The effect of different crossing angles to the radar cross section (RCS) of the target in FSR

ABDUL HALIM B AHMAD
Faculty of Electrical Engineering
Universiti Teknologi MARA
halim6362@gmail.com

***Abstract*— This paper presents on the analysis of the effect of different crossing angles to target's radar cross section (RCS) The target used is in this research is a BMW X6 model. The model of car designed using Autodesk 3DS Max and then export to CST Microwave Studio in order to simulate the RCS. The frequencies used for this simulation were based on UHF and VHF. Based on the simulation result, it is shown that the higher of the frequency and 90 degree angles of incident plane wave are the best position to define the maximum tracking and more information of RCS can be obtained.**

***Keyword* – FSR, RCS, UHF and VHF**

I. Introduction

FSR has been investigated over years mainly for air target detection and tracking [1]. Recently a micro FS radar network for ground target (vehicles and humans) detection has been developed [2]. FSR has a number of unique characteristics that make it interesting including the enhancement of the target radar cross section (RCS) relative to traditional monostatic radar, which improves the sensitivity of the radar system itself. The FSR effect gives some advantages in increasing target radar cross sections (RCS) for targets with dimensions bigger than the radar wavelength[3].The network includes four major segments: forward scatter radar that provides the target sensing capability (i.e., detection and parameters estimation); inter-nodes communication to transfer data within the net-work; navigation which operates at the initial stage to register node positions, and finally global communication for data ex-change between the network and the command centre[4].

UHF and VHF propagation characteristics are ideal for short-distance terrestrial communication, with a range generally somewhat farther than line-of-sight from the transmitter [5]. Using these lower frequencies it is easier to obtain high-power transmitters. The attenuation of the electro-magnetic waves is lower than using higher frequencies [6]. On the other hand the accuracy is limited, because a lower frequency requires antennas with very large physical size which determines angle accuracy and angle resolution.

Theoretically, the forward scattering RCS mainly depends on the physical cross section of the target radar and the wavelength used, and is independent of the surface shape of the target and any radar absorbing material (RAM) coating, which reduces the target's RCS in the case of traditional radar [7].

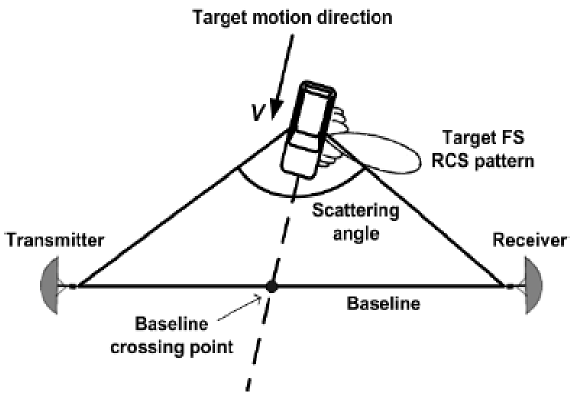

Figure 1: Plan view of the ground FSR topology[8]

This research is being conducted to evaluate the differences between the different angles of the target radar to RCS.

The objectives of this research are to design the target radar by using Autodesk 3DS Max and simulate it using CST software in order to see the RCS of the target for different frequencies and different angles of incident plane wave. The result of polar plot and farfield is examined and analyzed in order to see the differences and significant of RCS to detect the target.

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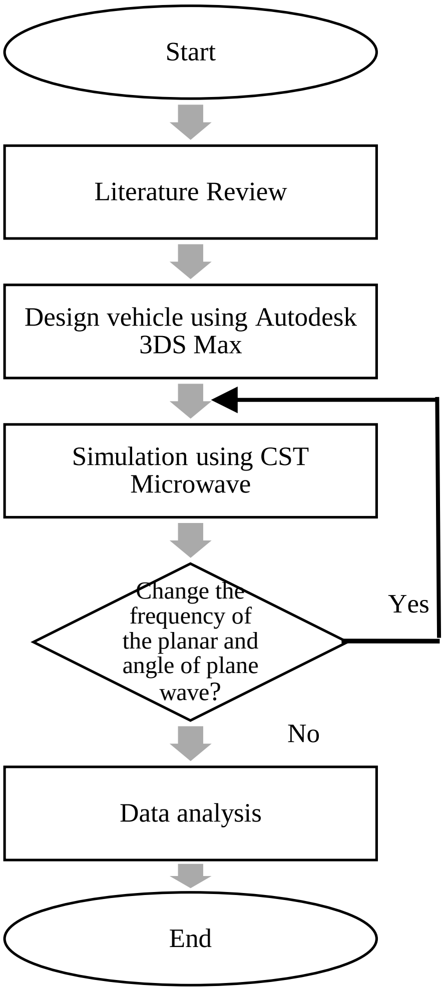
II. METHODOLOGY

Figure 2, shows the implementation and works of the research. The literature review section, previous research had been reviewed to understand the theory and the method which can be used this research. The model of the car has been designed using Autodesk 3DS Max based on the dimension of the car and in this case, BMW X6. Next, the design is exported to CST for simulation purposes. In CST, declaration of material for different parts of the vehicles has been done. RCS of the car is simulated for different frequencies: 60MHz, 150MHz and 400MHz and for different angles of incident plane wave (which reflect different crossing angle of a target) and the result is analyzed.

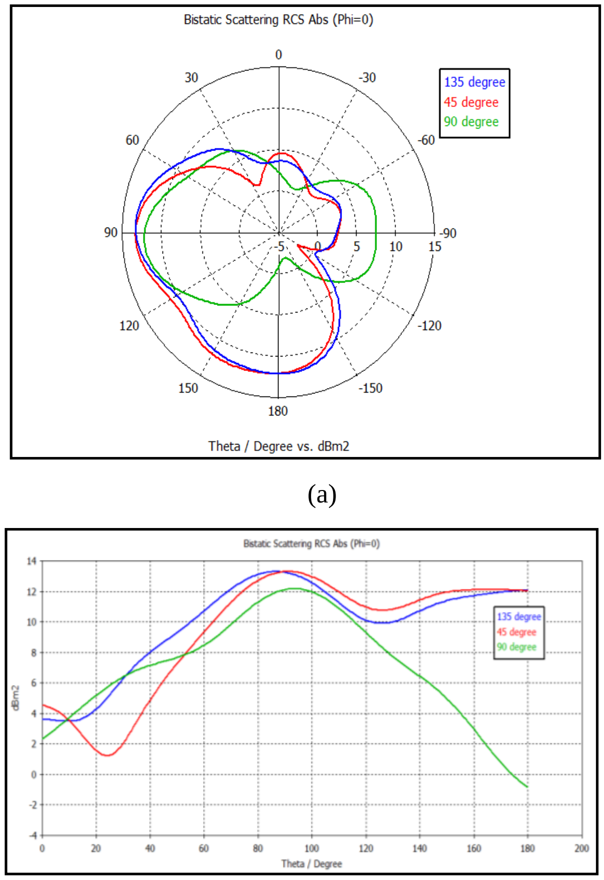
Figure 2 : Flow Chart



III. RESULT AND DISCUSSION

The result is plotted by the CST Microwave for three different frequencies (60MHz, 150MHz, and 400MHz).

A. 60MHz



(a)

(b)

Figure 3: Combination of 60MHz for three different angles: (a) Polar Plot and (b) Cartesian Plot

The results obtained from the analysis of polar plot and cartesian plot are presented in Figure 3 and the summarize is shown in table 1. The result indicates that for 45 degree and 135 degree of plane wave have the same value of main lobe magnitude meanwhile 90 degree of plane wave have slightly lower. The main lobe direction is higher at 90 degree of incident plane wave as compared to 45 and 135 degree where the lobe direction value is 93 degree. As we know, the large portion of the radiated energy contained in the main lobe magnitude could reduce the main-beam power. The side lobe level of 90 degree is bigger than the other two angles. A high side lobe level can cause jamming to the radar tracking and strong echoes signals to enter the receiver and appear as false targeted.

Table 1: Polar plot RCS value for different angles

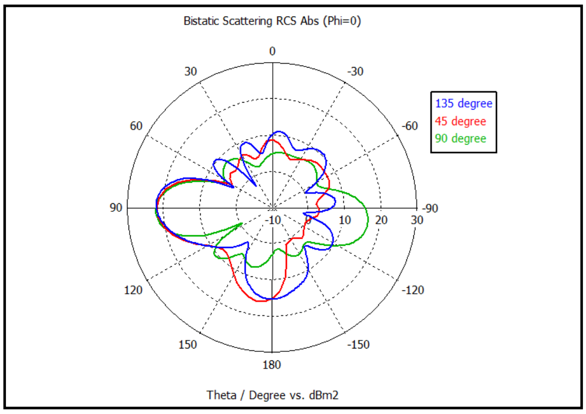
	45°	90°	135°
Main lobe magnitude	13.3dBm^2	12.2dBm^2	13.3dBm^2
Main lobe direction	91°	93°	87°
Angles width	137.2°	55.1°	60.6°
Side lobe level	-8.7dB	-4.6dB	-1.2dB

Table 2: Farfield RCS value for different angles

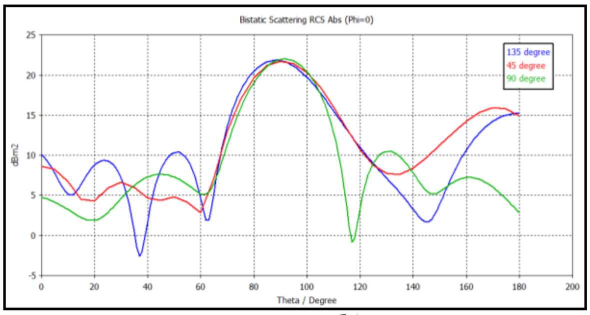
	45°	90°	135°
Total RCS	8.070dBm^2	8.284dBm^2	8.003dBm^2
RCS max(Abs)	13.30dBm^2	12.91dBm^2	13.30dBm^2
RCS max(Phi)	13.27 dBm^2	12.84 dBm^2	13.26 dBm^2

Table 2 shows that total RCS at 90 degree is bigger compared to another angle since the power per unit area of tracking is high. RCS max at 45 and 135 degree is higher compared to the 90 degree which will define the maximum tracking at 45 and 135 degrees.

B. 150MHz



(a)



(b)

Figure 4: Combination of 150MHz for three different angles: (a) Polar Plot and (b) Cartesian Plot

The information in figure 4 is summarized in Table 3. The main lobe magnitude of 90 degree angle of the incident plane wave is larger compared to 45 degree and 135 degree where this main lobe magnitude indicates the direction of maximum tracking. The result also indicates that the angle width for 90 degree incident wave is smaller compared to 45 and 135 degree. In addition, as the angle width increase, there is decrement in side lobe level.

Table 3: Polar plot RCS value for different angles

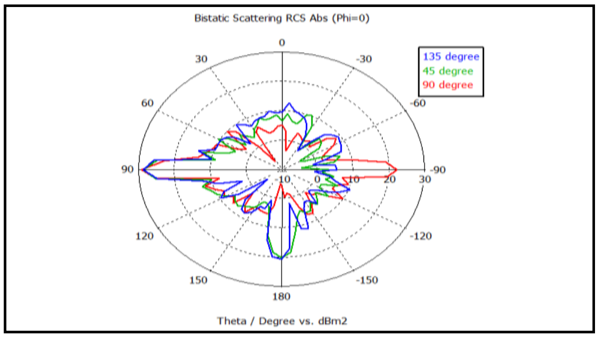
	45°	90°	135°
Main lobe magnitude	21.7dBm^2	22dBm^2	21.8dBm^2
Main lobe direction	90.0°	92.0°	88.0°
Angles width	26.1°	23.0°	26.1°
Side lobe level	-5.8dB	-5.4dB	-6.6dB

Table 4: Farfield RCS value for different angles

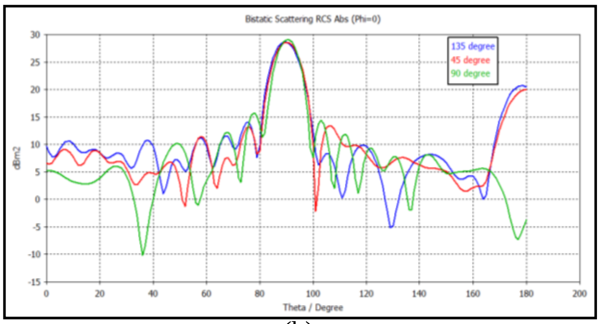
	45°	90°	135°
Total RCS	10.7dBm^2	10.88dBm^2	10.88dBm^2
RCS max(Abs)	21.74dBm^2	22.20dBm^2	21.8 dBm^2
RCS max(Phi)	21.67 dBm^2	22.16 dBm^2	21.78 dBm^2

Table 4 shows, total RCS at 45 degree is the lowest compared to other angles since the power per unit area of tracking is low. RCS max at 90 degree is higher compared to 45 and 135 degree the which will define the minimum tracking at 45 and 135 degrees.

C. 400MHz



(a)



(b)

Figure 5: Combination of 400MHz for three different angles: (a) polar plot and (b) Cartesian plot

Based on Table 5, main lobe magnitudes for 45 degree and 135 degree of incident plane wave have the same value. Side lobe level decrease when the main lobe magnitude is increase. When side lobe level is too small, the RCS produced better target detection. High main lobe magnitude indicates that RCS receive more information. Compared to previous frequencies (60MHz and 150MHz), the analysis performance in terms of main lobe magnitude and side lobe level values is better.

Table 5: Polar plot RCS value for different angles

	45°	90°	135°
Main lobe magnitude	28.6 dBm^2	29.1 dBm^2	28.6 dBm^2
Main lobe direction	90°	90°	90°
Angles width	8.7°	6.4°	8.9°
Side lobe level	-8.6dB	-7.1dB	-8.1dB

Table 6: Farfield RCS value for different angles

	45°	90°	135°
Total RCS	10.51 dBm^2	10.75 dBm^2	10.51 dBm^2
RCS max(Abs)	28.63 dBm^2	29.08 dBm^2	28.63 dBm^2
RCS max(Phi)	28.63 dBm^2	29.08 dBm^2	28.63 dBm^2

From the table 6, the main lobe for 45 degree and 135 degree of incident wave also same value. Higher frequency will effect on the accuracy of target detection. A high side lobe level cause jamming in radar tracking. RCS max at 90 degree compared to the other angles shows gain in side direction is increase.

IV. Conclusion and Future Work

The objective of this research is achieved. The radar cross-section is simulated using CST Microwave Studio software. The proposed of the research was to compare the cross-section between three types of frequency due to different angle of plane wave. From the results, it is shown that the frequency affect the performance of the radar. The higher the frequency and 90 degree angles of incident plane wave are the best position to define the maximum tracking and more information of RCS can be obtained. From this research, we can see that the experimental result is concurrent with theory.

In future, this research can be improved by concentrating on another higher frequency for RCS. The car model can be improved with accessories.

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