AEROSPACE RECOMMENDED PRACTICE

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ARP 958

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Revised

BROADBAND ELECTROMAGNETIC INTERFERENCE MEASUREMENT ANTENNAS; STANDARD CALIBRATION REQUIREMENTS AND METHODS

1. SCOPE

1.1 This ARP outlines a standard method and technique for the checkout and calibration of broadband electromagnetic interference measurement antennas.

1.2 This ARP covers conical logarithmic spiral antennas identified by the following USAF drawing numbers:

62J4040	200 to 1000 MHz
62J4041	1 to 10 GHz

2. REFERENCED DOCUMENTS

2.1 MIL-STD-826

2.2 Proposed MIL-STD-461

2.3 Proposed MIL-STD-462

3. REQUIREMENTS

3.1 For an antenna to be useful in measuring electromagnetic interference, an antenna correction factor (ACF) must be specified which permits converting voltage at the input of a receiver (v) to field intensity in volts per meter v/m or into units suitable for comparison with so-called radiated interference limits (dBμv) of Reference 2.1.

$$\text{Thus: } v/m = ACF_1 v$$

where: ACF_1 is the antenna correction based upon power gain of the antenna, and:

$$dB\mu v = 20 \log_{10} (ACF_2 v)$$

where: ACF_2 is the antenna correction factor based upon an antenna calibration similar to gain, henceforth referred to as apparent gain, but performed under conditions characteristic of the actual use of the antenna for component-level EMC specification compliance testing. Numeric antenna gain (G) and wavelength (λ) in a 50-ohm system express the correction factor as follows:

$$ACF = \frac{4.88}{\lambda} \cdot \frac{1}{\sqrt{G}} = \frac{4.88}{\lambda\sqrt{G}} \tag{1}$$

Antenna gain in a matched (50-ohm) system is the ratio of the radiation intensity in a certain direction to the average radiation intensity. For the conical logarithmic spiral antenna the direction of maximum radiation intensity should be that of a line coincident with the longitudinal axis extending from the apex into space.

The average radiation intensity is the average radiated power density over the surface of a sphere of unit radius.

3.2 Conical logarithmic spiral antenna gain may be obtained by antenna pattern measurements which satisfy the following expression of antenna gain in integral form:

$$\frac{\Phi(\theta, \phi)}{\frac{1}{4\pi}\int_0^{\pi}\left[\int_0^{2\pi} \Phi(\theta, \phi) d\phi\right] \sin\theta d\theta} \tag{2}$$

where: θ, φ are spherical coordinates. Φ is the power radiated per unit solid angle in a given direction.

3.3 However, an adequate gain determination method is to use two identical conical logarithmic spiral antennas. The relationship for power received is:

$$P_R = \frac{P_T G_T}{4\pi R^2} \cdot \frac{\lambda^2}{4\pi} \cdot G_R \tag{3}$$

where: G_T and G_R are the numeric power gain of the transmitting and receiving antennas, respectively.

P_T is power transmitted,
R is distance between antennas in meters, and
λ is wave lengths in meters.

$$\text{If: } G_T = G_R, \text{ then: } G^2 = \left(\frac{4\pi R}{\lambda}\right)^2 \frac{P_R}{P_T} \tag{4}$$

If both receiving and transmitting systems are matched (50 Ω), voltage measurements may be made in lieu of power measurements to that:

$$G = \frac{4\pi R}{\lambda} \cdot \frac{V_R}{V_T} \tag{5}$$

It should be noted that G is the numeric power gain even though it is determined by two voltage measurements, because these are used to form a ratio which is dimensionless. It should also be noted that the numeric G so obtained is for circularly polarized waves which must be halved to obtain G for linearly polarized waves.

3.4 Because the conical logarithmic spiral antenna will be used to make field intensity measurements and specification compliance measurements, both gain and apparent gain must be determined for each antenna.

3.4.1 Measure gain using the two-identical-antenna technique, taking care to ensure that both antennas are in their respective far fields. A minimum distance between the apex of each antenna is four meters.

3.4.2 Measure apparent gain using the two-identical-antenna technique at a distance of one meter between the apex of each antenna, as the antenna will be placed one meter from the test sample for EMC specification compliance testing of components and subsystems.

3.4.3 Measurements should be made at a sufficient number of frequencies to describe their gain and apparent gain within the specified operating bandwidth of the conical logarithmic spiral antenna. Gain and apparent gain should be measured at a minimum of ten frequencies per decade equally spaced from the low end to the high end of the antenna's specified passband. Such additional measurement frequencies should be chosen to precisely identify and define any anomalies in the antenna gain and apparent gain characteristics.

3.5 Two antenna gain factors, ACF_1 and ACF_2, for field intensity measurements and component-level specification compliance testing, respectively, should be determined.

3.5.1 Antenna gain obtained as a numeric utilizing two identical antennas at least four meters apart is substituted in equation (1) to obtain ACF_1.

3.5.2 Apparent antenna gain for lineraly polarized waves obtained as a numeric utilizing two identical antennas one meter apart is substituted in equation (1) to obtain ACF_2.

3.5.3 Fig. 1 is a plot of $20 \log_{10} \frac{4.88}{\lambda}$ as a function of frequency. When gain, G, and apparent gain, G_a, is a numeric, ACF_1 and ACF_2, respectively, in dB may be found by the following expression:

$$20 \log_{10} \frac{4.88}{\lambda} - 10 \log_{10} G.$$

When gain, G, and apparent gain, G_a, is in decibels, ACF_1 and ACF_2 may be found by:

$$20 \log_{10} \frac{4.88}{\lambda} - G.$$

3.6 The appropriate antenna correction factor is added to the voltage at the receiver input which is indicated in decibels above one microvolt, along with cable-loss factors to obtain field intensity in decibels above one microvolt per meter.

3.6.1 Section 4 outlines procedure for obtaining gain of the conical logarithmic spiral antenna utilizing the two-identical-antenna technique. The gain so determined is that for circularly polarized wave (see paragraph 3.3). When making field intensity measurements and when the received wave is linearly polarized, the gain used to calculate antenna correction factor, ACF_1, must be decreased by three dB. Antenna gain for linearily polarized signals should be used to calculate ACF_2.

3.6.2 Antenna correction factors, ACF_2, based upon apparent gain, for use in specification compliance testing in accordance with Reference 2.1, should not exceed 20 dB between 100 and 1000 MHz; above 1 GHz the antenna correction factor, ACF_2, should increase from 20 dB at 1 GHz to 45 dB at 10 GHz or at a rate no greater than 30 dB per decade. See Fig. 2.

4. PROCEDURE FOR TWO IDENTICAL ANTENNA GAIN MEASUREMENTS

4.1 Apparatus

- Signal generators with 50-ohm impedance capable of generating test functions over the frequency ranges specified for the conical logarithmic spiral antennas.
- Pad, ten dB, 50-ohm attenuator.
- Calibrated receiver (or tunable vacuum tube voltmeter) tuning over the frequency ranges specified for the conical logarithmic spiral antennas. The receiver input impedance shall be 50 ohms VSWR within 1.25. An isolating pad can be used at the receiver input to achieve 1.25 VSWR.
- Coaxial cables of 50-ohm characteristic impedance and appropriate connectors for mating with antennas, 10 dB pad, signal generators, and receivers.
- Adapter for connecting two coaxial cables.

4.2 Set-up - The basic set-up is shown in Fig. 3. The area in which the set-up is situated should be clear of obstructions to achieve a free-space environment. A chamber permitting the four meter spacing between antennas is acceptable if the chamber is anechoic at all measurement frequencies.

4.3 Measurement - At each measurement frequency, using the receiver as a transfer device, the following operations should be performed:

a. Adjust signal generator output to obtain a receiver indication. Be sure the receiver is tuned for maximum response to the signal.

b. Make fine adjustment of the alignment of the antennas for maximum indication and record the signal generator setting.

c. Disconnect the receiver and signal generator cables from their respective antennas and connect the signal generator and the receiver to each other using the same cables with the addition of a 50-ohm coupling adapter.

d. Reduce the signal generator output to obtain the same receiver output meter indication as obtained in step (b). Record the signal generator setting.

e. Solve for gain with four meter spacing and apparent gain with one meter spacing between antennas utilizing equation (5) in which V_R and V_T are equivalent to the signal generator readings recorded in steps (d) and (b), respectively.

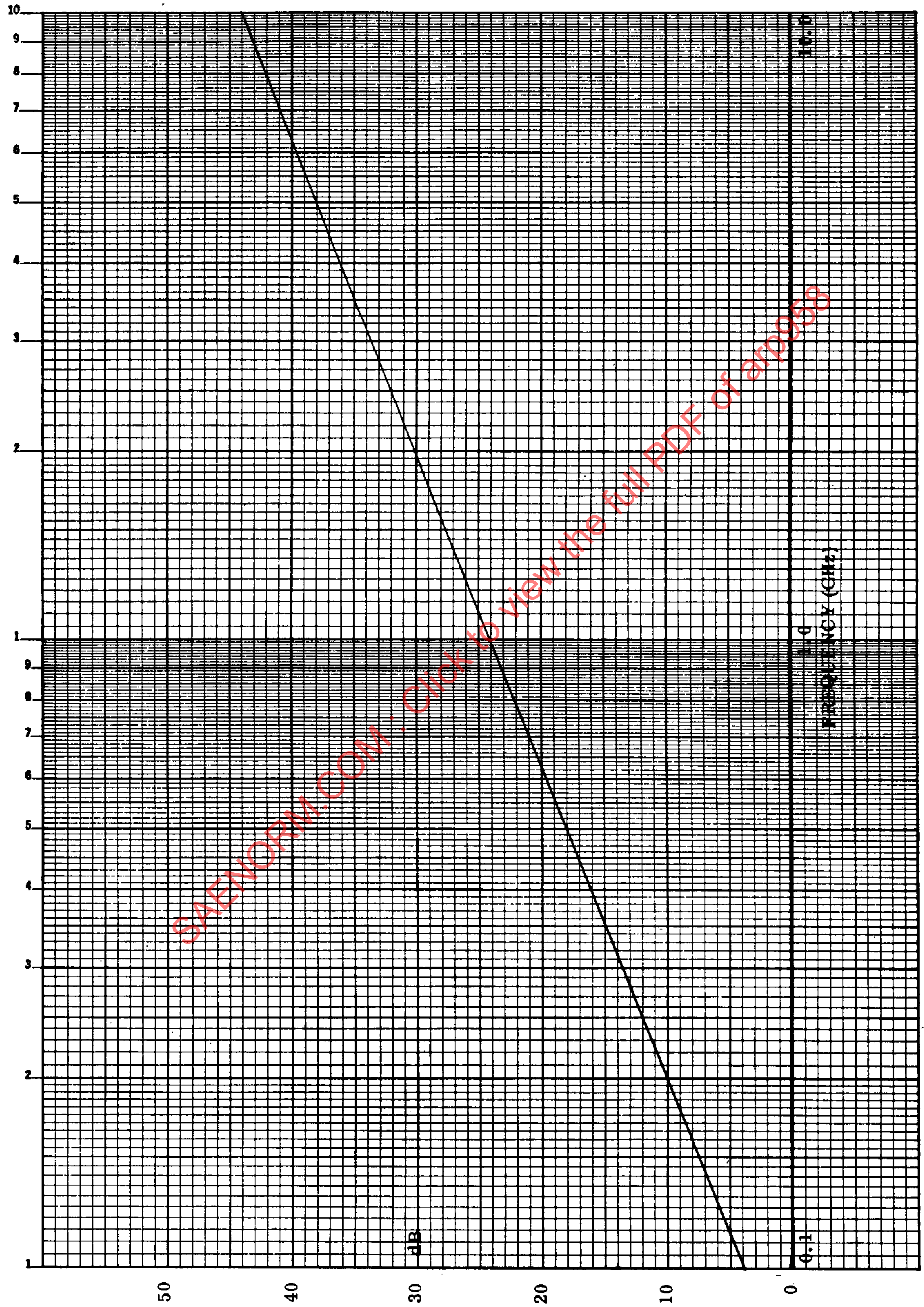

FIGURE 1

PLOT OF 20 $\mathrm{LOG}_{10}\ \frac{4.88}{\lambda}$ AS A FUNCTION OF FREQUENCY.
USE FOR CALCULATING ANTENNA CORRECTION FACTORS ACF_1 AND ACF_2.

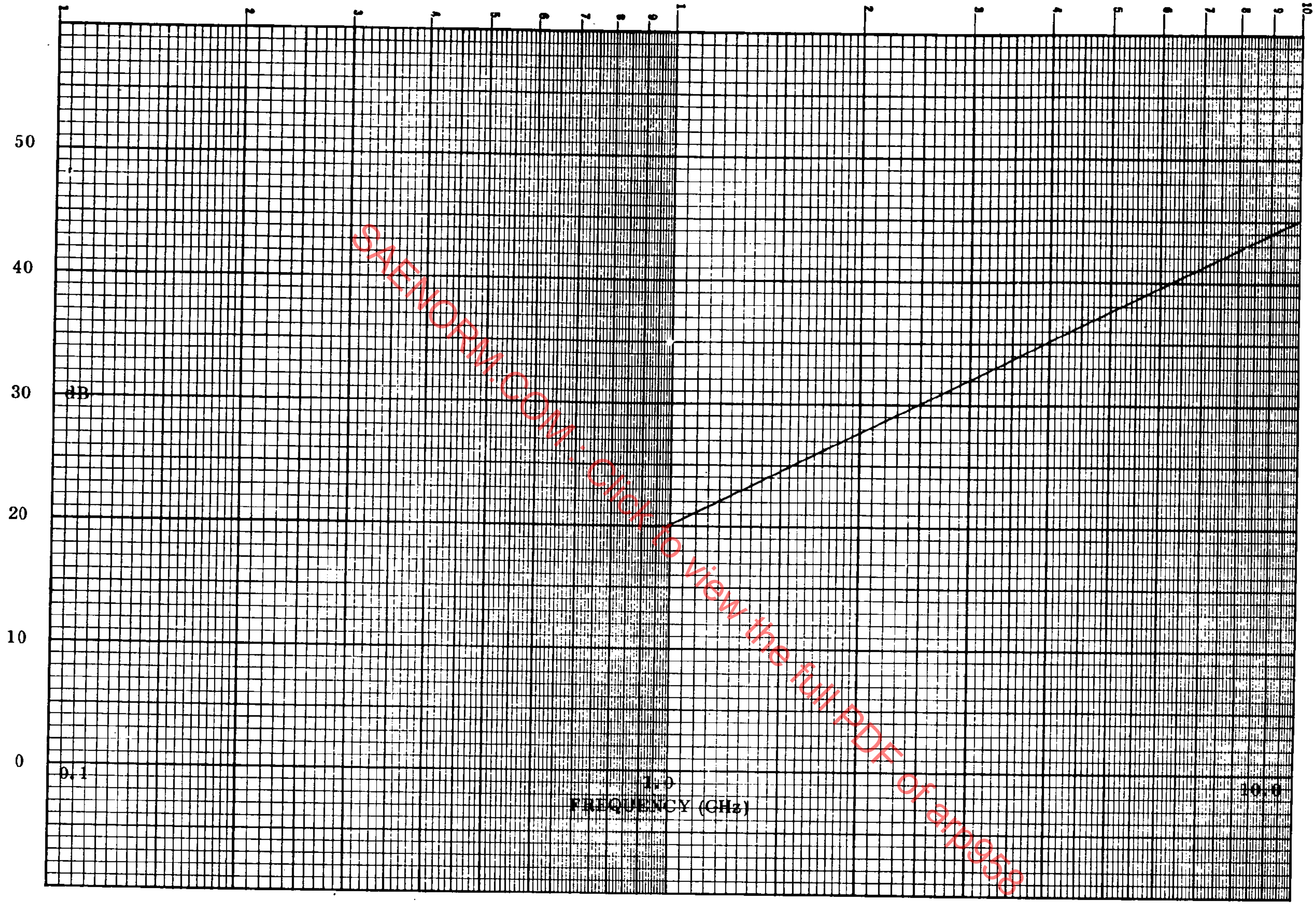

FIGURE 2

UPPER LIMITS FOR ANTENNA CORRECTION FACTOR ACF_2.
(ADD TO RECEIVER METER READING LOGARITHMIC SPIRAL ANTENNA IS ONE METER FROM TEST SAMPLE.)