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A Survey on Frequency Reconfigurable Antenna Techniques

Cincy Mary Sebastian[1], Shiney Thankachan[2], Alphonsa George[3], Greeshma R Nath[4]

M. Tech Scholar (Wireless Technology), Department of ECE, College of Engineering, Kidangoor, India[1, 3, 4]

Assistant Professor, Department of ECE, College of Engineering, Kidangoor, India[2]

ABSTRACT: Frequency reconfigurability means to change the frequency by arranging or organising the parts of the antenna for a particular purpose, that have been focused in researches for recent years. Reconfigurable antenna with ability to operate in more than one frequency state offers several operational freedoms to antenna designer. The desired characteristics in reconfigurable antennas can be achieved mainly by mechanical and electrical switches. In this paper, various frequency reconfigurable antenna designs have been reported in literature are discussed.

KEYWORDS: Frequency reconfiguration, Antenna, Mechanical switches, Electrical Switches, P-I-N diode

I. INTRODUCTION

Modern wireless systems usually have multiple standards so that they require modern antenna systems with multiple capabilities and functions without enlarging occupied volume. The reconfigurable antenna becomes a popular solution because it provides variety in antenna performance to satisfy diverse communication requirements and decrease the interference.

Frequency reconfigurable antenna switches its frequency from one to other. Most common methodology adopted for reconfigurable antenna design is inclusion of some form of switching circuitry and mechanical adjustment of movable parts. In this paper the mechanisms used for frequency reconfiguration are classified as "mechanical" and "electrical". For mechanically reconfigurable antennas frequency turning is obtained by adjusting the movable parts. Electrical reconfigurable antennas are more popular, which can be classified as "band switching" and "continuous switching". An example for band switching is p-i-n diode that is it can switch among different frequency band. Varactor diode is an example for continuous switching which means frequency is tuned smoothly within the operating frequency band.

The idea of reconfigurable antenna came in 1930s by changing the shape of a rhombic antenna. The adjustment of shape is done with the help of pulleys and motors. Later the movable pulleys replaced by electronic switches. The mechanical reconfigurable antennas are preferable in certain application where electric power will not get. The bulky size and cost are reasons for new technics.

II. MECHANICAL RECONFIGURABLE ANTENNA

Frequency-reconfigurable antenna using metasurface

Mechanically reconfigurable antenna changes the shapes, size or dielectric of antenna mechanically. One of such mechanical reconfiguration of dielectric can be done using meta-surface (MS) shown in Fig. 1.

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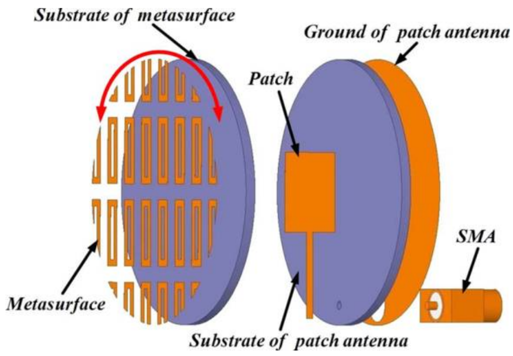

Fig. 1.Assembly schematic of FRMS antenna.

The frequency-reconfigurable meta-surfaced (FRMS) antenna shown in Fig.2 consists of a simple circular patch antenna and a circular MS [1]. The MS is mounted directly at the top of the patch antenna, to make the FRMS antenna very compact and low profile. The MS is made up of rectangular-loop unit cells placed periodically in the vertical and horizontal directions, i.e. in x-direction and y-direction of x-y plane. The change in operating frequency of the antenna can be obtained by mechanically rotating the MS around the centre with respect to the patch antenna. A continuous tuning can be accomplished using physical turning and the antennas can be frequency tuned smoothly within the operating frequency bands. Mechanical parts faces some problems such as wear and tear, short life of movable parts, large size etc.

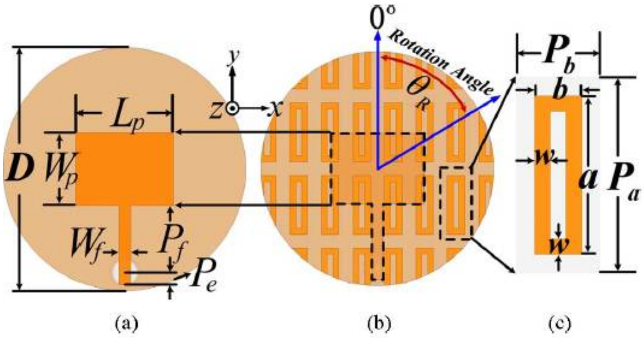

Fig. 2. Geometries of (a) patch antenna (source antenna), (b) metasurface, and (c) unit cell.

The MS which is placed at the top the patch antenna behaves like a dielectric substrate and rotating the MS changes the equivalent relative permittivity of the substrate and hence the operating frequency of the FRMS antenna. The FRMS is comparatively a slow process.

III. ELECTRICAL RECONFIGURABLE ANTENNA

A. Optically Pumped Frequency Reconfigurable Antenna Design

This frequency reconfigurable antenna mainly focuses onthe antenna design using photoconductive silicon elements as optical switches. The technique used is light energy to electrical energy. When light falls on the silicon element with suitable wavelength, the physical property changes from semiconductor to metal.

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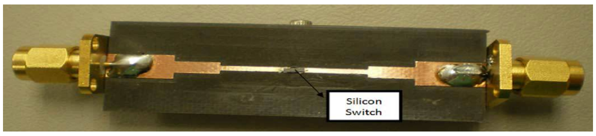

Fig. 3.The fabricated prototype.

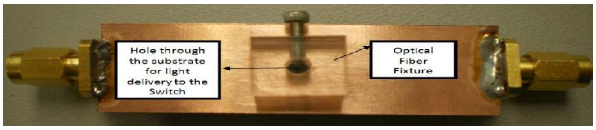

Fig. 4.The backside view of the fabricated prototype.

A stripline circuit (shown in Fig.3 and 4) employing a single silicon switch under light illumination is used to implement this technique [10]**.** The optical switch possesses fast switching speed in the range of nano seconds. As compared to active switches (e.g. Micro-electro-mechanical system (MEMS), p-i-n diode) the optical switches does not require any biasing. To increase the conductivity silicon switches are doped with N-type element such as phosphorous.

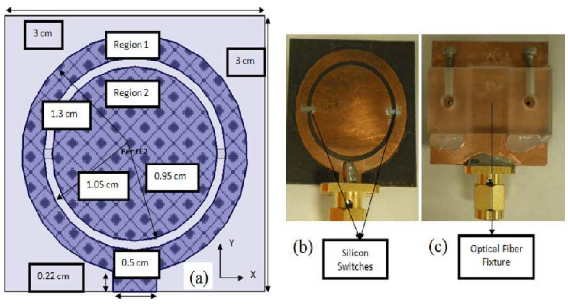

Fig. 5. (a) The antenna dimensions. (b) The antenna top layer. (c) The antenna bottom part.

Fig. 5. shows the photoconductive switches are illuminated by laser light (of suitable wavelength) which is coupled through an optical fiber cable and extends from the ground plane to just beneath the photo-conducting element placed on the radiating face of the antenna structure.

The drawback in this design is that the energy lost in the switches reduces the radiating efficiency of the antenna.

B. Wirelessly Reconfigurable Antenna

The reconfigurable characteristic of the wirelessly reconfigurable antenna is achieved by wireless switches shown in Fig. 6. Each switch in this antenna is controlled by control signals which are transmitted along with the transmission signal.

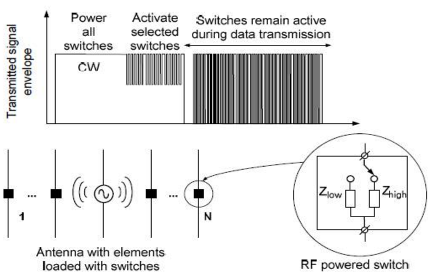

Fig. 6. Wirelessly reconfigurable antenna

In the Fig. 7 the reconfigurable antenna composed of three parasitic dipole antennas with two switches. UHF (Ultra High Frequency) RFID tag ICs which have unique ID's is one of the best examples for wireless switch [7]. The advantages of these switches are it does not require any biasing also switches that are powered by the antenna itself.

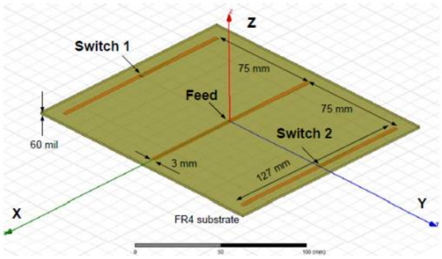

Fig. 7.Three-element antenna array with two switches.

The RF (radio frequency) technology turns the RF switches on or off by control signals. RFID ICs, composed of internal power harvester, capacitor, demodulator, ID logic, and modulator, allowing them to go to low impedance state for a certain duration of time (defined by the capacitor value). This antenna system is found to be costly and complex.

Such switches can be realized as custom ICs or as discrete circuits with low power microcontrollers, similar to discrete UHF RFID tags. The constant wavelength carrier powers all switches. Then comes a command addressing and activating specific switches (instructing them to switch to low impedance state). The main data transmission follows. Depending on which switches are activated, the antenna properties, such as radiation pattern, can be changed.

C. A Reconfigurable Antenna using Active Devices

Reconfigurable Antenna using active devices means the reconfiguration is done using p-i-n diode, GAs FET, MEMS switches etc. This antenna consists of longer strip, a short strip and a p-i-n diode as shown in Fig. 8 [13]. Coupling is done between shorter strip and longer strip. Depends on the on/ off stage of p-i-n diode the reconfiguration happens.

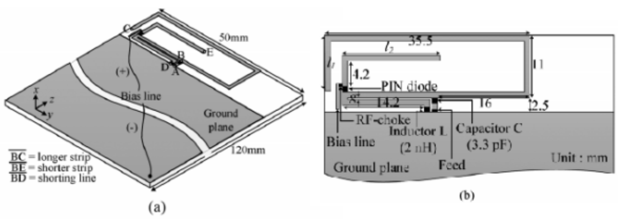

Fig. 8.Geometry of the proposed antenna.(a) 3-D structure and (b) top view.

The antenna covers two ranges of frequencies such as higher band and lower band. At low band antenna coversthe LTE700/GSM850/900 bands while high band covers GSM1800/ 1900/ UMTS/ LTE2300 /2500 bands. The internal antenna for LTE operation band processes a large 3D structure which is not suitable for the recent mobile gadgets. Antenna covers a band of LTE700 by couple feed technique also it has a ground clearance of 18mm. The physical size of the antenna is very small and complexity is less.

The reconfigurability for the antenna is done by on/off operation of pin diode. The proposed antenna can cover the LTE700 (698–787 MHz), GSM850 (824–894 MHz), and GSM900 (880–960 MHz) bands. Therefore, the proposed antenna can cover the GSM1800 (1710–1880 MHz), GSM1900 (1850–1990 MHz), UMTS (1920–2170 MHz), LTE2300 (2305–2400 MHz), and LTE2500 (2500–2690 MHz) bands

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IV. CONCLUSION

Mechanical and electrical switching are major switching techniques described for the reconfigurability. Much research has been done on switching of antenna using active devices. The reconfigurability for meta-surface, reconfigurability using optical pump and wireless reconfigurability are really complex techniques with bulky size. All the techniques can be realized only with the huge setup for the switching. Recently the mobile gadgets are mainly focus on antenna with less complexity and small size along has the property of fast switching. To achieve all these requirements antennas with active switches are preferred.

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