Proceedings of CECNet 2022
A.J. Tallón-Ballesteros (Ed.)
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doi:10.3233/FAIA220525

Study Analysis of Printed Monopole Antenna for C and X Band Application

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Abstract. In this design, dimension of the proposed antenna is 20 X 25 X 1.6 mm^3 with FR4 substrate having circular patch fed with co-planar waveguide (CPW) that operates at numerous resonance frequencies between 5 and 10 GHz. The proposed antenna can be used well for low range communication transceivers in the C and X bands, according to simulation results. The optimal parameters for UWB antenna are the fractional bandwidth, which should be greater than 85%, and VSWR, which is another parameter. For the best and most efficient technique of using printed monopole antenna, the range of Ultra wideband (UWB) bandwidth should be lower than 2. Simulate data suggest that the proposed antenna has outstanding impedance matching capabilities, achieving a peak gain of 8 dBi. Results indicate that the ground plane's dimensions of 15.9 mm and 11.4 mm are the most suitable for UWB due to its return loss of -41.86 dB, fractional bandwidth of about 89%, and Voltage standing wave ratio(VSWR) of less than 2 within the frequency spectrum. This modified prototype antenna has a decent, omnidirectional radiation pattern.

Keywords. Return loss, C and X bands, Ultra wideband (UWB), Voltage standing wave ratio (VSWR), Co-planar waveguide (CPW)

1. Introduction

Due to their inherent characteristics, such as their portable dimension, high speed signal over short distances, maximum bandwidth, low profile hardware, little power utilization, omnidirectional field pattern, and linearly shift, ultra-wideband systems have become necessary for many applications in recent years. The Federal Communication Commission (FCC) granted the radio spectrum upto 10 GHz to UWB in the year 2002 to overcome the flaw to pre existing narrow band communication [1]. The antenna system is highly desired in wireless communication due to its numerous characteristics, including short pulse length, wide frequency band, low distortion, multipath immunity, and low intercept probability. Monopole antennas are frequently employed as effective radiators in a wide range of applications, including radio receivers, mobile phones, mobile navigation, and communication. It is because of its key characteristics, including its cost effective, continuous conformal construction, light weight, simplicity of manufacture, integration with RF devices, etc. In recent years, wireless technology has advanced more rapidly. Through 3G and 4G, the technology advanced to the fifth generation (5G). In the past, planar microstrip

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antennas were used by2G technology for sending and obtaining microwaves at the necessary centre frequency[2][3]. The working frequency of the cellular technology determines the antenna's size. For modern uses, the antenna gets progressively smaller, takes up very little room, and is simple to place. In contemporary wireless networks, such a small antenna is also favoured for low-power transceiver applications. The cellular band's spectrum allocation became congested as internet technologies advanced. Modern communication devices are a result of growing demand for wireless service in contemporary wireless communication networks.

Additionally, the antenna is crucial to the mobile communication system's ability to expand the coverage area, boost cellular system capacity, and simplify the network. The substrate's dielectric constant of printed antenna naturally affects the antenna's size[4-8]. Gangwar et al. [9] implemented slit and slot in the radiating element to accomplish multi-band operation. A thorough study by Carver et al.[10] revealed that changing the patch dimension from rectangular to another can provides impedance matching characteristic. Li et al.[11] created a wide range dual polarisation which is circular in nature, FR4 as substrate with CPW fed modifying the patch with slot.

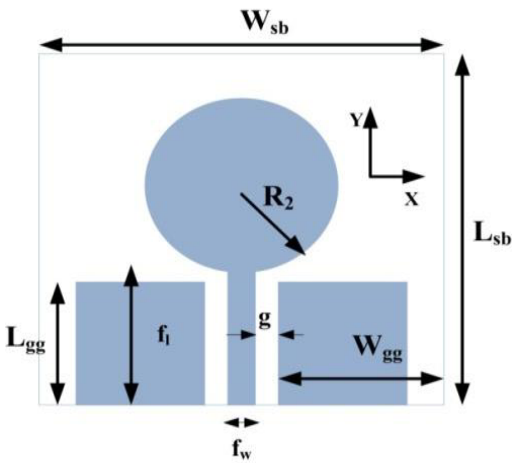

Figure 1. Proposed Antenna Design

2. Proposed Antenna Design

The design of the proposed monopole antenna with circular disc shaped patch can be found out from the following equations, Eqs (1) and (2) [12].

$$R_2 = \frac{R_{fe}}{\sqrt{1+\frac{2h}{\pi\varepsilon_r R_{fe}}\left[\ln\left(\frac{1.57 R_{fe}}{h}\right)+1.78\right]}} \tag{1}$$

$$R_{fe} = \frac{8.79\times10^9}{f_{rs}\sqrt{\varepsilon_r}} \tag{2}$$

Where, h = substrate's height in mm, ε_r = dielectric constant of the substrate, f_{rs} = the resonating frequency.

The standard formulation given for estimating the lower band-edge frequency of printed monopole antennas can be used to evaluate the lower band-edge frequency of the antenna. With the right modifications, a cylindrical monopole antenna can be used [10-15]. These equations hold good for the antenna with planar model with monopole structure.

The lower band edge frequency is given in [11-15], if H represents height of the monopole antenna with cylindrical shaped and r denotes the effective radius of the corresponding antenna, the following equation describes the lower band edge frequency.

$$f_{fe} = \frac{c}{\lambda_l} = \frac{7.2}{\left(H+R_{ef}+f_l\right)} GHz \tag{3}$$

When compared to planar antennas with circular shaped monopole properties with the printed layout having a single sheet of dielectric on the antenna. In this, f_l denotes feed length in order to match with 50Ω input impedance. The dielectric substrate act as to increase the effective size of the antenna thus decrease in the lower band edge frequency.

In Figure 1. the proposed antenna geometry is displayed. Substrate with FR-4 epoxy has the following dimensions: L_{sb} = 30 mm, W_{sb} = 35 mm, h = 1.6 mm, ε_r = 4.4 and a patch circular radius R_2 = 8.5mm is put on the upper portion of the substrate in order to matched 50Ω CPW fed line.The length and width of the stripline are f_l=18mm, f_w = 1.6 mm respectively. Optimised dimension of ground plane is L_{gg}=19.5mm and W_{gg} =11.4m for better bandwidth.

3. Result and Discussion

The ground plane dimensions are an important design consideration for monopole antennas due to the significant influence of gain, bandwidth, and radiation pattern on ground plane size. When simulations are run for different ground plane dimensions, the effects of the ground structure on the centre frequency are seen in Figure 2.

Table 1. Simulated result of return loss(S_{11})on various ground dimension

Ground plane dimension	**Operating Centre frequency(GHz)**	**$\|S_{11}\|$dB**	**-10dB Bandwidth(GHz)**	**Fractional Bandwidth(GHz)**
L_{gg}=15.9mm W_{gg}=13.4mm	f_{cen1}=7.4 f_{cen2}=15.4	-25.30 -17.97	(5.1- 12.9) (14.2-19)	86.6 28.9
L_{gg}=15.9mm W_{gg}=12.4mm	f_{cen1}=6 f_{cen2}=16	-27.69 -31.9	(5.2-12.8) (14.0-18.0)	84 25
L_{gg}=15.9mm W_{gg}=11.4mm	f_{cen1}=6 f_{cen2}=16	-41.86 -39.91	(5.2-13.6) (14.1-18.2)	89 25
L_{gg}=15.9mm W_{gg}=10.4mm	f_{cen1}=6 f_{cen2}=17.4	-41.58 -26.68	(5.3-13.5) (14.4-19.7)	87 29.5
L_{gg}=15.9mm W_{gg}=9.4mm	f_{cen1}=6 f_{cen2}=15.8	-21.97 -21.97	(5.4-13.4) (14.6-17.0)	85 15

As seen in Table 1, the conventional prototype proposed antenna has dimensions of L_{gg} = 15.9 mm, W_{gg} = 13.4 mm, an impedance bandwidth of 5.1 GHz to 12.9 GHz, and a fractional bandwidth of 86.6%, or more than 10 GHz, which satisfies the requirement of UWB on its first resonance frequency, f_{cen1}=7.4 GHz. However, it does not meet the requirements for UWB at its second resonance frequency. Bandwidth, return loss, and VSWR can all be enhanced by altering the ground plane's length and width.

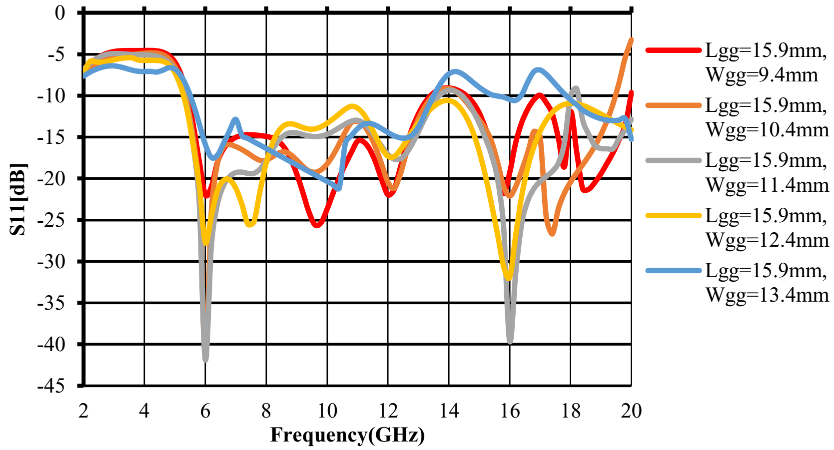

Figure 2. S_{11}[dB]vs Frequency response

According to Figure 3 and Table 1, the distance between the ground plane and the patch is a key factor in boosting bandwidth; the smaller the distance, the greater the bandwidth. Therefore, the optimal ground plane length is Lgg=15.9mm, however decreasing the ground plane's width causes an increase in bandwidth and return loss. Further narrowing in breadth would result in inadequate bandwidth, hence the ground plane's width was tuned to be 11.4 mm. The conditions for UWB are met when Lgg=15.9mm and Wgg=11.4mm, which results in a bandwidth of 5.2GHz to 13.6GHz, return loss of -41.86dB, and fractional bandwidth of 89%.

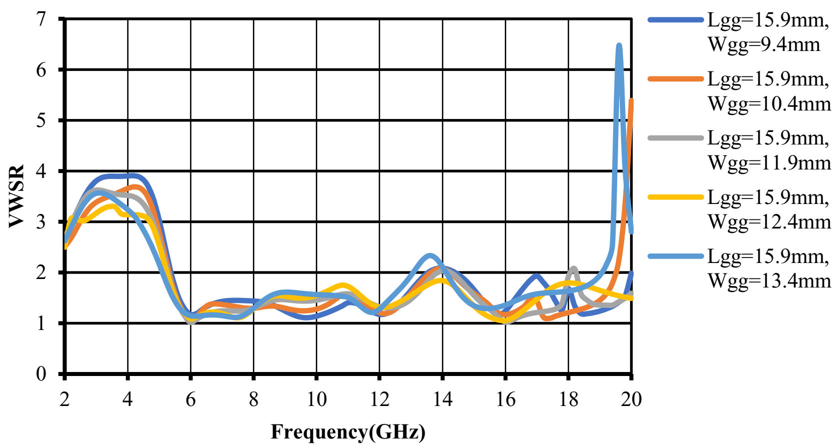

Figure 3. VSWR vs Frequency response

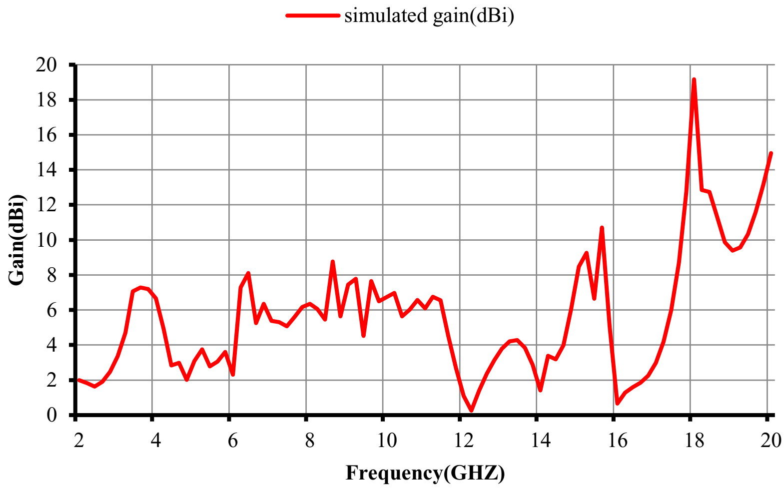

Figure 4. Gain(dBi) response of proposed antenna

The fluctuation of gain within the frequency ranges from 5 to10 GHz is depicted in Figure 4. Additionally, it can be deduced that the suggested antenna achieves a maximum gain of 8.1 dBi at 6.4 GHz, first resonance frequency for the optimal ground plane dimension, and another significant gain of 8.77 dBi at 8.6 GHz, which is another resonance frequency for the next bandwidth. It is clearly seen that a good gain can be achieved with this modified ground plane.

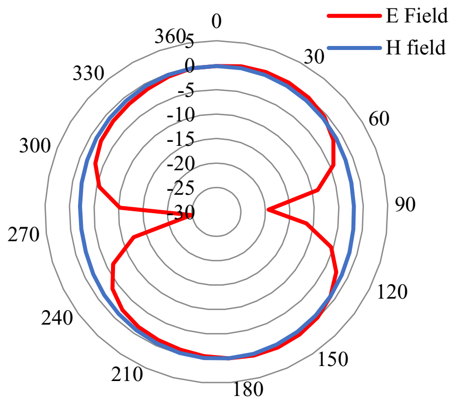

Figure 5. Radiation pattern of the proposed antenna

Figure 5. illustrates how the E-plane and H-plane radiation patterns of the suggested antenna behave, and it is obvious that it exhibits an omnidirectional pattern. It is reasonable to assume from this that it is transmitted uniformly in all directions by a printed monopole antenna.

Table 2. Comparision of performance for different proposed antenna

Ref	Dimensions (mm)	Bandwidth(GHz)	Gain(dBi)
[16]	60X56X1.6	1.3 to12	4 to7
[17]	50X50X1.575	2.6 to10.8	0.2 to 4
[18]	50X50X1.575	2.2 to11	0.2 to4
[19]	42X42X1.5	2.6 to10.6	2 to7
Proposed antenna	30X35X1.6	5.2 to12.8	4 to 8.77

Table 2. provides the literature of different proposed antenna, that cover the ultra wideband range. But in this proposed antenna, it focus on C and X band that is within the range from 4GHz to 12GHz.When compare to previous proposed antenna, the volume of the antenna is reduced as well as a better gain is obtained .

4. Conclusion

Proposed antenna provides impedance bandwidth greater than 10GHz, making it a good fit for C and X band applications. When the ground plane's size is reduced, the impedance bandwidth and return loss continue to grow. If the ground plane's size is still reduced, the bandwidth will eventually start to decline. The optimal ground plane dimension is the one at which the bandwidth is decreasing. Modified ground planes provide an efficient means of increasing bandwidth in comparison to standard prototype antennas. The electromagnetic and electric fields' radiation patterns closely resemble the dipole radiation patterns of the E and H planes. Regarding the gain response of the proposed antenna, it gives a gain of about 8dBi, which is better than the conventional prototype printed monopole antenna.

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