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A review of achieving frequency reconfiguration through switching in microstrip patch antennas for future 5G applications

M. Kamran Shereen [a,b,*], M.I. Khattak [a], Jamel Nebhen [c]

[a] *Microwave and Antenna Research Group, Electrical Engineering Department, UET Peshawar, Pakistan*
[b] *US-Pakistan Centre for Advanced Studies in Energy, Pakistan*
[c] *Prince Sattam bin Abdulaziz University, College of Computer Engineering and Sciences, P.O. Box 151, Alkharj 11942, Saudi Arabia*

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Abstract This paper discusses a review of frequency reconfigurability through switches for 5G applications. A new switching technique (varying values of lumped parameters) for frequency reconfiguration is analysed and validated by investigation a difference between a simple (non-reconfigurable) and a reconfigurable antenna for 60 GHz resonant frequency. Different switching techniques for frequency Reconfigurable Antenna (RA) and formulations for the parameters of Microstrip Patch Antenna and slot insertion. Generic interconnections of switches for antenna array is addressed for RA design. important aspect of this paper is that these techniques have been discussed for the frequency switching of Reconfigurable microstrip antennas designed for 5G applications i.e. their frequency of operation is in millimetre-wave range (>6GHz).

Contents

* Corresponding Author.
E-mail address: engrkamran@uetpeshawar.edu.pk (M. Kamran Shereen).

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1. Introduction

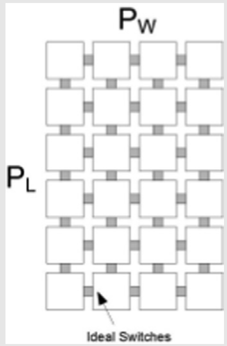
By the end of 2021, the next generation of telecommunication networks (also known as 5G) will have a peak demand in the market, and it will continue to expand worldwide. 5G is intended to generate a massive IoT (internet of things) infrastructure in which networks would fulfil the connectivity requirements and demands of billions of connected devices, while maintaining the necessary speed, latency, and cost standards. By transmitting data through millimetre waves (mmWaves), 5G mobile communication systems would have a major effect on digital technology, which will be faster, simpler to handle, and more efficient than current communication systems for technical reasons [1]. Observing a connected globe filled with smart devices, the ever-increasing mobile data use predicts a significant increase in data traffic in the near future. Global mobile data traffic increased 71 percent in 2014, according to a Cisco Systems white paper, and is projected to expand at a compound annual growth rate of 77 percent from 2018 to 2022 [2]. As a result, high data rates of 10 gigabits per second (Gb/s) are planned for fifth-generation (5G) mobile communication systems [3,4]. Moreover, the Internet of Things, the next great evolution of wireless communications is currently in progress. IoT effectively links a range of devices to wireless networks, including RFID tags, cell phones, and various sensors, all of which are uniquely defined and capable of device to device communication. These devices can communicate and collaborate with one another to complete a task without requiring human-to-computer engagement. As a response, network and data traffic are becoming more focused on things, with human contact traffic accounting for just a small portion of the total [5]. The millimetre wave (mmwave) band, which covers 30–300 GHz (GHz) and relates to wavelengths of 1–10 mm, has significant potential bandwidths, enabling for the high data traffic and rates [6]. Higher frequencies (such as millimetre waves) that are proposed to be used for 5G (for IoT devices) have substantially different channel properties, such as multi-radio systems, multi-channel communication systems, interference rejection, cognitive radio (CR) systems. Therefore, 5G brings a new dimension not only to the vision of communication but also for the perception of problems.

As modern wireless devices must be compliant with multi-radio systems, they are fitted with many single-band or multi-band antennas to access multiple wireless networks [7]. In the current situation, in order to support many communication protocols, several fixed performance antennas are combined into a single device [8]. Some instances in which a separate radio and antenna are allocated for each protocol and thus occupy a huge portion of the limited space inside a portable unit. In this case, frequency reconfigurable antennas are very suitable and others like it, as a single antenna is enough to replace several single-function antennas and satisfy many requirements [9]. Besides this, they are often useful for replacing a multi-channel communication system's conventional wideband antenna, which usually includes a wideband antenna to cover all frequency channels. The use of a frequency reconfigurable antenna would therefore be a very intelligent and realistic solution, as it would greatly reduce the system size and ensure portability and compactness, which are essential criteria for any wireless application.

Frequency reconfigurable antennas are useful in space constraints and are ideal for reducing costs and energy consumption. In application or indirect systems, since they allow the use of a single antenna in many systems, these antennas will also enable mobile communication in the future, as one could cope with the growing demand for cellular communications. They also provide integration of multiple applications on the same platform [10]. There is a possibility of modifying characteristics in the reconfigurable antenna, and multiple antennas are replaced with several frequencies. Regardless of the frequency, the reconfiguration process [11–15], or the radiation mode, [16,17] and polarization [18,19] can be performed. It is not possible to solve all frequency bands simultaneously using a reconfigurable antenna, but it is possible to configure various frequencies as needed by generating a chord or notch for the reflection coefficient in the antenna. In some cases, reconfigurability is achieved by using multiple switches.

For interference rejection, frequency reconfigurable antennas can also be used. Interference from the signal band can be removed by making deliberate band-notches or filtering out the interfering band from the antenna's frequency responses. This refers to wideband applications that overlap several communication bands and need filtering to prevent congestion [20]. This approach removes the need for additional filters which are used at the various stages of the communication system [21]. Most notably, the frequency reconfigurable antenna can be an integral part of another notable principle of science, introduced as cognitive radio (CR) systems a few years back [22]. Depending on the existing allocation, use, and behaviour of the spectrum channels available (white spaces), the CR transceivers decide on the allocation of the spectrum and adjust the frequency channel to function within a free or unused band, thereby running simultaneous communications and enhancing the efficiency of radio operations. It can also be efficient in overcoming the unforbidden challenges in the advanced technologies like smart cities, 5G and Internet of Things (IoT), Cognitive [23] and delivery probability, packet loss ratio, Interest Satisfaction Ratio (ISR) and average

Table 1 Generic derivation for switches interconnection and Reconfigurable Antenna.

Generic Derivation for Switches Interconnections	Reconfigurable Antenna Web
P_w = *Switches along width* P_L = *Switches along length* *So* *Number of horizontal switches* $= (P_w - 1)P_L$ *Number of vertical switches* $= (P_L - 1)P_w$ *Total number of switches in a matrix* $= (P_w - 1)P_L + (P_L - 1)P_w$ $= P_wP_L - P_L + P_wP_L - P_w$ $= 2P_wP_L - (P_L + P_w)$ $2P_w^2 - 2P_w$ if $\parallel P_L = P_w \parallel$	

End-to-End delay in a highway and an urban scenario of a vehicular environment [24]. Recent advances of switching techniques for frequency reconfiguration as shown in Fig. 12 for microstrip patch and reconfigurable antennas are discussed in this Paper, with an emphasis on antennas and practical concerns related to their better implementation. Based on the requirements for 5G, antennas with lightweight, low profile, low-cost mass production, ease of installation, conformal to planar surface and also non-planar surface, mechanically robust when mounted on a rigid surface and compatible with monolithic integrated circuits are quite important [25]. Micostrip slot antenna has the potential to be a better candidate for frequency reconfiguration because it offers a wide frequency range turning and conveniences of the resonant frequency turning with switches of varactors across the slop The microstrip patch antenna (MPA) has various advantages such as low cost, lightweight and easy to manufacture, despite various advantages. Also, correlation with the frequency reconfiguration, MPAs are the true solution for this cause by changing (increasing or decreasing the patch size) the patch size [26].

To achieve the reconfigurability in the antenna systems, RF switching devices such as PIN diodes, photoconductive switches, MEMS (micro-electrical mechanical systems) and FETs are needed [27]. Researchers prefer PIN diodes [28,29] for reconfigurability in contrast to MEMS because of their faster switching speed, handling of high currents, enhanced reliability and ease of fabrication. Based on the effects of contact potential and inertia, outdated and electromechanical RF switching elements are typically naturally slow response devices [30–33]. A typical switching speed of 100nsec is common in PIN diodes, with additional resistive characteristics in the microwave range of frequencies. In case of the biasing characteristics, the range of resistance could be 110–10 kΩ, while a current of 10 mA bias is needed for the ON state operations. Recently, FETs have also been utilized, comprised of PIN diodes and MEMS, performing the aspect of switching in the process of reconfigurability; the main principle of this switch is the regulation of the RF current to flow in the desired direction. Therefore, the state of the RF switch plays a critical role in the reconfigurability characteristics of the antenna. This paper presents different techniques for achieving frequency reconfiguration. There are many designed approaches available to achieve antenna frequencies and their reconfiguration. These are discussed in Refs. [34–39] and their effects are shown in Table 3.

This paper provides a brief overview of techniques for designing a microstrip antenna with frequency reconfiguration. Researchers have established a number of methods that can be used to include and enhance the switching frequencies technique in a single terminal antenna. This paper looks at the various methods that have been used in some of the research to achieve various operating frequencies and lead us to a solution that the reconfigurable frequency includes varying the patch size, reconfigurable matching network, changing the current flow, mechanically configuring using metasurface, varying the length of the slot and varying the values of lumped elements. Observing Section 3 and 4 of this review paper shows a novelty with respect to published review literature that, a new method of frequency switching technique (analyzed and validated in Section 3) lead us to a solution that varying the values of lumped elements is the most effective way for frequency switching, as all the modifications can be validate in the software before fabrication. Also, we don't have modify the patch size or by any other means which results in reshaping our end antenna. These lumped parameters are cheap, light in weight and easily available in the market.

The structure of paper shows that in Section 2, a general architecture of reconfigurable antenna is discussed by showing generic derivation for switches interconnections. A comparative analysis of a simple and frequency reconfigurable antenna radiating at 60 GHz WLAN is shown in Section 3. In Section 4, different frequency reconfiguration methods have been discussed with examples of published literature.

2. General architecture of reconfigurable antenna

An antenna with the ability to change its shape in accordance with the frequency of operation is called a reconfigurable antenna. To achieve this, authors of [40] have interconnected a series of square patches through ideal switches. The patches selected were 4 mm × 4 mm each, and an array consisting of 6 × 4 elements was constructed where each sub-patch is connected to its neighbours as shown in Table 1. The generic derivation of the number of switches needed for complete interconnection is given in Table 1.

$$2P_w^2 - 2P_w \quad \text{if } \parallel P_L = P_w \parallel \tag{1}$$

It can be noted that the above equation has a complexity of $O(n^2)$ (derived in Table 1). A large number of switches will be needed if sub-patches are increased and their reconfigurability is the goal. In the above case, the antenna has a total of 38 switches. The design of the rectangular patch antenna is based on the procedure derived in [40]. We consider a ground plane that is perfect and infinite and find out the width, height, length and power positions of the patch antenna. The antenna structure design is based on a microstrip line with the use of slot techniques, taking the gain and directivity into consideration. The purpose of the slot is to control the radiation pattern in order to obtain an increased bandwidth.

3. Investigation results of simple and reconfigurable antenna

In this section a comparative analysis is investigated between a simple (non-reconfigurable) [41] and RA (Frequency reconfiguration) [42] antenna as shown in Figs. 1 and 2. A compact T-shaped slotted microstrip patch antenna has been deliberated for high-speed Wi-Fi systems, which is then converted to a Frequency Reconfigurable Antenna for different structure as a parametric analysis.

The four antenna models as shown in Fig. 2 are designed on a 60 GHz resonant frequency standardized unlicensed band for future 5G wireless local area network (WLAN) applications modified for frequency reconfigurable antenna using Switch. Their Return Loss result can be seen in Fig. 3. Table 2. shows that changing the Resistive values of Switch changes the frequency above and below the resonant frequency. It can be seen from Fig. 2 clearly that by placing different values of switches (Lumped resistors) the resonant frequency move forward and backward direction, making the same antenna as frequency reconfigurable.

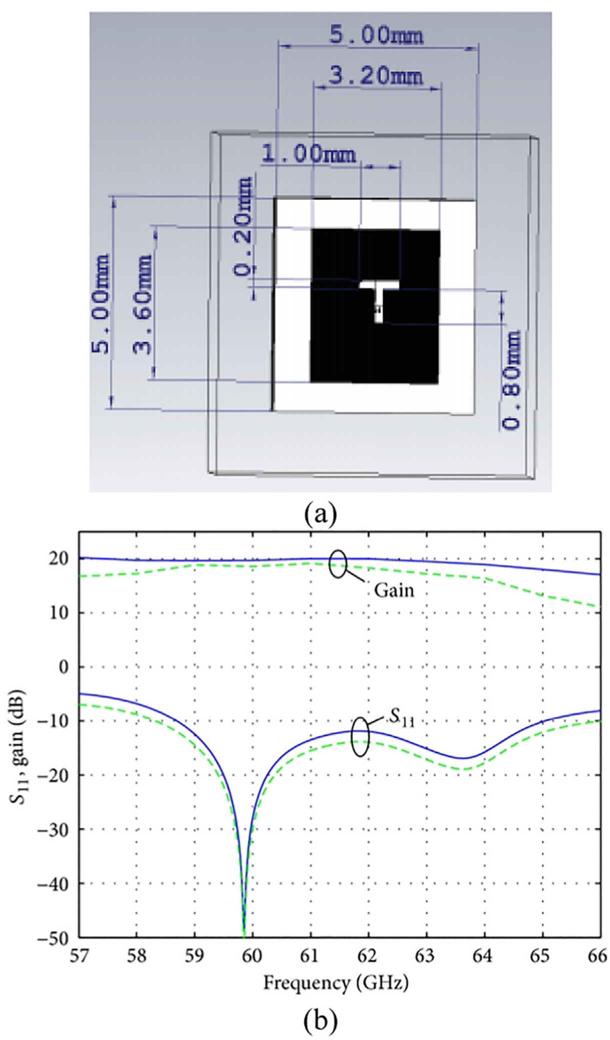


Fig. 1 Non Reconfigurable Antenna (a) Top View of Proposed Antenna (b) Simulated Return Loss Plot (Magnitude in dB) [41].

The variable resistors as a lumped parameter are used in the slotted microstrip patch antenna to achieve the reconfigurable

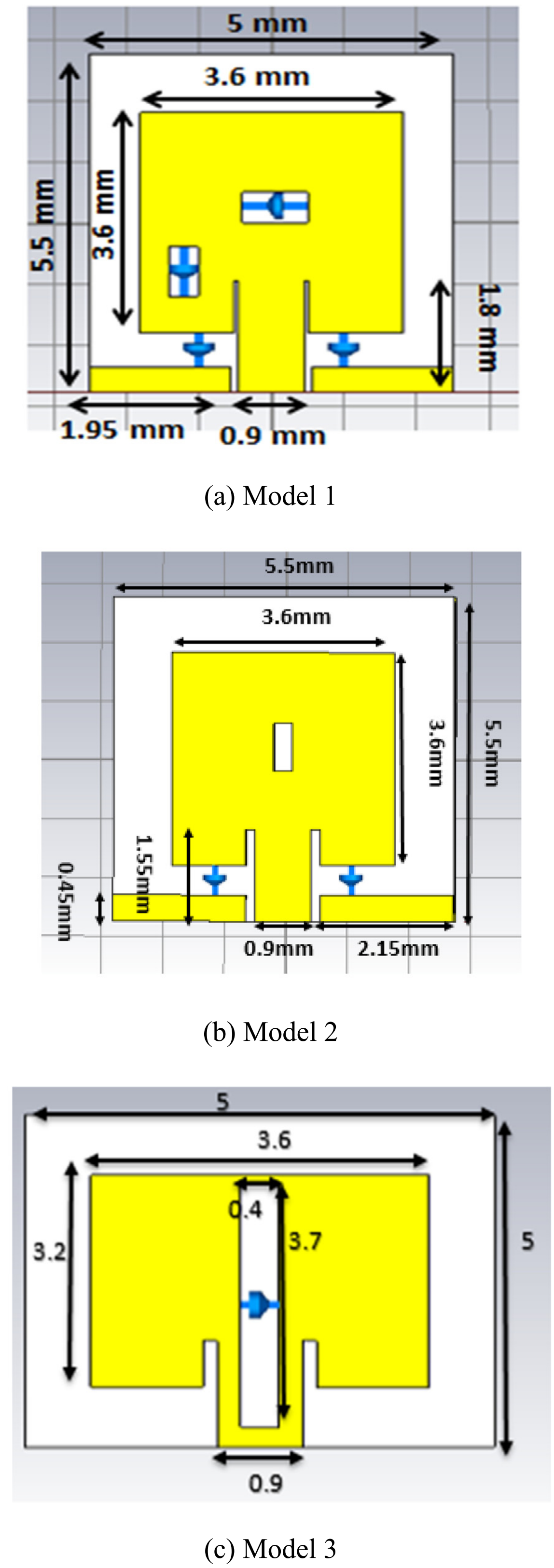
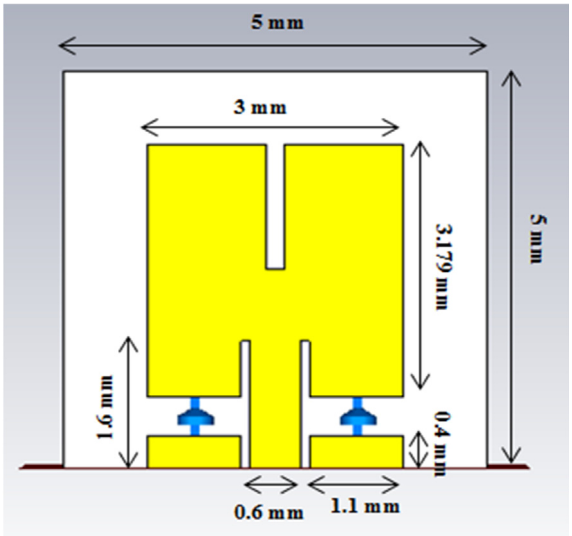
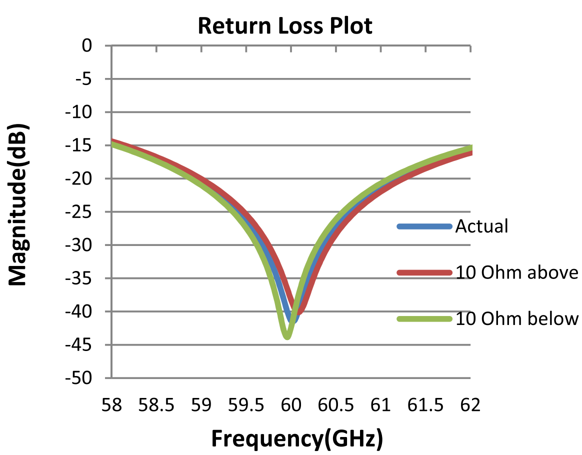


Fig. 2 Investigation of different Models for Frequency Reconfiguration.

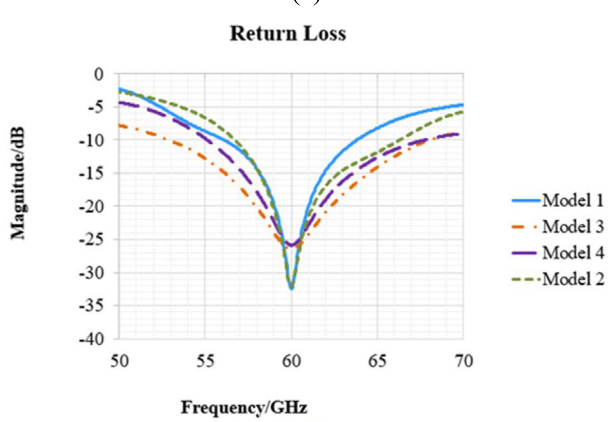


(d) Model 4

Fig. 2 (*continued*)



(a)



(b)

Fig. 3 (a) Return Loss of Model 1 (b) Return Loss of all Models.

mechanism. Four models are presented, analyzed, simulated and their results are compared in this paper to validate frequency reconfiguration mechanism via varying values of lumped parameters. The material of ground and patch used is the same material copper while the material used in substrate is named as Roger-RT5880, relative permittivity 2.2($\varepsilon r = 2.2$). The substrate material used is the same in all four models with changed in thickness of the substrate. All models are simulated by CST (Computer Simulated Technology) software.

The antenna dimensions of Model 1 as shown in Fig. 2(a) are $5.5 \times 5 \times 0.562\ mm^3$. The main radiating element is square shaped patch having small slots and dimensions of $3.6 \times 3.6\ mm^2$. The radiating patch is fed using GCPW feed with length *2.05 mm* and thickness *0.4 mm*. Reconfigured frequency is achieved by using four resistors, two connected between GCPW and patch and other two in the slots in the patch. In Model 2 the same feeding technique is used as shown in Fig. 2 (b), but here reconfigured frequency is achieved by using two resistors connected between ground and patch. In this case the substrate thickness is of *0.1 mm*. The radiating patch is fed using CPW feed with length *2.15 mm* and thickness *0.45 mm*. In Model 3 antenna has the dimensions of $5 \times 5 \times 1.571\ mm^3$ as shown in Fig. 2(c). The radiating patch is fed using Microstrip line feed with length *1.6 mm* and width *0.9 mm*. Similarly, in Model 4 the dimensions of antenna are $5 \times 5 \times 1.3\ mm^3$ as shown in Fig. 2 (d). The radiating patch is fed using CPW feed with length *1.1 mm* and thickness *0.4 mm*.

3.1. Return loss/VSWR/gain

In this section, Reflection coefficient, VSWR, Gains and Directivity of Model 1 individually and all the models combine is observed. First of all, the models were designed at 100 Ω resistance (the 100 Ω value was chosen after parametric analysis) as shown in Fig. 3(b). As you can see that different models have same resonant frequency i.e. 60 GHz with different return loss i.e. Model 1 @-34.2 dB, Model 2 @-33.6 dB, Model 3 @-27.3 dB and Model 4 @-26.5 dB. To analyze and validate frequency reconfiguration, only model 1 was observed with different resistive values i.e. 10 Ω above and 10 Ω below the actual value (i.e. 100 Ω) as shown in Fig. 3(a). As you can see the resonant frequency radiates above and below the 60 GHz with varying resistive values.

The similar cases of Model 1 individually and combination of all the models were observed for VSWR. It can be clearly seen in Fig. 4 (a) and (b) VSWR at the resistance values of resistors $R1 = R2 = R3 = R4 = 100$ and resonating frequency of 60 GHz, is 1.017, when the value of resistor is increased from 100 Ω to 110 Ω then it results in the increase of the VSWR value which is observed as 1.019. Below 100 Ω, a decrease in VSWR value, is observed which 1.012.

In case of gain the far field plot of the Model 1 individually and all the models combine is shown in Fig. 5(a) and (b). Initially gain of 5.65dBi observed at 100 Ω resistance, while varying the resistive value above and below the actual value 5.64dBi and 5.66dBi was achieved.

3.2. Comparison of all parameters

The comparative analysis of four reconfigurable antenna models is given below. The comparison is based upon the antenna

Table 2 Parametric Comparison at different resistive values.

Resistance (Ohm)		Frequency (GHz)	Return Loss (dB)	Bandwidth (GHz)	Gain (dBi)	Directivity (dBi)	VSWR (dB)
10 ohm below desired frequency	Model #01	59.94	−41.60	8	5.76	9.83	1.02
	Model #02	59.86	−39.11	7.76	5.43	9.35	1.02
	Model #03	59.86	−27.16	12.63	7.17	8.8	1.09
	Model #04	60	−26.46	14.92	5.2	6.29	1.09
10 ohm above desired frequency	Model #01	60.08	−38.62	8.35	5.74	9.82	1.02
	Model #02	60.02	−49.59	7.81	5.38	9.41	1.00
	Model #03	60.14	−24.92	12.63	7.04	8.73	1.12
	Model #04	60	−26.46	14.92	5.2	6.29	1.09

Table 3 Effects of Different Frequency Switching Techniques.

Switching Technique	Effects
Varying the Patch Size	This technique can easily achieve the desired operating frequency by analyzed the total size of patches. However, the drawback of this method is complicated antenna design and biasing circuit. It mostly effects the return loss, reflection coefficient, surface current and gain of the antenna while VSWR is least effected as the patch size is modified.
Reconfigurable Matching Network (Stub Tuner)	This design offers a simple antenna geometry, but gives limited frequency reconfiguration. It highly effects the return loss and VSWR.
Changing the Current Flow	The biasing circuit requires components such as capacitor, inductor and PIN diode to be properly located so the antenna is not becoming a short circuit. Moreover, the antenna needs to add small slot between switches to provide different state of configuration. Furthermore, the changing structure of the antenna will affect the operating frequency and antenna performances. The radiation pattern is effected, while the return loss, reflection coefficient is slightly disturbed
Mechanically configure using Meta Surface	This kind of method categories is mechanically reconfigurable antennas, where the parts of the antenna structures (metasurface) consist of movable parts for turning the frequency. The drawback of such designs was the difficulties of the fabricated process to ensure the moveable part can be still attached to the antenna and the same time can be flexible tuneable. It effects (modify the values) of all the parameters.
Varying the Length of the Slot	Varying slot size effect, the radiation efficiency. The transmission line properties is effected, also the return loss, radiated gains are disturbed
Varying the Values of Lumped Elements	varying the values of lumped elements is the most effective way for frequency switching, as all the modifications can be validate in the software before fabrication. Also, we don't have modify the patch size or by any other means which results in reshaping our end antenna. These lumped parameters are cheap, light in weight and easily available in the market. It only varies the resonant frequency without changing the return loss, gain ad VSWR.

parameters which are return loss, gain, directivity, VSWR and resonant frequency. The parameters behavior is checked on by changing the value of resistance of resistors from original value of resistance 10 Ω above and 10 Ω below. All the four models are designed on 60 GHz resonant frequency. The overall results of the parameters 10 Ω above and 10 Ω below are mentioned in the table given below. From the analysis it is observed performance parameters vary with different shapes of model. The analysis shows that the Model 1 have good return loss with high directivity value and VSWR is low, which shows that Model 1 is to be used as a high directional antenna in comparison with other models, because it can focus more power in a specified direction. Similarly, Model 2 has low radiation efficiency, Model 3 has high gains and is efficient to use to transmit maximum power, in the direction of peak radiation. Model 4 is poor in all the parameters but have the highest bandwidth among all the four models so due to high bandwidth value this antenna model can be used for speed transmission of radio waves.

4. Frequency switching methods

4.1. *Varying the patch size*

A multiple band C slot as well as a reconfigurable antenna has elements with a dual patch as suggested and investigated in Fig. 6. The compact volume 3925 mm, is occupied by it and a ground plane is also included. The resonant frequency can be tuned from 5 GHz to 7 GHz by controlling the total patch size. C slots, two in number and parallel to each other, are used for surface perturbing for the excitation of the dual as well as wideband modes across the current paths. Making use of PIN diodes, two switches are implemented which, on the connecting lines of a network with simple feed, are placed on the ele-

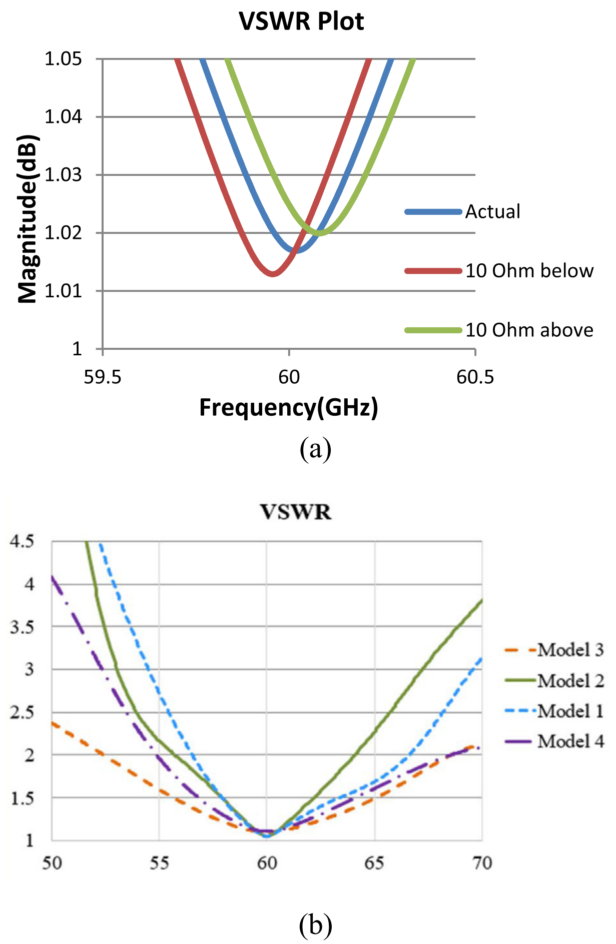


Fig. 4 (a) VSWR of model 1 (b) VSWR of all the models.

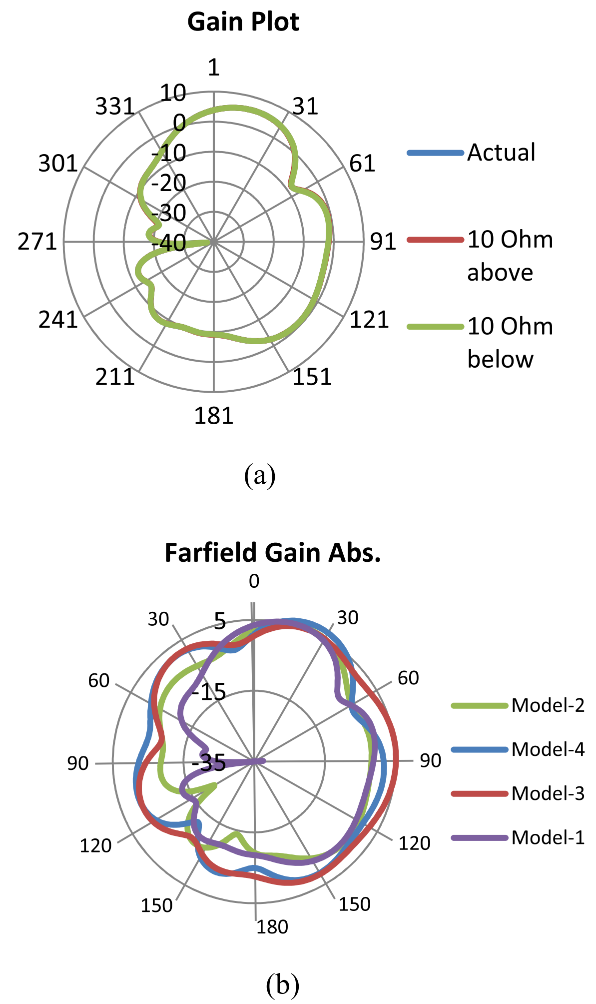


Fig. 5 (a) Gain of Model 1 (b) Gain of all the models.

ments used as a patch. The ON switching often results in one or two patch components being used in the dual band modes. With an impedance bandwidth of 33.53 percent, when both patch elements are turned ON, the wideband mode is obtained. The frequencies can be controlled independently in the dual band modes by making changes in positions and C slot measurements, which do not affect the wideband mode. The benefit of this proposed antenna is that it is possible to accomplish the operation of two or dual bands, with one wideband operation, using similar dimensions. Two PIN diodes are placed on the connecting lines to the patch elements and used as switches. Just to prove our design concept, we have used the practical PIN diodes, SMP1320-079 from Skyworks Solutions Inc. with a size of $1.5 \times 0.7\ mm^2$, as the switches. In computer simulation, these two diodes are modeled using the resistance, inductance, and capacitance (RLC) boundary sheet which gives 0.9 ohm as the impedance value of the PIN diode in the ON state and 0.3pF as the capacitance value in the OFF state. These PIN diodes are turned "ON/OFF" using a dc biased signal, so two coupling chip capacitors (C_1 and C_2) each with 10pF are used to prevent the dc signal from flowing to the main feed line but allow the RF current to pass through. The biasing networks for the two PIN diodes are also shown in Fig. 4, where the inductors L_1, L_2, L_3 and L_4, all with 12nH, are used as radio-frequency (RF) chokes to provide high impedance for the RF signals. The resistors R_1, R_2, R_3, and R_4,

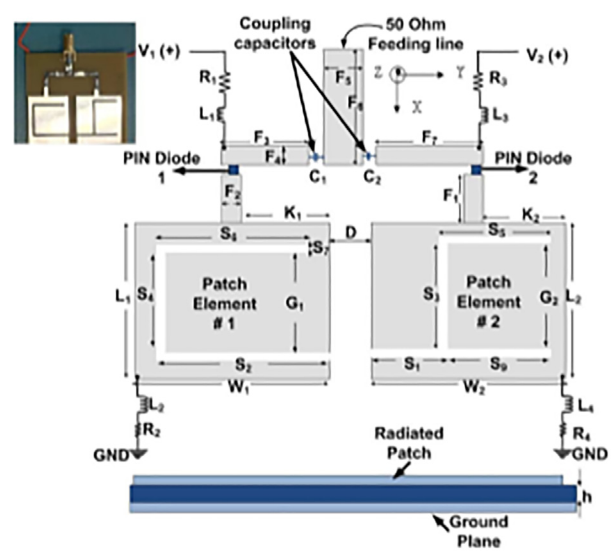


Fig. 6 Configuration of Proposed Antenna with DC Biasing Network [34].

each with 10kohm, are used to control the dc biasing current to (or dc biasing voltage of about 0.7 V across) the PIN diodes. These lumped components will have insignificant effects on the antenna performance because the impedances of the RL circuits are much higher than the impedance of the antenna, allowing very little currents to flow through. It overcomes the need to increase the surface area that is usually incurred when designing wideband patch antennas. Via prototypes, the simulation findings are experimentally tested. The radiation patterns are measured, and the peak gains, which are both in good agreement, demonstrate stable responses. The relation between two patch elements plays a major role in achieving broad bandwidth. The mutual coupling effect is also studied between the patch elements [34].

4.2. Reconfigurable matching network (Stub Tuner)

The antenna suggested in [35], which is recognised for its special higher frequency execution, is usually built for the liquid crystal polymer (LCP) as shown in Fig. 7. Inside the geometry of the antenna, a radiating patch, in the form of a tuning fork, and two stubs are inserted, which can be made a part of the radiating portion with the aid of two key switches. The proposed single-sided printed reconfigurable antenna consists of a shape of a tuning fork having two prongs of different lengths. Prong 1 of longer length Lp1 is connected with a stub 1 by means of a switch 1 (SW1), while prong 2 of length Lp2 is connected with stub 2 via switch 2 (SW2). The reconfiguration principle is simple as the patch antenna consisting of fork prongs and stubs can alter its radiating area by using switches, which ultimately changes the respective resonant frequency. The proposed antenna covers an impedance bandwidth of 20.7–33.2 GHz when both the switches are ON and both stubs are part of the radiating element (Mode 1). Frequency reconfiguration has been observed while altering switch configuration. All the four modes collectively cover the frequency range of 20.7–36 GHz. Where four different frequency bands can be matched using two PIN diodes as a switch. The antenna is matched at, 32.3 GHz when SW1 is forward biased (ON state), at 22.4 GHz when SW2 is forward biased (ON state). When both the switches are forward biased (ON state), the

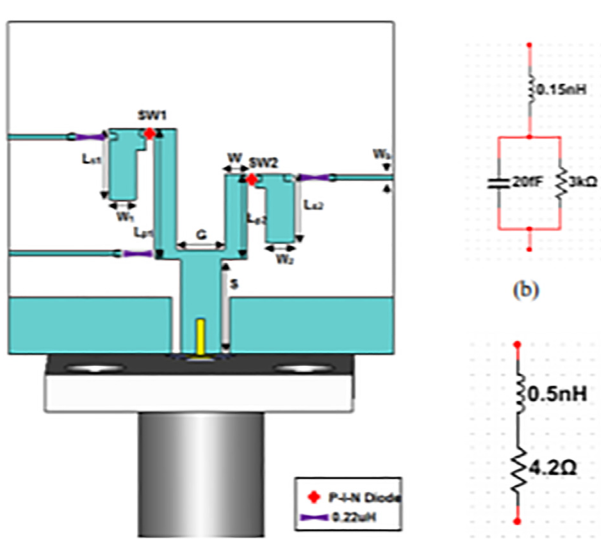


Fig. 7 Simulated Layout, Diode OFF/ON State Circuit Model [35].

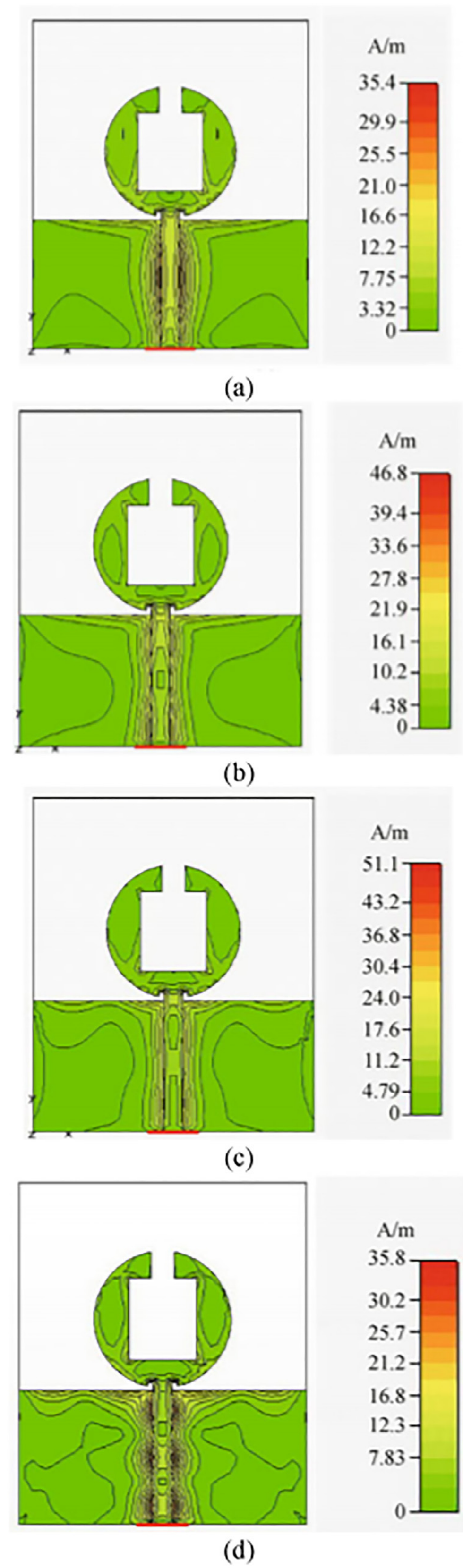


Fig. 8 Simulated Amplitude Surface Current Distribution [36].

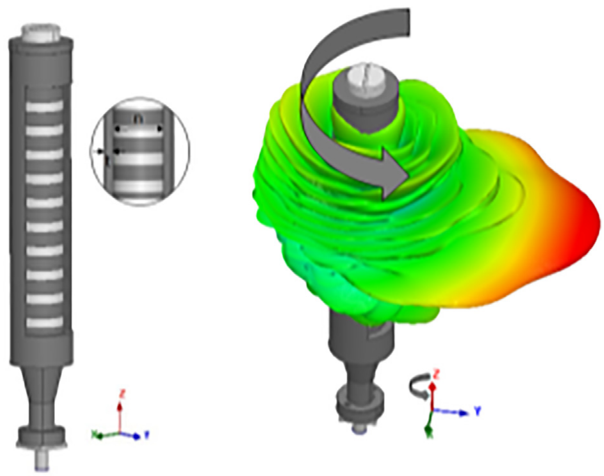


Fig. 9 Mechanically Reconfigurable Antenna [37].

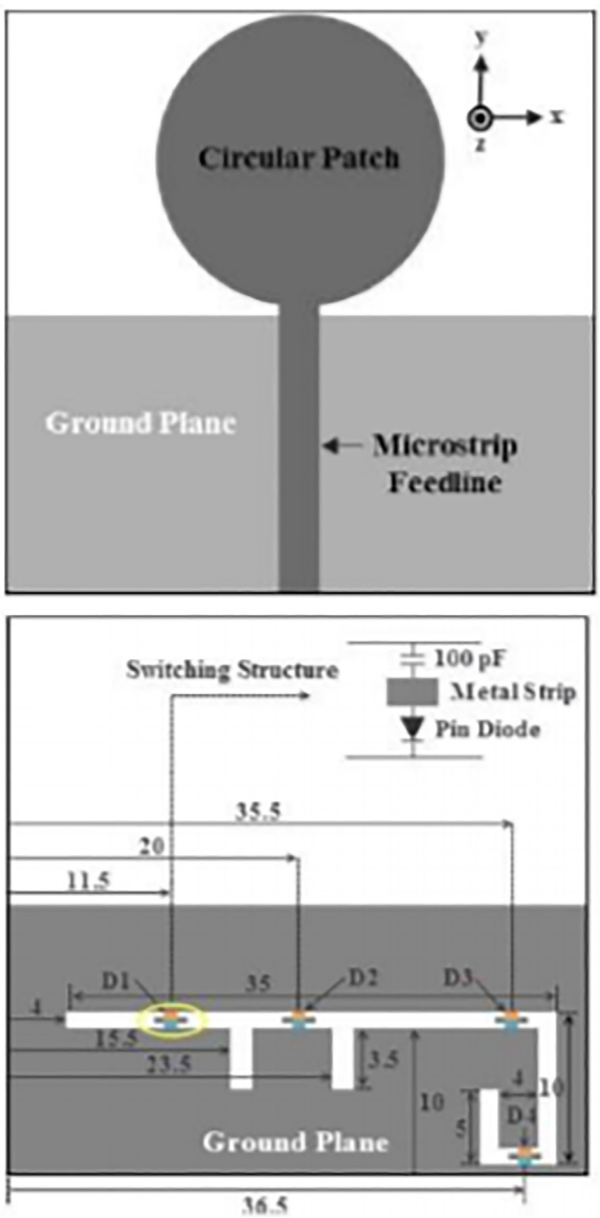


Fig. 10 Configuration of Monopole Antenna Structure [38].

antenna is matched at 31.7 GHz. Similarly, when both the switches are reversed biased (OFF state), the proposed antenna is matched at 28.8 GHz. The suggested antenna is well-suited for wearable communications systems as well as for applications that are body-centric for 5G networks due to the conformity features, lighter weights, better and improved efficiency and reconfigurable frequency.

4.3. Changing the current flow

In Fig. 8, an antenna is suggested. It is simply fed with a cut notch and circular patch using a microstrip line that is defined in this investigation [28]. An ultra-wide band (UWB) is otherwise explicitly designed to carry wireless communications and other applications across the band over 3.1–10.6 GHz. By using a microstrip thread, one transmission stage and a plane of ground that is partial to it, the notch cut in this circular patch antenna is fed. The suggested voltage of 2.1 VSWR (voltage standing wave ration) and the (S11 < −10 dB) bandwidth of the antenna covers the federal communications (FCC) UWB application range defined in the 3.1–10.6 GHz range. Impedance bandwidth can be achieved with the proposed antenna in the 8.6 GHz (2.4–11 GHz) frequency range. The loss return, pattern of radiation, VSWR, gain, delay in the group and current suggested antenna distribution are all included in this investigative work. The outcomes of simulation and the suggested antenna details are shown on the microwave studio by CST [36].

4.4. Mechanically configure using Meta Surface

The ring-shaped slotted wave guide antennas, based on arrays, are analysed for mechanically reconfigurable antennas with greater gain, as shown in Fig. 9. Apps for MMW applications. The maximum scanning range is ensured in the azimuth position by the metallic jacket, which is a properly rotating unit and partially covers the collection of radiating frames. In the azimuth axis, this technique provides a beam width of 37o and the net gain is 17.41 dBi, which is operable in the

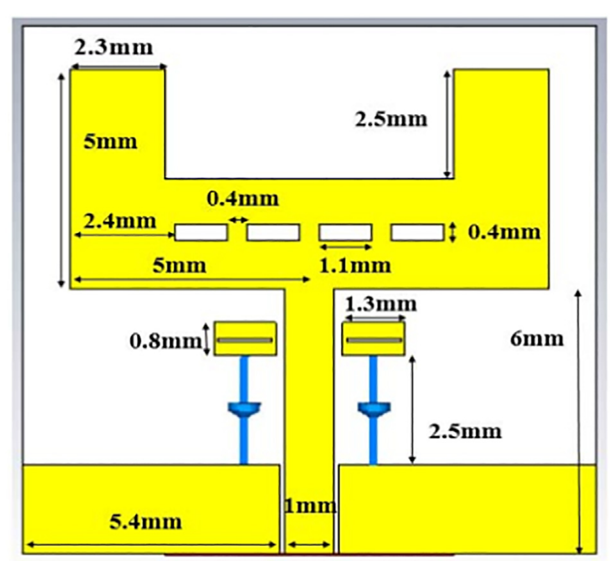


Fig. 11 Proposed Slotted Y-Shaped RA [39].

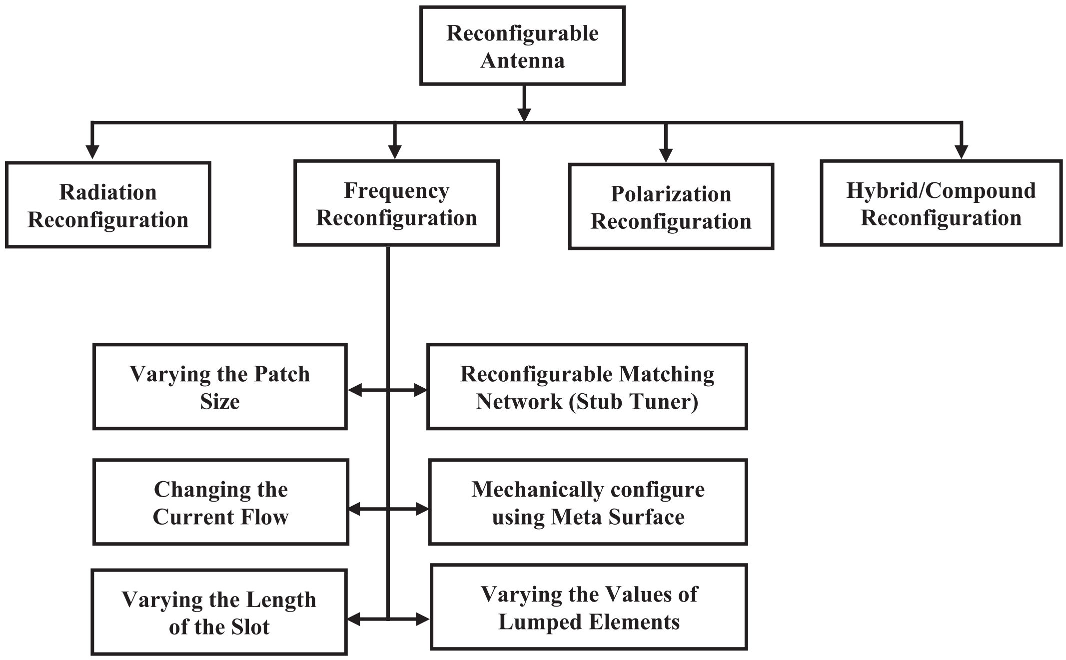


Fig 12 General frameworks for different types and sub-types of reconfigurable switching techniques.

27.3 GHz frequency range. Most significantly, there are a number of benefits in comparison to the traditional phase array, as this method does not always suffer from scanning loss, SLL degradation, beam extension, etc. The outcomes of the experiment for the element array and antenna's numerical outcomes and their array show that it is applicable in 5G cell phone networks [37].

4.5. Varying the length of the slot

As they provide a broad range of turning frequencies, the microstrip antenna has the potential to be a nicer candidate for frequency reconfigurable antennas, and varactor switch resonant frequency turning is generally seen around the slot. To vary the slotted size of the antenna [38], PIN diodes are used. Along the slotted lines of the antenna, four PIN diodes that have the ability to configure frequency bands of five different ranges are used. Uh, Fig. 10. The structure of a switchable frequency on the ground plane of the antenna proposed is shown below. A different size and structure was produced for the slot as the PIN diode has ON/OFF. Therefore, the range of frequency varies from 2.11 to 10.92 GHz.

4.6. Varying the values of lumped elements

The implementation of the MMW on a frequency reconfigurable antenna in the real world setting is demonstrated. The broad bandwidth characteristic of such waves is the generation of 5G networks. A feeding technique is used to apply the CPW (coplanar waveguide) so that the reconfiguration is accomplished in the slotted and Y-shaped antenna, as shown in Fig. 11. Two main resistors that are variable and help to achieve 10 dB return loss in the resonating variable frequency, which is about 26–29 GHz, are added to the model of this suggested antenna. A comparative analysis is observed among gain, directivity and efficiency of radiation pattern for the variable resistance. Along with this, there is a compassion of this CPW-fed technique with the GCPW grounded CPW for increased and enhanced efficiency in dB, which is S11 [39].

5. Conclusion

Different frequency switching techniques are discussed with showing a difference between a simple and a reconfigurable antenna for 5G applications. As seen, the microstrip patch antennas operate in resonance. All these operations are nicely modelled and acknowledged. If the designer is well-informed, the structure of antenna can be manipulated and composition changed various ways for reconfiguration properties. A resistor as a lumped parameter is used for frequency reconfiguration, while, an inductor, capacitor and simple diode may be used in direction for future work.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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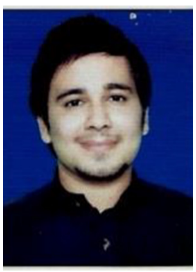
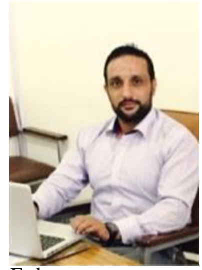


M. Kamran Shereen received the B.Sc. & M.S degree in Electrical Communication Engineering from University of Engineering & Technology Peshawar, Pakistan in 2014 and 2016. He is currently working as a PhD scholar at UET Peshawar in Microwave and Antenna Lab. He is teaching antenna subjects in the same institute. His field of interest is reconfigurable Antenna, MIMO.



M.I. Khattak is working as an Associate professor in the Department of Electrical Engineering in University of Engineering and Technology Peshawar. He did his BSc Electrical Engineering from the same University in 2004 and did his PhD from Loughborough University UK in 2010. His research interest involves Antenna Design, On-Body Communications, Anechoic Chamber Characterization, Speech processing and Speech Enhancement.

Jamel Nebhen received the M.Sc. in Microelectronics from the National Engineering School of Sfax, Tunisia in 2007, and the Ph.D. degrees from the Aix-Marseille University, France, in 2012, all in Microelectronics. From 2012 to 2018, he worked as a Postdoctoral Researcher in France in LIRMM-Lab Montpellier, IM2NP-Lab Marseille, ISEP Paris, LE2I-Lab Dijon, Lab-Sticc Telecom Bretagne Brest, and IEMN-Lab Lille. Since 2019, he joined the Prince Sattam bin Abdulaziz University in Alkharj, Saudi Arabia, as an Assistant Professor. His research interests are mainly in the design of analog and RF integrated circuits, IoT, biomedical circuit, and sensors instrumentation.