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MULTIBAND RING SHAPED FRACTAL MIMO ANTENNA

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Abstract

A Ring shaped multiband fractal 2×2 MIMO antenna is proposed. The monopole antenna supports applications such as Bluetooth, GPS and PCS. The proposed antenna is fed with microstrip line feed. The antenna is designed with two different orientations 0° fractal ring antenna and 180° shifted fractal ring antenna. The antenna is simulated on 2D EM-simulator of ADS software. FR4 substrate is used and the overall size of the designed antenna is 70mm×45.3mm×1.6mm. The antenna is designed to operate for multiple frequencies with increase in gain, directivity, bandwidth and radiation efficiency. The 0 Fractal Ring configuration is better in terms of gain compared with 180 ring design.

Keywords:

Ring Antenna, MIMO, Fractal, Multiband

1. INTRODUCTION

Antennas are the first and the foremost part of the communication system. According to IEEE definition, "an antenna is a means for radiating and receiving radio waves". The rapid evolution in wireless technology the ability to communicate with people has evolved remarkably. MIMO (Multiple Input Multiple Output) is used for wireless communication. MIMO systems can achieve significantly higher data rate than SISO. MIMO is used to enhance the performance of a single data signal, such as beamforming and diversity. Fractals are geometric shapes that repeat itself over a variety of scale sizes so the shape looks the same when viewed at different scales. They can improve the performance of antenna and antenna arrays. Fractal arrangement can combine the robustness of a random array and the efficiency of a regular array, with a quarter of the number of elements. Fractal bridges the gap because they have short-range disorder and long- range order.

This paper attempts at designing a fractal antenna which resonates at multiple frequencies. It is designed to serve modern wireless service such as Bluetooth, Wireless Local Area Network (WLAN) and Personal Communication System (PCS). Measured results are presented to validate the antenna performance.

Many research works have been carried out to improve the gain and bandwidth of MIMO antenna. Firmansyah et al. [9] designed and analysed conventional MIMO antenna (C-MA), ring parasitic MIMO antenna (RP-MA), and circular parasitic MIMO antenna (CP-MA). Here the antenna is designed at a centre frequency of 2.5GHz on FR4 substrate. The overall size of the antenna is 50mm×130mm×23.2mm.

Srivastava et al. [4] addressed an O-shaped multiband monopole antenna under there different orientations (0°, 90° and 180°). The antenna resonates for multiband operation hence useful for wireless communication. The antenna is designed on FR4 substrate. The overall geometric dimension of the antenna is 60mm×50mm.

Yang et al. [6] presented a dual band Multiple Input Multiple Output (MIMO). The antenna configuration consists of three inverted F antennas (IFA's) loaded with lumped inductors designed by The antenna elements along with lumped inductor can cover GSM 1800/1900, UMTS2100 and LTE700/2300/2500 bands. Four L stubs are connected under the IFA's with the ground plane. The overall geometric dimension of the antenna is 140mm × 70mm × 1mm.

Malviya et al. [7] proposed 2×2 circularly polarised MIMO antenna with power divider which resonates at 5.8GHz IEEE 802.11 WLAN for NLOS communication. Here rectangular slots are etched at the centre of the patch. The proposed MIMO antenna covers 5.49-6.024GHz, the CP antenna achieves circular polarisation. The antenna is fabricated on FR4 dielectric substrate. The overall size of the antenna is 27.69mm×97mm [7].

Mitra et al. [10] proposed a compact two element MIMO antenna system for WLAN applications which resonates at 5.4GHz. Here Rogers RT Duroid 5880™ is used as a substrate. The overall size of the antenna is 30mm×50mm×1.6mm. Co-axial feeding is employed here.

Singh et al. [2] analysed the MIMO antenna system for compensating the users induced loss. The paper addresses the OTA performance of the MIMO antenna system and influence on OTA performance of LTE terminal. This paper addresses the reduction in total radiated power and total isotropic sensitivity of the MIMO antenna system is due to the introduction of extra antenna. The overall size of the antenna is 110mm×50mm×1mm.

Tu et al. [3] suggested a dual band MIMO system with enhancement in isolation and WLAN application. This MIMO resonates for two resonant frequencies 2.6GHz. 7GHz using Defected Ground Structure (DGS). The antenna is designed on FR4 Substrate. The antenna consists of 1×2 rectangular patches and two double rectangular DGS and 1×7 EBG structure between antenna elements. The overall size of the antenna is 24mm×17mm.

Babu and Anuradha [5] proposed a compact MIMO antenna for decreasing the mutual coupling as well as to increase the return loss. Here rectangular slots are made at the square patch. The antenna is suitable for WLAN application. The antenna resonated for multiband. This antenna is designed on FR4 substrate. The overall dimension of the antenna is 60mm×40mm.

Ali et al. [1] proposed a very compact size MIMO antenna. This antenna consists of two radiators with partial ground plane and is designed on FR4 substrate. The proposed antenna is designed with a decoupling structure for increasing isolation. Microstrip Multimode Resonator (MMR) is used as decoupling structure which acts as band stop filter. The overall size of the antenna is 4cm×4cm.

Pahadsingh and Sahu [8] designed a MIMO system using cylindrical Dielectric Resonator Antenna (CDRA). Two CDRA's are integrated on the radiator to form the proposed antenna. Tri-band operation is targeted using T feed microstrip. The antenna is on Roger substrate. The overall geometrical dimension of the antenna is 35mm×52.2mm. This integrated design is suitable for CR applications.

2. ANTENNA DESIGN

An O-shaped fractal multiband monopole antenna is designed with the following specifications. An O-shaped MIMO antenna is designed that envelopes the present day wireless communication application bands. The proposed antenna is uses FR-4 as substrate with relative permittivity ε_r = 4.4, thickness h = 1.6mm. The layout is as shown in the Fig.1. The antenna is simulated using ADS software. The outer radius of the fractal ring is calculated from,

$$R = \gamma/4 \quad (1)$$

The width of the ring is calculated to be 3mm to match the 50 ohm impedance.

$$\gamma = \frac{c}{f\sqrt{n_r}} \quad (2)$$

$$n_r = \frac{\varepsilon_r + 1}{2} \quad (3)$$

where,

c - velocity of light in vacuum

f - resonating frequency

n_r - relative permittivity of the substrate

R - Radius of the ring

Using the above formulas each ring is designed to resonate at different frequencies. Here O-shaped fractal antenna is designed with different orientations. The first ring resonates at 2.8GHz, second ring resonates at 3.5GHz and similarly the other rings are designed.

3. DESIGN PARAMETERS

The parameters used for the design of fractal ring antenna are given in Table.1. Here, r_1, r_2, r_3, r_4, r_5 and r_6 indicate the radius of the fractal ring. l and b indicates the length and height of the ground plane respectively. The h and w indicates the height and width of the feedline of the radiating patch. The distance between the two fractals is denoted as d in MIMO configuration.

Table.1. Design Parameters

Length, Width and radius	Units in mm
r_1	16
r_2	13
r_3	10
r_4	7
r_5	4
r_6	1
l	60
h	13.08
b	13
w	3
d	34

4. DESIGN CONFIGURATION

The radiating patch consists of O-shaped fractal ring with 0° and 180° orientation. In the first iteration, two circles of radius r_1 and r_2 are made to form a ring in addition to a ground plane. In the second iteration, the second ring is blended with the first ring such that the lower part of both the ring coincides. In the third iteration, the third ring is blended with the first two rings such that the lower portion of the rings coincides. In the fourth iteration, the fourth ring is blended with the first three rings such that the lower portion of the rings coincides. In the fifth iteration the fifth ring is blended with the first four rings such that the lower portion of the rings coincides with each other. The upper gap between the rings should be 3 mm.

The brown colour indicates the radiating patch structure and green colour indicates the ground plane. As per the design parameters the Single 0° Fractal Ring Antenna is designed and shown in Fig.1.

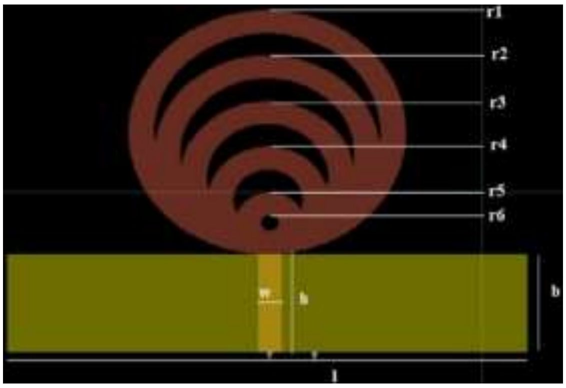

Fig.1. Design layout of single 0° Fractal Ring Antenna

The 0° Fractal Ring MIMO Antenna is depicted in Fig.2. The distance d between the antennas is 34mm.

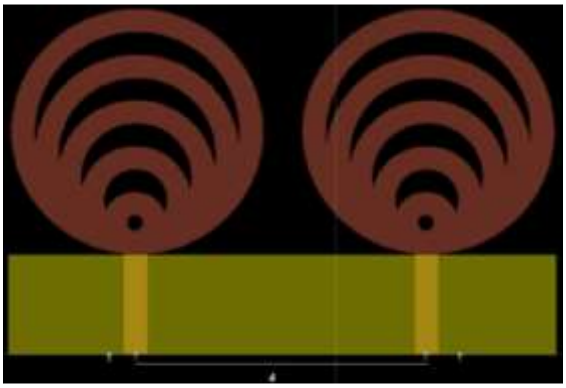

Fig.2. Design layout of 0° Fractal Ring MIMO Antenna

The 180° Fractal Ring Antenna is obtained by shifting the 0° Fractal Ring Antenna. As per the design parameters the Single 180° Fractal Ring Antenna and 180° Fractal Ring MIMO Antenna is given in Fig.3 and Fig.4 respectively.

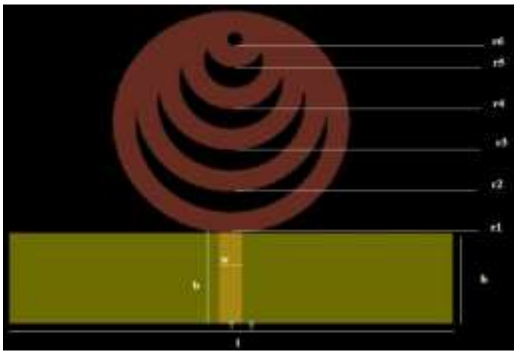

Fig.3. Design layout of Single 180° Fractal Ring Antenna

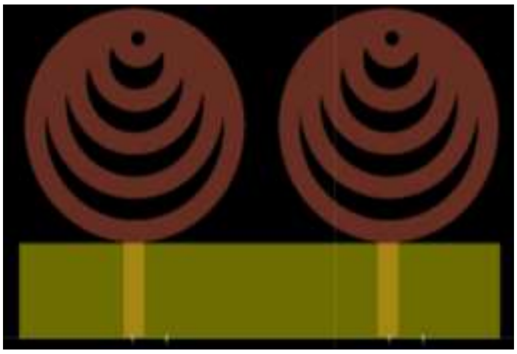

Fig.4. Design layout of 180° Fractal Ring MIMO Antenna

5. SIMULATION RESULTS

5.1 0° FRACTAL RING ANTENNA

The Fig.5(a) and Fig.5(c) represents the return loss of Single 0° fractal ring antenna and 0° fractal ring MIMO antenna. Here m_1, m_2, m_3, m_4 and m_5 denote the markers indicating the return loss of the respective antennas.

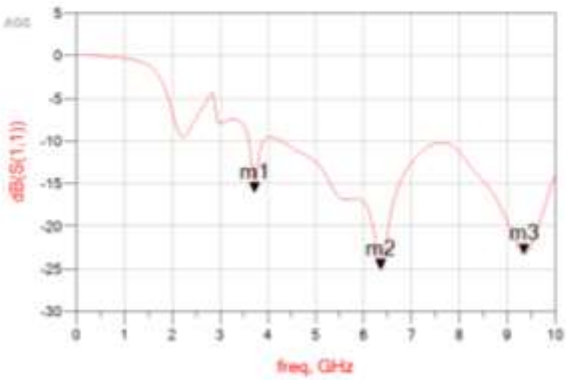

Fig.5(a). Single 0° fractal ring antenna

The Fig.5(a) shows the return loss of single 0° fractal ring antenna resonates at three frequencies 3.5GHz, 6.3GHz and 9.3GHz with return losses -16.05dB, -25.063dB and -23.242dB respectively.

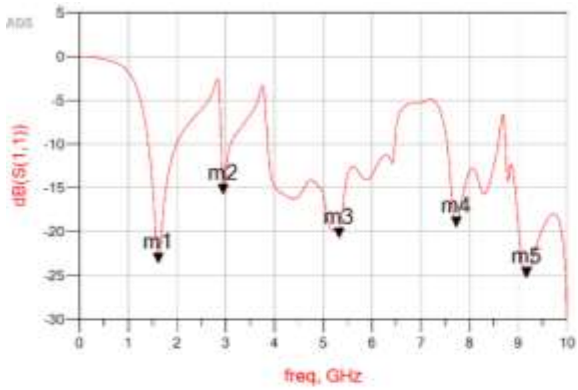

Fig.5(b). 0° Fractal Ring MIMO Antenna

The Fig.5(b) shows the return loss of single 0° fractal ring MIMO antenna resonating at five frequencies 1.5GHz, 3GHz, 5.18GHz, 7.57GHz and 9.1GHz with return losses 23.639dB, -15.76dB, -20.770dB, -19.487dB, and -25.257dB respectively.

5.2 180° FRACTAL RING ANTENNA

The Fig.5(c) and Fig.5(d) represents the return loss of Single 180° Fractal Ring Antenna and 180° Fractal Ring MIMO Antenna.

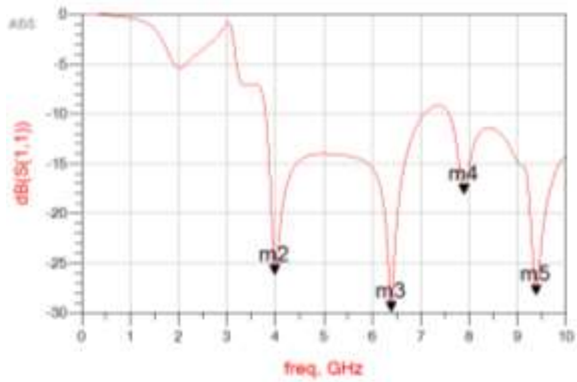

Fig.5(c). Single 180° Fractal Ring Antenna

The Fig.5(c) shows the return loss of single 180° Fractal Ring MIMO Antenna resonating at frequencies 4GHz, 6.45GHz, 7.9GHz and 9.47GHz with return losses -26.160dB, -29.855dB, -18.060dB and -28.207dB respectively.

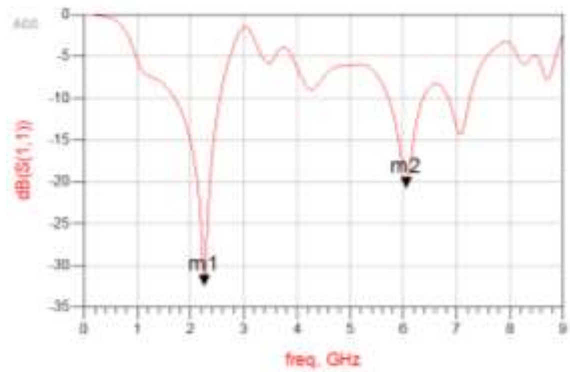

Fig.5(d). 180° Fractal Ring MIMO Antenna

The Fig.5(d) shows the return loss of 180° Fractal Ring MIMO Antenna resonates at frequencies 2.3GHz, 6.1GHz and 6.9GHz with return losses -32.381dB, -20.670dB and -14.9dB, respectively.

6. ANALYSIS

The radiation pattern of Single 0° Fractal Ring Antenna and 0 Fractal Ring MIMO Antenna are depicted in Fig.6(a) and Fig.6(b).

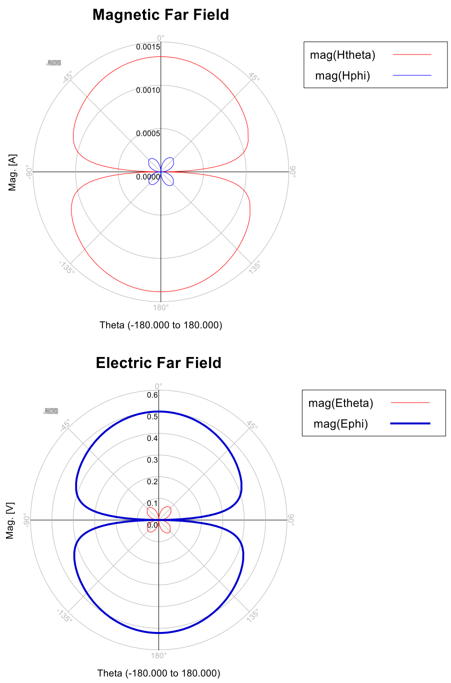

Fig.6(a). Radiation pattern of Single 0° Fractal Ring Antenna

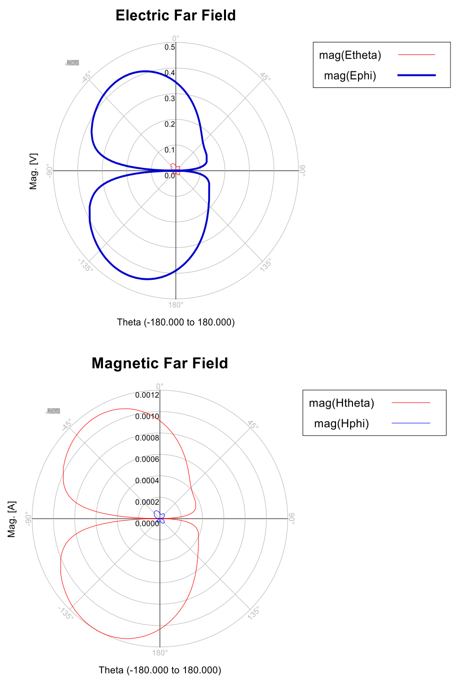

Fig.6(b). Radiation pattern of 0° Fractal Ring MIMO Antenna

The linear and circular polarisation of the single 0° fractal ring antenna and 0° fractal ring MIMO antenna are depicted below in the Fig.6(c) and Fig.6(d) respectively.

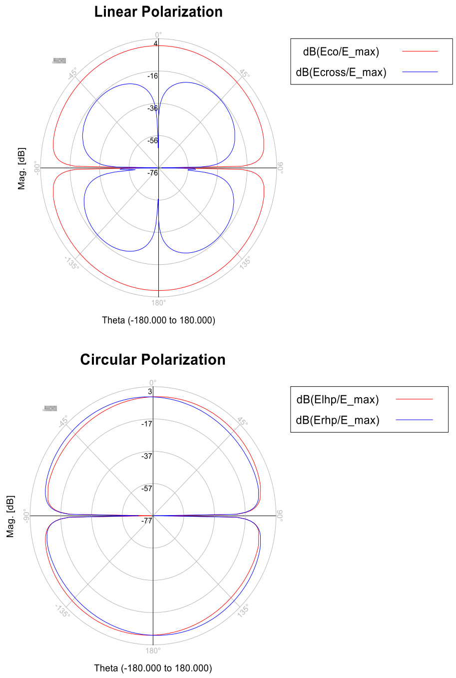

Fig.6(c). Linear and Circular Polarisation of single 0° fractal ring antenna

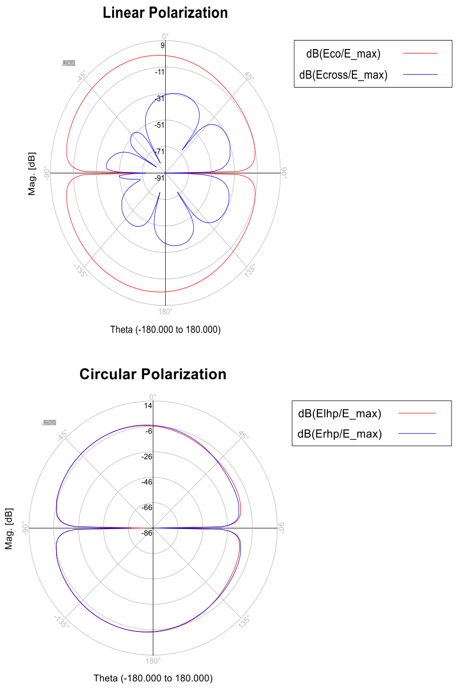

Fig.6(d). Linear and Circular Polarisation of 0° fractal ring MIMO antenna

The radiation pattern of Single 180 Fractal Ring Antenna and 180° Fractal Ring MIMO Antenna are depicted in Fig.6(e) and Fig.6(f) respectively.

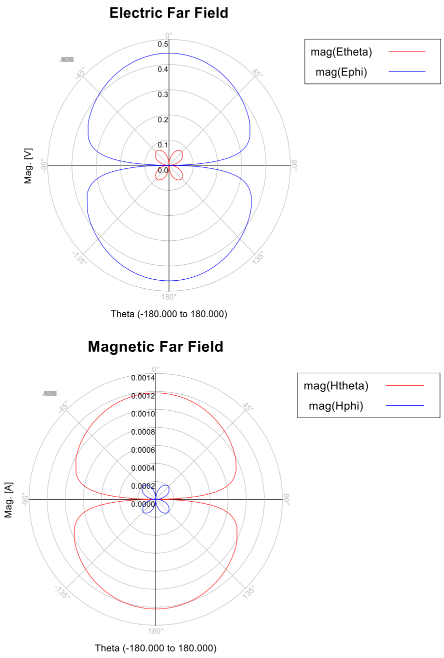

Fig.6(e). Radiation pattern of Single 180° Fractal Ring Antenna

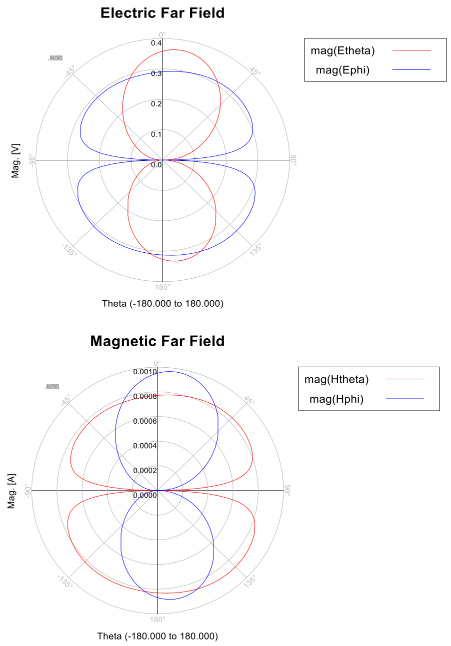

Fig.6(f). Radiation pattern of 180° Fractal Ring MIMO Antenna

The linear and circular polarisation of the single 180° Fractal Ring Antenna and 180° Fractal Ring MIMO Antenna are depicted below in the Fig.6(g) and Fig.6(h) respectively.

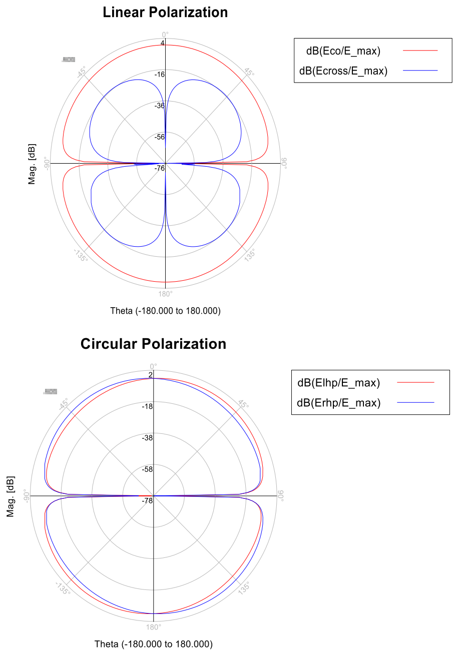

Fig.6(g). Linear and Circular Polarisation of single 180° Fractal Ring Antenna

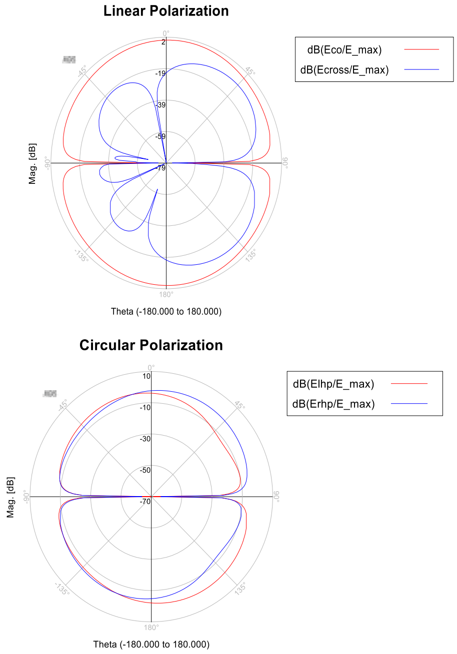

Fig.6(h). Linear and Circular Polarisation of 180° Fractal Ring MIMO Antenna

Table.2. comparison of 0° Fractal Ring Antenna

Parameter	**Single 0° antenna**	**0° MIMO antenna**
Frequency	3.8GHz	3.8GHz
Directivity	4.2554dB	5.4dB
Radiation efficiency	35%	100%
Gain	0.299dBi	5.4dBi
Bandwidth	347MHz	2.6GHz

Table.3. comparison of 180° Fractal Ring Antenna

Parameter	Single 180° antenna	180° MIMO antenna
Frequency	4GHz	4GHz
Directivity	5.7dB	4dB
Radiation efficiency	27%	67%
Gain	0.08dBi	2.3dBi
Bandwidth	2.9GHz	1.3GHz

The Table.2 and Table.3 shows the comparison of 0° fractal ring MIMO antenna and 180° fractal ring MIMO antenna. The bandwidth and radiation efficiency of 0° fractal ring MIMO antenna is better with 180° fractal ring MIMO antenna.

7. CONCLUSIONS

The proposed fractal ring MIMO antenna resonates at multiple frequencies and it can be used for various applications like GPS, WiMAX and Bluetooth. It has additional features like low cost, low profile, easily mounted and fabricated. The antenna is simulated from 0-10GHz. The 0° fractal ring MIMO antenna achieves better bandwidth and radiation efficiency compared with 180° fractal ring MIMO antenna. Further improvements can be made by adopting different patch orientations in the monopole MIMO antenna.

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