RCS Predictions through Angle of Ground Moving Target using LTE-Based Passive Forward Scattering Radar

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***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 forward scattering radar (PFSR). Moving target also can be classified in positions using conventional processing approaches, which we performed a simulation using Computer Simulation Technology (CST) Microwave studio. The target bistatic radar cross-section gives a realistic calculation on passive bistatic radar (PBR) performance with the requirement of complete treatment. A model of a car, Toyota Rush as a ground moving target had been designed to observe the performance of RCS due to the changes of bistatic angle between the transmitter and the receiver with the frequency transmit signal from LTE based station at 2.6 GHz and far-field conditions. The results of the simulation show that the largest area of moving target, which is 90 degree of transmitting signal had better outcome compared to the other angle, which is reliable with Babinet's principle that declares a target of physical cross-sectional area is proportionate to RCS. Different angle of transmitting signal gave smaller RCS, which is the cause from the reduction area of reflected signal from the ground moving target such as 45 degree according to the front side view of Toyota Rush and 135 degree according to back side of Toyota Rush. This might improve the sensitivity of elevation targets with an adjustment of the receiver angle to the target and transmitter for a better RCS performance.**

***Index Terms*—Angle; CST; LTE; Moving Target; RCS.**

I. INTRODUCTION

This paper describes the prediction of passive bistatic radar cross section (RCS) of moving target with simulation using Computer Simulation Technology (CST) Microwave studio. Passive bistatic radars use illuminators of opportunity as transmitters. Illuminators of opportunity are transmitters that are already present in the environment, such as analog TV transmitters, digital video broadcast - terrestrial (DVB-T) TV transmitters, or mobile phone base transceiver stations (BTSs). We propose to use one or multiple illuminators of opportunity as a source of radar illumination, as in [1]. Different characteristics of the signals are transmitted from illuminators of opportunity such as their location, modulation, polarization and frequency, which could not be controlled. Hence, we choose to use long-term evolution (LTE) as an illuminator of opportunity for passive radars investigation [2]. Figure 1 shows the bistatic geometry for passive radar using illuminator of opportunity.

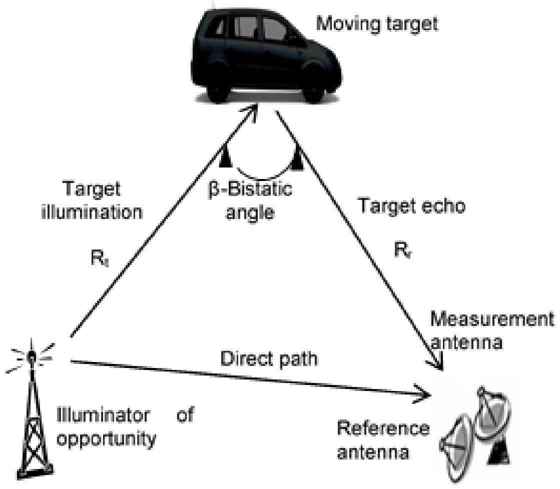


Figure 1: Bistatic geometry for passive bistatic radar.

II. DESCRIPTIONS

A. Target bistatic radar cross-section

The forward scatter region is encountered when the bistatic angle is increased to 180°. In this region, ground moving target radar cross-sections can be considerably enhanced [3]. This is explained by Babinet's principle, which claims that the forward scatter from a perfectly absorbing target is the same (apart from a 180° phase shift) as that from a target-shaped aperture in a perfectly conducting sheet, which for a target of physical cross-sectional area (A) gives a radar cross-section of,

$$\sigma_b = 4\pi A^2/\lambda^2 \tag{1}$$

where A is the silhouette area and λ is the radar wavelength.

The angular width of the scattered signal in the horizontal or vertical plane is given by

$$\theta_b = \lambda/d \tag{2}$$

where d is the target linear dimension in the appropriate plane. Figure 2 shows the dependence of σ_b and θ_b on frequency, for a target with A is 10 m^2 and d is 20 m, showing that σ_b increases with the frequency as the forward scatter in concentrated into an increasingly narrow beam.

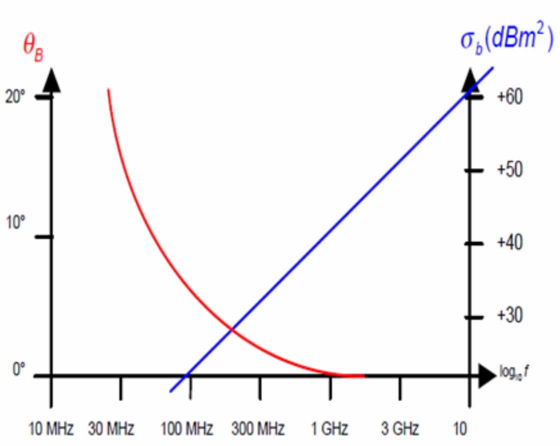


Figure 2: Variation of forward scatter radar cross-section (RCS) and angular width of response (A=10 $m^{2,}$ d=10 meter).

B. LTE

Long-Term Evolution (LTE) is a standard for wireless communication of high-speed data for mobile phones and data terminals. Based on the Global System for Mobile Communications (GSM) or Enhanced Data rates for GSM Evolution (EDGE) and Universal Mobile Telecommunications System (UMTS) or High Speed Packet Access (HSPA) network technologies, it increases the capacity and speed using a different radio interface together with core network improvements [4,5]. The standard is developed by the 3rd Generation Partnership Project (3GPP). For urban areas, higher frequency bands such as 2.6 GHz are used to support high speed mobile broadband [6]. Thus, 2.6 GHz is used for simulation on a moving target to measure radar cross section.

C. Autodesk

Autodesk is the software for the architecture, engineering, construction, manufacturing, media, and entertainment industries [7]. Autodesk was once the best known AutoCAD software but now there exists a broad range of software for design, engineering, and entertainment as well as a line of software for consumers, which are mostly used in the manufacturing industry to simulate, visualize, and analyze real performance using digital model. This software is used to design the model of ground moving target, which is a sport utility vehicle (SUV) of Toyota Rush that had been used in our experimental study. Figure 3 shows a model of Toyota Rush in real shape and Figure 4 shows a model of Toyota Rush that had been designed using Autodesk software.

Figure 3: A model of Toyota Rush in real dimension.

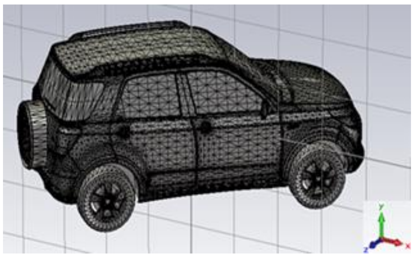


Figure 4: A model of Toyota Rush design in Autodesk.

D. Angle

Figure 5 shows the moving target of Toyota Rush in front of the target echo antenna receiver (baseline), which was used as a reference for simulation in measuring radar cross section. From the start of the baseline, the angle of moving target was 45^0 from the antenna. Next, the angle of moving target in the middle of baseline was 90^0 and at the end of baseline, the angle was 135^0.

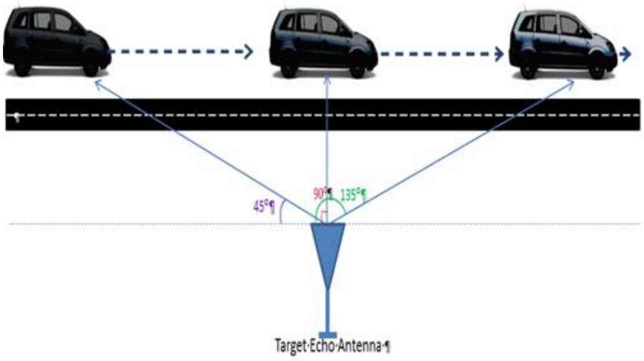


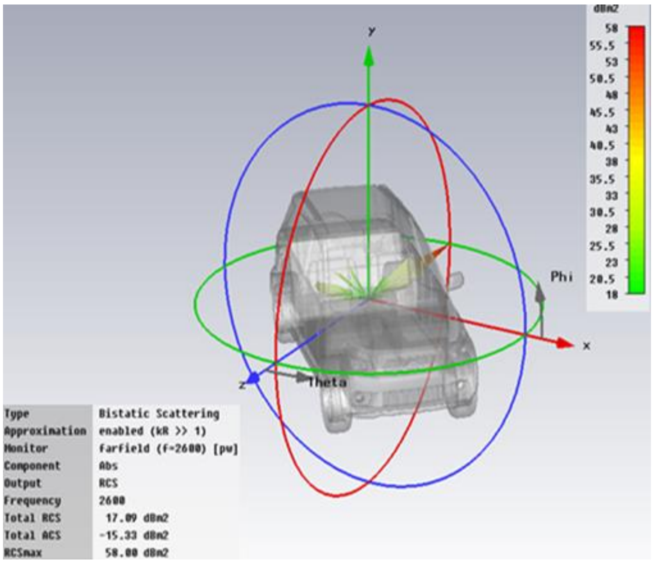
Figure 5: Baseline of ground moving target and angles of the car position.

III. METHODOLOGY

A model of Toyota Rush as a ground moving target was designed in Autodesk software with a real dimension of length, width and height. The model was imported to CST for computing the bistatic RCS and to observe the performance of RCS due to the changing of bistatic angle. The setting and conditions in CST for the model of moving target were based on the frequency transmit signal from long-term evolution (LTE), which is 2.6 GHz and with far-field conditions.

IV. RESULTS

Figure 6 shows the model of Toyota Rush using CST program with the angle of moving target at 45^0 from the transmitter. The conditions were bistatic scattering, far-field and frequency of 2.6 GHz. Figure 7 and Figure 8 also show the same conditions in CST, but with different angle, which are 90^0 and 135^0 respectively. Figure 9 until Figure 11 show the RCS bistatic scattering profiles of Toyota Rush with the angle of 45^0, 90^0 and 135^0 respectively. Figure 12 shows the RCS maximum and Figure 13 shows the bistatic scattering profiles of Toyota Rush with different angles.



Type	Bistatic Scattering
Approximation	enabled (kR >> 1)
Monitor	farfield (f=2600) [pw]
Component	Abs
Output	RCS
Frequency	2600
Total RCS	17.09 dBm2
Total ACS	-15.33 dBm2
RCSmax	58.00 dBm2

Figure 6: Toyota Rush with angle of 45^0 in CST

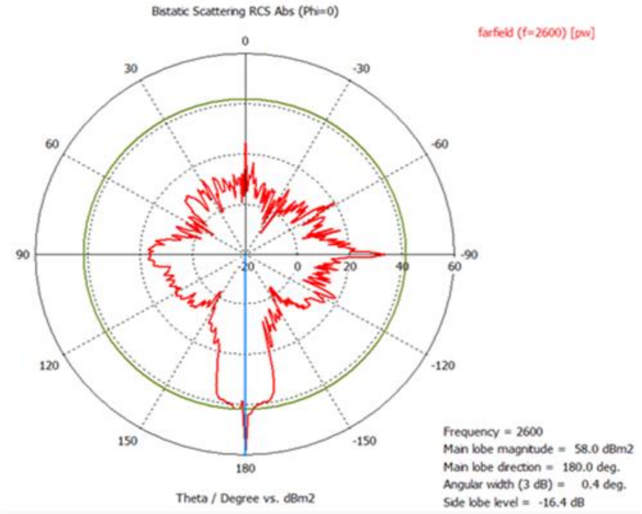
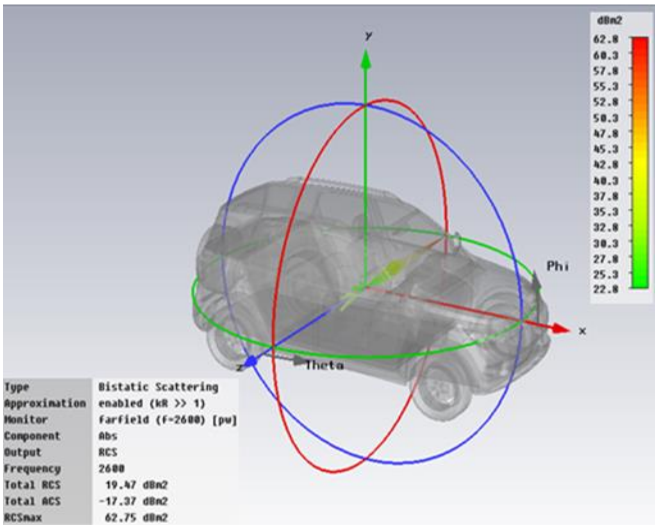


Figure 9: RCS bistatic scattering of Toyota Rush with angle of 45^0



Type	Bistatic Scattering
Approximation	enabled (kR >> 1)
Monitor	farfield (f=2600) [pw]
Component	Abs
Output	RCS
Frequency	2600
Total RCS	19.47 dBm2
Total ACS	-17.37 dBm2
RCSmax	62.75 dBm2

Figure 7: Toyota Rush with angle of 90^0 in CST

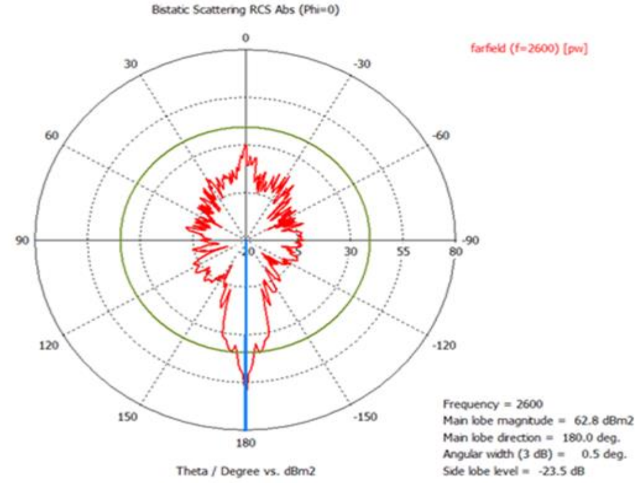
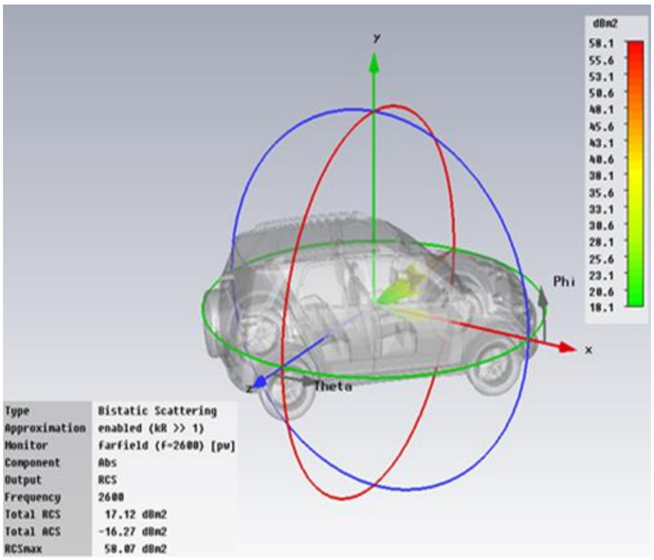


Figure 10: RCS bistatic scattering of Toyota Rush with angle of 90^0



Type	Bistatic Scattering
Approximation	enabled (kR >> 1)
Monitor	farfield (f=2600) [pw]
Component	Abs
Output	RCS
Frequency	2600
Total RCS	17.12 dBm2
Total ACS	-16.27 dBm2
RCSmax	58.07 dBm2

Figure 8: Toyota Rush with angle of 135^0 in CST

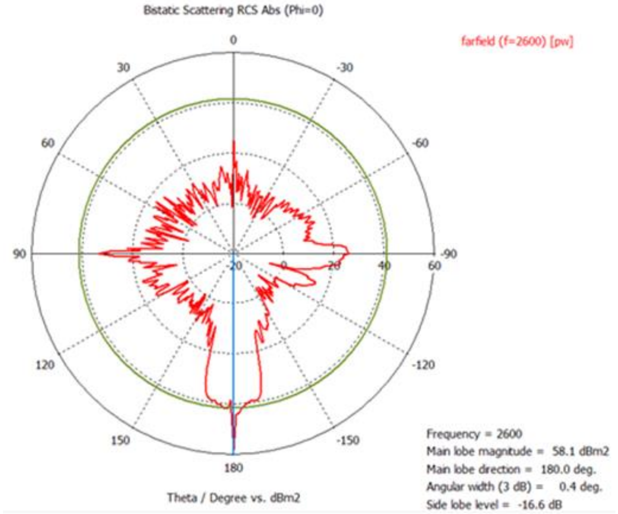


Figure 11: RCS bistatic scattering of Toyota Rush with angle of 135^0

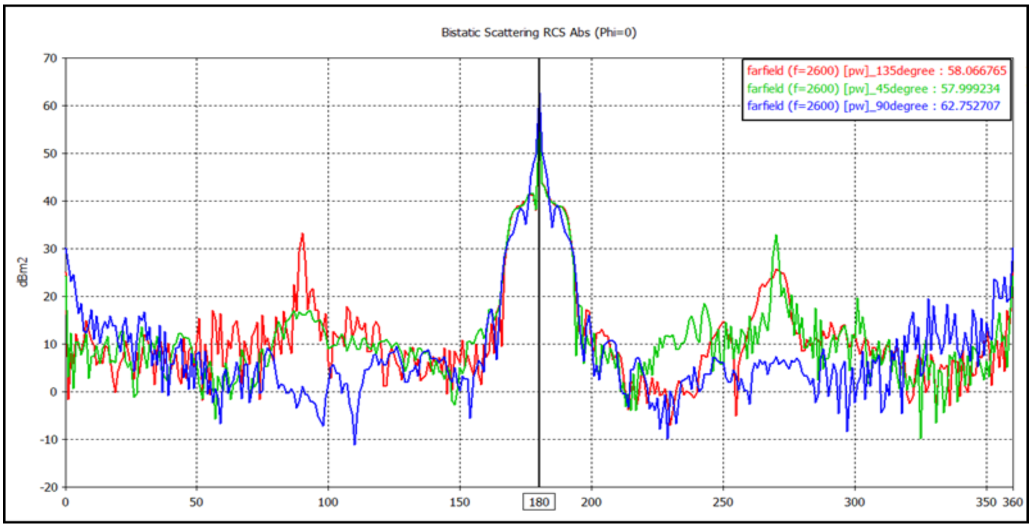


Figure 12: Comparison of RCS maximum with different angles of Toyota Rush (green: 45^0, blue: 90^0 and red: 135^0)

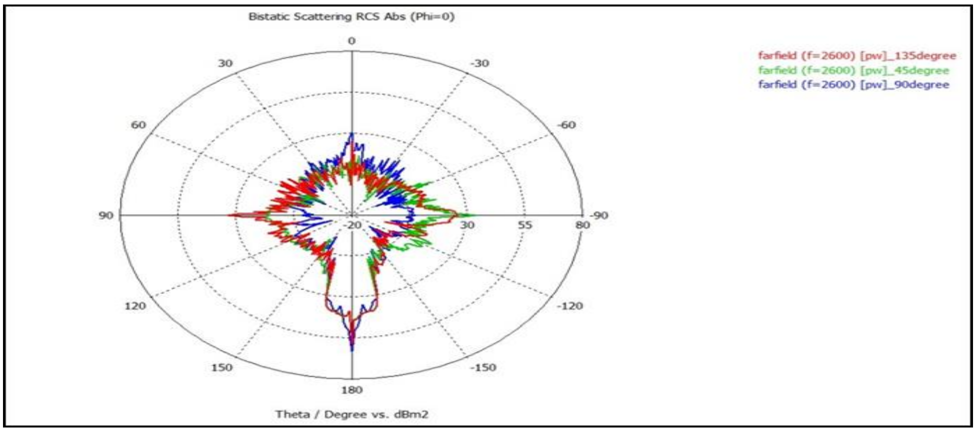


Figure 13: Comparison of bistatic scattering profiles from different angles of Toyota Rush (green: 45^0, blue: 90^0 and red: 135^0)

Table 1 shows the results of RCS maximum from three angles of moving target of Toyota Rush, which were 45^0, 90^0 and 135^0. It seems that the angle of 90^0 has the higher RCS maximum, which was 62.75 dBm^2. RCS from angles 45^0 and 135^0 gave almost similar values, which were 58.00 dBm^2 and 58.07 dBm^2 respectively. These results are understandably because a perfect conduct sheet from 90^0 of Toyota Rush has higher physical cross-sectional area, which is proportional to the radar cross-section. Nevertheless, 45^0 and 135^0 have slighter physical cross-sectional area.

Table 1
Radar Cross-Section (RCSmax) for RUSH with 2.6 GHz

Angle (°)	RCS maximum (dBm2)
45	58.00
90	62.75
135	58.07

V. CONCLUSION

LTE is a new wireless communication technology that offers last mile broadband wireless access with expected broad accessibility. In the experimental study, LTE signal was used as a source for passive forward scattering radar (PFSR) that used 2.6 GHz. To predict the RCS of ground moving target through LTE signal as a transmitter, it can be performed using CST Microwave studio. The model of ground moving target, Toyota Rush had been designed in Autodesk software and the performance of RCS in CST has been computed. The simulation results show that the largest area of ground moving target, which was 90^0 of the transmitting signal had better outcome in comparison to the other angle which is reliable to Babinet's principle. The results also declare a target of physical cross-sectional area that was proportionate to RCS. Different angle of transmitting signal gave smaller RCS which was caused by the reduction area of reflected signal from the moving target, such as 45^0 according to front side view of Toyota Rush and 135^0 according to back side of Toyota Rush. This might improve the sensitivity elevation targets with an adjustment of receiver angle to the target and transmitter for a better RCS performance.

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