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Design of Novel Planar Antenna for Wideband Applications

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Abstract: Over the past decades, various wireless networks have been prosperously developed for different applications. Generally, they operate at different frequencies. Due to limited space, it is difficult to install numerous antennas operating at different frequencies in a compact wireless terminal. To solve such problems, many novel planar wideband antennas have been developed. A single planar antenna can be designed, to support wideband applications. In this work, it is proposed to design a novel planar antenna for wideband applications by incorporating Ground Co-operative Radiating Structure (GCRS).The radiating element has a radius of 12.5mm placed on the FR4 (Flame Retardant 4) substrate with CPW (Co-Planar Waveguide) feeding. The proposed antenna radiates from 3.6GHz – 11.6GHz. The resonant frequencies are obtained at, 3.6GHz, 4.3GHz, 6.4GHz, 8.1GHz, 10.6GHz, 11.6GHz. The single antenna can be used for many wireless communication applications. The design and simulation of antenna are done. The antenna parameters such as gain, radiation pattern, return loss and VSWR have been improved. The simulation was done by using HFSS software tool.

Keywords: Planar antenna, Wideband, Ground Co-Operative Radiating Structure (GCRS), Co-Planar Waveguide (CPW), HFSS.

I. INTRODUCTION

The performance of an antenna greatly influences the effectiveness of the wireless devices. The features expected from an antenna are application specific. High data rate applications require an antenna to operate in wideband applications. The desire of having more compact, lightweight, handy equipment made the most optimum choice for an antenna as a planar antenna. The planar antenna is suitable for wideband applications for increasing the performance of the antenna.

In [1], a Hexagonal monopole antenna (HMA) was designed for WLAN/UWB/LTE application by adding Ground Co-operative Radiating Structure for uniformity radiation pattern. In [2], a compact reconfigurable antenna was developed by utilizing PIN diodes to flexibly switch the operating frequencies among five frequency bands covering the upper ultra-wideband of 6.0-10.6 GHz. Recently, we also developed a reconfigurable antenna covering the bands of 2.6-11.0 GHz for cognitive radio applications by using optically controlled switches [3], reconfigurable antennas have satisfactory compact size. However, one shortcoming of them is non-simultaneous operation in different frequency bands. Fixed multiband antennas can overcome such disadvantage. In [4], a compact antenna of fixed dual-bands was developed to simultaneously operate at 950 MHz and 2.45 GHz. It is possible to make an antenna operate in more fixed bands simultaneously by adding more resonating structures [5] [6]. However, due to fixed frequency bands, such antennas typically limit to some of the wireless networks whose operating frequencies just fall in their operating bands. Comparatively, UWB antennas provide a more competitive and simpler method for simultaneously accessing to different wireless networks while occupying small space since they can operate within a very wide frequency band by a single antenna structure. In order to support many wireless services including GSM-1800 (1.711.88 GHz), PCS-1900 (1.93-1.99 GHz), Wireless Local Area Network (WLAN, 2.5 or 5-6 GHz), multi-band GNNS and UWB (3.1-10.6 GHz), a printed elliptical antenna with compact dimensions of 124 × 110 mm2 and an extremely wide operating bandwidth of 1.02-24.1 GHz was demonstrated [7]. Unfortunately, most of UWB antennas exhibit beam-splitting in their upper-frequency bands [7-10]. The beam-splitting effect may result in angular blind communications and lead to severe degradation of communication performance. Therefore, it is desirable to develop compact UWB antennas of stable beam patterns within their full operation bands for multiple wireless network applications.

In this proposed work, a novel planar antenna with improved antenna performance for wideband applications is demonstrated. Here, we design a circular planar antenna by adding ground-cooperative radiating structure (GCRS), which is structured by two additional metal arms etched in the lateral edges of the upper metal ground. Most importantly, our results show that by proper design, the metal ground of the antenna can be exploited to simultaneously reduce the antenna size, broaden impedance bandwidth, and achieve stable beam Patterns, over a wide frequency band. With the aid of the GCRS, the new antenna achieves remarkable size reduction, enhanced impedance bandwidth, Voltage Standing Wave Ratio (VSWR) and quite stable omnidirectional patterns over the entire operating band 3.6 GHz - 11.6 GHz. In addition to that in order to minimize the return loss and improve the gain

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performance, the Co-planar waveguide (CPW) feeding technique has also been proposed. These merits make it qualified as a compact antenna to reduce the number of antennas installed in compact wireless devices for wideband applications.

II. CONFIGURATION OF THE PROPOSED ANTENNA

Fig. 1. Illustrates the geometrical structure of the proposed antenna. The planar antenna is printed on FR4 substrate of thickness 1.6 mm and permittivity 4.4 (tan δ= 0.02, size: 50×50 mm^2).A circular patch is printed on the upper surface of the substrate. The ground plane also printed on the upper surface by using GCRS technique. The big difference from the hexagonal monopole antenna [1] is that the new antenna introduces a GCRS into the ground. In this technique incorporating Ground Co-operative Radiating Structure (GCRS), a supplementary metal structure that is added into the lateral edges of the upper ground of the novel planar antenna and forms two semi-closed metal arms to encompass the primary radiating patch. The circular patch is fed by 50Ω Co-Planar Waveguide (CPW) feeding. In CPW, the signal conductor is present in between two ground conductors, where all the ground conductors are on the top of the dielectric layer. It provides consistent ground performance and good impedance matching for all the resonant frequencies. In the later sections, we will detail the design of novel planar antenna and introduce its functionality and be improving the performance of the antenna.

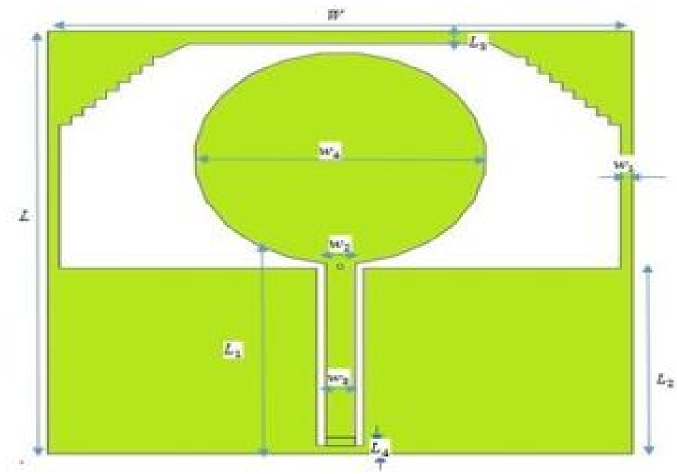

Fig.1. Configuration of the Proposed Antenna

Table I: Dimensions Of Proposed Antenna (Unit: mm)

w	w_1	w_2	w_3	w_4
50	1	0.4	2.5	25
L	L_1	L_2	L_3	L_4
50	21.55	21	1.5	1

Table I shows the dimensions of the proposed antenna. Based on these value novel planar antenna is designed for wideband applications.

Table Ii: Parameters Of Proposed Antenna

Operating frequency	3.6 GHz- 11.6 GHz
Feeding of the antenna	CPW(Coplanar Waveguide)
Substrate material	FR4 (Flame Retardant 4)
Relative permittivity(ε_r)	4.5
A height of substrate(h)	1.6 mm
A radius of the patch	12.5 mm

Table II shows the parameters of proposed antenna. The elementary of the proposed circular patch antenna is designed using the equations from the transmission line model (TEM). The radius of the patch is designed based on the resonant frequency using the following equations (1) and (2)

$$R(a) = \frac{F}{\left\{1+\frac{(2h)}{\pi \varepsilon r F}\left[\ln\left(\frac{\pi F}{2h}\right)+1.7726\right]\right\}^{\frac{1}{2}}} \qquad (1)$$

$$F=\frac{8.791\times 10^{9}}{f_r\sqrt{\varepsilon_r}} \qquad (2)$$

Where,

a- actual radius of the patch
h- Height of the substrate
c- Velocity of light in free space.
ε_r- Dielectric constant of the substrate
f_r- Resonant frequency

Based on the above transmission line equations, the radius of the circular patch is calculated as 12.5mm.

III.DESIGN OF PROPOSED ANTENNA

In proposed work, the novel planar antenna is designed for wideband applications by adding GCRS technique. This method is used to improve the antenna parameters such as radiation pattern, return loss, VSWR, and gain. A circular patch is printed on the upper surface of the substrate. The radiating element has the radius of 12.5mm.The ground plane also printed on the upper surface by using GCRS technique, which is structured by a metal loop extending from the lateral side edges of the metal ground and completely encloses the circular patch. It is to exploit the metal ground for reducing the antenna dimensions, and improve the antenna parameters such as radiation pattern, return loss, antenna gain, VSWR, and bandwidth over a wide frequency band. We find that the metal ground of the planar antenna is finite size. In such case, the resonating and radiation properties of the antenna are physically determined by both the radiating patch and metal ground. To illustrate the effects of the metal ground on the resonating property of the antenna, we first introduce a simple ground cooperative radiating structure (GCRS) into the proposed antenna.

The circular patch is fed by 50Ω Co-Planar Waveguide (CPW) feeding. In CPW, the signal conductor is present in between two ground conductors, where all the ground conductors are on the top of the dielectric layer. It provides good impedance matching for all the resonant frequencies and the main advantages of CPW feeding are dispersion is low, design flexibility is high and it's improve the overall performance of the antenna gain and minimizes the return loss.

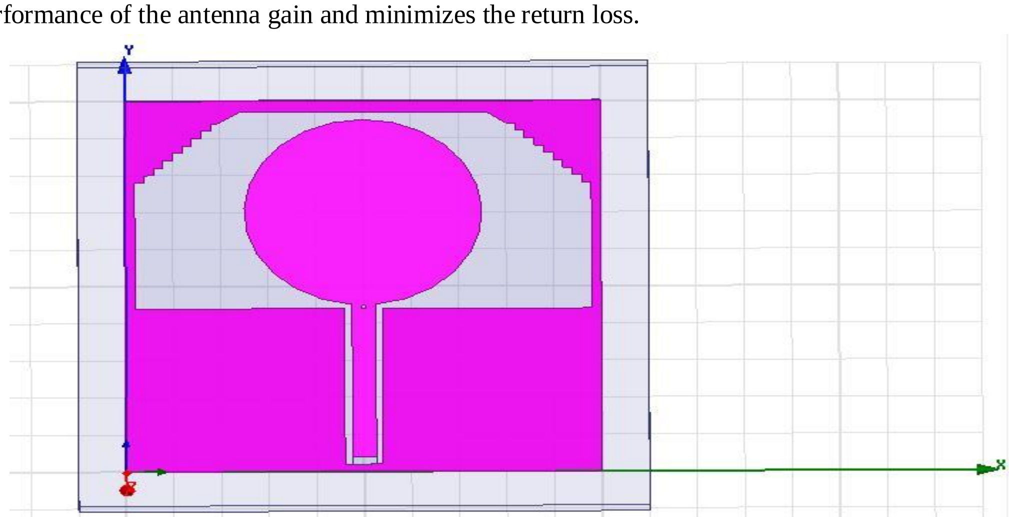

Fig.2. Simulation Design of the Proposed Antenna

The proposed antenna, GCRS can work cooperatively with the inner patch radiator. In the lower frequency band, the GCRS works as a radiator to radiate the electromagnetic waves while in the high-frequency band the inner circular patch does. The lower edge-frequency of the antenna is primarily determined by the loop length of the GCRS, instead of the size of the circular patch. Therefore,

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the antenna size can be reduced by properly decreasing the circular patch size. It achieves Omnidirectional Radiation pattern and also it's reduce the number of antennas installed in compact wireless devices for simultaneous multiple wideband applications.
Next, one slot is introduced into the patch antenna for better impedance matching and more stable omnidirectional patterns. Slot 1 is of 0.4 mm × 0.4 mm, which is cut from the center junction between the defected patch and the CPW-feed line. This slot is for reducing the reflection from the defected circular patch and achieving better gain and impedance matching and good VSWR. The proposed antenna is simulated by using HFSS (High-Frequency Structural Simulator) version 13. Fig.2. shows the simulation design of the proposed antenna.

IV. RESULTS AND DISCUSSIONS

The proposed antenna is simulated using High Frequency Structural Simulator (HFSS) version 13.0. In this design have to simulate various parameters such as return loss, VSWR, gain, bandwidth, radiation pattern at different resonant frequencies. The frequency range is from 3.6 GHz -11.6 GHz.

A. Return Loss

The overall goal of the proposed antenna design is to achieve good return loss below -10dB. The return loss characteristics of the proposed antenna are shown in Fig.3. It has a good impedance matching for all the resonant frequencies. The graph illustrates minimum reflection loss at multiple frequencies such as 3.6 GHz, 4.3 GHz, 6.4 GHz, and 8.1 GHz, 10.6 GHz, 11.6 GHz. The corresponding return loss is obtained as -36dB, -24dB,-48dB, -36dB and -25dB,-33.9dB respectively at these frequencies. It is showing good matching at large bandwidth. The bandwidth of the proposed antenna is 9.2 GHz.

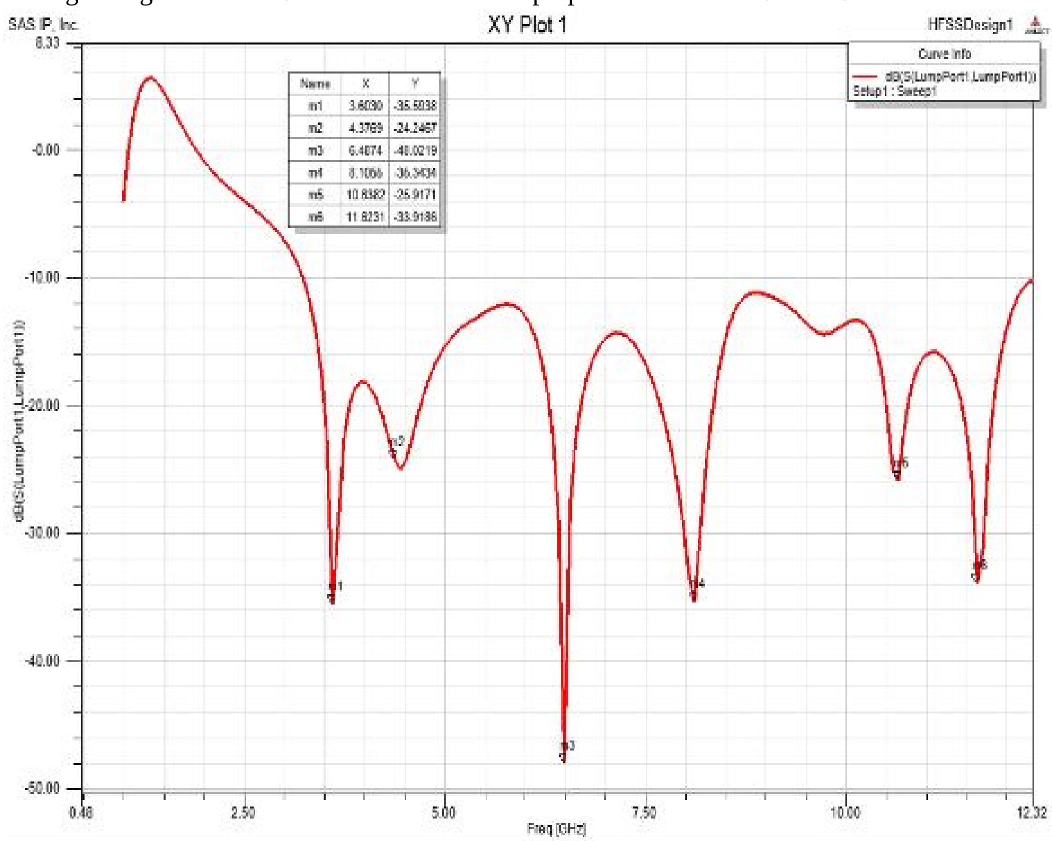

Fig.3. Return Loss of the Proposed Antenna

B. Voltage Standing Wave Ratio (VSWR)

Voltage Standing Wave Ratio (VSWR) is also an important performance parameter that describes the impedance matching between the antenna and transmission line, throughout the entire operating bandwidth. The lower value of the VSWR indicates that the antenna is better matched to the transmission line and that more power is being delivered to the antenna. Fig. 4 shows the VSWR vs. frequency plot of proposed antenna design for wideband applications.

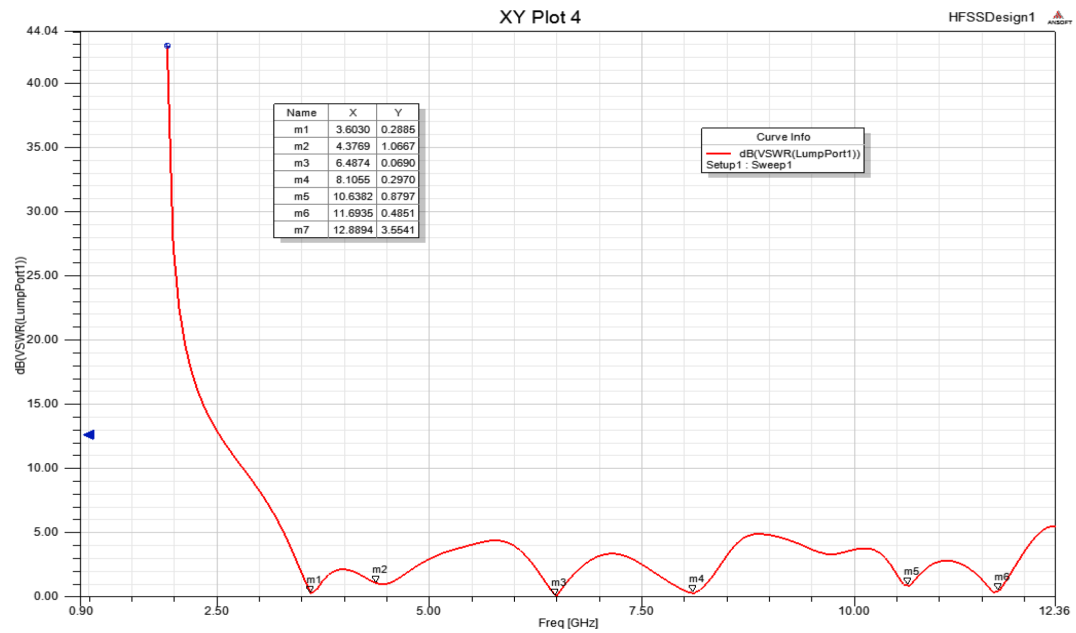

Fig.4. VSWR of the Proposed Antenna

It is observed that the value of the VSWR is less than 2 for the frequency range from 3.6 GHz to 11.6 GHz, which indicates that the power reflected from the antenna is minimum throughout this bandwidth and that the proposed antenna is well matched to the transmission line. The graph illustrates the frequencies such as 3.6 GHz, 4.4 GHz, 6.4 GHz, and 8.1 GHz, 10.6 GHz, 11.6 GHz. The VSWR is obtained as 0.2dB, 1.0dB and 0.06dB, 0.29dB, 0.87dB, 0.48dB respectively at these frequencies.

B. Gain

The gain of the proposed antenna is shown Fig. 5. A gain of the antenna is the overall efficiency of the system. The term antenna gain describes how much power is transmitted in the direction of peak radiation to that of an isotropic source. Here the proposed antenna achieves maximum gain as 9dB.

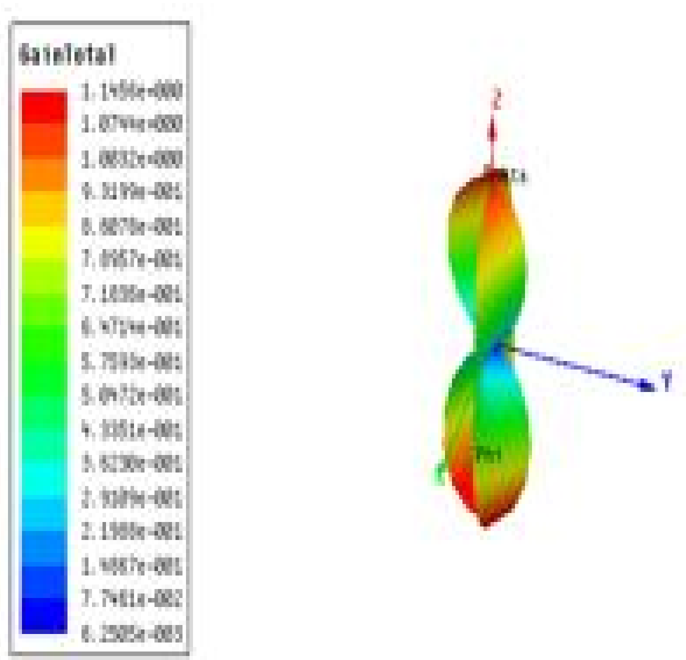

Fig.5. Gain of the Proposed Antenna

C. Radiation Pattern

Fig.6 shows the radiation pattern of the proposed antenna. At 3.6 GHz- 11.6 GHz, the radiation patterns shows omnidirectional characteristics. It can be found that the proposed antenna has much better radiation performance. The proposed antenna, no patterns split into multiple beams at higher frequencies. It also has excellent linear polarization features over the full operating frequency band.

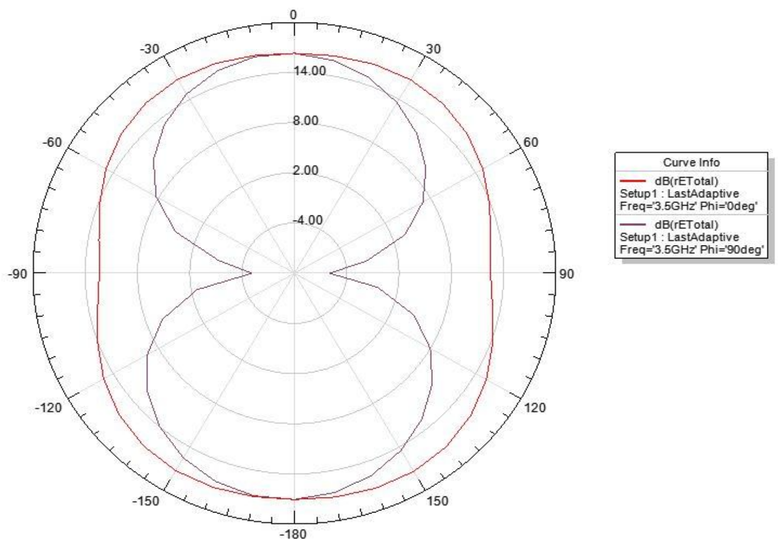

Fig.6. Radiation Pattern of the Proposed Antenna

V. CONCLUSION

In this communication, we exploit a GCRS rather than primary radiators for performance improvement of novel planar wideband antennas to have minimum reflection loss, high gain, and better VSWR, stable Omni-directional radiation patterns, much more compact size, and wide bandwidth. By utilizing the GCRS, a new novel planar antenna based on a CPW-fed circular patch is successfully developed. The simulated results demonstrate that the new antenna achieves excellent performance, with stable omnidirectional patterns, significantly reduced size, a full frequency band of 3.6GHz -11.6GHz. The proposed antenna is suitable for wideband applications. The future work of this project is added Koch boundary for integrating wideband and Ku band for short distance communications.

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