DESIGN AND PERFORMANCE OF A NEW S-BAND TRANSMITTER

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Summary This paper describes a telemetry transmitter designed for the 2.2-2.3 Gc band. Design philosophy followed to achieve minimum size, wide deviation capability, high reliability and high efficiency are discussed in detail. The paper presents extensive measured data to indicate achievement of design goals set by IRIG 106-60 and ARTC-34. Construction details of the transmitter are illustrated.

Introduction The Eimac EM4527 S-Band transmitter was designed to satisfy the following requirements:

1. 3 Mc deviation and flat response to 1.2 Mc modulation rates.
2. Achievement of all electrical and environmental requirements of IRIG 106-60 and the Aerospace Industries Association Report ARTC-34.
3. Size of 50 cubic inches and an overall efficiency greater than 10%.
4. Suitability for large volume manufacturing.
5. Tuning and service in the field.
6. High reliability performance.

The electrical and environmental requirements can be met by a number of technical approaches. However, when the requirements of simplicity, serviceability, reliability, and cost are added, the possibilities are greatly reduced. A. complex transmitter may meet the technical requirements but will be too expensive for large volume use and too difficult to align and service in the field. From the viewpoint of the manufacturer and the user, complexity is not measured by the number of circuit elements but rather by the labor required to assemble, adjust and maintain those elements. From the viewpoint of reliability one must not only analyze the active components but also the adjustments and interconnections of a system. Experience of users indicates that transmitter failures most commonly occur in the adjustments and interconnections, rather than in the components. Our design philosophy has been to reduce the number of circuits that require special lead dress in assembly, r.f. interconnections, adjustable temperature compensators, and alignment necessitating special test equipment and skilled personnel. This significantly improves reliability of the complete transmitter.

Many users require ±. 00176 frequency stability over -40° C to +85° C and an incidental frequency modulation of less than 3. 5kc rms under 15 G vibration. It is anticipated that frequency stability and accuracy of ±0.001% will be mandatory at all major test ranges, to eliminate adjacent channel interference. No present S-Band microwave tube, whether it be a klystron, voltage tunable magnetron, or a traveling wave tube, has this stability along with the required deviation band width. Also, no single solid state device in an appropriate circuit can meet these requirements. In order to achieve stability, one is therefore forced to use a large number of circuit elements to link a microwave output device to a low frequency crystal.

There are two basic alternatives open to the designer: (1) one can develop a stable modulated carrier at a frequency in the 10 to 100 Mc range and multiply it to S-Band; or (2) one can generate a modulated carrier at the output frequency and stabilize it with a crystal referenced servo system. Because of the guide lines set down above we have chosen to servo-stabilize a single stage S-Band power source. Servo circuitry, in contrast to rf circuitry, is adaptable to economical high quantity assembly techniques. It can utilize non-selected parts, is virtually free of adjustments and can be made extremely compact.

In the EM4527 (Figure 1) the modulated carrier is compared to a crystal reference by an ultra stable and linear wide band fm discriminator. The correction signal thus derived is applied to the varactor modulator along with the modulation. This is a standard technique for stable microwave systems. However, the EM4527 has some unusual features: (1) the servo system (excepting the crystal oscillator) does not contain any tuned circuits, thus eliminating adjustments; (2) the S-Band source is never swept in order to bring it into capture range of the servo system, thus eliminating complicated search and lock circuits, preventing adjacent channel interference; (3) spurious modulation components up to 10 kc arising from vibration are degenerated; (4),during alignment, the servo system serves as a receiver for setting deviation and frequency, thus eliminating complicated external check out equipment; (5) adjustable temperature compensation is not used in the rf or servo circuitry.

Figure 2 shows the power oscillator. It was specifically designed to facilitate field tuning. It has only three adjustments. These adjustments, plus one on the crystal oscillator, are sufficient to set the transmitter to crystal accuracy anywhere in the 2.2 to 2.3 Gc band. By the use of one additional adjustment in the servo system, the crystal calibration error can be cancelled if desired. The oscillator is integrated with a terminated circulator, a signal sampler and a fixed low pass filter to make a complete rf assembly module. Since only one rf stage is required, reliability is greatly improved. By itself, the oscillator has an efficiency of 25% minimum over the 100 Mc band, a deviation linearity of 2% over its 20 Mc peak to peak capability, and an FM to AM conversion of less than 1% per 3 Mc peak to peak deviation. Since the rf is generated only at the output frequency, spurious radiation is limited to harmonics which are adequately reduced by a non-tunable low pass filter. In contrast, frequency multiplier chains, if used in the rf source, produce spurious radiation over a wide spectrum. Such widespread spurious radiation can be eliminated only by a narrow band pass filter which has high loss and must be returned for each change of channel.

Figure 3 shows one of the six plug-in, encapsulated servo modules. This packaging approach allows easy field replacement of modules, for repair or modification. The crystal oscillator, multiplier and mixer assembly is shown in Figure 4. The arrangement of all the modules is shown in Figure 5. The overall transmitter, including power supply, shown here and in Figure 6, has a displaced volume of 48 cubic inches and weighs 4 1/2 pounds. This transmitter has now been delivered to several customers. The ability of the servo system to degenerate vibration-induced frequency modulation is illustrated by Figure 7. Figure 8 shows the ability of the servo system to limit temperature-induced frequency drift. Modulation response up to 2 Mc is shown in Figure 9, and modulation linearity is shown in Figure 10. Figure 11 illustrates spurious amplitude modulation caused by carrier deviation up to 8 Mc.

Figure 12 shows the capability of the DC-DC converter to provide regulated power which maintains high stability of frequency and rf power output over a 2/1 swing in primary voltage. Low AM produced by primary power fluctuation is illustrated by Figure 13, and spurious fm by Figure 14. Figure 15 shows suppression of conducted interference. Figure 16 is a signature of frequency at the antenna terminal.

Last, characteristics of the EM4527 transmitter are summarized in the table, Figure 17.

Conclusion An S-Band transmitter suitable for economical large-scale production has been produced and delivered to customers. The transmitter is field tunable by semi-skilled personnel with only standard simple test equipment. This transmitter achieved the goals of IRIG 10660 and ARTC-34 in a compact, rugged, highly reliable package. The design philosophy subsequently has been extended to 4 watt (Model EM4575) and 10 watt (Model EM4567) S-Band transmitters, and a 3 watt (Model EM4534) L-Band transmitter. All use a single varactor modulated triode oscillator at the output frequency, and all models have been delivered to customers. In addition, deviation up to 15 Mc peak to peak at S-Band has been obtained, making this approach useable for television and other wide band transmissions.

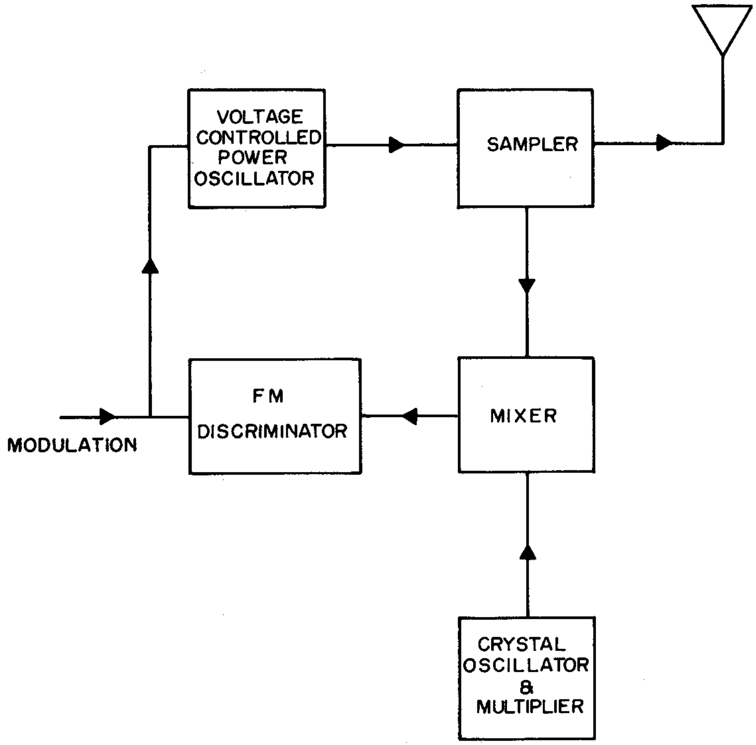

Fig. 1 -Simplified Block Diagram of Transmitter

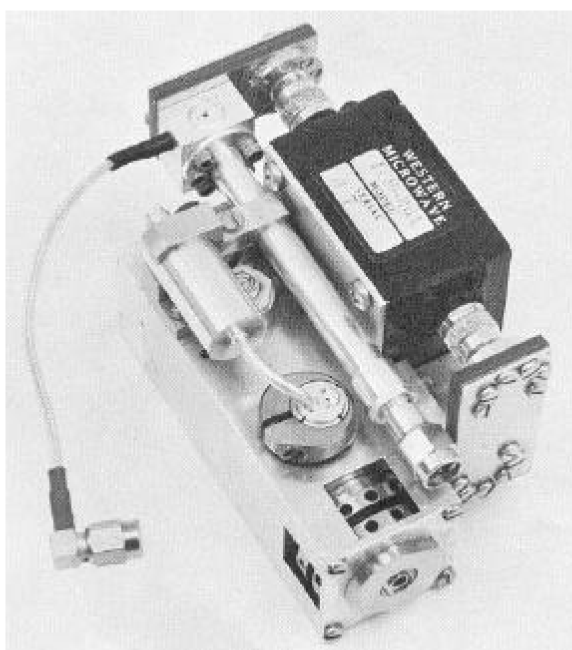

Fig. 2-Rf Power Oscillator

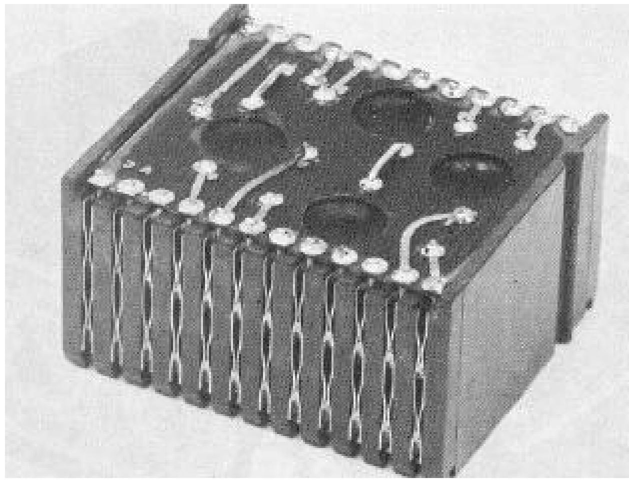

Fig. 3-Typical AFC Servo Module

Fig. 4-Crystal Oscillator-Multiplier-Mixer Module

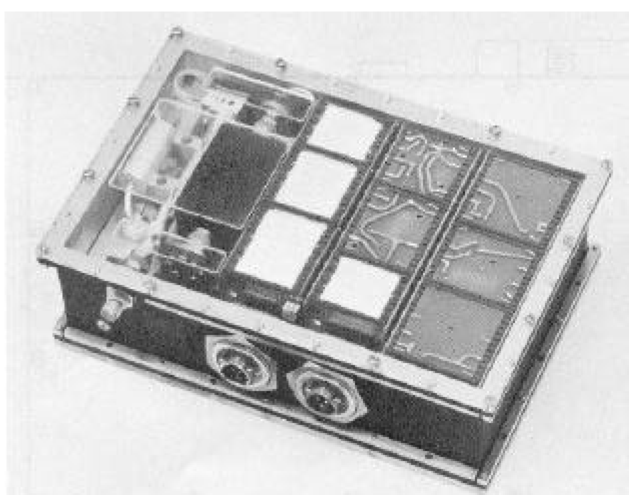

Fig. 5-Model EM4527 S Band 2 Watt Transmitter

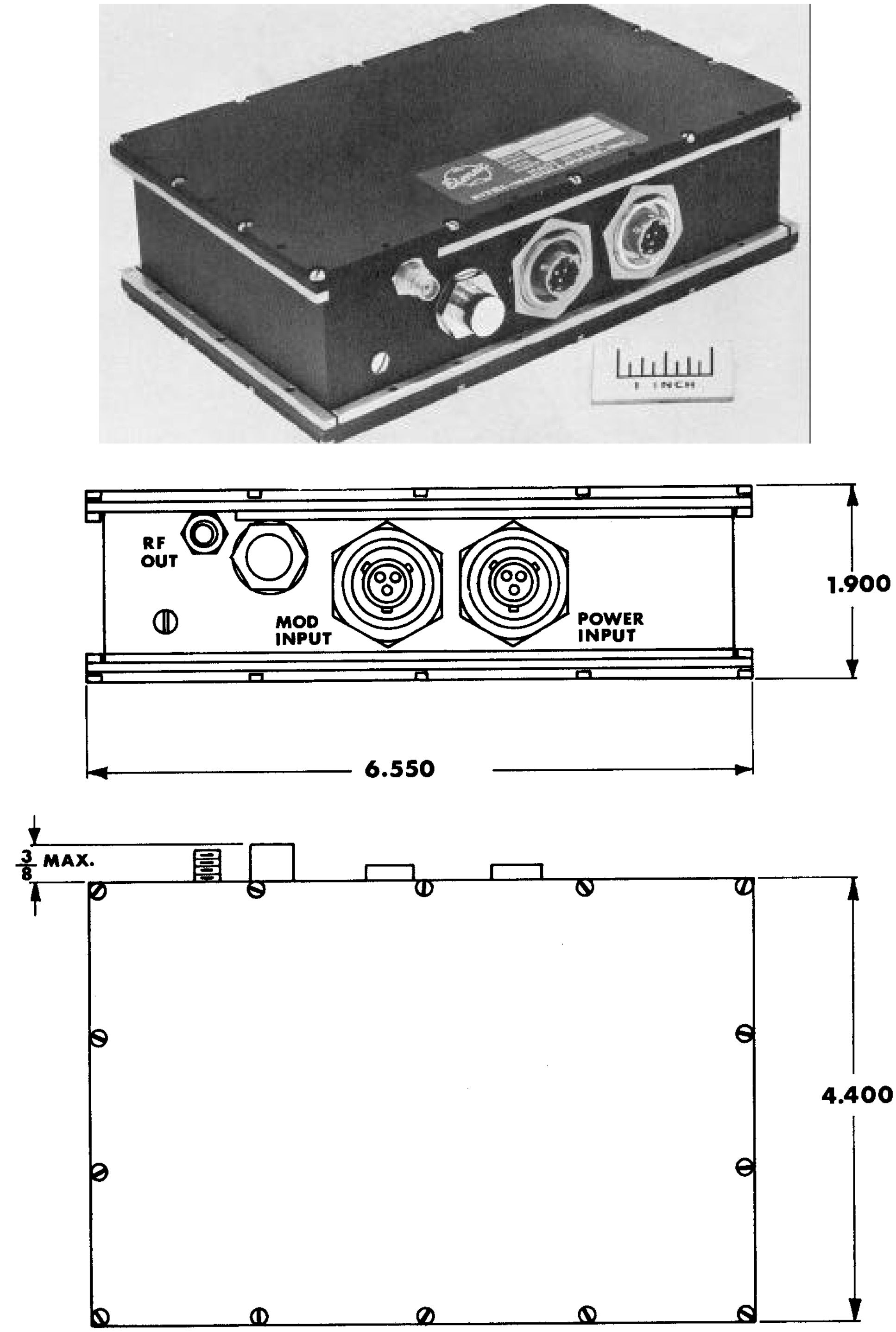

Fig. 6-Model EM4527 Transmitter Outline Dimensions

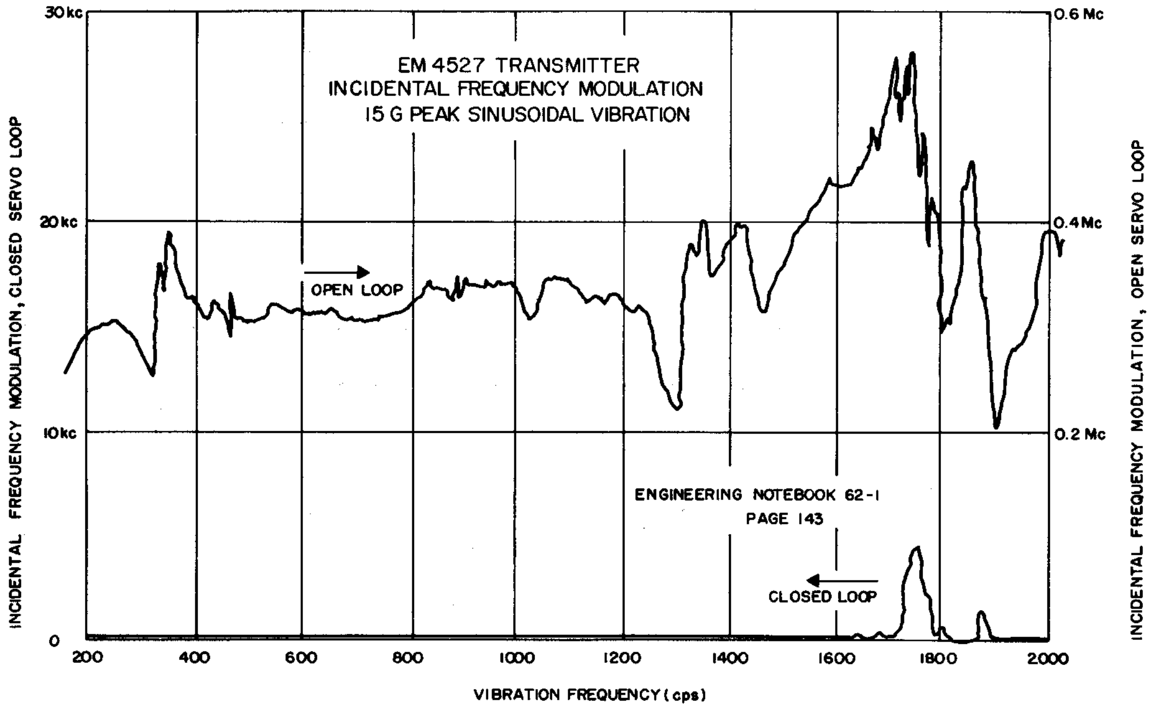

Fig. 7-Incidental Frequency Modulation under Vibration

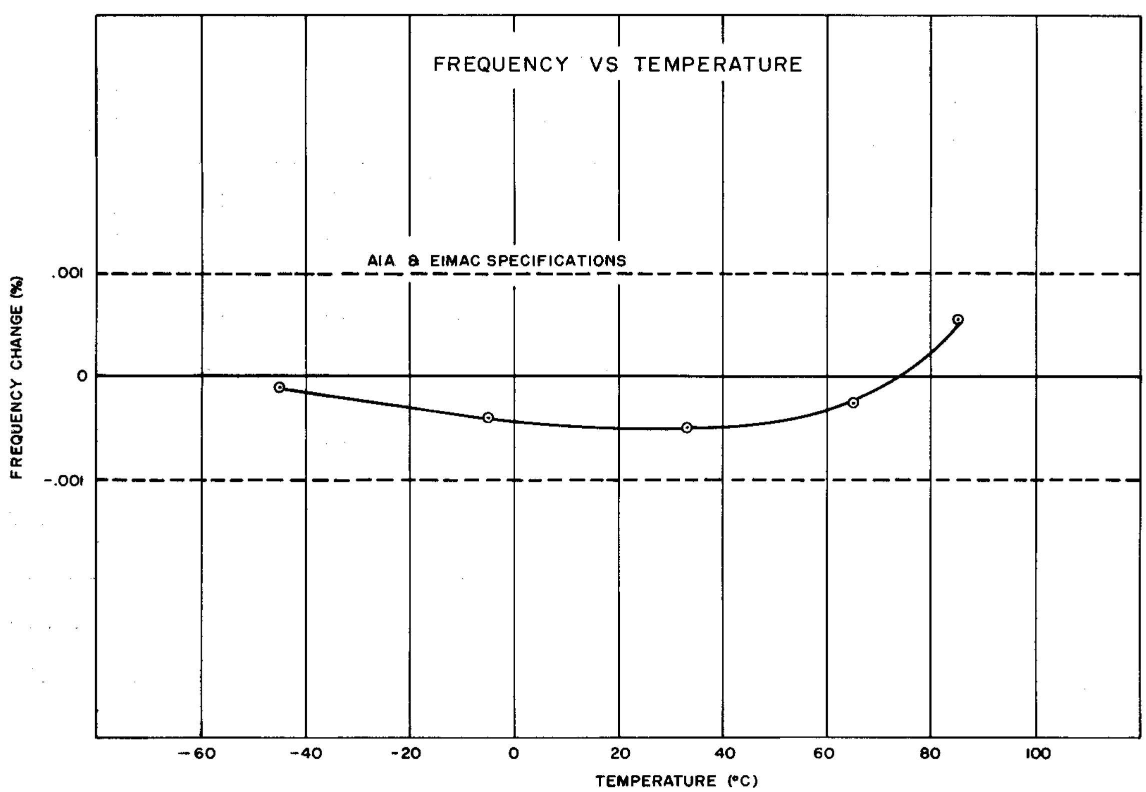

Fig. 8-Frequency Variation as a Function of Temperature Change

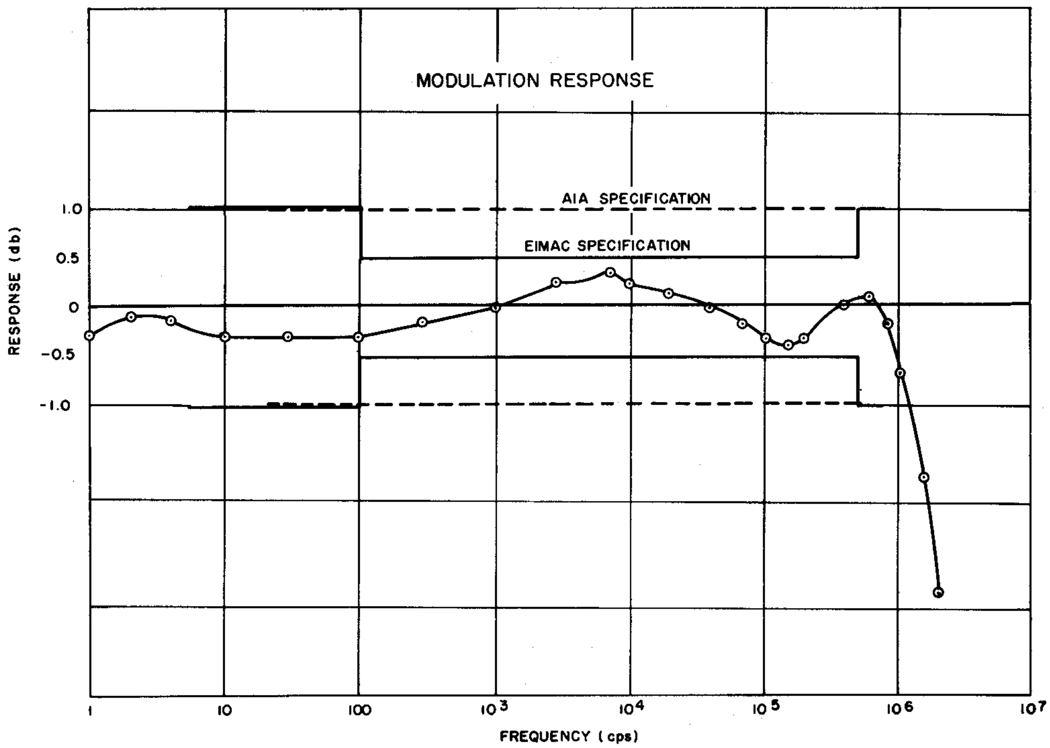

Fig. 9-Modulation Bandwidth

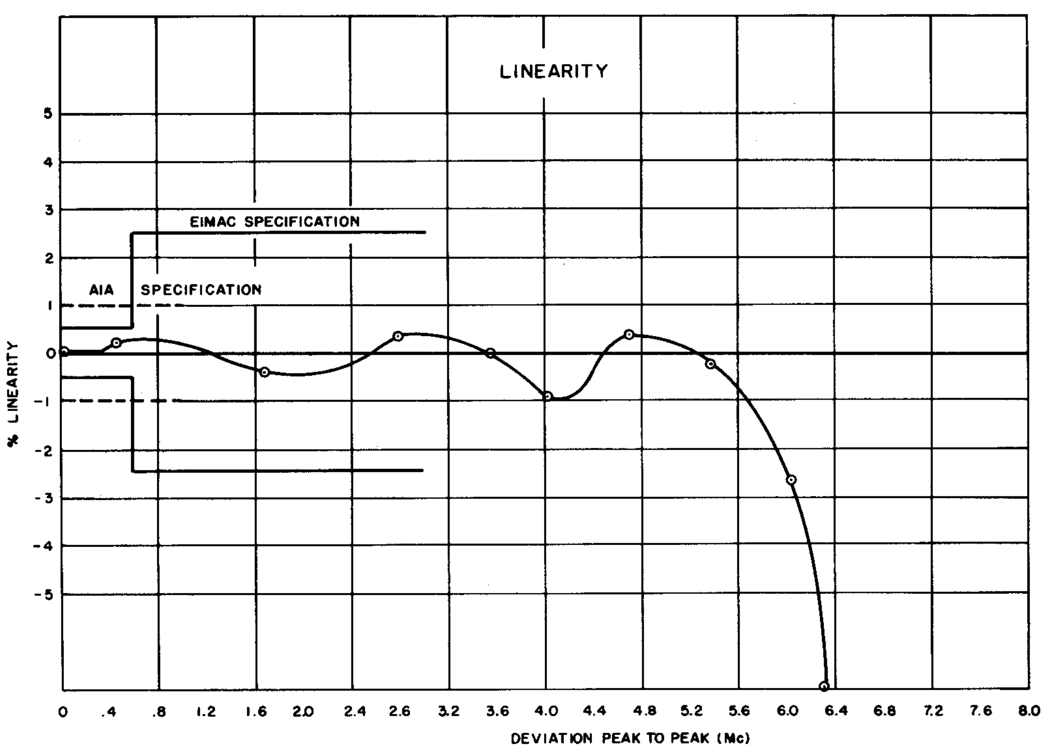

Fig. 10-Modulation Linearity

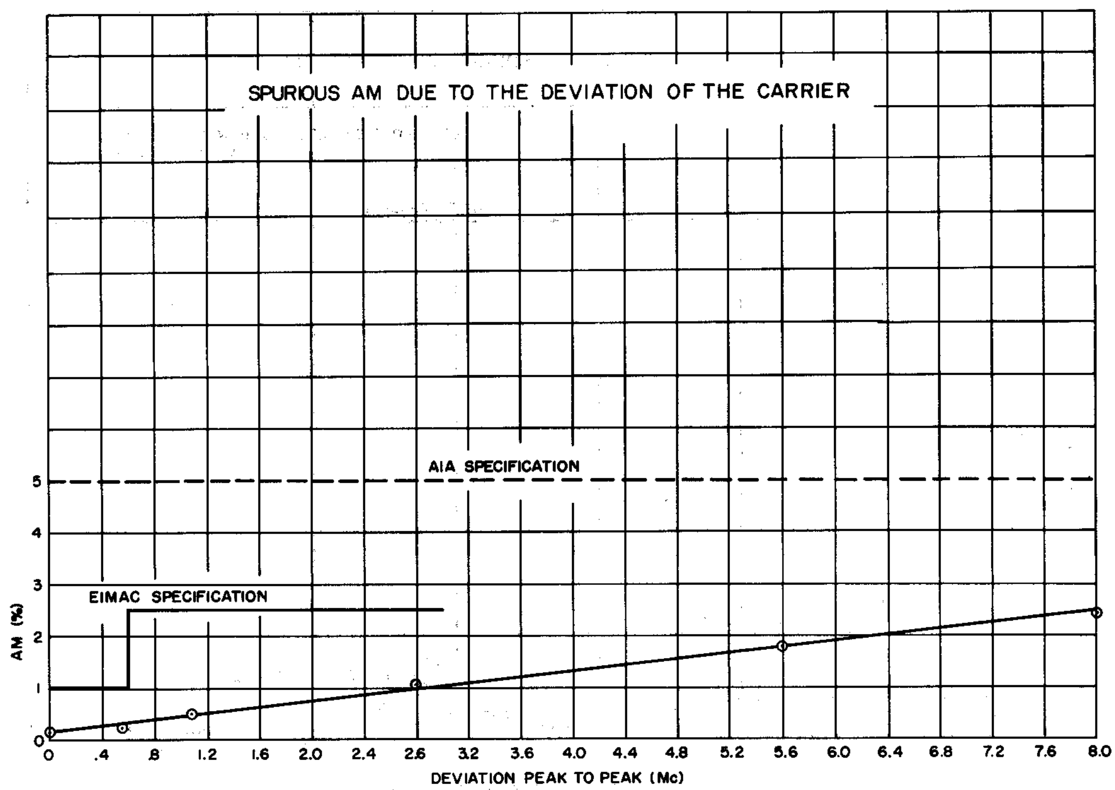

Fig. 11 -Spurious AM due to Deviation of the Carrier

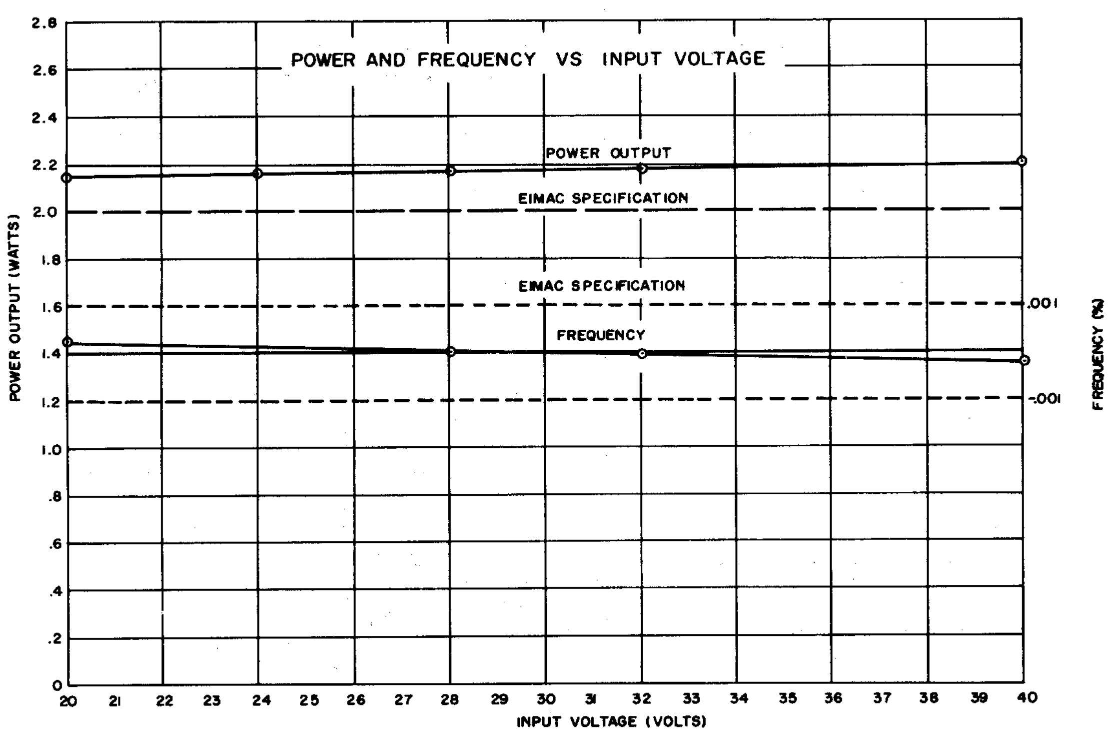

Fig. 12-Power and Frequency As a Function of Input Voltage Variation

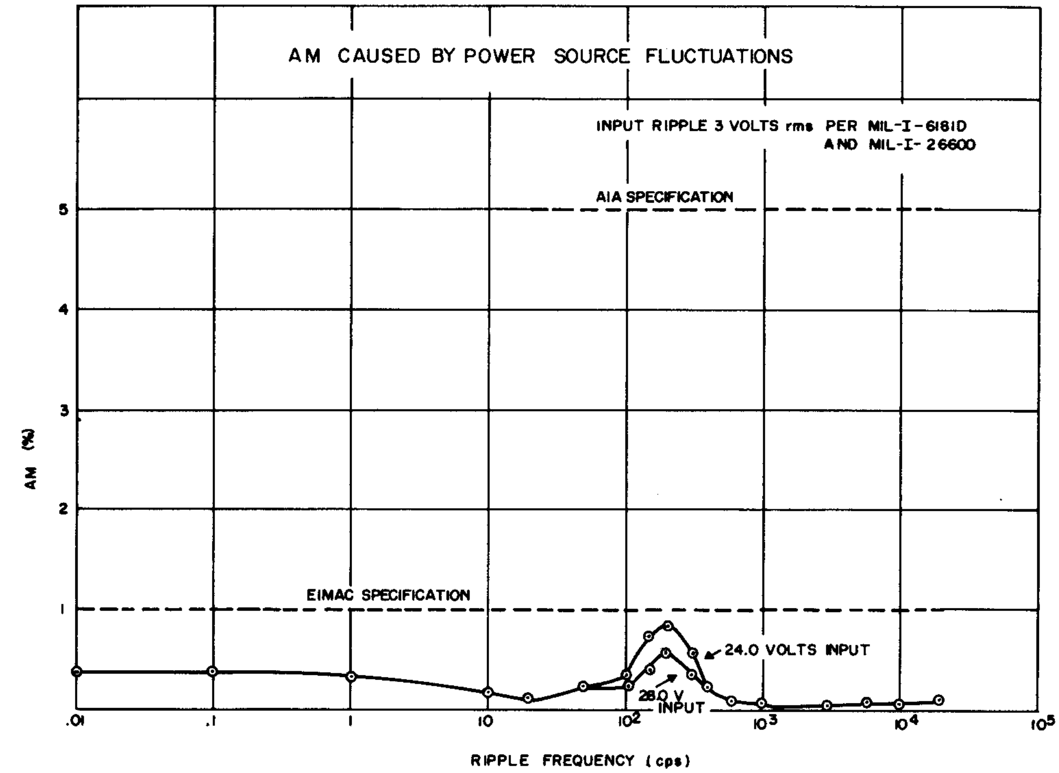

Fig. 13-AM Caused by Power Source Fluctuations

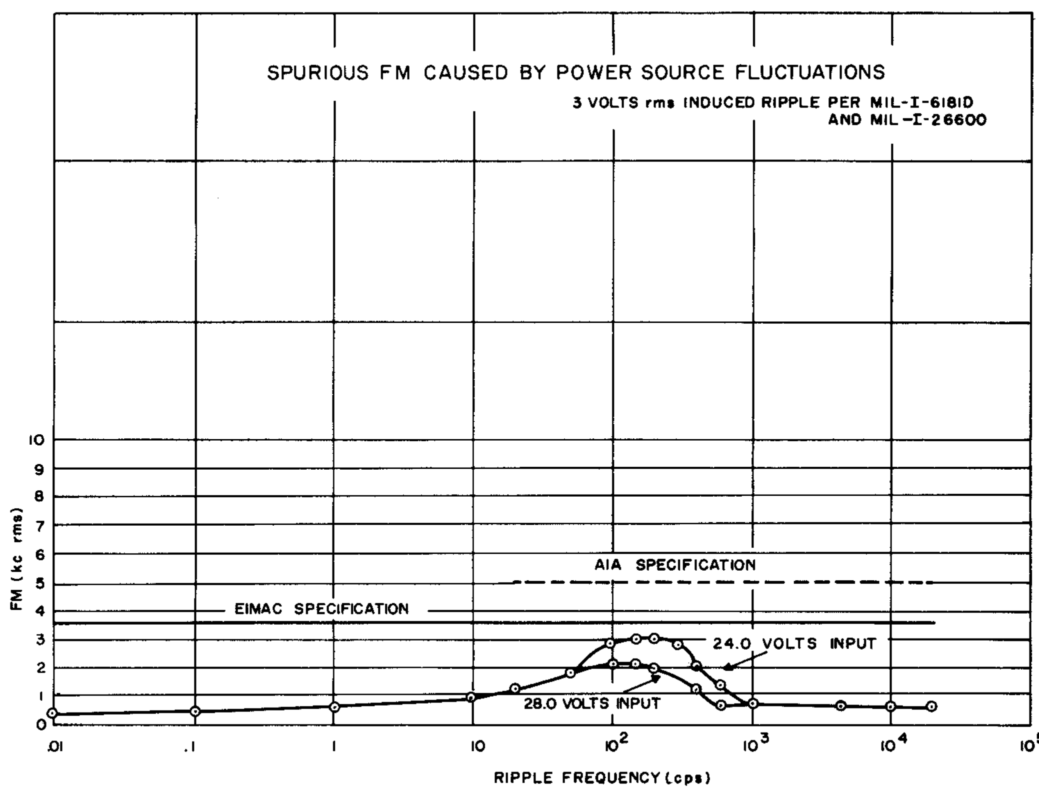

Fig. 14-Spurious FM Caused by Power Source Fluctuations

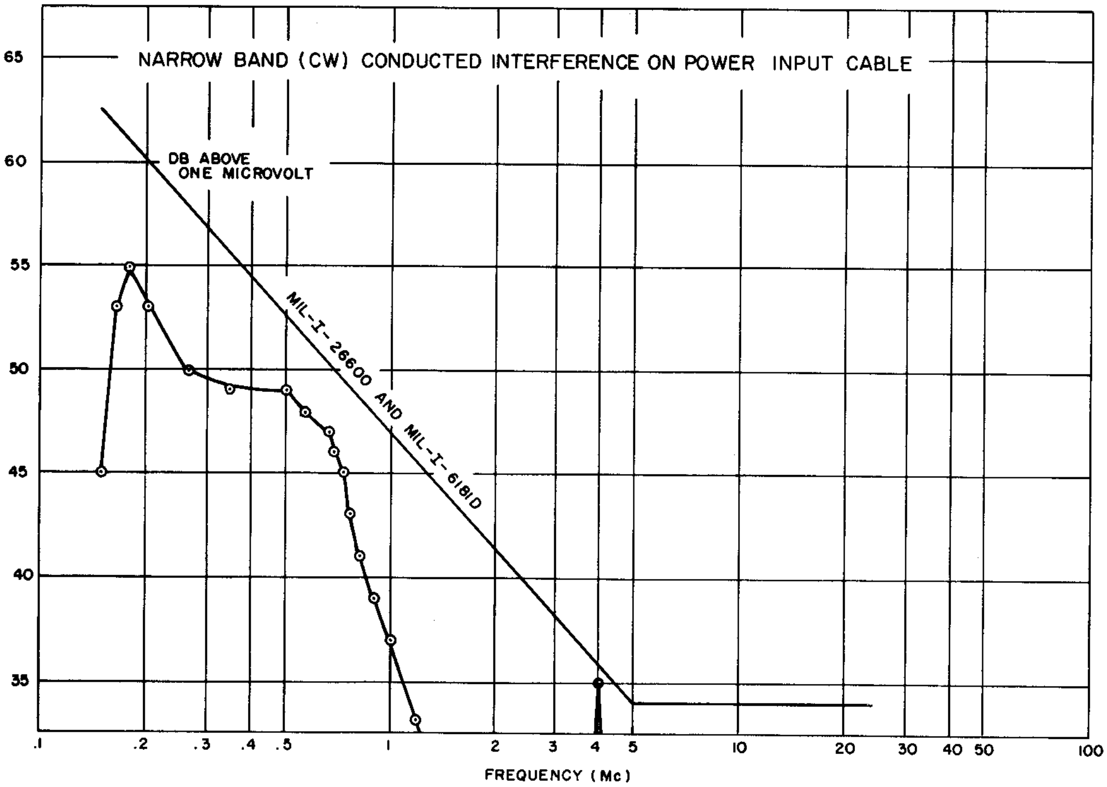

Fig. 15-Narrow Band (CW) Conducted Leakage on Power Input Leads

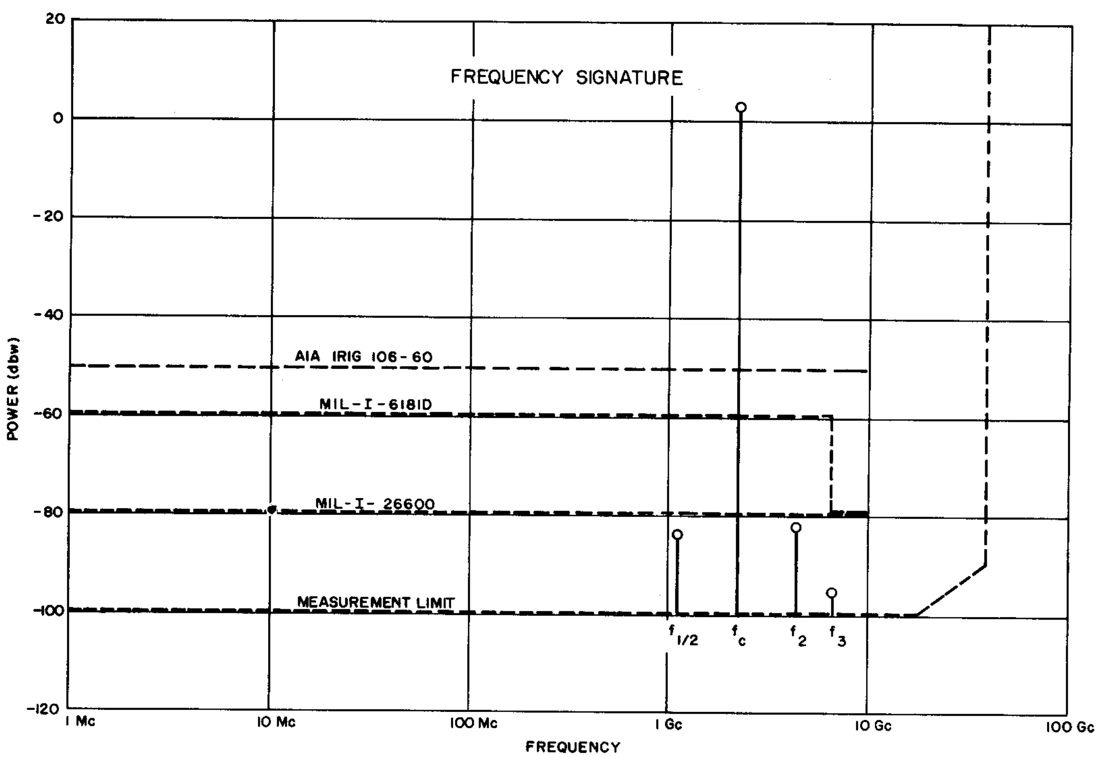

Fig. 16-Frequency Signature

CHARACTERISTICS, MODEL EM4527

ELECTRICAL

Frequency, Tunable	2200-2300 Mc
Power Output, CW Minimum	2 Watts
Frequency Accuracy	±0.001%
Frequency Stability	±0.001%
Carrier Deviation, Adjustable, peak-to-peak	2Mc/Volt to 30Kc/Volt
Modulation Bandwidth, Flat within ±0.5 db	100 cps to 500 Kc
Flat within ±1 db	5 cps to 800 Kc
Modulation Linearity, Deviation from B.S.L.,	
For ±300 Kc peak Deviation	±0.5%
For ±1.5 Mc peak Deviation	±2.5%
Incidental Frequency Modulation, Maximum	3.5 Kc rms
AM, Maximum, due to environmental conditions	1%
due to ±300 Kc carrier deviation	1%
due to ±1.5 Mc carrier deviation	5%
Modulation Input Impedance, Minimum, 5 cps to 800 Kc	10,000 Ohms
Primary Voltage required	$28 ^{+8}_{-4}$ Vdc
Primary Current required, maximum, at 28 Vdc	700 mA
Primary Ripple, maximum, peak-to-peak from Dc to 20 Kc	8 volts
Transients, Maximum positive	80 volts for 20 microseconds
Input current rise above nominal, due to fault maximum	130%
VSWR Maximum, any phase, for 2 watts output	1.5:1
Load Impedance required	50 ohms
Warm-up time to meet all specifications	120 seconds
Interference	All applicable requirements of MIL-I-26600 and MIL-I-6181D are met

PACKAGING

Volume displaced	48 cubic inches
Dimensions, including mounting flanges	6.5" x 4.4" x 1.9"
Weight	4 pounds
Pressurization	30 psia
Cooling	Conduction to heat sink

ENVIRONMENTAL SPECIFICATIONS

Temperature at heat sink (Continuous Operation)	-40° C to +85° C
Altitude	Any
Vibration (MIL-STD-810, Figure 514-3 Curve D)	15G peak to 2 Kc
(MIL-STD-810, Figure 514-4, Curve E)	0.2 G^2/cps

Fig. 17-Characteristics of Model EM4527 Transmitter

Air Induced Vibration - - - - - - - - - - - - - -	150 db above $2x10^{-4}$ dynes/CM^2 from 150 to 2000 cps, 30 minutes
Explosive Atmosphere - - - - - - - - - - - - - -	Capable of operation without igniting an explosion
Sustained Acceleration - - - - - - - - - - - - - -	30G for 5 minutes, three axes
Shock, per MIL-STD-810 Method 516, Procedures I and V,	
half-sine shocks - - - - - - - - - - - - - -	15G for 11 milliseconds
sawtooth shocks - - - - - - - - - - - - - -	100G