IRE STANDARDS ON NAVIGATION AIDS: DIRECTION FINDER MEASUREMENTS, 1959

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CORRECTION

The following correction should be noted in "IRE Standards on Navigation Aids: Direction Finder Measurements, 1959," which appeared on pages 1349–1371 of the August, 1959, issue of PROCEEDINGS.

Section 1.1.4.6, page 1358. The equation in this Section should be as follows:

$$\text{Pick Up Factor (Meters)} = \frac{\left[\text{Field Strength of Section 1.1.4.5}\right]\left[\frac{\text{Effective Height of Dipole of Section 1.1.4.6}}{2}\right]\left[1 - \frac{R_{\text{series}} \text{ of Section 1.1.4.4}}{\text{Dipole Cable Impedance}}\right]}{\text{Field Strength of Section 1.1.4.1}}$$

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IRE Standards on Navigation Aids: Direction Finder Measurements, 1959*

59 IRE 12. S1

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* Approved by the IRE Standards Committee, April 10, 1958. Reprints of this Standard, 59 IRE 12.S1, may be purchased while available from the Institute of Radio Engineers, 1 East 79 Street, New York, N. Y., at $1.00 per copy. A 20 per cent discount will be allowed for 100 or more copies mailed to one address.
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NOTE ON THE USE OF STANDARD FREQUENCY BAND DESIGNATIONS

In the following Standard, reference is made to Frequency Bands by number (*e.g.*, see page 1354). For the benefit of the user who is not familiar with those band designations, a few words of historical background and explanation are in order.

Attempts have been made to designate portions of the RF spectrum by such nomenclatures as "long waves," "short waves" and similar names since radio's early beginnings. One of the earliest classifications was adopted at the first CCIR meeting at The Hague in 1929. In this system, the spectrum from below 100 kc to above 30,000 kc was divided into five bands: "low frequency," "medium frequency," "medium-high frequency;" "high frequency" and "very-high frequency."

At the Atlantic City Radio Conference of 1947, a further modification was adopted as below:

VLF	(Very-low frequency)
LF	(Low frequency)
MF	(Medium frequency)
HF	(High frequency)
VHF	(Very-high frequency)
UHF	(Ultra-high frequency)
SHF	(Super-high frequency)
EHF	(Extremely-high frequency)

This usage has persisted to the present day, as evidenced by frequent references to the "VHF" and "UHF" television bands. It has obvious disadvantages in that the designations are qualitative, ambiguous, and not extendable without coining new terms which add to the potential confusion.

Realizing the limitations of the above system, the CCIR, meeting in London and Warsaw (in 1953 and 1956) adopted a number designation system, based on CCIR Recommendation No. 225. The following table and notes are taken from this Recommendation:

Band No.	Frequency Range (lower limit exclusive, upper limit inclusive)	Metric Subdivision
4	3 to 30 kc	Myriametric waves
5	30–300 kc	Kilometric waves
6	300–3,000 kc	Hectometric waves
7	3,000–30,000 kc	Decametric waves
8	30–300 mc	Metric waves
9	300–3,000 mc	Decimetric waves
10	3,000–30,000 mc	Centimetric waves
11	30,000–300,000 mc	Millimetric waves
12	300,000–3,000,000 mc	Deci-millimetric waves

Note 1: "Band N" extends from 0.3×10^N to 3×10^N cps.

Note 2: When a service adopts a reference number or letter to designate a specific frequency band allocated to it and situated, wholly or for the most part, in band "N" of the above nomenclature, the prefix N should normally precede the reference in question. For example, for the 41- to 68-mc band, to which broadcast users give the reference "I," the appropriate designation is "broadcast band 8-I," since it refers to a part of "band 8." This practice, applicable in the drafting of CCIR documents, is generally recommended for all cases where such a definition would obviate the risk of confusion in designating the numerous frequency bands and subbands.

It is hoped that the above words of explanation will enable the reader to translate readily from one system to the other and further, will eventually result in wider use of the numerical references.

—*IRE Standards Committee*

INTRODUCTION

THE TERM "Radio Direction Finding," as used in these standards, is a procedure for determining the bearing, at a receiving point, of the source of a radio signal by observing the direction of arrival and other properties of the signal. Direction Finders may be used for navigation and other purposes without necessitating the specialized transmissions generally required by other radio navigational devices.

The purpose of standardizing measurement methods and procedures is to enable the determination of a Direction Finder's characteristics which will permit analysis of DF performance in a uniform manner or the correlation of data when two or more types of Direction Finders are to be compared. An effort has been made to follow and adapt previously-used methods of measurement and limit the measurement procedures to those suitable for the majority of types of Direction Finders. It is probable that certain tests have been omitted which might be required for some specialized types. Such shortcomings may be offset by supplementing the standardized procedures, as necessary, for a particular design.

ABBREVIATIONS AND DEFINITIONS OF TERMS USED IN THIS STANDARD

Accuracy (in Direction Finding). The correctness of an indication in terms of its deviation from the true value of the quantity indicated when the probability that this deviation will be exceeded is less than a stated value.

Apparent Bearing. The direction of arrival of the signal with respect to some reference direction.

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Bearing Accuracy (in Direction Finding). The correctness of DF indication expressed as the deviation (of the indicated bearing from the direction of arrival of the signal) whose probability of being exceeded is less than some stated value.

Bearing Accuracy, Instrumental DF. The systematic component of *Bearing Accuracy*. The deviations involved include such factors as structure and imbalance among elements of the *DF Antenna System*, Goniometer, balanced modulator of the DF equipment itself, etc., and errors in the calibration of the indicating system. It does not include errors due to distortions of the signal field caused by effects exterior to the DF equipment, nor does it include offsets which can be corrected by a fixed displacement of the indicator scale.

Bearing Error Curve (DF Equipment). A plot of the *Instrumental Bearing Errors* vs Indicated Bearings.

Bearing Error Curve (DF Installation). A plot of the combined *Instrumental Bearing Error* (DF Equipment) and site error vs Indicated Bearings.

Bearing Offset, Indicated. The difference between the indicated and apparent bearings of a number of signal sources, substantially uniformly distributed in azimuth.

Bearing Reciprocal (in Direction Finding). The opposite direction to a bearing.

Blur (in Null-Type DF Systems). In null-type systems, the output (including noise) at the bearing of minimum response expressed as a percentage of the output at the bearing of maximum response.

DF Antenna. A *DF Antenna* may consist of a single loop, orthogonal loops, spaced differentially-connected dipoles or Adcock antennas, or any other antenna combination included in a Direction Finder for obtaining a phase or amplitude reference with respect to the received signal.

DF Antenna System. One or more *DF Antennas*, their combining circuits and feeder systems, together with the shielding and all electrical and mechanical items up to the termination at the receiver input terminals.

DF Dummy Antenna. An electrical network that simulates the impedance characteristics of the *DF Antenna*.

DF Dummy Antenna System. An electrical network which simulates the impedance characteristics of the *DF Antenna System*.

Note: When a signal generator is used to excite a *DF Dummy Antenna* or *DF Dummy Antenna System*, the generator impedance must be considered in the design of the *Dummy*.

DF Noise Level. In the absence of the desired signals, the average power or rms voltage at any specified point in a Direction Finder System.

Note: In RF and audio channels, the *Noise Level, DF* is usually measured in terms of the power dissipated in a suitable termination. In a video channel, it is customarily measured in terms of voltage across a given impedance, or of the cathode-ray deflection.

Null. In direction finding systems wherein the output amplitude is a function of the direction of arrival of the signal, or of the rotation in bearing of the response pattern of the *DF Antenna System*, the minimum output amplitude (ideally zero).

Note: The *Null* is frequently employed as a means of determining bearing. The term "minimum" is often used to indicate an imperfect Null.

Overload Point, Signal. For any setting of receiver controls, and with an input signal increasing from any level within the linear operating range of the receiver, that input signal amplitude at which the ratio of output to the input first differs by 3 db from the ratio of output to input observed within the linear operating range.

Pick-up Factor, DF Antenna System. An index of merit expressed as the quotient of the voltage across the receiver input impedance divided by the signal field-strength to which the antenna system is exposed, the direction of arrival and polarization of the wave being such as to give maximum response.

Polarization, Desired. The polarization of the radio wave for which the *DF Antenna System* is designed.

Note: The *Desired Polarization* is ordinarily either vertical or horizontal.

Polarization, Undesired. Any polarization of the radio wave other than that for which the *DF Antenna System* is designed.

Note: When the *Desired Polarization* is vertical or horizontal, then the *Undesired Polarization* is horizontal or vertical, respectively.

Reference Test Field. That field strength, in microvolts per meter, numerically equal to the DF Sensitivity.

Sensitivity, DF. That field strength, in microvolts per meter, to which the *DF Antenna System* is exposed at the DF site, which produces a ratio of signal-plus-noise to noise of 20 db in the receiver output, the direction of arrival of the signal being such as to produce maximum pickup in the *DF Antenna System* (see Sensitivity at Maximum Response Position, 1.2).

Note: If, because of equipment limitation, a 20-db signal-plus-noise to noise ratio cannot be attained, the sensitivity can be calculated by extrapolating from an attainable signal-plus-noise to noise ratio within the linear region.

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Standard Multiples. The *Standard Multiples* of measurement shall be 1×10^n and 3×10^n for all pertinent (*i.e.*, positive, negative and zero) integral values of n.

Standard Output Levels (Audio). The *Standard Output Levels*, into a *Standard Output Load*, shall be 0.006, 0.050 or 0.3 watt, depending upon the output capabilities of the equipment.

Standard Output Load (Audio). The *Standard Output Load* (*Audio*) shall be resistive and shall be of a value equal to the load into which the audio channel of the receiver is designed or specified to operate.

Standard Test Frequencies. The *Standard Test Frequencies* shall be the mid-frequency and nominal limits of each tuning band of the DF receiver. Where the band-tuning ratio is less than one and one-half to one, two frequencies, approximately 10 per cent inside the nominal limits of the band coverage, will suffice.

Standard Wave Error. The DF bearing error produced by a wave incident at 45°, having equal vertically- and horizontally-polarized electric fields, the relative phases of the two components being such as to produce the maximum DF bearing error.

Target Transmitter. A source of radio frequency energy suitable for providing test signals at the test site.

STANDARD TEST CONDITIONS

Test Sites

Two types of test sites, suitable for DF measurements, are described, together with methods of calibrating field strength.

The selection of and method of establishing known field strengths at a site such as may be used for actual operation are described under Section 1. Where the DF Antenna System is sufficiently compact, the use of a screen room and transmission line is recommended and this is described in Section 2.

Standard conditions of temperature, installation alignment, warmup, and modulation are described in Section 3.

1. Site Requirements for DF Testing

For proper evaluation of Radio Direction Finders, it is necessary to make measurements at a site where the electrical characteristics are such that the effects of absorption, reflection, refraction, and radiation of radio frequency energy are negligible. Therefore, a site should be selected very carefully with regard to the terrain and electrical characteristics.

1.1 Visual Inspection

1.1.1 The area should be substantially flat in all directions from the DF Antenna for a distance of at least one wavelength at the lowest operating frequency and should have no more than a gentle slope for several times that distance. Mountainous or hilly country should be avoided.

1.1.2 In order that shoreline refractive errors shall be negligible, the site must be located a distance of five wavelengths or more from the shoreline of large bodies of water.

1.1.3 The conductivity of the soil at the site should be uniform and high. Areas uniformly covered with grass or vegetation usually meet this requirement. Rocky or sandy soil generally is unsatisfactory. Sites having low but uniform conductivity are preferable to sites having high conductivity spotted with rock formation, sand or varying moisture content.

1.1.4 Regions where there are abrupt terrain irregularities such as cliffs, cuts, fills, ravines, or gaps should be avoided.

1.1.5 The site should be free from buildings, tall trees, wire fences, radio antennas, railroad tracks, sharp ground contours, buried metal conductors, overhead conductors, chimney stacks and small bodies of water or other objects capable of reradiating RF energy. No hills or objects should appear above an elevation angle of 3°.

1.1.6 Distances to be maintained between the Direction Finder and various types of obstruction to minimize their effect on DF accuracy are given in Table I.

TABLE I

Obstruction	Minimum Distance to be Maintained
Scattered trees and single small buildings	150 yards
Wire fences	150 yards
Buried conductors (other than DF supply lines)	300 yards
Towers, etc.	500 yards
Overhead conductors and railroad tracks	500 yards
Small bodies of water	150–500 yards
Forests and metal structures	500–1,000 yards
Mountains	5–25 miles

1.2 Electrical Inspection

After the available sites have been visually inspected, the following electrical tests should be made.

1.2.1 Noise Measurement. The noise level of a proposed site should be checked with a field-strength meter to ensure that excessive electrical noise will not prohibit the performance of any desired measurement selected from this standard.

1.2.2 Field Pattern. The purpose of this test is to determine the suitability of a site for Target Transmitter testing of a Direction Finder. This test shall be made prior to the installation of any ground screen.

1.2.2.1 Place a field-strength meter at the spot where the DF Antenna System is to be erected.

1.2.2.2 Position a Target Transmitter at a point at least two wavelengths from the field-strength meter and in a known direction (such as magnetic north); record

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the field strength at this bearing for all standard test frequencies. Repeat the procedure after moving the Target Transmitter at a constant radius for all specified bearings.

1.2.2.3 Plot the data on rectangular coordinate paper as field strength vs bearing for each frequency. Any irregularities indicate an absorption or reflection or refraction of the wave which would affect the accuracy of the Direction Finder.

1.2.2.4 If significant irregularities are evident in the plot, compute the mean value of the field strength for each frequency. If the field strength deviates more than 5 per cent from the mean at any point, the site should not be used without taking corrective steps.

1.2.3 Ground Conditions. Site conditions shall be recorded, including measurements of ground conductivity and dielectric constant and statement made of the methods employed.

1.3 Discussion

A site intended for Target Transmitter tests need not satisfy requirements of *1.1* (*Visual Inspection*) as far as regions beyond the distance to the Target Transmitter are concerned. A site to be used for Statistical Bearing Data, however, should be selected with the greater emphasis upon *1.1* (*Visual Inspection*).

1.4 Method of Establishing a Known Field Strength at the DF Antenna System Site

Where measurement of DF Sensitivity or Pick-up Factor is to be made at the DF site, it is necessary to establish a known field at the center of the DF Antenna Array. The most convenient procedure for establishing a known field depends upon the characteristics of the particular equipment being measured.

1.4.1 Conditions. A Target Transmitter shall be coupled to an antenna connected to provide the Desired Polarization.

1.4.2 Normal Procedure.

1.4.2.1 Install a Target Transmitter at least two wavelengths from the center of the test site.

1.4.2.2 With the DF equipment removed, locate a field-strength meter at the center of the test site. Adjust the Target Transmitter to produce the desired field strength at this test site.

1.4.2.3 Locate a second field-strength monitor or a second field-strength meter at a convenient point behind the Target Transmitter and record the level corresponding to the desired field strength at the test site and record a measure of the target transmitter power.

1.4.2.4 Remove the first field-strength meter and install the DF equipment.

1.4.2.5 Set the Target Transmitter to the power recorded in 1.4.2.3 and read the monitor. This reading is the reference level.

1.4.2.6 Perform the required tests, while adjusting the Target Transmitter to produce the monitor-level determined in 1.4.2.5.

Where the DF Antenna Array cannot be moved without inconvenience, a known field can often be established at its center as follows:

1.4.3 Alternate Procedure.

1.4.3.1 Locate a Target Transmitter at a point at least two wavelengths from the test site.

1.4.3.2 Locate a field-strength meter at a point that is the same distance from the Target Transmitter as is the DF Antenna, and removed by at least two wavelengths from the DF Antenna.

1.4.3.3 Orient the Target Transmitter antenna to produce maximum field-strength response and adjust the Target Transmitter to produce the desired field strength at the field-strength meter location.

1.4.3.4 Reorient the Target Transmitter antenna to produce maximum signal at the DF.

1.4.3.5 Observe the new reading of the field-strength meter as a reference level, and maintain the signal at this level. Under these conditions, the signal field strength at the DF Antenna site has approximately the value obtained in 1.4.3.3 provided that the field at the Monitor is not appreciably distorted by DF Antenna.

1.4.4 Special Requirements for Low-Level Measurements. When measurements requiring controlled field strengths at low levels are to be made in the field, the following procedure may be used for calibrations or monitoring the Target Transmitter.

It is assumed that the available field-strength measuring equipment does not have sufficient sensitivity to measure the low field-strength levels which are required by some of the measurements. Also, it is often the case that the Target Transmitter is not equipped with a calibrated attenuator, although generally some means are provided for decoupling the power from the transmitter to the antenna.

A suggested procedure is to measure the field strength from the Target Transmitter with the transmitter adjusted to produce a sufficiently strong field to be recorded on the meter. The field-strength meter may then be moved close to the Target Transmitter, preferably behind the transmitter and on a line with the center of the collector system and the field strength again established at that point. If the Target Transmitter is readjusted to a new level, a measurement of the field at the second location will establish the ratio of change from which the corresponding field at the center of the collector system may be readily calculated. It is often convenient to monitor the Target Transmitter with an absorption type of wave-meter equipped with a thermocouple meter. The change in transmitter output may be obtained from the meter. The type of meter should be noted to determine whether the meter indications are proportional to the power or to the current.

2. Screen Room and Transmission Line for DF Testing

A laboratory method of simulating, in a shielded room, a radiated field having vertical polarization and

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