IEEE Standard #211
Definitions of Terms for
RADIO WAVE PROPAGATION

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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 its interaction with matter.

Angular Frequency The angular frequency of a periodic function is 2π times the frequency.

Atmospheric Duct A layer in the troposphere within which radio waves of sufficiently high frequency propagate with an abnormally low rate of decrease of amplitude with distance. The duct extends from the level of a local minimum of the modified index of refraction as a function of height down to the level where the minimum value is again encountered, or down to the surface bounding the atmosphere if the minimum value is not again encountered.

Attenuation Of a quantity associated with a traveling wave in a homogeneous medium, the decrease of its amplitude with increasing distance from the source, excluding the decrease due to spreading.

Attenuation Constant The real part of the propagation constant.

Attenuation Ratio The magnitude of the propagation ratio.

Attenuation Vector Of a field quantity, the vector pointing in the direction of maximum decrease of amplitude, whose magnitude is the attenuation constant.

Circularly Polarized Wave An electromagnetic wave for which either the electric or the magnetic field vector at a fixed point describes a circle. (*Note*: This term is usually applied to transverse waves. *See* Left-Handed Polarized Wave and Right-Handed Polarized Wave.)

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.

Conical Wave A wave whose equiphase surfaces asymptotically form a family of coaxial circular cones.

Critical Frequency The limiting frequency below which a magneto-ionic wave component is reflected by, and above which it penetrates through, an ionospheric layer when the waves are incident normal to the layer.

Cyclotron Frequency Same as Gyro Frequency.

Cylindrical Wave A wave whose equiphase surfaces form a family of coaxial or confocal cylinders.

***D* Layer** An ionized layer in the *D* region.

***D* Region** The region of the terrestrial ionosphere between about 40 and 90 kilometers altitude responsible for most of the attenuation of radio waves in the range 1 to 100 megahertz.

Debye Length 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 cloud surrounding it. Over this distance a net charge density can exist in an ionized gas. The Debye length is given by

$$l_D = \sqrt{\frac{\epsilon_0 k T_e}{e^2 N_e}}$$

where ϵ_0 is the permittivity of vacuum, k is Boltzmann's constant, e is the charge of the electron, T_e is the electron temperature, and N_e is the electron number density.

Direct Wave A wave propagated directly from a source to a point.

Direction of Polarization For 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 time-average energy flow.

***E* Layer** An ionized layer in the *E* region.

***E* Region** The region of the terrestrial ionosphere between about 90 and 160 kilometers altitude.

Effective Radius of the Earth An effective value for the radius of the earth, which is used in place of the geometrical radius to correct approximately for atmospheric refraction when the index of refraction in the atmosphere changes linearly with height. (*Note*: Under conditions of standard refraction the effective radius of the earth is 8.5×10^6 meters, or $\frac{4}{3}$ the geometrical radius.)

Electric Field A state of the region in which stationary charged bodies are subject to forces by virtue of their charges.

Electric Field Strength Same as Electric Field Vector. (*Note*: This term has sometimes been called the *electric field intensity*, but such use of the word "intensity" is deprecated in favor of field strength, since intensity connotes power in optics and radiation.)

Electric Field Vector At a point in an electric field, the force per unit charge acting on a stationary positive charge. (*Note*: This may be expressed either in newtons per coulomb or in volts per meter. This term has sometimes been called the *electric field intensity*, but such use of the word "intensity" is deprecated in favor of field strength since intensity connotes power in optics and radiation.)

Electric Flux Density A quantity related to the charge displaced within the dielectric by application of an electric field. The electric flux density is that vector point function

whose divergence is the charge density, and which is proportional to the electric field in regions free of polarized matter. The electric flux density is given by

$$\mathbf{D} = \epsilon\mathbf{E}$$

where **D** is the electric flux density, ϵ is the permittivity, and **E** is the electric field vector. (*Note 1*: In a nonisotropic medium, ϵ is a tensor and **D** is not necessarily parallel to **E**. In an isotropic medium, ϵ is a scalar and **D** is parallel to **E**. *Note 2*: The concept of a disk-like (Kelvin) cavity, properly oriented normal to **D**, is frequently used to visualize and compute the **D** vector in material media. *Note 3*: The electric flux density at a point is equal to the charge per unit area which would appear on one face of a small thin metal plate introduced in the electric field at the point and so oriented that this charge is a maximum.)

Electric Vector Same as Electric Field Vector.

Electrical Length For a wave of a given frequency, a distance in a medium expressed in wavelengths of the wave in the medium. (*Note*: The electrical length is sometimes expressed in radians or degrees.)

Electromagnetic Wave A wave characterized by variations of electric and magnetic fields. (*Note*: Electromagnetic waves are known as radio waves, heat waves, light waves, etc., depending on the frequency.)

Elliptically Polarized (Electromagnetic) Wave An electromagnetic wave for which either the electric or the magnetic field vector at a point describes an ellipse.

Envelope Delay The time of propagation, between two points, of the envelope of a wave. It is equal to the rate of change with angular frequency of the difference in phase between these two points. It has significance over the band of frequencies occupied by the wave only if this rate is approximately constant over that band.

Equiphase Surface Any surface in a wave over which the field vectors at the same instant are in the same phase or 180° out of phase.

Extraordinary-Wave Component The magneto-ionic wave component in which the electric vector rotates in the opposite sense to that for the ordinary-wave component. (*See* Ordinary-Wave Component.)

***F* Region** The region of the terrestrial ionosphere above about 160 kilometers altitude.

***F*$_1$ Layer** The lower of the two ionized layers normally existing in the *F* region in the day hemisphere.

***F*$_2$ Layer** The single ionized layer normally existing in the *F* region in the night hemisphere and the higher of the two layers normally existing in the *F* region in the day hemisphere.

Fading The variation of radio field strength caused by changes in the transmission path with time.

Faraday Rotation The process of rotation of the polarization ellipse of an electromagnetic wave in a magneto-ionic medium. (*See* Elliptically Polarized Wave.)

Ground Wave From a source in the vicinity of a planetary surface, that wave which would exist in the vicinity of that surface in the absence of an ionosphere.

Group Velocity Of a traveling wave, the velocity of propagation of the envelope, provided that this moves without significant change of shape. The magnitude of the group velocity is equal to the reciprocal of the rate of change of phase constant with angular frequency. (*Note*: Group velocity differs in magnitude from phase velocity if the phase velocity varies with frequency, and differs in direction from phase velocity if the phase velocity varies with direction.)

Guided Wave A wave whose energy is concentrated within or near boundaries between materials of different properties, which is propagated along those boundaries.

Gyro Frequency The lowest natural frequency at which charged particles spiral in a fixed magnetic field. It is a vector quantity expressed by

$$\mathbf{f}_h = \frac{1}{2\pi}\frac{q\mathbf{B}}{m}$$

where q is the charge of the particles, **B** is the magnetic induction, and m is the mass of the particles.

Horizontally Polarized Wave A linearly polarized wave whose electric field vector is horizontal.

Hybrid Wave An electromagnetic wave in which either the electric or magnetic field vector is linearly polarized normal to the plane of propagation and the other vector is elliptically polarized in this plane. (*See* Transverse-Electric Hybrid Wave and Transverse-Magnetic Hybrid Wave.)

Incident Wave In a medium of certain propagation characteristics, a wave which impinges on a discontinuity or a medium of different propagation characteristics.

Incoherent Scattering When waves encounter matter, a disordered change in the phase of the waves.

Ionosphere That part of a planetary atmosphere where ions and electrons are present in quantities sufficient to affect the propagation of radio waves.

Ionospheric Wave A radio wave propagated by reflection or refraction from an ionosphere. (*Note*: This is sometimes called a Sky Wave.)

Left-Handed (Counterclockwise) Polarized Wave An elliptically polarized electromagnetic wave in which the rotation of the electric field vector with time is counterclockwise for a stationary observer looking in the direction of the wave normal. (*Note*: For an observer looking from a receiver toward the apparent source of the wave, the direction of rotation is reversed.)

Limiting Polarization The resultant polarization of a wave after it has emerged from a magneto-ionic medium.

Linearly Polarized Wave An electromagnetic wave whose electric and magnetic field vectors always lie along fixed lines at a given point.

Lowest Useful High Frequency The lowest high frequency effective under specified conditions for ionospheric propagation of radio waves between two specified points on a planetary surface. (*Note*: The lowest useful high frequency is determined by factors such as absorption, transmitter power, antenna gain, receiver characteristics, type of service, and noise conditions.)

Magnetic Field A state of a region such that a moving charged body in the region is subject to a force in proportion to its charge and to its velocity.

Magnetic Field Strength The magnitude of the magnetic field vector.

Magnetic Field Vector At any point in a magnetic field, the magnetic induction divided by the permeability of the medium.

Magnetic Vector Same as Magnetic Field Vector.

Magneto-Ionic Medium An ionized gas which is permeated by a fixed magnetic field.

Magneto-Ionic Mode Same as Magneto-Ionic Wave Component.

Magneto-Ionic Wave Component At a given frequency, either of the two plane electromagnetic waves which can travel in a homogeneous magneto-ionic medium without change of polarization.

Maximum Usable Frequency The highest frequency of radio waves that can be used between two points under specified conditions for reliable transmission by reflection from the regular layers of the ionosphere.

Modified Index of Refraction In the troposphere, the sum of the refractive index at a given height above the mean geometrical surface and the ratio of this height to the mean geometrical radius.

O Wave Same as Ordinary-Wave Component.

Optimum Working Frequency The most effective frequency for ionospheric propagation of radio waves between two points under specified conditions.

Ordinary-Wave Component That magneto-ionic wave component deviating the least, in most of its propagation characteristics, relative to those expected for a wave in the absence of a fixed magnetic field. More exactly, if at fixed electron density, the direction of the fixed magnetic field were rotated until its direction was transverse to the direction of phase propagation, the wave component whose propagation would then be independent of the magnitude of the fixed magnetic field.

Penetration Frequency Same as Critical Frequency.

Periodic Electromagnetic Wave A wave in which the electric field vector is repeated in detail in either of two ways: 1) at a fixed point, after the lapse of a time known as the period, or 2) at a fixed time, after the addition of a distance known as the wavelength.

Phase Constant (Wavelength Constant) The imaginary part of the propagation constant.

Phase Vector Of a wave, the vector in the direction of the wave normal, whose magnitude is the phase constant.

Phase Velocity Of a traveling wave at a single frequency, the velocity of an equiphase surface along the wave normal.

Plane Earth Factor The ratio of the electric field strength that would result from propagation over an imperfectly conducting plane earth to that which would result from propagation over a perfectly conducting plane.

Plane of Polarization For a plane polarized wave, the plane containing the electric and magnetic field vectors.

Plane of Propagation Of an electromagnetic wave, the plane containing the attenuation vector and the wave normal; in the common degenerate case where these vectors have the same direction, the plane containing the electric vector and the wave normal.

Plane Polarized Wave At a point in a homogeneous medium, an electromagnetic wave whose electric and magnetic field vectors at all times lie in a fixed plane.

Plane Wave A wave whose equiphase surfaces form a family of parallel planes.

Plasma Frequency A natural frequency of oscillation of charged particles in a plasma given by

$$f_N = \frac{1}{2\pi}\sqrt{\frac{Nq^2}{\epsilon_0 m}}$$

where q is the charge per particle, m is the particle mass, N is the particle number density, and ϵ_0 is the permittivity of free space. (*Note*: For electrons, $f_N = 8.979\sqrt{N}$ in SI units.)

Plasma Sheath A layer of charged particles of substantially one sign which accumulates around a body in a plasma.

Polarization Of an electromagnetic wave, a description of the angular variation of either the electric or the magnetic field vector at a fixed point. (*See* Elliptically Polarized Wave.)

Power Density Of a traveling wave, the time average of the Poynting vector.

Power Flux Density Same as Power Density.

Propagation Constant Of a traveling wave in a homogeneous medium, the negative of the partial logarithmic

derivative, with respect to distance in the direction of the wave normal, of the phasor quantity describing the wave. (*Note*: In the case of cylindrical or spherical traveling waves, the amplitude factors $1/\sqrt{r}$ and $1/r$, respectively, are not to be included in the phasor quantity.)

Propagation Factor For a wave propagating from one point to another, the ratio of the complex electric field strength at the second point to that value which would exist at the second point if propagation took place in a vacuum.

Propagation Ratio For a wave propagating from one point to another, the ratio of the complex field strength at the second point to that at the first point.

Propagation Vector For a traveling wave at a given frequency, the complex vector whose real part is the attenuation vector and whose imaginary part is the phase vector.

Radio Field Strength The electric or magnetic field strength at radio frequency.

Radio Frequency A frequency at which electromagnetic radiation may be detected and amplified as an electric current at the wave frequency.

Radio Gain Of a radio system, the reciprocal of the system loss.

Radio Horizon Of an antenna, the locus of the farthest points at which direct rays from the antenna become tangential to a planetary surface. (*Note*: On a spherical surface the horizon is a circle. The distance to the horizon is affected by atmospheric refraction.)

Radio Wave An electromagnetic wave of radio frequency. (*Note*: Current usage includes frequencies up to 3000 gigahertz.)

Radio Wave Propagation The transfer of energy by electromagnetic radiation at radio frequencies.

Refracted Wave That part of an incident wave which travels from one medium into a second medium.

Refractive Index Of a wave transmission medium, the ratio of the phase velocity in a vacuum to that in the medium.

Refractive Modulus In the troposphere, the excess over unity of the modified index of refraction, expressed in millionths. It is represented by M and is given by the equation

$$M = (n + h/a - 1)10^6$$

where a is the mean geometrical radius of the surface and n is the index of refraction at a height h above the local surface.

Relative Refractive Index Of two media, the ratio of their refractive indices.

Right-Handed (Clockwise) Polarized Wave An elliptically polarized electromagnetic wave in which the rotation of the electric field vector with time is clockwise for a stationary observer looking in the direction of the wave normal. (*Note*: For an observer looking from a receiver toward the apparent source of the wave, the direction of rotation is reversed.)

Selective Fading Fading which is different at different frequencies in a frequency band occupied by a modulated wave.

Shadow Factor The ratio of the electric field strength which would result from propagation over a sphere to that which would result from propagation over a plane, other factors being the same.

Sinusoidal Electromagnetic Wave In a homogeneous medium, a wave whose electric field vector is proportional to the sine (or cosine) of an angle that is a linear function of time, or of a distance, or of both.

Sky Wave Same as Ionospheric Wave.

Spectral Power Density The power density per unit bandwidth.

Spectral Power Flux Density Same as Spectral Power Density.

Spherical Wave A wave whose equiphase surfaces form a family of concentric spheres.

Standard Propagation The propagation of radio waves over a smooth spherical earth of uniform dielectric constant and conductivity, under conditions of standard refraction in the atmosphere.

Standard Refraction The refraction which would occur in an atmosphere in which the refractive index decreased uniformly with height above the earth at the rate of 39×10^{-9} per meter. (*Note*: standard refraction may be included in ground wave calculations by use of an effective earth radius of 8.5×10^6 meters, or $\frac{4}{3}$ the geometrical radius of the earth.)

Standing Wave A wave in which, for any component of the field, the ratio of its instantaneous value at one point to that at any other point does not vary with time.

Surface Duct An atmospheric duct for which the lower boundary is the surface bounding the atmosphere.

System Loss Of a radio system, the transmission loss plus the losses in the transmitting and receiving antennas.

Transmission Loss Of a radio system consisting of a transmitting antenna, receiving antenna, and the intervening propagation medium, the ratio of the power radiated from the transmitting antenna to the resultant power which would be available from an equivalent loss-free receiving antenna.

Transmitted Wave Same as Refracted Wave.

Transverse-Electric Hybrid Wave An electromagnetic wave in which the electric field vector is linearly polarized normal to the plane of propagation and the magnetic field vector is elliptically polarized in this plane.

Transverse-Electric Wave An electromagnetic wave in which the electric field vector is everywhere perpendicular to the wave normal.

Transverse-Electromagnetic Wave An electromagnetic wave in which both the electric and magnetic field vectors are everywhere perpendicular to the wave normal.

Transverse-Magnetic Wave An electromagnetic wave in which the magnetic field vector is everywhere perpendicular to the wave normal.

Transverse-Magnetic Hybrid Wave An electromagnetic wave in which the magnetic field vector is linearly polarized normal to the plane of propagation and the electric field vector is elliptically polarized in this plane.

Traveling Plane Wave A plane wave each of whose frequency components has an exponential variation of amplitude and a linear variation of phase with distance.

Troposphere That part of a planetary atmosphere in which temperature generally decreases with altitude, clouds form, and convection is active. (*Note*: Experiments indicate that the earth's troposphere occupies the space above the earth's surface to a height of about 10 kilometers.)

Uniform Plane Wave A plane wave in which the electric and magnetic field vectors have constant amplitude over the equiphase surfaces. (*Note*: Such a wave can only be found in free space at an infinite distance from the source.)

Vertically Polarized Wave A linearly polarized wave whose electric field vector is vertical. (*Note*: The term "vertical polarization" is commonly employed to characterize ground wave propagation in the medium frequency broadcast band; these waves, however, have a small component of electric field in the direction of propagation due to finite ground conductivity.)

Virtual Height The apparent height of an ionized layer determined from the time interval between the transmitted signal and the ionospheric echo at vertical incidence, assuming that the velocity of propagation is the velocity of light in a vacuum over the entire path.

Waveguide A system of material boundaries capable of guiding waves.

Wave Interference The variation of wave amplitude with distance or time, caused by the superposition of two or more waves. (*Note*: As most commonly used, the term refers to the interference of waves of the same or nearly the same frequency.)

Wavelength Of a sinusoidal wave, the distance between points of corresponding phase of two consecutive cycles. The wavelength λ is related to the phase velocity v and the frequency f by $\lambda = v/f$.

Wave Normal Of a traveling wave, the direction normal to an equiphase surface taken in the direction of increasing phase.

X Wave Same as Extraordinary-Wave Component.