# Electronic Counter-countermeasures in Bistatic Radars

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**Abstract**— Bistatic configuration of radars has become a topic of great interest for Electronic counter-countermeasures designers. The paper emphasized the need for bringing about a trend of employing bistatic radars in place of traditional monostatic radars which are no more useful under the hostile environment that is created by the electronic counter measures effect. It has been shown that noise and deception jamming can be countered using bistatic configuration of the radar system. Moreover, low observability of the target threat can also be dealt with using this configuration.

## 1. INTRODUCTION

Electronic counter measures and electronic counter-countermeasures are the two major types of electronic warfare that are always seem to be in competition with each other [1]. There has been a rapid increase in performance of both radar and electronic warfare since World War II [2]. Bi-static radars are gaining attention over the past decade because of its ECCM abilities [3]. Apart from the physical isolation of the system, most of the advantages of bi-static radar are because of the geometric properties of the system [4]. With the advancements in the ECM systems, there is a constant need to counter and hence nullify the effects of ECM and hence to make the radar capable of detection and localization of the target threat. Study of techniques in ECCM is promising [5]. Bistatic radar's history dates back to the earliest days of its invention [6]. Bistatic radar approach is not something which has to make a comeback in the radar technology, rather it has already a number of specialized applications in physics, wind measurements and by astronauts [7]. The important operation in passive bistatic processing is to keep apart the transmitter-to-receiver path and target-path (i.e., transmitter-to-target-to-receiver signals) [8]. Bistatic and multistatic radar configuration are promising areas of research which also require advances in many other areas as well [9]. There are a number of reasons which shows that the interests in multistatic configuration of radars will continue to grow [10, 11]. There is no doubt that a lot of research and development is in progress related to bistatic radars but still there are a lot of loopholes considering bistatic clutter [12]. MIMO radar which is more easily realized in bistatic configuration is a topic of great interest for radar designers interested in ECCM of radar systems. Nevertheless, considering this, there exist many engineering challenges that are needed to be addressed. Moreover, there has to be a better understanding of bistatic and multistatic radar cross section phenomenon [13]. MIMO radars have more degrees of freedom than typical monostatic radar. This enables improved angular resolution [14, 15], variable time energy management and improved parameter identification [16].

## 2. TRANSMIT POWER AND THE SIGNAL TO NOISE RATIO ANALYSIS

Figures 1 and 2 show the transmit power analysis of bistatic radar corresponding to max range product. For Fig. 1 baseline length has been set to 10 km, the bistatic angle is 10 and RCS of the target is 20 dBsm whereas for Fig. 2, baseline length has been set to 2 km and the bistatic angle is 20 and RCS of the target is 10 dBsm. The figure shows if the RCS is reduced, greater transmitted power is required. Figures from 1 to 6 and 8 are drawn using [22].

Figures 3 and 4 show the signal to noise ratio analysis of bistatic radar corresponding to max range product. From these figures, it can be concluded that if the bistatic angle is increased, the corresponding SNR is reduced. The bistatic angle, i.e., positioning of transmitter and receiver has a big role to play in the overall working of the system.

## 3. RADAR CROSS SECTION ANALYSIS

The detection ability of the target is dependent upon a parameter which is the radar cross section. It describes the strength of the electromagnetic wave reflected from the target threat. RCS in terms

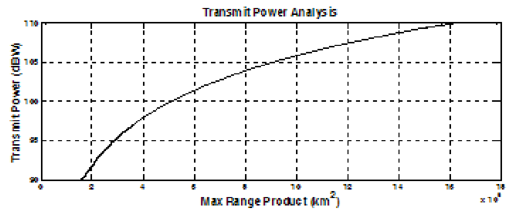


Figure 1: Transmit power analysis for Bistatic angle of 10 degrees and RCS of 20 dBsm.

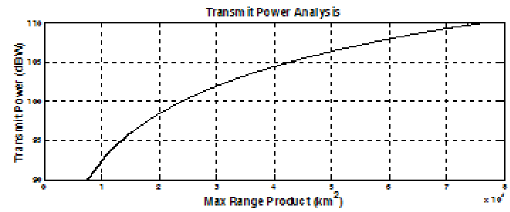


Figure 2: Transmit power analysis for Bistatic angle of 20 degrees and RCS of 10 dBsm.

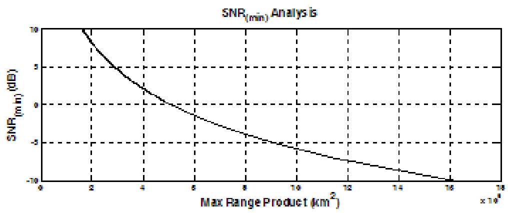


Figure 3: SNR analysis where angle is 10 and RCS of the target is 20 dBsm.

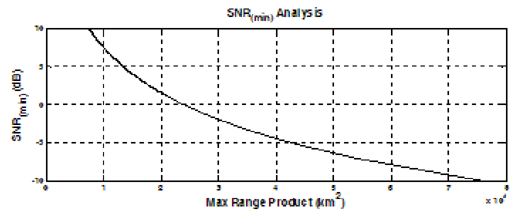


Figure 4: SNR analysis where angle is 20 and RCS of the target is 10 dBsm.

of electric field is given by [17].

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

Bistatic target RCS, denoted by $\sigma_B$ is different from typical monostatic RCS. In the case of a small bistatic angle, the bistatic RCS is similar to the monostatic RCS: but, as the bistatic angle approaches 180°, the bistatic RCS becomes very large and can be approximated by [18].

$$\sigma_{B_{\max}} \approx \frac{4\pi A_t^2}{\lambda^2} \tag{2}$$

where $\lambda$ is the wavelength and $A_t$ is the target project area.

Power delivered to signal processor by the receiver's antenna is

$$P_R = \frac{P_t G_t G_r \lambda^2 \sigma_B}{(4\pi)^3 R_t^2 R_r^2 L_t L_r L_p} \tag{3}$$

The subscripts '$t$' and '$r$' denote transmitter and receiver respectively. $L_p$ is medium propagation losses and $G$ is the gain of the antenna.

With a bistatic system, the energy is not scattered back directly but with an angle, $\beta$. The radar cross-section for scattering is dependent on this angle.

Bistatic radar range is written as

$$\sqrt{R_T R_R} = \left( \frac{P_t G_t G_r \sigma_B F_t^2 F_r^2 c^2}{(4\Pi)^3 k T B D_2 L f^2} \right)^{1/4} \tag{4}$$

The subscripts '$t$' and '$r$' denote transmitter and receiver respectively. $\sigma_B$ is the bistatic radar cross-section. $G$ is the gain of the antenna. $F$ is the propagation factor. $c$ is the velocity of light, $k$ is Boltzmann's constant, $T$ is the system noise temperature in $K$. DS is the signal-to-noise ratio required for detection, $f$ is the frequency of the radar and $L$ is the product of the losses.

Figure 5 shows the target RCS analysis of bistatic radar corresponding to max range product. The baseline length has been set to 10 km if the bistatic angle is set to 10° whereas, Fig. 6 shows the target RCS analysis of bistatic radar for the bistatic angle of 20° and baseline length has been set to 2 km. For a maximum range product of 4 km$^2$, target RCS is 18 dBsm for Fig. 5 where as it is about 14 dBsm for the case where bistatic angle is greater, i.e., in Fig. 6. The beta angle is dependent upon the corresponding positioning of transmitter, receiver and the target. The liberty of deploying the transceiver system by taking into consideration the target threat gives an immense advantage to bistatic radar configuration as compared to the corresponding monostatic system.

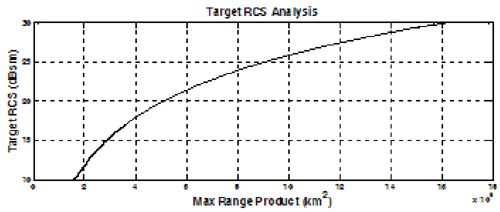


Figure 5: Target RCS analysis for Bistatic angle of 10°.

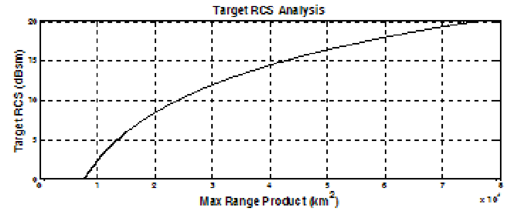


Figure 6: Target RCS analysis for Bistatic angle of 20°.

Low observable targets usually scatter in various directions where monostatic radar usually fails to detect. In such situations bistatic radar is far more probable for detecting such a target.

Figure 7 shows bistatic angle versus the radar cross section of a fuselage for an incidence angle of 30 degrees for radar's transmitted frequency of 2 GHz where, fuselage permittivity is 3.7 [23]. We can see that there is a range of angles where RCS is considerably greater and hence it would be easily detectable.

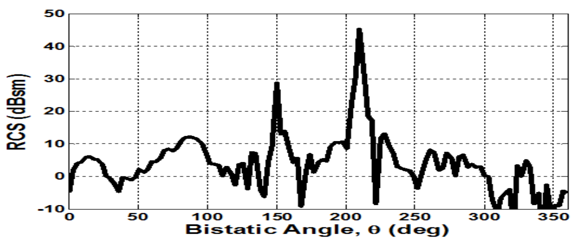


Figure 7: RCS vs. Bistatic angle.

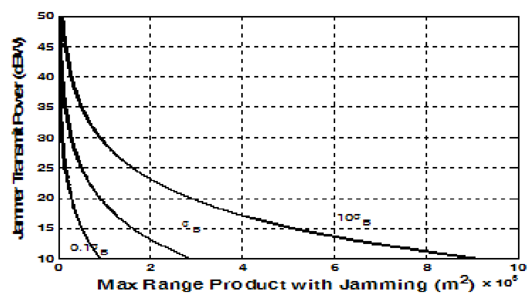


Figure 8: Jammer transmit power vs. max range product for jammer receiver range of 1 km.

The advancement in technology has enabled the radar designers to place the transmitter and receiver so much so that either of these can be even on ships or other carriers. The delocalization of transceiver system has enabled the designers to improve the detection abilities of the radar [19].

RCS reduction is achieved by shaping the target in a way that it does not scatter in the direction of transmitted signal. This shaping may reduce the RCS when looking at the front of a target using monostatic radar; however, it is often the case that the RF wave will scatter in a different direction, providing a large RCS in some "bistatic" direction [20].

A noise jammer typically radiates with a bandwidth that is wider than the radar receiver's. The effect is the raise in total power spectral density of the background noise in the receiver from $N_0$ to $N_0 + J_0$.

Where

$$J_0 = \frac{P_J G_J G_R F_J^2 \lambda^2}{(4\pi)^2 B_J R_J^2 L_J} \tag{5}$$

Under usual jamming conditions, jammers bandwidth is greater than receiver's noise bandwidth [21].

Figure 8 shows that as the RCS increases, jammer requires more transmit power for some value of maximum range product with jamming. Also, as the jammer receiver range is decreased, maximum range product is decreased for fixed values of jammer transmit power.

## 4. CONCLUSION

The paper has shown the advantages that the radar designers can exploit from a bistatic radar approach, courtesy of the geo placement of the distant receiver. Similarly bistatic approach allows simultaneous accomplishment of ECCM techniques which improves the probability of detection. Bistatic radars can also give the liberty to designers of employing MIMO functionality by making an intelligent transceiver system on both the sites. Low observable stealthy targets which scatter the incoming transmitted wave in various directions can be best dealt with if there is a corresponding receiver or a transceiver system in best probable direction. Moreover for such targets, there is a range of aspect angles which can be exploited by using bistatic system. In addition to this, jammers which target the antenna sight of the radar for a typical monostatic system, no longer remains effective if there is a receiver at a distant sight.

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