Reconfigurable Antenna for sub-6 GHz and C band Applications

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Abstract

The future of 5G New Radio (NR) development has many significant concerns. To overcome the working frequency band issue, a frequency-reconfigurable patch antenna based on pin diodes is presented and investigated. The antenna's compact dimensions (30 mm x 20 mm x 1.6 mm) are due to its construction on FR-4 substrate material with a relative permittivity of ε_r = 4.4. A feed port and two switches allow frequency reconfiguration in the antenna module. C-band service is provided by this antenna module's ability to switch between operating at 3.4 GHz, 4.8 GHz, and 7.5 GHz. Simulation of the proposed antenna is accomplished in the CST microwave studio. The presentation and discussion of the radiation pattern and S parameter demonstrate the feasibility of the proposed antenna. Antenna module's size and performance are both precisely appropriate.

Keyword: Reconfigurable Antenna, sub-6 GHz, C band applications

1. Introduction

Due to the increasing demand for modern wireless communication services, frequency-reconfigurable antennas have emerged as a solution for efficiently using the frequency spectrum [1]. A reconfigurable antenna's resonant frequency can be altered simply by changing the antenna's structure, with no effect on emission patterns or polarization. Therefore, frequency-reconfigurable antennas can be used across a broad arrangement of frequency bands or numerous frequency bands [2]. It has proven difficult to successfully convert an antenna into a device that can be reconfigured by using various approaches to change the internal structure of the antenna. A variety of factors must be regarded, including establishing a decent gain, good efficiency, a reliable radiation pattern, and a good impedance match across the antenna's entire range of operation states [3]. Several studies of patch antennas have been carried out to achieve frequency-or polarization-selective functionality. The antenna proposed in [4] could operate at dual frequencies while preserving its LP feature [5] proposed a switchable dual-band patch antenna with the circularly polarized (CP) characteristic. RHCP, which stands for left-hand circular polarization, was used by the antenna described in [6]. In reference [7], a slot antenna with the ability to show polarization diversity was shown.

A reconfigurable microstrip-patch antenna with frequency diversity features is proposed in this paper. The antenna is successfully simulated, and the simulation results are presented.

2. Microstrip Patch Antenna

A microstrip patch antenna is one type of antenna. This is the most commonly used type of antenna. It comprised of a conducting patch on one side of a dielectric substrate and a ground plane on the opposite side of the substrate. The conducting patch can have any planar or non-planar geometry. The metallic patch is regularly made of a conducting material such as copper, gold, tin, or nickel, and the metal itself must be corrosion resistant. The patch's shape could be changing from rectangular to circular to ring-shaped, for example. Microstrip patch antennas are characterized by their low-profile configuration and their capacity to operate at dual and triple frequencies [8]. Because of these benefits, these antennas are best suited for use in applications related to aerospace and mobile devices. Their primary drawbacks, however, include a restricted bandwidth, poorer gain, and extraneous radiation from both the feed and the junction[9]. These restrictions can be overcome by further loading these antennas with stubs, shorting pins, and diodes to achieve compactness, dual frequency operations, frequency agility, and polarization control. This will allow the antennas to function more effectively. Consequently, these antennas are discovered. Increasing commercial applications, particularly in Global Positioning System (GPS), Satellite Digital Audio Radio Services (SDARS), and Wireless Local Area Network (WLAN) [10], [11].

An effective dielectric constant (εreff) can be obtained by:

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

Where,

ε_{reff} = effective dielectric constant

ε_r = dielectric constant of substrate

h = height of dielectric substrate and

W = width of the patch.

In Fig. 1 we can see a rectangular microstrip patch antenna with dimensions of L x W x h sitting on a substrate of height h. Co-ordinate axes are chosen so that x represents length, y represents width, and z represents height.

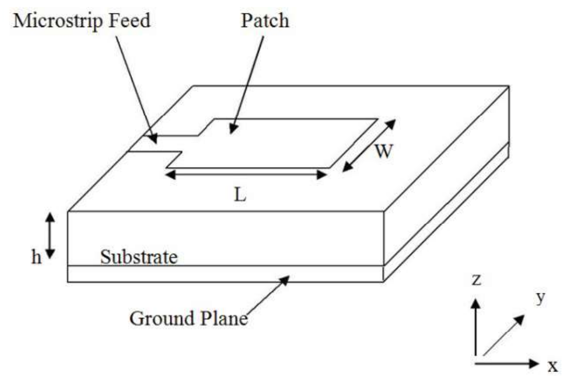

Fig 1. Microstrip Patch Antenna

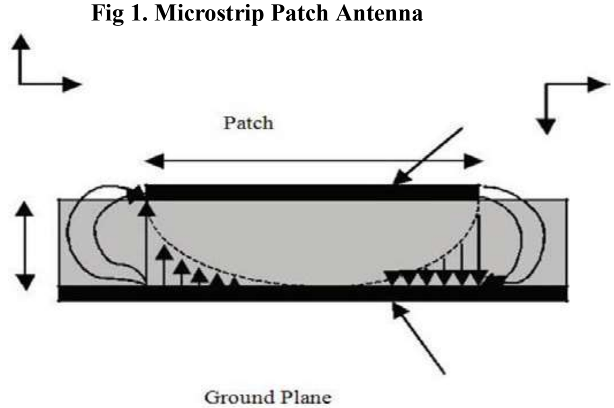

Fig 2. Side View of Antenna

We can deduce from Fig. 2 that the electric field normal components along the two edges along the width are in opposing directions and out of phase because the patch is λ/2 long, and thus cancel each othe out along the broadside direction. The tangential components must be in phase with one another in order to maximize the radiated field normal to the structure's surface (as shown in Figure 2). As a result, the edges of the width can be modeled as two excited slots separated by a phase shift of /2 and radiating in the half space above the ground plane. Each end of the patch has been lengthened by an amount L, which is empirically supplied as [12].

$$\frac{\Delta L}{h} = 0.412\,\frac{(\varepsilon_{rff}+0.3)\left(\frac{W}{h}+0.264\right)}{\left(\varepsilon_{ref}-0.258\left(\frac{W}{h}+0.8\right)\right.} \quad (2)$$

The effective length of the patch Leff becomes:

$$L_{eff} = \mathrm{L} + 2\Delta \quad (3)$$

$$L_{eff}\,\frac{C}{2f_0\sqrt{\varepsilon_{ref}}} \quad (4)$$

$$f_0 = \frac{c}{2\sqrt{\varepsilon_{rff}}}\left[\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2\right]^{\frac{1}{2}} \quad (5)$$

$$W = \frac{C}{2f_0\sqrt{\frac{(\varepsilon_r+1)}{2}}} \quad (6)$$

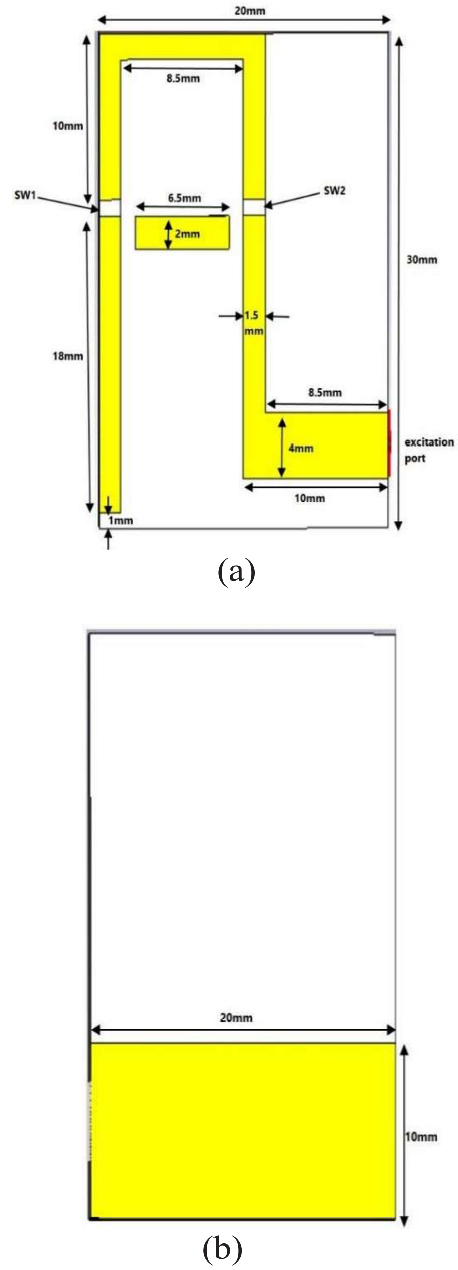

Fig 3. The proposed reconfigurable micro strip-patch antenna's geometry (a) top view, (b) bottom view

3. Design of antenna

Fig. 3 below depicts the proposed geometry of the reconfigurable microstrip patch antenna.

This model uses a 1.6-mm substrate with a 4.4-relative permittivity to create a 30x20-mm patch supplied by a single feeder. Figure 1 shows an n-by-n slot. Antenna employs PIN diodes. PIN diodes generate a reconfigurable circle to tune frequency.

PIN diodes prevent excessive RF voltages in low-distortion toggles. This diode works best at 3GHz. Figure 4 shows the device's PIN diode circuit. The PIN diode's OFF state was modeled as a parallel setup with 3K and 0.17pF. ON PIN diode was a 2.1 resistor. Switching the diode enabled a dual-frequency, continuous band. In n-slot side apertures, PIN diodes are installed. Toggle diodes to modify antenna frequency diversity. If both diodes are on, current passes directly through them and the antenna's lower resonance frequency of 3300 MHz is reached. This lengthens the current route, and the LP antenna resonates at 4250 MHz.

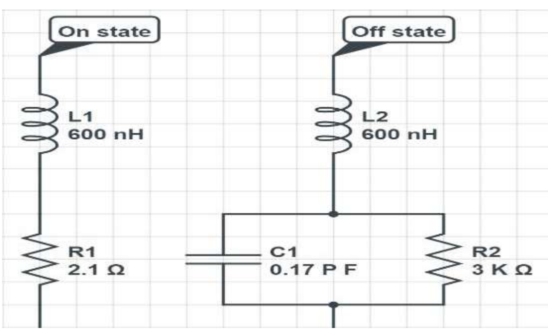

Fig 4. PIN diode equivalent circuit

There are two resonant frequency areas of about 4350 MHz and7500 MHz where the wave can be produced when diode 1 is off and diode 2 is on.

4. Results & discussion

Assuming the previous analysis holds true, the ground dimensions = 20 mm x 10 mm, and the switching condition of both diodes looks like the following. Here are some photographs from a simulated examination of the proposed antenna module.

The proposed antenna's computed S parameters are displayed in Fig. 5 below.

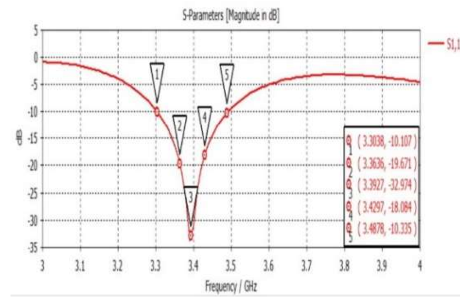

Fig 5. (a) SW1 off, SW2 off

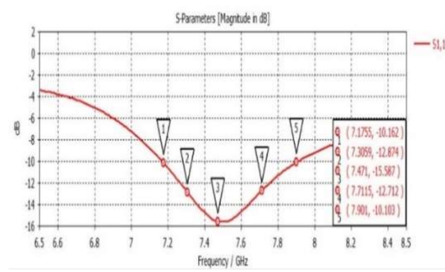

Fig 5. (b) SW1 off, SW2 on

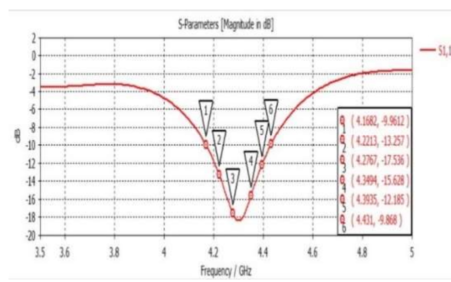

Fig 5. (c) SW1 off, SW2 on

The simulated Impedance matching of the proposed antenna is shown in Fig. 6 below:

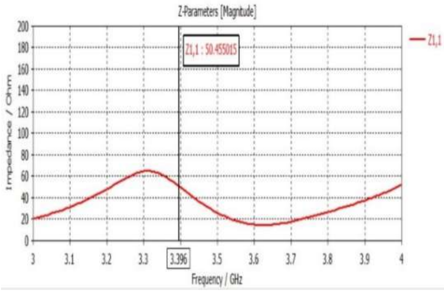

Fig 6. (a) SW1 off, SW2 off

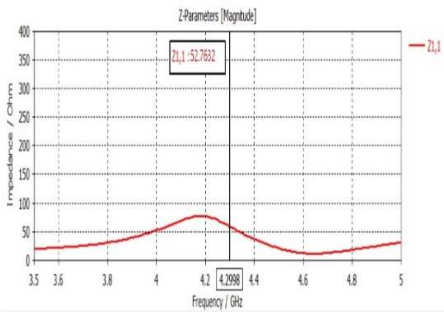

Fig 6. (b) SW1 off, SW2 on

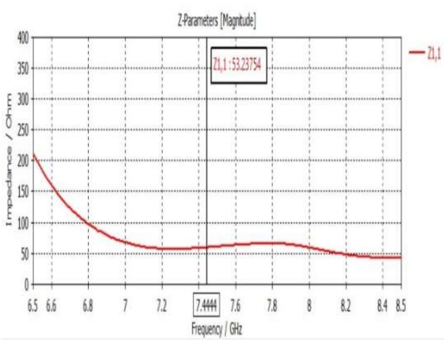

Fig 6 (c) SW1 off, SW2 on

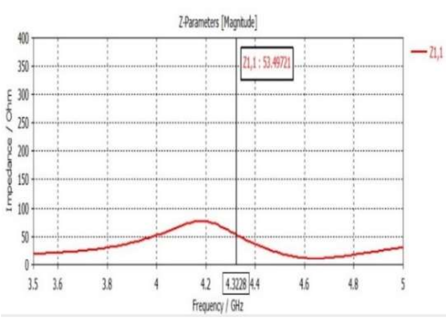

Fig 6. (d) SW1 on, SW2 on

The simulated radiation efficiency of the proposed antenna is shown in Fig. 7 below:

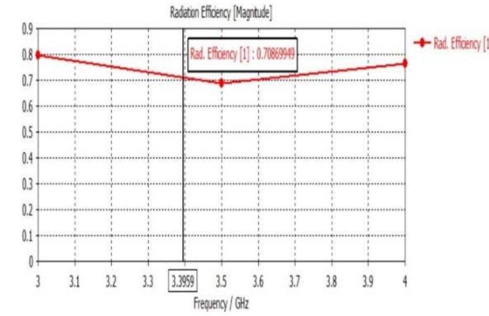

Fig 7. (a) SW1 on, SW2 off

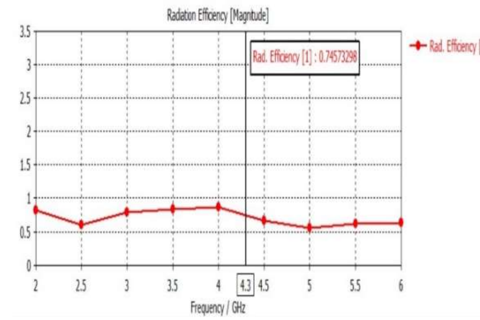

Fig. 7 (b) SW1 off, SW2 on

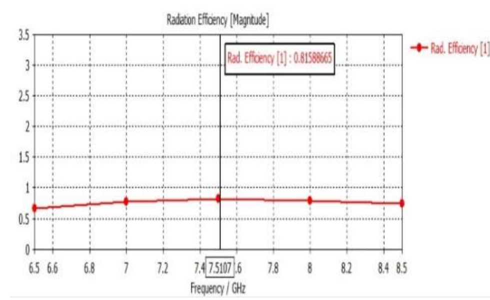

Fig 7. (d) SW1 off, SW2 on

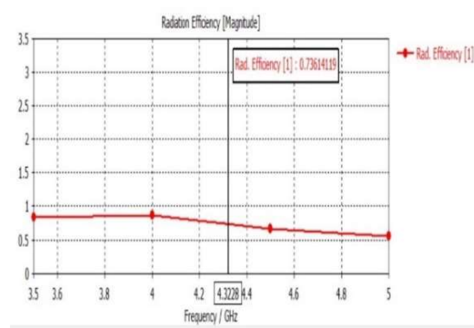

Fig 7. (c) SW1 on, SW2 on

When the frequency reconfigurable antenna module is used in the 3.3 GHz-3.5 Ghz frequency band, S11 characteristics are below-15 dB and can reach -35.23 dB at the center frequency, as shown in the figures above. As an additional benefit, the efficiency of radiation at the fundamental frequency is almost 80%. It means that the antennas are a good complement to one another. When the antenna covers c bands 4.2 GHz-4.4 GHz, the return loss parameters are best than -12.91 dB, with an ideal value of-16.92 dB. The radiation efficiency at the central frequency is close to 75% with minimal frequency shift and excellent antenna matching. The antenna operates at frequencies ranging from 7.2 to 7.8 GHz, and its return loss characteristics are better than -12.31 dB, with an optimum value of -15.54 dB. Assuming there isn't much frequency shift and the antenna is perfectly matched, the antenna's radiation efficiency is close to 81% at the most important frequency.

5. Conclusions

This paper presents a design for an antenna module that utilizes frequency-reconfigurable technology and is suitable for mobile terminal devices. Applying a biasing circuit to the switching group can be toggled between four operating frequency modes. The mobile terminal for 5G spectrum applications is met by the 10-dB impedance bandwidths of 11.8% and 14.8% of the resonance frequency, encompassing 3.4 GHz (3.3-3.6 GHz), 4.3 GHz (4.2-4.4 GHz), and 7.5 GHz (7.2 -7.8 GHz). The simulation results also show that the reconfigurable frequency antenna has a good match and an S11 greater than -15 dB, regardless of the operating resonant frequency.

6. References

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