RESEARCH ARTICLE

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Hybrid Fractal Boundary MIMO Antenna for Multiband Applications

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Abstract

A novel 2×2 MIMO antenna using crown square curve and koch curve is proposed and designed on RT/duroid having thickness of 3.175mm, loss tangent of 0.0009 and dielectric constant of 2.2, by employing MoM based IE3D software. In this geometry, koch curve is etched at the boundary of the iterated crown square patch antenna to produce a fractal boundary and fractal elements are placed parallel to each other at an inter-element distance of 25mm for good isolation. The resulting MIMO system operating at four resonating frequencies, gives much higher gains and bandwidths for all the operating frequencies. Furthermore, it exhibits impedance bandwidth (S_{11}Â 5 10dB) with isolation better than -15dB, which are accepted threshold values for the MIMO systems. Hence, a good MIMO antenna is designed giving excellent output characteristics.

Keywords: MIMO antenna, hybrid fractal, crown square curve, koch curve.

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Introduction

In the age of digitization, there has been a dramatic rise in network bandwidth demand as more and more wireless users are switching towards the smart devices and demanding higher quality network services. As a result of the advancement in wireless technologies, high speed communication has become the dire need for all users. However, today all wireless technologies possess some setbacks. To exemplify, signal fading, multipath, increasing interference and limited spectrum; and hence, it has driven the deployment of MIMO technology in wireless networks. MIMO stands for Multiple Input Multiple Output. It is a radio communications technology which involves multiple antennas at transmitter and receiver ends. Multiple antenna configurations can be wielded to subdue the conflicting effects of multipath and fading. MIMO technology takes advantage of multipath to yield higher throughput [1], together with an increase in range and reliability of networks without dissipating extra radio channel frequency. MIMO's ability to increase the channel capacity has made it a core component in various wireless technologies and communication standards like IEEE 802.11n (Wi-Fi), 4G, 3GPP, LTE, WiMAX [2].

Literature Review

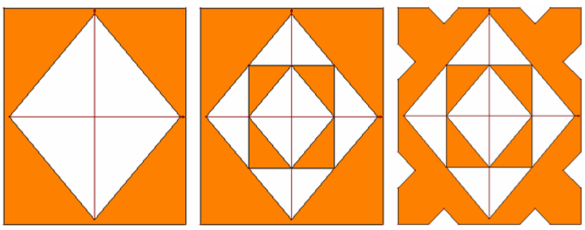
Tripathi et al. in [3] designed a compact koch fractal MIMO antenna resonating in the range of 2GHz-10.6GHz, providing return loss and isolation better than -10dB and -17dB respectively. Authors in [4] evaluated the behavior of a hybrid fractal antenna using koch and minkowski curves, operating at

2.45GHz, 3.85GHz and 4.45GHz. It gives return loss values of -12.44dB, -14.95dB and -15.21dB and gain values of 6.80dBi, 5.69dBi and 3.08dBi at respective resonating frequencies.[5] propounded the prototype of a miniature MIMO antenna using altered dragon curve and inverted Koch curve, resonating at 433MHz, 2.4GHz, 3.9GHz, 4.7GHz and 5.8GHz. The antenna exhibits S_{11}< -10dB and S_{12}< -16dB for all the operating frequencies. The authors in [6] proposed a combination of minkowski and koch curves for designing a MIMO antenna operating in the 1.65GHz-1.9GHz and 2.68GHz-6.45GHz bands, with maximum gains of 2dBi and 7dBi and isolation below -10dB and -15dB in the two bands respectively.

Proposed Antenna Design

Design of Hybrid Fractal Boundary Antenna

For designing a MIMO antenna system, a hybrid fractal antenna element having high gain and low return loss value is required. Fractal properties, in particular, self-similarity and space filling are utilised to design the geometry. For this, a novel fractal geometry inspired from the crown square geometry [7] is designed. Post that, a koch curve is appended as the fractal boundary at the edges of the geometry. Fig.1 illustrates the three iterations of the hybrid fractal boundary antenna element.



0^{th} Iteration 1^{st} Iteration 2^{nd} Iteration

Figure 1: Three Iterations of Hybrid Fractal Boundary Antenna Element

The propounded antenna is designed on RT/duroid 5880 substrate with thickness = 3.175mm, dielectric constant = 2.2 and loss tangent = 0.0009. Out of different feeding techniques, co-axial probe feed is adopted to feed the antenna. The feed point of the antenna structure is selected using trial and error method to determine the best optimum results. The base geometry of the proposed antenna consists of a rectangular patch of Length (L) = 69.3mm and Width (W) = 78.4mm. Here, a slot is produced by subtracting a rectangle which is rotated by 45° from the rectangular patch, such that each vertex of the slot is at a distance of 2mm from its respective edge of the patch. In the first iteration, the above geometry is repeated by inserting a rectangle inside the slot in such a way that the vertices of the rectangle touch the mid-points of the corresponding edges. Following that, a slot is carved out and then, koch curve shown in Fig. 2is etched at the boundary of the fractal antenna

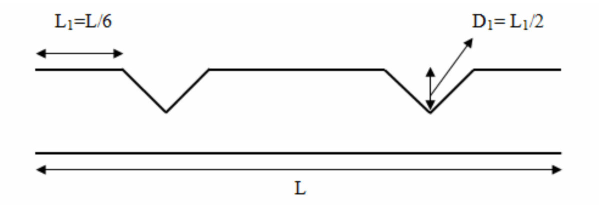


Figure 2: Koch Curve

obtained in the first iteration which results in the second iteration,

The dimensions of the curves used in second iteration are derived by dividing the Length (L) and Width (W) into six equal parts. Next, the values, L_1 = L/6 = 11.55mm, W_1 = W/6 = 13.066mm, D_1 = L_1/2 = 5.775mm and D_2 = W_1/2 = 6.533mm are obtained using the MATLAB program.

Design of Two-Element MIMO Antenna

Two identical hybrid fractal antenna elements are placed parallel to each other at an inter-element distance (d) of 25mm on the single RT/duroid substrate as shown in Fig.3.The two antenna elements are fed at matched feed points to minimize the return losses. In the proposed antenna, the elements are fed at (10.5, 26.5) and (104.8, 26.5) respectively. Feed is given at a horizontal distance of 24.15mm from the right side of the antenna edge and at a vertical distance of 26.5mm in both the elements.

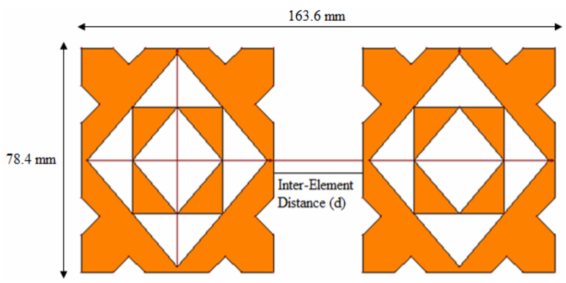


Figure 3: Spatial Arrangement of Fractal Antenna Elements for MIMO System

RESULTS AND DISCUSSIONS

First and foremost, a new hybrid fractal boundary antenna up to three iterations (0^{th}, $1^{st}$and 2^{nd}) is designed using IE3D software. The simulated results of base geometry, the first iteration and the second iteration of the proposed antenna element are analysed and compared. After this, the dual-element MIMO antenna system is designed and simulated for 2GHz–4GHz frequency range using the same designed antenna element. Subsequent to this, deviations in responses of a fractal antenna element and MIMO antenna are studied by comparing the simulation results of with different parameters such as field gain, return loss (S_{11} or S_{22}), isolation (S_{12} or S_{21}), etc.

Comparisons of Simulation Parameters of Three Iterations

As mentioned in Table 1, it is evident that the second iteration geometry gives the highest values of return losses i.e. -28.29GHz, -24.60GHz and -14.24GHz at the three frequency bands. It is exhibiting the peak bandwidth value of 40.24MHz at the resonant frequency of 3GHz. The return loss curve and the total field gain curve of the second iteration geometry of the fractal antenna are illustrated in Fig.4.

Table 1: Comparisons of Performance Parameters of Three Iterations

Performance Parameters	Resonant Frequencies (GHz)								
	0^{th} Iteration			1^{st} Iteration			2^{nd} Iteration		
	2.50	**2.88**	**3.06**	**2.50**	**2.88**	**3.08**	**2.42**	**3**	**3.20**
Return Loss (dB)	-20.01	-11.58	-14.43	-17.92	-10.39	-13.99	-28.29	-24.60	-14.24
Gain (dBi)	6.22	6.74	4.24	6.18	3.30	5.25	4.80	5.88	5.46
Bandwidth (MHz)	38	30	45.5	40.5	5.6	43.9	35.8	40	35

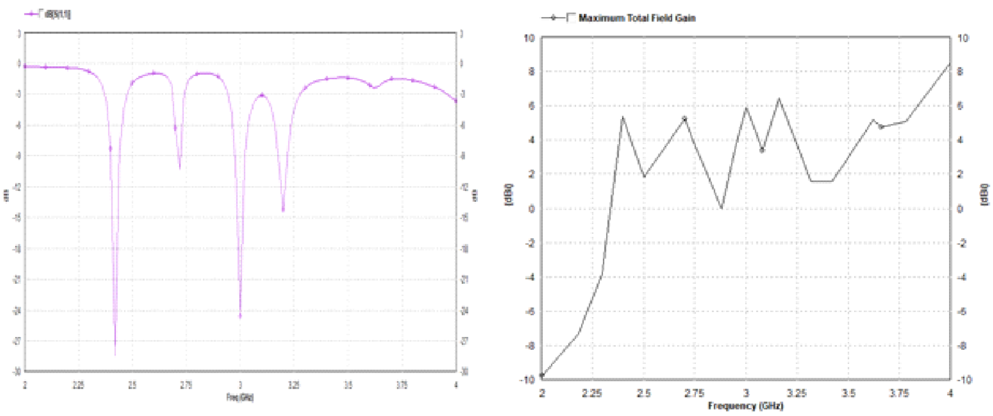


Figure 4: Return Loss Curve and Total Field Gain Curve for Second Iteration Geometry

Comparison of Fractal Antenna Element and MIMO Antenna

Table 2 delineates that the designed MIMO antennais resonating at 2.42GHz, 2.72GHz, 3GHz and 3.20GHz while the single antenna is resonating at 2.42GHz, 3GHz and 3.20GHz. The proposed MIMO antenna is giving higher values of return losses and higher values of gains are obtained i.e. 9.04dBi, 7.07dBi, 6.50dBi and 7.14dBi at the respective frequencies, as compared to the single antenna system, where a maximum value of 5.88dBi is obtained at 3GHz. Upper limit of bandwidth is also increased from 40.24MHz to 41.83MHz in designing the MIMO system. Eventually, the designed two-element MIMO antenna system has all the characteristics better than a single antenna. Hence, it provides a better functionality. The simulated results of the proposed MIMO antenna are shown in the Fig.5 below.

Table 2: Performance Parameters of MIMO Antenna

Performance Parameters	Resonant Frequencies (GHz) 2.42	2.72	3	3.20
Return Loss ($S_{11} = S_{22}$) (dB)	-27.53	-12.41	-19.38	-13.67
Isolation ($S_{12} = S_{21}$) (dB)	-24.41	-11.02	-16.39	-16.97
Gain (dBi)	9.04	7.07	6.50	7.14
Bandwidth (MHz)	36.6	11.76	41.83	33.98

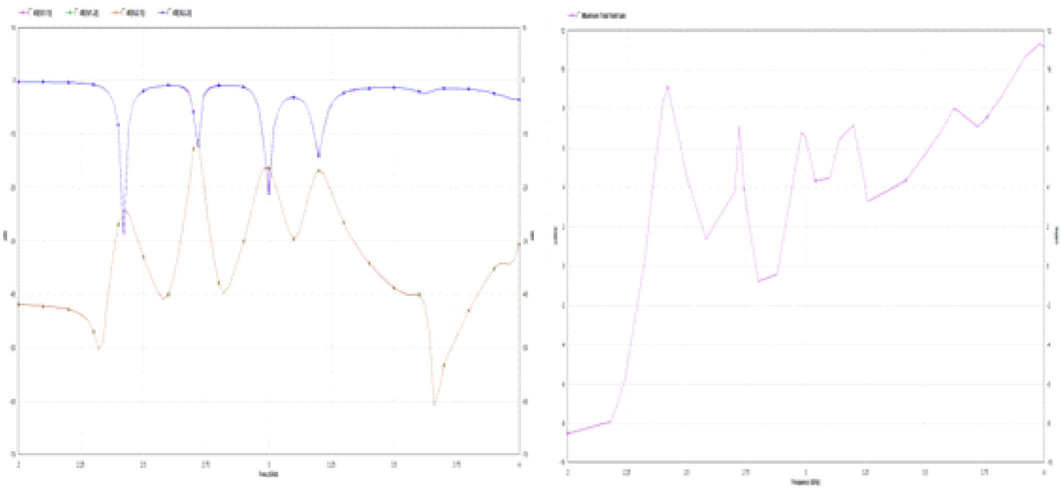


Figure 5: Return Loss/ Mutual Coupling andTotal Field Gain Curve for MIMO Antenna

Conclusions

A novel hybrid fractal boundary MIMO antenna is modelled. We have compared the single-element fractal element system and the dual-element MIMO antenna system and found that the proposed MIMO antenna resonates at 2.42GHz, 2.72GHz, 3GHz and 3.20GHz with return loss values of -27.53dB, -12.51dB, -19.38dB and -13.67dB and isolation values of -24.41dB, -11.02dB, -16.39dB and -16.97dB at the respective resonant frequencies. The comparisons of a single-element and the two-element antenna systems show that the MIMO system is advantageous owing to its better performance as it exhibits higher gains and bandwidths. Also, it gives improved return losses and mutual coupling.Hence, this is a viable MIMO antenna system that can be used for multiband applications.

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