Bandwidth Enhanced in Wave Rectangular Dielectric Resonator Antenna (WRDRA)

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Abstract- WLAN requires low-cost and compact antennas with sufficient bandwidth. Chip antennas are particularly attractive as they are not substrate dependent and are solderable with standard reflow processes. Therefore, low-cost substrates can be used for the circuit board with no major consequence on radiation. Among possible antenna solutions dielectric resonator antennas (DRAs) offer an assembly that is surface mount technology (SMT) process compatible and their manufacturing can be based on standard processes. They also exhibit excellent properties regarding bandwidth and quasi omni directional radiation. When compactness is a main issue, conducting plates can be placed at the electric walls of the fundamental mode of the DRA to reduce its dimensions. However, this also decreases the bandwidth. Wider bandwidth structures have been proposed but they remain larger compared to a wavelength. In this paper, we propose a new DRA topology with both reduced size and large bandwidth. It has been designed for the low band of Hiperlan2 and IEEE802.11a standards [5.15–5.35] GHz. The proposed structure has been optimised using 3D EM simulations and is compared to a more conventional compact design.

A novel technique for producing enhanced band width in micro and mm wave region of spectrum is presented. A new design of compact & broadband wave dielectric resonator antenna is proposed using co-axially probe feed technique. Two different WDRA are designed and their characteristic behaviors are compared. Finally, parametric study of Second Antenna has been done. With the proper design the resonant behavior of the antenna is found, over which the leaky wave DRA produces extended bandwidth. Numerous designs for the WRDRA are simulated and bandwidths exceeding 20% are achieved.

Index Terms- Wave Rectangular Dielectric Resonator Antenna (WRDRA), Resonant, Broad band

I. Introduction

Recently, interest in dielectric resonator antennas has increased because of their attractive features such as small size, high radiation efficiency (98%), wide bandwidth, and high power capability for radar applications and base stations. The dielectric resonator antenna is made from high dielectric constant materials and mounted on a ground plane or on a grounded dielectric substrate of lower permittivity.

Design curves will be provided for the circular disc and hemisphere dielectric resonators. Use of these models with other geometries is discussed. Different excitation mechanisms are demonstrates such as the probe, slot, image line and waveguides. Applications of dielectric resonators in arrays are provided with discussion on the mutual coupling level and the wide scanning capabilities of the dielectric resonator antenna array. The array bandwidth limit is discussed based on the element size and the spacing between the array elements. Techniques for broadband applications are discussed. Some of the techniques are based on the material properties and some depends on the DRA shape. Several examples are provided. Some elements would provide a matching bandwidth over 40% with reflection coefficients better than –10dB for 50 Ohms ports. Finally, Techniques for size reduction of the DRA are presented to demonstrate the flexibility of the DRA to satisfy the required small size for some applications. The technique will result in small size and keeping wide bandwidth. The applications of the DRA for spatial power combiners are presented. The DRAs are placed in an oversized hard horn to provide uniform field distribution. Recent developments of the dielectric resonators as a multifunction device will be also provided. In this application we will show the use of the same DR as an antenna with low quality factor and as a resonator with high Q-factor.

Modern communication systems require wide bandwidth to support the demand of high data rate transfer for various multimedia applications. To fulfill this requirement, most wireless mobile systems have to be operated at the millimeter wave frequencies [1]-[2]. For ease of space allocation, it is highly desirable to have small size, low profile equipment. Hence, the antennas for modern wireless communication system should be low in profile and efficient in high frequencies.

Dielectric resonator antennas (DRA) have been the interest of research and investigation due to its highly desirable characteristics such as small size, light weight, highly efficient in microwave and mm wave spectrum. The most popular shape studied for practical antennas applications have been the cylindrical dielectric resonator antennas, rectangular dielectric resonator antennas, spherical dielectric resonator antennas and many more different structure are reported. The stacked DRA has also been tested [3]-[7] with a resulting increase in bandwidth that is much wider than the bandwidth of the micro strip antennas.

The dielectric resonator antennas based on NRD guides have few publications. The technique of NRD guided antenna was proposed by Yoneyama and Nishida [8]-[10] . Although, it is classified as open dielectric waveguide, it has attractive feature of no radiation [11]-[13]. However, introducing suitable perturbation to the NRD guide structure can produce leaky waves

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that propagate away from the dielectric slab to the open ends. This mechanism makes the NRD guide working as a leaky wave antenna.

Several techniques have been proposed to generate leaky waves from NRD guide, such as foreshortened sides of parallel metal plate's technique, Asymmetric air gape technique, Trapezoidal dielectric slab technique and many more.

A NRD guide itself is a transmission line and so it is non-radiative. In this research paper a novel dielectric antenna based on NRD guide model has been presented. A wave rectangular dielectric resonator antenna (WRDRA) has been designed. WRDRA is excited by coaxial probe feed mechanism. The WDRA is parametrically studied and different approaches are presented to achieve an extended bandwidth nearly20% at -10dB. The study also shows the dual resonance behavior WRDRA at frequency value of 22.14GHz and 24.97GHz. The dependence of band width on the various parameters and the geometries of the system show that higher band width with desired radiation characteristics can be achieved with such dielectric resonator antenna based on NRD guides. Therefore, it is necessary to extend extensive research and study on this topic, because it can provide an alternative device to achieve wider band width characteristics.

II. Antenna Design

First proposed design uses a substrate of relative permittivity of 2.4 and dimension 210mmX 152mmX 0.6mm. The upper surface of the substrate has finite conductivity layer. This has been done to minimize the back-lobe radiation phenomenon. The rectangular dielectric resonator of relative permittivity 8.2 is used, having dimension of 148mmX 6mmX 5.2mm. The top layer surface of the dielectric resonator is perturbed by embedding a strip of thickness 0.8mm and length equal to that of the dielectric material. The co-axial probe feed mechanism is used for the excitation of WDRA. In Fig. 1(a), the proposed antenna is presented in 3D view. The proposed First Antenna is shown in fig. 1(b). In the second antenna design the perturbation is increased by just modifying the embedded dielectric material strip of First Antenna design, by removing material of thickness 0.1mm from between the upper face. The antenna design is shown in fig. 1(c). This is termed as Second Antenna designed. The parametric study of the Second Antenna is done by varying the probe penetration length, l into the dielectric material of the resonator. The variation of the length is done from -0.6mm to 5.4mm in step size of 0.6mm. The antenna designed for parametric study, showing probe length l, is shown in fig. 1(d).

III. Simulations

The designed antenna is simulated on Ansoft HFSSv10 simulation software. The simulation of LWRDRA has been done in three stages. At first, the First Antenna was simulated and results were recorded. In second stage, the Second Antenna was simulated and the results which were obtained were compared with that of the First Antenna. At last, the parametric variation of the project variable, l was done. The result obtained was studied in detail to know the relation between probe positions, probe length and the height of the dielectric material.

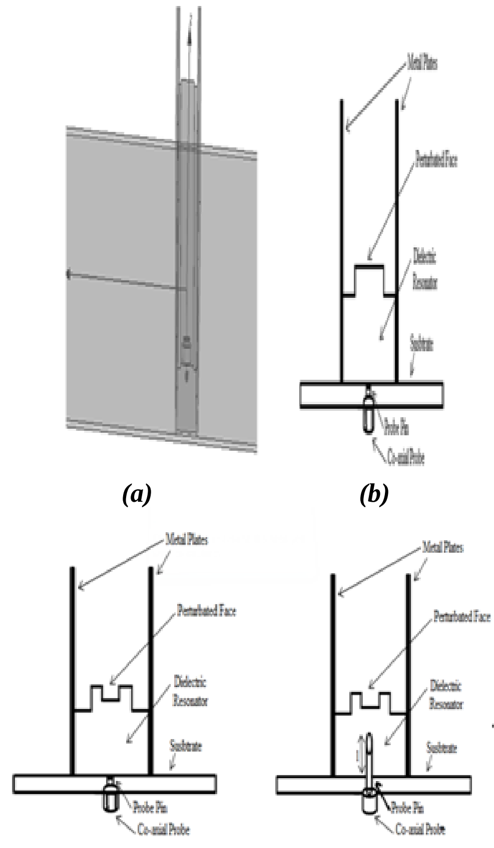

Figure 1(a) WRDRA Designed & Simulated on HFSS 3D view, (b) First Antenna Designed, (c) Second Antenna Design and (d) Second Antenna Design, with probe pin, l set as project variable for parametric study of Antenna

A. Simulation Result of First Antenna

The S_{11}Vs Frequency plot of first antenna is shown in Fig. 2. It can be seen that antenna is well matched at 9.89GHz having return loss of -23.01dB. It has a bandwidth (-10dB) of 800MHz which corresponds to nearly 8.2% in the frequency range of 9.3GHz-10.1GHz.

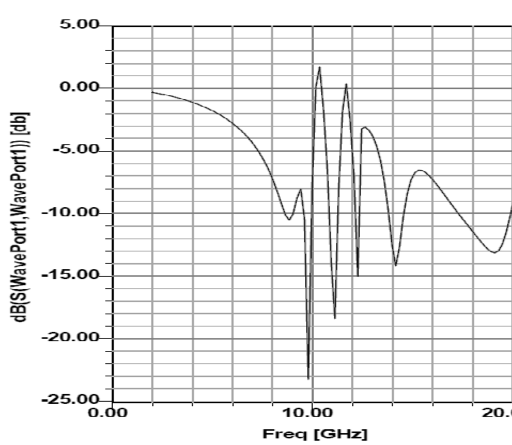

Fig. 2 S_{11}Vs Frequency Plot of First Antenna

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B. Simulation Result of Second Antenna

The S_{11}Vs Frequency plot of second antenna is shown in fig. 3. This graph shows that the second antenna is well matched at frequency of 24.25GHz and having return loss of -28.59dB. It has -10dB bandwidth of 16.54% in the frequency range of 22.34GHz-26.37GHz. This shows the 100% increase in the bandwidth as compared to the first antenna design.

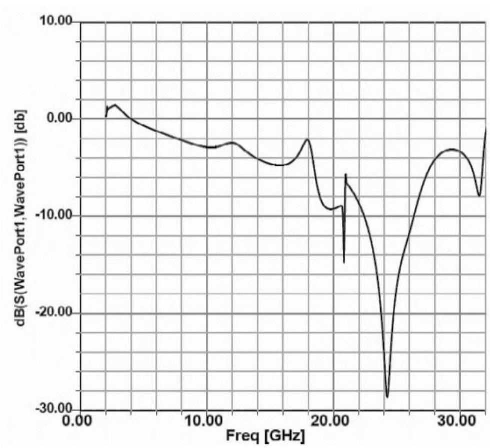

Fig. 3 S_{11}Vs Frequency Plot of Second Antenna

C. Simulation Result of Parametric Study of Second Antenna by Varying the Probe Length, l Penetration into the Dielectric Resonator of WRDRA

As discussed in Section II, the parametric variation in the probe length, l was done by setting, l as project variable. The simulated results are shown in Fig. 4(a), 4(b), 4(c). During the variation of probe length, l, for l = -0.6mm to 0.6mm, it is observed that the there is decrease in bandwidth as well as increase in return loss. The matching frequency gets shifted to higher value. The frequency range over which the bandwidth is calculated gets shifted to higher value (shown in Fig. 4(a)). For l = 1.2 and l=1.8, there is increase in bandwidth as well as resonant frequency. For l = 2.4mm to 3.6mm, the resonant frequency tends to decrease and bandwidth along with return loss starts to increase. At l = 4.2mm, we observed a dramatic decrease in the return loss to -31.60dB, the resonant frequency decrease to a value of 18.63GHz at -10db, calculated bandwidth is 8.4%. At l = 4.8mm, dual resonance behavior of the antenna is observed. The WRDRA resonates in the frequency range of 21.62GHz-25.03GHz. The bandwidth obtained at this frequency range is nearly 20%. The tabulated result of the parametric variation of probe length, l has been presented in Table I.

Fig. 5 shows the S_{11} Vs Frequency plot of Second Antenna at resonant condition. It is found that as l = 4.8mm, the WRDRA acts as dual resonant leaky wave antenna. The resonant frequencies of WRDRA are 22.14GHz and 24.97GHz. Calculated bandwidth for the design at dual resonance is found to be 14.6% (-10dB) with overall bandwidth of the WRDRA at -10dB bandwidth is nearly 20%.

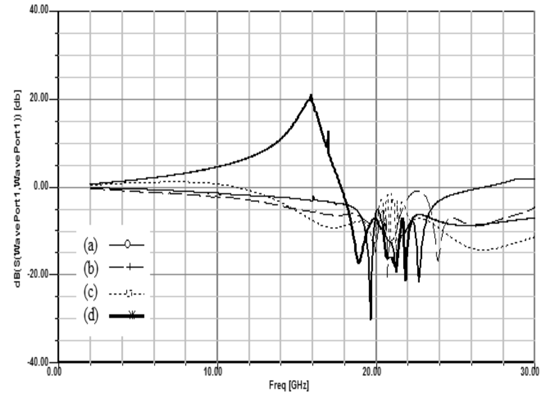

Fig. 4(a) S_{11}Vs Frequency Plot of Second Antenna graph showing parametric variation of Probe length, l inside the WDRA(a) l = -0.6mm, (b) l = 0mm (c) l = 0.6mm (d) = 1.2mm

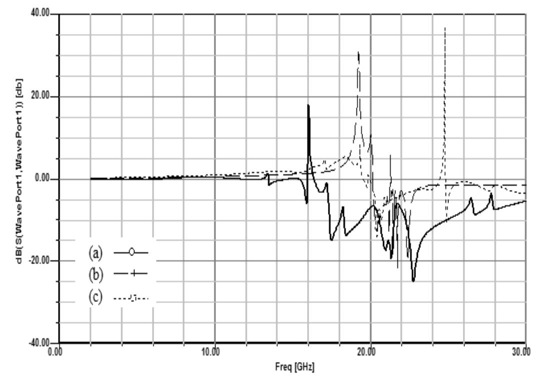

Fig. 4(b) S_{11}Vs Frequency Plot of Second Antenna graph showing parametric variation of Probe length, l inside the WDRA (a) l = 1.8mm, (b) l = 2.4mm (c) l = 3.0mm

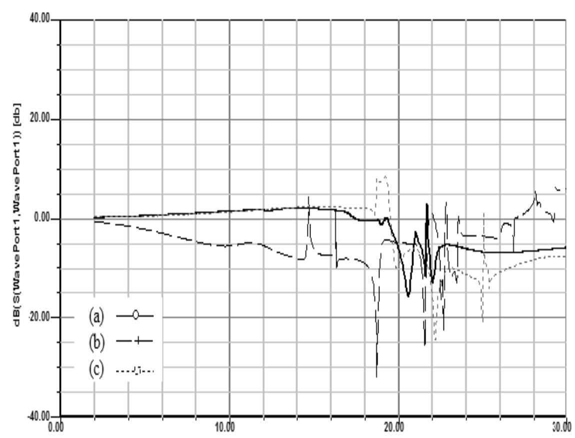

Fig. 4(c) S_{11}Vs Frequency Plot of Second Antenna graph showing parametric variation of Probe length, l inside the LWDRA (a) l = 3.6mm, (b) l = 4.2mm (c) l = 4.8mm

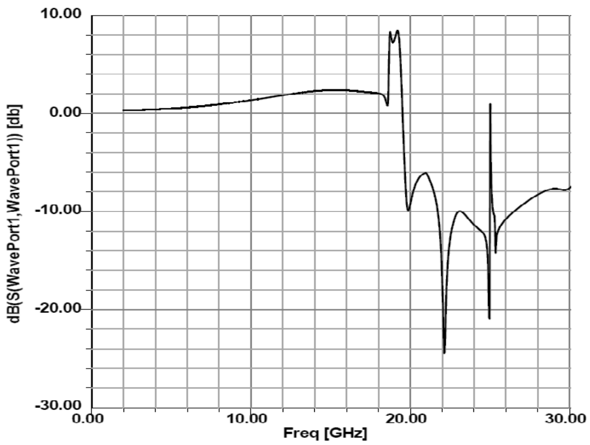

Fig. 5 S_{11}Vs Frequency Plot of Second Antenna at l = 4.8mm showing the Dual Resonance Behavior of WRDRA at -10dB

TABLE I VARIATION OF PROBE LENGTH INSIDE WRDRA

S. No.	Probe Length (mm)	Low Freq. (GHz)	High Freq. (GHz)	Reso-nant Freq. (GHz)	Band-width (%)	Return Loss (-dB)
1	-0.6	19.24	19.97	19.66	3.72	30.58
2	0.0	20.58	21.31	20.74	3.48	20.55
3	0.6	21.05	21.47	21.26	1.97	15.63
4	1.2	21.62	22.14	21.82	2.37	21.41
5	1.8	22.29	24.82	22.76	10.7	25.10
6	2.4	22.08	22.60	22.85	2.32	20.18
7	3.0	20.14	20.84	20.33	3.41	14.12
8	3.6	20.18	20.89	20.85	3.45	15.72
9	4.2	18.21	18.93	18.63	8.40	31.60
10	4.8	21.62	26.53	22.14	20.3	24.52

IV. CONCLUSION

A new, comprehensive dual resonance WRDRA has been designed. It is found that the First Antenna which has less perturbation on dielectric resonator's upper surface has bandwidth of 8.2% (-10dB) and good matching at frequency 9.89GHz but as the perturbation is increased as seen in Second Antenna design, the bandwidth gets increased to a new value of 16.54% (-10dB) and good matching of the system occurs at 24.25GHz.Thus, it is found that as the perturbation of dielectric resonator of WDRA increases, the bandwidth of the system along with matching frequency gets shifted to some higher value. In First Antenna perturbation of upper surface of dielectric resonator was half as compared to that of Second Antenna, and the numerical results obtained shows that values of bandwidth and the resonant frequency of WRDRA depends upon the perturbation of the surface. Analysis suggests the relation of direct proportionality between perturbation of dielectric resonator surface and the bandwidth and resonant frequency of the WRDRA. Further 16% increase in the bandwidth is obtained by increasing the probe penetration into the dielectric material. Results obtained by the parametric study of probe penetration length inside the dielectric resonator material of the antenna demonstrate that the dual resonance behavior of the WRDRA is obtained when the antenna is co-axially feed and the position of excitation is at the 3/4^{rth} distance from the center of the resonator and the penetration length is equal to 0.8 times that of the height of the rectangular dielectric resonator. By applying the composite technique the extended band width can be produced.

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