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Research paper

Bi and Mono Static Radar Cross Section Computation for Various Target's Materials

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Abstract

Radar cross section (RCS) is important parameter which gives an indication about the spatial waveform of the return signal from the target to the radar (Echo) which can be consider as a signature. RCS signature measurements for any physical objects like aircraft, tanks, and vessels is sophisticated processes and expensive, due to of using microwave instruments which should has the capability of illuminate the target with adequate energy, so that the radar can recognize the reflected signal from that object against the other objects in the floor which consider noise floor. In this paper, Computer Simulation Technology (CST) software is used to simulate the RCS for several targets material, and different angles. The target is modeled and simulated for different material and analysis of RCS is carried out with different angles using two systems. The first system is Monostatic and the second is bistatic with selected frequency for both is 9.4 GHz (X-band frequencies). The results of this work show that the target with steel material has a significant RCS for both bistatic and monostatic radar compared to the FR4 and wood materials; where FR4 is a composite material composed of woven fiberglass cloth with an epoxy resin binder that is flame resistant.

Keywords: *cross section area, bistatic radar, monostatic radar, scattering power*.

1. Introduction

After the world war, second war, many tools are become important tools for defense and security for countries, Radar is one of these tools. Additionally, to the mentioned tools, many tools have been added as a new tool, such that processing algorithms, Ultra-Wide Band (UWB), digital signal processors, and so on. With these techniques and tools the hardware stills the essential issue even though the new techniques are depending on software, for signal processing to improve the ability of detection especially for radar, because of the radar system using microwave equipment's which consider more expensive comparing to the equipment used by low frequency circuits [1].
Radar cross section (RCS) is important parameter which gives an indication about the spatial waveform of the return signal from the target to the radar (Echo) which can be consider as a signature. The signature is different for each target or objects, due to that each object has own signature, and this specific signature is exploited to identify the type of structure which will be examined. The current along the metal surface is excited due to electromagnetic energy of the incoming signal, and then reradiating will be carried out for several directions. The radar, which placed on the ground or anywhere, will receive this field [2].
Monostatic radar signature means that the receiver signal would be captured and then processed at the same location of transmission, in contrast with the signature of bistatic which means that the signal can be transmitted and spread in other direction and captured in other location. A square meter is used as a unit for surface, so that it has a relation to an analogous physical area, which scatters the same energy [3].
RCS signature measurements for any physical objects like aircraft, tanks, and vessels is sophisticated processes and expensive, due to of using microwave instruments which should has the capability of illuminate the target with adequate energy, so that the radar can recognize the reflected signal from that object against the other objects in the floor which consider noise floor. Furthermore, the measurements are carried out at the ground does not be the true environment, due to that during real flights there is no ground plane. In point of view of complexity, many software's and simulations are used to analyze and expect the signatures of radar. For example, stealth plane, i.e. vehicles which their RCS signature is almost very low comparing to the real physical size, was designed depending on the analysis using computer software to obtain geometrical shape has the ability of scattering the incident wave on the body of the plane, in consequence the received signal will be very small as possible [3], [4].
Long term evolution wave was applied as a source for passive bistatic radar (PBR) with the experimental study carried out by [4],[8] which studied the detection and location of the moving target as a function of dependent bistatic radar cross section and the parameters were designed according to the mention study. Computer Simulation Technology (CST) microwave studio was selected to perform the analyzing and processing the traditional approaches which sort out the moving target in location for several bistatic radar angles [4].
Radar Cross Section (RCS) reduction is presented with preparatory study on fighter aircraft. Firstly, a priori knowledge about the area of the aircraft which consider vulnerable area to the radar threats was exploited to study the RCS computationally. Additionally, the Radar Absorbing Materials (RAM) applications is evaluated and used to obtain RCS reduction [2]. A simple overview was presented about the numerical process used in the microwave analysis, with this process the bistatic and Monostatic

were simulated the real short range signatures; air to air missile was introduced, the measurements and comparisons were carried out for previous numerical process and presented with [1]. Additionally, several numerical methods are applied to solve the perfect electric conductor (PEC) for variable size targets using I-solver; these methods used an operating frequency of 10 GHz, comparison in point of view of advantages and disadvantages were performed for each solver [3].
In this paper, CST software is used to simulate the RCS for several targets material, and different angles. The target is modeled and simulated for different material and analysis of RCS is carried out with different angles using two systems. The first system is Monostatic and the second is bistatic with selected frequency for both is 9.4 GHz, i.e. X-band frequencies. As results, polar and Cartesian RCS are examined and analyzed and its show that the obtained RCS for a target made of steel is a significant.

2. Radar Cross Section (RCS)

The common definition of reflection is; when an electromagnetic wave incident upon articles, currents will be produced at the surface of the articles. In consequence, scattered field created and radiated due to these currents. The incident electromagnetic wave energy of an illuminated object disperses in all directions. Size, shape, frequency, the composite material of the object, and the nature of incident wave are factors effect on the spatial distribution of incident energy [3], [5]. Scattering means the distribution of incident energy, and Scatterer is the object itself which produce the scattering. While, Radar Cross Section (RCS) is the terms used for describing the amount of scattered power obtained from the object due to the incident energy as shown in Figure (1) which show the schematic of bistatic geometry of radar cross section. Cross section refers to Monostatic when the radar antennas of transmitter and receiver are collocated, while the in bistatic the radar of source and receiver are separated and the cross section refers to the scattering toward the receiver [2], [6].

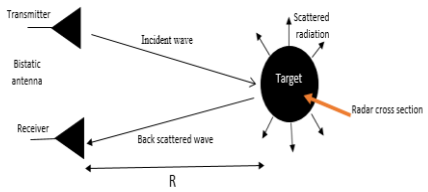

Fig. 1: Schematic of bistatic geometry of radar cross section

In the military application, the aim of reducing the radar cross section is to treat the distance which the object can be detected by the inimical radar. The impact of reduction RCS is described by the radar equation which provides quantitative way for analyzing the relation between the RCS and distance, radar equation for radar is defined with eq. (1) [5].

$$R_{max} = \left[{(P_t G_2 \lambda_2 \sigma)} \Big/ {(4\pi)3\ P_{min}\ L} \right]^{1/4} \qquad (1)$$

Where: -
R_{max} is the maximum range of radar detection.
P_t is the power transmission of the radar.
P_{min} is the minimum power detected by the radar.
$G = G_r = G_t$ is the radar gain.
L is the losses due to the radar electronics and environment.
σ is the radar cross section.
When we are looking for and analyzing equation (1) we obvious that all variables are essential and associated with hostile radar and environment excepting the RCS which can be controlled by the target aircraft, consequently, the radar parameters can be considered a constant. The maximum detection distance can be reduced to the half if the RCS of target reduced sixteen times of original RCS [7] [4].

3. RCS Calculation on CST MWS

Using different methods to calculate the RCS consider as a validation to the traditional methods, one of these method using CST MWS software. The evaluation of the simulation is carried out in terms of Monostatic and Bistatic RCS which its value in decibels relative to square meter (dBsm). The object of this work is illuminated by plane wave with frequency of 9.4 GHz, using the integral equation solver.

4. Results and Discussion

Small object was selected as a target with cuboid shape and with dimensions 150 mm, for width and length, with 20mm, of height, respectively as shown with figure (2).
Horizontal polarization for illumination angles, 0° to 360° is selected.

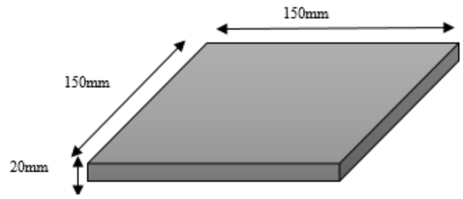

Fig. 2: RCS of a cuboid with l, w = 150 mm and h = 20 mm in H polarization

The effects of the nature of the material made of object on the RCS signature pattern are presented in the following figures with selected angle and frequency values of 90° and 9.4 GHz, respectively. The figures show the patterns of RCS in polar and Cartesian plots. As shown with figure (3, 4, and 5) the obtained RCS, with different materials of target, is presented for Bi-static radar.

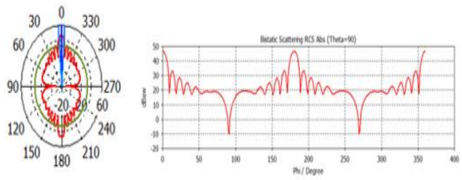

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Fig. 3: steel bistatic a. polar b. Cartesian

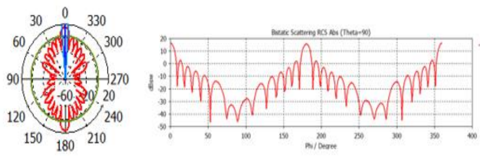

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Fig. 4: wood bistatic a. polar b. Cartesian

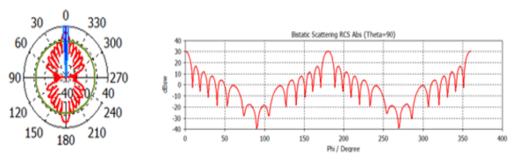

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Fig. 5: FR4 bistatic a. polar b. Cartesian

Reflection from a cuboid shape is dominated by the edge contributions for aspects beyond that bounded by main lobe. Close to the angle ±40° its observe that an increasing obtained with ripples due to that existence of surface current wave, which is induced due to edge diffraction. Appearance of these ripples is an indication, that the RCS is smaller at these corners compared to the circular flat and curvature surfaces. The results of RCS for several materials are tabulated with table (1) for small target. From this table it can be seen that the value of RCS for a target made of steel is higher than other materials, particularly at main lobe's value. Thus, the target with steel material is more easily to detect up compared to the others.

Table 1: Comparison of RCS In Several Materials At Angle 90o

Angles(°)	Wood Steel FR4		
	Bistatic monostatic	***Bistatic monostatic***	***Bistatic monostatic***
	16.3 16.28 46.7	46.65 16.2	16.3
30	-12.5 0.7 19	20.1 - 12	-12.5
60	-14 -0.6 15.1	19 - 21.4	-14
90	-44.2 -39.5 16	-8 - 18.3	-44.2
120	-15.8 -0.7 15.1	18.9 - 23.4	-15.8
150	-12.8 0.68 19	19.6 - 12.2	-12.8
180	15.6 30.2 46.7	46.6 16.2	15.6

With Monostatic procedure, it's required to rotating the transmitter around the target, i.e., the transmitter and the receiver are located in the same direction point. Electromagnetic environment is different for every position, thus computationally it is more testing task and generating several system matrixes. Figure (6-8) depicts the monostatic RCS for different materials of object.

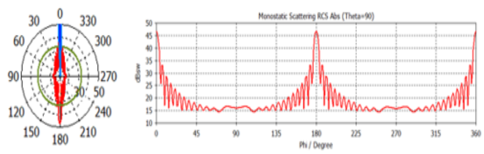

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Fig. 6: steel Monostatic a. polar b. Cartesian

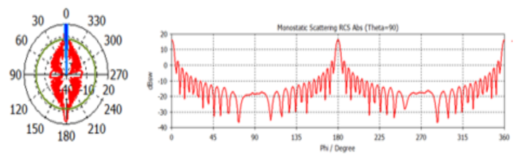

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Fig. 7: wood monostatic a. polar b. Cartesian

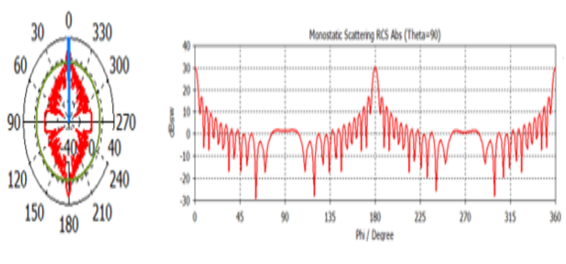

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Fig. 8: FR4 monostatic a. polar b. Cartesian

According to the obtained results, which presented in table (1), the values of main lobe with angles 90 and 270 is increased; besides, the ripple is decreased for both cases of mono-static and bi-static.

5. Conclusion

Study of the electromagnetic energy scattering for difference materials of small targets is decisively important in the understanding of RCS phenomena of a target. CST software was used to determine the RCS for different targets materials for bistatic and monostatic radar in the operating frequency of 9.4GHz. The results of this work show that the target with steel material has a significant RCS compared to the FR4 and wood materials, for both bistatic and monostatic radar.

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