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DESIGN OF HEXAGONAL MICROSTRIP PATCH ANTENNA FOR BANDWIDTH ENHANCEMENT AND MINITURIZATION

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Abstract - This paper presents the design and performance of inset feed hexagonal patch antenna for miniaturization, bandwidth enhancement and circular polarization. Along with the novel geometry, a 2X1 array and 2X2 array of hexagonal patch has also been implemented. The prototype of the antenna has been designed and simulated on ADS (Advanced Design System). By implementing the hexagonal geometry, impedance bandwidth has improved by 62.8% and the gain has been enhanced by 14.2%.The designed antenna resonates at a frequency of 5Ghz.Nowadays,this frequency band is being used extensively in various applications which primarily include Wi-Fi and WLAN, which earlier was used in 2.4 GHz frequency band. A comparative study of hexagonal geometry with rectangular geometry arrays has been presented in terms of impedance bandwidth, gain and polarizations. The designed hexagonal array antennas have been fabricated by CNC Engraver while the rectangular geometry arrays by photo-lithographic method. The design is fabricated and tested on Vector Network Analyzer (VNA).It is found that the stimulated results are in close proximity with the fabricated ones. The antenna design can be used in modern day mobile communication due to its optimized area coverage along with enhanced bandwidth.
Keywords: Impedance Bandwidth, Circular Polarization, Gain, CNC Engraver, Vector Network Analyzer.

1. INTRODUCTION

The field of wireless communication is one of the fields which are being extensively researched upon, in order to make communication more efficient and accurate. For wireless communication systems, antenna plays a crucial role in collecting and emitting signals [1].The recent developments in low cost and compact wireless communication systems have largely been possible due to advent of antennas with smaller dimensions which are capable of delivering output with high efficiency.

In recent years compact antenna with multiband characteristics is topic of interest for research work for application in wireless Communication system. One of the techniques to design a compact microstrip antenna [MSA] is cutting slots or slits on the radiating patch to increase the length of the patch of the surface current. Some articles on the design of compact MSA were studied by the author [1-4].

MSAs are used in a broad range of applications from communication systems to biomedical systems, primarily due to several attractive properties such as light weight, low profile, low production cost, conformability, reproducibility, reliability, and ease in fabrication and integration with solid state devices. Among various antennas employed, microstrip patch antennas are the most prevalent ones and are being extensively used for numerous applications due to its alluring features which include low cost, ease in fabrication, low profile, conformity and most importantly smaller in dimension [2].

The architecture of microstrip patch antenna consists of metallic strip or a patch mounted on the dielectric over the ground plane. It is a low profile antenna and is conformable to planar and non planar surfaces. It is protean in terms of polarization, resonant frequency, patterns and impedance. Conventional microstrip patch antenna suffers from narrow bandwidth which limits its performance in various communication systems. Numerous numerical methods have been reviewed which have a profound effect on the bandwidth and gain of the microstrip patch antenna, so that the broadband criteria can be met.

Varying the geometry of patch is one of the methods which are effective in enhancing the bandwidth of the antenna. Microstrip patch antennas can be designed in various shapes, in which most frequent ones used for analysis are rectangular, circular, triangular and elliptical [3]. Further more, miniaturization has been a topic of interest for a long time, especially in today’s era where each device is getting more compact with every passing day [4]. Previously, various miniaturization techniques have been implemented but at the cost of other antenna parameters. This paper presents a hexagonal geometry of a patch using an inset feeding technique which minimizes the overall coverage area and also enhances the bandwidth and gain of the microstrip patch antenna. In addition to miniaturization and enhanced bandwidth, hexagonal geometry also provides circular polarization [5].

The antenna has been designed for the resonant frequency of 5GHz.Nowadays, this frequency band is being extensively used, majorly for applications like WIFI and WLAN [6].These applications previously used frequency band of 2.4Ghz but now it is being switched to 5GHz frequency band for better performance. The design along with the comparative analysis of 2X1 array and 2X2 array, using hexagonal geometry, with that of rectangular array has also been presented. In section I, a brief summary of wireless communication and its needs has been presented along with the introduction of microstrip patch antenna .Section II presents the mathematical modeling of hexagonal patch antenna. Results of hexagonal patch antenna parameters and its subsequent arrays are presented in Section III. Section IV discusses the conclusion and future scope.

2. DESIGN OF HEXAGONAL MICROSTRIP PATCH ANTENNA DESIGN

Hexagonal patch microstrip antenna is one of the geometries which can produce circular polarization[7].The modal distributions of hexagonal patch antenna is found to be similar to that of circularly polarized microstrip patch antennas. Hence, a mathematical modelling is presented by equating the areas of the above shapes.
The resonant frequency of patch antenna can be designed by the
Equation given below [8],

$$f_{re} = \frac{X_{mn} c}{2\pi a\sqrt{\varepsilon_{reff}}}$$

Where,
f_{re} is the resonant frequency
χ_{mn} =1.8411
c=3 x10^8 m/s
ϵ_{reff} is the relative permittivity of the substrate material a is the effective radius of the circular patch antenna.

$$a_{eff} = a\left\{1 - \frac{2h}{\pi a \varepsilon_{reff}}\left(ln\frac{\pi a}{2h} + 1.77\right)\right\}$$

Where,
a_{eff} is the actual radius of the circular patch antenna h is the height of the substrate
The equivalent areas of circular patch antenna and hexagonal microstrip patch antenna are equated and the expression is given below

$$\pi a_{eff}^2 = \frac{3\sqrt{3}}{2} s^2$$

Where,
s is the side of the hexagonal patch antenna
a_{eff} is the effective radius of the circular patch antenna.
Inset feed is used to feed this design and hence its feed location can be obtained by calculating feed line width and depth of the feed line [9].

$$W = \frac{7.48h}{e^{\frac{Z_0\sqrt{\varepsilon_{reff+1.41}}}{97}}} - 1.25t$$

Where,
W_L is the width of the feed line
H is the substrate height
Z_o is the output impedance
ϵ_r is the relative permittivity

$$Z_{in} = \frac{90\varepsilon_{reff}^2}{\varepsilon_r - 1}\left(\frac{L}{W}\right)^2$$

Where, Z_{in} is the input impedance

$$y = \frac{W}{\pi}\cos^{-1}\frac{1}{\sqrt{Z_{in}}}$$

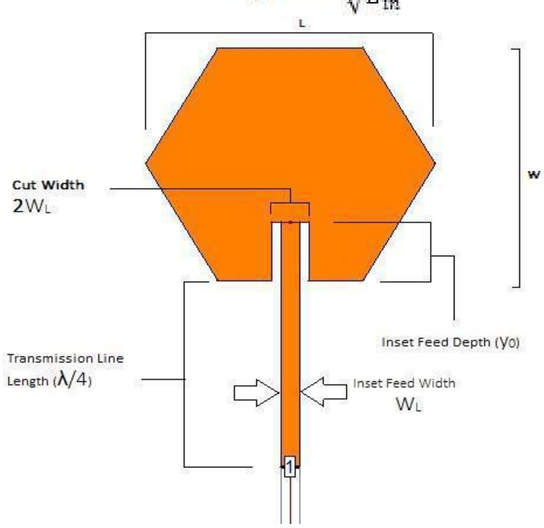

Fig. 2.1 Hexagonal Patch Design

3. RESULTS AND DISCUSSIONS

In this section, a hexagonal microstrip patch antenna has been designed which operates on the resonant frequency of 5GHz.The antenna uses FR4 substrate and has a height of 1.6mm.Concurrently, a rectangular microstrip patch antenna has also been designed for a comparative study.

3.1 Simulated Results

The various antenna geometries have been designed and simulated using Advanced Design System (ADS).

3.1.1 Single Hexagonal and Rectangular Patch

The side of the hexagonal patch(s) as calculated using the above equations is 8.229mm.The width of the feed line is 2.951mm and the depth of inset feed line is calculated to be 6.952mm.The length of the transmission feed line is 60mm.The layout of hexagonal and rectangular microstrip patch antenna are depicted in Fig. 3.1.

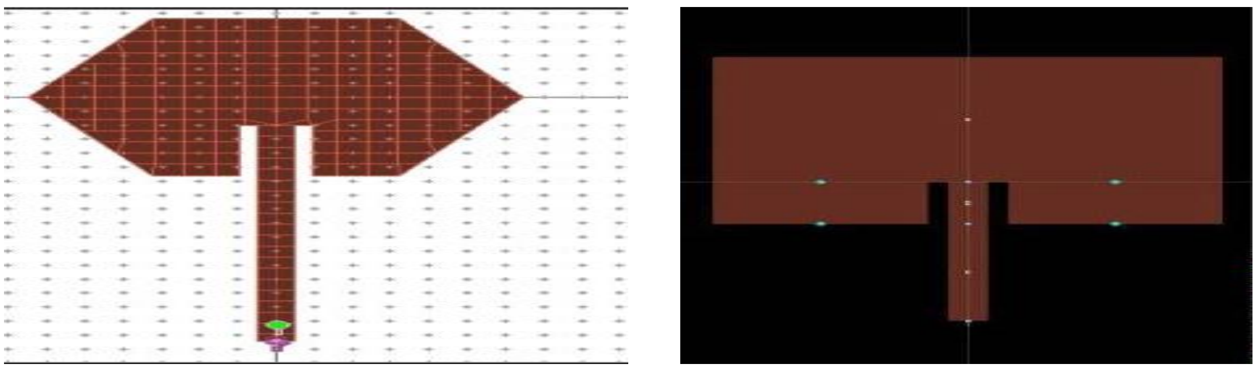

Fig. 3.1 Layout of Hexagonal and Rectangular Microstrip patch Antenna

The S_{11} parameters of the hexagonal patch antenna and that of rectangular microstrip patch antenna are depicted by the Fig 3.2. As can be seen from the figure the return loss has decreased to -15 Db and simultaneously the bandwidth has been enhanced to 134 MHz for hexagonal patch geometry whereas the rectangular patch provides an impedance bandwidth of 92 MHz.

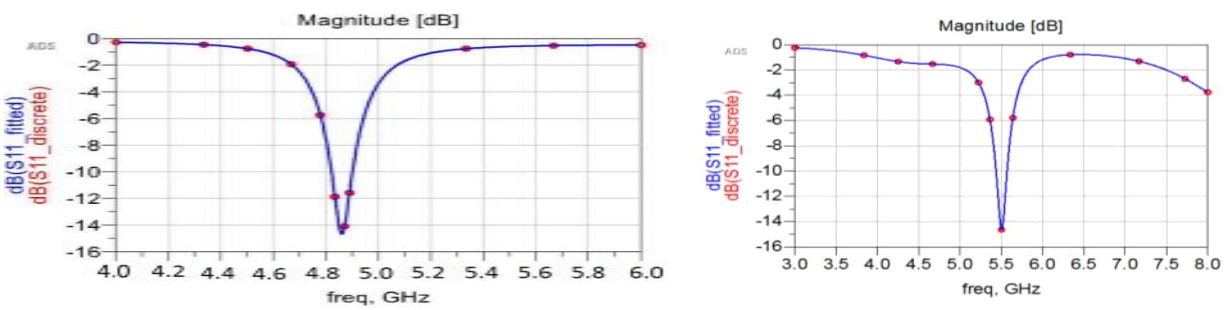

Fig. 3.2 Magnitude of S11 vs. Frequency of Rectangular and Hexagonal Microstrip Patch Antenna Respectively

The radiation pattern and 3D view of the hexagonal patch antenna is presented in Fig. 3.3.

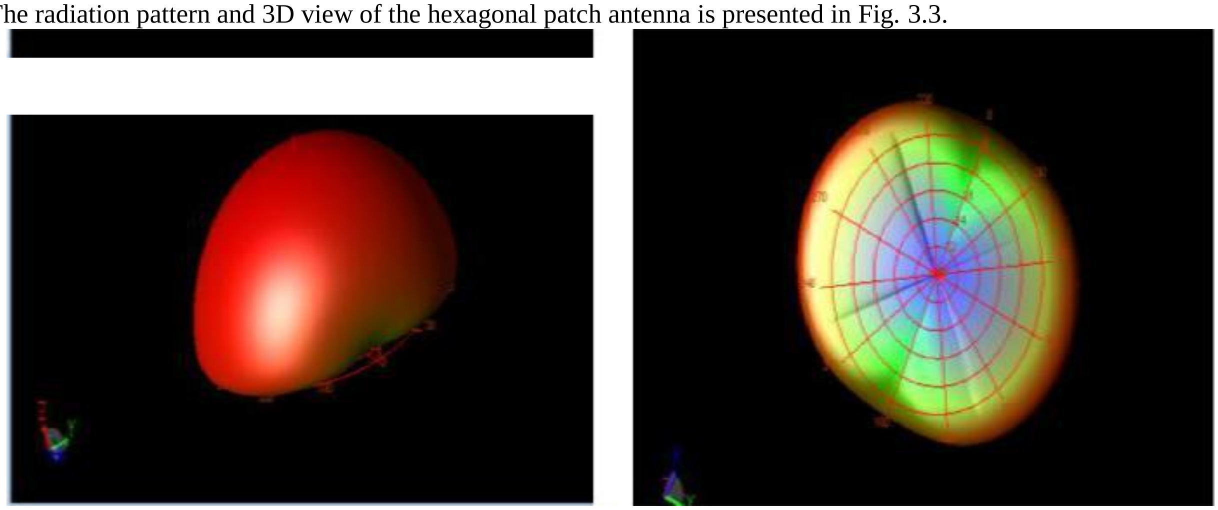

Fig. 3.3 Radiation Pattern

3.1.2 1x2 Hexagonal and Rectangular Microstrip Patch Array Antenna with Inset Feed

The 1X2 array antenna has been designed by using the hexagonal patch and rectangular patch operating on the resonant frequency of 5Ghz.The layout of the array designs is depicted in Fig. 3.4.

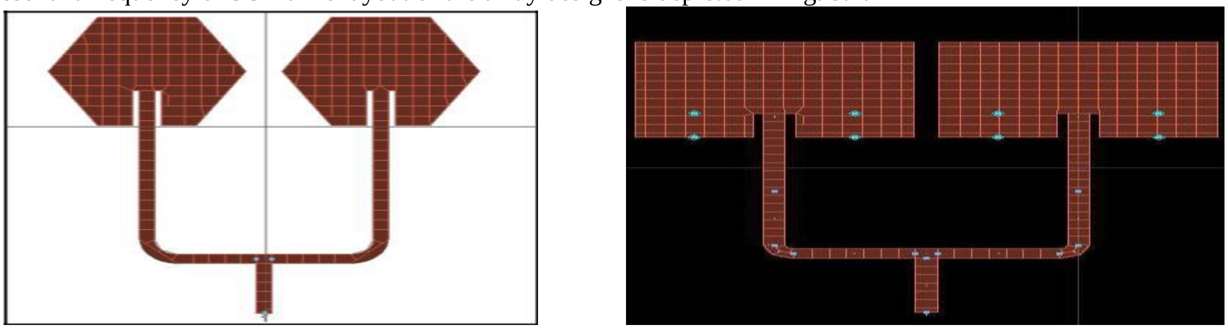

Fig. 3.4 Layout of 1x2 Hexagonal and Rectangular Microstrip Antennas

The S_{11} parameters of 1X2 array antennas are presented in the Fig. 3.5. From the figure it is observed that bandwidth has increased to 230 MHz as compared to single hexagonal patch antenna and simultaneously gain has also been enhanced. Along with bandwidth and gain, the return loss has reduced to a large extent. In comparison to hexagonal patch array antenna, the rectangular 1X2 array design provides an impedance bandwidth of 140 MHz.

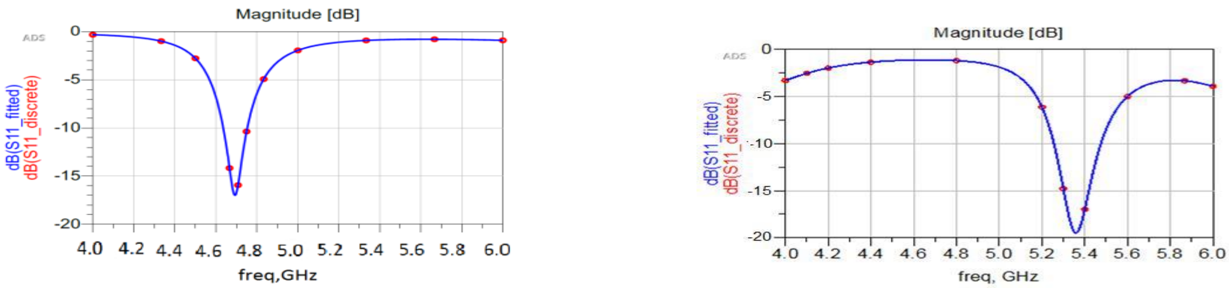

Fig. 3.5 Magnitude of S11 vs. Frequency Frequency of Rectangular and Hexagonal Microstrip Patch Antenna Respectively

The radiation pattern of 1X2 antenna array and its 3D view is given in Fig. 3.6.

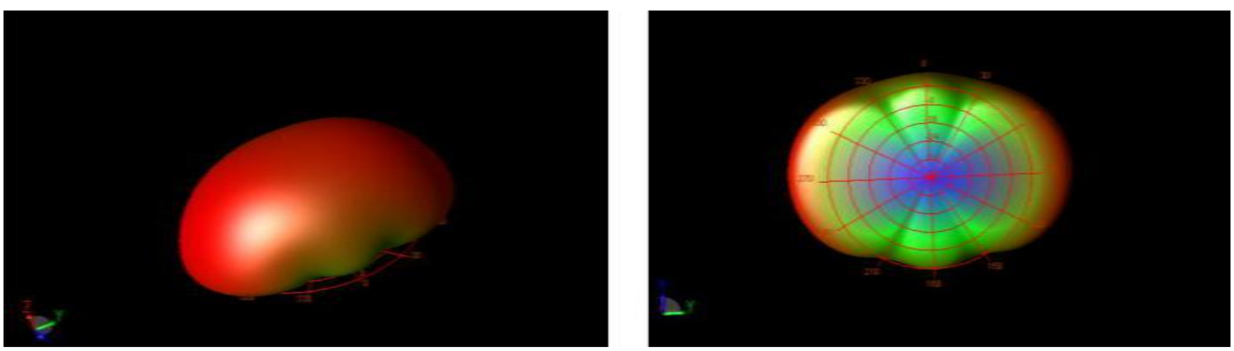

Fig. 3.6 Radiation Pattern

3.1.3 2x2 Hexagonal and Rectangular Microstrip Patch Array Antenna With Inset Feed

The 2X2 array antenna has been designed by using the hexagonal patch and rectangular patch operating on the resonant frequency of 5Ghz.The layout of the array designs is depicted in Fig. 3.7.

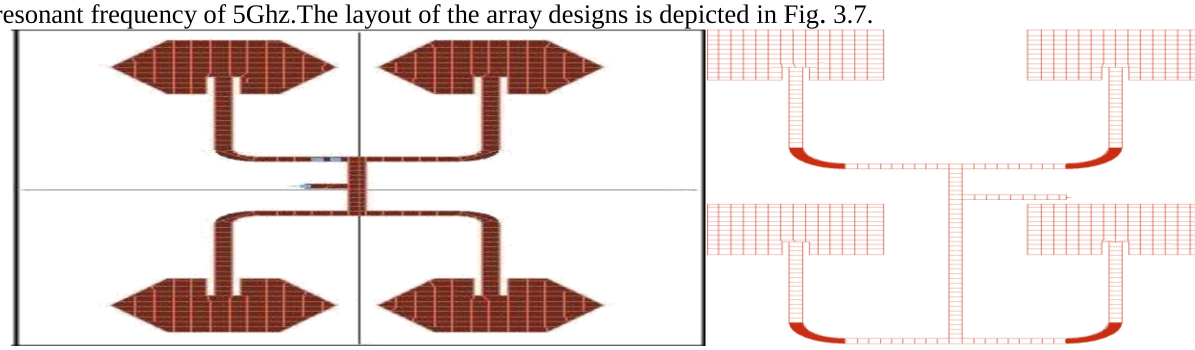

Fig. 3.7 Layout of 1x2 Hexagonal and Rectangular Microstrip Antennas

The S_{11} parameter graph of 2X2 hexagonal patch array antenna is shown in Fig. 3.8. As can be observed from the graph the bandwidth is increased to 380 MHz and the return loss has also been minimized. Along with enhanced bandwidth, the gain and directivity have also exhibited good results when compared with rectangular patch antenna arrays. The rectangular 2X2 array antenna provides an impedance bandwidth of 250MHz.

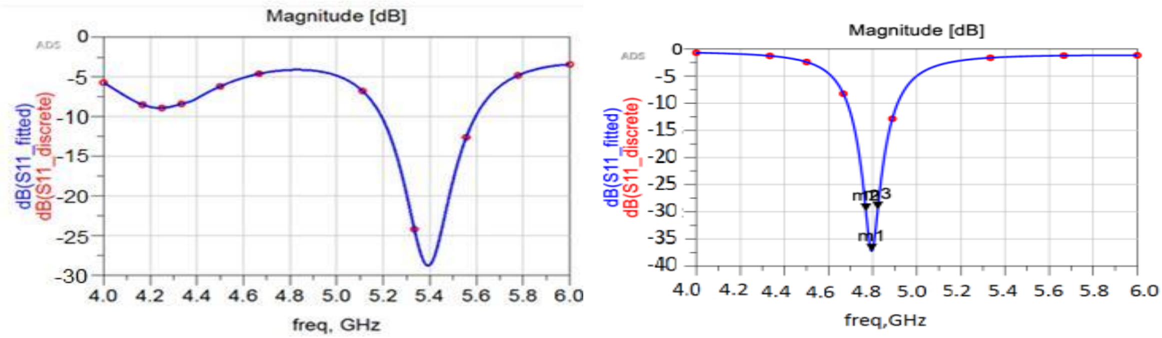

Fig. 3.8 Magnitude of S11 vs. Frequency of Rectangular and Hexagonal Microstrip Patch Antenna Respectively

The radiation pattern of 2X2 hexagonal patch antenna array and its 3D view is depicted in Fig. 3.9.

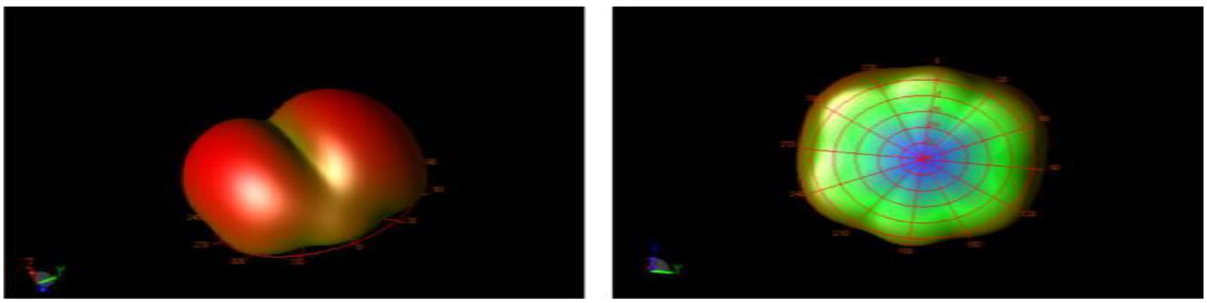

Fig. 3.9 Radiation Pattern

3.1.4 Comparative Study of Arrays

The hexagonal microstrip patch antennas due to their stated advantages have been widely employed. Antenna arrays are widely used in comparison to singe antennas and hence a comparative analysis is presented below:

Table-3.1 Comparative Study of Designs

Design	Return Loss(dB)	Bandwidth (Mhz)
Single Hexagonal Patch Antenna	-15	134
1X2 Array Design	-5.5	230
2X2 Array Design	-8	380

3.2 Measured Results

The antenna designs have been fabricated by using two methods, namely, by using CNC Engraver and by Photo-lithographic method .The hexagonal microstrip patch antenna and its arrays have been fabricated by using CNC Engraver .This machine uses laser technology to fabricate microstrip patch antennas and is shown in Fig. 3.10.

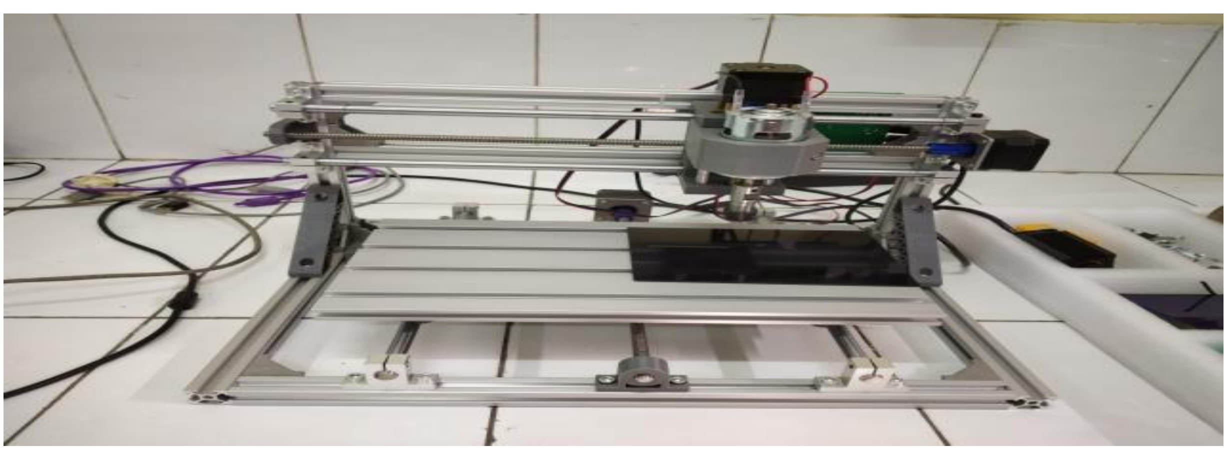

Fig. 3.10 CNC Engraver

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The rectangular microstrip patch antennas are fabricated by photo-lithographic method which is a chemical ethching process which removes the unwanted metal regions of the metallic layer.Fig. 3.11 depicts 2X2 rectangular microstrip patch array antenna.

Fig. 3.11 Fabricated 2X2 Recatngular Array Antenna

The fabricated antenna designs have been tested using Vector Network Analyzer(VNA).VNA is a netwrok analyzer which meausres both magnitude and phase of the response.By using Vector Network Analyser,S parameters can be easily determined as shown in Fig. 3.12.

Fig. 3.12Testing of 2X2 Rectangular Array Antenna using VNA

CONCLUSION AND FUTURE SCOPE

In this paper, hexagonal microstrip patch antenna and its subsequent arrays, operating at 5 GHz have been studied and analysed.The simple hexagonal patch provided a bandwidth of 134 MHz which is enhanced when compared with a rectangular patch antenna. Moreover, the return loss is also minimized to a large extent. In 1X2 hexagonal patch antenna array design, the bandwidth achieved is 230 MHz and also gain is enhanced. When 2X2 hexagonal patch antenna array is designed, it is found that a bandwidth of 380 MHz is obtained and furthermore, the gain and directivity is also enhanced. When the performance of hexagonal patch antennas is compared with rectangular patch antennas, it can be readily observed that there is enhancement of antenna parameters when hexagonal geometry is employed. The impedance bandwidth is improved by 62.8% whereas gain has been enhanced by 14.2% if compared with rectangular microstrip patch antenna.Moreover,it is observed that rectangular geometry produces linear polarization whereas hexagonal geometry provides circular polarization which can be utilized in various applications. These results have been verified by Vector Network Analyzer and they have been found to be in close proximity with the stimulated results. This antenna can be assuredly used in new generation Wi-Fi and WLAN communications which require an operating frequency of 5 GHz. It has been found that as the degree of array increases, losses also subsequently start to increase in inset feeding mechanism. Hence, the future scope involves devising improved feeding mechanisms to minimize microstrip line losses while implementing arrays.

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