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Novel Microstrip Patch Antenna (MPA) Design for Bluetooth, IMT, WLAN and WiMAX Applications

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ABSTRACT: In this paper, a multi resonant MPA capable of operating satisfactorily in the frequency range of 2.39 GHz to 5.79 GHz have been proposed. The antenna has been designed using substrate of FR4 material having dielectric constant of 4.4 with a conducting radiating patch on the substrate and a conducting ground plane on the bottom side of substrate. The ground plane has been partially reduced to improve the antenna bandwidth. The antenna performance has been analyzed in terms of various antenna parameters such as return loss (dB), impedance bandwidth (GHz), gain (dB), directivity (dBi), Half power Beam width (Degree), current density and VSWR. The antenna has been designed and simulated using CST Microwave Studio (2010). The designed MPA is suitable to be used for Bluetooth, IMT, WLAN and WiMAX applications. The antenna has bandwidth of 3.40 GHz and VSWR of less than 2. The antenna has been successfully fabricated and tested. It has been observed that the practical results obtained by testing the fabricated antenna using Network analyzer E5071C closely matches with the theoretical results obtained by simulating the antenna design in CST MWS 2010.

KEYWORDS: *Directivity, Gain, Half Power Beam width (HPBW), Reduced ground plane, Return loss (S_{11}), VSWR*

I. INTRODUCTION

The microstrip patch antenna also termed as patch antenna, is usually fabricated on a dielectric substrate which acts as an intermediate between a ground plane at the bottom side of substrate and a radiating patch on the top of substrate [1]. The patch is made up of perfect electric conductor (PEC) material. The patch can be designed in many shapes like rectangular, circular, triangular, elliptical, ring, square and many more but the rectangular shape is widely used [1] because of the simplicity associated with the design. The selection of substrate is the most important parameter while designing an antenna. The substrate consists of a dielectric material which perturbs the transmission line and electrical performance of antenna. The size of an antenna is dependent on the dielectric constant of a substrate. The size of antenna is inversely proportional to dielectric constant i.e. higher is the dielectric constant, lower is the size of antenna [2]. There are variety of substrates available with different dielectric constants but in the antenna design, Fire Resistance 4 (FR4) material with dielectric constant of 4.4 has been used. The antenna can be fed by various methods like coaxial feed, proximity coupled microstrip feed and aperture coupled microstrip feed [3]. The feeding can be defined as a means to transfer the power from the feed line to the patch, which itself acts as a radiator. The microstrip feed line is commonly used in MPA design because it is relatively simple to fabricate [3].The microstrip antenna has been commonly used for wireless applications because of small antenna size, low cost, light weight, better efficiency, ease of installation, ease of mobility, and is relatively inexpensive to manufacture on printed circuit board (PCB) of specific characteristics and dimensions. However, apart from its advantages, there are some drawbacks of MPA. It handles less power and has limited bandwidth [4].

The bandwidth of MPA can be improved by either using a slotted patch [5][6] or by using reduce ground plane [7]. The slot on the patch can be of any shape like H-slot, E-slot, circular, rectangular, etc. These techniques can also be used to improve the return loss along with the bandwidth enhancement. Different shapes of slots have different effect on antenna parameters. Slotting tends to improve the antenna performance in terms of return loss, bandwidth and VSWR.

II. ANTENNA GEOMETRY

Fig. 1 represents the top view of designed MPA. As shown in the Fig. 1, the shape of patch is rectangular with two rectangular slots (marked - dijk and lmno) cut on the patch, a rectangular notch (marked - abdc) added to the patch top and a step (efgh) between radiating patch and feed line. The patch has been fed by a feed line of certain specified width so as to properly match the antenna impedance with the port impedance for transfer of maximum power from port to the antenna. In Fig. 2, the bottom view of slotted MPA is shown. The ground plane has been designed at the bottom of substrate as shown in Fig. 2.The antenna is fabricated using FR4 substrate having dielectric constant of 4.4 and substrate thickness of 1.57 mm. The feed line width has been adjusted to make sure that the impedance of antenna is nearly 50 ohms so as to perfectly match with the connector impedance for maximum power transfer to antenna with minimal back reflections. The bottom of the substrate consists of ground plane which is partially reduced to improve antenna bandwidth. The dimensions of substrate, patch, feed, slots cut on patch, square notch on the patch and step are listed in Table 1.

TABLE 1: Antenna Parameters

Antenna Parameters	**Specifications**
Substrate Dimensions (Ls x Ws)	70 x 60 mm
Patch Dimensions (Lp xWp)	14.4 x 26 mm
Slot 1 (L3 x W3)	5 x 2 mm
Slot 2 (L4 x W5)	8.5 x 5.2 mm
Notch ((L2-L3) x W3)	1 x 1 mm
Step ((L5-L6) x W9)	1.6 x 6 mm
Feed line Dimensions (Wf x Lf)	22 x 5.6 mm
Ground Dimensions (Lg1 x Wg)	23 x60 mm
Ground Slot (Lg3 x (Wg – (Wg1 + Wg2))	0.5 x 0.9 mm

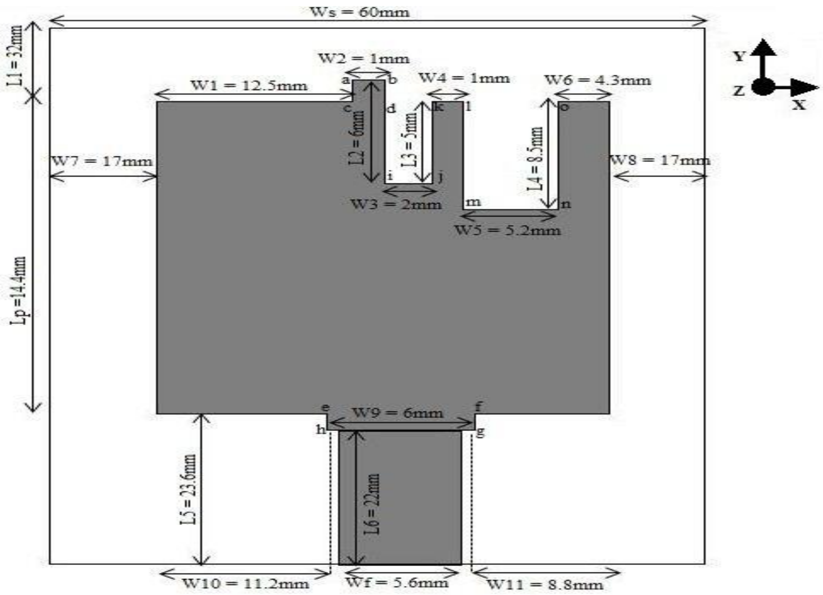

Fig.1 Top view of slotted MPA

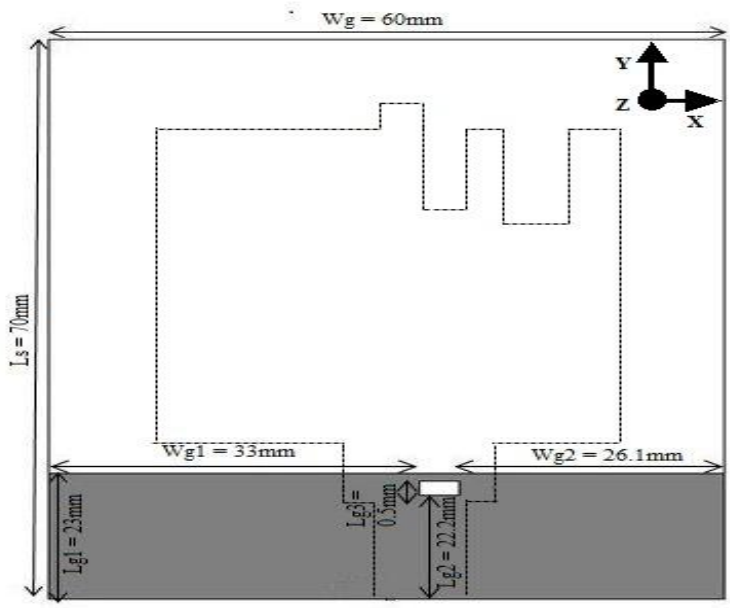

Fig.2 Bottom view of slotted MPA

Note: The dotted portion represented in Fig.2 indicates the projection of patch and feed line on ground.

III. ANTENNA GEOMETRY

The designed slotted antenna have been simulated using CST Microwave Studio 2010 and the performance of the antenna has been analyzed in terms of return loss, VSWR, radiation pattern, directivity, impedance, HPBW(Half Power Beam width) and gain. The experimental results have been also obtained using E5071C ENA series network analyzer and concluded that the practical results closely matches with the simulated theoretical results.

Return Loss : Fig. 3 represents the simulated results of return loss (s_{11}) for designed antenna. Practically, the return loss should be less form minimal back reflections. The return loss has been measured at the resonant frequencies. It has been observed that the return loss is -37.16 dB at 2.62 GHz, -25.26 dB at 3.8 GHz and -30.87 dB at 4.61GHz. The simulated bandwidth of proposed antenna is 3.40 GHz.

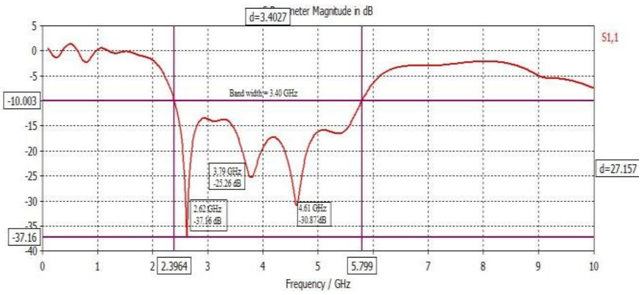

Fig. 3 Return loss plot of Slotted MPA

Directivity : The directivity at resonant frequencies has been obtained and analyzed. Fig. 4(a), Fig. 4(b) and Fig. 4(c) shows the 3D plot of directivity of slotted MPA at resonant frequencies of 2.62 GHz, 3.8 GHz and 4.61 GHz, respectively. The directivity is 2.61 dBi at 2.62 GHz, 3.66 dBi at 3.8 GHz and 3.5 dBi at 4.61 GHz.

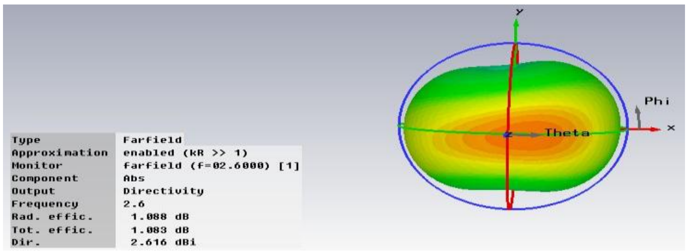

Fig. 4(a) 3D plot of Directivity of MPA at 2.6 GHz

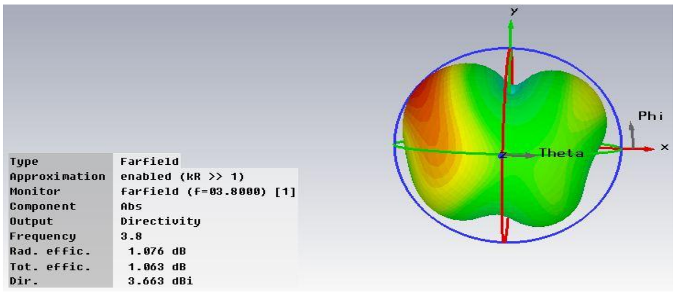

Fig. 4(b) 3D plot of Directivity of MPA at 3.8 GHz

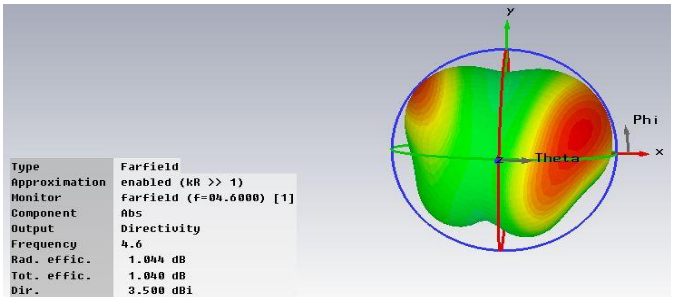

Fig.4(c) 3D plot of Directivity of MPA at 4.6 GHz

Gain

Fig. 5(a), Fig. 5(b) and Fig. 5(c) illustrates the 3D plot of gain for slotted MPA at resonant frequencies 2.62 GHz, 3.8 GHz and 4.61 GHz. The 3D plot shows that the gain is 3.7 dB at 2.62 GHz, 4.73 dB at 3.8 GHz and 4.54 dB at 4.61 GHz, respectively.

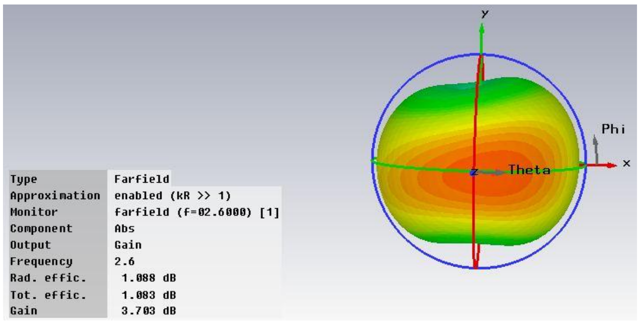

Fig. 5(a) 3D plot of Gain of slotted MPA at 2.6 GHz

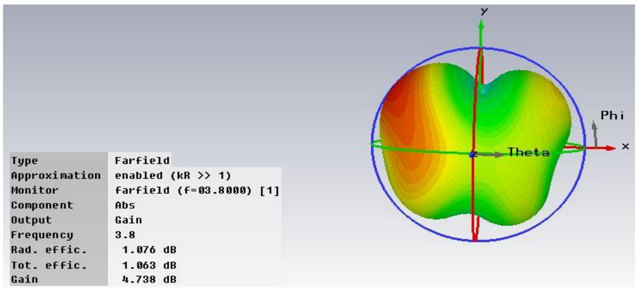

Fig. 5(b) 3D plot of Gain of slotted MPA at 3.8 GHz

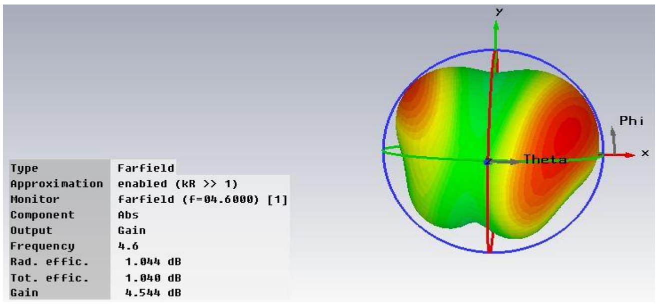

Fig. 5(c) 3D plot of Gain of slotted MPA at 3.8 GHz

Half Power Beam Width (HPBW)

Fig. 6(a), Fig. 6(b) and Fig. 6(c) indicates the half power beam width (HPBW) at resonant frequencies 2.62 GHz, 3.8 GHz and 4.61 GHz, respectively. The half power band width plot indicates the angular width (in degrees) in which maximum power is radiated by antenna. The Fig. 6(a), Fig. 6(b) and Fig.6(c) show that the angular width (3dB) at resonant frequency of 2.62 GHz is 83.3 degree, at 3.8 GHz is 77.0 degree and at 4.61 GHz is 90.1 degree, respectively.

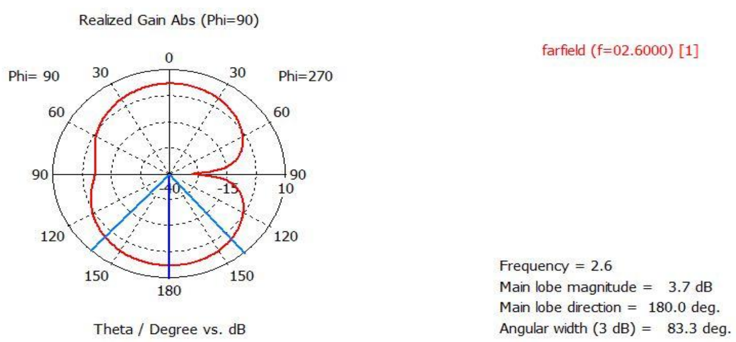

Fig. 6(a) HPBW plot of slotted MPA at 2.62 GHz

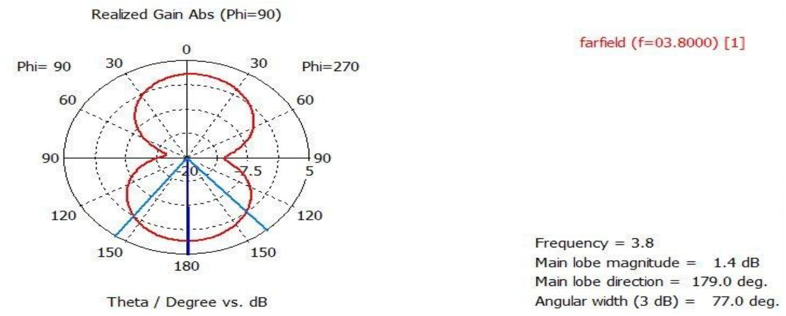

Fig. 6(b) HPBW plot of slotted MPA at 3.8 GHz

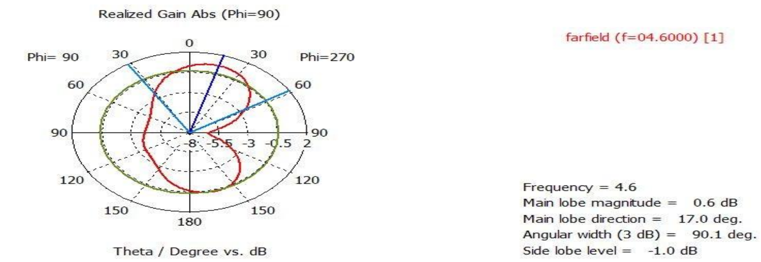

Fig. 6(c) HPBW plot of slotted MPA at 4.61 GHz

VSWR

Fig. 7 depicts the simulated VSWR plot for designed MPA. Practically, the required value of VSWR should be less than 2. Fig. 7 show that value of VSWR for designed MPA is less than 2 in the operating frequency range of 2.39 GHz to 5.79 GHz.

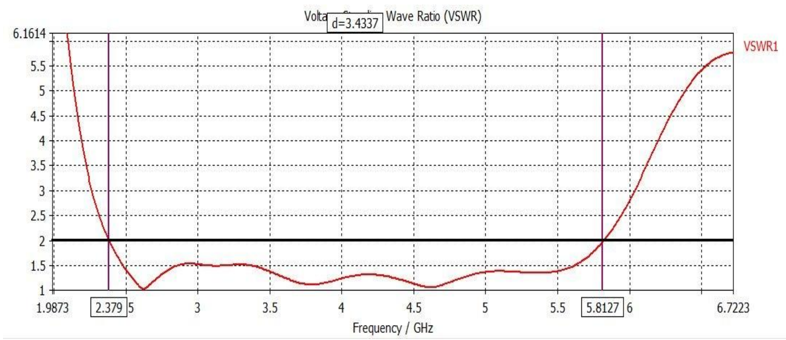

Fig. 7. VSWR plot of designed MPA

Smith Chart : Fig. 8 indicates Smith chart plot for designed MPA. The Smith Chart plot indicates that the variation of impedance of antenna with frequency. The value of impedance should lie near 50 ohms in order to perfectly match the port impedance with the antenna impedance for maximum transfer of power to antenna. The antenna impedance for designed MPA antenna is 49.85 Ω.

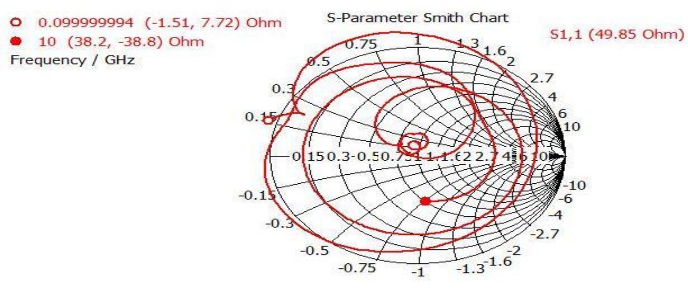

Fig. 8. Smith Chart plot of designed MPA

Current Density

The surface current (H-field) plot indicates the current distribution on the patch surface of antenna. The arrows indicate the direction of power flow back and forth per cycle from the feed to the patch. The arrows in forward direction indicate that the power is radiated in forward direction and the arrow in reverse direction indicates the power reflected back from antenna. The surface current plot at resonant frequencies of 2.6 GHz, 3.8 GHz, 4.61GHz is shown in the Fig. 9(a), Fig. 9(b) and Fig. 9(c), respectively.

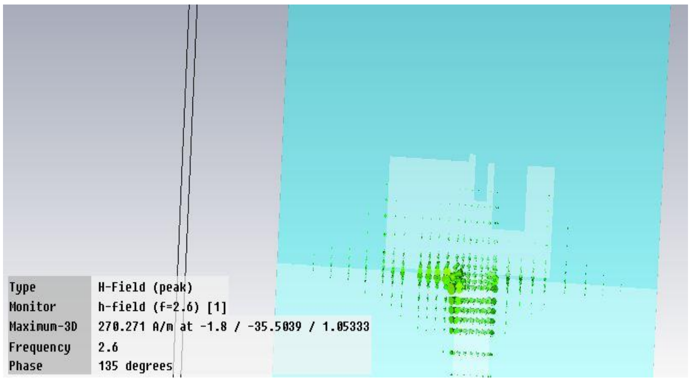

Fig. 9(a) Surface current plot of MPA at 2.62 GHz

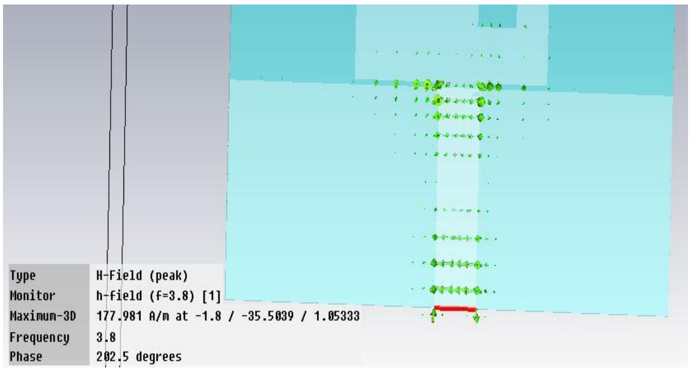

Fig. 9(b) Surface current plot of MPA at 3.8 GHz

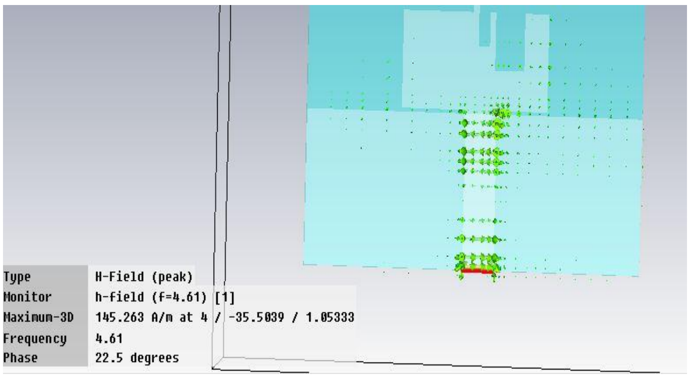

Fig. 9(c) Surface current plot of MPA at 4.61 GHz

IV. EXPERIMENTAL VERIFICATION

The proposed antenna has been physically designed as shown in Fig. 10 and tested using E5071C ENA series Network Analyzer. The Experimental practical results of designed slotted antenna are shown in Fig. 11. It has been observed that return loss at resonant frequencies of 2.62 GHz, 3.8 GHz, and 4.61 GHz is -24.89 dB, -20.925 dB, -28.991 dB, respectively. The bandwidth calculated from practical results of designed MPA is 3.23 GHz.

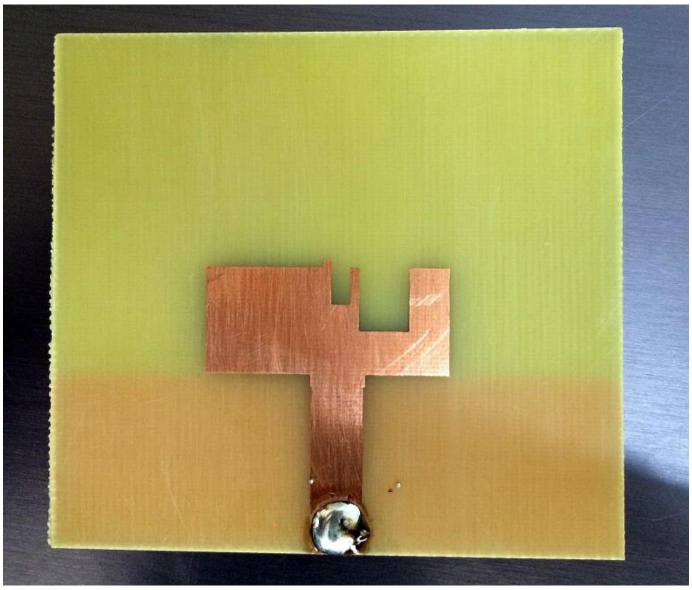

Fig. 10 Fabricated Microstrip Antenna

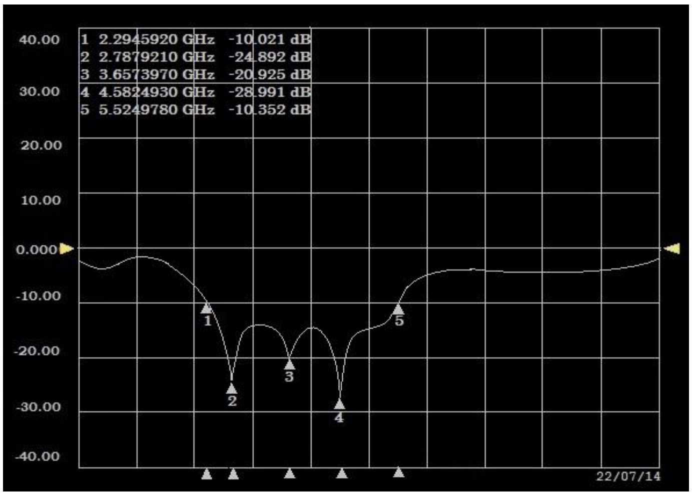

Fig. 11 Experimental Results for fabricated MPA

V. CONCLUSION

From the above discussion, it has been concluded that the slotted microstrip patch antenna has bandwidth of 3.40 GHz with operating frequency range from 2.39 GHz to 5.79 GHz and corresponding resonant frequencies are 2.62 GHz, 3.8 GHz and 4.61 GHz. The directivity corresponding to resonant frequencies of 2.62 GHz, 3.8 GHz and 4.61 GHz are 2.61dBi, 3.66 dBi and 3.5 dBi, respectively. The gain at 2.62 GHz, 3.8 GHz and 4.61 GHz is 3.7 dB, 4.73 dB and 4.54 dB, respectively. The return loss is -37.16 dB at 2.62 GHz,-25.26 dB at 3.8 GHz and -30.87 dB at 4.61 GHz, respectively. The VSWR for slotted microstrip patch antenna is less than 2. The simulated results of the designed slotted antenna closely match with practical results. It has been observed that the practical results of designed MPA have return loss of -24.89 dB, -24.89 dB, -20.925 dB, -28.991 dB at 2.62 GHz, 3.8 GHz and 4.61 GHz, respectively. The bandwidth obtained from practical results of designed MPA has been 3.23 GHz having frequency range from 2.29 GHz to 5.52 GHz. The designed antenna is suitable to be used for Bluetooth (2.4 GHz to 2.5 GHz [8]), IMT (2.3 GHz to 2.4 GHz, 2.7 GHz to 2.9 GHz, 3.4 GHz to 4.2 GHz, 4.4 GHz to 4.9 GHz [8]), WLAN standard (2.4 GHz to 2.484 GHz, 5.15 GHz to 5.35 GHz, 5.725 GHz to 5.825 [8]) and WiMAX (2.5 GHz to 2.69 GHz, 3.4 GHz to 3.69 GHz, 5.25 GHz to 5.85 GHz [8]) applications [8].

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