A Multi Band Mimo Antenna with A Square Shaped Funnel Like Ground Stub

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Abstract- Multi band multiple-input multiple-output (MIMO) antenna with a square-shaped funnel-like ground stub is experimentally investigated. Wideband performance are achieved by using this proposed system with multiple frequency. The dimension of the proposed MIMO antenna is 24x30mm^2 and consists of two rectangle patches modified monopole-antenna elements. The impedance bandwidth of the presented antenna is 9.6GHz (S11 < -10dB) ranging from 3.1GHz to10.6GHz, which is achieved by using square-shaped funnel-like ground stub with a vertical slot. The various parameters of diversity performance are also calculated. The simulated and measured results of the presented antenna are comparable, which indicates that the presented antenna can be utilized in UWB applications and can use multiple frequency applications also.

Indexed Terms- Iterated function system, Multiple-input-multiple-output antenna, Sierpinski carpet fractal antenna

I. INTRODUCTION

In 2002, the Federal communication commission (FCC) permitted the utilization of unlicensed frequency bandwidth ranging from 3.1GHz to 10.6GHz in commercial applications. The Ultra-wideband (UWB) is an interesting technology, which permits ultra-high speed communication at low power consumption for short-range applications. UWB systems experience multipath fading problem and this issue can be resolved by the utilization of Multiple-input-multiple-output (MIMO) techniques in UWB systems. MIMO techniques improve system reliability and channel capacity. But compact size MIMO antennas experience high mutual coupling, which degrades the performance of an antenna. Reducing mutual coupling in a compact MIMO antenna is always challenging. While techniques like electromagnetic band-gap structures, meta materials, meta surface and sometimes neutralization line are more favourable for minimizing mutual coupling between elements of narrow-band MIMO antennas. In the case of wideband and UWB MIMO antenna techniques like defected ground structures (DGSs), protruding ground stub like radial stub loaded resonator and sometimes neutralization line are more useful in reducing the mutual coupling. Many MIMO antennas for UWB applications are designed in the past. The Square-shaped, Octagonal-shaped fractal, and Triangular-shaped with slot MIMO antennas are reported in, which covers frequency bands 3.1GHz–10.6GHz, 3.1GHz–11GHz,3.3GHz–10.8GHz,2.0GHz–10.6GHz, and 3.1GHz–10.6GHz respectively.

II. ANTENNA DESIGN

2.1 ANTENNA CONFIGURATION

The geometry of a compact modified Sierpinski carpet fractal UWB MIMO antenna with a square-shaped funnel-like ground stub. The overall dimension of this antenna is 24X 30mm^2.It has two identical modified Sierpinski carpet fractal radiating elements. A square-shaped funnel-like ground stub is used for proper matching and a vertical slot is cut to enhance isolation. This proposed antenna is simulated by utilizing the CST simulation tool. This presented antenna is fabricated on an FR4 substrate (height = 0.8 mm, dielectric constant = 4.3, and loss tangent = 0.02) and its prototype photograph. The dimensions of the proposed MIMO antenna are listed in Table 1.

2.2 SUBSTRATE

Lot of work has been done on different substrates. Substrates use in microstrip patch antenna varies from $2.2 \leq \varepsilon \leq 12$. Lower the permittivity of dielectric material larger the size of the antenna but it achieves better efficiency and larger bandwidth. The Ɛr is limited by radio frequency or microwave circuit connected to antennas. When substrate of higher dielectric constants was used than the performance result degrades. The substrate used here is FR4 lossy material of dimensions 24X32 mm^2.

2.3 GROUND

Defected ground structures are the most popular techniques, especially when it comes to mutual coupling reduction between broadband and ultra-wideband MIMO antenna elements. Several review papers are available on DGSs in the existing literature to showcase its importance while MIMO antenna designing. Actually, DGS is a defect in a ground plane, which intensely disturbs the surface current distribution. As a result, the impedance of the transmission line will change. It acts as a band stop filter and suppresses the coupled fields between the adjacent antenna elements of the MIMO antenna by decreasing the current on the ground plane.

The evolution process of the ground plane for the proposed modified Sierpinski carpet fractal MIMO antenna. The simulated S-parameters of the MIMO antenna for different ground configurations. As antenna elements are symmetrical, so S22 and S12 are similar to S11 and S21 respectively.

For Ground 1, the lower cut-off frequency of S11 is 4.23GHz (for S11 < -10dB) and mutual coupling, S21 is above 15dB. Whereas the required lower cut-off frequency of S11 is 3.1GHz for the UWB systems and mutual coupling, S21 should be less than 15dB for the MIMO antennas. However, the square shaped funnel-like ground stub with a vertical slot (Ground 2) shifted the lower cut-off frequency of S11 from 4.23GHz to 3.0GHz. It has occurred because ground stub behaving as a reflector, the introduced vertical slot has improved the isolation S21 and now it is lower than 16.3dB for the entire operating frequency range. MIMO antenna with Ground 2 is suitable for UWB applications as it is covering the frequency band ranging from 3.1GHz to 10.6GHz. It Shows the effects of different ground planes on current distribution at 3.2GHz and 7.51GHz frequency. To analyse the surface current distribution, one port needs to be excited and the second port of the MIMO antenna needs to be terminated with a matched 50ohms load. Therefore, port-1 is excited and the port-2 of MIMO antenna is terminated with a 50ohms load in. It is clearly noticeable from that large current is coupled towards the square-shaped funnel like ground stub and a vertical ground slot. As a consequence, the surface current reduced near the next monopole element. It clearly indicates the reduction of mutual coupling between ports.

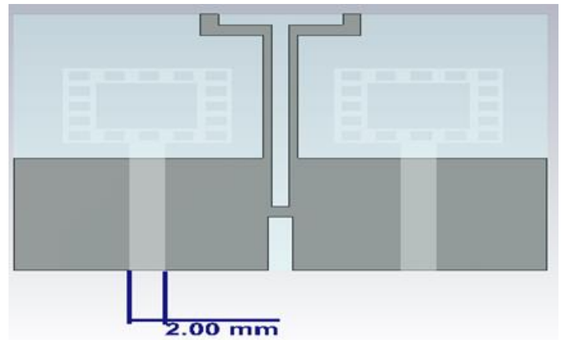


Fig 1: Ground Design

2.4 PATCH

The desired miniaturization, wideband and multiband characteristics can be obtained by using fractal structures in antennas. A Sierpinski carpet fractal structure is a self-similar structure. In iteration-0, a rectangle is used as a base structure. Then this base structure is scaled by a factor of three from both directions, creating nine small rectangles, then one central rectangle is removed from nine small rectangles; this is iteration-1, the same steps of the previous iteration are repeated on remaining eight small rectangle. A patch antenna is a type of antenna with a low profile, which can be mounted on a surface. It consists of a planar rectangular, circular, triangular, or any geometrical sheet or "patch" of metal, mounted over a larger sheet of FR4 lossy called a substrate. Here we used the PEC material as the patch.

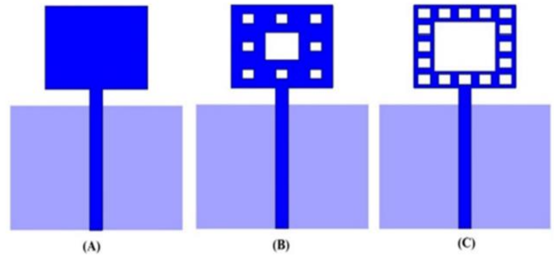


Fig 2: Sierpinski Carpet Fractal Structure

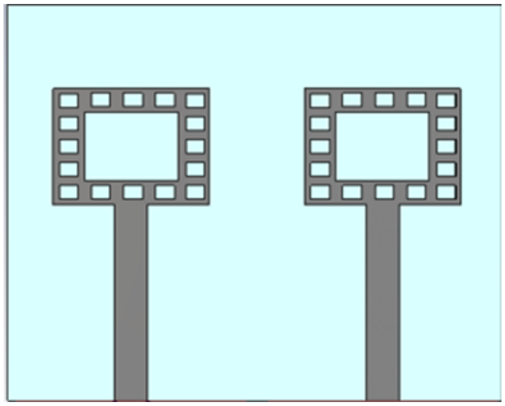


Fig 3: Patch Desgin

Table 1
Dimensions of the presented MIMO antenna (Unit: mm).

L	L_p	L_{p1}	L_{p2}	L_f	L_{g1}	L_{g2}	L_{g3}	L_{s1}	L_{s2}
24	7	4.2	0.84	11.9	10.5	2	1	5	16
W	**W_p**	**W_{P1}**	**W_{P2}**	**W_F**	**W_{G1}**	**W_{G2}**	**W_{G3}**	**W_{S1}**	
30	9.5	5.7	1.14	1.2	6.4	4.5	1	1	

FINALIZED DESGIN

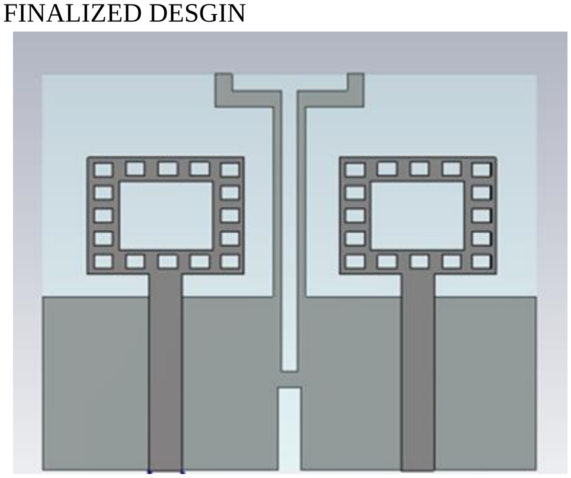


Fig 4: Finalized Design

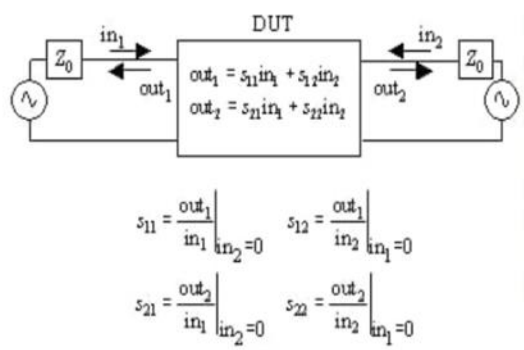
III. RESULTS AND DISCUSSION

The modified Sierpinski carpet fractal MIMO antenna is fabricated. The results of the fabricated antenna are compared to corroborate the simulation results. The results are measured using the Keysight vector network analyser (model N9916A). There is a slight variation in measured results when compared with the simulated results due to environmental setups, fabrication limitations, and SMA connectors. The comparison between measured and simulated S-Parameters are shown below. There is a slight mismatch between simulated and measured results due to fabrication limitations such as thickness and soldering of the connector as well as the improper copper etching. The impedance bandwidth and fractional bandwidth of the presented fractal MIMO antenna is 9.6GHz. 123.07%, respectively. It can observed that the isolation, S21 is greater than 16.3 dB over the entire working frequency range. Further improvement in the fractional bandwidth can be done with the help of ground stub matching. The use of a slot antenna loaded with stubs increases the fractional bandwidth. Also, slot antenna having CPW-feed will advocates higher fractional bandwidth. Some other general methods of increasing bandwidth are: using thick and low permittivity substrates; by introducing closely spaced parasitic patches on the same layer of the feed patch; using Stacked Parasitic patch; aperture Coupling; aperture Coupled Stacked Patches and L-Probe Coupling. Also, the two-port antenna system having increased fractional bandwidth can be extended to build a larger array antenna having shaped beams approximated through maximally-sparse planar arrays. The larger array has the benefits of better beam steering and higher bit rate without sacrificing additional spectrum and transmitted power. The normalized 2D-radiation patterns of MIMO antenna for all resonant frequencies (3.20GHz, 4.95GHz and 7.6GHz) in E-plane (XZ-plane) and H-plane (YZ-plane). The measured and simulated co-polarization and cross-polarization radiation patterns analysis for all the four resonant frequencies also presented for both the ports by exciting one port and terminating the other port by 65.2ohms load impedance. The radiation patterns are omnidirectional, except few dips, especially in the YZ planes at the higher frequency. So, we are almost getting an omnidirectional pattern, which is required and desirable for better performance of the MIMO antenna. Also, the normalized radiation pattern of Co and cross polarization shows the isolation of almost more than 20 dB in XZ plane and 15 dB in YZ plane mainly in the main lobe direction (which is slightly varying around ±90) at all the resonant frequencies, which clearly indicates that this antenna is a linearly polarized. The pattern diversity of this antenna is improving as we move from lower to the higher resonating frequency in the XZ plane of all the four frequencies as shown below. The realized peak gain of this antenna is shown below. The radiators of the proposed MIMO antenna are symmetrical in the structure; therefore, both radiators gain values are similar. Hence, the realized peak gain of one radiator is shown below. The measured gain varies from 2dB to 4.8dB throughout the working frequency band ranging from 3.1GHz to 10.6GHz.

S-PARAMETERS

Scattering parameters describes the input-output relationships between ports in an electrical system. Specifically at high frequency it becomes essential to describe a given network in terms of waves rather than voltage or current. Thus, in S-parameters we use power waves.

For a two-port network, s-parameters can be defined as



In RF design, we can’t use other parameters for analysis such as Z,Y,H parameters as we can't do short circuit and open circuit analysis as it is not feasible.

S11 is the input port voltage reflection coefficient
S12 is the reverse voltage gain
S21 is the forward voltage gain
S22 is the output port voltage reflection coefficient

S11 AND S22:

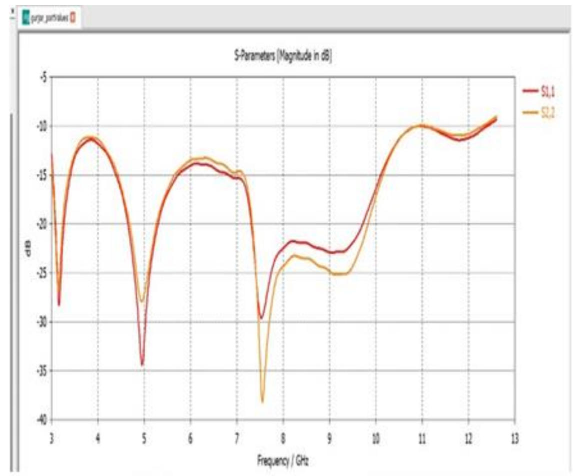


Fig 5: S11 AND S22

The S-parameter matrix can be used to determine reflection coefficients and transmission gains from both sides of a two-port network. This concept can further be used to determine s-parameters of a multi-port network.

S12 AND S21:

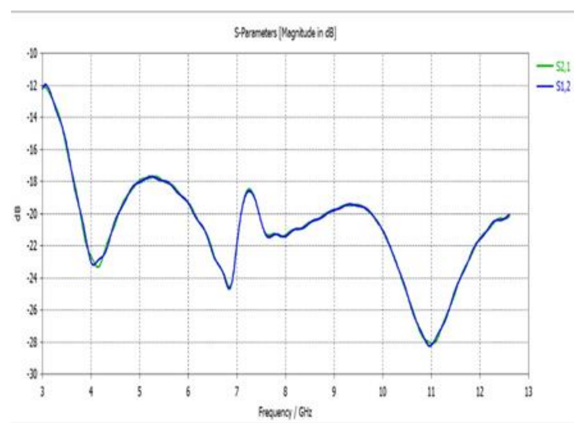


Fig 6: S12 AND S21

- VSWR

VSWR stands for Voltage Standing Wave Ratio, and is also referred to as Standing Wave Ratio (SWR). VSWR is a function of the reflection coefficient, which describes the power reflected from the antenna. If the reflection coefficient is given by s11 or reflection coefficient or return loss, then the VSWR is defined by the following formula:

$$VSWR = \frac{1+|\Gamma|}{1-|\Gamma|}$$

The VSWR is always a real and positive number for antennas. The smaller the VSWR is, the better the antenna is matched to the transmission line and the more power is delivered to the antenna. The minimum VSWR is 1.0. In this case, no power is reflected from the antenna, which is ideal.

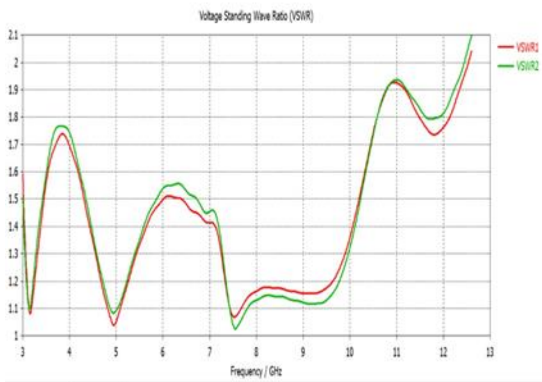


Fig 7: VSWR

Often antennas must satisfy a bandwidth requirement that is given in terms of VSWR. For instance, an antenna might claim to operate from 100-200 MHz with VSWR<3. This implies that the VSWR is less than 3.0 over the specified frequency range. This VSWR specifications also implies that the reflection coefficient is less than 0.5 (i.e., reflection coefficient<0.5) over the quoted frequency range.

- REFERENCE IMPEDENCE

Reference impedance is a number that is used to define S parameters. If you have S-Parameters and you want information about voltages and currents (or vice versa), you need the reference impedance.

But in general, the reference impedance can be complex and/or frequency-dependent.

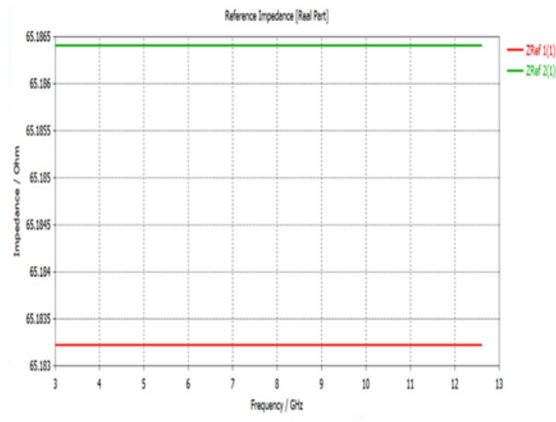


Fig 8: Reference Impedence

- EFFICIENCY

Antenna Efficiency is the ratio of power radiated (Prad) by the antenna to the power supplied (Ps) to the antenna. The efficiency of an antenna is usually measured in an anechoic chamber where an antenna is fed with some power and the strength of the radiated electromagnetic field in the surrounding space is measured. An ideal antenna has 100% antenna efficiency i.e., it transmits all the power fed to it. But in the real world, a good antenna radiates only 50 to 60% of power supplied to it.

$$Antenna\ Efficiency = \frac{P_{RAD}}{P_T}\ \%$$

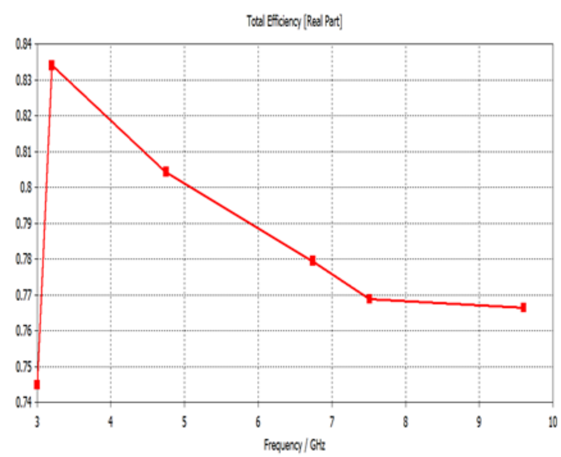


Fig 9: Efficiency

- FAR-FIELDS

The field, which is far from the antenna, is called as far-field. It is also called as radiation field, as the radiation effect is high in this area. Many of the antenna parameters along with the antenna directivity and the radiation pattern of the antenna are considered in this region only.

The field distribution can be quantifying in terms of field intensity is referred to as field pattern. That means, the radiated power from the antenna when plotted, is expressed in terms of electric field, E (v/m). Hence, it is known as field pattern. If it is quantified in terms of power (W), then it is known as power pattern. The field, which is very near to the antenna is reactive near field or non-radiative field where the radiation is not pre-dominant. The region next to it can be termed as radiating near field or Fresnel's field as the radiation predominates and the angular field distribution. The region next to it is radiating far-field region. In this region, field distribution is independent of the distance from antenna. The effective radiation pattern is observed in this region.

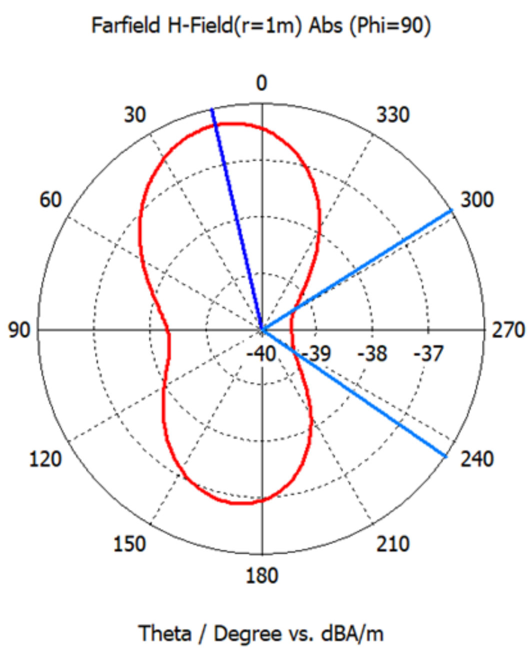


Fig 10:H-Field at 3.2GHz

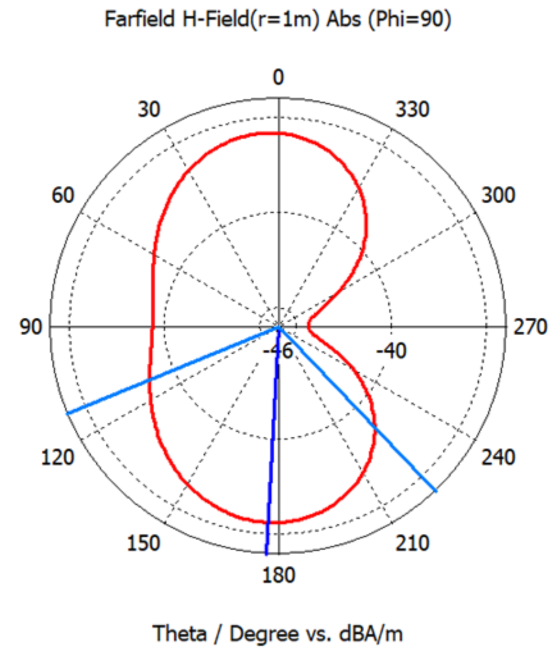


Fig 11:H-Field at 4.9GHz

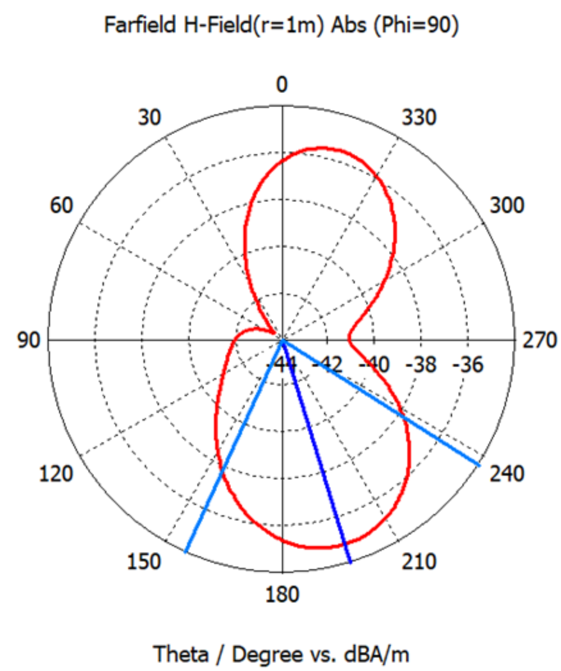


Fig 12: H-Field at 7.6GHz

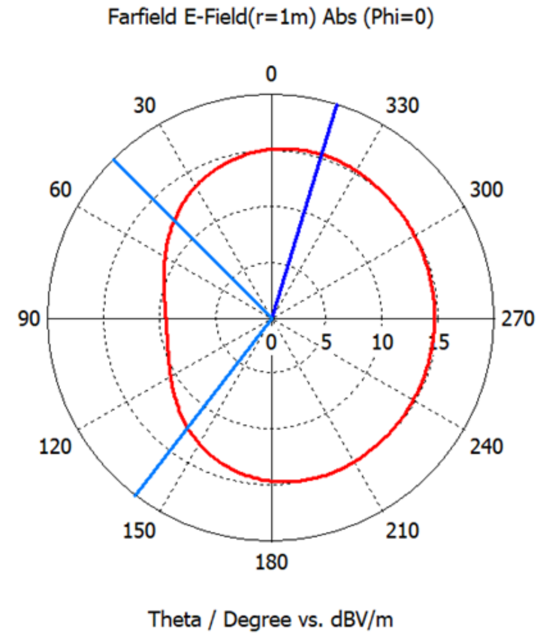


Fig 13: E-Field at 3.2GHz

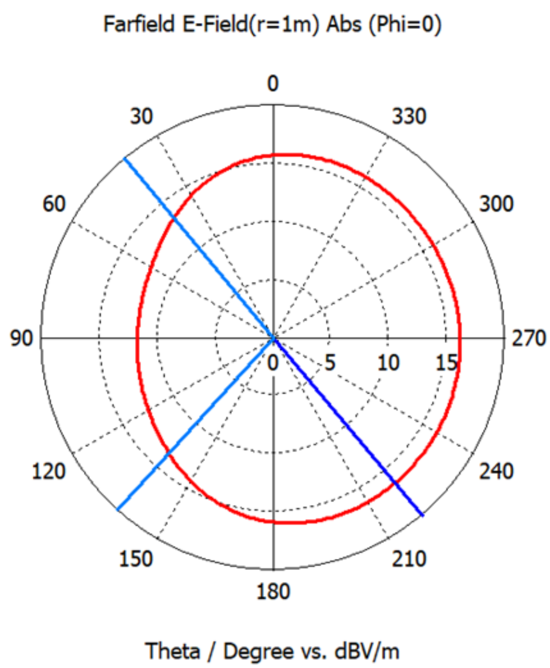


Fig 14: E-Field at 4.9GHz

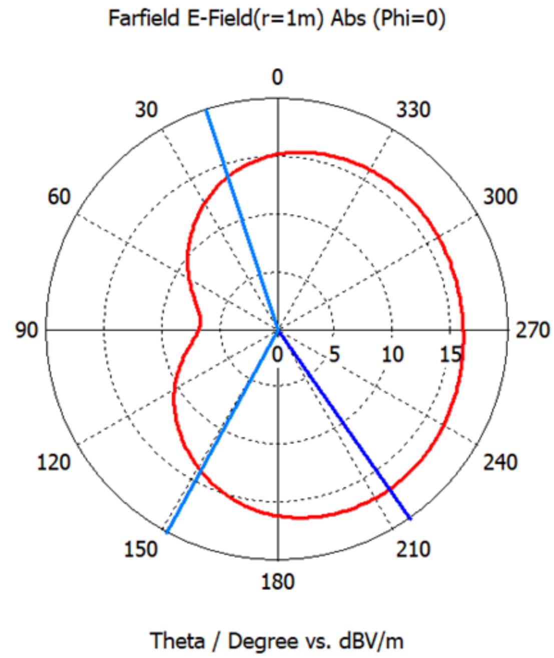


Fig 15: E-Field at 7.6GHz

IV. CONCLUSION

Multiple band MIMO antenna having dimensions 24X30mm^2 has been presented, fabricated (on FR-4 Substrate) and experimentally investigated. The two Rectangle patches modified monopole antenna elements are used to design this antenna, which covers the UWB operations ranging from 3.1GHz to 10.6GHz. The impedance bandwidth of the presented antenna is 9.6GHz (S11 < -10dB) ranging from 3.1GHz to 10.6GHz, which is achieved by using square-shaped funnel like ground stub with a vertical slot. Miniaturization and wideband performance are achieved by using this proposed system. The resonate frequencies of proposed antenna are 3.2GHz,4.9GHz, and 7.6GHz which used for wireless communications.

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