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Research Article

# Fabrication and Analysis of a Triple Band Patch Antenna

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**Abstract:** The paper presents the design and fabrication of a patch antenna of hexagonal shape on FR-4 lossy substrate of 1.6mm thickness. To achieve multi bands an inverted C-Shaped cut was etched in the patch. The antenna has over all dimensions of 61×48×1.6mm$^3$. Microstrip line feed has been used for the excitation purpose of the antenna. Measurements of Return Loss (RL), Voltage Standing Wave Ratio (VSWR) and Input Impedance were taken using Vector Network Analyzer (VNA) of Rohde & Schwarz Company. The antenna offered three bands with resonant frequencies of 3.36GHz, 4.06GHz and 7.01GHz lying in S and C bands. The -10dB bandwidths achieved are 60MHz (3.340GHz-3.400GHz), 76MHz (4.033GHz-4.109GHz) and 754MHz (6.391GHz-7.145GHz) with corresponding return losses of 20.23dB, 16.30dB and 25.24dB respectively. VSWR of the antenna for all the above mentioned three bands remains below 2. The antenna can be used for different military and commercial applications in S and C bands.

**Keywords:** Vector Network Analyzer, FR-4, Microstrip Line Feed, Triple Band, Patch Antenna

## 1. INTRODUCTION

Antenna plays a vital role in wireless communication. It converts the electrical energy into EM waves at the transmitter and EM waves into electrical energy at the receiver side. Modern communication devices like smart phones urge the development of smart and compact size antennas. Trends in recent development in communication show the demand of integrating many wireless systems in one single device. Demand for research on small and multiple antennas have correspondingly increased [1]. Multi band and wide band antennas are preferred instead of using multiple antennas. However,in order to design a single antenna to cover multiple bands like GSM, GPS, WiFi, WLAN, Bluetooth and LTE bands is a difficult task and is need of the hour. The Reciprocity Theorem can be applied to antenna, so if antenna is tested in the transmitting mode, the same characteristics can be used in the receiving mode as well. IEEE defines the electromagnetic spectrum of the S-band as well as C-band. S-band covers frequencies from 2 to 4 GHz. The C-band is a part of microwave band and it covers the frequency from 4 to 8GHz as given in Table-1. In this work a patch antenna has been fabricated and tested in the laboratory of one of the esteemed institutes of our homeland that gives good results in three different bands.

## 2. LITERATURE REVIEW

A microstrip patch antenna in its most simple form is a tri layer structure. The three layers are patch, ground and a dielectric substrate sandwiched between the two as shown in the Fig. 1 [2]. The patch and ground layers are prepared of a conducting material like Copper or Gold. The patch may be of any arbitrary shape but the most common shapes are shown in Fig. 2 [2]. The substrates used in the patch antennas have dielectric constant ranging from 2.2 to 12. Various techniques are used to excite the patch like micro strip line feed, coax feed, aperture coupling and proximity feed. The most common

**Table 1.** Bandwidth of S and C-Band

| Designation of Band | Bandwidth |
|---|---|
| S- Band | 2GHz-4GHz |
| C-Band | 4GHz-8GHz |

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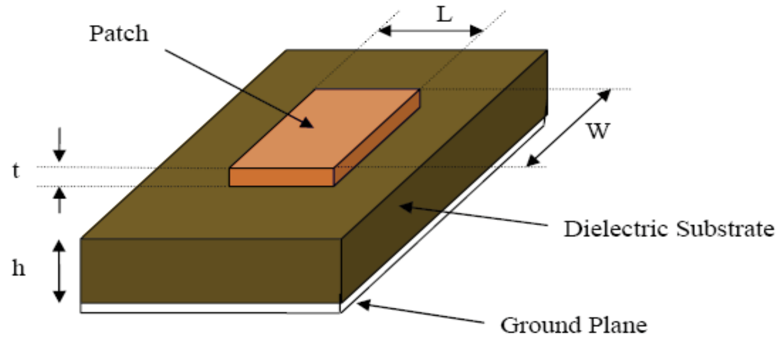


**Fig. 1.** Microstrip Antenna

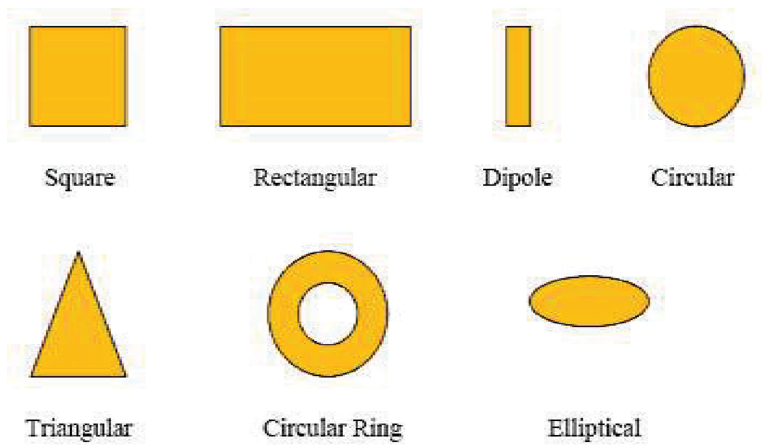


**Fig. 2.** Various common patch formats

method of analysis of patch antenna is transmission line model. Micro strip antenna has numerous benefits like small size, low profile, light weight, easy fabrication and conformability. The two main weaknesses associated with patch antenna are low bandwidth and reduced gain. Various studies have been conducted for finding broad banding techniques of micro strip patch antennas [3-11]. Many researchers have also focused their work on multi-banding techniques of micro strip patch antennas [12-16].

In [17] a multiband design of 42×54mm$^2$ have a bandwidth of 90MHz at the center frequency of 6.7GHz and the dB value of reflection coefficient(r) in this research is -17dB. In [18] a multiband design of 30×40mm$^2$ have a bandwidth of 190MHz at the center frequency of 6.3GHz and the dB value of r in this research is -30.56dB. In [19] a multiband design of 35×26mm$^2$ have the center frequency of 6.7GHz and the dB value of r in this research is -13dB, while the bandwidth has not been mentioned by the author. In [20] a multiband design of 47×50mm$^2$ has been elaborated which has got a bandwidth of 200MHz at the center frequency of 6.7GHz and the dB value of r at the mentioned frequency is -17.89dB [21] explains the multiband patch having length of 30mm and width of 30mm as well. The center frequency of 6.3GHz has attained a reflection coefficient of -14dB and its reported bandwidth is 200MHz.

## 3. DESIGN AND FABRICATION OF THE ANTENNA

The basic dimensions of the antenna were derived using formulas in [2] and [17]. To attain multiband behavior C shaped cut was employed in the hexagonal patch. The proposed antenna was practically fabricated and experimentally investigated. The complete sketch of suggested antenna is presented in Figure 3. The ground plane has same dimensions as the substrate so Lg and Wg in the following Fig.3 define the length and the

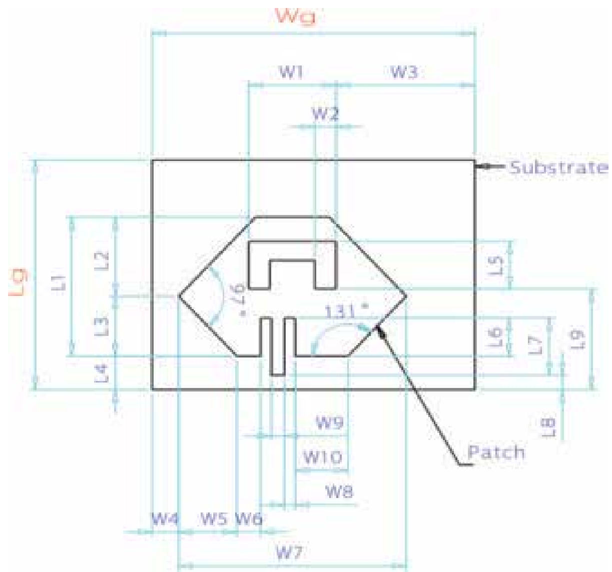


**Fig. 3.** Sketch of the planned antenna

**Table 2.** Geometrical measurements of the antenna

| Parameters | Size (mm) | Parameters | Size (mm) |
|---|---|---|---|
| Wg | 61 | W10 | 10 |
| Lg | 48 | L1 | 29 |
| W1 | 16.5 | L2 | 16.5 |
| W2 | 4 | L3 | 12.5 |
| W3 | 26.3 | L4 | 7 |
| W4 | 5 | L5 | 10 |
| W5 | 11 | L6 | 8 |
| W6 | 4.5 | L7 | 12 |
| W7 | 43 | L8 | 3 |
| W8 | 2 | L9 | 21 |
| W9 | 2.5 | | |

width of the ground. The geometrical dimensions are given in Table 2. FR-4 material is used for substrate and it has a thickness of 1.6mm. FR-4 has been selected for the substrate of this design as the antenna has been fabricated indigenously and this material is readily available in the local market and gives good results. The thickness of patch and ground conductor is 0.035mm. The patch is hexagonal shaped with a C-shaped cut as in Fig. 3.

## 4. RESULTS AND DISCUSSION

The fabricated indigenous antenna was experimentally tested for important performance parameters using vector network analyzer of Rohde & Schwarz, Model FSH20 as shown in Fig. 15.This vector network analyzer has the capacity to measure the bandwidth, return loss, antenna impedance under resonance condition and the voltage standing wave ratio. The measuring capacity of this analyzer is from 1KHz to 8GHz. The obtained results for Return loss, Voltage Standing Wave Ratio, Antenna impedance are briefed in Table 3.

The three resonant frequencies are 3.36GHz, 4.06GHz and 7.01GHz and these three central resonant frequencies are denoted by $M_1$, $M_2$ and $M_3$ in Fig. 4. The three frequency bands are

**Table 3.** Summary of the results of the fabricated structure

| Resonance frequency | 3.36 GHz | 4.06 GHz | 7.01 GHz |
|---|---|---|---|
| Bandwidth | 60 MHz | 76 MHz | 754 MHz |
| Bandwidth | 1.78 % | 1.87 % | 10.75 % |
| Return Loss | -20.23 dB | -16.30 dB | -25.24 dB |
| VSWR | 1.22 | 1.36 | 1.12 |
| Impedance (Ohm) | 56.5 - j8.31 | 48.8 + j15.4 | 54.7 – j3.36 |

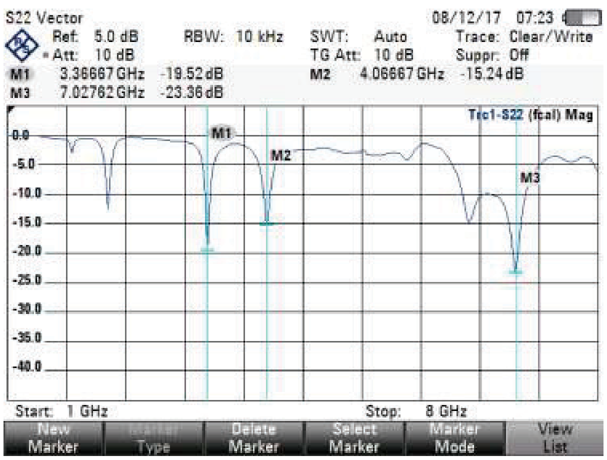


**Fig. 4.** Return Loss (RL) presenting triple bands

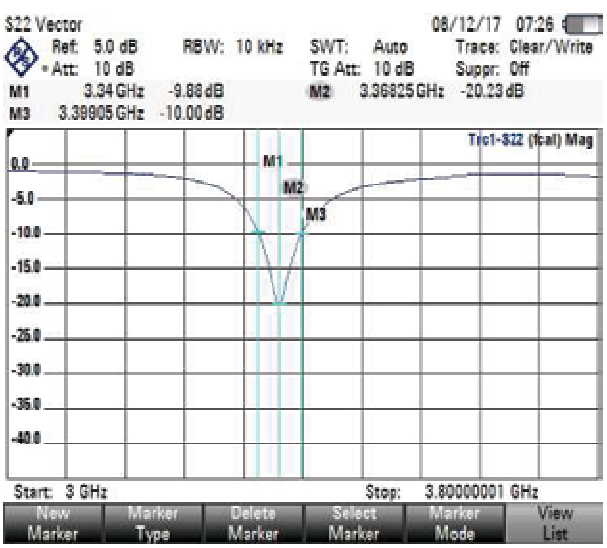


**Fig. 5.** Return loss (RL) of band 1

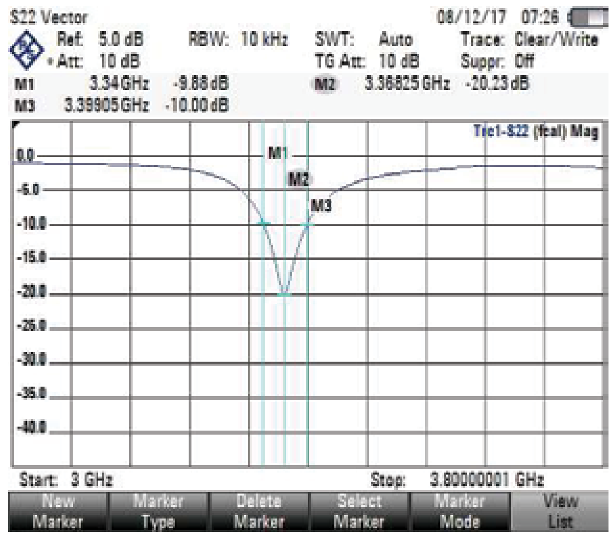


**Fig. 6.** VSWR' of band 1

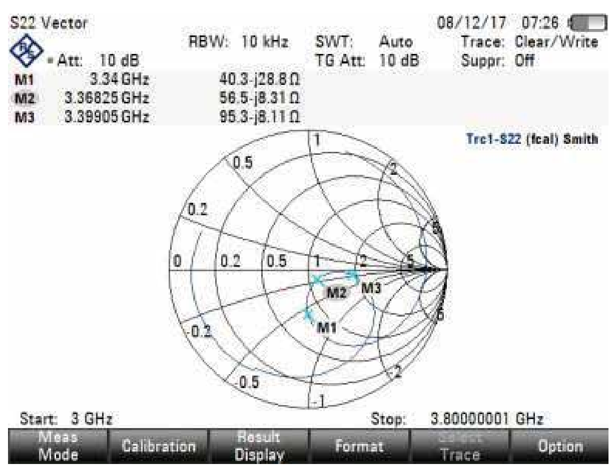


**Fig. 7.** Input impedance in band 1

independently elaborated and analyzed below.

## 4.1 DISCUSSION ON THE FIRST BAND

The band 1 resonates at 3.36GHz as depicted in Fig. 5 giving a -10 dB BW of 60 MHz whereas sustaining voltage standing wave ratio (VSWR) is under the standard level of 2 as presented in Fig. 6. $M_1$, $M_2$ and $M_3$ in Fig. 5 represent the initial, central and final frequencies of the first band which are 3.34GHz, 3.36GHz and 3.399 GHz respectively. The corresponding values of the voltage standing

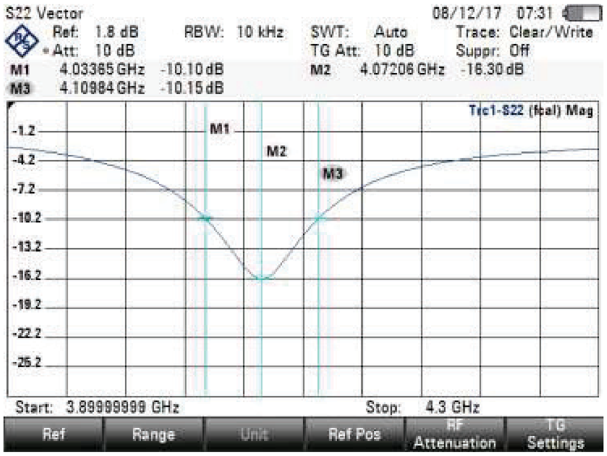


**Fig. 8.** Return Loss (RL) of band 2

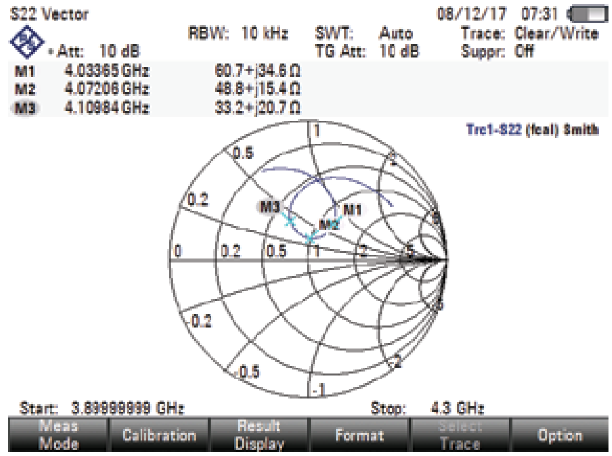


**Fig. 10.** Smith chart of band 2

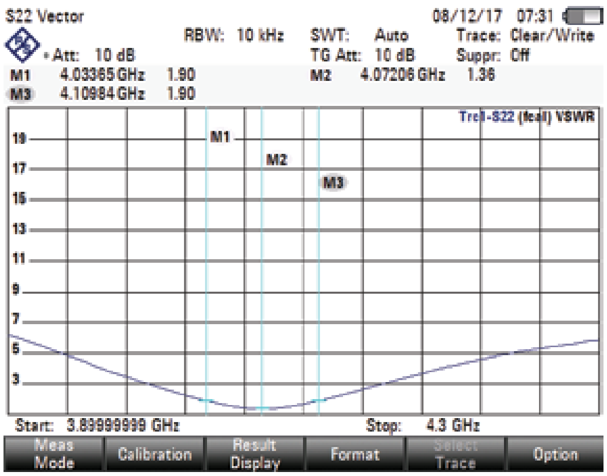


**Fig. 9.** 'VSWR' of band 2

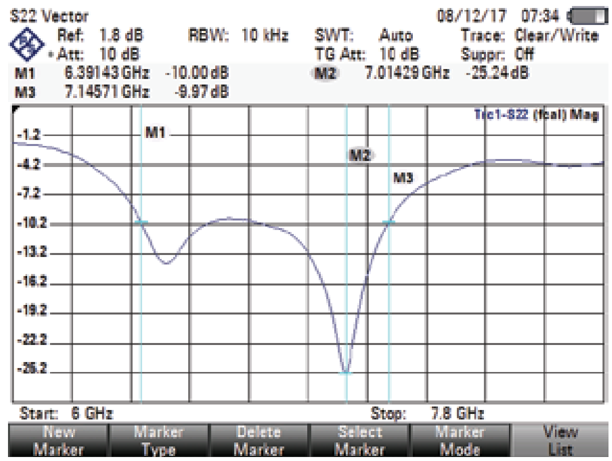


**Fig. 11.** Return Loss (RL) of band 3

wave ratios at the above mentioned frequencies are mentioned in Fig. 6 as 1.94, 1.22 and 1.92 respectively. Input Impedance of the antenna at central frequency is 56.5 - j8.31 Ω as presented in Fig. 7. This shows a good match of antenna with transmission line. The discussion on the results implies that this indigenous structure will work satisfactorily in the first band.

## 4.2 DISCUSSION ON THE SECOND BAND

Band 2 resonates at a frequency of 4.06GHz offering a -10 dB bandwidth of 76 MHz as given in Fig. 8. VSWR is displayed in Fig. 9 for band 2. The structure gives an acceptable ratio that guarantees the working of the fabricated design in band 2.$M_1$, $M_2$ and $M_3$ in Fig. 8 represent the initial, central and final frequencies of the 2nd band which are 4.033GHz, 4.072GHz and 4.109 GHz respectively. The corresponding values of the voltage standing wave ratios at the above mentioned frequencies aregiven in Fig.9 as 1.90, 1.36 and 1.90 respectively. The smith chart reveals the input impedance as 48.8 + j15.4 Ω at central frequency shown in Fig. 10, demonstrating a decent impedance match.

## 4.3 DISCUSSION ON THE THIRD BAND

Band 3 resonates at a frequency of 7.01 GHz. Its -10 dB bandwidth is 754MHz as shown in Fig. 11. $M_1$, $M_2$ and $M_3$ in Fig. 11 represent the initial, central and final frequencies of the third band which are 6.39GHz, 7.014GHz and 7.143 GHz respectively. The corresponding values of the voltage standing wave ratios at the above mentioned frequencies are given in Fig.12 as 1.92, 1.12 and 1.93 respectively. Input Impedance of the antenna at central frequency is 54.7-j3.36 Ω presenting a strong matching as demonstrated in Fig. 13. VSWR of band 3 is depicted in Fig. 12. The VSWR value rests under

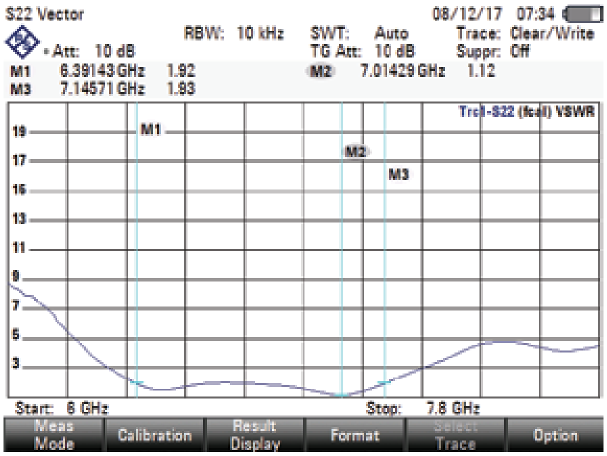

**Fig. 12.** 'VSWR' of band 3

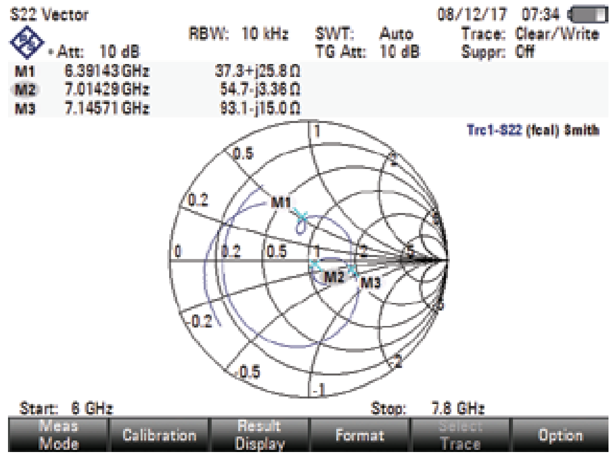

**Fig. 13.** Smith chart of band 3


**Fig. 14.** Front and back views of the fabricated antenna


**Fig. 15.** Pictorial view of the vector network analyzer

the tolerable range of 2 inside all the mentioned three bands. Figure 14 demonstrates front and back sight of the developed antenna.

## 5. CONCLUSION

In this work an indigenous hexagonal shaped patch antenna was implemented on FR-4 with overall dimensions of $61 \times 48 \times 1.6mm^3$. An inverted C-shaped cut was etched on the patch to produce multiple resonances. Important parameters were measured using VNA. The hexagonal type antenna demonstrated three bands with center resonant frequencies of 3.36GHz, 4.06GHz and 7.01GHz with corresponding return losses of 20.23dB, 16.30dB and 25.24dB respectively. The achieved impedance bandwidths were 60MHz, 76MHz and 754MHz. VSWR in all the above mentioned three bands remains below 2. The antenna is a better candidate for various government and military applications within S and C bands.

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