Multisegment Ultra Wide Band Antenna for 5G Applications

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Abstract: This paper presents a novel step-structured Multisegment Dielectric Resonator Antenna (MSDRA). Proposed structure is a combination of two segments with varying dielectric constants. Microstrip feed line in combination of PEC wall is used to couple electro- magnetic energy to the radiator. Application of Perfect electric conductor excites higher order modes to the structure. Size of ground plane is reduced to create multi-mode resonance to create Ultra Wide Band antenna. Amalgamation of modes created by partial ground structure with conducting walls yields a high impedance bandwidth of 87%. Partial ground structure along with entire ensemble provides multimode resonance which generates peak radiation efficiency of 90% throughout the operating frequency range of 3.2 GHz -8.2 GHz. Constant gain, High bandwidth and low delay makes this design extremely suitable for 5G and sub 6G frequency band. Proposed antenna is simulated on HFSS 3D simulators based on Finite Element method.

Keywords: Multi Segment, Partial ground structure, Rectangular Dielectric Resonator Antenna (DRA), Reduced Ground structure, Microstrip feed Line.

1. Introduction

Current scenario has changed the perception of consumers towards wireless communication technologies. Exponentially increasing customers are demanding high bandwidth, high data rates and less delay in communication services. To render all these requirements, technology paradigm is shifting from 4 G to 5G and sub 6G. All these features can be rendered by deploying light weight and compact antennas which can provide Wide band and Ultra Wide Band characteristics. DRA (Dielectric resonator antenna) is coined as an efficient antenna which inherently possess Wide band nature along with high efficiency and gain on account of conductor absence [1]. Rectangular Dielectric resonators can be viewed as an amalgamation of four magnetic boundary walls through which electric field starts emanating. Apart from these advantages offered by DRA, these devices can comfortably gel up all types of feeding technique available. These feed techniques can be named as probe-feed, micro-strip line coupling, Aperture coupling, Coplanar waveguide and dielectric image guide Coupling [2, 3].

2.Significance of The Study

Last three decades have witnessed evolution of various research techniques proposed by researchers in order to enhance bandwidth of the antenna. All these techniques can be further classified into three parts. Primitive technology used is reducing Q-factor of the device. Secondly external matching networks can be used to increase the bandwidth of the antenna. Last technique makes use of multi segmentation and multiple slabs of DRA to increase bandwidth. These three techniques are being utilized in single element method while in multi element structures, array is an effective technique which is used to increase gain as well as bandwidth [4]. Modification in the shape of DRA can drop Q-factor of the device. A split ring resonator is used to increase bandwidth in [5]. Excitation of multimode resonance along with their merging is done in [6] to enhance bandwidth. Enhancement of gain can be termed as the important task of the antenna researchers. To obtain high gain for Ultra Wide Band frequency is achieved by employment of conducting strips [7]. Hybridization of patch and DRA is investigated in [8] to get modified gain.Numerous shapes like H-shape [9], L-shape and stair shape DRA have been envisaged for bandwidth enhancements.Apart from these planar structures conical shape has also been investigated for band width enhancement.

Stacking of multiple slabs Multi segmented DRA can be defined as a resonator with low permittivity substrate under which one or more segments with different permittivity, are inserted to alter the impedance. Vertical stacking of substrates with different permittivity is implemented for obtaining enhanced bandwidth. Dielectric disks, Rectangular [11] and triangular slabs are stacked vertically for bandwidth enlargement. Conducting strips either placed symmetrically or asymmetrically used deliberately to reduce the dimensions of DRA with bandwidth increment.

3.Review of Related Studies

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4.Objectives of The Study

- Proposed work encompasses around the multi-segment structure designed and analysis for Ultra Wide Band applications.
- This two element structure is envisaged two segment step- structure of bandwidth increment is carried out.
- Partial ground structure or Defected Ground Structure has gained immense popularity in microstrip patch antennas [13] but still there is a research gap in case of DRA structures.
- In this work, Partial ground structure technique has been explored to get high impedance bandwidth. Conducting walls can create multiple higher order modes inside the DRA.
- This combination of Partial Ground Structure and PEC wall generates multimode resonance and yields an Ultra Wide Band Width of 5 GHz ranging from 3.2 to 8.3 GHz and a peak gain of 5.2 dB is achieved.

5.Hypotheses of The Study

- The Proposed antenna is highly efficient with high gain and bandwidth.
- The relative permittivity of the substrate for this model was varied
- Proposed antenna is simulated on HFSS which works on Finite Element Method
- High bandwidth and low delay makes this design extremely suitable for 5G and 6G.

6.1. Statistical Techniques Used in the Present Study

Geometrical aspects of the proposed antenna i.e. DRA (Multi Segment Resonator Antenna). In this antenna, two segment RDRA is designed with a partial ground structure. This DRA is instituted upon FR4 substrate with a permittivity of 4.4. Lower segment of DRA is fabricated with alumina of permittivity of 9.9. Upper segment of antenna consists of Gallium Arsenide with dielectric permittivity of 12.8. Simplest feeding mechanism i.e. Microstrip feed line is employed to couple electro- magnetic energy to the antenna. A Perfect electric conducting wall is used to generate higher order modes inside the antenna structure. This PEC wall is made up of the copper which is applied to create higher order modes in DRA structure.

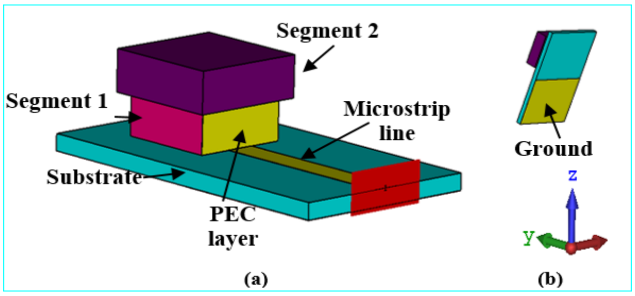


Figure 1 (a) Panoramic View (b) Bottom View of the Antenna

Fig. 1(a) represents top view of antenna depicting DRA with Both Segments, PEC layer and Microstrip Line. Fig. 1(b) represents Partial Ground Structure of antenna.

6.2. Data Analysis and Interpretation

Dimensions of the antenna have been tabulated in Table 1. Table 1 represents the dimensions of various parts of the antenna i.e. Segment 1, Segment 2, PEC Layer, Microstrip Line, Substrate and partial ground structure.

Table1. Dimensions of the Proposed Antenna

Parameter	Dimension (mm)	Parameter	Dimension (mm)
L_{sub}	35	L_{seg2}	12
W_{sub}	20	W_{seg2}	12
H_{sub}	1.6	H_{seg2}	4.6
L_{seg1}	10	W_{mstp}	3
W_{seg1}	10	L_{mstp}	20
H_{seg1}	4.6	L_{gnd}	17
W_{pec}	10	W_{gnd}	20
H_{pec}	4.6		

7. Results and Discussion

Reflection coefficient is a significant measure of the total amount of power coupled by the antenna in space. A good reflection coefficient represents the good radiation properties of any radiator. Fig. (2) represents simulated reflection coefficient parameters of the presented structure. It can be observed from the figure that antenna has reflection coefficient below -10 dB from a frequency range of 3.2-8.2 GHz. Fig. (3) represents Voltage standing wave ratio of the antenna. From the Fig. (3) it can be observed that perfect impedance matching is obtained for this design. VSWR ratio of 1.5:1 is obtained for a frequency range of 3.2 -8.2 GHz.

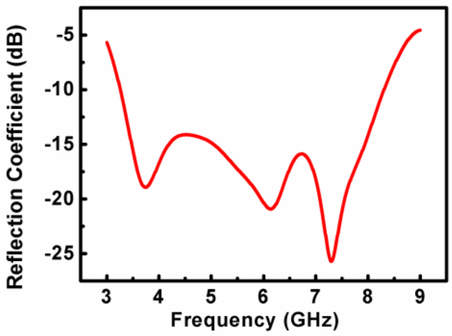


Figure 2. Reflection Coefficient of the Antenna

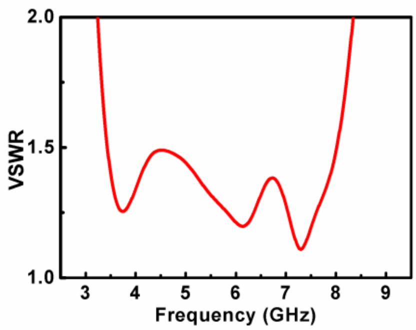


Figure 3. Voltage Standing Wave Ratio of the Antenna

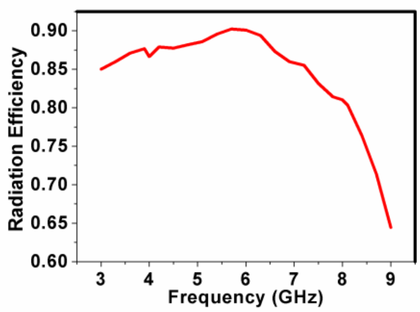


Figure 4. Radiation Efficiency of the Antenna

Fig. 4 represents radiation efficiency of antenna. Radiation efficiency is very important parameter, which signifies the role of radiator as sensor in the entire system. This figure presents normalized radiation efficiency of the antenna. It is interesting to observe that presented DRA reflects exceptionally high radiation efficiency in the operating bandwidth. The peak radiation efficiency of 90% is obtained with this sensor. Fig. 5 represents gain of antenna with respect to the frequency. As can be seen from the Fig. That gain is sustainable for entire frequency range of the antenna.

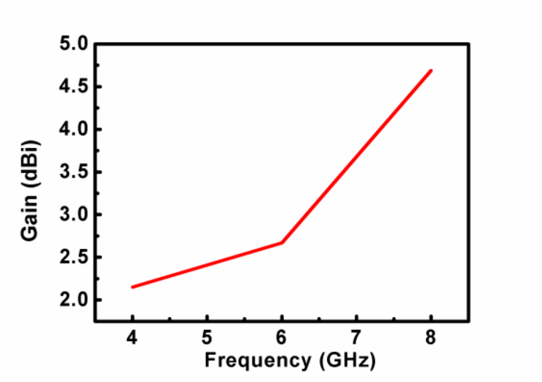


Figure 5. Gain of the Antenna

Fig. 6 represents the plot of electric field inside MSDRA. Antenna is theoretically designed to radiate at a frequency of 4 GHz. Fig. 6(a) represents the fundamental mode TE_{111} of the DRA at a frequency of 4 GHz. Further two other mode TE_{113} and $TE_{115}$are generated as can be seen from Fig. 6(b) and 6(c) respectively. As depicted in Fig.6, Mode merging of these three modes happens till 8 GHz. Rippling effect occurs due to generation of higher order modes at higher frequencies which affects the stability of the UWB system.

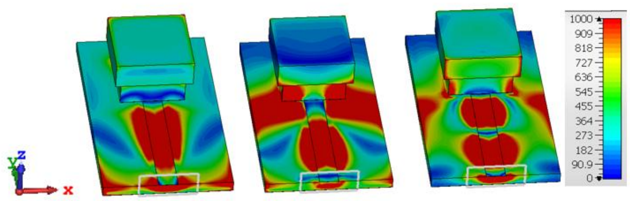
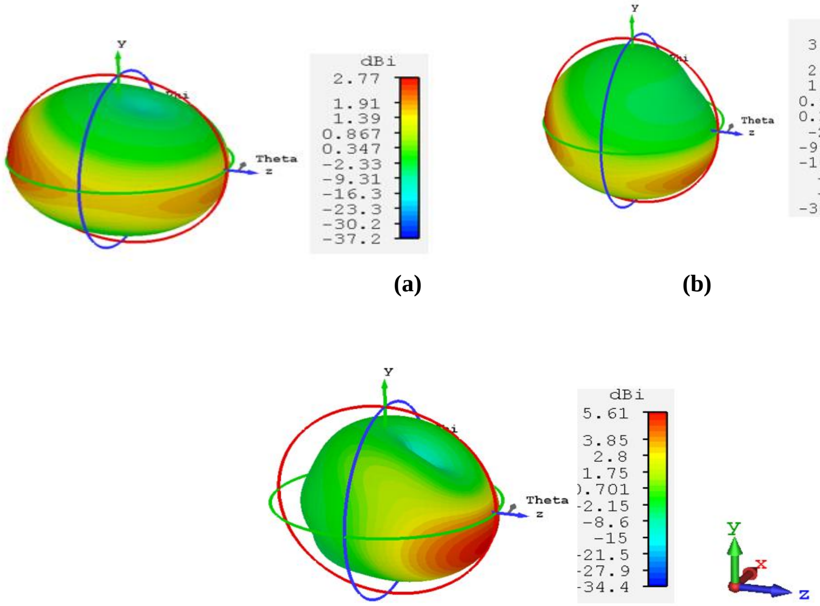


Figure 6. Electric field inside DRA at(a) 4GHz (b) 6 GHz (c) 8 GHz

Fig.7 represents the radiation pattern achieved by the proposed antenna. It is evident from the pattern that at 4 GHz antenna is behaving as magnetic monopole antenna. Good Cross-polarization and Co-polarization levels are obtained at frequency 6 GHz and 8 GHz. Fig. 7 rippling effect is also evident from the radiation pattern of 8 GHz. Due to generations of higher order modes irregularity in radiation pattern of the antenna can be observed.



(a) **(b)**

(c)

Figure 7. Radiation Pattern of the antenna at (a) 4 GHz (b) 6 GHz and (c) 8 GHz

IV. COMPARISON TABLE

Table 2. Comparison of Proposed Structure with Contemporary designs.

Ref. No.	DRA Size (mm)	Shape /Feed	BW (GHz)	F_r
14.	10.5x6x9.6	Two segment RDRA/Microstrip Line fed	3.32-7.456	5.84
15.	50 x50x9.5	Triangular shape MEMS/ Probe feed	5.1-8.0	7.65
16.	10 x10 x8	RDRA with air gap and metallic layer/ Probe Feed	10.97-23.33	20.75
17.	50 x50x13	MEMS H-CDRA/ Probe Feed	5.3-13.0	6.4
Reported Antenna	20x20x9.6	Two segment DRA with conformal PEC	3.2-8.2	4

*BW - Bandwidth, *F_r - resonant Frequency

8. CONCLUSION

This article proposed a highly efficient antenna with a high gain of 5 dB and bandwidth 5GHz.Antenna is theoretically designed for bandwidth of 4 GHz. Incorporation of Partial ground structure and PEC wall generate higher order modes. Multimode resonance is achieved by amalgamation of various modes generated inside the DRA. Hence it is concluded from the design that by reducing ground dimension, and inserting perfect electric layer, Ultra Wide Band antenna is achieved.Fabrication of antenna is done with low key materials that are available. The presented paper delineates that the rectangular DRA with partial ground structure and PEC layer can be considered as a promising candidate for 5G and sub 6G applications.

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