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Frequency Reconfigurable Ultra-Wide Band MIMO Antenna for 4G/5G Portable Devices Applications: Review

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ABSTRACT: The rapid development in the sector of wireless communication demands for system that fulfill multifarious needs and standard requirements which are increasing day by day. Existing antennas like wire, loop, travelling wave antenna does not meet the requirements of modern-days wireless communications. Design of reconfigurable antenna enables one antenna to be used for numerous applications. This antenna can switch its characteristics in real time condition. According to industrial requirements 5G wireless communication devices should be smaller in size and provide high data rate, channel capacity, multiband operations so that it can push the development of more versatile wireless technologies compared to single antenna. Design of reconfigurable MIMO antennas is the best solution to such requirements. MIMO antenna already proved in Wi-Fi, WiMAX and LTE wireless services that it can provide high data rate throughput and avoid interference. In MIMO system multiple antennas are existing for embedding MIMO in portable devices it should be compact in size. Therefore, it is a challenging job to design UWB MIMO antennas having high isolation and compact size. This survey concentrates on many researches carried out related to frequency reconfiguration, microstrip patch and frequency tunable MIMO antenna for various wireless application.

Keywords: Antenna mutual coupling coefficient, Frequency Switcher,4G/5G, Polarization, Printed circuit board (PCB), PIN Diode, Reconfigurable or Tunable Antenna Multiple-input-multiple-output (MIMO),Ultra-wide band (UWB).

I. INTRODUCTION

Working of Multiple input and Multiple output system based on spatial diversity and spatial multiplexing can be utilized by wireless systems to improve its performance and required through put. Lot of work has been carried out to improve multi-input multi-output system, like its channel modeling, codding technique, modulation scheme and antenna design technique. Advantage of propagation through various independent paths of MIMO improve the channel capacity and reduce fading/interference effect [1]. To achieve these advantages than one antenna at the front end of transmitter and receiver can be placed. "Instead of use of conventional antennas with drawbacks like, large size, compatibility, difficulty to perform multiple operations, work at fixed frequency, radiation shape and polarization, reconfigurable antennas in MIMO system can further enhance overall performance parameters". Reconfigurable antenna become problem solver for MIMO system as it can switch the frequency, polarization, radiation properties as per the system requirement and environmental change.

Use of conventional antennas for MIMO system has become a challenging job for designers as it need consideration of various characteristics like good impedance matching, gain in desired direction, radiation stability, reduced correlation coefficient. Mutual or correlation coefficient is inversely proportional to channel capacity, reduced correlation coefficient improves channel capacity [2]. Therefore, reconfigurable antenna has become a solution to reduce correlation effect by changing its radiation characteristics accordingly. 4G and 5G wireless devices are meant for multiband operation, for this antenna must be able to work with multiple frequencies. Frequency reconfigurable antenna is unique solution to the problems of 4G and 5G.

In this paper frequency reconfigurable antennas designed to achieve different UWB frequency bands and frequency reconfigurable MIMO antenna for portable devices is discussed.

A. Contributions

Microstrip patch antenna-multiband operation and reconfigurability- multiple input and multiple output antennas have gained widespread usage in the development of compact, low-profile, multifunctional antennas. The main contributions are as follows:

– Overview of the current research trends and approaches used for achieving frequency reconfigurability is provided.

– A critical review of the literature is performed. The key ideas that will help researchers in identifying the research gaps in the literature are presented.

II. LITERATURE REVIEW

The antenna is the important part of every communication system used for both transmitting and receiving electromagnetic radiation [3]. Antenna is a current carrying conductor which converts the electrical energy into electromagnetic waves and can be transmitted over a long distance. In recent years microstrip antennas are extremely used by various communication fields, such as wireless, radar, mobile and satellite communication systems. Assets of microstrip antennas are short, cost, ease of integration on PCB and with other circuit elements. Some antennas are having the capability of changing its radiation characteristics according to system requirements. Such antennas are named as reconfigurable antennas. Reconfigurable antenna attributes are operational frequency, pattern and polarization [4].

In keeping view of the requirements of 5G wireless communication such as multiple frequency operation. This paper is to review designs related to multiband, frequency reconfiguration multi-input-multi-output antennas.

A. Micro strip Patch Antenna

Microstrip element consist of an area of metallization support above the ground plane it is known as patch [4]. Support element is known as substrate. In microstrip antenna patch is present above the substrate and ground plate below the substrate as shown in Fig. 1. From last few years microstrip antennas are in huge demand due to their small size at high frequencies, light weight, planar surface, capability to work with multiband frequencies. Radiating patch of microstrip antenna can be of any shapes like rectangular, circular, annular ring, square, etc. Dimensions of patch can be determined from proper equations [5].

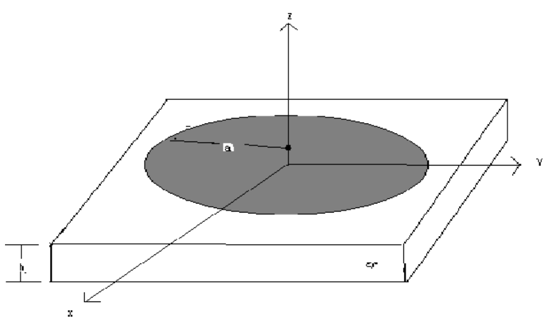

Fig. 1. Circular patch antenna.

Equations for Design: For proper design of CMSPA we have to choose substrate of height h, dielectric constant of patch, radius and resonant frequency is calculated as

$$a = F\left\{1+\frac{2h}{\pi F\varepsilon_r}\left[\ln\left(\frac{\pi F}{2h}\right)+1.7726\right]\right\}^{-1/2} \quad (1)$$

Where

$$F = \frac{8.791\times 10^9}{f_r\sqrt{\varepsilon_r}} \quad (2)$$

Consideration of fringing fields around the periphery of patch extends the dimension of patch outside. As a result, effective dimension of patch is greater than physical dimension. Effective length L is

$$L_{eff} = \frac{C}{2F\sqrt{\varepsilon_{eff}}} \quad (3)$$

Where, Height of substrate is h, F is resonating frequency, a is radius of patch, ε is dielectric constant

B. Antenna Reconfiguration Types

Based on which parameter is distinctly varied, that is the resonating frequency, radiation pattern or polarization [6] these antenna types are

– Frequency Reconfigurable
– Pattern Reconfiguration.
– Polarization Reconfiguration.
– Compound or Combined Reconfiguration.

(i) Frequency Reconfiguration: This type of aerial can dynamically vary its frequency. These aerials are especially useful in an environment where communication system converge with multiple antennas and can be replaced by a single frequency switching antenna. This antenna designed by modifying electrically or physically. The dimensions of antenna using RF-switches and Impedance loading.

(ii) Pattern Reconfigurable: It will be resultant of intentional modification of the spherical distribution of radiation pattern which can be reconfigurable and are usually designed using movable/rotatable structures.

(iii) Polarization Reconfigurable: These antennas are having capacity of switching between different polarizations modes. Switching between horizontal, vertical and circular plane can be used to reduce polarization mismatch losses in wireless devices. Such reconfiguration can be made feasible by changing the balance between the distinct modes of multimode structures.

(iv) Compound Reconfigurable: Antenna of Compound reconfiguration type is having feature of simultaneously tuning several parameters, for example frequency, polarization and radiation pattern. The most common application of this configuration is the combination of frequency agility and beam scanning which will provide improved spectral efficiencies.

C. Techniques of Frequency Reconfiguration

Advantages of frequency reconfigurable antenna are significant:

– Utilization of single terminal for transmitting and receiving multiple frequencies.
– We can easily integrate it with switching devices and other circuit elements.
– Compact dimensions.

Basically, there are four techniques in use for achieving frequency reconfigurability [7]. Firstly, in electrical reconfiguration components in use are radio Frequency-Micro Electromechanical switches named as RF-MEMS, negative resistance PIN diodes, and Varactors. Secondly, in optically reconfigurable antenna photoconductive cells as switching component like silicon switches are in use. Thirdly, slots and cuts are used for structural modification of antenna in physical reconfiguration. Finally, smart materials like liquid crystals, ferrites, mercury can be used to meet reconfiguration.

(i) Electrically Reconfigurable Antennas or Switch Based Reconfiguration: This method uses switching characteristics of various components such as negative resistance varactors, low power consuming pin diodes, RF-MEMS. When such devices are inserted into the antenna design it changes circuit characteristics which makes the antenna to resonate different frequencies. This method reduces design complexity.

1. Frequency Reconfigurable Antenna using PIN diodes: Frequency reconfiguration using PIN diodes is as shown in Fig. 1. Designed is a rectangular frequency reconfigurable 8 linear array antenna for various frequencies in tri-band, (i.e.) S, X and C-band applications.

Krishna *et al*., (2015) in his design to achieve the frequency reconfiguration used an antenna element involves the PIN diodes to control the connection between each rectangular patch [8]. These PIN diodes are energized with the help of an external biasing circuitry. The author has simulated the ON/OFF scenarios in his work by replacing the PIN diodes by a conductive strip. A single element of the array with the PIN diodes placed between each patch is shown in Fig. 2.

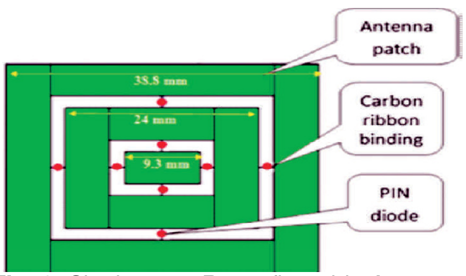

Fig. 2. Single 1 × 8 Reconfigurable Antenna.

(ii) Reconfigurable Antenna based on Radio Frequency-MEMS. Promising advantages of RF-MEMS such as higher linearity, lower signal distortion, low insertion loss, ease of integration is utilized to switch the resonant frequencies of antenna.

Faiza *et al*., (2012) proposed design is shown in Fig. 3. E-shaped micro strip patch is used in his design. Such antennas are useful for cognitive radios [9]. Integration of RF-MEMS with other elements in the design changes dimensions of slot which allow antenna to radiate frequency from 2 GHz to 3.2 GHz.

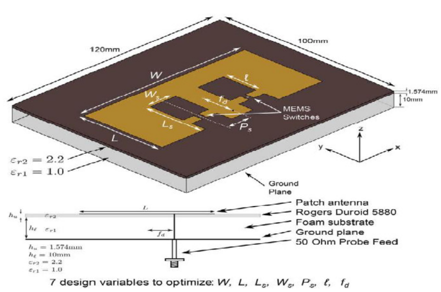

Fig. 3. E-shaped Patch Micro strip Antenna for Cognitive Radio Applications.

(iii) Optically Reconfigurable Antennas: Reliability of optical switches as compare to other switching mechanism can be utilized to change the resonating frequency. As an alternative laser diode can also be integrated directly into the antenna structure to achieve optical reconfiguration. Optical diodes exhibit less distortion and linearity.

Kayat *et al*., (2013) design is in Fig. 3. Proposed uses an optically controlled photoconductive switch to vary the resonating frequency [10]. The optical loading of stub on patch is changed accordingly to meet the frequency tunability in the resonant frequency with very less optical power of <60mW. With this technique, eight resonant frequencies were achieved using three photoconductive switches with very less optical power.

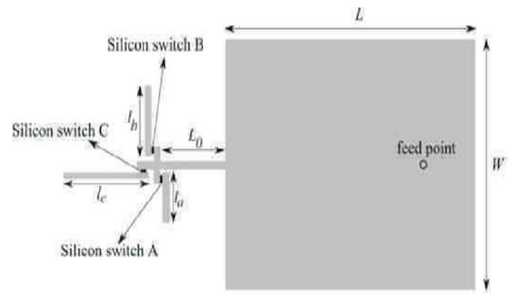

Fig. 4. Rectangular Patch Antenna Connected to Stubs through Photoconductive Switches.

(iv) Physically Reconfigurable or Non-Switch Based Reconfigurable: In this method radiating surface of the antenna is altered by physical means. Structural alteration in radiating shape can lead to physical reconfiguration. This technique is significant as it does not require any laser diodes, switches or bias lines [11]. The drawbacks of this method are slow response, more Costly, larger size of antenna, more power requirements, etc. In comparison with other techniques, the integration of reconfiguring element into the device can be complicated.

Zheng *et al.,* (2014) design is in figure. 4 proposed is an ultra-wideband antenna with notches. Circular rotational motor is used for rotating and controlling patch rotational patch. Designed antenna operate in UWB range from 3.2 GHz to 11 GHz with 3.32 to 4.2 GHz as a first stop band and 5 to 6 GHz as a second stop band. 3 WLAN frequency bands are 2.4 GHz to 2.9, 3.6 GHz to 4.4 and 5 to 6 GHz. Design includes rectangular patch with stub and slit [11].

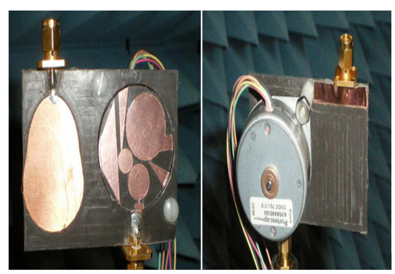

Fig. 5. Structure of antenna with stepper motor.

(v) Reconfigurability based on Smart Materials: In this method, Reconfiguration of antenna is by varying the thickness of Dielectric layer or change in substrate characteristics of material. Thickness reconfiguring or substrate characteristics variation changes resonant frequency. This can be achieved by tuning a applied voltage, variations in applied voltage further alter the distribution of molecules in material which further varies relative permittivity.

Fig. 6 which is reference of Farooq *et al.,* (2015) uses above discussed concept to achieve variations in resonant frequency, in design author used two circular patches with smart material such as crystal polymer layers and mercury [13]. Initially in the non-existence of liquid crystal polymer and mercury, inner patch of diameter 19.6 mm radiates at 5 GHz. When gap between inner and outer patch is loaded by liquid crystal polymer layers and mercury, diameter of radiating patch extends from initial 19.6 mm to 31.1 mm. It made the total patch to radiate 3.6 GHz frequency.

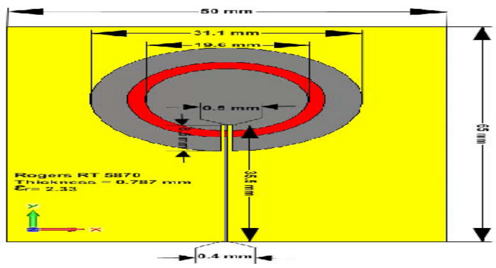

Fig. 6. Antenna designed using smart materials.

III. APPLICATIONS OF RECONFIGURABLE ANTENNA IN MIMO SYSTEM

Reconfigurable antennas are meant for multimode operation this feature made wireless devices to work with various frequencies using a single radiating element MIMO antenna concept can be used to improve the channel capacity of 4G/5G. In current year 4 × 4 or 8 × 8 MIMO antennas are available to see in smartphones.

Design of MIMO antenna using frequency reconfiguration concept for mobile phones by Parchin *et al.*, (2018) is shown in Fig. 6 [14].

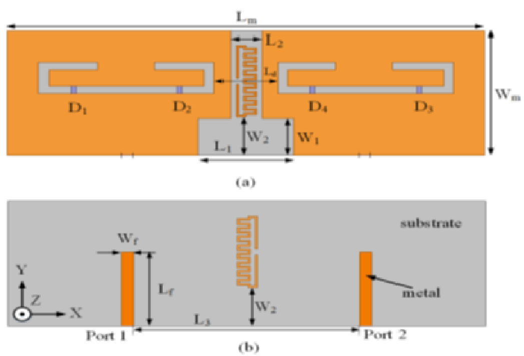

Fig. 7. Proposed design of frequency-reconfigurable MIMO antenna.

It uses four C shaped reconfigurable slot radiators. Pin diodes are integrated into slots, ON and OFF states of diode made design to work at 2.6 and 3.5 GHz frequencies. Design is capable to support 4G and 5G mobiles other performance parameters evaluated from design are Return Loss which was -10 dB, bandwidth of 400 MHz.

Pandit *et al.*, (2018) designed Multiple input Multiple output compact frequency reconfigurable slot antennas to work with S and C frequency bands [15]. Designed antenna uses sensor for sensing mm waves, 4 PIN diodes are used for electronically switching the antenna between WiMAX and WLAN frequency bands, with ratio of frequency 2.5:1. For gaining high isolation between antenna elements C structured resonator line is inserted, it also lower ECC and results in performance improvement. Measured ECC is less than 0.08 and isolation is above 25 dB, gains of antenna are 1 to 5.7 GHz respectively.

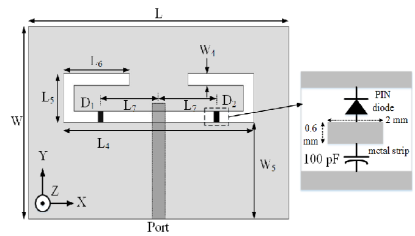

Fig. 8. Frequency reconfigurable antenna with slots for radiation.

Hussain *et al.*, (2016) proposed a reconfigurable MIMO antenna for an indoor application with improved channel capacity. Initially author designed 2 × 2 later 4 × 4 MIMO antenna structure. Design support either transmitter side or receiver side [16]. Using channel coefficient matrix channel capacity is evaluated, proposed design is providing frequency range from 0.7 GHz to 3GHz with radiation efficiency of every element at 2.45 GHz was 55%.

IV. COMPARISION OF DIFFERENT FREQUENCYRECONFIGURABLE TECHNIQUES

Table 1: Comparison of different techniques.

Electrically	Optically	Physically	Smart Material
Most popular technique, lower cost	Loss preferred, costs more	Circuit is complicated, costs more due to rotating structure	Lower cost but less efficient
Ese of integration, higher non-linear effects	Distortion less when controlled by laser, reduced interference, loses	Integration of reconfiguring component is complicated	These are less efficient when especially liquid crystal is used
High switching speed	More reliable compared to other switching mechanism.	Less reliable, need of rotatable structures	Unable to work with microwave frequencies
It needs bias lines	It doesn't require any bias lines	It does not require any biasing N/W	No need of bias lines

V. CONCLUSION

In this paper role of antenna in communication system and disadvantages of conventional antennas is discussed. In modern days wireless communication devices are meant for multiband operation, dual band antenna can be used for it but due to large size of dual band antenna these cannot accommodate in to the portable devices, where space is significantly small. Frequency reconfigurable antenna are best solution to a multiband antenna. 4G/5G wireless traffic demands for high data rate, improved channel capacity and compact in size. MIMO frequency reconfigurable antenna operating frequencies can be reconfigured to satisfy the frequency needs of 4G and 5G portable devices.

VI. FUTURE SCOPE

The integration of UWB MMO antennas with frequency reconfigurability permits frequency selectivity and size reduction and allows the antenna to be used for multiple wireless devices standards.

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Conflict of 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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