RCS ANALYSIS ON DIFFERENT TARGETS AND BISTATIC ANGLES USING LTE FREQUENCY

NOOR HAFIZAH A. A., HAZIQ HAZWAN M.Y., NUR EMILEEN A.R., RAJA SYAMSUL AZMIR R.A., ASEM S.

1,2,3Faculty of Electrical Engineering, Universiti Teknologi MARA (UiTM), Shah Alam, 40450, Malaysia
1,4,5Faculty of Engineering, Universiti Putra Malaysia (UPM), Serdang, 43400, Malaysia
E-mail: noor4083@salam.uitm.edu.my

Abstract— Moving target detection and location are a function of dependent bistatic Radar Cross Section (RCS) and radar design parameters which in our experimental study used long-term evolution (LTE) signal as a source for passive bistatic radar (PBR). Moving target also can be classified in positions of different bistatic radar angles using conventional processing approaches which we performed a simulation using Computer Simulation Technology (CST) Microwave studio. The target bistatic radar cross-section, \( \sigma_b \) will give a realistic calculation on PBR performance with the requirement of complete treatment. The targets used are Toyota Rush (SUV) and Proton Exora (compact MPV) as a moving target had been designed based on the actual size to observe the performance of RCS due to the changing of bistatic angle between transmitter and receiver. The frequency transmit signal from LTE based station is 2.6 GHz, far-field conditions and the material used for the moving target is perfect electrical conductor. Simulation used different bistatic angles which are 59° and 90° of plane wave propagation. The simulation results show that largest area of moving target had better outcome that reliable with Babinet’s principle, which declares a target of physical cross-sectional area is proportionate to RCS. The variation of RCS also depends on the shape of moving target, size of moving target and angles of plane wave. This might improve the sensitivity elevation targets with an adjustment of receiver angle to the target and transmitter for a better RCS performance.

Index Terms—Bistatic angles, LTE, Passive Bistatic Radar, Radar Cross Section.

I. INTRODUCTION

Recently, experimental study of Long Term Evolution (LTE) signals as new illuminators of opportunity has been conducted for passive bistatic radar applications [1]. Radar configurations can be classified as mono-static and bistatic as shown in Fig. 1. The configuration of passive radar is related to bistatic radar where LTE base station is considered as the transmitter. The transmitter and receiver are separated by a distance comparable to the maximum range of a target. The angle between the transmitted and reflected rays is a bistatic angle, \( \beta \) as shown in Fig. 1(b) [2]. Passive radar introduces a receiver without a co-located transmitter and much better than a conventional radar system [1]. In recent years, the use of illuminators of opportunity by passive radar systems have been employed in such things such as television [4], FM radio [5], digital video broadcasting (DVB) [6], digital audio broadcasting (DAB) [6], satellites [7], wireless fidelity (Wi-Fi) [8], global systems for mobile communications (GSM) in cellular phones [9] and worldwide interoperability for microwave access (WiMAX) [10].

In order to justify data for target classification, understanding about radar cross section (RCS) is needed. RCS stated that not all of the radiated signal fall on the target. Some of the signal might be absorbed and reflected signal is not distributed equally in all directions [2]. The RCS of target depends on the target’s physical geometry and exterior features, the direction of the illuminating radar, the radar transmitter frequency and the types of material used [3].

The 59° angle were obtained from experimental study where the receiver of the passive radar consists of direct antenna to receive the direct signal from the LTE and the reflected signal antenna which set to a bistatic angle, \( \beta \) of 59°. The reflected signal was used to receive the target echo signal that reflected from the moving target. The experimental setup shows in Fig. 2.

![Fig 1 Radar Systems: (a) Monostatic Radar (b) Bistatic Radar](image1)

The objectives of this research are to model the radar target by using Autodesk 3DS Max and simulate the model using CST software in order to see the RCS for different targets and different angles of incident plane
wave (bistatic angle). The results of polar and cartesian were examined and analyzed in order to observe the consequences on RCS.

II. METHODOLOGY

The model of the moving targets have been designed using Autodesk 3DS Max based on the dimensions of the actual car. In this paper, Proton Exora and Toyota Rush are used as moving targets. The dimension of Proton Exora is 4592mm x 1809mm x 1691mm (Length x Width x Height) and Toyota Rush is 3995mm x 1695mm x 1705mm. Fig. 3 shows the modeling of the moving targets using Autodesk 3Ds Max.

These models are exported to CST Microwave Studio for simulation purposes. In CST software, frequency, far field, material of the moving targets and plane wave should be defined. The plane wave at the z–direction is considered as radar source. RCS for both moving targets is simulated at frequency of 2.6 GHz and angles of incident plane wave are 59° and 90°. Fig. 4 shows the plane wave at z-direction towards the target of Proton Exora.

III. RESULTS AND DISCUSSION

The effects of different shape and size of moving targets are presented as RCS radiation pattern for different angles at 2.6 GHz. The results are analyzed in the form of polar and cartesian plot. Comparison of two angles for Toyota Rush is tabulated in Table I. Fig. 5 indicates that the value of RCS for 90° is higher than 59° that can be shown at main lobe magnitude. Thus, the result is defined that the target more easily detected at angle 90°. Moreover, the side lobe level of 90° is smoother compares to 59° which has more fluctuation. This is due to the fact that target silhouette of the moving target is much more visible at 90°.

![Fig. 3 Modeling of moving targets: (a) Proton Exora (b) Toyota Rush](image)

![Fig. 4 Radar source towards Proton Exora: (a) 59° (b) 90°](image)

![Fig. 5 Comparison RCS of Toyota Rush for two different angles: (a) Polar Plot (b) Cartesian Plot](image)

<table>
<thead>
<tr>
<th>TABLE I</th>
<th>RCS VALUE FOR DIFFERENT ANGLES OF TOYOTA RUSH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameters</td>
<td>Bistatic Angle (°)</td>
</tr>
<tr>
<td></td>
<td>59</td>
</tr>
<tr>
<td>Main lobe direction (°)</td>
<td>180.00</td>
</tr>
<tr>
<td>Main lobe magnitude (dBm²)</td>
<td>60.04</td>
</tr>
<tr>
<td>Side lobe level (dB)</td>
<td>-31.30</td>
</tr>
</tbody>
</table>
Fig. 6 shows the comparison of two angles for Proton Exora of RCS radiation patterns at angle 59° and 90°. Table II observed that RCS value for 59° is larger than 90°. Again, the side lobe of 59° of the moving target is has more fluctuations compared to 90°. The result indicates that a slight change made on the target could give different readings of RCS [3].

Fig. 7 shows the graph of RCS radiation pattern of Proton Exora and Toyota Rush at angle 59°. Table III indicates that RCS value for Toyota Rush is larger compared to Proton Exora since large main lobe magnitude makes the target silhouette more visible. Thus, Toyota Rush more easily to detect.

### Table II

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Bistatic Angle (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>59</td>
</tr>
<tr>
<td>Main lobe direction (°)</td>
<td>180.00</td>
</tr>
<tr>
<td>Main lobe magnitude (dBm²)</td>
<td>11.22</td>
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<tr>
<td>Side lobe level (dB)</td>
<td>-18.30</td>
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</table>

Fig. 8 and Table IV show the main lobe magnitude for Proton Exora is smaller than Toyota Rush. The results show that differentiation of two moving targets at angle 90° for Toyota Rush is also more visible compared to Proton Exora.
Fig. 8 Comparison RCS at angle 90° for two different moving targets: (a) Polar Plot (b) Cartesian Plot

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Main lobe direction (°)</th>
<th>Main lobe magnitude (dBm²)</th>
<th>Side lobe level (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exora</td>
<td>180.00</td>
<td>7.438</td>
<td>-16.60</td>
</tr>
<tr>
<td>Toyota Rush</td>
<td>180.00</td>
<td>62.75</td>
<td>-23.50</td>
</tr>
</tbody>
</table>

**TABLE IV**

**RCS VALUE FOR DIFFERENT MOVING TARGETS**

**CONCLUSION**

LTE signal is used in the experimental study as a source for passive bistatic radar (PBR) which is 2.6 GHz. The purpose of this research is to compare the radar cross-section between Proton Exora and Toyota Rush through LTE signal as a transmitter due to different bistatic angles. From the results using CST Microwave studio, the different shape and size of moving targets and different angles of plane wave give some effect to the radar cross section. The simulation results show that largest area of Toyota Rush, which is 90° of transmitting signal had better outcome compared to 59° which reliable with Babinet’s principle, and also declares a target of physical cross-sectional area is proportionate to RCS. For Proton Exora, it seems the simulation results are not concurrent with theoretical where larger area of target will give better value of RCS. This is because of mesh cells in CST for Proton Exora is too small compared to Toyota Rush, which could be improved and adjusted at different simulation for a better RCS performance.

**REFERENCES**


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