A Review on Reconfigurable Antenna

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Abstract: —The advancement of wireless communication is markedly accountable from the past two decades, In the past, various sustaining designs of reconfigurable multiband antennas for different wireless services have come into existence. The smart and adaptive frameworks is required reconfigurable antennas for the great utility. Now a days, a high quality of communication with reduced size is required for new generation wireless system. The re-configurability offers plethora of advantages in wireless networks such as 4G & 5G networks. A reconfigurable antenna should have sufficient number of active elements, which helps to achieve the reconfiguration in antenna characteristics. The characteristics of antenna can be manipulated and revamped by changing the current flow in the radiating element of antenna with the help of active elements/switches such as; MEMS switch, varactor diode and p-i-n diodes. These high-quality active elements are responsible to increase the biasing complexity as well as cost of the networks. A reconfigurable system along with minimal interference level over the fixed or non-reconfigurable transceivers has been discussed in detail. Therefore, this work attempts to present a review of reconfigurable antennas for state of the art wireless techniques mainly focus from 2005 to 2018.

Keywords: Cognitive Radio; MIMO; Reconfigurable Techniques for Antenna; Multiple Reconfiguration; Switching Devices; Feeding Techniques.
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1. Introduction

Since, last 100 years the antennas have been used transceiver for radio signals, but still have a noteworthy scope for more research. The first antenna came to the public notice in 1887 when Hein Rich Hertz designed a set of wireless set up to test the hypothesis of James Clerk Maxwell[1]. The transmitting and receiving antennas used in Hertz experimental setup were flat dipole antenna and single turn loop antenna respectively. Since the inception of the antenna technology, the next fifty years were based on radiating elements configured out of wires and generally supported by wooden poles. The bandwidths of 1st generation antennas were narrow and their directivity was increased by installing them in arrayed fashion. In 1926, Hidetsu Yagi and Shintaro Uda[1] have developed a high directive antenna known as Yagi-Uda antenna.

The antennas as well as filters are play the very important role as front-end circuits in predefined frequency operation of wireless communication systems. The components are defined on the basis of some fixed parameters such as bandwidth, gain, radiation pattern, reflection coefficient and polarization. However, the modern technologies such as cellular radio system, unmanned airborne vehicle (UAV) radar, satellite, microwave imaging and aircraft require more flexibility to support a number of wireless standards such as; UMTS, UWB, Bluetooth, WiMAX, WLAN, Wi-Fi etc. The antenna is considered as a grate utility device for accept or reject the signals at various frequencies along with the front-end circuits in RF/microwave modern wireless application systems presents in 2008[1]. There exists a continued challenge to design an RF/microwave reconfigurable antenna with linear phase, low insertion loss, lightweight, small size, high

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selectivity and lower cost due to the limitation of the frequency spectrum[1, 2].

The reconfiguration capability to change the operating characteristics of individual radiators may be through electrical, mechanical, or by material change. Reconfigurable antenna is capable to alter the values of their operating frequencies, impedance bandwidth, radiation pattern and polarization independently as per the needs of communication. The frequency reconfigurable antenna has been classified continuous frequency tuning and switched tuning. In continuous frequency tuning, the antennas allow the smooth transitions between operating bands without jumps. On the other hand, the switching mechanism decides the distinct frequency bands operation of the antennas. In general, both the categories share a common theory of reconfigurable operation[3-6]. "A significant number of reconfigurable antennas have been proposed which are capable to switch between two particular narrow bands"[7,8]. The combination of wideband and narrowband reconfiguration in the antenna system has the grate utility for multiband frequencies operation over the fixed or non-reconfigurable transceivers[9-11], as it offers a pre-filtering. The wideband antenna can support the multiple bands simultaneously at the cost of weak reception quality. Hence, the multiband reconfigurable antenna is a viable solution for the previously mentioned issue in the antenna design and therefore getting attention nowadays[12]. The review article highlighted about various types of reconfigurable antenna in the field of wireless communications with single and multiple re-configurability functions as shown in Figure 1.

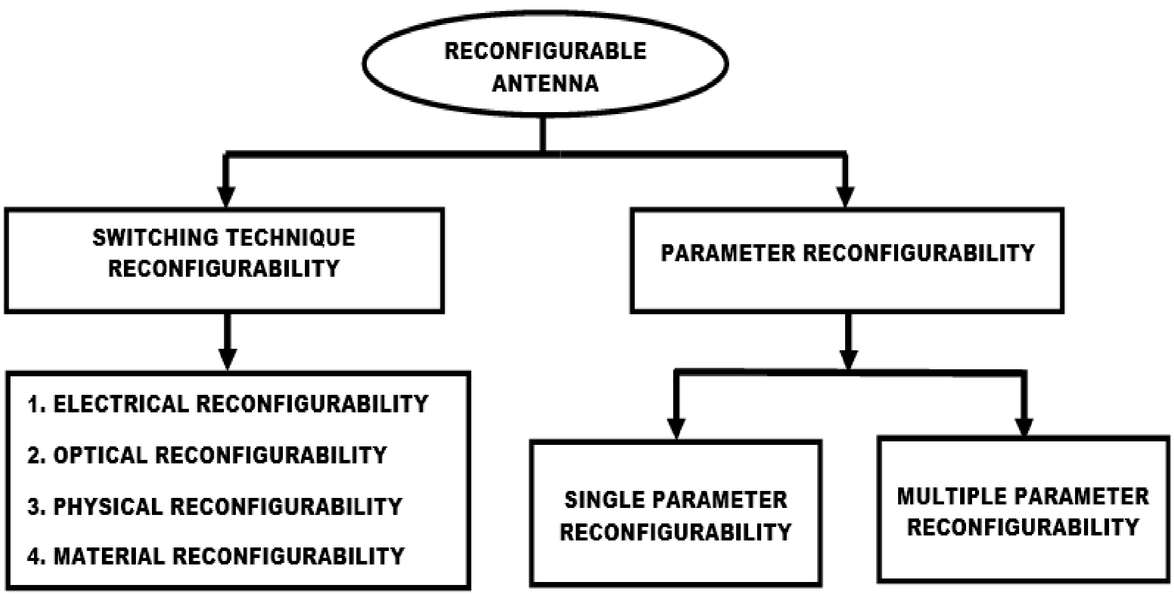

FIGURE 1: CLASSIFICATIONS OF RE-CONFIGURABILITY

1.1 Classification Based on Switching Techniques

The techniques to generate the reconfiguration capability in antenna system have been discussed below. The electrification techniques for reconfiguration in antenna system can not be implemented without switches such as: RF-MEMS, Varactor & PIN diode. Antennas in which the photoconductive switches are used are called optically reconfigurable antennas and in those antennas are have structural variation to generate the reconfigurable characteristics are called physically reconfigurable antennas. Also, the reconfigurability in the antenna system can be developed by using smart materials such as liquid crystals and ferrites are called material reconfigurability.

1.2 Electrical Switching Techniques in Reconfigurable Antennas

By electronic switching in the antenna system the electrical length of the antenna is varied. As change in electrical length of the antenna system the frequency, polarization and radiation pattern can be change. New reconfigurable Vee-antenna architecture with MEMS switch has been reported in 1999[13]. This Vee-antenna is designed at 17.5 GHz with optimal angle of 82.5^0 which gives maximum directivity of 5.6 dB with half power beam widths is 37.9. In the same year, an article has been reported on reconfigurable aperture which highlighted the measure bandwidths of 18% and 16% for reconfigured and reference antennas respectively[14]. The gains of two antennas have been measured at 8.5 GHz and found the same level of 12 dB. A novel microstrip patch antenna with electronic switchable slots has been reported[15], which has the circular polarization diversity. The switching ON or OFF of diodes, decide whether the polarization of antenna radiation is RHCP or LHCP. The axial ratio is 3dB from -70^0 to 70^0 broad angular range has been achieved at 4.64 GHz with 3% CP bandwidth.

A single-layer, single-feed dual-band, microstrip antenna was discussed in 2003[16]. The antenna structure has the narrow slots and on-chip capacitors. The frequency ratio (FR) range has been extended up to 1.25. The chip capacitors are connected across the narrow slots for producing the further capacitive loads.

A reconfigurable antenna with perturbed slot-ring architecture has been presented[17]. This architecture allows the switching in polarization diversity. The PIN diodes have been used for switching in perturbed slot-ring. This structure has been produced the ARB's 4.3% and 3.4% for LHCP and RHCP respectively with minimum axial ratio of 0.9 dB.

A novel microstrip antenna has been reported in 2004[18], which perform the pattern and frequency reconfigurability with the help of switched connections. The fundamental antenna setup is linearly polarized at 3.7 GHz. Two different types of antenna connections have been discussed. Out of these two one provides a re-directed radiation pattern and maintaining a common operating impedance bandwidth as per the baseline configuration, and the second set of connections provides operation at 6 GHz with broadside patterns.

An antenna with double rectangular patch has been reported in 2004[19]. The PCB substrate has been used to print the both patch which are connected via 4-bridges to obtain the dual frequency band operations 2.4 GHz and 5.5 GHz respectively. These 4-bridges play the important role in switching the frequency band. The resultant gain of the antenna system is 5 dBi and 3.7 dBi at 2.4 GHz and 5.5 GHz respectively.

An adept, compact and electronically tenable antenna has been designed[20]. The proposed fundamental structure has a single-fed slot resonator which is loaded with a series of four PIN diode switches. The four PIN diode switches have been used in order to tune the antenna over the frequency range 540 MHz - 950 MHz. A better return loss (-20 dB) has been observed which proves the best impedance matching for the operating frequency band along with measured gain of 11 dBi, which reflect an antenna efficiency of 47%. In 2007, re-configurability of frequency and polarization in MSA has been submitted[21]. A U-slot is incorporated into a square patch which is connected with a PIN diode and the frequency reconfiguration characteristic depends on the switch states (ON or OFF). The 3 dB CP bandwidths have been determined at 35 MHz and 40 MHz by introducing PIN diodes in U-slot.

An annular slot antenna (ASA) has been reported[22]. The PIN diodes are used to create reconfiguration of radiation pattern at three different frequencies 5.2, 5.8 and 6.4 GHz. The stubs have been used to matching the input impedance of the ASA. The PIN diodes are working as switch to connect or disconnect the stubs those are responsible for matching the network to get reconfigurable characteristics.

The polarization re-configurability with RHCP/LHCP in the compact MSA design is presented[23]. The basic antenna structure is fed by a Coplanar-waveguide (CPW). The proposed reconfigurable antenna is used as a transmitting antenna, which is having the output power level from 16 dBm to 26 dBm. The gain of the antenna is 6.02 dB with axial ratio 2.06.

A new reconfigurable multiband microstrip antenna has been presented in 2007[24], which is printed on a hexagonal substrate of six armed star shaped patch. When the different switches activate then the multi frequencies from 3 GHz and 4.5 GHz are generated. The antenna is also responding to the wide band range (3.5 GHz to 3.8 GHz and 4.3 GHz to 4.7 GHz).

A reconfigurable patch antenna with slotted ground has been demonstrated[25]. The dual-frequency operation is being achieved by having a PIN diode in slots. Ground plane with Slots play important role in increasing the electrical length and reducing the system size by 53%. When the diode is in the off-state, the antenna works for K-PCS (1.85 GHz) and offers the bandwidth of 60 MHz. A reconfigurable patch antenna with wide operational bandwidth for wireless communication system has been presented[26]. The reconfigurable antenna has an E-shaped patch structure and with the help of integrated switches (ON/OFF) its operating frequency can be changed. The covered operational frequency range of the proposed antenna is 9.2 GHz to 15.0 GHz and 7.5 GHz to 10.7 GHz with the relative bandwidths of 48% and 35% respectively.

In 2011, an antenna structure has been proposed, which provides the frequency reconfiguration characteristics with the help of PIN diode[27]. The structure is appropriate for multi-standard personal communication systems. Two different configurations have been studied for dual-band behaviour. The proposed structure provides the 10% improvement in SNR with respect to a fixed antenna configuration. In 2008, a frequency reconfigurable microstrip patch antenna has been presented[28]. In this work, it was found that introduction of a U-shaped slot in the radiating patch offers a wide bandwidth with flat input resistance and a linear input reactance in comparison to the conventional patch antenna. The frequency of antenna has been changed by using tunable inductor and capacitor at the input of antenna and obtained the frequency range i.e. 2.6 GHz to 3.35 GHz.

A reconfigurable antenna with pattern diversity using single-feed was introduced[29]. The presented antenna having rectangular slot that utilizes metallic cubic cavity will radiate and in all three cases at 5.2 GHz, the matching of impedance is attained. The frequency bandwidth for the configuration-2 is (-10 dB) 8.8% and 5.4% is for configuration-1. While, in the third configuration the shared bandwidth is 285 MHz, having a range between 5.025 GHz to 5.31 GHz.

The development of RF-MEMS actuators (DC Contacts) with cantilever type double and single arm and is monolithically integrated with an antenna architecture to create the frequency reconfigurability has proposed[30]. The operating frequency bands can be switched by activating/deactivating the RF MEMS actuators, which have been loaded in the antenna geometry and microstrip feed line. The two reconfigurable modes of operation have been observed at high frequency f_h = 5.2 GHz and low frequency f_l = 2.4 GHz with the frequency bandwidths 100 MHz and 650 MHz, that covers the ISM allocated frequency range.

In 2010, a compact U-slot microstrip patch antenna for wireless local area network (WLAN) applications with the polarization reconfigurable characteristics has been proposed[31]. To change the effective length of the U-slot arms, 2 PIN diodes have been used, which makes the antenna as polarization reconfigurable. It is found that the circular polarization (CP) and linear polarization (LP) modes of the antenna are 13.61% and 6.12% respectively both at centre frequency 5.9 GHz.

The measured bandwidth with the 3 dB axial ratio is 5.69 GHz to 5.87 GHz.

A reconfigurable multiband compact microstrip antenna has been presented[32]. The multiple frequency bands with 56% effective bandwidth have been achieved using the concentric metallic semicircles around a central semi-circular microstrip patch of the antenna and can increased the operating frequencies up to 75%. A Vivaldi antenna, which is having the capability of dynamically rejecting interference, has been reported in 2011[33]. The main objective of design was to allocate the dynamic frequencies which are useful for multi standard communication. This Vivaldi antenna was being operated from 2.5 to 8 GHz and suitable for vehicle to vehicle communication with a stop band from 1.8 to 5.8 GHz. The antenna shows better impedance matching at 2.5 GHz - 8 GHz with band rejection between 1.8 GHz - 5.8 GHz. So, antenna covers the important wireless standards such as WiFi, WLAN (802.11a), Bluetooth (802.15.1), WiMAX (802.16) etc. Finally, the absolute gains measured at 2.5 GHz, 5.5 GHz and 8 GHz are 5 dBi, 7.9 dBi and 11 dBi respectively.

In 2012, a new pixel slot antenna structure with frequency reconfiguration has been proposed for wireless communication[36]. In the antenna the various radiating structures are connected together with the help of canonical switched slot element. In order to generate various resonant frequencies to attain the higher degrees of freedom, the conventional slot or slot with a loop is used to resonate the pixel slot antenna. The 4-switch single-pixel slot have been used in antenna structure. The cover frequency range is 1.56 GHz to 3.30 GHz. A novel reconfigurable slot antenna with three switchable frequencies has been proposed[39]. The uniqueness of this design is that it allowed passing the various frequency bands by selecting states (ON/OFF) of and used 3-switches. The measured resonance bands of the antenna are 2.47, 3.60 and 5.70 GHz with the measured gain values 2.34, 3.16 and 2.91 dBi respectively.

All electrical switching techniques presented in this section have both advantages and disadvantages. In comparison of all the design, there is a shift in use from RF-MEMS to PIN-Diodes to achieve switching. While PIN or Schottky diodes require less biasing lines, the difficulties encountered with biasing RF-MEMS are not alleviated by the use of PIN or Schottky diodes. RF-MEMS switches are used because of their significance in frequency re-configurability.

1.3 Optical Switching based Reconfigurable Antenna

An optically controlled reconfigurable antenna has been proposed[37], which is used for integration of wideband and narrowband for Cognitive Radio (CR) applications. The four conductive silicon switches have been used to get the frequency reconfiguration. The ON and OFF position of switches is depend on light illumination. The switch behaves as short circuit when light beam fall on the switch and will be off when there is no beam of light. The structure of the inner antenna varied by combining different slender ring parts which are controlled by optical switch. The four reconfigurable frequency bands are obtained i.e. Band1: 5.8 GHz – 6.8 GHz, Band2: 6.7GHz – 7.3 GHz, Band3: 7.0 GHz – 8.4 GHz and Band4: 7.9 GHz – 9.2 GHz, those focus on the upper frequency sub-band to obtain the UWB application. The gain variation for UWB is 2.6 to 4.1 dBi and for narrowband is varies from -0.1 to 4.5 dBi at all achieved bands.

1.4 Physical Angular Alteration based Reconfigurable Antenna

The angular alteration or mechanical movement in the geometry of antenna can provide a vast frequency shifts as compared to electrical switching changes, but there is big challenge to design this kind of antenna that have actuation mechanism and also maintain the other characteristics with significant structural changes.

A novel antenna designed for CR Applications has been presented[35]. The antenna structure works on wideband (UWB) range with frequency reconfigurable characteristics. In this proposed system the UWB antenna is used to scans the frequency bands as a channel while the tuning section of reconfigurable system for communication to cover these bands. To acquire frequency agility, the patch antenna is rotated to cover the entire band i.e. 2 GHz - 10 GHz. It is also observed that the measured gain of the antenna is 6.2, 6.67, 7.4, 7.77 and 8.4 dB depending on different the shapes of antenna system.

An antenna system is having a rectangular patch with microstrip fed-line presented in 2017[35]. The ground plane structure of the antenna is separated in three sections, one is moving plane and others two are fixed. The two actuators are controlling the moving ground plane, that allow vertical movement and tilting position. The actuators controlling is based on pulse width modulation, which is governed by Arduino board.

Antenna system for cognitive radio has been proposed that has two antennas, one antenna is used for channel detecting and the second one is utilised for transfer of information[38]. A printed monopole antenna has been designed for sensing, which is having the position out of the plane of a reconfigurable antenna at some height below the surface of patch. In this system, a slit cut in the hardened wall supports the whole antenna system and the sensing antenna is positioned inside the slit. The sensing antenna's position provides a better isolation with the communicating antenna.

1.5 Reconfigurable Antenna Based on Material Change

The change in the material characteristics of the antenna design can make it possible for the antenna system to tune at the different frequency is possible for the antenna system. As we know, the relative permittivity and permeability of the ferroelectric material is changed by applying the static electric field and static magnetic field respectively. The variation in relative permittivity and permeability can change the effective electrical length of an antenna, which produces the operating frequency shift. If the relative permittivity and permeability are high as compared to commonly used substrate materials, then it is very useful to reduce the antenna size. The main drawbacks of using standard ferroelectric and ferrite bulk materials apart from any complexities resulting from the bias structure are their high conductivity about other substrates that can severely degrade the efficiency of the antenna.

In 2011, a reconfigurable structure based on smart materials has been presented[34]. It has seen that the proposed structure has the potential to realize the adaptive antennas for emerging communication devices. In this work, a reconfigurable axial mode helical antenna has been designed. The height of the antenna has been adjusted by an alloy spring actuator. The measured and simulated results have been compared for some helix height of the proposed antenna (60, 70, 80 mm). It is observed that good impedance matching has been shown from 4 GHz to 4.5 GHz for all sweep points of the conical helix. The conical helix with 6 turns has 18 mm maximum radius at the radius ratio of 0.55 and the variation in height is from 50 - 90 mm which ratifies the pertinent matching for a wideband of 3 GHz approximately. Accordingly, at 3 GHz the patterns of the conical helix for the cylindrical helix were shown by changing the height of the helix from 40 to 95 mm. Also, with the total fixed length of the helix wire, the gain has been obtained with from 10 -11.5 dB range and the HPBW is 65^0 to 50^0.

1- Conclusion

After performing in-depth literature survey mainly from 2005 to 2018, it has been observed that immense research has done on the reconfigurable antenna design and the various feeding methods. Various antenna designs have been offered and every design has its own advantage and disadvantage in terms of performance. It is found that antenna size and its bandwidths are average in almost every case. Literature survey shows that reconfigurable antenna with reduced size has been very rarely presented. In view of the above, study has been made by incorporating new designs of reconfigurable antenna geometry for lower frequencies which are suitable for wireless applications. In addition, the presentation highlights a design requirement to achieve the ability of an antenna with simultaneous and independently flexible reconfigurations of frequency, radiation patterns and polarization characteristics.

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