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TH-3 Microwave Radio System:

4A FM Transmitter and Receiver

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FM terminals form an important subsystem of long-haul microwave radio systems as the link between the baseband signal and the 70-MHz FM signal. Designed primarily for use on the TH-3 system, 4A FM terminals are also compatible with the TD-2 and TD-3 long-haul microwave radio systems. Using solid state circuitry throughout, emphasis was placed on reliability and performance consistent with TH-3 objectives with up to sixteen FM terminal pairs in tandem in 4000 miles. The FM transmitter utilizes the capacitance of two voltage-controlled varactor diodes in a resonant circuit of an oscillator operating at an IF frequency of 70 MHz. The diode capacitance is varied by applying a baseband signal across the diodes resulting in a frequency-modulated 70-MHz signal. The FM receiver uses a balanced, parallel resonant type discriminator preceded by two limiter circuits which ensure good AM suppression and a wide dynamic range. The FM terminal pair gain is 16 dB with a balanced baseband input and output impedance of 124 ohms.

I. INTRODUCTION

FM terminals perform the initial and final modulation steps in non-remodulating type microwave radio systems. The 4A FM transmitter converts the baseband signal to a frequency-modulated signal centered at 70 MHz while the 4A FM receiver performs the function of recovering the baseband modulation from the FM signal. The 4A FM terminal equipment will be used to provide improved performance in the TD and TH-3 microwave radio systems.

Design emphasis was placed on: (*i*) improved performance and reliability; (*ii*) reduced cost and size. The 4A FM terminal equipment (see Fig. 1) is capable of carrying up to 1800 message circuits comprising three multiplex mastergroups or one NTSC color television

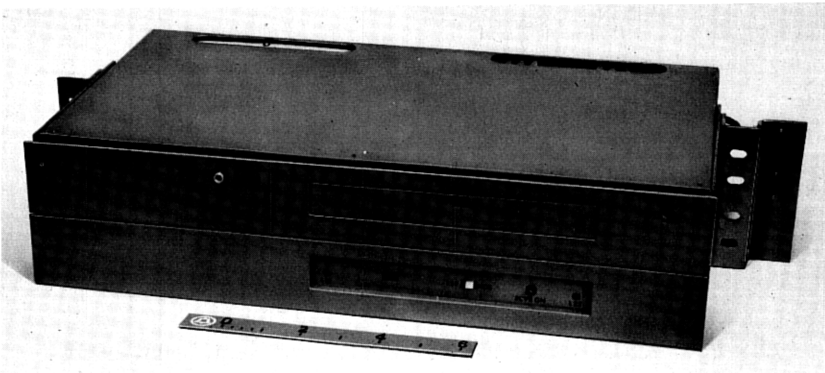

Fig. 1—4A FM terminal pair.

signal. FM terminals are required at each end of a radio route and at intermediate points where some portion or all of the baseband signal must be dropped or added.

II. DESIGN OBJECTIVES

The design objectives assigned to a terminal pair apply with pre-emphasis shapes which are chosen to optimize the overall radio system performance. The pre-emphasis shape used for 1200-circuit loading on TD systems is also used for 1800-circuit loading on TH-3 with little compromise from the ideal shape. With appropriate assumptions about the law of impairment addition, the system allocation to a single pair of terminals is given in Table I.

The modulating signals carried by TH-3 have an upper frequency limit of approximately 8 MHz. However, to minimize the influence of terminals on high-end frequency response and to allow fcr future applications, the high frequencies are controlled to 12 MHz. Phase distortion of the low-frequency components of the TV signal is satisfactorily controlled by maintaining the transmission response essentially flat down to 6 Hz.

Total FM terminal noise is a combination of fluctuation noise and cross-modulation distortion produced by circuit nonlinearities. In design and maintenance it is the linearity of the facility which is measured and adjusted to control cross modulation. However, since the desired end result is low noise, this is used as a final objective rather than the causative linearity requirements.

Undesired radio signals which leak into a repeatered radio system can cause interfering baseband beat tones at the receiver output. These same spurious signals in earlier radio systems which used klystron

TABLE I—DESIGN OBJECTIVES FOR ONE FM TERMINAL PAIR

Baseband transmission Bandwidth (±0.1 dB point) (±0.25 dB point) Gain stability	 6 Hz to 10 MHz 10 MHz to 12 MHz ±0.25 dB per six-month maintenance interval
Load	1800 message circuits or one NTSC color television signal
Total noise contribution with an 1800-circuit pre-emphasized message load Television weighted signal-to- low-frequency-noise high-frequency-noise	<17 dBrnc0 >40 dB >73 dB
Center frequency of FM transmitter Peak frequency deviation Deviation sense Transmitter longitudinal suppression Carrier spreading	70 MHz ± 100 kHz 4 MHz Positive signal on input tip produces a decrease in transmitter frequency >53 dB up to 1 MHz 12 dB reduction of radio frequency interfering tone per 3-kHz band
Change in receiver demodulation sensitivity for a 10-dB reduction in IF input Microphonics	<0.25 dB Negligible
Change in transmitter carrier frequency between zero and full-level modulation Operating temperature range	<20 kHz 0 to 50°C

FM generators were less of an interference problem because the relatively unstable klystron-generated carriers caused the baseband beat frequency to spread randomly over several telephone channels rather than appear as a tone in a single channel. In the 4A transmitter design this same unstable carrier effect is simulated by modulating the carrier at a relatively high index with low-frequency noise when the system is used for telephone message transmission. The carrier is spread or deviated 22 kHz rms to achieve a 12-dB reduction in tone interfering effects in a 3-kHz telephone channel.

The requirement relating to carrier frequency stability as a function of modulation level is associated with the use of the carrier null or Crosby technique to accurately set the transmitter deviation.[1] Since the detection of a carrier null in the presence of adjacent sidebands requires a narrow-band receiver, it is essential that the application of modulation does not shift the carrier outside the receiver passband.

III. FM TRANSMITTER

The block diagram of Fig. 2 shows the general circuit features of the 4A FM transmitter. The balanced input signal is amplified and converted to a low-impedance unbalanced signal which is then applied to the deviator. The signal voltage applied to a pair of hyper-abrupt junction varactor diodes modulates the frequency of a 70-MHz oscillator. All circuitry of the deviator, comprising oscillator, varactor diode biasing circuits, and IF buffer amplifier, is located in a controlled temperature environment to maintain the IF output frequency within the prescribed limits of ±100 kHz. The IF is filtered to reduce the harmonic content and amplified to produce the desired output level.

Three peripheral circuits outside the transmission path are included: an oven temperature control circuit, a 0–1-kHz noise generator, and a voltage regulator. The noise is inserted into the baseband signal to spread the carrier slightly and improve radio repeater tone interference performance. The regulator provides −20 volts for each of the units except the oven heater. Primary power for the oven heater and regulator is −24-volt battery.

The individual blocks in Fig. 2 are contained within a single die-cast chassis. Terminal bay cabling plugs into connectors located in the rear of the transmitter unit. Baseband and IF connectors are wired to a patchfield on the terminal bay.

3.1 *Baseband Amplifier*

The baseband amplifier provides a nominal 9 dB of voltage gain controlled to ±0.05 dB in the frequency band of 6 Hz to 10 MHz and ±0.25 dB from 10 MHz to 12 MHz. It also provides 53 dB of low-frequency common mode rejection.

Figure 3 is a simplified schematic diagram of the amplifier. A differential amplifier, Q_1 and Q_2, was selected for the input stages to provide common mode rejection. The emitter resistors of this amplifier provide local feedback for gain stability, but this configuration is inherently noisy. Transformers were not a practical solution to either the transistor noise or the common mode rejection problem because of the prohibitively wide transmission band of 6 Hz to 12 MHz. The noise difficulty was overcome by negative feedback of the combined noise from the collectors of the differential transistors Q_1 and Q_2 through the high-impedance current source of transistor Q_4. This feedback reduces the transistor noise by more than 12 dB. Transverse

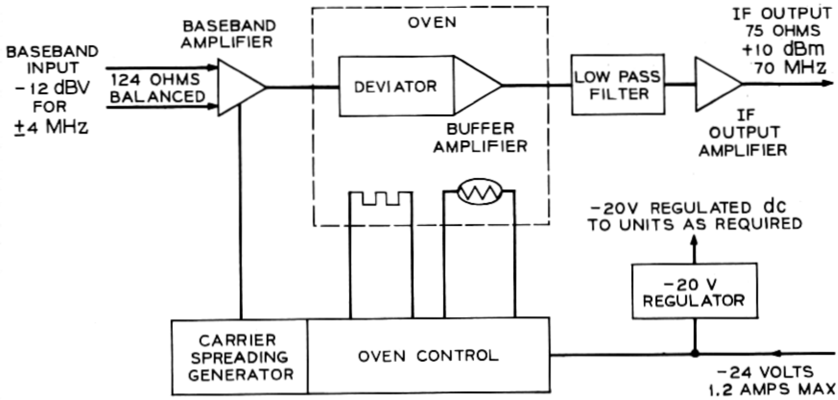

Fig. 2—Block diagram of 4A FM transmitter.

or out-of-phase signals cancel in the resistive combiner. This results in normal applied signals being unaffected by the noise feedback loop.

The gain control potentiometer is connected to equal dc voltage points which eliminates bothersome transients during gain adjustments.

A filter is used to isolate the deviator oscillator circuit from the baseband amplifier circuit. The design of this filter is complicated by the small separation between the 12-MHz upper baseband frequency and the corresponding 58-MHz first-order lower sideband of the deviator output. It would be impractical for this filter to also meet

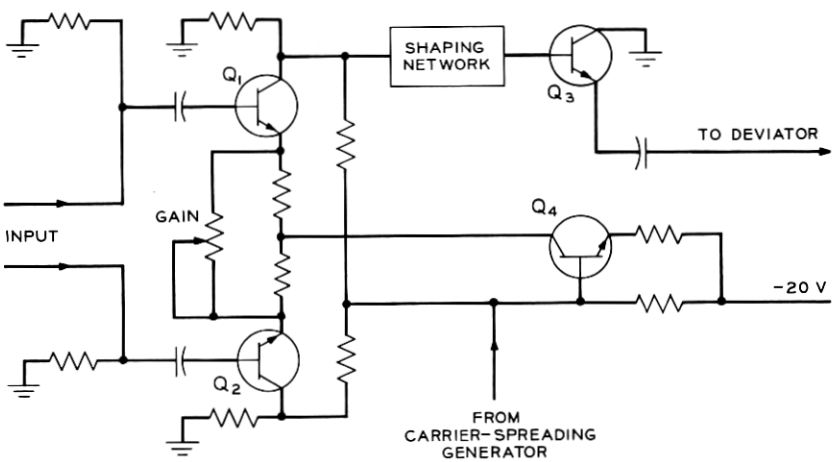

Fig. 3—Simplified schematic diagram of transmitter baseband amplifier.

the baseband frequency response requirements while terminated in the IF resonant circuit of the deviator. Therefore a simple split-apart filter is used for isolation and the resultant baseband transmission is equalized by the shaping network in the baseband amplifier.

3.2 *Deviator*

Frequency modulation in the FM transmitter is performed by the deviator. A direct deviator was used because a new design hyperabrupt junction varactor diode makes it possible to achieve broadband linearity needed in a deviator oscillating at the IF frequency of 70 MHz. Advantages of this approach, relative to the heterodyne deviator, are the absence of any spurious tones from the mixing process, reduced thermal noise problems due to higher oscillating levels, and a greater bandwidth. The principal disadvantage of the direct deviator is the difficulty in separating the oscillator and baseband signals due to their frequency proximity.

To ensure IF frequency stability, temperature control was chosen in preference to automatic frequency control. This was based on economic advantage, the elimination of low-frequency response limitations associated with an automatic frequency control loop, and the general advantages which accrue from temperature stabilization of the semiconductor circuit environment. However, the lack of an automatic frequency control circuit imposes stringent requirements on oscillator frequency stability.

The deviator is essentially a 70-MHz oscillator that is made up of a low-phase-shift amplifier with a variable phase feedback circuit (see Fig. 4). The feedback loop phase shift plus the residual phase

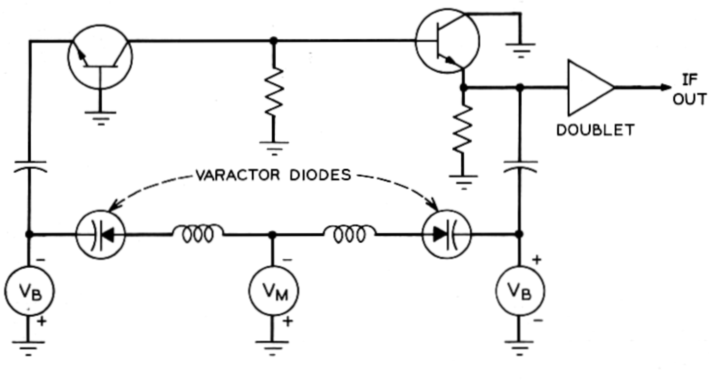

Fig. 4—Basic configuration of transmitter deviator.

shift of the amplifier equals zero degrees at the oscillating frequency.

A new hyperabrupt junction diode coded 511A was developed specifically for this application.[2] Figure 5 shows a typical diode capacitance versus voltage characteristic. Of particular interest from the standpoint of its effect on modulation linearity is the slope of the capacitance-voltage curve in the neighborhood of the operating point.

Assuming that near the operating point the diode capacitance voltage relationship can be written in the form

$$C_d = K_1 V^{-m},$$

a deviator with a single diode and inductor in the feedback path will oscillate at a frequency given by the following relationship:

$$f = \frac{1}{2\pi\sqrt{LC_d}} = \frac{V^{m/2}}{2\pi\sqrt{LK_1}}.$$

This assumes that the oscillator frequency is essentially determined by the resonant frequency of the feedback circuit.

For f to be linearly dependent on V, m must equal 2. In practice, however, a number of factors modify the preceding idealized situation. Stray capacitance for example generally requires m to be higher than the theoretical optimum. In addition, the assumed capacitance law is not accurately descriptive of the real life relationship. This is illustrated in Fig. 6 where $m = [d(\log C)/d(\log V)]$ is plotted versus bias voltage. Only in a very narrow region near the peak of the curve is m approximately constant, corresponding to an operating point in the maximum slope region of the C-V characteristic of Fig. 5. Since the maximum value of m is a diode parameter of special interest, it has been designated m.*

The diode characteristic illustrated in Fig. 6 is too narrow to obtain satisfactory deviation linearity over the desired sweep range. However, the linear operating range can be extended by using a technique analogous to the double-tuned transformer. Two diodes are connected in series as shown in Fig. 4 with individually adjustable biases. When the biases are identical at the value corresponding to m^* the series-tuned circuit will behave like the single diode case. If now the biases are offset in opposite directions, the individual m characteristics (Fig. 6) will separate to produce a broadening of the region in which m is reasonably constant. This is illustrated in Fig. 7 where the computed deviation sensitivity has been plotted against oscillator frequency with the bias offset V_B as a parameter. The analogy with undercoupled and overcoupled tuned transformers is evident. The

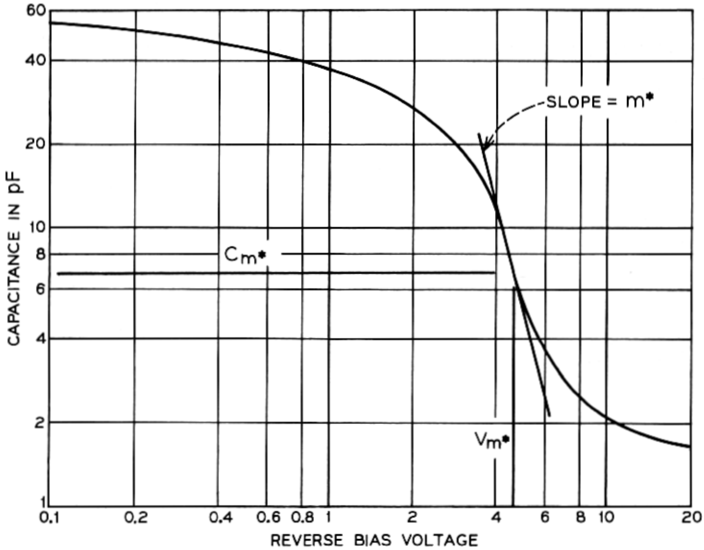

Fig. 5—Hyperabrupt junction diode capacitance vs voltage.

characteristics of Fig. 7 were obtained in a very straightforward manner starting with the capacitance-voltage characteristic of an actual diode. With two such diodes in series, the resonant frequency versus the modulating voltage V_m (Fig. 4) can be determined for each V_B. The derivative of these characteristics gives the deviation sensitivity in MHz/volt which is then plotted against resonant frequency. The deviation sensitivity plot of Fig. 7 is essentially the characteristic that

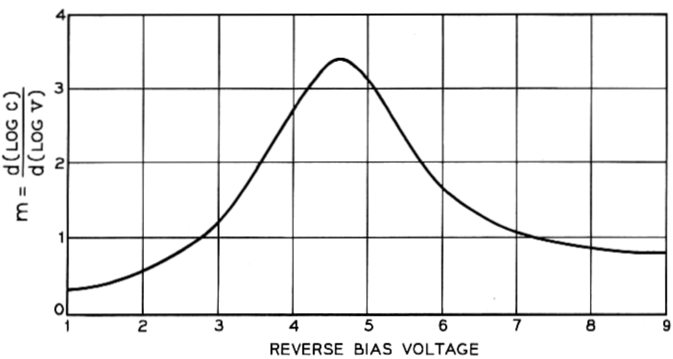

Fig. 6—Hyperabrupt junction diode m vs voltage.

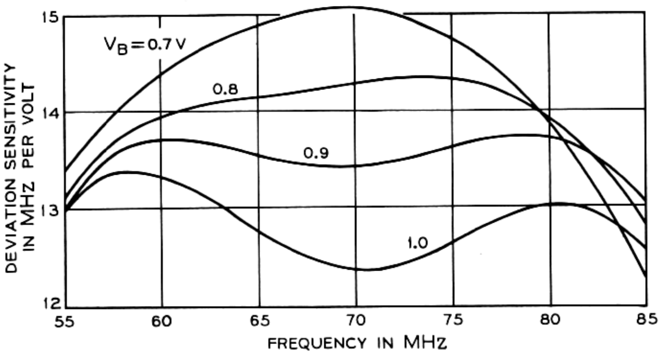

Fig. 7—Deviation sensitivity vs oscillator frequency.

would be seen on a linearity test set. Such a test set usually displays the result in percent of nonlinearity as shown in Fig. 8 for a 4A transmitter. The similarity, at least in shape, of the optimum curve in Fig. 7 with the measured characteristic in Fig. 8 is evident.

A common-base, common-collector amplifier configuration was chosen to complete the oscillator loop. The low amplifier input-output impedances and the high varactor impedances at baseband frequencies provide the required filtering needed to separate the IF and baseband frequencies. This assures that most of the baseband signal voltage drop occurs across the varactors while the IF signal present at the point of insertion is at a minimum. The loop amplifier has a gain slightly greater than unity with the common-collector stage biased to limit the loop oscillating level to a predetermined value. This

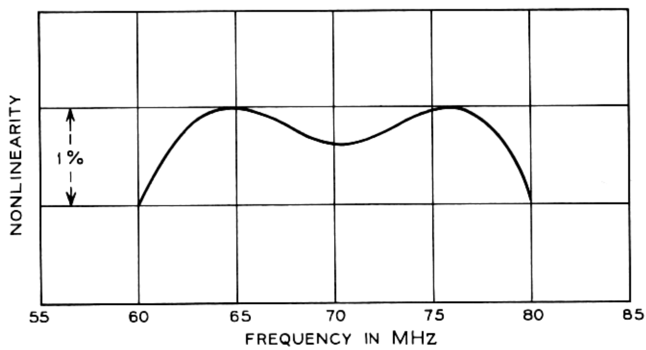

Fig. 8—Typical nonlinearity of a 4A FM transmitter.

limiting action maintains the loop gain at unity and allows for slight variations in amplifier gain and feedback loss. In practice each diode in the feedback network has an independent bias which is adjusted to produce a linear frequency deviation over the range of 62 to 78 MHz.

The oscillator loop is tapped at the amplifier output and fed to a doublet amplifier. This amplifier sets the proper IF operating level for the entire transmitter and also serves to buffer the oscillator from external impedances. A low-pass constant resistance filter at the output of the buffer amplifier reduces the harmonic components of the IF output signal.

The frequency elements most sensitive to temperature are the varactor diodes. The frequency is stabilized by isolating the diodes from heat generated by nearby circuitry. This is accomplished by placing the diodes as far as possible from heat-producing transistors and resistors and by cutting a slot in the printed wiring board between the heat source and the diodes. Also, the biasing circuits are temperature compensated for capacitance changes of the varactor diodes. This approach is good for only the average diode capacitance versus temperature characteristic and produces a stability within ±10 kHz per degree Celsius (Centigrade).

The greatest stabilizing factor is the temperature control of the entire oscillator, including the biasing and buffering circuits. By placing the sensing element for the oven control circuit as close as possible to the varactor diodes, the capacitance changes are reduced considerably. Two factors influence the selection of circuit operating temperature. On the one hand, reliability of components, particularly active ones, makes a low operating temperature desirable; on the other hand, the need for frequency stability up to 50°C ambient makes an oven temperature at least this high a necessity. As a compromise, 50°C was chosen for circuit operation with loss of control at approximately 43°C due to power dissipation of the circuitry within the oven. These factors result in a stability of ±1 kHz per degree within the control range and ±10 kHz per degree above 43°C.

3.3 *Carrier-Spreading Circuit*

The carrier-spreading circuit supplies noise with an upper bandwidth limit of 1 kHz to deviate the FM carrier at a high modulation index. This carrier deviation is analogous to an unstable carrier in spreading the beat frequency of interference-generated baseband tones into random noise interference in several message channels. This technique using 22 kHz rms deviation results in a 12-dB reduction of the interfering tone level appearing in a disturbed channel.

Noise which originates in a diode back-biased into the noise region is filtered by a 1-kHz low-pass R-C network with 18 dB per octave rolloff. A field effect transistor is used to transform the high impedance of the low-pass filter for insertion into the baseband amplifier. A switch for disabling the noise generator is provided since the low-frequency noise would interfere with television transmission.

3.4 *IF Output Amplifier*

The IF output amplifier consists of a harmonic suppression filter and doublet amplifier with a fixed gain of approximately 8 dB. Harmonic components of the IF signal are reduced by the combined filters of the deviator and amplifier to a level that is lower than that generated in the output amplifier. The doublet is a two-transistor amplifier with series-shunt feedback.[3] The 70, 140, 210, and 280 MHz output levels of the transmitter are +10, −10, −20, and −40 dBm, respectively.

IV. FM RECEIVER

A block diagram of the 4A FM receiver, including the IF and baseband levels, is shown in Fig. 9. In the input amplifier-limiter the 70-MHz signal is amplified and fed to a limiter circuit in order to reduce any amplitude modulation which may be present on the signal. The limiter output is further amplified and applied to a filter-equalizer which attenuates harmonics generated in the limiter. This network also provides envelope delay equalization for the overall receiver. The

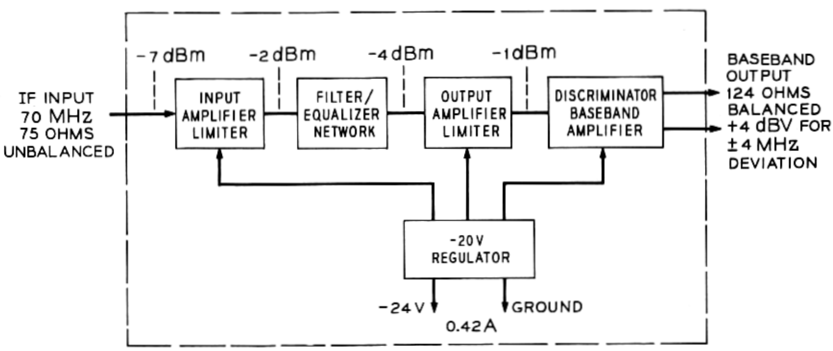

Fig. 9—Block diagram of 4A FM receiver.

signal then passes to a second amplifier-limiter which provides an additional 18 dB of AM suppression. In addition, due to the combined action of the two limiter circuits, the dynamic range of the receiver is extended so that a 10-dB reduction in IF input produces a change of less than 0.25 dB in the receiver baseband output. The signal is then applied to a discriminator where the baseband information is recovered from the frequency-modulated IF signal. After detection, the demodulated baseband signal is amplified by a balanced baseband amplifier. The receiver circuitry is powered from a series transistor regulator which provides a stable output voltage for line voltage variations and changes in temperature. The regulator operates from the −24-volt office battery supply.

4.1 *Input Amplifier-Limiter*

The basic IF amplification stage in the 4A receiver utilizes a doublet amplifier comprised of two transistors with series-shunt feedback. This same amplifier configuration is used in the TH-3 IF main amplifier.[3]

The doublet stage is followed by a limiter circuit. Two series-connected diodes amplitude-clip the frequency-modulated signal to remove any undesired amplitude modulation resulting from residual transmission distortions which may be present on the IF signal. The amplitude modulation suppression exceeds 28 dB for modulating frequencies up to 10 MHz.

In the series-type diode limiter used in the 4A receiver, limiting is accomplished with two forward-biased expitaxial silicon Schottky barrier diodes[4] as shown in Fig. 10. Any amplitude modulation on the FM signal is removed by clipping the signal current when it exceeds the diode bias current. However, the amount of AM suppression is limited by the magnitude of the signal shunted across the diodes

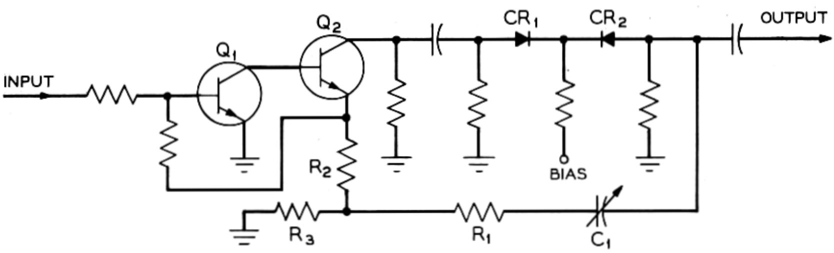

Fig. 10—Compensated limiter circuit of 4A FM receiver.

by the parasitic capacitance of the diodes when in the reverse-biased state. This limitation is overcome by applying a signal at the limiter output which is 180 degrees out-of-phase with the capacitively-bypassed signal. This antiphase signal cancels the leakage current shunted across the diodes thereby increasing the AM suppression and decreasing the amplitude-to-phase conversion.

The compensating circuit used to derive the antiphase signal consists of capacitor C_1 and resistors R_1 through R_3 of Fig. 10. The amplitude of the out-of-phase signal is reduced by the ratio of resistors R_2 and R_3. The R-C network comprised of R_1 and C_1 further reduces the amplitude and adjusts the phase of the compensating signal. The through signal and the antiphase signal are combined at the limiter output resulting in a significant improvement in performance. The efficiency of the balancing technique is illustrated in Fig. 11 which shows the AM suppression and AM-PM conversion as a function of amplifier-limiter input level. The compression characteristic of the input amplifier-limiter is shown in Fig. 12.

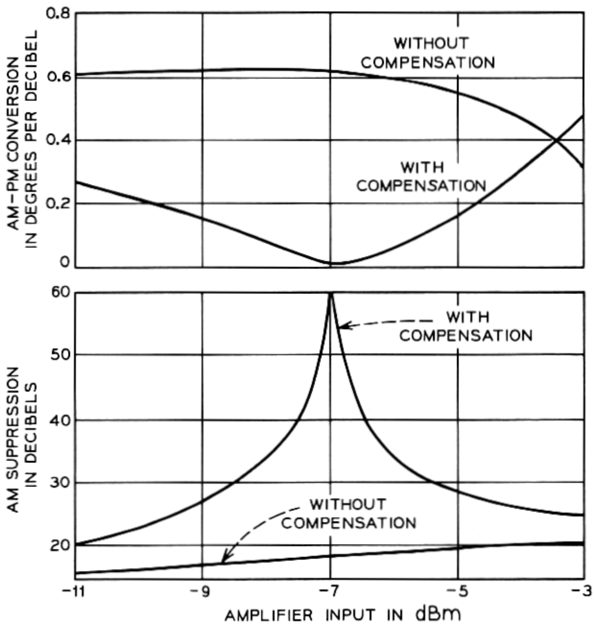

Fig. 11—AM-PM conversion and AM suppression vs amplifier input level of 4A FM receiver input amplifier-limiter (100-KHz modulating frequency).

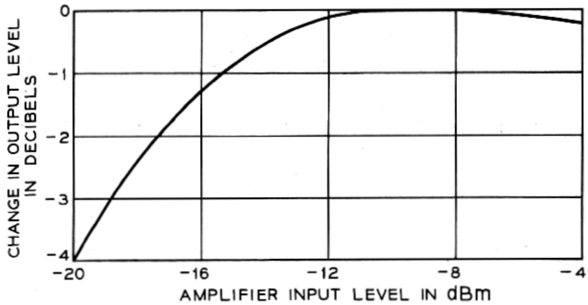

Fig. 12—Output change vs amplifier input level of 4A FM receiver input amplifier-limiter.

Gain and slope adjustments are provided in the doublet stage following the limiter circuit to set the output level and reduce the transmission slope of the input amplifier-limiter over the 60- to 80-MHz band to less than 0.05 dB.

4.2 *Output Amplifier-Limiter*

The output amplifier-limiter consists of a stage of amplification, an uncompensated limiter, and a harmonic filter. Since the amount of amplitude modulation at the input to this limiter will generally be small, compensation is unnecessary. The limiter reduces amplitude modulation by 18 dB for modulating frequencies up to 10 MHz. A constant resistance low-pass filter attenuates harmonic tones generated by the limiter circuit. The nominal input and output levels are −4 and −1 dBm, respectively.

4.3 *Discriminator Baseband Amplifier*

The discriminator consists of a doublet stage, a balanced resonant discriminator, and a baseband amplifier as shown in the simplified sketch of Fig. 13. The high- and low-frequency parallel resonant tank circuits are tuned to specific frequencies thereby eliminating the complexity of simultaneously adjusting receiver sensitivity, crossover frequency, and linearity. The common tank circuit provides an independent receiver linearity adjustment, thereby minimizing the interaction between adjustments. The overall receiver linearity is less than 0.3 percent for a peak-to-peak deviation of 10 MHz.

An R-L-C impedance network at the output of each detector diode provides a constant impedance over the baseband-to-IF frequency band. By controlling the impedance in this region a source of second-

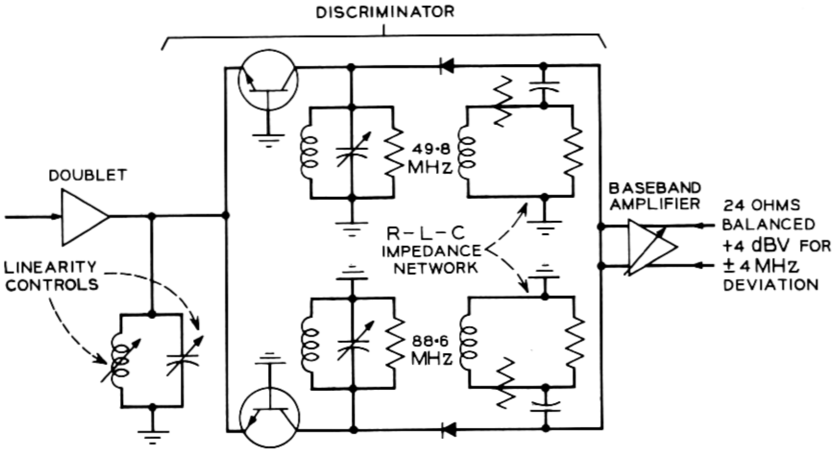

Fig. 13—4A FM receiver discriminator circuit.

order distortion is controlled. Otherwise, the generation of these A − B type products results in excessive modulation noise in the bottom message channels.

The balanced baseband amplifier circuit remains essentially unchanged from its 3A counterpart.[5] Minor modifications were introduced in the shaping network used to adjust baseband frequency response in order to control the flatness of the frequency characteristic to within 0.1 dB out to at least 12 MHz.

V. TANDEM PERFORMANCE

Laboratory experience on the tandem performance of the 4A FM transmitter and receiver has shown a very satisfactory degree of reproducibility.

5.1 *Noise Load Performance*

The most satisfactory measure of terminal performance from the standpoint of message applications is based on the use of bandlimited fluctuation noise to simulate the multichannel speech load. Noise and cross-modulation performance measured in this manner is presented in Figs. 14 and 15 corresponding to 1200- and 1800-circuit message loading, respectively. The performance at reference drive with 1800-circuit loading is well within the objective of 17 dBrnc0.

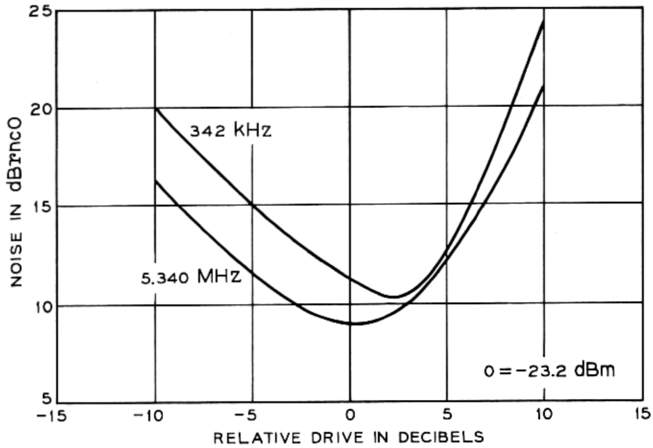

Fig. 14—4A FM terminal pair, 1200-circuit noise load, 457D pre-emphasis.

5.2 *Fluctuation Noise*

Fluctuation noise generated by a tandem transmitter and receiver and measured at the receiver output is shown in Fig. 16. This total noise is made up of several distinguishable contributors as indi-

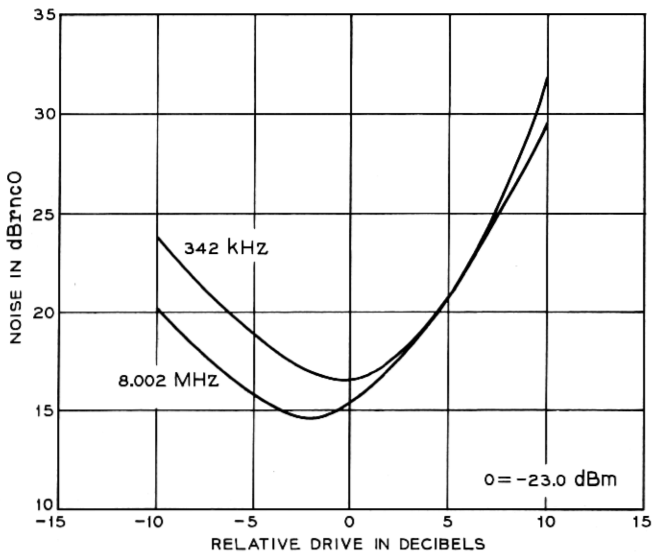

Fig. 15—4A FM terminal pair, 1800-circuit noise load, 457D pre-emphasis.

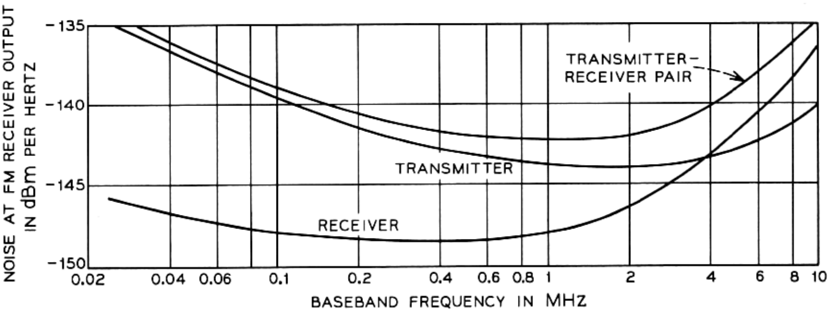

Fig. 16—4A FM terminal pair: fluctuation noise.

cated in the figure. Fluctuation noise at high baseband frequencies is controlled by the noise figure of the receiver input amplifier-limiter which has the lowest signal level of the terminal pair. In the baseband region below about 3 MHz, the main fluctuation noise source is the transmitter baseband amplifier.

For television transmission, the ratio of peak-to-peak video signal to weighted noise is the most meaningful measurement of performance. For this measurement the weighted baseband noise is generally separated into two regions, one encompassing the low-frequency end of the band up to 4 kHz and the other encompassing the range from 4 kHz up to approximately 4.5 MHz. The noise is measured at the FM receiver output following the video de-emphasis network. Typical values for signal-to-weighted low-frequency noise and signal-to-weighted (color) high-frequency noise are 106 and 97 dB, respectively, meeting the corresponding 40- and 73-dB objectives with a comfortable margin.

5.3 *Transmitter Carrier Frequency Shift With Modulation*

When an FM transmitter is modulated there is generally a small shift in the output carrier frequency relative to the unmodulated value. On the 4A transmitter with ±4 MHz sine-wave modulation, this shift is less than 2 kHz.

5.4 *Transmitter Carrier Frequency vs Voltage*

Transmitter performance variations due to −24-volt line changes are minimal. In particular the output frequency changes are small. Typical frequency change over the entire operating range of 21 to 27 volts is less than ±1 kHz per volt.

5.5 *Baseband Amplitude Response*

The baseband response is flat to within ±0.05 dB from 6 Hz to 11 MHz and rolls off gradually beyond those frequencies. The high end at 12 MHz is down less than 0.2 dB relative to 10 MHz.

For television purposes the low-frequency response is frequently characterized by the response to a 60-Hz square wave. Slope on the square wave output expressed as a percentage of the peak-to-peak signal is a measure of the phase fidelity at the fundamental frequency. Typical slope measured at the output of a 4A terminal pair is 2.0 percent which approximates a low-end 3-dB cutoff frequency of 0.7 Hz.

5.6 *Differential Gain, Differential Phase, and Linearity*

The differential gain and phase as measured with pre-emphasis are within 0.02 dB and 0.25 degree for a deviation of ±1.69 MHz. Nonlinearity for the terminal pair with 12 MHz peak-to-peak deviation is less than 0.5 percent.

5.7 *Transmitter Longitudinal Suppression*

Longitudinal suppression is a measure of sensitivity to extraneous signal and transient pickup on balanced shielded cable used for video trunking. Figure 17 shows the suppression achieved over the frequency range useful for television transmission.

VI. EQUIPMENT FEATURES

The physical features of a 4A receiver, which is essentially the same as a transmitter, are shown in Fig. 18. A single die-cast framework containing five shielded sections which house the individual printed wiring boards is used for a transmitter or receiver unit. Each printed wiring board is attached to a metal shield separated by a distance of approximately one-half inch by metal studs. This type of construction provides a good mechanical as well as a good electrical connection between the circuit board and ground. The subassembly is inserted into a compartment and fastened to the framework. Each metal shield performs a second function by serving as a portion of the bottom cover for the unit as well as an individual circuit ground plane. The opposite side of the chassis is enclosed by a single cover as illustrated in the photograph.

Radiation between compartments is prevented by a rubber gasket containing numerous small pieces of wire. The cover is tightened

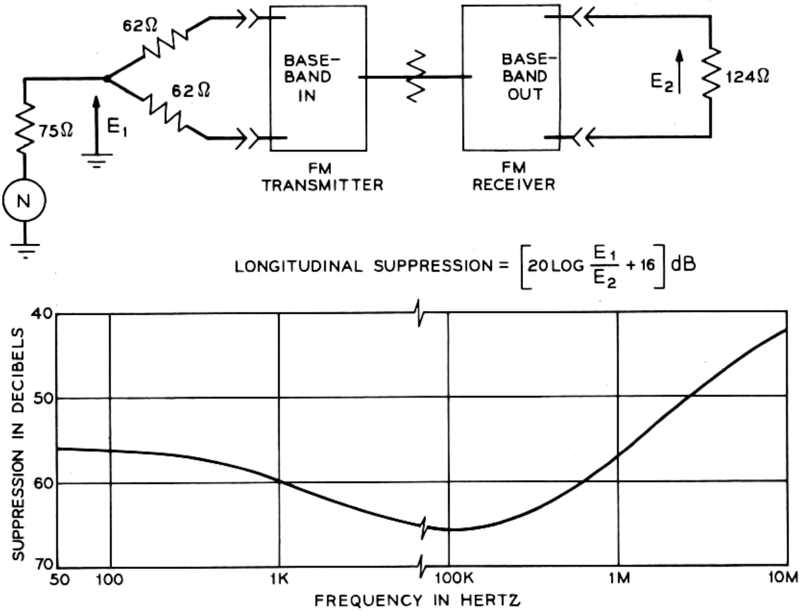

Fig. 17—4A FM terminal pair: longitudinal suppression.

down against the gasket material and inserted into a channel surrounding each compartment, establishing a continuous ground at the junction of the sidewall and the cover.

A transmitter or receiver unit, two inches high and weighing approximately seven pounds, slides on nylon tracks into a special shelf which is designed to mount on a 19-inch bay framework. Three shelf

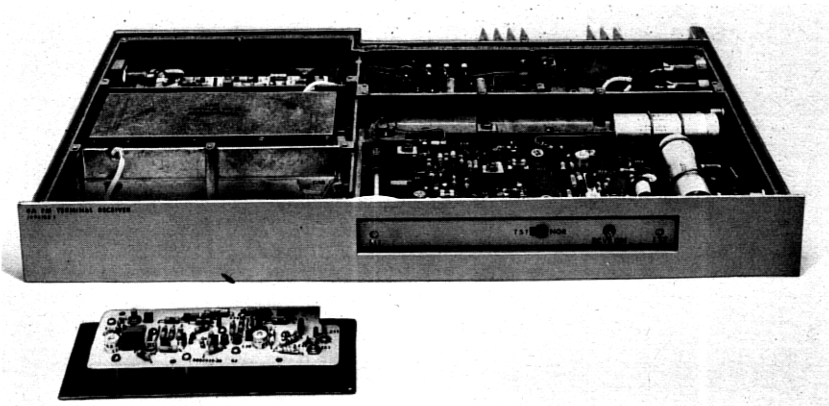

Fig. 18—Assembly features of 4A FM transmitter or receiver.

arrangements are available housing two, three, or five units. Each unit is fastened to the shelf by a special latch arrangement located at the rear of the bay.

The power, IF, and baseband connections are located at the rear and sides of the unit, respectively. The IF and baseband connections are wired to a patchfield on the FM terminal bay to provide access for test purposes. A nine-foot FM terminal bay can be equipped with up to fifteen 4A FM transmitters and fifteen 4A FM receivers.

A portable version of the 4A FM terminal unit, weighing approximately 45 pounds, was also designed. This unit consists of a portable housing with accessories designed to provide a complete portable FM terminal facility. Auxiliary equipment supplied with the housing includes two balanced-to-unbalanced transformers, balanced-to-unbalanced pre- and de-emphasis networks, a pad for the back-to-back terminal interconnections, and a jackfield. For normal usage an associated 117-volt, 60-Hz rectifier unit is available with an output capability of 1.6 amperes at −24 volts. A direct connection to the −24-volt central office battery is also available. A photograph of the portable FM terminal is shown in Fig. 19 with the front cover of the portable housing removed.

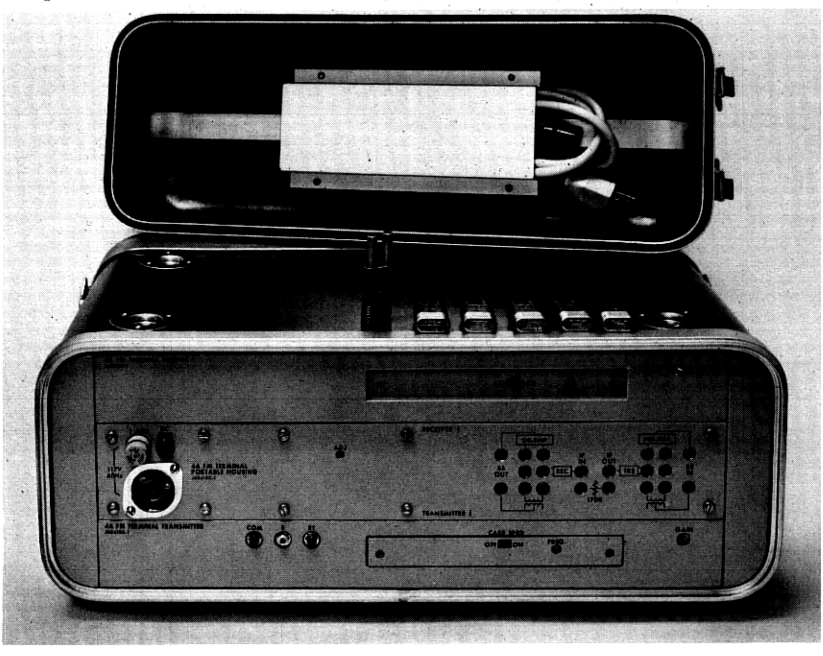

Fig. 19—Portable 4A FM terminal pair.

VII. SUMMARY

The 4A FM terminal pair has been designed to provide a better performing, lower cost, and physically smaller replacement for the 3A FM terminal pair. Operating at an IF center frequency of 70 MHz, the terminal pair can be used on all TD microwave radio system applications as well as on the TH-3 microwave radio system.

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