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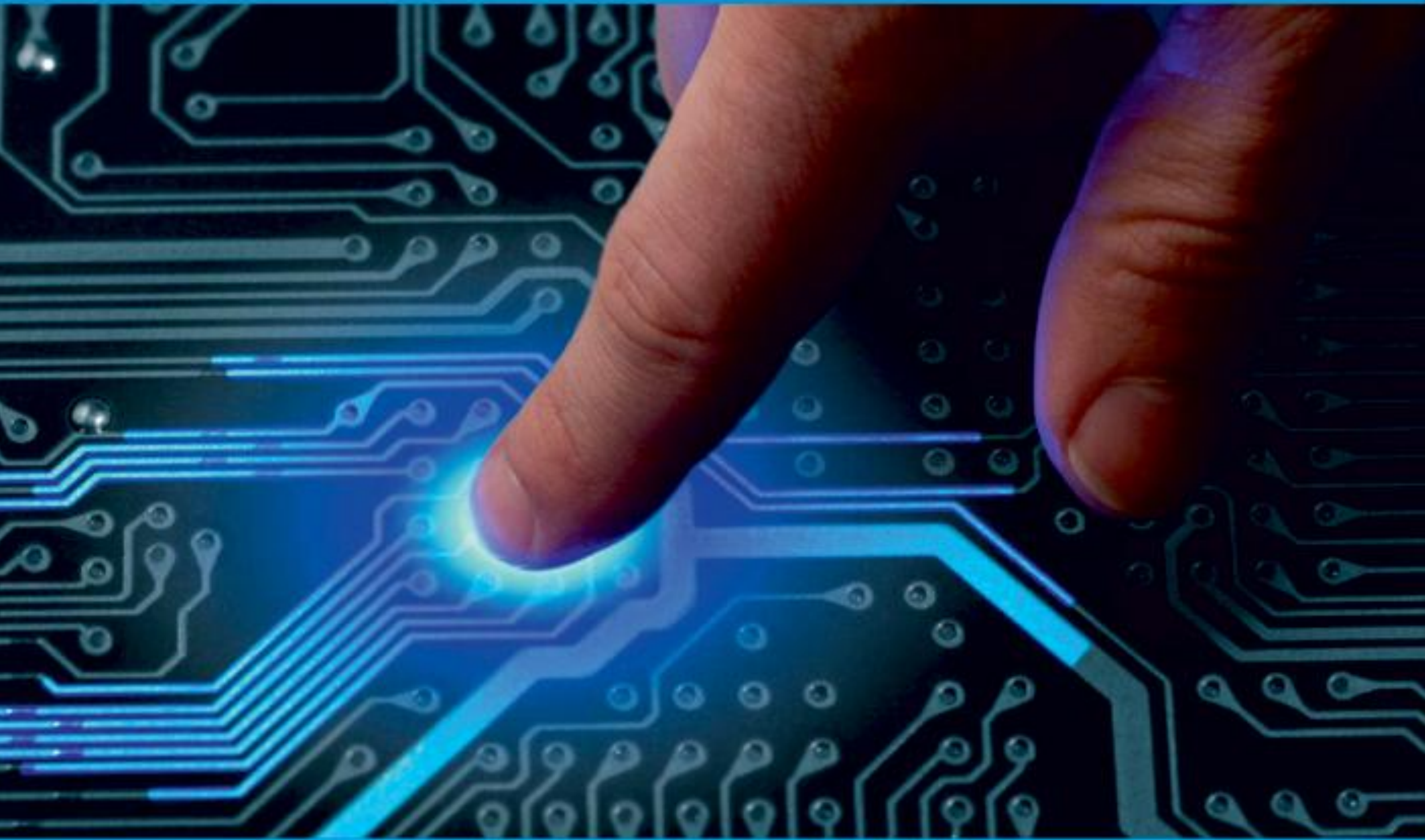

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Design and Analysis of Ultra-Wideband MIMO Diversity Antenna using Characteristic Mode Analysis

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ABSTRACT*:* Increasingly, MIMO technology has been considered to be the best communication technique. In this work, we are designing and analyzing a 2-port UWB MIMO diversity antenna to operate from 2.7-10.5 GHz and to have an impedance bandwidth of 118.18%. The proposed design has a size of 0.57λ2.7*0.28λ2.7 (λ2.7 indicates the lowest operating wave-length). It consists of bi-planar printed fractal radiators with feeds that are curved in geometry and are diametrically fed. For design, we used Characteristics mode analysis (CMA). The analysis includes detailed evaluation of modal dynamics, resonance mechanisms, and bandwidth potentials.. The port-isolation is ≥ –15 dB when ground plane is truncated by rectangular slots via ellipsoid slot. The ground thin neutralization lines reduce mutual coupling even further by 7.5 dB (> - 22.5 dB). The diversity performance metrics include ECC, CCL, DG, multiplexing efficiency, MEG, and TARCECC is low < 0.17 (from far-field magnitudes) and the mean effective gain for both ports is MEG > 3 dB with MEG1/MEG2 *1, which may be appropriate for multi-standard ad-hoc mobile/wireless diversity applications. We also develop an equivalent circuit model and build a prototype antenna to measure its performance.

I. INTRODUCITON

The MIMO (multiple-input-multiple-output) antenna is regarded as the future of communications, antennas are becoming smaller and smarter in design due to technological evolution, which has indefensible performance-centric aspects such as higher data capacity with lower power consumption, spectrum efficiency, and enlarged transmission capacities. Universities and RF engineers focus on combining UWB and MIMO technologies for mobile/wireless/sensor ad-hoc diversity systems. So blending UWB and MIMO technologies makes sense for multi-standard mobile/wireless/sensor ad-hoc diversity systems. This design novelty primarily focuses on antenna configurations for better performance, isolation improvement, and MIMO diversity metrics:

- A planar printed antenna must have a simpler design. In order to facilitate fabrication, we designed fractal radiators with biplanar feeds and diametrically fed feeds. A transformer for impedance matching is a contorted feed. Compared with conventional feed, diametrically fed systems offer good impedance bandwidth and directional far-field patterns.
- Antennas should be isolated in order to prevent coupling. For good port isolations and mitigation of near-field radiated waves, ground plane is truncated by rectangular slots horizontally and vertically on major and minor axis of compressed ellipsoid slot, which results in > -15 dB isolations. A further reduction in mutual coupling is achieved when end-connected ground thin neutralization lines are introduced (measured >–22.5 dB). Antenna performance is not affected by the slots or neutralization lines.
- MIMO diversity performance metrics. Diversity metrics, such as low envelope channel coefficients (ECCs) and mean effective gains (MEGs), determine how well the design can operate in different channel environments, such as isotropic and indoor.
- Study of CMA dynamics in proposed antenna . Antenna performance and design have been investigated using a classical approach based on the CMA. A resonance mechanism, bandwidth potential, and radiation behaviour are predicted by this analysis.
- Antennas such as UWB and super wide band (SWB) antennas were discussed as research considerations because of the above mentioned reasons. The antennas have a number of advantages, such as simplicity in fabrication, low power

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consumption, and high transmission rate. Although SWB antennas have many advantages, they also have some limitations, such as multipath fading and channel capacity, which affect their overall performance. There has been recent progress in MIMO antenna structures that have multiple radiating elements that combat such problems without consuming more bandwidth or power. In most communication systems (i.e., transmitters and receivers), MIMO antennas are used to enhance the communication quality and capacity. Because multiple radiating elements are deployed close together, MIMO antennas result in mutual coupling, and one solution is to move radiating elements several miles away, which will increase the size of the antenna. Most of the current research focuses on overcoming these two major challenges. Many techniques have been developed to minimize mutual coupling, for instance, in MIMO antennas.
Due to the above challenges, this dissertation examined the design and analysis of a compact planar MIMO antenna with good performance in terms of bandwidth, gain, and efficiency with a simple design structure. Mutual coupling between radiators in MIMO communications is reduced using a T-shaped decoupling stub that extends over the entire bandwidth while maintaining optimized values of ECC > 0.1 and diversity gain (DG) > 9.98 dB and comparable values of gain and efficiency.

II. METHODOLOGY

A. *Characteristic Mode Analysis of the MIMO Antenna*

In a computer simulation using the version 2017 of computer simulation technology, the characteristic mode theory was applied to the two-element MIMO monopole antenna without feeding structure. Current modes are measured by normalized amplitude. The size and shape of the conducting object determines the normalized amplitude, not the feeding port. It shows the modal significance of three modes, as can be seen that only mode 1 had modal significance of up to 1 at the resonant frequency of 5.8 GHz. Mode 2 and mode 3 were at 5.5 GHz and 4.8 GHz. Therefore, mode 1 will become dominant in the antenna. It presents the characteristics angle for the MIMO antenna at three different modes. Characteristic angle is defined in as:

$$\Theta=180-\tan-1(\lambda n)$$

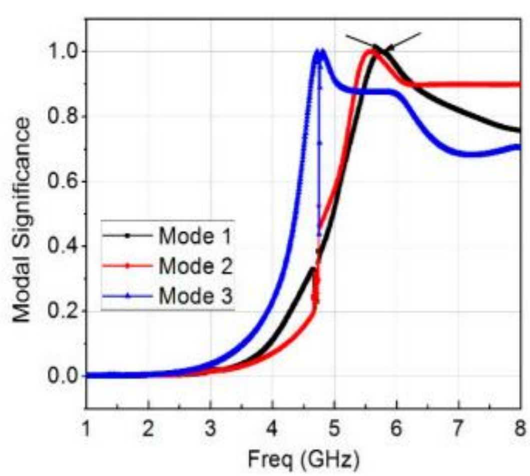

Figure 1. Modal significance of three modes at 5.8 GHz

An explanation of how MIMO arrays store energy is provided by the above equation. Modes with a characteristic angle of 180° or greater resonate, modes with an angle of 110° or less store magnetic energy, and modes with an angle of 180° or greater store electric energy G) >9.98 dB and comparable gains and efficiency. In mode 1, the resonance frequency was around 5.8 GHz, as mentioned earlier. At 5.8 GHz, there are modal surface currents and modal 3D radiation patterns. Being the dominant mode, mode 1 had a greater gain than the others, indicating it is also an important mode for reducing mutual coupling. It presents the eigen values of the three modes. When *n = 0, there was a noticeable resonance between

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the three modes, yet mode 1 was more dominant. The following figures illustrate normalized 2D radiation patterns for modes 1, 2 and 3.

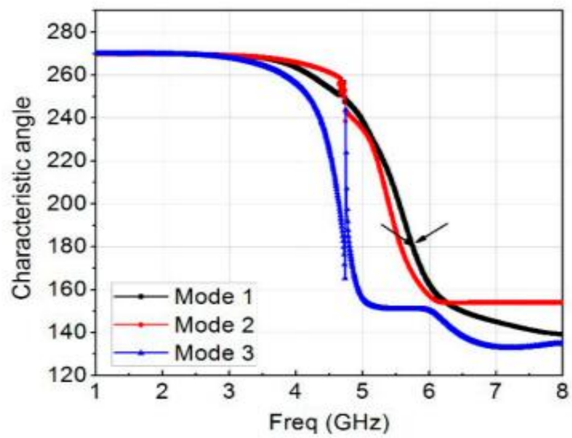

Figure 2. Characteristic angle of three modes at 5.8 GHz

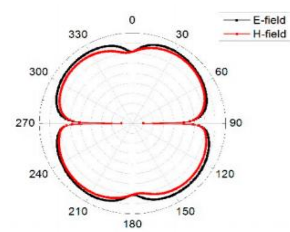

Figure 3. Radiation pattern for mode 1 at 5.8GHz

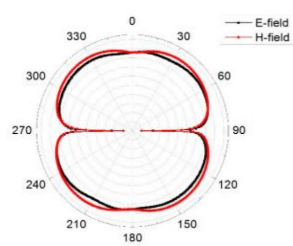

Figure 4. Radiation pattern for mode 2 at 5.8GHz

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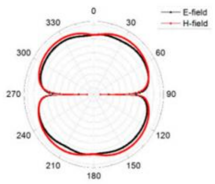

Figure 5. Radiation pattern for mode 3 at 5.8 GHz.

III. PROPOSED ANTENNA CONFIGURATION

A bi-planar fractal radiating structure is proposed with a truncated slot ground structure on the bottom, printed on a FR-4 substrate of 1.6mm thickness, εr = 4.3, tanδ = 0.027 shown in Figure 6. A 115-order Koch-fed space filling set is used as the radiating outer boundary. To maintain consistent electrical properties, the 2nd order iteration is scaled to K/3 (primary generator) and its successive self-similar copies are down-scaled to K/9 (secondary generator). .

A proposed space filling set is the 2nd order Koch geometry due to its ease of fabrication and wideband characteristics. It has the advantage of increasing the electrical length of fractal boundaries, which compress the inductive surface currents of its alias copies. Thus, the geometry encompass multi-resonances. A contorted feed has been used to increase impedance matching response, and excitation is fed diametrically opposite the feed, which is unique.

The feed contortion enforce impedance mismatch due to different wavelengths resonating at its collocated intersection. When the front-end of the feed is connected to a magnetic fractal boundary, as a result the asymmetricity in the collocated feed has an impedance mismatch that transducer coupling energy due to variable resonating wavelengths, which generates an UWB response with multi-resonances on the counter influence of snowflake symmetry

A. *CMA on a planar printed 2-port UWB MIMO antenna design*

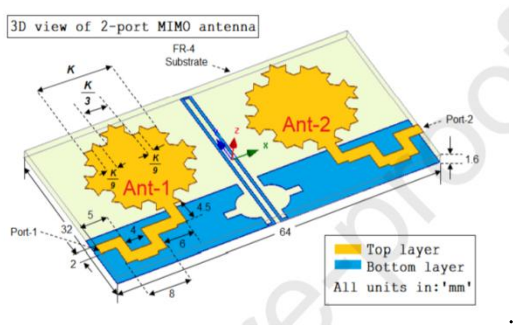

Figure 6. Geometry of the proposed 2-port MIMO antenna.

B. Equivalent circuit design

An understanding of the behaviour of several circuit components is necessary for designing equivalent RLC circuits. It begins with (i) input excitation, (ii) 10 modelling of proposed UWB antenna and (iii) output extraction. Figure 7 shows the equivalent circuit design for proposed 2-port MIMO antenna, and Figure 7 shows the circuit simulation response with EM-simulated responses. Two simulations show good agreement, indicating the proposed antenna design is valid.

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As a consequence of the contorted feed acting as an inductive coupling transformer with excited ports, it can be realized as an impedance coupling transformer. Antenna elements are coupled with the source impedance by the magnetic energy of the transformer. Each antenna element is coupled along symmetric lumped paths to balance its effect on the decoupling circuit. Modeled are antennas-1 and antenna-2 which are parallel-fed RLC elements in series. Inductive neutralization lines are realized as current-blocking stubs and offer a resistance Rconn to stub currents. The gaps between neutralization lines and elliptical slots can be modelled as capacitive elements Cgap and Cs Optimized and validated equivalent circuit design and lumped parameters are performed using Advanced Design Simulation (ADS).

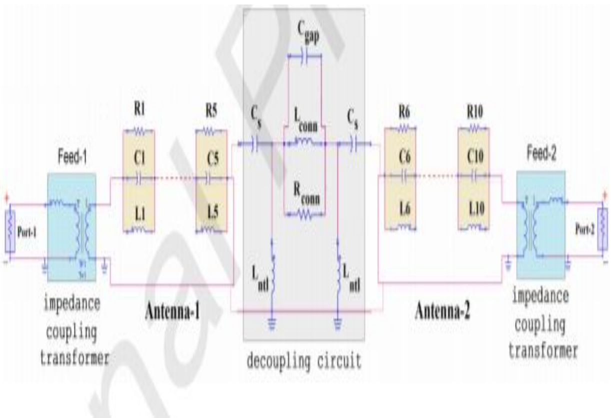

Figure 7. Equivalent circuit diagram of proposed 2-port antenna ,

The circuit parameters with lumped values are:- Feed1 = 0.81 nH, Feed2 = 1.02 nH, R1 = R10 = 20 Ω, R2 = R9 = 90 Ω, R3 = 31 Ω, R8 = 60.14 Ω, R4 = 34.84 Ω, R7 = 28.08 Ω, R5 = 43 Ω, R6 = 40.5 Ω, C1 = 1.95 pF, C2 = C9 = 3.99 pF, C3 = 0.81 pF, C4 = 1.99 pF, C5 = 2.05 pF, C6 = 1.91 pF, C7 = 1.69 pF, C8 = 0.79 pF, C10 = 5.85 pF, L1 = 0.84 nH, L2 = L9 = 0.81 nH, L3 = 1.21 nH, L4 = 0.44 nH, L5 = L6 = 0.14 nH, L7 = 0.39 nH, L8 = 1.4 nH, L10 = 0.71 nH, Cs = 1.5 pF, Cgap = 0.5 pF, Lntl = 6 nH (Left), Lntl = 0.091 pF (Right), Lconn = 0.125 pF, Rconn = 15 Ω. Number of primary turns : Number of secondary turns = T : 1, where (T = 1).

V. SIMULATION RESULTS

The simulated antenna is operated at a frequency range from 2.7-10.5 GHz with an impedance bandwidth of -10db.In the below figure 8 has 2-ports which are in red colour indicates that we are using 2-port MIMO antenna. The yellow colour part is called as patch and rest part is called substrate **.** Initially the ground plane was designed and laterally patch .

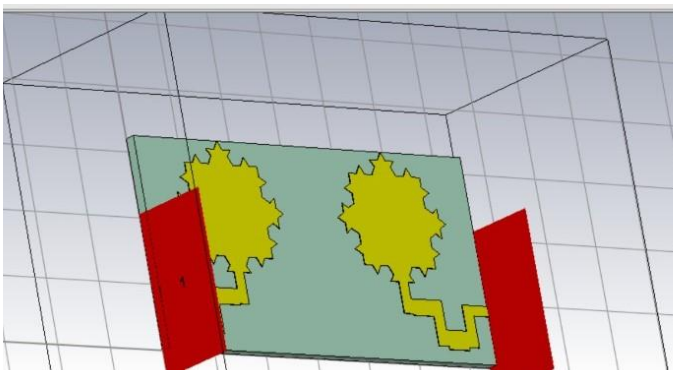

Figure 8. 3-D view of 2-port MIMO antenna

The proposed 2-port UWB MIMO antenna is investigated using CMA, some important parameters which are observed are enumerated:-

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The antenna operates at UWB mode 2.7-10.5 GHz with S11 < -10 dB as shown in Figure 9. Based on antenna resonances, the modal dynamics are computed to validate CMA.

A. ***Response***

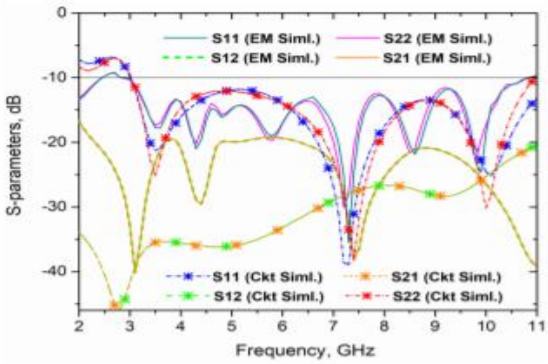
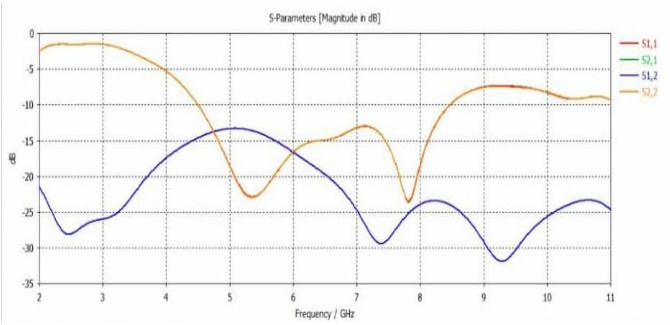
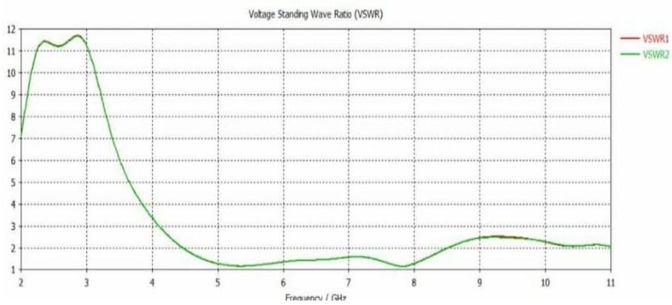


Figure 9**.** Equivalent circuit response and EM-simulated response of the proposed antenna.

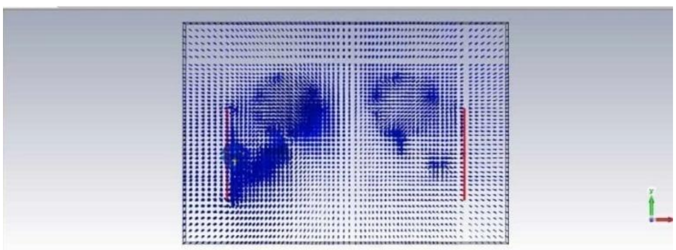
B. ***s-parameters***



C. VSWR – parameters



D. H-field distribution between 2-antennas



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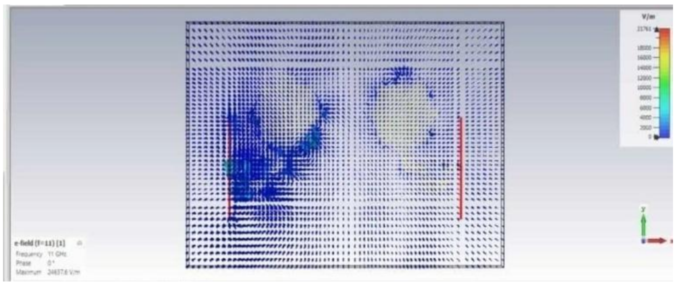
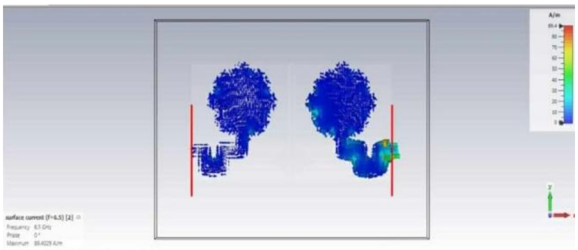
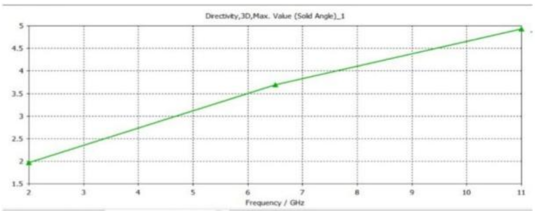
E. E-field distribution between2-antenna

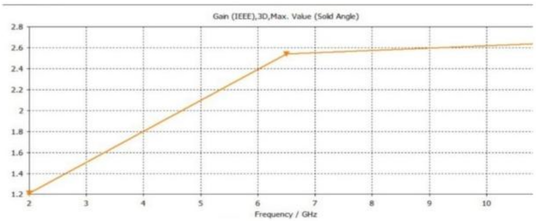


F. Surface current distribution between antennas

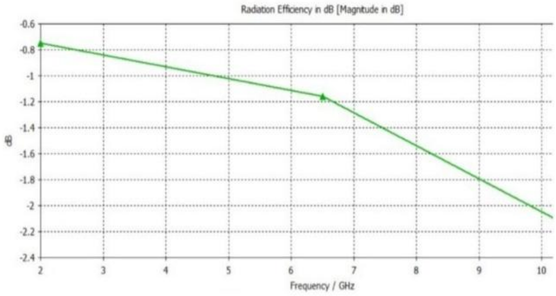


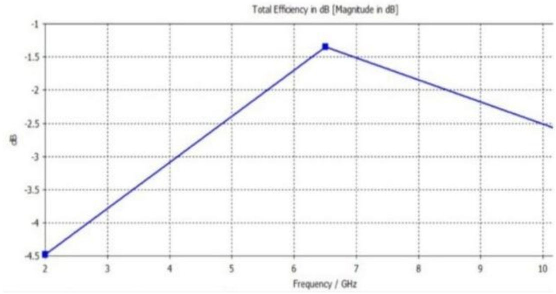
G. Gain and Directivity of 2-port MIMO antenna





H. Radiation Efficiency and total Efficiency of both antennas





VI. CONCLUSION

Two-port UWB MIMO diversity antennas with a measured band from 2.4-10.4 GHz are designed, fabricated and tested. Through the use of neutralization lines and slots, the port isolation measures >-22.5 dB. The initial investigation of the design is carried out with CMA, 220, which aids in improvising feeding configurations by analyzing characteristics modal parameters. Optimized design has an impedance bandwidth of 118.18%, and has a maximum gain of 8.4 dBi (that can be extended to MIMO array applications). A MIMO pattern diversity application can greatly benefit from the calculated performance metrics. Simulated, measured, and circuit validation has demonstrated that the proposed multi-standard UWB ad-hoc diversity antenna has 225 strong potentials for use in multi-disciplinary UWB systems.

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