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# Design and Analysis of a Hexa-Band Frequency Reconfigurable Antenna for Wireless Communication

I. A. Shah , S. Hayat, A. Basir, M. Zada*, S. A. A. Shah, S. Ullah, and S. Ullah

**Abstract**

**A compact (33 × 16 × 1.6 mm$^3$) and novel shaped hexa-band frequency-reconfigurable antenna with a very wide tuning band is proposed. The proposed antenna operates at two single band modes (i.e., 3.5 GHz and 4.8 GHz) and two dual band modes (i.e., 2.10 GHz, 4.15 GHz and 2.4 GHz, 5.2 GHz) depending upon the switching states. The lumped elements are used in the simulation environment to achieve tunable capacitance, which is responsible for frequency reconfigurability. The measured tuning capability of the fabricated antenna ranges from 2.1 to 5.2 GHz. The proposed antenna has a VSWR < 1.3 for all the resonant bands. The radiation efficiency of the proposed structure ranges from 80.41% to 96% at the corresponding frequencies. The far field and the scattering parameters of the proposed antenna are analyzed using Computer Simulation Technology (CST) Microwave Studio 2014. The designed antenna, due to its compact and affordable geometry, can be easily integrated in the modern communication devices such as smart phones, laptops and other portable electronic devices. A prototype of the designed antenna is fabricated and measured using PIN diode switches to validate the simulation results. The proposed reconfigurable antenna demonstrates a reasonable agreement between the measured and simulated results.**

**Index Terms**

Communication devices, pin diodes, reconfigurable antenna, VSWR.

## I. Introduction

DUE to the rapid evolution in electronics and wireless communication, the demand for the portable electronic devices operating at different frequency bands for multiple applications has been increased. The multi-band and reconfigurable antennas are the need for modern communication devices. The reconfigurable antennas have received a significant amount of attention due to their applicability in modern mobile communications services. The properties of the reconfigurable antennas have been adopted to achieve selectivity in the polarization, pattern, and frequency of the radiating structure, thus can replace the multi-band conventional antennas. The future of wireless communication is a cognitive radio system, which needs a sensing antenna having the capability to observe the spectrum, and can be tuned to a desired frequency band [1–3].

The frequency reconfigurable antennas are used in satellite communications and multi radio wireless applications [4]. For multiple input multiple output (MIMO) services, the pattern reconfigurable antennas are selected because of the advantage in their beam reconfigurability. The pattern reconfigurable antennas alter the radiation pattern to enhance the directivity and gain

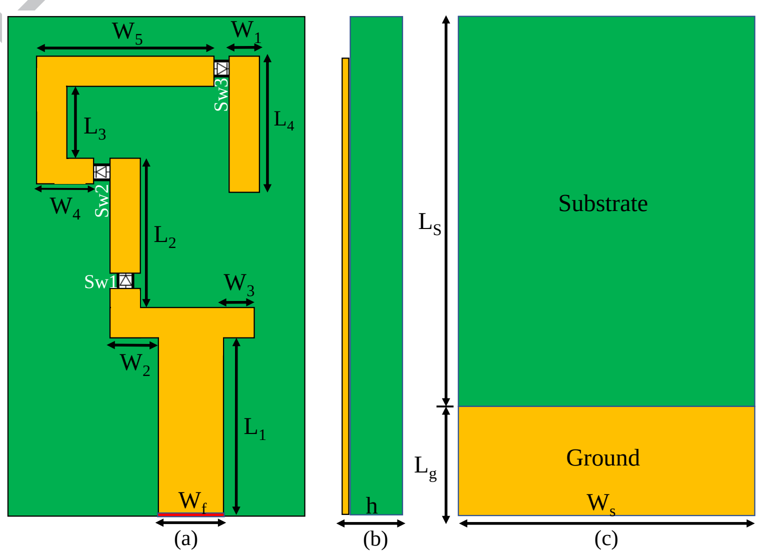


Fig. 1: The geometry of the hexa-band frequency reconfigurable planner antenna: (a) Front view. (b) Side view. (c) Rear view.

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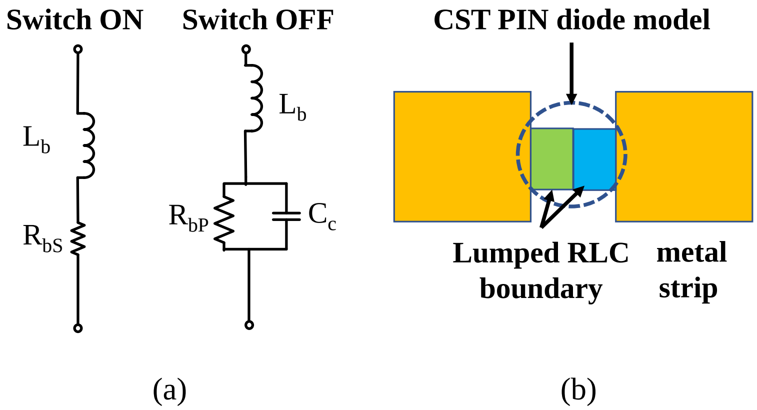


Fig. 2: The configuration of the RF pin diodes: (a) Equivalent circuit models for the ON and OFF states of the switch. (b) CST model.

Table I
Detailed dimensions of the hexa-band antenna

| Parameter | Values (mm) | Parameter | Values (mm) |
|---|---|---|---|
| $L_1$ | 13 | $W_2$ | 2.5 |
| $L_2$ | 9.1 | $W_3$ | 3 |
| $L_3$ | 4.5 | $W_4$ | 2 |
| $L_f$ | 6.8 | $W_5$ | 6.3 |
| $L_s$ | 33 | $W_f$ | 3 |
| $L_g$ | 7.5 | $W_s$ | 16 |
| $W_1$ | 2 | $h$ | 1.6 |

of the antenna in the desired direction, depending upon the wireless channel [5]. The polarization reconfigurable antennas are employed to reuse the frequency and reduce the fading in a wireless communication system [6], [7].

The frequency reconfigurable antennas are capable to tune at the resonant frequency of the antenna according to the user-end requirements. The reconfigurability of the antenna can be obtained by employing various switching techniques that change the current flow distribution in the radiating structure [8]. To obtain the reconfigurability feature, the PIN diodes [9], micro-electro-mechanical switches (MEMSs) [10], lumped elements [11], optical (photo conductive) switches [12], varactor diodes [13], and electronic radio frequency (RF) switching devices can be used [14]. The drawbacks of MEMS are their lower reliability and high cost as compared to PIN diodes [15].

With the attractive features: low cost, compact size, optimum efficiency, easy to fabricate, simple integration, and omni directional pattern, the research community has focused their attention towards reconfigurable antennas. In [16], the author has discussed the different radiating structures with different switching techniques. In [17], 9-shaped frequency reconfigurable antenna is introduced, which is intended for different wireless applications, (i.e., wireless fidelity (Wi-Fi), worldwide interoperability for microwave access X (Wi-MAX), and wireless local area network (WLAN) depending upon the switching state. The slotted rectangular patch antenna is presented in [18], which demonstrates that the modern wireless system needs the property of reconfigurability and flexibility in the antenna system. In the varying switching states, the antenna works in different frequency modes (i.e., K, Ku, and Ka bands). In [19], a simple and compact dual band T-shaped antenna has been introduced. The designed T-shaped antenna operates at the frequency bands used for WLAN and WI-FI applications. In [20], a slotted L-shaped frequency and pattern reconfigurable antenna is presented, in which the authors employed a PIN diode switch to attain the pattern and frequency reconfigurability for the antenna. In [21], a dual band frequency reconfigurable patch antenna is presented for wearable wireless applications (i.e., Wi-Fi and Wi-MAX). For the frequency reconfigurability, the authors incorporated a lumped element switching technique in the radiating structure. The tunable frequencies of the antenna are 2.44 and 3.54 GHz. The fractal reconfigurable antenna is demonstrated in [22], which operates in four different modes and can be used for different wireless applications. The multi-band inverted-F frequency reconfigurable antenna for wireless applications is presented in [23], which works in four different bands i.e., 900, 1800, 1900, and 2400 MHz. In [24], a wide-band G-shaped antenna is presented to cover the WLAN applications. The designed antenna can provide two separate impedance bandwidths of 22.9% at 2.45 GHz and 50.9% at 5.60 GHz. In [25], F-shaped frequency reconfigurable antenna is presented to cover the GSM, Wi-Fi, Wi-MAX, and WLAN band. Two reconfigurable antennas with the combined narrow band and wide-band functionality have been presented in [26]. The varactor and PIN diode switches are used to obtain the reconfigurability of

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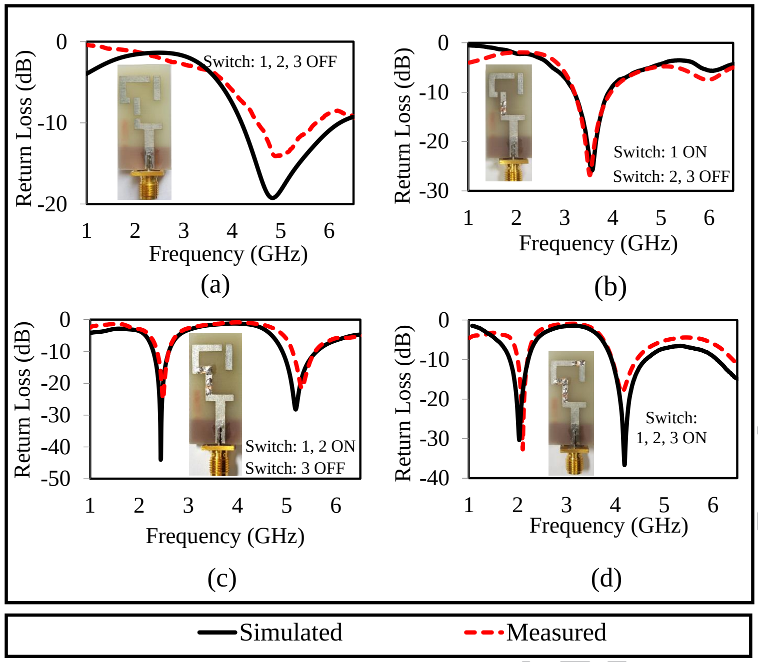


Fig. 3: The simulated and measured reflection coefficient for operation states: (a) 4.82 GHz. (b) 3.5 GHz. (c) 2.43 and 5.18 GHz. (d) 2.1 and 4.14 GHz.

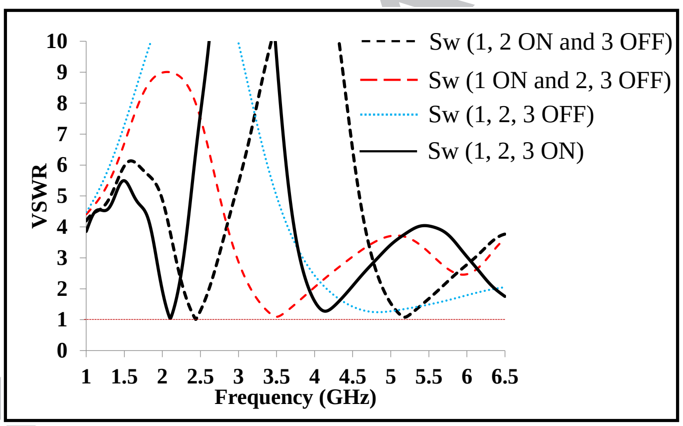


Fig. 4: The voltage standing wave ratio (VSWR) of the proposed antenna.

the corresponding antennas. In [27], the frequency reconfigurable antenna is presented, which operates in the ultra wide band (UWB) mode and three narrow band modes by using four photo conductive switches. By altering the switching conditions, the micro strip patch antenna can operate in four different frequency bands. Several antennas with various reconfigurability techniques have been discussed in [28]–[40]. However, the suggested antennas in the above-mentioned papers have deficiency either in the bandwidth, gain, size or multi-band characteristics.

In this paper, a compact novel shaped, hexa-band, and efficient frequency reconfigurable monopole antenna is designed on the FR-4 substrate with thickness of 1.6 mm. The monopole antenna radiates in six different frequency bands, including WLAN, Wi-Fi, WiMAX, and universal mobile telecommunication systems (UMTS) band. The lumped element components (i.e., RLC; resistance, inductance, and capacitance) are used as the switches within the radiating structure of the designed antenna to attain the frequency reconfigurability in the simulation. A slot of 1 mm is reserved for the integration of each switch. However, in the measurement PIN diodes are used to achieve frequency reconfigurability. The rest of the paper is organized in the subsequent pattern. Section II reports the theory, geometry, and switching techniques of the novel hexa-band antenna. Section III covers the simulated and measured environments and results. Section IV concludes the paper.

## II. Methodology

This section introduces the basic geometry, the design theory, and the switching techniques of the proposed hexa-band frequency reconfigurable monopole antenna. The designed antenna is reconfigured by employing the lumped element switches

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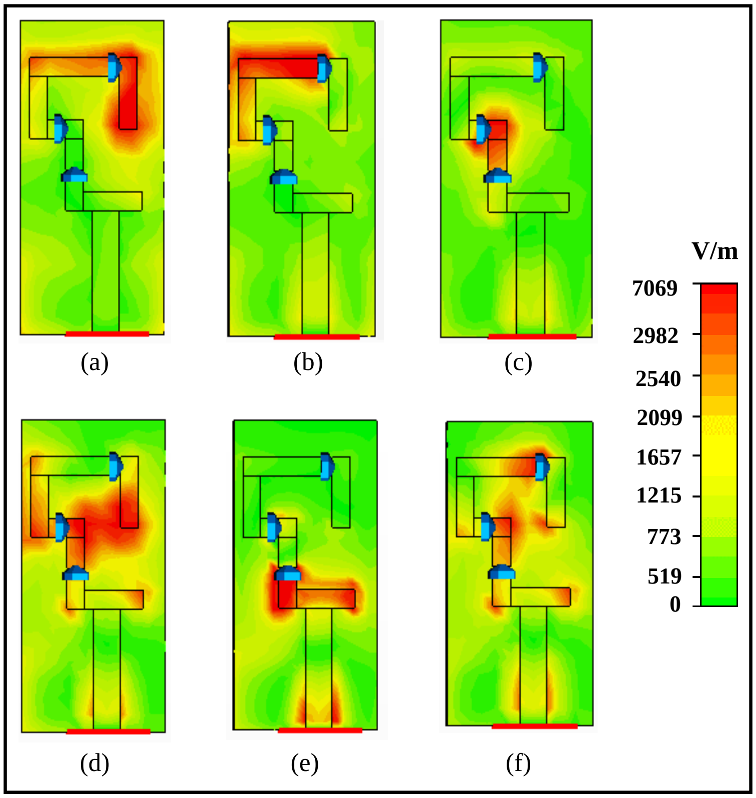


Fig. 5: The electric-field distribution of the proposed antenna at: (a) 2.10 GHz. (b) 2.43 GHz. (c) 3.50 GHz. (d) 4.1 GHz. (e) 4.8 GHz. (f) 5.2 GHz.

in the simulation environment to achieve two single bands and two dual band modes. Moreover, PIN diodes are used in the measurement setup to attain reconfigurability. A truncated metallic ground plane on the back is used to obtain better efficiency and satisfactory far field radiation patterns.

### A. Geometry of the proposed antenna

The structural dimensions and geometry of the proposed hexa-band frequency reconfigurable antenna for UMTS, Wi-Fi, WiMAX, WLAN, Radio Altimeter, and Fixed Mobile Communication applications is presented in Fig. 1. The radiating element of the designed antenna is printed on the lossy FR-4 substrate (having relative permittivity ($\varepsilon_r$) of 4.5 and tangent loss (tan$\delta$) of 0.019) backed by the truncated metallic ground surface. The FR-4 substrate is commercially available, which makes the design of the antenna more affordable and feasible. The advantage of the truncated metallic ground surface is to obtain optimum gain, efficiency, and directivity. A 50 Ω micro strip line of width 3 mm is used for the antenna excitation. The waveguide port assigned to the feed line is used to excite the antenna. Three slots with 1 mm width are reserved in the radiating structure for the integration of lumped element switches, as shown in Fig. 1. The volume of the proposed monopole antenna is 33 × 16 × 1.6 mm$^3$. Table I summarizes the detail dimensions of the proposed structure.

### B. Design theory of the proposed antenna

For the integration of the switches within the proposed structure, 1 mm slots are reserved at the adequate positions in the radiating patch. The resonant lengths of the designed antenna are calculated using the transmission line model theory [35], i.e., S2.1, S2.4, S3.5, S4.1, S4.8, S5.4. The desired frequency modes are achieved by changing the switching states. The guided wavelength and the resonant lengths are referred as

$$S_{2.1} = \lambda_{2.1}/4 \tag{1}$$

$$S_{2.4} = \lambda_{2.4}/4 \tag{2}$$

$$S_{3.5} = \lambda_{3.5}/4 \tag{3}$$

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Table II
Tuning states of the hexa-band antenna

| S. No | Sw1 | Sw2 | Sw3 | Frequency states |
|---|---|---|---|---|
| 1 | *ON* | *ON* | *ON* | Dual band (2.10 and 4.14 GHz) |
| 2 | *ON* | *ON* | *OFF* | Dual band (2.43 and 5.18 GHz) |
| 3 | *ON* | *OFF* | *OFF* | Single band (3.50 GHz) |
| 4 | *OFF* | *OFF* | *OFF* | Single band (4.82 GHz) |

$$S_{4.1} = \lambda_{4.1}/4 \tag{4}$$

$$S_{4.8} = \lambda_{4.8}/4 \tag{5}$$

$$S_{5.4} = \lambda_{5.4}/4 \tag{6}$$

The guided wavelength and the quality of the designed antenna is optimized for satisfactory radiation efficiency, which can be calculated from equation given in [38]. When the antenna is excited at the right point, the efficiency goes higher, resulting in the reduction of the reflection coefficient, which is defined mathematically as

$$|\Gamma| = \frac{Z_a - Z_c}{Z_a + Z_c} \tag{7}$$

where $Z_c$ represents the characteristic impedance of the feed line and $Z_a$ is the impedance of the antenna. The reflection coefficient ($S_{11}$), and VSWR are interrelated parameters of the antenna. VSWR is defined as

$$VSWR = \frac{1 + |\Gamma|}{1 - |\Gamma|} \tag{8}$$

The antenna in a perfectly matched condition gives a lower value of reflection coefficient ($S_{11}$ <-10 dB) in the desired frequency band. The directivity (D) and gain (G) of the proposed antenna is linked by the radiation efficiency. The gain is normally expressed in decibels (dB) and given as follows

$$G(dB) = 10 \times log_{10}(\eta_{rad} D). \tag{9}$$

### *C. Switching Techniques*

In the RF frequency, PIN diodes act as a variable resistor. However, for ON and OFF states, PIN diodes having little bit more complex circuitry. For both states (ON and OFF) PIN diodes have an inductance ($L_b$) in the equivalent circuit. The low resistance ($R_{bS}$) was included in the ON state (forward biased), while in the OFF state (reversed biased), the equivalent PIN diode circuit consist of a parallel combination of resistance ($R_{bP}$) with capacitance ($C_c$) as depicted in Fig. 2(a). As can be seen from the figure 2(b), the PIN diodes are designed as two lumped RLC boundary conditions.

The reconfigurable characteristics of the proposed antenna have been simulated in terms of resistor only. In the simulation, we did not consider the capacitance and inductance values because the switch ON-state in both RLC lumped model and PIN diode model offers a short circuit phenomenon, which allows the flow of currents on the radiating path of the structure. However, in the OFF state, both models offer an open circuit phenomenon, thus blocking the current flow. In the PIN diode model, the equivalent circuit model for both ON state and OFF state has been discussed earlier and in [39]. From the literature, it has been studied that the ON state in the PIN diode model is realized as a series RL component with small values that behaves as a short circuit, allowing the current to flow along the radiator. In contrast to this phenomenon, the OFF state in PIN diode is modeled as a parallel RLC component with such values that exhibits an open circuit behavior in which current cannot flow along the radiator. To simplify our model, the open circuit and short circuit behavior have been focused and the switch was realized as an RLC lumped element model with resistor values only. A resistor ($R_{bS}$) with a small value of 1 Ω behaves as a short circuit and allows the normal flow of current. On the other hand, a resistance ($R_{bP}$) of 1 MΩ has exhibited an open circuit behavior and blocks the path for the current to flow along the radiating structure.

## III. Simulated and Measured Results

To study the performance of the hexa-band antenna, the radiating structure is designed, simulated, and analyzed using CST microwave studio MWS 2014. A waveguide port is used as a source for the excitation of the designed antenna. The VSWR, gain, directivity, far field pattern, reflection coefficient, and surface electric-field are evaluated with open-add-space boundary conditions using transient solver in CST Microwave studio 2014.

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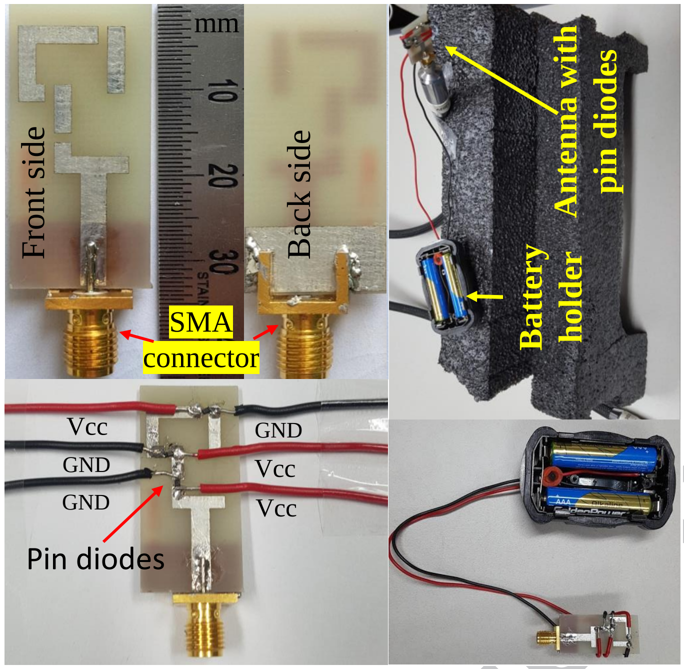
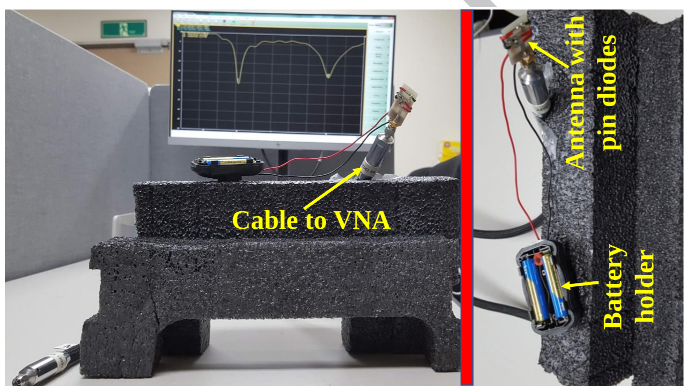
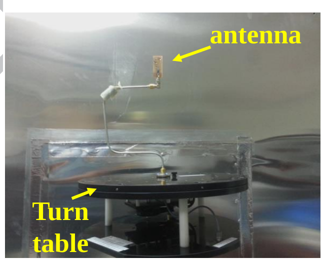
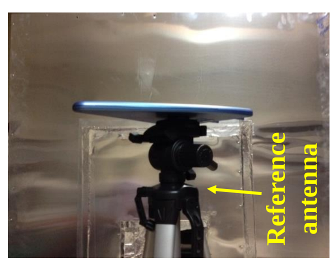



Fig. 6: The fabricated prototype of the proposed hexa-band antenna.




(a)




(b) (c)

Fig. 7: The measurement setup for the reflection coefficient ($S_{11}$) and radiation pattern: (a) Agilent N5242A PNA-X VNA. (b) Azimuth turntable. (c) Log periodic probe.

When all the three switches (Sw1, Sw2 and Sw3) are in the ON state, the proposed antenna operates in a dual band frequency mode with a return loss of -32.73 and -18.27 dB at 2.10 and 4.1 GHz, respectively. When the two switches (Sw1 and Sw2) are ON and Sw3 is OFF, the antenna performs in the dual band mode i.e., 2.4 and 5.2 GHz with a return loss of -44.02 and -28.50 dB, respectively. If one switch (Sw1) is turned ON and the other two switches (Sw2 and Sw3) are turned OFF, the antenna operates in a single band mode at 3.5 GHz with a return loss of -26.81 dB.

When all the switches are in the OFF state, the designed antenna operates in a single band mode at 4.8 GHz with a return loss of -19.24 dB. The proposed monopole antenna provides a maximum bandwidth (-10 dB return loss) of 9.35, 13.2, 21.49,

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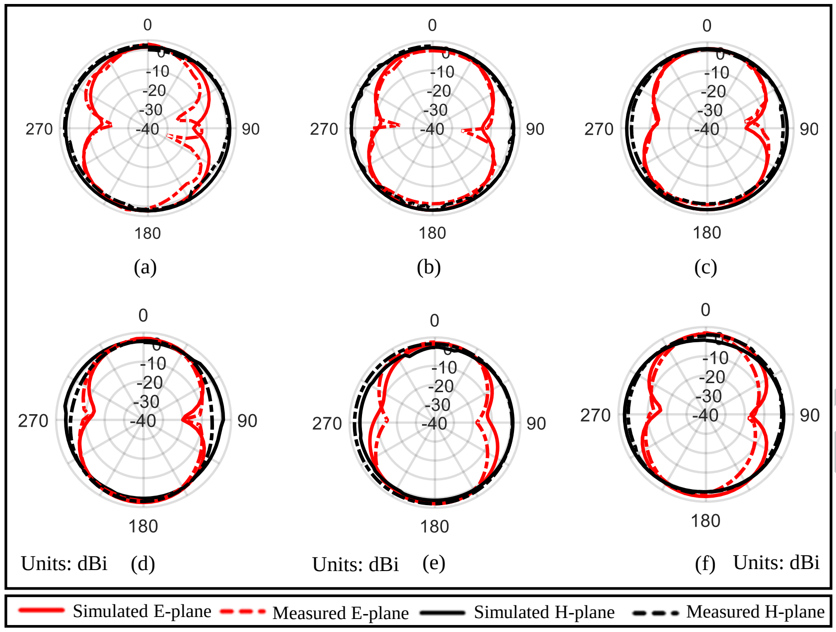


Fig. 8: The simulated and measured radiation Pattern of antenna in E–plane (XOY) and H–plane (XOZ) at: (a) 2.10 GHz. (b) 2.43 GHz. (c) 3.50 GHz. (d) 4.14 GHz. (e) 4.82 GHz. (f) 5.18 GHz.

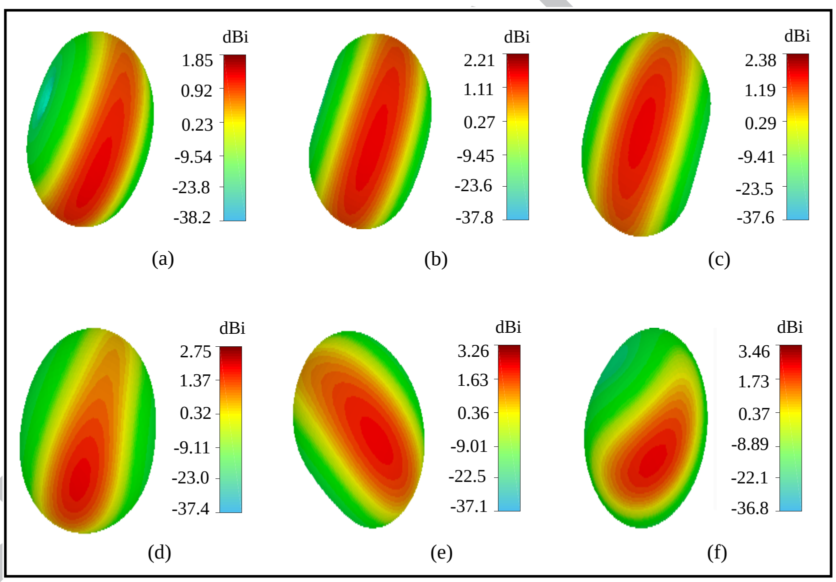


Fig. 9: The 3D far-field gain pattern at: (a) 2.10 GHz. (b) 2.43 GHz. (c) 3.50 GHz. (d) 4.14 GHz. (e) 4.82 GHz. (f) 5.18 GHz.

11.71, 41.56, and 9.35% at 2.10, 2.43, 3.50, 4.14, 4.82, and 5.185 GHz, respectively. Fig. 3 depicts the measured and simulated reflection coefficients of the monopole hexa-band antenna. It is worth mentioning that the measured results are found in a good agreement with the simulated results.

The VSWR of the designed antenna is less than 1.3 for all the frequency bands, which proves that the antenna is optimally matched. VSWR at 2.10, 2.43, 3.50, 4.14, 4.82, and 5.18 GHz is 1.04, 1.01, 1.09, 1.27, 1.24, and 1.08, respectively, as illustrated in Fig. 4.

The electric field distribution on the conductive path of the radiating structure at 2.10, 2.43, 3.50, 4.1, 4.8, and 5.2 GHz is shown in Fig. 5, which clearly indicates the effective resonant lengths at the respective frequencies in the whole patch, demonstrating the inverse relation with the frequency.

Fig. 6 represents a fabricated model of the proposed antenna, which is fabricated on the FR-4 substrate with a thickness of 1.6 mm and relative permittivity $\varepsilon_r$ = 4.5. For practical operations, the antenna is fed through an SMA port. Three lumped elements (RLC) switches are used to achieve the different modes of operation in the antenna, as shown in Table II. The lumped element switch is selected since, it can be easily modeled in CST MWS as a resistor of 1 Ω and 1 MΩ, to represent

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Table III
Detailed summary of the simulated results for the hexa-band antenna

| ***Parameters*** | ***SW (1,2,3) ON*** | | ***SW(1,2,3) OFF*** | ***SW(1,2 ON and 3 OFF)*** | | ***SW(1 ON and 2,3 OFF)*** |
|---|---|---|---|---|---|---|
| Frequencies(GHz) | 2.10 | 4.14 | 4.82 | 2.43 | 5.18 | 3.50 |
| Gain (dBi) | 1.85 | 2.75 | 3.26 | 2.21 | 3.46 | 2.38 |
| Return Loss (dB) | -32.73 | -18.27 | -19.24 | -44.022 | -28.50 | -26.81 |
| Directivity (dBi) | 2.71 | 3.70 | 4.36 | 2.5 | 5.35 | 2.75 |
| VSWR | 1.04 | 1.27 | 1.24 | 1.01 | 1.08 | 1.09 |
| Bandwidth % | 9.35 | 11.71 | 41.56 | 13.21 | 13.47 | 21.49 |
| Efficiencies % | 90.58 | 89.61 | 88.09 | 96.75 | 80.41 | 95.83 |

Table IV
Comparison of the recommended antenna with aforementioned works

| Ref. | No of operating bands | Dimensions ($mm^2$) | Freq. (GHz) | BW (MHz) | Gain (dBi) |
|---|---|---|---|---|---|
| **This work** | **six** | **16 x 33** | **2.1, 2.4, 3.5, 4.1 4.8, 5.2** | **196–2003** | **1.85–3.46** |
| [11] | triple | 35 x 40 | 2.45, 3.45, 5.4 | 500–1250 | 1.92–3.02 |
| [16] | triple | 40 x 40 | 2.45, 3.50, 5.20 | 147–1820 | 1.7–3.4 |
| [17] | triple | 35 x 40 | 2.45, 3.50, 5.20 | 330–1250 | 1.48–3.26 |
| [32] | triple | 39 x 37 | 2.45, 3.0, 5.20 | 550–1220 | 1.32–2.32 |
| [36] | four | 20 x 40 | 2.4, 3.4, 5.1, 5.8 | 769–1278 | 1.72–2.96 |
| [37] | four | 28 x 30 | 1.6, 2.5, 5.8, 9.8 | 200–900 | 1.8–2.9 |
| [38] | six | 35 x 40 | 2.1, 2.4, 3.3, 3.5, 5.28, 5.9 | 335–1220 | 1.92–3.88 |
| [41] | UWB | 24 x 32 | 3.2, 6, 9 | 2.7–12 GHz | 2.1–4.3 |

the switch-ON and-OFF state, respectively.

In the measurement setup PIN diodes (Skyworks SMP 1345-079LF) having low capacitance with good performance up to 6 GHz are selected. In each case, when the diode is forward biased, it performs as a series resistor with 1.5 Ω, while in reverse biased works as a series capacitor of approximately 0.17 pF. It is worth mentioning that the feeding path of the fabricated antenna is completely isolated from the DC path. Since, the capacitors having the ability to block DC and pass RF signal, while RF chokes block RF and passing DC, a combination of the two concerns to do the trick. The inductors of 125 nH are used for RF choking and capacitors of 470 pF are used to short the RF signals leaked from the choking inductor. The biased voltage is 3V and its biased current is about 10 mA supplied by two Alkaline AA batteries, as depicted in Fig. 6.

The reflection coefficient ($S_{11}$) of the reconfigurable monopole antenna is measured using an Agilent N5242A PNA-X Series Vector Network Analyzer (VNA), as shown in Fig. 7(a). The H- and E-plane gain patterns of the proposed antenna are measured in the open space scenario using the setup shown in Fig. 7(b). A log periodic antenna is used as a probe (reference transmitter) antenna, as depicted in Fig. 7(c). The fabricated antenna is fixed on the elevation over an azimuth turntable. The antenna is linearly polarized, therefore, its H-and E-plane radiation patterns are deliberated to get an insight about the radiation properties of the antenna in the two orthogonal planes.

It is worth mentioning that the proposed hexa-band antenna radiates omni directionally and its patterns are dominant in the horizontal H-plane at all the six frequency bands. Which gives a “figure of 8” shape radiation pattern in the vertical E-plane with a dominant null lobe occurring at an angle of 90 degrees. The simulated and measured H- and E-plane gain patterns for the frequencies of 2.10, 2.43, 3.50, 4.14, 4.82, and 5.18 GHz are depicted in Fig. 8. When all the switches (Sw1, Sw2, Sw3) are in the ON state, the antenna radiates in the far field region with the peak gain values of 1.85 and 2.75 dBi, at 2.10 and 4.14 GHz, respectively. By changing the states of the switch, the antenna operates in a single band mode with a peak gain value of 3.26 dBi at 4.82 GHz. When the Sw1 and Sw2 switches are ON and Sw3 switch is OFF, the proposed antenna performs in a dual band mode with a peak gain values of 2.21 and 3.46 dBi at 2.43 and 5.18 GHz frequency bands, respectively. When Sw2 and Sw3 are in the OFF state and Sw1 is in the ON state, the antenna operates in a single resonant mode with a peak gain value of 2.38 dBi at 3.50 GHz. As can be seen from Fig. 8, the measured H-plane of the proposed antenna has an omni directional radiation pattern, whereas the E-plane has nearly a “figure of 8” shape in all the six resonant bands. For further clarification, the 3D far-field radiation plots are shown in Fig. 9 for the corresponding frequency bands.

The designed antenna radiates efficiently because of the matched feeding mechanism employed in the design at the appropriate position. The radiation efficiency of the proposed antenna is 90.58, 96.75, 95.83, 89.61, 88.09, and 80.40% at 2.10, 2.43, 3.50, 4.14, 4.82, and 5.18 GHz frequency bands, respectively. The gain of the antenna is 2.21 dBi at 2.43 GHz, 3.46 dBi at 5.18 GHz, and 2.38 dBi at 3.5 GHz, which are satisfactory for the monopole antenna in the intended applications. The overall performance of the proposed hexa-band antenna is summarized in Table III.

The proposed hexa-band antenna's comparison with the aforementioned literature is summarized in Table IV, which shows that the proposed antenna is smaller in size, with maximum number of operating bands, higher gain, and provides maximum bandwidth as compared to [11], [16], [17], [32], [36], [37], and [38]. Moreover, in [41] an UBW antenna is designed with relatively large size as compared to the proposed hexa-band antenna.

## IV. CONCLUSION

In this work, a novel hexa-band frequency reconfigurable monopole antenna has been designed and experimentally validated. The monopole antenna was reconfigured to operate in two dual bands and two single band modes. The different switching states were responsible for achieving the desired operating characteristics. When all the switches were in the ON state, the proposed antenna operated in a dual band mode (UMTS at 2.10 GHz and Radio Altimeter at 4.1 GHz). In contrast, by altering the state of the switches (all switches = OFF), the designed antenna performed in a single band mode (4.82 GHz used for military applications and fixed Mobile Communication). When two switches (Sw1 and Sw2) were in the ON state and one switch (Sw3) was in the OFF state, the reconfigurable hexa-band antenna operated in a dual band mode (Wi-Fi at 2.43 GHz and WLAN at 5.18 GHz). The antenna operated at a single resonant band (WiMAX at 3.50 GHz), when the two switches (Sw2 and Sw3) were in the OFF state and one switch (Sw1) was in the ON state. The outstanding efficiencies, satisfactory radiation patterns, acceptable gain, better impedance matching, and directivity values were achieved for the different operating conditions of the propose hexa-band antenna. The -10 dB impedance bandwidth values of 9.35, 13.2, 21.49, 11.715, 41.6, and 13.47% have been obtained at frequency bands of 2.10, 2.43, 3.50, 4.14, 4.82, and 5.18 GHz, respectively. The proposed antenna has many advantages due to its characteristics such as light-weight, compact size, low-cost, easy to fabricate, and simple in integration. The designed antenna was intended for use in the satellite communications, military purposes and in the modern communication devices (i.e., laptops and tablets). Moreover, the measurement were conducted for the reflection coefficient and radiation patterns using PIN diodes in the fabricated prototype. The measured results of the proposed antenna were in a good agreement with the simulated results.

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