

Phased array radar



**ASSIGN
BUSTER**

PHASED ARRAY RADARS Intro 1. Phased arrays, an enabling tech for modern radar sys, provide the diversity needed to enhance the performance of the radar sys far beyond the caps of rotating parabolic antenna radars of the past. Today's modern phased arrays incorporated active components for high average transmit power, superior low noise performance, unprecedented sensitivity and indep elm lvl phase and amplitude con.

They can op over narrow-bands and produce single and multiple beams.

Multi-functional phased arrays can perform radar, comm and EW ops simultaneously. Aim 2. Tech Terms 4. Definitions of tech terms that will be used frequently in this lec are att at Anx A.

Basic Radar 5. Basic Pulsed Radar Block Diagram. The most elementary concept of a radar (Fig 1) consists of a pulse modulated transmitter emitting pulses at a certain PRF which defines the min / max range of the radar, a duplexer and a receiver which displays the tgt loc and range on the presentation unit.

Fig - 16. TX. TX generates a short rectangular pulse.

On receipt of pulse duplexer connects the antenna to TX. Antenna sends out the pulse in the dir in which it is pointing at the time. At speeds the antenna is still locking in the same dir when the echo returns and it is collected by it.

7. Duplexer. RX is now connected by the duplexer to the antenna and TX is disconnected at the same time.

8. RX. Received pulses are processed in the RX which forwards them to a presentation unit where they can be displayed. The cycle is now complete and the set is ready for the next pulse transmission. 9.

Posn of Tgt. Radar shows the posn of tgt as azimuth and elevation of antenna are known. PPI Fig ??” 210. Range. Dist is given by the time taken by the pulse on its fwd and return journey.

Thus with a PRF of 1000 the transmitted pulse length is 1 milli sec, with a listening time of 300 u sec the max range of the radar will be 45 kms. A simulation tool used during the design of near-field ranges for phased array antenna testing is presented. This tool allows the accurate determination of scanner size for testing phased array antennas under steered beam conditions Fig 3 shows the various pulse timings and the calcs with the help of a simple radar equation. 300 u sec 699 u sec 699 u sec

$$\text{Range} = C \times T_r$$

$$3 \times 10^8 \times 300 \times 10^{-6} = 3 \times 10^8 \text{ m/s}$$

$$\text{Range} = 300 \times 300 T_r = \text{Travel Time of pulse}$$

$$\text{Max } 2 = 90,000 \text{ m } 2 = 45 \text{ Kms}$$
 Fig ??” 311. Velocity. Velocity of tgt can be calc from the posns of successive echoes. 12.

Limitations of Basic Radars. Traditional radars having parabolic shaped (Fig 4) antennae steered via mech means, have no of limitations:-Fig -4 a.

Positioning the Antenna. Positioning antenna rotation is relatively slow due to antenna inflexibility and inertia. b. Limit on the Max Scanning Speed.

A limit on max scanning speed will be imposed by antenna mechanics. c. Constant Beam Production. Additionally the problem encountered with a single antenna of fixed shape is that the shape of the beam it produces is constant. d.

Antenna Pts in One Dir at a Time. Difficulty is caused by the fact that a single antenna can pt in only one dir at a time, therefore sending out only one beam at a time. e. Reduced reaction time. f. Tracking of Multiple Tgts. It is also rather difficult to tr a large no of tgts simultaneously. g.

Accuracy. Accurate tracking of multiple tgts simultaneously is difficult. h.

Less Sensitive. Unable to tr tgts with smaller cross secs. j. Reduced Range.

Reduced range for radars, performing both tr/search functions.

Phased Array Radar¹³. Block Diagram. In the block diagram (Fig-5)the sig to be Tx is sent by the divider / combining network to Transmit / Receive (T/R) switch and then to a phase shifter. Another switch directs this phase shifted sig to a med power amplifier (MPA) which is fol by the final high power amplifier (HPA). The HPA output is fed to the circulator and then antenna elm. For transmission / reception modes the switch posns are changed from T to R and vice versa. The path of received sig would be antenna elm, circulator, limiter, low noise amplifier (LNA), T/R switches, Phase shifter, T/R switch and divider/combiner network¹⁴.

Phased Array Antenna. A phased array antenna is composed of lots of radiating elements each with a phase shifter. Beams are formed by shifting the phase of the signal emitted from each radiating element, to provide constructive/destructive interference so as to steer the beams in the desired direction. ¹⁵. In the figure 6 both radiating elements are fed with the same phase.

The signal is amplified by constructive interference in the main direction. The beam sharpness is improved by the destructive interference. Figure 6: two

<https://assignbuster.com/phased-array-radar/>

antenna elements, fed with the same phase¹⁶. In the figure 6a, the signal is emitted (here therefore in the past) by 10 degrees phase shifted by the lower radiating element than of the upper radiating element. Because of this the main direction of the signal emitted together is moved up. ¹⁷.(Radiating elements have been used without reflector in the figure. Therefore, the back lobe of the shown antenna diagrams is just as large as the main lobe.

)Figure 6a: two antenna elements, fed with different phase¹⁸. The main beam always points in the direction of the increasing phase shift. Well, if the signal to be radiated is delivered through an electronic phase shifter giving a continuous phase shift now, the beam direction will be electronically adjustable.

However, this cannot be extended unlimitedly. The highest value, which can be achieved for the Field of View of a phased array antenna is 120° (60° left and 60° right). With the sine theorem the necessary phase moving can be calculated. ¹⁹.

The following figure graphically shows the matrix of radiating elements. Arbitrary antenna constructions can be used as a spotlight in an antenna field. For a phased array antenna is decisive that the single radiating elements are steered for with a regular phase moving and the main direction of the beam therefore is changed.

Figure 6b: phased array: a controlled phase shifter is located at each radiating element²⁰. A phased array antenna with a freely swivelling main direction is composed of a high number of radiating elements, and an electronic phase shifter is located to each radiating element. E. g. the

<https://assignbuster.com/phased-array-radar/>

antenna of the RRP? 117 consists of 1584? radiating elements. | Advantages | Disadvantages || High gain with low side lobes | The coverage of one facet is limited to a 120 degree sector || Ability to permit the beam to jump from one target to the next in a few | in azimuth and elevation || microseconds | Deformation of the beam while the diversion || Ability to provide an agile beam under computer control | Low frequency agility || Beliebige Raumabtastung | Very complex structure (processor, phase shifters) || Freely eligible dwell time | Still high costs || Multifunction operation by emitting several beams simultaneously | || Fault of single components reduces the capability and beam sharpness, | || but the system remains operational | |

21. Radiation Pattern and Beam Steering.

The radiation pattern (Fig 7a) of a phased array radar antenna is determined by the amplitude and phase of the current (Fig 7b) at each of its elm. Fig ??“ 7b22. The phased array antenna has the advantages of being able to have its beam electronically steered in angle by changing the phase of the current at each elm. The beam of a large fixed phased ??“ Array Antenna therefore, can be rapidly steered from one dir to another without a need of mech repositioning a large and hy antenna. A typical Phased Array Antenna for microwave radar application might have several thousands indl radiating elms that allow the beam to be switched from one dir to another in fraction of a sec. Concept of Phased Array23. Coherent Superposition of Electromagnetic Waves.

The electromagnetic waves possess the property of super positioning coherently at each pt in space. It is of two types, constructive and destructive. In constructive super positioning (Fig 8a), the incident waves are

<https://assignbuster.com/phased-array-radar/>

in phase and hence the resultant waves is the sum of amplitude incident waves. That is the resultant wave has doubled energy. On the other hand, in destructive super positioning (Fig 8b), if the same waves are out of phase at any particular pt in space, the amplitudes are cancelled and energy is lost.

Thus forming an area of max electromagnetic radiation activity, perpendicular to the plane of antenna array. In this way a radiation pattern of simultaneous radiating elms can give a constructive or destructive interference as per their phase diff, which leads to steering of the main beam. Fig ??“ 8 a Fig ??“ 8 b24.

Array Elms. An array of antenna elms is an extended collection of multiple similar radiators or elms which have the same radiation patterns and they are all fed with the same frequency defined by a fixed amplitude and phase angle for the drive voltage of each elm. Fol array patterns can be configured as per req of the application:-a. Linear Array. Consists of antenna elms arranged in a straight line (Fig 9). Fig ??“ 9 b.

Planer Array. It is a two dimensional configuration of antenna elms arranged to lie in a plane (Fig 10). In both the linear and planner arrays the elm spacing usually are uniform (equal spacing). Fig -10 c. Broadside Array. The arrays in which the dir of max radiation is perpendicular to the plane of the antenna (Fig 11) is known as broadside array.

. Fig -11 d. Endfire Array. In Endfire arrays, dir of max radiation is parallel to the array (Fig 12).

Fig - 12 e. Conformal Array. In this case the antenna elms are distributed over a non planer surface. Example of such array is a sphere mounted with antenna elms to cover 3600 (Fig 13). Antenna Elms Fig - 1325.

Electromagnetic Radiation of Phased Arrays. Consider an array of equally spaced elms. Phased shifters are set at same phase.

As explained earlier the EM radiations have the quality of coherent super positioning. The waves from each antenna, after a certain dist interface with those of other antennas. Thus forming an area of max electromagnetic radiation activity as depicted by crossing wave fronts (Fig 14). 26. Beam Positioning. Fig 15 Illustrates the dir and the pt where the beam energy would be max. All in phase participating elms join to maximize electromagnetic energy at pt ??? P??™. Fig - 1527.

Beam Steering. If all the elms are allowed to radiate in phase then the max energy beam will mov in a straight line. The beam of an array antenna can be steered in angle by changing the relative time or phase delay b/w the elms (Fig 16). It changed the posn of pts where the max constructive interference would occur, thus changing the dir of antenna beam. In the fig the area of max electromagnetic radiation activity, as depicted by crossing wave fronts, is at an angle to the plane of antenna.

1 2 3 4 Beam Steering in Linear Array Antenna Fig ??“ 16 Beam Steering in Linear Array Antenna Fig ??“ 1728. Methods of Beam Steering. Beam of an array antenna is steered by providing relative phase differences to the array elms. There are two methods of achieving this; mech steering and elect

steering. We will discuss electronic beam steering methods being the latest tech. it is of the following types:- a.

Time Delay Scanning. Consider Fig 18 below, two elements of a many element array spaced a distance d apart. The signal arrives at element 2 before it arrives at element 1. If the signal is delayed at element 2 for a certain time it will be in coincidence with signal at element 1.

If these two elements are added together, it would be as though the main beam of this simple two element array was in the direction 0 . Time delay scanning requires costly and heavy equipment and is therefore unattractive. Fig - 18 b. **Phase Shift.** It is much simpler to employ a phase shift in the frequency of adjacent elements (Fig 19). The signals are then in phase rather than coincident in time. In a linear array, phase shift needs to be increased at each of elements in order to have all the signals with the same phase relative to reference element. c.

Frequency Scan. Another but unpopular method is the frequency scanning. In this method the physical length of the waveguide is changed to change the frequency interval. Advantages of Phased Array²⁹. Phased array is capable of performance, not possible or difficult to obtain with other types of antennas. Its chief attributes are given in subsequent paragraphs. a.

Flexibility in Operation (Electronic Beam Steering). It permits the radiation pattern to be steered rapidly from one direction to another in a very short time without the need for heavy mechanical movements. Electronically scanned beam aligns with the target while antenna remains fixed, for example:- (1) Simultaneous Monitoring/Tracking of Multiple Targets. (2) Multimode capabilities.

b. Various Modes. The flexibility of this antenna allows beams to be placed precisely where they are req to perform diff functions. For example :-

(1)Surv. (2)Tgt acquisition and tracking. (3)IFF interrogation.

(4)Msl guidance. c. ECCM Cap. The cycle of op mode can be varied to match the tac needs of the moment thus inc the problems facing an en ECM analyst or op. d.

Con of Radiation Pattern. The aval of a large no of elms, methods of con phase and amplitude of indl elms also allow con over the rad pattern. e. Elect Beam Stabilization.

The radiated beam can be stabilized electronically by means of phase shifters rather than stabilizing the entire antenna mechanically. This is particularly imp when radar is mtd on ship or ac which are subj to pitch, roll and yaw. f. Suitable Configuration. Phased arrays have suitable shapes for mtg on vehs and hardening against nuc blasts. g. Graceful Degradation.

The distr nature of the array means that it falls gradually rather than all elms at once. h. Potential for Large Peak and Average Power.

Each elm of an array can be fed by a separate high power tx which can be comb to obtain a total power greater than that of a single tx. Applications of Phased Array Radars³⁰. Phased Array antennas are today the state of the art tech for radar applications. Phased array antennas are used in specialized radar applications such as Scan-while-Tr radars e.

g, AN/tpq-36, sars (SYNTHETIC Aperture Radars), ISARs (Inverse Synthetic Aperture Radars), GBRS (Ground Based Radars) e. g. US Army THAAD

<https://assignbuster.com/phased-array-radar/>

(Theatre High Altitude Area Def), X band GBR for tac and ballistic msl def) and E Wng from msl attk e. g L/M-2080 L Band Radar for Israeli Arrow Tac Msl Def Sys.

The phased array radar sys like S-300V1 (Msl guidance radar-Grill Pan) of Russia, which is used as SAM under all weather conditions and KS-1A, which has multi tracking and multi engagement cap. Some of the application are also found in AWACS (Airborne Wng and Con Sys) where phased array radar is used in airborne EW sys. Latest developments in the fd of phased array antenna include dev of antenna for volumetric search for e. g. Volume Array Crow Nest.

Freq Bands Used in Radar Application

31. CI	HF (3 to 30 MHz)	-	Obsn at Sea (OTH)
	VHF (30 to 300 MHz)	-	Satellite detection
	UHF (300 to 1000 MHz)	-	Airborne E Wng
	L Band (1 to 2 GHz)	-	Land based Long Range Surveillance Radars (513/514B)
	S Band (2 to 4 GHz)	-	Precision Tracking / Med Range Air Surveillance (AWACS)
	C Band (4 to 8 GHz)	-	Long Range Precision Msl Tracking Radars / Multi Function
	X Band (8 to 12.5 GHz)	-	Mil Wpn Con Tracking Radar (Skygd / FCS-702A)
	Ku Band (12.5 to 18 GHz)	-	Airport Surface Detection Radar
	Mm Wavelength (> 40 GHz)	-	Space Applications
	Laser Freq	-	Tgt info gathering (Range Finders)

32.

Band Applications (L, S, C & X) a. L Band (1.0 to 2.0 GHz). This is performance freq band for land-based long-range air surv radars, such as the 200-nmi radars used for en route air tfc con. The advantages are as fol:-

(1) Advantages (a) It is possible to achieve good MTI performance at these

freqs. (b) High power with narrow-beam width antennas can be made in this band. (c) External 3D radars can be found at L band.

(d) L band is also suitable for large radars that must detect extraterrestrial tgts at long range. b. S band (2.0 to 4.0 GHz). Freqs lower than S band are well suited for air surv. Freqs above S band are better for info gathering, such as high data rate precision tracking and the recognition of indl tgts. The advantages and disadvantages of S band are as fol:- (1) Advantages (a) It is the preferred freq band for long-range weather radars that must make accurate estimates of rainfall rate.

(b) It is good freq for med-range air surveillance applications such as the airport surv radar (ASR) found at air terminals. (c) The narrower beam widths at this freq can provide good angular accuracy and resolution and make it easier to reduce the eff of hostile main-beam jamming that might be encountered by mil radars (d) Mil 3D radars and height radars are also found at this freq because of the narrower elevation beam widths that can be obtained at the higher freqs. (e) Long range airborne air surv pulse Doppler radars, such as AWACS (Airborne Wng and Con Sys) also op in this band.

(2) Disadvantages. (a) Long range usually is more difficult to achieve than at lower freqs. (b) The echo from rain can significantly reduce the range of S band radars. c.

C Band (4.0 to 8.0 GHz). This band lies b/w the S and X bands and can be described as a compromised b/w the two. It is difficult, however, to achieve long-range air surv radars at this or higher freqs. It is the freq where one can

find long-range precision instrumentation radars used for the accurate tracking of msIs.

This freq band has also been used for multifunction phased array AD radars and for med range weather radars. Giraffe and FCS-702A radars op in this freq. The advantages of this freq band are as fol:- (1) Advantages (a) Antenna size is small. (b) The beam width is smaller due to small antenna size.

(c) Power consumption of C band radar is low as compared to other bands. (d) Freq range is well suited for long range, precision tracking radars. d. X band (8 to 12.5 GHz). This is popular freq band for mil wpn con (tracking) radar and for civ applications.

Skygd and FCS-702A radars op in this freq. The advantages and disadvantages are as fol:- (1) Advantages (a) Shipboard navigation piloting and the police speed check radars are all found in X band. (b) Radars at this freq are generally of convenient size and are thus of interest for application where mob and It wt are imp and long range is not. (c) It is advantageous for info gathering as in high resolution radar because of the wide bandwidth that makes it possible to generate short pulses and the narrow beam widths can be obtained with relatively small-size antennas.

(d) X band radar may be small enough to hold in one??™s hand or as large as radar with 120-ft-diameter antenna and average radiated power of about 500 KW. (2) Disadvantages (a) Rain can be debilitating to X band radar. (b) Long range is not easy to achieve. Concl33. It is apparent that array configuration has great potential, it is also apparent that the array radar is

<https://assignbuster.com/phased-array-radar/>

quite complex and costly. Since instl of an array will usually be considered in the context of inc sys eff, the sub of cost eff will no doubt receive considerable attn. The principle advantages offered by the array configuration lies in its ability to cope with a relative large no of maneuverable tgts.

Keeping in view its utterly superior features regardless of cost the array configuration appears mandatory in most radar applications of tomorrow.

DEFINITIONS OF TECH TERMS1. Antenna. An antenna is a conductor or sys of conductors, which radiates or receives energy in the form of electromagnetic waves.

2. Duplexer. It is the device that allows a single antenna to serve both Tx and Rx. 3. Question Pd. Total time interval between the transmission of two consecutive pulses. This time pd is measured after the transmission of one pulse to the start of transmission of next pulse.

4. Dead Time. This is the time taken between transmission and reception of particular pulse. It can also be defined as the two way travel time of a particular pulse. It is termed as length of time base, too. 5. Listening Time. The time during which the reception takes place.

During this time, transmitter is switched off. 6. PRF. Number of pulses being transmitted in one second. Freq is transmitted in small bursts or packets and the number of these bursts or packets in one sec constitutes the PRF. 7. Radiation Pattern.

It is the measurement of energy leaving an antenna. 8. Lobe.

It is the area of a radiation pattern that is covered by radiation. 9. Null. It is the area of radiation pattern that has min radiation. 10. Dipole. A radiator which couples electromagnetic fd to the surrounding space is called a dipole.

11. Elm. The basic elm is gen a dipole. 12. Array.

An array is a combination elms/dipoles op together as single antenna. 13.

Phase Shifter. Also called a phasor, is a device for obtaining a change in phase of an electromagnetic wave. 14. Power Amplifier. It amplifier the IRF sig so that higher power transmission can be obtained.

15. Circulator. A device which offers separation of Tx and Rx without the need of conventional duplexer. 16.

Low Noise Amplifier. It is a sensitive low sig power amplifier used at receiver end. 17. Noise.

It is the unwanted electromagnetic signal which interferes with the ability of the receiver to detect wanted sig. 18. Coherent Waves. By coherent waves it is meant that the transmitted wave is in phase with a ref wave.

19. Eff Aperture Area. It may be regretted as a measure of the eff area presented by the antenna to the incident waves. 20.

Aperture Illumination. The process of hitting / distributing incident waves on eff aperture area of the antenna is called aperture illumination. 21. Limiter. It rejects undesired freq sigs / noise which may interfere receiver op and allows only useful info to pass through. PHASED ARRAY RADAR

PHASED ARRAY RADARSPHASED ARRAY RADARSPHASED ARRAY RADARS—————

TxAntennaDuplexerRxPresentation UnitTransmitter= TXReceiver =
 RXTXPULSEPULSEWIDTHQUIESCENTQUIESCENTTX PULSESTIME BASEPRF
 1000LISTENINGTIMEDEAD TIMER TMPAHPACirculatorAntennaLIMLNAT
 RPhase ShifterRTDivider/ CombinerPlane of AntennaDir of RadiationPlane of
 AntennaDir of radiationAll waves arrive in phase at PPhase ShiftersRF
 InputAntennaPhase ShiftersRF InputAntennaPhase ShiftersRF
 InputAntennaPhase ShiftersRF InputAntennaFd Super positioning of Linear
 Array AntennaFig - 14Phase ShiftersRF InputAntennaPhase ShiftersRF
 InputAntennaPhase ShiftersRF InputAntennaPhase ShiftersRF
 InputAntennaWave Fronts of Max EnergyBeamBoresight AxisBoresight
 AxisRadiating in PhaseAltering the Phase to Change the AxisTime
 Delay2100Od[pic]Fig ??“ 7a[pic]IN PHASEOUT OF
 PHASEResultantConstructiveResultantDestructiveO1000Phase delayFig -
 19ANGLEBeamPhase ShifterP