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A Review on Frequency Reconfigurable Circular MicrostripPatch Antennas

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Abstract- **to cater the need of modern wireless communication systems, the antenna requires to be multiband and reconfigurable. Reconfigurable Antennas have more advantages and improved prospects compared to conventional antennas. They are lighter in weight, smaller in size and cheaper in price. As a result of this, these antennas have got increased attention; many reconfigurable antennas are proposed and investigated in last decade. Inthis paper, a comparative study of different frequency reconfigurable disc antennas based on their design technique is presented. Example of each design technique is discussed along with its working, advantages and applications.**

Keywords- Frequency Reconfigurable; Reconfigurable Antenna; Circular Patch.

I. INTRODUCTION

Hardware design procedures of antennas and radio frequency (RF) front end have greatly influenced bythe increasingdemandfor development and deploymentof new wireless services on a single radio platform. Hence, there is a growing demand of new solutions that are multiband, multimode, low profile, low cost and easy to integrate into the feature-rich compact devices.

In the past, wireless deviceswere designed for one specific task and they had antennas of fixed parameters such as frequency band, radiation pattern, polarization, and gain for example. These days the modern smart wireless devices such as mobile phones or laptops are required to support different communication standards, such as Bluetooth, UMTS, WLAN networks, Wi-Max, Wi-Fi, 3G, and 4G. The antennas of such devices need to operate at several frequency bands. A frequency reconfigurable antenna (also called as tunable antenna) is the best solution for such wireless communication devices that can cover multiple bands with noise rejection in the bands whichare not in use. Frequency Reconfigurability of an antenna is the capacity to change its fundamental operating frequency through electrical, mechanical, optical or other means while maintaining the polarization and radiation pattern stable across the entire frequency tuning range. These antennas are classified as continuous and switched reconfigurable antennas depending on how the radiator's operating frequency is changed. For continuous frequency RAs there is a continuous smooth transaction between operating bands while switched antenna use switching mechanism for separate frequency bands. The basic operating principle in both e of antennas is same, i.e. change in effective length will change the antenna's resonant frequency.

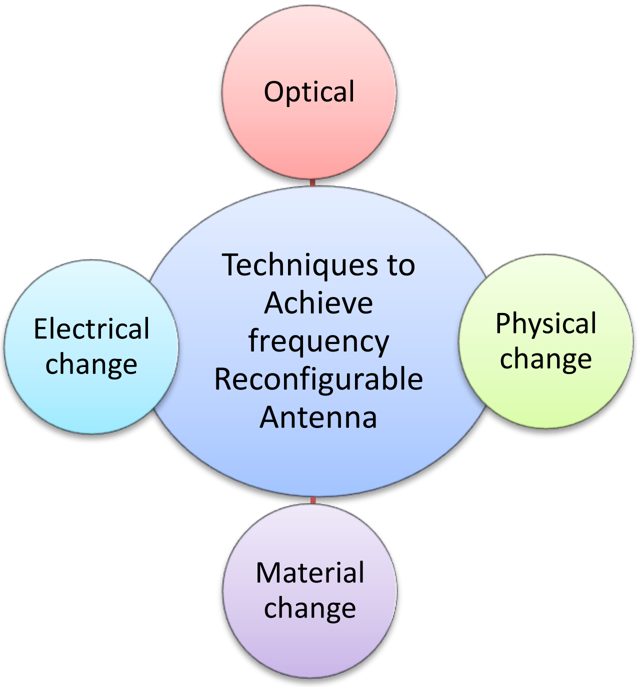

Fig.1. Reconfiguration techniques

Four major types of reconfiguration techniques are used to change effective length of antenna to implement frequency reconfigurability, as shown in Fig. 1. The operating frequency of antenna can be changed by changing antenna's effective length through electrical change, optical change, physical change and material change. With the help of radio-frequency micro-electromechanical systems (RF-MEMS) and/or PIN diodes and/or varactors electrical change for reconfigurability is achieved. Photoconductive elementscan be used for optical changes. Physical alteration is done in antenna structure itself for physicalchange and for

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material change,smart material such as ferrites and liquid crystals are usedto achieve reconfigurability.

II. CIRCULAR MICRO-STRIP ANTENNAS

Microstrip antennas are very common in small wireless devices,as they are low profile, light weight and have low manufacturing costs. These antennas can be easily integrated on a PCB with other planar circuitries. In addition to these advantages, by choice of shape and feeding arrangement microstrip antennas can be madevery flexible in terms of impedance, resonant frequency, radiation pattern, polarization and operating mode,.

A micro-strip antenna is a simple structure made up of dielectric substrate which has radiating patch on its one side and ground plane on other side as shown in figure 2. The radiating patch can be of different shapes but Square, rectangular and circular shapes are the most common because of ease of analysis and fabrication. Circular micro-strip patch antennas are more compact than rectangular patch of same resonant frequency.

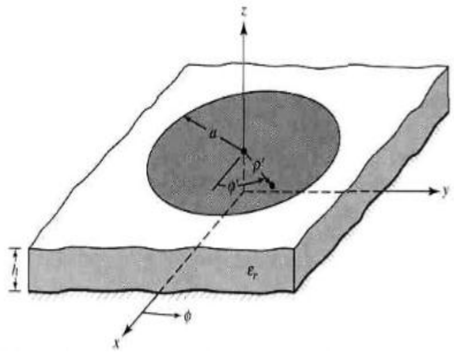

Fig. 2. Circular Microstrip Patch Antenna

a. Calcuation of radius of circular patch-

Radius of a circular microstrip patch is given by followingequation[1]

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

where, F is constant

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

Where,

r=effective radius of the patch
f_r=resonating frequency
a=radius of the circular patch
h=height of the substrate
ε_r=dielectric constant of the substrate
a_e=effective radius

$$a_e = a\left\{1+\frac{2h}{\pi\epsilon_r a}\left[\ln\left(\frac{\pi}{2h}\right)+1.7726\right]\right\}^{1/2} \quad (3)$$

$$f_r = \frac{1.84118c}{2\pi a\left[\varepsilon_{eff}\left\{1+\frac{2h}{\pi\epsilon_r a}\left(\ln\frac{a}{2h}+(1.44\,\epsilon_r+1.77)+\frac{h}{a}(0.268\,\epsilon_r+1.65)\right)\right\}\right]} \quad (4)$$

$$h \leq \frac{0.3c}{2\pi f_r\sqrt{\epsilon_r}} \quad (5)$$

b. Feeding Methods-

Micro-strip patch antenna can be fed by various methods such as coaxial, strip-line, aperture-coupling and proximity-coupling. Comparison of these techniques is summarized in below table [2].

Table 1. Comparison of feeding techniques

Feeding Method	Parameter				
	Fabrication	Impedance Matching	Spurious Radiation	Bandwidth	Modelling
Coaxial	Easy	Simple	High	Narrow	Difficult
Stripline	Easy	Simple	High	Narrow	Simple
Aperture-Coupling	Difficult	Difficult	Low	Narrow	Simple
Proximity -Coupling	Difficult	Difficult	Low	High	Simple

In most of the reviewed papers,micro-strip feed line technique is used to feed the antenna.For this feed arrangement same substrate can be used to give feed which results into a planar arrangement. This is an easy feeding scheme as it provides simplicity to manufacture and simplicity in model and impedance matching.

III. RECONFIGURATION TECHNIQUES OF FREQUENCY RECONFIGURABLE CIRCULAR PATCH MICROSTRIP ANTENNAS

Based on the reconfiguration techniques frequency reconfigurable antennas can be classified into four categories as below.

[A]Electrically Reconfigurable Antennas-

In case of electrically reconfigurable antenna, radiating structure and/or radiating edges of antenna are altered by changingthe surface current distribution with the help of electronic switcheslike RF-MEMs, PIN diodes, or varactors.It's easier to reach the desired reconfigurable frequency with the integration of switches into the antenna structure.But this type of reconfiguration technique facesnumerous issues such as the nonlinearity of switches, power losses, and effect of the biasing lines on the antenna radiation pattern.

Electrical reconfigurability in antenna can be obtained by using slots&stubs. In these cases electronic switches are used to change the effective length of slots or stubs or to change the location of the feeding point or antenna's connection to the ground to reach the corresponding function.

a. Using stub -

In open literature we can find several papers on frequency reconfigurability using stubs. In paper [8],frequency reconfigurability is achieved by using 15 stubs of different length. Electrical length of the stub is changed by using multiple switches thereby resonance frequency is changed. Each stub acts as a band stop filter around its resonance

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frequency. These band stop filters along with basic circular UWB patch result into multiband antenna. The geometry of antenna is shown in figure 3. When all stubs are disconnected from the antenna feed, antenna works in UWB mode. Using different combinations of switches antenna can be tuned to different operating frequencies.When switches f, f' are turned on, antenna gets tuned to 2.4GHz. When switches f, f', g, h are on, antenna tunes to 3.2GHz and 4.4GHz and when switches c, c', d, d', e, e', f, f', g, g', h, h' are on, antenna resonates at 5GHz.

This antenna is very simple, operates over a wide range and has a reasonably good radiation pattern over the entire bandwidth.The flexibility in terms of the availability of different reconfiguration bands makes this antenna suitable for Cognitive radiofront ends.

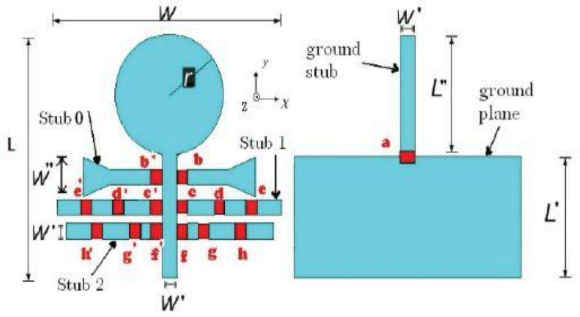


Fig. 3-Geometry of Reconfigurable UWB circular disc antenna

In paper [12] the same concept of UWB-multiband using stubs isused. Here GaAs field effect transistor (FET) switches are used instead of PIN diodes to obtain frequency reconfigurability by connecting multiple stubs of different lengths to the main feed line of the monopole. The main advantages of using GaAs FET switches are: i) simple biasing circuit with few external biasing components does not have a severe effect on the antenna performance; the antenna radiation patterns and gain don't get degraded, ii) due to their low insertion loss and low on resistance, antenna efficiency also remain unaffected and iii) the total dc power consumption of theantenna switches is very low. Thus the antennacan be used in portable communication systems cognitive radio front ends.FET is used for connection between given four slots.

b. Using slots-

Use of slots or slits(ring, square, U-shape etc) is another technique to obtain electrically reconfigurable antennas. The radiators surface current path gets elongated when slots or slits are cut out of the radiator. This will lead to increase the number of operating modes while maintaining the dimensions compact. It is possible to have multiple resonant paths in the same antenna with the use of this technique. Thus, by closely distributing the resonances, multiband performance andoverlapping the resonances,broadband performance can be achieved.

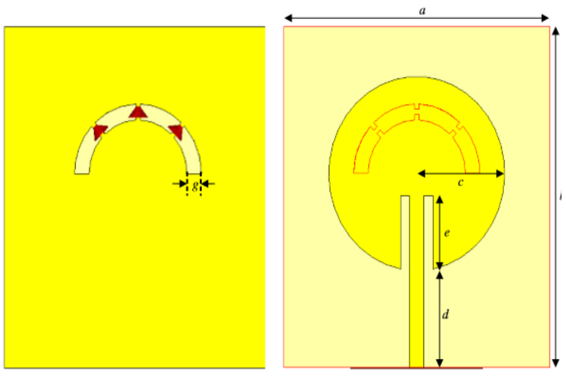


Fig.4 -Frequency Reconfigurable Circular Patch Antenna

Above concept is used in paper [6] and [4] to obtain multiband operation. The antenna presented in [6] is shown in figure 4, it consists of a radiating circular patch with a slot below the circular patch. Three switches (metal strips are used as switch) are placed in the slot. With different combination of switches, six reconfigurable frequency bands are obtained. Radiation pattern is directional at the higher frequencies, while it is gradually changed to omni-directional pattern at the lower frequencies.

In paper [4] 'U' shaped slot and partial ground plane is used to achieve reconfigurability. The geometry of antenna is shown in figure 5. Two switches are inserted at corner of slots.Antennas in paper [4] and [6] can be used in various wireless standards like 3G,4G,Wi-Fi,Wi-Max etc.

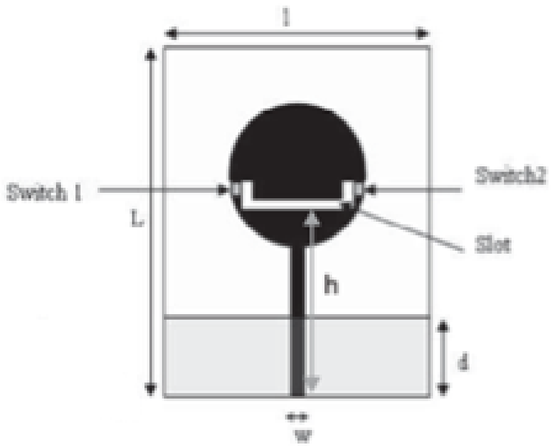
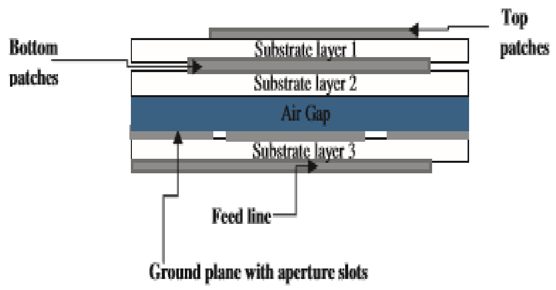
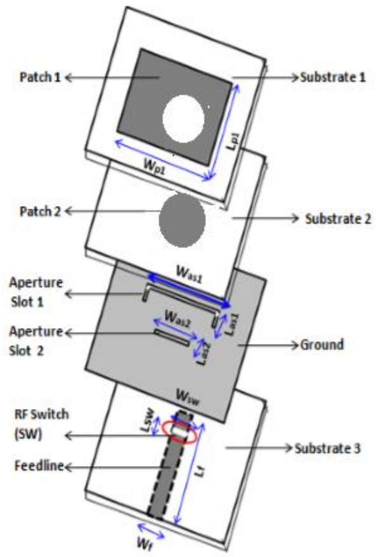


Fig.5-Geometry of Compact Reconfigurable Antenna

c. Using Stacked Patch Micro-strip Antenna -



(a)



(b)

Fig.6.-(a) Side and (b) Top view of frequency reconfigurable stacked micro-strip antenna

Frequency reconfigurability can also be obtained by modifying feeding structure or/and adding parasitic radiators. Paper [9] presents a novel design of a Frequency Reconfigurable Stacked Patch Microstrip Antenna. This antenna uses an aperture coupler feeding method and stacked technology as shown in figure 6. The advantage of using an aperture coupler feed is that it eliminates the spurious signal radiation between feedline and radiating patch and stacked technology improves bandwidth.

Antenna operates in S/X band separately by changing the switch mode at the feedline. The change in mode at feedline activates two patches at different substrate sequentially to achieve frequency reconfigurability. Two small electrical apertures in the ground plane, electromagnetically couple feedline and both patches. A stacked patch improves the bandwidth. When controlling switch, 'SW', is ON, two patches get connected and the coupled energy from slot 1 and slot 3 activates both patches. This leads to the big patch and it works at frequency of band S i.e. lower resonant frequency. When 'SW' is OFF, energy from slot 2 makes patch 2 active and that leads antenna to resonate at X band.

[B]Optically Reconfigurable Antennas-

Antennas can also be reconfigured optically by using optical switch. An optical switch is formed by exciting a semiconductor material (silicon, gallium arsenide) with a laser light.

Anovel frequency reconfigurable antenna design using optical switches is presented in letter [11]. This is shown in figure 7. Photoconductive silicon elements are used as switching elements. The physical properties of these silicon elements are changed i.e. from semiconductor to metal by illuminating them with light of suitable wavelength, which in turn alters the radiation properties of the antenna structure.

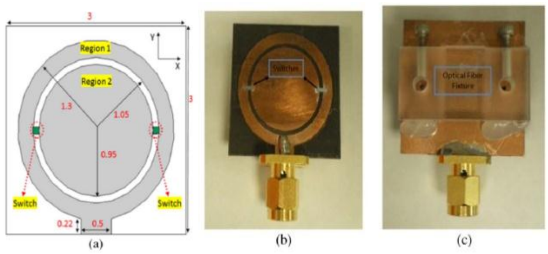


Fig.7-Optically pumped frequency reconfigurable antenna

Optical fiber used to transmit light from laser diode to switches. They are fixed below substrate and plastic fixture. When the two silicon switches are not illuminated by a laser light, the circular ring region 1 will be active. This makes the antenna to resonate with frequency of 18 GHz to 19 GHz. When switches illuminated by laser light antenna resonate at 12GHz.

The main advantage of this technique is that the optical switches are linear and they don't need biasing. But they are lossy compared to electronic switches and need laser light to activate them. The main issue of optically reconfigurable antennas is the activation mechanism of such switches on the antenna structure. Optically reconfigurable antennas can be used in satellite communication and surveillance radar applications.

[C]Physically Reconfigurable Antennas-

The antenna can be tuned to different frequencies by a structural modification of its radiating parts. The main advantage of this technique is that it does not depend on any switching mechanisms, biasing lines, or optical fiber/laser diode incorporation. But the major drawback is that the technique depends on the limitation of the device to be physically reconfigured.

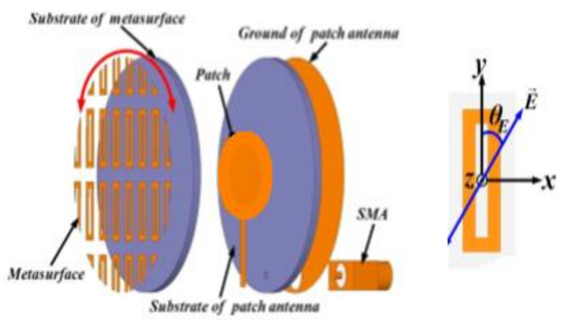


Fig.8-Frequency Reconfigurable Antenna with Metasurface

In figure 8, a frequency-reconfigurable antenna using metasurface (MS) is designed to operate at around 5 GHz [7]. The antenna is implemented using planar technology. To make the antenna more compact and low profile, the circular patch antenna and MS of same diameter are placed together in direct contact. The MS contains periodically placed rectangular-loop unit cells in the vertical and horizontal directions. The MS behaves like a dielectric substrate whose equivalent relative permittivity changes with rotation of the MS. Thus, by rotating the MS around the center and relative

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to the patch antenna, the operating frequency of the antenna can be continuously changed. Physically Reconfigurable Antennas are more suitable for space applications.

[D] Smart Material based Reconfigurable Antennas

Materials such as liquid crystals or ferrites can be used as substrate to obtain frequency reconfigurability in an antenna. Antennas are made reconfigurable through change in the material characteristics, i.e. by changing the relative electric permittivity or magnetic permeability of material. For a liquid crystal, dielectric constant can be changed by changing voltage levels due to change in molecular orientation. And for a ferrite material, a static applied electric/magnetic field can change the relative material permittivity/permeability.

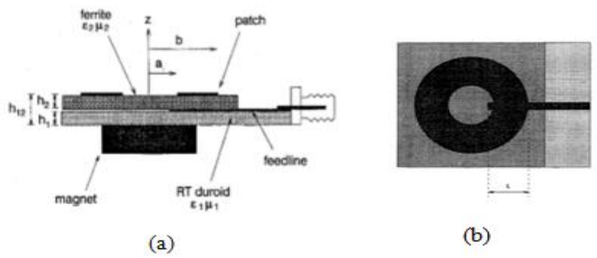

Figure 9-circular patch antennas on ferrite substrates

In [10], a circular patch antenna on ferrite substrate is designed and described. The geometry of antenna is shown in figure 9. DC magnetic field is used for biasing of ferrite. Frequency tuning is done by changing the applied DC magnetic field, thereby changing permeability of ferrite material. The main advantage of implementing smart materials is that their relative permittivities and permeabilities are large compared to commonly used substrate materials, hence, significant antenna size reductions can be achieved using them. However, the high conductivities of these materials can severely degrade the efficiency of the antennas, typically with thicknesses of the order of millimeters [13]. Material based reconfigurable antennas are suitable for wireless communication, space communications, satellites, space vehicle navigation and airplanes.

Table 2.Comparison of design techniques

Antenna Type	Advantage	Disadvantage
Electrically Reconfigurable	Small size, good isolation, low cost	reliability of the electronic components and the DC sources
PhysicallyReconfigurable	Does not require Biasing circuits for switches	Use of actuator for movement lead to complex circuit and expensive structure.
Optically Reconfigurable	removes surplus interference, losses, and pattern distortion	Lossy behavior, complex mechanism
Smart Material Based	Material characteristics greatly reduce size of antenna ,minimizes loss	Materials high conductivity relative to other substrates can degrade the efficiency of antenna

CONCLUSION

In this paper characteristics and classification of frequency reconfigurable antenna, specifically circular patch micro-strip antenna, is discussed in detail. Also, the operating principle, advantages and disadvantages of different techniques are discussed with examples. These techniques include electrical (slot, stub, stack), mechanical, optical and material change tunable structures.

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