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# Design a Frequency Reconfigurable Antenna for 5G\6G Applications

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## Abstract:

In present scenario, a lot of attention has been gained by the antennas operating on multiple frequency bands (4.3 GHz, 4.5 GHz, 5.2 GHz, 5.8 GHz, 7.5 GHz) due to the expansion of modern wireless technology and the demand for the multiple services in a single device. The proposed design which is effortless, changeable and pliable frequency reconfigurable antenna uses a flexible roger RT/duroid 5880 (0.508 mm thickness) as a substrate with the miniature dimensions of $30 \times 28.4$ mm$^2$. The resonant frequency can be controlled by adjusting the mode of switches through bricks either in connected or disconnected state. The two bricks are arranged on the surface of an antenna which is used to change the current distribution thus accordingly changes the resonant frequency under different conditions of the switch. The proposed reconfigurable antenna is very much useful for different recent 5G\6G communication applications and this antenna is designed using CST tool. The simulated antenna has VSWR < 2 and a good radiation pattern.

## Keywords:

Flexible Antennas, frequency reconfigurable antenna, switches, roger RT/duroid 5880, current distribution, resonant frequency.

## 1. Introduction

The rapid expansion of wireless technology during the last years has led to increase in demand for miniature, affordable and multiband antennas for commercial communications systems. In the recent year, the reconfigurable antennas are very helpful to improve the performance up to maximum level of a radio frequency (RF) system. This kind of antennas can facilitate the future and advance generation of wireless communication and mobile systems. By using other techniques the parameters can be achieved with the help of active elements such as switches or capacitor. A wireless system may reduce the complexity, size and cost if the front-end circuitry parameters are reconfigurable such as frequency, pattern and polarization.

The switches such as RF-MEMS [1] (Radio Frequency – Micro electro mechanical systems), varactor diodes [2], PIN diodes [3] and well as the optically activated switches can be used to change antenna characteristics. A high switching speed has a great advantage to change the antennas operation fast. The ranging of RF-MEMS switches lies between (1–200) ns, which is normally low for most applications. An antenna (which is embedded with a varactor diode) can have wide tuning range at the cost of very high nonlinearity. While, a PIN diodes can be used in reconfigurable antenna system designs due to its fast switching (1–100) ns, which helps fast dynamic reconfiguration.

The switches are employed to change the electrical length of the resonator which is subsequently changes the resonant frequency. Thus, by applying switches at an appropriate location in the proposed design, frequency reconfiguration is possible for different applications like aeronautical radio navigation, AMT fixed services, WLAN, Unlicensed WiMAX and X-band. Microstrip based frequency and pattern reconfigurable antenna is discussed in [4] that utilizes five pin diode, which consists of three operating modes; omni-directional at 2.4 GHz, unidirectional operating respectively. In [5], frequency reconfigurable antenna utilizes a thick substrate (3.3 mm thickness) is presented in which resonance is operated by shorting strips; in addition to that, the conical radiation pattern is maintained on a par with higher frequencies. A compact frequency reconfigurable antenna suggests a simple square shaped radiating patch for Bluetooth, WLAN and WiMAX applications. Three pin diodes are attached in the ground plane that controls switching bands. A novel frequency reconfigurable antenna is designed byutilizing the FR4 substrate that operates between an ultra wide band, narrow band, and a dual band mode in [6]. Switching is achieved by four pin diodes along with the slotted structure that is attached on the ground plane. Microstrip based frequency reconfigurable antenna is discussed in [7].Nevertheless, the designs which are mentioned above undergoes some drawbacks; primarily is their larger dimensions, next it is limited to certain impedance bandwidth and finally its design complexity in terms of number of switches and tangled structure.

In these days, as discussed earlier flexible antennas grabbed a lot of priority because of their user friendly characteristics like low profile, thin weight, robustness[8]. In [8-12], we have presented different types of substrates which are flexible. The crescent-shaped antenna using flexible RO4003 Rogers[14] with impedance bandwidth of 7.1 GHz is presented in [8]. Flexible Liquid Crystal polymer as a substrate in Dual frequency rejection at 5.25 GHz and 5.775 GHz is proposed and successfully achieved in [9]. Multi-band antenna using Kapton® polyamide as a substrate is presented in [10]. For 2.4 GHz WLAN application, which is paper-based antenna is demonstrated in [11]. Non reconfigurable functions of the flexible antennas are discussed above. There are several feeding techniques are being used in flexible antennas, however the most preferable feeding technique is coplanar waveguide which reduces the disadvantages by placing an antenna element and a patch on the same side of the substrate which is coplanar waveguide for different applications like WLAN and WiMAX. The only drawback is gain is comparatively low and the fabrication process costs more[12].

In the proposed design, a simple, flexible frequency reconfigurable antenna is put forwarded. Here both pliable and changeable properties are additionally added in this design which makes more understandable and easily designable which is also conformal and useful for many applications. Bricks are employed to change the electrical length of the radiator which in turn changes the resonant frequencies. Thus using this design we may apply it for 5G applications. From this our main contribution is for 5G applications like Aeronautical Radio Navigation (ARN), AMT fixed services, WLANWiMAX and X-band applications. Useful frequency bands are drawn by applying bricks accordingly to operate different frequencies in the antenna. Gain and bandwidth enhancement using pliable substrate.

## 2. Antenna Design and Reconfiguration

The proposed antenna design is depicted in figure. 1. The proposed frequency reconfigurable antenna consists of a flexible Rogers RT/Duroid 5880 as a substrate. The loss tangent is 0.0009 with a thickness of 0.508 mm and the dielectric constant of the substrate is 2.2. The miniature dimensions of the proposed antenna are of size 30 mm × 28.4 mm. The antenna is fed by a 50 Ω microstrip line.

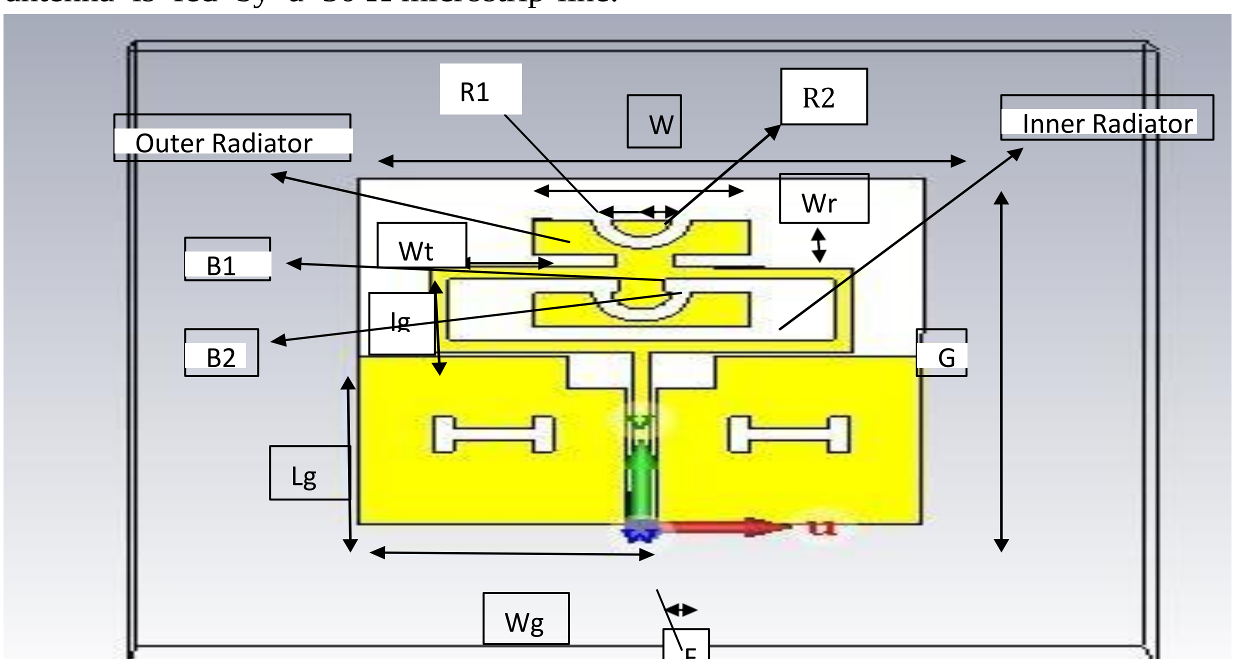


**Fig. 1:** Antenna Design (Top View). Yellow region representsmetal and white represents substrate.

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The Co-Planar Waveguide feed line consists of the width 1 mm is connected to the main radiator. The inner and the outer radiator is connected to the main radiator via bricks. Primarily, CPW fed rectangular antenna which has a single band at 4.214 GHz is designed. The rectangle is introduced inside and outside the main radiator to acquire more resonance frequencies. The arc-shaped slots are introduced in appropriate locations in the inner and outer rectangle to obtain the desired band. The width of slot controls the current intensity and minimizes the return loss. The bricks condition is used to implement the switches in CST® MWS®. Different parameters are described in Table 1.

**Table 1:** Optimized parameters

| Name | Values (mm) | Name | Values (mm) |
|---|---|---|---|
| W | 28.4 | Gx | 3.5 |
| L | 30 | Wt | 5.2 |
| st | 0.508 | wr | 11 |
| Wg | 13.45 | M | 5.3 |
| lg | 14.642 | G2 | 1.15 |
| ct | 0.035 | Ir | 3 |
| G1 | 0.25 | R2 | 2.5 |
| F | 1 | R1 | 1.5 |
| G | 0.358 | D | 5.5 |

## 3. Results and Discussion

The simulation is done on the proposed antenna. The description of states (1 to 4) in terms of the position of the two bricks is tabulated in Table. 2. The position of the brick, i.e.

whether the brick is connected or not actually defines the electrical length of the antenna structure that contributes for radiating a particular frequency band. B1 and B2 are the bricks that are implemented using conductor/conducting wires between two conductors to provide the path. Actually diodes can be used to provide the path, but this conductor is used because of limitations. When both B1 & B2 are shorted simultaneously, the current circulates in the main radiator as well as in the inner and outer radiator. When both B1 and B2 are open, the current circulatesonly in the main radiator.

**Table 2:** Configurations

| States | B1 | B2 | Frequency (GHz) |
|---|---|---|---|
| State 1 | ON | ON | 4.2 & 7.5 |
| State 2 | ON | OFF | 5.1 |
| State 3 | OFF | ON | 4.3 |
| State 4 | OFF | OFF | 5.5 |

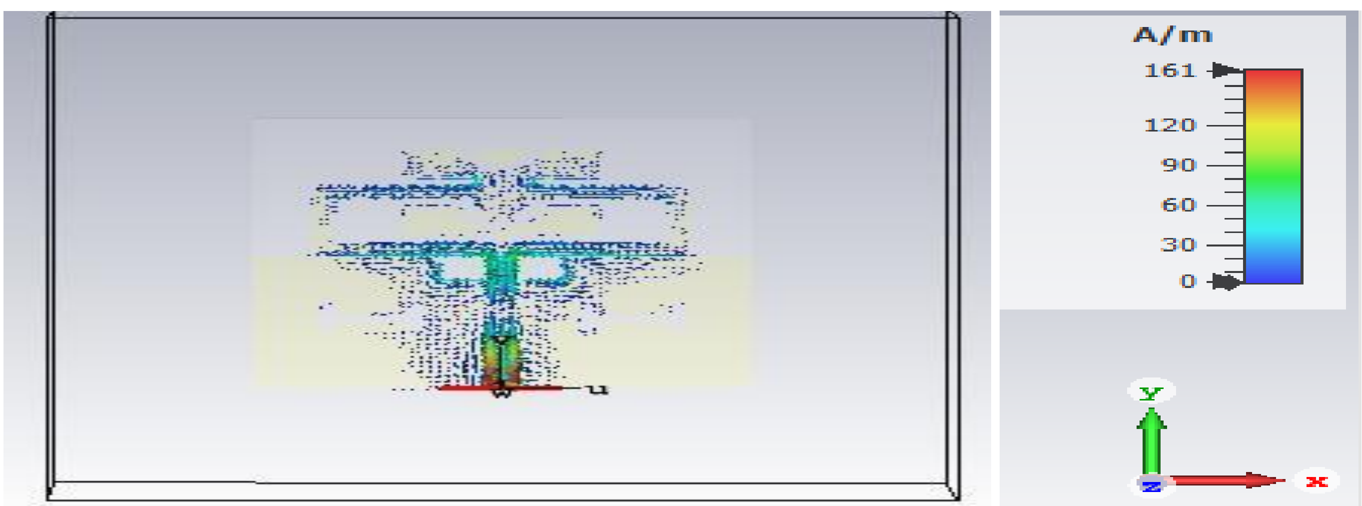


**Figure 2:** current distribution at 4.2 GHz

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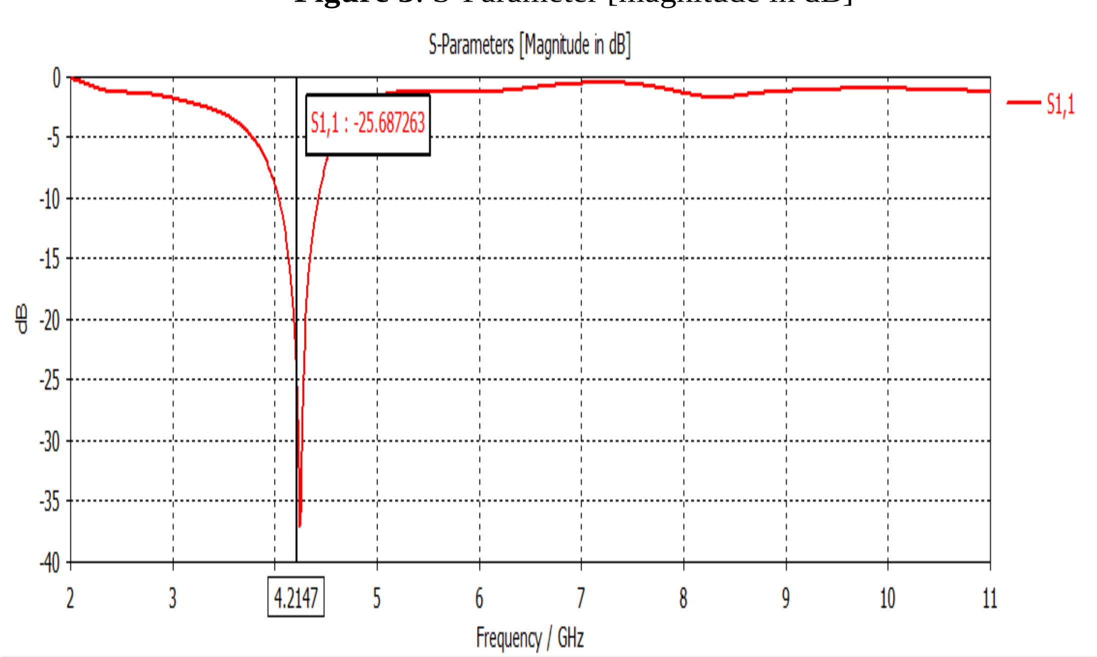
The simulated surface current distribution of the proposed antenna at various frequencies under different states of switches is shown in Figure 2 suggests that inner radiator radiatesdue to coupling with surrounding walls of the main radiator. The main radiator and the outer radiator also radiate. In this case, the current follows the longer path, hence antenna resonates at a low frequency of 4.2 GHz with an impedance bandwidth of 630 MHz (3.9–4.53 GHz) that covers 4.3 GHz Aeronautical Radio Navigation. Due to strong current intensity around B1 and B2 another frequency band from 7.2 GHz to 7.8 GHz with an impedance bandwidth of 600 MHz is also observed in state 1. It is noticed that in state 2 the antenna covers the frequency range of (4.7– 5.4 GHz) with an impedance bandwidth of 700 MHz that covers 5.2 GHz WLAN. The impedance bandwidth in state 3 is 700 MHz (3.9–4.6 GHz) that is sufficient for the standard of 4.5 GHz AMT Fixed Services. In state 4, the only main radiator is contributing to the radiation, hence, current follows the shortest path so, and resonance at 5.5 GHz with a very wide bandwidth of 1 GHz (5–6 GHz) is achieved. It covers 5.5 GHz WLAN and 5.8 GHz unlicensed Wi-MAX. As mentioned earlier that single rectangular antenna operates at 5.8 GHz. Therefore, the change in frequency from 5.8 GHz to 5.5 GHz is due to the presence of strong coupling that exists in the gap between the main radiator, arc-shaped radiators and around the bricks.

**Figure 3**: S-Parameter [magnitude in dB]



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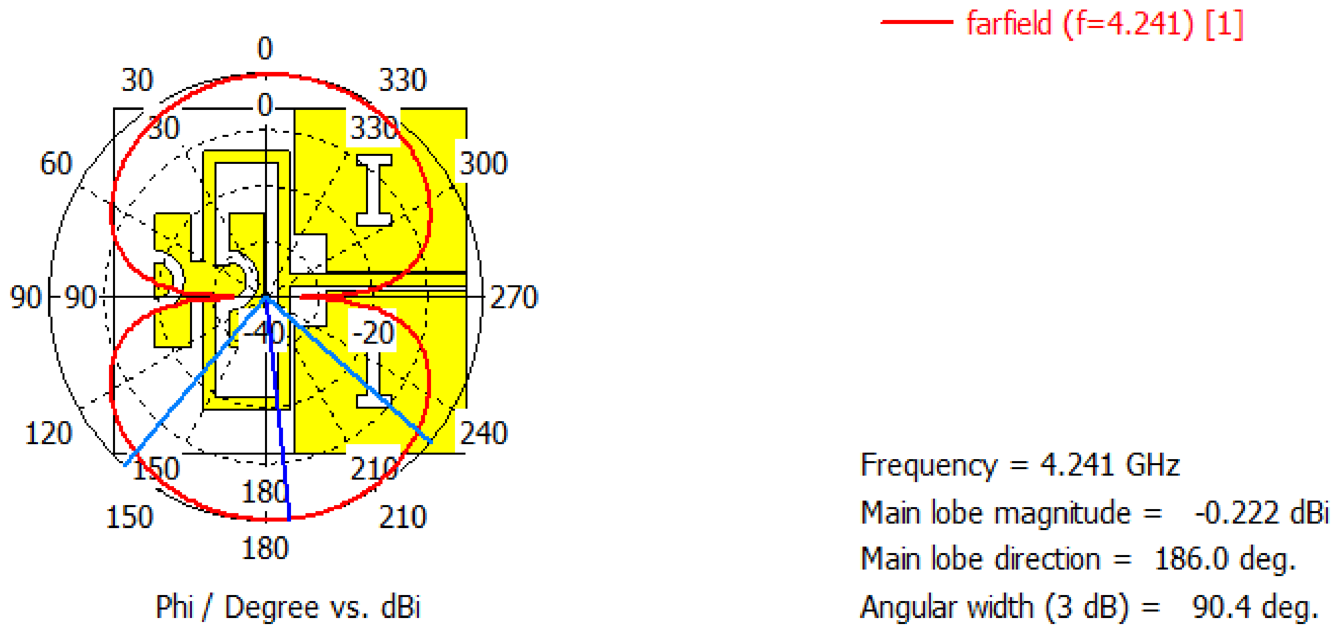


**Figure 4:** Radiation pattern at 4.2GHz.

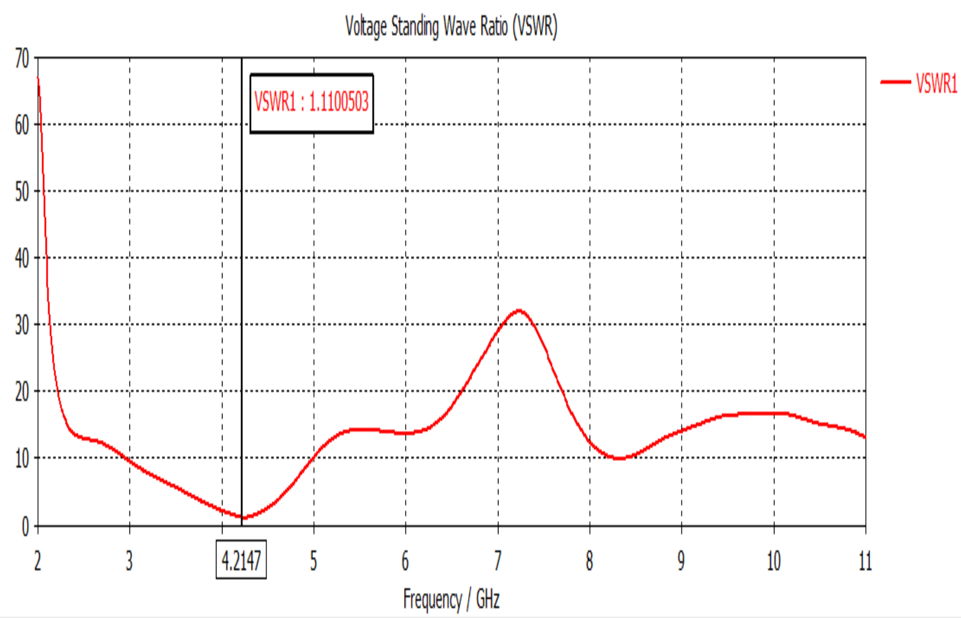


**Figure 5:** VSWR (Frequency in GHz vs VSWR in dB )

From the simulated results we've observed the readings of input reflection coefficient, VSWR, gain [13] and radiation patterns are discussed in this section. Figure 3 shows the simulated reflection coefficient of the proposed antenna for states of bricks arranged. Figure 4 shows the radiation pattern and figure 5 shows VSWR. VSWR < 2 has been successfully achieved at required resonance bands.

## 4. Conclusion

For the 5G\6G applications, the frequency reconfigurable antenna is proposed. The potent electrical length of the antenna is variable by providing bricks that employs the wide frequency bands. The antenna operates efficiently at desired bands and provides a very good radiation pattern in addition with VSWR < 2 which is much more suitable for antenna design. Effortless, close, changeable and pliable are some of the features of our proposed antenna which makes it a favorable one for the wireless i.e. 5G\6G applications.

## 5. Acknowledgement

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