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# Design, Simulation and Analysis of Individual Transmitting and Receiving Micro Strip Patch Antennas for Communicating with a Satellite in S- band Communication

Karedla Chitambara Rao<sup>1</sup>, Prudhivi Mallikarjuna Rao<sup>2</sup>

Associate Professor, Department of ECE, AITAM Engineering College of Engineering, Tekkali, Andhra Pradesh, India<sup>1</sup>

Professor, Department of ECE, AU College of Engineering, Visakhapatnam, Andhra Pradesh, India<sup>2</sup>

**ABSTRACT:** Now- a -days Submarines play an important role in our Country. Submarine based antenna technology was used in World War I and World War II. At present for combined operations and Network Warfare concepts, the modern Submarines are required for communicating with Satellites. There are so many types of Satellites. Among them point to point communication and Broadcasting Satellites are very useful in 3G and 4G Network services. For communicating with Satellites, a compact antenna is needed and it must have circular polarization characteristics, positive gain at  $\pm 45^\circ$  points of the main beam and the main beam position has to be in vertical direction to track the Satellite directly. In this paper a square type of micro strip patch antenna is proposed as a radiating element fed by a single probe type of feeding along a diagonal and the RT/ Duroid 5880 material of dielectric constant 2.2 and thickness of 1.575mm have been used as the substrate of the antenna. The proposed antenna has been designed at the centre frequency of 2.595GHz in the Satellite frequency range (2.5GHz to 2.69GHz) of the S- Band Communication. After designing one square micro strip patch antenna for transmitting, another square micro strip patch has been designed for receiving as the same dimensions of the transmitting patch antenna. After designing the both transmitting and receiving antennas, individually transmitting and receiving patch antennas will be simulated and analysed for various characteristics such as VSWR, Gain, Axial ratio and radiation patterns at the transmitting and receiving frequencies of the Satellite

**KEYWORDS:** Micro strip patch antenna, Rectangular micro strip patch antenna, Square micro strip patch antenna and S-band Communication.

## I. INTRODUCTION

Now a days Satellite systems are using Worldwide in almost every aspect of Radio Communication from narrowband to broadband including Telecommunication, Positioning and Broadcasting. There are so many types of Satellites. Among them point to point communication and Broadcasting Satellites are useful in 3G and 4G Network services. Micro strip patch antennas are more popularly used now a days due to its various advantages such as light weight, less volume, compatibility with integrated circuits, easy to install on the rigid surface and low cost. Micro strip patch antennas can be designed to operate in dual-band and multi-band applications either dual or circular polarizations. There are so many types of micro strip patch antennas. Among them square micro strip patch antennas are used to generate a pencil beam.

**Previous Research work:** So for many authors had discussed the characteristics, design equations and applications of the Micro strip patch antennas but no one is used as a micro strip antenna in a S-band communication for communicating with a Satellites. The authors had designed a rectangular micro strip patch antenna with and without

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Vol. 6, Issue 10, October 2017

defected ground structure at the operating frequency of 2.4GHz. The designed antenna was simulated for various characteristics such as beam width, return loss and VSWR and tested in laboratory. They also said that the various characteristics like VSWR, return loss, beam width and bandwidth can be improved by using the defected ground structure in the micro strip patch antenna [1]. The rectangular MSPA was designed for WLL- Cor- DECT Technology at the resonant frequency of 1.88GHz. For designing such as antenna they had used the silicon material as substrate with a dielectric constant of 11.9 and height was 31mm along with a single feed. They obtained return loss of 35dB at resonant frequency [2]. The circular and circular slot patch antennas were designed analysed and compared them by changing the substrate thickness. They had observed that gain is increased first and then decreased when thickness increases from 1mm to 2mm for the circular patch antenna but for the case of circular slot antenna, the gain decreased with increase in the substrate thickness. Finally they observed that the circular slot patch antenna is showing better results compared to circular patch antenna [3]. The Ultra-Wide band micro strip patch antenna was designed by integrating slotted partial ground with stair and addition of tuning stub with rectangular patch antenna. The designed antenna was simulated, fabricated and tested for various characteristics like gain, return loss and radiation patterns in the frequency range of 3.2 GHz – 15.7GHz. Moreover the bandwidth of 12GHz, maximum gain 7.5dB and return loss up to -40dB were obtained [4]. The elliptical patch antenna was modified by using three orthogonal sector slots. The same antenna was simulated and compared their simulation and experimental results. The size of the modified antenna marginally reduced but the performance of antenna is significantly improved [5]. The Micro strip patch antenna has been designed at a resonant frequency of 2.4GHz. The gain value of 8.27dB and VSWR value of 1.18 were obtained [6]. The rectangular and square patch antennas were compared with and without dielectric superstrates at the operating frequency of 2.4GHz. The authors had measured the various parameters like VSWR, return loss, beam width and gain. The resonant frequency increases with the dielectric constant of the superstrats thickness [7]. The broadband asymmetric U-slot patch antenna with narrow probe was presented and designed in the band width from 1.9GHz to 2.5GHz. The asymmetrical U-slot antenna has been compared with U-slot symmetrical antenna and the authors had noticed that the U-slot asymmetrical antenna has reduced size, low probe dielectric without reduction in bandwidth [8]. The authors reviewed the micro strip patch antenna in terms of feeding technics, advantages, disadvantages and applications [9]. Sixteen element rectangular micro strips patch array antenna with inset feed has been designed at the resonant frequency of 2.4GHz [10]. Square spiral shaped patch antenna with suitable tuning elements has been designed. A good impedance matching was observed near the frequencies 1.6GHz, 2GHz and 2.4GHz using two symmetrical turning elements [11]. An electronically polarization reconfigurable circular patch antenna with fixed resonant frequency and operating at WCAN frequency band (2.4GHz to 2.48GHz) was presented. The proposed antenna consists of a circular patch as a radiating element fed by a co-axial probe, co-operated with four equal length slits etched on the edge along x-axis and y-axis. The proposed antenna has been switched in to three types LP, LHCP or RHCP [12]. Broadband micro strip patch antenna with parasitic elements fed by co-axial probe feed has been proposed and designed in the frequency range from 5.22GHz to 6.27GHz and nearly bandwidth was 1.04GHz. The maximum gain of the proposed antenna was around 9.31dB [13]. A novel wide band dual frequency slotted antenna which was constructed by two diamond shapes slots in the middle and four triangular slot structures in the side of the patch is presented. The proposed antenna provides two separated impedance bandwidth of 970MHz and 890 MHz [14]. The micro strip patch antenna has been compared for wireless communication applications by using different feeding techniques in the antenna. Out of various feeding systems, co – axial probe feed micro strip patch antenna provides a bandwidth of around 20% [15]. A rectangular micro strip patch antenna was designed at a frequency of 2.34GHz. The total bandwidth and gain were obtained as 67MHz and 3.92dB respectively [16]. The various techniques such as modified shape patch, multi resonators technique, multi layered technique and stacked multilayered technique were used for enhancing the bandwidth of micro strip patch antenna. Out of all techniques, multi-layered and stacked multi-layered techniques yield maximum bandwidth [17]. The micro strip patch antenna has been reviewed for its types, merits, demerits and its application [18]. An inset feed rectangular micro strip patch antenna has been designed at a frequency of 10GHz and derived the relation between resonant frequency on the notch gap and feed line geometry. They found that narrower notch gave better impedance matching for micro strip patch antenna [19]. A rectangular micro strip patch antenna with EBG substrate has been designed at an operating frequency of 10MHz and compared with the conventional antenna. After comparison, the EBG based micro strip patch antenna gave better performance than the conventional antenna [20]. Micro strip patch antenna with four slits at each corner was designed at an

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Vol. 6, Issue 10, October 2017

operating frequency of a 2.18GHz for WLAN and Bluetooth technologies [21]. Four element Yagi-Uda patch antennas had designed at the frequencies of 1.5GHz and 1.62GHz. The main lobe magnitude of the antenna covered the elevation angle from  $20^{\circ}$  to  $70^{\circ}$  with a peak gain of 8.4dBi at 1.5GHz and 11.7dBi at 1.6GHz [22]. A twin L-probe coupled patch antenna has been designed based on the feeding of two L-probes with proper separation. The gain 10dBi had achieved across the wide operating band of 25% ( $SWR \leq 1.5$ ) [23]. An overview of band frequency patch antenna has been carried out with special emphasis on the configurations. They also focused on the geometry of the radiators [24]. The FSS screen based patch antenna has been designed with I slots at a frequency of 9.1GHz. Moreover gain improvement of about 2dB was achieved [25]. The authors had designed the two antennas such as rectangular micro strip patch antenna and slit slotted rectangular micro strip patch antenna at a frequency of 1800MHz for GSM communication. They had discussed the return loss, electric field distribution and radiation patterns. Finally they had achieved the return loss of antenna in slit – slot patch was decreased about 92.52% and antenna directivity was also increased a bit and total efficiency of slit – slot RMPA was increased about 12.48%. Finally they said that the slit slotted rectangular micro strip patch antenna was better than the rectangular micro strip patch antenna [26]. A compact multiband planar octagonal shaper micro strip patch antenna has been presented. They investigated that this antenna provides sufficient isolation between the two operating bands and an area reduction of 29% with respect to a circular patch antenna in the same band [27]. Micro strip patch antenna has been designed and analysed at the different resonant frequencies between the 1GHz to 10GHz. They had obtained the better antenna parameters such as directivity was 5.4dBi, directive gain was 4.98dBi and HPBW H- plane was  $99.6123^{\circ}$  [28]. A micro strip patch antenna over an electromagnetic band gap surface was investigated. It was found that size of EBG substrate based micro strip patch antenna has been reduced when compared to the normal micro strip patch antenna. They said that the reduction of size antenna could be useful for antenna miniaturization [29]. Rectangular micro strip patch antenna was designed at a frequency of 2.4GHz and simulated for various characteristics like return loss, gain and radiation pattern characteristics [30]. A wideband slotted circularly polarized patch antenna was presented for 5GHz to 6GHz WLAN applications. The square patch on duroid 5880 substrate was used for wideband slotted circularly polarized patch antenna. This wideband antenna provides a return loss band width of 11% and an axial ratio bandwidth of 8% with a single feed [31]. Single layer monopole hexagonal micro strip patch antenna has been carried out using IE3D. The patch reduction as obtained by cutting three unequal slots, which are the combinations of one circle and two irregular rectangular slots from the conventional micro strip patch antenna. It was shown that the proposed antenna has a gain of 3.36dB at 9.61GHz and -0.43dBi at 13.57GHz and beam width  $162.8^{\circ}$  at 9.61GHz and  $53.45^{\circ}$  at 13.57GHz [32]. Three shapes of antennas such as U, E and H are developed from a rectangular of width (W) =32mm and length (L)=24mm. The three shapes of antennas were simulated and analysed for bandwidth. The simulation results showed that the bandwidth of conventional rectangular micro strip patch antenna can be enhanced from 4.81% (100MHz) to 28.71% (610MHz), 28.89% (630MHz) and 9.13% (110MHz) respectively using U, E and H- patches over the substrate. Out of three shapes of patch antennas, the E- shaped patch antenna has the highest bandwidth followed by U-shaped patch and H- shaped patch antenna [33]. The folded patch antennas were investigated for strain measurement resolution, range and crack sensing performance of a wireless battery free antenna sensor. From the test results it was shown that the antenna sensor can measure strain as small as  $20\mu\epsilon$  and as high as  $10,000\mu\epsilon$  [34]. A novel reconfigurable micro strip patch antenna with frequency and polarization diversity [35] was proposed. A U- slot is incorporated into a square patch and PIN diode was used to switch the slot on and off which realizes the frequency diversity characteristics. Moreover the polarization diversity among LP, RHCP and LHCP are also obtained by switching three PIN diodes on the slot and the trucking corner of a square patch on and off [35]. Patch antenna was designed based on the concept of metamaterial. By using this antenna, the return loss of 38.4dB was achieved at the frequency of 2.2GHz [36]. Three types of methods were used to increase the band width of micro strip patch antenna. First method was a 60GHz antenna built up on a silicon membrane with an upper BCB (Benzo Cyclobuten dielectric) thin film deposited and excited with a U or T – shape micro strip feeder via a dielectric gap. Second method was the stacked micro strip patch antenna. Third method was an open circulated stub concentrated in shunt with the micro strip line. Out of the three methods gap couple U – micro strip feeder method was the best for enhancing the bandwidth [37]. An UWB micro strip patch antenna has been proposed at the frequencies of 3.7GHz, 7.2GHz and 8.97GHz respectively with impedance bandwidth of 4.875GHz. The antenna exhibits the return loss well below -10dB for the frequency range 3.1GHz to 10GHz [38].

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Vol. 6, Issue 10, October 2017

## II. ANTENNA DESIGN

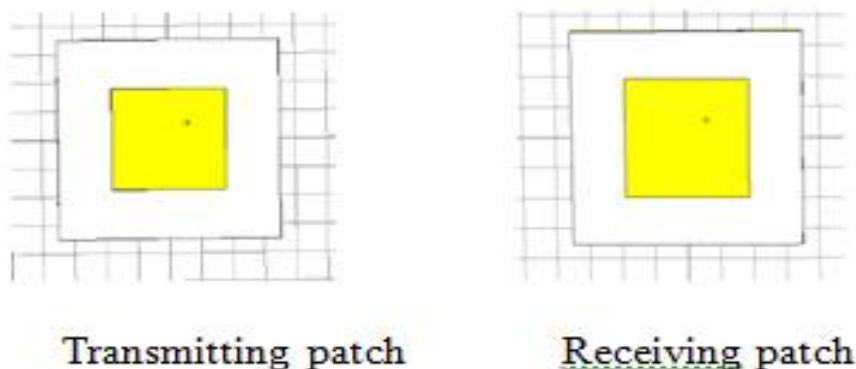


Fig.1.Individual transmitting and receiving patch antennas

Dimensions: Length: 45.66mm  
Width : 45.66mm  
Substrate : RT duroid 5880(1.575mm thick)

For communicating with Satellites, the circularly polarized antenna is required. Square type of micro strip patch can provide the circular polarization characteristics by setting the single feed point along the diagonal of the antenna. Feeding the element along the diagonal starting at the left corner towards the upper right corner yields ideally LHCP at broad side. RHCP can be achieved by feeding along the opposite diagonal which starts at the lower right corner and proceeds towards the upper left corner.

### A: Design equations of a rectangular micro strip patch antenna.

To design a square type of micro strip patch antenna first the rectangular micro strip patch antenna is to be designed and then relate their ratio of lengths which makes the patch nearly square. The rectangular micro strip patch antenna is to be designed based on the following equations.

1. For an efficient radiator, a practical width that leads to good radiation efficiencies.

$$W = \frac{c}{2f_r} \sqrt{\frac{2}{\epsilon_r + 1}}$$

Where c is the free space velocity of light

2. Determine the effective dielectric constant of the micro strip patch antenna.

$$\epsilon_{\text{reff}} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left(1 + 12 \frac{h}{w}\right)^{-1/2} > 1$$

3. Once W is found using equation (1), determine the extension of the  $\Delta L$  using following equation.

$$\Delta L = 0.412h \frac{\epsilon_{\text{reff}} + 0.3}{\epsilon_{\text{reff}} - 0.258} \frac{\left(\frac{W}{h} + 0.264\right)}{\left(\frac{W}{h} + 0.8\right)}$$

4. Effective length ( $L_{\text{eff}}$ ) can be calculated by using the formulae.

$$L_{\text{eff}} = \frac{c}{2f_r} \frac{1}{\sqrt{\epsilon_{\text{reff}}}}$$

5. The actual length of the patch can be determined by using the formulae.

$$L = L_{\text{eff}} - 2 \Delta L.$$

6. Find the quality factor by using the following equation.

$$\frac{\Delta f}{f_o} = \frac{VSWR - 1}{Q_t} \frac{1}{\sqrt{VSWR}}$$

7. Obtain the relative ratio of the two lengths by using the formulae.

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Vol. 6, Issue 10, October 2017

$$L = W (1 + 1/Q_t)$$

8. The resonant frequencies  $f_1$  and  $f_2$  of the bandwidth associated with the two lengths  $L$  and  $W$  of a rectangular micro strip are given by the equations.

$$f_1 = \frac{f_0}{\sqrt{1 + \frac{1}{Q_t}}}$$

$$f_2 = f_0 \sqrt{1 + \frac{1}{Q_t}}$$

### B: Specifications.

Based on the specifications, the length and width of an antenna are determined.

Dielectric constant of the RT/Duroid substrate ( $\epsilon_r$ ) = 2.2.

Height of the substrate ( $h$ ) = 1.575mm.

Resonant frequency ( $f_r$ ) = 2.595GHz.

Fractional bandwidth = 7.32%

VSWR = 2:1

### C: Steps to calculate the design parameters.

Step1: The width of the rectangular micro strip patch antenna is by the formulae.

$$\begin{aligned} W &= \frac{300}{5.19} \sqrt{\frac{2}{2.2+1}} \\ &= 57.80 \times 0.79 \\ &= 45.66 \text{mm} \end{aligned}$$

Step2: The effective dielectric constant of the micro strip patch antenna is given by

$$\begin{aligned} \epsilon_{\text{reff}} &= \frac{2.2+1}{2} + \frac{2.2-1}{2} \left( 1 + 12 \frac{1.575}{45.66} \right)^{-1/2} \frac{W}{h} > 1 \\ &= 2.1 \end{aligned}$$

Step3: Using the values of  $W$ ,  $\epsilon_{\text{reff}}$  and  $h$ , the incremental length  $\Delta L$  can be calculated by using the formulae.

$$\begin{aligned} \Delta L &= 0.412 \times 1.575 \text{mm} \frac{(2.1+0.3)}{(2.1-0.258)} \frac{(\frac{45.66}{1.575} + 0.264)}{(\frac{45.66}{1.575} + 0.8)} \\ &= 0.83 \text{mm} \end{aligned}$$

Step4: Effective length can be calculated by using the following formulae

$$\begin{aligned} L_{\text{eff}} &= \frac{300}{5.19 \sqrt{2.1}} \\ &= \frac{300}{5.19 \times 1.44} \\ &= 40.16 \text{mm} \end{aligned}$$

Step 5: The actual length of the patch can be calculated by using formulae as

$$\begin{aligned} L &= L_{\text{eff}} - 2 \Delta L \\ &= 40.16 - 2(0.83) \\ &= 38.5 \text{mm} \end{aligned}$$

Step 6: The quality factor can be calculated by using the formulae

$$\begin{aligned} \frac{\Delta f}{f_0} &= \frac{VSWR-1}{VSWR} \frac{1}{Q_t} \\ \frac{0.19}{2.595} &= \frac{2-1}{Q_t \sqrt{2}} \\ Q_t &= 11.11 \end{aligned}$$

Step 7: The relative ratio of the two lengths by using the formulae.

$$\begin{aligned} L &= W (1 + 1/Q_t) \\ L &= W (1 + 1/11.11) \\ L &\approx W \end{aligned}$$

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Vol. 6, Issue 10, October 2017

Step8: The resonant frequencies  $f_1$  and  $f_2$  of the bandwidth associated with the two lengths L and W of a rectangular micro strip are given by the equations.

$$f_1 = \frac{f_0}{\sqrt{1 + \frac{1}{Q_t}}} = \frac{02,595GHz}{\sqrt{1 + \frac{1}{11.11}}} = 2.5GHz$$

$$f_2 = f_0 \sqrt{1 + \frac{1}{Q_t}} = 2.595GHz \sqrt{1 + \frac{1}{11.11}} = 2.69GHz$$

### III. SIMULATION RESULTS

According to the simulated results, it has been observed that from Table1, the antenna design provides  $VSWR \leq 2.1$  at the transmitting frequencies and  $VSWR \leq 1.5$  at the receiving frequencies. Fig.2 and Fig.3 shows the plot of VSWR versus frequency for transmitting and receiving patch antennas. From Table1 it is also observed that the lower values of VSWR are obtained at the receiving frequencies when compared to the transmitting frequencies. Fig.4&Fig.5 shows the plot of maximum gains versus frequencies for transmitting and receiving patch antennas. Almost equal gain of 7.33dB was obtained at the transmitting and gain  $\leq 7$ dB was obtained at the receiving frequencies respectively. From Table II it has been observed that high gain values were obtained at the transmitting when compared to receiving. Fig.6&Fig.7 shows radiation patterns of transmitting and receiving patch antennas. From Table III to Table VI, it has been observed that equal bandwidth and side lobe levels are obtained at the transmitting and receiving frequencies..Fig.8 & Fig.9 shows the plot of axial ratio for transmitting and receiving patch antennas. From Table VII, it has been observed that the antenna provides the  $AR \leq 7$  at transmitting as well as receiving frequencies.

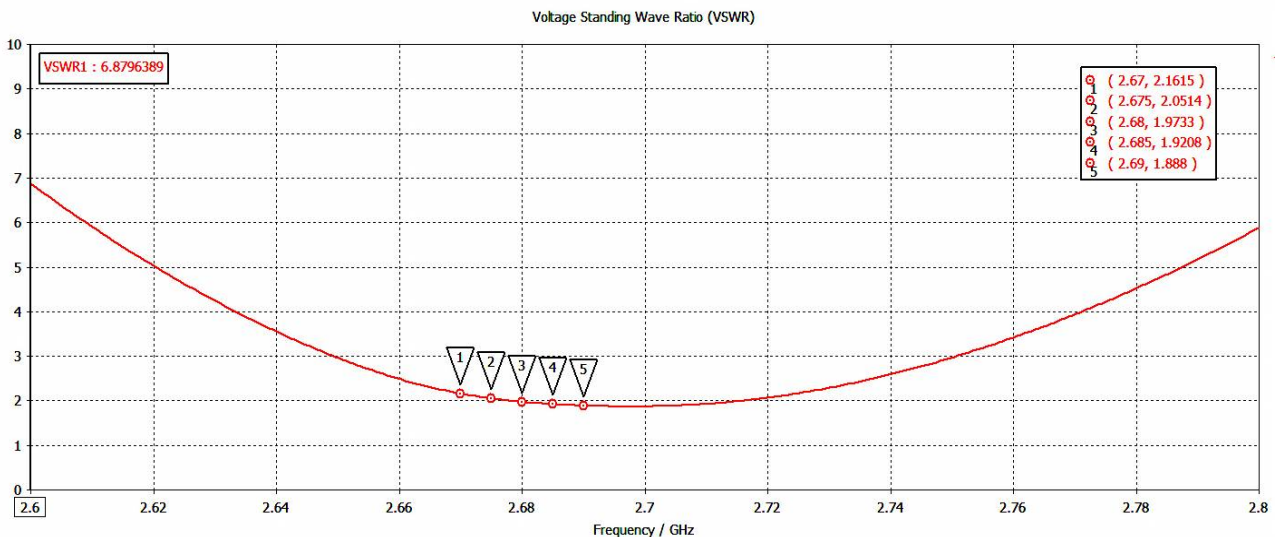


Fig.2.VSWR of Transmitting patch antenna

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Vol. 6, Issue 10, October 2017

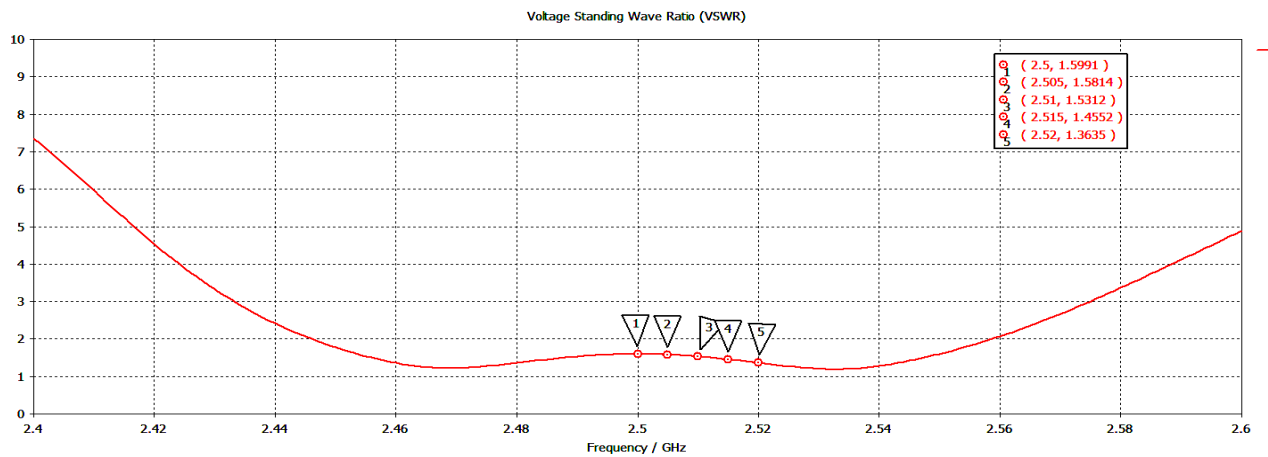


Fig.3.VSWR of Receiving patch antenna

TABLE I  
VSWR at various transmitting and receiving frequencies

Frequency(GHz)	VSWR
2.67	2.1615
2.675	2.0514
2.68	1.9733
2.685	1.9208
2.69	1.888
2.5	1.5991
2.505	1.5814
2.51	1.5312
2.515	1.4552
2.52	1.3635

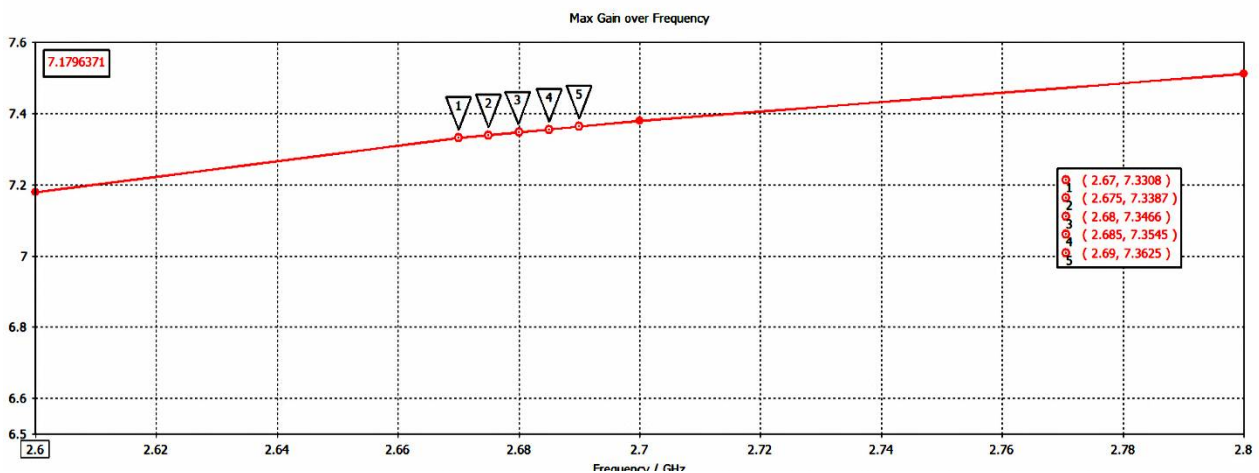


Fig.4.Maximu Gain of Transmitting patch antenna

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Vol. 6, Issue 10, October 2017

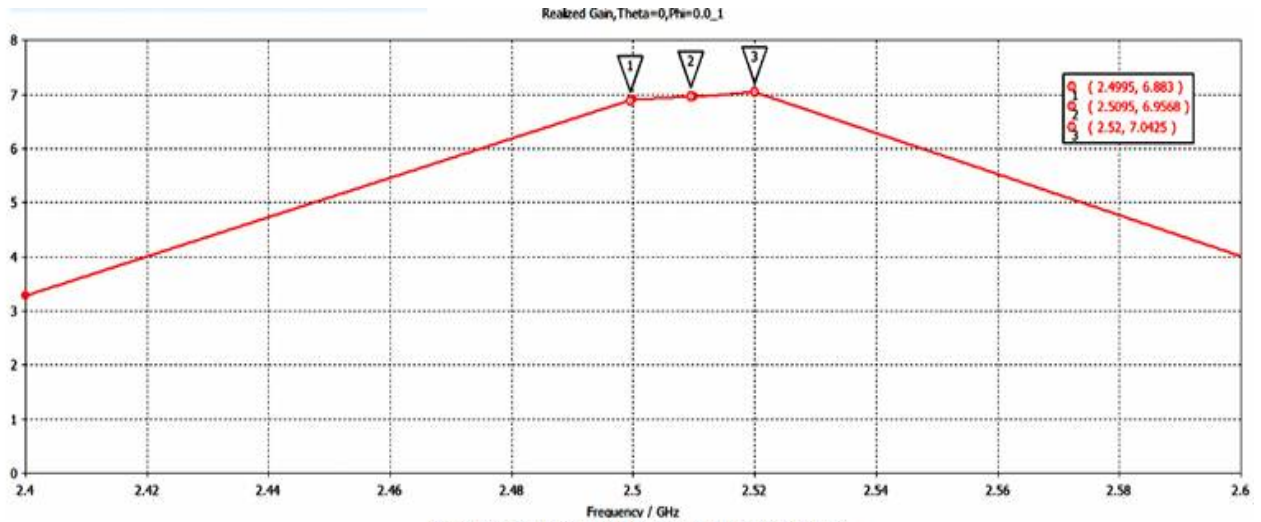
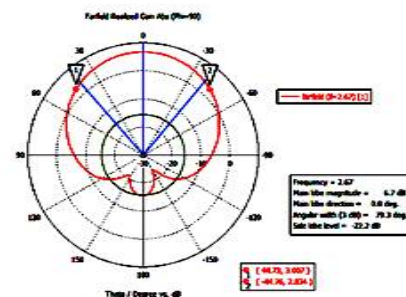
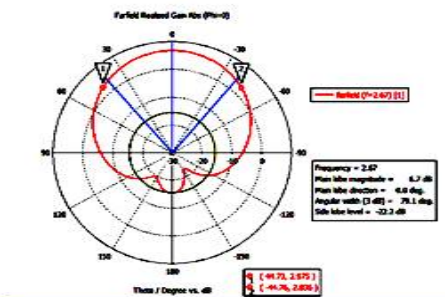


Fig.5 Maximu Gain of Receiving patch antenna

Fig.5.Maximu Gain of Receiving patch antenna

TABLE II  
Maximum gains at various transmitting and receiving frequencies

Frequency(GHz)	Gain(dB)
2.67	7.3308
2.675	7.3387
2.68	7.3466
2.685	7.3545
2.69	7.3625
2.4995	6.883
2.5095	6.9568
2.52	7.0425





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Vol. 6, Issue 10, October 2017

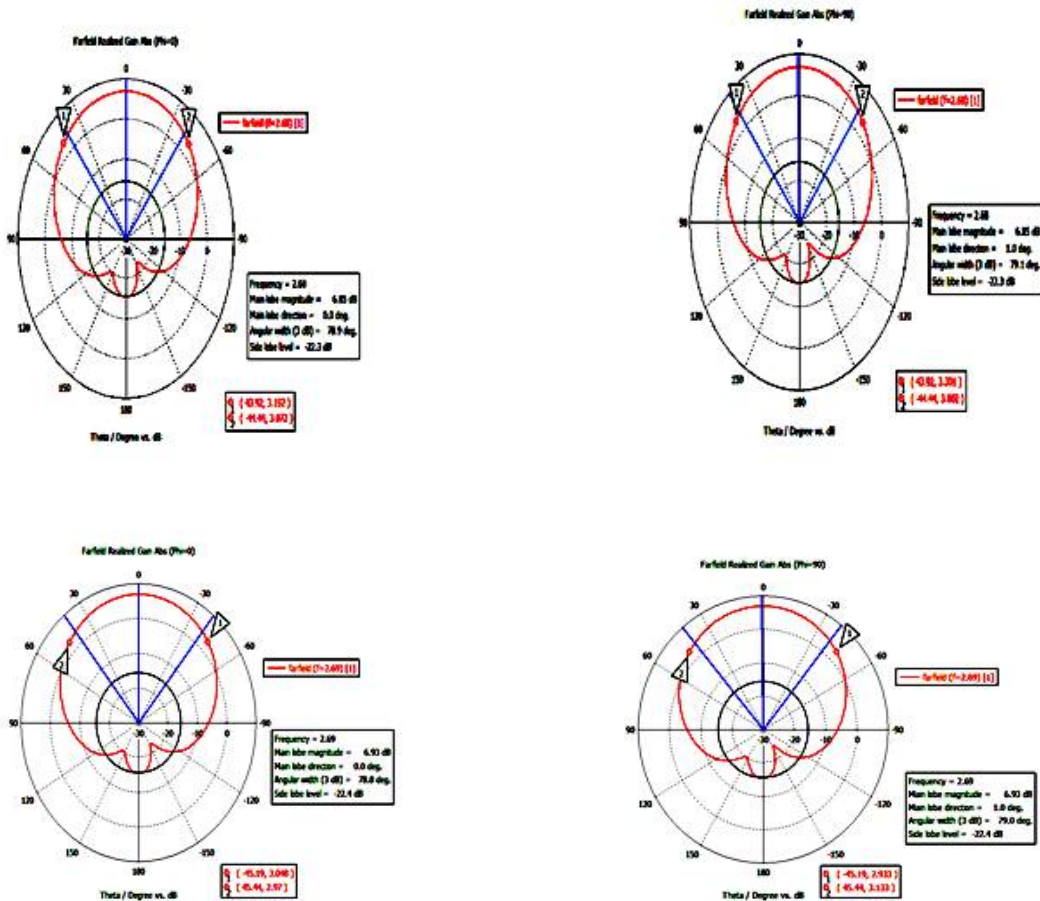
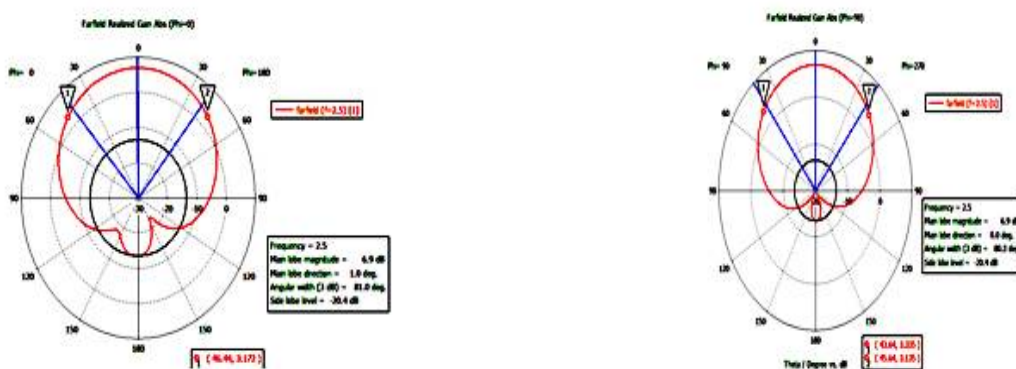


Fig.6.Radiation patterns of Transmitting patch antenna



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Vol. 6, Issue 10, October 2017

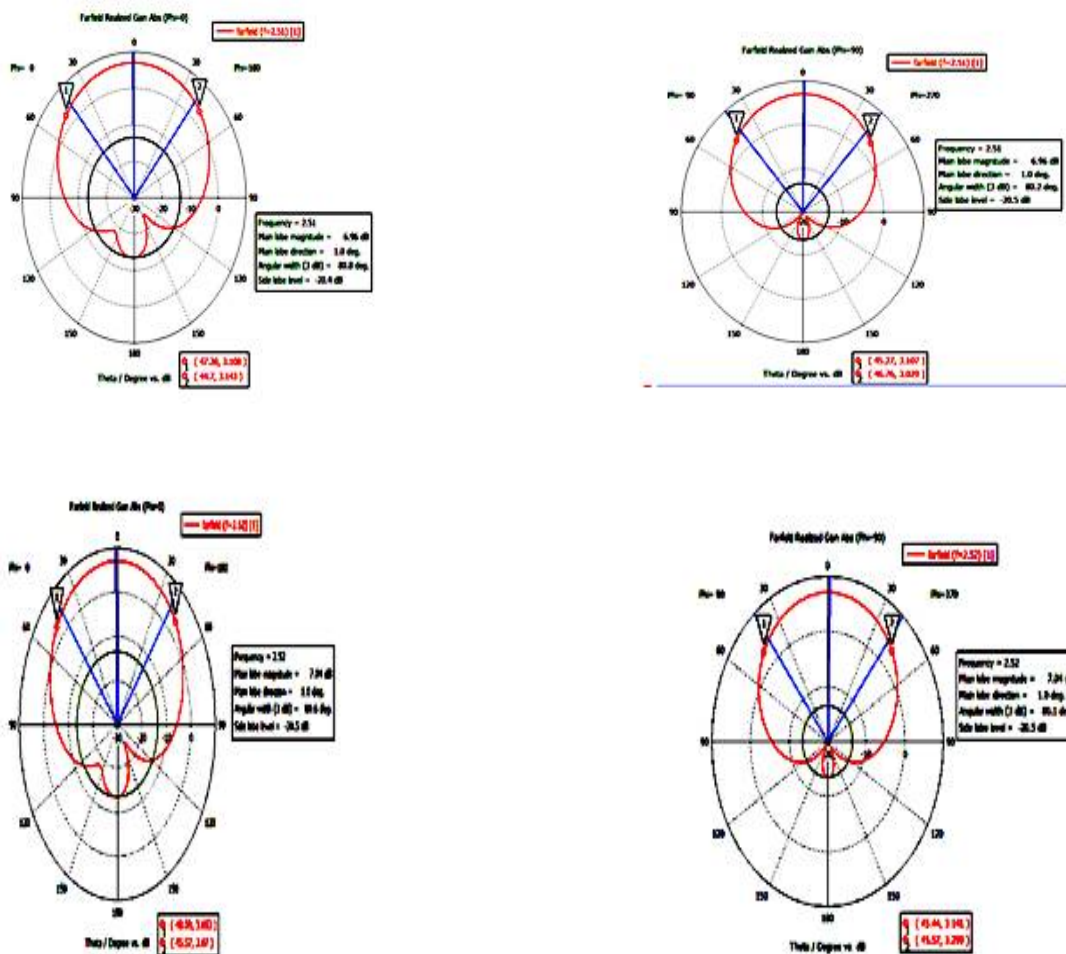


Fig.7.Radiation patterns of Receiving patch antenna

TABLE III

Main lobe magnitude, Main lobe direction, Angular width and Side lobe level at various transmitting frequencies for  $\theta=0^\circ$

Frequency (GHz)	Main lobe Magnitude(dB)	Main lobe direction(degrees)	Angular width(degrees)	Side lobe level(dB)
2.67	6.7	0.0	79.16	-22.2
2.68	6.85	0.0	78.9	-22.3
2.69	6.93	0.0	78.8	-22.4

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Vol. 6, Issue 10, October 2017

TABLE IV

Main lobe magnitude, Main lobe direction, Angular width and Side lobe level at various transmitting frequencies for  $\theta=90^\circ$

Frequency (GHz)	Main lobe Magnitude(dB)	Main lobe direction(degrees)	Angular width(degrees)	Side lobe level(dB)
2.67	6.7	0.0	79.3	-22.2
2.68	6.85	1.0	79.1	-22.3
2.69	6.93	1.0	79.0	-22.4

TABLE V

Main lobe magnitude, Main lobe direction, Angular width and Side lobe level at various receiving frequencies for  $\theta=0^\circ$

Frequency (GHz)	Main lobe Magnitude(dB)	Main lobe direction(degrees)	Angular width(degrees)	Side lobe level(dB)
2.5	6.9	1.0	81.0	-20.4
2.51	6.96	1.0	80.8	-20.4
2.52	7.04	1.0	80.6	-20.5

TABLE VI

Main lobe magnitude, Main lobe direction, Angular width and Side lobe level at various receiving frequencies for  $\theta=90^\circ$

Frequency(GHz)	Main lobe Magnitude(dB)	Main lobe direction(degrees)	Angular width(degrees)	Side lobe level(dB)
2.5	6.9	0.0	80.3	-20.4
2.51	6.96	1.0	80.2	-20.5
2.52	7.04	1.0	80.1	-20.5

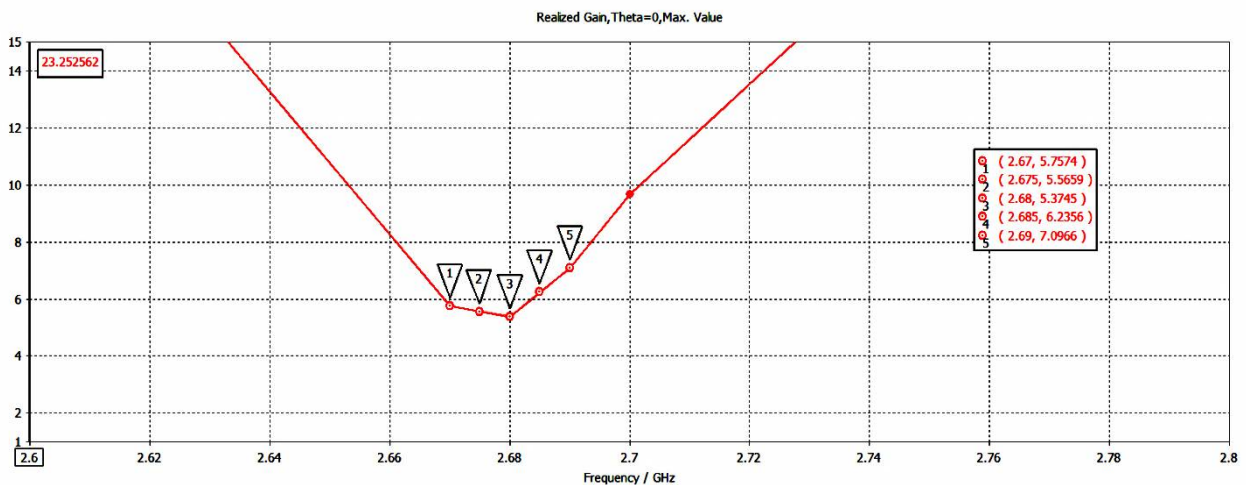


Fig.8. Axial ratio of Transmitting patch antenna Fig.8. Axial ratio of Transmitting patch antenna

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Vol. 6, Issue 10, October 2017

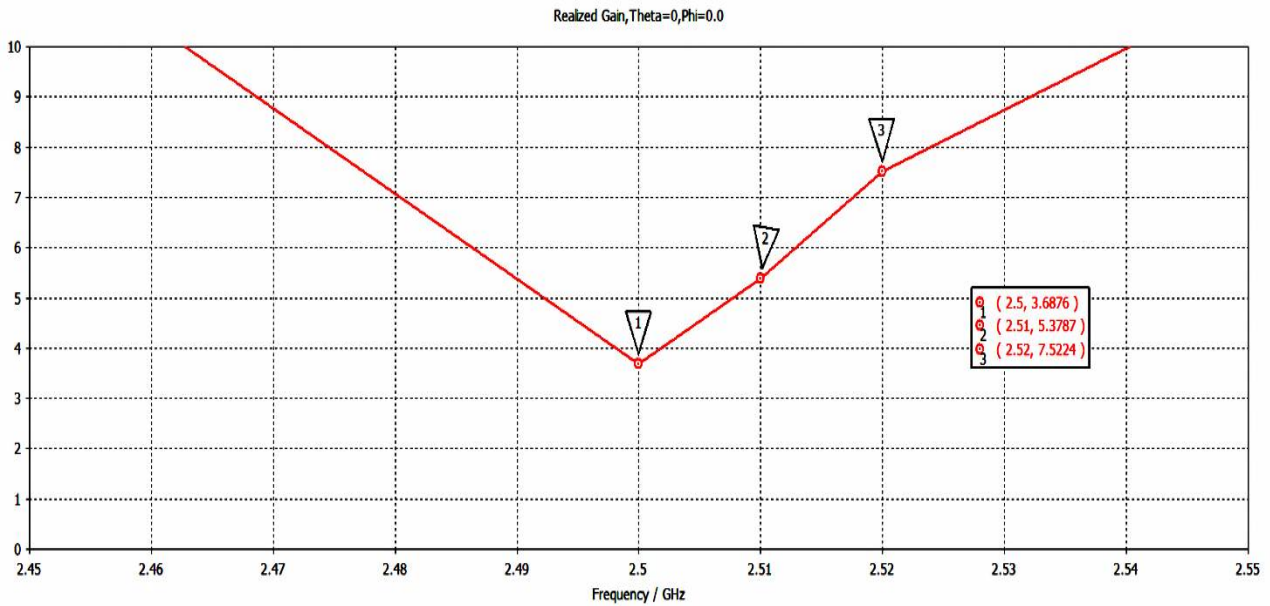


Fig.9. Axial ratio of Receiving patch antenna

TABLE VII

Axial ratio at various transmitting and receiving frequencies

Frequency(GHz)	Axial ratio
2.67	5.7574
2.675	5.5659
2.68	5.3745
2.685	6.2356
2.69	7.0966
2.5	3.6876
2.51	5.3787
2.52	7.5224

## IV. CONCLUSION AND FUTURE WORK

It is concluded that the square micro strip patch antennas have been designed at a centre frequency of 2.595GHz. The designed antennas such as transmitting and receiving were simulated and analysed for various characteristics such as VSWR, gain, axial ratio and radiation patterns at the transmitting and receiving frequencies. From the simulated results, it has been analysed that the better values were obtained for  $VSWR \leq 2.1$ , maximum gain of 7.33dB and  $AR \leq 7.5$  at the transmitting and receiving frequencies. Moreover the better radiation characteristics were obtained at the transmitting as well as receiving frequencies. Our future work will be integrated the transmitting and receiving patch antennas as single antenna for working as both transmitting and receiving purpose.

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Vol. 6, Issue 10, October 2017

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Vol. 6, Issue 10, October 2017

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