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Design and analysis of M-shape printed Monopole antenna for GPS/ISM/W-LAN applications

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Abstract-In this article M-shape multiband antenna is proposed for wireless communication systems such as GPS, WLAN and ISM. The proposed antenna resonates at four bands, I (1.436 GHz -1.586 GHz), II (2.313 GHz-2.50 GHz), III (4.844 GHz -5.150 GHz) and IV (5.714 GHz-5.951 GHz) with improved return losses and impedance matching. These bands covering GPS band 1.57GHz, WLAN bands 2.4GHz, 5.0GHz, and 5.8GHz and ISM bands 2.45GHz and 5.75GH with radiation efficiency 65.15%, 76.69%, 59.95%, 54.31%, 73.17% and 53.68% respectively and VSWR<2 for all bands. The antenna has size of 43.8mmx18.6mm with defected ground structure (DGS) and fed by 50ohm micro strip feed line. The antenna is designed on FR-4 substrate material with thickness of 1.6mm, relative permittivity is 4.3 and tangent losses are 0.025. The proposed design is simulated in CST (computer simulation technology) microwave studio. The proposed antenna is fabricated and results are measured with help of network analyzer. The measured and simulated results are compared.

***Keywords-*:**Defecated Ground Structure (DGS), Parallel Rectangular Open Slots (PROS), Microstrip Patch Antenna (MPA)

I. INTRODUCTION

Antenna is the key component in wireless communication systems and plays a vital role in the design of wireless communication systems. So for many types of antennas such as wire antennas, Aperture antennas, micro-strip patch antennas (MPA), reflector antennas, lens antennas and array antennas have designed and developed for different uses in wireless communication systems like satellite communication, radar and airplane, smart phones, medical equipment, devices used for security systems, remote area control and telemetry units in industries etc. All antennas are good and suitable in accordance with their uses, however the micro-strip patch antenna [i] attracted attention of researchers and antennas developing community due to its low profile, conformability to a shaped surface, ease of fabrication, compatibility with integrated circuit technology, low power consumption, and inexpensive compared with other types of antennas. The disadvantages of MPA are narrow bandwidth, low gain and a potential decrease in radiation efficiency due to surface-wave losses. However many techniques have developed to improve the performance of MPA[ii]. So for lot of work has done to improve performance of multiband micro strip patch antenna. MPA having multi-strip with different shapes have used to achieve wide bandwidth [iii]. Different techniques have been proposed for gain enhancement [iv-vii]. To improve the efficiency of multiband MPA a design of rectangular patch with parasitic element is presented in [iv]. Excellent return losses have achieved while using square split ring resonator in [viii].

Two technique are used to feed MPA [ix]; connecting feeding and non-connecting feeding. Coaxial cable, and micro-strip line are connecting feeding techniques. Proximity coupling and aperture coupling are non-connecting feeding techniques. In the early stages MPA ware using in military sector due to low profile however with the rise of wireless mobile technology in communication systems it became more and more favorite in this area.

Wireless communication system is world of wireless devices. Some of the wireless devices dealing with single service and many of them like smart phones can support more than one service such as GPS, GSM, 3G, 4G, WLAN and WiMAX, concurrently. According to FCC each service operates in its own frequency band. To achieve this multi-service functionality of wireless devices a number of antennas will be required in a signal device, which enlarge the size, increase energy consumption and cost of device. To make the multi services function beneficial a multi-band antenna is best solution. Multiband antenna can operate simultaneously at more than one frequencies. Multiband antennas can reduce the number of antennas and remove the band pass filters used in a multiband system, which is critical for mobile devices to minimize the overall size [i], fit the severe physical space constraints, and save the cost [x-xiii]. The main challenging feature of multi-band antenna is its shape, size, volume, return losses, impedance matching, bandwidth, efficiency and energy consumption while keeping its performance in best conditions.

Till the date different methods and techniques have been studied and used to design a multi band MPA. Multi band MPA can be design using Defected Ground Structure (DGS). DGS was used to achieve multiband features, enhance bandwidth, and reduce the size of MPA. In DGS technique, slots of different shapes such as U-shape, E-shape, I-shape, L-shape, S-shape and Z-shape etc. etched in the ground of MPA. Many design have been proposed for MPA with DGS [iii, xiv-xviii]. Multi band feature of MPA can be achieved by etching slots in patch [xiv]. Split ring resonator SSR is one of the approaches used for multi band MPA [xix]. Many researcher have used more than one patches of different size and shape as a radiating element to design multi band MPA[xvi, xx].

Until now different shapes have been proposed for multi band MPA. A fractal Sierpinski triangle shape is used in [x-xii] where in [xiii] two strips of very small size, a feeding strip and shorting strip are used. An antenna is designed having rectangular patch surrounded by meander strip with L shape slot [xxi]. A planar rectangular patch monopole antenna with two L shape slots and a meandering strip have different width at its different part is proposed in [xxii]. The antenna designed in [xxiii] consisting three fractal s-shaped patches with different lengths. The materials, shape, size and feeding point of antenna has a great influence on its characteristics and performance. These aspects are studied in [xxiv].

Many researchers have worked on multiple MPA and designed a lot of multiple antennas. A trapezoidal shape multi band antenna with SRR is presented to cover three bands 2.4GHz, 3.5GHz and 5.8GHz [xix]. A multiband MPA, with multiple patches having different shapes and size, is proposed which accommodate three bands [iii]. Square Split Ring Resonator (SSRR) multi band MPA is proposed for UMTS/3G 2.1GHz and Wi-Fi/WLAN 2.4GHz application [viii]. A U-shape MPA with DPS (Defected Parasitic Structure) is used to achieve three bands 2.4GHz, 3.6GHz and 5.8GHz [xxv]. A rectangular patch MPA is designed with an L-shape slot and two I-shape slots to get five bands [xxvi].

In this article M-shape multi band MPA is presented for GPS, WLAN and ISM applications. The M-shape radiating patch is mounted on FR-4 substrate of relative permittivity ε_r=4.3 and ground on back sides of substrate with two PROS (parallel rectangular open slots). DGS is used for impedance matching. The proposed MPA has small size and improved return losses, bandwidth and efficiency comparatively to other design studied in literature survey.

The proposed design is compared with other antennas designed on FR-4 substrate in table 1, in term of size, gain, return losses and bandwidth of achieved bands. It is clear from the table that the proposed design has better return losses, more bands and wide bandwidth as compare to the other designs.

TABLE I
COMPARISON OF PROPOSED ANTENNA WITH LITERATURE

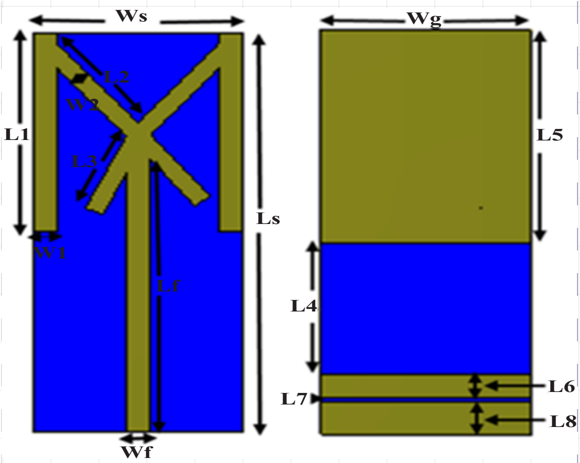
Ref	Size (mm^2)	f_r (GHz)	Return losses (dB)	Gain (dB)	Bandwidth (MHZ)
3	35x31	2.1 2.4	-27.10 -25.21	2.9 3.1	36.20 36.40
14	43.8x18.6	1.4 2.4 3.4 4.6	-12.86 -14.58 -22.69 -15.16	- - - -	15.17 21.40 19.35 13.43
Proposed antenna	43.8x18.6	1.5 2.4 5.0 5.8	-24.12 -15.52 -20.51 -18.77	1.42 1.58 1.74 1.53	155.60 181.13 300.80 238.15

II. ANTENNA DESIGN

To design the proposed M-shape antenna the main radiating patch is etched on top and the ground having two PROSs is etched on bottom of FR-4 substrate with dielectric constant ε_r=4.3 tangent losses of 0.025 and the thickness is 1.6mm. The dimensions of ground and substrate is 43.8x18.6mm^2 (LsxWs). Dimensions of side arms of "M" are L1xW1, middle arms are (L2 xW2) and legs of middle arms are (L3xW2). The M-shape patch is fed by 50Ω micro strip line of dimension LfxWf. Front view and back view of the proposed antenna is given in figure 1(a, b) with dimension's parameters. The prototype of proposed antenna is shown in Fig. 2.

As shown in Fig. 1 (b) two PROSs are adopted in ground to achieve multiband feature. Because of the versatile structure of patch the etched PROSs are also used for impedance matching. The PROSs etched in the ground has proper dimension. The position and dimension of the PROSs has a great impact on results. Furthermore the width and angles of M's arms has a remarkable influence on the antenna operating bands. All these parameters are studied and optimized to get best results.

The trial-and-error technique is typical approach used by many researcher and authors to design antenna. The maintained method is adopted to design and optimized the parameters and dimension of the proposed antenna to achieve the desired bands. Firstly, the PROSs and dimension of the patch elements is optimized to get multiple resonating frequencies and then the angles between the arms of M-shape patch and feed line are adjusted to achieve desired bands. All the optimized parameter are listed in Table II. And the angles are shown in Fig. 3. The two bands, 1.5 GHz (1.436 GHz -1.586 GHz), and 5.8GHz (5.714 GHz-5.951 GHz), are obtained by the middle arms Y-shape patch, 2.4 GHz (2.313 GHz-2.50 GHz) band is achieved by the side arms and 5GHz (4.844 GHz -5.150 GHz) band is results of two extra legs of middle arms of M-shape patch. When the length of M shape and Y shaped radiator increased, the respective bands are shifted toward lower frequencies and similarly when the length of same radiating patches decreased, the bands are moved higher frequencies, which is justified from Fig. 13.



(a) (b)

Fig. 1. Proposed antenna (a) front view (b) back view

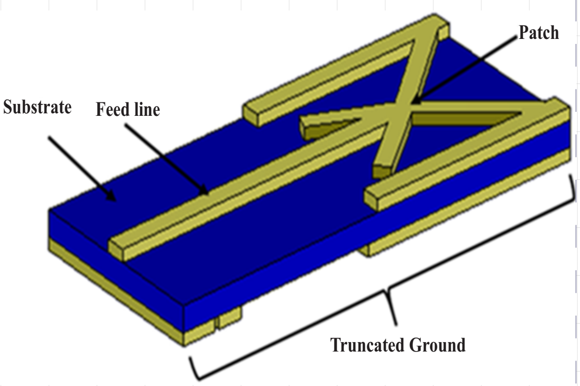


Fig. 2. Prototype of proposed antenna

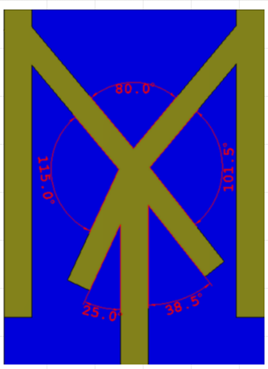


Fig. 3. Angles between arms and feed line of m-shape patch

TABLE II
OPTIMIZED PARAMETERS

Parameter	Valve (mm)	Parameter	Valve (mm)
Ls	43.8	L8	3.6
L1	21.9	Ws	18.6
L2	12.3	W1	2
L3	9.3	W2	1.75
L4	23	Wg	18.6
L5	14.3	Wf	2
L6	2.5	Lf	33.35
L7	0.3		

III. SIMULATION RESULTS AND ANALYSIS

The proposed antenna is designed and simulated in CST microwave studio which is based on Finite Integration Technique (FIT). The performance of the proposed antenna is studied in terms of Return loss, impedance matching bandwidth, and efficiency, gain, and radiation patterns.

A. Return loss

As shown in Fig. 4, the designed MPA have for bands for return losses < -10dB. 1.5GHz, 2.4GHz, 5.0GHz and 5.8GHz are the resonance frequencies. The reflection coefficient are -24.12dB, -15.52dB, -20.51dB and -18.77dB respectively

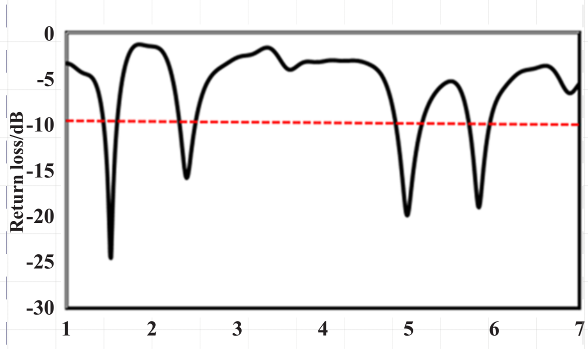


Fig. 4. Return losses of proposed antenna

B. VSWR

The voltage standing wave ratio (VSWR) describe impedance matching of transmission line. VSWR graph of the proposed antenna is shown in Fig. 5, the value of VSWR< 2 for all the resonance frequencies. VSWR is 1.1 for 1.5GHz, 1.3 for 2.4GHz, 1.2 for both 5.0GHz and 5.8GHz.

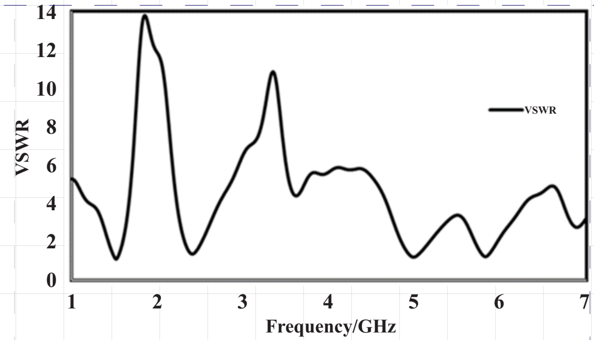


Fig. 5. VSWR of proposed antenna

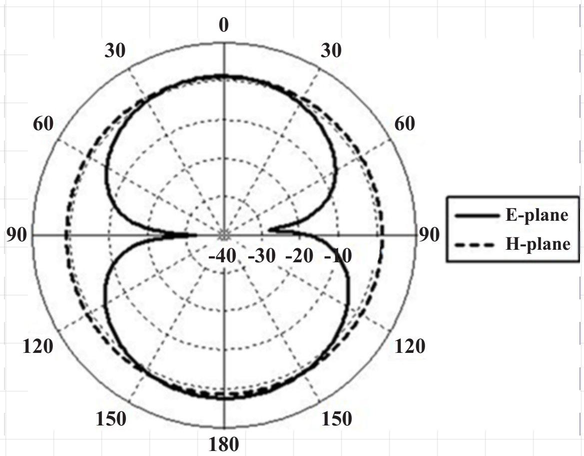
The characteristic parameters, frequencies, return losses, directivity, bandwidth, and efficiency of the proposed multiband MPA are given in Table III.

TABLE III
CHARACTERISTIC PARAMETERS OF PROPOSED ANTENNA

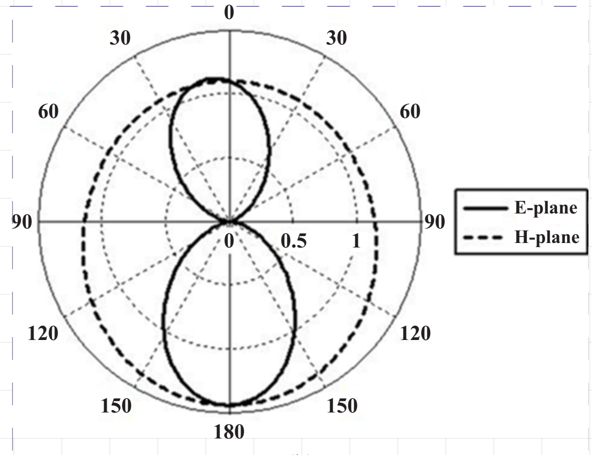
Frequency (GHz)	Return losses (dB)	Directivity	Bandwidth (MHz)	Efficiency (%)
1.5	24.12	2.205	155.60	65.15
2.4	15.52	2.667	181.13	77.63
5.0	20.51	3.891	300.80	60.89
5.8	18.77	4.059	238.15	55.86

IV. GAIN PLOTS

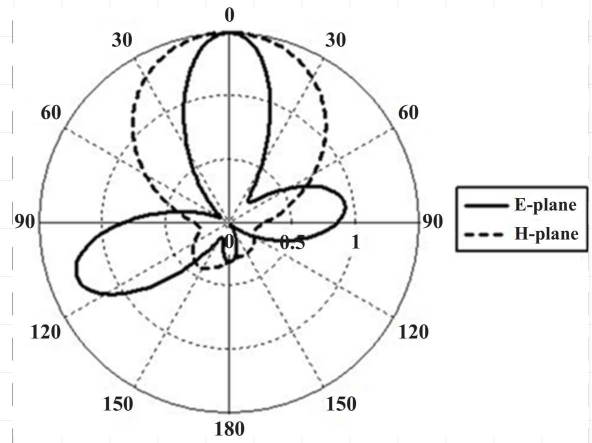
Gain plots for all four bands of proposed antenna are given in Fig. 6(a-d). It is depicted in Fig. 6 (a) and (b) that the suggested MPA behaves like a dipole for 1.5GHz and 2.4GHz and (c) and (d) show that antenna is vertically polarized for 5.0GHz and 5.8GHz.



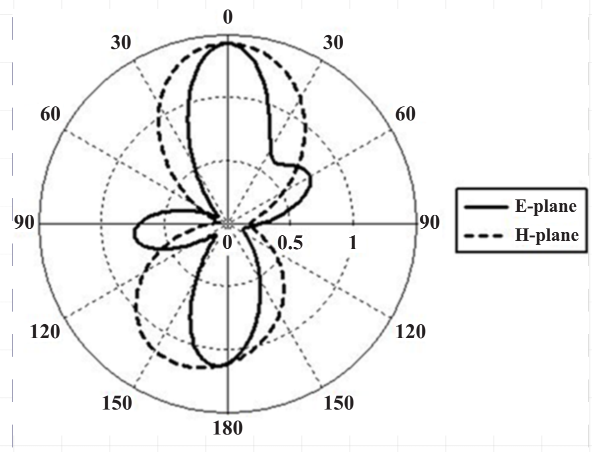
(a)



(b)



(c)



(d)

Fig. 6. Gain polar plots of proposed antenna (a) 1.5 GHz (b) 2.4GHz (c) 5.0 GHz (d) 5.8 Ghz

V. SURFACE CURRENT DISTRIBUTION

The current distribution of proposed antenna is shown in Fig. 7(a-d). At 1.5GHz current is distributed at middle arms and feed line. At 2.4 GHz current is dense

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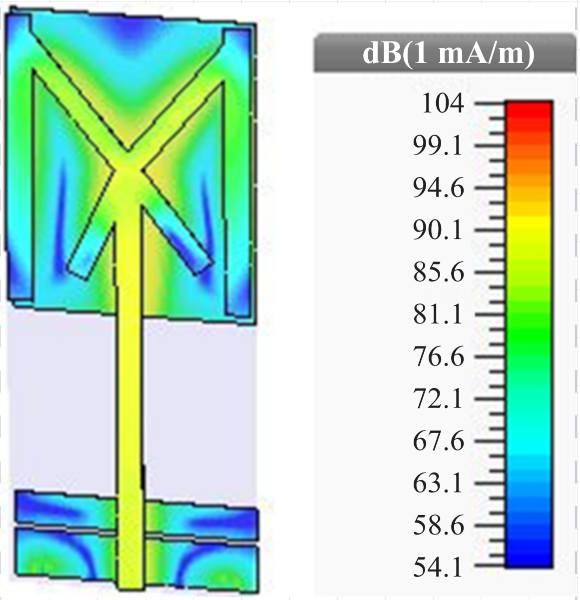
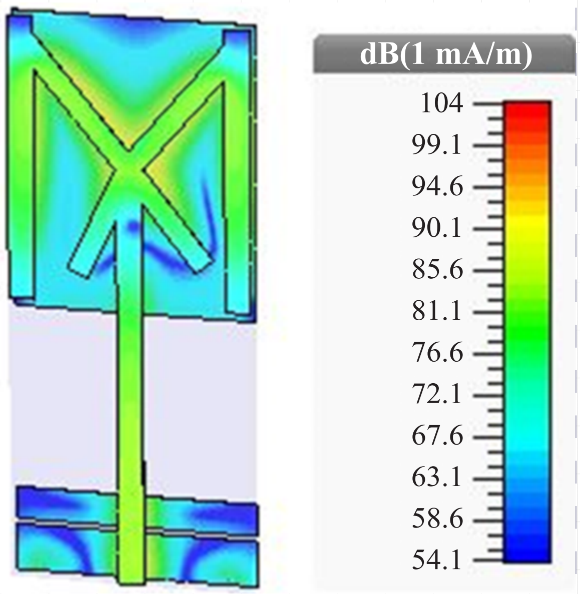
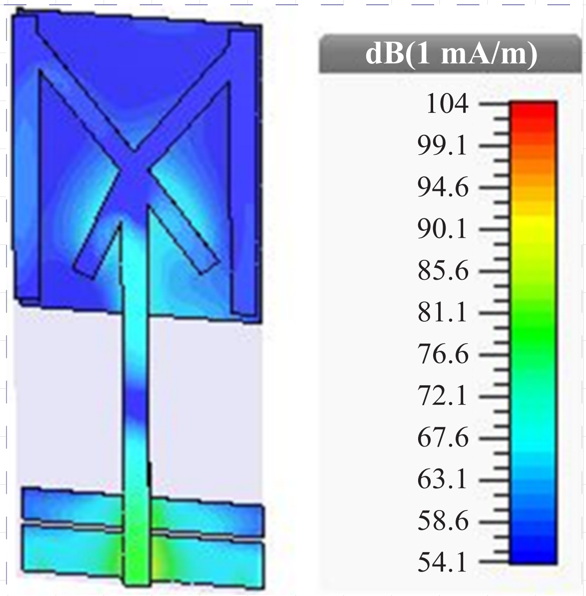
at bottom of feed line, side arms and middle arms. At 5.0 GHz surface current is dense at extreme bottom of feed line. At 5.8 GHz current is dens at bottom of feed line and extra legs of middle arms.



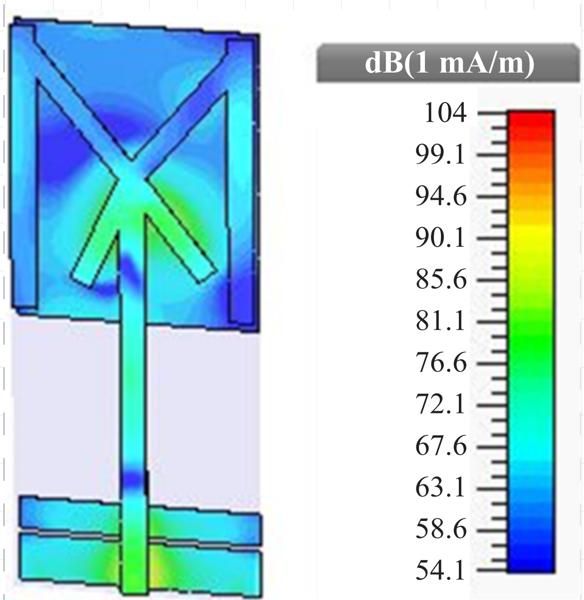
(a)



(b)

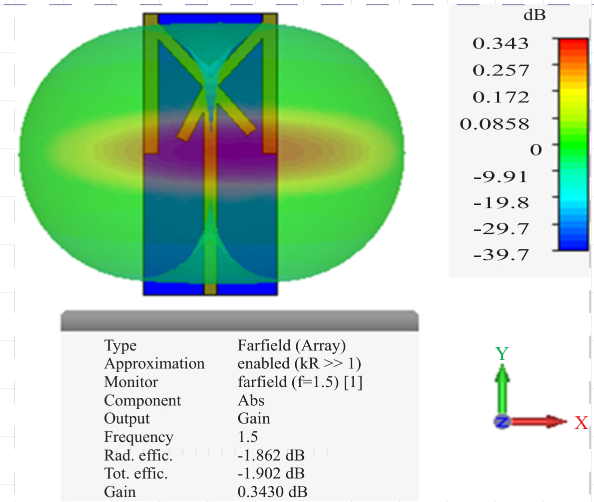


(c)

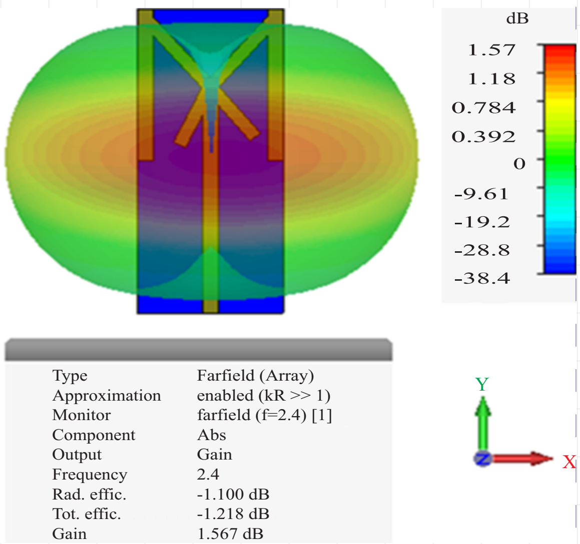


(d)

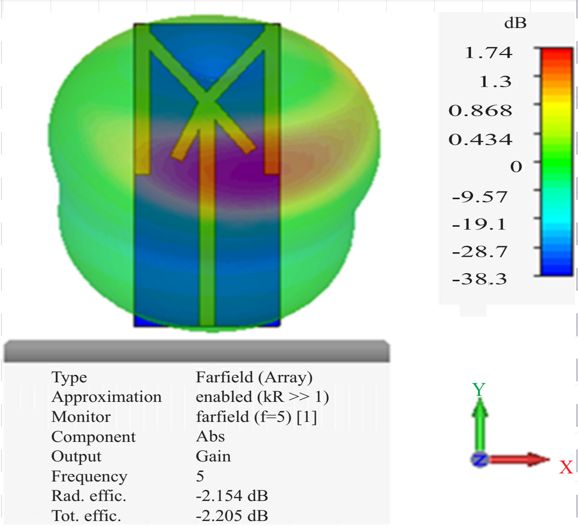
Fig. 7. Current distribution of proposed antenna (a) 1.5 GHz (b) 2.4 GHz (c) 5.0 GHz (d) 5.8 GHz



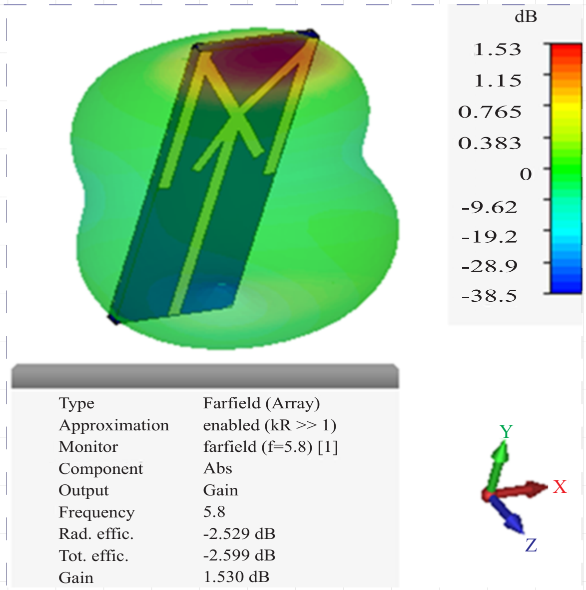
(a)



(b)



(c)



(d)

Fig. 8. 3D gain plots of proposed antenna (a) 1.5 GHz (b) 2.4 GHz (c) 5.0 GHz (d) 5.8 Ghz

VI. Fabrication and Measured Results

The proposed antenna is fabricated and results are measured with the help of network analyzer. Female SMA Connector is used to feed the fabricated antenna. The prototype of fabricated antenna is shown in Fig. 9 and the measured results are given in Fig. 10. VSWR is depicted in Fig. 11. The measured results show that three operating bands have return losses<-10. The operating bands are 1.42GHz, 5.15GHz and 6.16GHz with return losses of -22.98dB, -27.17dB and -37.72dB respectively. At 1.42GHz VSWR is 1.12, at 5.15GHz is 1.09 and at 6.16 is 1.03.

(a) (b)

Fig. 9. Fabricated prototype of proposed antenna (a) front view (b) back view

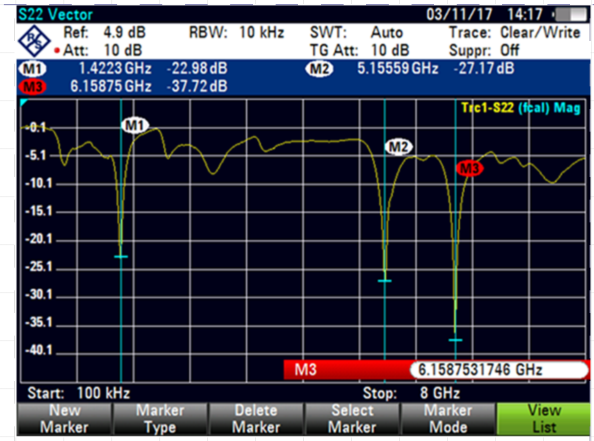


Fig. 10. Measured results of fabricated antenna

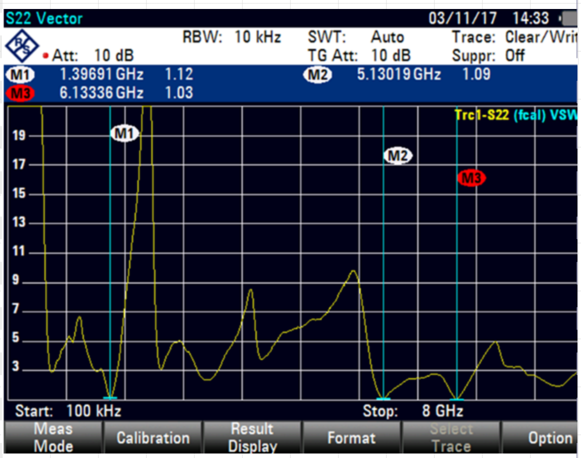


Fig. 11. VSWR of fabricated antenna

VII. Comparison of Simulated and Measured Results

The simulated and measured are compared in term of return losses and VSWR are compared and shown in Fig. 12 and 13 respectively. The measured results shows that the resonance frequencies are slightly shifted toward higher frequencies from simulated results. However the measured results have good return losses, wider bandwidth and VSWR values than simulated results. The compared results are tabulated in Table IV.

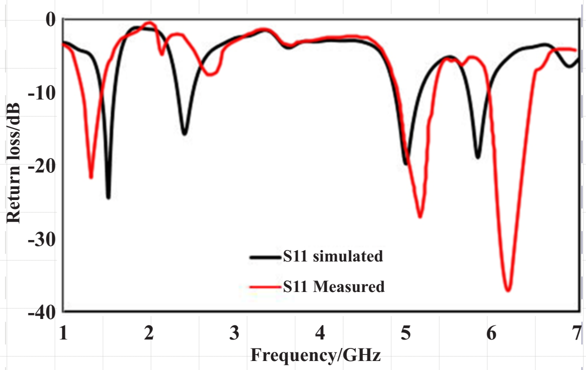


Fig. 12. Simulated and measured results

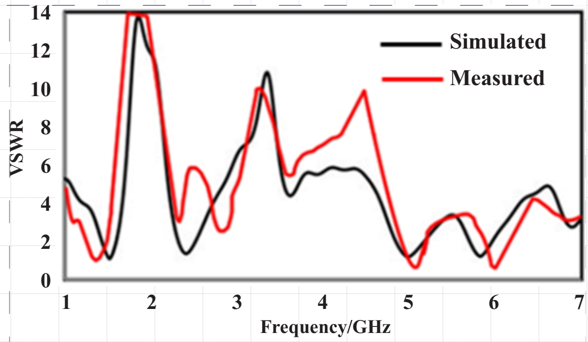


Fig. 13. Simulated and measured VSWR of proposed antenna

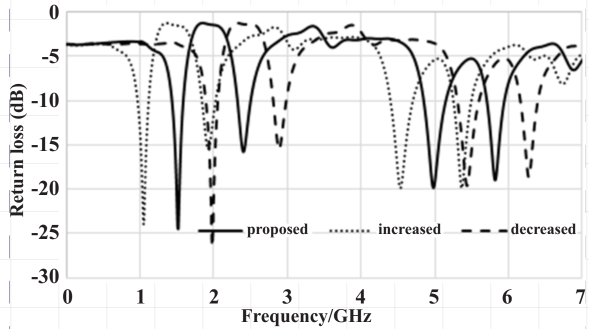


Fig. 14. Simulated return loss of proposed antenna for different values of radiator

TABLE IV
Compression of Simulated and Measured Results of Proposed Antenna

Results	Freq. Ghz	Return loss (dB)	VSWR	Bandwidth (MHz)
Simulated	1.5	-24.12	1.1	155.60
	2.4	-15.52	1.3	181.13
	5.0	-20.51	1.2	300.80
	5.8	-18.77	1.2	238.15
Measured	1.42	-22.98	1.12	180.98
	2.5	-8.650	1.09	170.63
	5.15	-27.17	1.67	324.86
	6.16	-37.72	1.03	260.51

VIII. Conclusion

In this article an M-shape multiband micro-strip patch antenna is presented. The antenna consists of M-shape main radiating patch, defected ground having two PROSs and single micro-strip feed line. To examine the performance in term of return losses, gain, efficiency, and radiation pattern; the proposed antenna is simulated in CST and fabricated as well. The simulated results show that the antenna resonates at four bands (1.436 GHz -1.586 GHz), (2.313 GHz-2.50 GHz), (4.844 GHz -5.150 GHz) and (5.714 GHz-5.951 GHz) with central frequencies 1.5GHz, 2.4GHz, 5.0GHz and 5.8GHz respectively. Simulated and measured results have good resemblance with a slight shift at higher frequency bands. Both the simulated and measured results show that proposed antenna has good return losses, peak gain of 1.57 and stable radiation pattern. The proposed antenna finds application in GPS, WLAN and ISM for wireless communication systems.

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