Bandwidth Enhancement of Small L-shaped UWB Monopole Antenna with a Modified Ground Plane

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Abstract **- Broadband monopole antennas have received considerable attention owing to their attractive merits, such as ultra-wide frequency band, good radiation properties, simple structure and ease of fabrication. Since the Federal Communications Committee (FCC) permitted the unlicensed use of the ultra-wide band (UWB) frequency band in 2002, large interests in both academic and industrial fields have been attracted to research various UWB devices. Small UWB antennas have found a wide range of applications including ground penetrating radars, high data rate short range wireless local area networks, communication systems for military, UWB short pulse radars for automotive and robotics applications, C and X band applications, and UWB microwave imaging systems. In this paper, a novel compact planar UWB monopole antenna with enhanced bandwidth by use of slots and Defected Ground Structure (DGS) is presented. The size of the antenna is 50 mm x 50 mm and it has microstrip feedline. Design and analysis of the antenna has been performed by HFSS software. Simulation results show that the designed antenna has broad frequency band which covers the band between 3.1 GHz and 10.6 GHz. According the return loss results, this antenna can be used for especially radar-based UWB systems applications which require low to high frequencies.**

Keywords **– Planar monopole antenna, UWB antenna, bandwidth enhancement, defected ground structure.**

I. INTRODUCTION

Since the Federal Communications Committee (FCC) permitted the unlicensed use of the ultra-wide band (UWB) frequency band in 2002 [1], large interests in both academic and industrial fields have been attracted to research various UWB devices. The UWB covers a frequency band ranges from 3.1 to 10.6 GHz that can be used in the field of Wireless Local Area Networks (WLAN), Wireless Body Area Networks (WBAN), Wireless Personal Area Networks (WPAN), Ground Penetrating Radar (GPR) technology, communication systems for military and microwave imaging (MI) systems which wide bandwidth is required [2,3]. Broadband antennas have received considerable attention owing to their attractive merits, such as ultra-wide frequency band, good radiation properties, simple structure and ease of fabrication.

Recent UWB antenna designs focus on small printed antennas for many applications because of their ease of fabrication and their ability to be integrated with other components on the same PCBs [4-6]. A dual band UWB slotted antenna [7] and antenna with elliptical slotted ground plane [8] are designed for C and X band applications. A number of UWB antennas have been designed for GPR applications [9-11]. The study based on the lower frequency band is conducted mainly to improve the penetration depth while the designing in the higher frequency band is performed to achieve better resolution imaging for GPR systems. This operation mechanism is notable for the UWB MI system which is radar-based. There are various antenna design for the MI systems such as horn, vivaldi, elliptical and circular monopole etc [12-15]. Some of the works focus on the entire UWB frequency range to further enhance the bandwidth while others focused on gain enhancement.

Printed monopole antenna, which has little differences in comparison with microstrip antenna, is one of the among various forms of the wide-band antenna which has simple structure and easy to fabricated and integrated with printed circuit board.

Microstrip antennas are compact and have low-profile but they have narrow bandwidth. However, microwave broadband systems, for example MI systems, need UWB signal to transmit short pulses for obtain sufficient range resolution. The modified microstrip antennas which has partial ground plane is called monopole planar antenna and they are the most choosen antennas in the UWB applications because of their wide bandwidth. They are named according to their radiation patch shapes such as elliptical, square circular, rectangular or any session of these shapes.

In this study, firstly a L-shaped planar monopole antenna is showed with its return loss results. Then some modifications are done on the ground plane to improve the bandwidth and impedance matching of the antenna. Also, parametric study is demonstrated to understand the effect of probe length and results are discussed for the different cases. At the end of the design process, the aim is to say that the proposed antenna is valid for the several UWB applications.

II. L-SHAPED PLANAR MONOPOLE ANTENNA

Planar monopole antennas are named according to their radiation patch shapes. In this study, rectangular patch with shifted feedline which printed on a FR4-Epoxy substrate is used and examined. It can be developed many different combination of patch and microstrip feed line. Here we select a rectangular patch with the length (L) and width (W) of 15 mm and 22 mm, respectively. The length and width of the feedline are taken as 15 mm and 3 mm, respectively to achieve the 50Ω impedance matching. The geometry of the antenna is showed in Figure 1.

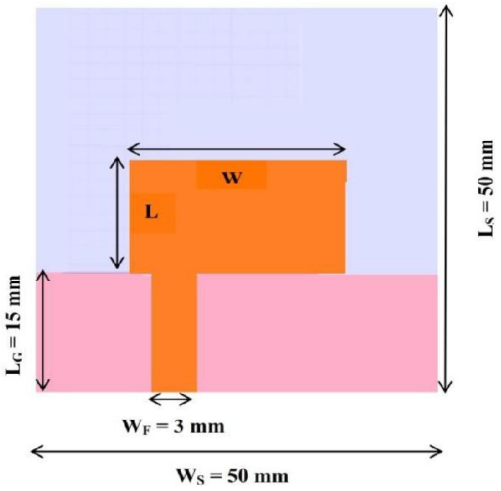


Figure 1: Printed L-shaped monopole antenna

To calculate the lower band-edge frequency of planar monopole antennas, the standard formulation is given in [16] as below:

$$f_L = \frac{7.2}{L + r}\ GHz$$

where L is the length of the rectangular patch, r is equal to W/2π and they are in centimeters.

According to the patch dimensions which we determined before, it is expected to see the lower frequency will be about 4 GHz for L=1.5 cm and W=2.2 cm. Indeed, this value is obtained in the return loss graphic of the antenna as it is seen from the Figure 2.

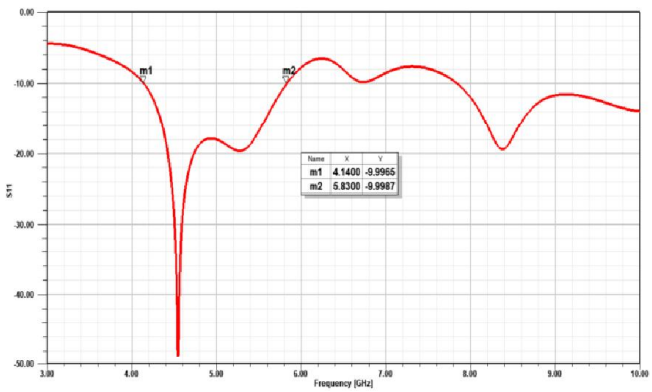


Figure 2: Return loss result of the L-shaped antenna

III. BANDWIDTH ENHANCEMENT TECHNIQUES

As mentioned above, the UWB covers a frequency band ranges from 3.1 to 10.6 GHz that can be used in the various implementations and different areas. However, according to return loss result given in Figure 2, the bandwidth is not at the desired range. Therefore, it is required to force antenna to be UWB that covers 3-10 GHz range. There are a lot of modification methods to provide bandwidth enhancement. One of these methods is using defected ground structure (DGS) to improve impedance matching and increase bandwidth of a compact UWB planar monopole [17-19]. Before starting to make some modifications on the ground plane, effect of the gap length between the ground plane and feedline is examined. After this stage, required development will be showed.

A. Effect of the Distance Between the Ground and Feedline

In the Figure 2, the return loss result has been given for the equal lengths of the ground plane and feedline. The length is equal to 15 mm which can be seen in the Figure 1. In this stage, effect of the different lengths will be investigated. In Figure 3, there is a distance ***g*** between the ground and feedline. Return loss results for g = 0 mm, g = 0.5 mm and g = 1 mm is given in Figure 4.

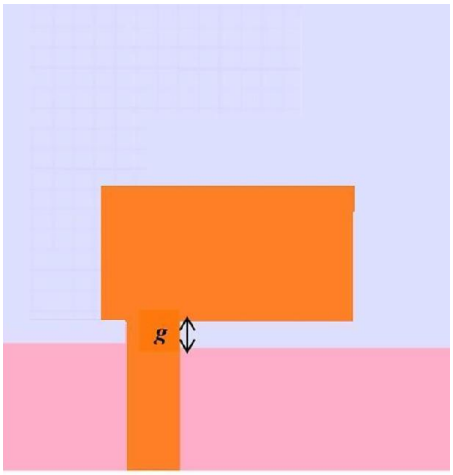


Figure 3: L-shaped monopole antenna with gap between ground plane and feedline

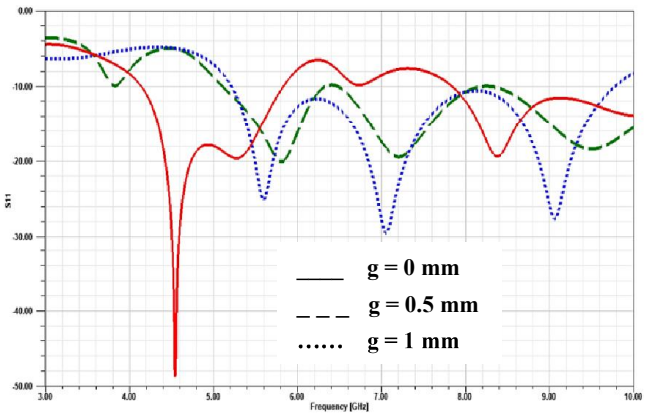


Figure 4: Return loss results for the different values of gap

B. *Slots on the Ground Plane for Bandwidth Improvement*

In the Figure 4, it is clearly seen that using gap between the ground and feedline affects the return loss well, but it still need to be improved for exactly covering the entire UWB range. For this aim there are many techniques such as etching notch or slot, adding parasitic element, changing dimension etc. In this study, we intend to use defected ground structure and it will provide by etching T-shaped slot on the ground plane. The new geometry of the antenna is shown in Figure 5. The detailed design parameters of the developed antenna are given in Table 1.

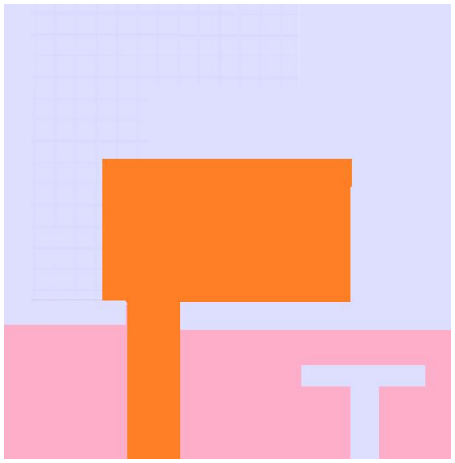


Figure 5: L-shaped monopole antenna with gap and T-shaped slot

Table 1: Design values of the proposed antenna.

Parameters	Values (mm)
Length and width of the substrate	50 x 50
Length and width of the patch	15 x 22
Length and width of the feedline	15 x 3
Length and width of the ground plane	15 x 50
Gap between the ground and patch	1
Length and width of the horizontal part of the slot	1 x 4
Length and width of the vertical part of the slot	4 x 1

IV. Results and Discussions

Performance analysis of the developed antenna has been performed by HFSS software which based on full-wave finite elements method and widely used in the design of electromagnetic structures [20]. The rate of convergence maximum delta S was taken as 0.005. Radiation boundary was located at 25mm (λ/4 for 3 GHz) away from the edges of the antenna in all directions.

The return loss graph of the L-shaped planar monopole antenna with T-shaped ground slot is given in Figure 6. It is clearly seen that the bandwidth has been increased and impedance matching has been improved by using DGS approach. The aim of the UWB antenna design, which is valid for the several UWB applications, is accomplished according to these results.

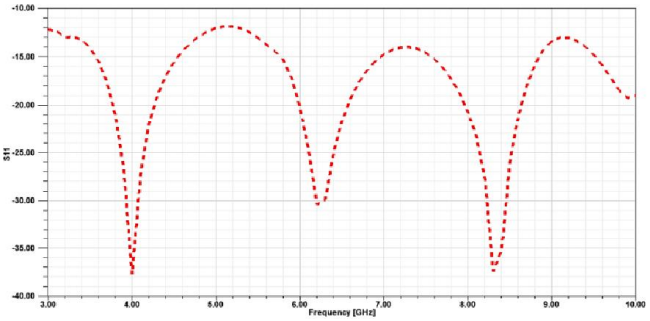


Figure 6: Return loss result of the proposed antenna

In addition to return loss result, radiation pattern of the antenna for 6 GHz is given in the Figure 7. The results confirm that the antenna has an omnidirectional radiation pattern.

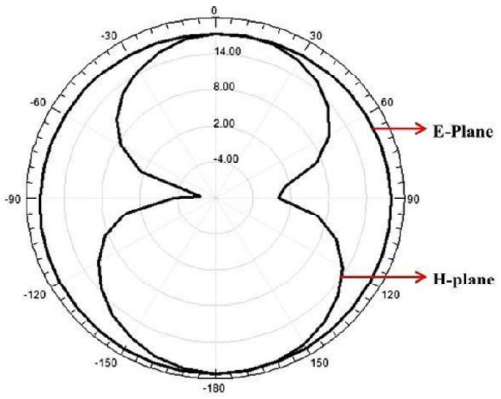


Figure 7: Radiation pattern of the antenna for 6 GHz

V. Conclusion

The modified microstrip antennas which has partial ground plane is called monopole planar antenna and they are the most preferable antennas in the UWB applications because of their broad bandwidth, compact and easy assembled structure. They are named according to their radiation patch geometry. In this study a L-shaped patch is choosen and lower frequency of the bandwidth is determined by the size of this shape. According to the antenna return loss result, it is seen that the bandwidth need to be improved. Effect of the length difference between the feedline and ground plane is investigated and optimum value has found as 1 mm. After that, DGS approach is implemented to design. T-shaped slot is used to improve both bandwidth and impedance matching. Good return loss result is obtained at the end of the design process. Bandwidth covers the entire UWB frequency range, which has permitted by the FCC in the USA for the unlicensed use of the ultra-wide band as 3.1-10.6 GHz.

This return loss result shows that the proposed can be used for the several UWB applications such as WLAN, WBAN, WPAN, GPR technology, communication systems for military and MI systems, C and X band applications etc. But some of these applications need the directional radiation patterns. In future, radiation characteristic of this antenna can be changed to obtain different patterns for desired application.

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