

IEEE Standard Definitions of Terms for Radio Wave Propagation

Sponsor
**Wave Propagation Standards Subcommittee
of the
IEEE Antennas and Propagation Society**

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Abstract: IEEE Std 211-1990, *IEEE Standard Definitions of Terms for Radio Wave Propagation*, identifies terms currently in use in the field of radio wave propagation. Standard definitions for those terms are established.

Keywords: Radio wave propagation; glossary; terminology; definitions; dictionary

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Foreword

(This Foreword is not part of IEEE Std 211-1990, IEEE Standard Definitions of Terms for Radio Wave Propagation.)

This constitutes the second revision to the original ANSI/IEEE Std 211-1969. The early history of ANSI/IEEE Std 211 was described in a Foreword to the first (1977) revision. The work on this second revision started on "tabled" definitions almost as soon as the 1977 version went to press. Chairmen of the Wave Propagation Standards Committee Subcommittee on Definitions have included Kurt Toman, C. H. Liu, John M. Kelso, and George H. Hagn, the current chairman. The primary developers of this second revision are listed in the acknowledgements along with others who materially assisted the work. Within the IEEE, the work has been coordinated with the APS Antenna Standards Committee and the following societies: EMC, COM, and Instrumentation and Measurements. It has also been coordinated with the IEEE Dictionary (SCC10). The current version has been coordinated with the CCIR (International Radio Consultative Committee), the IEC (International Electrotechnical Commission), and with U.S. and Canadian officials of URSI (International Union of Radio Science).

The fields covered include the following where pertinent to electromagnetic wave propagation: radio astronomy, optical waves, gravity waves, plasma waves, ionosphere, magnetosphere, and magneto-hydrodynamic, acoustic, and electrostatic waves.

S.I. (rationalized MKS) units have been used throughout.

As aptly noted in the Foreword to the first revision, "The need for revising a definitions standard transcends its publication date and is essentially continuous." The current revision is one step in the continuous flow of this process.

This standard was prepared by a Wave Propagation Standards Committee (WPSC) Subcommittee on Definitions consisting of:

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The subcommittee, the WPSC, and the APS appreciate the assistance of all those who contributed to this standard.

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IEEE Standard Definitions of Terms for Radio Wave Propagation

absorption. The irreversible conversion of the energy of an electromagnetic wave into another form of energy as a result of wave interaction with matter.

absorption (frequency) band. A band of frequencies for which a medium is considered to be an absorbing medium.

absorption, deviative. Ionospheric absorption that occurs when the refractive index is appreciably less than unity.

absorption, ionospheric. The loss of energy from an electromagnetic wave caused by collisions in the ionosphere, primarily between electrons and neutral species and electrons and ions.

absorption, non-deviative. Ionospheric absorption that occurs when the refractive index remains close to unity.

absorption, polar cap. The intense absorption of radio waves in polar regions caused by the arrival of high energy solar protons, concentrated in this region by the lines of force of the Earth's magnetic field.

acoustic-gravity wave. In the atmosphere, a low-frequency wave whose restoring forces are compressional, gravitational and buoyant.

albedo. (1) In astronomy (where the sizes of objects/surfaces are extremely large in comparison to a wavelength), the ratio of the total radiation reflected (scattered) from an object to the total incident power.
2) In transport theory or particle scattering (where the size of the object is not extremely large), the ratio of the total scattering cross-section to the sum of the scattering and absorption cross-sections.

Alfvén velocity (V_a). The characteristic velocity of an Alfvén wave, given by:

$$V_a = H_o \left[\frac{\mu}{\rho} \right]^{1/2}$$

where μ is the permeability, H_o is the static magnetic field strength, and ρ is the mass density of the conducting fluid.

Alfvén wave. In a homogeneous magneto-ionic medium, the magneto-hydrodynamic wave that propagates in the direction of the static magnetic field, with associated electric and magnetic fields and fluid particle velocities oriented perpendicular to the direction of propagation.

amplitude. Of a sinusoidally varying quantity, the maximum value of this quantity. *Note:* Sometimes the rms value, rather than the peak value, is used to characterize the amplitude of a sinusoidal oscillation.

angle of arrival. Of a wave, the angle between the negative of the propagation vector and a reference direction.

angle of incidence. At a point on a surface, the acute angle between the normal to this surface and the direction of propagation of an incident wave.

angular frequency (ω). Of a sinusoidal wave, 2π times the frequency. The angular frequency is also called the radian frequency.

antenna temperature. The temperature of a black body that, when placed around a matched antenna that is similar to the actual antenna but loss-free, produces from this antenna the same available noise power, in a specified frequency range, as the actual antenna in its normal electromagnetic environment.

antipodal focusing. Ionospheric focusing observed in the vicinity of the antipodal point.

atmospheric radio duct. A layer in the atmosphere within which radio waves propagate with low attenuation.

atmospherics. Transient bursts of electromagnetic radiation arising from natural electrical disturbances in the lower atmosphere. *Note:* In the past, the term “static” was used to include atmospherics and other radio noise. The term “sferics” is in current use.

attenuation, of an electromagnetic wave. The decrease in amplitude of a field with distance or with changes in the propagation path in excess of the decrease due to a geometrical spreading factor. *See also:* **spreading factor.**

attenuation constant. The magnitude of the attenuation vector.

attenuation vector ($\vec{\alpha}$). The real part of the propagation vector ($\vec{\gamma}$). The attenuation vector points in the direction of maximum decrease in amplitude.

aurora. Collective name of optical, electrical and magnetic phenomena, generally at high latitudes, resulting from direct excitation of the upper atmosphere by energetic particles.

auroral attenuation. The attenuation of radio waves propagating through the D and E regions of the ionosphere when additional ionization is produced by an aurora.

auroral hiss. Audio-frequency electromagnetic noise associated with auroras.

auroral zone, auroral oval. An annular region situated between approximately 60 degrees and 70 degrees geomagnetic latitude, north or south, in which auroras are frequently present.

backscatter. The scattering of waves back toward the source.

bandwidth, coherent; dispersive bandwidth. *Same as:* **frequency selective bandwidth.**

bandwidth, frequency selective. The inverse of the product $2\pi\sigma_\tau$, where σ_τ is the time delay spread.

Brewster angle. The angle of incidence of a wave on the planar bounding surface of a lossless medium for which the reflection coefficient for parallel polarization is zero. *Note:* For a lossy medium, the pseudo-Brewster angle is that angle at which the modulus of the reflection coefficient is a minimum.

brightness of surface. The power radiated per unit area, per unit bandwidth, per unit solid angle.

brightness temperature. Of a region on an extended source at a given wavelength, the temperature of a black-body radiator that has the same brightness.

characteristic impedance. Of a transmission line, the ratio of the complex voltage between the conductors to the complex current on the conductors, taken at a common reference plane. These voltages and currents must be associated with waves traveling in the same direction.

characteristic wave. A wave that propagates in a homogeneous anisotropic medium with unchanging polarization. *See:* **ordinary wave** and **extraordinary wave.**

circularly polarized wave. An electromagnetic wave for which the locus of the tip of the electric field vector is a circle in a plane orthogonal to the wave normal. This circle is traced at a rate equal to the angular frequency of the wave. *See also:* **left-handed polarized wave** and **right-handed polarized wave.**

coherence. The correlation between electromagnetic fields at points separated in space or in time or both.

coherence function $[R(\Delta\vec{r}, \tau)]$. The expected value of the product of a component of the complex field (F_x) at a given location ($\vec{r}$) and time t and the complex conjugate of that field component (F_x^*) at a different location ($\vec{r} + \Delta\vec{r}$) and time ($t + \tau$):

$$R(\Delta\vec{r}, \tau) = [F_x(\vec{r}, \tau) F_x^*(\vec{r} + \Delta\vec{r}, t + \tau)]$$

Notes: (1) This definition assumes that the statistics of the fields are homogeneous and stationary. (2) The normalized coherence function, also called the mutual coherence function, is the coherence function divided by the expected value of the square of the magnitude of the field.

collision frequency. In a plasma, the average number of collisions per second of a charged particle of a given species with particles of another or the same species.

conductivity (σ). A macroscopic material property that relates the conduction current density ($\vec{J}$) to the electric field ($\vec{E}$) in the medium. For a monochromatic wave in a linear medium, that relationship is described by the (phasor) equation:

$$\vec{J} = \vec{\sigma} \cdot \vec{E}$$

where $\vec{\sigma}$, the conductivity, is a tensor, generally frequency dependent and $\vec{J}$ is in phase with $\vec{E}$. For an isotropic medium, the tensor conductivity reduces to a scalar conductivity.

cosmic noise. Noise-like radio waves originating from extragalactic sources.

critical frequency, of an ionospheric layer. The limiting frequency below which a normally incident magneto-ionic wave component is reflected by, and above which it penetrates through, an ionospheric layer.

cross-polarization. The polarization orthogonal to a reference polarization. *See: orthogonal polarization.*

cross-polarization discrimination. The ratio of the signal level at the output of a receiving antenna, nominally co-polarized with the transmitting antenna, to the output of a receiving antenna of the same gain but nominally orthogonally polarized to the transmitting antenna.

cross-polarization isolation. The ratio of the wanted signal level to the unwanted signal level in the same receiver channel when the

transmitting antenna is radiating nominally orthogonally polarized signals at the same frequency and power level.

cyclotron frequency. *See: gyro-frequency.*

cylindrical wave. A wave whose equiphasic surfaces form a family of coaxial cylinders.

D layer. An ionized layer in the D region.

D region. The region of the terrestrial ionosphere between about 50 and 90 km altitude. *Note:* The D region is responsible for most of the daytime attenuation of LF, MF and HF radio waves.

Debye length (L_D). That distance in a plasma over which a free electron may move under its own kinetic energy before it is pulled back by the electrostatic restoring forces of the polarization (ion) cloud surrounding it. Over this distance, a net charge density can exist in an ionized gas. The Debye length is given by:

$$L_D = 6.9 \left[\frac{T_e}{N_e} \right]^{1/2}$$

where T_e is the electron temperature, and N_e is the electron number density.

decorrelation distance. The direction-dependent distance over which the mutual coherence function falls to $1/e$ of its maximum value. Also called correlation length.

decorrelation time (τ_o). The time required for the mutual coherence function to decay to $1/e$ of its maximum value.

defocusing. The failure of rays to converge.

diffracted wave. An electromagnetic wave generated when an incident wave encounters one or more obstacles or is limited by openings.

diffraction. The deviation of the direction of energy flow of a wave, not attributable to reflection and/or refraction, when it passes an obstacle, a restricted aperture, or other inhomogeneities in a medium.

direct wave. A wave propagated over an unobstructed ray path from a source to a point.

direction of polarization. Of an elliptically polarized wave, the direction of the major axis of the electric vector ellipse.

direction of propagation. At any point in a medium, the direction of the time-averaged energy flow. *See: Poynting vector.*

dispersion (of a wave). The variation of the phase velocity with frequency.

dispersion relation. The functional relationship between the angular frequency, ω , and the wave vector, $\vec{k}$, for waves in a source-free medium. For a dispersionless medium, $\vec{k}$ is linearly proportional to ω .

dispersive medium. A medium where the phase velocity depends on frequency.

Doppler effect. For an observer, the apparent change in frequency of a wave when there is relative motion between the source and the observer.

Doppler spread. *See: spread, Doppler.*

ducting. Guided propagation of radio waves inside a tropospheric radio duct. *See also: atmospheric radio duct and tropospheric duct.*

E layer. An ionized layer in the E region. The ionization within the E region is highly correlated with the incident solar flux. Therefore, the normal E layer is present only during daytime.

E region. The region of the terrestrial ionosphere between about 90 and 150 km altitude.

edge diffraction. Diffraction by a transverse obstacle with a relatively sharp profile, located between the transmission and reception points. Diffraction over a very sharp profile is frequently called knife-edge diffraction.

effective radius of the earth. An effective value for the radius of the earth that is used in place of the geometrical radius to correct approximately for atmospheric refraction when the index of refraction changes linearly with height, and the rays propagate nearly

parallel to the earth (with low grazing angles). *Note:* Under conditions of standard refraction, the effective radius of the earth is 8.5×10^6 meters, or 4/3 the geometrical radius.

electric displacement ($\vec{D}$). *Same as: electric flux density.*

electric field ($\vec{E}$). The electric force that acts on a unit electric charge independently of the velocity of that charge.

electric field strength ($|\vec{E}|$). The magnitude of the electric field at a point in the field. *Note:* This term has sometimes been called the electric field intensity, but such use is deprecated, since intensity connotes power in optics and radiation.

electric flux density ($\vec{D}$). A vector quantity related to the charge displaced within the medium by an electric field. The electric flux density is that function whose divergence is the charge density. *Note:* Using phasor notation, the electric flux density is given by:

$$\vec{D} = \bar{\epsilon} \cdot \vec{E}$$

where $\vec{D}$ is the electric flux density, $\bar{\epsilon}$ is the permittivity in the medium, and $\vec{E}$ is the electric field. In an isotropic medium, ϵ is a scalar and $\vec{D}$ is parallel to $\vec{E}$. In an anisotropic medium, $\bar{\epsilon}$ is a tensor and $\vec{D}$ and $\vec{E}$ are not necessarily parallel.

electrical length. For a wave of a given frequency, a distance between field points, expressed in wavelengths of the wave in the medium. *Note:* The electrical length is sometimes expressed in radians or degrees.

electromagnetic field. A time-varying field, associated with the electric or magnetic forces and described by Maxwell's equations.

electromagnetic pulse (EMP). A transient high-intensity electromagnetic field. EMP is commonly associated with nuclear explosions in or near the Earth's atmosphere; however, electromagnetic pulses can arise from other sources, such as lightning.

electromagnetic spectrum. The spectrum of electromagnetic radiation, consisting of: gam-