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A Dual Band Microstrip Patch Antenna with RF Switch

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ABSTRACT: In this paper, a frequency reconfigurable microstrip patch antenna is designed with coaxial feeding technique. A varactor diode is used as RF (Radio Frequency) switch for switching between different frequency bands. The RF switch is integrated within the antenna for frequency reconfiguration for multiple applications. This RF switch enables intentional redistribution of RF currents over the antenna surface and produces significant changes in its resonant frequencies and radiation properties. The reconfigurable antenna consists of a rectangular patch and the patch is divided into two halves by a narrow slot to place the varactor diode and the capacitors. A reverse bias DC voltage is applied to the varactor diode. A transmission line and a radial stub acts as RF choke for DC path completion. The proposed antenna has been designed and simulated using Agilent Advanced Design System (ADS) EM simulator and resonates at 1.9 GHz and 2.4 GHz. The proposed antenna finds application in cellular communication GSM at 1900 MHz and also in wireless applications such as Wi-Fi, Bluetooth, and RFID system at 2400 MHz.

KEYWORDS: Rectangular patch, varactor diode, reconfigurable, radial stub, transmission line

I. INTRODUCTION

Reconfigurable antennas are used for the modern wireless communication systems because of its multifunctional operations. The reconfigurable antenna can replace multiple antennas used and can save the space and the cost. Thus reconfigurable antennas are very important and needed to satisfy the complex requirements of wireless systems. There are many research works and developments done in designing a reconfigurable antenna to enhance the antenna performance. The reconfigurable antenna uses an inbuilt switching mechanism within the antenna for multiband and multiservice operations [1] and [13]. An antenna can be reconfigured using different reconfiguration techniques such as electrical reconfiguration, optical reconfiguration, structural alteration or the use of smart materials which enables intentional redistribution of the RF current over the antenna surface and modifies its electrical behavior and properties. The electrical reconfiguration technique is mostly used in designing the reconfigurable antennas by using varactor diode, PIN diode, and RF-MEMs (Radio-Frequency Micro Electro Mechanical) switches. Based upon the system requirements frequency reconfigurable, polarization reconfigurable or radiation pattern reconfigurable antennas or the combination of any two properties are designed [5]. Frequency reconfigurable antennas have been designed largely than other reconfigurable antennas for multiband operations. Microstrip patch antennas are widely used in designing a reconfigurable antenna because of its low profile, low cost, and ease of fabrication [15]. Though microstrip patch antennas provide narrow bandwidth, the use of slots within the patch helps to enhance the bandwidth. The microstrip antenna is in different shapes among which a rectangular patch is used in the proposed design since the microstrip antenna is capable of producing dual and multiple frequencies. Mostly varactor diodes are used for switching between different frequency bands by electronic tuning [4] – [7]. The varactor diode produces less noise compared to other diodes and has fast tuning capabilities. A single varactor diode is used in the proposed antenna design. In this paper, a frequency reconfigurable microstrip patch antenna is proposed by using a single varactor diode as RF switch.

II. RELATED WORK

RF-MEMs and PIN diodes, when used as switches, have many disadvantages compared to the varactor diodes. In [2] two RF-MEMs switches were used for frequency reconfiguration which leads to DC biasing complexity and interferences. RF-MEMs switches are complex, larger in size and unsymmetrical structure. In [3] frequency and pattern reconfiguration are achieve with 5 PIN diodes using a planar monopole with a microstrip patch antenna producing omnidirectional and unidirectional pattern mode. The antenna covers 2.2 GHz to 5.5 GHz for multi-standard wireless

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applications but the antenna impedance changes with each mode and the PIN diodes leads to non-linearity and high power loss.

In [4] a circularly polarized patch antenna with frequency reconfiguration is presented where 12 varactor diodes are used which leads to high insertion losses. The antenna operates in five bands from 1.93 GHz to 2.5 GHz but it increases the design complexity by the use of more diodes, inductors and shorting pads. A single varactor diode is used in [5] with a simple square patch antenna for frequency reconfiguration but the antenna has poor reflection coefficient and covers unused frequency bands from 2.2 GHz to 4.3 GHz. A frequency and polarization reconfiguration is achieved in [6] operating from 2.4 GHz to 3.6 GHz. But this antenna requires 12 varactors with 12 stubs with independent voltages although stubs provide impedance matching and tuning of different independent voltages. In [7] frequency and pattern reconfiguration have been proposed with 6 open circuit stubs and 6 varactor diodes operating from 2.7 GHz to 3.5 GHz in broadside and monopole mode but has less efficiency and requires higher varactor capacitance.

To overcome these design complexity and to reduce the number of lumped components, this paper proposes a technique to design a simple patch antenna with only one varactor diode for frequency reconfiguration. The proposed design extends the concept in [5] to a rectangular patch antenna to operate in 1.9 GHz for GSM communications and 2.4 GHz for wireless applications with good reflection coefficient and gain. The electronic tuning is done by DC biasing and the DC path completion with a transmission line and a radial stub. The proposed antenna design procedure is described and simulated results are presented.

III. PROPOSED SYSTEM

A. *Antenna Design:*

The geometry of the proposed reconfigurable antenna is shown in Fig. 1.

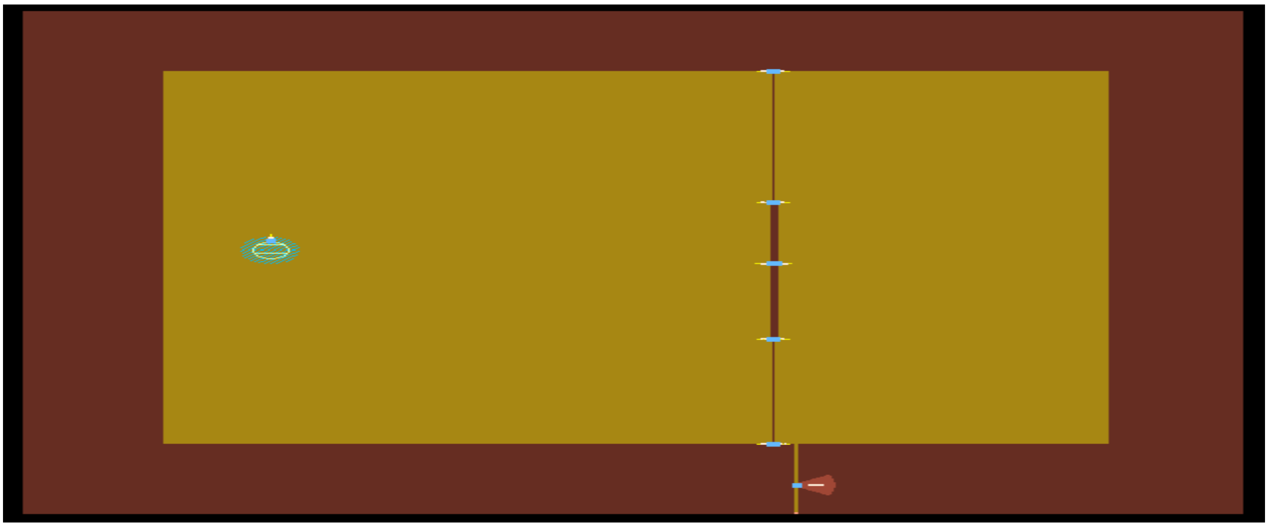

Fig. 1. The geometry of the proposed reconfigurable patch antenna.

The antenna consists of a rectangular patch with narrow slots in the middle. The rectangular patch is designed by using the patch antenna design equations for the desired resonant frequency. The length and width of the patch antenna are designed as 58mm and 65.5mm and the length and width of the ground plane are 73.7mm and 84.6mm respectively. The slots divide the patch into two equal halves. The major slot is 0.5mm where a single varactor diode is placed. Two minor slots are etched on the both sides of the major slots with a dimension of 0.2mm to place the lumped capacitors. Four capacitors namely 0.6pF, 0.8pF, 1pF, and 1.1pF are placed in the minor slots for RF continuity. Coaxial feeding technique is used which enhances the gain, impedance matching and has low spurious radiation. The antenna is built on a Roger RT/duroid 5880 substrate with permittivity 2.2 and thickness 3.175mm [17].

The varactor diode (SMV 1430) from Skyworks is implemented in the design [16]. Electronic tuning is done by the DC bias circuit. For the DC path completion, the right part of the patch extends to a transmission line and a radial stub

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with a metallic via. The transmission line and the radial stub acts as RF choke allowing only the DC signals and blocking the high-frequency signals.

B. *Varactor Diode:*

The varactor diode produces frequency reconfiguration in the patch antenna with varying DC voltages. Reverse bias DC voltage is applied to the varactor diode. The varactor diode produces changes in the RF current and thus making the antenna to resonate at different frequencies over the entire operational band as the reverse voltage varies. The capacitance of the varactor diode varies with the applied bias voltages and produces changes in the current distribution of the antenna. The tuning range of the varactor diode is $0.31 \leq C \leq 1.24$ pF with the DC bias voltage of 0V to 30V. This change in capacitance thus produces the change in the operating frequencies of the antenna. The varactor diode (SMV 1430) acts as RF switch switching between various frequency bands when a DC voltage is applied. The equivalent circuit of the varactor diode (SMV 1430) is shown in Fig. 2 and implemented in the slot of the patch antenna for frequency reconfiguration.

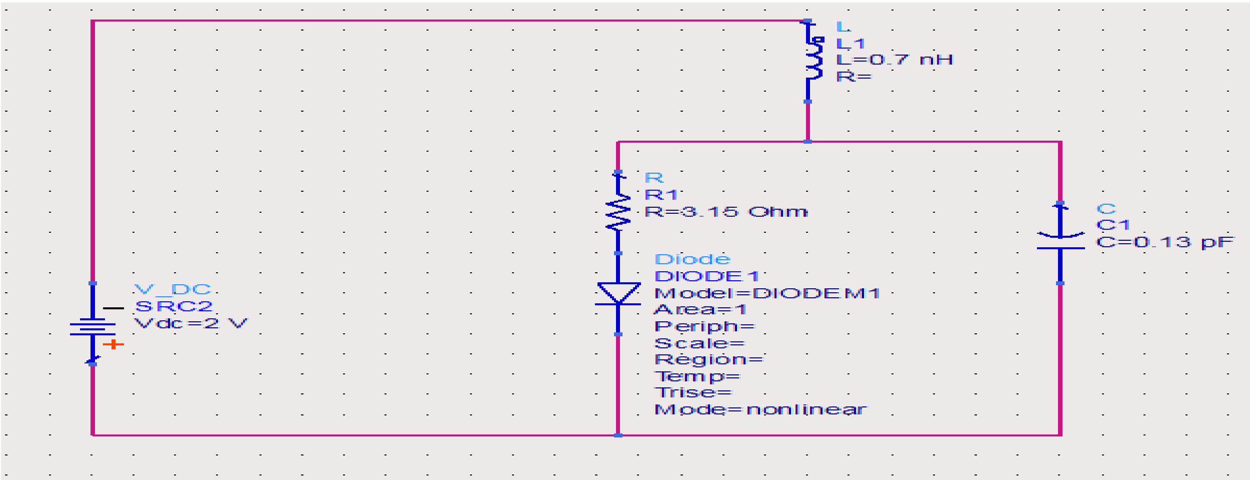

Fig. 2. The equivalent circuit of varactor diode (SMV 1430).

IV. SIMULATION RESULTS

The proposed antenna design is simulated using Agilent Advanced Design System (ADS). The reverse bias voltage is varied and the changes in the operating frequencies are obtained. For 2V DC voltage, the reconfigurable patch antenna resonates at 1.96 GHz which is approximately 1.9 GHz and can be used for GSM cellular communication. For 5V DC voltage, the reconfigurable patch antenna resonates at 2.38 GHz which is approximately 2.4 GHz and can be used for wireless applications such as Wi-Fi, Bluetooth, and RFID systems.

A. *Reflection Coefficient:*

The reflection coefficient for 1.9 GHz frequency is obtained from simulations as -44.7 dB and the reflection coefficient for 2.4 GHz frequency is obtained as -32.2 dB. This shows that the antenna has good impedance matching for these resonant frequencies compared to [5]. The reflection coefficient for 1.9 GHz and 2.4 GHz are shown in Fig. 3 and Fig. 4

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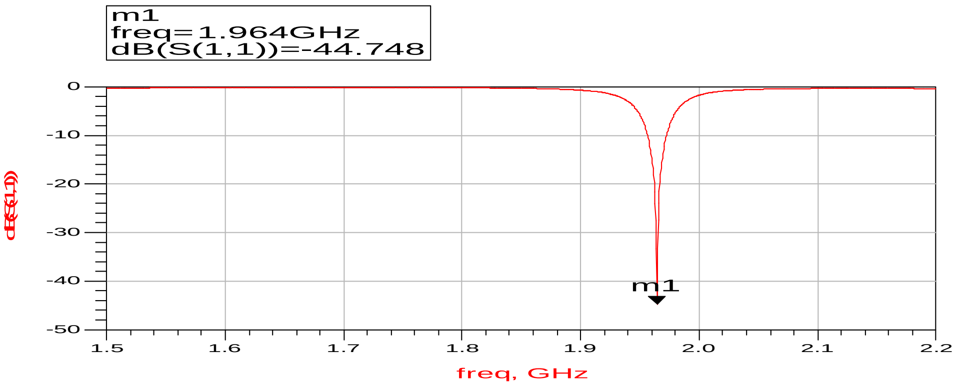

Fig. 3. Simulated Reflection Coefficient for 1.9 GHz frequency.

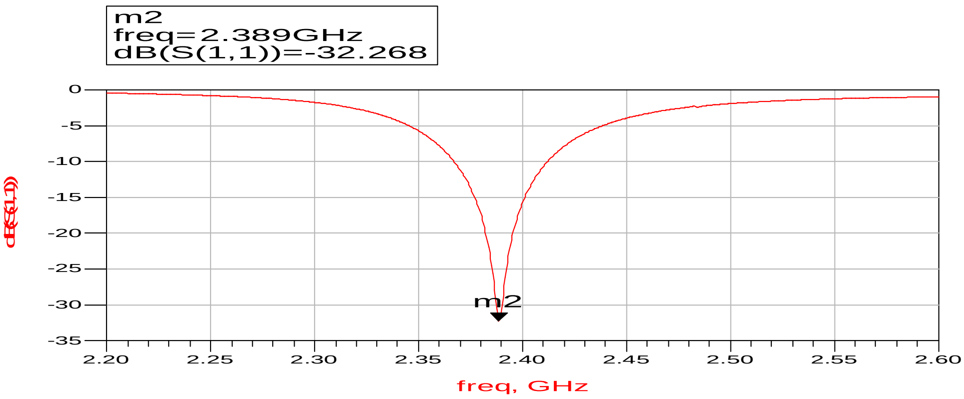

Fig. 4. Simulated Reflection Coefficient for 2.4 GHz frequency.

B. *Radiation Pattern:*

The radiation properties are simulated using ADS and are stable across the operating frequencies. The 3-D radiation patterns for 1.9 GHz and 2.4 GHz are shown in Fig. 5 and Fig. 6.

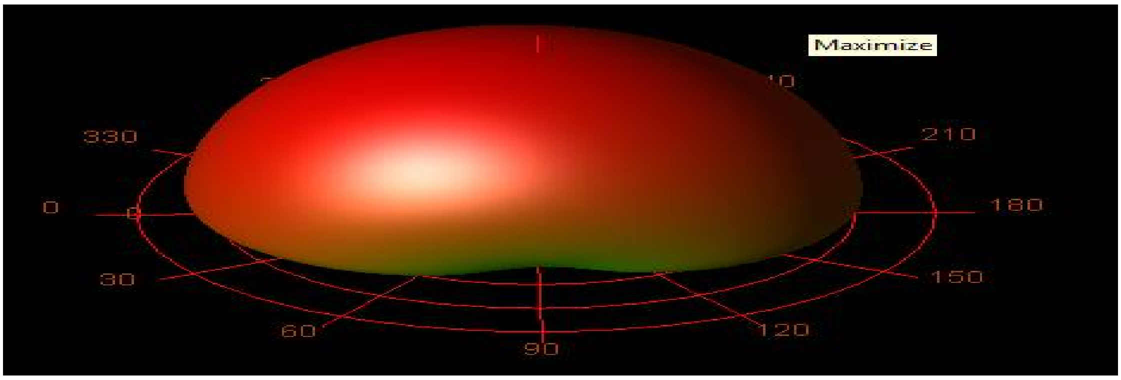

Fig. 5. Radiation pattern for 1.9 GHz.

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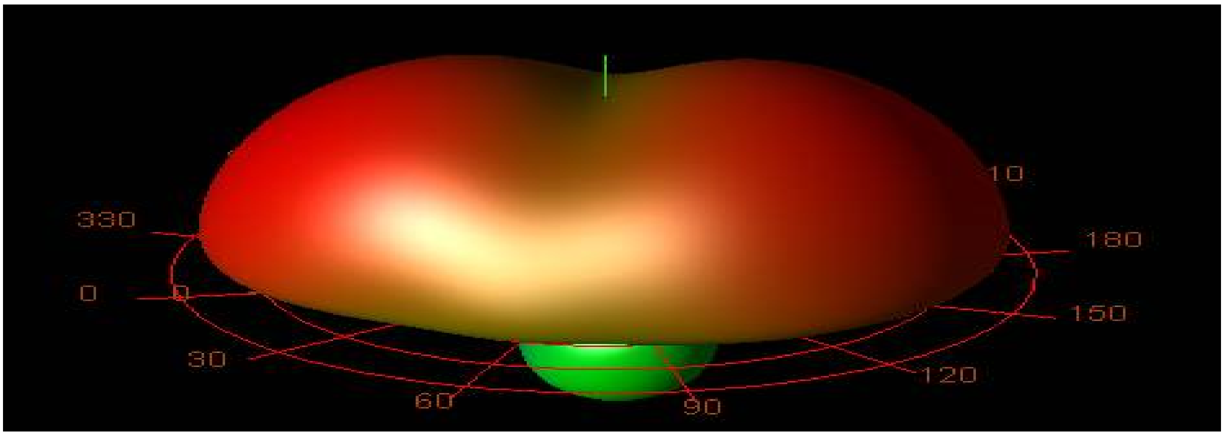

Fig. 6. Radiation Pattern for 2.4 GHz.

C. Antenna Gain and Efficiency:

The gain of the proposed reconfigurable antenna for frequency 1.9 GHz is obtained as 5.2 dBi and for 2.4 GHz is 4.7 dBi. The efficiency for the frequency reconfigurable antenna is 67% for 1.9 GHz and 58% for 2.4 GHz.

V. CONCLUSION AND FUTURE WORK

In this paper, a frequency reconfigurable microstrip patch antenna with varator diode as RF switch has been introduced. Only a single varactor diode has been used for frequency reconfiguration so it reduces the design complexity and the antenna size as compared to [3] **-** [7] and hence it is a very simple design. A bias tee can be used at the end of the coaxial probe feed for both the RF and DC supply for easy fabrication. Simulated results prove that this reconfigurable antenna has improved antenna performances in terms of reflection coefficient compared to the design proposed in [5]. This antenna finds application in cellular communications, wireless applications and also in cognitive radio applications for other unused frequencies at different voltages.

In the future, it is proposed to use additional varactor diodes to have higher capacitances of the varactor diode and also to obtain multiple resonant frequencies for multiple applications by tuning the varactor diodes.

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