Design and Simulation of Reconfigurable Microstrip Patch Antenna with Frequency Switching

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Abstract: **In this paper, a single reconfigurable rectangular spiral microstrip patch antenna with frequency switching is simulated and designed, which operates at two different frequencies. But main lobe direction of radiation pattern remains same. The Designed Antenna has Return Loss which is less then -10 dB and Gain which is greater then 2.2 dBi. Frequency Reconfiguration is achieved by electrical reconfiguration technique in which we change the structure length of antenna with the help of PIN diode switch. When PIN diode is in off state then antenna radiate at 1.78 GHz, and when switch is in on state then antenna radiate at 2.38 GHz. This will help us to reduce antenna size, cost and improve efficiency. We can replace two antennas radiating at 1.78 GHz and 2.38 GHz by this designed reconfigurable antenna. Thus it can be used in receiver station in IRNSS (Indian Regional Navigation Satellite System).**

Keywords: **Rectangular Spiral Microstrip Patch, PIN diode, Frequency reconfigurable.**

1. INTRODUCTION

Microstrip antenna consist of low loss dielectric material which is covered by conducting ground plane on one side and radiating patch element on other side. Microstrip antenna becomes most popular because it has advantage like low profile, low cost, light weight, easy to fabrication etc and variety of applications like GPS, GSM and space satellite Television etc[1].

Microstrip patch antenna has various shapes like square rectangular, circular etc., here we take rectangular spiral shaped micro strip patch antenna. It has property of reduced size and frequency independence over large bandwidth. Spiral patch antenna operates in three modes. First one is travelling wave formed on spiral arms, allows for broadband performance, Second is fast wave due to mutual coupling phenomenon occurring between arms of spiral and Third is leaky wave leaks the energy during propagation through spiral arms to produce radiation. Spiral Antenna are circularly polarized and has low gain.

Reconfigurability is the ability to change individual radiator's fundamental operating characteristics like frequency, pattern, polarization etc. through electrical, physical or other means[2].

Frequency Reconfigurable antenna has property to change resonant frequency by changing structure while radiation pattern and polarization remains unchanged. The effective electrical length of antenna decides radiation frequency. The electrical length of antenna and also its operating frequency can be altered by adding or removing part of the antenna effective length through electronic, mechanical, or any other means. If we have to make antenna to operate at high frequency the antenna length can be shortened to correct length corresponding to half wavelength at new resonant frequency. The radiation pattern of this new modified length antenna will deploy same characteristics as first one because current distribution will remain same[3-4].

We can change length of antenna by Electrical MEMS, PIN Switch, optical or by Mechanical Methods. Here, we choose switching by electrical PIN diode method due to its fast switching speed, pure resistance at RF frequency, high current handling capacity and excellent isolation[5-7].

2. THEORY AND DSIGN

Ring theory explains the basic working principle of spiral shaped antenna. The theory describes that spiral antenna radiates from a region called active region where the circumference of spiral equals to wavelength. Many parameters are defined in this spiral antenna like spacing between the turns 's', width of arm 'w', inner radius 'r1' and outer radius 'r2'. The inner radius is measured from centre of the spiral to centre of the first turn while the outer radius is measured from centre of the spiral to centre of the outermost turn.

Spiral antennas have lowest and highest operating frequencies which can be measured from the following relations where 'c' stands for speed of light.

$$f_{high} = c/2\pi r_1$$

$$f_{low} = c/2\pi r_2$$

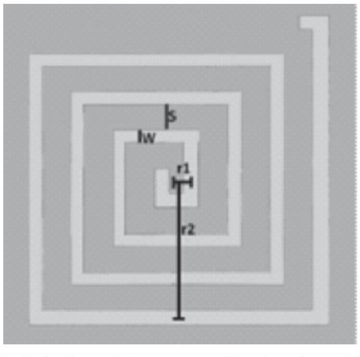

Fig.1. Spiral Patch Repersentation in Ring Theory

The spiral patch is printed on a fix-size dielectric substrate backed by a fix-size conducting ground plane. Both the substrate and ground planes are square with a side length of less than 0.6 λ (λ: wavelength in free space).Here outermost spiral arm length C is within $\lambda_g < C < 2\lambda_g$ (λ_g: Guide wavelength) so, Spiral patch radiate axial beam. Coax connector is used here as feeding network to patch antenna. Feeding is applied at starting point of first turn of spiral patch with probe radius of 0.07 mm. The coaxial connector is screwed to bottom side of FR4 Substrate and coax probe wire after passing through substrate soldered to patch. The square dielectric substrate has permittivity∈, thickness B and side length L. The horizontal spiral arm is composed of multiple filaments, whose first two arm length is a_0, next two arm length is $2a_0$, next three arm length is $3a_0$ and so on. The air boundary is taken around the substrate to extract radiation from patch to outward direction. The air boundary must be at least λ/4 height above normal to patch. The radiation pattern is dependent on the outermost arm peripheral length. The main advantage of coax feeding is that it can be placed at any desired location inside the patch in order to match with its input impedance. The coax feed method is easy to fabricate and low spurious radiation[8].

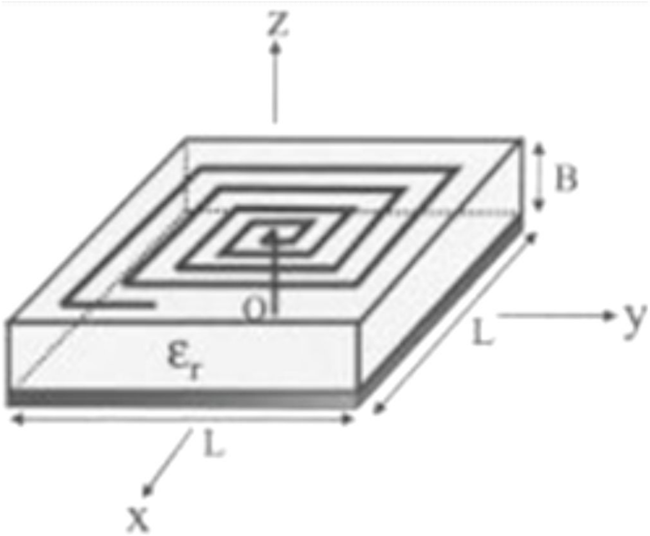

Fig.2. Perspective Diagram of Rectangular Spiral Patch Antenna

A. Switching with PIN Diode

Practical PIN diodes used with a size of 1.5 x 0.7 mm2, as the switches. In HFSS simulation, these diodes are modeled using the Lumped Network which gives 0.9 Ω as the impedance value of the PIN diode in the ON state and 0.1 pF as the capacitance value in the OFF state. These PIN diodes are turned "ON/OFF" using a DC biased signal[9].

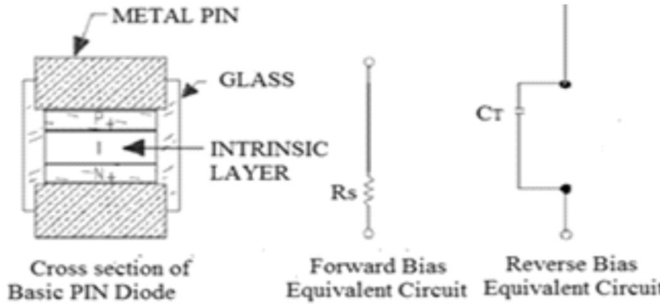

Fig.2. PIN Diode Circuit and Repersentation

So this PIN diode is used to prevent DC signal from flowing to the main feed line but allow the RF current to pass through.

First we design spiral antenna such that it resonant at base 1.78GHz frequency then we check different positions along the length of patch where PIN diode can be positioned to make antenna to resonant at other 2.38 GHz frequency. Then we placed PIN diode at desired position.

A. Design Parameters

Test Frequency F = 2.5GHz.

C-speed of light = 3×10^8

Wavelength λ = C/F = 120nm

Width of patch w = 0.0135λ = 1.62mm

Dielectric Constant ε = 4.4

Thickness of Substrate t = 0.134λ = 16.2mm

First length of patch a_0 = 0.0503λ = 6.04mm

Peripheral Length = C = $4Ma_0$ = 0.804 λ_0 = 1.23 λ_g

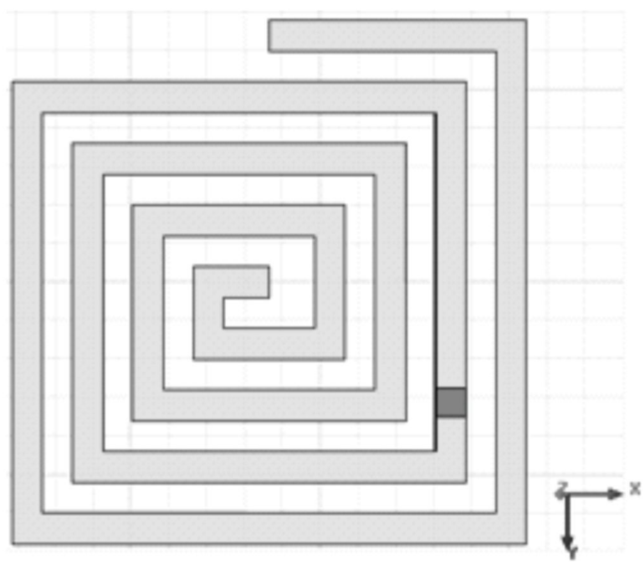

Fig.4. Designed Spiral patch Antenna

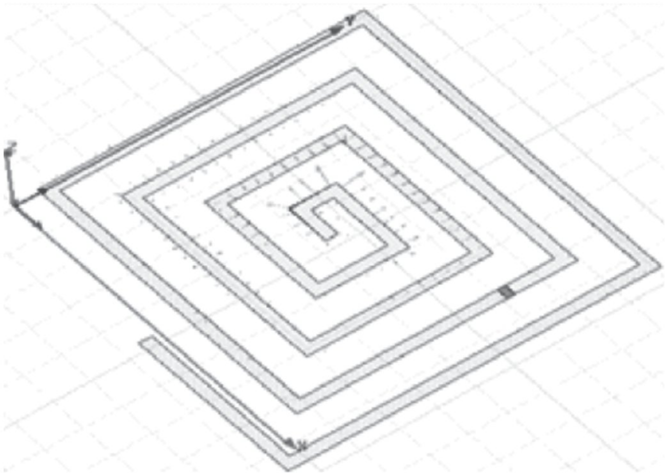

Fig..5(a). Surface electric field vector when switch ON

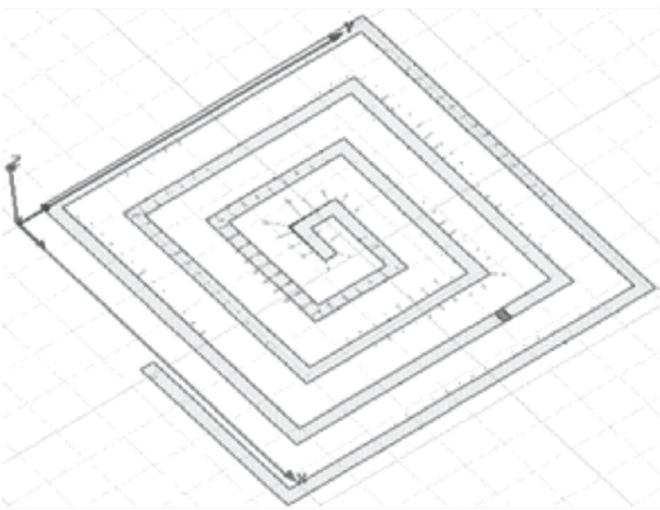

Fig.5(b). Surface electric field vector when switch OFF

A. RETURN LOSS PLOT

Figure shows simulated result of Return Loss for designed antenna. It shows -28db loss at Resonant Frequency 1.78 GHz when PIN Diode is ON and -13 db at Resonant Frequency 2.38 GHz when PIN Diode is OFF

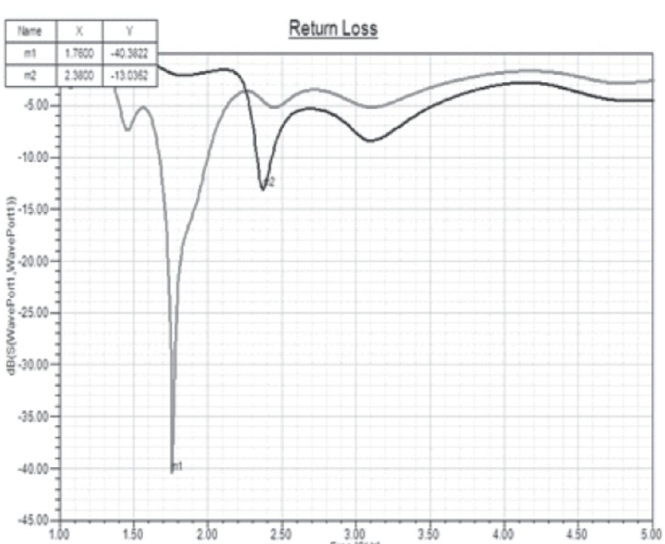

Fig.6. Reflection coefficient Vs. Frequency plot

A. SMITH PLOT

Smith Chart shows at radiation frequencies 1.78 and 2.38Ghz, inductance is very low. So, Impedance is purely resistive.

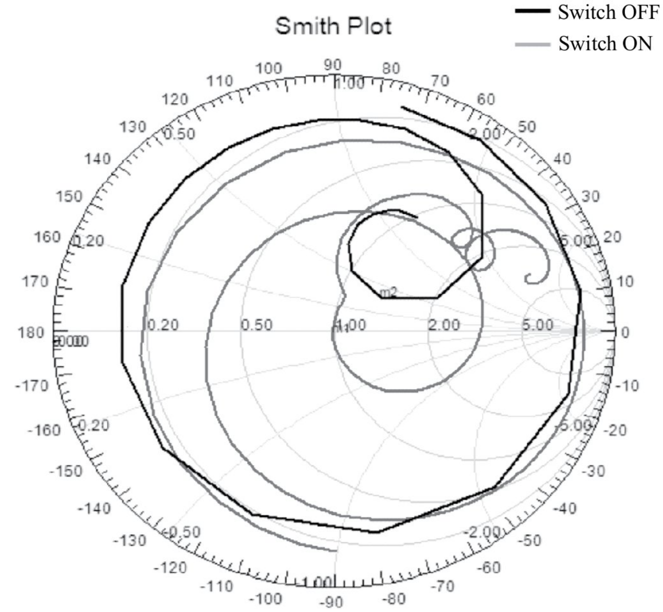

Fig.7. Smith Chart plot

A. GAIN PLOT

Figure shows simulated result of Gain for designed antenna. When PIN Diode is switched ON Gain is 1.59dB and when PIN Diode is switched OFF Gain is 1.99dB. So, Gain is almost same and positive.

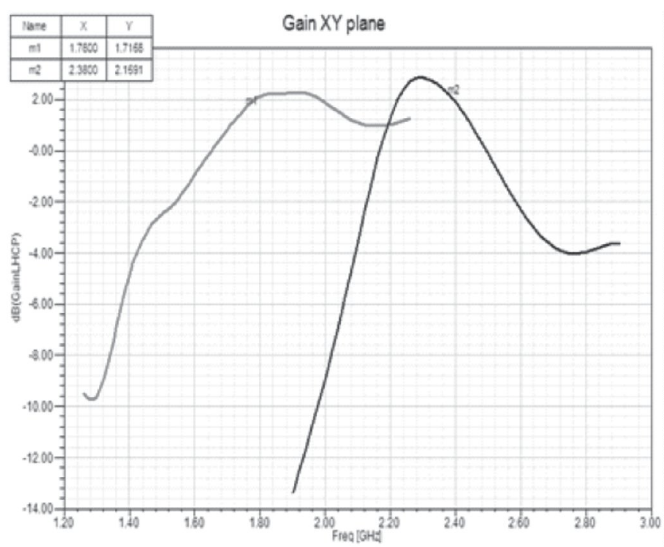

Fig.8. Gain Vs. Frequency plot

A. AXIAL RATIO

Axial Ratio indicates deviation from circular polarization. Here, Figure shows Axial Ratio for desired antenna. When PIN Diode is switched ON, Axial Ratio is 2.64 dB and when PIN Diode is switched OFF, Axial Ratio is 2.57 dB. So, Axial Ratio is almost same and less then 3.

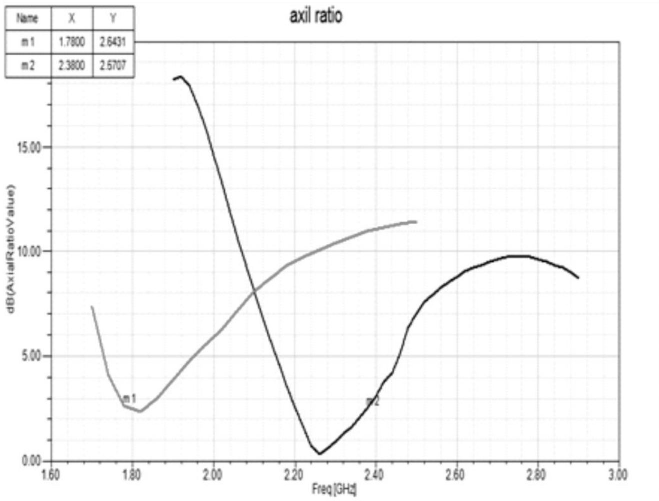

Fig.9. Axial Ratio Vs. Frequency plot

A. 3-D POLAR PLOT

Fig shows 3D pattern is almost same for both states of PIN Diode. 3D pattern of antenna looks like Omni directional Antenna pattern same radiation intensity in all the directions.

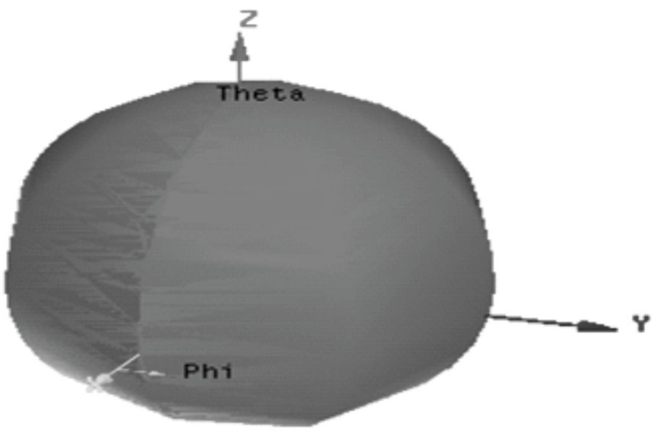

Fig.10 (a). 3-D polar plot (LHCP) in elevation plane with maximal beam direction 0° in ON state

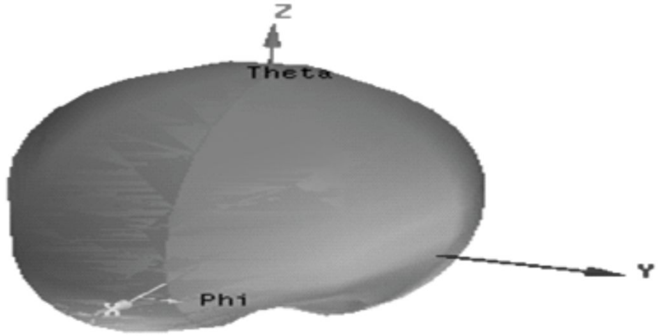

Fig.10 (b). 3-D polar plot (LHCP) in elevation plane with maximal beam direction 0° in OFF state

3. CONCLUSION

We have designed spiral shape microstrip patch antenna which is printed on dielectric substrate supported by ground plane with coax feeding at center of patch and Pin Diode at third arm length of patch and frequency Reconfigurability has been shown. After giving excitation through coaxial line, the spiral patch radiate axial beam of circular polarization. Spiral patch make to radiate at different frequency by changing state of PIN Diode. We get bandwidth of 320 MHz when patch antenna resonant at 1.78 GHz and 250 MHz when antenna resonant at 2.38GHz.

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