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A Novel Compact Ultra Wide-Band MSRDRA for X- and KU-BAND Applications

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Abstract

The proposed article presents a novel MSRDRA for ultra wideband applications in the domains of military and satellite communication operating in X and Ku frequency bands. The proposed design consists of a notched RDRA of FR4 with a high permittivity insert of Alumina together mounted inside the U-shaped Rogers 5880 segment. The excitation used to obtain the high gain along with UWB response is 50 Ω Coaxial feed. Consequently in the presented antenna structure the achieved impedance bandwidth is 130% with peak gain of 8.5 dBi obtained at 11.2 GHz. The radiation patterns are Omni directional in nature and the average radiation efficiency of 92.1% along the entire impedance bandwidth.

1. Introduction

The rise of the high speed wireless applications has stimulated the need for UWB antennas catering to the ever increasing bandwidth requirements. The dielectric resonator antennas appear to be valuable candidate for such handheld and other portable wireless devices. The merits like compact, lightweight, enhanced flexibility and versatility, wide bandwidth, higher efficiency, low surface wave losses and ease of fabrication [1-3]. In addition to the above dielectric resonator antenna integrated with UWB patch is presented for wideband and narrow band cognitive radio requirements [4]. UWB response is obtained using two segments of dielectric resonators along with high gain[5]. A MIMO design configuration employing DRA to obtain UWB response with notch band characteristics is reported thereby enhancing the versatility of DRAs further [6]. The compactness of dielectric resonator antennas at lower frequency bands is depicted in [7] as an added degree of freedom o the antenna designers where size of the device is also the criteria. [8] presents the use of multi-DR segments to enhance impedance bandwidth with stable gain characteristics attaining the peak gain value of 8.2 dBi however such designs are complex and arise the difficulty of fabrication.

The purposed article presents a novel compact MSDRA to obtain UWB characteristics to address the emerging broadband applications of the world. Consequent to the above the ground plane of the proposed antenna structure is drastically reduced to meet the needs of the portable wireless devices.

Section II depicts the proposed antenna geometry with segments and DR insert. The results and discussions are elaborated in Section III. Section IV and V describe the parametric study and conclusion.

2. Antenna Configuration

Figure 1 depicts the geometry of the proposed antenna structure. The first segment rectangular U-type DR of material Rogers RT5880, permittivity 2.2 of dimensions [W_{sg1} x L_{sg1} x H_{sg1}] is erected on the copper ground plane of dimensions[W_g x L_g]. On to this a second rectangular notched segment DR of Fr4 epoxy [W_{sg2} x L_{sg2} x H_{sg2}] with permittivity 4.4 is placed. An dielectric insert measuring [W_i x L_i x H_i] of material alumina ceramic 9.8 permittivity is sandwiched between the two segments. Lastly a vertical conducting strip with dimensions [W_{cs1} x H_{cs1}] is added at left face of the DR segment 1 to enhance the impedance bandwidth. The MSRDRA is fed with 50 Ω coaxial feed. The coax feed is drilled in to the proposed MSRDRA in order to avoid leaky wave losses thereby achieving higher radiation efficiency. The proposed antenna structure is simulated using Finite Integration Technique based software Microwave CST Studio Version 2016.

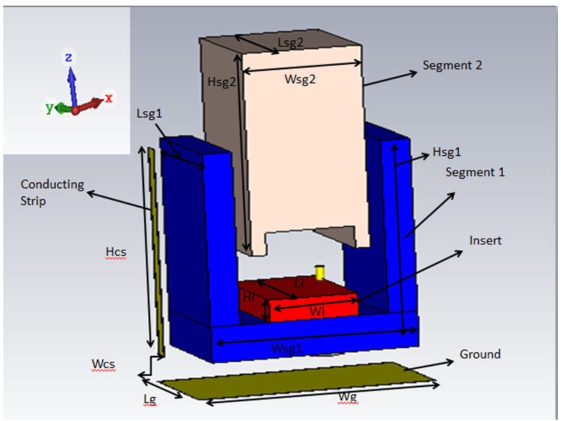

Figure 1. Geometrical Representation of the proposed Antenna Structure.

Table 1. shows the details of the dimensions of the proposed antenna structure.

S.N	Segment Name	Dimensions (mm^3)	Material used(ε_r)
1.	Segment1 [W_{sg1} x L_{sg1} x H_{sg1}]	12.0 x 8.0 x 18.6	RT5880(ε_r= 2.2)
3.	Segment2 [W_{sg2} x L_{sg2} x H_{sg2}]	8.0 x8.0 x18.0	FR4(ε_r=4.4)
4.	Insert [W_i x L_i x H_i]	6.0 x8.0 x1.6	Alumina(ε_r= 9.8)
5.	Conducting Strip [W_{cs1} x H_{cs1}]	2.0 x19.6	Copper
6.	Ground Plane [W_g x L_g]	12.0 x8.0	

3. Results and Discussions

Figure 2 shows the reflection coefficient plot of the purposed MSRDRA. The impedance bandwidth of the presented MSRDRA as per the plot is 130% from 8.0 -20.8 GHz along with excellent return loss at resonant frequency of 10GHz. VSWR parameter as shown in the Figure 3 agrees considerably well the reflection coefficient response. The fundamental radiating modes of the proposed antenna structure are TE^x_{111}, TE^x_{113} and other higher order modes which contributed in attaining the UWB characteristics using mode merging technique. Also the conducting strip 1 helped shifting the impedance bandwidth further by 2GHz. Figure 4 depicts the broadband radiation patterns in both E and H- planes (ϕ=0°and ϕ = 90°). As per the requirements of the modern times bandwidth requirements the presented antenna structure yields an overall Omni-directional patterns over the entire impedance bandwidth. In addition to this the radiation patterns in ϕ=0° and ϕ = 90° planes at resonant frequency 10 GHz are shown in Figure 5 and are also broadband in nature. The peak value of the gain obtained by the presented MSRDRA is 8.5 dBi at 11.5 GHz and 7.6 dBi at the resonant frequency 10GHz as shown in Figure 6. The gain is fairly stable and positive along entire bandwidth. The radiation efficiency of the presented MSRDRA if averaged around 92% with a peak value of 97% at 9.8 GHz as depicted in Figure 7. Figure 8 shows the distortion in the group delay parameter of the proposed MSRDRA less than 1.5 ns for entire functional bandwidth. Table 2 shows the performance of the proposed antenna structure with respect to the recent DRAs and it is inferred that the proposed structure offers greater bandwidth at higher gain in the operational bandwidth. In addition to the above the proposed antenna structure is found to be much more compact as compared to the existing antenna design operating under similar frequency bands.

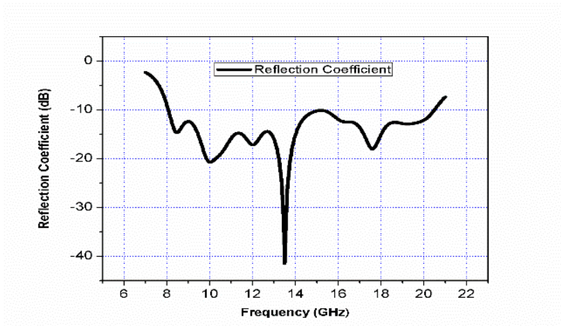

Figure 2. Reflection Coefficient Response (Simulated).

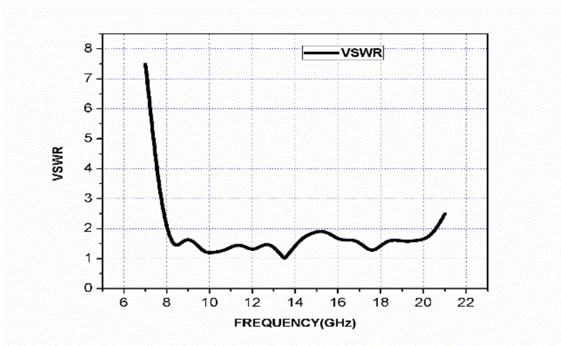

Figure 3. Simulated VSWR plot.

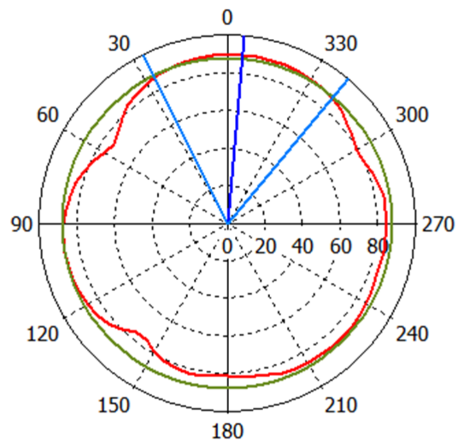

Figure 4. depicts the broadband radiation patterns.

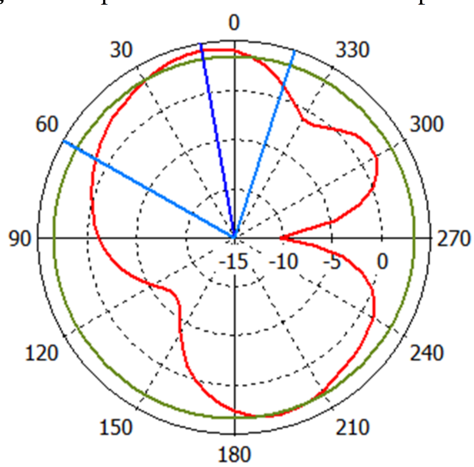

Figure 5. depicts the Radiation pattern in ϕ = 0°and ϕ = 90° planes at resonant frequency 10 GHz.

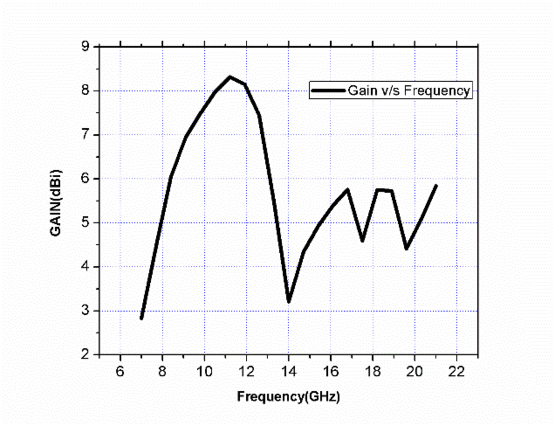

Figure 6. Gain v/s Frequency graph of the antenna.

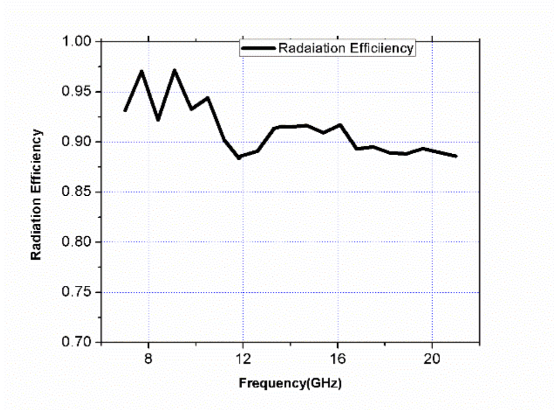

Figure 7. Radiation Efficiency of the antenna.

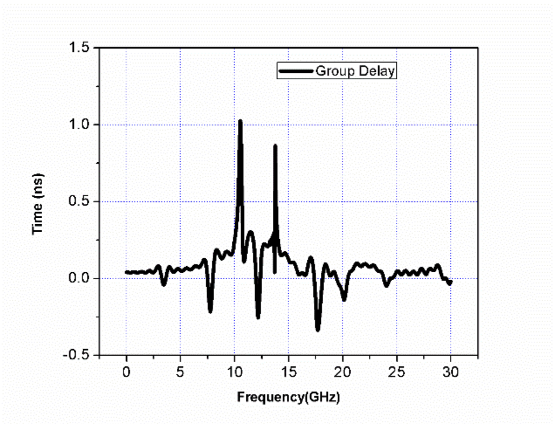

Figure 8. Group Delay of the antenna.

Table 2. shows the performance of the proposed antenna structure with respect to the recent DRAs.

S. N.	Dimensions (mm^3)	Band width	Gain (dBi)	Efficiency	References
1.	42x40x 6.3	2.6-12 GHz	7.1	98.4 %	Idris Messaoudene(2013)
2.	48x50x 1.6	103.83 %	5.2	More than 90%	Anand Sharma(2015)
3.	29x29x 5	106%	5.3	NM	M. Abedian
4.	67x67x 34	25.6%	7.5	NM	Feibiao Dong
5.	40x40x 24	128%	8.2	NM	Taruna Sharma
6.	12x8x2 2.8	130%	8.5 dBi	97%	Proposed Antenna

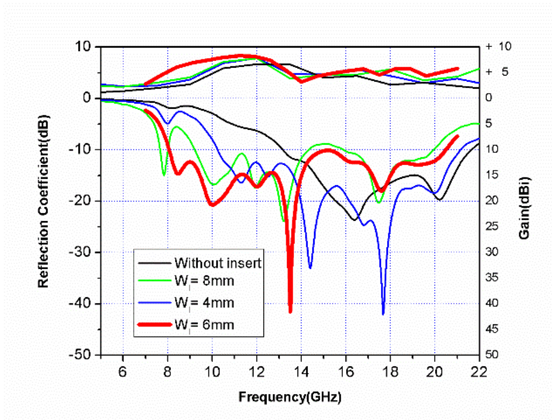

Figure 9. Parametric study with and without Alumina insert

4. Parametric Analysis of the effect of the Alumina DR inserted on the proposed MSDRA

Figure 9 represents the significance of Alumina DR insert on the impedance bandwidth and gain of the proposed antenna structure. It can be seen that in absence of the DR insert whole X- band (8 - 12 GHz) is lost and the peak value of gain drops to 5.1 dBi. However the width of the insert is also optimized to value 6mm where complete mode merging is exhibited and an UWB characteristics are obtained. The proposed antenna attains both X- and Ku-bands completely (8 - 21GHz).

5. Conclusion

A compact ultra wideband multi segment rectangular dielectric resonator antenna MSRDRA is analyzed. The proposed antenna structure consists of two segments rectangular ring and rectangular notch shaped dielectric resonators including an alumina DR insert fed with 50 Ω coaxial probe. The proposed MSRDRA can be employed in high speed LTE/ wireless applications, vehicular radar application system, unmanned guided vehicles, UWB short pulsed radars, robotics and satellite applications.Consequently, the proposed MSRDRA is an excellent contender in a congregate of ultra wideband antennas.

6. References

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