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Broadband CPW-Fed U-Shaped Dielectric Resonator Antenna for Wireless and WiMAX/WLAN Applications

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Abstract: In this article, a new U-shaped dielectric resonator antenna (DRA) for broadband applications is proposed. The antenna consists of a modified stepped CPW trimmed to excite the U-shaped dielectric resonator with a relative dielectric constant of 10.2. A parasitic strip along the other side of the DRA is joined to the coplanar waveguide structure acts as tuning element for the antenna frequency band. The proposed antenna is designed using the FR4 substrate of 4.6 relative dielectric constant and 1.6 mm thickness. The antenna is designed, analyzed, and optimized using a full-wave electromagnetic simulator. The results reveal that the proposed DRA has an impedance bandwidth for VSWR<2 from (3.22-5.92) GHz with 59 % bandwidth efficiency. The antenna operating band covers the IEEE 802.11 and many bands of wireless systems like C-band, 5.2, 5.5 & 5.8 GHz-WLAN and WiMAX. The antenna provides a stable quasi-omnidirectional radiation pattern in the H plane and bidirectional radiation pattern in the E plane with a gain ranging from (2.5- 4.6) dB across the operating bandwidth. The proposed antenna could be also used for lower European UWB frequency band (3.4-5.0) GHz applications and for medical microwave imaging purposes. The overall dimension of the antenna is 26mm×32mm×1.6mm and the thickness of the dielectric resonator is only 8.12 mm; so, the antenna can be categorized as a compact size and low profile antenna.

Keywords: Broadband applications, Dielectric resonator antenna, Low profile antenna, CPW feed

Introduction

The large bandwidths and high capacity are the important parameters in modern communication requirements. The researchers have been focusing on using a resonators with minimum radiation loss in the design and implementation of modern antennas. Microstrip is one of the most famous types of antennas used in the modern communications. The properties of microstrip antennas in terms of ease of design and manufacturing as well as cost have made it the most widely used and preferred by designers and researchers in the field of wireless communications. In general, dielectric resonators (DRs) works at microwave and millimeter wave bands. As metal surfaces become more lossy reflectors at millimeter wavelengths, so the dielectric resonators are used at these frequencies. When a DR is not totally surrounded by a conductive boundary, it can behaves as radiators, and so it becomes an antenna.

In the last two decades, many research topics related to the design and implementation of dielectric resonator antennas (DRAs) have been published. Many designs and implementations of the DRAs can be found in literature. Some of those will be reviewed to highlight the important features of the DRAs design.

(Sheng-M. D., Tsung-W. C., Hsiao-H. K., 2001) presents an open-ended coplanar waveguide (CPW) fed rectangular DRA with a high dielectric constant. The input impedance of the CPW-fed DRA can be tuned by changing the distance from the open-ended slot center to the center of the dielectric resonator.

(Rao Q., Denidni T. A., 2005) demonstrate experimental technique for enhancing impedance matching of an aperture coupled CPW fed DRA array. He was employ a CPW feed line into a coupled slot. Good impedance matching simply achieved by tuning the location of the LPDRAs on the coupled slot.

(Rezaei P., Hakkak M., Forooraghi K., 2006) use a configuration consist of two rectangular dielectric sections separated by a metal plate to stimulate two contiguous resonant frequencies. Exploiting the two-segment thin DRA and changing its aspect ratio, more than 76.8% bandwidth efficiency at (3.32–7.46) GHz frequency band has been achieved.

(Tze-H. C., Jean-F. K., 2007) propose a broadband DRA comprises of a DR coated with metal on three sides and placed on a ground plane. A terminating slots with coplanar waveguide (CPW) is used as a feeder to the designed antenna. The obtained results show a wide bandwidth over which the pattern on the horizontal plane is quasi omnidirectional and it can be used for WLAN 802.11a applications.

(Jungsuek O., Taejong B., Donghoon S., Jinkoo R., Sangwook N., 2007) presents a coplanar waveguide fed DRA above patch antenna operate at 60 GHz using μ-machining technology. A dielectric post was used to support the patch in the air and the DRA is fixed above the patch. The realized antenna demonstrates wideband features of 17.5 GHz with a fractional bandwidth of 29.2%. The measured antenna gain found at 60 GHz was about 3.6 dBi.

(Aldo P., Apisak I., 2010) offerings a historical evaluation of the accomplished studies on DRAs over the last three decades. The studies accomplishments are emphasized and the state of the art of DRA technology is revised. The miniaturization, wideband, low profiles, and high gain were considered as an important features of DRAs.

(Joshua M. P., Satish K. S., 2012) propose an aperture-coupled right hand circular polarization DRA working in Ku-band that was excite through a bow-tie cross-slots driven by single feeding system. The realized DRA displayed operation centered at 12GHz, with adequate radiation patterns. This DRA can be used in Ku-band satellite communication applications.

(Mohsen K., Mohamad K. A., Ahmed A. K, Shadi D., 2013) presents a P-shaped dielectric DRA for wideband wireless application. Wideband impedance bandwidth was achieved and the antenna covers the C-band, 5.2, 5.5 & 5.8 GHz WLAN and WiMAX wireless communication applications. The dielectric resonator thickness is 5.12 mm that has been considered as a low profile antenna.

(Roslan S. F., Kamarudin M. R., Khalily M., Jamaluddin M. H., 2015) introduce a CPW rectangular DRA with metallic strip operating at 2.6 GHz for long term evolution (LTE) mobile device. The proposed antenna operate with two bands of 67 % bandwidth efficiency (1.74 - 3.47 GHz) and 66 % bandwidth efficiency (1.83–3.54 GHz) respectively. The antenna has a cause-omnidirectional radiation pattern and it provides gain of 3.12dBi.

(Aftab A. K., Rizwan K., Sajid A., Jamal N., Owais, 2016) present a two port multiple input multiple output (MIMO) antenna system using DRA. The antenna is operating at 3.6 GHz and covers WiMAX band from 3.4 to 3.7 GHz. Two symmetric feed lines excite two different TE modes at 3.6 GHz with high isolation was achieved and compared with other DRAs in literature. A gain of 5.84 dBi for port one and 5.87 dBi for port two has been achieved, respectively.

(Massinissa B., Salih A., Idris M., Boualem H., Farouk C., Youcef B. C., 2016) introduce a reconfigurable cylindrical DRA fed by switching network and proposed to use for wireless applications. The antenna operating bands are (3.77-3.81) GHz and (5.38-5.6) GHz that covers the WiMAX band and the WLAN. The radiation pattern of the designed antennas is omnidirectional at E-plane and unidirectional at H-plane for the designed frequency band.

(Messaoudene I, Denidni T. A., Benghalia A., 2016) designed, and fabricate a DRA that has a U-shaped and fed by microstrip feeding system. The antenna operates at (5.45-10.8) GHz. A modified ground plane was used to improve the impedance bandwidth. A second modification have been achieved by introducing a microstrp patch through the DRA. The designed antenna shows an improved bandwidth that attained an operative band from (2.65-10.9) GHz. The obtained results indicate that the suggested antenna can deliver an UWB and a symmetric radiation patterns.

(Bhayana E., Agarwal A., 2017) presents an analysis of investigation on DRA’s over the last three decades. It is mentioned that the evaluation has been done depending on vital parameters that include bandwidth, efficiency, realized gain, dielectric constant, dimensions, and DRA material used**. A** comparison of various configurations of DRA’s for various applications have been reviewed. From the comparison, it is clear that rectangular DRA gives the best results.

This paper introduce a wideband antenna using U-shaped dielectric resonator with 10.8 relative dielectric constant. Stepped CPW structure was used to feed the proposed antenna. A frequency tuning element was attached to the feeding system in order to tune the impedance bandwidth. The antenna is designed to cover the C-band and the IEEE 802.11 band used for WLAN and WiMAX as well as the lower European UWB frequency applications. The antenna dimensions and results are optimized using full wave electromagnetic simulator. The resonator and the feeding structure is placed on substrate with relative dielectric constant of 4.6 and thickness of 1.6 mm.

The paper are organized as follow: section one give a literature review on the design aspects of DRAs. Antenna configuration and design analysis are presented in section two. In section three, parametric study of the frequency tuning element is demonstrated. The simulation and results are given in section four. The last section give conclude and highlight the main consideration points in this work.

Antenna Configuration and Design

The proposed DR antenna configuration is shown in Figure 1. The proposed antenna is designed to operate within the frequency (3-6) GHz. The antenna consists of dielectric resonator with dielectric constant 10.8 and thickness of 8.2 mm in the form of U-letter in English. A 50 ohm CPW feeder is designed in a stepped manner to ensure the matching between the feeder and the resonator.

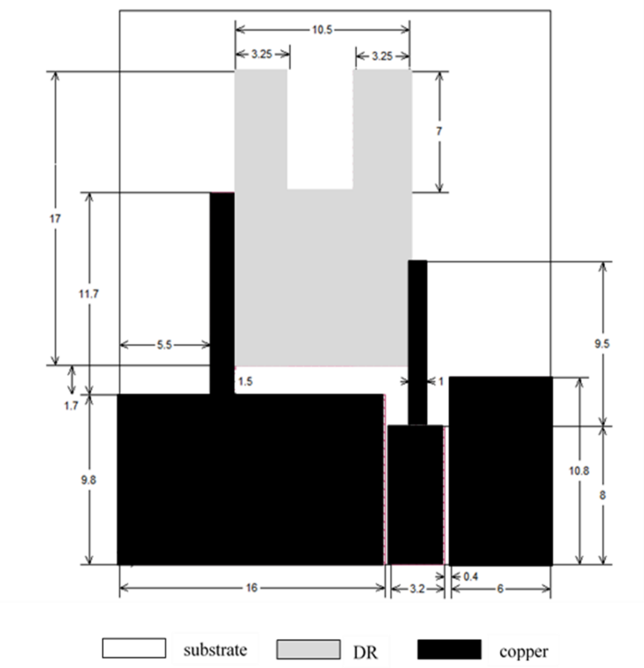

Figure 1. Proposed antenna configuration

This feeder is edge type feeding commonly used to feed the DRs. This type of feeding is used to expand the antenna frequency band. The heights of the ground planes for CPW feeding structure are asymmetric; this gives another expansion to the impedance frequency response. A piece of metal stripe is connected from the lower side to the upper edge of the left CPW ground and extends along the left edge of the resonator. The upper end of the metal strip is used to tune the frequency range of the resonator. The resonator and feeding system are all placed on the substrate with 4.6 relative dielectric constant and 1.6 mm thickness. All dimensions are given in millimeters (mm) and they have been optimized to meet the proposed antenna requirements.

Parametric Study of the Frequency Tuning Element

In this section, the effect of changing the length of the metallic strip on the antenna impedance bandwidth will be discussed. For this purpose, the full wave electromagnetic simulator is used to find the optimum frequency characteristics of the suggested DRA for different lengths of the metallic strip (*Ls*). The return loss (S11) of the proposed antenna against frequency for different lengths of a metallic strip is drawn in Figure 2.

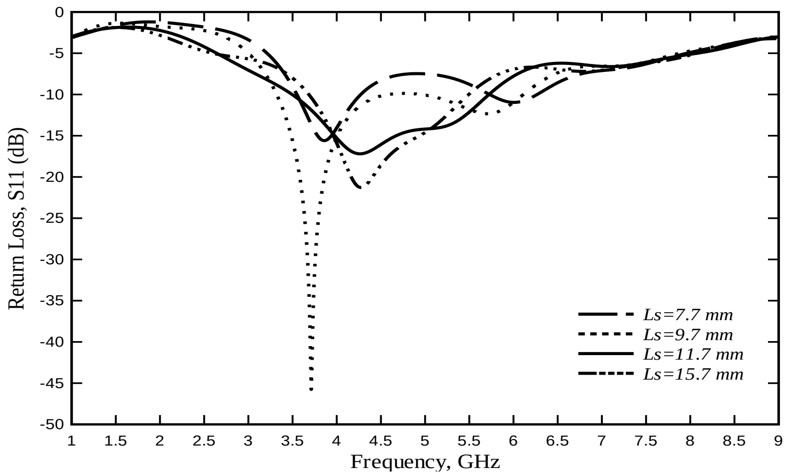

Figure 2. The effect of metallic strip length on DRA impedance bandwidth

It is clearly noted that the variation of *Ls* from 7.7 mm to 15.7 mm has a substantial influence on the frequency impedance variation. When the length *Ls*=7.7 mm and 9.7 mm, it was observed that for these lengths the frequency impedance did not meet the requirements for the proposed antenna. When *Ls*=11.7 mm, the results demonstrate that the planned DRA has an impedance bandwidth from 3.22-5.92 GHz with S11=-16 dB and 59 % bandwidth efficiency. For *Ls*=15.7 mm the impedance bandwidth is from 3.68-5.48 GHz with S11=-21.26 dB and 39.3 % bandwidth efficiency. Accordingly, the length *Ls* is fixed to 11.7 mm to meet the proposed DRA requirements.

Simulation and Results

In this section, the final design of the proposed antenna with optimized dimensions will be simulated using full wave simulator. These dimensions give the optimal impedance response that's meets the specifications of the proposed DR antenna. The length of the metal segments has been fixed at 11.7 mm and the response is redrawn in Figure 3. It is observed that the operating frequency band of the proposed antenna (the gray region in Figure 3) covers the suggested frequency specification of the designed antenna.

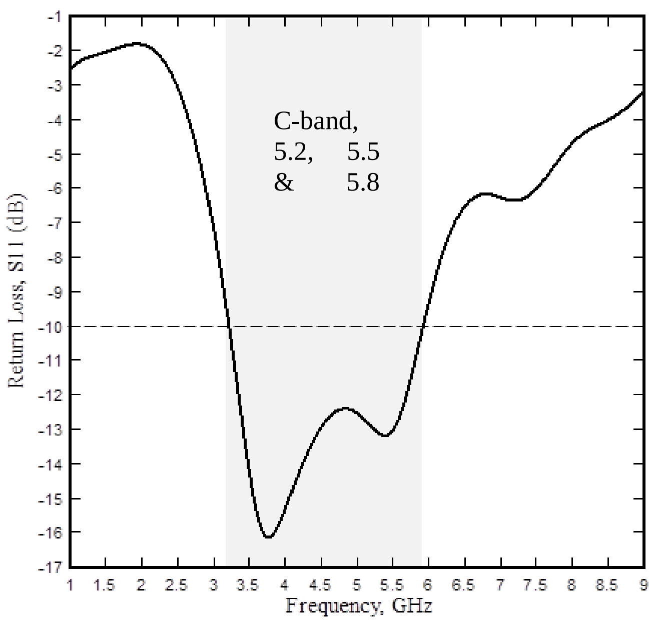

Figure 3. Return loss of the proposed DRA

The far field radiation pattern simulated results of the suggested DRA is illustrated in Figure 4. From the figure it can be realized that the E-plane radiation patterns are almost symmetrical and stable through the operating frequency range, while the radiation patterns in the H-plane are not as symmetrical as in the E-plane. The proposed antenna exhibits good broadside radiation patterns in both planes.

Figure 5 plots the simulated peak gain of the proposed DR antenna. The gain is plotted against frequency range from 3.5 GHz to 6 GHz which covers all the designed antenna bands. It can be noted that the peak gain is about 0.9 dBi for frequency equal to 3.5 GHz and 4.7 dBi for frequency equal to 6 GHz and it is almost linearly and stable in the entire operating frequency range.

These results reveal that the proposed antenna can demonstrate very stable radiation patterns within the designed frequency range. With orientation to Figures 4 and 5, the proposed DRA shows good features that highly recommended in the modern wireless communication applications.

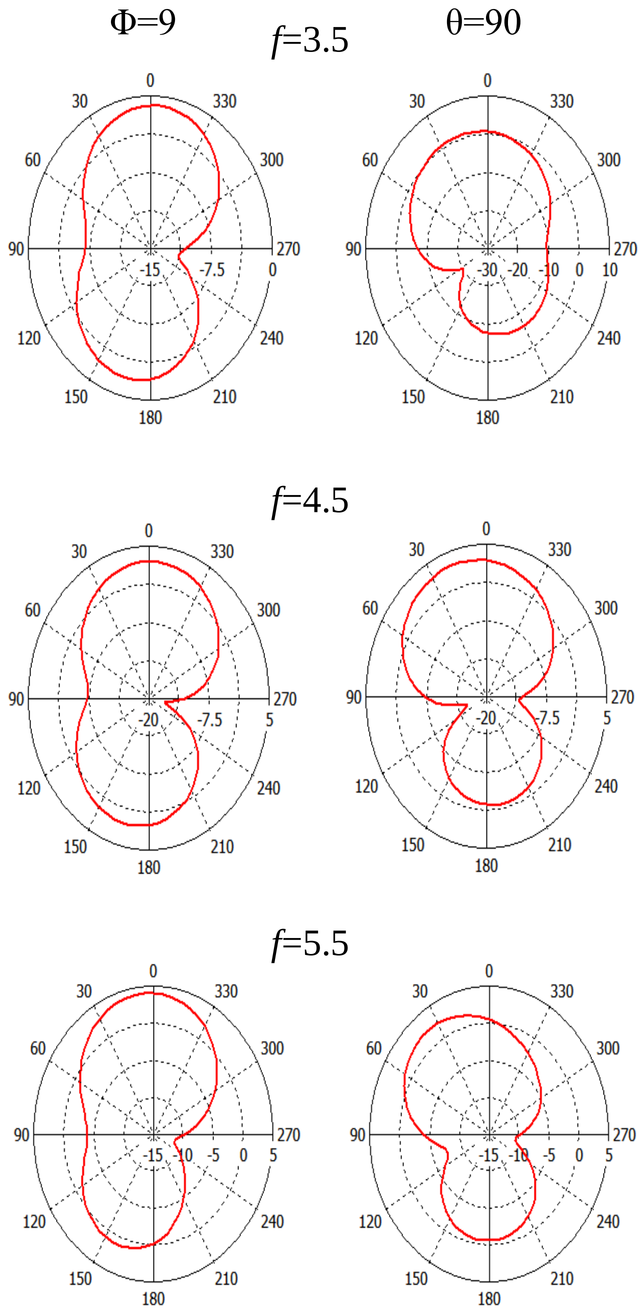

Figure 4. Radiation pattern of the proposed

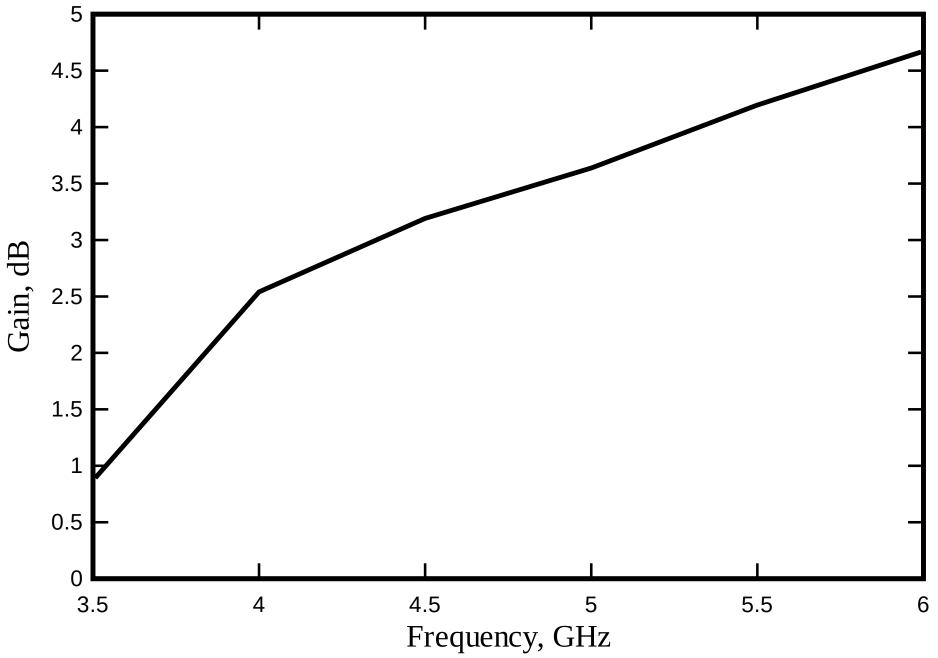

Figure 5. The proposed DRA gain against frequency

Conclusion

In this study, a CPW-fed broadband DRA is recommended for wireless applications. The operating band of the dielectric resonator is coupled to extract a wideband operation with bandwidth efficiency of 59%. The impedance bandwidth can be adjusted by tuning the frequency modes of the dielectric resonator. Further tuning can be achieved by adding a metal strip to the CPW structure and close to the edge of the dielectric resonator. The proposed antenna covers a useful bands that used in wireless communication. The designed DR antenna demonstrate good broadside radiation field patterns in both the principal planes as well as high, stable and linear gain over the whole antenna band. The size of the proposed DRA is 26mm×32mm×1.6mm with DR thickness of only 8.12 mm. The antenna can be categorized as a compact size and low profile antenna.

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