Shielding and Mutual Coupling Effect of Ground Penetrating Radar Antenna

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Abstract— This paper discusses the shielding and mutual coupling effect of ground penetrating radar (GPR) antenna for buried object detection. In this study, bi-static radar system is considered. The antenna used in this system is designed at wide operational frequency, 0.5 GHz to 3.0 GHz. To observe the shielding effect and mutual coupling between antennas, two antennas with the same operating frequency are placed in an individual shielded box. The study is accomplished using Computer Simulation Technology (CST) software. The antenna is designed using substrate Taconic TLY-5 with dielectric constant of 2.2 and thickness of 1.57 mm. The study and discussion includes the simulated results of radiation pattern, reflection coefficient and gain.

1. INTRODUCTION

Ground penetrating radar (GPR) is one of the non-destructive detection methods that have been tremendously explored mainly in the area of research and development. One of the important parts in the GPR system is the antenna itself. In a bi-static radar system, two antennas with the same specifications are used for transmitting and receiving the signal. When the transmitter sends the radio wave signal into the ground, the receiver will capture the reflected signal from the ground.

Generally, the antenna performance usually affected by mutual coupling and signal from other sources. As a result, the position or the distances between two antennas need to be considered [1–3].

Figure 1 shows the proposed GPR antenna. The antenna is shielded to minimize the coupling effect between antennas and isolate the antenna from undesired signals in the air.

As shown in Fig. 2, the signal is travelling from a transmitter to a receiver along a number of paths. The purpose of shielding is to selectively enhance some signals and supress others. Thisstudy leads to the objectives of [2]:

a. Maximize the energy on the path AA' to and from subsurface target (i.e.: focus on direct signal downward).

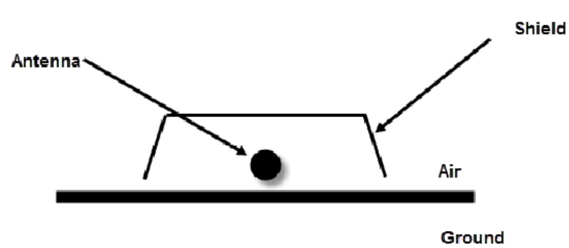


Figure 1: A shielded ground penetrating radar (GPR) antenna.

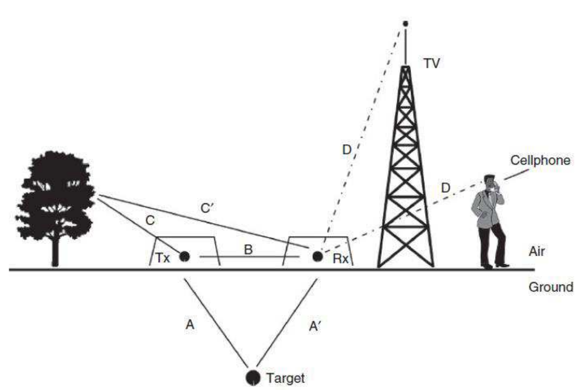


Figure 2: A Ground Penetrating Radar (GPR) system emits and detects radio wave signals. There are many possible signals and paths and the objective to maximize the target response and minimize others.

b. Minimize the direct transmitter to receiver energy on path B.
c. Minimize the energy that escape into the air as on path CC'.
d. Minimize external EM noise as indicated by signal D.

2. DESIGN

The proposed GPR antenna is designed and simulated using Computer Simulation Technology software (CST). All the dimension of the proposed antenna with and without casing are shown in Table 1. The distance between antennas without casing, d_1 is 250 mm while distance between shielded antenna is 150 mm. The distance for both antennas is optimized to obtain a good results in term of return loss, gain and coupling effect and these antenna operates at 0.5 GHz until 3.0 GHz which is suitable for GPR applications. The formula for circular patch antenna was used to calculate the dimension of the antennas [4].

$$a = \frac{F}{\left\{1 + \frac{2h}{\pi \epsilon_r}\left[\ln\left(\frac{\pi F}{2h}\right) + 1.7726\right]\right\}^{1/2}} \quad h \text{ must be in cm} \tag{1}$$

where,

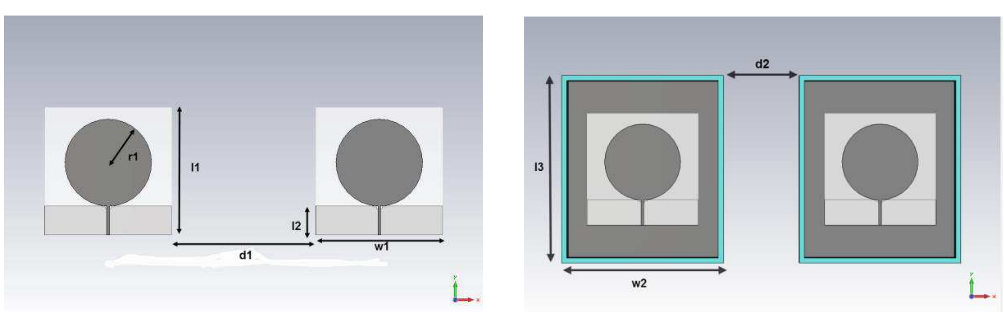
$$F = \frac{8.791 \times 10^9}{f_{r\sqrt{\varepsilon_r}}} \tag{2}$$

Table 1: Dimension of dual separated GPR antenna.

Descriptions	Dimension (mm)
l_1	200
l_2	50
l_3	200
w_1	200
w_2	320
d_1	250
d_2	150
r_1	75

3. RESULT AND DISCUSSION

Figure 4 shows the reflection coefficient, S_{11} and transmission coefficient, S_{21} of the proposed antennas. The antennas with and without shielded box give a similar results across 0.5 GHz to 3.0 GHz. The optimization of the antenna parameters and gap for both antennas is depending on resonant frequency. The closer the antennas will give more directives but will introduce higher mutual coupling effect which will degrade the performance of the antennas.



(a) (b)

Figure 3: Dual separation antenna, (a) without casing, (b) with casing.

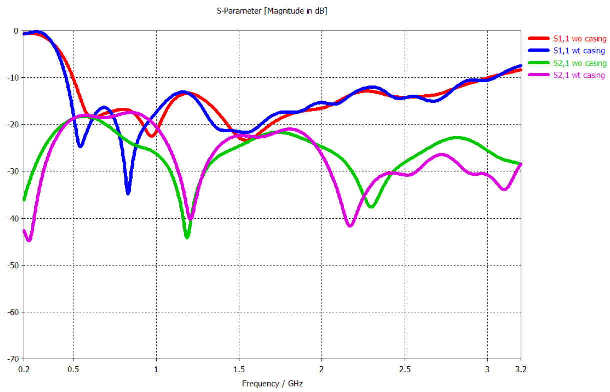
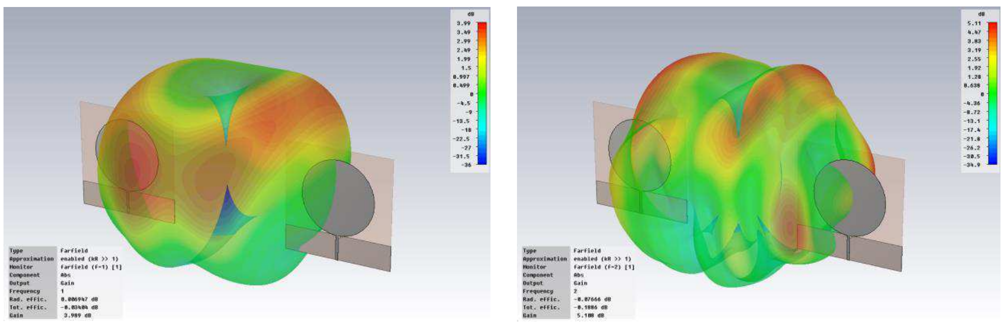
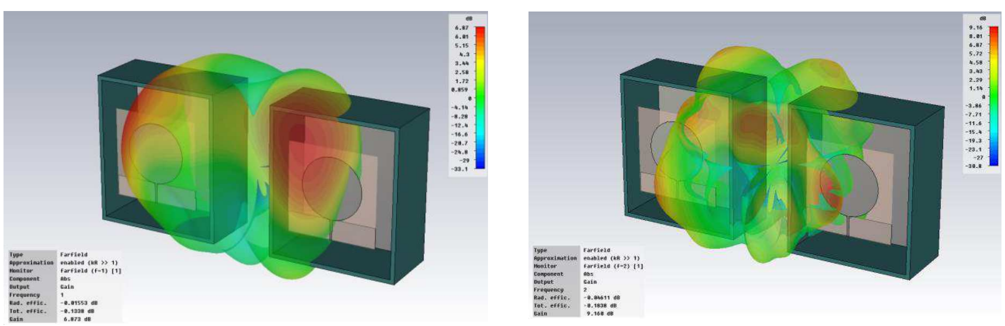


Figure 4: S-parameter for GPR antenna with and without casing.



(a) At 1.0 GHz (b) At 2.0 GHz

Figure 5: Radiation pattern of GPR antenna without casing at 1.0 GHz and 2.0 GHz.



(a) At 1.0 GHz (b) At 2.0 GHz

Figure 6: Radiation pattern of GPR antenna with casing at 1.0 GHz and 2.0 GHz.

Figures 5 and 6 show the simulated radiation pattern at 1.0 GHz and 2.0 GHz for shielded and unshielded GPR antennas. As can be seen, the gain of the antenna rise up to 6.68 dB and 9.17 dB at 1.0 GHz and 2.0 GHz compared to unshielded antenna respectively. This is due the reaction of the shielding effect which reflect the back lobe radiation to the front indirectly increase the gain of the antennas. So that, instead of eliminate the unwanted signal from various sources, the function of the shielded box also can increase the gain of the antennas.

4. CONCLUSION

Shielding and mutual coupling effect of Circular patch ground penetrating radar antenna which operates at 0.5 GHz until 3.0 GHz is discuss in this paper. The performance of the shielded antenna is better compared unshielded in term of radiation pattern and gain which increase 4 dB to 5 dB. Shielded antenna also can avoid antenna from receive undesired signal in the air.

REFERENCES

1. Daniels, D. J., *Ground Penetrating Radar*, 2nd Edition, D. N. Steward and P. H. Griffiths, Eds., The Institue of Electrical Engineers, 2004.
2. Annan, A. P., *Ground Penetrating Radar Principles, Procedures and Applications*, Sensor & Software Inc., 2003.
3. Jol, H. M., *Ground Penetrating Radar Theory and Applications*, Elsevier, 2009.
4. Balanis, C. A., *Antenna Theory Analysis and Design Book*, 2nd Edition, John Wiley, 1997.
5. Li, L., A. E. Choon Tan, K. Jhamb, and K. Rambabu, "Buried object characterization using ultra-wideband ground penetrating radar," *IEEE Transaction on Microwave and Techniques*, Vol. 60, No. 8, Aug. 2012.
6. Cao, P., Y. Huang, and J. Zhang, "A UWB monopole antenna for GPR applications," *6th European Conference on Antenna and Propagations, EuCAP*, 2012.
7. Agrawall, N. P., G. Kumar, and K. P. Ray, "Wideband planar monopole antennas," *IEEE transaction Antenna and Propagation*, Vol. 46, 1998.
8. Atteia, G. E., A. A. Shaalan, and K. F. A. Hussein, "Wideband partially-covered Bowtie antenna for ground penetrating radar," *Progress In Electromagnetics Research*, Vol. 71, 211–226, 2007.