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Design of a MIMO Antenna using Fractal Shape Monopole for Wi-Fi, WLAN and Satellite Communication Applications

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Abstract: This paper investigates the development of two compact fractal Multiple-Input-Multiple-Output (MIMO) antennas with an improved isolation. The MIMO antenna structures consist of two monopoles which are mirror image of each other. The fractal geometry in monopole is used to improve the effective path length. The antennas show triband characteristics with respect to impedance bandwidth. These MIMO antennas have dimensions of 43 x 47 x 1.6 mm^3 with two different stub designs at ground plane. One antenna has simple slots in ground plane and while the other antenna has H-shaped slot in ground plane. These stubs helped to achieve isolation between two monopoles. The results show that both antennas are good candidates for WLAN, Wi-Fi and satellite communication applications.

Keywords: Multiple-Input-Multiple-Output (MIMO), Fractal, triband, Isolation

I. Introduction

Microstrip antennas and UWB antennas have attracted lot of researchers due to their integral benefit of low profile and broadband characteristics [1] therefore being able to be easily utilized in compact wireless communication systems. At the same time, Multiple Input Multiple Output (MIMO) antennas are in demand as today's world needs compact and reliable communication devices. The use of MIMO systems significantly improved the system performance with respect to system capacity. But MIMO systems are required to keep balance between attaining compact size and ensuring low mutual coupling. To achieve this objective, several techniques like use of Slitted patterns, use of unique designs of stubs, DGS, placing antenna elements perpendicular to each other, diagonal feed, etc. have been tried.

A. Literature Review

Fractal antennas are also popular because of its miniaturization property. The combination of Fractal geometry with MIMO system makes the antenna more efficient in terms of size and performance. To improve the performance, various methods are used to reduce the mutual coupling in MIMO like, A UWB MIMO CPW fed antenna with slot and band notch characteristics is realized, here to reduce the mutual coupling, a Minkowski fractal stub has been placed at 45^0 between the monopoles [3]. The theory of characteristics mode is used in a planar ultra-wideband multi-input multi-output antenna with pattern diversity and isolation improvement [4]. Slot-line-based, 4 element pentagonal MIMO antenna system is discussed. This design was a tri-band antenna system with an ultra-wide tuning capability [6]. The technique of bending the feed line and using a protruded ground is introduced in planar rectangular monopole mimo antenna [8] because of which low frequency isolation is achieved [10]. A novel complementary

Sierpinski gasket fractal antenna for high data rate 4G/5G mimo applications is discussed. The defected ground is used for improving antenna performance. The 8 shaped fractal MIMO antenna up to second iteration is presented [11] for improving isolation and increase in impedance bandwidth, a ground stub and vertical slots were cut on stub. A band notch feature is embedded in a fractal shaped MIMO antenna by etching split ring rectangular resonating structures [12]. The antenna has impedance bandwidth from 3.1 to 11.1 GHz with band notch feature centered around 3.5 GHz.

In this paper, the design of fractal MIMO antenna up to second iteration is discussed. For improvement in isolation, two techniques were presented. Details of design steps and Results with both techniques like S_{11}, S_{21} parameters and ECC values at different frequency values are reported.

II. Antenna Design

A. Antenna Configurations

MIMO fractal antenna designs with two different stub techniques have been developed. The geometries of proposed antennas are illustrated in Fig. 1. The primary fractal curve, initiator is created with outer radius 10.2 mm and is calculated by considering circular UWB monopole antenna for both the geometry designs. The FR-4 substrate with relative dielectric constant 4.4, loss tangent 0.02 and thickness of 1.59 mm is used. The proposed antenna is designed up to two iterations with iteration factor 0.8 and 0.6. The radius values for first and second iterations are calculated as,

$$I_1 = I \times m_1$$
$$O_1 = O \times m_1 \quad (1)$$

Where m_1 (iteration factor for first iteration) = 0.8

ie. $I_1 = 5 \times 0.8 = 4$ mm

$O_1 = 10.2 \times 0.8 = 8.16$ mm

$$I_2 = I \times m_2$$
$$O_2 = O \times m_2 \quad (2)$$

Where m_2 (iteration factor for second iteration) = 0.6

ie. $I_2 = 5 \times 0.6 = 3$

$O_2 = 10.2 \times 0.6 = 6.12$

I, I_1 and I_2 are inner circle radius and O, O_1 and O_2 are outer circle radius. The optimized value for O_1 and O_2 used in proposed geometry are 8.2 mm and 6.2 mm.

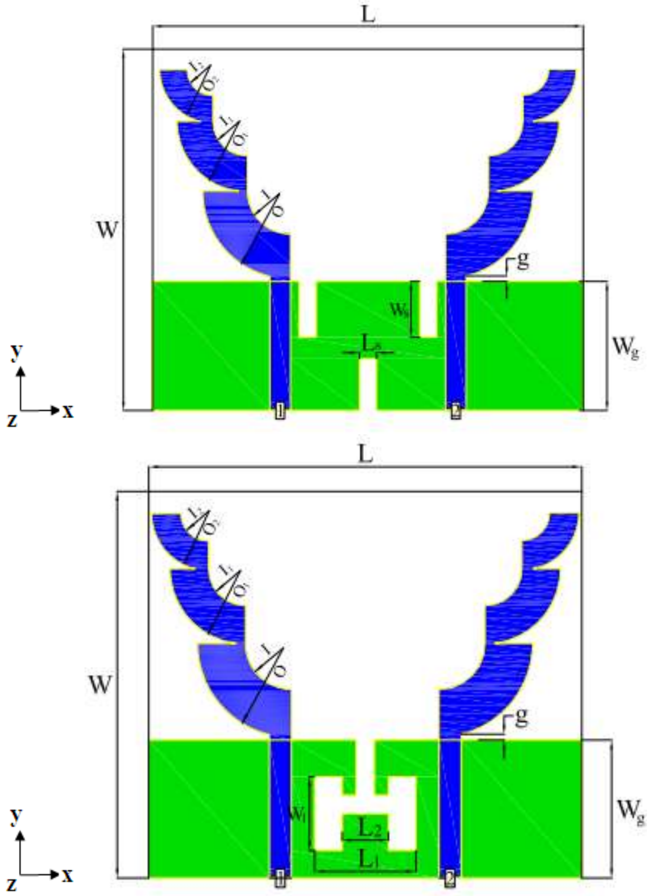


Figure 1. Antenna Geometries (a) Fractal MIMO antenna with three rectangular slots in ground plane(b) Fractal MIMO antenna with H-shaped slot in ground plane.

Table 1. Optimized Dimensions of the Proposed Antenna

Parameter	Dimension	Parameter	Dimension
L	43 mm	I_2	3 mm
W	47 mm	O_2	6.2 mm
L_g	43 mm	g	0.4 mm
W_g	15 mm	L_s	2 mm
I	5 mm	W_s	6.5 mm
O	10.2 mm	L_1	11 mm
I_1	4 mm	W_1	8 mm
O_1	8.2 mm	L_2	5 mm

Table 1 shows the dimensions of the proposed MIMO antenna geometries.

B. Effect of Stubs

The ground plane plays vital role on the performance of the antenna. The stubs shown in figure 1(a) and (b) enhance the isolation between antenna elements. This can be clearly observed from surface current distribution for the antenna geometries with both stub designs. When antenna is excited with port 1 and port 2 is terminated, then with rectangular stubs there is less coupling current exists on ground plane as well as at port 2 as compared to the current distribution with H- shaped stub. This is observed from surface current distribution diagrams shown in figure 2. Figure 3 demonstrates the antenna correlation nature for proposed MIMO antenna (50Ω termination) with rectangular stubs and H-shaped stubs, it is clearly observed that the antenna correlation (ECC) is less than 0.5 for frequencies 2 GHz onwards and the value is less for rectangular stubs compared to H-shaped stubs. So, it is confirmed that proposed MIMO antenna with rectangular stub design is more effective than with H-shaped stubs.

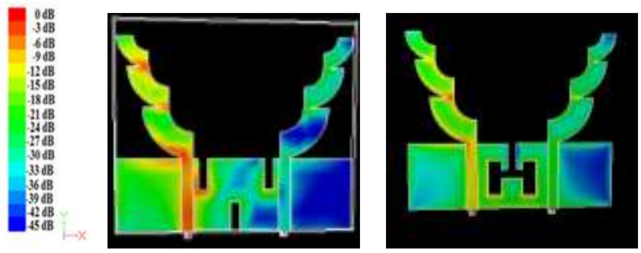


Figure 2. Surface Current Distribution a) Fractal MIMO antenna with three rectangular slots in ground plane b) Fractal MIMO antenna with H-shaped slot in ground plane

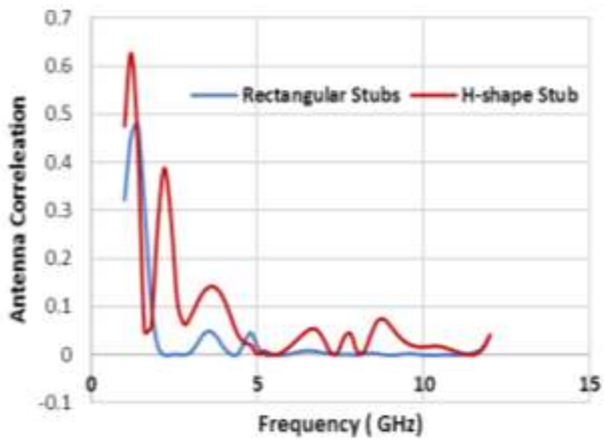
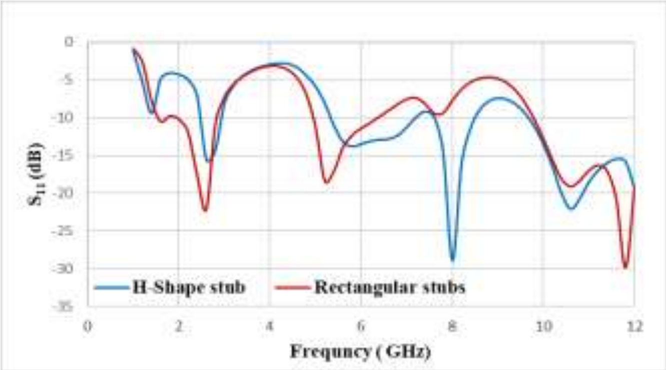


Figure 3. Simulated ECC plot for both stub designs

III. Results and Discussion

MIMO antennas are designed and simulated using method of moments based IE3D software. Due to fractal geometry and iterations the average electrical length increases resulting in multiband performance of the antennas. To reduce the mutual coupling between MIMO antennas, two types of stubs are used.

Figure 4 a) shows the S_{11} plots for proposed MIMO antennas with both stub designs and figure 4 b) shows S_{21} plots for the same.



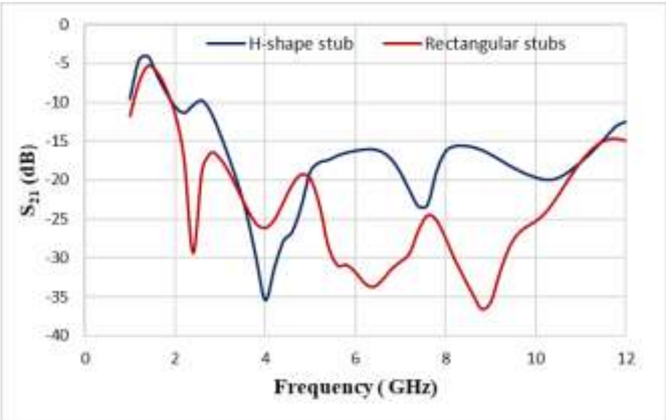


Figure 4. Simulated plots of (a) S_{11} plot for both proposed MIMO designs (b) S_{21} plot for both proposed MIMO designs

It can be seen from Figure 4, with H-shape stub design, proposed antenna has both S_{11} and S_{21} parameters less than -10 dB for frequency bands 2.46 -2.95 GHz, 5.31 -8.53 GHz and 9.62 Ghz onwards. Also, with rectangular stubs, proposed antenna has both S_{11} and S_{21} parameters both are less than -10 dB for frequency bands 1.54 – 2.86 GHz, 4.93 -6.41 GHz and 9.75 Ghz onwards. It can be observed that this antenna covers both ISM bands and finds applications for wifi, 4Gwimax, WLAN and satellite communication systems.

2-D radiation patterns at 2.6 Ghz, 7 Ghz and 9.8 Ghz are observed in Figure 5 for the MIMO antenna. Nearly omnidirectional radiation patterns are observed but at higher frequencies radiation patterns are getting weakened because of splitting of the radiation lobes and gain variation is less than 3 dB.

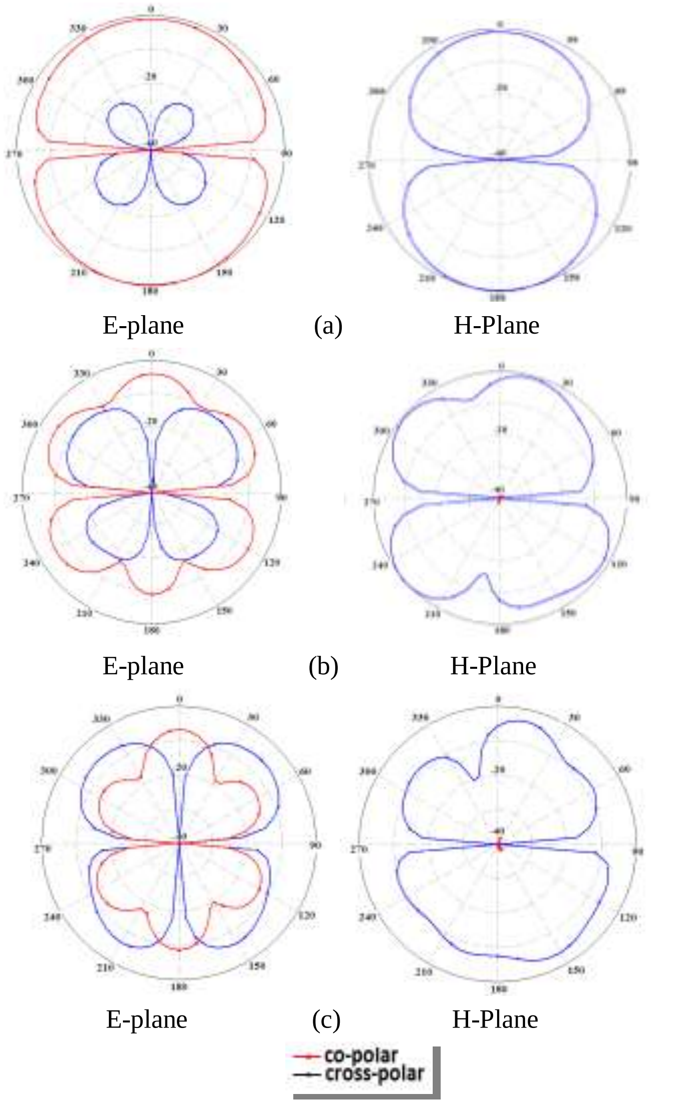


Figure 5. Simulated Radiation patterns for proposed antenna at (a) 2.6 GHz (b) 7 GHz and (c) 9.8GHz

IV. CONCLUSION

This work pertains to development of compact MIMO antenna using fractal shape monopole. By using two different stub techniques, the mutual coupling is reduced remarkably. It is observed that the antenna correlation (ECC) is less than 0.5 for frequencies 2 GHz onwards for both stub designs. From S_{11} and S_{21} plots it is seen that the proposed MIMO antenna is a good candidate for WLAN, Wi-Fi and satellite communication applications with compact dimensions.

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