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STANDARD

Minnimum Standards for
Communication Antennas
Part I - Base Station Antennas

EIA/TIA-329-B

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ELECTRONIC INDUSTRIES ASSOCIATION

ENGINEERING DEPARTMENT

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MINIMUM STANDARDS FOR COMMUNICATION ANTENNAS

PART I - BASE STATION ANTENNAS

(From Standards Proposal No. 1362, formulated under the cognizance of EIA Subcommittee TR-8.11 on Land-Mobile Services)

1. INTRODUCTION

SCOPE

This standard, consisting of two parts, describes:

Part A. The test conditions and methods for measuring the characteristics of base or fixed station antennas used in the Land-Mobile service.

Part B. The minimum performance requirements.

PART A

TERMS AND CONDITIONS OF MEASUREMENT

1. INTRODUCTION

1.1 Object

The object of this standard is to define terms and conditions of measurement used to ascertain the performance of antennas within the scope of this standard and to make possible a comparison of the results of measurements made by different observers on different equipment.

This section deals only with linearly polarized antennas for use in the frequency range 25 MHz to 1 GHz.

Unless otherwise specified, the measurements detailed in this section shall be conducted on an appropriate test range.

Terminology used generally conforms to that in the International Electrotechnical Vocabulary (IEV) and in other IEC publications on antennas. Other definitions will be found in Section One of this part.

1.2 Scope

The supplementary terms and definitions and the conditions of measurement set forth in this standard are intended for type tests and may be used also for acceptance tests.

Test conditions and methods for measuring the characteristics of antennas are given for establishing conformance to the requirements. For the purpose of this standard, an antenna is defined as a device for coupling a transmission line to space for the purpose of radiating or receiving electromagnetic waves. It includes any matching, balancing, phasing or other coupling devices up to the point of connection of the transmission line.

2. ELECTRICAL STANDARDS

Standard References and Test Conditions

Standard references and test conditions are those which shall apply to an antenna while it is being tested for performance requirements. These conditions apply unless otherwise specified.

2.1 DEFINITION

Base or fixed station antennas are antennas or combinations thereof used for the Mobile Communication service at the base station or fixed station in a radio relay link.

2.1.1 Standard Impedance

The characteristic impedance of the transmission lines and test equipment shall be 50 Ohms ± 5%.

2.1.1.1 Impedance Measurement Procedure

The antenna impedance may be measured with a radio frequency impedance bridge or other suitable device at the specified frequency.

2.1.1.2 Presentation of Results

Measured impedance shall be stated in the form
$R + jX$ at frequency F MHz, or graphically.

2.1.2 Half-Wave Dipole Antenna

A dipole whose electrical length is half a wavelength and is formed by a straight metallic radiator, one-half wavelength long, whose diameter is small compared to its length, so energized that the current has two nodes, one at each end, producing maximum radiation in the plane normal to its axis.

2.1.3.1 Standard Gain Unit (25 MHz -1 GHz)

The gain of a theoretical (lossless) half-wave dipole shall be used as the standard gain unit. The gain of the standard gain antenna in the plane perpendicular to its axis is therefore zero dBd. The gain of an antenna (see 2.11) shall be expressed in dB over that of a theoretical (lossless) half-wave dipole in dBd.

2.1.3.2 Standard Gain Unit (1 GHz and Above)

The gain of a theoretical isotropic point source, shall be used as the standard gain unit. The isotropic point source radiates uniformly in all directions, therefore the gain of the isotropic point source shall be zero dBi. The gain of an antenna (See 2.11) shall be expressed as that over a theoretical isotropic source in dBi.

2.1.4 Standard Antenna

A transfer-standard antenna is used for the measurement of antenna gain.

For specific frequency bands below 1 GHz, the configuration of the standard antenna is shown in Fig. 1a. It consists of two parallel half-wave dipoles connected in parallel by two symmetrical sections of balanced open wire line as shown. The dipoles are one-half wavelength apart, and are located one-quarter wavelength away from a conducting ground screen one wavelength by one wavelength in size. There shall be one standard antenna for each of the bands noted.

Table 1a. gives the dimensions for each antenna. The gains of these standard antennas, as determined by measurements made by the U.S. National Bureau of Standards are given in Table 1b.

For frequency bands 1 GHz and above, the configuration of the standard antenna is shown in Fig. 1b, and is comprised of an optimal pyramidal microwave horn, fed by a standard waveguide and flange configuration. The horn's detailed construction is described within Naval Research Laboratory Report No. 4433. The antenna gain is accurately determined by the physical dimensions of the pyramidal horn. Microwave horn dimensions and gain values are given in Table 2. Standard waveguide part numbers and dimensions are given in Table 3. Gain calculations can be derived from equation 5, p. 8, and Table A-1, p. 18, NRL Report No. 4433.

NOTE: The use of pyramidal waveguide horns for antenna transfer standards below 1 GHz, can be employed when deemed practical for the specific application. Standard antenna dimensions defined in the predecessor standard are valid and may be used for their specified frequency bands.
Microwave Standard Gain Horn design dimensions and gain data are taken from NRL Report No. 4433 "Design and Calibration of Microwave Antenna Gain Standards", Slayton, W.T., November 9, 1954, p. 22.

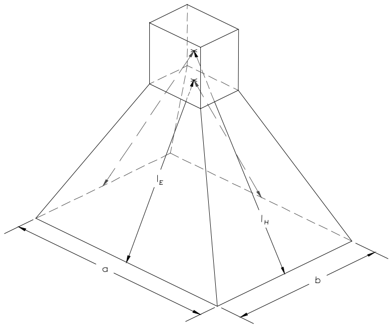


Figure 1b. Physical dimensions for calculating the gain of a pyramidal horn

Table 2

Microwave Standard Gain Horn Antenna Dimensions

Frequency Band (GHz)	Dimensions, Interior				Design Point		Band Edges	
	a inches(cm)	b inches(cm)	l_H inches(cm)	L_E Inches(cm)	Frequency (GHz)	Gain (dBi)	Frequency / (GHz)	Gain (dBi)
0.950 – 1.150	**21.931 (55.705)**	**16.245 (41.262)**	**28.730 (72.974)**	**24.000 (60.960)**	**1.000**	**13.7**	**.950/ XXXXX**	**1.150/ XXXXX**
1.150 – 1.700	**21.931 (55.705)**	**16.245 (41.262)**	**24.955 (63.386)**	**21.325 (54.166)**	**1.300**	**15.5**	**1.150/ XXXXX**	**1.700/ XXXXX**
1.700 – 2.600	**14.508 (36.850)**	**10.747 (27.297)**	**16.508 (41.930)**	**14.107 (35.832)**	**1.970**	**15.5**	**1.700/ XXXXX**	**2.600/ XXXXX**
2.600 - 3.950	**12.760 (32.410)**	**9.450 (24.003)**	**18.682 (47.452)**	**16.593 (42.146)**	**3.000**	**18.0**	**2.600/ XXXXX**	**3.950/ XXXXX**
3.950 - 5.880	**8.507 (21.608)**	**6.300 (16.002)**	**12.462 (31.653)**	**11.062 (28.097)**	**4.500**	**18.0**	**3.950/ XXXXX**	**5.880/ XXXXX**
5.880 – 8.330	**11.360 (28.854)**	**8.415 (21.374)**	**20.014 (50.836)**	**18.700 (47.498)**	**6.315**	**22.1**	**5.880/ XXXXX**	**8.330/ XXXXX**

TABLE 3

Microwave Rectangular Waveguide Reference

Frequency Band (GHz)	**EIA Wave Guide Designation WR ( )**	**RG ( ) /U* Designation**	**Dimensions, Interior**	
			Inches	**SI Units (cm)**
.950 - 1.150	**770**	**205**	**7.700 x 3.850**	**19.558 x 9.779**
1.150 – 1.700	**650**	**103**	**6.500 x 3.250**	**16.510 x 8.255**
1.700 - 2.600	**430**	**105**	**4.300 x 2.150**	**10.922 x 5.461**
2.600 – 3.950	**284**	**75**	**2.840 x 1.340**	**7.214 x 3.404**
3.950 – 5.880	**187**	**95**	**1.872 x 0.872**	**4.755 x 2.215**
5.880 – 8.330	**137**	**106**	**1.372 x 0.622**	**3.485 x 1.579**

* Assumes aluminum construction

2.1.2 Half-Wave Dipole Antenna

A dipole whose electrical length is half a wavelength and is formed by a straight metallic radiator, one-half wavelength long, whose diameter is small compared to its length, so energized that the current has two nodes, one at each end, producing maximum radiation in the plane normal to its axis.

2.1.3 Standard Gain Unit

The gain of a theoretical (lossless) half-wave dipole shall be used as the standard gain unit. The gain of the standard gain antenna in the plane perpendicular to its axis is therefore zero dBd. The gain of an antenna (see 2.11) shall be expressed in dB over that of a theoretical (lossless) half-wave dipole in dBd.

2.1.4 Standard Antenna

A transfer-standard antenna is used for the measurement of antenna gain. The configuration of the standard antenna is shown in Fig. 1. It consists of two parallel half-wave dipoles connected in parallel by two symmetrical sections of balanced open wire line as shown. The dipoles are one-half wavelength apart, and are located one-quarter wavelength away from a conducting ground screen one wavelength by one wavelength in size. There shall be one standard antenna for each of the bands noted.

Table 1 gives the dimensions for each antenna. The gains of these standard antennas, as determined by measurements made by the U.S. National Bureau of Standards are given in Table 2.

NOTE: Standard antenna dimensions defined in the predecessor standard are valid and may be used for their specified frequency bands.

DETAILS OF A 50 OHM TRANSFER-STANDARD ANTENNA

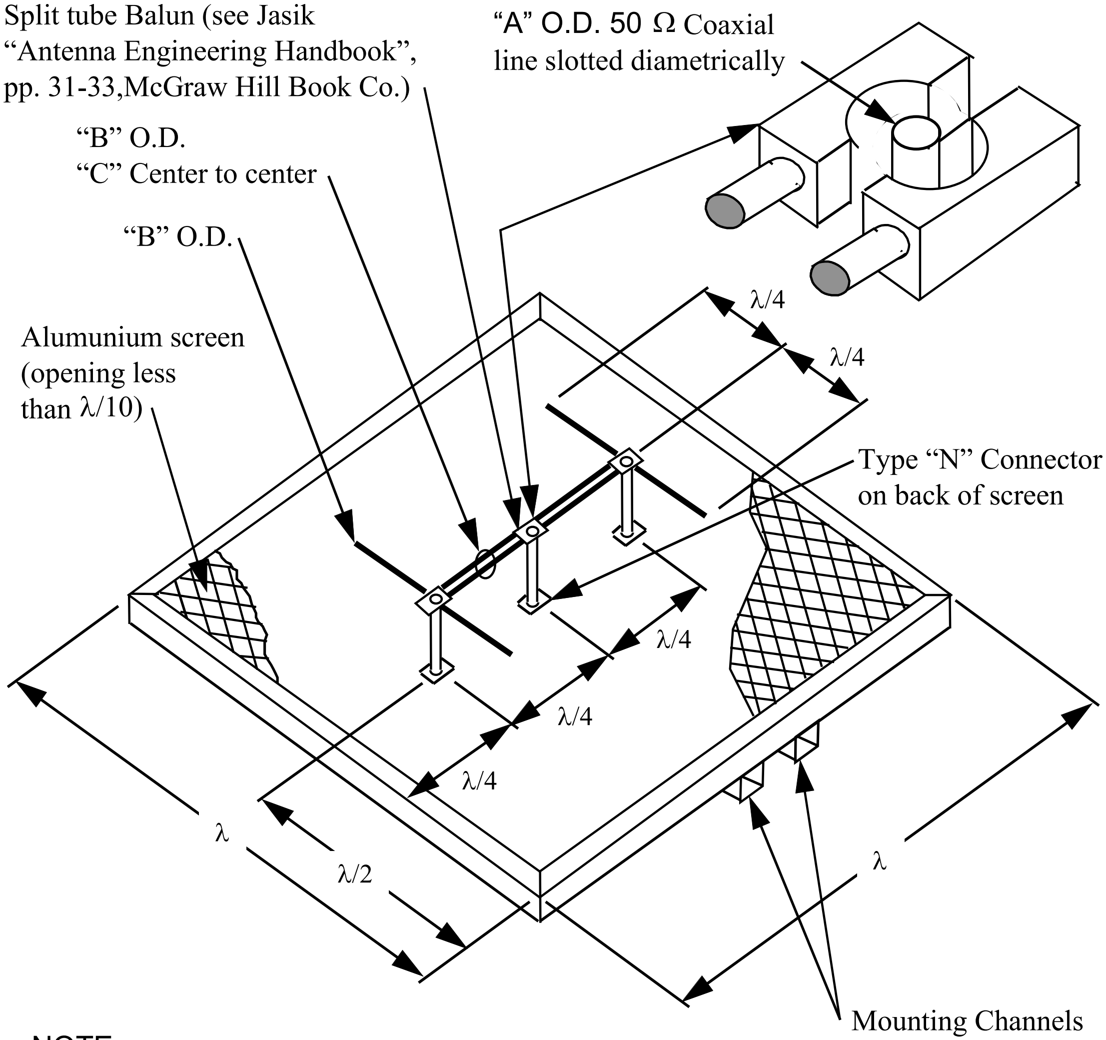
TABLE 1

BAND	WAVELENGTH	A	B	C
148-174 MHz	1875. mm (73.8 in)	41.1 mm (1.62 in)	17.45 mm (0.687 in)	38.38 mm (1.511 in)
216-222 MHz	1389. mm (54.7 in)	41.1 mm (1.62 in)	17.45 mm (0.687 in)	38.38 mm (1.511 in)
406-450 MHz	701. mm (27.6 in)	22.1 mm (0.87 in)	7.92 mm (0.311 in)	17.45 mm (0.687 in)
450-512 MHz	622. mm (24.5 in)	22.1 mm (0.87 in)	7.92 mm (0.312 in)	17.45 mm (0.687 in)
800-960 MHz	343. mm (13.5 in)	7.9 mm (0.31 in)	4.75 mm (0.187 mm)	10.44 mm (0.411 in)

TABLE 2

BAND	FREQ., MHz	G_S , GAIN of the STANDARD
148-174 MHz	148	7.5
	160	7.7
	174	8.0
216-222 MHz	216	7.7
	219	7.7
	222	7.8
406-450 MHz	406	7.6
	428	7.7
	450	7.9
450-512 MHz	450	7.5
	481	7.7
	512	7.9
800-960 MHz	800	7.5
	882	7.7
	960	8.0

NOTE: The gain figures are subject to a measurement uncertainty error level of ± 15.2% or 0.6 dB per a paper titled "TESTING OF ELECTRONIC INDUSTRIES ASSOCIATION LAND-MOBILE COMMUNICATION ANTENNA GAIN STANDARDS AT THE NATIONAL BUREAU OF STANDARDS" Authored by N.E. Taggart AND J.F. Shafer. (IEEE Vol. VT-27 No. 4, November 1978, pp 259, IEEE #0018-9245/78/1100-0259).



NOTE:

1. λ is the wavelength of the center frequency of a given band, namely, 160, 219, 428, 481, and 882 MHz. For dimensions of A, B, and C see table 1.

2. Detail Construction drawings are available from EIA Engineering Department.

Figure 1 - Gain Standard Antenna

2.1.5 Antenna Test Site

The test site is the general vicinity of the antenna under test. Specific conditions for the test are stated in detail in Section 2.3.2 for VSWR test and in Sections 2.4.3 and 2.11.3 for pattern and gain measurements.

2.1.5.1 Effective Antenna Volume

The effective antenna volume is the actual volume occupied by the radiating part of the antenna plus one-half wavelength all the way around, taking into account all appropriate positions of the antenna under test. For certain applications, such as a side-mounted vertical antenna, the supporting structure is in the RF field. In this case, the supporting structure shall be included in the effective antenna volume.

2.1.5.2 Source Antenna

The source antenna is any antenna that illuminates the antenna under test for gain or radiation pattern within specified conditions.

2.1.5.3 Antenna Test Range

The test range is the space occupied by the source antenna, the antenna under test, the space between them, and the equipment for gain and radiation pattern measurement (see Fig. 2).

2.1.6 Ambient Conditions

Measurement of VSWR, radiation pattern and antenna power gain may be made at outdoor test sites and ranges under prevailing weather conditions.

2.1.7 Polarization

The polarization of an antenna is the orientation of the electric vector of the wave radiated by the antenna.[1]

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[1] The electric vector magnitude varies as a function of rotation angle. For linear polarization it is suggested that the ratio of the maximum to minimum electric vector be greater than 20 dB.

2.1.8 Antenna Voltage Rating

The Antenna Voltage Rating is the maximum instantaneous peak voltage which may be applied repetitively to the antenna input connectors without degrading its performance.

2.1.9 Voltage Rating Test Procedure

A radio frequency signal of specified frequency and peak voltage shall be applied for a duration of 50 seconds 10 times directly to the antenna under test during a period of five minutes. A suitable indicating device shall be provided to show whether a breakdown or a flashover has occurred. The average power applied shall not exceed the rated power.

2.2 SPECIAL TEST AND CONDITIONS OF MEASUREMENT

2.2.1 Scale Model Measurements

Methods for the antenna radiation pattern and gain measurements are stated in Sections 2.4.3 and 2.11.3. However, at frequencies below 132 MHz, meaningful and accurate results of these measurements are difficult to obtain on a fullsize antenna. In this case, scale model techniques shall be used. It shall be stated in the published literature that the results are obtained by scale model measurements.

2.2.1.1 Scale Ratio

The scale ratio is the ratio for the operating frequency of the scale model to that of the full-size antenna. The ratio shall not exceed 6.

2.2.1.2 Linear Accuracy

The scale model shall be constructed to at least the following accuracy or better:

$$Ls = (L \pm 0.01\ L)/R$$

where R is the scale ratio, Ls is any significant linear dimension of the scale model, and L is the corresponding linear dimension of the full-size antenna.

2.2.1.3 Materials

The parts of the scale model shall be constructed of materials which simulate the electrical characteristics of the corresponding parts of the full-size antenna.

NOTE: Although this is not in strict conformance with scale model techniques, the errors introduced are small enough that the accuracy of the measurement will not be impaired noticeably, provided that the scaling factor is not too large.

2.2.1.4 Supporting Tower

If the supporting tower and mast are electrically essential parts of the antenna, or affect the electrical performance of the antenna, they shall also be scaled.

2.3 VOLTAGE STANDING WAVE RATIO (VSWR)

2.3.1 Definition

Standing wave ratio (VSWR) of the antenna is the ratio of the maximum to the minimum values of voltage in the standing wave pattern that appears along a theoretical (lossless) 50 ohm line with the antenna as load.

2.3.2 Method of Measurement

2.3.2.1 Test Procedure

The antenna under test shall be connected to a suitably matched signal source at the desired frequency, through a VSWR measuring device; such as a network analyzer, bridge or other device, that has a characteristic impedance equal to that of the transmission line and a residual VSWR of not more than 1.05:1 below 500 MHz and 1.10:1

above 500 MHz. This residual VSWR should be measured with all connectors to be used in the measurement included and with the line terminated in a matched load. The VSWR, as read on the measuring device, will be the VSWR of the antenna under test at the selected frequency. The measurement shall be made at each frequency of interest. If the RF loss in the line connecting the antenna to the VSWR measuring device exceeds 1/2 dB, the measured VSWR values shall be properly corrected to eliminate the effects of the line loss.

2.3.2.2 Presentation of Results

The (corrected) VSWR for each frequency of interest or the maximum over the specified band of frequencies shall be provided, together with the nominal impedance of the measuring device.

2.3.2.3 Test Site

The antenna under test shall be located in a space relatively free from reflections and sufficiently far from the test equipment and personnel. The test site is considered satisfactory if the change in VSWR is less than 10% when the antenna under test is moved in a horizontal direction a minimum of 1/2 wavelength on each of eight azimuth direction, 45 degrees apart, and up and down ± 1/2 wavelength.

2.3.2.4 Effect of Supporting Structure

For certain applications such as side-mounted vertical radiators, the supporting structure is in the RF field of the antenna. In this case, the antenna supporting structure shall be included in the mounting of the antenna under the VSWR test.

2.4 RADIATION PATTERN

2.4.1 Definition

The radiation pattern is a graphical representation of the magnitude of the relative electric field strength radiated from an antenna in a given plane plotted against direction from a given reference. The radiation pattern, when given, shall be for either the horizontal plane or the vertical plane. The polarization shall be specified.

2.4.2 Method Of Measurement

By the principle of reciprocity, test results obtained with the source antenna transmitting and the antenna under test receiving, are the same as those obtained with the source antenna receiving and the antenna under test transmitting. For convenience, the following sections assume that the source antenna is a transmitting antenna.

2.4.2.1 Test Range

A typical arrangement for radiation pattern measurement is shown in Fig. 2 (see IEEE Std. 149-1979, pp 20-29 for additional information pertaining to test ranges). Three possible types of test ranges are described as follows:

1. Ground Level Range; also known as a Ground Reflection Range - A ground range is a range where both antennas are close to the ground. In order that the resultant field of the source antenna and its image be substantially uniform at the test antenna, the source and test antenna heights, Ha and Hs in Fig. 2, are adjusted to place the first maximum of the interference pattern of the source antenna and its image, at the center of the test aperture.

2. Elevated Range - An elevated range is a range where both test and source antennas are elevated sufficiently to place a minimum of the source antenna at the reflection point, while simultaneously aligning the major lobe maxima of both antennas. The two heights Ha and Hs in Fig. 2 are generally equal.

3. Slant Range - A slant range is a range where the source antenna is placed near the ground, and the antenna under test is placed at an elevated point. The angle "a" in Fig. 2 is adjusted to achieve a null along the ground (Zero Degrees).

2.4.2.2 Test Procedure

A signal source tuned to the test frequency is connected to a source antenna. The radiated signal is received on the antenna under test. The latter is so mounted that it is similarly polarized to the source antenna. The antenna under test is connected to a radio receiver calibrated to measure the signal level at its input. The antenna under test is rotated around an axis perpendicular to the line between its center and the center of the source antenna, as shown in Fig. 2, and the received signal is recorded continuously through 360 degrees of rotation.

CAUTION: RF Coaxial cables in the test range will be in the field of radiation and may affect results. Such cables must be electrically isolated (decoupled).

1. Horizontal Pattern - for horizontal pattern test, the vertical direction of the antenna in its normal operating position shall be parallel to the axis of rotation in the test.

2. Vertical Pattern - for vertical pattern test, the vertical direction of the antenna in its normal operating position shall be perpendicular to the axis of rotation in the test.

2.4.2.3 Test Conditions

The antenna under test together with its mounting system shall be installed on a test range (see Fig. 2), where:

a) both antennas have the same polarization;

b) the separation between the source antenna and the antenna under test shall be at least 10 wavelengths, or

$$\frac{2L^2}{\lambda}$$

where L is the maximum dimension of the antenna under test and lambda is the wavelength of the test frequency in meters, whichever is greater.[2]

1. The radio receiver used as the signal detector shall present an impedance of 50 Ohms (1.5:1 VSWR or less) to the antenna under test, for all frequencies used for the measurements.
2. Both the signal output of the signal source and the sensitivity of receiving equipment shall be monitored so as to insure that they are maintained constant during the test.

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[2] The field intensity variation is typically ± 1/2 dB or less.

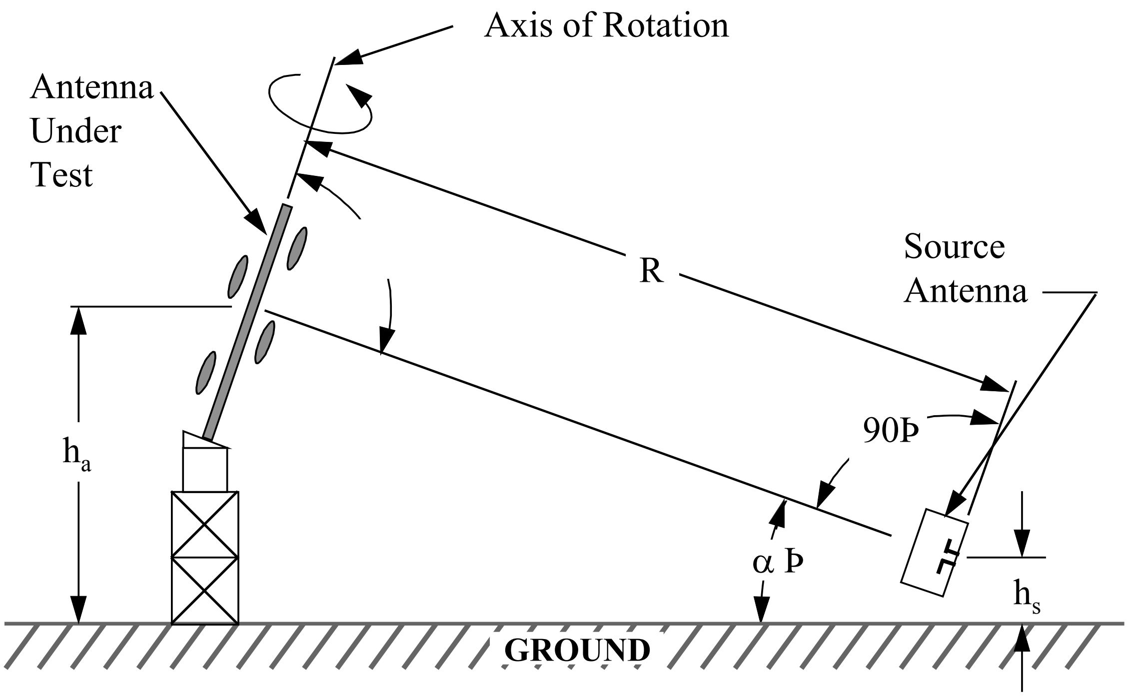

Figure 2 - Test Range

3. The antenna under test shall be placed in an area where the field is substantially uniform. The field shall be probed by a half-wave dipole over the effective antenna volume (see 2.1.5.1) of the antenna under test. If the field intensity variation is greater than ± 3/4 dB, the test site shall be considered unusable.[3]

2.4.2.4 Presentation of Results

The results for each test frequency should be plotted on a graph showing levels as a function of angle of rotation, expressed in decibels or voltage ratios relative to the maximum recorded value. All measured values to 20 dB below the maximum should be shown.

Test frequency and polarization shall be stated and the orientation of the antenna shall be shown by a diagram.

2.5 OMNIDIRECTIONAL MEASUREMENT

2.5.1 Definition

An omnidirectional antenna is an antenna having a non-directive pattern in azimuth, at a specified elevation angle, and a directive pattern in elevation.

2.5.2 Method of Measurement

Same as that for the Radiation Pattern Test (2.4.2).

2.6 PATTERN CIRCULARITY

2.6.1 Definition

The pattern circularity of an omnidirectional antenna is the deviation from a true circle of its horizontal radiation pattern at a specified elevation angle.

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[3] The field intensity variation is typically ± 1/2 dB or less.

2.6.2 Presentation of Results

The departure from circularity measured from a mean value shall be stated as plus or minus dB by the manufacturer.

2.6.3 Method of Measurement

Same as that for Radiation Pattern Test (2.4.2).

2.7 Orthogonally Polarized Diversity Antenna

2.7.1 Definition

An orthogonally polarized antenna is an antenna which is capable of receiving or radiating radio waves in two orthogonal polarizations. The antenna will typically posses two or more input ports, one corresponding to each polarization.

2.7.1.1 Gain

Gain will be determined by comparing the antenna under test to an antenna of known gain using the gain-comparison method. The source antenna is oriented so that it is similarly polarized to the nominal polarization of the antenna under test. When the gain-standard antenna is substituted, it will be at the same nominal polarization as the antenna under test. Appropriate measurement techniques should be used to assure accurate results.

2.7.1.2 Beamwidth

Azimuth and elevation beamwidth is the angular width including the maximum radiation, and measured between the two points on the major lobe of the pattern 3 dB below the maximum. The radiation patterns for this determination will be measured with the polarization vector of the source antenna oriented so that it is similarly polarized to the nominal polarization of the antenna under test.

2.7.1.3 Front-to-Back Ratio

Front-to-back ratio is defined as the difference in level, in dB, between the antenna pattern at boresight, at its nominal polarization, and the worst case of either of two source polarizations, co-polar or cross-polar to the nominal polarization, 180 degrees from boresight.

2.7.1.4 Polarization Quality Ratio (PQR)

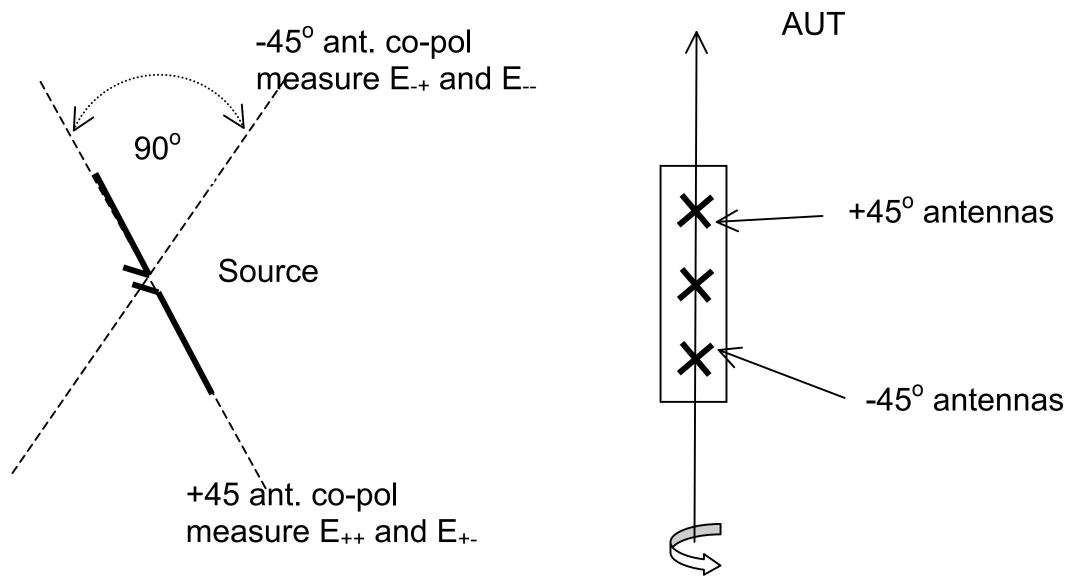
Polarization Quality Ratio is a measurement that encompasses both orthogonality and cross-polarization discrimination in one measurement. Since poor cross-polarization discrimination and loss of orthogonality both lead to a decrease in diversity quality, it is important to make this a single measurement.

This measurement requires two radiation patterns with the source antenna oriented at two orthogonal polarizations, co-polar and cross-polar to the nominal polarization. The same two source polarizations must be used for both antenna ports, and four patterns will result. Over the 3 dB and sector beamwidths, the worst case ratio between the two orthogonal polarizations shall be the figure used. This will be done for both antenna ports.

(For example, an antenna under test has two ports – one at +45 degrees slant polarization and one with – 45 degrees slant polarization. For the first port, a measurement of the radiation pattern is made with the source antenna oriented at +45 degrees and then a second measurement is made with the source antenna oriented at -45 degrees. For the beamwidth of interest, the PQR is the worst case ratio between levels of the two orthogonally polarized, radiation patterns. The measurements are then repeated for the –45-degree port (see figure below). Polarization is defined looking in the direction of propagation.)

While this is not a direct measurement of orthogonality, it indicates a deviation from the desired polarization, in conjunction with cross polarization discrimination, and provides a measure of the quality of the polarization of the antenna.

It is important to orient the source antenna to within +/- 1-degree of the polarization required, or significant errors can result.



PQR is the lowest of $|E_{++}|/|E_{+-}|$, $|E_{++}|/|E_{-+}|$, $|E_{--}|/|E_{+-}|$ and $|E_{--}|/|E_{+-}|$.

2.7.1.5 Port-to Port Isolation

Port-to-port Isolation is defined as a two port measurement of transmission (S21 or S12) between the two input ports of the antenna under test while the antenna is radiating toward a appropriate non-reflective surface or free space. The worst case value over the operating band of the antenna shall be utilized.

2.7.1.6 Pattern Tracking

Pattern tracking is defined and the maximum deviation in dB of the patterns of the two orthogonal ports over the 3 dB beamwidth. There will be separate values for azimuth and elevation planes.

2.7 DIRECTIONAL ANTENNA

2.7.1 Definition

A directional antenna is an antenna which radiates or receives radio waves more effectively in some azimuthal directions than others.

2.7.1.1 Radiation Lobe

Radiation lobe is a portion of a radiation pattern bounded by one or two angular regions of minimum radiated electric field.

2.7.1.2 Major Lobe

The Major Lobe is the radiation lobe containing the direction of maximum radiation.

2.7.1.3 Method of Measurement

Same as that for Radiation Pattern Test (see 2.4.2).

2.8 AZIMUTH (Horizontal) BEAMWIDTH

2.8.1 Definition

The Azimuth Beamwidth of an antenna is the angular width including maximum radiation measured between the two points on the major lobe of the azimuth pattern 3 dB below the maximum.

2.8.2 Presentation of Results

The Azimuth Beamwidth shall be stated by the manufacturer.

2.8.3 Method of Measurement

Same as that for the Radiation Pattern Test (see 2.4.2).

2.9 ELEVATION (Vertical) BEAMWIDTH

2.9.1 Definition

The Elevation (Vertical) Beamwidth of an antenna is the angular width including maximum radiation measured between the two points on the major lobe of the elevation (vertical) pattern 3 dB below the maximum .

2.9.2 Presentation of Results

The Elevation (Vertical) Beamwidth shall be stated by the manufacturer.

2.9.3 Method of Measurement

Same as that for the Radiation Pattern Test (see 2.4.2).

2.10 ELEVATION BEAM TILT

2.10.1 Definition

Elevation Beam Tilt of an antenna is the angle between the direction of maximum elevation radiation and the horizontal plane.

2.10.2 Presentation of Results

Elevation Beam Tilt and gain in the azimuth plane shall be stated by the antenna manufacturer or indicated in the published elevation (vertical) radiation pattern.

2.10.3 Method of Measurement

Same as that for the Radiation Pattern Test (see 2.4.2).

2.11 ANTENNA GAIN

2.11.1 Definition

The gain of an antenna is the ratio of its maximum radiation intensity in a stated direction to the maximum radiation intensity of a theoretical (lossless) reference antenna with identical input power. Unless otherwise specified, the "stated direction" of gain is in the horizontal plane.

2.11.2 Presentation of Results

The theoretical gain of the antenna shall be expressed in dB over the gain of a lossless halfwave dipole in dBd. The gain shall be stated by the manufacturer. The measured gain shall not be less than that stated by the manufacturer at any stated frequency or band of frequencies.

2.11.3 Method Of Measurement

2.11.3.1 Test Range

Same as that for pattern test (see 2.4.2.1) as shown in Fig. 1.

2.11.3.2 Test Procedure

Substitution Method shall be used for measuring the antenna gain.

1. A signal source tuned to the test frequency is connected to a source antenna. The radiated signal is received on the antenna under test. The latter is so mounted that it is similarly polarized to the source antenna. The antenna under test is connected to a radio receiver calibrated to measure the signal level at its input. The antenna under test is rotated and adjusted until the receiver signal level reaches the maximum. This level is designated as Pa.

2. The antenna under test is removed and the standard antenna, with gain G_s listed in Section 2.1.4, is substituted in its place. The standard antenna is then rotated and adjusted until the receiver signal power level reaches the maximum. This level is designated as Ps.

3. The measured gain of the antenna in the direction of its maximum radiation is:

   $$Ga = 10 \log (Pa/ Ps) + Gs \text{ dBd}$$

   It is noted that measured gain referred to the maximum direction has the advantage that the reading, P_a obtained in Step 1, is steady and insensitive to small antennamovement or vibration, and that measurement accuracy is improved. How-ever, two corrections shall be made according to Steps 4 and 5 whenever they are applicable.

4. Beamtilt Correction - If the intended direction of radiation from the antenna differs from the direction of maximum radiation due to beamtilt (2.10.1), then the measured gain Ga shall be corrected to give:

   $$G_b = G_a - L_b \text{ dBd}$$

   where L_b is the loss due to beamtilt. The value of L_b can be obtained from the vertical radiation pattern of the antenna.

   Note: Beamtilt correction may be eliminated if, when the antenna under test is mounted and adjusted as described in paragraph (1) above, its radiation on its normal horizon is directed towards the source antenna.

5. Circularity Correction - If the antenna is intended for omnidirectional coverage in the horizontal plane, measured gain shall be further corrected to give:

   $$G_o = G_b - L_b \text{ dBd}$$

   where G_b is obtained in Step 4 and L_b is the level difference in dB between the azimuthal average value and the value from which Gb is obtained Go is ????????????

6. The antenna gain shall be measured for frequencies (at least three) sufficient to define the variation over the specified frequency band.

2.11.3.3 Presentation of Results

The gain of the antenna under test, with reference to a lossless half-wave dipole, shall be stated as a function of frequency in either tabular or graphical form or the minimum over the specified band of frequency if applicable. All measured values across the frequency range of the antenna under test shall be shown. Orientation of the transfer-standard antenna and the antenna under test shall be stated.

2.12 ANTENNA POWER RATING

2.12.1 Definition

Antenna power rating is the maximum CW power which can be continuously applied to the antenna without degrading its performance.

2.12.2 Presentation of Results

The maximum power rating shall be stated by the antenna manufacturer. The results shall state the power rating, the test frequency and the environmental temperature and humidity. Where the power rating is determined analytically, the method of analysis shall be shown.

2.12.3 Method of Determination

The stated power rating may be proven either by an analytical method or by physical measurements.

The antenna under test shall be connected to a RF signal source through a VSWR measuring device, and a specified power at the specified frequency shall be applied for a period of 4 hours, under specified temperature and humidity conditions.

2.13 BANDWIDTH

2.13.1 Definition

The INSTANTANEOUS bandwidth of the antenna is the frequency ranges over which it will perform within specification without changing tuning adjustments.

The TUNEABLE bandwidth of the antenna is the frequency range or ranges over which the instantaneous bandwidth may be adjusted.

2.14 Intermodulation (IM) Performance

2.14.1 Introduction

Non-linearities in regions of high RF current density flowing within an antenna structure can lead to the generation of extraneous frequencies when two or more carrier frequencies are incident on the antenna. These extraneous frequencies have a well defined relationship to the incident carrier frequencies and are usually termed intermodulation (IM) products. For example, if two carrier frequencies are denoted as f_1 and f_2, then third order products arise at $2.f_1 - f_2$ and $2.f_2 - f_1$; fifth order products arise at $3.f_1 - 2.f_2$ and $3.f_2 - 2.f_1$, etc. Usually, but not exclusively, the third order product level has the highest power of all the products present.

Causes of excessively high IM levels in antennas and transmission lines can be primarily traced to poor metallic contact within high current paths in the antenna or use of ferromagnetic materials in regions of high current density. Extreme care needs to be taken in the design and manufacture of antennas and transmission line connections to avoid poor or intermittent metal contact. Some preventive measures include: avoidance of metallic contact over large distributed areas – use point contacts with high fastener pressure as much as possible, suitably cleaned components to be used within the antenna, high contact pressures in connectors, clean connector surfaces, use of non-ferromagnetic materials where appropriate, scrupulous removal of metal chips, particles, etc. during the antenna manufacture, etc.

The effects of poor IM performance will depend to a great extent on the particular system application. As an easily understood example, an antenna generating high IM levels will radiate these as unwanted emissions having frequencies other than those originally planned. A specific example will reveal more subtle problems. A typical non-duplexed cellular base station site will use separate transmit and receive antennas for each of three 120 degree sectors. A transmit antenna possessing high levels of IM may generate a signal at a frequency that lies in the receive passband and the coupling path that exists between the transmit and receive antennas in close proximity on the base station tower may mean that interference effects are encountered. In a duplexed cellular base station site, where the same antenna is used for transmit and receive functions but the bands are separated out by a duplexer located in the equipment cabin, the IM level arising in the receive passband reflected from the antenna will give rise to even more severe interference problems since the loss which occurs in the coupling path is no longer present.

Definition

The IM performance of an antenna is defined as the power level of one of the third order products, at a frequency of $2.f_1 - f_2$ or $2.f_2 - f_1$ which will be stated, generated as a result of energizing an antenna under test with two unmodulated RF carriers at stated frequencies f_1 and f_2 and of equal and stated power levels.

Presentation of Results

The power level and frequency of the third order product, as well as the frequencies and power level of the two input carriers must be presented.

Example: The intermodulation performance of antenna type XYZ is –108 dBm at a frequency of 850 MHz for two input carriers at frequencies 870 and 890 MHz and having power levels of + 40 dBm.

Method of Determination

The IM performance is determined by subjecting the antenna under test to two specified high power input carrier levels and monitoring the reflected signal at the desired third order product frequency. The input power level will typically be +40 or + 43 dBm (to be stated). Equipment is commercially available to measure the IM performance of an antenna in the above manner. It is recognized that in principle the measurement method could be extended to cater for a transmission measurement, the input carrier frequencies could be swept over a frequency band of interest, the carriers could be modulated, more than two carriers could be used, etc. It is believed, however, that this would potentially place an excessive burden in respect of equipment required for some users of this standard and hence these extensions will not be put forward at this time.

In the event that this equipment is not available to users of this standard, some guidelines can be given as follows. The frequency generators will typically need to be stable frequency synthesizers and will typically act as low power drivers inputting into high power (10 to 20 watts) amplifiers. The monitor device used for determining the product level will typically need to be a frequency stable, i.e. synthesized, spectrum analyzer operating at suitably low resolution bandwidth and possessing suitably low sensitivity. The third order product level and frequency can be read directly from the spectrum analyzer.

Particular importance needs to be given to ensuring that the four port frequency triplexer, cables and connections typically used in such a set up do not generate excessive IM levels themselves. Excessive is defined as being at a level which would start to significantly influence the desired measured result. The IM performance of the test set up must be at least 10 dB and ideally should be more than 20 dB below that of the IM performance of the antenna under test. The IM performance of the test set up should be measured regularly with a low residual IM load. The RF cable and connectors used to connect the antenna under test to the test set-up are particularly vulnerable to damage and degradation caused by repeated use. A suitable calibration procedure will need to be established and followed to ensure that losses in the connecting cables and triplexer will be taken into account and that the stated power levels of the carriers and the IM product are referred to the antenna under test input port.

Great caution is also advised in respect of conducting the tests since high RF powers are involved. It is recommended that the antenna under test is placed into an anechoic chamber since it is radiating high powers and that good high power safety practices are strictly followed by personnel. The chamber needs to be of sufficient IM performance so as to avoid excessively influencing the desired, measured result.

3. STRUCTURAL STANDARDS

3.1 FACTOR OF SAFETY

3.1.1 Definition

The factor of safety of a member under rated stress is the number which results by dividing the yield point of the material by the actual unit stress on the section area.

3.1.2 Method of Determination

The factor of safety shall be determined by dividing the yield stress of the material by the maximum working stress of the material. The maximum working stress shall be measured or calculated.

3.2 WIND LOAD

3.2.1 Definition

Wind loading on an antenna assembly shall be those projected area moments and forces caused by the specified wind pressure acting in the direction which produces the maximum value of those projected area moments and forces.

3.2.2 Ice Loading

The additional wind loading (projected area moments and forces) on the antenna and supporting structure due to ice. When ice is considered, it shall not be less than the minimum specified radial thickness on all members of the antenna structure. Unless otherwise stated, ice accumulation will be considered covering all surfaces uniformly with a radial thickness of 0.5 inches.

3.2.3 Method of Determination

Maximum forces due to wind load on the assembly shall be calculated. If the area includes several members of different shapes, appropriate shape factors shall be used. The shape factor for round surfaces is 2/3 of that of flat surfaces. The added projected area due to ice accumulation should be considered as cylindrical even though the projected area may be flat. The shape factor of 2/3 for cylindrical surfaces would then apply to this added projected area only. For circular sections, the 2/3 factor would apply to the full projected area. Maximum torque due to wind load shall be calculated assuming that the direction of the wind pressure is that which produces maximum torque on the antenna support. Refer to examples provided in Figures 3, 4 and 5.

NOTE 1: Wind pressure is proportional to the square of the actual wind velocity. Expressed as a formula, $p = kv^2$, where p is the wind pressure in pascals (lbs/ft^2), k is the wind conversion factor assumed to be 0.96 (0.004), and v is the actual wind velocity at the antenna in meters/s (mi/h).

NOTE 2: Often, the term Effective Flat Panel (EFP) is used to characterize the effect of the antenna geometry on wind loading. EFP is defined as the flat panel area that would result in the same wind load as the antenna under the same wind conditions.

3.2.4 Deflection

The deviation from the mounting axis of the furthest extension from the mounting point of the antenna when subjected to a wind load.

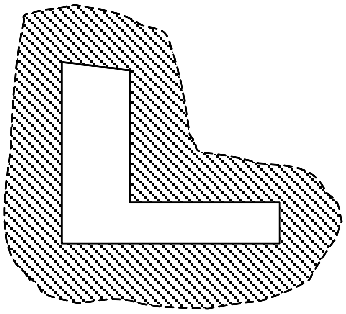


Figure 3

Radial Ice Accumulation - - - - - -
Structural Members ________

NOTES :

1. Radial ice accumulation means that the ice builds uniformly on all surfaces to the radial thickness specified as illustrated by the shaded area
2. The added projected area due to ice accumulation should be considered as cylindrical even though the bare projected area is flat. The 2/3 factor for cylindrical surfaces would then be applicable to this added projected area only. For circular sections, the 2/3 factor would apply to the full projected area.

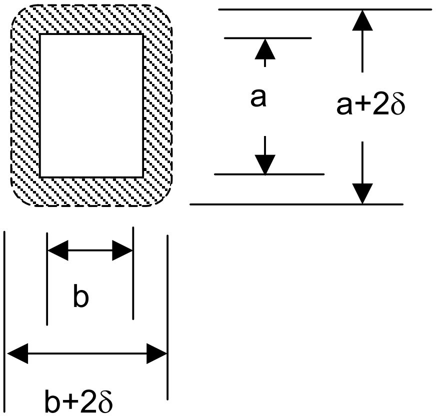


Figure 4

Assuming maximum torque with wind direction perpendicular to the axb surface, we have (from section 3.2.3) :

Wind projected area (no ice), $A = ab$
Added projected area (ice), $A= (2/3)[(a+2\delta)(b+2\delta) - ab]$
EFP (no ice) $= ab$
EFP (w/ice) $= ab + (2/3)[(a+2\delta)(b+2\delta) - ab]$
Wind Pressure, $p=kv^2$
Wind Loading Force, $T = p(\mathrm{EFP})$

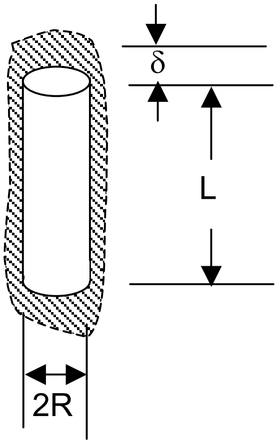


Figure 5

Assuming maximum torque with wind direction perpendicular to the cylinder axis, we have (from section 3.2.3) :

Wind projected area (no ice), $A = (2/3)(2RL)$
Added projected area (ice), $A = (2/3)[(2R+2\delta)(L+2\delta) - 2RL]$
EFP (no ice) $= (2/3)(2RL)$
EFP (ice) $= (2/3)(2RL) + (2/3)[(2R+2\delta)(L+2\delta) - 2RL]$
$= (2/3)[(2R+2\delta)(L+2\delta)]$
Wind Pressure, $p=kv^2$
Wind Loading Force, $T = p(\mathrm{EFP})$

3.2.4 Deflection

The deviation from the mounting axis of the furthest extension from the mounting point of the antenna when subjected to a wind load.

3.2.4.1 Presentation of Results

The deflection should be stated either as linear displacement from the mounting axis or as Beam Tilt angle from the no load position of the beam. Both the deflection and the corresponding wind speed shall be specified at a pressure of 30 pounds/square foot on flat surfaces without ice coatings.

3.3 GALVANIC CORROSION

3.3.1 Definition

Galvanic corrosion is the acceleration of corrosive action due to dissimilar metals in contact in the presence of moisture. The action is that of a galvanic cell, in which the metals act as electrodes, with the metal that is corroded acting as an anode with respect to the other metal.

3.3.2 Recommended Practice

Good engineering practice shall be followed in design, using compatible materials. The qualitative tables in the latest MIL-E-16400 may be used as a guide.

3.4 RESISTANCE TO WEATHERING, FATIGUE, AND COLD FLOW

3.4.1 Definition

Resistance to weather, fatigue, and cold flow is the ability to operate in exposed positions over prolonged periods of time without appreciable degradation of structural strength or electrical characteristics due to corrosion or other chemical decomposition, or fatigue, or cold flow.

3.4.2 Recommended Practice

The composition of materials and finishes used shall be a characteristic of the antenna model (or type) which is claimed by the manufacturer to meet this standard. These compositions shall be available from the manufacturer and shall not be changed without changing model (or type) number unless such changes do not degrade resistance to weathering fatigue or cold flow.

PART B

BASE OR FIXED STATION ANTENNAS

THE FOLLOWING ARE RECOMMENDED MINIMUM STANDARDS APPLICABLE TO THE SUBSEQUENT TERMS AND CONDITIONS OF MEASUREMENT

1.0 Minimum VSWR Standard (Ref. A2.3)

1.1 The VSWR shall not exceed 1.5 at the specified frequency or over the specified band of frequencies.

2.0 Minimum OmniDirectional Standard (Ref. A2.5)

2.1 The relative gain of an omnidirectional antenna in any azimuth direction shall not vary from the mean value by more than 1 1/2 dB for 360 degrees of rotation at the same specified elevation angle. If not specified, the elevation angle shall be zero degrees.

3.0 Minimum Directional Standard (Ref. A2.7)

3.1 A directional antenna shall have one or more major lobes in the azimuth pattern whose maximum relative gain shall exceed the minimum relative gain by more than 3 dB.

The manufacturer shall show all the lobes down to 20 dB below the major lobe on the radiation pattern.

4.0 Minimum Power Rating Standard (Ref. A2.12)

4.1 No damage or deformation of the antenna shall be observed; the change in VSWR shall be less than 10%. Subsequent tests shall not make further permanent change in the VSWR.

5.0 Minimum Factor Of Safety Standard (Ref. A3.1)

5.1 The factor of safety for antenna assemblies shall be not less than 1.65 based on the yield point of the material.

6.0 Minimum Windload Standard (Ref. A3.2)

6.1 Antenna assemblies when fully loaded shall be designed for a wind pressure of not less than 30 pounds per square foot on flat surfaces, without ice coatings. The manufacturer of antenna assemblies shall furnish the maximum calculated forces and moments at the point of attachment where maximum calculated forces and moments occur. Structural calculations shall consider a temperature range of -40 degrees C to +60 degrees C (-40 degrees F to + 140 degrees F).