Band Enhanced Diamond Sierpinksi Fractal Antennas for MIMO Applications

Omar Masood Khan, Zain Ul Abedin, and Kamran Raza

***Abstract*—Dual element diamond Sierpinski Fractal MIMO antenna is presented with bandwidth enhanced characteristics. The antenna operates for the frequency bands of 1.8 GHz, 2.4 GHz, 3.5 GHz and 5.8 GHz for DCS, WIFI, WIMAX and WLAN applications with S11 = -10 dB matching criteria (VSWR 2:1). The *two* fractal elements are symmetrically placed at the adjacent sides of the substrate for overall compact size of the antenna. The proposed MIMO antenna is designed on FR4 substrate with dielectric constant of 4.4 and height of 1.6 mm. The optimization of the frequency bands of the proposed antenna on the desired operational frequencies is done by tuning the dimensions of the different slots embedded on the bottom ground plane of the substrate. The results for the s-parameters, 3D gain plots and surface currents are presented for the verification of the concept, with the gain of 2.5 dB over the whole frequency range.**

Keywords*-component*; monpole, fractal antenna; miniaturization; multiband;

I. INTRODUCTION

MIMO is an essential technology for the modern wireless communication systems that can significantly improve the network coverage, capacity and throughput without a need for supplementary bandwidth. Also portable wireless terminals are designed to have several functions and supporting various standards on a miniaturized handset. Hence it is pertinent to develop reduced size and closely arranged multiband antennas to cater for multifunctional MIMO held wireless terminals. Recently many antennas are proposed for MIMO terminal applications. The MIMO antenna system in [1] provides two identical microstrip monopole antennas with inter element spacing of 0.097 λ. Each element has a capacitive feeding mechanism and is made of a parasitic loop, couple of twisted lines and shorting strip that generates five resonant bands. A MIMO antenna for cognitive radio applications is proposed in [2], where ultra-wide band sensing antenna is integrated with dual elements and frequency reconfiguration is achieved by embedding varactor and PIN diodes with the antennas. For the reconfigurability of the system the MIMO antennas are tuned and swept over two modes over a wide frequency band below 1 GHz by varactor diodes. Meandered loop antennas having low profile are implemented for MIMO applications in [3] targeting several communication bands for wireless access points and routers that includes the WLAN, WIMAX 4G LTE and UMTS bands with matching criterion of -6 dB. In these bands the antennas demonstrated omnidirectional radiation patterns with considerable antenna efficiency and gain having small envelope correlation under 0.5 dB. A planar MIMO fractal antenna is presented in [4] for mobile applications covering various wireless communication bands from 1.65 to 1.9 GHz and 2.68 to 6.25 GHz. The fractal antenna proposed is a hybrid of Koch and Minkowski island curves. The isolation and impedance matching between the two antennas is improved by inserting strip and slots at the bottom and top layers of the antennas. A reduced size MIMO antenna is illustrated in [5] for ultra wide band applications consisting of two antennas inserted with L shaped slots in the antenna elements and inclined slot in the ground plane for the purpose of reducing the mutual coupling between the two MIMO. The antennas have a bandwidth larger than 7 GHz and antennas and envelope correlation coefficient better than 0.02 over the frequency band that is appropriate for ultra wide band applications. A frequency reconfigurable MIMO antenna with compact size is demonstrated in [6] for laptop LTE services having multiband characteristics. The antenna consists of two PIFA elements having feeding through proximity coupling and two pin diodes. The dc line is used in conjunction with the feeding mechanism for reducing the overall dimensions of the antenna and improving the performance by reducing the inter element interferences. The illustrated antenna covers the LTE 17/13 and LTE 20/7 frequency bands. Dual antenna is proposed in [7] for Long Term Evolution systems where structural dimensions are manipulated for impedance matching and single feed is used to produce current distribution with high modal significance for multiple modes and wider bandwidths.

This paper presents a novel two element printed MIMO antenna by using diamond Sierpinski fractal. The fractalization of the diamond embedded triangular patch is done upto the second order and the two antennas are placed symmetrically fed by microstrip transmission lines. The proposed antenna is radiated on multiple frequency bands by the fractalization process. The bandwidths of the multibands are enhanced by optimizing the slots on the ground plane of the antenna. The antenna covers frequency bands for PCS, DCS, WIFI, UMTS, WLAN and WIMAX frequencies.

II. ANTENNA DESIGN

The proposed Diamond Sierpinski MIMO fractal antenna is shown in Fig. 1, which consists of two fractal antennas printed on top layer of the FR4 substrate with height is 1.6

mm with dielectric constant of 4.4. Both the MIMO antennas are fed by microstrip transmission lines. Several slots are incorporated at the bottom ground layer of the substrate for the purpose of achieving band enhancement and optimization according to the desired frequency bands. SMA connectors are soldered at the end of the feed lines for the testing and integration purposes. The two proposed fractal MIMO antenna elements are placed symmetrically at the two sides of the substrate for overall compact size of the antenna. The inclined slot line embedded in the bottom layer of the substrate provides isolation between the two proposed fractal MIMO antennas by reducing the mutual coupling between the two antennas. There are two slots that are horizontally and vertically placed below each of the proposed MIMO antenna at the bottom layer of the substrate. The dimension details of the proposed fractal MIMO antennas along with the transmission lines and ground plane slots are illustrated in Fig. 2. The top layer of the proposed Diamond Sierpinski MIMO fractal antenna is illustrated in Fig. 2a. The antenna consists of two elements placed in the adjacent sides of the substrate with minimum distance for maximum overall size reduction of the antenna and minimum mutual coupling between the elements for maximum efficiency. The length and width of the diamond slot embedded within the smaller cells of the fractal is 1.06 mm and 0.31 mm respectively. The length of each side of the proposed diamond Sierpinski fractal antenna is 8.06 mm, where the length and width of the transmission feed line, feeding from the SMA connector to the fractal antenna is 8.59 mm and 0.68 mm respectively. The bottom layer of the proposed MIMO fractal antenna is shown is Fig. 2b. The bottom ground layer consists of three slots for the mutual coupling reduction and bandwidth enhancement for the proposed antenna. The narrow slot embedded at an angle of 45 degrees between the two MIMO fractal elements has the length and width of 12.5 mm and 1 respectively. Two slots are placed vertically and horizontally below the MIMO fractal elements for multibands and bandwidth enhancement, with the first slot having length and width of 18 mm and 5.84 mm respectively while the second slot is optimized at 8 mm and 5 mm respectively. The overall length and width of the substrate is taken to be 32 mm each. The complete detail of the dimensions is illustrated in Table I.

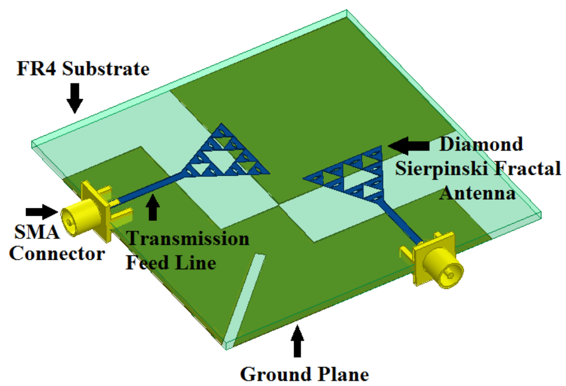

Fig. 1. Proposed MIMO Dual Element Diamond Sierpinski Fractal Antenna labeled diagram

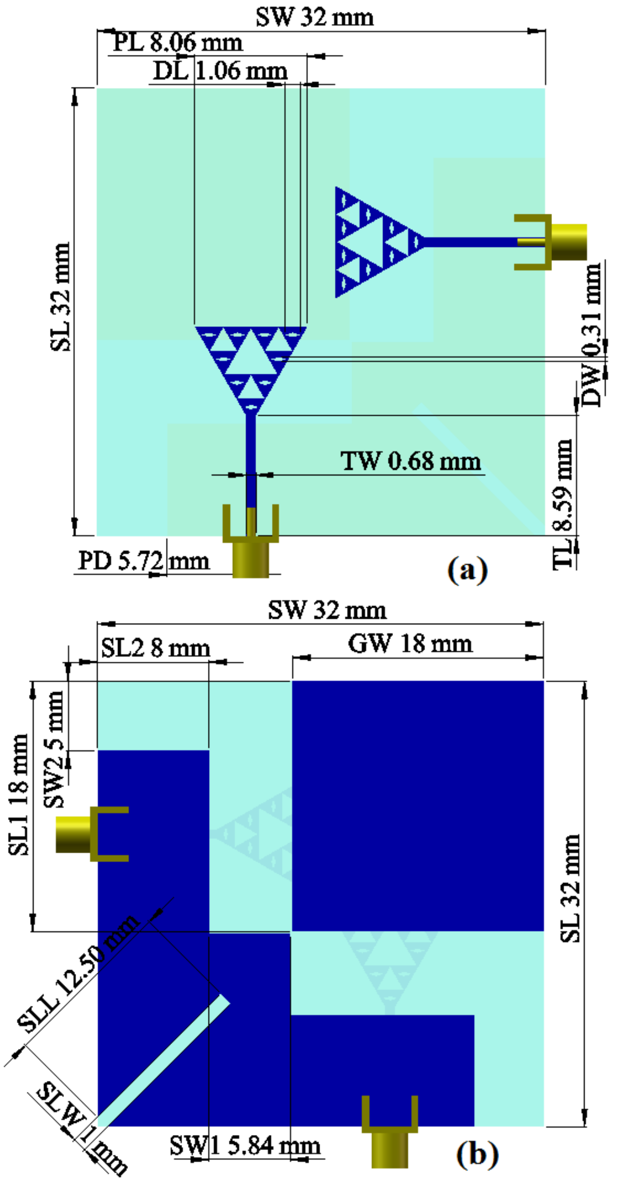

Fig.2. Dimensions Diagram of the proposed MIMO Diamond Sierpinski Fractal Antenna, (a) Top Layer, (b) Bottom Layer.

TABLE I: MIMO DIAMOND SIERPINSKI FRACTAL ANTENNA LABELS, DESCRIPTIONS AND DIMENSIONS

Label	Description	Dimensions (mm)
SL	Substrate Length	32.00
SW	Substrate Width	32.00
PL	Sierpinski Length	08.06
PD	Sierpinski Shift	05.72
DL	Diamond Length	01.06
DW	Diamond Width	00.31
TL	Line Length	08.59
TW	Line Width	00.68
SLL	Slot Cut Length	12.50
SLW	Slot Cut Width	01.00
SL1	Slot 1 Length	18.00
SW1	Slot 1 Width	05.84
SL2	Slot 2 Length	08.00
SW2	Slot 2 Width	05.00
GW	Ground Patch Width	18.00

III. Simulation And Measured Results

The proposed fractal MIMO antenna is simulated and analyzed in CST Microwave Studio. The optimized frequency response of the proposed antenna is shown in Fig. 3. Antenna patch length and the slot lengths and widths in the ground plane are optimized to produce dual frequency bands. The first band is optimized for wider bandwidth with the bandwidth for S11< -10 dB from 1.57 GHz to 4.44 GHz. This band includes frequencies of 1.8 GHz, 2.4 GHz and 3.5 GHz for the applications of DCS/PCS, WIFI and WIMAX respectively. The second band is optimized for the bandwidth for S11< -10 dB from 5.76 GHz to 6.67 GHz for WLAN applications.

The frequency band optimization for different geometrical values of the slot 1 length is shown is Fig. 4. The MIMO fractal antenna radiates with the bandwidth for S11< -10 dB from 4.11 GHz to 6.62 GHz for the slot length of 14.16 mm, which is appropriate for the WLAN applications at 5.8 GHz but does not cover the PCS/DCS, WIFI and WIMAX frequency bands of 1.8 GHz, 2.4 GHz and 3.5 GHz respectively.

Further optimization is done with respect to the length of the slot 1 for achieving the desired bands and for length of 22.16 mm three bands are realized, with the bandwidth of the first band for S11< -10 dB is from 1.42 GHz to 1.73 GHz which is still not covering the 1.8 GHz frequency band. The second band with the bandwidth for S11< -10 dB is from 3.14 GHz to 4.3 GHz, which covers the WIMAX frequency band and the third band with the bandwidth for S11< -10 dB from 5.78 GHz to 7.53 GHz covers the WLAN frequency band. Thus for including the 1.8 GHz and 2.4 GHz frequency bands for DCS and WIFI applications the length of the first slot is further optimized at 18.16 mm.

Width of the first slot is also critical for tuning the frequency bands according to the frequency of operation of desired applications as illustrated in Fig. 5. With the increase in slot width 1 from 4 mm to 6 mm, the frequency band with the bandwidth for S11< -10 dB from 3.17 GHz to 6.75 GHz is enhanced to produce three distinctive frequency bands covering the critical frequencies of 1.8 GHz, 2.4 GHz, 3.5 GHz and 5.8 GHz.

Increase in the slot width 1 from 6mm to 8 mm produces three bands with the first band having bandwidth for S_{11}< -10 dB from 2.22 GHz to 2.80 GHz, second band having bandwidth for S_{11}< -10 dB from 3.97 GHz to 4.35 GHz and third band having bandwidth for S_{11}< -10 dB from 6.15 GHz to 7.27 GHz. Hence increase in the slot width from 6 mm to 8 mm degrades the first frequency band and third frequency bands and does not include the critical 1.8 GHz and 5.8 GHz frequency bands. The tuning of the desired frequency bands can also be achieved by optimizing the distance of patch from ground plane slot as shown in Fig. 6.

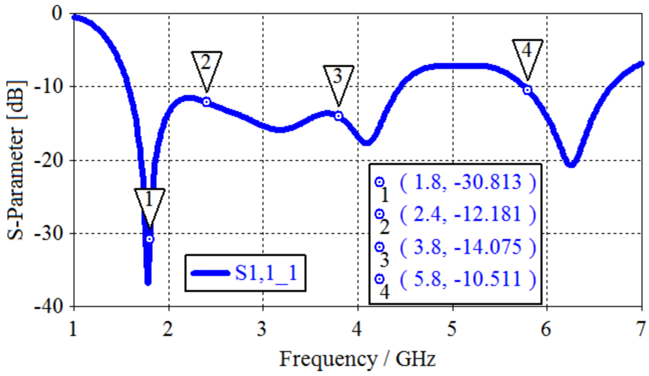

Fig.3. S11 Frequency Response of proposed Diamond Sierpinski MIMO fractal Antenna

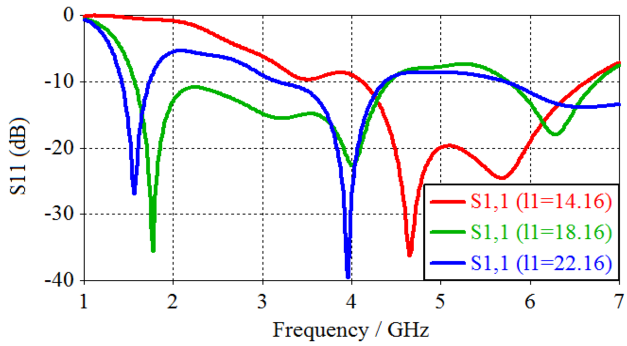

Fig.4. Frquency response of the proposed diamond Sierpinski MIMO fractal antenna with respect to the slot length1

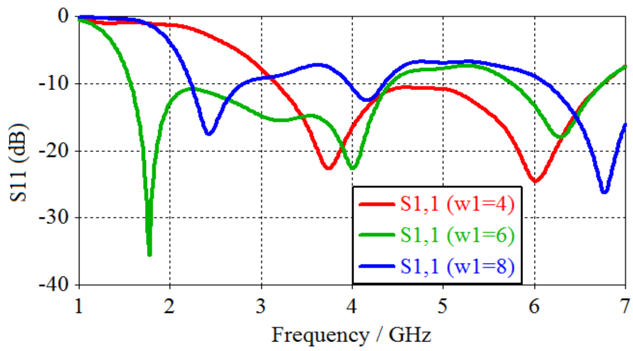

Fig.5. Frquency response of proposed diamond Sierpinski MIMO fractal antenna with respect to the slot width 1

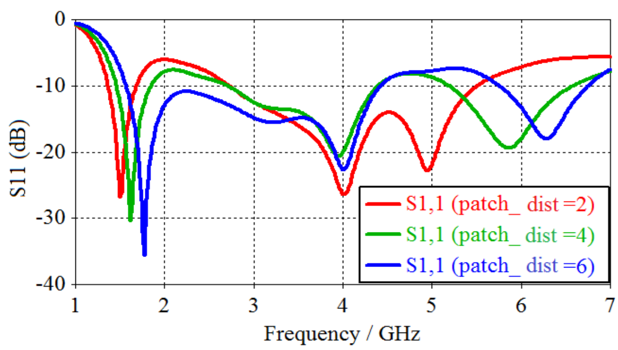

Fig.6. Frquency response of proposed diamond Sierpinski MIMO fractal antenna with respect to the patch distance from the ground plane slot

IV. Simulation And Measured Results

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For the patch distance of 2 mm, the impedance bandwidth for S11< -10 dB is from 1.36 to 1.67 GHz for first resonating band and impedance bandwidth for S11< -10 dB is from 2.75 GHz to 5.51 GHz, which only includes the 3.5 GHz frequency band for the WIMAX applications. To improve the overall frequency response of the antenna the patch distance is increased from 2 mm to 4 mm to obtain three frequency bands that do not include the 2.4 GHz WIFI frequency band. Further optimization of the patch distance from 4 mm to 6 mm produces three resonant bands as shown in Fig. 6 that also includes the 1.8 GHz and 2.4 GHz frequency bands.

The 3D gain pattern plots of the proposed MIMO fractal antenna are shown in Fig. 7 for the frequency bands of 1.8 GHz, 2.4 GHz, 3.5 GHz and 5.8 GHz. The gain value of the proposed antenna over the whole frequency range is illustrated in Fig. 8 with more than 2.5 dB in the lower frequency range and more than 4.5 dB for the WLAN applications at 5.8 GHz band. The surface currents of the proposed MIMO fractal antenna is demonstrated in Fig. 9 with varying current intensities around the Diamond Sierpinski, transmission lines and ground plane slots for different frequency bands.

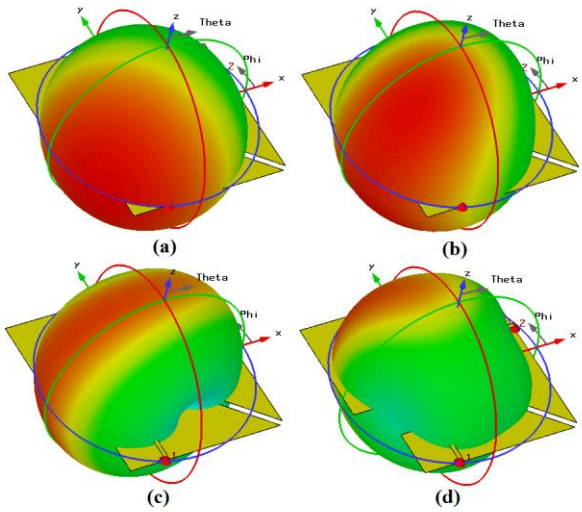

Fig.7. 3D Radiation Patterns of the proposed diamond Sierpinski MIMO Fractal Antenna for the frequencies, (a) 1.8 GHz, (b) 2.4 GHz, (c) 3.8 GHz, and (d) 5.8 GHz

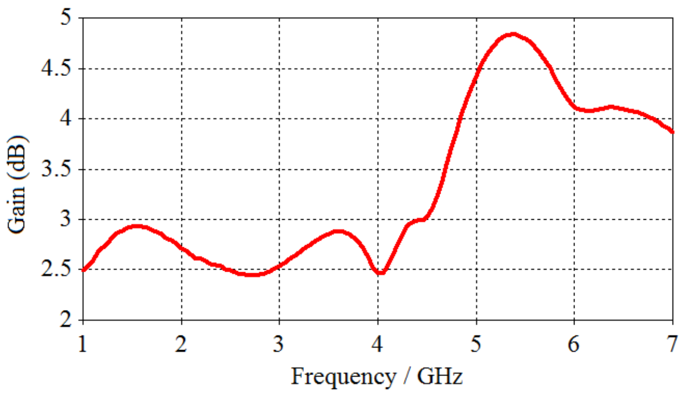

Fig.8. Gain vs Frequency of the proposed diamond Sierpinski MIMO fractal antenna

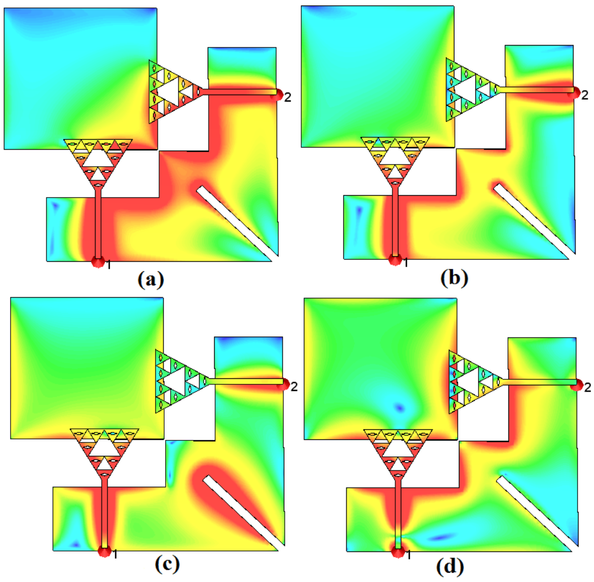

Fig.9. Surface currents of proposed diamond Sierpinski MIMO fractal antenna for frequencies, (a) 1.8 GHz, (b) 2.4 GHz, (c) 3.8 GHz, (d) 5.8 GHz.

V. Conclusion

A multiband bandwidth enhanced diamond Sierpinski fractal MIMO antennas with dual elements is presented, which covers 1.8 GHz and 2.4 GHz for DCS and WIFI applications and 3.5 GHz and 5.8 GHz frequency bands for WIMAX and WLAN applications. The individual frequency bands are optimized with respect to different geometrical configuration of the ground plane slot lengths and widths and the distance of the patch from the ground plane slots. The surface current and 3D gain pattern plots are presented for the desired frequency bands. The gain vs frequency plot depicts gain of more than 2.5 dB over the whole frequency range.

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