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NUMERICAL SIMULATION OF THE D-SHAPED RING RESONATOR ANTENNA

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ABSTARCT

This paper discussed the design and numerical simulation of circular ring resonator with D-shape for dual band applications at 8.98 GHz and 11.64 GHz. The numerical simulation has been done with the aid of Computer Simulation Technology (CST) software. The primary design was carried out using mathematical calculation. Then the design is constructed and simulated numerically to get the optimized design. Optimized geometrical parameters are length and width of the microstrip feed and radius of the circular ring resonator. According to the optimal results a minimum return loss of -10.36 dB and -19.15 dB have been obtained at the frequencies of 8.98 GHz and 11.64 GHz, repectively.

Keywords: *Numerical Simulation, Circular ring resonator, Computer Simulation Technology (CST), Dual band.*

1. INTRODUCTION

The new multiprocessor, incredible PC arranged innovative progressions prodded the quick and wide development of the present remote unavoidable climate. For offering incorporated types of assistance through shared remote correspondences, there is an incredible interest for climate agreeable, cheap, minimal, convenient devices [1]. The antenna as center part in remote correspondence devices are mentioned to plan for multifunctional operability. This will empower the device to interconnect with more than one organize and guarantee living together, interoperability, and brought together exchange of signals. The antenna having two or more bands [2] usefulness can substitute a number of single-band antenna and along these lines are favorable by guaranteeing conservativeness, diminished expense, and further developed feel.

Microstrip patch antennas have been the most needed device for researchers because of their several benefits like low cost, low profile, fabricated easily, miniaturization size, and integrated with high frequency components. It is commonly used in wireless industries. But the limitations of the patch antennas are narrow bandwidth, low efficiency and surface wave excitation [3]. To overcome this draw backs, circular ring resonator antenna is employed and it is an man-made artificial design to achieve negative permeability and negative permittivity. Ring resonator acts as a magnetic dipole antenna which tends to raise the magnetic response of the antenna [4].

To design an antenna, a researchers should have good mathematical background and have knowledge with computer tools [5]. As Numerical methods have hold the place of an analytical model due to lots of advantages such as reduce computational time, decrease labors, economical, etc.

The proposed design separated the corners of the antenna into small partition called meshing and that partitions can be moved in the normal direction of the corners to make improvement in the return loss of the antenna. The geometry can be extended beyond the limited boundaries in this meshing approach. Also, the geometry of the design is constructed without any definite form. The CST simulator deals with the Maxwell's equations and it governs the characteristics in electric and magnetic fields. A circular ring resonator antenna is used to investigate the radiation patch and ground on the equal plane and it has operated in two band. The accuracy and computative efficiency display that the proposed antenna satisfies the requirement.

2. RELATED WORK

Yiming Li [6] developed antenna designed on simulation based optimized technique for multiband operation. Optimizing of the antenna design is carried out with a assist of numerical electromagnetic solver. Omni-directional radiation pattern is obtained by using Maxwell's equations. Where, the return loss of the antenna is improved after optimizing the geometrical parameters.

Ke Wang & Robert Nelson [7] implemented the broadband dipole antenna based on numerical simulation technique. MlNDEC software is used to do mathematical calculation for designing the dipole antenna. This software is used methods of moments technique to mathematically analysis the antenna design. The dipole antenna utilizes this technique to calculate the antenna factor in the near fields and far fields.

Kiani et al [8] presented the design of uniform leaky wave antenna based on mathematical analysis of closed form formula. This has been designed with the structure of tapered long slots antenna, which reduces side lobes of the antenna radiation pattern. It has obtained the side lobe level of -45 dB. The antenna is constructed in computer simulation technology software.

Christophe Roblin & et al [9] introduced antenna modeling and simulation analysis. To evaluate the antenna performance CST software is used. The antenna design is addressed for Body Area Networks (BAN) Applications. Both the band of wide band and narrow band are reported numerically.

Selvakumar Ulaganathan et al [10] presented data driven model based antenna structures. Metamodels or data driven models are offer to design the antenna on computation intensive simulators. Though, this simulators have enough speed and flexibility, but it suffers from an exponential increase of the samples. Then, this issue is eliminated using Gaussian process approach called as Gradient enhanced kriging approach.

Md Rezwanul Ahsan et al [11] implemented multiband microstrip patch antenna. The antenna is designed by employing with High Frequency Structural Simulator (HFSS) software. The optimized geometrical parameters are used to design the antenna prototype from the numerical simulation. This software follows finite element method. The overall dimension of the antenna is 17x24x1 mm^3. But, the radiating element occupies only 17x17 mm^2.

Liang Chao et al [12] introduced plasma antenna using FDTD method based on numerical simulation. FDTD technique is very suitable to solve electromagnetic properties. This properties are used to implement reconfigurable antenna on dynamically. Comparing with copper antennas, plasma antennas have more advantages such as radar cross section is switchable and reconfigurable of antenna is possible on dynamically.

Shujing Wang et al [13] developed microwave coaxial slots antenna based on numerical simulation. The operating frequency is 2.45 GHz with 50 ohms of impedance. The slots are constructed like H shape structure with length is 12 mm and width is 2 mm. Then the simulation softwares like ANSYS and HFSS are used to analyze the geometrical parameters of the antenna.

Ali Hanafiah Rambe et al [14] presented rectangular patch antenna at the operating frequency of 3.35 GHz on numerical simulation. The numerical simulation is done through AWR microwave software. The length and width of the patch is optimized and the return loss and bandwidth are obtained as -15.98 dB and 93 MHz, respectively.

Kushwah V.S. & Tomar G.S. [15] developed patch antenna by using neural network. While designing, the antenna with neural network technique, the size of the antenna has major drawbacks, especially in wireless applications. Outcome of the results are incorporated with a help of Graphical User Interface (GUI) of MATLAB coded program. The algorithm of back propagation is used in neural network to minimize the error and computation of time.

3. PROPOSED ANTENNA DESIGN

Common steps for FDTD implementation on ring resonator antenna

Commonly, the Maxwell's curl equations can be considered to formulate FDTD method for numerical simulation in CST software. The curl equations define the propagation of electric and magnetic fields in all medium, whether, it can be homogeneous, uniform and isotropic. Also, the medium is considered as a lossy. Hence, the Maxwell's curl equations are as follows,

$$\mu = \frac{\partial \mathbf{H}}{\partial \mathbf{t}} = -\nabla \times \mathbf{E} \qquad (1)$$

$$\boldsymbol{\varepsilon} = \frac{\partial \mathbf{E}}{\partial \mathbf{t}} = \nabla \times \mathbf{H} \qquad (2)$$

where, $\mu = \mu_0\mu_r$ and $\boldsymbol{\varepsilon} = \boldsymbol{\varepsilon}_0\boldsymbol{\varepsilon}_r$

The solution of this equation by FDTD is a partial differential equation and it is used for time and space in a first order finite difference.

Mathematical calculation

The proposed antenna structure with microstrip feed line has been designed in this research paper is depicted in Figure 1. The antenna is composed of inner radius and outer radius, which act as a circular ring resonator. Inside this ring resonator, the D shape structure is formed by cutting the circular shape and inside the D-shape one slot is constructed. The resonator and D shape is made up of copper sheet with thickness of 0.035 mm. This behaves as a radiating element and next layer is sandwiched with FR4 substrate with thickness of 1.6 mm and its relative permittivity, $\boldsymbol{\varepsilon}_r = 4.4$. Also, its loss tangent is, $tan\delta = 0.01$. The third layer (i.e) below the substrate, 0.035 mm of copper sheet is sandwiched and it is called as ground plane of the resonator antenna. The overall dimension of the proposed antenna is chosen as 32 x 29 x 1.6 mm^3. In this research work, the proposed antenna is chosen as fully ground plane. So the length and width of the substrate and the ground plane are selected as a same dimensions, (i.e.) length, $L_a = 32$ mm , width $W_a = 29$ mm and the height is, h = 1.6 mm.

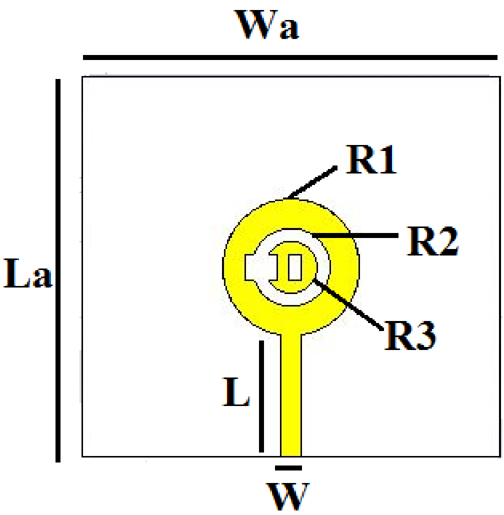

Figure 1: Geometrical Dimension of Proposed Antenna

The radius of the antenna is related to the effective wavelength (λ_{eff}). Then, the λ_{eff} is correlated to the operating frequency and relative permittivity. The formula for calculation is given as [16],

$$\lambda_{\text{eff}} = \frac{c}{f\sqrt{\varepsilon_r}} \qquad (3)$$

where, λ_{eff} represents the effective wavelength, c denotes the speed of light at vacuum, f is the operating frequency of the antenna and ε_r is the relative permittivity.

To calculate the inner radius and outer radius, while designing the antenna the following factors should be considered [16],

1. The wavelength should be satisfied the following condition.

$$\lambda > 1.1\lambda_c = 1.1\pi\,(a+b) \qquad (4)$$

where, λ_c is the operating wavelength, the inner and outer radius are ‘a’ and ‘b’, respectively in mm.

2. When designing antenna, it is necessary to check whether the antenna deliver large power and less attenuation. In order to this, the characteristic impedance can be chosen as 50 ohms. Hence, the characteristic impedance for the radius can be calculated as,

$$Z_c = \frac{60}{\sqrt{\varepsilon_r}} \ln\left(\frac{b}{a}\right) \qquad (5)$$

Where, Z_c is the characteristic impedance.

The slot inside D shape is calculated as follows,

$$l = \frac{1}{2}\left(\frac{\lambda_{eff}}{1+\sqrt{\varepsilon_r}}\right) \qquad (6)$$

Where, l is the slot length.

While designing the antenna, it is necessary to calculate the length and width of the feed. The dimension of the substrate and the ground plane are equal here and its value is known. From this known value, the length and width of the feed is calculated as follows,

$$L_a = 6h + L \qquad (7)$$

$$W_a = 6h + W \qquad (8)$$

where, L_a and W_a are length and width of the ground plane and the substrate. L and W are length and width of the microstrip feed line. h is the thickness.

Once finish calculating all the parameters of the antenna using formula and then, the design of the antenna is made on CST software to carry out the numerical simulation, But the results are not good for all parameters, so in order to get good results, the geometrical dimensions of the proposed antenna is optimized using numerical simulation software (CST software) by running the design in series sequence. (i.e) The optimization is carried out using trial and error method in mathematically to reduce computation time. Therefore, the optimized dimensions are reported in Table 1.

Table 1: Optimized Geometrical Dimensions

Parameters	**Dimensions (mm)**
L_a (Substrate and ground length)	32
W_a (Substrate and ground width)	29
L (Antenna feed length)	19.5
W (Antenna feed width)	1.6
R1 (Outer radius of resonator)	5.24
R2 (Inner radius of resonator)	3
R3 (Radius of the circle)	2
l (Length of the slot inside the D shape)	0.4

Meshing Technique

CST Microwave Studio (CST MWS) software is used for doing analyzation in electromagnetic fields and simulate the antenna at high frequency range. It is capable to give a perfectly automated meshing for all electromagnetic device. There are two types are meshing available in CST. One is Tetrahedrons mesh analysis and another one Hexahedral mesh analysis. In this research, Tetrahedrons mesh has been used to solve the proposed antenna using simulation techniques. This mesh is a high frequency mesh. The proposed ring resonator antenna is divided into 90,647 mesh cells during simulation which is presented in Figure 2a and Figure 2b shows the solver results of meshing of the proposed antenna in CST software simulation. To solve mesh cells, this numerical software has been taken 12 s for matrix setup time, 35 s for solver setup time, 6 s for solver time and total time had taken as 53 s. Also it took iterations to solve the mesh cells for the proposed antenna.

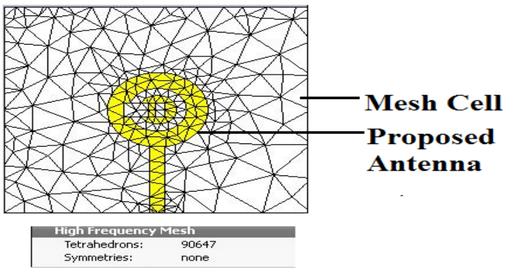

Figure 2a: Tetrahedrons Meshing

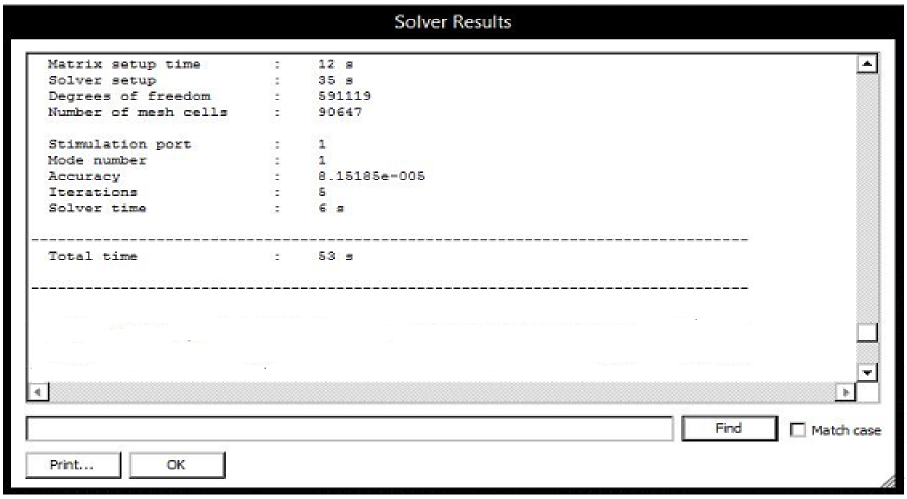

Figure 2b: Solver Results

4. Results and Discussions

Return loss

The mid frequency is chosen as the one at which the return loss is least. Figure 3 displays the return loss of S_{11} parameters for the proposed ring resonator antenna. The proposed antenna resonates at two frequencies of 8.98 GHz and 11.64 GHz and it is the operating frequencies of the proposed antenna. This is because, one frequency

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band introduced for ring resonator and another frequency band occurred for slot in D-shape. The two frequencies are operated in X band applications. The X band covers the frequency range from 8 GHz to 12 GHz. For both operating frequencies, the return loss of S_{11} is below -10 dB. The return loss is -10.36 dB and -19.15 dB for the frequencies 8.98 GHz and 11.64 GHz, respectively.

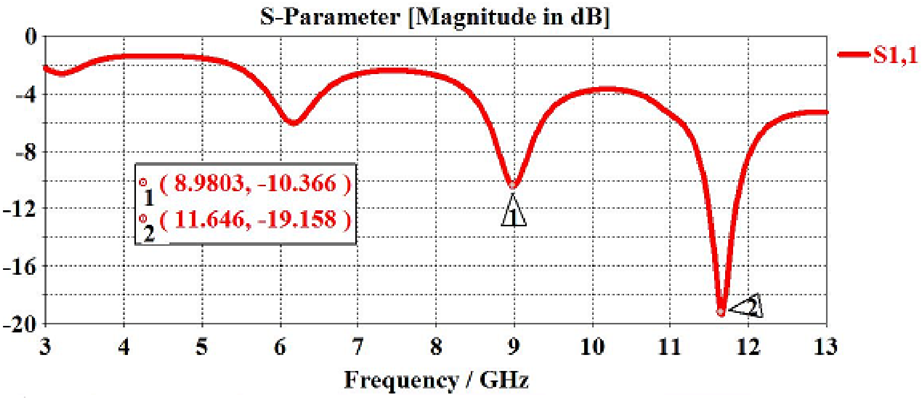

Figure 3: Return Loss

Voltage Standing Wave Ratio (VSWR)

Figure 4 shows the graph of VSWR versus frequency of the simulated proposed antenna. In Figure 4 VSWR should lie in the scope of 1-2 which has been accomplished for both frequencies of 8.98 GHz and 11.64 GHz. The below graph in Figure 4 shows the plot of frequency versus VSWR and the VSWR is 1.8 and 1.2 for the frequencies 8.98 GHz and 11.64 GHz, respectively and it is acceptable range of <2.

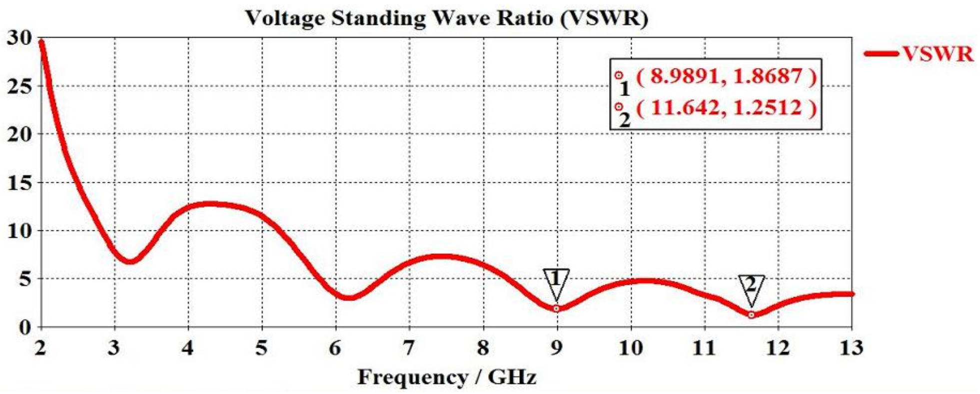

Figure 4: VSWR

Radiation Pattern

The radiation pattern of the proposed antenna is normal to its radiating element surface. The elevation of radiation pattern of E field Cartesian plot has been drawn with respect to $\varphi = 0^0$ and $\varphi = 180^0$. The elevation of H field Cartesian plot has been drawn with respect to $\varphi = 90^0$ and $\varphi = 270^0$. For E fields, the main lobe magnitude is 4.82 dBV/m for frequency 8.98 GHz and the main lobe magnitude is 13.7 dBV/m for frequency 11.64 GHz. For H fields, the main lobe magnitude is -36.8 dBA/m for frequency 8.98 GHz and the main lobe magnitude is -35.1 dBA/m for frequency 11.64 GHz. Compare to both the frequency, the main lobe magnitude is highest at 11.64 GHz frequency. In practical, there is a small amount of radiation in back lobes. But, in main lobes, the antenna delivers more amount of radiation power. The radiation pattern of E fields are shown in Figures 5 & 6 and the radiation pattern of H fields are presented in Figures 7 & 8.

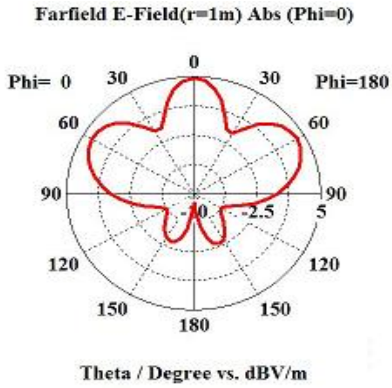

Figure 5: Radiation Pattern – E Field at 8.98 GHz

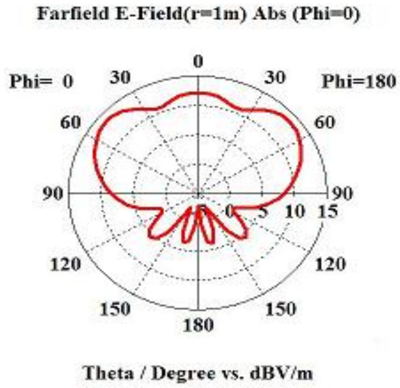

Figure 6: Radiation Pattern – E Field at 11.64 GHz

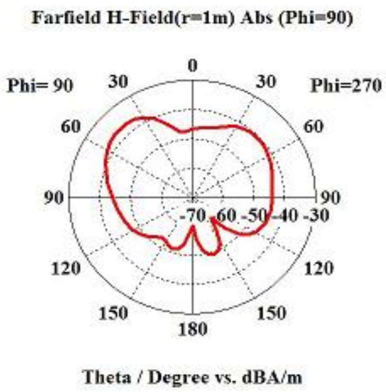

Figure 7: Radiation Pattern – H Field at 8.98 GHz

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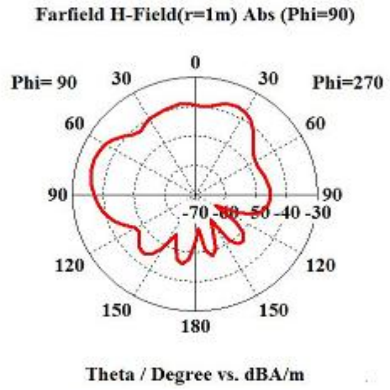

Figure 8: Radiation Pattern – H Field at 11.64 GHz

Gain

The gain of the proposed antenna is depicted in Figures 9 & 10. From the Figures 9 & 10, the gain of the antenna is highest at the frequency 11.64 GHz than the frequency 8.98 GHz. The gain of the antenna is 3.1 dB and 5.47 dB at frequencies 8.98 GHz and 11.64 GHz, respectively.

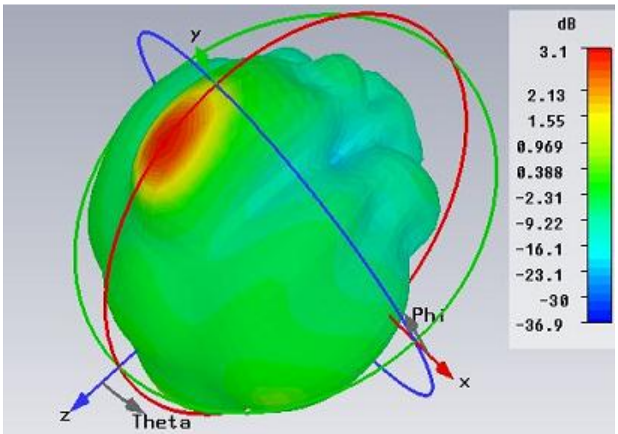

Figure 9: Gain at 8.98 GHz

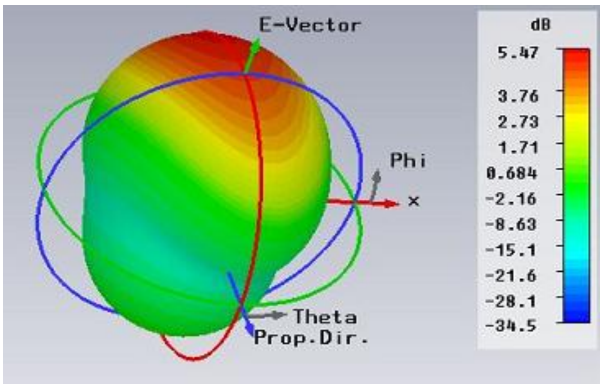

Figure 10: Gain at 11.64 GHz

5. CONCLUSION

A novel circular ring resonator with D shape antenna has been designed and simulated mathematically using numerical simulation software. The antenna excited by 50 ohms impedance characteristic. The back lobe radiation of the proposed is reduced because of the fully ground plane is used. Also, the moderate gain of 3.1 dB and 5.47 dB are obtained. The proposed antenna covers dual band applications on X band. Recently, All types of antennas have been broadly utilized in portable interchanges, radio ,TV, radar navigation, satellite meteorology, distant detecting and various fields. Antennas are used in numerous attributes of develop science and it is applied in dynamic field. Hence, this proposed antenna is a suitable candidate in the dynamic field of technologies.

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