IEEE Std 377-1980

IEEE Recommended Practice for Measurement of Spurious Emission from Land-Mobile Communication Transmitters

Sponsor

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Foreword

(This Foreword is not a part of IEEE Std 377-1980, IEEE Recommended Practice for Measurement of Spurious Emission from Land-Mobile Communication Transmitters.)

This standard was initiated as Project No 712-53, by the IEEE Electromagnetic Compatibility Group Committee 27.0. The project was approved by the IEEE Standards Committee on June 3, 1971. Subcommittee 27.7 was assigned the task. This subcommittee had recently completed a standard covering Measurement of Radio Noise Generated by Motor Vehicles. Continuing coordination with The IEEE Group on Vehicular Technology, the Electronics Industries Association and the International Electrotechnical Commission via common membership, was maintained.

The purpose of the measurement procedures is to enable design and system engineers engaged in a variety of development projects, to achieve uniform results, in recognizing sources and nature of radio frequency spurious emissions emanating from vehicular communications transmitters. The measurement procedure enables quantitative results, which determine the magnitude of undesired by-products of a transmitters RF carrier generation. The specific spurious emissions measured, are not readily recognized, except as they deprecate the performance of receivers associated with the transmitter or which are located in a moderately near field environment. In a modern vehicle employing a computerized fuel management system, the spurious emissions can be quite destructive.

A prime objective of the standard was to develop methods employing basically standard laboratory measuring equipment and produce useful planning or design data from which performance characteristics could be accurately derived.

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CLAUSE PAGE

IEEE Recommended Practice for Measurement of Spurious Emission from Land-Mobile Communication Transmitters

1. Scope

This recommended practice covers definitions of terms, controlled test conditions, test apparatus, test methods and data presentation, all of which form the basis for establishing the energy levels of spurious emissions of mobile communication transmitters designed to generate frequency-modulated (FM) signals in the frequency range of 25 MHz to 1000 MHz. Procedures for measuring both broadband and narrowband spectra are provided for both conducted and radiated emissions. Specified limits are not included. However, reference values which are not limited by the state of the art are provided. Transmitter test conditions, apparatus and method are based on standard instrumentation and measuring techniques and do not require any special apparatus other than necessary terminal simulators. The procedures do not cover the associated antenna and transmission lines.

1.1 Subsystems

In those cases where transmitters are equipped with special function subsystems, such as selective calling, dialing supervision or other keying devices, said systems shall be disabled. An exception is continuous tone modulated equipment.

This recommended practice does not provide for testing of transmitters which include subsystems that cannot be disabled or bypassed.

1.2 Limitations

This recommended practice is limited to measurements of single channel voice modulated transmitters independent of their application to any specific communication system. Spurious energy levels contained within the transmitter's integral control system are not measured. Methods of testing or specific apparatus for use in testing of *personal* portable type transmitters employing integral antennas and audio input devices are not included.

1.3 Supplementary Testing

Special function subsystems which may require supplementary test methods are not covered by this recommended practice.

2. Definition of Terms

2.1 General

Definitions given are limited to those terms or expressions unique to the purpose of this recommended practice. Terms used in standard texts, related industry standards or recognized by common usage are not defined, except where the application within the context of this recommended practice requires specific limitation.

2.2 Standard Reference Terms

narrowband spurious emission: Any spurious output emitted from a radio transmitter, other than on its assigned frequency, which produces a disturbance of spectral energy lying within the bandpass of the measuring receiver in use.

near field region: The region of the field of an antenna between the reactive near field region and the far field region wherein radiation fields predominate and wherein the angular field distribution is dependent upon distance from the antenna.

NOTES:

1 — If the antenna has a maximum overall dimension which is not large compared to the wavelength, this field region may not exist.

2 — For an antenna focused at infinity, the radiating near field region is sometimes referred to as the Fresnel region on the basis of analogy to optical terminology.

far field region: The region of the field of an antenna where the angular field distribution is essentially independent of the distance from the antenna.

NOTES:

1 — If the antenna has a maximum overall dimension (D) that is large compared to the wavelength (λ), the far field region is commonly taken to exist at distances greater than $2D^2\lambda$ from the antenna.

2 — For an antenna focused at infinity, the far field region is sometimes referred to as the Fraunhofer region on the basis of analogy to optical terminology.

spurious transmitter output, conducted: Any spurious output of a radio transmitter conducted over a tangible transmission path.

NOTE — Power lines, control leads, radio frequency transmission lines and waveguides are all considered as tangible paths in the foregoing definition. Radiation is not considered a tangible path in this definition.

broadband spurious emission: The term as used in this recommended practice is applicable to modulation products near the carrier frequency generated as a result of the normal modulation process of the transmitter and appearing in the spectrum outside the authorized bandwidth (FCC). The products may result from overdeviation or internal distortion and noise and may have a Gaussian distribution.

standard transmitter test modulation: The standard test modulation shall be 60% of the maximum rated deviation at 1 kHz.

spurious emission power: Any part of the radio frequency output that is not a component of the theoretical output, as determined by the type of modulation and specified bandwidth limitations.

conducted spurious emission power: Any part of the spurious emission power output conducted over a tangible transmission path. Radiation is not considered a tangible path.

radiated spurious emission power: Any part of the spurious emission power output radiated from the transmitter enclosure, independent of any associated transmission lines or antenna, in the form of an electromagnetic field composed of variations of the intensity of electric and magnetic fields.

spurious emission power radiation field: That portion of the spurious emission power which may be radiated from a transmitter enclosure and which can be measured in the near or far field regions.

near field region, radiating: (See **near field region**.) Measurement is limited to the region external to the induction field and extending to the outer boundary of the reactive field which is commonly taken to exist at a distance of $\lambda/2\pi$. Either the electric or magnetic component of the radiated energy may be used to determine the magnitude of power present.

far field region, radiating: (See **far field region.**) Measurement is performed at or beyond a distance of 3λ, but not less than 1 m.

antenna correction factor: A factor (usually supplied with the antenna) which, when properly applied to the meter reading of the measuring instrument, yields the electric field strength in V/m or the magnetic field strength in A/m.

NOTES:

1 — This factor includes the effects of antenna effective length and impedance mismatch plus transmission line losses.

2 — The factor for electric field strength is not necessarily the same as the factor for the magnetic field strength.

2.3 Performance Characteristics

spurious transmitter output, extraband: Spurious output of a transmitter outside of its specified band of transmission.

intermodulation spurious emission: External radio frequency (RF) emission of a transmitter which is a product of the nonlinear mixing process in the final stage of the transmitter which occurs when external RF power is coupled through the antenna output.

modulation sideband spectrum: The sideband energy produced at a discrete frequency separation from the carrier due to all sources of unwanted noise within the transmitter in a modulated condition.

SINAD: An acronym for *signal plus noise plus distortion to noise plus distortion ratio,* expressed in dB, where the *signal plus noise plus distortion* is the audio power recovered from a modulated radio frequency carrier, and the *noise plus distortion* is the residual audio power present after the audio signal is removed. This ratio is a measure of audio output signal quality for a given receiver audio power output level.

3. References

[1] ANSI C63.2-1979, Specifications for Electromagnetic Noise and Field-Strength Instrumentation, 10 kHz to 1 GHz[1]

[2] ANSI C63.3-1964, Specifications for Radio-Noise and Field-Strength Meters, 20 to 100 Megacycles/Second

[3] ANSI/IEEE Std 100-1977, Standard Dictionary of Electrical and Electronics Terms

[4] IEEE Std ANSI/IEEE Std 152-1953 (Reaff 1971) Recommended Practice for Volume Measurements of Electrical Speech and Program Waves,

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[1] ANSI documents are available from the American National Standards Institute, 1430 Broadway, New York, N.Y. 10017.

[5] ANSI/IEEE Std 184-1969, Test Procedure for Frequency-Modulated Mobile Communications Receivers

[6] ANSI/IEEE Std 376-1975, Standard for the Measurement of Impulse Strength and Impulse Bandwidth

[7] IEEE Std 151-1965 (Reaff 1971), Standard Definitions of Terms for Audio and Electroacoustics

[8] IEEE Std 291-1969, Standards Report on Measuring Field Strength in Radio Wave Propagation

[9] IEC Pub No 106-1974, Recommended Methods of Measurement of Radiated and Conducted Interference from Receivers for Amplitude Modulation, Frequency Modulation, and Television Broadcast Transmissions[2]

4. Test Conditions, Apparatus and Assembly

4.1 Test Conditions

In order to reproduce and verify the data resulting from the tests included in this test procedure, the temperature and humidity shall be specified in the data presentation. The test supply voltage shall be equivalent to the voltage which is normally applied to the input of the power cables supplied with the transmitter. The voltage shall be recorded with the data presentation. The following requirements provide measurements with reasonable accuracy and illustrate minimum test equipment configurations to support the method of measurement recommended.

4.1.1 Environmental

Case radiation of narrowband spurious and harmonic emissions are measured by the open field measurement technique. Figure 1 illustrates the configuration of the measurement system. The measuring equipment is located within a shielded enclosure, separate from the equipment to be tested. The equipment to be tested is mounted on a turntable in an open area. The ambient electromagnetic energy level within the shielded enclosure shall be at least 10 dB below the minimum level to be measured. The open area should provide unobstructed clearance in all directions from the antenna probe and the unit under test for a distance of at least 30 m to prevent multipath from reflecting or conducting objects (for example, large buildings, electric lines, buried pipes, metallic fences and trees).

The turntable shall have an effective ground plane defined by the following. The area shall not be less than 2.25 m^2. The thickness shall not be less than 0.25 mm for copper, 0.63 mm for brass. The smallest lineal dimension shall not be less than 76.0 cm. It shall be bonded by a single conduction point to a common earth reference point with a minimum bonding resistance of 2.5 mΩ. The equipment base plate shall be connected to this point by a minimum of four bonding straps. The bonding straps shall have a length not greater than 5 times the width, with a maximum thickness of 0.064 cm. Braid shall not be used. Preferred metals are copper or brass. Equipment mounting bases of dissimilar metals shall not be used unless they are close together in the electromotive series or suitably plated to minimize galvanic or electrolytic corrosion. The ground plane or its mounting structure shall not be used as a ground return for power. The case of the unit under test together with any test devices shall be electrically connected to the ground plane at one point only. This point on the ground plane shall be located so as to permit the shortest possible metallic path to each equipment's common ground return. The point on the ground plane shall be located as close as possible to its earth reference. Power input leads shall be shielded up to the point of attachment but without a shield to case electrical path. Water mains, grounded metal building frames or similar buried metallic structures 10 m or longer can be used for an earth reference. A line stabilization network shall be used in each power lead, with its case grounded by the shortest path to the earth reference point of the ground plane. The power line shields shall be connected to the line stabilization network case ground reference point for their shield return.

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[2] International Electrotechnical Commission (IEC) documents are available from the American National Standards Institute, 1430 Broadway, New York, N.Y. 10017.

4.1.2 Standard Electrical Test Conditions

Direct current or alternating current voltages applied to the inputs of the equipment under test shall be regulated to the specified limits required by the manufacturer and shall be measured at the inputs of the power cable with a meter having an accuracy of ± 1.0% full scale reading.

4.2 Test Apparatus

4.2.1 Frequency Selective Voltmeter

A frequency selective voltmeter or calibrated receiver which can tune over the full range of radiated or conducted frequencies of interest is required. Standard noise and field strength measuring sets which meet the requirements of ANSI C63.2-1979 [1][3] or ANSI C63.31964 [2] and include calibrated loops and dipole antennas will normally satisfy this requirement. The instrument's susceptibility to radiated energy should be well below the shielded enclosure's internal ambient RF field level as determined by its attenuation versus frequency characteristics (see 4.1.1). Any spurious responses should be clearly identified and recorded. Any harmonic responses should be clearly identified and recorded. Any harmonic responses not identified with the unit under test shall be isolated by use of high pass filters and included in the calibration record. The instrument's background noise spectrum shall be measured and recorded. This may be done by terminating the input with a resistive load (50 Ω) and adjusting the peak calibration control, that is, aural null slideback bias, to the threshold of audibility. Then replace the load with a calibrated impulse generator and adjust its output to match the background noise spectrum level. Record this value. A similar technique should be used to establish the test site ambient noise level. Replace the antenna or probe with the impulse generator. Means shall be provided to enable meter readings over the full range of the input attenuator, including frequencies below 20 MHz down to 0.15 MHz. The impulse bandwidth, if not specified, should be determined and recorded. See ANSI/IEEE Std 376-1975 [6].

4.2.1.1 Signal Detection

The average mode of signal detection is preferred for narrowband measurements since it is independent of carrier modulation within the modulation acceptance bandwidth of the receiver with less than 2.0 dB measurement error. In the substitution process, this error can be accounted for when the modulation characteristic is known when using a calibrated input source. The combined receiver and antenna sensitivity shall be adequate to permit measurement of –120 dBW/m^2 up to 300 MHz and –110 dBW/m^2 from 300 MHz to 1000 MHz after accounting for the insertion losses of all interconnecting cables, input couplers, filters, isolation networks or attenuators.

4.2.2 Modulation Sideband Receiver

A receiver having frequency selectivity characteristics which conform to those illustrated in Fig 2 is required to perform the tests described in 5.1.2.1 and 5.2.2. The operating frequency range of this receiver must be equivalent to that of the transmitter under test.

The receiver selectivity should be measured in accordance with ANSI/IEEE Std 184-1969 [5] and displayed on semilog graph paper as shown in Fig 2. Its 6 dB half bandwidth should be noted and recorded.

4.2.3 Modulation Monitor Receiver

The receiver shall be of the FM type and be such that the minimum intermediate frequency (IF) bandwidth is ±75 kHz at the 6 dB points. The discriminator and audio circuit frequency response shall be fiat to within ± 1 dB from 100 Hz to 10 kHz. The receiver shall be capable of being tuned over the frequency range of 25 to 1000 MHz. The residual hum and noise level shall be measured at the audio output terminals of the receiver when the output is terminated in a standard load and shall be expressed in dB below rated power output. A standard input signal source shall be connected

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[3] The numbers in brackets correspond to those of the references in Section 3.

to the antenna terminals of the receiver. With 1000 µV input at standard test modulation, the receiver volume control shall be adjusted for rated power output. The modulation shall be turned off and the hum and noise ratio shall be measured as the difference in dB between the two output meter readings. The FM hum and noise quieting capability shall be at least 50 dB.

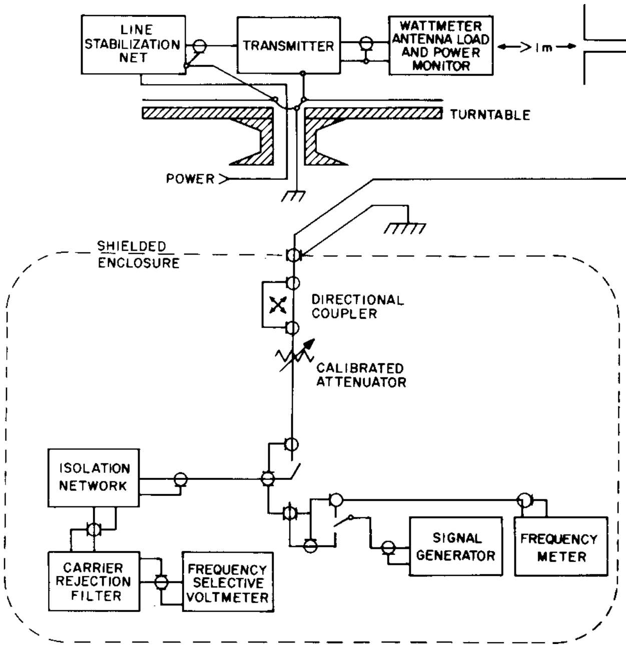


Figure 1—Open Field Measurement System

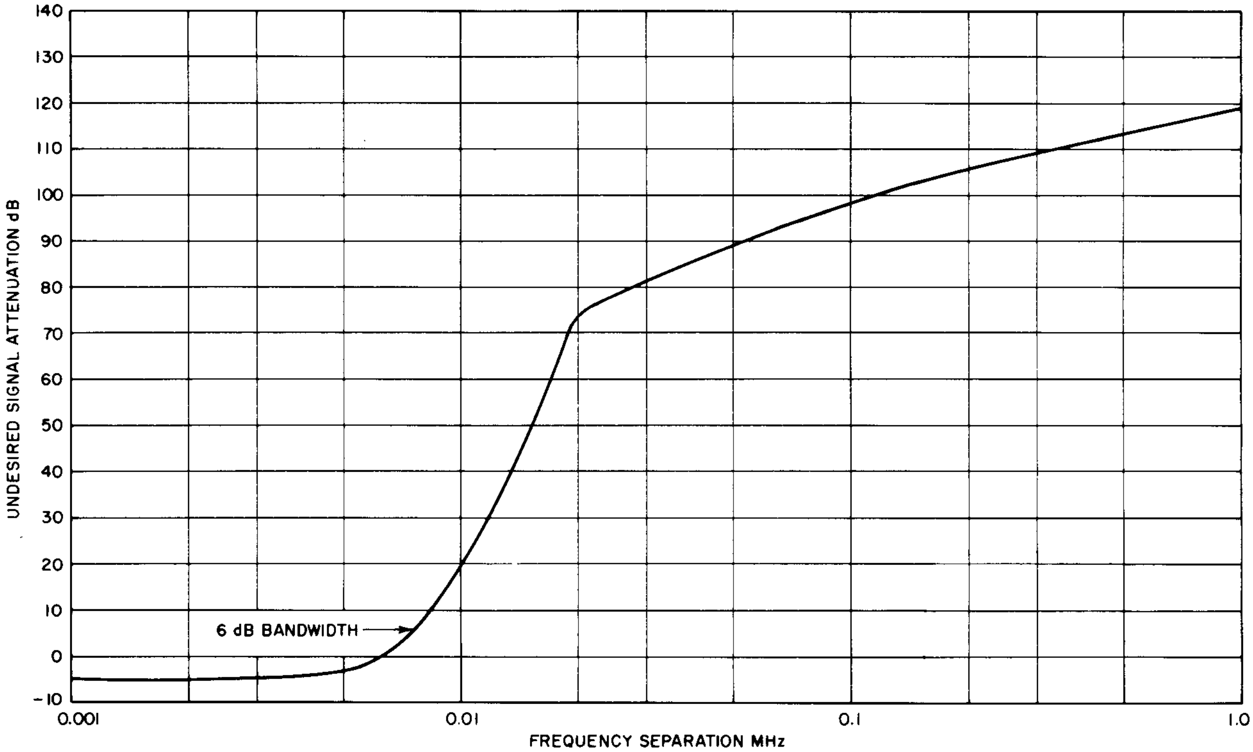


Figure 2—Selectivity of Modulation Sideband Receiver

4.2.4 Measurement Probes

4.2.4.1 Electric and Magnetic Field Measurement Antennas

In the frequency range 150 kHz through 1000 MHz, the narrowband spurious and harmonic field emissions can be detected with calibrated rods, loops and dipole antennas. Loops or rod antennas, or both, should be used for electromagnetic fields in the frequency range 150 kHz through 30 MHz. For most transmitters, the electric field will he predominant in the near field region; hence, the dipole or rod is preferred for this measurement. The use of the loop should be limited to far field measurements. (See IEEE Std 291-1969 [8].)

A 1.0 m rod may be used in the 150 kHz to 30 MHz range if the frequency selective voltmeter is calibrated by use of an equivalent impedance. A calibrated signal generator connected in series with a capacitor having an impedance equivalent to that of the rod antenna system may be used to establish the reference point of the internal (noise diode) calibration source. (See IEEE Std 291-1969 [8].) The rod antenna must be separated at least I m from any other object or surface. Greater distance may be necessary for an abnormally large surface. Adjustable dipole antennas are used for frequencies in excess of 30 MHz for the electric field and the open field radiation measurements. (See IEEE Std 291-1969 [8].)

Alternatively, broadband type antenna, such as the biconical antenna (see ANSI/IEEE Std 100-1977 [3]) may be used. For measurements above 200 MHz, the conical log spiral antenna, which is a broadband circularly polarized device, is preferred. Compensation or calibration, or both, should be performed over the frequency range of interest to account for the 6 to 8 dB variations in gain. The dipole or broadband antenna induced voltage should be corrected to account for losses or mismatch, or both, in the transmission line output impedance. The transfer impedance correction can be calculated, using the following expression when the antenna is adjusted to $^1/_2$ λ at the frequency of interest.

$$A_\mathrm{i} \quad = \text{meter reading}\left[1 + \frac{72}{Z_i}\right]$$

where

A_i = antenna induced voltage
Z_i = line input impedance

Alternatively, a balanced antenna can be coupled to the unbalanced transmission line and radio frequency interference (RFI) meter input with a broadband impedance matching unity gain balun having a maximum insertion loss of $^1/_2$ dB. The voltage standing wave ratio (VSWR) looking into the meter input attenuator should be 1:1.1 or better. The meter reading should be corrected to include the transmission line loss at the measurement frequency.

4.2.4.2 Current Probe

The transmitter spurious output appearing in the external wiring should be measured with a clamp-on current transformer capable of measuring to the limits specified herein and should have sufficient bandwidth, linearity and sensitivity to detect the range of frequencies at all specified levels. The transfer impedance of the probe should be included in the test report.

4.2.5 Signal Generator

A calibrated signal generator shall be used for determining the absolute value of the measured signal by the substitution method. It shall be equipped with an output control calibrated in dB referenced to a milliwatt [dBm] and include a vernier meter scaled in μV. The output control should indicate the available power at the 50 Ω output terminal. (See IEEE Std 151-1965 [7].)

The signal generator shall be adequately shielded and filtered to limit any RF energy leakage within the shielded enclosure, both radiated and conducted, to a level 6 dB less than the minimum signal level required to be measured, including the insertion losses of all interconnecting cables, couplers, filters, isolation networks and attenuators. The frequency stability shall be such that the test signal remains at the receiver tuned frequency to within 5% of the rated system deviation (see ANSI/IEEE Std 100-1977 [3], **frequency deviation),** that is, the transmitters' specified maximum permissible carrier frequency deviation.

4.2.5.1 Frequency Meter

A calibrated frequency meter shall be used in conjunction with the signal generator to verify the frequency being generated.

4.2.6 Noise Generator

A calibrated noise generator, the output of which is flat within ± 1 dB from 25 MHz to 1000 MHz across a 50 Ω resistive load, shall be used as an equivalent source of broadband white noise energy and should be calibrated in units of dB above kT_0B, where k is Boltzmann's constant, T_0 the reference temperature (°K) and B the bandwidth in Hz. An output level of at least 20 dB above kT_0B is required.

4.2.7 Deviation Monitor

A deviation monitor having a crystal controlled calibration adjustment with an accuracy of ± 3% shall be used in establishing the operating conditions for standard test modulation. The monitor meter should maintain a full scale accuracy of ± 3% for deviations up to 15 kHz and modulating frequencies of 100 Hz through 6000 Hz.

4.2.8 Voice Modulation Simulator (VOSIM)

A simulated voice modulation device should be provided. The VOSIM output is a pulsed random noise spectrum having a pulse duration of 0.1 s and repetition rate of 2 pulses/s. The rms amplitude of the noise during each pulse should be 24 dB above its amplitude between pulses. The noise spectrum should be limited to 300 Hz to 3000 Hz with the following relative levels.

f (Hz)	Level (dB)
300	–3 to –5
1000	0
3000	-6 to -8

4.2.9 Noise and Distortion Meter

The noise and distortion meter shall be of the type that integrates the total noise and distortion produced by the receiver while balancing or filtering out the fundamental frequency of the audio test signal. The distortion meter is normally equipped with a continuously variable null frequency network; however, for the purpose of this test procedure there is a minimum requirement of 1000 Hz for the null network. The noise and distortion meter may, in addition, have the capabilities of measuring audio output voltage, though a separate instrument may be used, to measure audio power, quieting and frequency response. The output indicator shall have volume-unit characteristics as defined by ANSI/IEEE Std 152-1953 [4].

4.2.10 Test Adapters

4.2.10.1 Coupling Devices

Coupling devices, including baluns where necessary, shall be used to minimize the interaction and optimize the impedance match between the antenna system, transfer switches, test instruments and filter networks. Directional coupling devices or circulators are sometimes necessary to eliminate potential intermodulation products occurring in sensitive RF voltmeters and to provide suitable isolation between mutually coupled signal generators.

4.2.10.2 Carrier Rejection Filter

A carrier rejection filter is required to enable identification of spurious emissions within the adjacent alternative channel spectrum and to prevent overloading the RF voltmeter when searching at the maximum sensitivity level.

4.2.10.3 Bandpass Filter

A suitable bandpass filter may be used in lieu of a carrier rejection filter to attenuate a carrier to a suitable level. With the spurious frequency to be measured within the filter passband, the filter skirts should provide at least 60 dB of attenuation to the carrier. It is required that the selectivity of the field strength voltmeter, prior to its mixer, will provide at least an additional 30 dB attenuation of the carrier, with respect to the spurious emission signal under measurement, in order to avoid the nonlinear response in the meter.

4.2.10.4 Dummy Load

A fully shielded nonreactive terminating load having a built-in power monitor should be used to absorb the RF carrier power.

4.2.10.5 Line Stabilization Network

Power lines shall be isolated by means of a line stabilization network in each line. This network also provides means to measure conducted interference. A recommended configuration is illustrated in Fig 3. The impedance characteristics are given in Fig 4.

4.2.10.6 Variable Attenuator

A calibrated variable attenuator may be needed to provide for the adjustment of the output of the line stabilization network or RF carrier sampling device in a manner so as not to overload the frequency-selective voltmeter or receiver.

4.2.10.7 Coaxial Switches

Coaxial switches (or other suitable means) shall be provided, as shown in Figs 1, 5, 6 and 14, to enable the carrier rejection filter to be removed from the circuit during carrier output level measurement and to substitute the calibrated signal generator for the transmitter during calibration.

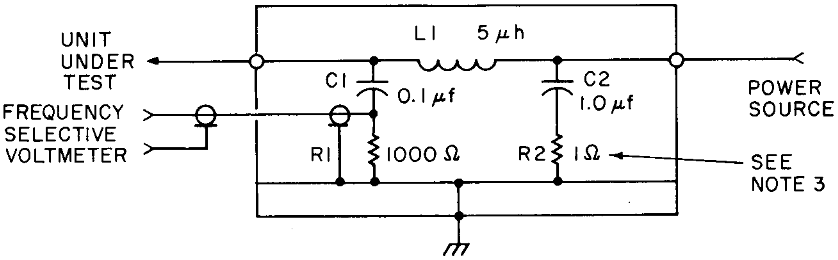
4.2.10.8 Calibration Requirements for Test Adapters

All nondissipative networks, filters, couplers, attenuators, transfer switches and terminating devices shall be calibrated for insertion loss over the frequency range of interest at a VSWR of 1.3:1 or better. The transmitter load is allowed a VSWR of 1.5:1. The nominal impedance of the measurement system shall be 50 Ω.

4.2.11 General Measuring Instrument Requirements

All measuring instruments and test adapters shall have a common earth reference established at the shielded enclosure access point by means of a 3.05 m rod driven into the earth or a counterpoise system, whichever is required to reduce the ground resistance to 20 Ω. The external antenna lead-in transmission line shall be brought through the wall of the shielded room and to the measuring system input point in a conduit grounded to the earth reference point.

The ac powered measuring instruments shall be connected to the primary power through a shielded isolation transformer whenever the measuring system and the system being measured have a common source of power.



Construction Details

Enclosure:	14 gauge (B and S) aluminum suggested size 24.0 cm by 10.0 cm by 10.0 cm
Coil form:	13.0 cm length, 7.6 cm diameter (OD), 0.35 cm wall. Drill 1.0 cm hole 1.0 cm from each end
Wire:	No 6 AWG 600 V, 4.116 mm diameter (OD) suggested for use up to 50 A
Coil:	L1 5 μH, 13 turns per single layer, 10.0 cm winding length
Capacitors:	C1.1 μF, 600 V dc C2 1 μF, 600 V dc, single terminal case mounted on ground
Resistors:	1000 Ω, 5 W carbon 1 Ω, 10 W carbon [see Note (3)]
Design tolerance:	± 20%

NOTES:

(1) The values given for the component parts of the network are nominal. Regardless of the construction or deviation from nominal values. the network must have an impedance within 20% of that given in Fig 4.

(2) Connecting leads to capacitors and resistors should be as near zero length as possible. Capacitor C1 shall be mounted on a 1 in insulating block above ground, with the coaxial line extended within the enclosure right up to the junction of C1 and R.

(3) Networks may also be constructed having a 1 Ω series resistor between the line and capacitor C2. This 1 Ω resistor shall be made up from ten 10 Ω, 1 W composition resistors.

(4) The data given in this figure is suitable for the construction of 50 A networks. Other networks having different current-carrying capacity may be constructed by adjusting the wire size given for the coil and the size of the overall enclosure, but retaining the impedance characteristics called for in Note (1).

Figure 3—Typical Powerline Stabilization Network

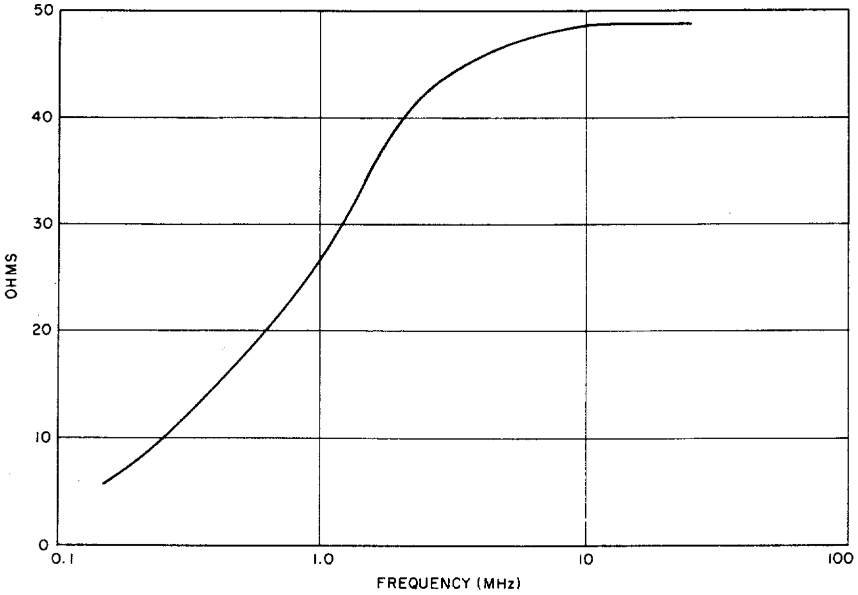


Figure 4—Input Impedance at Test Sample Terminal of Stabilization Network Coaxial Connector Terminated in 50 Ω, Power Terminal Open

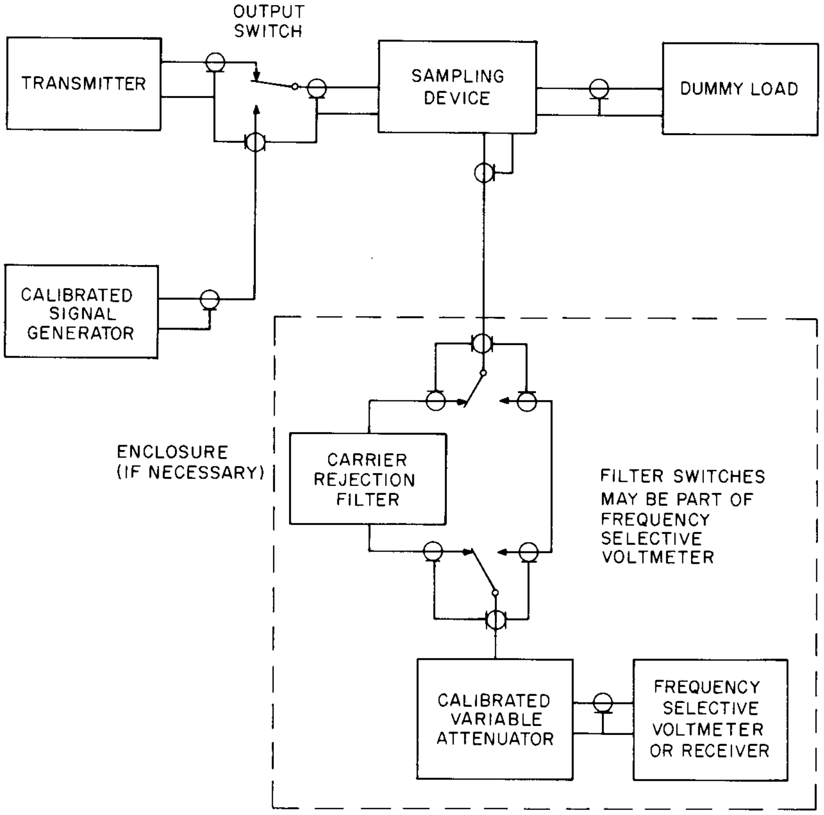


Figure 5—Narrowband Spurious Emission at Transmitter Output

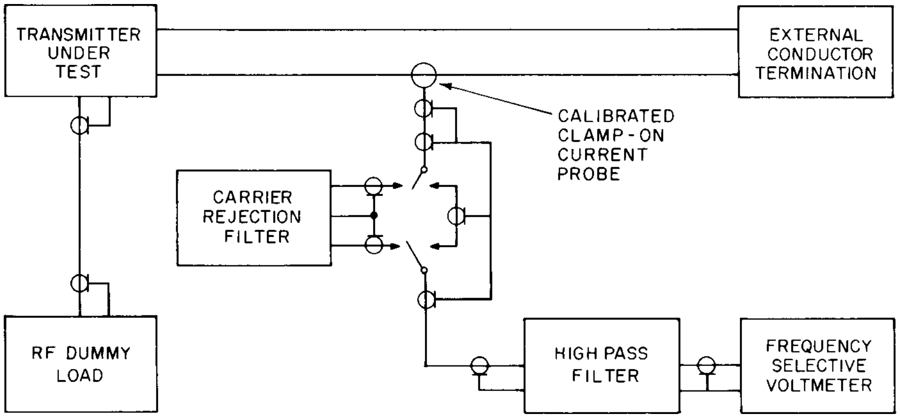


Figure 6—Narrowband Power and Control Cable Spurious Radiation Measurement

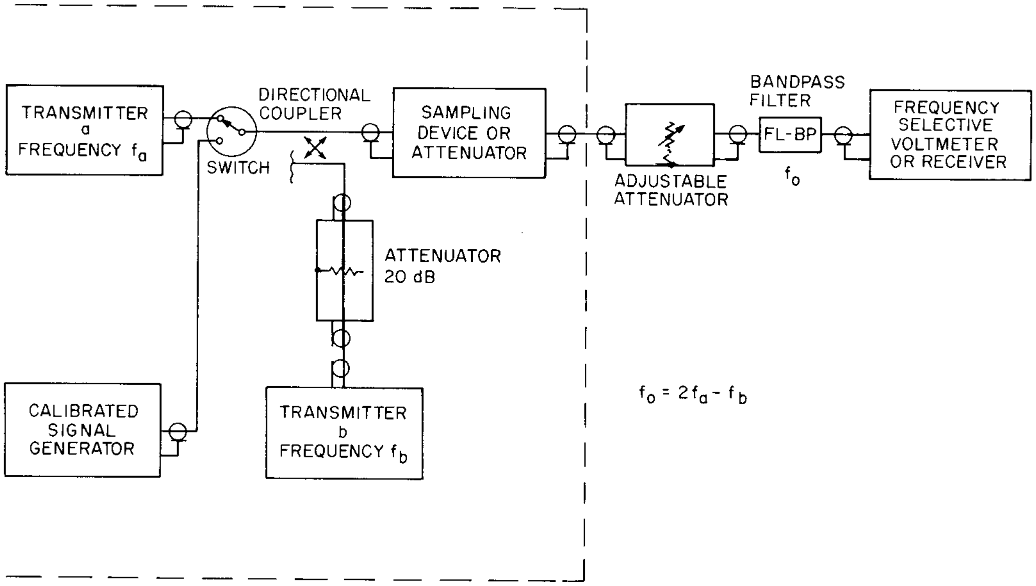


Figure 7—Conducted Spurious Test Apparatus

4.3 Test Assembly

The transmitter and measurement system shall be arranged as illustrated in Figs 1, 6, 7 and Figs 11 and 14. The measurement systems of Figs 6, 7 and Figs 11 and 14 are laboratory measurement methods; Fig 1 applies to open field measurement of radiated energy.

5. Test Procedures and Presentation of Data

The following sections provide methods of measurement which can be used periodically to evaluate equipment performance. The characteristics listed herein have the greatest impact upon overall system performance.

1) Modulation sideband noise products
2) Broadband modulation noise products
3) System interference protection ratio
4) Unmodulated harmonic and nonharmonic RF energy outputs
5) Transmitter intermodulation spurious conversion ratio
6) Power line or control cabling narrowband conducted spurious emission energy level, or both
7) Power level of narrow band spurious emissions radiated from transmitter enclosure

5.1 Conducted Spurious Emission

Conducted interference appearing at the antenna output is undesired electromagnetic energy generated as a result of the normal operation of the transmitter.

5.1.1 Introduction

This test includes measurements of the spectrum of the frequency modulation sidebands of the FM transmitter which are dependent upon the modulation deviation limiting circuit and the postlimiter filter response characteristic. Since the filter may be an integral part of the limiter circuits and will function simultaneously in the creation of the spurious sidebands, the method of measurement is based on the overall audio characteristics of the transmitter, which can include other factors such as distortion products resulting from the limiting action.

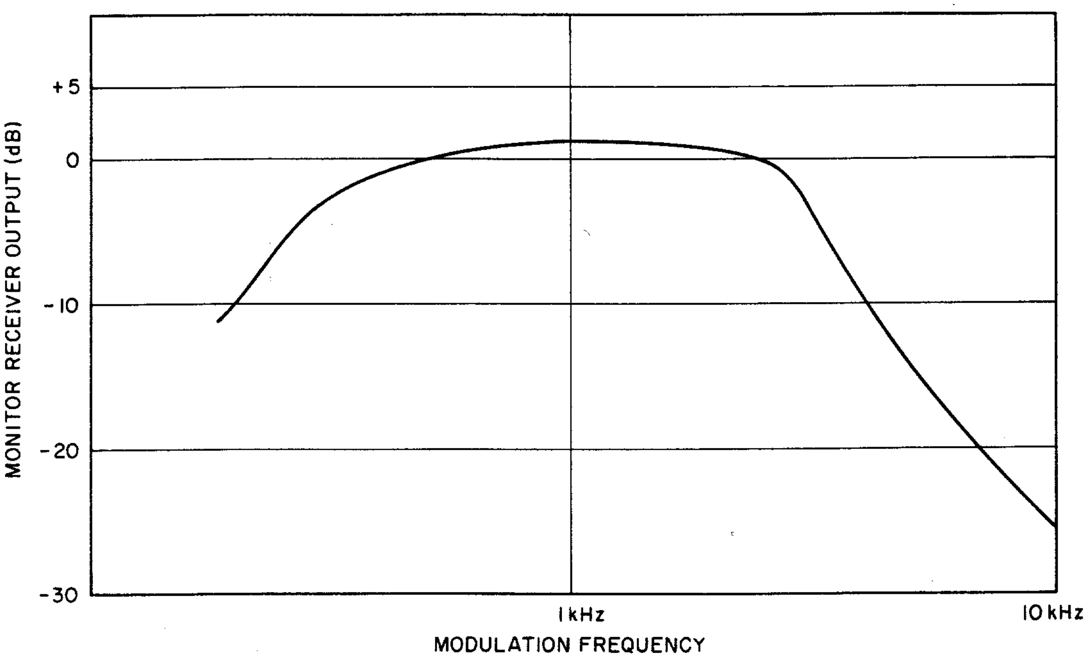


Figure 8—Transmitter Audio Characteristic

5.1.2 Modulation Sideband Spectrum

This test is only to demonstrate compliance with the requirements for authorized bandwidth measurements and does not in itself provide a means of evaluating adjacent channel interference.

5.1.2.1 Audio Characteristic

Connect the transmitter as shown in Fig 7 using the modulation monitor receiver (see 4.2.3) for the test receiver. Do not connect the voltmeter or signal generator. Modulate the transmitter with a 1000 Hz audio signal at +16 dB over that required for standard test deviation. Monitor the output with the modulation monitor receiver and, with the audio input voltage held constant, vary the modulation frequency from 100 Hz to 10 000 Hz. Record the receiver output voltage at discrete frequencies within this audio range.

5.1.2.2 Modulation Sideband Characteristic

Connect the equipment as shown in Fig 7, replacing the modulation monitor receiver with the modulation sideband receiver (see 4.2.2). Operate the transmitter as in 5.1.2 and tune the modulation sideband receiver to a frequency spaced by the adjacent channel from the transmitter. With the transmitter off, set the signal generator on the receiver frequency and adjust it to produce a 12 dB SINAI) level in the receiver. Record the output of the signal generator (V_2). Turn on the transmitter and adjust the attenuator until the 12 dB SINAD is reduced to 6 dB SINAD. Record the voltage reading on the RF voltmeter (V_1). Keeping the audio input voltage constant, vary the audio frequency between 300 Hz and 1500 Hz and readjust the attenuator to maintain 6 dB SlNAD. Record V_1 for several discrete audio frequencies.

Tune the receiver to the opposite side of the transmitter carrier spaced by the adjacent channel and repeat the procedure.

Determine the audio frequency at which the spectral components are greatest (that is, the highest attenuator level or highest V_1) and repeat the procedure at this audio frequency with the receiver tuned to plus and minus integer multiples of the adjacent channel spacing from the transmitter.

5.1.3 Presentation of Data

5.1.3.1 Audio Characteristic

On three-cycle, semilog paper plot the audio voltage at the output of the modulation monitor receiver in dB with reference to rated power output as a function of frequency as in Fig 8.

5.1.3.2 Modulation Interference

The modulation interference is calculated as follows:

$$\text{modulation interference} = 20 \log \frac{V_1}{V_2} \text{dB}$$

On three-cycle, semilog paper plot the plus and minus adjacent channel modulation interference function of audio frequency as in Fig 9. On linear paper, plot the modulation interference level in dB with reference to carrier level at the worst audio frequency as a function of the channel spacing from the transmitter as in Fig 10.

5.2 Modulation Sidebands and Broadband Noise Spurious Emission

These tests demonstrate system performance and are not normally used in production tests of transmitters.

5.2.1 Introduction

Systems operating in proximity to each other in both distance and frequency are prone to create mutual interference. Such interference can be caused by transmitter out-of-band emissions or result from inadequate receiver selectivity, or a combination of both. The cause of interference, although difficult to establish, should be determined as a prerequisite to system design. In general, the system interference protection ratio is controlled by transmitter out-of-band emission for all frequency spacings between transmitters and receivers, since state of the art receiver design, with the exception of intermodulation interference, has eliminated the problem of receiver selectivity. The following tests assume that state of the art receivers (see 4.2.2) are useful for measuring transmitter out-of-band emission. Receiver selectivity measured in accordance with receiver tests, as described in ANSI/IEEE Std 184-1969 [5], is adequate for evaluation of the system interference protection ratio. For those interference levels beyond the capabilities of standard noise signal generators, which are limited to approximately 20 dB above kT_oB, a transmitter equipped with a carrier rejection filter may be used to generate noise energy up to 50 dB above kT_oB. The noise output level should be calibrated with a broadband receiver (see 4.2.3), calibrated noise generator (see 4.2.6) and calibrated attenuator (see 4.2.10.6).

5.2.2 Method of Measurement

Arrange the transmitter, the modulation sideband receiver (see 4.2.2) and test equipment in accordance with Fig 11. Disconnect the transmitter and attenuator and leave the noise generator connected. With the noise generator turned off and the signal generator connected by the directional coupler to the receiver, adjust the desired signal level to produce 12 dB SINAI) ratio. Turn on the noise generator and increase its output until 12 dB SINAD ratio is reduced by 6 dB. Record this output power level in dB above kT_oB and designate as P_1 The power level recorded is approximately 0.2 dB above the noise factor for ± 5 kHz deviation type receivers.

Disconnect the noise generator and reconnect the transmitter and attenuator. Turn the transmitter on, modulate with the VOSIM (see 4.2.8) and adjust the frequency spacing between the transmitter and receiver to 10 kHz. Adjust the attenuator until the 12 dB SINAD is reduced by an average of 6 dB. The noise or modulation sideband output of the transmitter, expressed in dB above kT_0B, is equal to the noise power level measured above (P_1) plus the attenuator setting, that is,

$$\text{dB above } kT_0B = P_1 + \text{dB}_{\text{att}}$$

Adjust the transmitter to a series of frequencies above and below the receiver desired frequency and repeat the above measurements. If at any frequency separation the attenuation of the receiver selectivity does not exceed the attenuation of the transmitter by at least 10 dB, it will be necessary to add adequate filters at the receiver input to minimize errors in measurement.

5.2.3 Presentation of Data

The results of the system interference protection ratio measurement should be presented on four-cycle, semilog graph paper. The upper and lower sidebands shall be plotted separately, as illustrated in Fig 13.

5.3 Narrowband Spurious Emission

5.3.1 Introduction

This test provides a measure of the level of the conducted narrowband spurious emission and is a measure of the level of harmonic and other nonharmonic outputs of a transmitter compared with the carrier level at the tuned frequency.

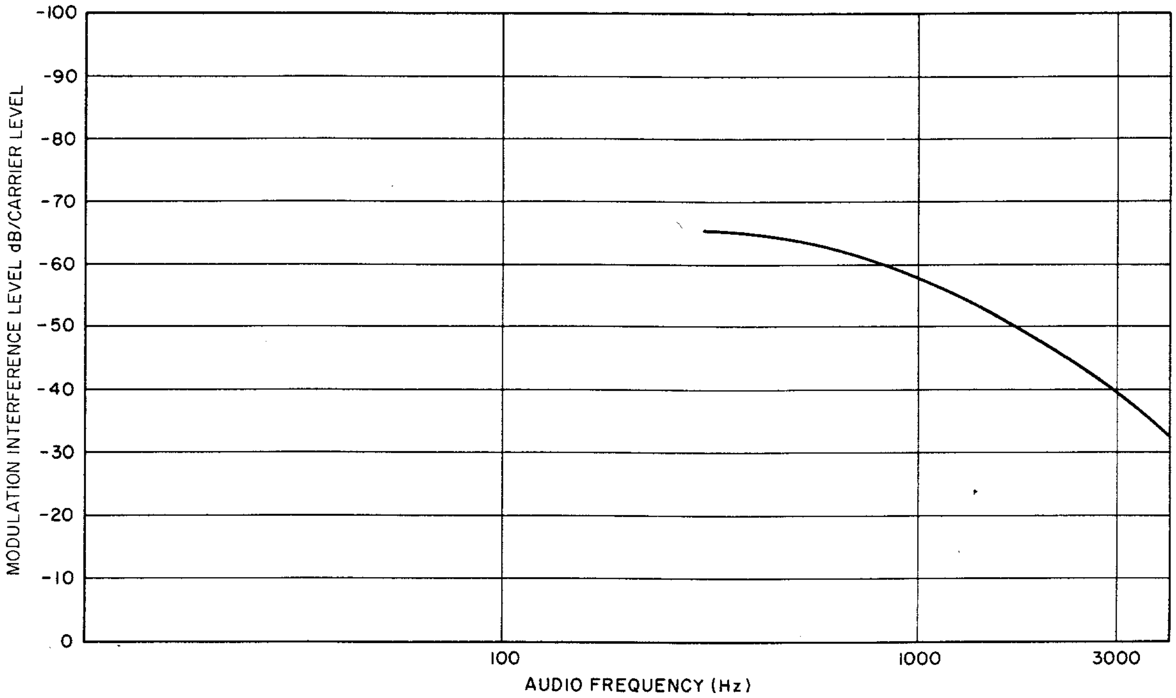


Figure 9—Ajacent Channel Modulation Interference

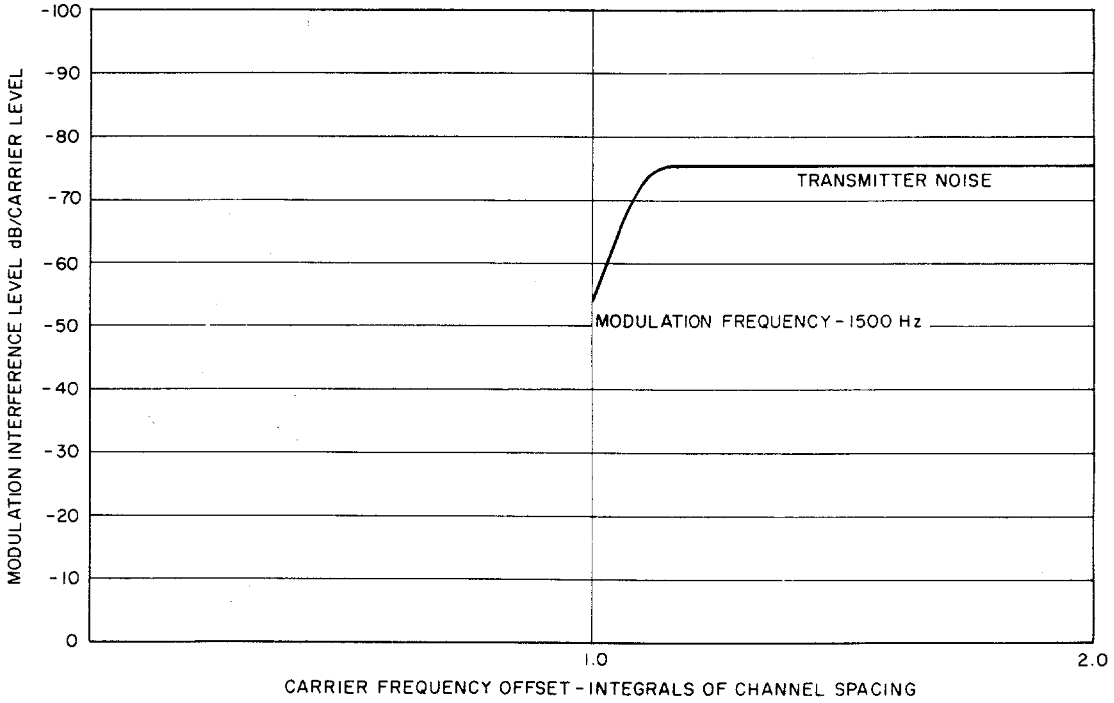


Figure 10—Adjacent Channel Worst Case Modulation Interference

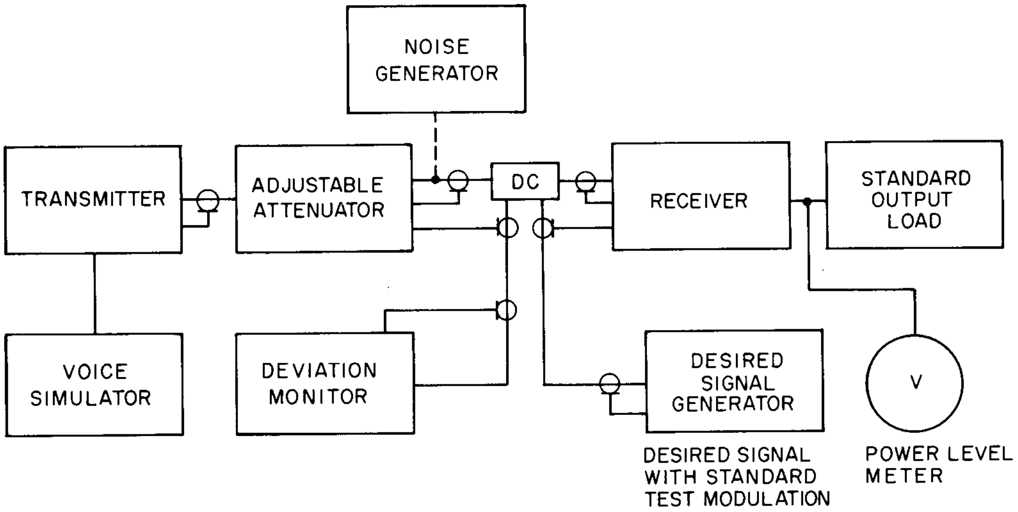


Figure 11—System Interference Protection Ratio Test Apparatus

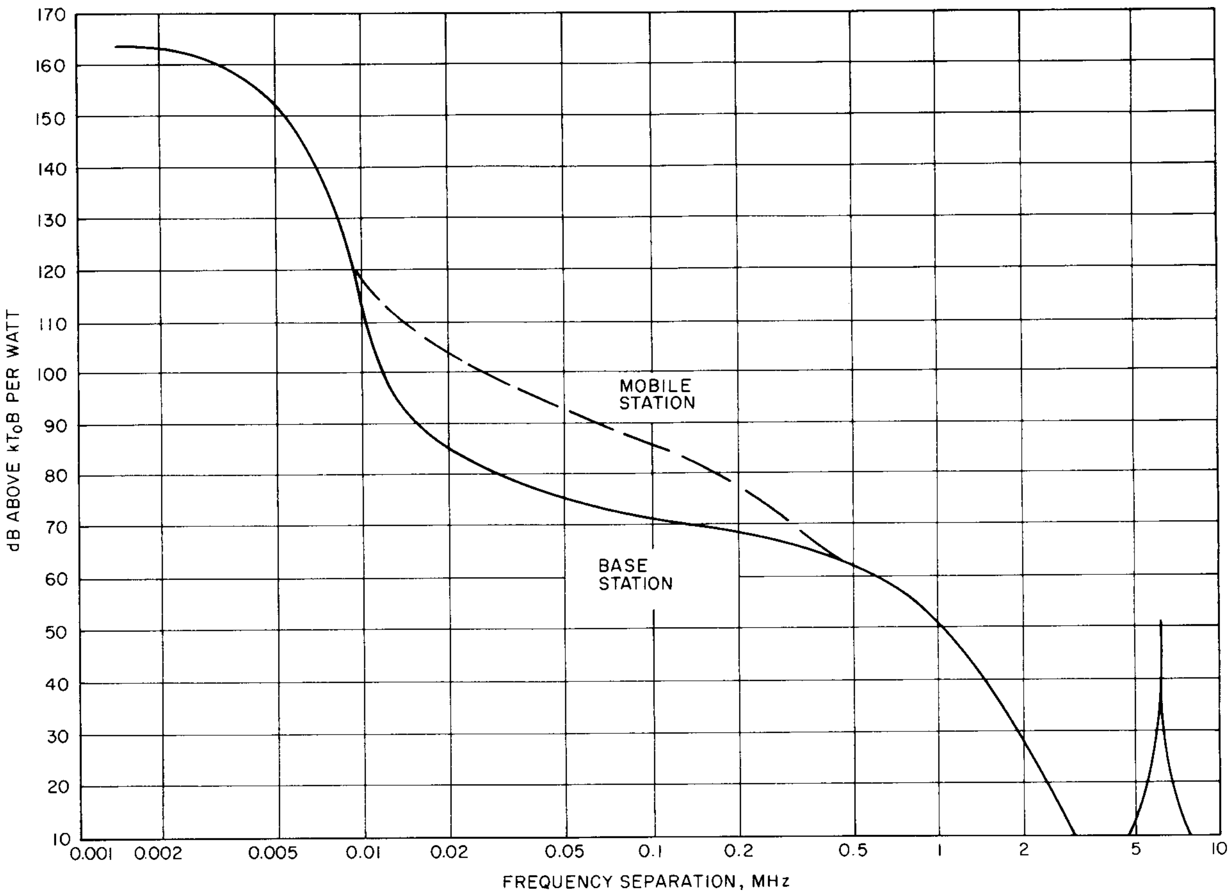


Figure 12—Conducted Noise and Modulation Sideband Spurious Emission

5.3.2 Method of Measurement

5.3.2.1

Use test apparatus illustrated in Fig 5. Place the switches (or other connection means) to disconnect the carrier rejection filter from the measuring circuit. Operate the transmitter through the sampling device to the dummy load.

5.3.2.2

With the transmitter operating in the intended manner, adjust the sampling device so that a suitable reference indication is obtained on the frequency-selective voltmeter or receiver output indicator when it is tuned to the carrier frequency and the variable attenuator is adjusted to approximately maximum attenuation.

5.3.2.3

Substitute the calibrated signal generator for the transmitter, adjust its output frequency to the carrier frequency and operate it at a power level which will enable the reference level of 5.3.2.2 to be obtained with adjustment of the variable attenuator.

5.3.2.4

From the output level of the calibrated signal generator and the change of attenuation of the variable attenuator, the power level of the carrier output can be determined. If the attenuator is calibrated in dB, the carrier output power of the transmitter will be the change in attenuation in dB above the power output of the signal generator. If the carrier output power of the transmitter is otherwise accurately known, as by means of a dummy load power indicator, correlation of the two power readings provides an indication of the correctness of the transmitter spurious output measuring setup.

5.3.2.5

Reconnect the transmitter to the dummy load through the sampling device and place the switches (or other connection means) to insert the filter in the measuring circuit. If the filter is tunable, adjust until maximum attenuation of the carrier output is obtained as indicated by the frequency-selective voltmeter or receiver output indicator.

If it is desirable to measure the attenuation obtained with the tunable filter, adjust the variable attenuator to obtain the same reference reading as 5.3.2.2. The attenuation of the carrier output frequency by the rejection filter is the change in the attenuator readings of adjustments between 5.3.2.2 and the above. The same procedure can be used if bandpass filters (see 4.2.10.3) are used instead of a tunable filter. In either case, the attenuation to the carrier output frequency must be sufficient to prevent overloading of the measuring equipment when it is properly adjusted for measurement of transmitter spurious outputs.

5.3.2.6

Tune the frequency-selective voltmeter through the frequency range of interest with the variable attenuator adjusted for maximum sensitivity of the measuring circuit (minimum attenuation of the variable attenuator). When a transmitter spurious output is found, adjust the attenuator to obtain a suitable reference reading at the output indicator.

5.3.2.7

Substitute the calibrated signal generator for the transmitter, adjust its output frequency to the transmitter spurious output frequency and operate it at a power output level which will enable the reference level of 5.3.2.6 to be obtained with adjustment of the variable attenuator.

5.3.2.8

Now, from the output level of the calibrated signal generator and the change of attenuation of the variable attenuator, the power level of the transmitter spurious output component can be determined. If the attenuator is calibrated in dB, the power of the transmitter spurious output will be the change in attenuation in dB above the power output of the signal generator.

5.3.2.9

The ratio of the fundamental output power, as determined in 5.3.2.4, to the power of the transmitter spurious output component, as determined in 5.3.2.8, is usually expressed in dB.

5.3.3 Presentation of Data

The results of the narrowband spurious emission test should be presented in graph form, as illustrated in Fig 13.

5.4 Intermodulation Spurious Emission

5.4.1 Introduction

Intermodulation spurious emissions are generated in the final stage of a transmitter when external signals are conducted into it, through its antenna terminal. Although a large number of odd order spurious emissions are normally generated, only the third order of the opposite frequency side is of sufficient amplitude to be considered. The parameter to be measured is the conversion attenuation for various frequency spacings between the transmitter under test and the external signal.

5.4.2 Method of Measurement

5.4.2.1

Use the test apparatus illustrated in Fig 14. Operate both transmitters under standard test conditions. Adjust the frequency (f_b) of transmitter B to a frequency of four times channel spacing above or below the frequency of transmitter A (f_a). Adjust the frequency of RF selective voltmeter (f_o) and filter in accordance with the following equation:

$$f_o = 2f_a - f_b$$

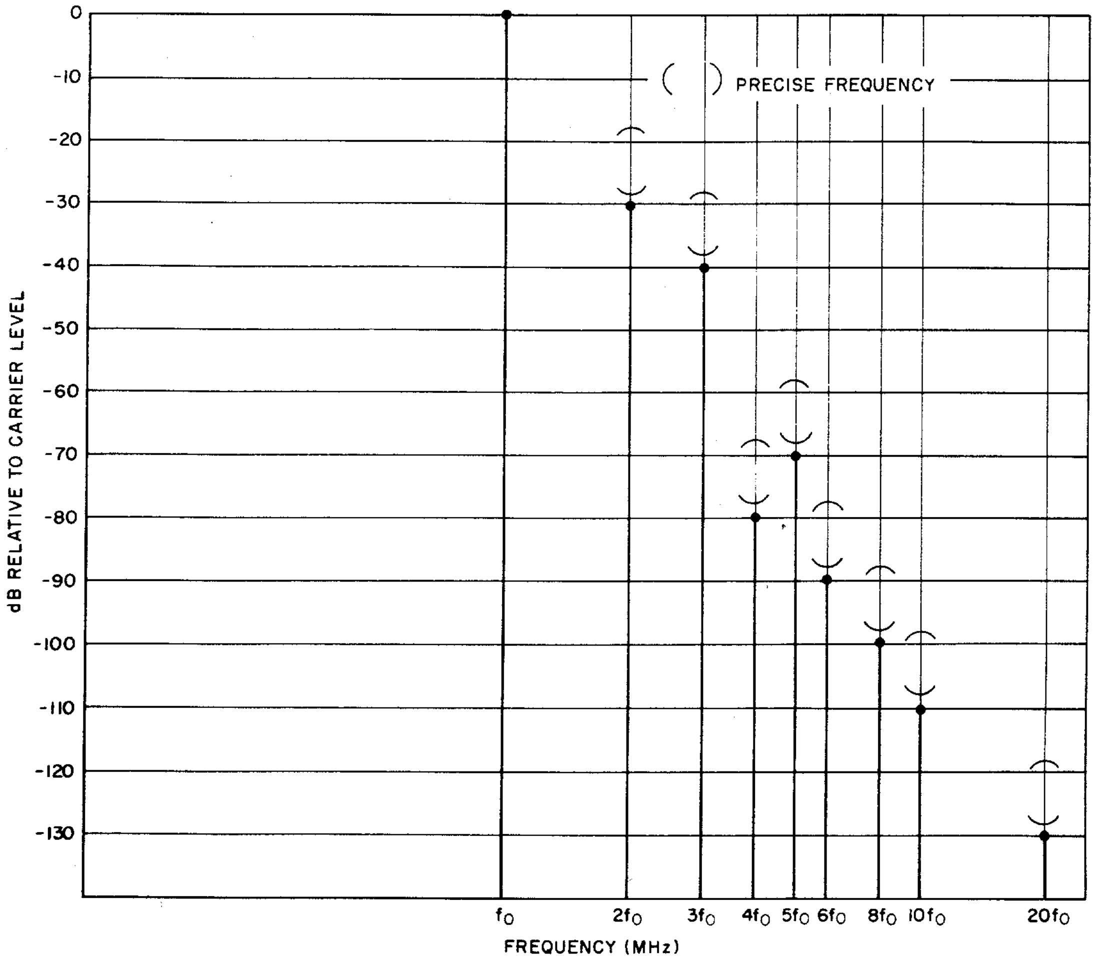


Figure 13—Narrowband Spurious Emission

5.4.2.2

Measure available power at the output of transmitter A from transmitter B after it has been attenuated by the directional coupler and 20 dB attenuator and record as P_b. Measure power output of transmitter A at frequency f_0 by substituting the calibrated signal and adjusting for the same reading as obtained on the frequency selective voltmeter; record as P_0. Calculate the conversion attenuation, C, as follows:

$$C \quad = 10 \log\left(\frac{P_b}{P_o}\right) \text{dB}$$

5.4.2.3

Repeat the above measurements at a number of frequency spacings with the frequency of transmitter B both above and below that of transmitter A until the conversion attenuation exceeds 60 dB.

5.4.3 Presentation of Data

The conversion attenuation shall be plotted on multicycle, semilogarithmic paper, as shown in Fig 15. A separate curve showing high side and low side may be plotted on the same graph if properly identified.

5.5 Conducted Spurious Emission on Power, Ground Return and Control Lines

5.5.1 Introduction

The transmitter spurious output appearing in the external wiring may be determined by measuring the current induced in a clamp-on current transformer of known characteristics in conjunction with a calibrated RFI meter.

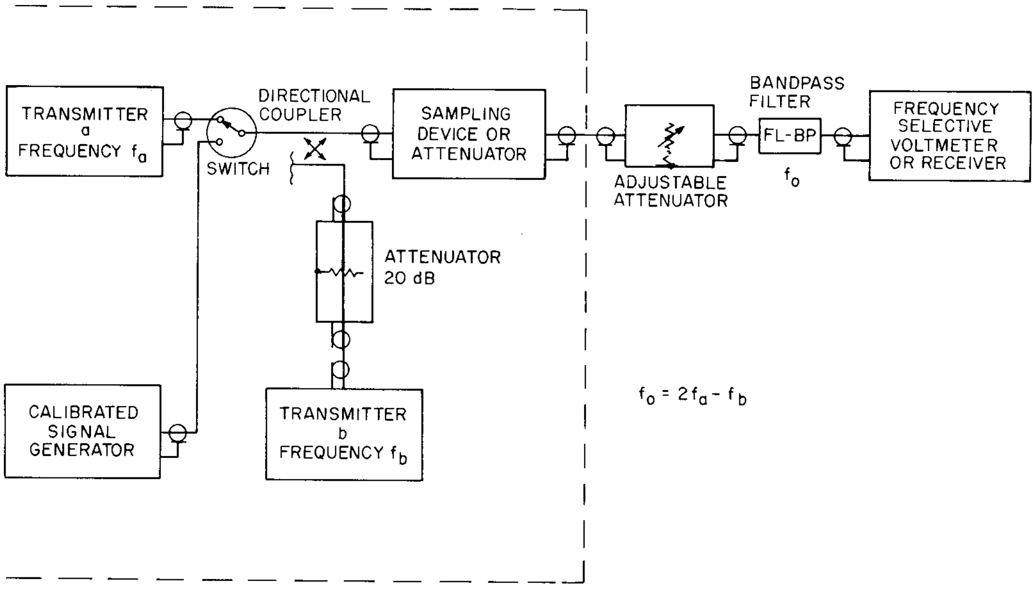


Figure 14—Intermodulation Spurious Emission Test Apparatus

5.5.2 Method of Measurement

Connect the equipment as shown in Fig 6. Operate the transmitter into a dummy load. With the transmitter off, calibrate the meter for background noise. The high pass filter used in current probe measurements should have a cutoff frequency four times the power line frequency. A notch filter of the bridged T or parallel T type may be inserted ahead of the high pass filter, if needed to reduce completely the power line components to the background noise level. Turn on the transmitter and record the power output. Tune the meter across the frequency band of interest while reading the transmitter spurious outputs in terms of dB above 1 µA. Apply the transfer impedance correction factor for the frequencies for which spurious outputs were obtained and the nominal frequency to which the transmitter is adjusted. The result is the conducted spurious RF energy output in terms of dB above 1 µA. For the purpose of system evaluation, this value can be translated into equivalent power levels expressed in dBW.

5.5.3 Presentation of Data

The transmitter conducted spurious output shall be plotted on multicycle, semilogarithmic graph paper, as shown in Fig 16.

5.6 Radiated Spurious Emission from Cabinet

5.6.1 Narrowband Spurious Emission

5.6.1.1 Introduction

The spurious energies to be measured will primarily occur on the same frequencies identified in the tests described in 5.3, narrowband spurious emissions at the antenna terminal. In addition, a general search of the spectrum in the near and far fields, above and below the fundamental is required to determine whether or not other frequencies may be present. Each spurious signal should be correlated with the modulation sideband spectrum products. The fundamental carrier should be modulated using standard test modulation as an aid to identification. The measurements should be made on a site of known characteristics, such as described in IEC Pub No 106-1959, [9].[4]

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[4] IEC Pub Nos 106 and 106A cover 30 MHz to 1000 MHz in two increments of spectrum. The basic details of 106, subclause 4.2.1, should be used in conjunction with the modified details of 106A, subclause 6.2, for all measurements. Substitute the word *transmitter* wherever *receiver* is used in Pub 106 and delete the instructions with respect to the receiver oscillator.

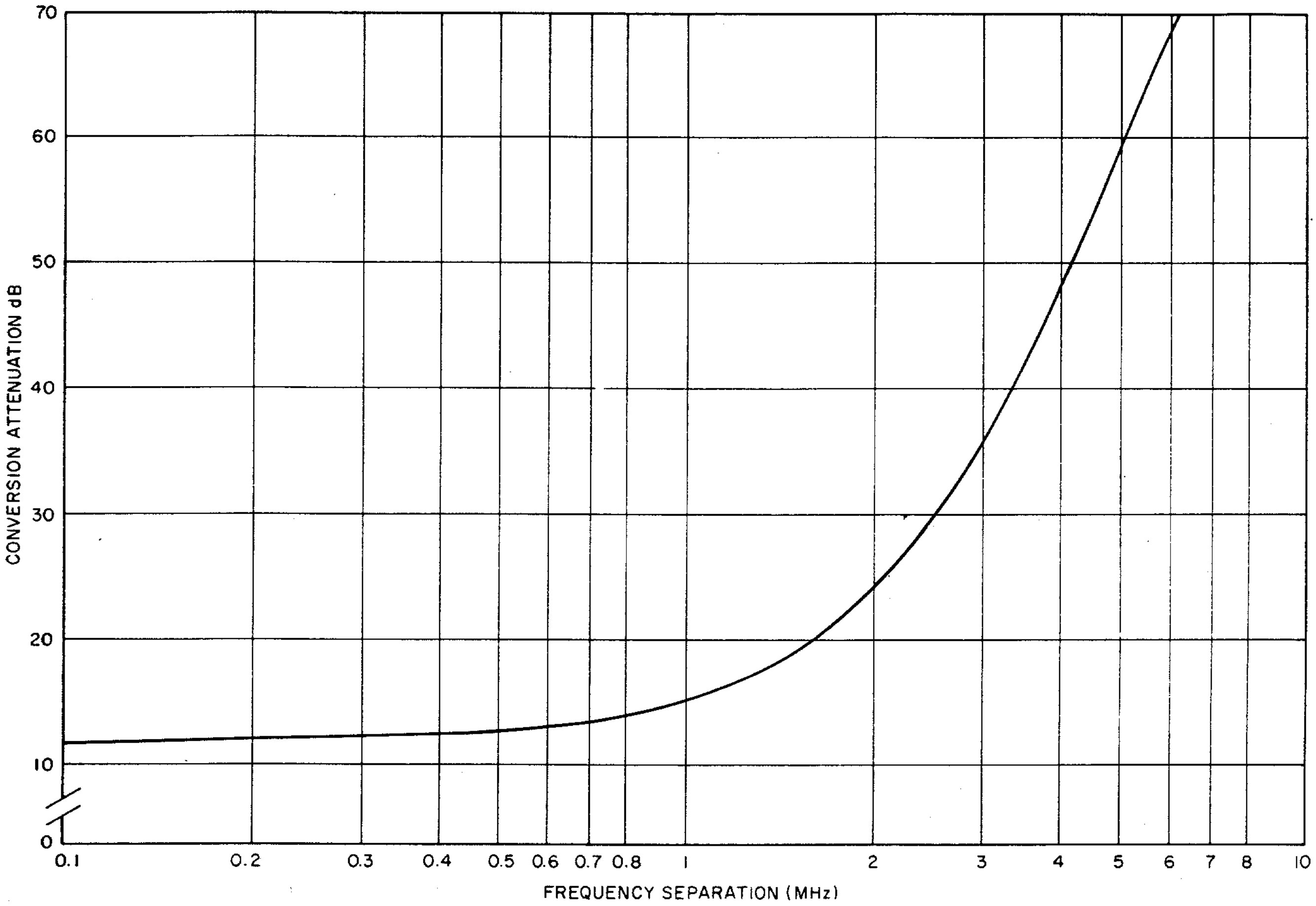

Figure 15—Intermodulation Spurious Conversion Attenuation

The data should be limited to those signals exceeding 20 dB over the ambient noise level. The transmitter power should be monitored during each measurement. The signal level data obtained in µV/m shall be converted into dB with reference to 1 µV/m, that is, dBµV/m. Alternatively, it may be expressed in power received (Pr), using the following relation:

$$\mathrm{Pr} = \frac{3.12 \cdot 10^{-11} E_o^2}{(F_{\mathrm{MHz}})^2}$$

where:

E_o = µV/m

5.6.1.2 Method of Measurement

The transmitter and measuring equipment shall be arranged as illustrated in Fig 1. Adjust the transmitter for normal operation and power output on its specified operating carrier frequency. The power output and frequency should be recorded on a sheet that identifies the transmitter by type and serial number.

The initial frequency identification measurements are made in the near field with an 8.0 cm loop antenna probe located approximately 7 cm, as measured from the center of the loop with its plane parallel to the controlling surface, from the most likely leakage points (for example, seams, connectors or covers). Tune the frequency-selective voltmeter until a signal is found. Record this frequency. Do not search for emissions below the susceptibility threshold of the planned peripheral equipment.

Move the loop antenna probe, maintaining the orientation previously described, in the vicinity of the case until a point of maximum radiation is found. Use the variable attenuator to control overload of the meter using minimum input that assures a positive stable reading. Rotate the loop antenna probe in both horizontal and vertical planes to maximize the reading. Record location, orientation, distance and voltmeter output. Note that this is a relative value for search and identification purposes only.

5.6.1.3 Near Field Radiation Power (see near field region, radiating)

Transfer the frequency-selective voltmeter input of the isolation and filter network point to the output of the calibrated signal generator. Adjust the signal generator frequency to maximize the voltmeter reading and identify it with the frequency meter. Reduce its output to agree with the reading obtained in the previous step. Calculate the signal power appearing at the dipole antenna probe output, using the procedure described in IEEE Std 291-1969 [8]. Include the antenna correction factor and take into account the insertion loss of the interconnecting transmission lines, connectors, switch, attenuator and coupler. Record the signal generator frequency and the dipole antenna probe signal level output in dBμV/m using procedures outlined in IEEE Std 291-1969 [8]. Repeat the previous steps until all radiation sources and frequencies have been located, in the range of 150 kHz to 1000 MHz.

The far field tests, for frequencies less than 30 MHz, can be performed with a calibrated 30 cm loop antenna or a 1 m rod. Frequencies above 30 MHz should be measured with an adjustable dipole or calibrated broadband antenna (see 4.2.4.1) within the confines of the test range (see 5.6.1.1). Locate the probe antenna at or beyond 3λ (λ = wavelength of fundamental frequency) but not less than 1 m. Orient the probe facing the points of maximum leakage determined in the previous steps. This may be done by rotating the transmitter and keeping the antenna in a fixed location.

Search the frequency spectrum through the range 150 kHz to 1000 MHz. Stop at each detected emission. Adjust the antenna length, if the dipole is used, to λ/π (effective length of a dipole) at the emitted frequency; otherwise, no further adjustment is required when the broadband biconical or conical log spiral antenna is used. Orient the antenna for maximum reading by rotating in both horizontal and vertical planes.

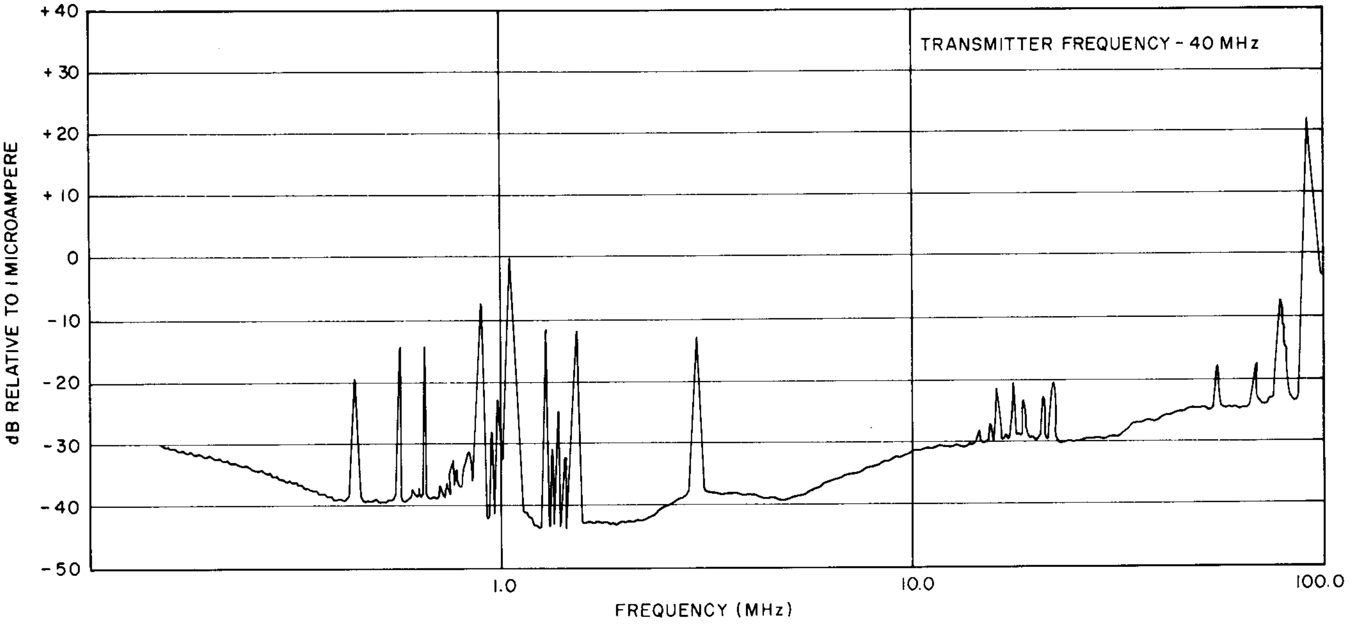

Figure 16—Power, Ground and Control Line Conducted Spurious Output

Table 1—Narrowband Spurious Emission Radiation from Case Tabulation of Values

Transmitter Type____________**Serial No**_______________**Operating Frequency**____________**Power Output**_____

Spurious Frequency (MHz)	**Measurement Antenna**			**Transmitter**		**Spurious Radiated Electric Field Strength (dBμ V/m)**
	Polarization	Orientation	Elevation	Location	Orientation	

Use the attenuator to prevent overloading the meter input on strong signals. When the maximum reading is obtained, switch the meter from the antenna probe system to the signal generator. Adjust the generator to provide the same reading. Calibrate the frequency with the frequency meter. Calculate the signal power at the output of the antenna utilizing methods described in IEEE Std 291-1969 [8] and 5.6.1.2 to match the known generator signal output at the input to the meter, taking into account the insertion losses of the interconnecting devices. Record the frequency, transmitter location and orientation, measurement antenna polarization, orientation and elevation, and electric field strength received in dBμV/m. See Table 1.

5.6.1.4 Presentation of Data

A spectrum of frequency versus dBμV/m shall be plotted on multicyle, semilog graph paper. The data may be tabulated in Table 1.