Research Article

Reconfigurable Antennas and its recent developments

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Abstract: In the fast growing research and development, the Radio Frequency front end should be conceptual in a natural scenario; reconfigurable antennas have become crucial, for the upcoming generation of wireless communication. Systems are sensible because of their ability to change the radiation characteristics dynamically. They have many advantages such as good isolation, out of band rejection, multifunctional capabilities, low volume, low front end processing efforts without the need for filtering element which made them useful in wireless communications applications such as fourth-generation (4G) and fifth-generation (5G) mobile terminals. Reconfigurable antennas threw a novel challenge to antenna designers and researchers as they can be tuned to any frequency of operation without changing the radiation pattern. For the past three decades lot of improvement was done in the advancement of reconfigurable antennas. This review paper emphasizes the recent advancements in reconfigurable antennas..

Keywords:

1. Introduction

Wireless communication systems are moving towards multiple functions of wireless services for different applications. These are used at different times and for different purposes like defense, naval, or domestic purposes. The congestion of the electromagnetic spectrum became one of the reasons for enhancement. To take up this challenge, the upcoming wireless communication systems must be cognitive in nature and reconfigurable. The most suitable communication approach is based on the frequency of operation, the direction of the main beam, and different modulation schemes used in the system. To accomplish this, the traditional antennas are replaced by reconfigurable antennas (RA) because of their adaptive nature to different radiation characteristics.

They can also be used as control elements that can be programmed with proper feedback to increase the output, to reduce noise and errors, to avoid obstruction, increase security, less weakening of the signal caused by fading due to multipath, and also to expand the lifetime of the whole system. Some of the examples of promising applications comprise software-defined radio, cognitive radio, multiple-input multiple-output (MIMO) systems, multifunction wireless devices, and phased arrays with very good performance. A clear understanding of the fundamental characteristics like gain, radiation pattern, frequency of operation, and impedance matching will help in designing a good antenna. Reconfiguration can be achieved by re-distributing the currents on the antenna or the electromagnetic fields in the antenna's aperture edges [15, 16, 17, and 18]. The modifications in the operation of the antenna permit its usage in multiple wireless communication applications. Antenna reconfiguration can be done by varying the following parameters like frequency, polarization, and radiation pattern or by combining all of them.

The classification of RAs (shown in Fig.1) mostly depends on the above three parameters and are further divided into four groups such as RF-MEMS, PIN diodes, and Varactor diodes, with optical devices like photoconductive devices, by physically altering the structure and by changing the material like ferrites, liquid crystal, etc.

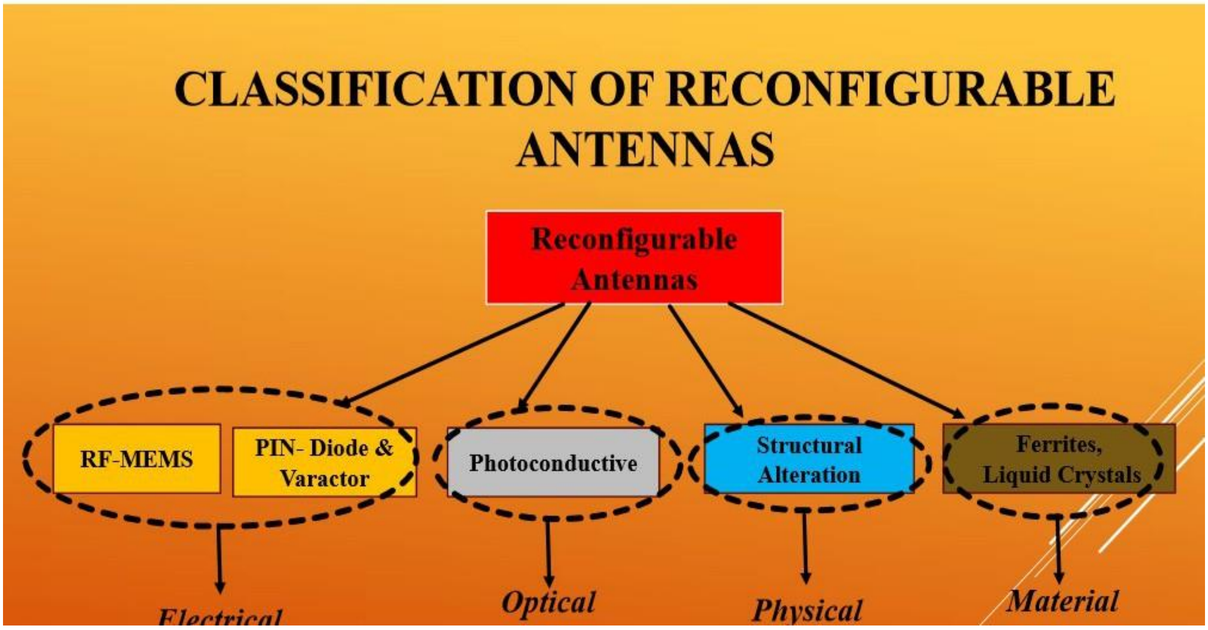

Fig.1 Classification of Reconfigurable antennas

2. Re-Configurability Of Antenna

A reconfigurable antenna is defined as one that has tunable elemental characteristics which include frequency of operation, impedance, bandwidth, radiation pattern, and polarization. The main aim is to modify the characteristics without affecting the others. As antennas are mainly electromechanical elements, the characteristics in which they are altered are electrical, mechanical, or electromechanical.

3. Frequency Reconfigurable Antennas (Fras)

Frequency reconfigurable antennas can change their frequency of operation. They are most helpful in situations where many communication systems congregate since the multiple antennas necessary can be exchanged by a single reconfigurable antenna. Frequency reconfiguration is obtained by a physical or electrical variation to the antenna dimensions using RF-switches, impedance loading, or tunable materials. They can reconfigure the resonant frequency by changing the structure, while the radiation patterns and polarization remain unchanged.

Generally, a definite radio tool has to take care of many services on a wide range of frequencies. However, antennas are necessary to cover multiple operating bands. But if a particular band is to be selected, then reconfigurable antennas are preferred over a wide band and multiband antennas because RAs can be made more compact, they present very good noise rejection, and reduces the number of filters required at the front end. Frequency RAs can be classified into two types; frequency continuous tuning and discrete tuning.

Continuous Tuning

Continuous frequency tuning can be achieved by using Varactor diodes. The edges through which the patch antenna radiates is connected to Varactor diodes to comprehend frequency sharpness [1, 12]. The required frequency tuning ratio can be produced by varying the well-organized electrical dimension of the patch which is achieved by varying the bias voltage of the Varactor diodes. A differentially-fed frequency-response Microstrip patch antenna was proposed [5] as shown in Fig. 2

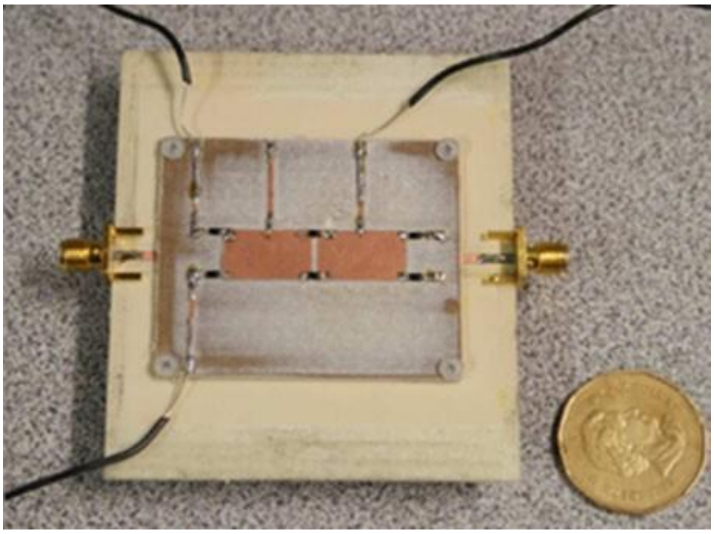

Fig. 2 Microstrip patch antenna with Differentially-fed frequency-agile [5]

The antenna is capable of achieving a 2.0 frequency tuning ratio on the Microstrip patches by attaching three pairs of Varactor diodes. These antennas act as better devices for different designs of frequency RA. Generally, Varactor diodes are used to vary the dimension of the slot which helps in regulating the frequency of the antenna. The slot frequency RAs can provide a broader regulation ratio around 3.52 but at the cost of gain and efficiency.

The frequency reconfiguration modifies the electrical length of the dipole with the help of Varactor diodes or switches. A good frequency reconfigurable design can provide better selectivity of the frequency and also lowers the undesirable effect of co-site intervention and congestion.

3.2 Discrete Tuning

Discrete frequency tuning can be achieved through PIN diode and MEMS switches. A microstrip patch antenna with a compressed frequency response can be considered as the best example [3]. Using PIN diodes the central patch is coupled to four dissimilar peripheral elements. All of them are designed according to the specifications and operate at a certain frequency, self-sufficient from the others. For a broad range of frequencies between 0.8 to 3.0 GHz, the patch antenna can attain the whole of 24 different states.

4. Polarization Reconfigurable Antenna (Ra)

By varying the angles of linear polarizations, or exchanging among linear and circular polarizations, or between left-hand circular polarization (LHCP) and right-hand circular polarization (RHCP), polarization reconfiguration can be achieved. Polarization diversity is used to enhance the competence of multiple-input-multiple-output (MIMO) system [8, 9]. Antennas that employ this system, can be used to offer polarization diversity to reduce the signal fading in multipath propagation conditions. The most important challenge faced in designing an antenna is achieving polarization agility. This can be done without any alteration in the antenna input impedance characteristics. Hence it is a challenge for the designers to devise a polarization reconfigurable antenna that can change among linear and circular polarization as it becomes complicated in achieving impedance matching for these two polarizations. The two degenerate orthogonal linear modes and generate circular polarization (CP), but its input impedance varies from the one that is used to generate a linear polarization (LP). In comparison with a single band antenna, the interdependence of polarization characteristic of CP and its frequency response are much prominent. Because, it is difficult to design a dual-band polarization reconfigurable antenna, it becomes a challenge for the designers to sustain the state of polarization that belongs to the dual/multiple bands by maintaining the frequency stability. In the section given below different methods are presented that switch among linear, circular, and double-band polarization reconfigurable antennas.

Polarization RA with Single Band

To exchange between circular and linear polarization, many interesting polarization reconfigurable antenna designs are proposed. To operate in LP and CP modes a slot antenna with square rings and four pin diodes was designed by Dorsey [2]. In combination with four-pin diodes with small bandwidth on a compact square patch to create CP and LP, radiation was proposed by Sung et al. [11]. A Microstrip circular patch antenna with coupled ring-slot was devised. It can change among linear and circular polarizations. This covers the bandwidth of 2.2 %. The figure of polarization reconfigurable antenna with the circular path is shown in Fig 3.

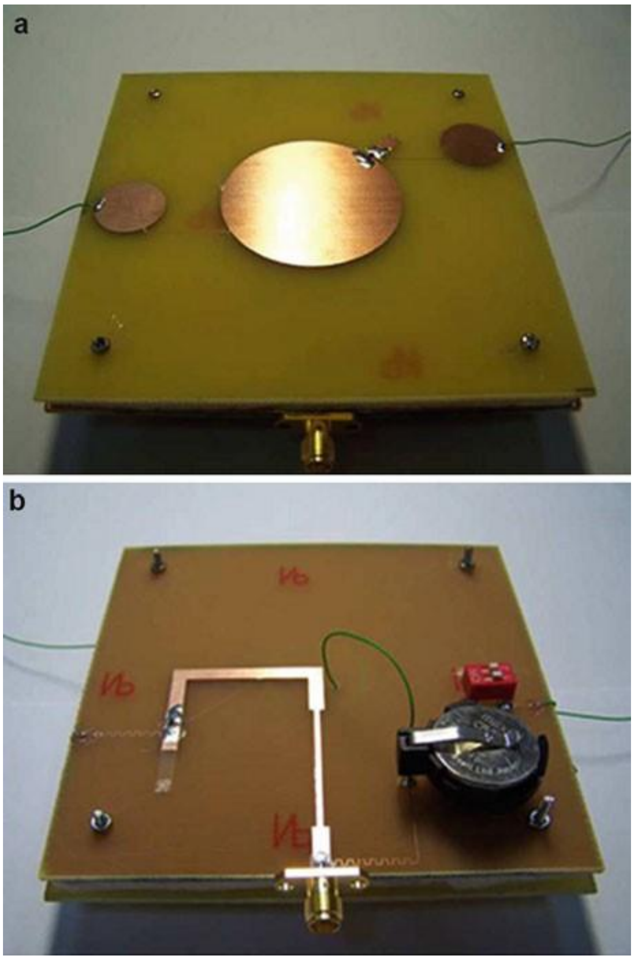

Fig 3 Reconfigurable antenna with Circular patch: (a) Top layer; (b) Bottom layer [11]

4.2 Dual-band Polarization RA

In the present scenario, a dual-band operation is very important in the WLAN devices. A frequency band operating at 2.4 and 5.8 GHz band is preferred for polarization RA. A polarization reconfigurable antenna with single aperture- fed was devised by Qin et al. [10] to meet this requirement. In both 2.4 and 5.8 GHz bands, it continuously changes between horizontal, vertical, and 45^0 linear polarizations.

4.3 Pattern Reconfigurable Antenna

Pattern Reconfigurable Antenna can minimize interference by varying the null positions so that it can save energy. By adjusting the main beam, a large area can be covered which intends to direct the signal towards the required number of intended users. These RA's have the potential to modify the shape of the main beam or scan the main beam. Further, the overall system ability is enhanced by using multiple-input-multiple-output (MIMO) systems. The antenna structure helps in finding the radiation pattern with the flow of current through the structure. The reconfigurability is accomplished by changing the current distribution. Further, the frequency characteristics should not be changed for various radiation patterns of the antenna. Without changing the operating frequency it is very difficult to get pattern reconfigurability. Various procedures have been implemented to get through this challenge. The change in antenna structure such as parasitically coupled antennas or reflector antennas is one of them. This helps in achieving an independent input feed port for the reconfigured structure. This makes the frequency characteristics steady.

5. Main-Beam Shape

The wideband circular patch antenna is used as an example that can be switched among boresight and conical radiation patterns. The switching can be done using L-probe feeds [14]. For boresight radiation, TM_1 mode is stimulated and for conical radiation, TM01 is stimulated by the two feeds. The conical pattern mode's resonant frequency is reduced by attaching the patch with shorting posts. This helps in increasing the frequency of operation of the modes. Reconfiguration of the radiation pattern is done by using an integrated matching network with sufficient switches. It was also devised that broadband tunable Coplanar Waveguide (CPW)-to-Slot line transition feed for a particular pattern can be used [13]. Reconfiguration of the feed mode among left side slotline (LS) mode, right side slotline (RS) mode, and Coplanar Waveguide mode is done by PIN diodes. The left side slotline (LS) mode and the right side lot line (RS) mode stimulate both the patterns along the axis and their radiating beams are intended in reverse order.

5.1 Main Beam Scanning

To guide the major beam to already defined directions, several antennas have been proposed. By using PIN diodes or any other electronic switches, to activate one or several elements. A four-element L-shaped antenna array was proposed byLai et al [6]. It can easily accomplish beam direction-finding upon 3700 in the plane of azimuth with a gain of approximately 0.6 -2.0 dB. Substantial advances have been made in creating the beam-steering pattern RA. Their application is limited because of low gains.

6. compound reconfigurable antennas

The aim of designing a reconfigurable antenna is to achieve the ability to alter the radiation pattern, polarization, and operating frequency. This can easily be achieved in a compound reconfigurable antenna. The Compound RAs are more flexible and diverse than any single characteristic antenna and hence plays a very important role in wireless communication systems.

Radiation pattern reconfigurability and combined frequency can be easily achieved [7]. The direction of the null can be changed by proper loading the PIN diodes from corner to corner of the slot at definite locations. The frequency of operation of the antenna can be altered by redesigning the network.

6.1 Reconfigurable Leaky Wave Antennas

These antennas are considered to be the transmission lines that slowly give away their energy into free space. With the help of the phase constant β, the radiated energy θ can be found for the leaky wave throughout the distance of the transmission line [4]. The output of the leaky-wave antenna is shown in Fig.4

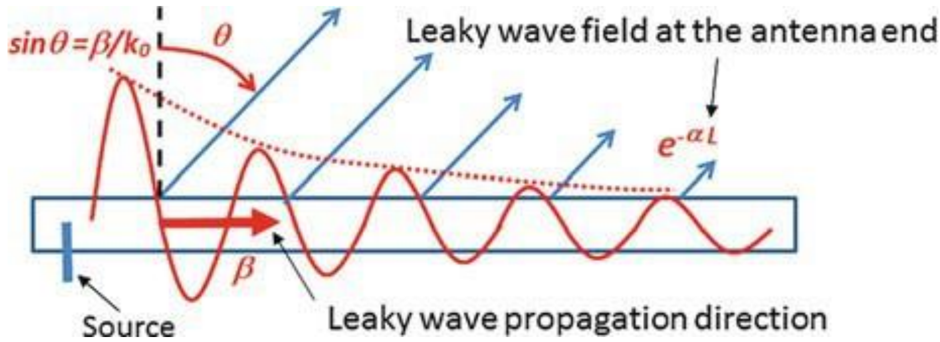

Fig. 4 Output of leaky wave antenna

The beamwidth is illuminated by controlling the leakage rate α and is found from the length of the leaky aperture. The advantage of leaky wave antennas over reflector and lens antennas is that it can perform well without expanded feed and can also maintain a minimum profile. When they are compared with arrays a network with the feed is not required, because this feed sometimes becomes lossy for big arrays. The beam direction can be steered by sweeping the operating frequency, as the phase constant of the leaky-wave antenna depends on the operating frequency.

The wireless communication industry and its standards have grown at a fast pace in the last decade. The spectrum regulators have defined a frequency band on which the wireless communication works, and thus the inbuilt frequency scanning nature of leaky-wave antenna is inadequate. This gives rise to the progress of pattern reconfigurable (beam- steering) leaky wave antennas that exploit the complex nature of the propagation channel.

Further, they have a relatively narrow bandwidth. But Frequency Reconfigurable (tunable) Leaky wave antenna can still solve the purpose and become very useful in many applications.

7. Conclusion

In this paper, queries interrelated to the design of reconfigurable antennas are addressed. They form the most important element of the advanced communication system. Depending on cognition and response to emerging situations they form the basis for novel communication. A dynamic communication system that relies on antenna structure is required to cope up with the emerging trends.

Future work in this area of the reconfigurable antenna includes their design that can distribute the full reconfiguration of the antenna. Such a RA is functional to numerous wireless communication systems. Control over the frequency of operation, its polarization, and the radiation pattern is extremely challenging for the tough relationship between the antenna's frequency reaction and its radiation characteristics. To realize the full reconfiguration of an antenna, novel and useful techniques are required to come out of the linkage.

The future work can also be extended to RF and also to the signal processing in the physical layer. As antennas form a part of the entire communication system, the remaining parts in the system must be capable of reconfiguring their features so that they can be utilized in a diversified manner. Therefore reconfigurable antennas play a very important role in enhancing the next generation communication systems considerably.

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