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A REVIEW PAPER ON RADAR DETECTION TECHNIQUE

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ABSTRACT

The objective of this paper is to study Radar detection technique and analyze the technical methods that we use in radar detection using the general concept of radar and its structure, as well as previous studies in this field and to find obstacles to detecting the target and factors thataffect the detection of the target, such as the range speed and force.

1. INTRODUCTION

Radar is a system that uses electromagnetic waves to identify the range, altitude, direction, or speed of both moving and fixed objects such as aircraft, ships, motor vehicles, weather formations, and terrain. The term RADAR was coined in 1941 as an acronym for: **Ra** Radio **D**etection **A**nd **R**anging. The term has since entered the English language as a standard word, radar, losing the capitalization in the process. Radar was originally called RDF (Radio Direction Finder) in Britain. A radar system has a transmitter that emits radio waves that are reflected by the target and detected by a receiver, typically in the same location as the transmitter. Although the radio signal returned is usually very weak, radio signals can easily be amplified. This enables a radar to detect objects at ranges where other emissions, such as sound or visible light, would be too weak to detect. Radar is used in many contexts, including meteorological detection of precipitation, measuring ocean surface waves, air traffic control, police detection of speeding traffic, and by the military.[1]

Several inventors, scientists, and engineers contributed to the development of radar. The first to use radio waves to detect "the presence of distant metallic objects via radio waves" was Christian Hülsmeyer, who in 1904 demonstrated the feasibility of detecting the presence of a ship in dense fog, but not its distance. He received Reichspatent Nr. 165546 for his pre-radar device in April 1904, and later patent 169154 for a related amendment for ranging. He also received a patent in England for his telemobiloscope on September 22, 1904.

Before the Second World War, developments by the Americans (Dr. Robert M. Page tested the first monopulse radar in 1934), the Germans, the French (French Patent n° 788795 in 1934) and mainly the British who were the first to fully exploit it as a defence against aircraft attack (British Patent GB593017 by Robert Watson-Watt in 1935) led to the first real radars. Hungarian Zoltán Bay produced a working model by 1936 at the Tungsram laboratory in the same vein.[2]

In 1934, Émile Girardeau, working with the first French radar systems, stated he was building radar systems "conceived according to the principles stated by Tesla". The war precipitated research to find better resolution, more portability and more features for the new defence technology. Post-war years have seen the use of radar in fields as diverse as air traffic control, weather monitoring, astrometry and road speed control.[3]

2. Architecture

A practical radar system requires seven basic components as illustrated below:

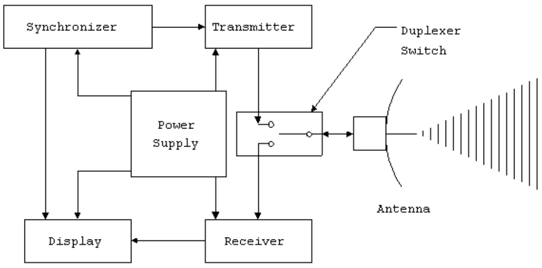


Figure (2-1) Basic Radar System architecture.

2.1 Transmitter

The transmitter creates the radio wave to be sent and modulates it to form the pulse train. The transmitter must also amplify the signal to a high power level to provide adequate range. The source of the carrier wave could be a Klystron, Traveling Wave Tube (TWT) or Magnetron. Each has its own characteristics and limitations.[4]

2.2 Receiver

The receiver is sensitive to the range of frequencies being transmitted and provides amplification of the returned signal. In order to provide the greatest range, the receiver must be very sensitive without introducing excessive noise. The ability to discern a received signal from background noise depends on the signal-to-noise ratio (S/N).

The background noise is specified by an average value, called the noise-equivalent-power (NEP). This directly equates the noise to a detected power level so that it may be compared to the return. Using these definitions, the criterion for successful detection of a target is:
Pr > (S/N) NEP, (1)
Where Pr is the power of the return signal.

Since this is a significant quantity in determining radar system performance, it is given a unique designation, S_{min}, and is called the Minimum Signal for Detection.
$S_{min} = (S/N)\ N$ (2)

Since S_{min}, expressed in Watts, is usually a small number, it has proven useful to define the decibel equivalent, MDS, which stands for Minimum Discernible Signal.
$MDS = 10 \text{ Log } (S_{min}/1 \text{ mW})$ (3)

When using decibels, the quantity inside the brackets of the logarithm must be a number without units. I the definition of MDS, this number is the fraction S_{min} /1 mW. As a reminder, we use the special notation dBm for the units of MDS, where the "m" stands for 1 mW. This is shorthand for decibels referenced to 1 mW, which is sometimes written as dB//1mW.[5]

In the receiver, S/N sets a threshold for detection which determines what will be displayed and what will not. In theory, if S/N = 1, then only returns with power equal to or greater than the background noise will be displayed. However, the noise is a statistical process and varies randomly. The NEP is just the average value of the noise. There will be times when the noise exceeds the threshold that is set by the receiver. Since this will be displayed and appear to be a legitimate target, it is called a false alarm. If the SNR is set too high, then there will be few false alarms, but some actual targets may not be displayed known as a miss). If SNR is set too low, then there will be many false alarms, or a high false alarm rate (FAR).[6]

Some receivers monitor the background and constantly adjust the SNR to maintain a constant false alarm rate, and therefore all called CFAR receivers. Some common receiver features are:

2.3 Pulse Integration

The receiver takes an average return strength over many pulses. Random events like noise will not occur in every pulse and therefore, when averaged, will have a reduced effect as compared to actual targets that will be in every pulse.[7]

2.4 Sensitivity Time Control (STC)

This feature reduces the impact of returns from sea state. It reduces the minimum SNR of the receiver for a short duration immediately after each pulse is transmitted. The effect of adjusting the STC is to reduce the clutter on the display in the region directly around the transmitter. The greater the value of STC, the greater the range from the transmitter in which clutter will be removed. However, an excessive STC will blank out potential returns close to the transmitter.[8]

2.5 Fast Time Constant (FTC)

This feature is designed to reduce the effect of long duration returns that come from rain. This processing requires that strength of the return signal must change quickly over it duration. Since rain occurs over and extended area, it will produce a long, steady return. The FTC processing will filter these returns out of the display. Only pulses that rise and fall quickly will be displayed. In technical terms, FTC is a differentiator, meaning it determines the rate of change in the signal, which it then uses to discriminate pulses which are not changing rapidly.[9]

2.6 Power Supply

The power supply provides the electrical power for all the components. The largest consumer of power is the transmitter which may require several kW of average power. The actually power transmitted in the pulse may be much greater than 1 kW. The power supply only needs to be able to provide the average amount of power consumed, not the high power level during the actual pulse transmission.[10]

Energy can be stored, in a capacitor bank for instance, during the rest time. The stored energy then can be put into the pulse when transmitted, increasing the peak power. The peak power and the average power are related by the quantity called duty cycle, DC. Duty cycle is the fraction of each transmission cycle that the radar is actually transmitting. Referring to the pulse train in Figure 2, the duty cycle can be seen to be:

$$DC = PW / PRF \quad (4)$$

2.7 Synchronizer

The synchronizer coordinates the timing for range determination. It regulates that rate at which pulses are sent (i.e. sets PRF) and resets the timing clock for range determination for each pulse. Signals from the synchronizer are sent simultaneously to the transmitter, which sends a new pulse, and to the display, which resets the return sweep.[11]

2.8 Duplexer

This is a switch which alternately connects the transmitter or receiver to the antenna. Its purpose is to protect the receiver from the high power output of the transmitter. During the transmission of an outgoing pulse, the duplexer will be aligned to the transmitter for the duration of the pulse, PW. After the pulse has been sent, the duplexer will align the antenna to the receiver. When the next pulse is sent, the duplexer will shift back to the transmitter. A duplexer is not required if the transmitted power is low.[12]

2.9 Antenna

The antenna takes the radar pulse from the transmitter and puts it into the air. Furthermore, the antenna must focus the energy into a well-defined beam which increases the power and permits a determination of the direction of the target. The antenna must keep track of its own orientation which can be accomplished by a synchro-transmitter. There are also antenna systems which do not physically move but are steered electronically (in these cases, the orientation of the radar beam is already known a priori).

The beam-width of an antenna is a measure of the angular extent of the most powerful portion of the radiated energy. For our purposes the main portion, called the main lobe, will be all angles from the perpendicular where the power is not less than ½ of the peak power, or, in decibels, -3dB.[13]

The beam-width is the range of angles in the main lobe, so defined. Usually this is resolved into a plane of interest, such as the horizontal or vertical plane. The antenna will have a separate horizontal and vertical beam-width. For a radar antenna, the beam-width can be predicted from the dimension of the antenna in the plane of interest by:

$\square = \square/L$ (5)

where

is the beam-width in radians,

is the wavelength of the radar,

L is the dimension of the antenna, in the direction of interest (i.e. width or height).

In the discussion of communications antennas, it was stated that the beam-width for an antenna could be found using □ = 2□/L.[14]

So it appears that radar antennas have one-half of the beam-width as communications antennas. The difference is that radar antennas are used both to transmit and receive the signal. The interference effects from each direction combine, which has the effect of reducing the beam width. Therefore when describing two-way systems (like radar) it is appropriate to reduce the beam-width by a factor of ½ in the beam-width approximation formula.The directional gain of an antenna is a measure of how well the beam is focused in all angles. If we were restricted to a single plane, the directional gain would merely be the ratio 2□/□. Since the same power is distributed over a smaller range of angles, directional gain represents the amount by which the power in the beam is increased. In both angles, then directional gain would be given by:

$G_{dir} = 4$

Since there are 4□ steradians corresponding to all directions (solid angle, measured in steradians, is defined to be the area of the beam front divided by the range squared, therefore a non-directional beam would cover an area of 4□$\mathbf{R}^2$ at distance R, therefore4□ steradians). Here we used:

□ = horizontal beam-width (radians)

□ = vertical beam-width (radians)

Sometimes directional gain is measured in decibels, namely 10 log (Gdir).[15]

2.10 Display

The display unit may take a variety of forms but in general is designed to present the received information to an operator. The most basic display type is called an A-scan (amplitude vs. Time delay). The vertical axis is the strength of the return and the horizontal axis is the time delay, or range. The A-scan provides no information about the direction of the target.[16]

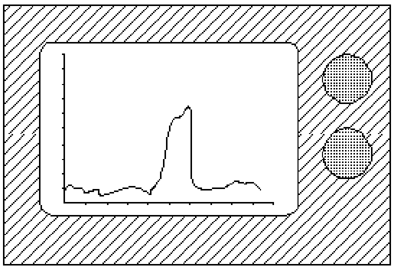


Figure (2-2) The display.

The most common display is the PPI (plan position indicator). The A-scan information is converted into brightness and then displayed in the same relative direction as the antenna orientation. The result is a top-down view of the situation where range is the distance from the origin. The PPI is perhaps the most natural display for the operator and therefore the most widely used. In both cases, the synchronizer resets the trace for each pulse so that the range information will begin at the origin.[17]

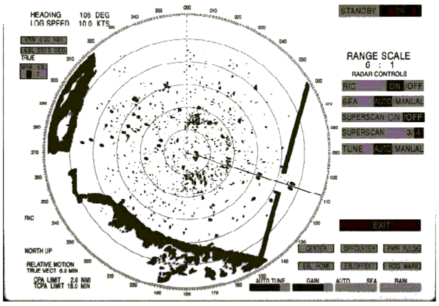


Figure (2-3) plan position indicator.

In this example, the use of increased STC to suppress the sea clutter would be helpful.[5]

A radar detects the present of an echo signal reflected from a target and extract information about the target (such as its location).[18]

3. Types of radar detection technique

3.1 Single Pulse Detection

3.1.1 Single Pulse with Known Parameters

In its simplest form, a radar signal can be represented by a single pulse comprising a sinusoid of known amplitude and phase. Consequently, a retuned signal will also comprise a sinusoid. Under the assumption of completely known signal parameters, a returned pulse from a target has known amplitude and known phase with no random components; and the radar signal processor will attempt to maximize the probability of detection for a given probability of false alarm. In this case, detection is referred to as coherent detection or coherent demodulation. A radar system will declare detection with a certain probability of detection if the received voltage signal envelope exceeds a pre-set threshold value. For this purpose, the radar receiver is said to employ an envelope detector.[19]

3.2 Detection of Fluctuating Targets

Detection was introduced in the context of single pulse detection with completely known (i.e., deterministic) amplitude and phase. The underlying assumption was that radar targets were made of non-varying (non-fluctuating) scatterers. However, in practice that it is rarely the case.

First, one would expect the radar to receive multiple returns (pulses) from any given target in its field of view. Furthermore, real-world targets will fluctuate over the duration of a single pulse or from pulse to pulse.[20]

3.2.1 Radar pulse integration

The process of combining radar returns from many pulses is called radar pulse integration. Combining the returns from all pulses returned by a given target during a single scan is very likely to increase the radar sensitivity (i.e., SNR). The number of returned pulses from a given target depends on the antenna scan rate, the antenna beamwidth, and the radar PRF.[21]

3.2.1.1Coherent integration

Pulse integration can be performed on the quadrature components prior to the envelope detector. This is called coherent integration or predetection integration. Coherent integration preserves the phase relationship between the received pulses. Thus a buildup in the signal amplitude is expected. In coherent integration, and when a perfect integrator is used (100% efficiency) to integrate pulses, the SNR is improved by the same factor. Otherwise, integration loss occurs, which is always the case for noncoherent integration. Coherent integration loss occurs when the integration process is not optimum. This could be due to target fluctuation, instability in the radar local oscillator, or propagation path changes.[22]

3.2.1.2 Noncoherent integration

Pulse integration performed after the envelope detector (where the phase relation is lost) is called noncoherent or post-detection integration, and a buildup in the signal amplitude is guaranteed. When the phase of the integrated pulses is not known, so that coherent integration is no longer possible, another form of pulse integration is done. In this case, pulse integration is performed by adding (integrating) the individual pulses' envelopes or the square of their envelopes. Thus, the term noncoherent integration is adopted. A block diagram of a radar receiver utilizing noncoherent integration is illustrated in Fig. (3-1).[23]

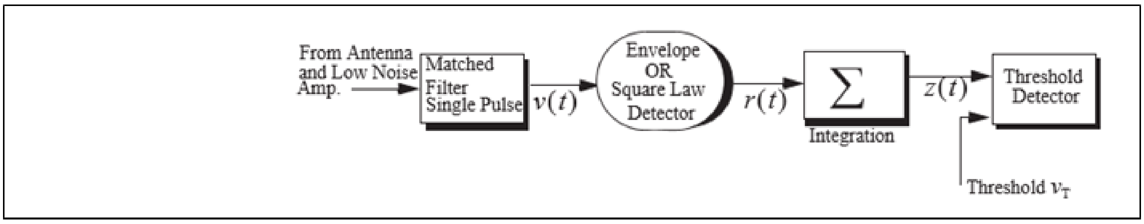


Figure (3.1) Simplified block diagram of a radar detector when noncoherent integration is used.

3.2.2 Improvement Factor and Integration Loss

Noncoherent integration is less efficient than coherent integration. Actually, the noncoherent integration gain is always smaller than the number of noncoherently integrated pulses. This loss in integration is referred to as post-detection or square-law detector loss.[24]

3.2.3 Target Fluctuation: The Chi-Square Family of Targets

Target detection utilizing the square law detector was first analyzed by Marcum1, where he assumed a constant RCS (nonfluctuating target). This work was extended by Swerling2 to four distinct cases of target RCS fluctuation. These cases have come to be known as Swerling models. They are Swerling I, Swerling II, Swerling III, and Swerling IV. The constant RCS case analyzed by Marcum is widely known as Swerling 0 or equivalently as Swerling V. Target fluctuation introduces an additional loss factor in the SNR as compared to the case where fluctuation is not present, given the same and . Swerling V targets have constant amplitude over one antenna scan or observation interval; however, a Swerling I target amplitude varies independently from scan to scan according to a chi-square probability density function with two degrees of freedom. The amplitude of Swerling II targets fluctuates independently from pulse to pulse according to a chi-square probability density function with two degrees of freedom. Target fluctuation associated with a Swerling III model is from scan to scan according to a chi-square probability density function with four degrees of freedom.[25]

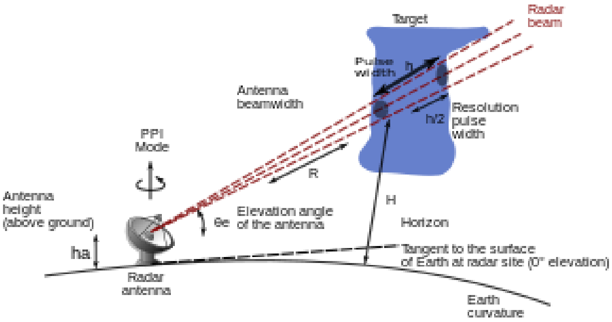
Finally, the fluctuation of Swerling IV targets is from pulse to pulse according to a chi-square probability density function with four degrees of freedom. Swerling showed that the statistics associated with Swerling I and II models apply to targets consisting of many small scatterers of comparable RCS values, while the statistics associated with Swerling III and IV models apply to targets consisting of one large RCS scatterer and many small equal RCS scatterers. Noncoherent integration can be applied to all four Swerling models; however, coherent integration cannot be used when the target fluctuation is either Swerling II or Swerling IV. This is because the target amplitude decorrelates from pulse to pulse (fast fluctuation) for Swerling II and IV models, and thus phase coherency cannot be maintained.[26]

3.3 Limiting factors

A radar beam follows a linear path in vacuum but follows a somewhat curved path in atmosphere due to variation in the refractive index of air, which is called the radar horizon. Even when the beam is emitted parallel to the ground, the beam rises above the ground as the curvature of the Earth sinks below the horizon. Furthermore, the signal is attenuated by the medium the beam crosses, and the beam disperses. The maximum range of conventional radar can be limited by a number of factors

- Line of sight, which depends on the height above the ground. Without a direct line of sight, the path of the beam is blocked.
- The maximum non-ambiguous range, which is determined by the pulse repetition frequency. The maximum non-ambiguous range is the distance the pulse can travel to and return from before the next pulse is emitted.

Radar sensitivity and the power of the return signal as computed in the radar equation. This component includes factors such as the environmental conditions and the size (or radar cross section) of the target.[27]



Figure(3-2) Echo heights above ground.

Where

r: distance radar-targetke: 4/3

ae: Earth radius

θe: elevation angle above the radar horizon

ha: height of the feedhorn above ground

3.3.1 Noise

Signal noise is an internal source of random variations in the signal, which is generated by all electronic components. Reflected signals decline rapidly as distance increases, so noise introduces a radar range limitation. The noise floor and signal to noise ratio are two different measures of performance that affect range performance. Reflectors that are too far away produce too little signal to exceed the noise floor and cannot be detected. Detection requires a signal that exceeds the noise floor by at least the signal to noise ratio.[28]

Noise typically appears as random variations superimposed on the desired echo signal received in the radar receiver. The lower the power of the desired signal, the more difficult it is to discern it from the noise. Noise figure is a measure of the noise produced by a receiver compared to an ideal receiver, and this needs to be minimized.[29]

Shot noise is produced by electrons in transit across a discontinuity, which occurs in all detectors. Shot noise is the dominant source in most receivers. There will also be flicker noise caused by electron transit through amplification devices, which is reduced using heterodyne amplification. Another reason for heterodyne processing is that for fixed fractional bandwidth, the instantaneous bandwidth increases linearly in frequency. This allows improved range resolution. The one notable exception to heterodyne (downconversion) radar systems is ultra-wideband radar.[30]

Noise is also generated by external sources, most importantly the natural thermal radiation of the background surrounding the target of interest. In modern radar systems, the internal noise is typically about equal to or lower than the external noise. An exception is if the radar is aimed upwards at clear sky, where the scene is so "cold" that it generates very little thermal noise. Matched filtering allows the entire energy received from a target to be compressed into a single bin (be it a range, Doppler, elevation, or azimuth bin). On the surface it would appear that then within a fixed interval of time one could obtain perfect, error free, detection.[31]

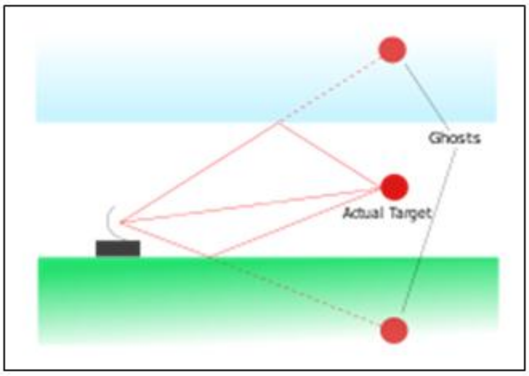
3.3.2 Interference

Radar systems must overcome unwanted signals in order to focus on the targets of interest. These unwanted signals may originate from internal and external sources, both passive and active. The ability of the radar system to overcome these unwanted signals defines its signal-to-noise ratio (SNR). SNR is defined as the ratio of the signal power to the noise power within the desired signal; it compares the level of a desired target signal to the level of background noise (atmospheric noise and noise generated within the receiver). The higher a system's SNR the better it is at discriminating actual targets from noise signals.[32]

3.3.3 Clutter

Clutter refers to radio frequency (RF) echoes returned from targets which are uninteresting to the radar operators. Such targets include natural objects such as ground, sea, and when not being tasked for meteorological purposes, precipitation (such as rain, snow or hail), sand storms, animals (especially birds), atmospheric turbulence, and other atmospheric effects, such as ionosphere reflections, meteor trails, and Hail spike. Clutter may also be returned from man-made objects such as buildings and, intentionally, by radar countermeasures such as chaff.[33]

Some clutter may also be caused by a long radar waveguide between the radar transceiver and the antenna. In a typical plan position indicator (PPI) radar with a rotating antenna, this will usually be seen as a "sun" or "sunburst" in the center of the display as the receiver responds to echoes from dust particles and misguided RF in the waveguide. Adjusting the timing between when the transmitter sends a pulse and when the receiver stage is enabled will generally reduce the sunburst without affecting the accuracy of the range, since most sunburst is caused by a diffused transmit pulse reflected before it leaves the antenna. Clutter is considered a passive interference source, since it only appears in response to radar signals sent by the radar.[34]



Figure(3-3): Radar multipath echoes from a target cause ghosts to appear.

Clutter may also originate from multipath echoes from valid targets caused by ground reflection, atmospheric ducting or ionospheric reflection/refraction (e.g., anomalous propagation). This clutter type is especially bothersome since it appears to move and behave like other normal (point) targets of interest. In a typical scenario, an aircraft echo is reflected from the ground below, appearing to the receiver as an identical target below the correct one.[35] The radar may try to unify the targets, reporting the target at an incorrect height, or eliminating it on the basis of jitter or a physical impossibility. Terrain bounce jamming exploits this response by amplifying the radar signal and directing it downward.[36]

3.3.4 Jamming

Radar jamming refers to radio frequency signals originating from sources outside the radar, transmitting in the radar's frequency and thereby masking targets of interest. Jamming may be intentional, as with an electronic warfare tactic, or unintentional, as with friendly forces operating equipment that transmits using the same frequency range. Jamming is considered an active interference source, since it is initiated by elements outside the radar and in general unrelated to the radar signals. Jamming is problematic to radar since the jamming signal only needs to travel one way (from the jammer to the radar receiver) whereas the radar echoes travel two ways (radar-target-radar) and are therefore significantly reduced in power by the time they return to the radar receiver in accordance with inverse-square law.. Jammers therefore can be much less powerful than their jammed radars and still effectively mask targets along the line of sight from the jammer to the radar (mainlobe jamming).[37] Jammers have an added effect of affecting radars along other lines of sight through the radar receiver's sidelobes (sidelobe jamming). Mainlobe jamming can generally only be reduced by narrowing the mainlobe solid angle and cannot fully be eliminated when directly facing a jammer which uses the same frequency and polarization as the radar. Sidelobe jamming can be overcome by reducing receiving sidelobes in the radar antenna design and by using an omnidirectional antenna to detect and disregard non-mainlobe signals. Other anti-jamming techniques are frequency hopping and polarization.[38]

3.3.5 False alarms

False alarms are generated when thermal noise exceeds a pre-set threshold level, by the presence of spurious signals (either internal to the radar receiver or from sources external to the radar), or by equipment malfunction.[39]

3.3.6 Radar echo

Radar echo an electronic signal that has been reflected back to the radar antenna; contains information about the location and distance of the reflecting object. types: blip, pip, radar target. a radar echo displayed so as to show the position of a reflecting surface. clutter.

In digital transmission, the number of bit errors is the number of received bits of a data stream over a communication channel that have been altered due to noise, interference, distortion or bit synchronization errors.[40]

3.3.7 Fading

In wireless communications, fading is variation of the attenuation of a signal with various variables. These variables include time, geographical position, and radio frequency. Fading is often modeled as a random process. A fading channel is a communication channel that experiences fading. In wireless systems, fading may either be due to multipath propagation, referred to as multipath-induced fading, weather (particularly rain), or shadowing from obstacles affecting the wave propagation, sometimes referred to as shadow fading.[41]

3.4 Radar performance

All of the parameters of the basic pulsed radar system will affect the performance in some way. Here we find specific examples and quantify this dependence where possible.

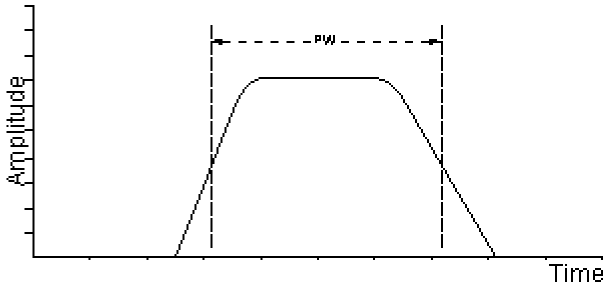
3.4.1 Pulse Width

The duration of the pulse and the length of the target along the radial direction determine the duration of the returned pulse. In most cases the length of the return is usually very similar to the transmitted pulse. In the display unit, the pulse (in time) will be converted into a pulse in distance. The range of values from the leading edge to the trailing edge will create some uncertainty in the range to the target.[42] Taken at face value, the ability to accurately measure range is determined by the pulse width. If we designate the uncertainty in measured range as the range resolution, R_{RES}, then it must be equal to the range equivalent of the pulse width, namely:

$R_{RES} = c\ PW/2$ (7)

Now, you may wonder why not just take the leading edge of the pulse as the range which can be determined with much finer accuracy.[43]

The problem is that it is virtually impossible to create the perfect leading edge.
In practice, the ideal pulse will really appear like:

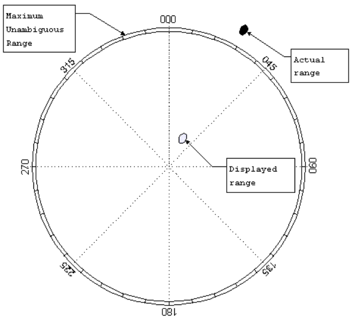


Figure(3-3) ideal pulse.

3.4.2 Pulse Repetition Frequency (PRF)

The frequency of pulse transmission affects the maximum range that can be displayed. Recall that the synchronizer resets the timing clock as each new pulse is transmitted. Returns from distant targets that do no reach the receiver until after the next pulse has been sent will not be displayed correctly. Since the timing clock has been reset, they will be displayed as if the range where less than actual. If this were possible, then the range information would be considered ambiguous.

An operator would not know whether the range were the actual range or some greater value.[44]



Figure(3-5) the maximum unambiguous range.

The maximum actual range that can be detected and displayed without ambiguity, or the maximum unambiguous range, is just the range corresponding to a time interval equal to the pulse repetition time, PRT. Therefore, the maximum unambiguous range,

R_{UNAMB} = c PRT/2 = c/(2PRF) (8)

When a radar is scanning, it is necessary to control the scan rate so that a sufficient number of pulses will be transmitted in any particular direction in order to guarantee reliable detection. If too few pulses are used, then it will more difficult to distinguish false targets from actual ones. False targets may be present in one or two pulses but certainly not in ten or twenty in a row. Therefore to maintain a low false detection rate, the number of pulses transmitted in each direction should be kept high, usually above ten. For systems with high pulse repetition rates (frequencies), the radar beam can be repositioned more rapidly and therefore scan more quickly. Conversely, if the PRF is lowered the scan rate needs to be reduced.[45]

3.4.3 Radar Frequency

Finally, the frequency of the radio carrier wave will also have some affect on how the radar beam propagates. At the low frequency extremes, radar beams will refract in the atmosphere and can be caught in "ducts" which result in long ranges.

At the high extreme, the radar beam will behave much like visible light and travel in very straight lines. Very high frequency radar beams will suffer high losses and are not suitable for long range systems. The frequency will also affect the beam-width. For the same antenna size, a low frequency radar will have a larger beam-width than a high frequency one. In order to keep the beam-width constant, a low frequency radar will need a large antenna.[46]

3.5 Factors affecting radar performance

The performance of a radar system can be judged by the following:

1. The maximum range at which it can see a target of a specified size.
2. The accuracy of its measurement of target location in range and angle,
3. Its ability to distinguish one target from another.
4. Its ability to detect the desired target echo when masked by large clutter echoes, unintentional interfering signals from other “friendly” transmitters, or intentional radiation from hostile jamming (if a military radar).

5. Its ability to recognize the type of target.
6. Its availability (ability to operate when needed), reliability, and maintainability.[47]

3.5.1 The bit error rate (BER)

The bit error rate (BER) is the number of bit errors per unit time. The bit error ratio (also BER) is the number of bit errors divided by the total number of transferred bits during a studied time interval. Bit error ratio is a unitless performance measure, often expressed as a percentage.

The bit error probability pe is the expected value of the bit error ratio. The bit error ratio can be considered as an approximate estimate of the bit error probability. This estimate is accurate for a long time interval and a high number of bit errors.[48]

3.5.2 The delay

The common way to measure range with a radar is to measure the time delay between transmission and reception of a pulse timing the delay between transmission of a pulse of radio energy and its subsequent. return. If the time delay is Dt, then the range may be determined by the simple. formula:[49]

$R = cDt/2.$[25] (9)

3.5.3 False Alarm Rate

A false alarm is "an erroneous radar target detection decision caused by noise or other interfering signals exceeding the detection threshold". In general, it is an indication of the presence of radar target when there is no valid aim. The False Alarm Rate (FAR) is calculated using the following formula:

$$FAR = \frac{\text{false targets per PRT}}{\text{Number of rangecells}} \quad (10)$$

False alarms are generated when thermal noise exceeds a pre-set threshold level, by the presence of spurious signals (either internal to the radar receiver or from sources external to the radar), or by equipment malfunction. A false alarm may be manifested as a momentary blip on a cathode ray tube (CRT) display, a digital signal processor output, an audio signal, or by all of these means. If the detection threshold is set too high, there will be very few false alarms but the signal-to-noise ratio required will inhibit detection of valid targets. If the threshold is set too low, the large number of false alarms will mask detection of valid targets.[50]

The false alarm rate depends on the level of all interferences, like noise, clutter or jamming. Near the radar site the influence of the fixed clutter is higher than the noise level. At large distances the influence of the noise level is higher. This has the effect, that the false alarm rate depends on the range. But the equation doesn't give any range dependences. To achieve a higher probability of detection in large distances by using a lower threshold level, the false alarm rate rises at close range.[51]

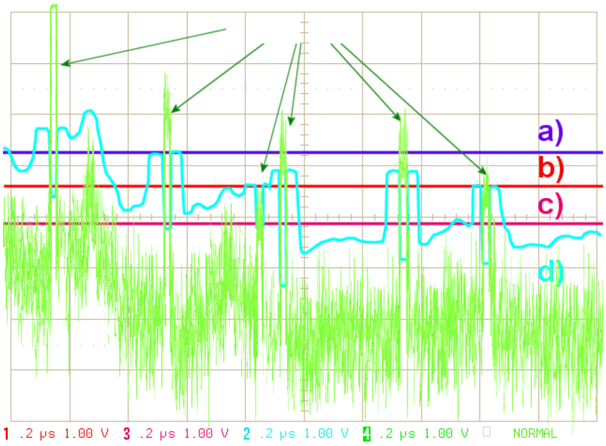


Figure (3.4): Different threshold levels.

4. Previous Status

There different type of MSc & PHD & scientific papers which discuss the radar detection technique as shown in this table:

thesis	Author	Type of thesis	objective	conclusion
Microwave Instrument for Human Vital Signs Detection and Monitoring.	. Jensen, B. S, Johansen, T. K., & Krozer, V	Phd	this work investigates how to design microwave systems for vital signs detection (vsd) and monitoring (i.e. Of respiration and heartbeat signals). Typical system types include ultrawideband (uwb) and continuous wave (cw) radars. Due to its ease of implementation and potential for a low-power low-cost system,	in the pursuit of an even more compact solution, the work on a fully integrated sige:c vsd radar front-end was initiated. With nancial support from the danish fund h. C. Rsteds fonden, the ic was fabricated in the sg25h3 sige:c bicmos technology from innovations for high performance

			emphasis is on the cw type of vsd radars. The signal theory governing both homodyne and heterodyne cw vsd architectures is thoroughly examined. Throughout the discussion it is shown, how heterodyne systems using a low intermediate frequency (if) can overcome some of the commonly encountered problems with homodyne systems, i.e. Channel mismatches and dc offsets resulting from hardware imperfections.	microelectronics (ihp) gmbh in germany. The radar transceiver has been measured and although some adjustments could be of benefit, it is assessed that the radar chip can contribute to a full vsd system. Time did not allow for this latter system implementation of the ic.
pulsed radar measurements and related equipment.	Mikko puranen	Phd		In this thesis, measurement methods and related hardware for pulsed radar experiments were presented and evaluated. Additionally, several uncertainty issues were discussed.
signal processing algorithms for mimo radar	Chun-yang chen	Phd	The purpose of this thesis has been to develop novel methods for pulsed radar measurements, creating practical tools for verifying the operation of a modern pulsed radar, and to build working prototypes suitable for field use.	The most difficult challenges a radar engineer will face when dealing with modern pulsed radars come from the pulse length, and in some cases also from the really high or really low power levels. Even the most modern measuring instruments cannot handle radar signals properly; radar technologies develop rapidly and instrument manufacturers have always been one step behind the latest

				developments.
the modelling of radar sea clutter	simon watts	Phd	The main contribution of this thesis is to study the signal processing issues in mimo radar and propose novel algorithms for improving the mimo radar system	Several measurement methods for verifying the operation of the radar have been demonstrated. The equipment and methods have been designed keeping the usability in the field in mind, which sets some additional challenges, when, for example, robustness, portability, effects of the weather and electromagnetic compatibility have to be taken into account. With some clever arrangements, normal laboratory equipment can be used and still very good results will be achieved. The performance of different kind of equipment has been extensively tested in practice and thoroughly documented in this thesis. The achieved results will provide some alternative tools for a researcher, when other measuring methods or instruments are not either commercially available, or cannot be used in challenging environment.
detection and jamming low probability of intercept (lpi) radars	Aytug denk	Msc	This work has been based on the development and exploitation of the compound k distribution model for the amplitude statistics of radar sea clutter. It has covered the	A radar calibration system was presented in publication . It provides a convenient way to use the radar's own signal in calibration, and it still

			development of the model, through the analysis of recorded radar data, to establish its validity over a wide range of conditions and for both coherent and non-coherent radar processing.	is a rather simple setup.
an overview of detection in mimo radar	Şafak bilgi akdemir	Msc	•The primary objective of this thesis is to investigate methods and means to counter lpi radar threats	In the first part of this thesis, we focus on the mimo radar receiver algorithms. We first study the robustness of the beam former used in mimo radar receiver. In this thesis, we propose an adaptive beamformer that is robust against the doa mismatch. This method imposes constraints such that the magnitude responses of two angles exceed unity. Then a diagonal loading method is used to force the magnitude responses at the arrival angles between these two angles to exceed unity.
evaluation of automotive commercial radar for human detection	Marc mir tutusaus	Msc	An evaluation of the capabilities of automotive long range radar generation 2, manufactured by bosch, for detecting humans is presented. The main goal is to improve the security of workers in work machine environments by detecting the presence of humans and thus avoiding accidents.	In order to characterize the limitations of the radar when the target is a human instead of a car, several measurements are performed. As was expected, the measurements have shown important differences from the specifications of the radar. The maximum range has decreased

				from 200 m to 90 m and the angular resolution is poor. The range resolution between humans is acceptable in near range but increases when the range is large. Also, detecting a human is difficult when he is close to a larger target . The range resolution has been identified as the main drawback in this radar. However, this radar may be able to provide better values in range resolution if the measurement configuration of the radar is changed. Different techniques for human identification have also been presented. The use of two different frequencies seems to be the most potential method to identify humans from other targets.
Software Defined Radar implementations	Alvaro Rocha	Scientific paper	•To design a high resolution L-Band Software Defined Radar system. •To obtain a higher slant-range resolution with respect to the existing Software Defined Radar implementations. •To demonstrate the accurate target detection capability of the proposed software radar architecture.	to the Gigabit Ethernet interface, is exploited to obtain a higher slant-range resolution with respect to the existing Software Defined Radar implementations. A specific LabVIEW application, performing radar operations, is discussed, and successful validations are presented to demonstrate the

				accurate target detection capability of the proposed software radar architecture. In particular, outdoor and indoor test are performed by adopting a metal plate as reference structure located at Target position, The Universal Software Radio Peripheral USRP NI2920, a software defined transceiver so far mainly used in Software Defined Radio applications, is adopted in this work to design a high resolution L-Band Software Defined Radar system. The enhanced available bandwidth, due different distances from the designed radar system, and results obtained from the measured echo are successfully processed to accurately reveal the correct with the predicted slant-range resolution equal to 6 m.

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