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Frequency Reconfigurable Meander Slot Antenna for Cognitive Radio Applications

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***Abstract* -Cognitive radio communication plays a major role in the modern world communication. An antenna used in cognitive radios plays a key role in the communication system in terms of sensing and switching. To sense the vacant spectrum the antenna has to operate in ultra- wide band range and for switching between different bands the antenna must be frequency reconfigurable. Designed antenna is frequency reconfigurable in its operation and has a defective ground structure for its high gain. Four Switches are placed in meander slot for switching between different bands. The designed antenna is working in ultra-wideband when all switches are off. It is operating at 8.5 GHz when all switches are in on state and the antenna operates at 5 GHz when two switches are in on condition.**

***Keywords*:** Meander slot; Defective ground structure; Reconfigurable antennas.

I. INTRODUCTION

Cognitive radio (software defined radio) is the trending technology in wireless communication. To overcome the effect of spectrum scarcity (which is a limited quantity available in the nature) different technologies are evolved from last few decades. Cognitive radio is one of the important techniques implemented in the present day scenario. Spectrum sensing, spectrum sharing and spectrum mobility are the main techniques used in cognitive radio communication. For the spectrum sensing an ultra-wide band (UWB) antenna is essential. After finding the vacant spectrum the secondary user must switch to vacant spectrum with a reconfigurable antenna [1].

Different reconfigurable antennas are designed for last few years and these are developed using switches like photo conducting silicon elements. When these switches are illuminated by light they act like metals which in turn change the distribution of the current [1]. Frequency reconfigurability can be acquired by introducing capacitors along the slot of the antenna and varying the electrical properties of one capacitor while fixing another capacitor [2]. The antenna operating frequency can be modified by rotating the slot for different slot positions so that various resonant frequencies can be obtained (this is one way to design a frequency reconfigurable antenna without using switches) [3].

An ultra-wide band antenna is united with frequency reconfigurable antenna on the same substrate and the frequency agility can be obtained by rotating the patch by means of an external force [4]. The antenna is designed by employing inductors and capacitors in the feed line and the frequency can be varied by using these tuning elements [5]. Reconfigurable antennas are enormously used in the antenna miniaturization and these antennas exclude the usage of multiple antennas for different types of communication systems.

In this paper an antenna is designed for frequency reconfigurable operation. Four switches are placed in the mender slot which results in operating three different frequency bands. The antenna operates mainly in 3 switching modes:

I. When all switches are in off state
II. All switches are in on state
III. Two switches are in on state and two switches are in off state.

When all switches are in off state the antenna operates in ultra-wide frequency range which can be used as a sensing antenna. For the remaining two cases the antenna can be used as reconfigurable antenna for the switching between two bands. Designed antenna is useful for the cognitive radio communication.

II. **ANTENNA DESIGN**

The designed antenna structure can be divided into 3 parts. The antenna is designed and simulated using Ansoft HFSS software.

I. Rectangular patch antenna with Mender slot and defective ground structures
II. Edge discarded patch antenna
III. Switches placed in antenna for the frequency reconfigurability.

Initially the simple rectangular patch element is designed which is a simple, low profile and is united with the mender slot in the ground for the high gain and large bandwidth [8]. Antenna is designed with FR4 Epoxy substrate. Patch element edges are discarded for the antenna to achieve high gain because at the edges the antenna radiates more efficiently than a smooth element. Further the switches are incorporated for the frequency reconfigurability [9]. These switches are PIN diodes or MEMS. For the simulation these diodes are modelled as lumped RLC elements. By inserting these four PIN diodes as switches and for different operating states the antenna is resonating in UHF, L and X bands.

A. *Rectangular Patch Antenna:*

The basic element in this antenna is simple patch. The substrate element used for the design is FR4 Epoxy substrate with thickness of 0.8 mm with ε_r=4.4. The microstrip line feeding is used for the antenna with 50Ω transmission line. The antenna gain and bandwidth performance is improved by implanting the mender slot and the defective ground structure elements [5].

TABLE I
DESIGN PARAMETERS OF PATCH ANTENNA

parameter	dimension (mm)
Length of ground L_G	45
Width of ground W_G	45
Length of substrate L_S	29
Width of substrate W_S	40
Length of Patch L_P	24
Width of Patch W_P	27

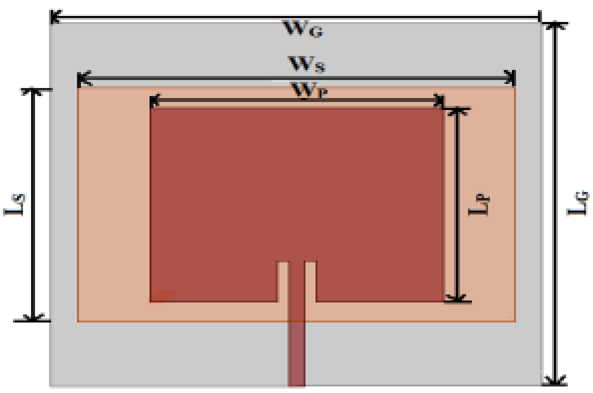

Fig.1: Rectangular patch Antenna

The simulated patch antenna parameters are given in table 1 and rectangular patch with parameters is shown in Fig.1

Another feature used in this design is defective ground structure (DGS) which is one of the distributed microwave technique used to improve the performance of the antenna. The DGS introduce delay in the transmission lines and effectively reduces the side lobe levels [6]. These are broadly used for the bandwidth enhancement and size reduction [7]. Using slots in the ground reduces the weight of the antenna. Different types of DGS are described in [7] are

i. Unit DGS,

ii. Periodic DGS

Unit DGS is slot placed in the ground plane in forms like square, rectangle, circle, and ellipse. These are used to regulate the slot frequency by changing the length of the slot. These have higher slow wave factor and more compact circuit [7].

Periodic structures like Photonic Band Gap (PBG) and DGS for planar transmission lines have drawn a wide interest for their wide applicability in antennas and microwave circuits. Transmission lines with a periodic structure have a finite pass and rejection band as low-pass filters. The increased slow-wave effect and the additional equivalent components are significant properties of periodic structure that can be realized and the circuit sizes can be made compact using these properties. The antenna designed in this paper used the unit DGS [6] to improve the gain.

The DGS structures are used as band eliminating filters and delay lines. Meander slot antenna is the one type of Defective structured antenna and in this the conducting element of an antenna is bent back and forth. The meander slot parameters affect the antenna performance characteristics. Embedding the meander slot in the antenna structure enhances the gain of the antenna and also it reduces the size of the antenna considerably by placing the long conducting material as a meander slot [6]. Based on babbinet's principle every slot in the antenna acts as a source element and how the slot antenna reradiates the power. In this paper half elliptical slot is connected with a meander slot [8].

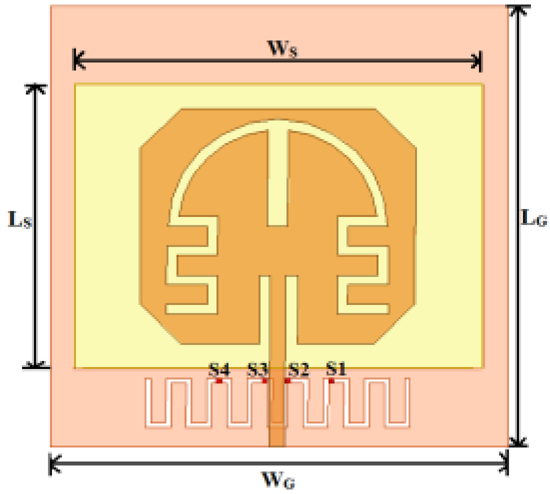

Fig. 2: Meander slot reconfigurable Antenna

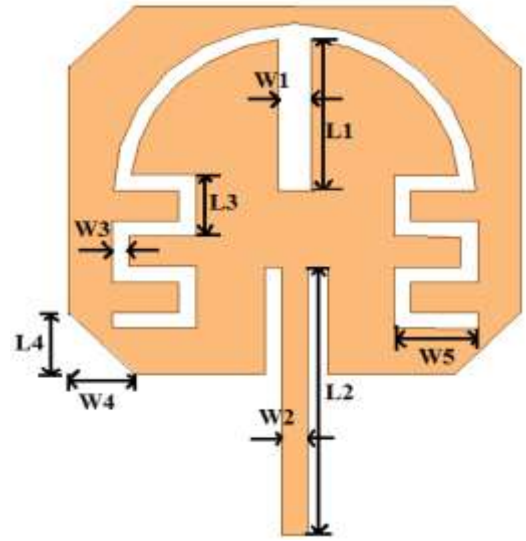

Fig. 3: Radiating patch

All these further techniques introduced in the patch antenna design are very useful for the enhancement of the gain and bandwidth of the antenna. Generally simple microstrip antenna has bandwidth in the range of MHz. In this paper the antenna bandwidth is more than 6 GHz. By integrating Meander slot, defective ground structure and edge -truncation with the conducting patch bandwidth enhancement and size reduction is made possible [6-8].The designed patch antenna with DGS and switches is shown in Fig.2 and the elliptical slot embedded with mender slot in the radiating patch is given in Fig. 3. The switches S1, S2, S3, and S4 are embedded in the antenna as shown in Fig.4.

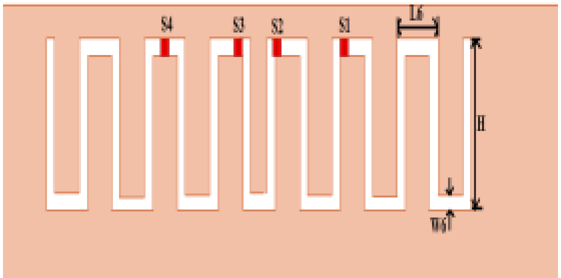

Fig. 4: Meander Slot structure

TABLE II

DESIGN PARAMETERS OF MEANDER SLOT RECONFIGURABLE ANTENNA

parameter	dimension (mm)	Parameter	dimension (mm)	parameter	dimension (mm)
L_G	45	L1	10	W1	1.5
W_G	45	L2	17.5	W2	1.5
L_S	29	L3	4	W3	1
L_P	24	L4	4	W4	4
W_S	40	H	5	W5	4

B.Inclusion of PIN diodes: Various designing methods are used to vary the operating frequency of the antenna. In this design RF PIN diodes (used as electronic switches) are included in the ground plane to alter the switching frequency. These diodes act as variable resistors at RF frequencies but they are modelled as a complicated equivalent circuit for ON/OFF states as shown in Fig.5 [9].

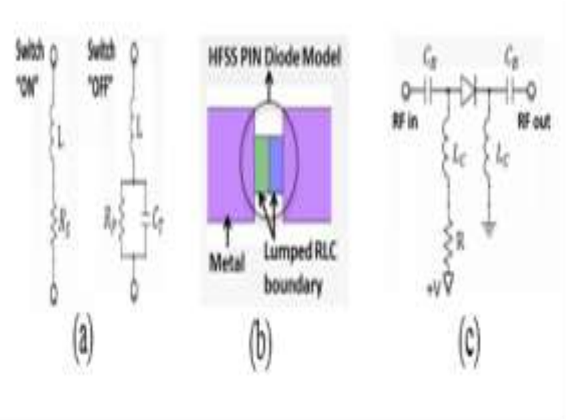

Fig. 5: RF PIN diode (a) Equivalent circuit model (b) HFSS model (c) Used to create seriesswitch

The on state circuit is modelled as a series combination of an inductor L with resistor R_s. For the OFF state inductor L in series with parallel combination of resistor R_p and capacitor C_r is shown in Fig 5 (a). For the simulation in HFSS these are modelled as two lumped RLC elements as shown in Fig.5 (b), First part is inductor and second one is a either resistor for on state or parallel combination of resistor and capacitor [9]. The diode switching state can be analysed by using the circuit shown in Fig.5 (c).

III. SIMULATION RESULTS & ANALYSIS:

The designed antenna is simulated using HFSS software [10] and is operated for three switching configurations as illustrated below.

I. All four switches are in on condition
II. All four switches are in off state.
III. Two switches are in on and two switches are in off condition

A. Return loss:

These antennas also have very high bandwidth and low return loss. The simulation is carried out for return loss, and bandwidth. The antenna operating range and bandwidth is mentioned in table 3.

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TABLE III
ON, OFF SWITCHES AND CORRESPONDING BANDWIDTHS

State of the switches		Resonate frequency (GHz)	Operating Range (GHz)	Bandwidth (GHz)
On switches	Off switches			
All	-	8.33	6.94 to 10.94	4 V.
1,2	3,4	7.5	4.17 to 10.77	6.6
-	All	5.06	3.6 to 13.2	9.6

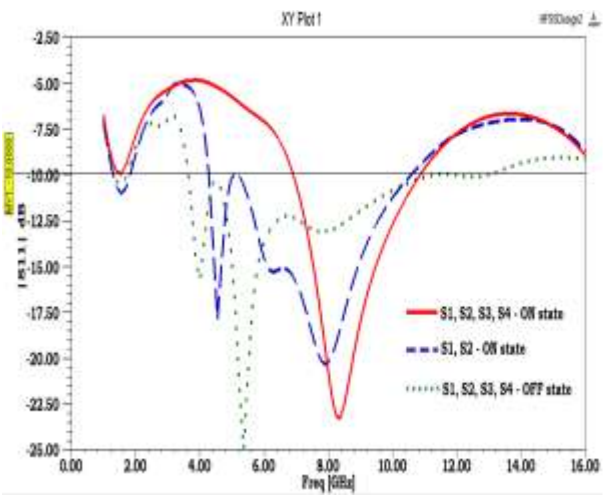

Fig. 6: Variation of Return loss for different switching modes of antenna

From the Fig.6, it is observed that the variations of return loss are less than - 10dB from 4-10 GHz for antenna with all switches in off condition. It is clear that return loss across a wide band necessarily result in an antenna along with satisfactory gain for 4-10 GHz band. The variation of return loss with frequency for different switching conditions of antenna is simulated. The simulation results with all switches in on state, all switches in off state and two switches in on state are presented in Fig.6. The antenna for all switches are in on state is having narrow bandwidth and it is operated at 8.5 GHz frequency (X-band). The antenna with two switches in on state is operating at 5GHz and (C- Band). The antenna with allswitches are in on state is operating over UHF range.

IV. CONCLUSION

The designed antenna is useful for the cognitive radio applications. To sense the spectrum in cognitive radio, antenna has to operate in ultra wide band range. This antenna is realized by using antenna with all switches are in off state. The operation of antenna `when two switches are in on state and two switches are in off state is useful for WI-MAX applications. With all switches are in on state the antenna is operated at 8.5 GHz frequency.
This single antenna is useful for both satellite and WI-MAX applications without modifying its structure. When the satellite band is found to be vacant in the spectrum, it is used for WI-MAX applications. By applying more switching configurations the antenna efficiency increases.

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