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Miniaturized Dielectric Resonator Antenna with Broadside Radiations for Ultra-Wideband Applications

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Abstract

This work carries a novel miniaturized Dielectric Resonator Antenna (DRA) that has radiations in the broadside region. The antenna was designed and simulated using Advanced Design System (ADS) software. The antenna proposed consists of a solid 'A' shaped dielectric resonator mounted on the edge of the ground plane to reduce the overall volume and excited by using a microstrip feed line. An air gap is introduced between the resonator and the ground plane inorder to improve the bandwidth. This antenna showed a high efficiency & gain over the proposed radiating frequency. Experimental results show that the antenna radiates at a frequency of 8.9 GHz with a return loss of -19.93 dB. This antenna can also be used alongside with portable wireless devices.

Keywords

Advanced Design System, A-Shaped Dielectric Resonator Antenna, Broadside Region, Microstrip feed line, Ultra Wideband.

1. Introduction

Significant growth in wireless communication market & consumer demands demonstrate the need for more reliable, power efficient & integrated wireless systems. Compact size, light weight, low profile, reliability & low cost are now quite important challenges for a system designer to accomplish in the design & performance of every wireless mobile component. Recently, a remarkable interest is growing towards Ultra Wideband (UWB) system design & implementation in both academic research and industrial applications.An important part of the UWB system, the antenna has received greater attention and significant research. The above said things along with UWB characteristics can be met only by using DRA.

Dielectric Antennas have proved themselves to be ideal candidates for several antenna applications by offering several advantages including simplicity, high bandwidth [1]. DRA's are available in various classical shapes such as rectangular, cylindrical, conical, spherical & hemispherical geometries [2 – 6]. This paper deals with a special type of DRA mounted on the ground plane. The paper is organized as follows. Section II deals with the literature works related to the proposed system. The proposed system is discussed in section III. Section IV contains results and relevant discussion. Finally section V holds the conclusion.

2. Related Works

DRA can easily be varied by choosing the dielectric constant of the material resonating & its dimensions [7, 8]. The impedance tuning can be performed using coupling methods like inductive coupling & capacitive coupling [9], other methods like using a photonic band gap [10]. Even though large impedance bandwidth could be obtained by these methods, they are rather complicated. Coupling between the resonator & the feeding line affects the resonating frequency of a DRA. So, different feeding lines like T-strip feed DRA, L-probe feed DRA & vertical strip feed DRA [11-13] have been proposed. The selection of the feed and its location plays a significant role in determining the input and its location plays a significant role in determining the input impedance and radiation characteristics of the DRA's.

Since the antenna size usually imposes limitation on the overall size of the portable wireless systems. Several methods have been applied for antenna size reduction, all at the expense of lower antenna gain and bandwidth. This is due to the fact that the

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antenna is used to transform a bounded wave into a radiated wave. Ofcourse, this transformation suffers in efficiency when the antenna is much smaller than the design wavelength. Although the loss in signal level can often be corrected by amplification, the same is not true of the loss in bandwidth [14].

3. Design Procedure for Miniaturized DRA

A Dielectric Resonator Antenna (DRA) consists of a dielectric layer and a conducting layer. This conducting layer is formed on the dielectric surface layer. For transferring the signal between the dielectric layer and the transmission line an electrical contact is formed on the surface. The proposed antenna radiates in the ultra wideband region. UWB is a radio technology that can be used at very low energy levels for short-range, high-bandwidth communications by using a large portion of the radio spectrum. UWB antennas can legally operate in the range from 3.1 GHz to 10.6 GHz.Fig 1 shows the basic configuration of a DRA along with its feed line and ground plane.

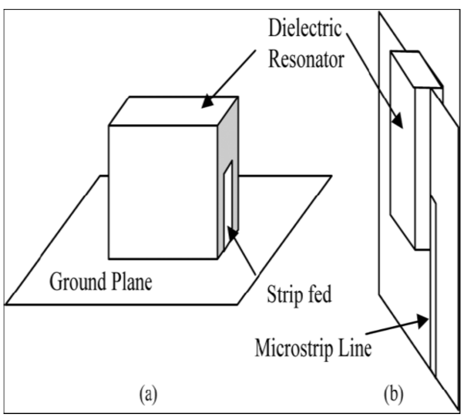

Figure 1: (a) DRA overall view (b) DRA cross sectional view

The proposed novel miniaturized DRA has geometry as shown in fig 2. It's side and isometric views are shown in fig 2 (a) & (b) respectively. The antenna has two tunnels digged on it. Mounting the antenna in this way reduces the overall volume of the antenna as compared to the conventional ones. Along with this inorder to reduce the size further two well-known techniques are used. The most popular technique in reducing the size of a printed antenna is to use a high dielectric constant (ξ_r) material for its substrate. In doing so, the guided wavelength underneath the patch is reduced and hence the resonating patch size is also reduced. To reduce the size further, slots can be introduced onto the resonating patch. In doing so, the current on the patch or the field underneath the patch will resonate from one edge of the patch and take longer path around the slots to reach the opposite edge. Depending on the length of the slots, a 10% to 20% size reduction can be achieved.

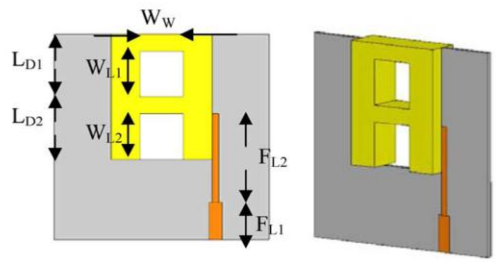

Figure 2: Proposed DRA's (a) side view (b) Isometric view

The proposed DR antenna is designed and developed purely in Advanced Design Systems (ADS) environment. It is built by using the Rogers RO 3010 substrate with a finite ground plane. This substrate possesses good thermal stability & excellent electrical and mechanical properties. The thickness of the substrate is 0.9 mm with a specific relative dielectric constant 'ε_r' of 10.2 and the substrate area is about 30*30 sq. mm. Ground plane is located on the bottom side of the substrate with shorting plates between them. A loss tangent of 0.001 is included for the design of the antenna so as to ensure that there is minimum loss. Fig 2 shows the multilayer PIFA designed in ADS.

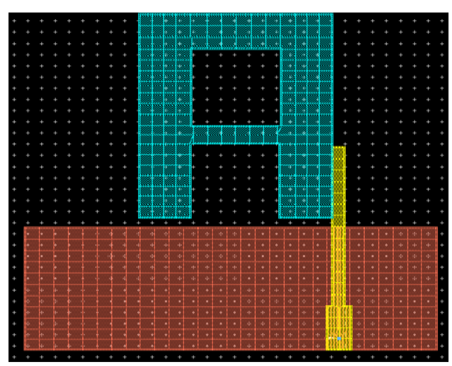

Figure 3: Proposed DRA designed in ADS

The 'A' shaped antenna designed in ADS is shown in fig 3. There is an air gap introduced in the structure purposefully inorder to improve the bandwidth. It is also used for one more purpose which is to strengthen the electric field at the opposite side of the feed probe and provides some balance between both the sides. The ground plane is printed on the substrate below the DRA. The ground plane size is about 11*30 sq.mm and the microstrip feed line ends with the 50 Ω line. The width of the proposed DRA is 15 mm and its length is about 19 mm. the gap between the resonator and the ground plane is about 2.5 mm. If the gap increases, then the operating frequency will also increases but gain gets decreased. Other specifications of the DRA are W_W = 6 mm, W_{L1} = W_{L2} = 6.3 mm, L_{D1} = L_{D2} = 8.3 mm, F_{L1} = 4.4 mm & F_{L2} = 1.3 mm. The 3D view of the antenna is shown in fig 4.

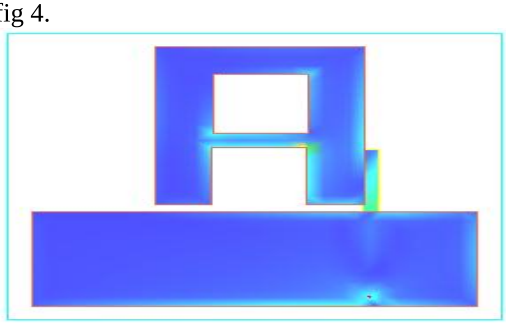

Figure 4: 3D view of the proposed DRA designed in ADS

4. Simulation Results and Discussions

The operating frequency of the proposed DRA can be clearly seen from the return loss plot i.e., $|S_{11}|$ shown in fig 5. The operating frequency of the antenna at which it will operate is shown as a dip at 8.9 GHz with a return loss of -19.93 dB.

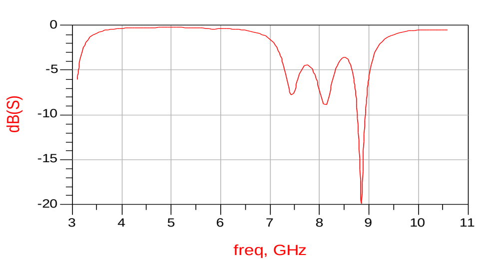

Figure 5: Return Loss Plot of the proposed DRA designed in ADS

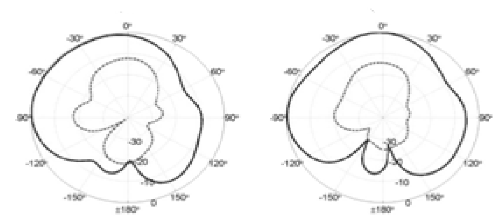

Figure 6: E-plane cut radiation pattern of the A-shaped DRA designed in ADS (a) without gap (b) with gap between the resonator & ground plane

This frequency falls under the ultra-wideband range which is suitable for portable wireless devices. The antenna proposed does not require any kind of adhesive to stick it on to the dielectric substrate. But the planar ones are needed to be glued over the substrate. Most of the dielectric resonator antennas have broadside radiation patterns that are excited by probes that tend to have broadside radiation patterns that are deformed due to the existence of the higher order modes. The pattern will be deformed either at the middle (or) at the end of the frequency band.

The fig 6 (a) & (b) shows the E-plane cut radiation pattern of the proposed DRA at 9GHz frequency with & without gap between the ground plane & the resonator respectively. The E-plane pattern shows a tilt due to the presence of higher order modes. The gap between the ground plane and the resonator is optimized inorder to get good impedance matching. The antenna proposed showed significant gain & directivity of 0.631 dB and 5.762 dB respectively. It can be seen from the following fig. 7.

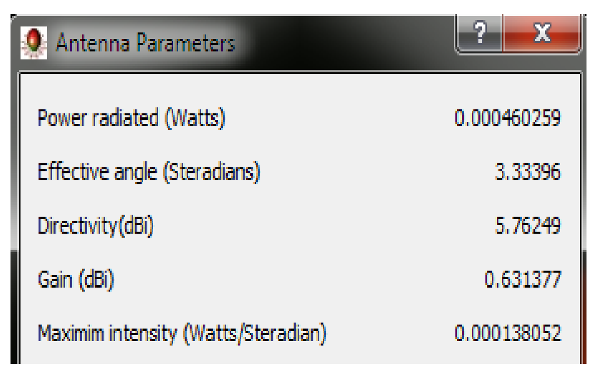

Figure 7: Directivity & Gain of the proposed A-shaped DRA designed in ADS

5. Conclusion

In the present paper, a miniaturized Dielectric Resonator Antenna (DRA) that effectively supports ultra wideband operation was proposed. The antenna proposed operates at a frequency of 8.9 GHz. The volume of the antenna structure is smaller than the conventional DRA over a ground plane. The present design of A-shaped DR overcomes the problem of deformed E-plane radiation patterns and it can be seen clearly from the experimental study. The proposed A-shaped DRA has very high antenna efficiency with stable gain over the frequency band of operation. The bandwidth of the antenna is about 300 MHz. This antenna is an effective option for wireless devices operating under UWB. The parametric study also showed that the proposed antenna has excellent characteristic features that make it a good technical option for sensor applications.

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