Analyzing the Conventional Mechanisms and Specific Technique Regarding Incrementing the Effective Radar Cross Section (RCS) For Utilizing It in Electronic Warfare Along with Their Related Features.

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ABSTRACT:
One of the most important features of the defense systems in each country is the abilities and capabilities of deceiving the other side(enemy) and reducing or increasing the target recognition by them. "Radar" is one of the most important tools for target detection. The effective Radar Cross Section (RCS) of each body (which is also unique) effects on distancing the speed, direction and distance of the targets (by means of Radar). Therefore, by changing the quantity of RCS, it is possible to involve the Radar to make a mistake in target acquaintance. This paper, while making clear some of the most important features of RCS and the particulars of the related structure and function, analyzes the current mechanisms and presents a particular technique concerning the reduction or increment of the effective RCS of the targets, with the aim of utilizing it in Electronic Warfare(EW). In the meantime some other items nomely: parameters and factors in RCS, Rayleigh curve, Corner reflectors, Dihedral and Trihedral corner reflectors, The effect of angle of exposure of radiation on the target in the above mentioned corner reflectors. Drawing the related conclusion, etc. are being analyzed and examined minutely, in this paper.

KEYWORDS: Radar Cross Section (RCS) - Effective RCS- Corner reflectors - Dihedral reflectors- Trihedral reflectors - Electronic Warfare(EW)- Electromagnetic waves.

1. INTRODUCTION

"RADAR" is one of the most important identification tools. "RADAR", is the abbreviated from of the phrase "Radio Detection and Ranging " [1].

In some cases, such as: commerical consignment and missile tests, the designs are such that the target identification by Radar should concisely stated. But, in defence subjects, particulary in the field of ElectronicWarfare(EW) domain, both sides seek the techniques and methods in order to reduce the target detection rate. On the other hand, the effective RCS of the targets is one of the impression parameters in distance finding by Radar, in which the related intensity of the reflected energy is effectively used concerning its description.

Therefore, it can be deduced that the change of RCS contributes to the fulfilment of the above mentioned domain by the Radar. for example, in order for proving to be true the better recognition, in missile tests and to create false targets, they increase the RCS, and in the secret techniques, they decrease the RCS. It is mentionable that the concealment technique started in 1950's by using Radar Absorbing Materials (RAM) in order to decrease the RCS, by American Air Force [2].

After having done making clear the RCS, the necessity of a soluation to increase it based upon the formation of the target is minutely analyzed and calculated in this article, as well.

2. THE EFFECTIVE RARAR CROSS SECTION OF THE TARGETS

After having hitted and encountered the emitted Electro Magnetics Waves(EMW), they dispresed and reflected in all directions. These scattered electromagnetic waves can be divided in two parts:

A) part of the waves(EMW), which will have the same polarization of the receiving antenna.

B) part of the waves(EMW), which will have a different polarization than the receiving antenna.

The intensity of the energy reflected from the target, which has the same polarization as the receiving antenna, is used to describe the RCS [3]. To that reason that has been mentioned, RCS is an equivalent imaginary assumed level which returns the same amount of energy to the radar [1].

3. RCS CALCULATION

We assume that the power density of the emitted on a target at the distance R is P_D (P_D is the radiation power of the source). Afterwords the reflected power of the target is P_r, that will be proportional to the effective RCS of the target (σ), and with respect to(WRT) the power density of the reflected Waves, we will deduce the equation (1) by which the effective RCS of the Radar is described.

$$\sigma = 4\pi R^2 \left(\frac{P_D}{P_r}\right) \quad (1)$$

Since the receiver antenna is usually at the far distance from the target, the equation (1) can be optimised as (2), because at a far distance, the reflection waves received by the antenna will be flat [3].

$$\sigma = 4\pi R^2 \lim_{R\to\infty} \frac{P_D}{P_r} = 4\pi R^2 \lim_{R\to\infty} \frac{|E_D|^2}{|E_r|^2} \quad (2)$$

$$= 4\pi R^2 \lim_{R\to\infty} \frac{|H_D|^2}{|H_r|^2}$$

It worths mentioning that, the returned waves from a target are always proportional to the ratio of the target to the wavelength of the radiation waves. That is, the radar will not be able to detect the targets having very small wavelengths. Taking care of this point can be helpful in Electronic Warfare.

4. THE EFFECTIVE PARAMETERS AND FACTORS IN RCS

The effective RCS of the target is a function of the parameters as follows [4]:

1.The position of the transmitter with respect to the target; 2. The position of the receiver with respect to the target; 3. The target geometry shape and composition of matter; 4. The angular position of the target with respect to the transmitter and receiver; 5. The frequency or related wavelength; 6. The polarization of the transmitter and receiver.

5. RAYLEIGH CURVE:

As mentioned above, one of the effective factors of the effective RCS level of the targets is the wavelength of the transmitted signal, and the manner of variation of the RCS, which is proportional to the frequency range of the wavelength. This serious and important affair, which has been inferred by Rayleigh, is summarized in the curve of Fig. 1 for the cross section of an orb.

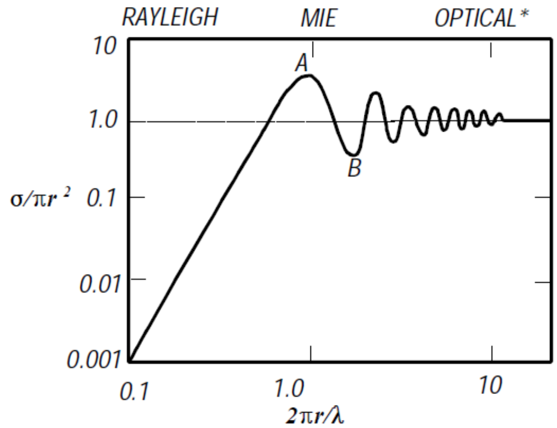

Fig. 1. The variation of the effective RCS of an orb due to the related variation of the wavelengths [5].

The Rayleigh curve indicates the special manner of RCS variation, versus the variation of the related wavelengths. In this manner, the variation of the wavelengths, divides the curve into three divisions, namely:

In the first region, the RCS has a liner relationship with its $\frac{2\pi r}{\lambda}$. In the second region, which occure for frequencies greater than the first one, is completely oscilating, that is, it doesn't result in the formation of a cross section with a constant value and it will not be known. The reason for this is that the interference interacting with the surface of the sphere with the spatial flux of the sphere; and the third region, it has a constant value, that is, the frequency change will not change the cross section, because having increased the frequency, the mechanism of the fluctuating waves disappears, and only the front surface will reflect the waves [4].

6. CORNER REFLECTOR ANALYSIS

In order to obtain a better comparison, easier calculation and easily deduce the related items, the RCS of the targets can be uniformed with an orb having an RCS of $1m^2$.

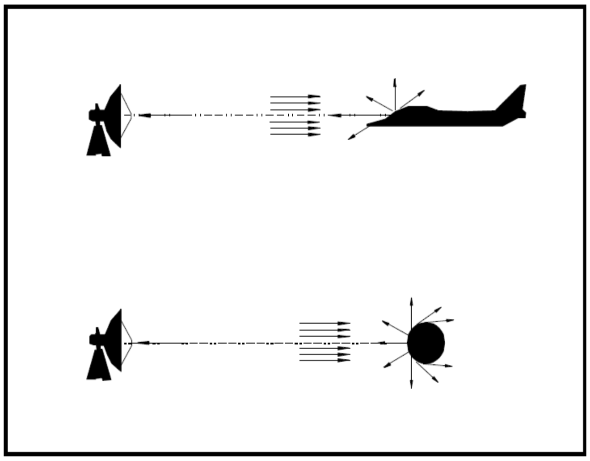

Fig. 2. The effective cross section of the Radar [5].

Now, depending on the amount of radiation frequency from the source, whose wavelength is smaller or greater than the radius of the sphere, and the angle of collision of the emitted rays onto the target, various modes occur in the calculation of RCS of the targets (such as the sphere and the flat surface).

But, the important thing concerning Electronic Warefare is to change this quantity, in order to make some mistakes in target diagnosis of the receiver Radar. One method for doing so, which can lead to an increase or decrease in the quantity of RCS, is based on objective formation. Creating a change in the target's shape can be performed by using a regular or unpredictable form, each of which will be tailored to the necessity of the implementation plan. in this paper, we will examine the shapes which reflect the larger rays in accordance with their characteristics. These shapes are called "Corner Reflectors", which usually consists of 2 or 3 surfaces of metal, and are arranged to form a 90 degrees angle with each other.

The hatted electromagnetic waves onto these targets are reflected several times as much, because, unlike a orb which reflects the wave of radiation equally in all direction. These shapes are reflected in one direction, thus, each object with a surface having small section, can have strong enough reflection [6].

Corner reflectors can be performed in a variety of shapes and sizes, but what has so far been important and common, is the standard shapes outlined below:

7. DIHEDRAL CORNER REFLECTOR

We assume that the longitudinal edge of the corner reflector is longer than the wavelength of emitted wave. The wave is exactly emits onto one of the surfaces, and the angle of radiation with the surface makes 45 degrees. Considering the recent assumption after the collision with the front surface and subsequently the second surface, the wave returns in the direction of it is twisted; therefore, an equilateral triangle with an equilirium angle appears, with a chord size of √2 times of the rectangle of the shaded surface and, given that the length does not differ, the area of the shadow that acts similar to a flat surface acts as (3):

$$A_{Proj} = A_{WR} \times \sqrt{2} \tag{3}$$

Where A_{Proj} represents the area of the shadow (this is a hypothetical plane that appears to reflect effectively all the beams after colliding with this plane.) and A_{WR} represents the area of a reflecting corner. equation (4) expresses RCS is a flat panel:

$$\sigma = \frac{4\pi A^2}{\lambda} \tag{4}$$

Where: A is a mirrorless flat panel.

We will put the equation (3) to (4) in place:

$$\sigma = \frac{4\pi}{\lambda^2}(\sqrt{2} \times A_{WR})^2 = \frac{8\pi \times A_{WR}{}^2}{\lambda^2} \tag{5}$$

That is to say that the maximum amount of RCS will be a dihedral corner reflector [6].

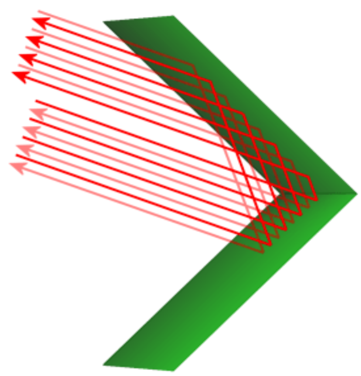

Fig. 3. A Dihedral corner reflector [6].

8. EFFECT OF THE ANGLE OF IMPACT ON THE TARGET, IN DIHEDRAL REFLECTION:

If the angle of radiation is not 45 ° with respect to the reflector surface, then, the reflection of the emitted wave will not be in the same direction with respect to the target. This causes that the target shadow area to be less than 45 °, and as a result of this, the produced quantity of the RCS, It will be less than that compared with.

$$A_{Proj} = 2A_{WR} \times sin\theta \tag{6}$$

$$\sigma = \frac{8\pi (A_{WR})^2}{\lambda^2} \sin^2\theta \tag{7}$$

The variation of RCS of the Dihedral corner reflector versus the variation of the angle of emitted wave having 0 ° <θ <90 °, is illustarated in Fig.4. It has been taken into account that: 0 ° <θ <90 ° and the area of the shadow is $1m^2$ and the reflected wavelength belong to 10GHz, using MATLAB software.

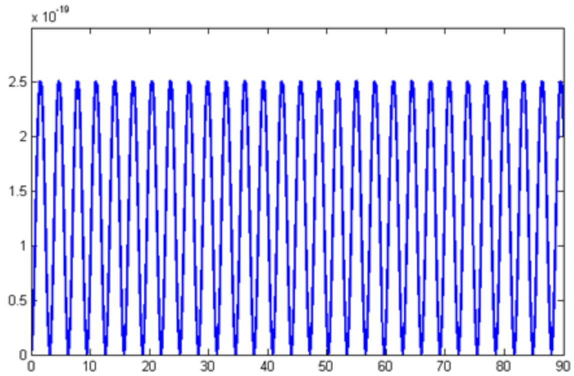

Fig. 4. The variation of RCS of the Dihedral corner reflector versus the variation of the angle of emitted wave having 0 ° <θ <90 °.

As can be seen from Fig.4 that, at high and constant frequeny, the variation of RCS of the targets versus the variation of the impaction degree is quite volatile. (In the second region of the Rayleigh curve)

9. TRIHEDRAL CORNER REFLECTOR

These reflectors are also formed of three surfaces which are perpendicular to each other. The quality of these surfaces are usually Aluminum, which of course, Iron has also been utilized in the related corners and edges in order to strengthen and protect them from deformation, as well as the physical alteration in aluminum surfaces [7].

Now, by changing the geometrical deformation of the surfaces which are formed as the different Trihedral forms as is mentioned hereunder, by which the produced effective RCS will also have different quality are established.

9.1. Trihedral rectangular cube

After having performed some experimentation, among the triangular reflectors, the rectangular cube has shown more stablity and reliability. Also, the produced RCS of that is higher than that the other one[7]. The quantity of the related RCS in maximum condition, which takes place in the angle of radiation which is 45°, is as follows:

$$\sigma = \frac{12\pi \times {A_{WR}}^2}{\lambda^2} \tag{8}$$

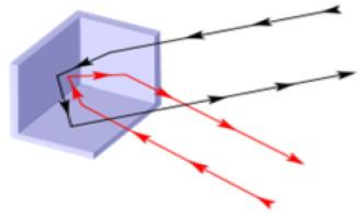

Fig. 5. Trihedral rectangular cube [8].

In this reflector, similar to dihedral corner reflector, the change of the effective shadow area and thus the quantity of RCS as well [6]:

$$\sigma = \frac{12\pi (A_{WR})^2}{\lambda^2} \sin^2 \theta \tag{9}$$

The variation of the RCS, versus the wavelength, is illustrated in Fig.6, in which: 0 ° <θ <90 °, assuming: the shadow area of $1m^2$ and the reflected wavelength of 10GHz, using the MATLAB software.

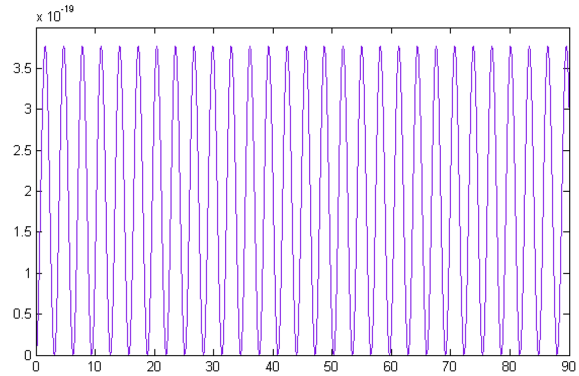

Fig. 6. The variation of RCS of the Trihedral of the corner reflector rectangular cube versus the variation of the angle of emitted wave having 0 ° <θ <90 °.

According to Fig.6, the quantity of cross sectional range is more than Dihedral one, but at a constant frequency, the effective radar cross section of the target is highly volatile by changing the degree of exposure to the radiation beam (In the second region of the Rayleigh curve).

9.2. Trihedral with surfaces of the equilateral triangles

The area of the surfaces in this kind of reflector is less than that of the Trihedral reflector of the kind of rectangular cube. Thus, the quantity of the effective reflector is also less [6].

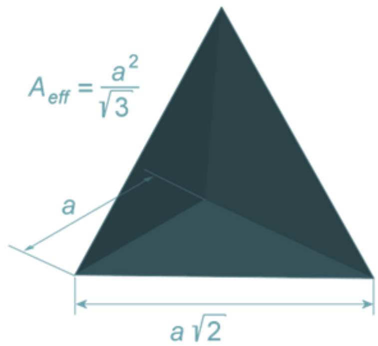

Fig. 7. Trihedral with surfaces of the equilateral triangles [6].

With due to attention of the effective reflected surface, and to take advantage of the equation (4), the maximum quantity of RCS is equal to the equation (10):

$$\sigma = \frac{4\pi \times a^4}{3\lambda^2} \qquad (10)$$

9.3. Trihedral with semicircle section [5]

In this Trihedral, the plane surfaces is in the form of a semicircle, and its maximum quantity of RCS is in accordance with equation (11):

$$\sigma = \frac{15.6\pi \times L^4}{3\lambda^2} \qquad (11)$$

Where L denotes the total length of the surfaces. The above cases are summarized in the table in Fig. 8:

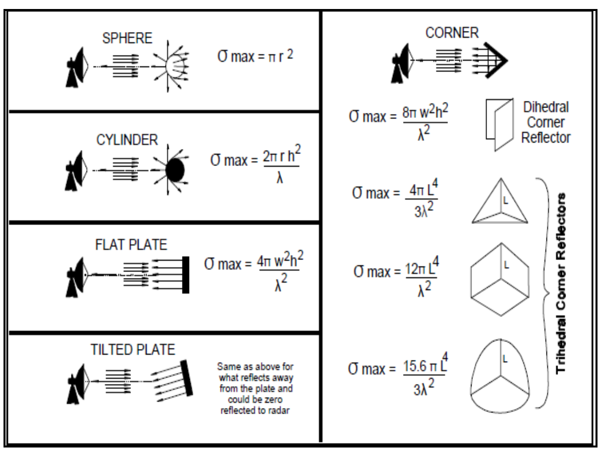

Fig. 8. Radar Cross section of the Objectives [5].

10. INFERENCE

With regard to the above mentioned shapes and cases, it can be deduced that, for the reflection to be irradiated to one of the plates of this form, there are three possible situations: First, the fact that the angle of radiation is somehow after having impacted with the first surface, returns to the receiver antenna. The second mode is when the reflected ray is similar to a Dihedral and before emitting to the third surface is reflected toward the receiver, and third mode is also the impact of the beam with the three surfaces till having the suitable angle for exit. But, in each of three states, if the angle of emitted ray is not suitable, the beam rises to the top of the three sided and the available useful, and as a result of this, This will leave the receiver antenna. but, if a surface is added to it, the reflected beams will return to the upper area, and thus, in the same conditions, the four-faced cross sectional area, will be more than the triangular shape of the previous.

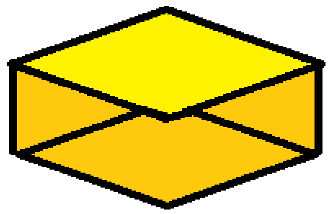

Fig. 9. Four-faced corner reflector

The next notiseable point, is that: if is changed the angle of two connected surfaces in Dihedral, from 90° to 120 °, the maximum effective cross section, having kept the angle of radiation in 60 °, compared with the above mentioned Trihedral rectangular cube, (with the angles of connecting surfaces of 90 ° and the angles of radiation of 45 °), is equal with each other.

The proof of this affair can be such that, if the size of the sides of the triangle created between the corners and the intersection of the location in Fig. 10 is a, the quantity of the area of the shadow panel is created and thus the resulting RCS will be as follows:

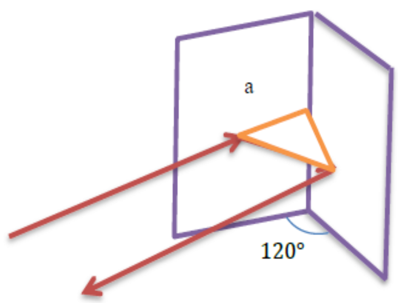

Fig. 10. Dihedral corner reflector with an angle of 120 degrees.

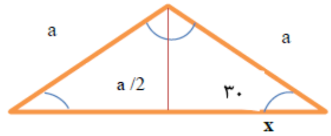

Fig. 11. The triangle created in the corner.

$$x = \sqrt{a^2 - \left(\frac{a}{2}\right)^2} = \frac{a}{2}\sqrt{3} \quad (12)$$

$$A_{proj} = \sqrt{3}\, A_{WR} \quad (13)$$

$$\sigma = \frac{12\pi \times A_{WR}{}^2}{\lambda^2} \quad (14)$$

This property can have different and useful applications, including the use of this point when it requires a less costly structure but with cross-section of the rectangular three-dimensional cube.

11. CONCLUSION

Because RCS has a direct relationship with radar range, so its deliberate alteration makes to an error in detecting the target distance (self-propagation) to the radar of the other party, thereby they will deceive them and reduce the probability that the mission will fail. The change in RCS can be either incremental or decreasing. one of its enhancement techniques is touse the use the corner reflectors in the target, because these reflectors will be more capable of reflecting the radiated beams toward the receiver's radar. Of course, The following points should be considered:
A) We need to know the radar radiation frequency, because it is one of the parameters of calculating RCS.
B) We need to know how much change can be made in the target shape, which cause to identify the mission, the unforeseen costs, not accepting it by the target due to weight gain and so on.
C) The angle of wave radiation of the transmitter (in Radar) is important, as it influences the quantity of RCS.

Other ways to increase RCS include: the use of bi-ststic radar, the use of various radar stations in a radar network, the use of honeycomb or gratings of metal, in order to increase the physical level of the target, or increase the working frequency.
Increasing the working frequency cause to a decrease in wavelengths and thus an increase in received energy, which will causes, for example cause the operator to see the equivalent surface of a squareshaped conductor plate, with a 7.5 cm side exposed to a waveform at 10 GHz , $1m^2$ [2].

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