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Fixed and Base Station FM Transmitters

NIJ Standard–0201.01

U.S. Department of Justice
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James K. Stewart, Director

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FOREWORD

This document, NIJ Standard-0201.01, Fixed and Base Station FM Transmitters, is an equipment standard developed by the Law Enforcement Standards Laboratory of the National Bureau of Standards. It is produced as part of the Technology Assessment Program of the National Institute of Justice (NIJ). A brief description of the program appears on the inside front cover.

This standard is a technical document that specifies performance and other requirements equipment should meet to satisfy the needs of criminal justice agencies for high quality service. Purchasers can use the test methods described in this standard to determine whether a particular piece of equipment meets the essential requirements, or they may have the tests conducted on their behalf by a qualified testing laboratory. Procurement officials may also refer to this standard in their purchasing documents and require that equipment offered for purchase meet the requirements. Compliance with the requirements of the standard may be attested to by an independent laboratory or guaranteed by the vendor.

Because the NIJ standard is designed as a procurement aid, it is necessarily highly technical. For those who seek general guidance concerning the selection and application of law enforcement equipment, user guides have also been published. The guides explain in nontechnical language how to select equipment capable of the performance required by an agency.

NIJ standards are subjected to continuing review. Technical comments and recommended revisions are welcome. Please send suggestions to the Program Manager for Standards, National Institute of Justice, U.S. Department of Justice, Washington, DC 20531.

Before citing this or any other NIJ standard in a contract document, users should verify that the most recent edition of the standard is used. Write to: Chief, Law Enforcement Standards Laboratory, National Bureau of Standards, Gaithersburg, MD 20899.

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NIJ STANDARD
FOR
FIXED AND BASE STATION
FM TRANSMITTERS

CONTENTS

COMMONLY USED SYMBOLS AND ABBREVIATIONS

A	ampere	H	henry	nm	nanometer
ac	alternating current	h	hour	No.	number
AM	amplitude modulation	hf	high frequency	o.d.	outside diameter
cd	candela	Hz	hertz (c/s)	Ω	ohm
cm	centimeter	i.d.	inside diameter	p.	page
CP	chemically pure	in	inch	Pa	pascal
c/s	cycle per second	ir	infrared	pe	probable error
d	day	J	joule	pp.	pages
dB	decibel	L	lambert	ppm	part per million
dc	direct current	L	liter	qt	quart
°C	degree Celsius	lb	pound	rad	radian
°F	degree Fahrenheit	lbf	pound-force	rf	radio frequency
diam	diameter	lbf·in	pound-force inch	rh	relative humidity
emf	electromotive force	lm	lumen	s	second
eq	equation	ln	logarithm (natural)	SD	standard deviation
F	farad	log	logarithm (common)	sec.	section
fc	footcandle	*M*	molar	SWR	standing wave radio
fig.	figure	m	meter	uhf	ultrahigh frequency
FM	frequency modulation	min	minute	uv	ultraviolet
ft	foot	mm	millimeter	V	volt
ft/s	foot per second	mph	mile per hour	vhf	very high frequency
g	acceleration	m/s	meter per second	W	watt
g	gram	N	newton	λ	wavelength
gr	grain	N·m	newton meter	wt	weight

area = unit^2 (e.g., ft^2, in^2, etc.); volume = unit^3 (e.g., ft^3, m^3, etc.)

PREFIXES

d	deci (10^{-1})	da	deka (10)
c	centi (10^{-2})	h	hecto (10^2)
m	milli (10^{-3})	k	kilo (10^3)
μ	micro (10^{-6})	M	mega (10^6)
n	nano (10^{-9})	G	giga (10^9)
p	pico (10^{-12})	T	tera (10^{12})

COMMON CONVERSIONS
(See ASTM E380)

ft/s × 0.3048000 = m/s	lb × 0.4535924 = kg
ft × 0.3048 = m	lbf × 4.448222 = N
ft·lbf × 1.355818 = J	lbf/ft × 14.59390 = N/m
gr × 0.06479891 = g	lbf·in × 0.1129848 = N·m
in × 2.54 = cm	lbf/in^2 × 6894.757 = Pa
kWh × 3 600 000 = J	mph × 1.609344 = km/h
	qt × 0.9463529 = L

Temperature: $(T_{°F} - 32) \times 5/9 = T_{°C}$

Temperature: $(T_{°C} \times 9/5) + 32 = T_{°F}$

NIJ STANDARD
FOR
FIXED AND BASE STATION
FM TRANSMITTERS

1. PURPOSE AND SCOPE

The purpose of this document is to establish performance requirements and methods of test for non-trunked frequency modulated (FM) fixed and base station transmitters. This standard applies to transmitters which either do not have special subsystems such as selective signaling or voice privacy, or in which such subsystems are bypassed or disabled during testing for compliance with this standard. This standard supersedes NILECJ-STD-0201.00, Fixed and Base Station FM Transmitters, dated September 1974. This revision has been prepared to include transmitters operating in the 806–866 MHz frequency band and it also provides modified requirements for FM hum and noise level and audio response. In addition, a revised radiation test site for transmitters operating at 400 MHz and above has been developed.

2. CLASSIFICATION

For the purpose of this standard, fixed and base station FM transmitters are classified by their operating frequencies.

2.1 Type I

Transmitters which operate in the 25–50 MHz band.

2.2 Type II

Transmitters which operate in the 150–174 MHz band.

2.3 Type III

Transmitters which operate in the 400–512 MHz band.

2.4 Type IV

Transmitters which operate in the 806–866 MHz band.

3. DEFINITIONS

The principal terms used in this document are defined in this section. Additional definitions relating to law enforcement communications are given in LESP-RPT-0203.00, Technical Terms and Definitions Used with Law Enforcement Communications Equipment [1].[1]

3.1 AM Hum and Noise

The residual amplitude modulation present on an unmodulated carrier.

[1] Numbers in brackets refer to the references in appendix A.

3.2 Audio Response

The degree of precision with which the frequency deviation of a transmitter responds to a designated audiofrequency signal level.

3.3 Authorized Bandwidth

The maximum width of the band of frequencies specified by the Federal Communications Commission to be occupied by an emission, i.e., 20 kHz for public safety agencies [2].

3.4 Carrier Attack Time

The time required for a transmitter to produce 50 percent of the rated carrier output power after the carrier control switch is activated.

3.5 Carrier Output Power

For a transmitter, the radio frequency (rf) power available at the antenna terminal when no modulating signal is present.

3.6 Conducted Spurious Emission

Any spurious signal conducted over a tangible transmission path. For fixed transmitters, power lines, control cables, and rf transmission lines are the most likely tangible paths.

3.7 FM Hum and Noise

The frequency modulation present on an unmodulated carrier.

3.8 Frequency Deviation

In frequency modulation, the difference between the instantaneous frequency of the modulated carrier and the unmodulated carrier frequency.

3.9 Frequency Stability

The maximum permissible departure by the center frequency of the frequency band occupied by an emission from the assigned frequency.

3.10 Harmonic Distortion

Nonlinear distortion of a system or transducer characterized by the appearance in the output of harmonics, in addition to the fundamental component, when the input wave is sinusoidal.

3.11 Modulation Limiting

That action, performed by an FM transmitter, which intentionally restricts the signal to the required spectral limits by restricting the total deviation of the emission.

3.12 Nominal Value

The numerical value of a device characteristic as specified by the manufacturer.

3.13 Occupied Bandwidth

The width of the frequency band containing those frequencies at which a total of 99 percent of the radiated power appears, extended to include any discrete frequency at which the power is at least 0.25 percent of the total radiated power.

3.14 Radiated Spurious Emission

Any spurious signal other than a conducted spurious emission.

3.15 Sampler

A series device which couples energy over a broad frequency range from a transmitter line into a third port. The attenuated output signal from the third port has the same waveform as the original signal.

3.16 Sideband Spectrum

The emissions generated by a modulated transmitter that are within 250 percent of the authorized bandwidth, i.e., ±25 kHz.

3.17 SINAD Ratio

The ratio, expressed in decibels, of (1) signal plus noise plus distortion to (2) noise plus distortion produced at the output of a receiver; from *SI*gnal *N*oise *A*nd *D*istortion *R*atio.

3.18 Spurious Emission

Any part of the rf output that is not a component of the desired output or exceeds the authorized bandwidth.

3.19 Standby Mode

The condition in a transmitting and/or receiving system when the system is energized but not receiving or transmitting.

3.20 Standing Wave Ratio (SWR)

The ratio of the maximum to the minimum amplitudes of the voltage or current appearing along a transmission line with a constant input source.

4. REQUIREMENTS

4.1 Minimum Performance Requirements

The transmitter performance shall meet or exceed the requirement for each characteristic as given below and in table 1. The performance requirements listed in table 1 meet or exceed those given in the Rules and Regulations published by the FCC [2].

4.2 User Information

A nominal value for each of the characteristics listed in table 1 shall be included in the information supplied to the purchaser by the manufacturer or distributor. In addition, the manufacturer shall provide the range of temperatures within which the transmitter is designed to be operated, the transmitter operating frequencies, and nominal values for the transmitter carrier output power and the standard supply voltage. The manufacturer shall also indicate the magnitude of the audio input signal necessary for rated system deviation and provide sufficient audio input impedance information to enable test personnel to design an impedance matching network for use between the audio generator and transmitter audio input circuits.

4.3 Performance at Environmental Extremes

The ability of the transmitter to operate in environmental extremes shall be determined using the test methods described in section 5.3. It is suggested that these tests be performed before the transmitter is tested for compliance with the requirements of sections 4.4, 4.5 and 4.6.

TABLE 1. *Minimum performance requirements for fixed and base station FM transmitters.*

Transmitter Characteristic	Minimum requirement frequency band (MHz) 25–50	150–174	400–512	806–866
Radio Frequency Carrier Characteristics				
A. Carrier Output Power Variance	−0.3 dB	−0.3 dB	−0.3 dB	−0.3 dB
B. Output Power Variance (Supply Voltage Varied ±10%)	−3 dB	−3 dB	−3 dB	−3 dB
C. Output Power Variance (Supply Voltage Varied −20%)	−6 dB	−6 dB	−6 dB	−6 dB
D. Carrier Frequency Tolerance	0.002%	0.0005%	0.00025%	0.00015%
E. Frequency Stability (Supply Voltage Varied ±15%)	0.002%	0.0005%	0.00025%	0.00015%
F. AM Hum and Noise Level	55 dB	55 dB	55 dB	55 dB
G. Carrier Attack Time	100 ms	100 ms	100 ms	100 ms
Audio Modulation Characteristics				
H. Audio Harmonic Distortion	5%	5%	5%	5%
I. FM Hum and Noise Level	40 dB	40 dB	40 dB	40 dB
J. Frequency Deviation	±(4.5–5) kHz	±(4.5–5) kHz	±(4.5–5) kHz	±(4.5–5) kHz
K. Modulation Limiting	±5 kHz	±5 kHz	±5 kHz	±5 kHz
Electromagnetic Compatibility Characteristics				
L. Conducted Spurious Emissions	55 dB	55 dB	55 dB	55 dB
M. Radiated Spurious Emissions	1.65 mV/m	1.65 mV/m	16.5 mV/m	16.5 mV/m
N. Sideband Spectrum (±10 kHz Frequency Separation)	25 dB	30 dB	30 dB	30 dB
O. Sideband Spectrum (±20 kHz Frequency Separation)	50 dB	60 dB	60 dB	60 dB
Temperature Stability				
P. Output Power	−3 dB	−3 dB	−3 dB	−3 dB
Q. FM Hum and Noise Level	34 dB	34 dB	34 dB	34 dB
R. Carrier Frequency Tolerance	0.002%	0.0005%	0.00025%	0.00015%
S. Audio Harmonic Distortion	9%	9%	9%	9%
Humidity Stability				
T. Output Power	−3 dB	−3 dB	−3 dB	−3 dB
U. FM Hum and Noise Level	34 dB	34 dB	34 dB	34 dB
V. Carrier Frequency Tolerance	0.002%	0.0005%	0.00025%	0.00015%

4.3.1 Temperature Stability

Low temperature tests shall be conducted at −30 °C (−22 °F) or the lowest temperature at which the manufacturer states (sec. 4.2) that the unit will operate properly, whichever is lower, and high temperature tests shall be conducted at 60 °C (140 °F) or the highest temperature at which the manufacturer states that the unit will operate properly, whichever is higher.

When the transmitter is operated at low and high temperatures, as defined above, its performance shall not vary more than 3 dB (item P) for rf output power, (item R) for carrier frequency tolerance and 9 percent (item S) for audio harmonic distortion. In addition, the FM hum and noise level shall be attenuated a minimum of 34 dB (item Q).

4.3.2 Humidity Stability

After the transmitter has been maintained at 50 °C (122 °F) and 90 percent relative humidity for at least 8 h, its performance shall not vary more than 3 dB (item T) for rf output power and (item V) for carrier frequency tolerance. In addition, the FM hum and noise level shall be attenuated a minimum of 34 dB (item U).

4.4 Radio Frequency Carrier Characteristics

The rf carrier characteristics of output power, frequency stability, AM hum and noise level, and carrier attack time shall be measured in accordance with section 5.4.

4.4.1 Output Power

Transmitter output power is specified by the FCC [2]. The carrier output power delivered to a standard output load shall not decrease more than 0.3 dB (item A) from the nominal value at any time during the standard test duty cycle, except for the initial second after applying power. When the standard supply voltage is varied ±10 percent, the output power shall not decrease by more than 3 dB (item B). When the standard supply voltage is reduced by 20 percent, the output power shall not decrease by more than 6 dB (item C).

4.4.2 Frequency Stability

The carrier frequency shall be within (Item D) of the assigned value at all times during the standard test duty cycle except for the initial second after applying power. When the standard supply voltage is varied ±15 percent, the frequency stability shall be within (item E) of the assigned value.

4.4.3 AM Hum and Noise Level

The AM hum and noise level shall be attenuated a minimum of 55 dB (item F) below the unmodulated nominal carrier output power level.

4.4.4 Carrier Attack Time

The carrier output power shall increase to 50 percent of its nominal value in less than 100 ms (item G).

4.5 Audio Modulation Characteristics

The audio modulation characteristics of harmonic distortion, FM hum and noise level, response, frequency deviation and modulation limiting shall be measured in accordance with section 5.5.

4.5.1 Audio Harmonic Distortion

The audio harmonic distortion shall be a maximum of 5 percent (item H).

4.5.2 FM Hum and Noise Level

The FM hum and noise level shall be attenuated a minimum of 40 dB (item I).

4.5.3 Audio Response

The audio response of the transmitter shall not vary more than +1, −3 dB from a true 6 dB per octave pre-emphasis characteristic from 0.3 to 3 kHz as referred to the 1-kHz level, as shown in figure 1, with the exception that a 6 dB per octave roll-off from 600 to 300 Hz and from 2.5 to 3 kHz may be present.

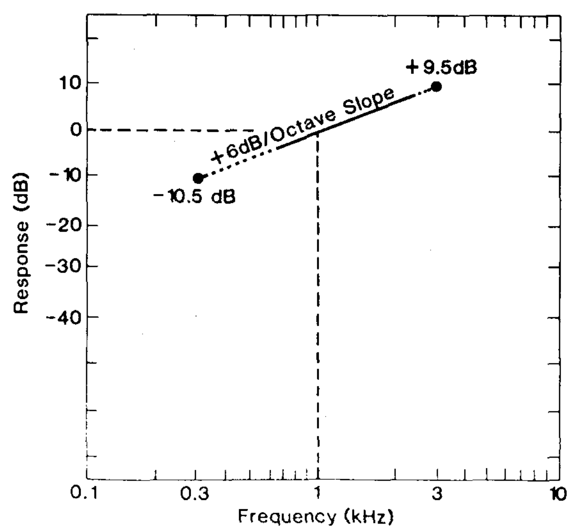

FIGURE 1. *Audio response characteristic of fixed and base station FM transmitters.*

4.5.4 Frequency Deviation

The maximum frequency deviation shall be between ±(4.5 and 5) kHz (item J).

4.5.5 Modulation Limiting

The instantaneous peak and the steady state frequency deviation shall not exceed the maximum value of rated system deviation of ±5 kHz (item K) with a 20 dB increase in audio above the nominal input level.

4.6 Electromagnetic Compatibility Characteristics

The electromagnetic compatibility characteristics of conducted spurious emissions, radiated spurious emissions and sideband spectrum shall be measured in accordance with paragraph 5.6.

4.6.1 Conducted Spurious Emissions

Each conducted spurious emission shall be attenuated a minimum of [55 (item L) + 10 $\log_{10}$ (output power in watts)] decibels below the level of the transmitter output power.

4.6.2 Radiated Spurious Emissions

Each radiated spurious emission shall be no larger than 1.65 mV/m (item M) at 30 m (Types I and II) or 16.5 mV/m (also item M) at 3 m (Types III and IV), i.e., each radiated spurious emission shall be less than 50 μW.

4.6.3 Sideband Spectrum

Each spurious sideband emission shall be attenuated greater than (item N) when the frequency is separated from the assigned carrier by ±10 kHz, and shall be attenuated greater than (item O) when the frequency is separated from the assigned carrier by ±20 kHz or more.

5. TEST METHODS

5.1 Standard Test Conditions

Allow all measurement equipment to warm up until the system has achieved sufficient stability to perform the measurement. Unless otherwise specified, perform all measurements under standard test conditions.

5.1.1 Standard Temperature

Standard ambient temperature shall be between 20 and 30 °C (68 and 86 °F).

5.1.2 Standard Relative Humidity

Standard ambient relative humidity shall be between 10 and 85 percent.

5.1.3 Standard Test Frequencies

The standard transmitter test frequency shall be the transmitter operating frequencies specified in section 4.2.

5.1.4 Standard Supply Voltage

The standard supply voltage shall be a nominal 120 V, 60 Hz, unless otherwise specified by the manufacturer. Voltage measurements should be made at the transmitter power supply input terminals, if practical, and adjusted to within 1 percent of the nominal value. The power wiring (including that external to the transmitter) shall be adequate to avoid a voltage drop due to load current of no more than 1 percent of the nominal value.

5.1.5 Rated System Deviation

Rated system deviation shall be ±5 kHz.

5.1.6 Standard Test Modulation

5.1.6.1 Audio Test Modulation

Audio test modulation shall be a 1-kHz signal (from a source with distortion less than 1 percent) at the level required to produce 60 percent of rated system deviation (i.e., ±3 kHz).

5.1.6.2 Electromagnetic Compatibility Test Modulation

Electromagnetic compatibility test modulation shall be a 2.5 kHz sine wave at an input level 16 dB greater than that required to produce 50 percent of rated system deviation at 1 kHz.

5.1.7 Standard Radiation Test Site

5.1.7.1 Type I and II Transmitters

The standard radiation test site shall be located on level ground which has uniform electrical characteristics (i.e., ground constants). Reflecting objects (especially large metal objects), trees, buildings, and other objects which would perturb the electromagnetic fields to be measured should not be located closer than 90 m (295 ft) from any test equipment or equipment under test. All utility lines and any control circuits between test positions should be buried underground. The ambient electrical noise level shall be as low as possible and shall be carefully monitored to ensure that it does not interfere with the test being performed. Preferably, the test site should be equipped with a turntable located at ground level.

5.1.7.2 Type III and IV Transmitters

In addition to the requirements described in 5.1.7.1, the standard radiation test site shall have microwave absorbing material placed on the ground between the transmitter and the receiving antenna to restrict standing waves, produced by reflections from the ground, to no larger than ±1 dB. If available, an anechoic chamber may be used instead (sec. 5.2.10). Preferably the test site should be equipped with a turntable located 1 m above ground level supported by nonreflective material.

5.1.8 Standard Test Duty Cycle

The standard test duty cycle shall be continuous operation in the transmit mode.

5.2 Test Equipment

The test equipment discussed in this section is limited to that equipment which is the most critical in making the measurements discussed in this standard. All other test equipment shall be of comparable quality.

5.2.1 FM Signal Generator

The FM signal generator shall have a 50-Ω output impedance, a maximum SWR of 1.2 and a calibrated variable output level accurate to ±2 dB when terminated in a 50-Ω load. It shall also have a single sideband 1-Hz bandwidth phase noise less than −135 dB below the carrier at 25 kHz separation for carrier frequencies of 500 MHz and lower (−130 dB at 900 MHz). The generator should include a digital frequency counter having an uncertainty no greater than one part in 10^6 and a deviation monitor or calibrated control for determining the peak frequency deviation with an uncertainty of no greater than 5 percent. If an integral frequency counter is not included, a separate frequency counter having the required accuracy shall be provided.

5.2.2 CW Sweep Signal Generator

The CW sweep signal generator shall have the same characteristics as the FM signal generator except that the FM capability and the low phase noise capability are not required. The sweep generator should have some means of slowly, automatically sweeping the frequency band, especially for the higher frequencies.

5.2.3 Distortion Analyzer

The distortion analyzer shall have a required input level of between 1 and 5 V rms, an input impedance of at least 50,000 Ω shunted by less than 100 pF and an accuracy of at least ±1 dB. It shall have the capability to measure both audio distortion and the voltage of audio signals to within ±3 percent. The analyzer shall incorporate a 1000 Hz band elimination filter for the audio distortion measurements.

5.2.4 Audio Voltmeter

The audio voltmeter shall measure rms voltage to an uncertainty of 1 percent or less.

5.2.5 Standard Audio Input Load

The standard audio input load shall consist of a low-noise load whose impedance is equal to the specified input impedance of the transmitter.

5.2.6 Test Receiver

The test receiver shall include a standard audio output load as specified by the manufacturer of the test receiver (sec. 5.2.6.6) and shall have the characteristics specified in the following sections.

5.2.6.1 Audio Response

The audio response characteristic shall not vary more than 1 dB from a 750 μs de-emphasis characteristic when the system deviation is held constant and the modulation frequency is varied between 0.05 and 3 kHz.

5.2.6.2 Harmonic Distortion

The audio harmonic distortion shall be less than 1 percent at standard audio test modulation. The harmonic distortion at 1 kHz (for larger than rated system deviation) shall be less than 3 percent. The harmonic distortion shall be measured when the test receiver is tuned to a nominal 1-mV rf source which is modulated by a sine wave at a level which produces a system deviation 50 percent greater than rated system deviation (i.e., ±7.5 kHz).

5.2.6.3 Hum and Noise Level

The unsquelched hum and noise level shall be at least 55 dB when measured with a 1-mV input signal.

5.2.6.4 Adjacent-Channel Interference

The test receiver shall differentiate by 85 dB or more between a desired modulated signal and a modulated adjacent-channel signal 30 kHz on either side, when the adjacent-channel interference degrades the desired signal from 12 dB SINAD to 6 dB SINAD.

5.2.6.5 Selectivity

The test receiver shall have a bandwidth of 24 to 30 kHz at the −80 dB points.

5.2.6.6 Standard Audio Output Load

The standard audio output load shall provide an impedance equal to the load impedance into which the test receiver normally operates.

5.2.7 Deviation Meter

The deviation meter shall be capable of measuring the peak deviation of a modulating waveform with an uncertainty no greater than 5 percent of the deviation being monitored.

5.2.8 Field Strength Meter

The field strength meter, consisting of an antenna and a well-shielded calibrated receiver which operate at the standard test frequencies, shall have a measurement uncertainty of ±2 dB or less. It shall be calibrated to accurately measure field strengths from approximately 0.1 mV/m to 1 mV/m over the frequency range of interest. When testing Type IV transmitters, field strength measurements are required at frequencies up to 3 GHz. The receiver should be located near the receiving antenna to keep the length of the cable between them as short as possible.

5.2.9 Microwave Absorber

The microwave absorber shall attenuate the reflected energy at least 20 dB at 400 MHz at an incidence angle of 56°.

5.2.10 Anechoic Chamber

The anechoic chamber shall be a room covered on the inside surfaces with microwave absorber such that standing waves produced by imperfect absorption are no larger than ±1 dB.

5.2.11 Environmental Chamber(s)

The environmental chamber(s) shall produce air temperatures from −30 to 60 °C (−22 to 140 °F) and relative humidities in the range of 90 to 95 percent. The test item shall be shielded from air currents blowing directly from heating or cooling elements in the chamber. The temperature of the test item shall be measured with a thermometer separate from the sensor used to control the chamber air temperature. Likewise, humidity shall be measured with a hygrometer separate from the sensor used to control humidity.

5.2.12 Band Rejection Filter

The band rejection filter shall have a minimum insertion loss of 40 dB at ±0.01 percent of the carrier frequency.

5.2.13 Standard RF Output Load

The standard rf output load shall be a 50-Ω resistive termination having an SWR of 1.1 or less at the standard test frequencies. If connectors and cables are used to attach the standard output load to the transmitter, the combined SWR, including the load, shall be 1.1 or less.

5.3 Environmental Tests

The environmental tests shall be performed using standard supply voltage and the measurement techniques described in sections 5.4, 5.5, and 5.6.

5.3.1 Temperature Test

Place the transmitter, with the power turned off and all covers in place, in the environmental chamber. Adjust the chamber to the required low temperature ±2 °C (±3.6 °F). Allow the transmitter to reach temperature equilibrium and maintain it at this temperature for 30 min. With the transmitter still in this environment, connect it to the standard supply voltage and operate it at the standard test duty cycle. Fifteen minutes after turn-on, test the transmitter to determine whether it meets the requirements of section 4.3.1. Repeat the above procedure at the required high temperature ±2 °C (±3.6 °F).

5.3.2 Humidity Test

Place the transmitter, with the power turned off and all covers in place, in the environmental chamber. Adjust the relative humidity to a minimum of 90 percent at 50 °C (122 °F) or more and maintain the transmitter at these conditions for at least 8 h. With the transmitter still in this environment, connect it to the standard supply voltage and operate it at the standard test duty cycle. Fifteen minutes after turn-on, test the transmitter to determine whether it meets the requirements of section 4.3.2.

5.4 Radio Frequency Carrier Tests

5.4.1 Output Power Test

Operate the transmitter without modulation. Measure the output power as shown in figure 2, using standard supply voltage and a power meter accurate to 5 percent. Change the standard supply voltage +10 percent, allow it to stabilize at least 5 s, and determine the output power. Repeat this for changes in standard supply voltage of −10 percent and −20 percent.

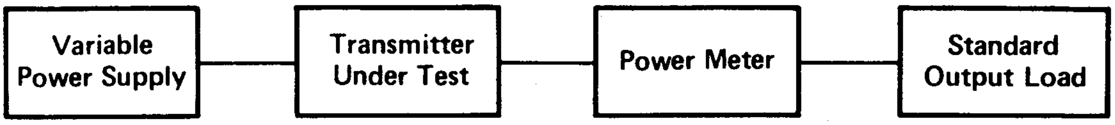

FIGURE 2. *Block diagram for output power measurement.*

5.4.2 Frequency Stability Test

Operate the transmitter without modulation. Measure the frequency as shown in figure 3, using standard supply voltage. Change the standard supply voltage +15 percent, allow it to stabilize for 5 s, and determine the change in frequency. Repeat this for a change in standard supply voltage of −15 percent.

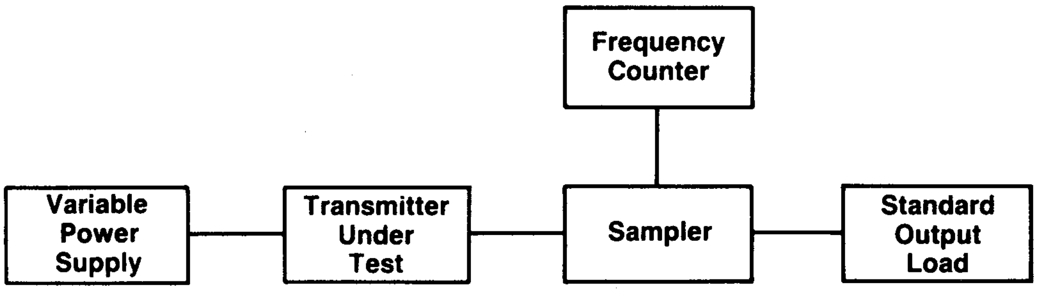

FIGURE 3. *Block diagram for frequency stability measurement.*

5.4.3 AM Hum and Noise Level Test

Connect the transmitter and test equipment as shown in figure 4. Use a linear peak-carrier responsive AM detector to detect the sampled output of the transmitter. With the transmitter operating at rated power with no modulation, measure the dc voltage across the detector load resistor with the high impedance dc voltmeter. Without adjusting the transmitter, measure the peak ac voltage with the oscilloscope. Calculate the AM hum and noise level as 20 $\log_{10} (V_p/V_{dc})$, where V_p is the peak-to-peak ac voltage and V_{dc} is the dc voltage.

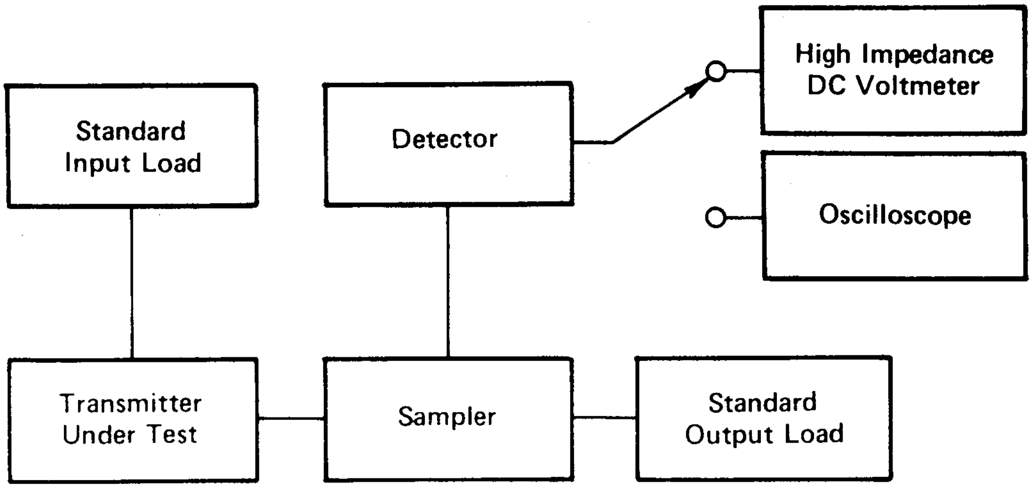

FIGURE 4. *Block diagram for AM hum and noise measurement.*

5.4.4 Carrier Attack Time Test

Although carrier attack time is defined in terms of rated carrier output power, the test method described herein uses a voltage measurement technique to determine the value of this characteristic. Make the measurement using a calibrated oscilloscope and peak detector connected as shown in figure 5. The peak detector should have a short time constant (<10 ms) and provide a linear response with amplitude. Close the trigger circuit of the oscilloscope through the transmitter control switch to start the time interval. The peak detector, sampling the rf carrier, provides a voltage to the oscilloscope vertical input. Measure the time required for the trace to reach 71 percent of the peak detector maximum output.

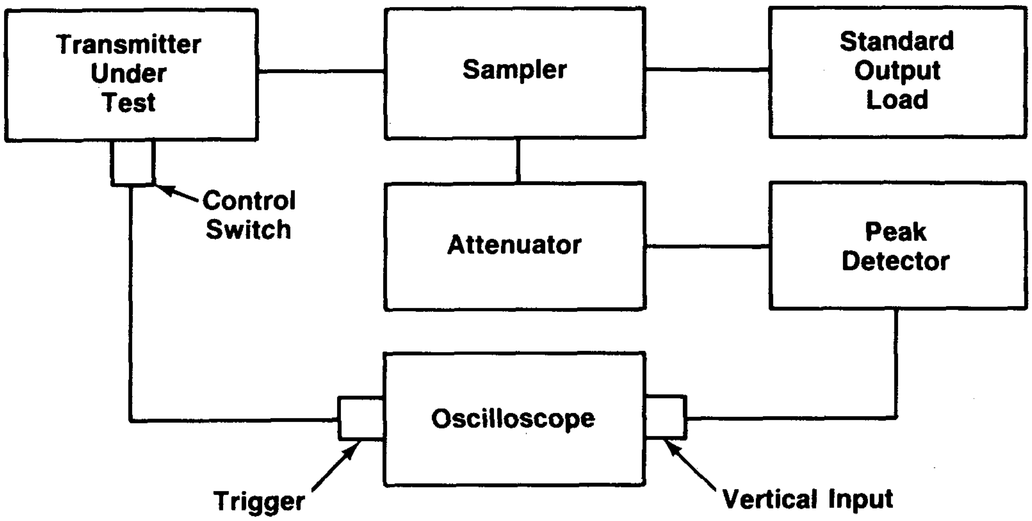

FIGURE 5. *Block diagram for carrier attack time measurement.*

5.5 Audio Modulation Tests

5.5.1 Harmonic Distortion Test

Connect the transmitter and test equipment as shown in figure 6. Operate the transmitter at nominal carrier output power and adjust the audio oscillator for standard audio test modulation. Ensure that the 1-kHz modulating signal has a total distortion of 0.5 percent or less. Process the sampled transmitter output with the test receiver (sec. 5.2.6). Connect the distortion analyzer across the standard audio output load to remove the 1-kHz tone and measure the remaining signal, which is a combination of all the noise and harmonic components.

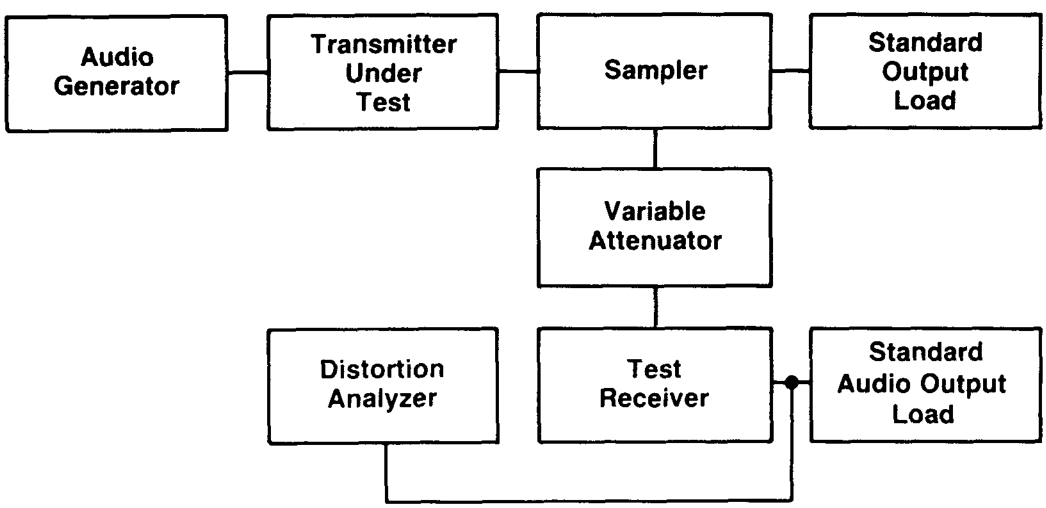

FIGURE 6. *Block diagram for harmonic distortion and FM hum and noise measurements.*

5.5.2 FM Hum and Noise Level Test

Connect the transmitter and test equipment as shown in figure 6. Operate the transmitter at nominal carrier output power and adjust the audio input for standard audio test modulation. Measure the audio output voltage, V_1, of the test receiver using the distortion analyzer as a voltmeter. Remove the modulation by disconnecting the audio generator and replacing it with the standard audio input load. Measure the resulting audio voltage, V_2, at the distortion analyzer. Calculate the FM hum and noise level as $20 \log_{10} (V_1/V_2)$. The method provides reliable measurements up to 50 dB.

5.5.3 Audio Response Test

Connect the transmitter and test equipment as shown in figure 7, using a broadband matching network to match the audio generator output impedance to the transmitter audio input impedance.

Apply selected audio frequencies from 0.3 to 3 kHz to the transmitter, and maintain the audio input level at a constant 30 percent of rated system deviation (i.e., 1.5 kHz) as observed with the deviation meter. Determine the audio voltmeter reading in decibels relative to the voltmeter reading at 1-kHz for each test frequency, and draw a graph similar to that shown in figure 1.

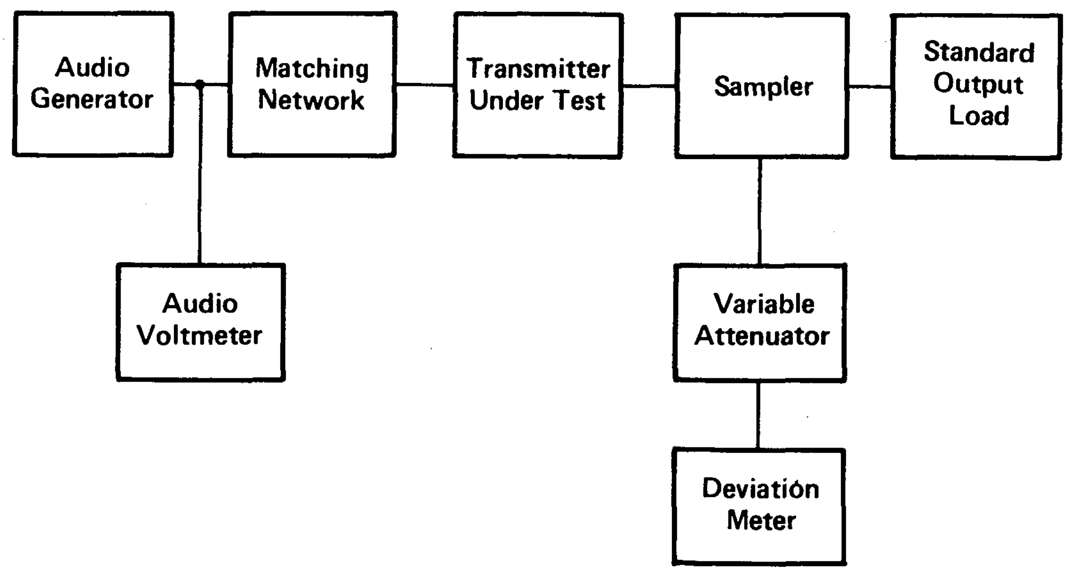

FIGURE 7. *Block diagram for audio response measurement.*

5.5.4 Frequency Deviation Test

Connect the transmitter and test equipment as shown in figure 8 and adjust the transmitter controls for normal operation. Adjust the audio input for standard audio test modulation, and increase the audio input level until maximum frequency deviation is observed. Measure the frequency deviation with the deviation meter and, if necessary, adjust it to conform to the requirement.

5.5.5 Modulation Limiting Test

Connect the transmitter and test equipment as shown in figure 8 and adjust the transmitter controls for normal operation. Adjust the audio input for standard audio test modulation and increase the audio input level 20 dB. Hold the audio input level constant, vary the frequency from 0.3 to 3 kHz and measure the frequency deviation with the deviation meter.

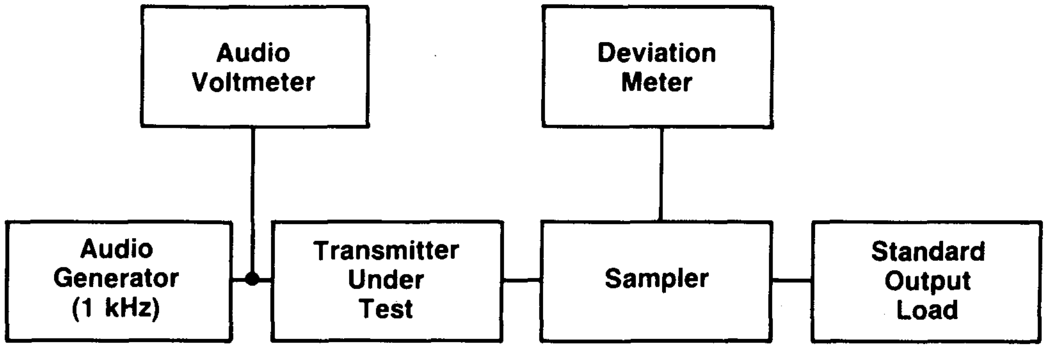

FIGURE 8. *Block diagram for frequency deviation and modulation limiting measurements.*

5.6 Electromagnetic Compatibility Tests

5.6.1 Test for Conducted Spurious Emissions at the Antenna Terminals

Using a signal generator with a calibrated output, connect the transmitter and test equipment as shown in step 1, figure 9. Use a selective rf voltmeter or spectrum analyzer capable of measuring signals at least 80 dB below the carrier level to measure the spurious emissions. Modulate the transmitter with the electromagnetic compatibility test modulation and measure the rated transmitter output power in decibels above 1 mW (dBm) (step 1). Record the transmitter spurious emissions. Disconnect the power meter, transmitter and audio oscillator from the circuit and connect the signal generator as shown in step 2. Adjust the signal generator to obtain the same frequencies and magnitudes of spurious signals as were recorded above, and record the corresponding outputs of the signal generator in dBm. The transmitter output power in dBm minus the signal generator output in dBm is the value sought.

Measure all frequencies from the lowest frequency generated within the transmitter to the tenth harmonic of the carrier or 3 GHz, whichever is lower.

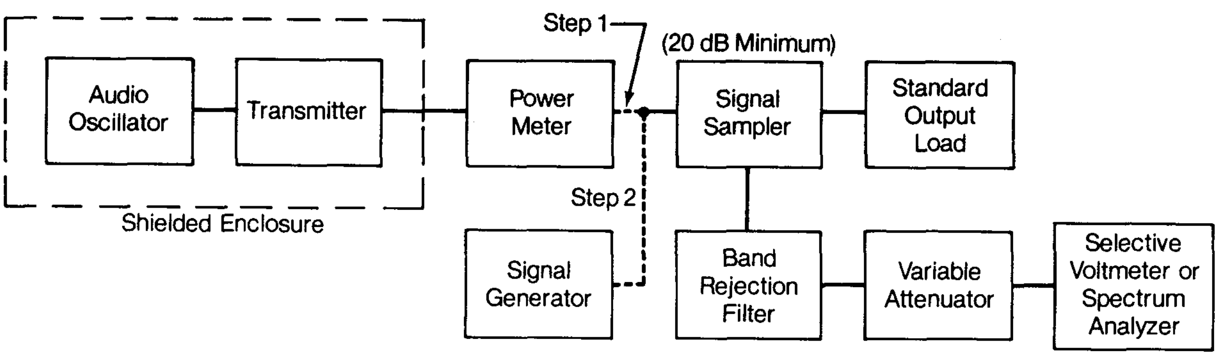

FIGURE 9. *Block diagram for conducted spurious emissions measurement at the antenna terminals.*

5.6.2 Radiated Spurious Emissions Tests

5.6.2.1 Radiated Spurious Emissions Test (Type I and II Transmitters)

Set up the transmitter and the test equipment as shown in figure 10 at a site that meets the requirements of section 5.1.7.1. Connect the transmitter to the standard output load and adjust it to produce nominal output power. Measure the spurious emissions with receiving antenna 30 m (98.4 ft) from the transmitter and 3 m (9.8 ft) above the earth. Tune the field strength meter from the lowest radio frequency generated in the transmitter equipment up to the tenth harmonic of the carrier or 1000 MHz, whichever is lower. Note each spurious emission.

For each spurious frequency noted, raise and lower the receiving antenna with a horizontal polarization to obtain a maximum reading on the field strength receiver. Rotate the transmitter to further maximize this reading. Repeat this procedure of raising and lowering the antenna and rotating the transmitter until the largest signal has been obtained and recorded. Then orient the antenna for vertical polarization and repeat the procedure for each spurious signal. Record the maximum field strength of the spurious frequencies.

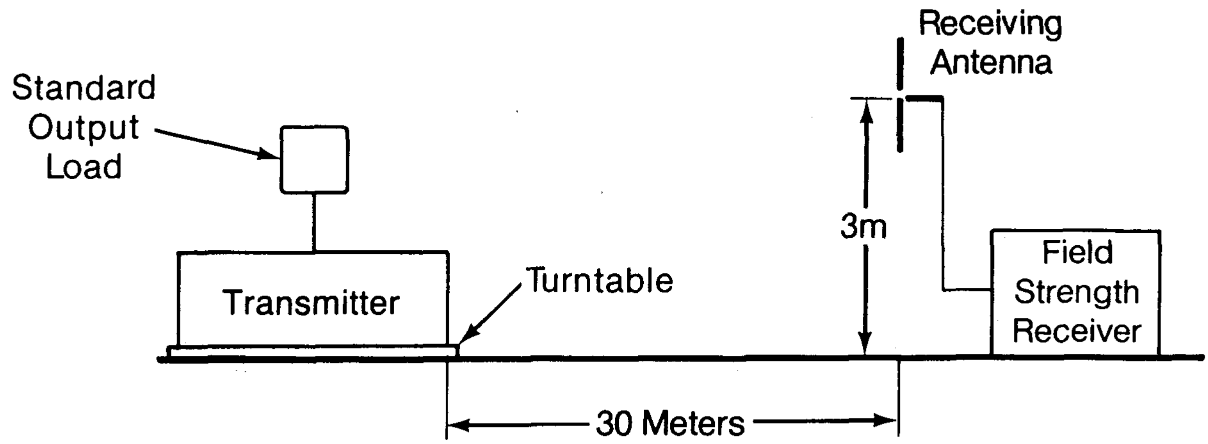

FIGURE 10. *Block diagram for radiated spurious emission measurement for Type I and II transmitters.*

5.6.2.2 Radiated Spurious Emissions Test (Type III and IV Transmitters)

Set up the transmitter and the test equipment as shown in figure 11 at a site that meets the requirements of section 5.1.7.2. Place the microwave absorber, at least 1.8 m (6 ft) wide, on the ground between the transmitter and the receiving antenna, as shown. Connect the transmitter to the standard output load and adjust it to produce nominal output power. Measure the spurious emissions with both the receiving antenna and the transmitter 1 m (3.3 ft) above the earth and the horizontally-polarized receiving antenna 3 m (9.8 ft) from the transmitter. Tune the field strength meter from the lowest radio frequency generated in the equipment up to 3 GHz. Note each spurious emission.

For each spurious frequency noted, raise and lower the receiving antenna with a horizontal polarization to obtain a maximum reading on the field strength receiver. Rotate the transmitter to further maximize this reading. Repeat this procedure of raising and lowering the antenna and rotating the transmitter until the largest signal has been obtained and recorded. Then orient the antenna for vertical polarization and repeat the procedure for each spurious signal. Record the maximum field strength of the spurious frequencies.

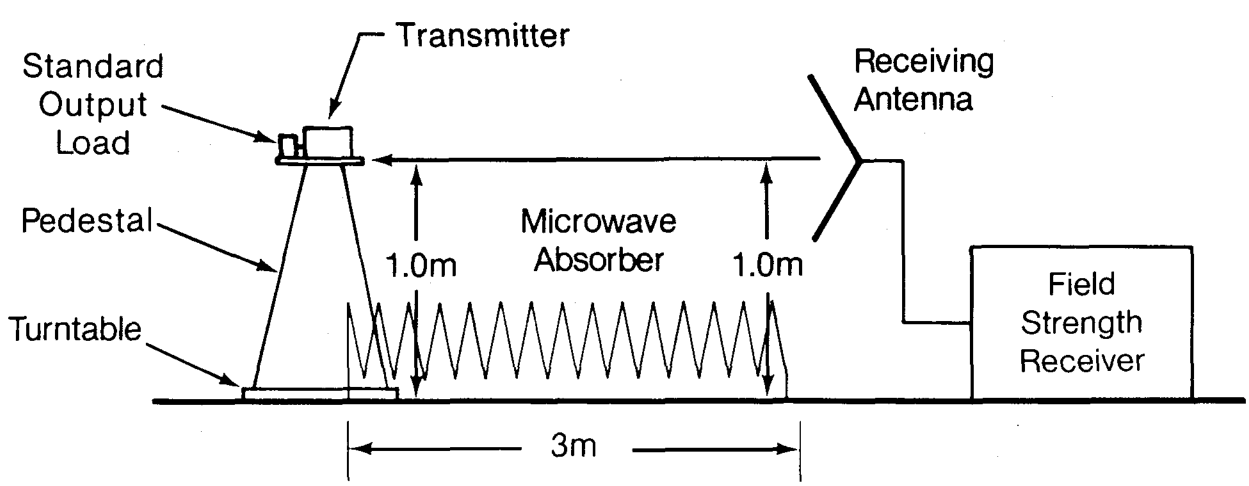

FIGURE 11. *Block diagram for radiated spurious emission measurement for Type III and IV transmitters.*

5.6.3 Sideband Spectrum Test

Connect the transmitter and test equipment as shown in figure 12. Using the variable attenuator, adjust the unmodulated carrier signal for a full-scale signal of at least 60 dB above the noise displayed on the spectrum analyzer. Apply electromagnetic compatibility test modulation and measure the average envelope of the resulting spectrum at both ±10 kHz and ±20 kHz from the center frequency. Adjust the spectrum analyzer controls so that approximately 50 kHz of transmitter spectrum is centered on the display. The image on the cathode ray tube of the spectrum analyzer should be similar to that shown in figure 13.

Record the sideband spectrum attenuations as the differences between the center frequency amplitude and the amplitudes of the sidebands located at ±10 kHz and ±20 kHz from the center frequency.

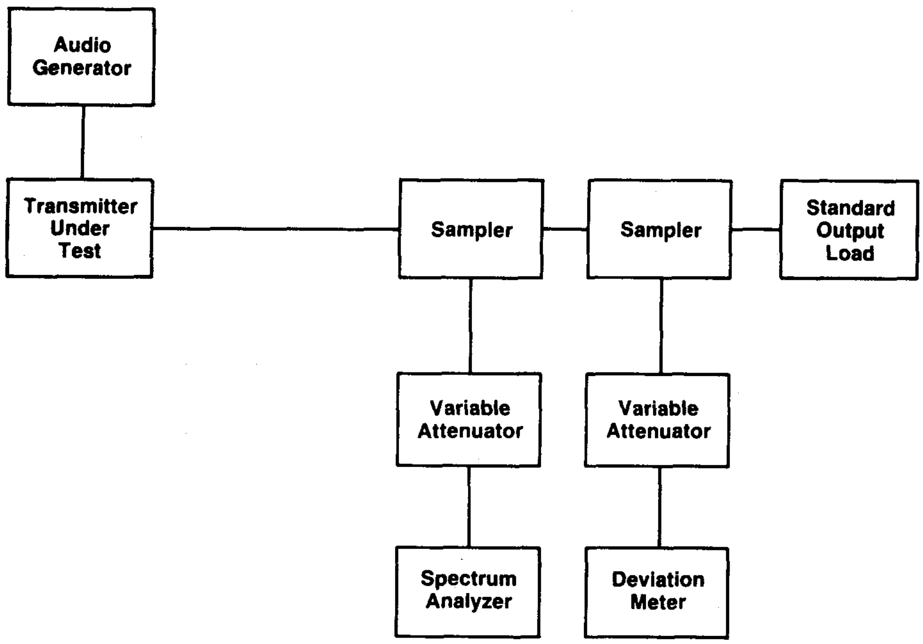

FIGURE 12. *Block diagram for sideband spectrum measurement.*

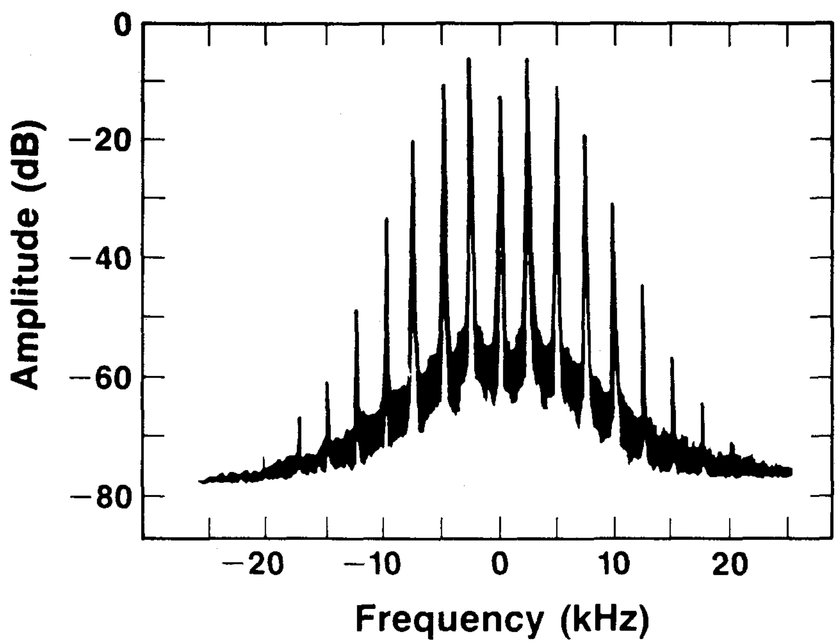

FIGURE 13. *Typical sideband spectrum of a transmitter using a 2.5 kHz tone 16 dB greater than that required to produce ±2.5 kHz deviation at 1.0 kHz.*

APPENDIX A—REFERENCES

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