ISSN 2278-3091
Volume 8, No.1.3, 2019
International Journal of Advanced Trends in Computer Science and Engineering
Available Online at http://www.warse.org/IJATCSE/static/pdf/file/ijatcse4381.32019.pdf
https://doi.org/10.30534/ijatcse/2019/4381.32019

# Ultra-Wideband Antenna with Monostatic/Bistatic Configurations for Search & Rescue Applications

**Jawad Ali[1, 2], Noorsaliza Abdullah[1], Roshayati Yahya[1], Ariffuddin Joret[1], Ezri Mohd[1]**
[1]Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia (UTHM), Malaysia
[2]Electrical Engineering Department, COMSATS University Islamabad (CUI) Lahore Campus, Pakistan,
engrjawad.ali@outlook.com

**ABSTRACT**

An arc shape ultra-wideband (UWB) antenna design with different configurations is the part of the discussion during this paper by implementing a ground-penetrating radar (GPR) technology specifically for search and rescue applications. The simulated antenna used a defected ground structure method for the bandwidth enhancement i.e. 3-16 GHz, possess gain around 6.2 dB. The complete detection model for multiple configurations i.e. monostatic and bistatic was simulated. The radar cross-section (RCS) for defined models is studied and compared in order to detect the obstacle. The analysis shows that a bistatic configuration for antenna developed a clear image for detection behind the obstacle.

**Key words:** Ultra-wideband antenna, Monostatic, Bistatic, Detection, GPR antennas.

## 1. INTRODUCTION

Not a long ago, Ultra-wideband (UWB) antenna technology is becoming popular among researchers as this radio technology operates over a greater band. The first experiment on the mentioned technology for the production of electromagnetic waves was conducted in 1893, during that time it was not commercially available so only a few experiments were reported [1]. Thereafter, US state department formally unlicense 7.5 GHz of band to recognize the researcher's contributions. The UWB assigned band is 3.1-10.6 GHz, which contributes advantageous properties such as less consumption of power as compared to other frequency bands, less implementation cost, and the lower frequency band of UWB make this technology capable of obstacle penetration [2]. The advantages of UWB, possess a number of applications in the field of communication engineering and radars mainly ground-penetrating radar (GPR), as well as in imaging and positioning [3, 4].

At present, many GPR based applications are using UWB antenna technology for land mines detection and buried victim's localization under the debris or trapped in the opaque environment [5]. GPR mainly consists a components which includes a receiver and a transmitter for the processing of reflected signals. UWB antennas involved in the process of transmitting and receiving the reflected signals for many applications. Therefore, the implementation of antenna for UWB based GPR applications varies such as Vivaldi, horn, planar, and bow-tie designs as studied previously.

The antennae designs reported met the requirements used in aforementioned applications which mainly includes gain, directivity, and frequency bandwidth, however, the most important is the complexity in antenna design [6, 7]. Based on the established study, this paper constitutes a simple design, and compact planar shape UWB arc antenna possess FR-4 based dielectric substrate. The acquired gain as well as the bandwidth for the proposed design is 6 dB and 13 GHz [8]. The design is derived with the well-known method called defected ground structure (DGS) [9] modified using current distribution concept. In order to validate antenna capability of the antenna for behind the wall detection in search and rescue operations, a modeled environment is developed and simulated with CST Microwave Studio. In the experiment, a monostatic as well as a bistatic based antenna configuration is commenced to study the targeted reflections and the subsequent results are then analysed further.

The rest of the paper contains a complete antenna configuration for the simulation of monostatic and bistatic experiments as a part of Section 2. While the discussion on acquired results are analyzed in Section 3. The final section summarized the conclusion.

## 2. ANTENNA DESIGN & CONFIGURATION

The postulated antenna along with a suitable configuration based on ground-penetrating radar (GPR) detection is designed for simulation using CST Microwave Studio under the technique called transient solver possess 50 ohms impedance fixed. This section carried out the design discussion of ultra-wideband (UWB) antenna and the simulation of monostatic and bistatic antenna configurational experiments for the detection behind the obstacle is carried out during this section.

The design implementation of UWB antenna for the defined frequency band i.e. from 3-10 GHz for GPR technology is proposed in this paper with a planar arc-shaped antenna having FR-4 based dielectric substrate possess $\varepsilon r = 4.2$. Whereas, for the development the proposed design a semi-circular slot is intruded towards the minor elliptical-shaped patch axis and the exact position for the circular slot is determined in order to match the scattering parameter using CST optimization tool. The design of a proposed arc based UWB antenna is illustrated in Figure 1, to shows establish the fact about size compactness in terms of the radiating patch and its subsequent ground structure.

The purpose of using half grounding in the design is mainly to match the bandwidth even at lower frequencies because UWB ranges from lower to higher frequencies with the allocated band [9]. The targeted gain of 6 dB is achieved, by introducing DGS method using slots with different geometries and at different positions over the ground surface as shown in Figure 1. A DGS method mentioned in this case is not only used for bandwidth matching over a complete UWB frequency band, however, it also used in directional radiation of the proposed antenna. Table 1 shows the dielectric material and dimensions in terms of length and width for the substrate, ground, the minor and major axis of proposed patch.

Thereafter, a simulation-based experimental model for monostatic and bistatic antenna configuration is investigated to analyze the detection capability of the proposed antenna using CST-MWS environment. Basically the terms, monostatic refers to the configuration where only single antenna element can be used for transmission as well as the reception of signal by switching between the modes [8]. While bistatic configuration mainly refers to the system with two dedicated antennas, one antenna can be used as a transmitter and other as a receiver throughout the entire process [4] to receive the reflections properly from the target.

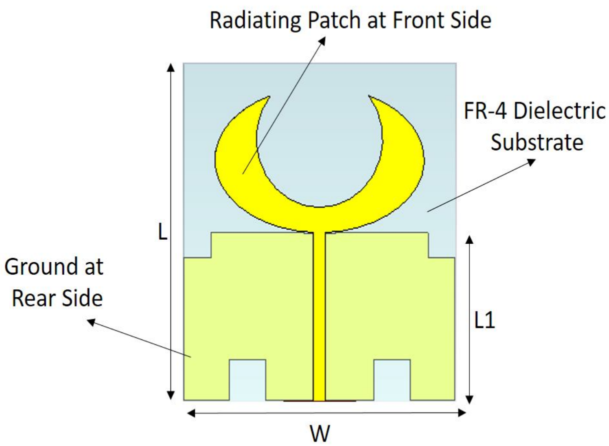


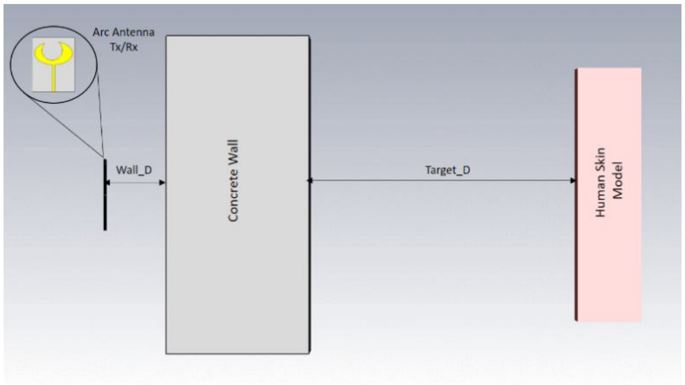

**Figure 1:** A Proposed design for an antenna

**Table 1:** Proposed design parameters

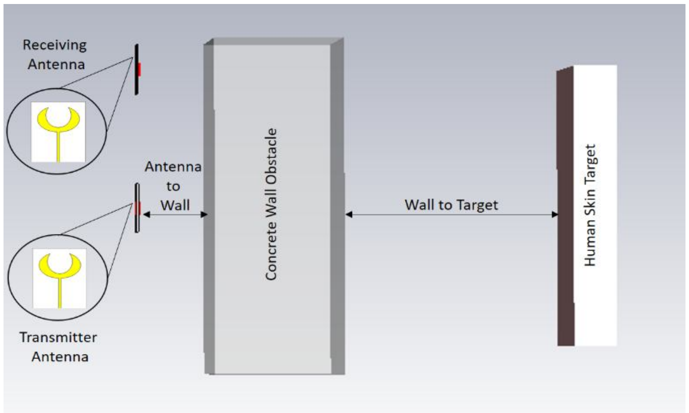
| Variables | Measurements (mm) |
|---|---|
| Major axis of patch | 27 |
| Minor axis of patch | 17.28 |
| Substrate (FR-4) | 40x35 (LxW) |
| Ground Plane | 20x35 (L1xW) |

The entire CST simulation scenario for monostatic and bistatic configuration of antenna is demonstrated in Figure 2. For monostatic configuration, only one antenna is used to transmit and received signal as mentioned previously, this antenna is placed at different position to study the desired response. While for bistatic configuration two antenna prototypes are placed over a certain distance from each other, the transmitting antenna position is fixed for the transmission of electromagnetic wave. Whereas the position of the receiver is varied for the analysis of the received reflections to make it suitable for detection operation.

The proposed antennas with discussed configurations are placed in front of the obstacle, taken as a concrete slab of thickness 90-100 mm for the validation of antenna penetration efficiency. Whereas a targeted human skin is placed behind the concrete obstacle. The reason for choosing human skin is mainly because it is the first and open part of the human body which is in contact with electromagnetic waves when penetrates through the wall. The distance between the antennae and obstacle is 50 mm in both cases, while between the obstacle and target is 150 mm. The available dielectric constant of concrete in the CST is Ɛr = 5.46 over the entire UWB band. However, the dielectric of skin varies i.e. Ɛr = 36-26, from lower to higher frequencies within the defined band. The analysis of the acquired result is the part of the study in results section.




(a)




(b)

**Figure 2:** Simulation-based configurations (a) Monostatic; (b) Bistatic

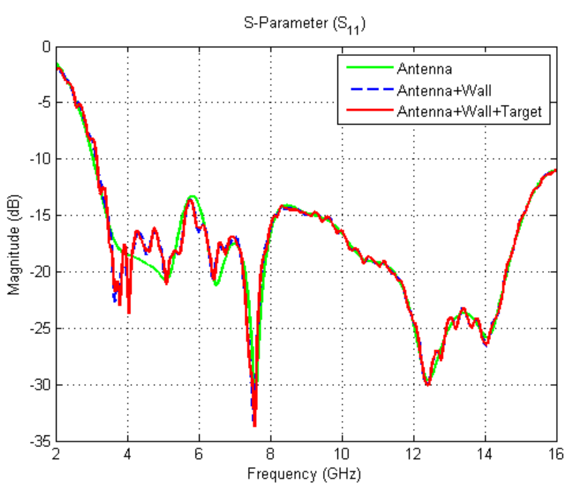
## 3. RESULT ANALYSIS

Aforementioned, the DGS structure method is used for the gain enhancement and the bandwidth matching for the proposed antenna. Table 2 summarizes the results where the simulated bandwidth without DGS is 5.5 GHz, which increased drastically to 13 GHz after DGS technique is applied. The reflections coefficients $S_{11}$ in case of monostatic and $S_{21}$ in case of bistatic configuration for the proposed UWB antenna in the presence and absence of obstacle, along with the demonstration of enhanced bandwidth is demonstrated in Figure 3. The secured $S_{11}$ ranges from 3-16 GHz possess the bandwidth of 13 GHz, which acquired 5.5 GHz more bandwidth than the allocated. Another required factor for UWB antenna design is the gain to evaluate the penetration efficiency, which is in this case in 6.2 dB using DGS. Therefore, the obtained results are useful for detecting the target behind the obstacle.

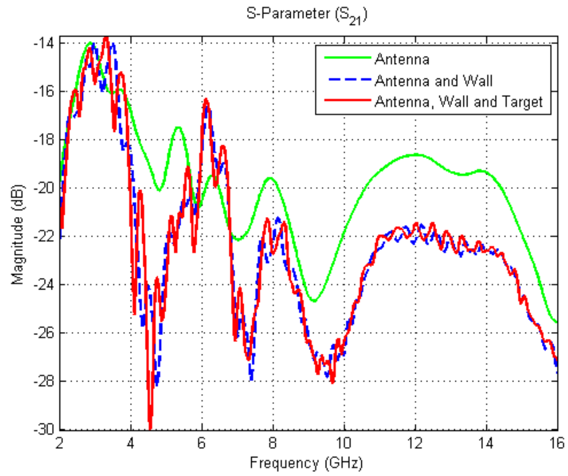
**Table 2:** Simulated BW and gain

| Antenna | Bandwidth (GHz) | Maximum Gain (dB) |
|---|---|---|
| Without DGS | 5.5 | 3.55 |
| With DGS | 13 | 6.2 |

Similarly, the experiments based on monostatic and bistatic configuration of antenna using the GPR methodology is conducted for revelation applications as discussed earlier. The obtained results for such simulated experiments are analysed in the form of scattering parameters, transmitting antennas, obstacle and target reflections from receiver antennas. Figure 3 illustrates the results obtained when electromagnetic waves penetrate through obstacle and the energy reflected from the target is being received by the receiver antenna.




(a)




(b)

**Figure 3:** Scattering parameters for (a) Monostatic; (b) Bistatic configurations

The $S_{11}$ of the monostatic antenna configuration when there is no obstacle in front is compared to the acquired results when the complete detection model including obstacle and target is simulated as illustrated in Figure 3(a). The figure shows that the acquired results in obstacle presence and target caused a disturbance, to demonstrate a notable resonance which is due to the backscattering of wall. While the similar results can be obtained in Figure 3(b) which is the reflection in the form of $S_{21}$ from target to receiver antenna. There again the same resonance is observed, which also shows the presence of the object which causes disturbance in antenna reflections.

The reflections of signal received are then collected and a MATLAB is programmed to develop a radar cross-section (RCS), which can be seen in Figure 4. From the figure, it can be illustrated that the red color near 2 GHz shows the presence of antenna and the reflected energy directly from the concrete wall in case of both monostatic and bistatic. But Figure 4(a) shows that the reflection received from the targeted object is not obvious and it is not clear if antenna is either receiving energy from the target behind the obstacle or not. Thereafter, the results acquired from bistatic configurations are analyzed as shown in Figure 4(b) where the wave signal disrupting in red color between 6-8 GHz representing the target presence. Based on the frequency in Figure 4, one can easily calculate the time magnitude t and the object distance d Equation (1) and (2) [10]:

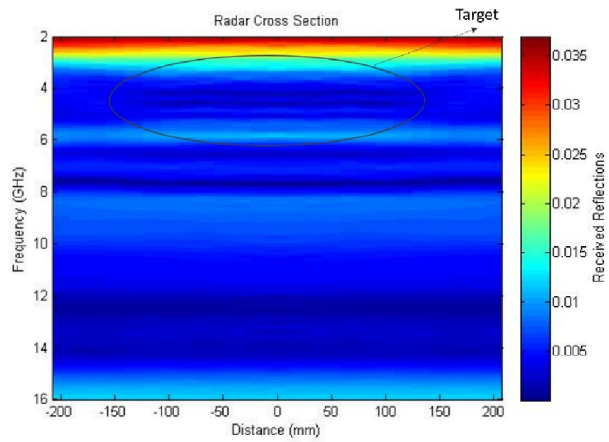
$$d = v\,\frac{t}{2} \tag{1}$$

**Definition 3.1:** *In this equations, v represents the propagation velocity, t the time and d the distance of the object.*

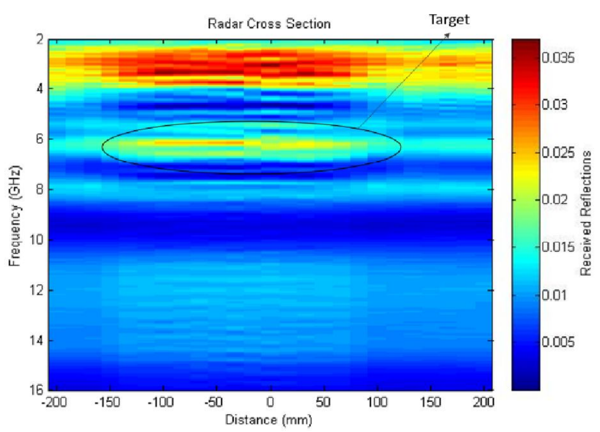
$$v = \frac{c}{\sqrt{\varepsilon_r}} \tag{2}$$

**Definition 3.2:** *In this equations, v the propagation velocity which represents the ratio of speed of light c to the dielectric value Ɛr of medium where the wave is traveling at a defined time.*

Therefore, from the discussed results it can be concluded that the RCS for monostatic configuration is hard to detect the object behind the wall compared to bistatic configuration. As for bistatic configuration, image for the object behind the wall is clear to detect the presence. It also concluded that bistatic configuration can be carried out for further study and antenna development.




(a)




(b)

**Figure 4:** Radar cross-section for (a) Monostatic; (b) Bistatic configurations

## 4. CONCLUSION

A planar arc-shaped ultra-wideband (UWB) antenna using FR-4 as a substrate has been investigated in this study for GPR search and rescue applications. Bandwidth matching and increased gain of the designed antenna is achieved using the DGS method. A comparison in the absence, as well as the presence of DGS, have been presented. The obtained gain as a result of DGS is 6.2 dB with a bandwidth of 13 GHz. For further analysis of the proposed antenna, different configurations have been simulated and as a result, a bistatic UWB configuration developed a clear RCS imaging as compared to the monostatic configuration. Therefore, the presented demonstrations provided an insight that a UWB bistatic configuration of an antenna is useful for detection purpose in ground penetrating radar (GPR) applications mainly for search and rescue.

## ACKNOWLEDGMENT

The authors would like to express their acknowledgment to ORICC Universiti Tun Hussein Onn Malaysia (UTHM) for supporting the work under TIER 1 grant VOT U860.

## REFERENCES

1. J. Ali, N. Abdullah, M. Y. Ismail, E. Mohd, and S. M. Shah, (2017), **Ultra-Wideband Antenna Design for GPR Application: A Review,** *International Journal of Advanced Computer Science and Applications*, 08, pp. 392-400. https://doi.org/10.14569/IJACSA.2017.080753
2. D. Valderas, X. Chen, C. Ling, J. I. Sancho, and D. Puente, (2010), ***Ultrawideband Antennas: Design and Applications*, London**: Imperial College Press, pp. 1-13. https://doi.org/10.1142/p684
3. J. Ali, N. Abdullah, R. Yahya, E. Mohd, A. Joret and N. Katiran, (2019), **Bistatic Configurational Analysis of Ultra-Wideband Antenna for Detection Applications,** *Indonesian Journal of Electrical Engineering and Computer Science*, 13, pp. 702-707. https://doi.org/10.11591/ijeecs.v13.i2.pp702-707
4. W. Kang C. R. Kim, J. H. Kim, S. G. Park, S. J. Cho, J. S. Son, and K. W. Kim, (2016), **A Study of Antenna Configuration for Bistatic Ground-Penetrating Radar**, *16th International Conference on Ground Penetrating Radar (GPR)*, pp. 1-4. https://doi.org/10.1109/ICGPR.2016.7572697
5. C. Warren and A. Giannopoulos, (2016**), Experimental and Modeled Performance of a Ground Penetrating Radar Antenna in Lossy Dielectrics**, *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, 09, pp. 29-36. https://doi.org/10.1109/JSTARS.2015.2430933
6. E. A. Etellisi, M. A. Elmansouri and D. S. Filipovic, (2016), **Wideband Monostatic Simultaneous Transmit and Receive (STAR) Antenna**, *IEEE Transactions on Antennas and Propagation*, 64, pp. 6-15. https://doi.org/10.1109/TAP.2015.2497356
7. G. Pochanin, S. Masalov, I. Pochanina, L. Capineri, P. Falorni and T. Bechtel, (2016), **Modern Trends in Development and Application of the UWB radar systems,** *8th International Conference on Ultrawideband and Ultrashort Impulse Signals*, pp. 7-11. https://doi.org/10.1109/UWBUSIS.2016.7724141
8. J. Ali, N. Abdullah, R. Yahya, and T. Naeem, (2017), **Monostatic Ultra-Wideband GPR Antenna for Through Wall Detection**, *European Physical Journal WOC*, 162, pp. 01076. https://doi.org/10.1051/epjconf/201716201076

9. R.A. Pandhare, P.L. Zade, and M.P. Abegaonkar, (2016), **Miniaturized Microstrip Antenna Array using Defected Ground Structure with Enhanced Performance**, *Engineering Science and Technology, an International Journal*, 19, pp. 1360-1367. https://doi.org/10.1016/j.jestch.2016.03.007
10. D. J. Daniels, (2004), ***Ground Penetrating Radar*, London**: The Institution of Engineering and Technology, pp. 23-30. https://doi.org/10.1049/PBRA015E