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# Design of Slot Based Frequency Reconfigurable Microstrip Antenna for Wireless Applications

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**ABSTRACT:** Reconfigurable antennas, with the ability to radiate more than one pattern at different frequencies & polarizations, are necessary in modern telecommunication systems. The requirements for increased functionality (e.g. direction finding, beam steering, radar, control and command) within a confined volume place a greater burden on today's transmitting and receiving antennas. Reconfigurable antennas are a solution to this problem. The antennas can be reconfigured in four ways based on: frequency, radiation pattern, polarization and a combination of all. I will choose frequency as a parameter to reconfigure our antenna. A radiating structure that is able to change its operating (notch) frequency by hopping between frequency bands is called frequency reconfigurable antenna. This can be done with the help of a pin-diode. The variation in configuration is achieved through individually controllable switch implemented as a pin-diode. The antenna tunes its operating frequency/radiation pattern according to the switch. The wireless applications used in this case are Bluetooth (2.4 GHz) and GPS (1.575 GHz). Initially, the antenna resonates at a single frequency of 1.575 GHz for the GPS application. After, the pin-diode comes into picture, the antenna is reconfigured to resonate at two frequencies i.e. 2.4 GHz for the Bluetooth application. Thus, with the help of the reconfigurable antennas we can overcome the drawback of dual band antennas with the radiation pattern same for both the frequencies.

**KEYWORDS**: Reconfigurable antenna; Microstrip antenna;IE3D Software;Wireless Application;Patch antenna.

## I. INTRODUCTION

The need for dynamic space applications has led to the realization of reconfiguring antennas for satellite communication, missile application & wireless communication. The reconfigurable antenna becomes a popular solution because it provides a variety in antenna performance to satisfy diverse communication requirements and decrease the interface. Reconfiguring an antenna is achieved by changing its frequency, polarization or radiation characteristics. An antenna with the ability to radiate the same radiation pattern at different frequencies & polarizations is a necessity in modern telecommunication systems. Frequency reconfiguration can be achieved by modifying antenna dimensions using RF switches or tunable materials. In order to construct the antenna, we are using the microstrip patch antenna. These antennas are low profile, simple & inexpensive and can be easily manufactured using PCB printed circuit board techniques.

Reconfigurable antenna is an antenna with the ability to radiate more than one pattern at different frequencies and polarization. A Reconfigurable Antenna is an antenna capable of modifying dynamically its frequency, polarization and radiation properties in a controlled and reversible manner. The reconfigurable capability of this antenna is used to maximize the antenna performance in a changing scenario or to satisfy changing operating requirements. They can address complex system requirements by modifying their geometry and electrical behavior, thereby adapting to changes in environmental conditions or system requirements. In order to provide a dynamical response, reconfigurable antennas integrate an inner mechanism (such as RF switches, varactors,pin didoes, mechanical actuators or tunable materials) that enable the intentional redistribution of the RF currents over the antenna surface and produce reversible modifications over its properties.

Frequency reconfigurable antenna (FRA) is also called as Tunable Antenna. It has been investigated in order to provide maximum connectivity. FRA offer the possibility to dynamically change the resonance frequency of the

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antenna through electrical means. The space consumption is greatly reduced for FRA as one single resonant element can be used to cover all the bands. Also this element is designed for its highest targeted band of operation which results in small size elements. In addition to smaller elements, size reduction in RF chain can be achieved by passing some of the filter requirements on a frequency reconfigurable narrow-band antenna design. Typical application of FRA can be divided into two categories, the antenna that aim at switching between distinct frequency bands, or the antennas that aim at providing continuous tuning within – or between – operating bands and standards.As the antenna is capable to change its operating frequency with ON or OFF condition of the switch, frequency reconfiguration is achieved.

The objective of this paper is to design and analyze the frequency reconfigurable antenna where the RF switch is employed at the feed network to achieve the frequency reconfigurability. By controlling the length of the switch, the antenna can operate at two frequency either at 1.7 GHz or 2.7 GHz.On comparing the software & the hardware results, we observe that both the results are almost similar with no change in radiation pattern. Hence, it is capable to operate at two frequencies.

## II.ANTENNA DESIGN

To design any antenna the basic parameters to be calculated are width and length of the dielectric and patch. The following were calculated for the antenna design with the design considerations listed below:

### A. *Design Considerations:*

Height of Substrate (h) = 0.003λo ≤ h ≤ 0.05λo.

Dielectric Constant of Substrate (€r) = 2.2 ≤€r ≤ 12.

| Substrate | Dielectric constant | Loss tangent |
|---|---|---|
| Glass PTFE | 2.2 | 0.0002-0.0005 |
| RT Duroid | 2.26 | 0.001 |
| FR4 | 4.4 | 0.001 |
| Sapphire | 9.4 | 0.0001 |
| Teflon | 9.6 | 0.001 |
| Alumina | 9.6-10 | 0.0002-0.0005 |
| GaAs | 11-13 | 0.0016 |
| Si | 12 | 0.015 |

A rectangular microstrip patch antenna for 1.8GHz with FR4 substrate having relative permittivity 4.4, loss tangent 0.02 and height of substrate 1.6mm was designed.
Given:
fr =1.8 GHz , €r =4.4 , δ =0.02 , h =1.6mm , c =3*10^8 m/s

### *B. Design calculations:*

Since, the loss tangent is small, we assume here that €r is real. Using the following equations the width and length of the patch can be calculated,

$$\lambda o = \frac{c}{fr} = \frac{3*10^8 m/s}{1.8*10^9 Hz} = 0.1666m = 16.66\ cm$$

**1. Width of the patch:**

$$W = \frac{\lambda o}{2\sqrt{€reff}}$$

$$€reff = \left(\frac{\lambda o}{2W}\right)^2 = \left(\frac{16.66}{2W}\right)^2 = \frac{69.3889}{W^2} \quad ..........................(1)$$

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The wave propagation of line is given by,

$$€reff = \frac{€r+1}{2} + \frac{€r-1}{2}\left[1+12\frac{h}{W}\right]^{\frac{-1}{2}} \ldots\ldots\ldots\ldots \left(\frac{W}{h}>1\right)$$

$$€reff = \frac{4.4+1}{2} + \frac{4.4-1}{2}\left[1+12\frac{0.16}{W}\right]^{\frac{-1}{2}}$$

$$€reff = 2.7 + 1.7\left[1+\frac{1.92}{W}\right]^{\frac{-1}{2}} \ldots\ldots\ldots\ldots(2)$$

Equating (1) and (2),

$$\frac{69.3889}{W^2} = 2.7 + 1.7\left[1+\frac{1.92}{W}\right]^{\frac{-1}{2}}$$

$$69.3889 = 2.7\,W^2 + 1.7\,W^2\left[1+\frac{1.92}{W}\right]^{\frac{-1}{2}}$$

By solving ,

W = 39.73 mm

**2.** $€reff = 2.7 + 1.7\left[1+\frac{1.92}{W}\right]^{\frac{-1}{2}}$

€reff = 4.09585

**3.** $\lambda eff = \frac{\lambda o}{2\sqrt{€reff}} = \frac{16.66}{\sqrt{4.09585}} = \frac{8.2319}{2}$

λeff = 4.11595 cm ≈ 41.1593 mm

**4.An appropriate relation for normalized extension of length in one side is,**

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

$$= 0.412\,\frac{(4.39585)(25.09525)}{(3.83785)(25.63125)}$$

ΔL = (0.16) (0.412) (1.12144) cm

ΔL = 0.073925 cm ≈ 0.73925 mm

**5.Length of the patch:**

$$L = \frac{co}{2fr\sqrt{€reff}} - 2\Delta L$$

$$= \frac{3*10^8}{2*1.8*10^9\sqrt{4.09585}} - 2\,(0.73925)$$

= 41.1762 – (2 * 0.73925)

L = 39.6977 mm ≈ 39.7 mm

Since, W > L, designated dominant mode is TM010.

**6.For excitation using 50 Ω Microstrip line on same substance of low dielectric constant 4.4, the feed line width Wf can be obtained from the equation below,**

$$Zo = \frac{377}{\sqrt{€reff}\left[\frac{Wf}{h}+1.4+0.667\ln\left\{\frac{Wf}{h}+1.444\right\}\right]} \quad \text{where } \frac{Wf}{h} > 1$$

$$50 = \frac{377}{\sqrt{4.09585}\left[\frac{Wf}{0.16}+1.4+0.667\ln\left\{\frac{Wf}{0.16}+1.444\right\}\right]}$$

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377 = 101.1910 $\left[\frac{Wf}{0.16} + 1.4 + 0.667 \ln\left\{\frac{Wf}{0.16} + 1.444\right\}\right]$

377= 632.443 Wf+ 141.6674 + 67.49 ln

Solving above;
Wf = 0.31 cm ≈ 3.1 mm

**7.Substrate width and length:**

Ws = W + λeff = 39.7 mm + 41 mm = 80.7 mm
Ls = L + λeff = 39.7 mm + 41 mm = 80.7 mm

## III. DESIGN OF MICROCHIP PATCH

Fig.1 illustratesthe microstrip patch antenna that is designed from the above calculated dimensions.This design was run through the IE3D software and the hardware was fabricated to measure and correlate the results.

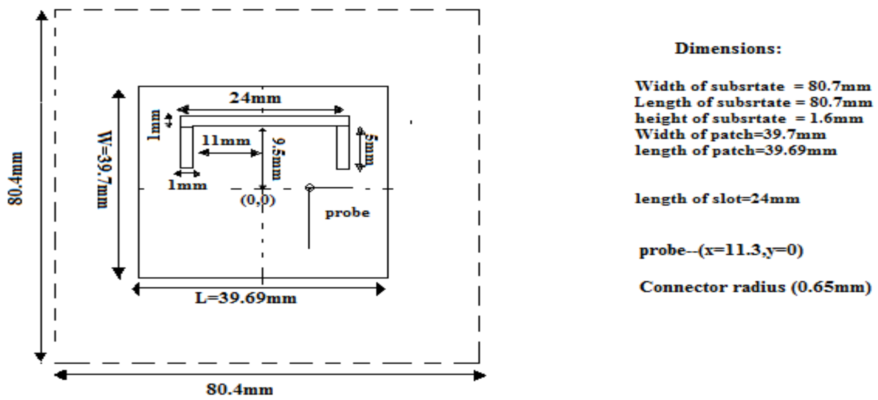


Fig1. Design of microstrip Patch

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## IV. SOFTWARE RESULTS -IE3D SOFTWARE

a. 1.8GHz Patch with C-Slot (Without Microstrip line)

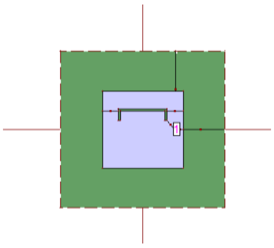

Fig2.'C' shaped Slot is made in patch.
The patch resonates at two frequencies1.8GHz & 2.45GHz.

Fig 2 shows a 'C' shaped slot patch which is designed on IE3D software.We have given probe feed towards the right side for impedance matching purpose. The antenna resonates at two frequencies 1.8GHz and 2.45GHz.

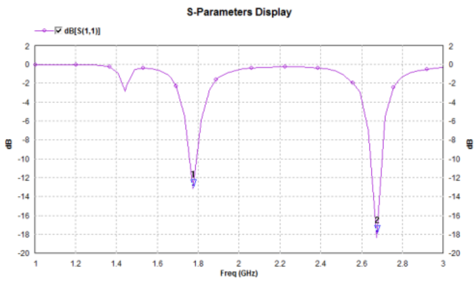


Fig3. Return Loss:-13.0322 dB (1.77603 GHZ) & -17.8265 dB (2.67508 GHz)

In Fig 3. S-parameters tell us about the return loss. Here, we get the return loss of. -13.0322 dB (1.77603 GHZ)& -17.8265 dB (2.67508 GHz).Since, antennas are typically designed to be low loss, ideally majority of the power delivered to the antenna is radiated.

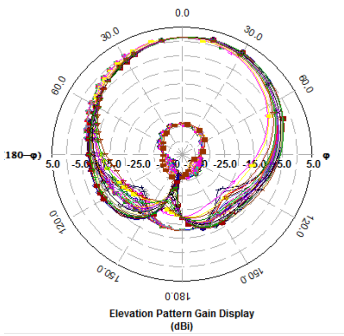


Fig4a). E-plane pattern

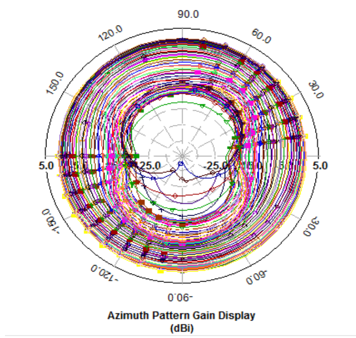


Fig 4b) H-plane pattern

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In Fig 4 a) 2-D radiation pattern of E-plane is observed. We can see that the radiation is in forward direction and the antenna produces a back lobe. This happens as the antenna is storing some energy. In the Fig 4b)H-plane pattern is observed .We can see a circle ,which tells the direction of max radiation.

b. 1.8 GHz Patch with C-Slot (With Microstrip line):

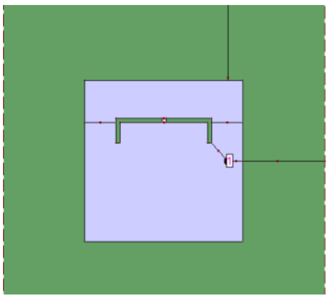


Fig5.’C’ Shaped Slot resonating at 1.8GHz

Fig5. Represents ‘C’ shaped slot antenna resonating at 1.8 GHz frequency with microstrip line. The probe is fed exactly at the center of the microstrip patch and hence, resonates at 1.8GHz frequency.

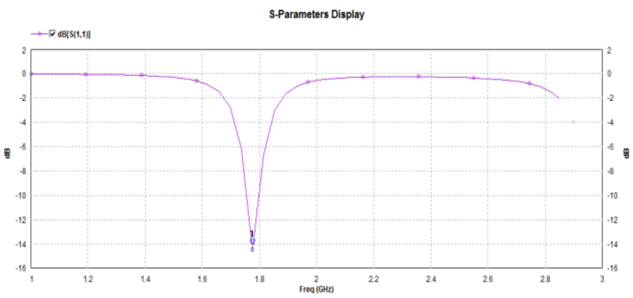
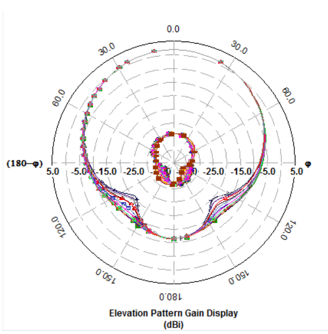



Fig6. Return loss = -14.2822 dB at 1.77554 Ghz.

A Return loss = -14.2822 dB at 1.77554 GHz is observed in Fig6.The good return loss characteristics and high bandwidth exhibited at these resonant frequencies make this antenna suitable for wireless applications.



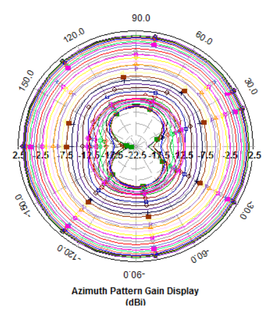




Fig7(a) E-Plane Pattern: (1.7755 GHz) Fig7(b) H-Plane Pattern (1.7755 GHz)

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At 1.8GHz band, the antenna exhibits patterns very much suitable for wireless mobile application. The H-plane pattern shown in Fig7( a) is suitable for handheld devices, which indicates minimum radiation from the antenna in that direction which faces the head. This is highly recommended from the point of adverse effects of radiation from handheld devices. The E-plane patterns shown in Fig7 (b) areomnidirectional which are very much suitable for wireless applications like WiMAX.

## V. HARDWARE RESULTS

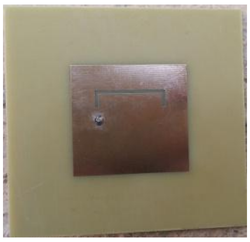

Fig8. Front View

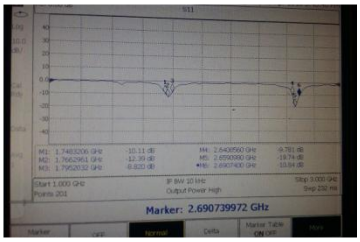


Fig9. S Parameter

In Fig 8 we see the front view of the fabricated chip.

S parameter is observed in Fig 9. Antenna resonates at 1.748GHz and 2.640GHz

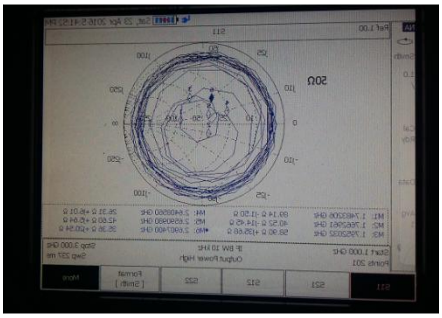

Fig10. E & H plane

Hardware results for E and H plane pattern are shown in Fig 10.

## VI. CONCLUSION FROM RESULTS

Software results:

- In Switch On (Pin Diode Conducting) Mode-
  Antenna resonates at two frequencies – 1.75Ghz & 2.58Ghz.
- In Switch Off ( Pin Diode off state) Mode-
  Antenna resonates at only one frequency – 1.75GHz.

IN BOTH CASES RADIATION PATTERN &POLARISATION ARE UNAFFECTED.

Hardware results:

- Antenna resonates at two frequencies – 1.748 GHz & 2.640 GHz.

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### VII. CONCLUSION

The antenna provides frequency reconfiguration characteristics on changing the way the antenna is excited. The reconfigurable antenna becomes a popular solution because it provides variety in antenna performance to satisfy diverse communication requirements & decrease interface. Due to which it is used in high- performance aircrafts, satellites, & missile applications. It is a best alternative for Multi-band antennas & MIMO systems. FRA offers the possibility to dynamically change the resonance frequency of the antenna through electrical means.

The space consumption is greatly reduced for FRA as one single resonant element can be used to cover all the bands. This element is designed for its highest targeted band of operation which results in small size of elements & it also provides filtering capability. For designing purpose IE3D antenna designing software has been used.

Using the p-i-n diode switches, it has been demonstrated that a microstrip antenna can be reconfigured to support two distinctly different operating frequency bands with varying the position of the probe.Frequency reconfiguration is generally achieved by modifying physically or electrically the antenna dimensions using RF-switches, pin diodes, impedance loading or tunable materials.The Antenna resonates at two frequencies: – 1.748 GHz & 2.640 GHz.As the antenna is capable to change its operating frequency with ON or OFF condition of the switch, frequency reconfiguration is achieved. Frequency Reconfigurable antennas find their applications in satellite communications, cognitive radio systems, and software defined radios.

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