Monostatic RCS of Rectangular Patch Antenna in C-Band Frequency

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Abstract—RCS is very significant to confirm data for target designation. The targets signature is different, because every target has own signature, and this specific signature is utilized to recognize the type of structure which will be tested. The monostatic radar utilizes one antenna on the body for reducing the scattering of signals for given polarization and receive and transmit in this type in the same location. Microstrip patch antenna is widely used in microwave systems, especially for space applications. In this paper, rectangular microstrip antenna in c-band frequency is designed and simulated as a target to calculate monostatic RCS area using CST software 2019. The strip antenna is simulated and modeled for different target angles (0, 45, 60and 90) degree. The monostatic radar cross section is simulated at 8GHz with incident angles from 0-180 degree. The best RCS of rectangular patch antenna is about -31m2 at the incident angle θ=60°.

Index Terms—RCS, monostatic RCS, rectangular patch antenna, target position angle

I. Introduction

Radar Cross Section (RCS) is very significant to confirm data for target designation. The RCS variety relies on the moving target shape, moving target size and plane wave angles. This might enhance the sensitivity elevation targets with receiver angle adjustment to the target and transmitter for a superior RCS performance [1]. Radar cross section is essential factor which give evidence about the locative waveform of the returned indicative of the object to the radar (Echo) that consideration as a signing up. Each target or objects have different signature, attributable into which every target have private signing up, and the specified signing up is utilized to identify the form of structure to be checked. The monostatic radar utilizes one antenna on the body for reducing the scattering of signals for given polarization and receive and transmit in this type in the same location [2].

Microstrip patch antenna is widely used in microwave systems, especially for space applications, because it has several characteristics, such as light weight, simple to manufacture and lower cost [3]. A new technique is presented to decrease the RCS area of a metal backed dipole antenna by using perfect accurately designed FSS instead of Perfect Electrical Conductor (PEC), the electromagnetic performing of the antenna is like in band, but the radar cross section of the body is safely lower out of band. The operating center frequency of this design is 4 GHz [4].

RCS reduction is presented by designing rectangular microstrip antenna with two circular apertures at DGS, and a shorting post. The usage high frequency electromagnetic software to design this antenna and these results are beneficial for low radar cross section applications. The proposed antenna has low RCS in a broadband, good return loss and gain [3]. An effective and simple approach is Proposed to minimize radar cross section of microstrip antenna in wide range. In The proposed design, a metallic ground plane of a conventional antenna is substituted by a hybrid ground consisting of bandstop FSS cells with fractional metallic plane [5]. A new design for RCS minimization of a monopole antenna is presented. This design used plasma helix based on around the antenna element. A plasma is selected in a medium that acts as absorbent and not affected on the antenna performing. The results show that the RCS of the designed antenna was minimized in a wide range of frequencies [6]. The radar cross section of the microstrip antenna was reduced using the design and experimental verification of a dual band metamaterial radar absorbing structure. The designed work was tested on the radar cross section and on the performance of the antenna through numerical and measured results. The results showed that the radar cross section was reduced within the x- band and the antenna characteristics were maintained without any unwanted differences [7]. Additionally, a dual-band metamaterial radar absorbing structure is designed to minimize RCS of a microstrip antenna. The designed antenna represents dual-band RCS reduction within X-band for different incident angles, while the radiation characteristics of the antenna are sustained without undesired changes [8].

In this paper, rectangular microstrip antenna in c-band frequency is designed and simulated as a target to calculate monostatic RCS area by depending on the variation of target angles corresponding to radar angle for a superior RCS performance as closely as possible.

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II. Radar Cross Section

The measurement directivity of an object visibility to radar is defined as RCS. The RCS is expressed as the area of electromagnetic waves that would reflect to the transmitting/receiving radar antenna.

The area of Radar Cross Section is depending on the [9]:

- Radar wavelength
- Polarization
- Aspect angle
- Shape and
- Target material properties.

When the antennas transmitter and receiver of radar are gathered, Cross section refers to Monostatic, while in bistatic type the radar of transmitter and receiver are split and the cross section refers to the scattering toward the receiver. Fig. (1) shows the geometry of radar cross section for monostatic type.

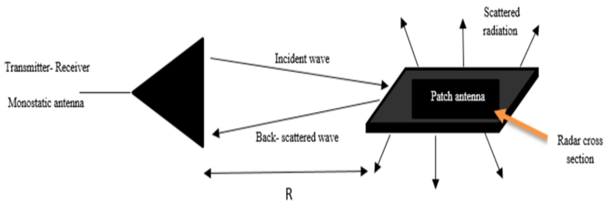


Fig. 1. Geometry of radar cross section for monostatic.

In defend and military purposes, the minimizing of radar cross section is essential aim to treat the distance which the target can be detected by the unfriendly radar. The relation between the radar cross section and the distance can be described using radar equation, and can be written as [2], [10]:

$$R_{max} = \left[(P_t G_2 \lambda_2 \sigma) \big/ (4\pi)3\ P_{min}\ L \right] * {}^1\!/_4 \qquad (1)$$

The parameters of equation can be noticed as:

R_{max} = maximum distance of radar detection,

P_t = transmitted power of the radar.

P_{min} = detected minimum power by the radar.

G = gain of the receiving/transmitting radar

L = losses of the medium

σ = radar cross section area.

According to equation above, we notice that the maximal detection distance can be minimized to the 0.5 if the RCS of target minimized 16 times of original RCS [2].

III. Microstrip Patch Antenna

The rapid development of communication systems requires an integrated antenna, which is affordable and easy to design. Therefore, the patch antenna is used at the present time because it is lightweight, low in cost, easy to design and can be used in portable devices. The patch antenna consists of three main parts: substrate, ground plane and metal patch. So the substrate is an insulating material and has a constant isolation constant, and likewise the ground level is an insulating material. A patch is a conductive material and takes several geometric shapes and the dimensions of this patch depend on the resonant frequency of the antenna.

The microstrip patch antenna depends on many factors: including length, width and height. The antenna width is symbolized by W and L is the length of the antenna and is specified between (0.3333 εr- 0.5 εr) where εr is the free space wavelength and h is the antenna height and specified between (0.003<h<0.05) and the dielectric constant of the substrate εr is typically in the range 2.2 < εr < 12.

IV. Rectangular Patch Antenna

There are many types of antenna use in wireless communication, the famous of their is rectangular patch antenna. The rectangular patch antenna is used in many applications such as mobile, GPS, router device and others. The reason of that, due to lightweight and small size as its constriction characteristics. Rectangular patch antenna is a simple antenna, it consists of three layers, first and third layers are made of conducting material called patch and ground plane respectively, while the second layer made of dielectric material called substrate. The design of rectangular patch antenna depends on four conditions [11], [12]:

1- The resonant frequency.
2- The type of material.
3- Dielectric constant.
4- Thickness of layers.

Therefore, to provide the better efficiency and large bandwidth must be chosen thick substrate with low dielectric constant as an example.

The dimensions of patch width (WP) and length (LP) are determine in equations (2) and equation (4) [13].

$$WP = \frac{c}{2f_r\sqrt{\frac{\varepsilon_{r+1}}{2}}} \qquad (2)$$

The height of the dielectric substrate (HS) is determined in eq (3):

$$HS = \frac{0.3c}{2\pi f_r\sqrt{\varepsilon_r}} \qquad HS \le 0.06\,\frac{\lambda d}{\sqrt{\varepsilon_r}} \qquad (3)$$

where $\lambda d = \lambda_0 / \sqrt{\varepsilon_{reff}}$, λd is the wavelength in dielectric medium, λ_0 is free space wavelength and ε_{reff} is the effective dielectric constant and it calculate as in equation (4)

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1 + 12\frac{HS}{WP}\right]^{\frac{-1}{2}} \qquad (4)$$

The length of patch (L_P) is calculated in eq (5):

$$LP = LP_{eff} - 2\Delta LP \qquad (5)$$

where *ΔLP* is the length extension, LP_{eff} is the effective length of the patch and they can determine as in equations (6), (7) respectively:

$$\Delta LP = 0.412HS \frac{(\varepsilon_{reff} + 0.3)\left[\frac{WP}{HS} + 0.264\right]}{(\varepsilon_{reff} - 0.258)\left[\frac{WP}{HS} + 0.8\right]} \quad (6)$$

$$LP_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} \quad (7)$$

The dimensions of ground plane and substrate must be equal, and depend on dimension of patch layer. The length of substrate (LS) and width (WS) are calculated as in equations (8), (9) [13]:

$$WS=6HS+WP \quad (8)$$

$$LS=6HS+LP \quad (9)$$

V. Evaluation of Monostaitic Radar Cross Section by CST

There are several programs for calculating Radar cross section of the antenna. CST MWS software is one of these programs. This paper deals with design and simulation rectangular microstrip antenna as a target to calculate monostatic RCS area by depending on the variation of target angles at 8 GHz.

VI. Results and Discussion

In this work, Rectangular patch antenna is designed for monostatic RCS calculations at frequencies band (3-13) GHz using CST software. The antenna is built at 6GHz frequency with dimensions LP=11 mm, WP= 15.5 mm and ts, hp =0.035, 1.55 mm respectively. The substrate material is FR4 with dielectric constant 4.4 and tangent loss 0.02, while the patch is made from copper material with dimensions LS= 22 mm, WS= 31 mm.

Fig. 2 shows RCS area simulation at 3-13 GHz frequency. It observed that best RCS of rectangular patch antenna is about -53m^2 at the incident angle θ=90∘.

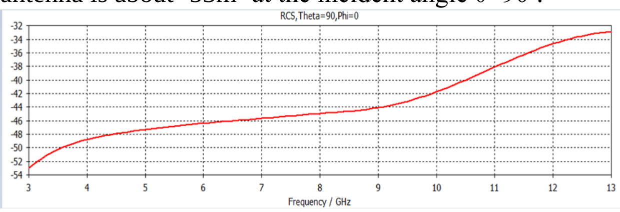


Fig. 2. Mon static RCS of the rectangular patch antenna under polarized incident (θ=90∘)

The monostatic radar cross section in cartisian and polar shape of the target is simulated at 8GHz with incident angles from 0-180 degree as shown in Figures 4 -7.

The target position angles are varied (theta =0∘, phi = 0°, (b) theta =45°, phi = 0° (c) theta =60°, phi = 0° and (d) theta =90°, phi = 0°) as shown in Fig. 3.

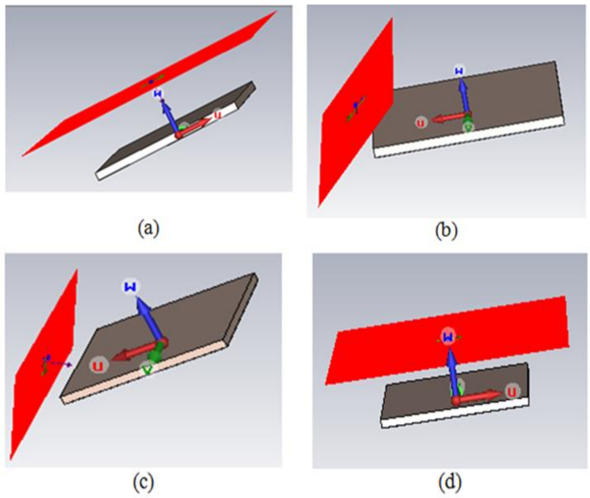
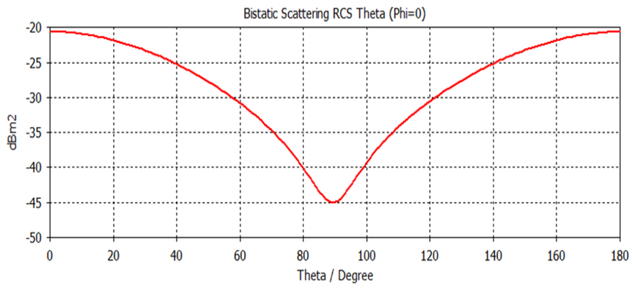
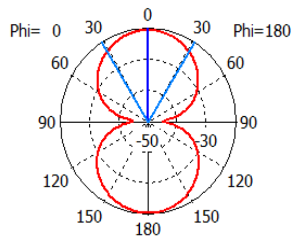


Fig. 3. The target position angles : (a) theta =0∘, phi = 0∘, (b) theta =45∘, phi = 0° (c) theta =60∘, phi = 0∘ and (d) theta =90∘, phi = 0∘.

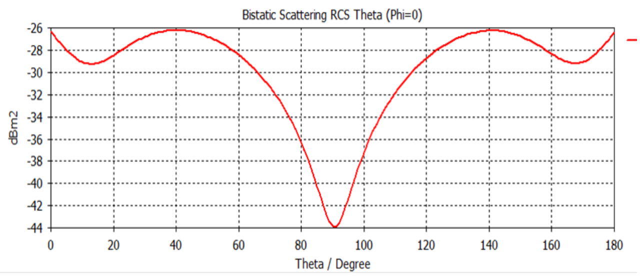


(a) carteisain



(b) polar

Fig. 4. monostatic RCS at (Theta= phi=0)



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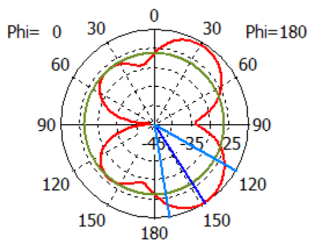
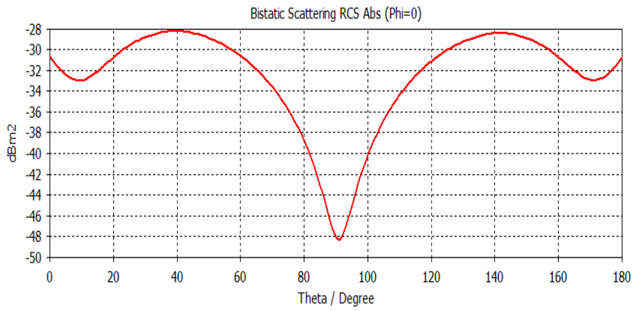
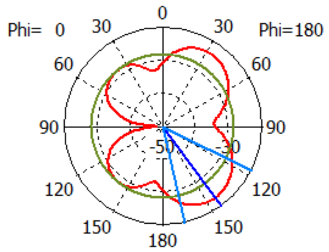


(b) polar

Fig. 5. Monostatic RCS at (Theta=45, phi=0)

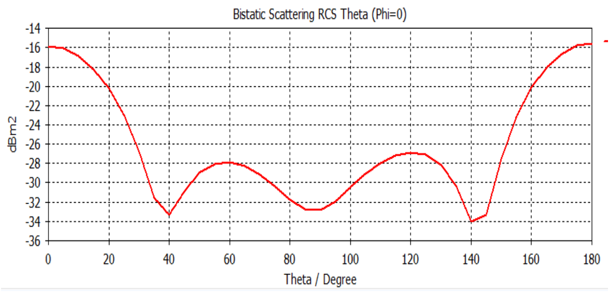


(a) carteisain

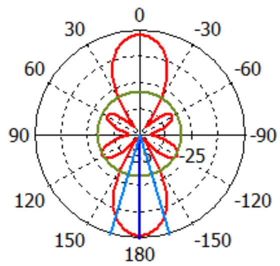


(b) polar

Fig. 6. Monostatic RCS at (Theta=60, phi=0)



(a) carteisain



(b) polar

Fig. 7. Monostatic RCS at (Theta=90, phi=0)

Table I shows the maximum RCS at position angle θ = 60◦ for all incident angles.

TABLE I: RCS WITH VARIOUS TARGET POSITION

Theta	RCS			
	(theta =0◦, phi = 0◦)	(theta=45◦, phi = 0◦)	(theta =60◦, phi = 0◦)	(theta =90◦, phi = 0◦)
0	-21	-26	-31	-16
20	-22	-28.5	-31	-20
40	-25	-26	-28	-31
60	-32	-28	-30.5	-28
80	-40	-36	-38	-32
100	-40	-37	-40	-31
120	-30	-29	-31	-27
140	-25	-26	-28.5	-34
160	-22	-28	-31	-20
180	-21	-26.5	-31	-15.5

VII. CONCLUSIONS

To understanding, the phenomena of monostatic RSC it must be studied the electromagnetic energy scattering for difference angles position of target. CST is one tools to calculate the RCS for different angles target in the operating frequency of 8GHz. The results of this work show that the target with position angle 60◦ has a significant RCS compared to other angles. The results of this work show that the target with position angle 600 has a significant RCS compared to other angles.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Huda I. Hamd and Israa Hazem Ali conducted the paper. Israa and Haraa Rahem wrote the paper and all of us had approved the final version.

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