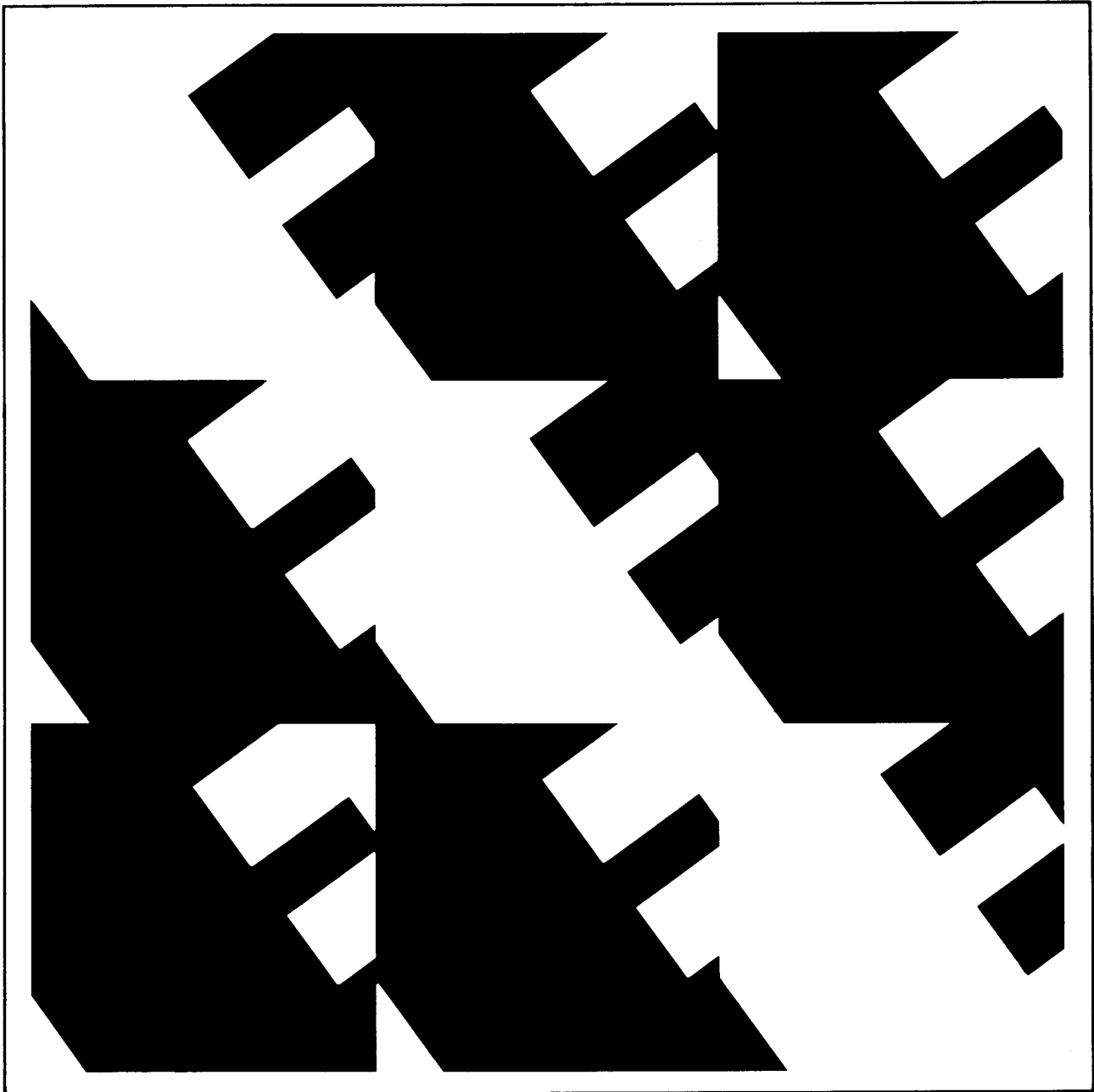


IEEE Standard Definitions of Terms for Antennas



IEEE Std 145-1983



Published by The Institute of Electrical and Electronics Engineers, Inc 345 East 47th Street, New York, NY 10017, USA

June 22, 1983

SH08730

IEEE
Std 145-1983
(Revision of ANSI/IEEE
Std 145-1973)

IEEE Standard Definitions of Terms for Antennas

Sponsor

**Antenna Standards Committee of the
IEEE Antennas and Propagation Group**

© Copyright 1983 by

**The Institute of Electrical and Electronics Engineers, Inc
345 East 47th Street, New York, NY 10017**

*No part of this publication may be reproduced in any form,
in an electronic retrieval system or otherwise,
without the prior written permission of the publisher.*

IEEE Standards documents are developed within the Technical Committees of the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Board. Members of the committees serve voluntarily and without compensation. They are not necessarily members of the Institute. The standards developed within IEEE represent a consensus of the broad expertise on the subject within the Institute as well as those activities outside of IEEE which have expressed an interest in participating in the development of the standard.

Use of an IEEE Standard is wholly voluntary. The existence of an IEEE Standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE Standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard. Every IEEE Standard is subjected to review at least once every five years for revision or reaffirmation. When a document is more than five years old, and has not been reaffirmed, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE Standard.

Comments for revision of IEEE Standards are welcome from any interested party, regardless of membership affiliation with IEEE. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments.

Interpretations: Occasionally questions may arise regarding the meaning of portions of standards as they relate to specific applications. When the need for interpretations is brought to the attention of IEEE, the Institute will initiate action to prepare appropriate responses. Since IEEE Standards represent a consensus of all concerned interests, it is important to ensure that any interpretation has also received the concurrence of a balance of interests. For this reason IEEE and the members of its technical committees are not able to provide an instant response to interpretation requests except in those cases where the matter has previously received formal consideration.

Comments on standards and requests for interpretations should be addressed to:

Secretary, IEEE Standards Board
345 East 47th Street
New York, NY 10017
USA

Foreword

(This Foreword is not a part of IEEE Std 145-1983, IEEE Standard Definitions of Terms for Antennas.)

This standard is a major revision of IEEE Std 145-1973 which it supersedes. It is the second revision of the standard since it was first issued in 1969.

A substantive change included in this revision is the deprecation of the term *directive gain* and its replacement by the term *directivity*. This change brings this standard in line with common usage among antenna engineers and with other international standards, notably those of the International Electrotechnical Commission (IEC).

The 1973 revision was notable in that the interrelationship of gain, impedance, and polarization upon the performance of antennas was recognized. That point of view has been further developed for this revision. The terms *partial gain*, *partial directivity*, *partial effective area* and *partial realized gain (for a given polarization)* have been added. The basic terms, gain, impedance and polarization are left as independent fundamental properties of antennas as before.

For the previous revision, the terms on polarization and array antennas were expanded. Additional terms have been added for this revision making it even more comprehensive in these areas.

The standard also includes terms reflecting the advances in antenna technology that have transpired since 1973. New terms include *microstrip antenna*, *printed circuit antenna*, *periscope antenna*, *active array antenna system*, *contoured beam antenna*, *conformal antenna* and *null-steering antenna*.

The previous revision contained several terms which apply to antennas in physical media. In almost every case it meant that there were two terms with only minor differences in language, one for free space and one for physical media. For this revision, where possible the two terms were combined into a single entry.

The terms pertaining to antenna patterns have been expanded in this revision. New terms include *axial ratio pattern*, *beam solid angle*, *co-polar* and *cross-polar pattern*, *difference pattern*, *directional null*, *far-field pattern*, *Fresnel zone*, *mean side lobe level*, *near-field pattern*, *null steering*, *phase pattern*, *polarization pattern*, *principal half-power beamwidths*, *radiation pattern cut*, *radiation sphere*, *solid beam efficiency* and *shoulder lobe*.

In addition to many new terms, an attempt has been made to improve the language of many of the remaining terms. The Antenna Standards Committee recognizes that further improvements can be made, therefore, suggestions for improvement of this standard will be welcome. They should be sent to:

Secretary
IEEE Standards Board
The Institute of Electrical and Electronics Engineers, Inc
345 East 47th Street
New York, NY 10017

This revision of IEEE Std 145 was prepared by The Working Group on Definitions of Terms for Antennas. The members of this working group were:

R. S. Elliott, Chairman	E. S. Gillespie, Secretary
N. G. Alexopoulos	W. V. T. Rusch
	A. T. Villeneuve

Members of the IEEE Antenna Standards Committee who contributed to this standard were:

E. S. Gillespie, Chairman

N. G. Alexopoulos	R. S. Elliott	W. V. T. Rusch
C. C. Allen	W. J. English	A. C. Schell
D. G. Bodnar	E. S. Gillespie	A. J. Simmons
A. D. Bresler	W. K. Kahn	P. H. Smith
H. V. Cottony*	D. Kajfez	W. T. Tilston
G. A. Deschamps	E. M. Kennaugh	G. P. Tricoles
R. B. Dybdal	D. J. Levine	A. T. Villeneuve
J. D. Dyson	A. C. Newell	M. S. Wheeler
	H. R. Raemer	

*Past chairman.

When the IEEE Standards Board approved this standard on March 11, 1982, it had the following membership:

I. N. Howell, Jr, *Chairman*

Irving Kolodny, *Vice Chairman*

Sava I. Sherr, *Secretary*

C. Y. R. Allen
J. J. Archambault
James H. Beall
John T. Boettger
J. V. Bonucchi
Edward Chelotti
Edward J. Cohen

Len S. Corey
D. C. Fleckenstein
Jay Forster
Kurt Greene
Joseph L. Koepfinger
John E. May

Donald T. Michael*
A. R. Parsons
J. P. Riganati
Robert W. Seelbach
Jay A. Stewart
Clifford O. Swanson
Robert E. Weiler

*Member emeritus

IEEE Standard

Definitions of Terms for Antennas

1. Scope

It is assumed in this standard that an antenna is a passive linear reciprocal device. Thus, where a definition implies the use of an antenna in a transmitting situation, its use in a receiving situation is also implicit unless specifically stated otherwise.

When an antenna or group of antennas is combined with circuit elements that are active, nonlinear, or nonreciprocal, the combination is regarded as a system which includes an antenna. Examples of such cases are an adaptive antenna system and a signal-processing antenna system; the complete conical-scanning, monopulse, and compound interferometer systems also fall in this category.

For terms that are quantitative, it is understood that frequency must be specified. For those in which phase or polarization is a significant part of the definition, a coherent source of power is implied. Whenever a term is commonly used in other fields but has specialized significance in the field of antennas, this is noted in the title.

When applying terms pertaining to the radiation characteristics, such as gain, polarization, beamwidth, etc., to multiple-beam antennas, each port shall be considered to be that of a separate antenna with a single main beam. For polarization-diversity systems which may include active devices, these terms apply to each polarization state for which the antenna is adjusted.

Throughout this standard where phasors are used, or are implied, the time convention shall be taken to be $\exp(j\omega t)$.

2. Definitions

2.1 The definitions of terms contained herein for the most part stand alone and are easily understood out of context. The terms pertaining to gain, directivity and polarization, however, are interrelated and hence require some elaboration.

The viewpoint taken for polarization is that

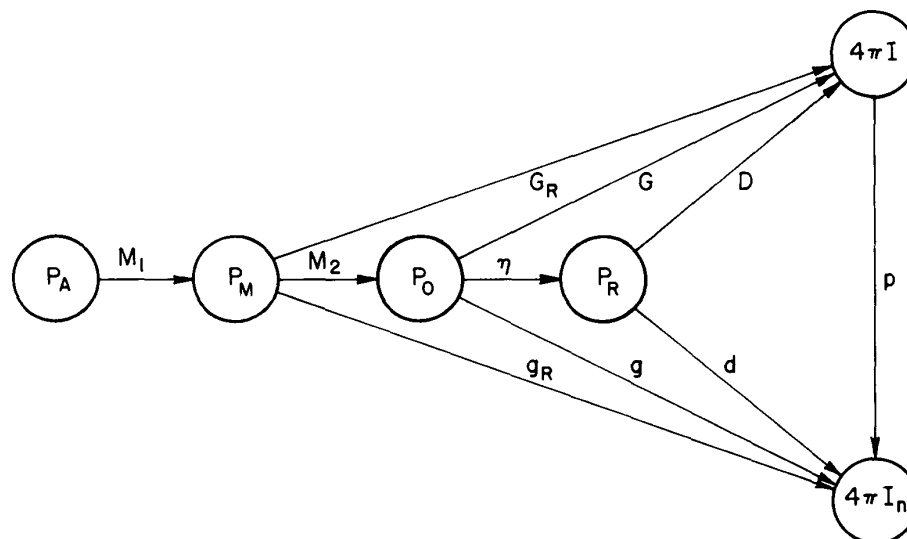
this term can be used in three related meanings.

It can apply

- (1) To a field vector at some point in space
- (2) To a plane wave
- (3) To an antenna

The *polarization of a field vector* specifies the shape, orientation and sense of the ellipse that the extremity of the field vector describes as a function of time. This applies to any field vector: electric field, magnetic field, velocity field in a plasma, displacement field in a solid, etc. In a single-frequency plane wave a specified field vector has the same polarization at every point in space. This is taken as the *polarization of the plane wave*. Conventionally in electromagnetics the electric field is considered rather than the magnetic field. However, in a non-isotropic medium the polarization state of the plane wave requires consideration of all its vector components. The third application of the term polarization is to antennas. The *polarization of an antenna* in a given direction is that of the plane wave it radiates at large distances in that direction. By reciprocity a plane wave coming from that direction whose polarization ellipse has the same axial ratio, orientation, and sense will yield for a given power flux density, the maximum response. For best understanding, the three related definitions of polarization should be read in the above order.

One departure from previous usage should be noted. The definition of the tilt angle of the polarization ellipse now requires that it be measured according to the right-hand rule with the thumb pointing in a reference direction. For a plane wave the reference direction is the direction of propagation. This is advantageous since it removes any ambiguity about the specification of the orientation of the polarization ellipse. It should be noted, however, that the polarization of the antenna is defined as that of the wave it radiates, whether it is used for transmitting or receiving. This means that for the receive case the coordinate system used to describe the polarization of the antenna and the incoming wave are oriented in opposite directions. (See ANSI/IEEE Std 149-1979,



P_A	power available from the generator	η	radiation efficiency
P_M	power to matched transmission line	G_R	realized gain
P_O	power accepted by the antenna	G	gain
P_R	power radiated by the antenna	D	directivity
I	radiation intensity	g_R	partial realized gain
I_n	partial radiation intensity†	g	partial gain
M_1	Impedance mismatch factor 1	d	partial directivity
M_2	Impedance mismatch factor 2	p	polarization efficiency

†All partial quantities correspond to a specified polarization, n .

Fig 1
Gain and Directivity Flow Chart

IEEE Standard Test Procedures for Antennas, Section 11, Polarization.) There are two ways to handle this situation. One is to transform the polarization of the wave into the antenna's coordinate system; or secondly, to define a *receiving polarization* for the antenna which is that of the wave to which the antenna is polarization matched. The latter was chosen both here and in ANSI/IEEE Std 149-1979. This should not be taken to mean that one cannot use the antenna's coordinate system, but rather that if it is done, it should be clearly specified as the polarization of the incoming wave referred to the antenna's (transmitting) polarization. The term *receiving polarization* can also be applied to a nonreciprocal antenna which may receive only.

The interdependence of gain, polarization, and impedance has led to the inclusion of several terms including *partial gain*, *partial directivity*, and *partial realized gain*. The inter-

relationships of these terms and the basic terms, *gain*, *directivity* and *realized gain* are best visualized by referring to the flow chart shown in Fig 1. A similar flow chart can be constructed for a receiving antenna.

2.2 In these definitions, words or phrases in parentheses which are part of the term can be omitted when the term is used, provided they are understood from context. Those words or phrases in brackets can replace the words or phrases which immediately precede them. If bracketed words or phrases appear in several places in the definition, then all bracketed words or phrases must be used together in the definitions. For those cases where two or more terms are used interchangeably, that is, they have the same definition, all of them will be listed with the single definition. The term listed first will be the recommended term. Abbreviations appear after the term enclosed in parentheses.

absolute gain (of an antenna). See **gain (of an antenna)**.

active array antenna system. An array in which all or part of the elements are equipped with their own transmitter or receiver, or both.

NOTE: (1) Ideally, for the transmitting case, amplitudes and phases of the output signals of the various transmitters are controllable and can be coordinated in order to provide the desired aperture distribution.

(2) Often it is only a stage of amplification or frequency conversion that is actually located at the array elements, with the other stages of the receiver or transmitter remotely located.

active impedance (of an array element). The ratio of the voltage across the terminals of an array element to the current flowing at those terminals when all array elements are in place and excited.

active reflection coefficient (of an array element). The reflection coefficient at the terminals of an array element when all array elements are in place and excited.

adaptive antenna system. An antenna system having circuit elements associated with its radiating elements such that one or more of the antenna properties are controlled by the received signal.

Adcock antenna. A pair of vertical antennas separated by a distance of one-half wavelength or less, and connected in phase opposition to produce a radiation pattern having the shape of the figure eight in all planes containing the centers of the two antennas.

aerial*.¹

Alford loop antenna. A multi-element antenna having approximately equal amplitude currents which are in phase and uniformly distributed along each of its peripheral elements and producing a substantially circular radiation pattern in its principal E-plane.

NOTE: This antenna was originally developed as a four-element horizontally polarized UHF loop antenna.

angle tracking. See **tracking**.

¹ A definition followed by an asterisk denotes deprecation.

annular slot antenna. A slot antenna with the radiating slot having the shape of an annulus.

antenna. That part of a transmitting or receiving system which is designed to radiate or to receive electromagnetic waves.

antenna array. See **array antenna**.

antenna effect*.¹

antenna efficiency of an aperture-type antenna. For an antenna with a specified planar aperture, the ratio of the maximum effective area of the antenna to the aperture area.

antenna [aperture] illumination efficiency; normalized directivity. The ratio, usually expressed in percent, of the maximum directivity of an antenna [aperture] to its standard directivity. See **standard directivity**.

NOTE: For planar apertures the standard directivity is calculated by using the projected area of the actual antenna in a plane transverse to the direction of its maximum radiation intensity.

antenna pattern. See **radiation pattern**.

antenna resistance. The real part of the input impedance of an antenna.

aperiodic antenna. An antenna which, over an extended frequency range, does not exhibit a cyclic behavior with frequency of either its input impedance or its pattern.

NOTE: This term is often applied to an electrically small monopole or loop, containing an active element as an integral component, with impedance and pattern characteristics varying but slowly over the extended frequency range.

aperture (of an antenna). A surface, near or on an antenna, on which it is convenient to make assumptions regarding the field values for the purpose of computing fields at external points.

NOTE: The aperture is often taken as that portion of a plane surface near the antenna, perpendicular to the direction of maximum radiation, through which the major part of the radiation passes.

aperture blockage. A condition resulting from objects lying in the path of rays arriving at or departing from the aperture of an antenna.

NOTE: For example, the feed, subreflector, or support structure produce aperture blockage for a symmetric reflector antenna.

aperture distribution; aperture illumination.

The field over the aperture as described by amplitude, phase, and polarization distributions.

aperture illumination. See **aperture distribution**.

aperture illumination efficiency. See **antenna illumination efficiency**.

area. See **effective area (of an antenna)**; **equivalent flat plate area of a scattering object**; **partial effective area (of an antenna)**.

areal beamwidth. For pencil-beam antennas the product of the two principal half-power beamwidths. See **principal half-power beamwidth**.

array antenna; antenna array. An antenna comprised of a number of identical radiating elements in a regular arrangement and excited to obtain a prescribed radiation pattern.

NOTES: (1) The regular arrangements possible include ones in which the elements can be made congruent by simple translation or rotation.

(2) This term is sometimes applied to cases where the elements are not identical or arranged in a regular fashion. For those cases qualifiers shall be added to distinguish from the usage implied in this definition. For example, if the elements are randomly located one may use the term **random array antenna**.

array element. In an array antenna, a single radiating element or a convenient grouping of radiating elements that have fixed relative excitations.

array factor. The radiation pattern of an array antenna when each array element is considered to radiate isotropically.

NOTE: When the radiation patterns of individual array elements are identical, and the array elements are congruent under translation, then the product of the array factor and the element radiation pattern gives the radiation pattern of the entire array.

artificial dielectric. A medium containing a distribution of scatterers, usually metallic, which react as a dielectric to radio waves.

NOTES: (1) The scatterers are usually small compared to a wavelength and embedded in a dielectric material whose effective permittivity and density are intrinsically low.

(2) The scatterers may be in either a regular arrangement or a random distribution.

axial ratio (of a polarization ellipse). The ratio of the major to minor axes of a polarization ellipse.

NOTE: The axial ratio sometimes carries a sign that is taken as plus if the sense of polarization is right-handed and minus if it is left-handed. See **sense of polarization**.

axial ratio pattern. A graphical representation of the axial ratio of a wave radiated by an antenna over a radiation pattern cut.

backfire antenna. An antenna consisting of a radiating feed, a reflector element, and a reflecting surface such that the antenna functions as an open resonator, with radiation from the open end of the resonator.

back lobe. A radiation lobe whose axis makes an angle of approximately 180 degrees with respect to the beam axis of an antenna.

NOTE: By extension, a radiation lobe in the half-space opposed to the direction of peak directivity.

back-scattering cross-section. See **monostatic cross-section**.

bandwidth of an antenna. The range of frequencies within which the performance of the antenna, with respect to some characteristic, conforms to a specified standard.

Bayliss distribution, circular. A continuous distribution over a circular planar aperture which yields a difference pattern with a side-lobe structure similar to that of a sum pattern produced by a Taylor circular distribution.

Bayliss distribution, linear. A continuous distribution of a line source which yields a difference pattern with a side-lobe structure similar to that of a sum pattern produced by a Taylor linear distribution.

beam of an antenna. The major lobe of the radiation pattern of an antenna.

beam angle. See **scan angle**.

beam axis (of a pencil-beam antenna). The direction, within the major lobe of a pencil-beam antenna, for which the radiation intensity is a maximum.

beam coverage solid angle (of an antenna over a specified surface). The solid angle, measured in steradians, subtended at the antenna by the footprint of the antenna beam on a specified