

IEEE Standard Radar Definitions

Sponsor

**Radar Systems Panel
of the
IEEE Aerospace and Electronic Systems Society**

Approved 16 September 1997

IEEE Standards Board

Abstract: Definitions for the purpose of promoting clarity and consistency in the use of radar terminology are provided. The definitions represent the consensus of a panel of radar experts.

Keywords: radar, terminology

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345 East 47th Street, New York, NY 10017-2394, USA

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ISBN 1-55937-958-8

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Introduction

(This introduction is not a part of IEEE Std 686-1997, IEEE Standard Radar Definitions.)

This standard is published for the purpose of promoting clarity and consistency in the use of radar terminology. The definitions represent the consensus (reached after several rounds of review, comment, and revision) of a panel of radar experts, including authors of several books on radar. It is intended that these definitions serve as a guide to standardization of meanings.

Originally, radar definitions were included in IEEE Std 172-1971, IEEE Standard Definitions of Navigation Aid Terms. In 1974 the Radar Systems Panel of the IEEE Aerospace and Electronic Systems Society set out to create a separate standard devoted to radar definitions. The result was the first edition of this standard, IEEE Std 686-1977, IEEE Standard Radar Definitions. In order to avoid overlap and conflict with the radar definitions then existing in IEEE Std 172-1971, the IEEE Standards Board allowed only new radar terms, not already in that standard, to be included in IEEE Std 686-1977.

The second edition, IEEE Std 686-1982, included terms formerly found in IEEE Std 172-1971, with the exception of a few terms that are common to both fields, and new or updated terms. IEEE Std 686-1982 updated, added, and/or deleted standard radar definitions. The third edition, IEEE Std 686-1990, continued the updating process. The current edition, IEEE Std 686-1997, adds new terms, revises others, and deletes a number of obsolete terms that no longer appear in radar literature or usage. As radar technology and literature evolve, new terms will appear; further updating at approximately five-year intervals is planned.

The work of preparing the drafts of this standard, integrating all the comments, resolving differences, and coordinating this standard with other IEEE standards was accomplished by the Terminology Committee of the Radar Systems Panel of the IEEE Aerospace and Electronic Systems Society. The Terminology Committee had the following membership at the time this standard was approved:

David K. Barton, *Chair*

Merrill I. Skolnik

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The Radar Systems Panel of the IEEE Aerospace and Electronic Systems Society participated in reviewing successive drafts of this standard and recommending revisions, additions, and deletions. The Radar Systems Panel comprised the balloting group of this standard and had the following membership at the time this standard was approved:

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The Terminology Committee wishes to thank Mr. George Hagn, Secretary of the Wave Propagation Standards Committee of the IEEE Antennas and Propagation Society, for his contributions to coordination with that standard and suggestions for many revisions to radar terms.

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IEEE Standard Radar Definitions

acquisition: The process of establishing a stable track on a target that is designated in one or more coordinates. A search of a limited given volume of coordinate space is usually required because of errors or incompleteness of the designation.

acquisition probability: The probability of establishing a stable track on a designated target.

AEW¹: Acronym for airborne early warning; describing an early-warning or air-surveillance radar carried by an airborne or spaceborne vehicle. *See also:* **early-warning radar.**

aided tracking: A tracking technique in which the manual correction of the tracking error automatically corrects the rate of motion of the tracking mechanism.

AI radar: *See:* **airborne-intercept radar.**

airborne-intercept (AI) radar: A fire-control radar for use in interceptor aircraft.

airborne moving-target indication (AMTI) radar: An MTI radar flown in an aircraft or other moving platform with corrections applied for the effects of platform motion, which include the changing clutter Doppler frequency and the spread of the clutter Doppler spectrum. *See also:* **displaced phase center antenna; space-time adaptive processing; time-averaged-clutter coherent airborne radar.**

airport surface detection equipment (ASDE): A high-resolution radar usually located on the airport control tower or other high point and used for observation of the positions of aircraft and other vehicles on the surface of an airport.

airport-surveillance radar (ASR): A medium-range (e.g., 100 km) surveillance radar used to control aircraft in the vicinity of an airport.

air-route-surveillance radar (ARSR): A long-range (e.g., 350 km) surveillance radar used to control aircraft on airways beyond the coverage of airport-surveillance radar (ASR).

air-surveillance radar: A surveillance radar whose function is to detect and track aircraft over a volume of space.

¹The abbreviations capitalized in this standard are in accordance with prevailing radar usage. Lowercase abbreviations are an acceptable alternative (and are preferred by some authors and editors) provided they are used in a consistent manner.

ambiguity function: The squared magnitude $|\chi(\tau, f_d)|^2$ of the function that describes the response of a radar receiver to targets displaced in range delay τ and Doppler frequency f_d from a reference position, where $|\chi(0,0)|$ is normalized to unity. Mathematically:

$$\chi(\tau, f_d) = \int u(t) u^*(t + \tau) \exp(2\pi j f_d t) dt$$

where

$u(t)$ is the transmitted waveform, suitably normalized
positive τ indicates a target beyond the reference delay
positive f_d indicates an approaching target

Ambiguity function is used to examine the suitability of radar waveforms for achieving accuracy, resolution, freedom from ambiguities, and reduction of unwanted clutter.

amplitude-comparison monopulse: A form of monopulse in which the angular deviation of the target from the antenna axis is measured as the amplitude ratio of the target as received by two antenna patterns. The patterns may be a pair of beams displaced on opposite sides of the antenna axis, or a difference-channel beam having odd symmetry about the axis and a sum beam having even symmetry. In the latter case the ratio may have positive and negative values (0° or 180° phase shift, or in some cases $+90^\circ$ and -90°). Distinguished from phase-comparison monopulse, in which the relative phase of the two patterns carries the information on target displacement. *See also:* **phase-comparison monopulse**.

amplitude fluctuation: *See:* **target fluctuation**.

amplitude noise: Used variously to describe target fluctuation and scintillation error. Use of one of these specific terms is recommended to avoid ambiguity.

AMTI: *See:* **airborne moving-target indication**.

angel: A radar echo caused by birds, insects, and atmospheric clear-air turbulence not usually visible to the eye. Often a term applied to any unknown radar echo that does not appear to be related to conventional targets. *Synonym:* **angel echo**.

angel echo: *See:* **angle**.

angle noise: The noise-like variation in the apparent angle of arrival of a signal received from a target, caused by changes in phase and amplitude of multiple, unresolved target-scattering sources. *Note:* Includes both glint and scintillation errors. *See also:* **glint**; **scintillation errors**.

angular resolution: The ability to distinguish between two targets solely by the measurement of their angle, usually expressed in terms of the minimum angle separation by which two targets at a given range can be distinguished. *Note:* The required separation should be specified for targets of given relative power level at the receiver. Equal powers are often assumed, but where resolution of targets of different powers is important it may be necessary to specify the separation at two or more power ratios.

antenna-pattern loss: *See:* **beamshape loss**.

anticlutter circuits: Circuits that attenuate undesired reflections from the natural environment (clutter) to permit detection of targets otherwise obscured by such reflections. *See also:* **clutter**.

antisubmarine warfare (ASW) radar: A radar used in ASW. It includes radars for the detection of submarines and submarine effects as well as radars on ships or aircraft employed in ASW operations to obtain situational awareness of the surface ships and aircraft in the vicinity of ASW operations.

anti-transmit-receive (ATR) switch: A radio-frequency switch that automatically decouples the transmitter from the antenna during the receiving period. *Note:* The ATR switch is employed when a common transmitting and receiving antenna is used.

area moving-target indication (MTI): A method of MTI based upon amplitude changes in corresponding resolution cells for radar returns obtained at different times.

ARSR: *See:* **air-route surveillance radar.**

ASDE: *See:* **airport surface detection equipment.**

ASR: *See:* **airport-surveillance radar.**

ASW radar: *See:* **antisubmarine warfare radar.**

ATR switch: *See:* **anti-transmit-receive switch.**

automatic detection and tracking (ADT): In a surveillance radar, the computer-based ADT of targets based on target locations obtained from scan-to-scan. *See also:* **track-while-scan.**

automatic tracking: Tracking with the use of electronic circuitry rather than a human operator in which a system employs some feedback mechanism, (e.g., a servo or computer) to follow automatically some characteristic of a signal or target, such as range, angle, Doppler frequency, or phase. *See also:* **tracking; tracking radar.**

automatic video noise leveling[†]: A constant-false-alarm-rate (CFAR) technique in which the receiver gain is readjusted to maintain a constant video noise level. The noise level is sampled at the receiver output at the end of each range sweep, prior to the next transmission. The resulting receiver gain is fixed throughout the next sweep. Under some jamming conditions, a fixed video noise can be maintained at the display.

[†]Obsolete

azimuth: The angle between a horizontal reference direction (usually north) and the horizontal projection of the direction of interest, measured clockwise.

azimuth markers: *See:* **azimuth marks.**

azimuth marks: Calibration marks used on a display for azimuth. *Synonym:* **azimuth markers.**

azimuth-stabilized plan-position indicator (PPI): A PPI on which the reference direction remains fixed with respect to the indicator, regardless of the vehicle orientation.

background return*: *See:* **clutter.**

*Deprecated

backscatter: Energy reflected or scattered in a direction opposite to that of the incident wave.

backscatter coefficient: A normalized measure of radar return from a distributed scatterer. For area targets, such as ground or sea clutter, it is defined as the average *monostatic* radar cross section per unit surface area. *Note:* The backscatter coefficient for area targets, often expressed in decibels and denoted by σ^0 , is dimensionless but is sometimes written in units of m^2/m^2 for clarity. For volume scatter, such as that from rain, chaff, or deep snow cover, it is defined as the average monostatic radar cross section per unit volume and is expressed in units of m^2/m^3 or m^{-1} . The volume backscatter coefficient is often expressed in decibels and denoted by the symbol η_v .

backscatter cross section: *See:* radar cross section.

bandwidth, root-mean-square: The root-mean-square (rms) deviation of the power spectrum of the received signal relative to zero frequency or the spectral center, in units of r/s. This bandwidth, β , is defined as the square root of

$$\beta^2 = \frac{\int_{-\infty}^{\infty} [2\pi(f - f_0)^2] |S(f)|^2 df}{\int_{-\infty}^{\infty} |S(f)|^2 df}$$

where

$S(f)$ is the Fourier transform of the signal.

$s(t - \tau_0)$ with true time delay τ_0 and f_0 is the center frequency of the spectrum.

Note: β^2 is the normalized second moment of the spectrum $|S(f)|^2$ about the mean, and β is sometimes called effective bandwidth.

Barker code: A binary phase code used for pulse compression, in which a long pulse is divided into n subpulses with the phase of each subpulse being 0 or π radians. Barker coded pulses have the property that after matched filter processing there are $(n - 1)/2$ sidelobes, or $n/2$ for n even, on each side of the main response, each at a voltage level $1/n$ relative to the main response. Barker codes exist with $n = 2, 3, 4, 5, 7, 9$, and 13. *See also:* coded pulse.

beacon: *See:* radar beacon.

beacon equation: An equation that gives the maximum detection range of a transponder or secondary radar as a function of system parameters for a given set of conditions. It is the one-way counterpart of the two-way radar equation.

beamshape loss: A loss factor included in the radar equation to account for the use of the peak antenna gain in the radar equation instead of the effective gain that results when the received train of pulses is modulated by the two-way pattern of a scanning antenna. *Synonym:* antenna-pattern loss.

bias error: A systematic error, whether due to equipment or propagation conditions. A nonzero mean component of a random error.

bipolar video: A radar video signal whose amplitude can have both positive and negative values; derived from a synchronous phase detection process. *Note:* Coherent detection produces one type of bipolar video. *See also:* coherent signal processing.

bistatic cross section: *See:* radar cross section.

bistatic radar: A radar using antennas for transmission and reception at sufficiently different locations that the angles or ranges from those locations to the target are significantly different.

bistatic-scatter cross section: *See:* radar cross section.

blind phase: In moving-target indication (MTI) radars, when the echo of interest is in quadrature to the reference signal. It occurs in systems that detect only the in-phase signal component. *See also:* **moving-target indication**.

blind range: A range corresponding to the time delay of an integral multiple of the interpulse period plus a time less than or equal to the transmitted pulse length. *Note:* A radar usually cannot detect targets at a blind range because of interference by a subsequent transmitted pulse. *See also:* **eclipsing**.

blind speed [radar using moving-target indication (MTI)]: Radial velocity of a target with respect to the radar for which the MTI response is approximately zero. *Note:* In a coherent MTI system using a uniform repetition rate, a blind speed is a radial velocity at which the target changes its distance by one-half wavelength, or a multiple thereof, during each pulse-repetition interval.

blip: A deflection or a spot of contrasting luminescence on a radar display caused by the presence of a target.

blip-scan ratio: The fraction of scans for which a blip is observed at a given range. *Synonym:* **single-scan probability of detection**.

blooming: An increase in the blip size on the display as a result of an increase in signal intensity or duration.

boresighting: The process of aligning the electrical and mechanical axes of a directional antenna system, usually by an optical procedure.

box-car detector[†]: In radar, a detector whose output is held at the amplitude of the last sample until the next sample arrives. *Note:* Functionally the same as a sample and hold.

[†]Obsolete

burst: *See:* **pulse burst**.

calibration markers: *See:* **calibration marks**.

calibration marks: Indications superimposed on a display to provide a numerical scale of the parameters displayed.

canceled video: In moving-target indication (MTI), the video output remaining after the cancellation process. *See also:* **clutter residue; moving-target indication**.

canceler: That portion of the system in which unwanted signals, such as clutter, fixed targets, and other interference, are suppressed by a process of linear subtraction.

cancellation ratio: (A) In moving-target indication (MTI), the ratio of canceler voltage amplification for fixed-target echoes received with a fixed antenna, to the gain for a single pulse passing through the unprocessed channel of the canceler. *Note:* This measure of MTI performance, in which high performance is represented by a low numerical value, has been largely replaced by the MTI improvement factor. *See also:* **moving-target indication**. (B) In interference-reduction techniques other than MTI, the cancellation ratio is the ratio of interference output power in the absence of the technique to that when the technique is applied, when the system gains for the two cases are adjusted to provide equal noise outputs. *Note:* High performance is indicated by a high numerical value, generally expressed in decibels to avoid ambiguity between power and voltage ratios.

capture effect: The tendency of a receiver to suppress the weaker of two time-coincident signals within its passband.

carrier-controlled approach (CCA) system: An aircraft carrier radar system providing information that facilitates direction of aircraft via radio communication.

C-band: A radar-frequency band between 4 GHz and 8 GHz, usually in the International Telecommunications Union (ITU) allocated band 5.2–5.9 GHz.

CFAR: *See:* **constant-false-alarm rate.**

chaff: Strips of lightweight metal or metallized material that are dispensed in large numbers (bundles) so as to simulate a true target, or, more usually, to create a large clutter signal that masks the detection of wanted targets. *Notes:* 1. Each bundle may contain thousands of individual reflectors whose lengths are related to the wavelength of the radar. 2. Chaff for use at HF and VHF frequencies is sometimes called “rope.” 3. During WWII, chaff was called “window” in Great Britain and “Dueppel” in Germany.)

chirp: A form of pulse compression that uses frequency modulation (usually linear) during the pulse.

clutter: Unwanted echoes, typically from the ground, sea, rain or other precipitation, chaff, birds, insects, meteors, and aurora. *Synonym:* **background return.**

clutter attenuation (CA): In moving-target indication (MTI) or Doppler radar, the ratio of the clutter-to-noise ratio at the input to the processor, to the clutter-to-noise ratio at the output. *Note:* In MTI, a single value of CA will be obtained, while in Doppler radar the value will generally vary over the different target Doppler filters. In MTI, CA will be equal to MTI improvement factor if the targets are assumed uniformly distributed in velocity. *See also:* **MTI improvement factor.**

clutter detectability factor: The predetection signal-to-clutter ratio that provides stated probability of detection for a given false alarm probability in an automatic detection circuit. *Note:* In MTI systems, it is the ratio after cancellation or Doppler filtering.

clutter fence: A barrier surrounding a ground-based radar to serve as an artificial horizon and suppress ground clutter.

clutter filter: A filter or group of filters (filter bank) included in a radar for the purpose of rejecting clutter returns and passing target returns at Doppler frequencies different from the Doppler frequencies of clutter. *Note:* Moving-target indication (MTI) and pulsed-Doppler processors are examples.

clutter improvement factor: *See:* **moving-target indication improvement factor.**

clutter map: Computer-stored values of radar-measured clutter for each range-azimuth resolution cell or local region, used to set thresholds for each cell in a constant-false-alarm rate (CFAR) detection system or to adjust other processing parameters.

clutter reflectivity: The backscatter coefficient of clutter. *See also:* **backscatter coefficient.**

clutter residue: The uncanceled clutter power remaining at the output of an moving-target indication (MTI) or Doppler signal processor. *See also:* **canceled video.**

clutter visibility factor: The predetection signal-to-clutter ratio that provides stated probability of detection for a given false alarm probability on a display. *Note:* In moving-target indication (MTI) systems, it is the ratio after cancellation or Doppler filtering.

coast: A radar memory feature that causes the range or angle tracking systems to continue to move in the same direction and at the same rate that an original target was moving. *Note:* Coast is invoked manually or automatically when the tracked target approaches a stronger echo (target or clutter) to prevent capture of the track by that echo or to maintain track over brief periods of signal loss.

coded pulse: A pulse compression waveform in which a long pulse is divided into many subpulses, with the phase of each subpulse assuming a discrete value (often 0 or π radians) chosen in a deterministic manner (as in Barker codes, which result in all time sidelobes being equal) or chosen in a pseudorandom manner (such as with linear recursive or maximal-length sequences). *See also:* **Barker code**.

coherent integration: Integration of radio frequency (RF), intermediate frequency (IF), or bipolar envelope signals over an interval in which phase or polarity is preserved. *Note:* Sometimes called “predetection integration.” *See also:* **integration**.

coherent moving-target indication (MTI): The usual form of MTI in which a moving target is separated from large clutter echoes as a result of a pulse-to-pulse change in echo phase relative to the phase of a coherent reference oscillator. *See also:* **moving-target indication**.

coherent processing interval: The time during which the radar signal is received and processed coherently. *Note:* Such processing is usually for Doppler filtering.

coherent signal processing: Integration, filtering, or detection of an echo signal using the amplitude of the received signal and its phase referred to that of a reference oscillator or to the transmitted signal.

coherent video: Bipolar video obtained from a synchronous (coherent) detector.

coho: A term derived from coherent oscillator, coho designates an oscillator used in a coherent radar to provide a reference phase by which changes in the phase of successively received pulses may be recognized. *Note:* In practice, a coho usually operates at the receiver intermediate frequency.

collapsing loss: The increase in required input signal-to-noise ratio to maintain given probability of detection for a given false alarm probability when resolution cells or samples containing only noise are integrated along with those containing signal and noise. *Note:* This type of loss occurs, for example, when radar returns containing range, azimuth, and elevation information are constrained to a two-dimensional display.

collapsing ratio: The ratio

$$(m + n)/n$$

where

m is number of noise-only samples
 n is number of signal-plus-noise samples

combination monopulse: A form of monopulse employing amplitude comparison in one angular coordinate plane and phase comparison in the orthogonal coordinate plane.

complex target: A target composed of more than one scatterer within a single radar resolution cell. A target may be both complex and distributed. *See also:* **distributed target**.

conical scanning: A form of angular tracking in which the antenna beam is offset from the tracking axis of the antenna. Rotation of the beam about the axis generates a cone whose vertex angle is of the order of the beamwidth. *Note:* Such scanning may be either rotating or nutating, according to whether the direction of polarization rotates or remains unchanged. The variation of signal amplitude as the beam scans provides information on the amount and direction of displacement of the target from the axis of rotation.

conical-scan-on-receive-only (COSRO): A method of angle tracking in which only the receiving beam is conically scanned.

conopulse: A tracking radar that uses two simultaneous squinted beams that are rotated around the antenna boresight to produce, on a time-shared basis, monopulse angle-error signals in two orthogonal coordinates (such as azimuth and elevation). *Notes:* 1. Only two receivers are required rather than three as in the usual monopulse tracker. 2. Also called “konopulse” and “scan with compensation.”

constant-false-alarm rate (CFAR) receiver: A radar receiver that maintains the output false-alarm rate constant in spite of the varying nature of the receiver noise level, echoes from the clutter environment, or from electronic countermeasures. *Note:* CFAR is usually achieved by establishing a threshold level that varies according to the local noise and/or clutter environment measured in the near vicinity of the target echo.

continuous wave (CW) Doppler radar: A radar that transmits a continuous-wave signal and discriminates desired targets from other targets or clutter on the basis of the Doppler shift due to radial motion. *See also:* **CW radar; Doppler radar.**

continuous wave (CW) radar: A radar that transmits a continuous-wave signal. *See also:* **continuous wave Doppler radar.**

corner reflector: Two (dihedral) or three (trihedral) orthogonal conducting surfaces, designed to return an incident electromagnetic wave toward its source. *Note:* A corner reflector is often used to provide a conspicuous radar target as a safety measure for a small sailboat, to enhance the detectability of a radar target on which it is mounted, or to calibrate a radar.

cosecant-squared pattern: A vertical-plane antenna pattern in which the transmitting and receiving power gains vary as the square of the cosecant of the elevation angle. *Note:* The unique property of this pattern is that it results in the received echo signal being independent of range if

- The target is of constant radar cross section
- The target moves at constant altitude
- The earth’s surface can be considered flat

See also: **modified cosecant-squared antenna pattern.**

Costas code: A frequency-hopping pulse compression waveform in which a long pulse is divided into n subpulses with the frequency of each subpulse chosen from n contiguous frequencies in a manner first suggested by John P. Costas.

crossover loss: For a tracker that uses an offset beam, such as a conical scan tracker, the reduction in signal-to-noise ratio for a target on the tracking axis relative to that for a target on the peak two-way antenna gain of the beam. *Note:* The crossover loss factor is the ratio of the signal-to-noise ratio for a target on the peak two-way antenna gain to that for a target on the tracking axis. *See also:* **conical scanning.**

cross polarization electronic countermeasures (ECM): An ECM technique that transmits with a polarization orthogonal to the principal polarization of the victim radar. *Note:* Since cross-polarized antenna patterns are often very different from the normal, copolarized patterns, tracking might be disrupted. *See also:* **electronic countermeasures.**

cross section: Often used as a shortened form of radar cross section. *Note:* This term should be avoided when there is a possibility of confusion with geometric cross section.

cumulative detection probability: The probability that a target is detected on at least one of n successive scans or detection opportunities of a surveillance radar.

CW Doppler radar: *See:* **continuous wave Doppler radar.**