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BASIC COMPACT TWO-ELEMENT ANTENNA WITH IMPROVED ISOLATION USING SUB-6GHZ FOR 5G APPLICATIONS

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Abstract— a basic MIMO antenna with two elements with a compact arrangement is designed to improve the isolation and impedance matching. These two identical elements of the antenna are fed by the microstrip line feeding given to the altered radiating elements which are rhombic in shape. Placed in the compact substrate area of 0.24λ0 × 0.42λ0 (where λ0 is the value of λ at 3.6 GHz) on an allocated rectangular ground plane. The pair of antennas which are being designed are sundered by a T-shaped ground stub to strengthen the isolation and impedance matching and the central axis of each radiating element is provided with the U-shaped stub for attaining the desired resonant frequency of 3.51GHz. The antenna system which is introduced, extends to a -10dB operating band of 3.22 to 3.75 GHz (530 MHz) with isolation of 19.8dB between the pair of antenna elements are analyzed and also the performance of this basic MIMO antenna are validated and analyzed. The measured performances and simulated performance of the desired antenna are symmetrical to each other. This proposed antenna can later be realized for a 4-element MIMO antenna. In various fields of 5G applications such as mobile communications, space, and satellite communications.
Keywords— FR4-Epoxy, Compact arrangement, Ultra-WideBand (UWB), Machine software Interface, Impedance Matching

I. INTRODUCTION

The demand in designing the MIMO antenna over a single antenna is arising day by day in the field of network communication [13]. This is because the 5th Generation (5G) Technology is being implemented all around the world. Using single antenna transmission only the basic 4G technology can be implemented. Many challenges were faced even while implementing the faster 4G technology by using the single antenna transmission. The problems such as Low reliability, Low quality of service, Low data rate, High latency have arisen while implementing the Faster 4G technology and basic 5G Technology by using Single antenna transmission[5,6,12]. Hence there is a need to master the complex issues of network communication. So, this technology in the antenna is Introduced so that the amount of information can be transmitted in much less Time with a high speed of data when compared to that of single antenna transmission. Also, all the limitations in the single antenna transmission can be overcome using the MIMO Technology [5,9]. The frequency bands that are effective for 5G communication are broadly classified into two types which are Low-mid frequency i.e., Sub-6 GHz (Spectrum below 6GHz), and 5G mm-Wave spectrum[10] (Spectrum above 24GHz). Even if the Data rate of the 5G mm-wave spectrum is higher than that of sub-6 GHz it is not preferable over sub-6 GHz because the distance covered is minimum in the 5G mm-wave spectrum when compared to that of sub-6 GHz[11]. This is the reason that

has made sub-6 GHz more demanding in many countries subjected to the wireless communication industries. The band range on which the industries have mainly focused in sub-6 GHz is from 3.4 GHz to 3.8 GHz. So, the MIMO antenna is to be designed in such a way that it meets the industrial requirements for its vast applications.
Isolation is considered one of the key factors while designing a MIMO antenna. Depending on the Isolation value, performance of the antenna is evaluated. More the value of isolation, greater will be the productivity of the MIMO antenna. To improve the isolation in the proposed system, the concept of Stub is introduced in the antenna design. Which are of two shapes namely, T-shaped stub and U-shaped stub in which, the two elements are separated by using a T-shaped stub and in the same way at the center of each radiating elements U-shaped stub is placed. Role of stubs mainly arises when the elements in the MIMO antenna are compactly arranged. These stubs which are also known as the transmission lines regulate the power absorption in between the antenna elements and hence helps in the enhancement of isolation in the antenna. Because of the moderate Isolation the proposed MIMO antenna could be widely availed in the applications of Ultra-wideband as well as LAN applications.

II. DELINEATION OF PROPOSED ANTENNA

The rudimentary design and simulation of this two element MIMO antenna include both the Software and Hardware processes later in which the simulation results of each process are compared to derive the better productivity of the proposed antenna [1,2].

Software

ANSYS HFSS is utilized to design the basic two element MIMO antenna as given in Fig.1

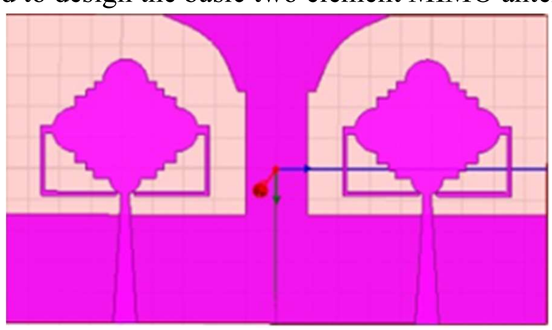

Fig.1. the Design of two element MIMO antenna

The design of proposed system can be classified based on the arrangement of the stub and the shape of antenna. The desired antenna is Rhombic in shape. FR4-Epoxy is the best-suited material to design the two-element MIMO antenna.FR stands for Flame Retardant. As per the standard values of the substrate, the dielectric constant for the proposed MIMO antenna is 4.4. Initially, the ground plane is placed in the free space later by clicking on the square-shaped box in the toolbar, the substrate of area, $0.24\lambda 0 \times 0.42\lambda 0$ (where $\lambda 0$ at 3.6 GHz) is designed [4]. The shape of the patch used in the designing process of the proposed antenna is “Rectangular” i.e., here a rectangular patch is designed, which is later placed above the surface of the ground plane. Here a patch is created by clicking on the rectangle which is available in the toolbar of HFSS and the dimensions are later specified as per the requirements by editing its fixed values to the designed values. The dimensions of the patch are Length, Width, and Height, where the L=20mm, W=35mm, H=0.8mm.

The feeding technique which is used in the designing process of Microstrip line feed. Using this technique, the position of the strip line is varied. Two identical Tapered, modified rhombus-shaped antenna is fed by using this microstrip line feed technique which is positioned in the identical orientation at the compact substrate area. This tapered line strip is considered because the T-shaped stub and the U-shaped stub which are placed on and in between the antenna elements have that contact on the ground plane at only one end. The word stub refers to the length of the Transmission line or the waveguide connected at one end only. To enhance the Isolation of the MIMO antenna T-shaped and U-shaped stubs are placed. Based on the positional arrangement of the elements, Impedance matching and Isolation can be ameliorated by placing the T-shaped stub in between each pair of radiating elements. Similarly, in order to achieve the required value of 3.6GHz which is resonant frequency, at the epicenter of each radiating elements a U-shaped stub is placed. In ANSYS HFSS, these stubs can be placed on the antenna which is currently designed as per the parameters, with the help of the net list symbols which are available in the library of the ANSYS HFSS.

Hardware

The Hardware processing of the proposed system includes the Fabrication which is carried out using the prototyping Machine as shown in Fig.2

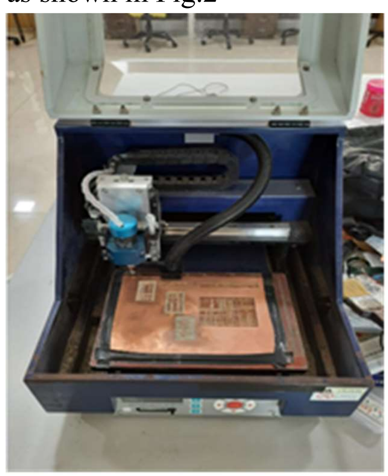

Fig.2 MITS-Eleven lab Prototyping Machine for Hardware processing of proposed system

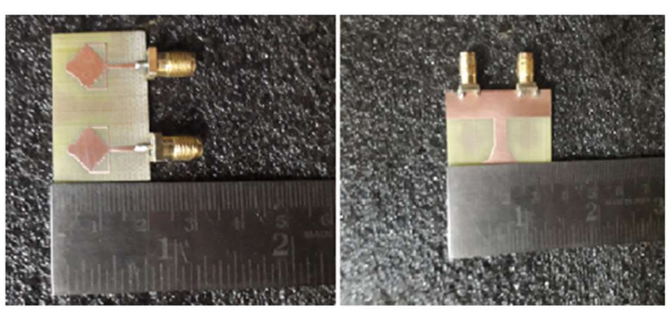

Fig.3: Hardware design of the proposed system using the MITS-11 Lab prototyping Machine.

Hardware design of the proposed system as mentioned in Fig.3. The fabrication of the antenna is done using the Micro Instrumentation and Telemetry Systems (MITS)-11 Lab Prototyping machine. Prototyping can be explained as a technique that uses 3D CAD data in order to fabricate the scale models of a designed physical part swiftly. MITS-11 Lab prototyping machine is used as the Machine interface Software to convert the given input file into a machine-readable file.

Initially, the model which has to be designed is given as the input to the Machine software interface. The machine software interface converts the give input file into a machine-readable file and this is given as input to the designing nib called Gerber. Now the substrate is placed on the circuit board to obtain the desired shape of the antenna and the designing nib prints the circuit on the Substrate as per the input given by the machine software interface. Depending on the Particular dimensions given as input the substrate is cut into Patches later on which the required circuit is printed.

III. MEASUREMENTS

As per the requirements, for the depicted two element MIMO antenna, all dimensions of the patch which includes Length, Width, and Height. Each dimension has its measurement equations to get the required values based on the considered resonant frequency (3.6GHz). The length of the patch which is required for the proposed antenna can be calculated using the Equation1.

$$L = \frac{1}{2f_r\sqrt{\varepsilon_0\mu_0\sqrt{\varepsilon_{reff}}}} - 2\Delta L = \frac{C}{2f_r\sqrt{\varepsilon_{reff}}} - 2\Delta L \tag{1}$$

$$\varepsilon_0 = \frac{1}{\mu_0 c}$$

$$\varepsilon_{reff} = -\left[\sqrt{\frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left[1+12\frac{h}{w}\right]}\right]$$

Is the extended effective length of a patch is given in Equation 2.

$$\Delta L = 0.412 \times h\left[\frac{(\varepsilon_{reff}+0.3)\left(\frac{w}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{w}{h}+0.8\right)}\right] \text{ Mm} \tag{2}$$

Where w is the width and h is the height of the substrate.

The width of Patch for the proposed system is calculated using Equation 3,

$$W = \frac{1}{2f_r\sqrt{\varepsilon_0\mu_0}}\sqrt{\frac{2}{\varepsilon_r+1}} = \frac{C}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \text{ Mm} \tag{3}$$

Effective dielectric constant

The effective dielectric constant can be calculated using Equation 4,

$$\varepsilon_{reff} = -\left[\sqrt{\frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left[1+12\frac{h}{w}\right]}\right] \tag{4}$$

The value of can be determined using the effective dielectric constant obtained from the equation 4 as mentioned above.

$$\Delta L = 0.412 \times h \left[\frac{(\varepsilon_{reff} + 0.3)\left(\frac{w}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{w}{h} + 0.8\right)} \right] \text{Mm}$$

$$\Delta L = 0.412 \times 0.8 \left[\frac{(4.205962)\left(\frac{35}{0.8} + 0.264\right)}{(4.205962 - 0.258)\left(\frac{35}{0.8} + 0.8\right)} \right]$$

$$\Delta L = 0.412 \times 0.8 \left[\frac{185.1212}{175.88} \right]$$

$$\Delta L = 0.34691$$

Length:

Based on ΔL the original length L of the patch can be derived with the help of Equation 5

$$L = \frac{1}{2 f_r \sqrt{\varepsilon_0 \mu_0 \sqrt{\varepsilon_{reff}}}} - 2\Delta L = \frac{C}{2 f_r \sqrt{\varepsilon_{reff}}} - 2\Delta L \quad (5)$$

$$L = \frac{C}{2 f_r \sqrt{\varepsilon_{reff}}} - 2\Delta L \ \text{Mm}$$

$$L = \frac{3 \times 10}{2 \times 3.6 \times 10 \sqrt{4.205962}} - (2 \times 0.34691)$$

$$L = 0.020m = 20mm$$

Therefore, the total projected volume of the designed antenna is 20 × 35 × 0.8 mm^3.

Length and Width of the Ground Plane

A Ground Plane can be explicated as the conducting surface which is connected to the transmitter ground wire, is large in comparison to the wavelength and serves as the reflecting surface for the RF waves [3]. Length of the ground plane is given as, length of the patch + 6(height of the substrate) mm20+6(0.8) =24.8mmWidth of the ground plane is given as, Width of the patch + 6(height of the substrate) mm35+6(0.8) =39.8mm

IV. RESULTS OF THE PROPOSED ANTENNA

The Designing of a basic two element MIMO antenna includes both software and hardware results. When both the results of software and hardware are compared, they appear to be accurate.

Software

The results of the proposed system include the software factors such as Return Loss, Isolation, Gain, Radiation Pattern, Impedance, Efficiency, Current distribution. Return loss plot of the designed antenna is shown in Fig.4

Return loss:

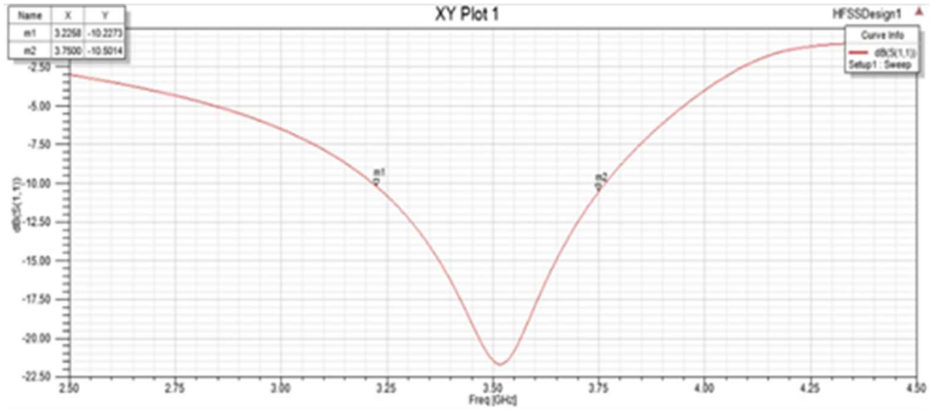

Fig.4: Return loss of the proposed antenna

It is explained as the measure of how small the Return or Reflection/echo is. Return loss is determined by the term called Reflection Coefficient. The reflection coefficient is elucidated as the ratio of incident signal to antenna and reflected signal from the antenna. Return loss helps us to determine the band ranges. Generally, Frequency less than 10db is considered as the operating range of the antenna .Theoretical and Practical values of the band ranges are 3.34 to 3.87GHz and 3.22 to 3.75GHz.

Isolation:

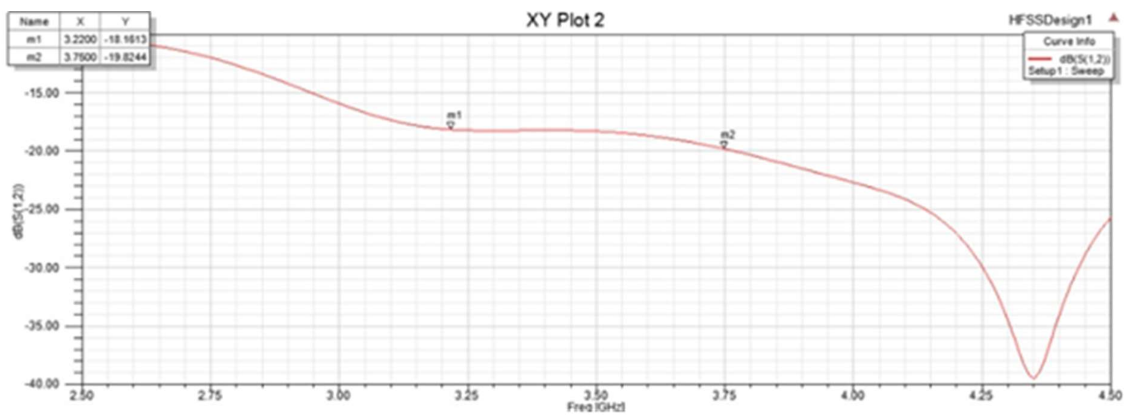

Fig.5: Isolation of the 2 element MIMO antenna

As mentioned in Fig.4, value of Isolation in the proposed antenna is obtained. Isolation is described as the ratio of power radiated by one antenna and output power generated by an adjacent one based on absorbed power.

To improve the Isolation T-shaped and U-shaped stubs are placed in between and on the elements. The Theoretical and Practical values of Isolation are 20db and 19.82db.

Gain plot:

The term Gain can be explained as capability of the antenna to radiate energy in any direction given in Equation 6

$$Gain = \left[\frac{9.73}{\lambda} \times 10\right]^2 \qquad (6)$$

$G = k \times D$

$G = 0.93 \times 2.73$

$G = 2.53$

Where, k is the efficiency factor which is 0.93 and the directivity (D) of the designed antenna is 2.73. The gain describes the capability of an antenna in converting the power to radio waves and vise-versa in a specified direction for both transmitting and receiving side antennas The gain value that has been obtained in the software simulation is 2.53dB. Gain of designed antenna is shown in Fig.6

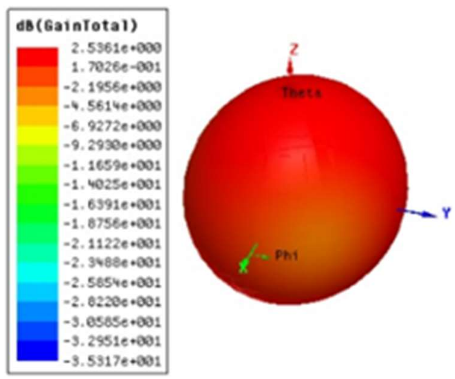

Fig.6: Gain plot of the proposed system

Radiation Pattern:

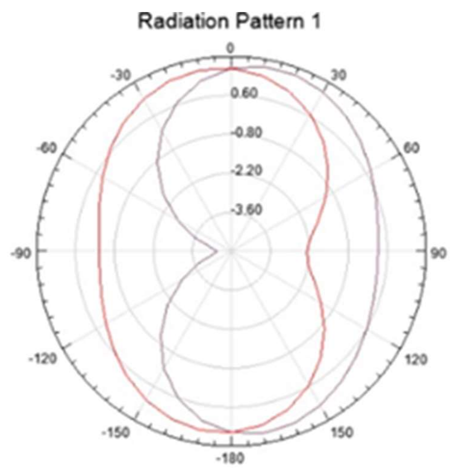

Fig.7: Plot of Radiation for 2 element MIMO antenna

In Fig.7 the radiation pattern of the proposed antenna is shown. .The energy radiated by an antenna is represented by the Radiation Pattern of the antenna. The term Radiation is generally used to constitute the releasing and absorption of wave front which specifies its strength. At a given time wave front is a surface which includes points that are affected in the same way by a wave. Because of periodically changing EM fields, these Electro Magnetic waves are created and they move in between the conductors.

Impedance Plot:

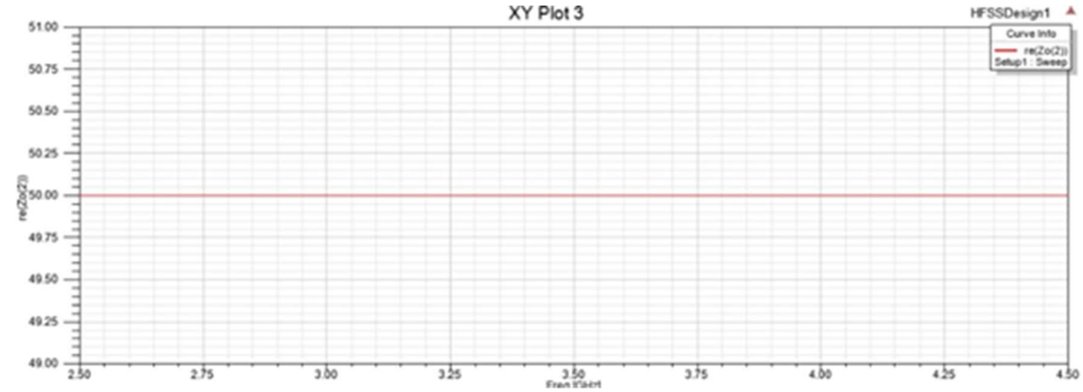

Fig.8: Impedance of the proposed two element MIMO antenna.

Impedance of the proposed antenna is shown in Fig.8. It is the procedure of matching the input impedance (ZL) and the corresponding output impedance (ZO), which is 50 Ω in most of the cases. A perfect match is obtained when ZL = ZO. Antenna Radiation occurs only when impedance matches. When the impedance matches the return loss plot is generated, In particular, the value of impedance cannot be determined, but when the impedance matches the antenna radiates. To radiate the maximum power from an antenna impedance matching is used.

Efficiency plot:

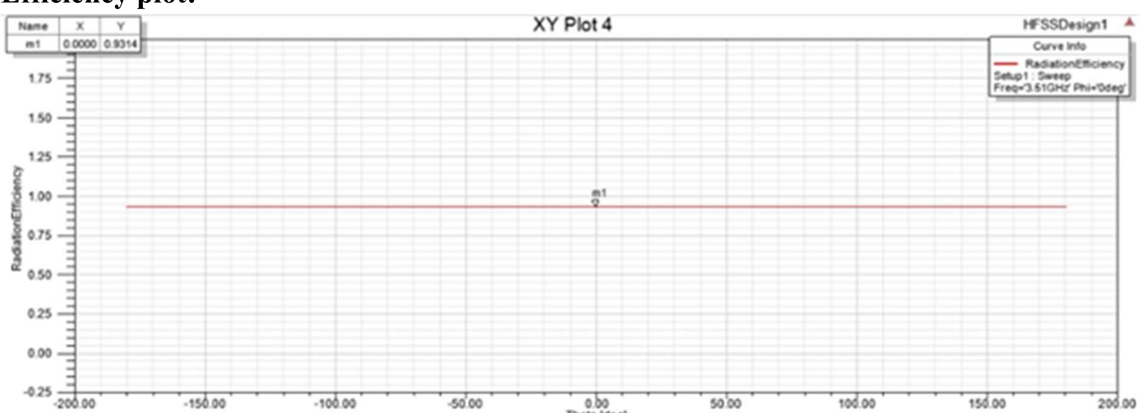

Fig.9: Efficiency of the proposed system

Fig.9 shows the efficiency plot of the proposed antenna. The ratio of power radiated by an antenna to the power supplied to it and is given in Equation 7.

$$E = \left[\frac{Pi}{\Pr} \times 100 \right] \quad (7)$$

Efficiency is one of the most important parameters in antennas. For Dish antennas, Horn antennas, half-wavelength dipoles with no loss materials around them have very high efficiency. Although the efficiency of the ideal antenna is 100%, which means it has the ability to transmit power completely to the receiving antenna. But, in practical cases, an antenna radiates only 50 to 60% of the power given to it. The efficiency of the proposed antenna is 93.14%.

Current distribution:

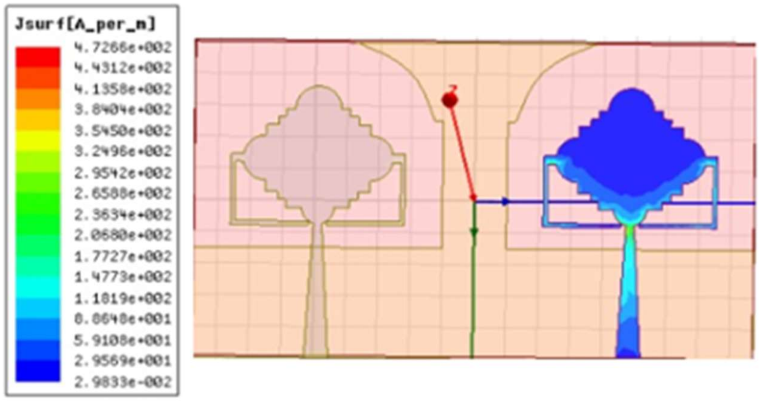

Fig.10: Representation of Current distribution for designed two element MIMO antenna.

Representation of Current distribution is shown in Fig.10. The change in pattern of current along the conductor is called the current distribution of the antenna. This distribution is crucial in understanding the radiation properties of various antenna lengths and feed arrangements. The current in each part of the antenna flows in the same direction. The charge and current on the dipole create fields that are perpendicular to each other. The electric field, E, flows from the positive charge to the negative charge placed on the elements by the voltage applied to the antenna.

Hardware:

Fig.11: Schematic view of the vector network analyzer

Illustrative view of the vector network analyzer is shown in Fg.11. The Testing process is carried out using this equipment.

Testing:

Testing of the antenna is done using Vector Network Analyze (VNA). The antenna is connected to a VNA using a Connector called SMA (Sub Miniature Aperture) connector.SMA Connectors are 50 Ohm RF Coaxial connectors that operate up to 18 GHz. They follow a screw-type coupling mechanism which helps them to minimize the reflections and attenuation caused during the transmission. Antenna characteristics in between the ranges from 2GHz to 6GHz are obtained in the vector network analyzer. As the proposed antenna is a 2 port circuit, it consists of 4 S-Parameters namely S11, S12, S21, and S22 where S11 and S22 represent the return loss and S21 and S12 represent the Isolation. All these Parameters can be obtained using Vector Network Analyzer. This whole testing is done by Placing the VNA around the surface of Absorbers, which helps to prevent the Multipath Reflection Caused due to antenna radiation.

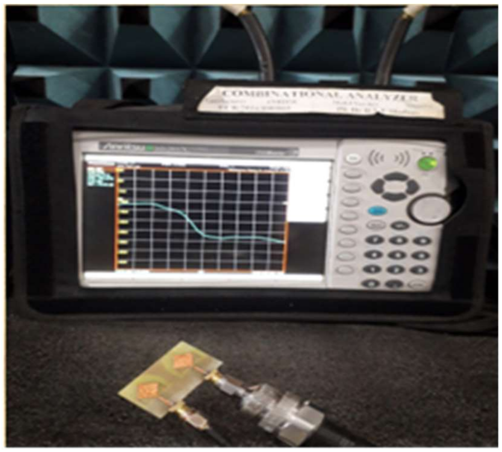

Fig.12: S-parameters of S12, S21, Isolation, and VSWR plots for the proposed two element MIMO antenna.

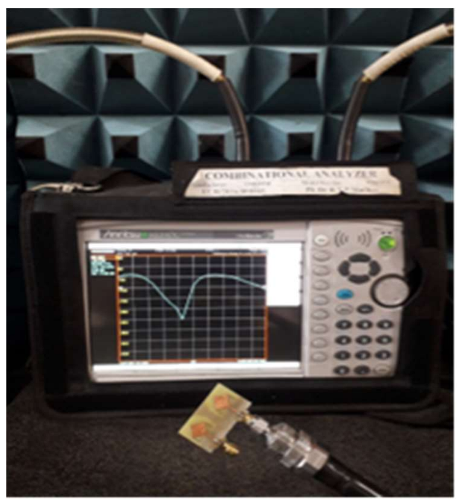

Fig.13: S-parameters of S11, S22, Return loss plot and reflection coefficient for the basic two element MIMO antenna.

S-parameters of designed antenna as given in Fig.12 and Fig.13.According to the Testing results that have been obtained, the VSWR acquires the reciprocity property and the Reflection coefficient acquires the symmetricity property.

The condition of S11=S22 and S12=S21 also determines the properties of symmetricity and reciprocity. The value of the Reflection coefficient according to the results obtained is 0.16. Similarly, the value of VSWR is 1.4. The directivity of the proposed two-element MIMO antenna can be obtained as 2.72. Gain is directly proportional to the directivity i.e., as the value of gain increases, simultaneously the directivity also increases.

V. CONCLUSIONS

In this paper, the design of MIMO antenna is implemented using microstrip feeding on two antenna elements. The antenna operates from 3.4-3.6GHz.Better isolation can be achieved by the placement of stubs in between the antenna elements. This can be later realized even for 4 elements. The issue of mutual coupling can also be avoided effectively with the positioning of stub (U-Shaped stub) at the center of each and every element of antenna. The design of the hardware and software of the introduced system is done and the Parameters are simulated. So, software design of the existing system is completed and its parameters are simulated. The simulated Parameters of existing and proposed systems are compared with their performance characteristics. As per the simulation Results of the existing and proposed system, we can conclude that the Proposed system is even more productive when compared to the existing one.

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