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Reconfigurable Antenna Design

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ABSTRACT :

Reconfigurable antenna with the features such as emitting multiple radiation patterns at different frequencies with different polarization are required in modern telecommunications systems. Requirements for improved functionality for example direction finding, beam steering are required in radar, control and command. In today's transmitting and receiving systems, reconfigurable antenna is the solution to such problems. In this paper, various types of re-configurability and reconfiguration techniques used are discussed. The reconfigurable techniques are based on the integration of radio frequencies Microelectromechanical systems (RF-MEMS), PIN diodes, varactors, photo conducting elements, or physical changes. Various activations with different reconfigurable and usable mechanisms in implementation help us to get optimal performance. This paper describes design of reconfigurable antennas for both ground and space applications: Applications of these include cognitive radio, 5G mobile, MIMO (Multiple-Input-Multiple-Output) systems, and satellite communications.

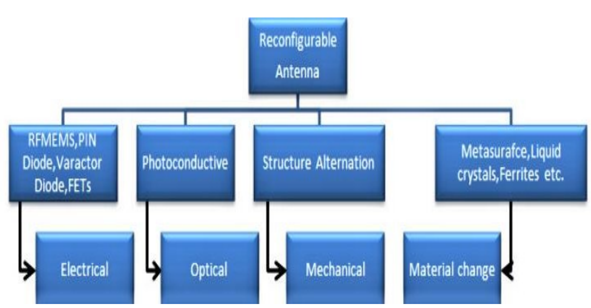
Key Words: frequency tuning; photoconductive switches; PINdiodes; polarization; radiation pattern; RFMEMS,reconfigurable antennas, varactors.

INTRODUCTION

Antenna re configurability is done by changing its frequency, polarization, or radiation characteristics [1]. This change is achieved by many techniques which redistributes and modifies the antenna current, the electromagnetic field generated by the effective aperture of the antenna. Reconfigurable antennas can meet complex system requirements by changing their shape, electrical design and behavior thereby adapt to changes in the environmental conditions or system requirements (ie. bandwidth improvements, operating frequency changes, polarization, and radiation pattern). Reconfigurability has become important and desirable features of the modern, radio frequency (RF) system, wireless and satellite communications, sensing and Imaging. There is a shift towards the integration of intelligent, cognitive and agile RF devices that can sense and communicate with the surrounding RF environment at the same time. Several new desirable features include frequency- agile, software definition, and cognitive radio, with scalability and reconfigurable multi-standard, multiservice, and multiband operation, also with efficient spectrum and power utilization. These ideas can significantly reduce the number of components, hence hardware complexity, and cost.

RECONFIGURATION TECHNIQUES

As shown in Figure 1, four major types of reconfiguration techniques are used to implement reconfigurable antennas [1]. PIN diodes, varactors that redirect surface currents and radio frequency microelectromechanical systems (RF-MEMS) are said to make antennas electrically reconfigurable. Antennas based on photoconducting switching elements are called optically reconfigurable antennas. By changing the structure of the antenna, a physically reconfigurable antenna can be realized. Finally, smart materials such as ferrite and LCD can be used to implement reconfigurable antennas.
Figure 1. Reconfiguration Techniques



1. TYPES OF RECONFIGURABLE ANTENNA Reconfigurable antenna has an ability to change any one of the antenna parameter (operating frequency, radiation pattern and polarization) without affecting the remaining parameters [2]. Based on the antenna parameter that is dynamically adjusted, the reconfigurable antennas are classified into four types.

Frequency Reconfigurable Antenna:

Frequency reconfigurable antennas can adjust their frequency of operation dynamically. They are particularly useful in situations where several communications systems converge because the multiple antennas required can be replaced by a single reconfigurable antenna. Frequency reconfiguration is generally achieved by physical or electrical modifications to the antenna dimensions using RF- switches, impedance loadingor tunable materials. These antennas can be developed by two mechanisms, electrical or mechanical. The electrical mechanism employs discrete tuning and continuous tuning methods. Discrete tuning can be achieved by radio frequency (RF) switches and continuous tuning can be achieved by varactor diodes. The mechanical mechanism employs the impedance loading tunable materials such as liquid crystals to achieve the frequency reconfiguration.

Radiation-Pattern reconfigurable antenna:

Radiation pattern reconfigurability is based on the intentional modification of the spherical distribution of the radiation pattern. Pattern reconfigurable antennas are usually designed using movable/rotatable structures or switchable and reactively-loaded parasitic elements.

Polarization Reconfigurable Antenna:

These antennas use switching between different polarizations,
i.e. from linear polarization to left hand circular polarization (LHCP) and righthand circular polarization (RHCP), using multi modes structures. To reduce the polarization mismatch, losses in portable devices, switching between horizontal, vertical and circular polarizations are needed.

Compound Reconfigurable Antennas:

These antennas use simultaneous tuning of several antenna parameters, e.g. frequency and radiation pattern, for independent reconfiguration of operating frequency, radiation pattern and polarization. The most common application of compound reconfiguration is the combination of frequency agility and beam-scanning to provide improved spectral efficiencies. Compound re configurability is achieved by combining in the same structure different single-parameter reconfiguration techniques or by reshaping dynamically a pixelsurface.

SWITCHING DEVICES USED FOR RECONFIGURATION

In order to demonstrate the reconfigurable antennas, various effective implementation techniques have been proposed and used in different wireless systems such as satellite, multiple- input multiple-output (MIMO) and cognitive ratiocommunications, which are classified as below:

- Electrical reconfiguration
- Optical reconfiguration
- Physical reconfiguration
- Reconfigurable antennas with smart materials.

The most common technique is electrical reconfiguration, which uses active elements such as positive- intrinsic-negative (PIN) diodes, varactors and radiofrequency microelectromechanical system (RFMEMS) switches.

4a Electrical Reconfiguration

In this type of reconfiguration method, the antenna characteristics are changed using electronic switching components such as PIN diodes, varactors or MEMS. Using these switches, the antenna structure can be reconfigured, which causes the redistribution of the surface current and alters the antenna's fundamental characteristics in terms of frequency, radiation pattern and polarization. The implementation of such a reconfigurable antenna with switching elements is easy and has received lots of attention inresearch. Next, different methods along with some examples ofelectrically reconfigurable antennas to obtain the corresponding reconfigurability function with their own advantages and disadvantages using PIN diodes, varactors or MEMS switches are described.

4b.PIN Diode

A PIN diode is a diode with a wide, undoped intrinsic semiconductor region between a p-type semiconductor and an n-type semiconductor region [3]. The wide intrinsic region makes the PIN diode a fast switch, photo detectors, and high voltage power electronics applications. PIN diodes are widely used as the switching components in different wireless systems.
The PIN diode needs a high tuning speed, a high bias current in the ON-state and a high power-handling capacity. Figure(2) shows the internal structure of PIN diode. It is very reliable andextremely low-cost which makes it a good choice for thereconfiguration technique.

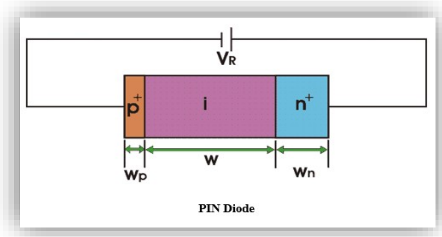


Figure (2) PIN diode

PROBLEM STATEMENT

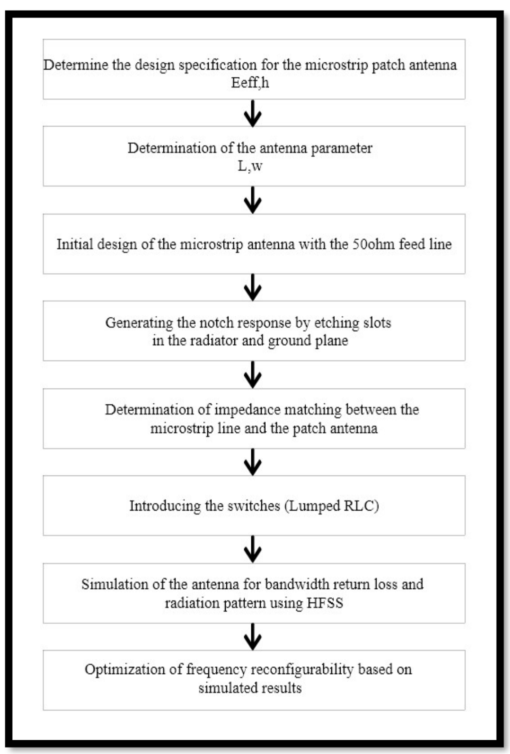
Antennas are the primary and critical components of every wireless communication systems and are being worn in cellular phones, radars, laptops, satellites and a lot of other applications ever since several past years. Novelties in contemporary communication systems need antennas to be capable of with intellectual competence. Systems have need of intelligent antennas that adapt their basic operating parameters for instance operating frequency, polarization and radiation pattern with the varying requests. This stimulates the researcher to investigate the novel field of antennas called "Reconfigurable Antennas". Those antennas have the capability of altering its elementary operational characteristics.

The objective of this work is to design Antenna for Frequency and Radiation pattern re configurability. Frequency range considered is 5-38 GHz, which is suitable for 5G mobile and WLAN applications.

Tool used to simulate the work is Ansys FHSS. Ansys HFSS is a 3D electromagnetic (EM) simulation software for designing and simulating high-frequency electronic products such as antennas, antenna arrays, RF or microwave components, high- speed interconnects, filters, connectors, IC packages and printed circuit boards [4]. Engineers' worldwide use Ansys HFSS to design high- frequency, high-speed electronics found in communications systems, radar systems, advanced driver assistance systems (ADAS), satellites, internet-of-things (IoT) products and other high-speed RF and digital devices.

2. ANTENNA DESIGN METHODOLOGY

Flow chart followed to design antenna for required specification in is shown in Figure (3). Once radiation pattern and return losses are obtained with FHSS, optimization in performance can be achieved by required changes in design.



Figure(3) Process flow

WORK DONE WITH RESULTS

Patch antennas are commonly used in the design of reconfigurable antennas. It consists of a metal "patch" on top of a grounded dielectric substrate. The patch may be in a variety of shapes, but rectangular and circular are the most commonly
used. They are low profile and easily fabricated antennas. In allour design, we have used patch antennas

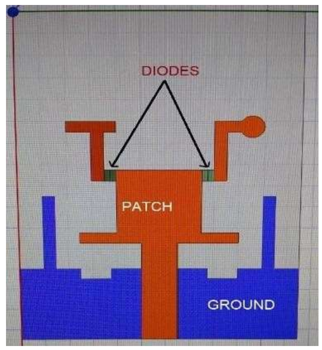
Design-1

A compact printed antenna having the functionality of frequency shifting reconfigurability is considered. The proposed antenna is switch-dependent. Depending on the ON and OFF states of the switches, four Modes provide various frequency bands for frequency reconfigurability.

Frequency reconfigurable microstrip patch antenna is designedwith the following specifications:

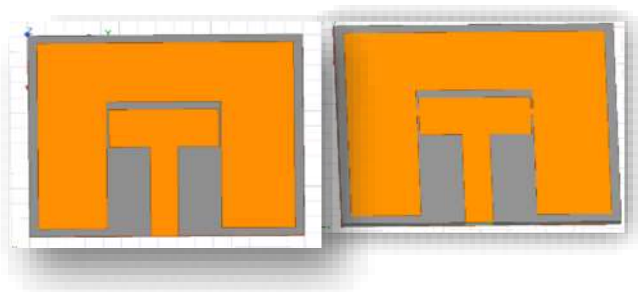
Resonant frequency:- 3.1GHz. Transmission line impedance: 50 Ohm.

The dielectric constant of the substrate: ξr = 4.4Thickness of dielectric substrate (h) : 1.6 mm Length(L) X Width(W) : 31 X 23 mm



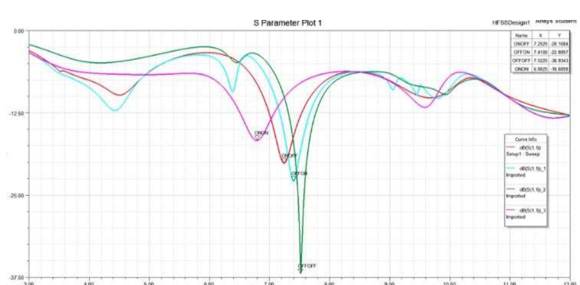
Figure(4) Reconfigurable patch antenna with PIN diodes

Antenna Geometry: The antenna configuration is shown in Figure 4. On one side of the substrate is the ground plane, microstrip feed line. Two PIN diodes (D1 and D2) are loaded to the patch to realize the frequency re-configurability,



Table(1) 4 Choices for frequency selection

Two PIN diodes are used to select 4 different frequencies. Table(1) below shows 4 different choices with switches-Y representing the reflection parameter in dB and X representingfrequency at which peak occurs. Frequency variation is from 6.8 GHz to 7.25GHz as shown in fig(5)



Figure(5) Reflection coefficient at 4 different frequencies

Design-2

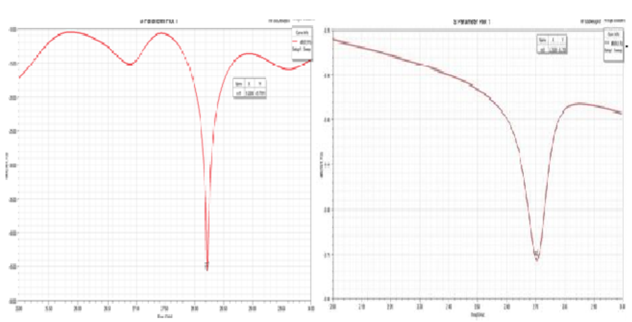
Reconfigurable antenna with the capability of transmitting 5G and wi-fi frequencies is considered in this design. The antenna is printed on a FR4 substrate with a dielectric constant of 4.4 and thickness of 1.6 mm. Its dimensions are 26.5x30 mm2 . A metal pad is used to switch the antenna between two frequencies 2.4 GHz correspond to Wi-Fi application and 28 GHz band for 5G application. Design specifications consideredare

Resonant frequency: 28 GHz(5G) & 2.4 GHz (WLAN)Transmission line impedance: 50ohm
The dielectric constant of the substrate: ξr = 4.4Thickness of dielectric substrate (h): 1.6mm Length(L) X Width(W): 30mm x 26.5mm

Name	X	Y
ONOFF	7.2525	-20.1684
OFFON	7.4100	-22.8897
OFFOFF	7.5225	-36.9343
ONON	6.8025	-16.6898

Figure(6a) Figure (6b)

In fig (6a) the conducting rods are closed and the antenna operates for 5G band. In fig (6b) the conducting rods are left open and the antenna operates for WLAN applications. Here State 1 corresponds to the antenna operating in the Wi-Fi Bandand State 2 corresponds to the antenna operating in the 5G Band.



Figure(7) Reflection coefficient for 2 different frequencies:28 GHZ, 2.7 GHz

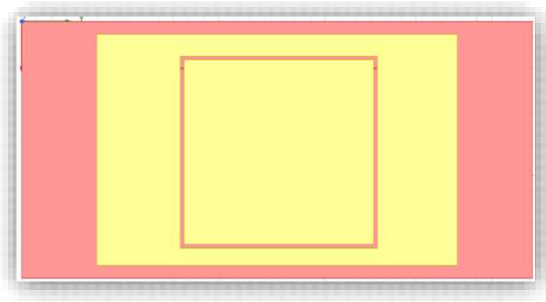
Design-3

In this design, 5G pattern reconfigurable antenna is attempted. The diversity in pattern can be achieved by a patch antenna enclosed by a hollow rectangular conductor. The spacing's in between the two conductors are used for enhancing the main beam and minimizing the level of side lobes. Depending on the ON and OFF states of the switches, three Modes provide a diverse radiation pattern. Directivity varies from 5.69 to 6.77 dB while gain fluctuates in the range 5.4 to 6.4 dB, whereas, the value for VSWR is from 1.01 to 1.05. The compact size of3.34x6.73mm2 will make it a first choice for integration with future 5G cellular communication systems.

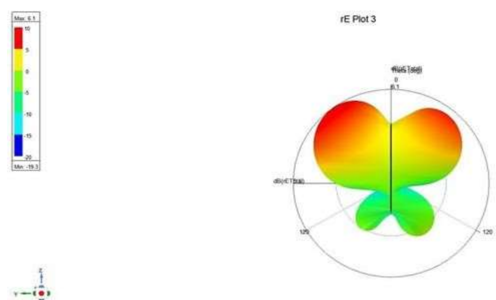
Dimensions of the design and the separation between radiating structures are given in the Table 2 which are optimized for operation in the resonance frequency of 38GHz covering a band of about 1.8 GHz, and also providing a return loss less than -10dB.
Design specifications considered areResonant frequency: 38 GHz
The dielectric constant of the substrate: ξr = 2.2Thickness of dielectric substrate (h): 0.381 mmLength(L) X Width(W): 6.73 x 3.34 mm
Fig(8) shows the antenna structure, fig(9) shows radiation pattern in 3 different modes. fig(10) shows return loss for 3 different modes. The figure(9) is showing diversity in radiationpattern in plane with 38° for Mode 1,-38° for Mode 2 and ±41°
for Mode 3

Table (2)

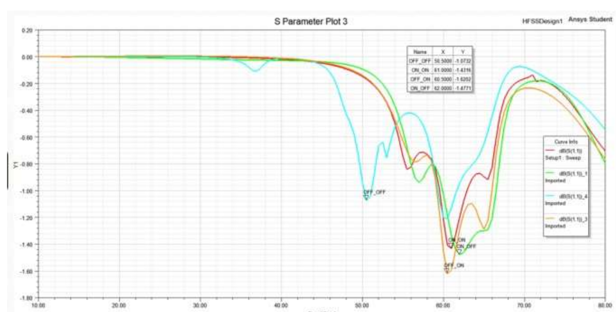
Table IV: Pattern re configuration for different modes			
Mode	Switch-1	Switch-2	Pattern (Degrees)
1	OFF	ON	38
2	ON	OFF	-38
3	OFF	OFF	±41



Figure(8) Reconfigurable patch antenna with different materials



Figure(9)



Fig(10) Return loss for different modesComparison of 3 designs

	Design-1	**Design-2**	**Design-3**
AntennaType	**Patch**	**Patch**	**Patch**

Dimensions(in mm)	**31X23X 1.6**	**30X26.5X1.6**	**6.73X3.34X0. 3**
Substrate (dielectricconst.)	**FR4epoxy (4.4)**	**FR4 epoxy(4.4)**	**Rogers RT5880 (2.2)**
Reconfigu-ration type	**Frequency**	**Frequency**	**Pattern**
Feeding Technique	**Transmi ssion Line**	**Transmissi on Line**	**Coaxial**
Freq.Range(GHz)	**6.8- 7.2GHz**	**28 & 2.7GHz**	**50 -62GHz**

CONCLUSIONS

In this work, achieving re-configurability in antennas are reviewed and classified. Three different designs are tried to get reconfigurability with antenna. A compact printed antenna having the functionality of frequency shifting reconfigurability(Design-1), supporting 5G and WLAN applications (Design-2) and both frequency and pattern reconfigurability (Design-3) issuccessfully designed

Challenge to designers is, will they be able to achieve their design objectives in the most efficient and less expensive way.

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