

A Meander Antenna with Reconfigurable Polarization for Wireless Communication

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Abstract: Microstrip antennas are most widely used for wireless communication due to its properties like low cost, low profile, smaller in dimension and easy to fabricate and conformity. There are various shapes of antenna like rectangle, square, circle, triangle, dipole, meander etc. In this paper, comparison of rectangular, square, circular and meander patch microstrip antenna are done using HFSS software and meander is found to be the most effective. So meander antenna is used to achieve polarization reconfigurability at operating frequency of 2.4GHz. This polarization reconfigurable meander antenna works on the principle of reconfigurability where same antenna can be used for multiple applications in wireless communication. The meander antenna is fabricated on FR-4 substrate with $\epsilon_r=4.4$ and thickness of 1.6mm. The simulation of all the antennas are carried out using HFSS software and measurement is done using Rohde & Schwarz ZVH8 Vector Network Analyzer.

Keywords: Microstrip antenna; rectangular; square; circular; meander; polarization reconfigurable; HFSS.

1. Introduction

An antenna is defined as a means for radiating or receiving radio waves. Nowadays, reconfigurable antennas are most widely used for wireless applications. Reconfigurable antennas adopt itself as per the requirement of the application and adjust parameters. Different shapes of microstrip antenna are being used to achieve reconfigurability. The use of multiple antennas for achieving different polarization increases the cost and complexity. Therefore, instead of using multiple antennas, reconfigurable antennas can be used to reduce cost and complexity. Reconfigurable antennas makes efficient use of limited area by taking advantage of combined multiple functions in one single antenna which results in significant reduction in the area occupied by multiple antenna elements with enhanced functionality and performances. The different reconfigurable technologies are frequency, polarization, pattern, hybrid etc.

A compact dual-band rectangular microstrip antenna is realized by two different single-slotted single-band rectangular microstrip antennas with slotted ground plane are discussed in [1]. In [2], the design of square patch microstrip antenna with enhanced bandwidth and directive gain has been proposed. This antenna can be used for wireless local area network application. A circular disc-shaped antenna with beam steering radiation pattern is presented in [3].

Empirical relation for designing the meander line antenna is proposed in [4]. The meander antenna achieves miniaturization in size. It makes an antenna shorter in size. It is made from continuously bend wire. Benefits include small, low profile antenna and simple structure. In [5], a meander line monopole patch antenna with microstrip line feed has been designed for wireless LTE application.

In [6], polarization reconfigurable wideband E-shaped patch antenna for wireless communication is proposed which is capable of switching its polarization from right hand circular

polarization (RHCP) to left hand circular polarization (LHCP) and vice versa. Two RF switches are used as switching elements and are placed at appropriate locations in the slot. A microstrip patch antenna with switchable slots is proposed in [7] to achieve circular polarization diversity. Two orthogonal slots are incorporated and two pin diodes are used to achieve RHCP or LHCP by turning the diodes on and off.

In [8], an antenna with ability to reconfigure the polarization between linear polarization, RHCP and LHCP through the modification of feeding network is proposed. Eight switches which are currently represented by copper strips for proof of concept are used to achieve reconfigurability. The patch antenna with polarization reconfigurability feature is proposed in [9]. Four switches which are represented by copper strips are used to obtain reconfigurability feature which are appropriately located at the specific position across the slit.

In this paper, a comparison of rectangular, square, circular and meander patch microstrip antenna is done. The behaviour of patch antennas with respect to return loss, VSWR and radiation pattern is studied and meander antenna is found to be the most effective, so it is used to achieve polarization reconfigurability. Thus, the polarization reconfigurable meander antenna is simulated and fabricated at 2.4GHz frequency and the measurement is done using Rohde & Schwarz ZVH8 Vector Network Analyzer.

The organization of paper is as follows. In section II, the antenna geometries are described. Design of antennas is explained in section III. In section IV, the simulated results of the designed antennas and the performances are discussed. Sections V explains the measured results of polarization reconfigurable meander antenna. Finally, the paper is concluded in section VI.

2. Antenna Geometry

2.1 Comparison of rectangular, square, circular and meander microstrip antenna

The proposed antennas are simulated on FR-4 substrate with thickness (h) of 1.6mm and relative permittivity $\epsilon_r=4.4$. The antennas are fed by a 50 Ω coaxial probe. Fig. 1 shows the geometry of the antennas.

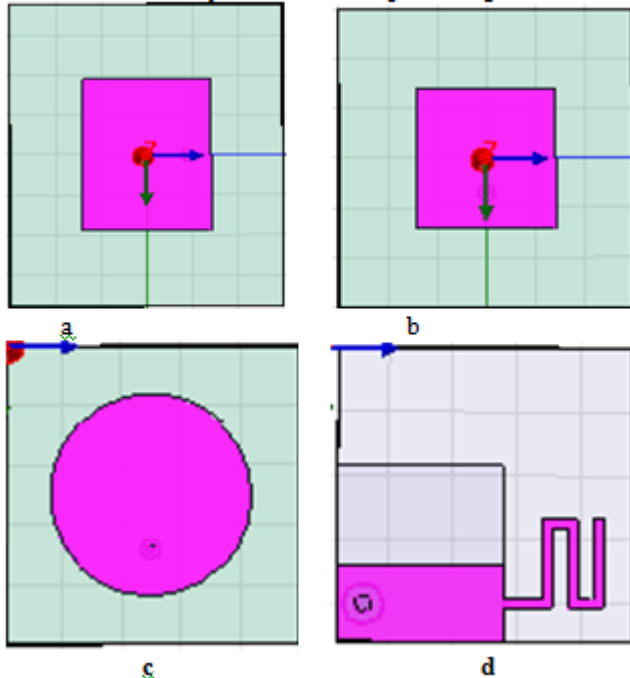


Figure 1: Geometry of patch antennas (a) Rectangular patch antenna, (b) Square patch antenna, (c) Circle patch antenna, (d) Meander patch antenna

2.2 Polarization Reconfigurable Meander antenna

The proposed antenna is simulated on FR-4 substrate with thickness (h) of 1.6mm and relative permittivity $\epsilon_r=4.4$. The antenna is fed by a 50 Ω coaxial probe. Fig. 2 shows the geometry of the antenna. The reconfigurability is achieved by alternatively exciting the two meander antenna depending on the switches (currently using copper strips as a proof of concept). When horizontal meander antenna is excited it is stated as state1 and when vertical meander antenna is excited it is stated as state 2.

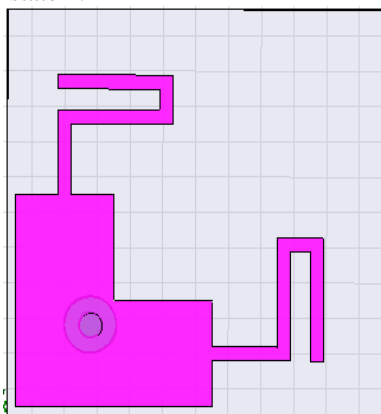


Figure 2: Geometry of Polarization Reconfigurable Meander antenna

3. Design of Antennas

3.1 Design equation of Rectangular and Square patch antenna

Calculation of width (W):

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

Where, c is velocity of light; fr is resonant frequency; ϵ_r is relative permittivity.

Calculation of length (L):

1) Effective dielectric constant (ϵ_{eff}):

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[1 + 12 \frac{h}{W} \right]^{-1/2}$$

Where, h is the height.

2) Effective length (L_{eff}):

$$L_{eff} = \frac{c}{2fr\sqrt{\epsilon_{eff}}}$$

3) Length extension (ΔL):

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

4) Calculation of actual length of patch (L):

$$L = L_{eff} + 2\Delta L$$

For Rectangular patch antenna, W=38.03mm and L=29.4mm.

For Square patch antenna, L=W=29.4mm.

3.2 Design equation for Circular patch antenna

The actual radius (a) of the patch is given as:

$$a = \frac{F}{\left\{ 1 + \frac{2h}{\pi\epsilon_r F} \left[\ln \left(\frac{\pi F}{2h} \right) + 1.7726 \right] \right\}^{1/2}}$$

Where,

$$F = \frac{8.791 \times 10^9}{fr\sqrt{\epsilon_r}}$$

Where, h is the height i.e. 1.6mm; ϵ_r is dielectric constant; fr is resonant frequency. After substituting the values we get, a=17mm.

3.3 Design equation of Meander patch antenna

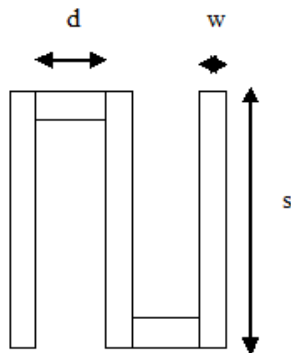


Figure 3: Dimensions of Meander antenna

From [9], dimensions of the meander antenna are calculated from the equations given below.

$$s = 0.102\lambda_g$$

$$d = 0.046\lambda_g$$

$$w = 0.013\lambda_g$$

Where, λ_g is the guided wavelength. After calculation we get, $s=7\text{mm}$; $d=1.2\text{mm}$ and $w=0.8\text{mm}$.

4. Simulated Results

The simulation has been performed using Ansoft HFSS (High Frequency Structure Simulator) software.

4.1 Rectangular, Square, Circular and Meander Microstrip antenna

1. Return Loss

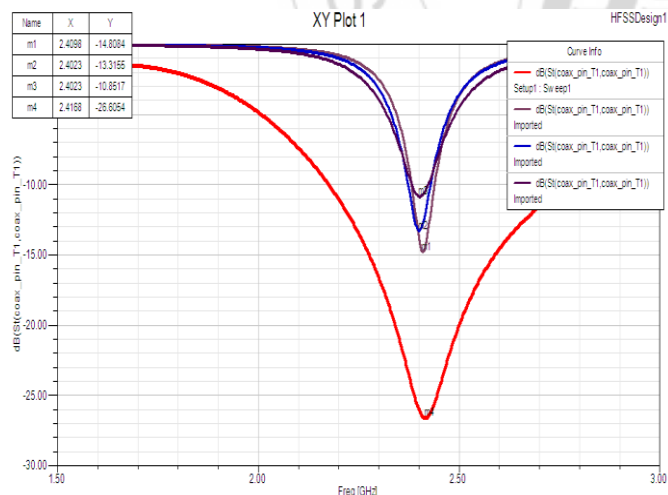


Figure 4: Comparison of return loss

Fig. 4 shows the comparison of return loss. It can be seen that the return losses obtained at frequency 2.4GHz are less than -10dB. The circular antenna exhibits return loss of -10.85dB, rectangular antenna exhibits return loss of -13.31dB, square antenna exhibits return loss of -14.80dB and meander antenna exhibits return loss of -26.60dB. Here, meander antenna has the least return loss and transmits maximum power as compared to others.

2. VSWR

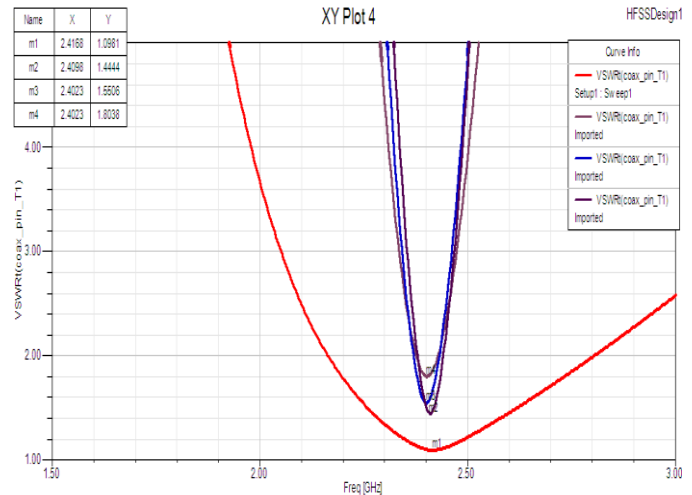
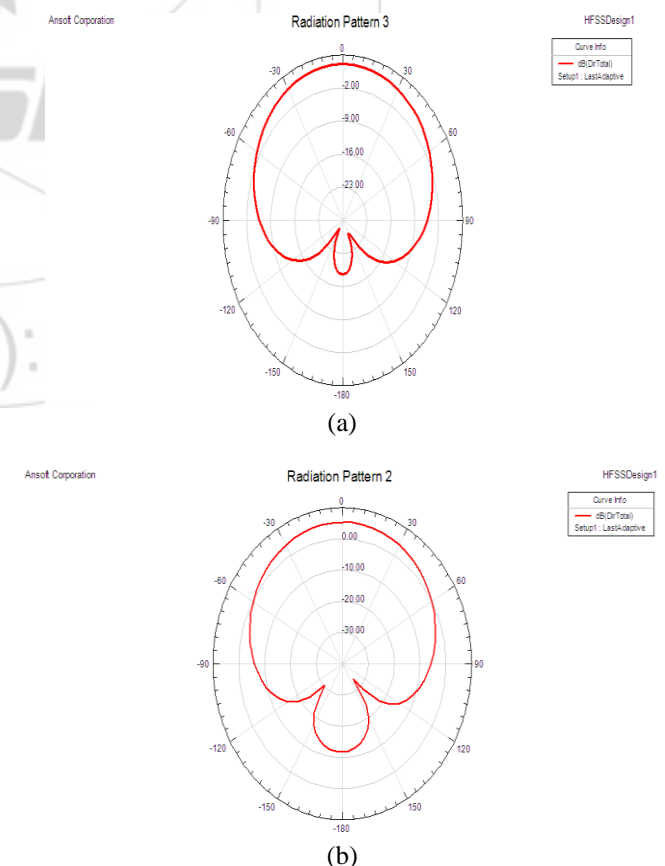


Figure 5: Comparison of VSWR v/s frequency

Fig. 5 shows the graph of VSWR v/s frequency. It can be seen that the VSWR obtained for all the four graphs is less than 2. The meander antenna obtained VSWR 1.09 and bandwidth obtained is 640MHz which is maximum than others.

3. Radiation Pattern

Fig. 6 shows the graph of radiation pattern. The radiation pattern obtained is dipole like radiation characteristics. Meander antenna achieves better dipole like radiation characteristics as compared to others.



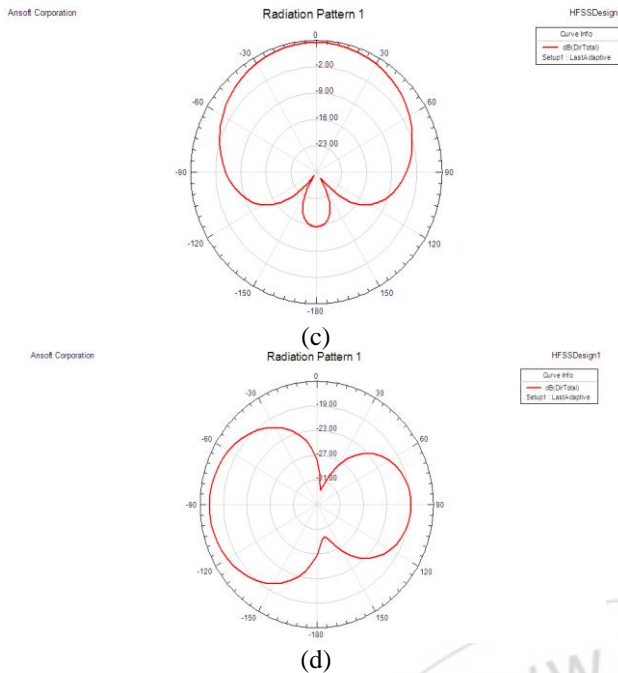


Figure 6: Radiation Pattern (a) Circular patch antenna, (b) Rectangular patch antenna, (c) Square patch antenna, (d) Meander patch antenna

Table 1: Comparison of Return Loss and VSWR

Shape	Return Loss (dB)	VSWR
Circular	-10.85	1.8
Rectangular	-13.31	1.5
Square	-14.80	1.4
Meander	-26.60	1.09

From the simulated results obtained above we can say that, meander antenna works more effectively as compared with others and is also more compact. Thus, meander antenna is used to achieve polarization reconfigurability.

4.2 Polarization Reconfigurable Meander antenna

1. Return Loss

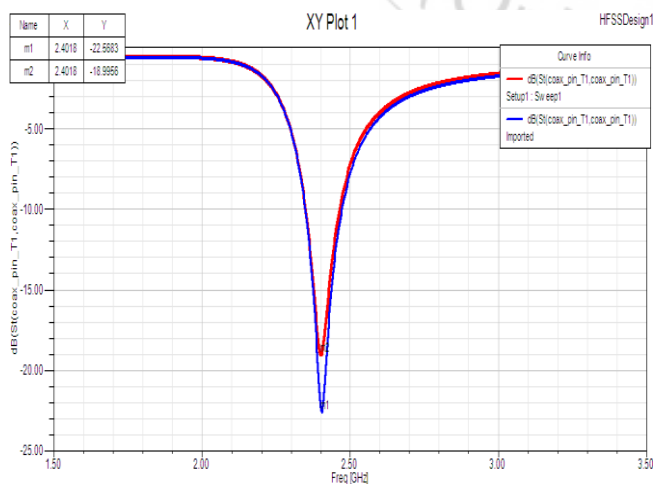


Figure 7: Comparison of return loss

Fig. 7 shows the return loss of state1 and state 2 of meander antenna. Thus, the return losses obtained at frequency 2.4GHz are lower than -10dB. State 1 exhibits return loss of -

22.56dB and state 2 exhibits return loss of -18.99dB.

2. VSWR

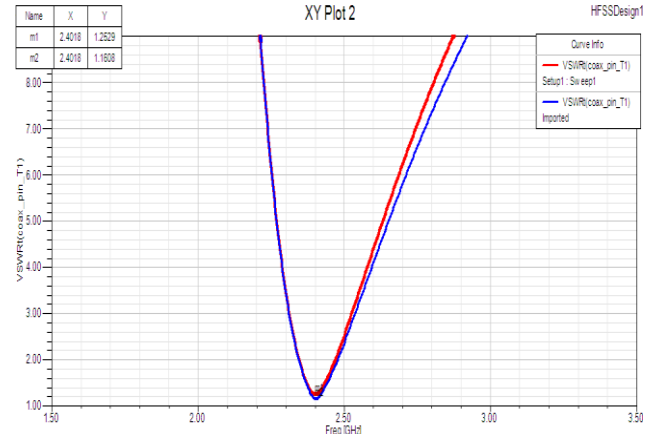


Figure 8: Graph of VSWR v/s frequency

Fig. 8 shows the graph of VSWR v/s frequency. The VSWR obtained for both the graphs is less than 2. State 1 obtained VSWR 1.16 and state 2 obtained VSWR 1.25.

3. Radiation Pattern

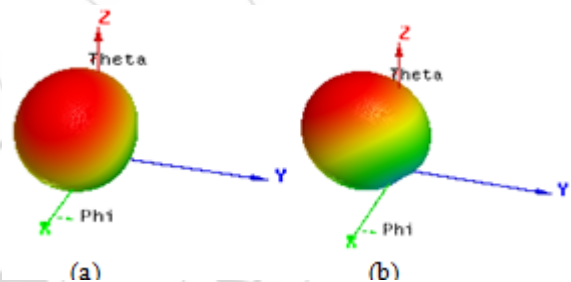


Figure 9: Radiation Pattern (a) State 1, (b) State 2

Fig. 9 shows the radiation pattern of state 1 and state 2. In state 1, horizontal meander antenna is excited and we get a radiation pattern in vertical direction. In state 2, vertical meander antenna is excited and we get a radiation pattern in horizontal direction.

In state 1, the polarization of the antenna lies along x-axis i.e. vertical direction, and in state 2, the polarization of the antenna lies along y-axis i.e. horizontal direction. Thus, looking from z-axis the polarization of the antenna can be reconfigurable between x and y axis.

5. Measured Results

The simulation design of polarization reconfigurable meander antenna is fabricated using FR-4 substrate. The radiating patch and ground both is of copper material. The prototype is shown in Fig. 10.

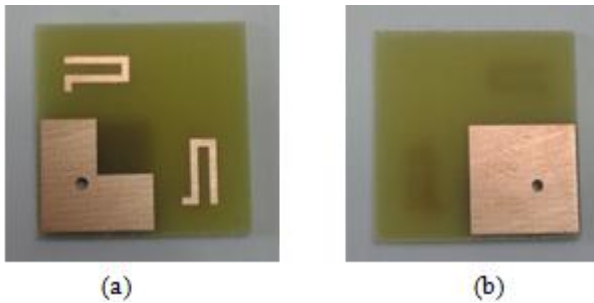
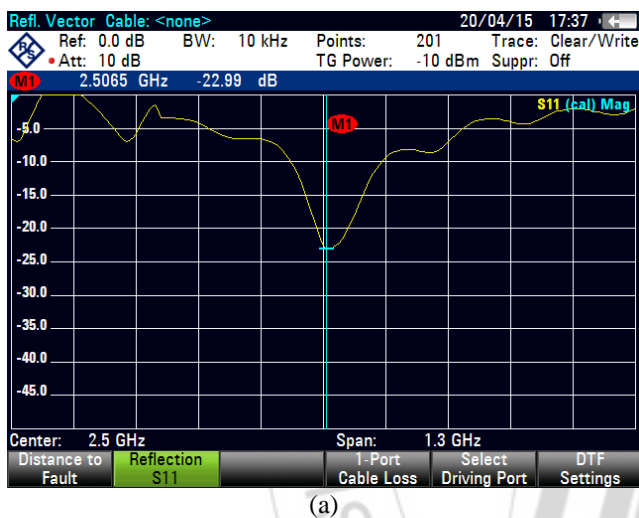
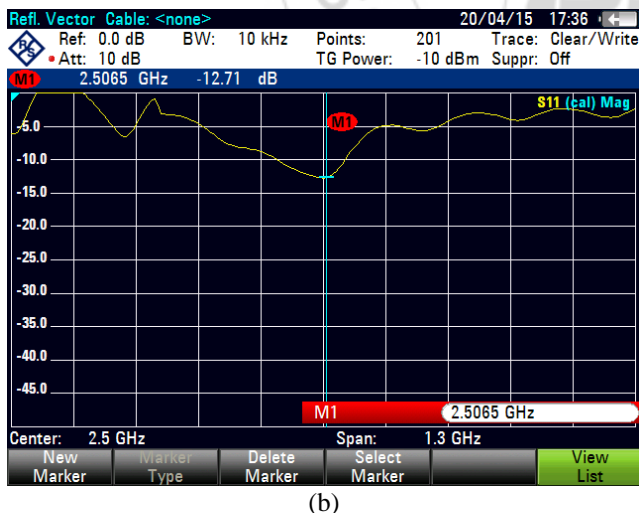


Figure 10: Photograph of fabricated antenna (a) Front View, (b) Back View

The fabricated antenna is measured using Rohde & Schwarz ZVH8 Vector Network Analyzer. The Vector Network Analyzer was calibrated before measuring the results. Fig. 11 and fig. 12 shows the measured results of Result Loss and VSWR.



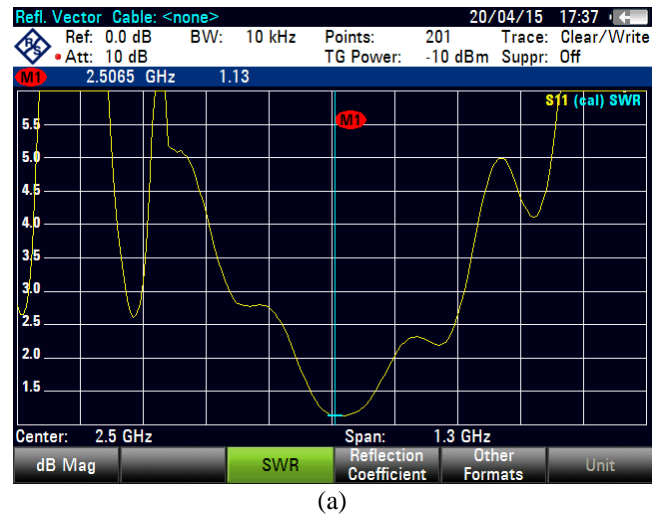
(a)



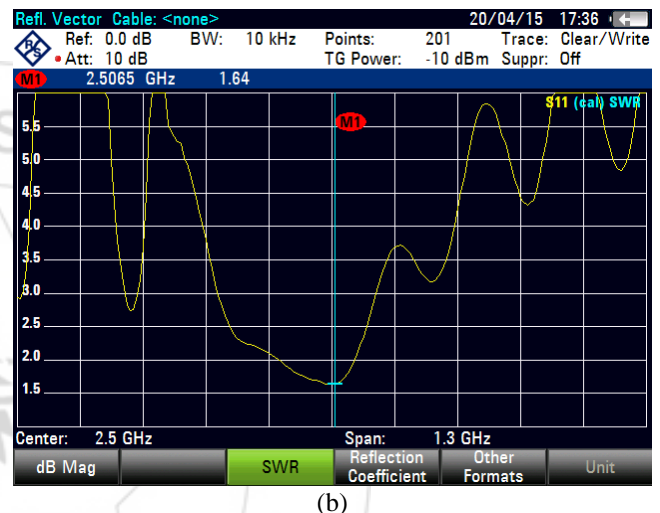
(b)

Figure 11: Measured Return Loss of fabricated antenna (a) State 1, (b) State 2

Fig. 11 shows the measured return loss results of the fabricated antenna. The return loss obtained for both the states are less than -10dB. The return loss obtained by state 1 is -22.99dB and by state 2 is -12.71dB at the frequency of 2.5GHz. There is a slight frequency shift as compared to the simulated results of return loss.



(a)



(b)

Figure 12: Measured VSWR of fabricated antenna (a) State 1, (b) State 2

Fig. 12 shows the measured VSWR results of the fabricated antenna. The VSWR obtained for both the states is less than 2. The VSWR obtained by state 1 is 1.13 and the VSWR obtained by state 2 is 1.64 at the frequency of 2.5GHz.

6. Conclusion

A rectangular, square, circular and meander patch microstrip antennas were simulated and meander antenna is found to be most effective through the comparison of return loss, VSWR and radiation pattern. From the measured results of the fabricated antenna, state 1 and state 2 both operate at a frequency of 2.5GHz and obtained return loss of -22.99dB and -12.74dB respectively. The VSWR obtained by state 1 and state 2 is 1.13 and 1.64 respectively. State 1 obtained vertical polarization and state 2 obtained horizontal polarization and hence the polarization reconfigurability is achieved.

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