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Low Cost Ultra-Wide Band Antenna for Radar Application - A Comparison of Two Designs

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Abstract

In this paper, the design of ultra-wide-band antenna for radar application has been proposed. The antenna consists of a circular patch and a ground plane on the adjacent side of the substrate. The proposed antenna is designed using FR-4 substrate with thickness of 1.6 mm thick and relative permittivity value 4.4. The dimension of the substrate is40 mm x 45 mm x 1.6 mm surface. The proposed antenna is designed and simulated using Ansoft HFSS. Also analysed the impedance matching property of two antenna designed with and without slotted patch.

Keywords: Ultra wideband, Ground Penetrating Radar, Low Cost

I. INTRODUCTION

There has been a greater demand in the ultra-wideband (UWB) system design after the release of the ultra-wide bandwidth of 7.5 GHz frequency band 3.1–10.6GHz by the Federal Communications Commission (FCC).Ultra Wideband (UWB) technology involves radiation, reception and processing of very wide bandwidth radio frequency emissions. There are many advantages of using ultra wideband systems.

According to Shannon-Hartley theorem, the channel capacity is proportional to bandwidth. UWB has wider bandwidth hence it can achieve huge capacity as high as hundreds of Mbps or even several Gbps with distances of 1 to 10 meters [1].UWB also has the ability to eliminate the effects of multi-path fading hence making it less susceptible to Interference. Data security will also be high as it is difficult to track transmitting data. Ultra wideband uses radio modulation technique, hence achieve a wide bandwidth by transmitting very short low power pulses [1][2].Radar is used in military applications, in ships, in air traffic control, and also to detect and analyze the subsurface structure. This paper mainly focusses on Ground Penetrating Radar (GPR) which consists of transmitter and receiver antennas, both operating at the same frequency range. The receiver antenna captures the backscattered signal from the subsurface [4][5]. The range of frequency used in GPR depends on the type of applications. The frequency range of 1GHz-2.5GHz is used to analyze the structure of buildings which does not require deep penetration, [6].

In this paper micro strip patch antenna for radar application has been proposed. Micro strip antenna offers a low profile, i.e. thin and easy manufacturability. A micro strip patch antenna (MPA) consists of a conducting patch , a dielectric substrate and a ground plane .Most commonly used patch is rectangular or circular in shape[3].Micro strip patch antennas have narrow bandwidth characteristics and there has been numerous methods developed for obtaining a greater bandwidth some of which include meandered ground plane [7], slot loading [8], meandering slots [9], tulip shaped monopole antenna [10] and T-slot in the radiating element [11].ANSYSS HFSS is used for simulation purpose.

II. ANTENNA GEOMETRY AND DESIGN

In this paper two micro strip patch antenna for GPR application is proposed.

A. Design 1:

In this design micro strip antenna consists of conducting patch on aground plane separated by dielectric substrate. Figure 1 represent radiation setup of the design 1 and figure 2 represents micro strip antenna without slotted circular patch and figure 3 ground plane with imperfections.

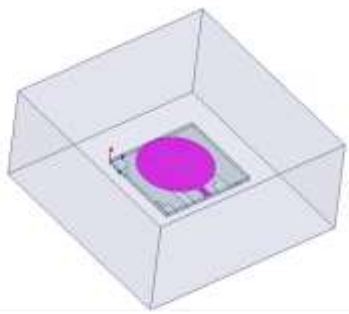

Fig. 1: Radiation setup of the design 1

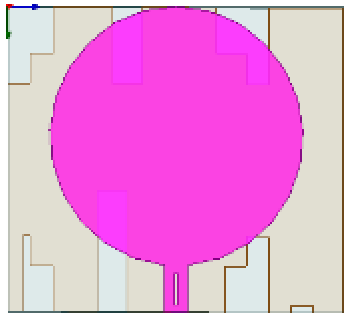

Fig. 2: Unslotted Patch of the design 1

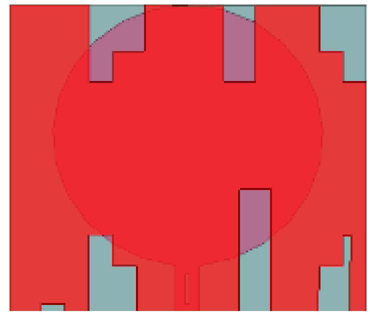

Fig. 3: Ground plane of the design 1

The FR4 substrate having a dielectric constant of 4.4 and having a thickness of 1.6 mm is used as the dielectric material. The size of the proposed antenna is 40 x 45 mm.T he upper circular patch has a radius of 17mm.The proposed antenna is fed by micro strip line. The characteristic impedance of feed is 50**Ω** By introducing imperfections on the ground plane the return loss of the antenna can be decreased. Rectangles of various sizes are used to create imperfections on the ground plane.

B. Design 2:

In this design micro strip antenna consists of conducting patch on aground plane separated by dielectric substrate. Figure 4 represent radiation setup of the design 2 and figure 5 represents micro strip antenna with slotted circular patch and figure 6 ground plane with imperfections.

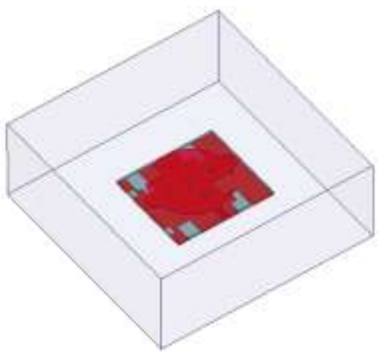

Fig. 4: Radiation setup of the design 2

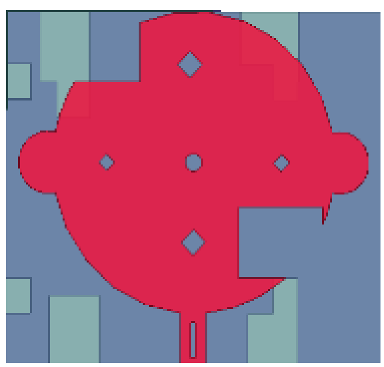

Fig. 5: Slotted patch of the design 2

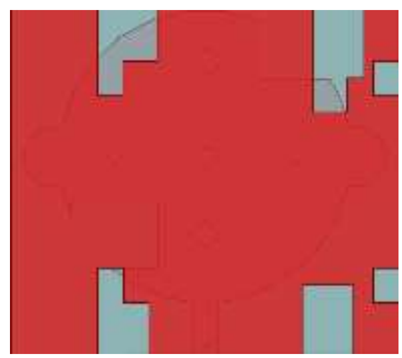

Fig. 6: Ground plane of the design 21

The FR4 substrate having a dielectric constant of 4.4 and having a thickness of 1.6 mm is used as the dielectric material. The size of the proposed antenna is 40 x 45 mm. The upper circular patch has a radius of 17mm.The proposed antenna is fed by micro strip line. The characteristic impedance of feed is 50**Ω.** The FR4 substrate having a dielectric constant of 4.4 and having a thickness of 1.6 mm is used as the dielectric material. The size of the proposed antenna is 40 x 45 mm. The upper circular patch has a radius of 17mm.The proposed antenna is fed by micro strip line. The characteristic impedance of feed is 50**Ω.** By introducing imperfections on the patch the bandwidth of the antenna can be increased. Circles and rectangles of various sizes are used to create imperfections on the patch.

Design Equations

The width (W) of microstrip patch is given by

$$W = \frac{c\sqrt{2}}{2f0\sqrt{(\varepsilon_r+1)}} \qquad (1)$$

where, c=3.0×10^(8)m/s is velocity of light ,f_o is Resonant Frequency & $\varepsilon_{r=}$ 4.4 is the Relative Dielectric Constant .

Effective dielectric constant(ε_{eff})

The effective dielectric constant is also a function of frequency. As the frequency of operation increases the effective dielectric constant approaches the value of the dielectric constant of the substrate is given by:

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2\sqrt{(1+\frac{12h}{w})}} \qquad (2)$$

Effective length (L_{eff})

The effective length is: which is found to be

$$L_{eff} = L+2\Delta \qquad (3)$$

Where,

$$L=\frac{c}{2f0\sqrt{\varepsilon_{eff}}} \quad (4)$$

$$\Delta L = 0.412h\,\frac{(\varepsilon_{eff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{eff}-0.258)(\frac{W}{h}+0.8)} \quad (5)$$

Circular patch radius,
Since the dimension of the patch is treated a circular loop, the actual radius of the patch is given by (Balanis, 1982)

$$a= \frac{F}{1+\frac{2h}{\pi\varepsilon_r F}[ln(\frac{\pi F}{2h})+1.7726]}1/2 \quad (6)$$

Where,

$$F = \frac{8.791\times10^9}{f_0\varepsilon_r} \quad (7)$$

Since fringing makes the patch electrically larger, the effective radius of patch is used and is given by (Balanis, 1982)
Effective radius,

$$a_e=a\{1+2h/(\pi\varepsilon_r a)[\ln(\pi a/2h)+1.77]\}^{\frac{1}{2}} \quad (8)$$

III. Simulation Results and Discussions

The proposed antenna is simulated using Ansoft HFSS 15. The antenna was analyzed by varying one of physical parameter such as slot width, radius of patch to get better results. It is found that the antenna is matched with return loss (S11) better than -10dB. Figure 7 shows return loss of the proposed antenna with slotted patch.

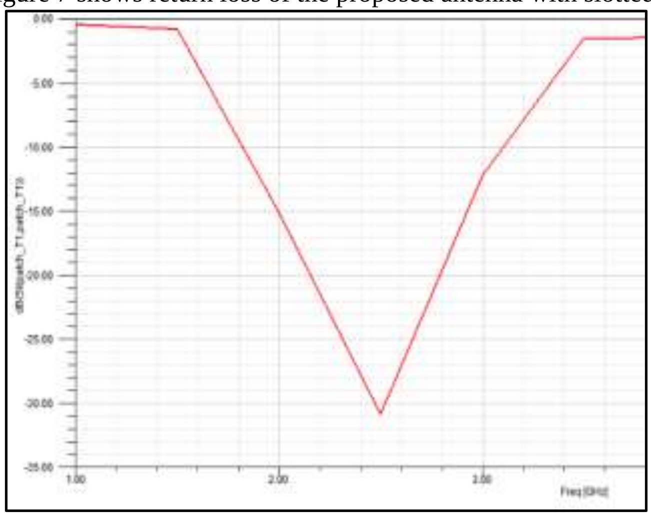

Fig. 7: Return loss of antenna with slotted patch

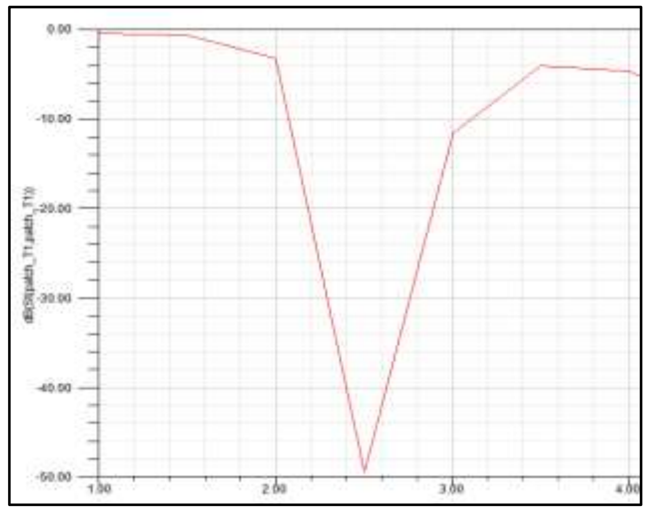

Fig. 8: Return loss of antenna with patch free of slots

It is found that the proposed antenna achieved a maximum return loss of -31dB with bandwidth of1.3 GHz. Fig 8 shows return loss of antenna with patch free of slots. By introducing imperfections on the ground plate the return loss of the antenna reached approximately to -50dB.But the antenna thus obtained has only bandwidth of the 0.8 GHz. the return loss reached -50dB at the expense of decreased band width.

The return loss value -50dB is obtained by analysing the performance of the antenna by fixing one physical parameter as varying and keeping all other parameters as fixed. By this method we obtained the optimised values for the physical parameter of the antenna, so that the antenna shows better performance.

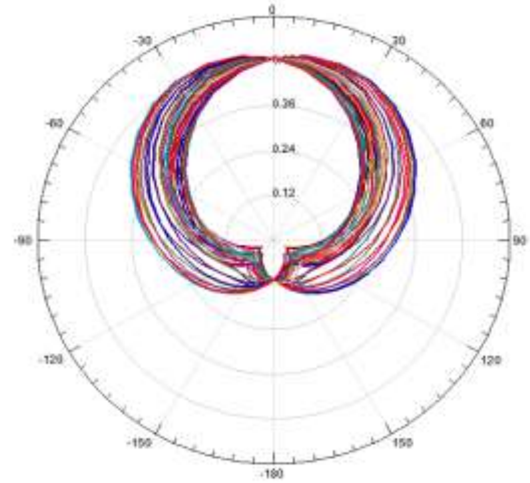

Fig. 8: Radiation pattern of design 2

The proposed antenna is for the GPR purpose so major lobe in forward direction is preferable than in the backward direction. With imperfections in the ground the ability of antenna to reflect back the power is increased so that the antenna lobe is projected more towards one direction and minimum in the other direction .Figure 8. Shows the radiation pattern of design 2. Ground imperfection is used to decrease the return loss close to-50dB. Return loss (S11) means the logarithm of reflected power to the power given to the terminal of antenna. As the return loss decreases, the amount of reflected power back to the antenna terminal decreases .This implies that more power is radiated by the antenna.

IV. CONCLUSION

In this paper the two antennas are designed for the frequency of 2.5Ghz..The effect on return loss and bandwidth due to imperfections on patch can be seen from the obtained results .A comparison between the obtained results is shown in Table 1.

Table – 1
Comparison of design1 and design 2

DESIGN	*RETURN LOSS*	*BANDWIDTH*
1	*-49dB*	*0.8Ghz*
2	*-31dB*	*1.3Ghz*

From this observation we can conclude that for applications which need more bandwidth the design 1(unslotted patch) can be used and for the application that requires very low return loss the design 2 (slotted patch) can be used .The two designs are suitable for GPR applications.

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