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Multiband Reconfigurable Microstrip Patch Antenna

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ABSTRACT

Reconfigurable Antenna is an alternative to multi-band Antenna. Different techniques are used to achieve multi-band and wideband operation of antenna. Reconfigurable antenna has a potential to add some functionality to mobile communication. A reconfigurable antenna is another solution to achieve multiple bands by switching ON and OFF some part of the antenna. To allow the operating frequency and the bandwidth to be reconfigurable switching components are normally used. In this paper microstrip patch-slot antenna is capable of frequency switching at different frequency bands from Frequency range. RF p-i-n diode is used for the switching purposes. The main aim of this paper is to provide multiband functionality form a single band frequency just by optimizing the antenna structure.

Keywords : Microstrip Patch, Reconfigurable antenna, optimization, PIN Diode

I. INTRODUCTION

Wireless communication systems are attracted toward multi-functionality. This multi-functionality provides users with options of connecting to different kinds of wireless services for different purposes at different times. It is very important to develop single radiating element which is having capabilities of performing different functions and multi-band operation in order to minimize the antenna's weight and area. An antenna that have the ability to modify its characteristics, such as operating frequency, polarization or radiation pattern is referred to as a reconfigurable antenna. Reconfigurable antenna is used for to reduce the number of antenna necessary for Multiband function, but they can also be designed to work in complex systems such as emerging applications include software defined radio, cognitive radio, MIMO systems. Re-configurability can be achieved using slot configuration in the microstrip rectangular patch antenna with switching devices are connected inside the slot with ON & OFF State working. Switching devices such as PIN diodes, MEMS switches and optical switches are used for switching purposes.

This paper provides detail information of all type of reconfigurable antennas. Section II introduces the concept of types of reconfigurable antennas. Section III presents Design parameters of reconfigurable antenna. Section IV presents optimization of structure. Section V presents result and conclusion.

II. METHODS AND MATERIAL

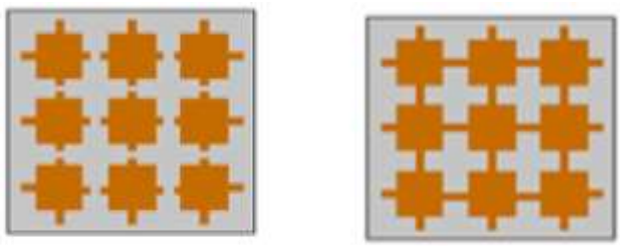
1. Reconfigurable Antenna:

Antenna reconfiguration is broadly classified as frequency, radiation, polarization, radiation and frequency reconfigurable antennas.

A. Frequency Reconfigurable Antenna

Latest communication systems demand transmitters and receivers with multi-band operation, as a result different techniques for achieving frequency reconfigurability have been proposed in system where weight and area are critical issue.

The reconfigurable patch module (RPM) proposed by J. T. Bernhard et al. consists of a 3x3 array of square patches connected together by the RF MEMS switches as depicted in Fig.1.Ideally, the RF MEMS switch has two operational states ON and OFF. The ON state represents a short circuit, while the OFF state exhibits an open circuit. When all the switches are in the OFF state, the total radiation pattern is formed by the pattern radiated by each small patch as shown in Fig. 1(a). As a result, the antenna resonates at a higher frequency band. On the other hand, when all switches are turned ON, the antenna effective area is clearly larger than the area of a singular patch array. The antenna accordingly resonates at a lower frequency band as shown in Fig. 1(b).Fig. (a) Antenna geometry when switches are turned OFF (b) Antenna geometry when switches are turned ON.



(a) Open (b) Closed Configuration

Figure 1: (a) Open and (b) Closed Configuration

B. Radiation Pattern Reconfigurable Antenna

Radiation pattern reconfigurability is based on the some modification of the spherical distribution of radiation pattern. Pattern reconfigurable antennas are usually designed using movable/rotatable structures or by using switchable and reactively-loaded parasitic elements. The antenna is designed to be able to reconfigure its radiation pattern during operation such that it maintains its broad pattern in the absence of interferences, and is capable of narrowing its pattern, when the interfering signals arrive at the antenna, to suppress these undesired signals as much as possible.

The total radiation pattern from the microstrip antenna originates from three things: direct space wave, edge diffracted space wave and edge diffracted surface wave. The Basic idea about the pattern reconfigurable antenna is antenna mounted on electrically thick substrates so that edge-diffracted surface wave field can be strong and which is having the magnitude higher than the diffracted space wave field.

C. Polarization Reconfigurable Antenna

Polarization reconfigurable antennas are capable of switching between different polarizations modes. The capability of switching between horizontal, vertical and circular polarizations can be used to reduce polarization mismatch losses in portable devices. Polarization reconfigurability can be provided by changing the balance between the different modes of a multimode structure. Antenna with polarization diversity is very important due to the rapid growth of wireless communications and radar systems.

D. Radiation and Frequency Reconfigurable Antenna

In general, most antennas are capable of either frequency or pattern reconfigurability. However, they can be made a combination of both frequencies and pattern reconfigurable simultaneously. Frequency and Pattern reconfigurable microstrip antenna are done by using multiple switch connections.

2. Design Parameters

The basic structure of the proposed antenna, shown in Fig.2, consists of 3 layers. The lower layer, which constitutes the ground plane, covers the partial rectangular shaped substrate. The middle substrate, which is made of GML 100 has a relative dielectric constant ϵr =3.2 and height 1 mm. the upper layer, which is the patch, covers the rectangular top surface. Simulations were performed using CST Microwave Studio.

Step 1: Calculation of the Width (W):

The width of the Microstrip patch antenna is given as

$$W = \frac{c}{2 f_0 \sqrt{\frac{\epsilon_r + 1}{2}}}$$

Where, C is velocity of light, f_0 is Resonant Frequency & εr is Relative Dielectric Constant of Substrate.

Step 2: Calculating the Length (L)

- ✓ Effective dielectric constant (εre)

The effective dielectric constant is also a function of frequency. As the frequency of operation increases the effective dielectric constant approaches the value of the dielectric constant of the substrate is given by:

$$\varepsilon_{re} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2}$$

- ✓ Effective length (Leff)

$$L_{eff} = \frac{c}{2 f_0 \sqrt{\varepsilon_{re}}}$$

- ✓ Length Extension (ΔL)

Length Extension (ΔL), which is a function of the effective dielectric Constant and the width-to-height ratio (W/h).The length extension are:

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

- ✓ Calculation of actual length of patch (L)

The length is a critical parameter and the above equations are used to obtain an accurate value for the patch length L.The actual length is obtained by:

$$Leff = L + 2\Delta L$$

3. Optimization of structure

The Dimension of proposed system is been specified in Table 1 below. This design is best suited for 9.4GHz frequency range.

The two separate diagrams are shown for PIN diode's state. Out of which connection between outer rectangular to inner rectangular is represented with microstrip line with 1mm width represents ON state of diode and provide connection between inner and outer surface. Absence of this connection indicates OFF state of diode.

Simulation results of two different antennas are shows with two different graphs of S_{11} scattering parameter. Frequencies below -10dB are considered as usable frequencies and represented with axis markers.

Sr.No.	Parameters	Dimensions
1	Length of Ground	39.1mm
2	Width of Ground Plane	39.1mm
3	Length of Patch	7.93mm
4	Width of Patch	10.3mm

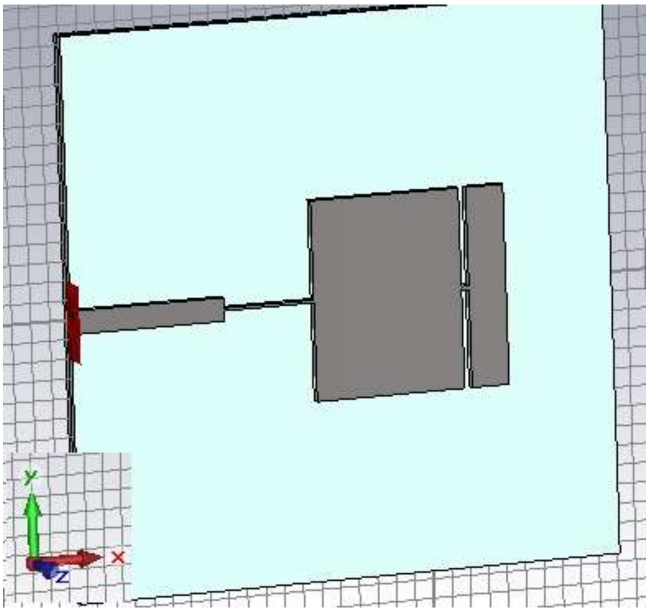


Figure 2: Design 1 with ON state

Above specified design from Table 1 is implemented using CST Microwave studio in Figure 2. Connecting strip is used as the functionality of ON and OFF state of PIN diode. This design provide S_{11} Vs Frequency graph for OFF state and ON state as shown in Figure 3 and 4 respectively.

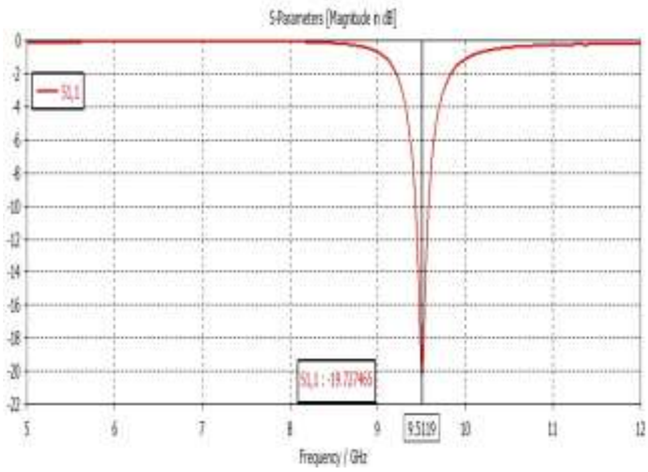


Figure 3: S_{11} Vs Frequency graph for OFF state

From the return loss parameter graph S_{11} for OFF state frequency of resonance is 9.51 GHz with -19.72 dB return loss value. The same structure with ON configuration of PIN diode gives 10.41 GHz resonance frequency with -23.79 dB return loss value.

Both these values are in acceptance range of antenna operation with good VSWR value i.e. VSWR less than 1. This structure gives a single band of operation at 9.4 GHz resonance for OFF and ON state. To make this multiband structure we need to cut the structure and add the extra slot inside the main Microstrip (MSA) structure.

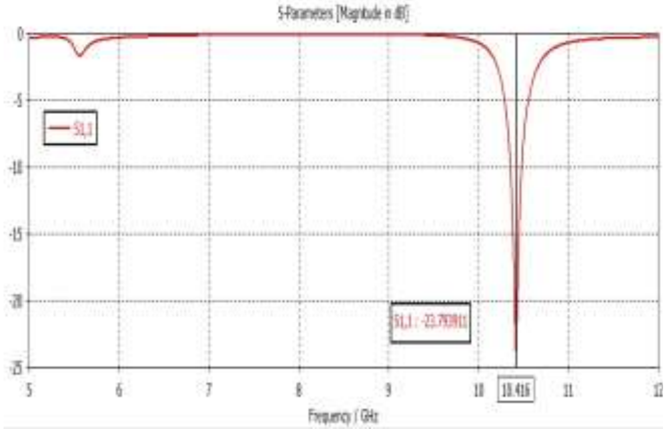


Figure 4: S_{11} Vs Frequency graph for ON state

So to achieve multiband operation considered 30*30mm ground plane and outer slot with 25*25mm dimension on GML substrate with 30*30mm dimensions and cut it with 20*20mm patch, within this rectangular patch is added of dimension 15*15mm.

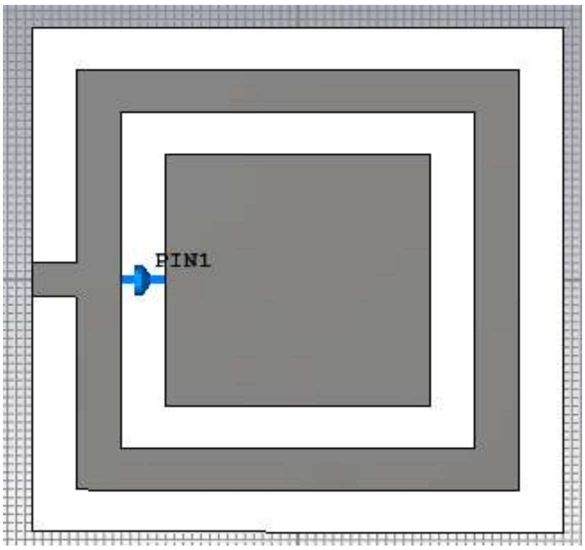


Figure 5: Design 2 with PIN Diode

Pin diode state can me made ON and OFF depending upon the status of lumped elements of PIN diode.

This design provide S_{11} Vs Frequency graph for OFF state and ON state as shown in Figure 6 and 7 respectively.

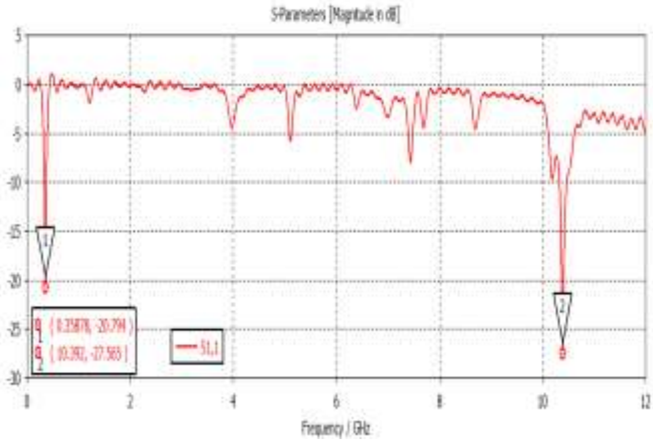


Figure 6: OFF state S_{11} scattering parameter

This design provides two usable frequencies (0.349 GHz, 4.449 GHz) in OFF state and four frequencies (0.279 GHz, 1.245 GHz, 4.067 GHz ,and 7.31 GHz).

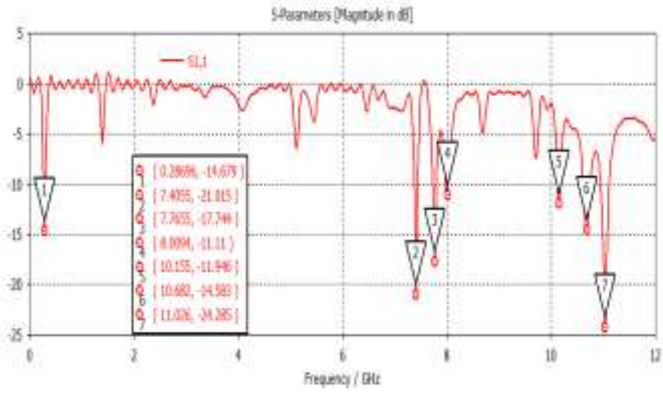


Figure 7: ON state S_{11} scattering parameter

III. RESULT & CONCLUSION

From above design, structure 2 provides two usable frequencies (0.349 GHz, 4.449 GHz) in OFF state and four frequencies (0.279 GHz, 1.245 GHz, 4.067 GHz, and 7.31 GHz).These obtained frequencies are in low frequency, C-band, X-band of frequency ranges. Also, structure from design four is optimal size reduction antenna with increase in multi-band functionality.

Thus, by adding extra patch inside the MSA structure one can achieve multiband operation of the same structure. This can be further extended to reduce more inner surface and to provide multiple switching devices to achieve multiband operations.

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