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Original Article

A Very Compact Printed DGS Antenna for Ultra-Wide Band Applications

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Abstract *- This article presents a miniature printed Defected Ground Structure (DGS) antenna with a flawed ground structure for Ultra-Wide Band (UWB) implementations. The ultra-wideband antenna is created by fabricating it on an FR4 dielectric substrate that is 1.6 mm thick, has a dielectric constant (Ɛr) of 4.6, and has a tangential loss (ỏ) of 0.02. The total area of the proposed antenna is about 30 x 28 mm^2, and to improve its bandwidth, a defective ground plane has indeed been integrated into its design. The UWB antenna's total impedance bandwidth is 10 dB, and its operating spectrum runs from 3 to 10 GHz. The antenna has a substantial directivity of about 3.54 dBi over the whole of the requisite operating spectrum in every respect. In order to get an understanding of the design insight of the proposed antenna, the performance of the antenna was studied with the use of Smith charts. In terms of its radiation pattern and its directivity, the antenna has improved radiation properties. The overall performance of the antenna reveals that it has the potential to be a strong contender for usage in settings that need an ultra-wideband. This potential is shown by the fact that the antenna can transmit and receive signals across a broad frequency range.*

Keywords *- UWB, DGS, Circular patch, Radiation pattern, Directivity.*

1. Introduction

Commercial and academic research has been focusing on the technology since 2002 when the FCC authorized the spectrum between 3.1 and 10.6 GHz for use in UWB communications [1].The fact that the spectrum between 3.1 and 10.6 GHz was made available for commercial use triggered a huge increase in demand for short-distance wireless communication systems as well as UWB technologies for wireless gadgets. Radar, remote sensing, and position confirmation are some applications that fall under this category. Maximizing gain while minimizing manufacturing efficiency, providing a broad bandwidth, and keeping a high degree of radiation efficiency should be the primary goals of the design approach for the UWB antenna. These should be carried out while ensuring a high degree of radiation efficiency is maintained throughout the process. When measured against the amount of compactness and compact design given by the recommended antenna design, the standard narrowband solutions simply are not able to compete. Additionally, there has been much interest in the employment of planar UWB antennas as a means for promoting simple wireless access to multimode communication networks. This interest comes as a result of the fact that such an approach has been shown to be rather effective. This article offers a small printed antenna designed for use in UWB applications; however, the ground construction is defective, and the antenna itself is problematic. The antenna has a total dimension of around 30 x 28 mm^2, and to boost the antenna's bandwidth, a defective ground plane has been included in the antenna design. The impedance bandwidth of the projected antenna is 10 dB, and the operational spectrum of the antenna ranges from 3 to 10 GHz. Across the whole of the necessary working band, the antenna has a maximum directivity of around 3.54 dBi at its disposal. Analyses of the antenna's performance using Smith charts were carried out to gain a design perspective of the developed antenna. The radiation qualities of the antennae have been significantly enhanced, both in terms of the pattern of the radiation that it emits and the degree to which it is directed. Based on its overall performance, the antenna has the potential to be an excellent candidate for use in situations that call for the utilization of extreme broadband. The reason for this focus is that a technique of this kind has been shown to have a good deal of success in the past. These antennas are not only very diminutive and lightweight, but their production is also comparatively straightforward. This is a significant benefit to consider. It is possible to create a printed monopole antenna that may be used in electronic devices by printing the antenna on a substrate that has a broad bandwidth and the capability to span UWB frequencies. Because of this, the antenna can cover a more expansive frequency band.

Section 2 includes some reading suggestions that one can find interesting. In the third part of this article, it is mentioned the characterization of the antenna in combination with the results of the simulation. In the next section, which is labeled "Section 4," one will discover an explanation of the results, as well as the radiation properties of the antenna. Section 5, which may be found in the very last part of this report, has a breakdown of the findings.

2. Review of Literature

An application for a monopole antenna in the form of a circular ring that might be used with UWB systems is investigated in detail in this research [4]. The study focuses on the potential uses of such an antenna. According to the research presented in [5–8], it is feasible to generate UWB utilizing monopole antennas that have a range of geometries. These geometries include curved, circular, elliptical, and rectangular configurations. This may be performed via the use of a variety of different approaches. Microstrip patches may be fashioned into a wide range of different forms if one so chooses. Circular patches have a variety of attributes, including acceptable lossy qualities, enhanced gain, and sufficient electric field and magnetic field strength patterns. Circular patches also have a number of other properties. These characteristics may all be found grouped together in circular patches. Circular patches provide a number of advantages, including the flexibility with which they may be created, a maximum bandwidth measured in gigahertz, and the ability to construct electric field and magnetic field intensity patterns that the user selects. Slots, which are structures with poor grounding, may be added to circular patch antennas to promote certain desirable features. This is done in order to improve signal strength. The absence of grounding is the defining characteristic of slots. It is possible that a co-planar circular antenna [9, 10] with a pentagonal aperture might be suitable for use in UWB applications. Researchers have suggested that circular patch antennas benefit from adding a taper [11] and using the slot method [12, 13] to improve their overall performance. Certain variations of these figures were used to produce patchwork patterns and ring patterns [14]. Numerous studies have been conducted on round discs and rectangular monopole antennas because of the simplicity with which they may be manufactured. This is due to the very simple nature of their production. This is owing to the fact that rectangular monopole antennas and circular disc monopole antennas have similar characteristics in terms of their physical makeup. It is possible to construct a band notch characteristic by combining the positioning of two open-ended slots, DRA, and slots in the ground plane with a variation in the angular distance between the slits of a circular patch. This combination may also include a slot in the ground plane. Utilizing a patch that has a circular shape is one way to accomplish this goal. It is common practise to put segments produced as quadratics in both the ground plane and the patch section [18]. This is done so that a CP-printed antenna can create ultra-wideband (UWB) radiation. This is done to give a diet that gradually decreases in intensity. [19] exploring slotting in radiating areas, posing a challenge to ground plane designs, and reducing ground planes [20]. It is proposed that a DGS be used to improve the qualities of the CP antenna [33]. UWB requires a monopole in the form of a fork [22] and a parasitic square patch in the form of an arc [23]. In addition, parasitic 23-patches are used in this process.

3. Characterization of the Antenna

A circular radiating surface and slots in the form of an I are featured on the antenna's ground plane. This adjustment broadens the frequency range that the antenna can receive. This characteristic has no rounded edges on its topmost points [24]. An ultra-wideband circular patch for circular rings, antenna 25 is a kind of circular patch antenna. Circle packing is used in the CPW-fed UWB antenna that was proposed [26]. By building various structures on the ground plane, the total efficiency of the antenna may be enhanced, as shown by the reference number [30].

Though all the presented works provided UWB operation, the overall dimension is comparatively larger for modern-day wireless devices. In this work, we presented a UWB antenna size as small as 18.5 mm x 30 mm. With this low profile, the proposed antenna achieves significant radiation characteristics. This work shows a compact and efficient MCP antenna as a workable solution that can potentially be used in UWB applications. To acquire UWB resonance characteristics, it is important that we design a radiating patch in a circular form with defected ground structure. These two steps must be completed in this order. This will make it possible for the resonance qualities to be brought into being. These two adjustments are made simultaneously in order to avoid any confusion.

4. Proposed Antenna Design and Geometry

Adjusting the particular height or compactness of the antenna patch is the first thing that has to be done in order to fine-tune the patch's width in this procedure. It does the calculations necessary to answer the following mathematical statement:

$$W = \frac{C}{2f_r(\frac{2}{\xi_r+1})} \quad (1)$$

Where,

C = light velocity,

ξ_r = dielectric surface constant,

f_r = required resonance frequency

$$\xi_{reff} = \frac{\xi_r+1}{2} + \frac{\xi_r-1}{2}\sqrt{[1+12\frac{h}{w}]} \quad (2)$$

h = height of the substrate,

ξ_{reff} = effective dielectric constant

w = width of the patch.

$$L_{eff} = \frac{C}{2f_r\sqrt{\xi_{reff}}} \quad (3)$$

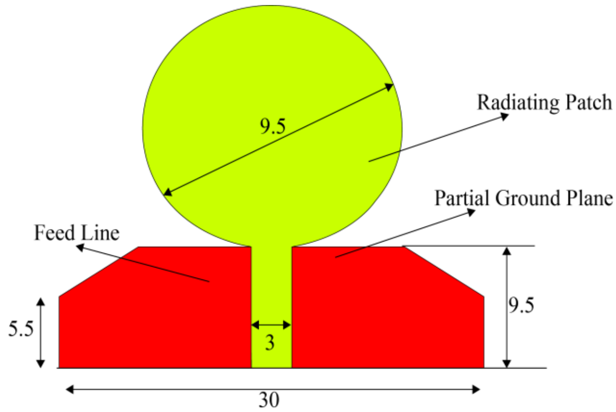

Fig. 1 UWB antenna structure and dimension

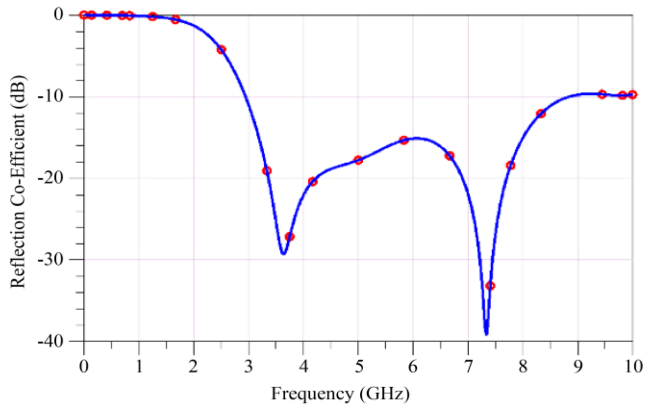

Fig. 2 Reflection Co-Efficient of the proposed antenna

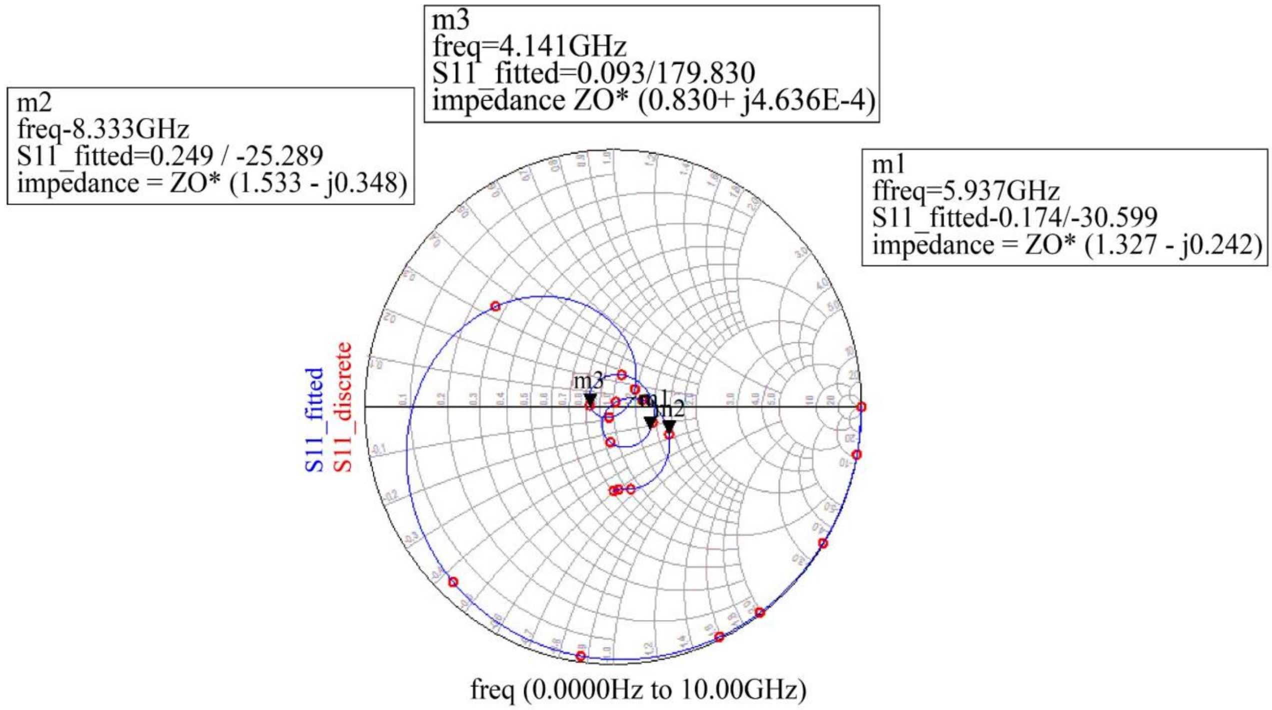

Fig. 3 Smith chart for the complete range of the spectrum

The proposed antenna consists of a circular radiating element of radius 9.5 mm, fed by a rectangular feed line of dimension 9.5 x 3 $mm^{2,}$ as seen in Fig. 1. The proposed antenna is designed on an FR4 substrate with a 1.6 mm thickness. The ground plane has been modified to enhance the overall impedance bandwidth. Initially, the length of the uniform ground plane has been reduced with the size of 30 x 28 mm^2 followed by a triangular cut at the ground plane's two side edges.

As can be seen in Figure 2, the antenna that has been proposed is capable of functioning anywhere on the electromagnetic spectrum between 3.1 and 10.5 GHz. This bandwidth range takes up the whole of the ultra-wideband spectrum that the FCC recommends. For the purpose of investigating the functioning of the proposed UWB antenna, a Smith chart, an example of which is shown in Figure 3, is used. The newly constructed antenna is capable of covering the whole spectrum while yet retaining a VSWR of 2:1, which indicates that only a small amount of power is returned to the transmitting end of the antenna.

The evolution of the antenna's design, which can be seen in Figure 4, can be observed in this section. In the beginning, the ground plane and its associated reflection coefficient, seen in Figure 5, completely cover the reverse side of the substrate. This can be seen in the figure.

An antenna with a uniform ground plane has been found not to contain anything capable of resonating inside the band of operation that is required. This was a discovery made by accident.

- When the area of the uniform ground plane is decreased to 30 x 9.5 mm^2, the antenna can demonstrate broadband functioning, which spans from 3 to 7.5 GHz and is more than the 10 dB reflection coefficient, as seen in Figure 5. The bandwidth has been increased even further by creating a slot in the form of a triangle at each of the two corners. As a result, ultra-wideband operation has been achieved from 3 to 10 GHz along the scale of 10dB.

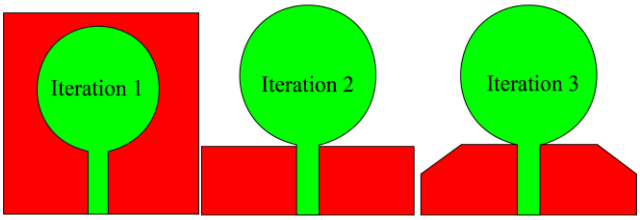

Fig. 4 Design evolution of proposed UWB antenna

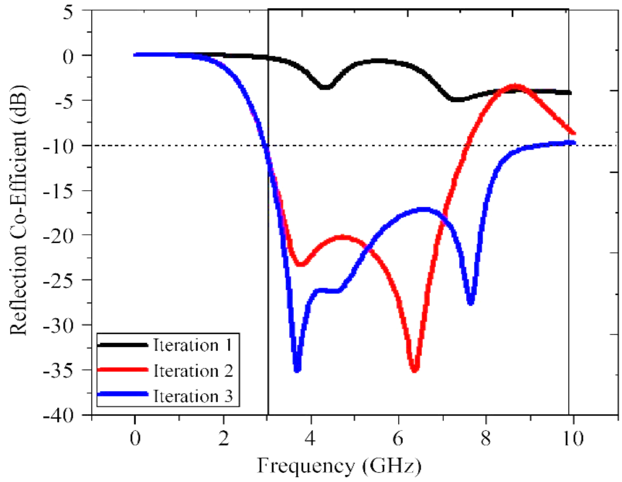

Fig. 5 Frequency response of the antenna during design evolution

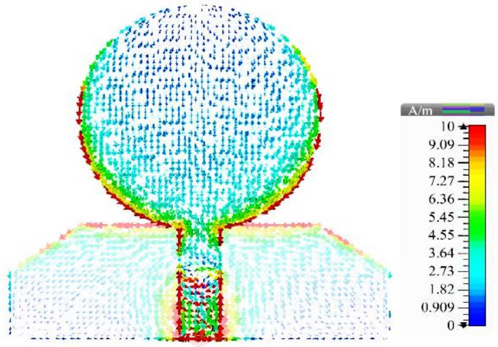

Fig. 6 Surface current distribution of the proposed antenna

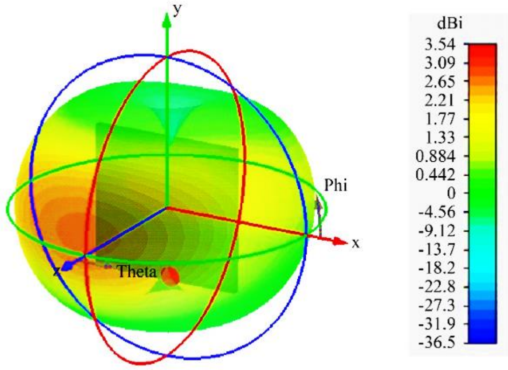

Fig. 7 3D radiation pattern of the proposed antenna at 5 GHz

- The distribution of the ground current for the antenna that was developed and is running at a frequency of 5 GHz may be observed in Fig. 6. It has been determined that the highest amount of current is travelling along the perimeter of the circular radiating patch, while the least amount of current can be found in the centre of the radiating element. This discovery was made possible by the fact that the circular radiating patch is spherical. The pattern mechanism of the recommended antenna is shown in Figure 7, which shows how it operates at 5 GHz. The antenna has been shown to radiate in a pattern similar to that of a dipole, and it also has a diversity of 3.54 dBi; as a result of these qualities, the antenna that has been proposed is suitable for use in applications that use ultra-wideband frequencies.

Table 1 provides a visual representation of a comparison between the MCP antenna and other models with regard to the overall size of the antenna, s-parameters, operating spectrum, realized gain and bandwidth. In earlier models that were proposed, the partial ground plane was employed, but there were no slots in it [5–7, 14, 20]. It is possible to increase the bandwidths by using radiating patches that are circular, tapered, edge-curved, or elliptical in form and that do not include slots.

The study described in [4] employed a slot in radiating element with a modified ground plane to boost the overall spectrum of the recommended antenna. In circumstances where bandwidth has to be increased, the previously outlined models function quite well.

The proposed DGS-based circular patch antenna provides better performance in terms of return loss, bandwidth and gain, thereby proving that the planned antenna possibly will be a viable entrant for 5G applications.

Table 1. Performance comparison of the ultra-wideband antenna with the literature

Ref. no.	Antenna size (mm^2)	Reflection coefficient (S11) (dB)	Frequency Range	Bandwidth (GHz)	Gain (dBi)
[4]	350 x 240	10	3.1 – 12.3	9.2	4.2
[5]	50 x 42	10	2.69 – 10.16	7.47	8
[6]	30 x 30	10	4 – 10	6	5
[7]	70.45 x 46	10	3.1 – 10.6	7.5	-2.36
[11]	22 x 24	10	3 – 11.2	8.2	5.4
[14]	50 x 42	10	2.78 – 9.78	7	NA
[20]	44 x 46	10	2.83 – 13.7	10.87	2-5
[22]	42 x 24	10	2.9 – 12.72	9.82	2-5
[29]	38 x 48	10	2.33 – 14.3	11.97	8.2
Proposed design (in this work)	30 x 28	10	3.1 – 10.5	7.6	7.56

5. Conclusion

A thin and efficient ultra-wideband antenna based on simple and small DGS has been thoroughly researched and found to be effective. The antenna has the capability of operating in the spectrum from 3 to 10 GHz across the impedance bandwidth of -10 dB. It has been determined that the efficacy of the antenna has been studied by analyzing the development of its design and verifying its respective reflection coefficient. The antenna has a very tiny size, measuring around 30 mm^3 in length, 28 mm^3 in width, and 1.6 mm^3 in-depth, and it has adequate performance. Because the antenna emits radiation in a way similar to a dipole over its whole spectrum of operation, we are able to comprehend how the suggested antenna works. In addition, the antenna achieves a peak diversity of approximately 3.54 dBi in the needed band of operation. Consequently, the antenna that was presented in this study has the potential to be an excellent contender for applications using ultra-wide bands.

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