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RECONFIGURABLE MULTI-BAND MICROSTRIP ANTENNA WITH DEFECTED GROUND STRUCTURE

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ABSTRACT

With the increase in the number of devices every day, the modern telecommunication world has been advancing to cater to the needs of every individual and has introduced the use of different frequency bands for different applications. This paper presents a multi-band antenna design tuning into different frequency bands which include 1.6 GHz, 2.4 GHz and 3 GHz using RF switches. The design is simulated using Ansys HFSS and the results for the same at the three frequency bands are presented here.

Keywords: reconfigurable antenna, microstrip antenna, RF switches, multi-band antenna.

1. INTRODUCTION

The modern-day mobile communication has been advancing rapidly, and with the increase in the number of devices every day, the need for higher data-rates has been increasing. To cater the same, various new bands are being introduced to cater to different services such as GSM at 0.9 GHz and 1.4 GHz, Wi-Fi at 2.4 GHz and 5 GHz (ISM Bands), Bluetooth at 2.45 GHz, and so on [1]. To cater to all such bands, multiple antennas are used in wireless devices such as smartphones, which introduces complexity to the mobile system, and hence new innovative antenna designs are being explored to operate on different resonant frequencies and hence cater to the user with all possible applications.

With the introduction to new technologies such as the internet of things [2] and vehicle-to-vehicle communication [3], the need for innovative antennas at different frequencies has been rising further. Microstrip patch antennas being easy to design, lightweight, and cost-effective, have been considered as one of the most suitable candidates for applications in almost all wireless communication systems. Various different iterations of microstrip patch antenna have been presented in the past for applications in mobile communication, Wi-Fi, Bluetooth, Wi-Max, radio systems, satellite, etc.

Reconfigurable microstrip antenna is a new area that is being explored by researchers and engineers all around the world. The Reconfigurable antenna helps in switching between different frequency bands and hence helps in operating multiple-bands using the same antenna [4]. Reconfigurable antennas can be achieved by using parasitic elements around the main patch or using active lumped components such as PIN diodes, RF MEMS switches, etc.

This paper presents a novel microstrip antenna design using four pin diodes to switch between three frequency bands, 1.6 GHz, 2.4 GHz, and 3 GHz. Using the pin diodes, the frequency bands are shifted by a change in patch dimensions. The next section explains the design methodology for patch antennas, followed by section 3 describing the proposed reconfigurable patch antenna design. The section further describes the equivalent circuit model of pin-diode and how the same is being used to change the frequency bands in the patch antenna, followed by discussing the results and conclusion in the last section.

2. REVIEW OF LITERATURE

Nand Kishore *et al.*, [5] recommended a circularly polarized multiband microstrip patch antenna for ITS applications. This antenna works for six band and can be used for Dedicated Short Range Communication, Global Positioning System, WiMAX, etc. It has a modified T shaped patch and a defected ground for improved performance. This antenna is suitable for modern ITS applications at 5.9 GHz frequency give 17% of bandwidth.

Mudasar Rashid *et al.*, [6] suggested a miniaturized Microstrip Patch Antenna (MSA), without deteriorating its other parameters, such as gain, bandwidth, directivity and return loss. A significant amount of 89% miniaturization has been made possible by careful and meticulous investigation of slots insertion in patch and ground of MSA antenna. Dielectric substrate used in this design is polyester which has shown better result. As the focus of this design is to miniaturize the MSA, the technique used here is Defected Ground Structure (DGS), along with Defected Patch Structure (DPS) which actually shifted the resonant frequencies to the lower range without increasing its physical dimensions. The shorting pin is also introduced between patch and ground for enhancement of parameters like gain and return loss. The pin position played an important role in the acquirement of better performance and radiation at desirable frequency band. Different shapes have been designed on Ground and Patch to obtain enhanced results. With the use of DGS, the designed antenna started radiation at multiple frequency bands. The frequency bands generated by this designed antenna are in the range of L band and S band of IEEE standard which made it apposite to use in variety of applications.

M. Mabaso *et al.*, [7] suggested a triple band microstrip antenna with the rectangular patch which is loaded with slots and the ground is made defective for achieving triple band operation. The design is optimized

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and simulated using CST microwave studio simulator for triple mode operation at 1.2 GHz, 2.45 GHz and 5.6372 GHz. The reflection coefficient plot of this antenna confirms the triple band characteristics. The maximum gain and maximum directivity of the antenna are 6.307 dB and 7.279 dBi, respectively. This antenna is suitable for wireless video transmission, wireless security systems, industry, scientific and medical (ISM) radio, and wireless local area networks (WLANs) applications.

M. Jenath Sathikbasha *et al*., [8] suggested a novel printed rectangular shape, multi-band frequency reconfigurable antenna with defected ground structure (FRDGS) for multi standard wireless communication systems. Here the ground plane is modified by embedding U shaped slots with open ends and I shaped slot in short ends to realize the multi band frequency of the antenna and to improve the parameters of the antenna design. The two U shape slots are etched symmetrical to each other to reduce the cross polarization of the antenna. The DGS in the ground plane altered the modeling characteristics of transmission lines with the equivalent values of inductance, capacitance and resistance. Three PIN diodes are inserted in the ground plane to acquire the switching characteristics of multi-resonance frequency. Simulated and measured output clearly depict that the antenna proposed is efficient to change between twelve dissimilar resonant frequency bands centered at 1.36, 1.8, 3.0, 3.9, 5.0, 6.2, 6.4, 7.4, 7.9, 8.2, 8.4, 8.6 GHz through different states of modes over the frequency spectrum from 1.33 to 8.7 GHz. The parameters such as reflection coefficient, VSWR, 2D and 3D radiation pattern, bandwidth, peak gain, peak directivity, gain and directivity are simulated using Ansoft HFSS 17.0v. It is used in various wireless communication system such as Wi-Fi (5 GHz), WLAN (5 GHz), WI-MAX, UWB (3.1-10.6 GHz) system, fixed mobile and satellite communication systems.

A Guruva Reddy *et al*., [9] recommended a novel compact Slotted Microstrip patch antenna with Defected Ground structure (DGS) operating for Wireless and satellite communication applications. This antenna generates six different resonances operate at 3.3 GHz (WLAN), 5.1 GHz (WiMAX), 5.9 GHz(Satellite Application), 7.12 GHz(Earth Exploitation Satellite), 10.4 GHz(Mobile & fixed Radio location) and 13.1 GHz(Satellite Application) while maintaining overall compact size of 32x32x1.6 mm3 using a FR-4 substrate commonly available with a permittivity of er = 4.4. This microstrip Patch Antenna (MSPA) consists of a square radiator in which a Log Periodic slot is etched out along with square defects on ground surface and a Microstrip feedline. The slotted patch with DGS modifies the total current path thereby making the antenna to operate at six useful bands. The structure shows the impedance bandwidth of3%, 3.3%, 5.2%, 14.7%, 5.6% and 9% with gains 3dB, 3.8dB, 2dB, 1.8dB, 3.1dB and 4.82dB respectively.

3. DESIGN METHODOLOGY

Dimensions of a rectangular patch antenna are dependent on the electromagnetic properties (electric permittivity and loss tangent) and thickness of the substrate. [10] presents the design equation for a microstrip patch antenna. The width of the microstrip patch antenna is calculated using eq. (1),

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\epsilon_r+1}} \quad (1)$$

Where c is the speed of light, f_r is operating frequency, ϵ_r is the dielectric constant of the material.

The length of the patch is defined using eq. (2),

$$L = \frac{c}{2f_r\sqrt{\epsilon_{reff}}} - 2\Delta L \quad (2)$$

Where ϵ_{reff} is the relative effective permittivity of the material, calculated because of fringing lines generated in the surrounding of the material and is calculated as,

$$\epsilon_{reff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left(1+\frac{10h}{W}\right)^{-\frac{1}{2}} \quad (3)$$

And electric length extension is defined as,

$$\frac{\Delta L}{h} = 0.412\frac{(\epsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\epsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)} \quad (4)$$

Where h is the height of the substrate. The length and width of the substrate are kept slightly bigger than the width and length of the patch. Using these equations, the width and length for the patch antenna are calculated at the three frequency bands.

The proposed antenna design has a rectangular patch divided into three parts. Evident from equation (1) and (2), and width and length of the patch are inversely proportional to the operating frequency, and hence the patch for 3 GHz will be larger compared to that of 3.6 and 6.5 GHz. The patch is divided in a way that the smallest of the three is designed for 6.5 GHz if the smallest and middle part is combined together, it operates at 3.6 GHz and if all the three works together, it will operate at 3 GHz. Figure-1 shows the proposed antenna design. A circular ring slot has been placed on the ground layer to optimize the design for the specified frequency bands. The design is made on an FR-4 substrate of height 1.6 mm and a dielectric constant of 4.4. The dimensions of the antenna are specified in Table-1.

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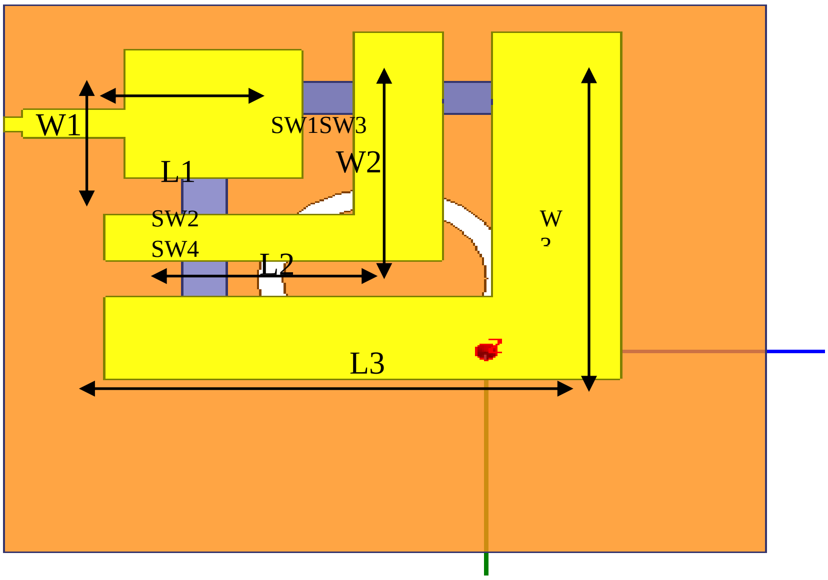

Figure-1. Proposed microstrip patch divided into three parts with defected ground structure.

Table-1. Dimensions of the proposed antenna design.

Dimension	Value	Unit
W1	38	Mm
W2	25	Mm
W3	14	Mm
L1	40.5	Mm
L2	26.5	Mm
L3	14	Mm

The blue joints between each element are PIN diodes and can be switched on or off to connect or disconnect further parts of the patch.

3.1 SWITCHING PROCESS

The PIN diode switches are used for switching between different frequencies and hence adding the reconfigurable nature to the design. A PIN diode can act as an ON switch when forward biased and as an OFF switch when reverse biased.

The proposed design uses 4 PIN diode switches (shown in blue in Figure-1) that can be controlled to select the operating frequency. Table-2 presents the three cases on the basis of switch configuration.

Table-2. Switch configurations.

SW1	SW2	SW3	SW4	Freq. (GHz)
ON	ON	ON	ON	1.6 GHz
ON	ON	OFF	OFF	2.4 GHz
OFF	OFF	OFF	OFF	3 GHz

A pin diode can be seen as an RLC circuit. Figure-2 shows the equivalent circuit model used for this design in both ON and OFF mode for the pin diode.

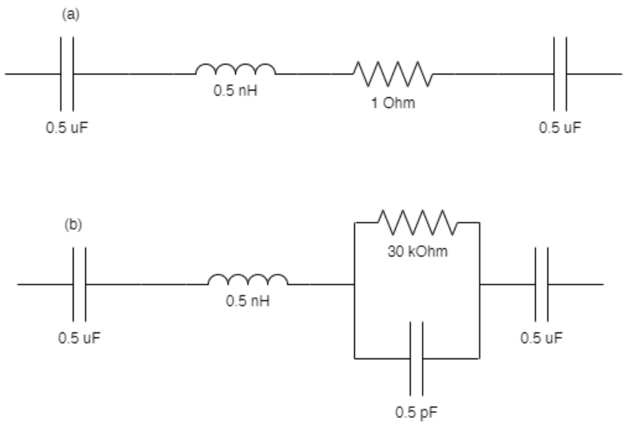

Figure-2. Pin diode equivalent circuit model in forward bias or ON and in reverse bias or OFF.

Hence, using the pin diode, the size of the patch is being varied and a reconfigurable antenna is presented. The next section discusses the results of the proposed antenna design.

4. RESULTS

As discussed earlier, the designed antenna can operate at three different frequency bands, and the same can be seen in Figure-3. Figure-3 presents the return loss for the antenna in the three cases (as described in Table-2). The voltage standing wave ratio (VSWR) is observed to be below 2.0 for all three bands in three cases respectively. All three bands provide a 10dB bandwidth of almost 200 MHz and have an efficiency of 86%, 88%, and 87.2% for the three cases, respectively.

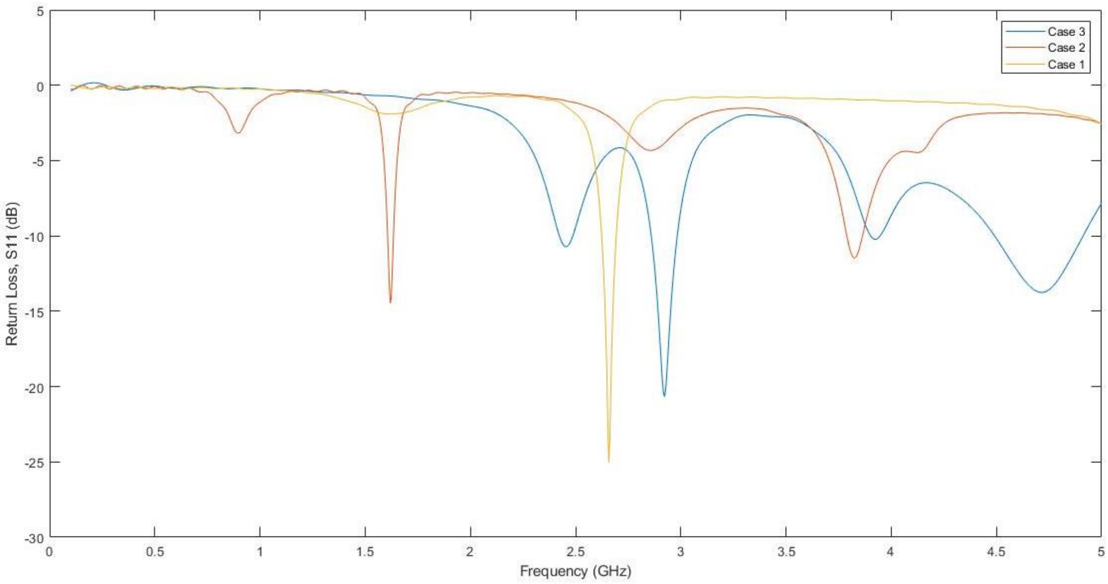

Figure-3. Return loss vs. frequency for 3 cases.

Figure-4 presents the radiation pattern for the antenna presenting a gain of about 6.7 dBi for all three cases.

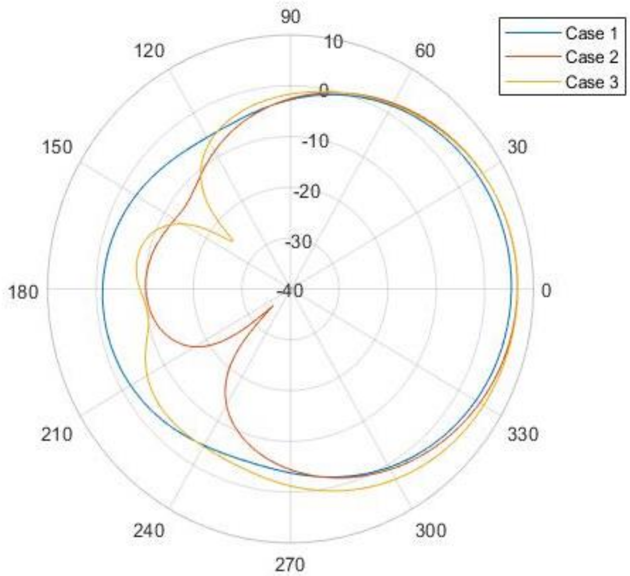

Figure-4. Radiation Pattern for the three cases of proposed reconfigurable microstrip antenna.

5. CONCLUSIONS

A multi-band reconfigurable microstrip patch antenna has been presented operating at three frequency bands, 1.6 GHz, 2.4 GHz and 3 GHz using 4 PIN diodes to switch between the three frequency bands. The same technique can be used to build an antenna for switching between multiple other frequency bands. The average efficiency of 87% has been presented through the proposed design with the directivity of 6.7dBi. The bandwidth for all three bands is measured above 200 MHz. All the simulations are done using Ansys high-frequency simulation software (HFSS).

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