Design and Fabrication of 5.8 GHz ISM Band Microstrip Patch Antenna Through Aperture Coupled Feeding Technique

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Email: jothi@svce.ac.in*Abstract:* - This paper presents the simple design and fabrication of a microstrip patch antenna with aperture coupled feeding technique. The designed antenna operates at 5.8 GHz, ISM band frequency. Most of the wireless applications such as wireless fidelity (Wi-Fi), Bluetooth, wireless keyboard and mouse, Microwave oven, Cordless phones uses 2.4 GHz ISM band. Since all the applications use the same 2.4 GHz band, interference occurs among them, because interference leads to reduction in signal strength. In addition to that 2.4 GHz also has low data rate. Due to complication in antenna design, 5.8 GHz ISM band are rarely used. The designed antenna operates at 5.8 GHz ISM band. Instead of using complicated patch design, simple rectangular patch with T-shaped aperture is designed. The designed antenna is simulated using CST microwave studio suite 2017 software. The simulated results were analyzed and discussed in terms of Return loss, Gain, Directivity, VSWR and radiation pattern.

Key-Words: - Stacked patch, Aperture coupled fed, Wireless applications

1 Introduction

In modern wireless communication systems wider bandwidth, multiband and low profile antennas are in great demand for both commercial and military applications. This has initiated antenna research in various directions, one of them is using fractal shaped antenna elements. Traditionally, each antenna operates at a single or dual frequency bands, where different antenna is needed for different applications.

The concept of microstrip radiators was first proposed by Deschamps in 1953. A patent was issued in France in 1955 in the names of Gutton and Baissinot. However, twenty years passed before practical antennas were fabricated. Development during the 1970 was accelerated by the availability of good substrates with low loss tangent and attractive thermal and mechanical properties, improved photolithographic techniques, and better theoretical models. The first practical antennas were developed by Howell and Munson. Since then, extensive research and development of microstrip antennas and arrays, aimed at exploiting their numerous advantages such as light weight, low volume, low cost, conformal configuration, compatibility with integrated circuits, and so on, have led to diversified applications and to the establishment of the topic as a separate entity within the broad field of microwave antennas.

A microstrip antenna in its simplest configuration consists of a radiating patch on one side of a dielectric substrate, which has a ground plane on the other side. The patch conductors, normally of copper or gold, can assume virtually any shape, but regular shapes are generally used to simplify analysis and performance prediction. Ideally, the dielectric constant of the substrate should be low to enhance the fringe fields that account for the radiation. However, other performance requirements may dictate the use of substrate materials whose dielectric constants can be greater than, say, and four.

The first aperture coupled microstrip antenna was introduced in 1985 by D M Pozar. An aperture-coupled design is proposed for Microstrip slot antenna to improve its radiation pattern as well as bandwidth. It is based on coupling of an aperture between the patch antenna and Microstrip slot line. Aperture coupling can solve back radiation problem. Aperture-coupled antennas have ability to be mounted in low profile applications. The flat and rectangular nature of aperture-coupled antennas is ideal for incorporation into mobile devices, wireless routers, and other types of communications technology. Because the aperture-coupled patch antennas are small in nature, they are very low cost to produce. The aperture coupled antenna is a suitable technology to research and develop because of its vast amount of applications, low production cost, and modularity.

2 Design of Antenna

The primary benefit of 5.8 GHz models is the avoidance of interference with 802.11b WLANs and microwaves. The 5.8 GHz antenna will provide higher data transmission rate, better security, and increased range.

The proposed aperture-coupled microstrip patch antenna as shown in Fig.1, It consists of a five layered structure with the combination of 3 layers of metallic conducting elements and 2 layers of the non-conducting dielectric substrate. Radiating patch as shown in Fig.2, Ground plane with T shaped aperture as shown in Fig.3 and Bottom feed line as shown in Fig.4. The ground plane is sandwiched in between the radiating patch and the feed line and in between each metallic layer there exist substrate material. There exists coupling aperture on the ground plane, usually created under the patch.

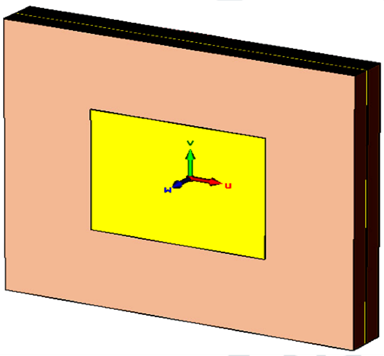

Fig.1 Proposed structure of Aperture coupled Microstrip antenna

Aperture coupling can solve back radiation problem. An aperture-coupled design is proposed for Microstrip slot antenna to improve its radiation pattern as well as bandwidth. By introducing a coupling of an aperture between the patch and the feed line, it can reduce the back lobe thus increases the F/B ratio. The major disadvantage of this feed technique is that it is difficult to fabricate due to multiple layers, which also increases the antenna thickness. This feeding scheme also provides narrow bandwidth.

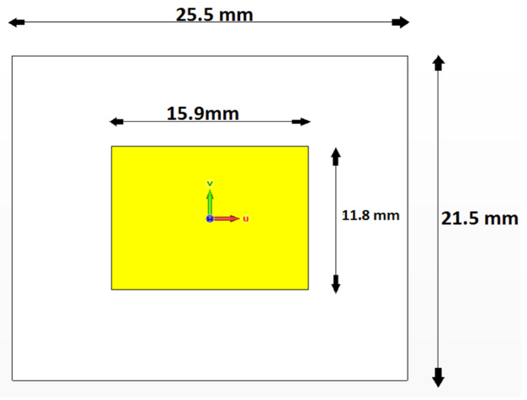

Fig.2 Proposed structure of Aperture coupled Microstrip antenna, Patch Top Layer

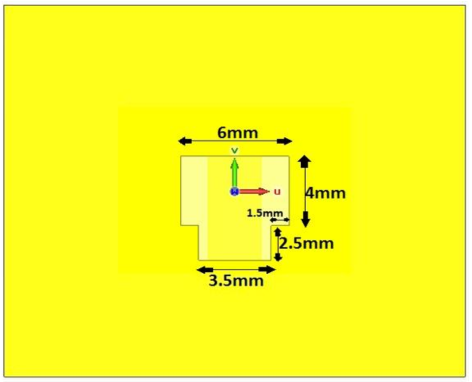

Fig.3 Proposed structure of Aperture coupled Microstrip antenna, Ground plane, Middle layer

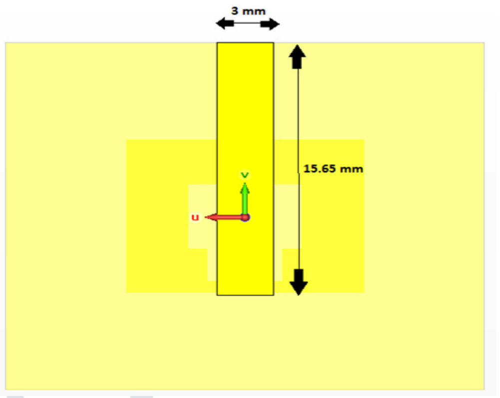

Fig.4 Proposed structure of Aperture coupled Microstrip antenna, Feed line, Bottom Layer.

It has 'T' shaped aperture. The brown coloured material is the FR-4 substrate. Its thickness is about 1.6mm. The silver colour represents the patch antenna. It is made up of copper.The ground plane has T-shaped aperture in it.It has length of 21.5 mm and width of 25.5.

The Fig.4 infers about the feed line of the antenna. It has the length of 15.65mm and width of 3 mm. It is of copper material. The SMA connector is soldiered to the feed line of the antenna.

In these paper FR-4, used as a Dielectric substrate whose permittivity is 4.3. FR-4 is a composite material composed of woven fiber glass cloth with an epoxy resin binder that is flame resistant (self-extinguishing). FR-4 glass epoxy is a popular and versatile high-pressure thermo set plastic laminate grade with good strength to weight ratios. With near zero water absorption, FR-4 is most commonly used as an electrical insulator possessing considerable mechanical strength.

2.1.1 Equivalent Circuit For Aperture Coupled Antenna

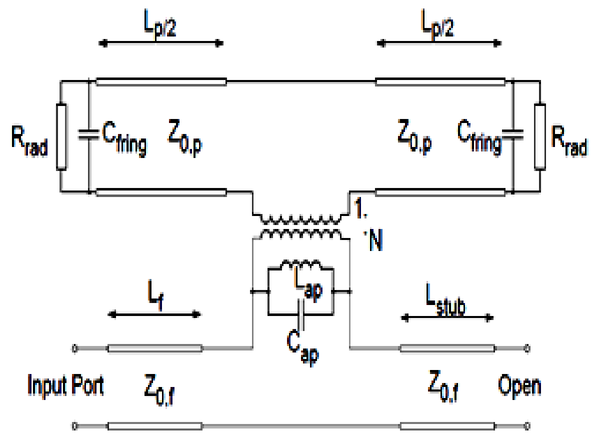

Fig.5 Equivalent Circuit for Proposed Aperture coupled microstrip antenna.

The ground plane slot acts as an impedance transformer and parallel LC circuit (L_{ap} and C_{ap}) in series with the microstrip feed line. The LC circuit represents the ground plane slot resonant behaviour. The N:1 impedance transformer represents the patch antenna's impedance effects being coupled through the ground plane slot. The patch is modelled as two transmission lines terminated by parallel RC components (R_{rad} and C_{fring}) due to patch edge fringing fields.

4 Results and Discussion

The simulated results shows that, the antenna operates at 5.8 GHz with the return loss of -21.96 dB, Generally bandwidth of the antenna is found from the return loss graph. Bandwidth is obtained from the intersection of return loss graph with -10 dB of the graph. The difference between the upper cutoff frequency and lower cutoff frequency gives the bandwidth of the antenna.

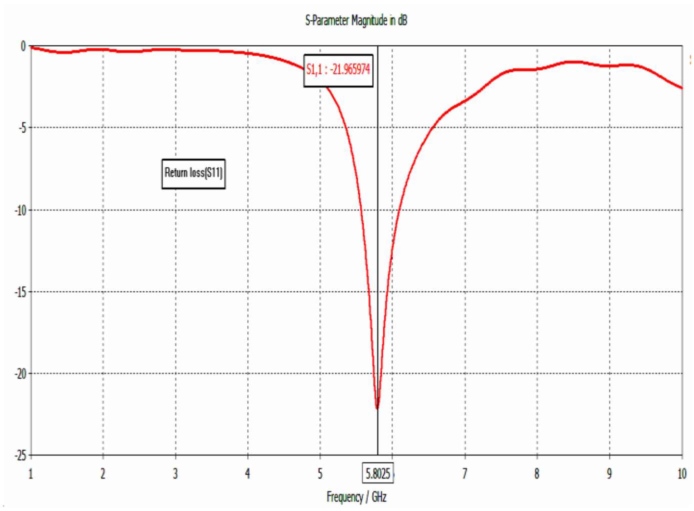

Fig.6 Simulated Return Loss against frequency for the proposed Aperture coupled microstrip antenna.

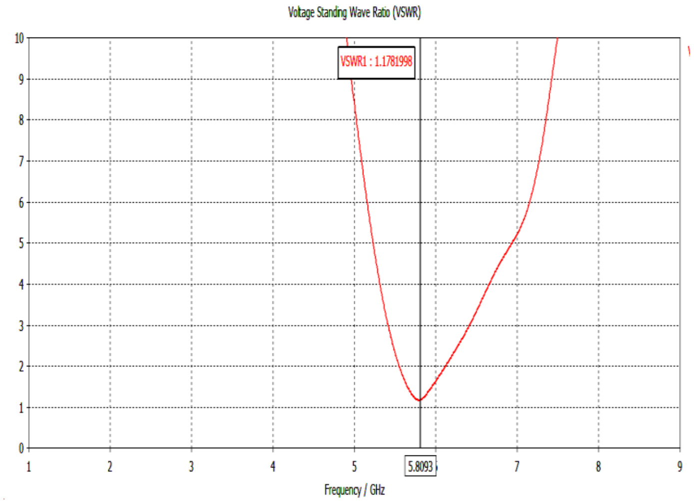

Fig.7 Simulated VSWR against frequency for the proposed Aperture coupled microstrip antenna

The antenna yields minimum VSWR value of 1.17, at the operating frequency 5.8 GHz as shown in Fig.6. The minimum VSWR is 1.0. In this case, no power is reflected from the antenna, which is ideal condition. VSWR is a function of the reflection coefficient, which describes the power reflected from the antenna.

Gain is a measure of the ability of the antenna to direct the input power into radiation in a particular direction and is measured at the peak radiation intensity. An isotropic antenna radiates equally in all directions. The simulated Gain of 4.866dB at the operating frequency 5.8GHz is obtained as shown in Fig.8.

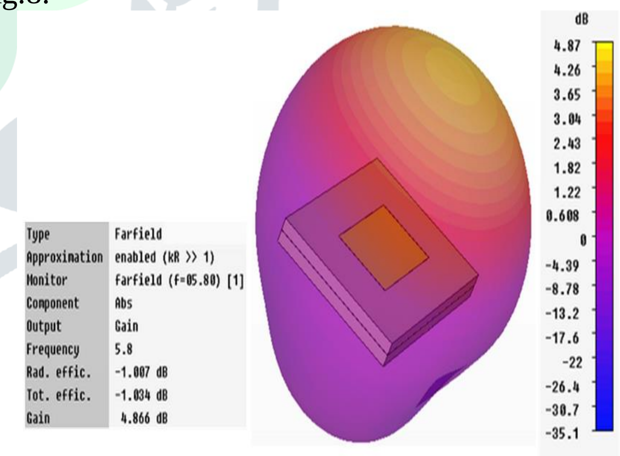

Fig.8 Simulated far-field 3D Gain Radiation pattern of proposed Aperture coupled microstrip antenna for resonant frequency 5.8 GHz.

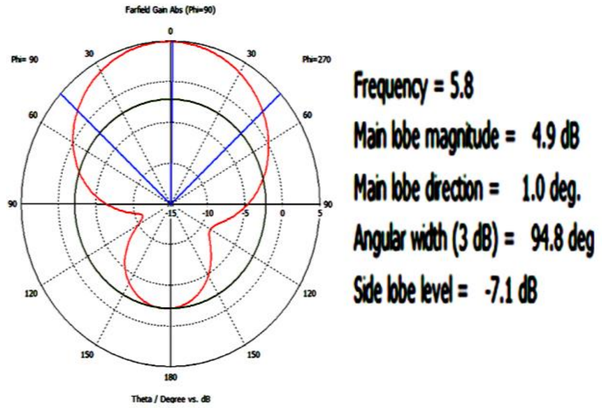

Fig.9 Simulated far-field 2D Gain Radiation pattern of proposed Aperture coupled microstrip antenna for resonant frequency 5.8 GHz.

The Fig.9 represents the 2D Gain Radiation pattern of proposed antenna. From the polar plot the magnitude of main lobe and side lobe is obtained. Here the main lobe of magnitude 4.7 dB is obtained and the side lobe magnitude of -7.1 dB, since the main lobe magnitude greater than side lobe level, the antenna has better efficiency.

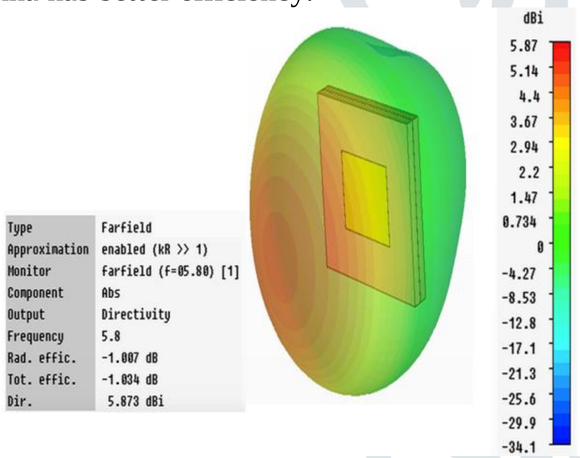

Fig.10 Simulated far-field 3D Directivity of proposed Aperture coupled microstrip antenna for resonant frequency 5.8 GHz.

Directivity measures the power density the antenna radiates in the direction of its strongest emission, versus the power density radiated by an ideal isotropic radiator radiating the same total power. The simulated results show that, the antenna has directivity of 5.873 dBi. As shown in Fig.10. It is seen that the Antenna Radiates much along the patch side and radiates less along the downside of the antenna. This shows that Aperture coupled feeding antenna prevents back radiation from patch to feed line.

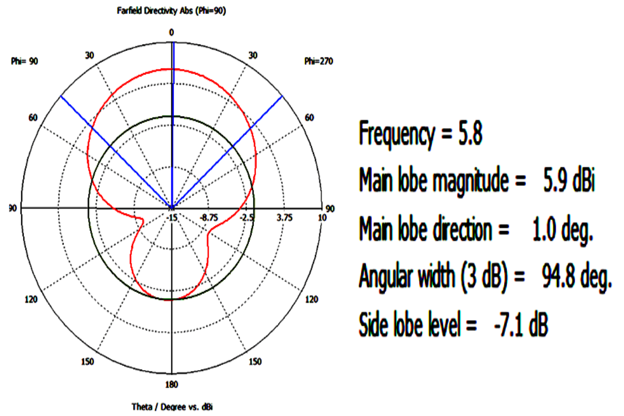

Fig.11 Simulated far-field 2D Directional pattern of proposed Aperture coupled microstrip antenna for resonant frequency 5.8 GHz.

The Fig.11 represents the 2D-Directivity of the antenna. From the polar plot the magnitude of main lobe and side lobe is obtained. Here the main lobe of magnitude 5.9 dB is obtained and the side lobe magnitude of -7.1 dB.

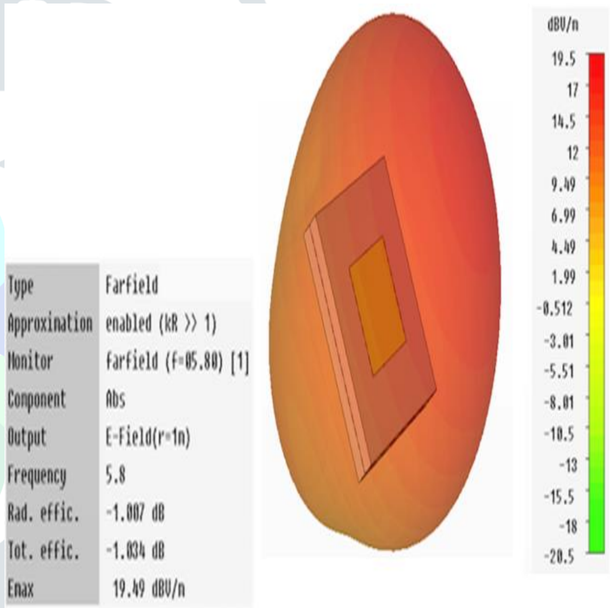

Fig.12 Simulated far-field 2D Directional pattern of proposed Aperture coupled microstrip antenna for resonant frequency 5.8 GHz.

The Fig.12 infers about the, E-field distribution around the patch antenna. The Proposed antenna maximum E-field distribution of the conducting patch, varying from 19.5 dBm to 6.89 dBm.

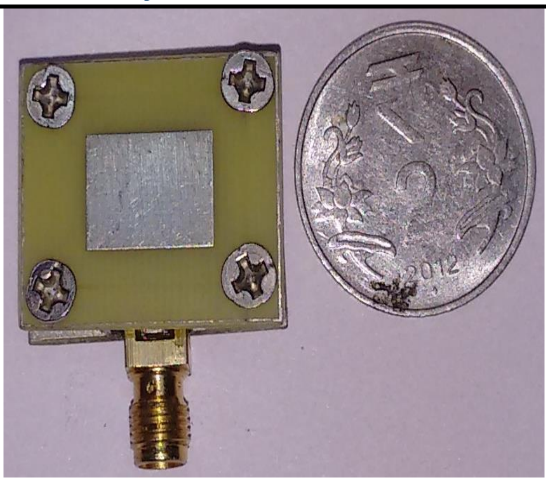

Fig.13 Fabricated Patch Antenna, Top layer

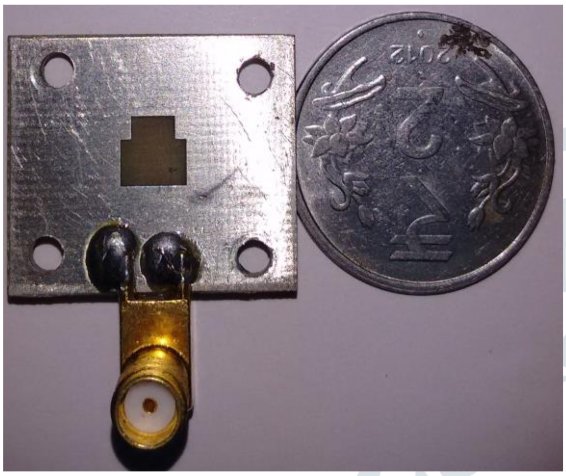

Fig.14 Fabricated Ground plane, T-shaped Aperture, Middle layer.

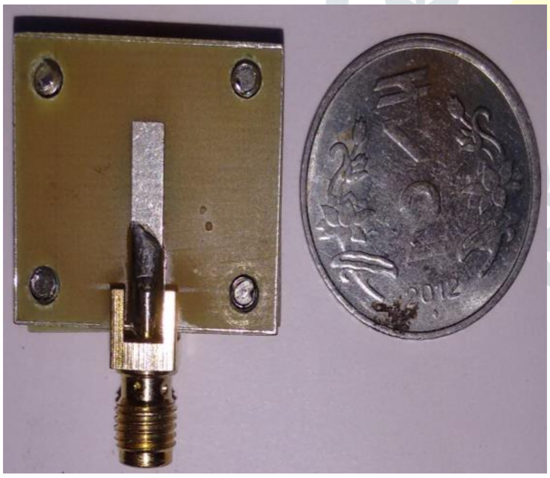

Fig.15 Fabricated Aperture coupled feedline, Bottom layer.

Fig.16 VNA Measurements setup for proposed aperture coupled patch antenna.

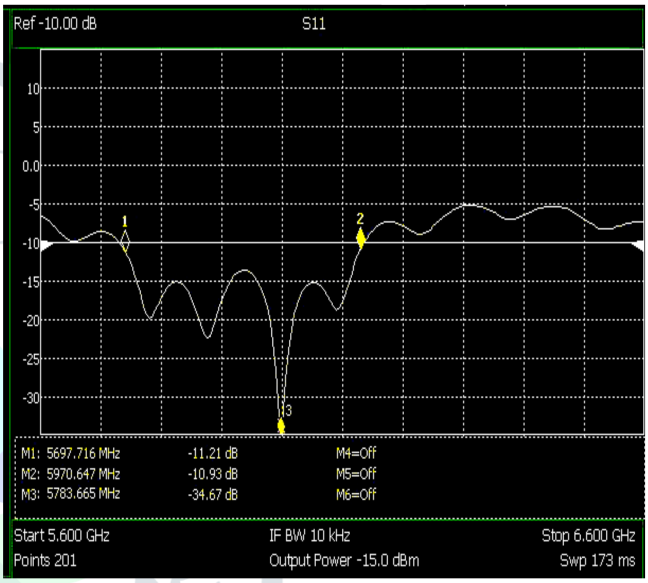

Fig.17 Measured Return Loss against frequency for the proposed Aperture coupled microstrip antenna.

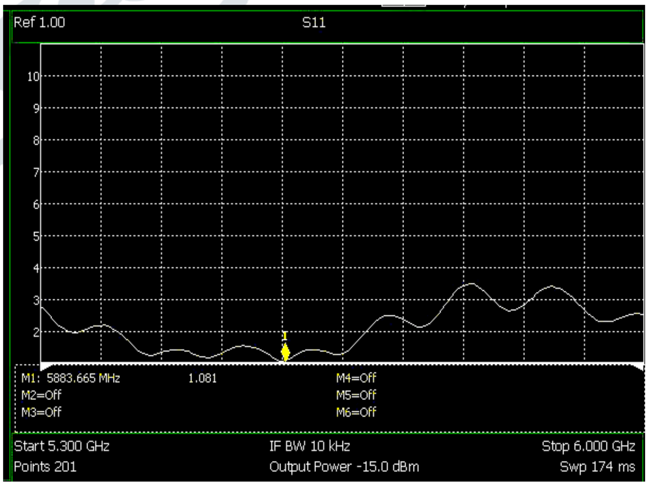

Fig.18 Measured VSWR against frequency for the proposed Aperture coupled microstrip antenna.

The Fig.13 represents fabrication of the patch antenna. The brown coloured material is the FR-4 substrate, thickness is about 1.6mm. It has dimensions of length 21.5 mm and width of 25.5 mm. The silver colour represents the patch antenna. It is made up of copper. In order to show about the size of the antenna, the antenna is compared with 2 Rupees coin. From the comparison, it is clear that the antenna is compact and very small. The Fig.14 represents the fabrication of ground plane of the antenna. The ground plane has T-shaped aperture in it. The Fig.15 represents fabrication of feed line. By the process of drilling and screwing along the four corners of the antenna , both substrate layers are couple together. The SMA connector is soldiered with the feed line, in order to couple the input signal with the feed line of the patch antenna.

Keysight Agilent Technologies N9926A Vector Network Analyzer is used to measure the proposed aperture coupled microstrip patch antenna. The measurement setup of proposed antenna as shown in Fig.16, Vector Network Analyzer measures both amplitude and phase properties. Network analyzers are used mostly at high frequencies, operating frequencies can range from 5 Hz to 1.05 THz.

Fig.17 shows fabricated measured result of Return loss. Fig.18 shows fabricated measured result of VSWR. The measured results are good agreements with simulation results. The Proposed antenna performs well in both simulation and measurements respectively.

4 Conclusion

This project provides the design and fabrication of Aperture coupled patch antenna, which operates at 5.8 GHz ISM band. The Proposed design of Aperture coupled patch antenna is designed using CST Microwave studio. Its return loss, Radiation pattern, VSWR, directivity, gain is obtained. The proposed Aperture coupled antenna has been fabricated using FR4 substrate and the antenna is synthesized using Network Analyzer. The comparison is made between simulated and measured VSWR , return loss. It is observed that the results was very good compared to previous results. In future, the results can be further enhanced by introducing slot in the patch.

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