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# Simulation and Analysis of Aperture Coupled Patch Antenna for S-Band Communication

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***Abstract—*** This paper proposes a novel compact microstrip stacked patch antenna for Mobile Satellite Service (MSS) application with 2 GHz operating frequency. The antenna consists of two stacked patches with air gap and it is used to avoid the coupling loss. The ground plane consists of slot which convert microwave from feed-line to radiating patch. The proposed multilayer aperture coupled antenna is designed low-cost FR4 substrate with log slots of plus symbol shape. The proposed antenna is compact in shape. The various performance parameters such as return loss, gain, bandwidth and radiation patterns are simulated and measured are presented.

***Keywords***— Gain, Mobile Satellite Service, Microstip Patch, Radiation graph, Return loss, Multilayer.

## I. INTRODUCTION

An antenna is defined as a component that facilitates the transfer of guided wave into free space wave and vice versa. An antenna is essentially a transducer that converts alternating currents into electromagnetic fields and vice versa works. Receive and transmit antennas are alike in characteristics, where the transmitter antenna allows radio frequency (RF) energy to be efficiently radiated from the output stage into free space [1-3]. The feed has the task to couple the electromagnetic wave propagating on a transmission line to the radiating element as efficiently as possible. The antenna input impedance is greatly controlled by the location of the feed point. The variation of feed location may produce a small shift in resonant frequency, but radiation pattern remains unaltered. A wide variety of method exists for feeding the antenna. There are two methods of feeding, contact and non-contact. In contact method, the feed line can couple the power directly to the radiating patch. The RF power coupling is indirect in non-contact method [4-6].

There are four important feed techniques used are, line feed, probe feed, slot coupled feed and proximity coupled feed. The strip-line feed and probe feed belongs to contacting method, aperture coupling and insect feed belongs to non-contacting method [7-8].

Back radiation is a major problem associated with microstrip patch antenna technology. This back radiation increases the return loss and reduces the gain and the directivity of the antenna [9-13]. In the aperture coupled feeding method, the conducting strip and the input line are detached by the bottom earth plane, prevents back radiation from the patch to the antenna. The designed antenna uses aperture coupled feeding technique and hence less back radiation problem. The slot will make a connection between conducting strip and the input line. The symmetrical configuration of the structure especially the center aperture leads lower cross polarization [14-16]. The shape of the patch and size of the patch and location of the aperture slot will decide the percentage of coupling between feed line and conducting patch. This feeding scheme provides wide Bandwidth. The proposed antenna radiates at 2 GHz operating frequency, which is mainly suitable for mobile communication satellite system.

## II. STRUCTURE AND DESIGN PROCEDURE

Based on the simplified formulation from basic design equations of microstrip patch antenna, the design values of required antenna have been developed. The design of microstrip patch antenna required to observe the relative permittivity of the substrate material ($\varepsilon_r$) for the specified operating frequency ($f_r$) and the height of the substrate, h. The following equations are used to design the proposed antenna. For getting excellent radiation efficiency the selection of width of the patch is very important and it can be selected such a way that,

$$W = \frac{C}{2 f_r \sqrt{\frac{(\varepsilon_r + 1)}{2}}} \quad (1)$$

The velocity of light is denoted as C, which is equal to, $3\text{x}10^8$ m/s, $\varepsilon_r$ is the relative permittivity of the substrate material and the operating frequency is $f_r$.

Effective Dielectric constant of the microstrip antenna has been determined using the below equation.

$$\varepsilon_{reff} = \frac{(\varepsilon_r + 1)}{2} + \frac{(\varepsilon_r - 1)}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} \quad (2)$$

Here the height of the substrate material is denoted as h and the width is W. The width was calculated first and the length extension (ΔL) is determined as,

$$\Delta L = \frac{0.412 * h(\varepsilon_{reff} + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_{reff} - 0.258)(\frac{W}{h} + 0.8)} \quad (3)$$

Hence the is the effective value of relative permittivity.

Actual Length of the patch and effective length can be determined by using equation (4) and equation (5).

$$L_{eff} = \frac{c}{2 f_r \sqrt{\varepsilon_{reff}}} \quad (4)$$

$$L = L_{eff} - 2\Delta L \quad (5)$$

where, $L_{eff}$ is the effective length and ΔL is the extension of length.

The basic aperture coupled antenna structure which consisting of five layers out of which three are metallic layers and two dielectric substrate layers.

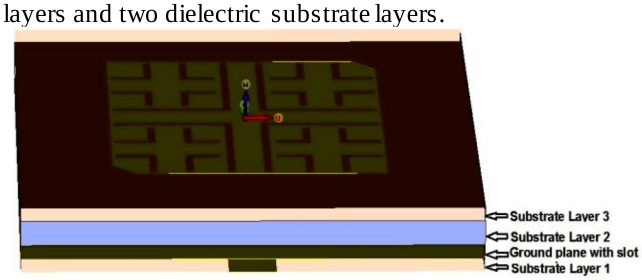


Fig.1. Proposed multi layer substrate with aperture coupled microstrip patch antenna

The proposed stacked antenna is composed of three dielectric layers of FR-4 Epoxy. The substrate layer arrangement is shown in Figure 1.The square substrate dimensions is 58* 58mm with a dielectric constant of €r= 4.4. The thickness of the substrate in first and second dielectric layers is $h_1$= 1.6mm and thickness is $h_2$=0.51mm in the third layer. An air layer is present between the second layer and the third layer and by adjusting the distance the second and third dielectric layer, better gain and bandwidth could be obtained.

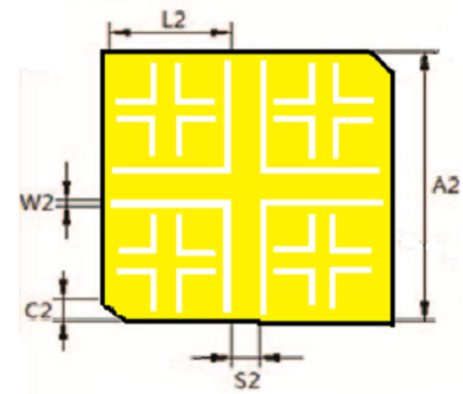


Fig.2. Radiating patch in the top substrate layer

The upper patch is employed on the third dielectric layer having size $A_2$ and the structure is analogous with the patch on the middle layer. Further four symmetrical narrow slots in 'L' shape with dimensions length $L_2$, gap $S_2$ and width $W_2$ were placed on the center. the diagonal two corners are etched at distance $C_2$ The radiating patch in the top substrate is shown in Figure 2.

The lower square patch is implemented on the second dielectric substrate was connected to the aperture couple feed is shown in Figure 3. The width of the patch was to resonant at the center frequency of 2GHz and the diagonal two corners are etched at distance $C_1$. Four symmetrical narrow slots of 'L' shape is placed on the patch with the length $l_1$, gap of width $s_1$ and width $w_1$.

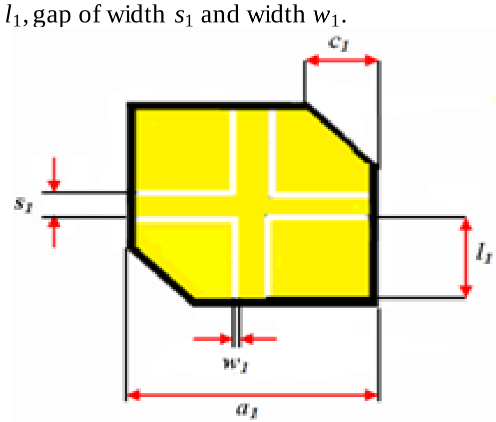


Fig.3. Patch in the middle substrate layer

 

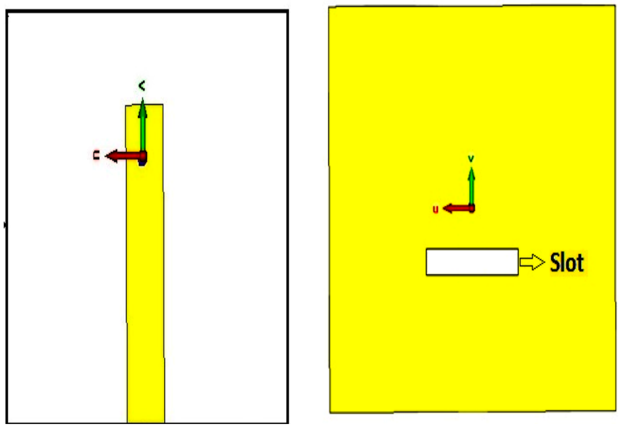


Fig.4. a) Feed line b) Ground plane

The first substrate layer is sandwiched between ground plane on the top and feed line at the bottom. In the metallic ground plane, there exists a slot to couple with the feed line. The physical dimensions proposed multilayer aperture coupled patch antenna with radiating patch on the middle and top substrate layers shown in the Figure 2 and Figure 3 are presented in Table 1.

Table 1: Physical dimensions of radiation patch of proposed stacked aperture coupled antenna

| $C_1$ | $w_1$ | $l_1$ | $s_1$ | $a_1$ |
|---|---|---|---|---|
| 5mm | 0.5mm | 7.1mm | 1.6mm | 16.5mm |
| $C_2$ | $W_2$ | $L_2$ | $S_2$ | $A_2$ |
| 3mm | 1mm | 15.5mm | 3.6mm | 36.3mm |

## III. SIMULATION RESULTS AND DISCUSSION

The proposed stacked antenna has been designed and optimized using CST Microwave Studio software. The simulated graphs show that the results are good. Figure 5 shows return loss of -24.574 dB at a frequency of 2.074GHz which indicates that the proposed multilayer antenna works well.

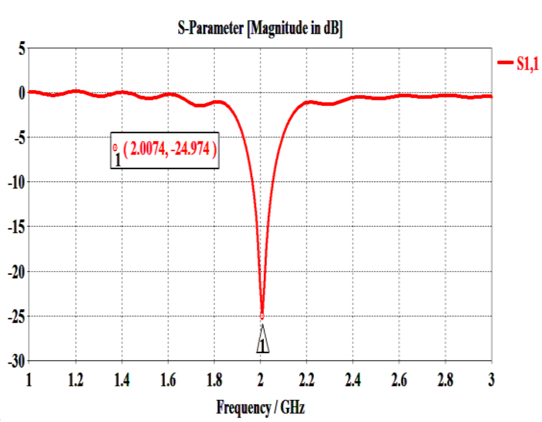


Fig.5. Simulated return loss of proposed stacked antenna

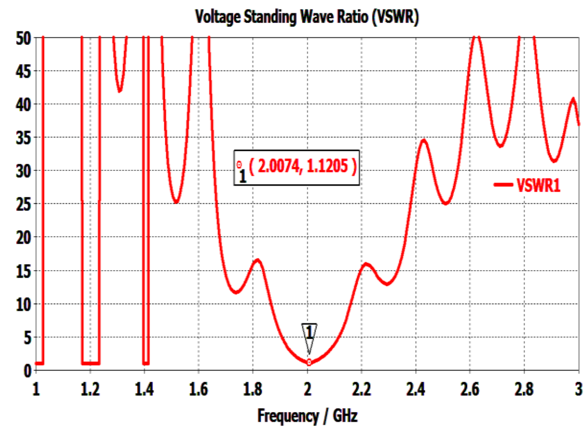


Fig.6. Simulated VSWR of proposed stacked patch antenna

Voltage standing wave ratio value is observed to be 1.1205 from Figure 6. The smaller the VSWR value, the better the antenna is matched. The simulated VSWR plot indicates that the value is smaller but greater than minimum VSWR value of one. Figure 7 and Figure 8 shows the simulated plot of antenna parameter such as directivity and gain.

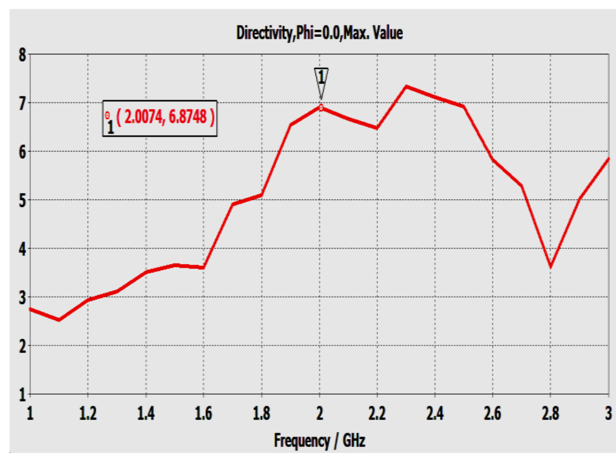


Fig.7. Simulated directivity of proposed aperture coupled stacked patch antenna

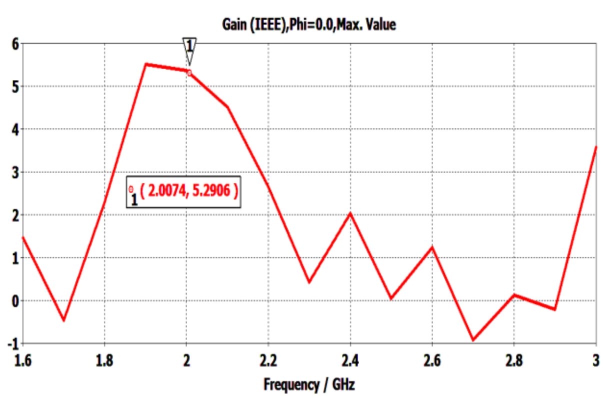


Fig.8. Simulated gain plot of proposed stacked patch antenna

 

The regions far from the antenna is said to be far field. In this region, the shape of the radiation pattern does not change with respect to distance. Also, this region is dominated by radiated fields, with the E- and H-fields orthogonal to each other and the direction of propagation as with plane waves.An isotropic antenna radiates equally in all directions and such antenna is said to be 100% efficient.. Figure 9 to Figure 17 represents the simulated 2D far field gain and directivity in theta and phi plots and also their 3D plots.

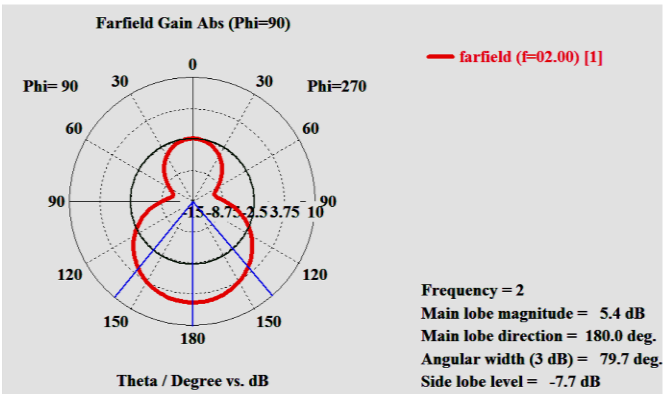


Fig.9. Simulated far field polar gain (Phi) plot

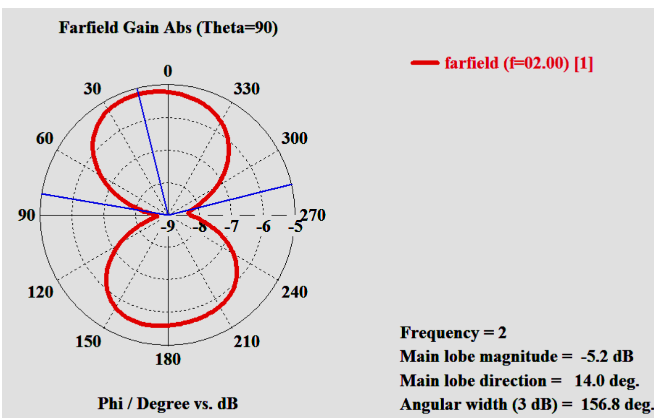


Fig.10. Simulated far field polar gain (Theta) plot

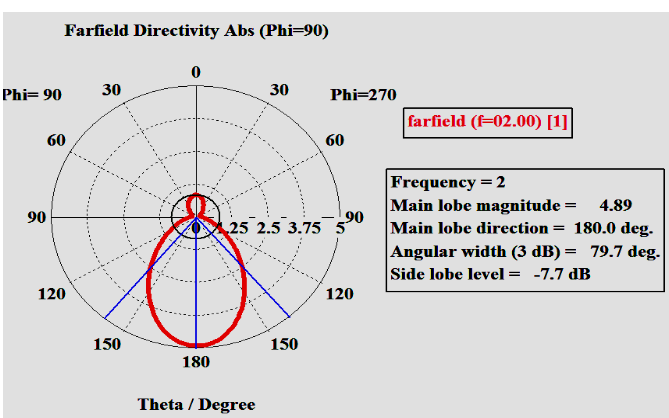


Fig.11. Simulated far field polar Directivity (Phi) plot

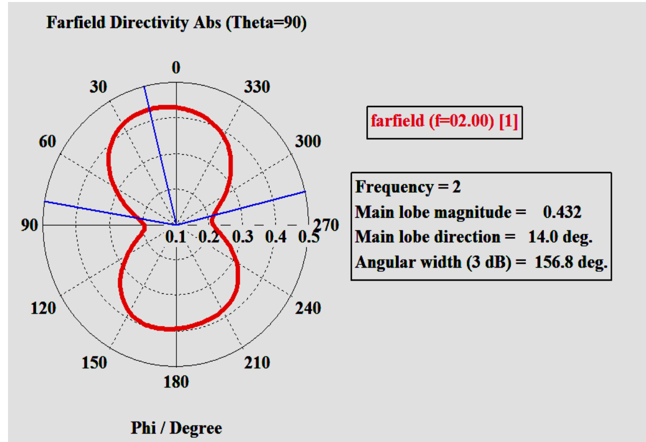


Fig.12. Simulated far field polar Directivity (Theta)

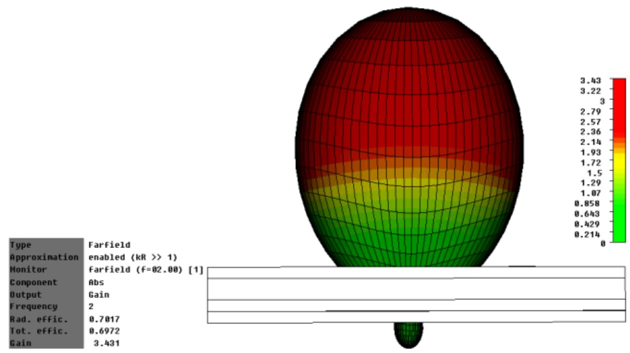

Fig.13. Simulated three dimensional far field gain plot

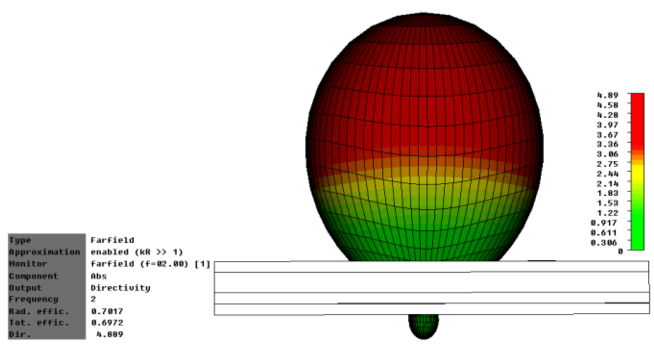

Fig.14. Simulated three dimensional far field directivity

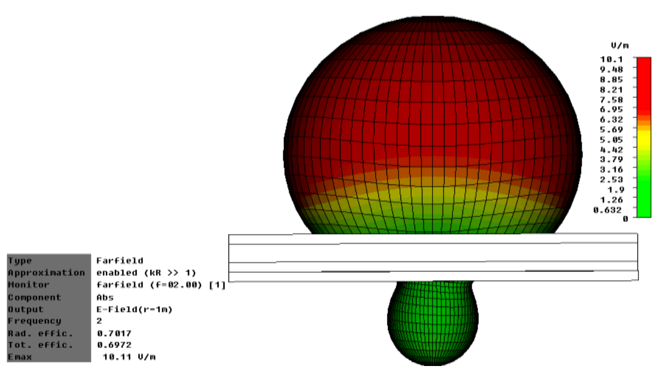

Fig.15. Simulated three dimensional far electric field plot

 

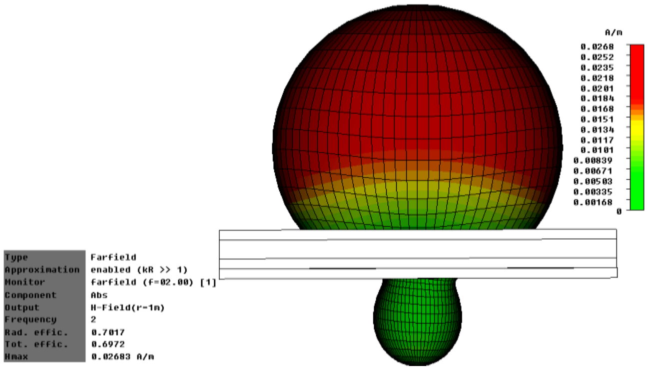

Fig.16. Simulated three dimensional far magnetic field

Table 2: Parameters extracted from the simulated results of proposed stacked antenna

| **Simulated parameters at frequency at 2.0074 GHz** | **Values** |
|---|---|
| Return loss ($S_{11}$) in dB | -24.974 |
| Voltage standing wave ratio | 1.1205 |
| Directivity(dB) | 6.8748 |
| Gain (dBi) | 5.2906 |
| Bandwidth | 350MHz |

## IV. PROTOTYPE AND RESULTS

The proposed multiple layer antenna structure has been fabricated. The antenna has been tested using ENA E5062 network analyzer. Figure 17 to Figure 20 shows the photograph of fabricated antenna. The dielectric material used is FR-4 Epoxy with dielectric constant of €r= 4.4. The conducting patch is made of copper. The test setup of fabricated aperture coupled stacked patch antenna with network analyzer is shown in Figure 21. The return loss and voltage standing wave ratio VBA file of proposed antenna is displayed in Figure 22 and Figure 23.

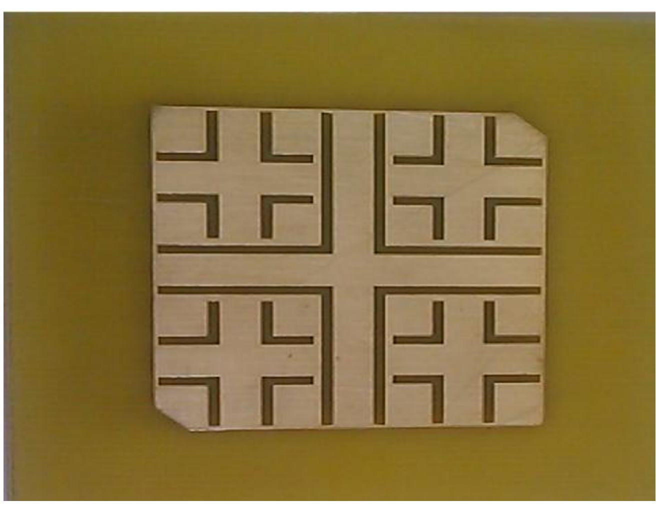
Fig.17. Top substrate layer with patch of fabricated multilayer antenna

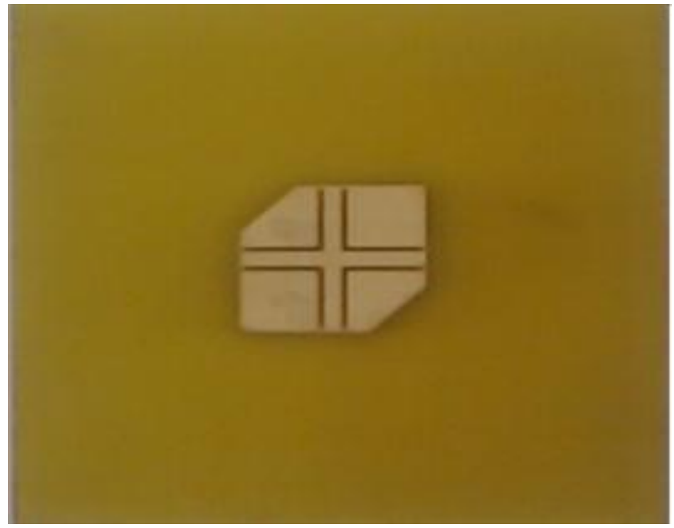
Fig.18. Middle substrate layer with patch of fabricated multilayer antenna

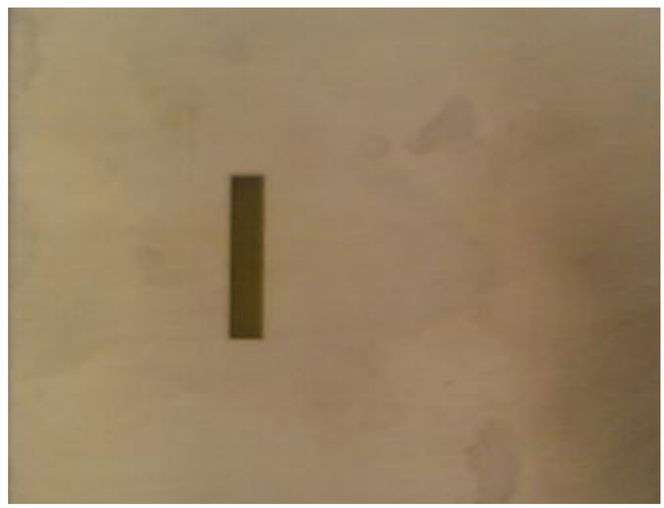
Fig.19. Ground plane of fabricated multilayer antenna


Fig.20. Back view of fabricated antenna showing feed line

 

Fig.21. Testing of proposed patch antenna with network analyzer

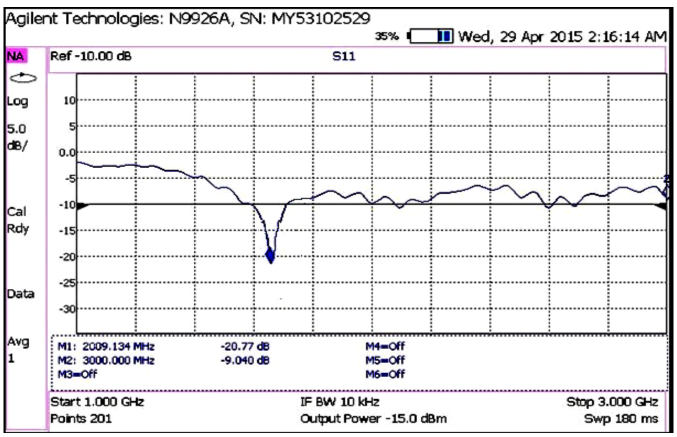


Fig.22. The return loss image file of implemented patch antenna using network analyzer.

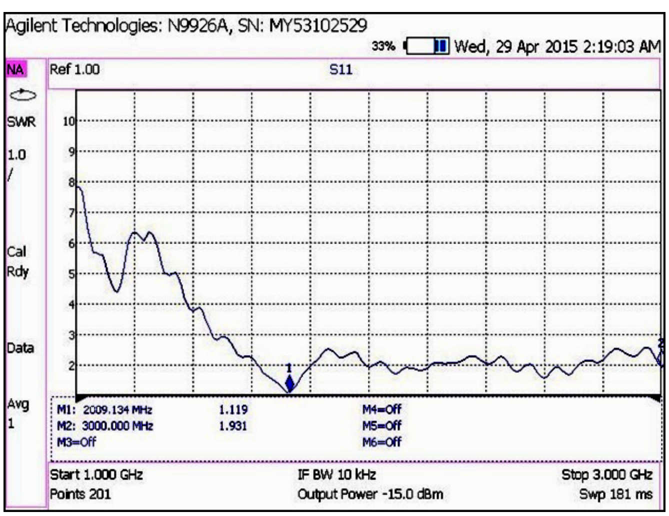


Fig.23. The Voltage standing wave ratio image file of implemented patch antenna using network analyzer.

The results exported from VBA file of the fabricated stacked antenna is compared with simulated results.

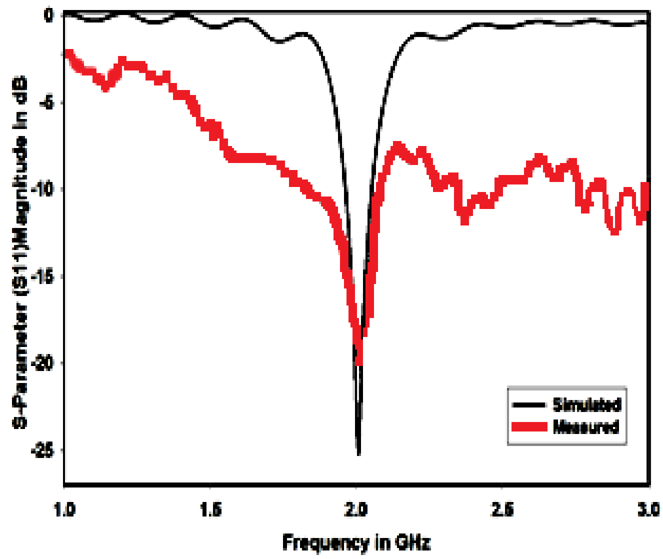


Fig.24. Comparison of return loss ($S_{11}$) between simulated and measured of proposed antenna

## V. CONCLUSION AND FUTURE SCOPE

This paper presents the design and implementation of three substrate layers aperture coupled microstrip antenna. The antenna was designed using CST Microwave studio suite software. The simulated and measured results show that the antenna has its advantage of low cost, better bandwidth and acceptable return loss. In future, the same antenna can be utilized for multiband with reconfigurable capability.

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Dr.P.Jothilakshmi has received her B.E. degree in Electronics and Communication Engineering from Thanthai Periyar Govt. Institute of Technology, Vellore, India in the year 1996 and M.E degree from Mepco Schlenk Engineering College, Sivakasi, India in the year 2000. She completed her Ph.D degree from Anna University, Chennai, India. Currently she is working as a Professor in Electronics and Communication Engineering Department at Sri Venkateswara College of Engineering, Chennai, India. She has been a teacher for the past 21 years and has guided more than sixty B.E and M.E Students projects. She has published more than hundred Journal and Conference papers both National and International level. Her research area is RF antenna design and wireless communication. She is a member in professional societies ISTE, IETE and IAENG.

 