A Novel Approach to Counter the Low Observable Characteristic of Stealthy Targets by Analyzing the Radar Cross Section

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Abstract— Stealth technology has added an inspiration in the field of electronic counter measure and has brought out the ineffectuality of the mono-static radars. The stealth aircrafts scatter very low intensity electromagnetic radiations due to its special geometry and absorbent material. However, if an electromagnetic wave is incident at 'good' angles, stealth aircraft though low observable cannot be called as invisible. In this paper, the results of the extensive simulations on a model stealth aircraft have been presented. Simulations are performed, on an aircraft model to prove the effectiveness of the proposed model. By energizing the aircraft at 'good' angle(s) of incidence, significant scattering can be observed over a range of aspect angles. Thereafter, a multi-static approach is proposed making a polygon arrangement of radar transceivers in order to guarantee the detection of a stealth aircraft.

1. INTRODUCTION

Shortly after the innovation of the radar in the third decade of the twentieth century, the research on the reduction of the RCS (radar cross section) got enormous attention especially for aircraft and military targets [1]. ECCM is mainly reactionary i.e., ECCM technology has been developed in reaction to observed threats. If the ECM (electronic counter measuring) impacts are observed in a particular system, a system resolution must be developed [2]. In this paper we propose a counter-counter measure to low observable technology. Radar cross section (RCS) dictates the strength of EM wave reflected from the target. In other words, detectability of a target is dependent on the strength of the reflected and/or scattered energy which in turn depends on the characteristics of the target (for example target's material, absolute and relative size), angle of incidence and reflection and polarization of the transmitted and received signal. Mono-static RCS in terms of electric field is given by the following equation [3].

$$\sigma = \lim_{r\to\infty} 4\pi r^2 \frac{|E_s|^2}{|E_I|^2} \tag{1}$$

where E_s is the scattered electric field intensity and E_i is the incident electric field intensity.

There are different methods for calculating the radar cross section of an object [4]. The method of moments is a popular technique that solves electric or magnetic field integral equations. This method gives accurate results but it is computationally intense. In the finite difference method (FDM), finite differences are used to approximate the differential operators in Maxwell's equations. The target must be discretized as in method of moments. Since this method calculates the fields in the region around the target, computing the RCS of large dimension would entail considerable time. An alternate method is the physical optics approximation that is simpler and gives accurate results for large targets. The POFACETS GUI is a convenient tool for electromagnetic professionals to design and analyze the complex models of the aircrafts. Typically, design of complex models is carried out by representing its components as triangular facets. The GUI calculates the radar cross section of the modeled object. This tool has been used frequently to calculate the RCS [3]. In this paper, POFACETS tool based on physical optics method is used for calculation of RCS. In the light of the attained results, we have discussed the importance of using bi-static radars to counter the stealth effects. The results show that if the aircraft is energized at a 'good' angle of incidence, significant scattering can be observed in a range of aspect angels. Thereafter, a multi-static approach is proposed making a polygon arrangement of radar transceivers in order to guarantee the detection of a stealth aircraft.

2. SIMULATIONS ON AIRCRAFT MODEL

Radar absorbing material and stealth material structures have re-entrant triangles inside the structure. Radar waves falling into the skin get entangled within these structures scattering off internal surfaces and losing energy with these facets. In order to study the 3-D RCS of a low observable aircraft, a model of the aircraft was built using POFACETS GUI [3]. The model is built using triangular facets and each facet's reflectivity is chosen to be 2. Such low reflectivity is chosen owing to stealth effects. The simulations for the computation of the RCS for both monostatic and bi-static radars have been performed. For mono-static radars the location of the transceiver unit is varied from 0° to 360° Figure 1 shows the model of the aircraft used for the simulations. If the mono-static radar is used for illuminating such a model, the RCS remains negative for most of the incident angles and frequencies. It can be seen that for a wide range of angles, the RCS is very low (less than $-20\,\mathrm{dB}$), see Figure 2. For only few angles, the RCS becomes positive and even those angles have a very small range and most of the time it would be practically impossible to place a radar transceivers at such angles whereas, bistatic angles in Figure 3 can overcome such situations for carefully placed receiver at that position.

Figures 4, 5 and 6 show plots of frequency vs. RCS. Rectangle in the figure denotes the aircraft, aero directions pointing the aircraft are the incident angles and the ones going away are showing the reflection.

2.1. Discussion on the Results

There is a greater range of frequencies with positive RCS when incidence, target and reception of EM wave make a triangle as shown in Figure 5 or the shadowed side of the aircraft had good

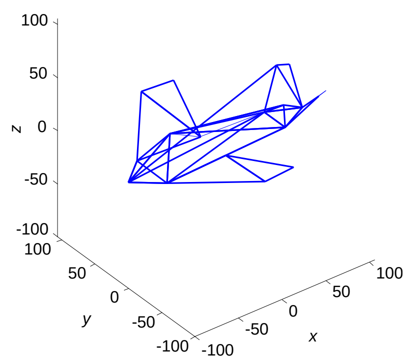

Figure 1: Model of aircraft, viewing angle −37.5° azimuth and 30° elevation.

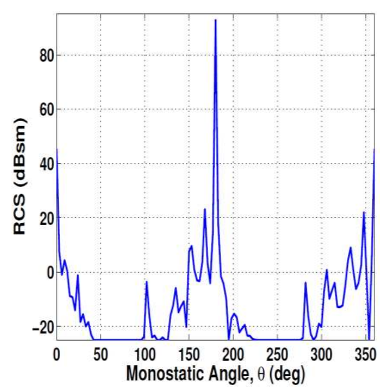

Figure 2: RCS vs. monostatic angles.

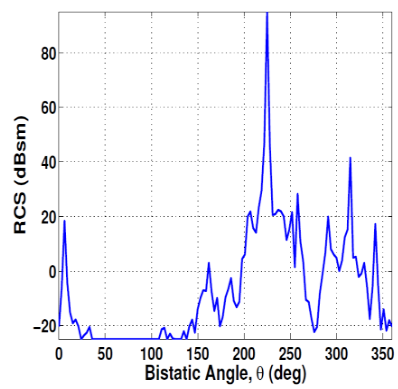

Figure 3: Bistatic radar RCS vs. angle for angle of incidence of 45 degrees.

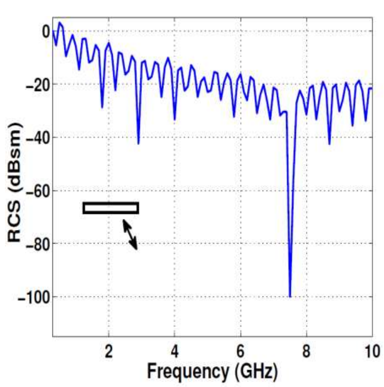

Figure 4: Bistatic radar RCS vs. frequency for 135 incidence angle and observed at the same (monostatic radar).

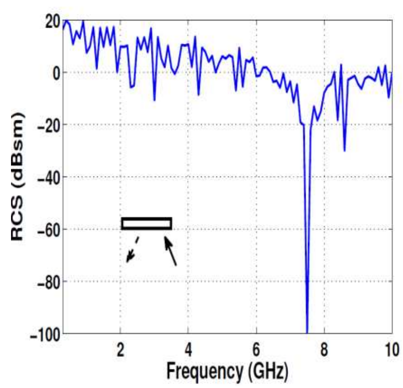

Figure 5: Bistatic radar RCS vs. frequency for 135 incidence angle and observed at 230 degree.

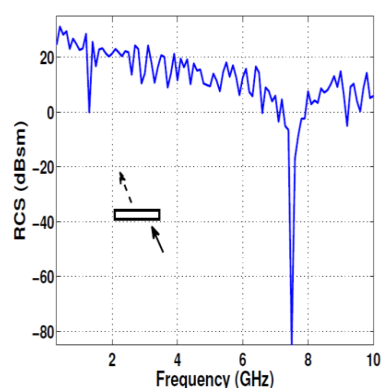

Figure 6: Bistatic radar RCS vs. frequency for 135 degree incidence and observed at 310 degrees.

scattering. These figures show that if there is a properly placed receiver on the other side of the aircraft, it would receive enough scattering to detect the target threat. Hence there are 'good' angles that can be set for the radar receivers in multistatic approach. The monostatic case in Figure 4 showed that RCS was negative even for lower frequencies and hence the probability of detection would be less. Now when we see Figure 5 and Figure 6, we conclude that there is even greater range of frequencies with greater RCS. The mono-static radar is a complete failure because there is greatest range of frequencies for negative RCS, when observed and incidence angle are same.

3. MULTI-STATIC RADAR CONFIGURATION IN A POLYGON

Taking into considerations all the simulations and effectiveness of stealth in making ground based radar helpless, we have come to the conclusion that there are two prime locations where a significant scattering can be received and that is explained in Figure 7.

We propose an idea of using a multi-static approach to limit the effectiveness of stealth aircrafts. We need four radar transceivers as shown in Figure 8. These four radars should be separated to each other and all acting as transceivers and their synchronism make a polygon. All the radars should be located at different heights from each other to take maximum benefit from the proposed idea. If radar A transmits; all the other radars receive the scatterings associated with radar A. Since the first demonstration of the multi port receiver, there has been significant interests in the various tangible multi port radar technologies [5]. All radars should be synchronized and should have multi port phased array antenna. Antennas could be active phased array with each subsequent array cross polarized with the neighbor.

Three possibilities of target approaching this configuration of radars are shown in Figures 9, 10 and 11. In the corresponding figures yellow lines showing incidence and red lines show the radar return, the thickness of lines show the strength of the scattered signal.

The multistatic radar configuration can use data in fusion in the process of information col-

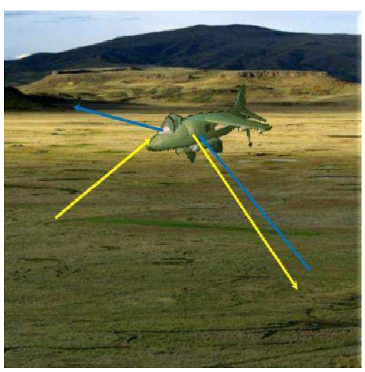

Figure 7: Significant scattering directions for a stealth configured aircraft.

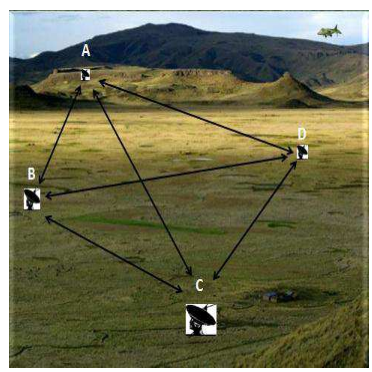

Figure 8: Our proposed solution of using 4 radar transceivers arranged in a polygon.

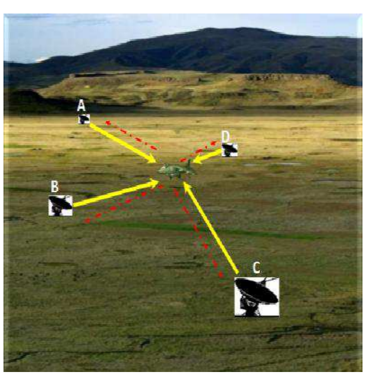

Figure 9: Case1: target is in the range of all radars.

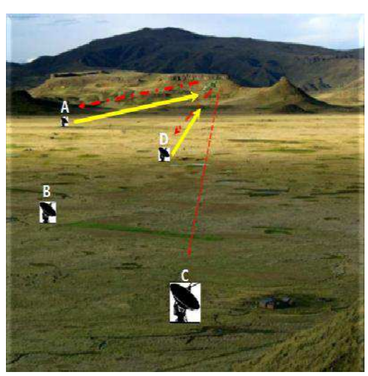

Figure 10: Case2: A, C and A, D making 'good' angles.

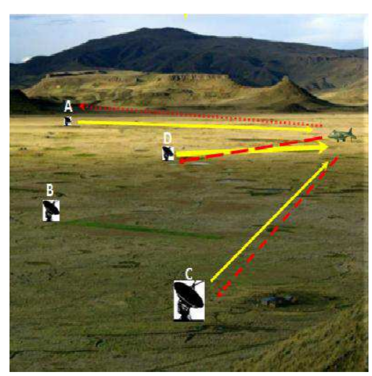

Figure 11: Case3: target is approaching or by passing the system of radars.

lection. The concealment feature of bi-static radar is not complete as the transmitter station is still electromagnetically exposed and can be easily attacked [6]. Our proposal even overcomes this situation. A concept of 'silent hard killer' is about an aircraft that arrives at a target area, where enemy's radars and weapon systems should be killed or at least crippled [7]. Our configuration can overcome the negative effects of such a situation since there are four radars working with each other. Our proposed configuration can also be used for low frequency radar since the radars are acting as transceivers for each other and by using correlation and proper filtering, clutters can be avoided and at the same time our proposed system can easily be upgraded with any desirable feature like changing of polarity, operating frequency or miscellaneous features.

4. CONCLUSION

From the observations we saw that there was a maximum positive RCS for greater range of frequencies at the shadowed side of stealth aircraft, so if there is a receiver there, it can make use of these scatterings to detect the target threat. Also there was a considerable RCS towards and away from the approaching target threat, i.e., when a triangle is made between transmitter, target and receiver. So our proposed configuration suggests that if there are 4 radars in a polygon arrangement they would be able to detect the target for all the three cases that have been discussed. Another advantage is this that the proposed configuration can be used for low frequency radar since there are 3 other radars that are acting as receivers and by using correlation and proper filtering, clutters can be avoided and at the same time it would have enough room for upgrading more features for increasing its anti stealth abilities. Thus as proposed, an active phased array radar with cross polarized arrays and using a 1 GHz Frequency (lower L band of radar) is highly probable of detecting a stealthy machine in its domain.

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