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Design and Analysis of a Metamaterial based Tri band Second Iterative Compact Fractal Antenna for L, S and C Band Applications

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Abstract— *In this paper, the design of a Compact Fractal antenna with only two iteration with the help of metamaterials is designed. The overall size of the antennas is only of 35×35×1.6mm the dielectric substrate used is Rogers RT/Duroid 5880 with dielectric constant 2.2. The first and second iteration of fractal geometry are designed based closed loop wire antenna model and the metamaterial incorporated here is a dual bent inter digital capacitance based metamaterial which gives combinations of inductance and capacitance variations to effectively manipulate the electromagnetic waves that interacts with it. The tuning of this metamaterial structure will provide tuning antenna to variety range of operating frequencies and also provide reconfigurable radiation. The proposed metamaterial based fractal antenna works at multiple bands around 2, 2.2 & 4.5GHz bands covering L, S, and C bands. The comparative analysis of first and second iterative fractal antenna with proposed metamaterial is presented with the help of return loss, current distribution, radiation pattern, efficiency and other antenna parameters.*

Keywords—Compact antenna, Fractal antenna, metamaterial, Multi band

I. INTRODUCTION

Now a days due to the vast technical advancements in modern communication systems and the new manufacturing developments the designing of new antennas become easy and the need to create advance reconfigurable antennas is very high. And the main consideration in these antennas is to reduce the size of the antenna considerably without effecting the antenna performance. Various methods have been implemented over the years to make the antenna compact and miniaturized. Fractal antennas are very useful in designing miniaturized compact antennas the fractal geometry helps us to reduce the size by yielding good results with less material needed for printing. And another useful structure is using the metamaterial based structures to reduce the antenna size material proved to be useful in several applications of antenna. A compact multi band antenna is designed for wireless applications in [1]. A compact dual band antenna is designed using meander lines for WiMax applications in [2]. A Compact Wideband Fractal-Based Planar Antenna with Meandered Transmission Line for L-Band Applications is designed in [3]. A compact complementary fractal antenna is designed for UHF applications in [4]. Sierpinski Geometry is used to design compact fractal antenna [5-7]. A compact tapered slot antenna for GPR applications is designed in [8]. similarly metamaterials also proved to be very effective in antenna applications[9] and reducing the antenna size as they can manipulate the electromagnetic waves in unique way some previous mentions of metamaterials in designing compact antennas are, a compact quad band antenna is designed using metamaterial in[10]. Another compact antenna for UWB applications designed with MM in [11].

In our Current work, the antenna is designed using fractal geometry and the ground is printed by using the dual bent inter digital capacitance based metamaterial to have compact tri band antenna which operates in L, S, and C bands.

II. PROPOSED ANTENNA DESIGN

The fractal Geometry of the proposed antenna is prepared by combination of four closed loops for each iteration the first and second iterations for the proposed compact fractal antenna is shown in the following Figure [1]. Here the fractal geometry of the antenna and the metamaterial design both are printed on a dielectric substrate Rogers RT/Duroid5880 of size 35mm×35mm×1.6mm size with dielectric constant 2.2.

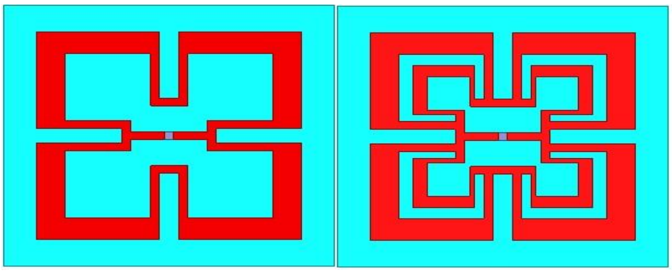

Figure [1] Design of the proposed Compact Fractal Antenna a) First iteration b) Second Iteration

Now for the proposed model the second iterative fractal antenna will have a designed dual bent inter digital fractal antenna to have lower resonance even though the antenna overall size is reduced considerably. Here the top and bottom views of the proposed compact fractal antenna and its design

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considerations are illustrated in the following Figure [2] and the Table 1.

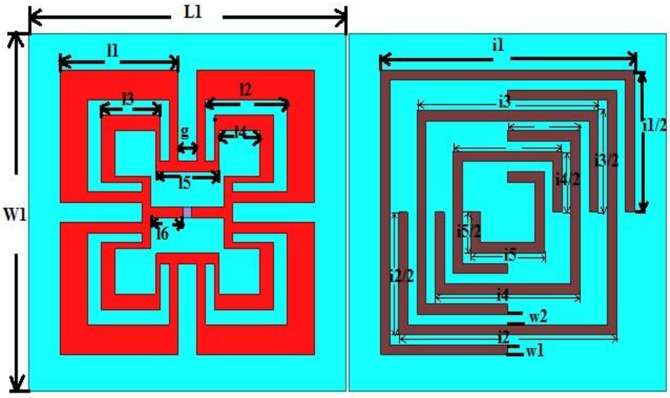

Figure [2] Proposed Compact Fractal Antenna a) Top View b) Bottom View

Table 1. Proposed antenna design parameters in mm

W1=16	L1=23	l1=12	l2=13	l3=1.6	l4=8
l5=3.7	l6=1	g=10	i1=7.5	i2=7	i3=5
i4=5	i5=1				

III. METAMATERIAL REFLECTION AND TRANSMISSION CHARACTERISTICS

The proposed Dual bent inter digital capacitance based metamaterial is analyzed with the help unit cell setup to check the reflectionS_{11} and transmissionS_{12} characteristics. The unit cell setup for the analysis is presented in the following figure [3] and its S_{11} and S_{12} characteristics are illustrated in Figure [4].

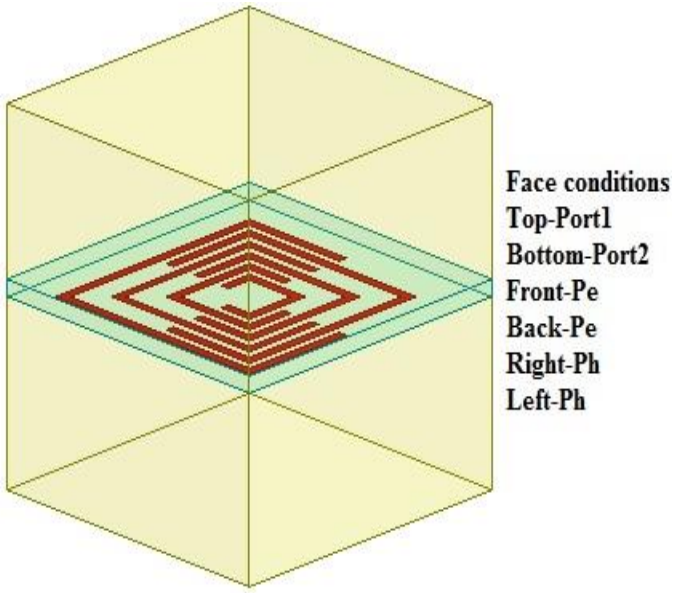

Figure [3] Unit cell setup for Proposed Metamaterial

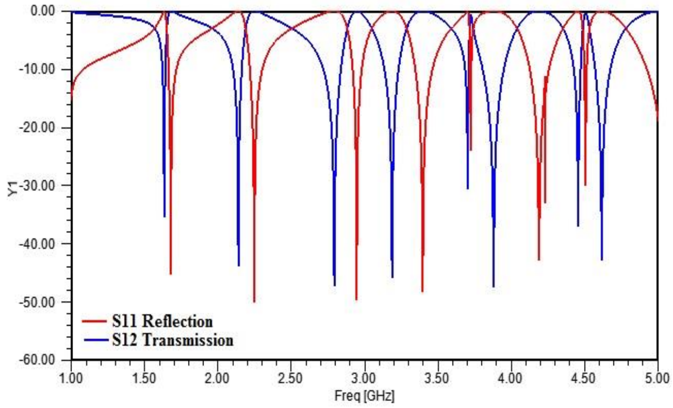

Figure [4] S_{11} and S_{12} Comparison for Proposed Metamaterial Structure

From the above Figure [4] data we can see that at some bands the resonance between the S11 and S12 is vice versa i.e the bands at which the S11 is maximum and S12 is minimum there the metamaterial reflects the back ward energy upwards and this will be added to forward energy improving the radiation and similarly the reverse characteristics will have opposite effect.

IV. SIMULATED RESULTS AND DISCUSSION

1st Iteration:

For the first Iteration mentioned in the Figure [1] the return loss comparison for without MM and with MM is presented in the following Figure [5].

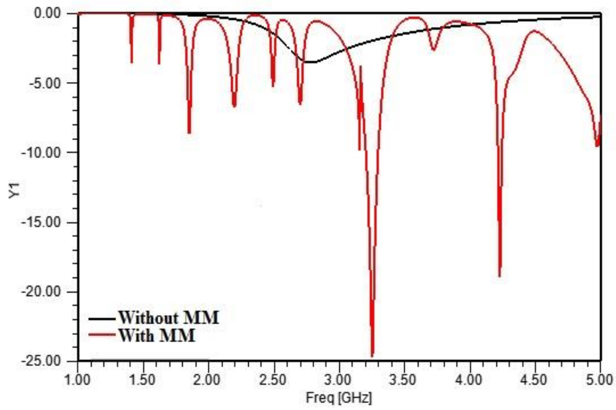

Figure [5] The return loss comparison curve for the first iteration without and with MM.

From the above figure we can see that without MM i.e without any ground plane backing the dielectric the loss is high in the lower resonance of 1-5GHz band this may have higher resonance around 10GHz due to its compact size. In order to get the resonance in lower frequency bands 1-5GHz we incorporated a designed dual bent inter digital capacitance based metamaterial. This MM will make the antenna resonant at multiple bands and it's also capable of tuning. from the figure data the first iteration with MM have two operating

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bands at 3.25Ghz and 4.2 GHz with return loss -24.6dB and -18.94dB respectively.

Now at the operating frequencies the 3D radiation plots, Current distribution, radiation patterns are illustrated in the following Figures [6,7, &8].

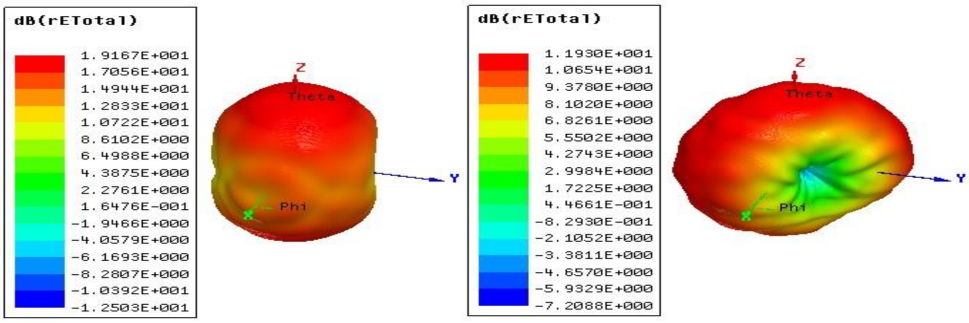

Figure [6] 3D radiation plot for first iteration a) at 3.25GHz and b) at 4.2GHz

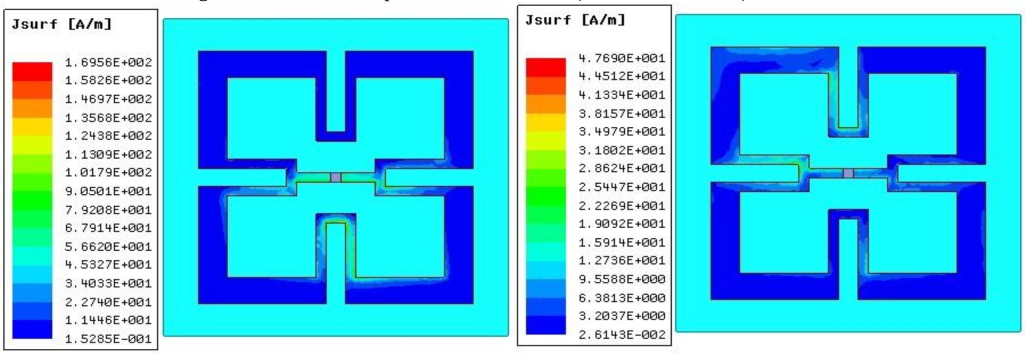

Figure [7] Current distribution for first iteration a) at 3.25GHz and b) at 4.2GHz

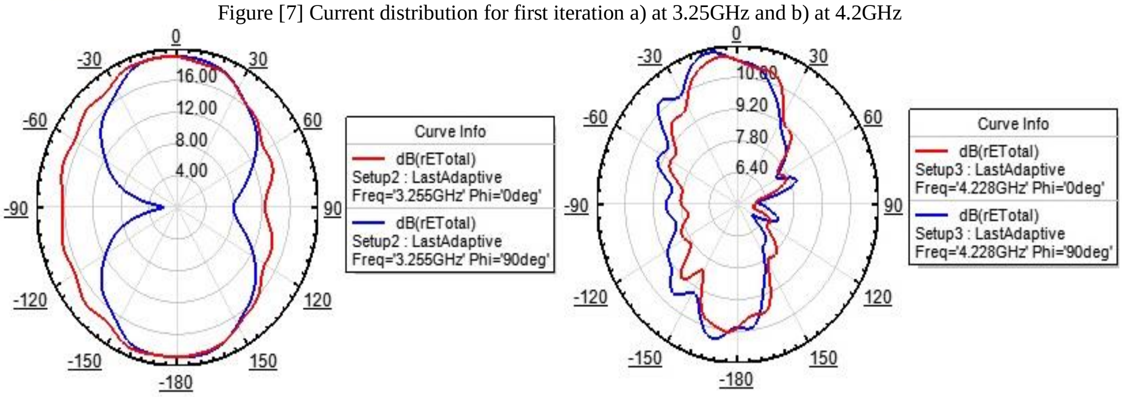

Figure [8] Radiation Pattern for first iteration a) at 3.25GHz and b) at 4.2GHz

2nd Iteration: The proposed Compact Fractal antenna

Now similarly the Proposed Compact fractal antenna will be analyzed without MM and with the proposed dual bent inter digital capacitance based metamaterial here without MM the fractal geometry shows high losses at lower resonance and it can be made resonate at lower resonance with the help of the proposed MM here the significance of MM is to tune the antenna to lower resonance while improving the antenna performance i.e. if we make the antenna size compact that means it will normally resonate at higher frequencies because if we design antenna for lower resonant frequencies then the size will be high we cannot have the compact antenna here the metamaterial played key role in achieving the lower operating frequencies with low size. The figure [9] Shows the return loss comparison of the proposed second iterative fractal antenna without MM and with MM here the antenna operates at tri bands with MM at 1.98GHz, 2.2GHz and 4.567GHz covering L, S, C bands with return loss -24.42dB, -14.88dB and -21.6dB respectively.

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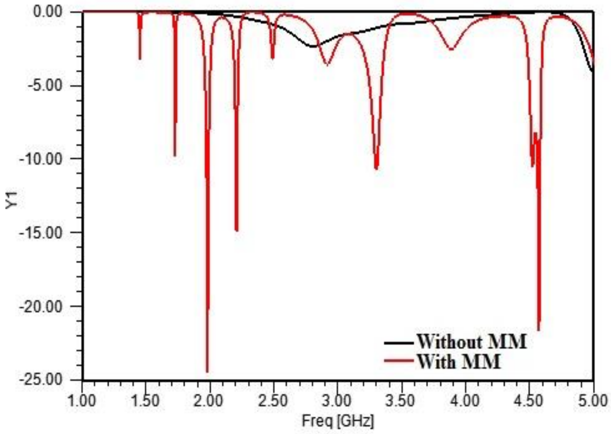

Figure [9] The return loss comparison curve for the Proposed Fractal antenna without and with MM.

The 3D radiation, current distribution, and radiation patterns at 1.98, 2.2, & 4.56GHz for the proposed compact fractal antenna with MM are presented in Figures [10,11, & 12].

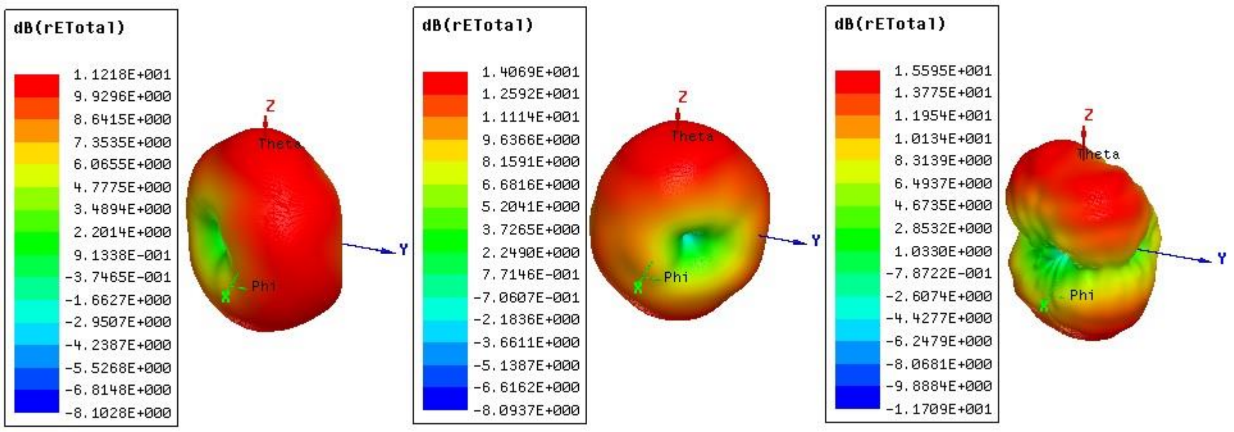

Figure [10] 3D radiation plot for Second iteration a) at 1.98GHz and b) at 2.2GHz and c) at 4.56GHz

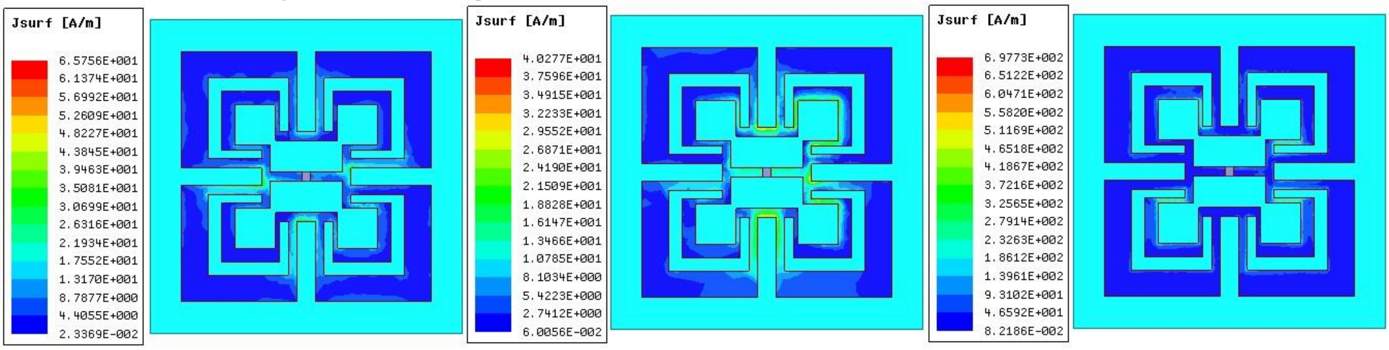

Figure [11] Current Distribution for second iteration a) at 1.98GHz and b) at 2.2GHz and c) at 4.56GHz

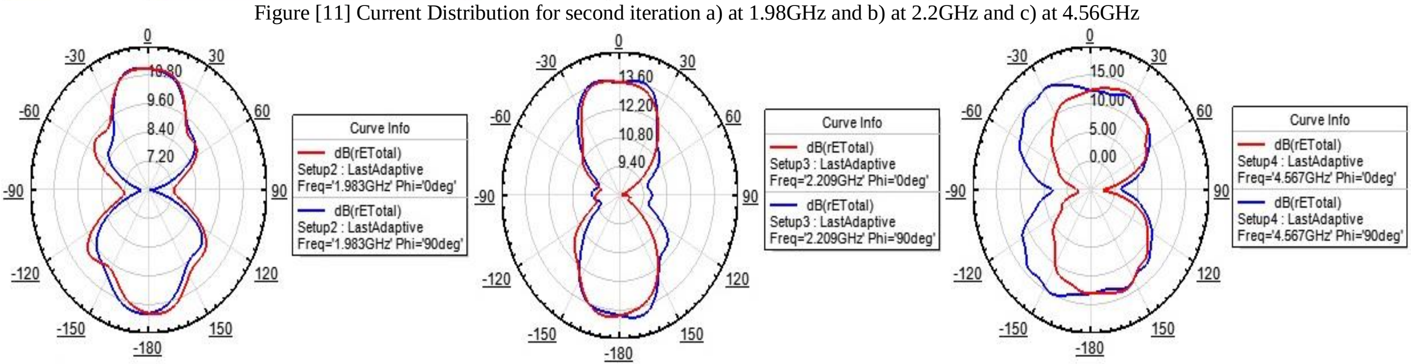

Figure [12] Radiation pattern for second iteration a) at 1.98GHz and b) at 2.2GHz and c) at 4.56GHz

V. COMPARITIVE ANALYSIS

Table 2. Frequency and return loss

S.no	Item	Iteration-1		Iteration-2		
1	Frequency	3.25GHz	4.2GHz	1.98GHz	2.2GHz	4.56GHz
2	Return loss	-24.64dB	-18.94dB	-24.42dB	-14.88db	-21.60dB

Table 3.Antenna Parameters Comparison

S.No	Quantity	Iteration - 1		Iteration - 2		
		3.25GHz	4.2GHz	1.98GHz	2.2GHz	4.56GHz
1	Max U	109.477433 mW/sr	20.682601 mW/sr	17.554445 mW/sr	33.849498 mW/sr	48.096730 mW/sr
2	Peak Directivity	2.455042	2.084767	1.717289	2.185667	3.368651
3	Peak Gain	2.588032	2.180418	1.759925	2.212757	3.098455
4	Radiation Efficiency	1.054170	1.045881	1.024827	1.012394	0.919791

VI. CONCLUSION

The proposed compact fractal antenna with size 35mm×35mm×1.6mm is designed and it operates at tribands 1.98GHz, 2.2GHz and 4.567GHz covering L, S, C bands with return loss -24.42dB, -14.88dB and -21.6dB respectively. Both first iteration and the second iteration of the fractal antenna showed good performance the comparative Table 2 and 3 illustrates the operating frequencies and their respective performance comparison both the fractal and metamaterial combination allowed us to design a compact antenna for lower frequency bands covering L, S and C bands.

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