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RADAR TARGET DETECTION WITH REDUCED RADAR CROSS SECTION

INTRODUCTION

There has been growing interest over the last 30 years in the application of bistatic and multiposition radar techniques for both long and short range surveillance radar. Currently, low observable (LO) aircraft have been designed to have a low backscatter cross section. It can be shown that using aircraft shaping techniques to reduce the backscatter return of LO aircraft tends to increase the bistatic RCS of the same aircraft, thereby increasing its probability of detection. Bistatic radar systems may have important advantages with respect to monostatic radar systems. Besides having greater freedom in selecting waveform modulations, getting more information out of every transmitted signal and are less vulnerable to ECM and ARM-threat.

Very important and interesting is using commercial sources as transmitter for illumination for example TV a radio broadcasting net or mobile telephone net. Processing of backscattered signal from air objects illuminated by commercial sources may be realised by detecting, tracking and measuring the position of these objects.

RCS REDUCTION

There are four basic techniques for reducing RCS [1]. They are:

- Shaping;
- Radar absorbing materials;
- Passive cancellations;
- Active cancellation.

The objective of shaping is to orient the target surfaces and edges so as to deflect the reflected energy in direction away from the radar. This cannot be done for all viewing angles within the entire sphere of solid angles because there will always be viewing angles at which surfaces are seen at normal incidence and there the echoes will be high. The success of shaping depends on the existence of angular sector over which low RCS is less important then over others.

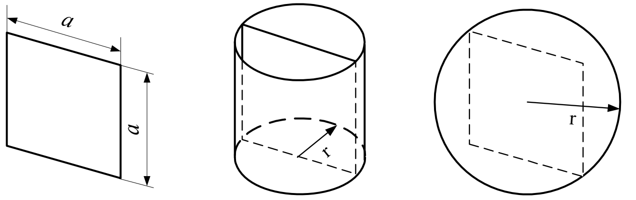
Shaping can best be exploited if threat sector are established. This is because shaping usually does nothing more then shift the region of high echoes from one aspect angle sector to another. The RCS reduction achieved over one sector is accompanied by an RCS enhancement over another. We might think that the surface of the target can be enclosed by a surface having a lower RCS. For example a square flat plate enclosed by a cylinder or sphere just large enough to accommodate the plate as depicted in Fig.1. The echoes from these three targets can be estimated and compared using these prescriptions

$$\sigma_{plate} = \frac{a^2}{\pi}\left[k\,a\cos\theta\frac{\sin(k\,a\sin\theta)}{k\,a\sin\theta}\right]^2 \tag{1}$$

$$\sigma_{cylinder} = \frac{2\pi\,r\,l^2}{\lambda} \tag{2}$$

$$\sigma_{sphere} = \pi\,r^2 \tag{3}$$

where a is the dimension of the plate, l is the length of the cylinder, r is the radius of the cylinder or sphere.



a, b, c,

Fig. 1. RCS of (a) flast plate reduced by (b) cylinder or (c) sphere

The RCS patterns are plotted for an arbitrary plate length of 25λ and have been normalized to the square of the plate length in Fig. 2. The flat plate has a large secular value for broadside incidence at $\theta = 0$ and falls off very quickly as the aspect angle increasing.

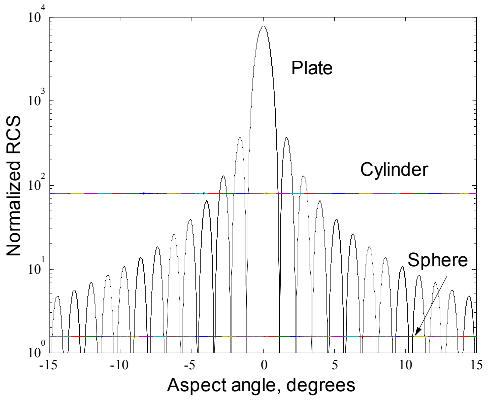


Fig. 2. RCS patterns of flat plate, cylinder and sphere

It is clear, that a substantial reduction in RCS is available if the plate can be oriented so that it is never seen broadside.The RCS of the cylinder is independent of θ because is rotationally symmetric about the axis normal to the direction of incidence and lies some 20 dB below the specular plate return. Similarly, the return from sphere is constant and lies nearly 30 dB below the specular plate echo.The display of Fig. 2 also illustrates hat a reduction of RCS at one angle is usually accompanied by an enhancement at another.

Radar absorbing materials reduce the energy reflected back to the radar by means of absorption. Radar energy is absorbed trough a kind of ohmic loss, dielectric loss or magnetic loss. Radar absorbers can reduce specular echo and creeping wave as well.

The basic concept of passive cancellation is to introduce an echo source whose amplitude and phase can be adjusted so as to cancel another echo source. This can be accomplished for relatively simple body. It is difficult to generate the required frequency dependence, and the reduction obtained for one frequency rapidly disappears as the frequency is changing. Moreover, the cancellation can revert to a reinforcement with a small change in frequency or viewing angle.

Active cancellation is the less discussed part of RCS reduction. In this case the target must emit radiation whose amplitude and phase cancels the reflected energy. Target must sense the angle of arrival, intensity, frequency and waveform of the incident wave. It must also know its own echo characteristics for that particular wave and angle of arrival. It must be fast enough to generate the proper waveform and frequency, and versatile enough to adjust and radiate a pulse of the proper amplitude and phase.

BISTATIC RADAR

Bistatic radars are sometimes grouped into two general types: narrow angle bistatic systems wherein the transmitting and receiving antennas are not widely separated, and wide angle bistatic systems wherein the angle the transmitting and receiving antenna beams at the target approaches 180°. In general monostatic and bistatic RCS are not equal. For small bistatic angles the bistatic RCS is closely approximated by the monostatic RCS. For larger bistatic angles such a simple equivalence is no longer valid.

Range of bistatic radar system is defined by:

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

where P_r is the received power, P_t is the transmitted power, G_t the transmit antenna gain, G_r is the receive antenna gain, λ is the wavelength of transmitted signal, σ is the target bistatic cross-section, R_t is the transmitter to object range, R_r is the object to receiver range, L_t are the propagation losses transmitter to object, L_r are the propagation losses object to receiver, L_s are the losses in processing system.

The principle of bistatic radar system is given in Fig. 3 [2, 3]. Where φ is azimuth of transmitter antennas characteristic, Θ is azimuth of receiver antennas characteristic, β is angle of observation base, v is velocity of target and α is the course of observed object.

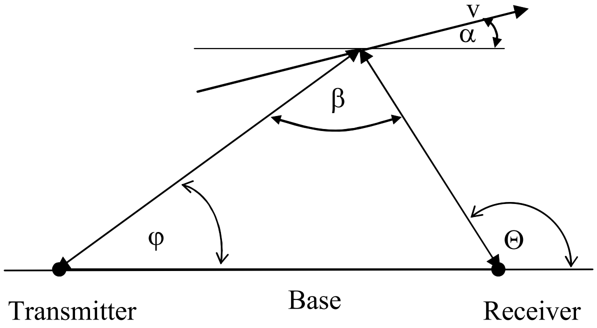


Fig. 3. Bistatic radar geometry

The co-ordinates of air object can be estimated by hyperbolic, elliptic, Doppler and bearing method. The co-ordinates can be evaluated by known relationships [1]. When bistatic radar system measure θ, φ parameters and $R_t+R_r = S$, then co-ordinates in rectangular system are defined by

$$x = \frac{\frac{S}{2}\left(\frac{2a}{S} - \cos\varphi\cos\theta\right)}{\left(\frac{2a}{S}\right)\cos\varphi\cos\theta - 1};\; y = \frac{\frac{S}{2}\left(\frac{4a^2}{S^2-1}\right)\cos\varphi\sin\theta}{\left(\frac{2a}{S}\right)\cos\varphi\cos\theta - 1};\; z = \frac{\frac{S}{2}\left(\frac{4a^2}{S^2-1}\right)\sin\varphi}{\left(\frac{2a}{S}\right)\cos\varphi\cos\theta - 1} \tag{5}$$

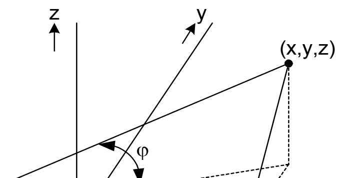


Fig. 4. The co-ordinate system

The measure of error of position an air object (Fig. 3) depends on base option B, ratio $(R_t+R_r)/B$ and on precision of measured parameters φ, θ and S. When the co-ordinates are estimated according to Doppler frequency shift, then relationships are more complicated and require more receivers.

The monitoring by bistatic radar includes more manners **Hiba! A hivatkozási forrás nem található.**4]. In Fig. 5 are presented two, which are convenient for using of commercial transmitter illuminator for radar purpose.

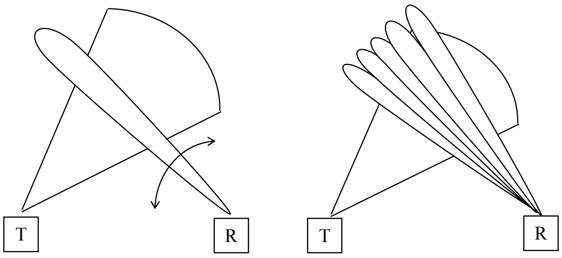
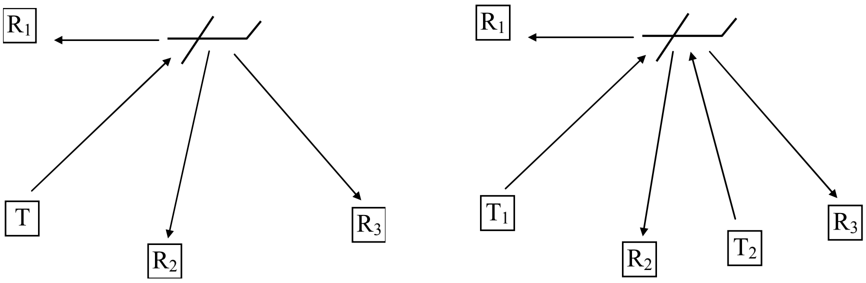


Fig. 5. Antennas characteristics of bistatic radar system

MULTIPOSITION RADAR SYSTEM

Multiposition radar system (MRS) include co-operate transmitter and receiver stations with different structure. The Fig. 6 presents structures of MRS, which are appropriate for non traditional radar methods [7].

For target detection and location in multiposition radar systems some kind of system coordination and synchronization between the different sites are required. This includes spatial, time and phase synchronization and the frequency, waveform as well as transmitter and receiver position must be known. Critical point of design and operation of MRS is the spatial controlling of distributed stations, mutual synchronisation, date transition between stations and reference signals generation for time coherent signal processing in receivers.



a.) b.)

Fig. 6. MRS with (a) one transmitter and (b) two transmitters

For mutual synchronisation of MRS navigation system can be used; for example GPS or special communication channel. Reference signals can be formed in central unit and transmitted to remote station by communication channels.
Coherent signal processing based on Doppler frequency shift requires delivering a pattern of transmitted signal to receiver station. High effectiveness of synchronization and time coherent processing of received signals can be achieved by directly receiving of transmitted signals in main lobe eventually in side lobes. The spatial position of object with desired accuracy is determined by evaluating of phase of received signals. One receiver and several transmitters with known positions or by one transmitter and some receivers may accomplish this.
Specific problem is design of special receivers for radio or TV signals. For radar purpose is very interesting using of transmitters mobile telephone net. Some problems are solved in **Hiba! A hivatkozási forrás nem található.**5, 6].

CONCLUSION

The inherent advantage of bistatic radar can have a direct impact the future development of radar systems. Using shaping techniques to reduce the backscatter return of LO aircraft tends to increase the bistatic RCS, thereby the bistatic radar become more popular. Development of communication systems, positioning systems, signal and data processing can allow create available bistatic radar system to detect targets even with reduced RCS.
Moreover, the multipositon radar system based on using commercial transmitter net seems to be a very useful source of radar information for short range use. This system can provide increasing amount of radar information in spatial monitoring with required accuracy. MRS using signals of commercial transmitters can detect and track air objects in complicated electromagnetic background.

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