A CPW Fed Super Wide Band Antenna with an Open Ring shaped Planar Monopole Disc

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Abstract—This paper presents a design of compact, super wide band CPW fed circular monopole antenna. The proposed antenna is having a compact size of 30×30 mm^2(W_s × L_s). The operating bandwidth of the proposed antenna ranges from 2.7 GHz to 40 GHz that provides a percentage bandwidth of 174% and impedance bandwidth ratio of 14.28:1. The peak gain is of 6.2 dBi. Moreover the group delay profile of the proposed antenna lies within 1ns. The radiation pattern of the proposed antenna is omni-directional as required for UWB communication.

Keywords—Super wide band (SWB), impedance bandwidth, CPW feed.

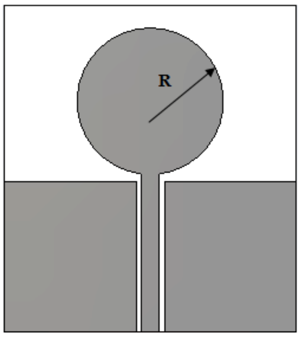
I. INTRODUCTION

Ultra wideband has become a popular research topic ever since the Federal Communications Commission (FCC) released its regulation allocating a large band of 7.5 GHz from 3.1 GHz to 10.6 GHz for unlicensed use by the end users[1]. This band has a bandwidth ratio of 3.4:1. Its application is mainly for short range, high bandwidth communications covering the WPAN (wireless personal area network). Several planar monopole UWB antennas[2-5] have been reported over the past decade. UWB has enormous application in the areas of communications, health monitoring, defence, public security and safety. Driven by the advantages of UWB communication, new research methodologies and techniques are developed by the researchers and antenna designers to design a kind of antennas which can support extremely high data rate for defence application and imaging systems. Such antennas can be designed so that they can cover a super wide band having impedance bandwidth ratio greater than 10:1, without resorting to Terahertz region. This will enable high-resolution sensing in free space, imaging and in matter including through-wall sensing and ground-penetrating radar. The SWB technology comprises of all the advantages of UWB technology along with the characteristics of enhanced channel capacity and much improved resolution in screening and ranging. Apart from various challenges, the design of SWB antenna is of much concern as it has to provide a good impedance matching over a very wide band. Few such planar super-wideband (SWB) antennas [7-10] have been designed and studied in order to enhance the bandwidth ratio for future communication application with the bandwidth ratio larger than about 10:1.

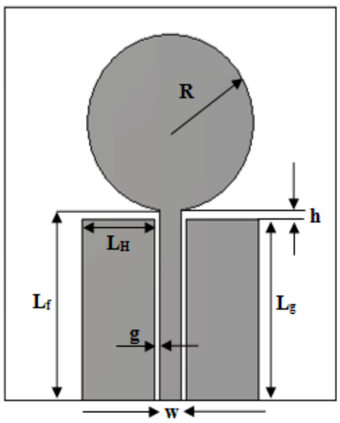
In this paper, a novel CPW fed open ring shaped SWB antenna is proposed. The radiator of the antenna is a planar asymmetric C shaped disc. The designed antenna has a compact size of 30mm × 30mm × 1.6 mm. The simulated results show that the proposed antenna achieves a bandwidth ranging from 2.7 GHz to 40 GHz with peak gain obtained is 6.2 dBi. The paper is arranged such that section 2 describes the details of the design and parametric study which is followed by result and discussion and conclusion in section 3 and section 4 respectively.

II. ANTENNA DESIGN

The structure of the proposed antenna is shown in Fig.1.(c). The antenna is realized on an FR4 substrate of ε_r= 4.3 with dimension of 30×30 mm^2 (W_s × L_s), thickness, S_t , of 1.6 mm with loss tangent of 0.025. The radiator patch is originated from a circular disc with radius of 7.5 mm (R). The

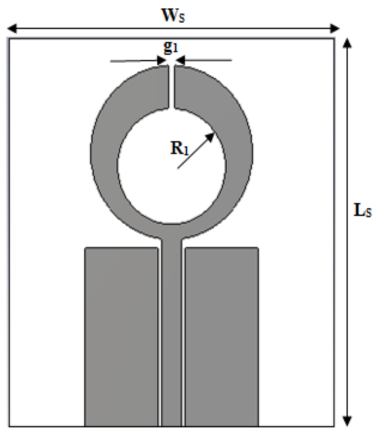


(a)



(b)

antenna is fed with 50 Ω CPW feed line.



(c)

Fig. 1 (a) Simple circular monopole antenna (b) Same antenna with horizontally reduced ground plane (c) Proposed antenna

The radius of the circular patch affecting the lowest frequency of operation is determined by

$$2R = \lambda_g/4 \quad (1)$$

where λ_g is the guided wavelength

$$\text{Therefore, } 2\times R = \frac{c}{4\times f\times\sqrt{\varepsilon_{reff}}}, \quad (2)$$

where ε_{reff} =effective dielectric constant of the substrate, c=velocity of light in free space, f= 1st resonant frequency

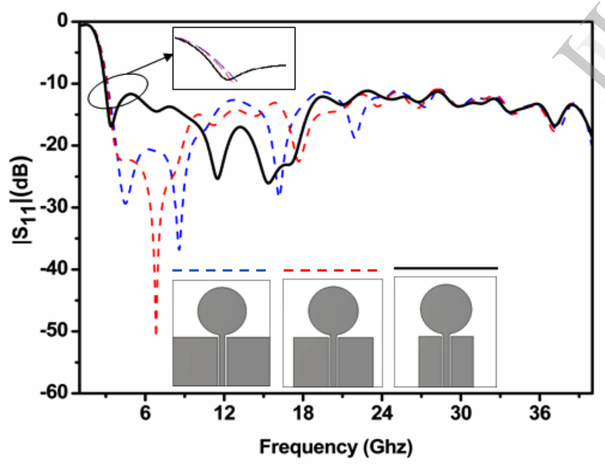


Fig. 2 Effect of horizontally reducing the ground from the substrate edge

Initially a CPW fed simple circular monopole antenna of radius R=7.5 mm is taken as shown in Fig.1(a). Then slowly the horizontal ground dimension is varied from the substrate end.

It is observed in Fig.2 that as the horizontal ground dimension is varied from the substrate end, the lowest frequency is shifted towards the lower frequency region. This signifies a reduction in the size of the antenna with an increased bandwidth. This observation can be explained taking into consideration the affect of Q-factor on bandwidth. As the ground size is reduced, the electric fields get more loosely bound, resulting in more fringing fields [10,11]. This reduces the Q-factor of the antenna and increases the bandwidth as Q-factor and bandwidth are inversely proportional to each other [10,11].

Open ring shaped radiator patch is designed by etching out a circular slot of radius R_1 from the initial monopole disc and a rectangular slit of width w from the upper portion of the radiator disc. The position and the radius of the circular slot is varied by parametric study to improve the matching at the lower frequency side. It is observed that by forming the open ring shaped patch, the lowest frequency also shifts to the lower frequency side, signifying size reduction of the antenna. Moreover formation of the open ring shaped slit inside the patch increases the effective path of current flow through the patch.

III. Results And Discussion

The proposed antenna is analyzed by finite integration method by using time domain solver of CST microwave studio [12]. The designed antenna has a compact size of 30×30 mm^2. The studied parameters of the proposed antenna are listed in Table 1.

TABLE 1: Parameters of the proposed antenna

Antenna Parameters	**Value (mm)**
L_s	30
W_s	30
R	7.5
h	1.8
g_1	0.6
L_f	16
R_1	5
w	1.9
g	0.625
Ground Plane parameters	**Value (mm)**
L_H	6.55
L_g	15.4

The simulated $|S_{11}|$ characteristics of the designed antenna is shown in Fig.3. and it is observed that the impedance bandwidth ranges from 2.7 GHz to 40 GHz. Fig.4 shows the simulated VSWR of the antenna which is below 2 over the entire band. The peak gain obtained is 6.2 dBi as shown in the Fig.5. The group delay profile is within 1ns as shown in Fig.6.

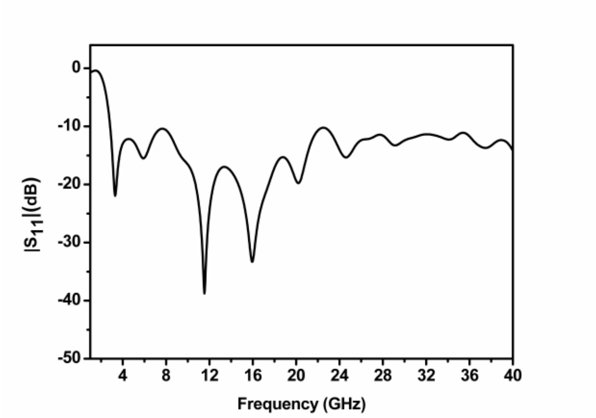


Fig. 3 Simulated $|S_{11}|$ plot of the proposed antenna

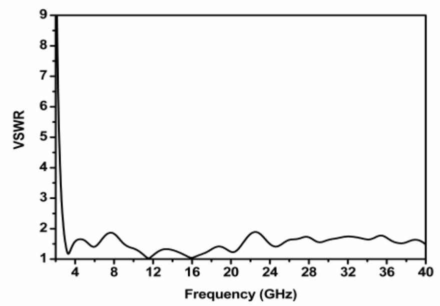


Fig. 4 Simulated VSWR plot of the proposed antenna

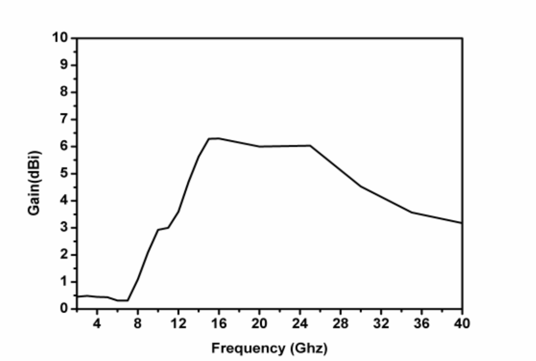


Fig. 5 Simulated gain of the proposed antenna

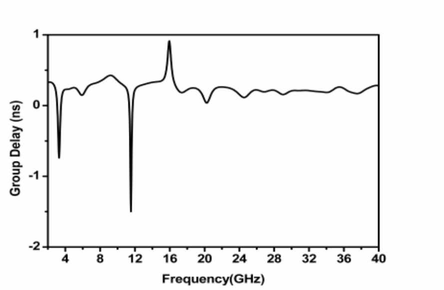


Fig. 6 Simulated group delay of the antenna

The notable feature of the antenna is its impedance bandwidth ratio of 14.28:1 which makes it a super wide band antenna with peak gain of 6.2 dBi and consistent radiation pattern stability. This makes the antenna suitable for future high data rate communication, implementation in high accuracy sensors and imaging systems. The size is also compact for integration with the MMICs.

From the current distribution it is observed that at lower frequencies, current is concentrated along the edges of the patch, along the feed line and on the upper portion of the ground. So it can be inferred that the gap, g, between the radiator and the ground is an important parameter for better impedance matching over the wide band. As the frequency increases, it is seen that current spreads towards the upper portion of the patch as shown in Fig 7. At higher frequencies, current slowly spreads and is distributed uniformly in the ring like metal patch.

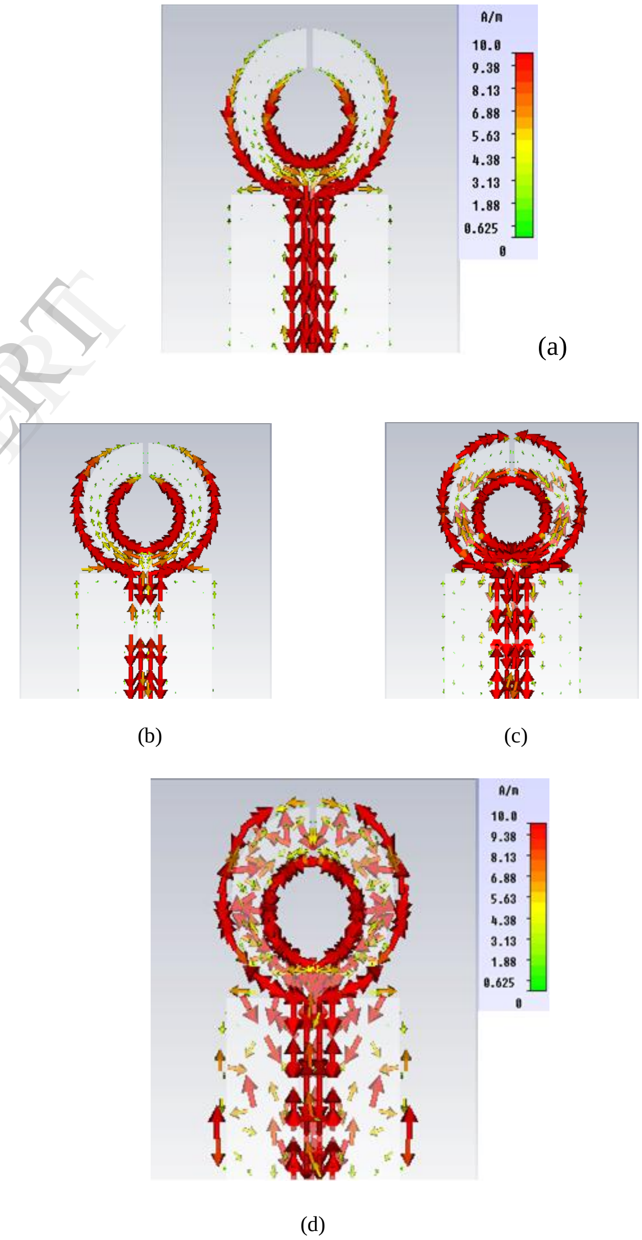
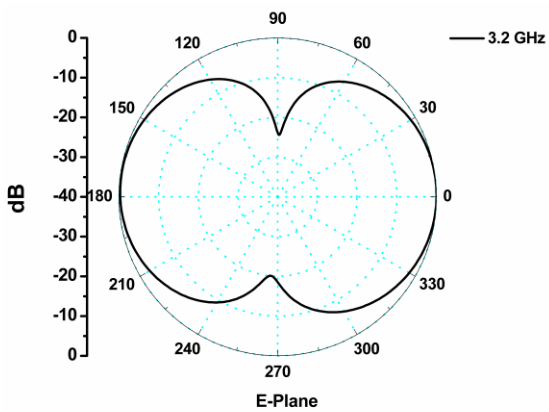
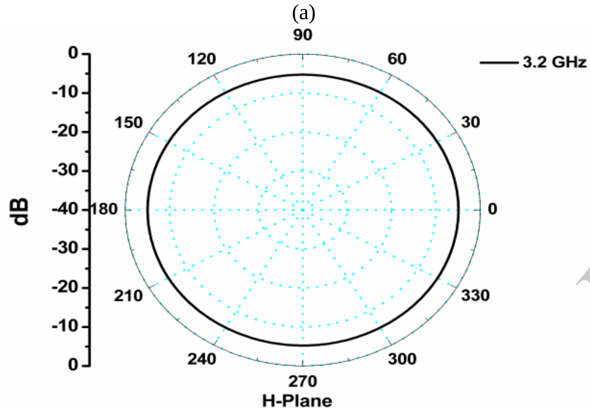


Fig. 7 Current distribution at frequencies (a) 2.8 GHz (b) 5 GHz (c) 20 GHz (d) 40 GHz

Far-field normalized radiation patterns of the proposed antenna at 3.2, 8, 25 and 40 GHz are depicted in Fig. 8. At lower frequencies, radiation characteristics is nearly omnidirectional. But at higher frequencies, undulated radiation pattern is observed by formation of ripples in the pattern. This phenomenon can be attributed to the diversified electric current distribution on the proposed antenna. It also occurs because at higher frequencies, higher order mode propagation occurs. Satisfactory omnidirectional radiation characteristics is observed throughout the operating band.



(a)



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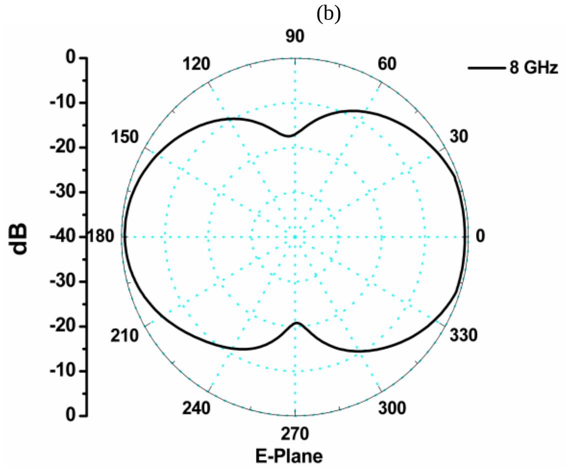

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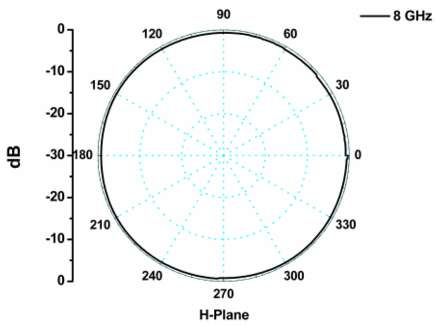

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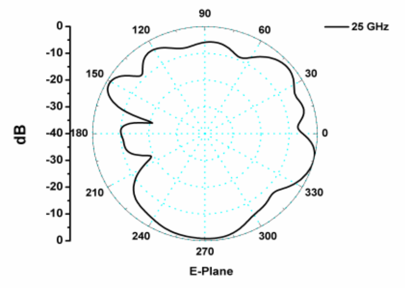

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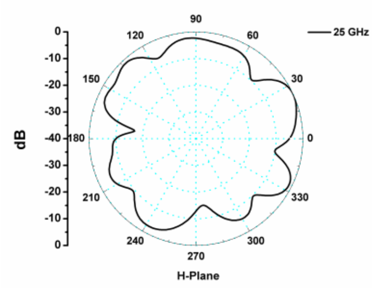

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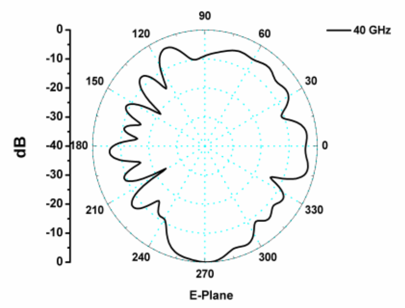
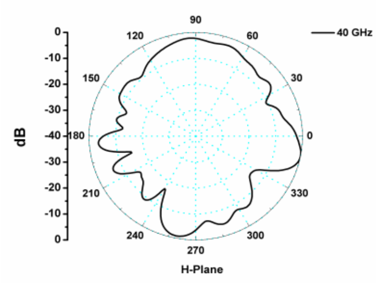


(g)



(h)

Fig. 8 Radiation pattern at frequencies (a),(b) 3.2 GHz (c),(d) 8 GHz (e),(f) 25 GHz (g),(h) 40 GHz

The gain of the antenna varies from 1 dBi to 6.2 dBi. But it gradually decreases at higher frequencies due to dielectric loss of the substrate at those frequencies. The group delay profile lies within 1 ns showing a flat response over the entire band confirming the antenna to be non dispersive in nature. This ensures satisfactory time domain characteristics and distortion less transmission of the antenna

IV. Conclusion

This paper presents a design of Super wide band antenna with an open ring shaped patch. The bandwidth ratio is 14.28:1 that corresponds to percentage bandwidth of 174%. The antenna is of compact size, 30×30 mm^2, such that it is compatible with the various monolithic microwave integrated circuits. The peak gain obtained is 6.2 dBi. The group delay profile shows a flat response over the entire bandwidth. The radiation pattern is stable throughout the entire range satisfying omnidirectional radiation characteristics as desired for this type of communication. The antenna thus meets the characteristics of SWB that is applicable for future high data rate communication and high precision imaging systems.

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