{A+B-C} \leq -90.5$ dB. A coaxial-to-waveguide transducer is integrated with the tube mount at the input. At the output of the TWT the signal is stripped of its second harmonic content in the TWT output network, which is the combination of a waffle-iron filter, stepped waveguide transformer, and an isolator. The signal is directed through the power monitor/coupler and shutter monitor assembly where the full-load RF power is approximately +25 dBm. The channel-combining filter combines the signal with the spectra of other radio channels.

### *3.2 Circuit descriptions*

#### *3.2.1 The IF predistorter*

Figure 7 is a block diagram of the predistorter used in AR6A. After amplification to a level of approximately +1 dBm, the spectrum enters the phase resolver circuit.[1] The phase resolver splits the input signal into two parts with the phase angle between the two output ports being adjustable. The signal passing through the delay line is the main signal and constitutes the reference. The phase-shifted signal is applied to the other path, which is referred to as the cuber path. The delay line in the main signal path is used to match the delay of the other path to within ±0.1 ns.

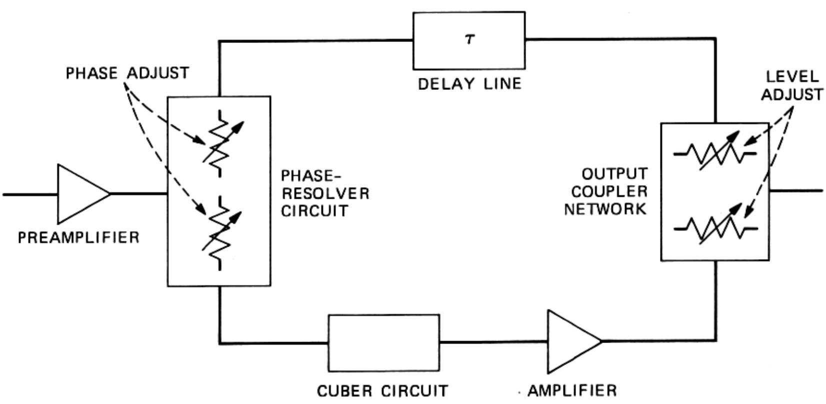


Fig. 7—Block diagram of a predistorter.

The cuber circuit[7] generates the desired complementary distortion products. The cuber circuit consists primarily of two pairs of back diodes connected antiparallel and in opposite branches of a bridge circuit. In this bridge arrangement fundamental frequency signals are canceled by at least 60 dB. The antiparallel pair of diodes generates predominantly odd-order intermodulation products. They are carefully selected for best conversion efficiency and performance that is not level-dependent. Other design considerations and requirements are described in a companion article in this issue.[5] The distortion amplifier brings these complementary distortion products to the desired level and feeds them directly into the output coupler, where the complementary distortions products are combined with the main signal.

The output coupler circuit contains two variable attenuators allowing the independent level adjustment of the main signal and distortion signal prior to combining them. At the output of the predistorter the main path nominal signal level is approximately −14 dBm and the complementary distortion products are at a level of about −71 dBm.

### 3.2.2 Amplifier/transmitter modulator

The amplifier/transmitter modulator, shown in Fig. 8, is used to translate a 59- to 89-MHz IF signal to the 6-GHz communications band with minimum distortion. The amplifier serves as a buffer between the IF input port and the Schottky diode of the transmitter modulator to minimize variations in the input return loss. Slope and gain compensation of the overall transmission characteristic is accomplished by adjustments located on the amplifier. The amplifier is also equipped with a p-i-n diode attenuator that protects the transmitter output networks by limiting the maximum input power to the transmitter.

The transmitter modulator combines the IF input signal from the amplifier with the microwave carrier. This combining or mixing action results in the creation of a lower sideband (LSB) and a upper sideband (USB) referenced to the microwave carrier.

The amplifier consists of two transistor stages. Ahead of these stages is a transmitter gain adjustment, which sets the transmitter output power by attenuating the IF input signal level. This adjustment is capable of varying the IF signal level over a 20-dB range although, typically, an adjustment less than ±3.9 dB is required.

The first amplifier stage is a common base configuration designed to exhibit very low third-order intermodulation distortion. A slope equalizer network follows the first amplifier stage. When the slope adjustment is rotated clockwise, the network forms a low-pass filter with a negative slope transmission characteristic. When rotated counterclockwise the network becomes a high-pass filter with a positive

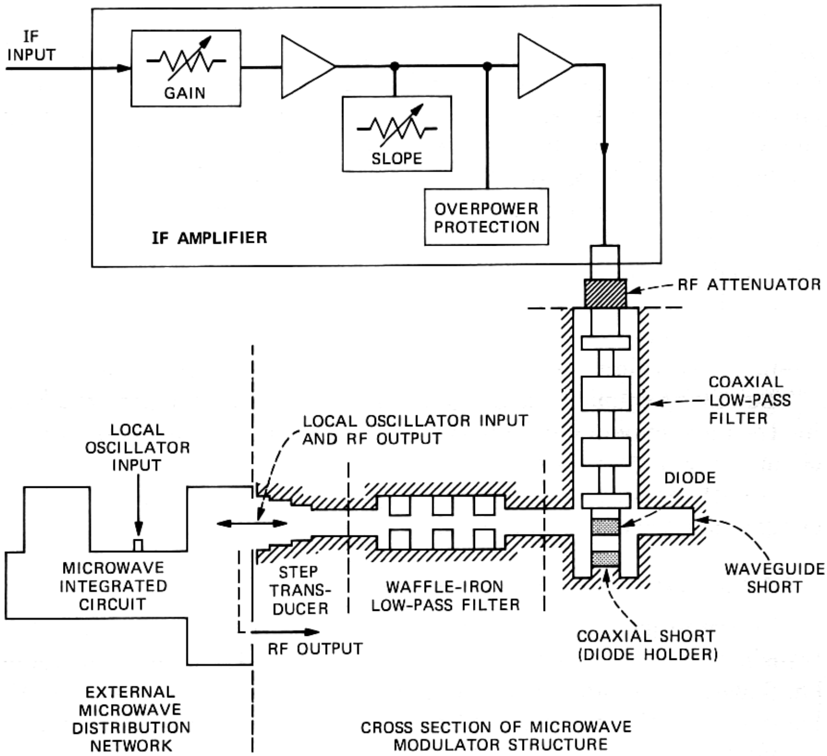


Fig. 8—Basic arrangement of an amplifier/transmitter modulator.

slope transmission characteristic. The slope equalizer network adjustment is capable of varying the IF channel slope over a range greater than ±1 dB although, typically, an adjustment less than ±0.2 dB is required.

The second amplifier stage is a common emitter configuration. It provides approximately 5 dB of additional gain and buffers the transmitter modulator Schottky diode from the slope equalizer network.

The p-i-n diode attenuator network is controlled by a third transistor. Under normal operating conditions, no dc current flows through the p-i-n diode and, therefore, its ac impedance is extremely high. However, should the transmitter output power increase to the point where limiting is required, the transistor will drive dc current through the p-i-n diode and cause its ac impedance to become very low. This loads down the collector of the first-stage transistor thereby attenuating the IF signal by a nominal 10 dB.

The 59- to 89-MHz IF signal from the amplifier and the dc bias for the Schottky diode are fed through an RF attenuator and low-pass coaxial filter to the diode in the transmitter modulator. The coaxial filter suppresses 6-GHz fundamental frequencies and their second and third harmonics while the attenuator provides additional loss at frequencies above 1 GHz to prevent this energy from feeding back to the amplifier. The combined insertion loss of the coaxial filter and attenuator is approximately 3 dB at 800 MHz and 50 dB at 6 GHz.

The microwave carrier frequency is applied to the Schottky diode through a waveguide input port, a stepped waveguide transformer and a waffle-iron filter. The Schottky diode is physically mounted between a coaxial short, which is also the diode holder, and one end of the coaxial low-pass filter. The distance that the coaxial short extends into the diode cavity and the position of the waveguide short are designed to achieve the desired conversion efficiency and eliminate second-harmonic waveguide resonances, which could adversely affect the linearity of the transmitter modulator circuit.

The stepped waveguide transformer provides a smooth transition of the RF transmission characteristic from the reduced height waveguide, used in the design of the waffle-iron filter and diode mount, to full-height WR159 waveguide. The waffle-iron filter prevents the second-harmonic frequencies, which are generated in the transmitter modulator, from appearing at the waveguide port. The waffle-iron filter has an insertion loss of approximately 3 dB at 8.2 GHz and 40 dB at 12 GHz.

The IF signal and the microwave carrier are mixed in the Schottky diode to obtain the RF sideband frequencies. The sideband frequencies appear at the waveguide port and are then filtered to select the desired sideband. The single-tone output power level of the transmitter modulator is nominally −16.7 dBm when a single-tone IF input power level of −13.8 dBm is applied to the amplifier and a microwave carrier power of +16 dBm is applied to the transmitter modulator. A supply voltage of −15 volts dc at approximately 155 mA is required to operate the amplifier/transmitter modulator.

### *3.2.3 Traveling-wave-tube amplifier*

The traveling-wave-tube amplifier supplies the necessary microwave gain. The amplifier has unique linearity requirements: it must provide low third-order intermodulation levels ($M_{A+B-C} < -90.5$ dB) and must have a constant gain and third-order intermodulation coefficient over a wide range of output power (from 23 to 35 dBm).

The amplifier, which is convection cooled, consists of a TWT envelope, focusing mount, and power supply. The input to the amplifier is through an SMA-coaxial connector. The output is reduced height (0.1-inch) WR159 waveguide. Focusing adjustments on the mount minimize helix current.

The power supply provides all voltages required by the TWT. The -24 volt battery, fed through a frame filter to reduce low-frequency (60-Hz harmonics) ripple, is used to operate the high-voltage TWT power supply. Front-panel meters measure helix and collector (or beam) currents. A helix voltage adjustment on the front panel is used to set the TWT to its proper operating point.

## IV. MICROWAVE NETWORKS

Various microwave components used in the TR bays were designed some time ago for applications in previous 6-GHz microwave radio systems. Therefore, we are limiting our discussion to new components designed for AR6A.

The 1379-type filter is used as both a channel-separating and channel-combining filter. This filter is mechanically identical to the 1340-type channel-combining filter of the TH-3 System.[8] It is a six-cavity, pseudodirectional filter in WR159 waveguide with a 3-dB bandwidth of 54.15 MHz. To reduce the passband insertion loss slope due to the inductive nature of discontinuities used in the design, the filter is tuned 1 MHz lower than the channel frequency. The insertion loss at the channel frequency should be less than 0.75 dB. In the stopband the loss follows well with the calculated loss of a six-cavity, maximally flat, waveguide bandpass filter.

The receiver modulator filter (1374 type) is a three-cavity directional filter in WR159 waveguide that couples the microwave carrier (LO) and the signal into the receiver modulator. The insertion loss at the LO frequency is no more than 1 dB and the 3-dB bandwidth is 17 MHz. Selectivity at frequencies ±25 MHz away from the center of the bandpass is more than 30 dB. The return loss for both signal and LO ports is required to be at least 30 dB.

The transmitter microwave network (1450 type) is used to block the unwanted sideband at the output of the transmitter modulator. It consists of a seven-cavity, maximally flat, bandpass filter (1373 type) in WR159 waveguide and a microwave delay equalizer.[9] The 1373 filter has a 3-dB bandwidth of 70 MHz. The return loss over the 34-MHz passband is required to be better than 30 dB. The insertion loss at midband is less than 0.65 dB. The delay equalizer adds no more than 0.35 dB to the filter passband loss. The residual delay distortion of the network should be less than ±0.2 ns over a 30-MHz passband.

The TWT output network (1451 type) serves the two functions of transducing the reduced height waveguide at the TWT output port to the full-height WR159 waveguide and of rejecting harmonics from the TWT. It consists of a three-section waffle-iron low-pass filter and a three-section quarter-wavelength step impedance transducer. The network has a 30-dB return loss requirement over the 6-GHz band. The insertion loss at the second-harmonic frequency is about 40 dB.

The 1452 network is a power-monitoring coupler in the transmitter. The main signal path consists of a 26.5-dB cross-guide coupler and a 90-degree step twist. The coupled arm has a two-cavity, band-reject filter to block the LO frequency and a waveguide-to-SMA coaxial transducer in the output port. A 30-dB return loss requirement over the entire frequency band is imposed on the main signal path. The coupled arm requires a 20-dB return loss over a 30-MHz band centered at the channel frequency. About 55-dB rejection is provided at the LO frequency by the band-reject filter.

To reduce multiple reflections in the RF signal path of the radio bay, a long section of bent semirigid coaxial cable in the transmitter was tuned and tested together with its two transducers to WR159 waveguide, as a network (1453 type). It requires 30-dB return loss over the entire frequency band. This network is particularly sensitive because of its connection directly to the 1379-type filter. If a mismatch occurs in the 1453 network, severe ripple may occur in the channel.

Three shutter monitors are also required in the bay: the 16A, used in the transmitter, consists of three sliding shorts and two probes; the 17A shutter-monitor, used in the shift modulator circuit, consists of one sliding short and one probe; the 16B, used in the receiver when the space-diversity switch is not used, is similar to the 16A. The shutter-monitor is a waveguide component that has an access port in the broad wall in which a coaxial probe can be inserted. Slides may be inserted into slots cut into the narrow wall, thus providing a short across the waveguide. The resulting assembly is similar to a coaxial-to-waveguide transducer. With the probe and slides removed, the assembly becomes a simple waveguide section. A minimum return loss of 23 dB can be expected from the coaxial probe, and about 35-dB insertion loss per inserted sliding short can be achieved.

## V. ALARM AND CONTROL INTERFACE CIRCUITS

The alarm and control interface circuits consist of six units that provide the alarms, indications, and commands needed for one TR bay. These circuits provide a means for external identification of the particular failure, visual indications of trouble conditions on the TR bay display panel, remote indications of trouble conditions, maintaining visual alarms when audible alarms are silenced or disabled, and converting a command from C- or E-type telemetry equipment to a TTL level for interfacing with the TR bay.

The command unit translates command pulses (generated by a contact closure) from a C- or E-type telemetry system to a latched logic-level change for the remote operation of a function in the TR bay. The command circuits in the bays use a multiplex scheme requiring two command pulses from the telemetry system for the operation of any one function. One command pulse from the telemetry equipment for each bay is used for addressing that bay. This is followed by a second command associated with a particular function. This second command is fed to all other radio bays in both directions of transmission but is accepted only by the addressed bay. It is necessary to readdress the bay for each subsequent operation of a function. The five operations that can be remotely performed by command are as follows: RESUPPLY INITIATE, FLAT EQUALIZER SHAPE, NOMINAL RECEIVER GAIN, GAIN MEASUREMENT REQUEST, and BAY RESET.

Conditions causing alarms and indications are listed in Table I. Inputs to the receiver alarm unit are from the receiver or common equipment only; inputs to the transmitter alarm unit are from the transmitter or common equipment only; and inputs to the common alarm unit are from the equipment shared by both the transmitter and the receiver.

The alarm fuse unit provides two fused sources of -24 volts. One source is used for powering all of the alarm and control interface circuit relays. The other is an additional source of power for the power alarm relays.

The alarm relay unit translates TR bay alarms into contact closures for the operation of external audible, visual, and remote alarms. The

Table I—Conditions causing alarms and indications

| Condition | Receiver Alarm | Transmitter Alarm | Remote Indication | Display Panel Indication |
|---|---|---|---|---|
| Space-diversity switch alarm | X | | | X |
| Receiver control alarm | X | | | |
| Resupply initiate alarm (delayed) | X | | | |
| Equalizer at maximum range (delayed) | X | | | |
| Shift oscillator loss of lock | X | | | X |
| Radio bay enabled | | | | X |
| Predistorter off | | X | | |
| Low or high transmitter power | | X | | X |
| Low dc power | X | X | | |
| Microwave generator low power | X | X | | X |
| Microwave generator loss of lock | X | X | | X |
| Transmitter gain normal | | | X | X |
| TWT beam fault | | | X | |
| Space diversity initiated | | | X | |
| Shift oscillator or microwave generator memory fault | | | X | X |
| Resupply initiated by command | X | | X | X |
| Receiver gain nominal by command | X | | X | |
| Equalizer flat shape by command | X | | X | |

unit also has an alarm cutoff function for silencing the audible alarms. LEDs on the faceplate provide a visual indication for a bay alarm or a power alarm.

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## AUTHORS


**Edmund F. Cook,** B.S.M.A., 1965, Fairleigh Dickinson University; Bell Laboratories, 1954—. At Bell Laboratories, Mr. Cook was first engaged in the development of radio telemetry and electronic switching systems. Since 1971 he has participated in the development of the AR6A Microwave Radio System with particular emphasis on modulator and traveling-wave-tube studies.

**Rudolf P. Hecken,** M.S.E.E., 1959, Ph.D., 1964, Technische Hochshule Aachen, West Germany; Institute for High Frequency Technology, Aachen 1959–1964; CERN, Geneva, Switzerland, 1964–1968, Bell Laboratories, 1968—. Mr. Hecken has been involved in the design of networks for the L5 coaxial system, FM microwave radio systems, and the AR6A Radio System. Since 1982 he has been Director of the Radio Systems and Terminals Laboratory.

**Richard C. Heidt,** A.S.E.E., Arlington State Jr. College, 1956; B.S.E.E., Southern Methodist University, 1959; M.E.E., New York University, 1963; Bell Laboratories, 1961—. Mr. Heidt worked first in microwave transmission circuits and antennas. Since 1969 he has been involved in the design of transmitters for the single-sideband microwave radio system. He is currently Supervisor of a group developing digital microwave radio systems. Member, IEEE, Eta Kappa Nu, Sigma Tau, Kappa Mu Epsilon.

**Robert W. Judkins,** Bell Laboratories, 1954—. Mr. Judkins' early work was directed towards design and development of microwave circuits, such as up converters, down converters, frequency multipliers, and waveguide networks for use in TD-3, TH-3, and TN-1 radio systems. Since 1975 he has worked on the design and development of solid state microwave switches, preamplifiers, and power amplifiers.

**J. Morgan Kiker, Jr.,** B.S.E.E., 1962, University of California at Berkeley; M.S.E.E., 1964, New York University; Bell Laboratories, 1962—. Mr. Kiker began work on high-resolution radar systems. Since 1971 he has supervised work on ultralinear IF amplifiers and low-noise carrier and oscillator supplies for the AR6A Radio System. He is now working on digital radio systems. Member, Tau Beta Pi, Eta Kappa Nu.

**Frank J. Provenzano, Jr.,** E.T., RCA Institutes, 1969; Merrimack College, 1982—; Bell Laboratories, 1969—. Mr. Provenzano has worked on various aspects of the single-sideband microwave radio system since starting at Bell Laboratories. He currently is working on alarm systems for digital radio systems.

**Han-Chiu Wang,** B.S.E.E., 1955, Cheng-Kung University, China; M.S.E.E., 1960, University of Notre Dame; Ph.D. 1965, Polytechnic Institute of Brooklyn; Bell Laboratories, 1965—. Mr. Wang has worked on microwave generators, microwave amplifiers, and various microwave and millimeter wave networks. Presently, he is Supervisor of the Microwave Network and Antenna Group supporting development of microwave radio transmission systems.