Active Phased Array Radars as an Effective ECCM systems

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Abstract— Phased Array Radars have started to regain some serious attention over the past few decades owing to its high accuracy, efficiency and less susceptible characteristics. The most basic requirement that one could wish for in a good modern radar is its beam agility, low distribution loss, maximum bandwidth, lower cost, maximum efficiency and effective resource management. Modern phased array radars can be best utilized to achieve characteristics of an effective radar system with minimum tradeoffs. The most basic thing that it can achieve is, that the antennas can be arranged to get the desired radiation pattern. The characteristics and detection abilities of active phased array radar systems are discussed. Moreover, the paper suggests that active phased array radar can be best suited as an electronic counter-counter measure system.

1. INTRODUCTION

Most recently aircrafts have been developing in higher detection capabilities are getting better in efficiency. Moreover, aircrafts and missiles are getting better in mobility and RCS reduction, therefore higher search and tracking is required for a better air defense system and there is a need for advances in the existing radar technologies [9]. Active phased array radars can be a very good solution for radar designers to overcome various issues faced during the designing. In active phased array antennas, transmission and reception is performed using transmit/receive modules which are known as T/R modules.

Phased array radars can be broadly categorized into passive phased array and active phased array radar system. In a passive phased array radar, the microwave feed network in the backside of the antenna is powered by a single radio frequency source, which send its source into phased shift modules which are fed to the emitting elements whereas in the active phased array there is a radiating source for each element. The significance of active phased array radar is the use of T/R module for each radiating element [1].

In this paper, we have presented an analysis of modern active phased array radar systems which are not only efficient but are also best suited to cope up the threats of electronic countermeasure system and hence fulfill the requirements of modern air defense system. Section 2 explains few notable characteristics of active phased array systems and Section 3 presents simulations highlighting the detection abilities of the phased array system.

2. CHARACTERISTICS OF AN ACTIVE PHASED ARRAY RADAR

2.1. Graceful Degradation

Most of the radars stop functioning in case there is an issue with the radiating element or the antenna. Phased array radars have multiple antennas and radiating element, so they overcome this issue. Active phased array radars provide graceful degradation so that many transmit receive modules may fail and radar would still not stop functioning.

2.2. Data Rate

High data rate is required for detection of fast moving aircrafts. Phased array radars are most suitable for such aircrafts as they can be expected to optimize energy beam adaptively to individual surveillance region in response to a threat environment. The overall system of the radar can be maneuvered with ease. Specifically, it can be expected to adaptively optimize energy, beam and time assignment to individual surveillance region in response to any external threat [9]. The beam agility of phased arrays causes fast time sharing between search, acquisition and tracking stage for radars in a diversified environment [10].

2.3. Maintenance and Flexibility

Owing to the advancement in the existing circuit technology, very small size and light weight modules can be mounted on the phased array system [2]. These modules are known as transmit receive modules. These T/R modules can provide tractability to the overall system. The modules can provide flexibility in the overall working of the system according to the nature of the target threat. If any module stops functioning owing to any reason, it can be disconnected and replaced quickly without affecting much the performance of the entire system. Antenna performance is improved by the use of T/R modules and such a system also provides a great amount of improvement in the choice of array architecture [11].

2.4. Power Management

Active array system also provides a great amount of improvement in the areas of power management and efficiency [3]. Power is radiated directly into space with minimum power loss and also power consumption cost is reduced. The usage is controlled by the managing radar waveforms and the corresponding beams energy. By doing this, the probability of target detection is also maximized. In addition to the reduction in transmission and reception losses, active arrays can provide wide instantaneous bandwidth and higher average radiated power [11].

2.5. Anti Jamming Capabilities and Polarization

Modern phased array radars are under a complicated electromagnetic surrounding, so they should have high resolution anti jamming potentialities. Jammers can be very effective if they can use the same polarization as that of the radar using DRFM (digital radio frequency memory). This can be overcome if the antenna elements have two orthogonal polarization channels and can receive dual polarization echo signals [6].

3. DETECTION ABILTIY OF MODERN PHASED ARRAY RADAR SYSTEM

Phased array radars have discovered many capabilities that were not present only a few years ago [7]. With the enhancement of microwave and signal processing technology, phased array radars have been designed and used in many areas of research [4, 5]. Since phased array antennas have higher cost, there use is cost effective only if they would handle multifunctional capabilities like search and multi target tracking. There saturation is also better than other radars against multiple targets [8]. Now we are going to present few simulations highlighting the detection abilities of active phased array system.

Figure 1 shows the normalized pattern of a 2d array with 10 elements on x axis and 100 elements on y axis, where as Figure 2 shows the normalized pattern with 100 elements on x axis and 100 elements on y axis. Clearly we can see that the side lobes amplitudes have decreased considerably. So by this, jamming can also be countered and more power can be concentrated in particular direction of interest. Figures 3 and 4 show the normalized pattern for different spacing between elements. Number of elements are 10 on both x and y axis. The spacing between elements in the Figure 3 is 1 and spacing between elements in Figure 4 is 0.5. Simulations in Figure 3 and Figure 4 show that spacing between the elements also affects the pattern and hence it needs to be taken into account while designing an effective ECCM system.

Now we will investigate the effect of squinting on the total electric field of the phased array system. Equation (1) shows the function of electric field that will be used in remaining simulations.

$$E_T(\theta, \Phi) = \sum_{n=1}^{N} A_n F_n(\theta_n, \phi_n) e^{-j(k|r_n|+\beta_n)} \tag{1}$$

where E_T is the total electric field in linear volts for N elements and F is the element pattern function for the nth element in linear form, 'A' refers to the amplitude of element in volts, 'R' is

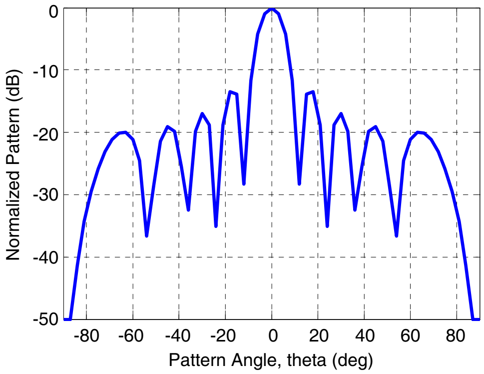

Figure 1: Normalized pattern vs. pattern angle for 10 elements on x axis.

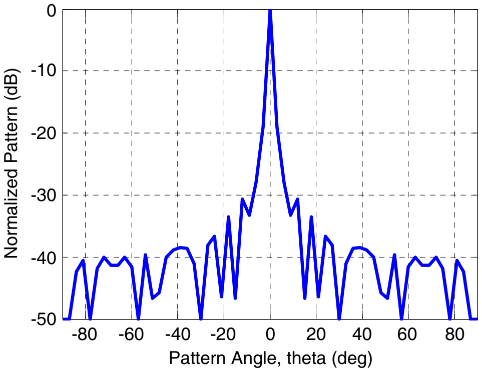

Figure 2: Normalized pattern vs. pattern angle for 100 elements on x axis.

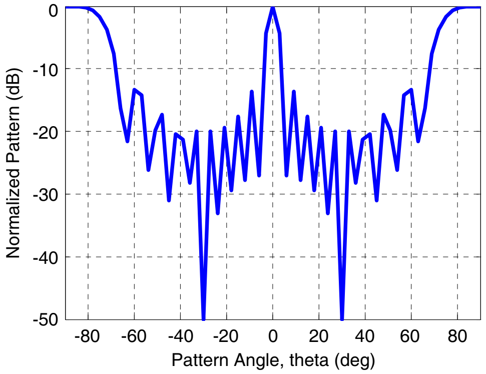

Figure 3: Normalized pattern vs. pattern angle for spacing of 1 between elements.

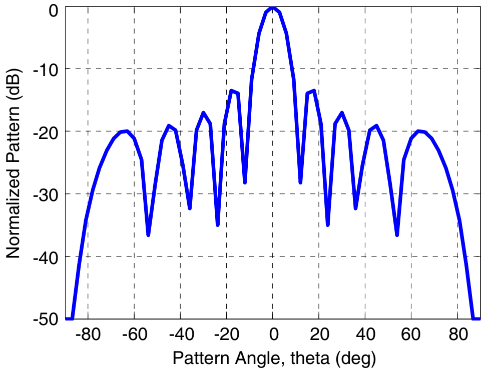

Figure 4: Normalized pattern vs. pattern angle for spacing of 0.5 between elements.

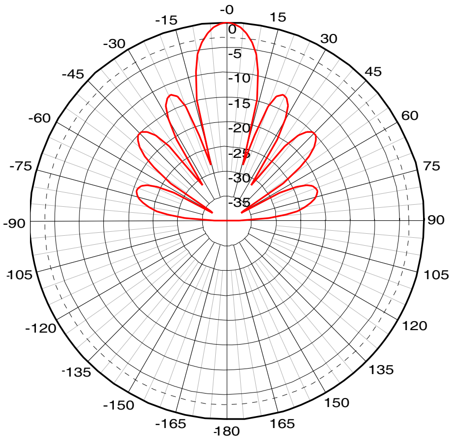

Figure 5: Electric field pattern for 5 elements.

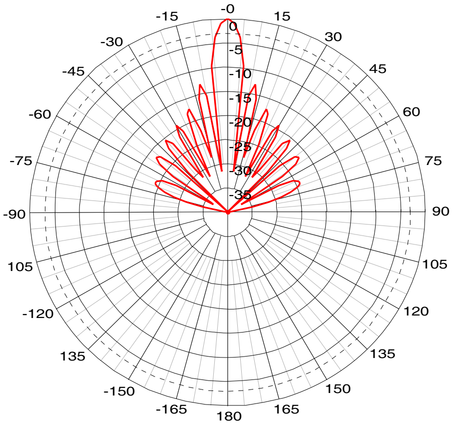

Figure 6: Electric field pattern for 10 elements.

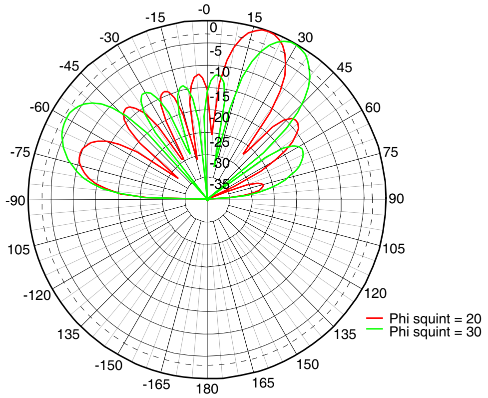

Figure 7: Electric field pattern for azimuth squint of 20° and 30°.

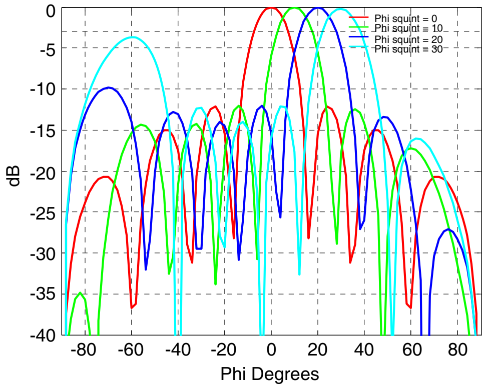

Figure 8: Pattern cuts for azimuth squint of 0°, 10°, 20° and 30°.

the distance from the element and 'B' is the phase of element in radians [12]. Figure 5 shows the pattern for 5 elements each on x and y axis and Figure 6 shows the corresponding pattern for 10 elements. These simulations are performed for operating frequency of 5 GHz. The results show that increasing number of elements is narrowing the lobe for each element. These properties also become useful while considering sidelobe blanking for overcoming the sidelobe jamming and hence proving an effective ECCM system.

Figure 7 is highlighting the pattern for phi squints of 20 and 30 degrees and Figure 8 is showing the power corresponding to various values of squint angles. The corresponding phi squints give the maximum peak at these values. Taking into consideration different T/R modules, we can also have an effect of a MIMO system and overall system can be able to transmit while having frequency diversity, different polarization and sidelobe blanking. The results shows that offsetting the transmission angle of different radiating elements of active phased array radar can give us a desired radiation pattern and hence can be very useful as it can overcome the effects of various forms of jamming.

The figures show that at specified phi squints, corresponding power is 0 dB. Such a system can be very effective against barrage,sweep and spot jamming. An active phased array tracking system is quite immune to ECM effects because they can quickly scan an area randomly and are not bound to scan its radar beam in a particular method as it is done in conventional radars. The irregular position of the beam would make it difficult for the opposing ECM system when and where to send false signals. If we have active phased array antennas depending upon the target threat, the TR modules at undesired directions can be silenced to get all power concentrated at focused direction, where the target threat is expected.

4. CONCLUSION

Modern active phased arrays radars can be exploited to have all properties that one could wish for in good military based radar. They provide an overall improvement in radar functionality and performance. They also provide improved anti-jamming ability, fast beam scanning and ability to track multiple targets at a time. The benefit we can extract from the active nature of the arrays is the modifications of TR modules which are independent of other TR modules. Hence active phased array radar can be casted by the user according to the demands of the situation. In future, modern phased array systems with MIMO functionality can make an ideal ECCM system. The benefit of active phased array would be the vigilance to approaching threats all across azimuth and elevation angles.

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