DESIGN OF UWB ANTENNA WITH IMPROVED RADIATION FOR CONVENTIONAL GSM, LTE NETWORK AND SUB 6GHZ SPECTRUM

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ABSTRACT

This paper presents a concept of ultra-wideband Antenna with a very large frequency ratio, which can be suitable for Conventional GSM and LTE network uses a frequency range below 4 GHz range and lower band (Sub 6GHz spectrum) which is the candidate for early deployment of 5G networks globally. The antenna consists of an exciting patch with slotted planar structure, which is designed to achieve ultra-wide bandwidth, enhancement gain and efficiency with enhancement radiation pattern in upper range. The impedance bandwidth, gain, and radiation pattern are improved by the coupling between a metal ground plane which represents a cooperative radiator and radiating source. Based on this approach, the design is validated numerically and experimentally in terms of return loss, radiation efficiency, gain, total scan pattern, and coverage efficiency.

KEYWORDS

Long Term Evolution (LTE), Global System for Mobil communication (GSM), Internet of service (IoT),Ultra-Wideband (UWB)

1. INTRODUCTION

A Conventional GSM and LTE network / sub 6GHz spectrum has been derived to give a wide range of applications including mobile communications, Internet of service (IoT), wireless local area network, industrial, scientific, and medical, virtual reality, smart energy, and smart vehicles. All of those applications will be integrated under the 2G/3G/4G/sub6GHz. In the upcoming technology, 5G will be the backbone technology to lead this service [1]–[4]. Each application may need different antenna characteristics in terms of operation frequencies, directivity, and switchable probability is a critical challenge [5]–[6]. As well as, the integration with the current 2G/3G/4G-based technologies may also be required in a single device. Unfortunately, most traditional multiband antenna techniques did not support a large frequency ratio with well-defined radiation characteristics. Recently, a substantial number of studies have been carried out to

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address the requirements of 4G/5G antennas [7]–[8]. Since, The antennas were designed to serve only the lower bands of 5G (sub-6 GHz) as in [9]–[10]- [14].Some others were designed to achieve lower band (0.8—to 2GHzas in Ikram *et al.* [11]. Besides, Liu *et al.* [12] introduced an antenna operating at sub-6 GHz bands and mm-wave bands based on a combination of meander and L-shaped SIW sections to cover lower bands and eight-slot antennas to cover mm-wave bands. Most of the aforementioned antennas has a total size of antenna often approximates the sum of the two or three used antennas, as well as a complicated structure.

In this paper,avery simple antenna presents ultra-wideband frequency with improved radiation pattern, which covers a wide microwave frequency range, i.e., 2G/3G/4G and sub-6 GHz 5G bands.

2. Analysis of a Semi-Circular Aperture Etched on a Metal Ground Plane

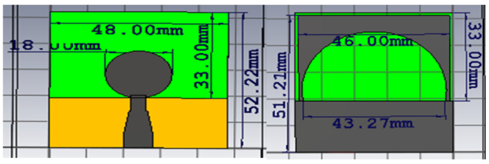
The Theory of Characteristic Modes (TCM) gives modal analysis of a slot inserted in a finite ground plane, giving physical understanding of its radiation behavior and the interaction effects between the slot and the plane[15]. This paper shows that:

a. The modes of slotted planar antennas do not appear as independent modes.
b. The slot resonance fixes the upper frequency of the excited modes in the combined structure formed by the slot and the finite plate.

Moreover, the modal analysis demonstrates that the radiation pattern stability and the radiation bandwidth of the slot antenna are directly related with the size of the finite ground plane. The conclusions reached with the application of TCM can be employed to optimize the geometry and the size of the finite plate in order to prevent the excitation of non-desired modes.

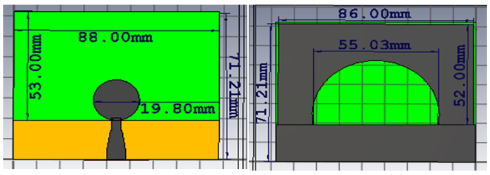
In this section, all the studied cases are designed usingmaterials with thickness$t = 1.57$ mm, dielectric constant $\varepsilon_r = 1$ and tangential loss$\tan\delta = 0.0009$. All simulation results are carried out using the time-domain solver of microwave studio computer simulation technology.

In order to clarify the operating mechanism associated with the semi-circular aperture etched on metal ground plane, the simulated surface current distributions on the radiating patch were carried out in two cases using a substrate of relative dielectric constant 1. Case-(a) used a finite ground plane and case-b used infinite ground plane. Figure.1 illustrates the geometry and dimensions of two cases. Figure.2 to Figure.4 illustrates the current distribution and radiation field of the semi-circular aperture at different frequencies. It is observed that the non-desired higher-order modes are reduced till 10GHz.



Top view Metal ground plane

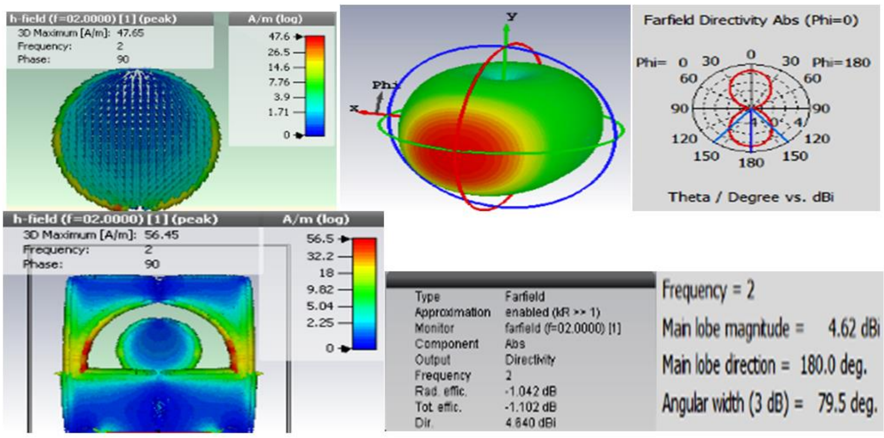
(a) Finite metal ground plane with relative dielectric constant $\varepsilon_r = 1$



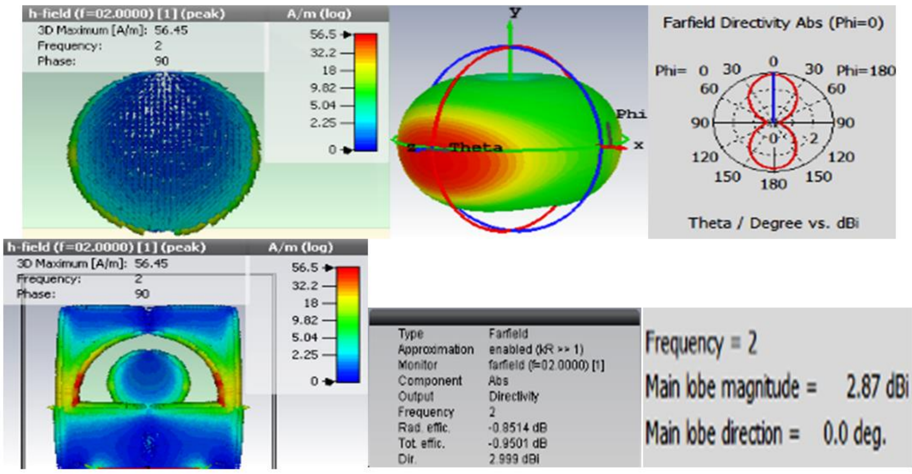
Top view Metal ground plane

(b) Infinite metal ground plane with relative dielectric constant $\varepsilon_r = 1$

Figure 1

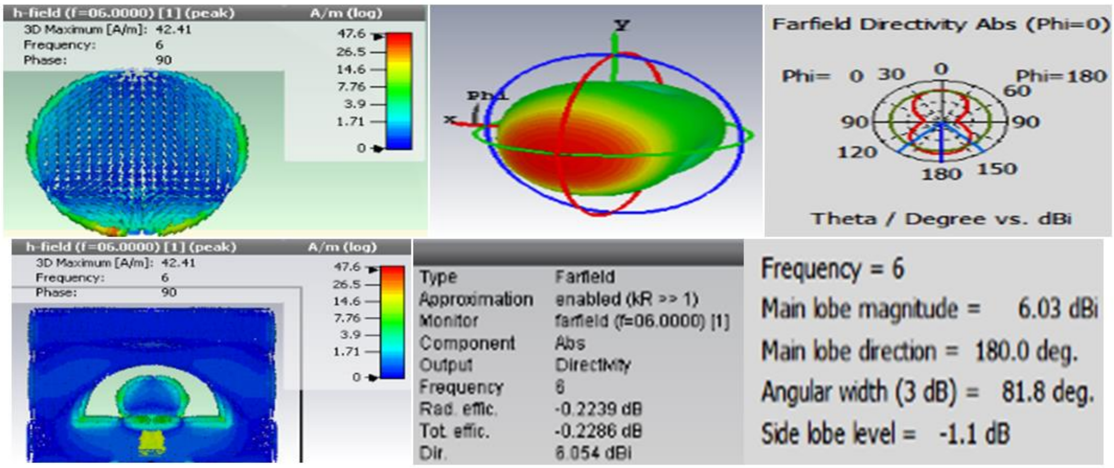


Case-a

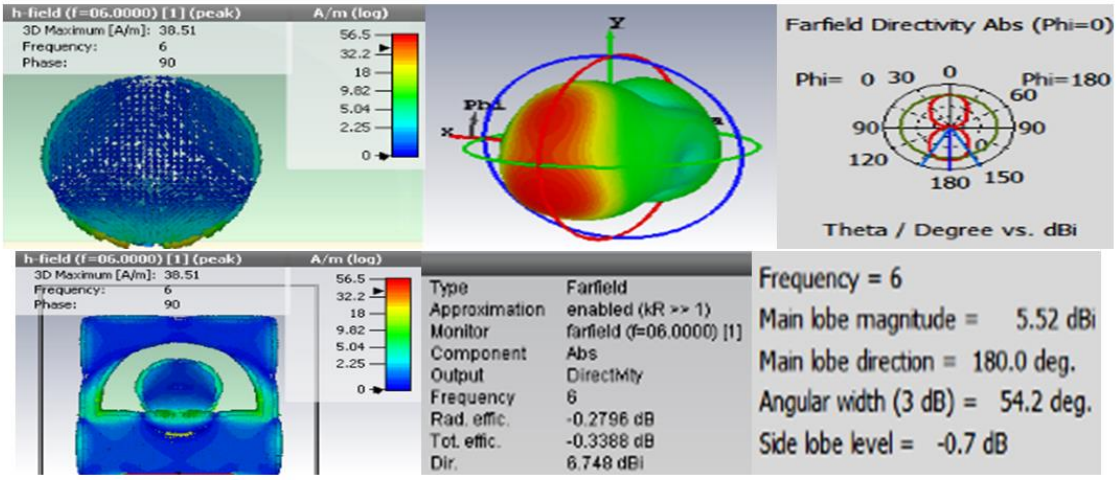


Case-b

Figure 1Simulated current distribution and radiation patterns at 2GHz

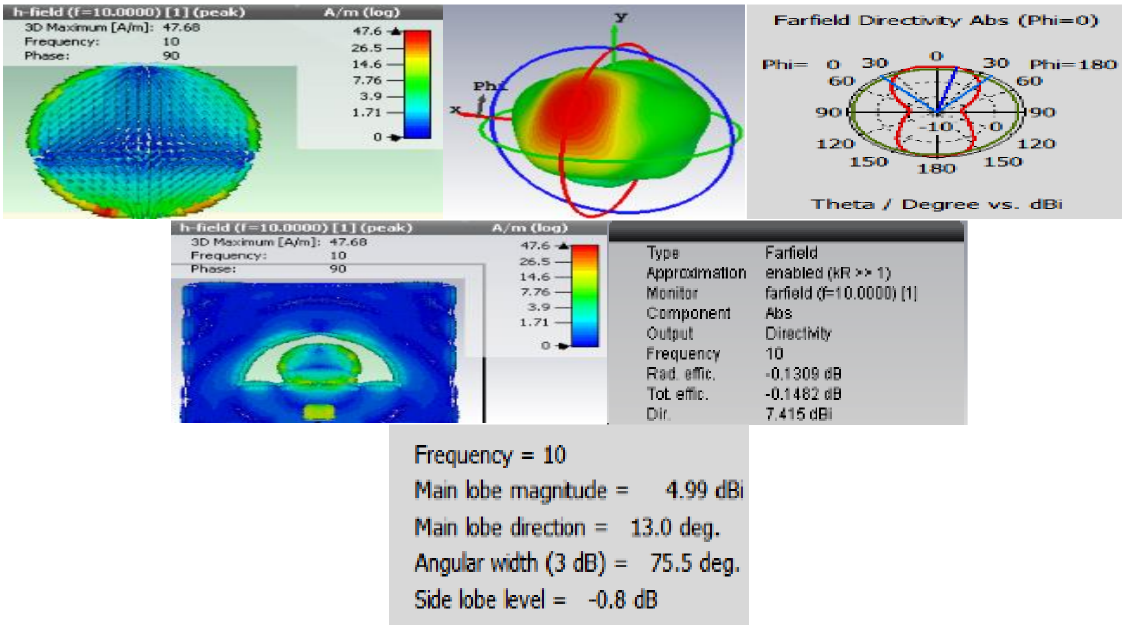


Case-a

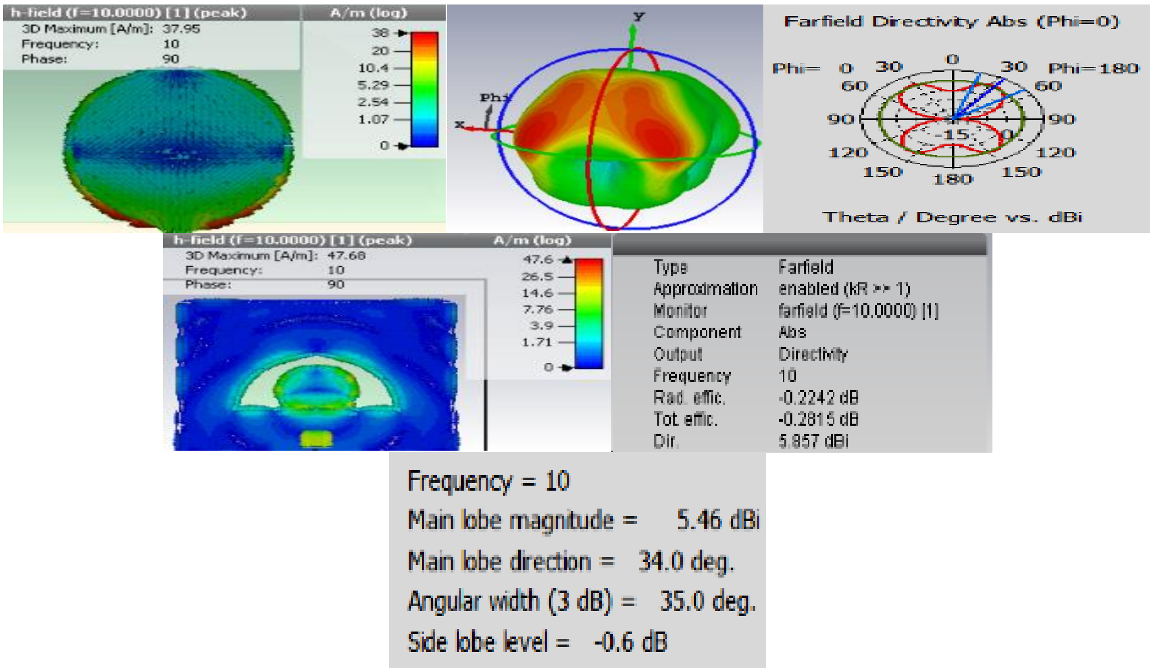


Case-b

Figure 2 Simulated current distribution and radiation patterns at 6GHz

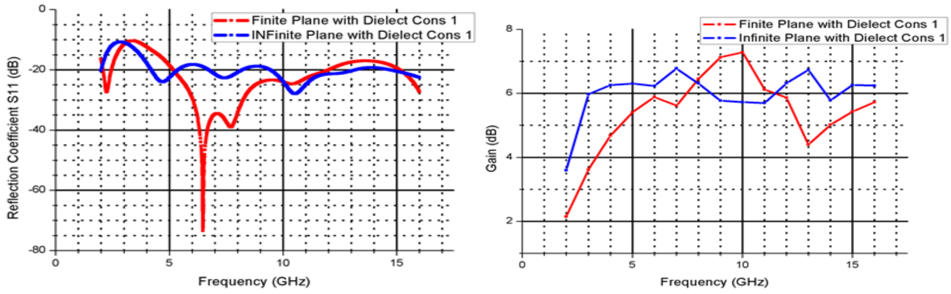


Case-a

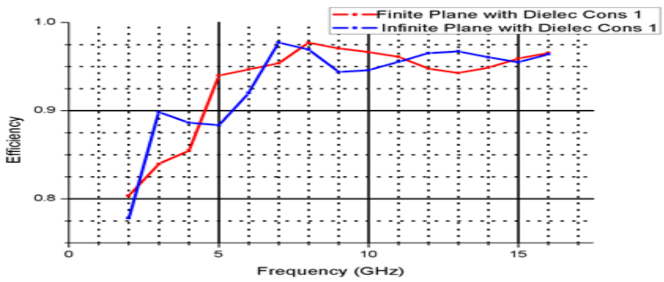


Case-b

Figure 3 Simulated current distribution and radiation patterns at 10GHz



(a) Reflection coefficient S11 (dB)   (b) Gain (dB)



(C) Total efficiency.

Figure 4Simulated parameters of Printed planar UWB antenna

3. Results and Discussion

Based on Babient's principle [13], the density of modes excited decreased with a semi-circle. In the comparison of the radiation fields at different frequencies in Figure.2 to Figure.4, it is observed that the non-desired higher modes appear early in case-b than in case-a, this effect is associated to the metal ground plane reduced size. Science, the number of modes are increased with the size area of metal ground plane. As a result, the degradation can be associated to the excitation of increased number of higher order modes of the ground plane that combine with the first order modes of the aperture. Figure.5 illustrates simulations results, since case-b achieved broaden impedance matching, good efficiency and gain with stable radiation pattern over broadband frequency range. But case-a with reduced size achieved impedance matching bandwidth of starting frequency 1.65GHz up to 16GHz and stable radiation pattern up to 10GHz.

4. Practical Results and Discussions

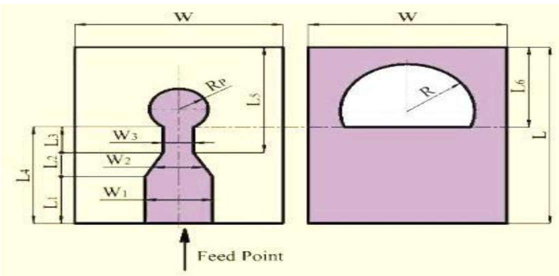


Figure 5 Construction of Proposed Antenna

Proposed antenna is implemented on Rogers RT5880 with thickness t = 1.57 mm, relative dielectric constant $\varepsilon_r = 2.2$and tangential loss tan δ = 0.0009. Figure.6, table.1 and figure.7 illustrate the construction and simulated results.

Table 1Antenna Description

a. R = 18mm

W	**L**	**R**	R_p	**εr**	W_1	W_2
40	**43.2**	**18**	**8.6**	**2.2**	**4.77**	**2.4**
W_3	L_1	L_2	L_3	L_4	L_5	L_6
3.8	**4**	**2.2**	**3**	**9.2**	**37**	**34**

b. R = 22mm

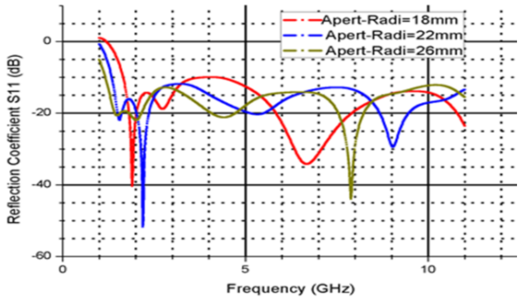
W	**L**	**R**	R_p	**εr**	W_1	W_2
47.5	**56.7**	**22**	**10.5**	**2.2**	**4.77**	**2.4**
W3	**L1**	**L2**	L_3	L_4	L_5	**L6**
3.8	**4**	**7.7**	**3**	**14.7**	**45**	**42**

c. R = 26mm

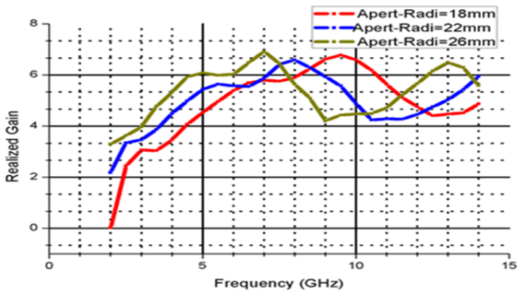
W	**L**	**R**	R_p	**εr**	W_1	W_2
56.5	**62.2**	**26**	**12.25**	**2.2**	**4.77**	**2.2**
W_3	L_1	L_2	L_3	L_4	L_5	L_6
3	**4**	**9.2**	**3**	**16.2**	**49**	**46**

Table 2Simulated Results of Proposed Antenna

Antenna Description	Operating Frequency(GHz)	Max Gain(dB) over Frequency
$R = 18mm, R_p = 8.6mm$	1.66 up to 14	7
$R = 22mm, R_p = 10.5mm$	1.36 up to 14	7
$R = 26mm, R_p = 12.5mm$	1.17 up to 14	7.2



a- Reflection coefficient S11 (dB)



b- Realized Gain (dB)

Figure 6 Simulated Results

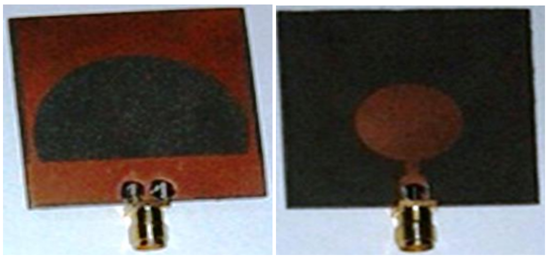


Figure 7 Photograph of UWB Antenna

Figure.8 shows the photograph of proposed antenna with dimensions given in table.1a. Figure.9 andfigure.10illustrates the measured reflection coefficient S11 and radiation pattern respectively. Measured parameters indicate that the proposed antenna achieves good impedance matching with starting frequency 1.7GHz up to 20GHz and better radiation pattern up to 10GHz.

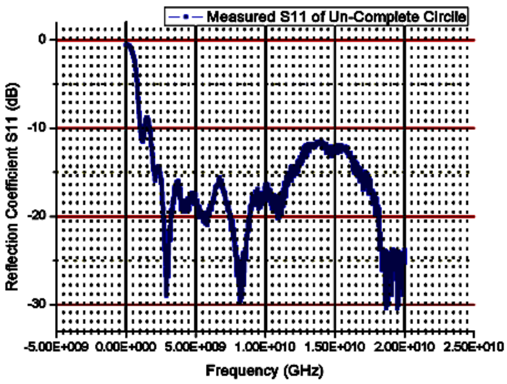
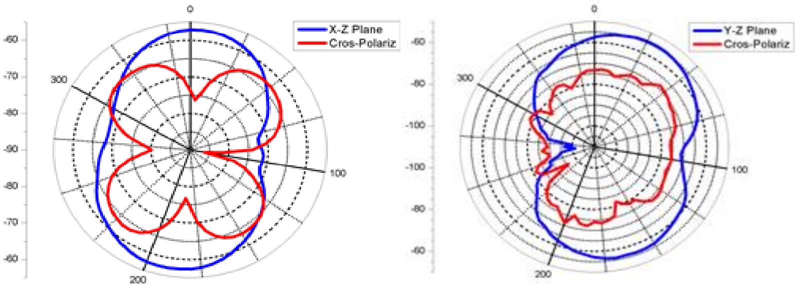
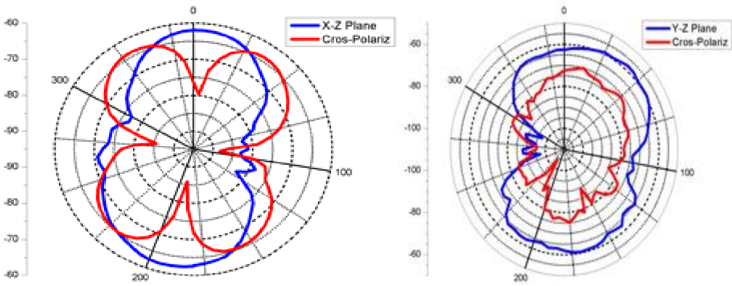


Figure 8 Measured S_{11} of proposed antenna



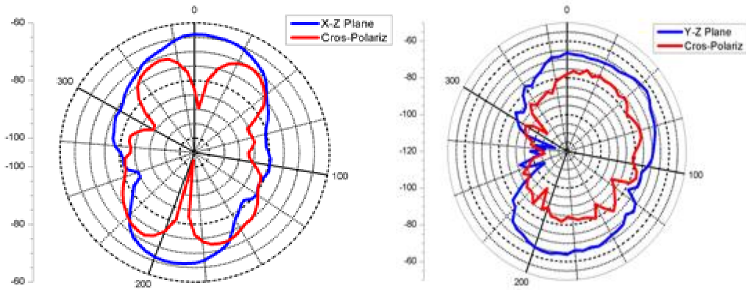
X-Z Plane Y-Z Plane

(a) Radiation Patterns at 6 GH



X-Z Plane Y-Z Plane

(b) Radiation Patterns at 8 GH



X-Z Plane Y-Z Plane

(c) Radiation Patterns at 10 GH

Figure 9Measured Radiation Patterns at 6, 8 and 10 GHz

As can be seen, proposed antenna achievesUWB frequency suitable for wireless communications with good antenna performance as gain, and radiation pattern uniformity over broadband range. For most wireless applications such as compact wireless sensors, it is quite eagerly expected that the antenna has more compact size, broader bandwidth, lower edge-frequency, and more stable radiation patterns to access multiple wireless networks. Proposed antenna achieve reduced size ($0.22x0.24\lambda_o^2$), and UWB impedance bandwidth of 168% (|S11|< -10dB) from 1.7 to 20 GHz, and stable radiation pattern are also obtained at both E – plane and H – plane till 10 GHz with maximum gain equal 7.2 dB.

5. CONCLUSION

In this paper, we introduce a ground cooperative radiating structure into the metal ground plane of microstrip fed line monopole antenna. The proposed antenna introduces a modified ground plane operates as cooperative radiating structure. We present the design, manufacturing, and testing of a modified UWB monopole antenna with improved performance and stable radiation pattern as well as the starting frequency can be achieved by the mutual coupling between a modified ground plane and a circular patch. Both simulated and measured results demonstrate that the proposed antenna achieves good performance. The proposed antenna can be designed to achieve the requirements as light weight, reasonable directivity; uniform radiation pattern in upper range as well as it is suitable for applications in small/large wireless devices and for see through wall and concert application.

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