A Novel Frequency Reconfigurable Microstrip Patch Antenna using Pin Diode

V. Nandalal, G. Indumathi, G. Suseendran, A. Athithya Janani

Abstract: In recent study, in the growth of wireless technology single antenna that works with a specific frequency is becoming outdated. The antenna which is capable to work dynamically is encouraged. To make an antenna to work dynamically, modification in any of the antenna characteristics can be applied. In this proposed work, the antenna which can reconfigure its frequency is designed and analyzed. Microstrip patch antenna is most popular printed type antenna which is suitable for diverse applications. The antenna design consists of three PIN diodes which are placed in different positions on the patch. Depending upon the switching state of PIN diode the antenna can operate in different frequency ranges. The frequency range obtained ranges from 1.38 GHz to 3.24 GHz. Return loss value, VSWR obtained is of optimum level. The various gain of antenna is obtained in simulation. The analysis of the antenna is done in ANSYS HFSS software.

Keywords: Frequency Reconfigurable, Microstrip patch antenna, PIN Diode, Return Loss, Gain, ANSYS HFSS.

I. INTRODUCTION

In the development of wireless technology antenna is applicable in all fields such as for ISM band application, Satellite communication, in mobile communication such as for LTE, WIFI, WIMAX. The growth in this domain can be attained by improving the performance and quality of antenna. By taking this into consideration, the various needs of upcoming technology can be satisfied by applying antenna that has the capacity to work for multiple systems at particular instant.Thus, reconfigurable antennas are introduced.Reconfigurable antennas can provide diverse functions in Frequency, Polarisation, pattern configuration which gains considerable attention in recent technology. Reconfigurable antenna has some smart advantages such as multi-band function, steerable radiaton pattern, and polarization diversity which leads to reduced size, less complexity , reduced cost of antenna and improvement in the total performance of entire system. For reconfiguration to be achieved active elements such as PIN diode, RF MEMS, varactor diode can be used as Switching elements to attain reconfigurability. RF MEMS switches has the switching speed of 1- 200μsec.

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This is low range for most applications. In varactor diode, the capacitance in the diode can be controlled by varying the bias voltage which produce wide tuning range. PIN diode has a switching speed of 1-100μsec.This element provides fast switching and fast dynamic reconfiguration and hence this element is preferred for reconfiguration. Antenna characteristics is modified by altering the current flow through the antenna structure. Frequency reconfiguration is in huge demand in wireless communication. This can make the antenna to work for more than one system. Microstrip antennas have several advantages when compared to several other conventional antennas. The structure and geometry of the antenna is simple and complexity is less. It is the most commonly used printed type antenna that can be easily fabricated and analysed.

They can be easily designed to have any shape and dimensions. The basic structure of this antenna is a patch is created over a substrate and ground plane. The measurement of the antenna mainly patch is adjusted based on the substrate and design is created. The material assigned for the substrate is FR4 Epoxy whose dielectric constant is 4.4. This antenna functions by exchanging currents through fringing effects between the edge of patch and the substrate.

In this work, antenna with single reconfiguration feature is applied. For reconfiguration to be obtained the diodes are placed in between patches of different shape. The diode is activated through the switching condition. PIN diode is a semiconductor diode that operates such that when the input current is applied it converts the incoming Alternating Current to Direct Current and it can flow in a particular direction. Three diodes are implemented in this design and under 8 swicting conditions such as making the diode to ON and OFF reconfiguration is attained. In ON state the diode is in forward bias and alternately it is in reverse bias under OFF condition. The frequency range obtained ranges from 1.38 GHz to 3.24GHz. The simulated return loss value obtained is of optimum level. The various gain of antenna is obtained in simulation. The analysis of the antenna is done in ANSYS HFSS software.

II. RECONFIGURABLE ANTENNA

An antenna which has multifunctional characteristics is said to be reconfigurable antenna .This is usually achieved by working on the characteristic or parameter of antenna. Application of reconfigurable antenna is widely appreciated in present wireless technology field. The achievement of reconfigurability is done by using active elements such as PIN diode, Varactor Diode and RF MEMS. The deigning of this antenna has many advantages such as reduced size, multifunctional capabilities.

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A. Frequency Reconfiguration:

Frequency reconfiguration is making the antenna to work for various frequency at a single time.

Antenna with single design can be made to work with multiple frequency of operation. It cannot cover entire frequency band but it can work dynamically to different frequency according to need. The reconfigurability is achieved by changing the design approach . Active element can be used for switching in antenna design. Modification in antenna can be achieved by redistribution of current.

B. Pin Diode:

Diode can conduct electricity in only one direction. It can act as rectifiers, signal modulators and demodulators, switches and oscillators By development of semiconductor switches, reconfigurable antennas are fabricated using PIN diode. The advantages of using this element are they have less insertion loss, switching speed is high , small size and low cost. Thus, it can be easily fabricated on the surface of antenna and can be switched to attain frequency reconfigurability. The switching condition can be applied to the diode to attain required reconfiguration.

III. RECONFIGURABLE MICROSTRIP PATCH ANTENNA

The proposed antenna is designed with multiple patches united to work as a single patch. The design is excited with 2.4GHZ of frequency basically. The dimension of the substrate is 60x60. The geometry of the patch is adjusted according to the substrate. The material used for substrate is FR4 epoxy. This has 4.4 as dielectric constant. The substrate has thickness of 1.6 mm. The material can be easily available for fabrication and has advantages when compared to other material. Ground is applied less for better performance of antenna. The current flows from the patch to the substrate. The patch and substrate connects through fringing fields. In between the patches PIN diode is placed. Three diodes D1, D2, D3 are placed at different places. Diode dimension is 1.6x0.8 mm.
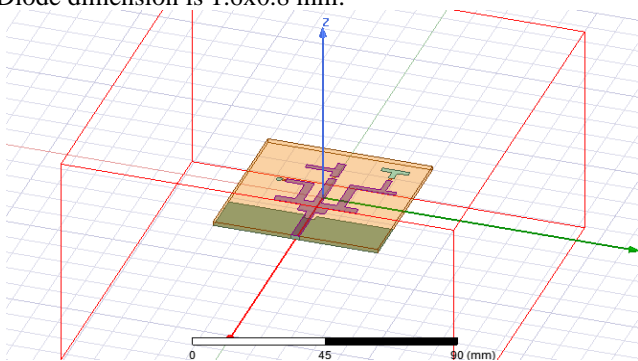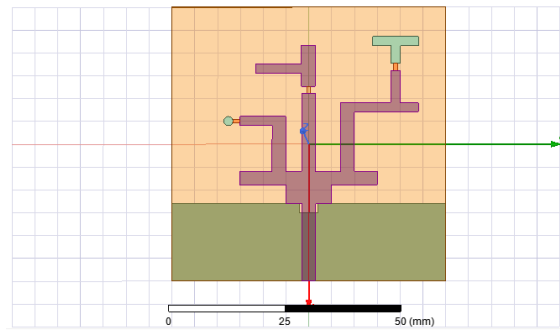

Fig.1 Overview of antenna.

Fig.2 Top view of antenna.

3.1 Diode Switching:

The diode used in the design can work in two conditions ON and OFF condition. The switching condition followed is BAR 64-02V as it can provide negligible inductance. The diode can allow the current to pass through in only one direction. The three diodes are switched so that the antenna work for 8 different conditions.
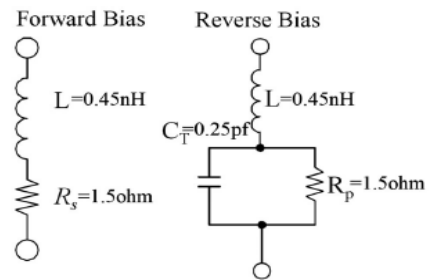

Fig.3 BAR 64-02V Switching condition

When the diode is in ON condition it will be in forward bias, the resistance and inductance will be active and in series and in OFF condition diode will be in reverse bias. the circuit has a parallel combination of capacitor and resistance with series connection of inductance.

Table.1 Frequency ranges obtained after reconfiguration.

D1	D2	D3	FREQUENCY RANGE(GHZ)	S-PARAMETER (db)	GAIN	VSWR
OFF	OFF	OFF	1.38-3.18	-12.90-(-18.82)	1.98	1.94
ON	ON	ON	1.4-3.24	-13.01-(-21.06)	1.95	1.53
ON	OFF	OFF	1.355-3.10	-11.99-(-24.49)	2.23	1.13
ON	ON	OFF	1.35-3.14	-11.45-(-28.26)	2.21	0.74
OFF	ON	ON	1.38-3.24	-13.09-(-20.85)	1.96	1.68

OFF	OFF	ON	1.38-3.24	-13.05-(-18.88)	1.97	1.93
ON	OFF	ON	1.39-3.24	-13.09-(-19.32)	1.97	1.9
OFF	ON	OFF	1.45	-41.09	1.98	1.5

IV.   SIMULATED RESULTS

A. D1,D2,D3 are Off Condition:

When all the diodes are in OFF condition (i.e) forward bias the frequency reconfiguration attained is with the range of 1.38- 3.18 GHZ and the return loss obtained is -18.32 db. The gain obtained is measured as 1.98 db.
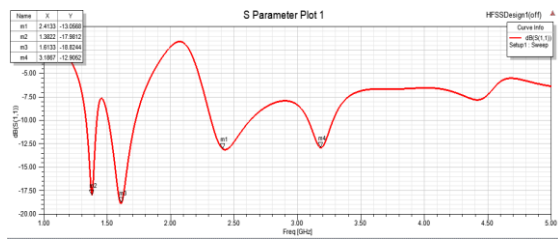
Fig.4 S-parameter for 1st condition

B. D1,D2,D3 Are OFF Condition:

When all the diodes are in OFF condition (i.e) reverse bias ,the frequency reconfiguration attained is with the range of 1.4- 3.24 GHZ and the return loss obtained is -21.06 db. The gain obtained is measured as 1.95 db.
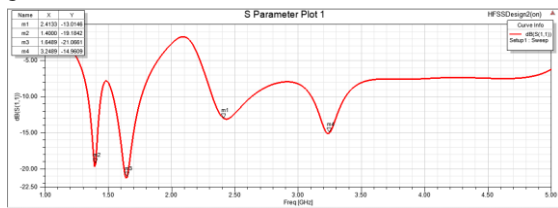

Fig.5 S-parameter for 2nd condition

C. D1is ON, D2 and D3 OFF Condition:

When the diode D1 is in ON condition (i.e) forward bias and D2,D3 are in OFF condition (i.e) reverse bias ,the frequency reconfiguration attained is with the range of 1.35- 3.10 GHZ and the return loss obtained is -24.49 db. The gain obtained is measured as 2.23 db.
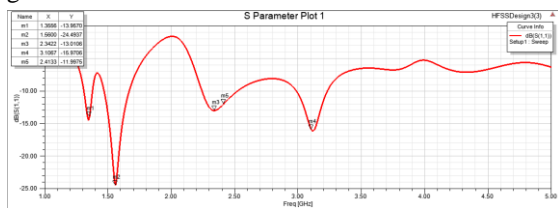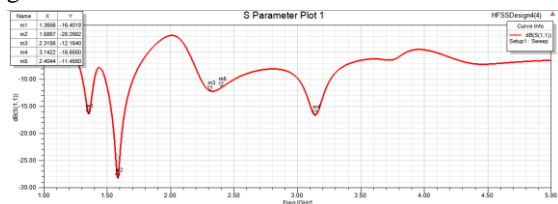

Fig.6 S-parameter for 3rd condition

D. D1,D2 is ON and D3 is OFF Condition:

When the diode D1,D2 are in ON condition (i.e) forward bias and D3 is in OFF condition (i.e) reverse bias ,the frequency reconfiguration attained is with the range of 1.35- 3.14 GHZ and the return loss obtained is -28.26 db. The gain obtained is measured as 2.21 db.

Fig.7 S-parameter for 4th condition

E. D1is OFF and D2,D3 are ON Condition:

When the diode D1 is OFF condition (i.e) reverse bias and D2, D3 are in ON condition (i.e) Forward bias ,the frequency reconfiguration attained is with the range of 1.38-3.24 GHZ and the return loss obtained is -20.85 db. The gain obtained is measured as 1.96 db.
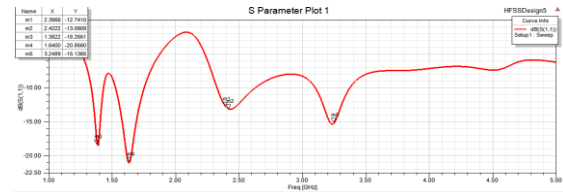

Fig.8 S-parameter for 5th condition

F. D1,D2 are OFF and D3 is ON Condition:

When the diode D1,D2 are OFF condition (i.e) reverse bias and D3 is in ON condition (i.e) Forward bias ,the frequency reconfiguration attained is with the range of 1.38-3.24 GHZ and the return loss obtained is -18.88 db. The gain obtained is measured as 1.97 db.

Fig.9 S-parameter for 6th condition

G. D1 is ON,D2 is OFF, D3 is ON Condition:

When the diode D1,D3 are in ON condition (i.e) forward bias and D2 is in OFF condition (i.e) reverse bias ,the frequency reconfiguration attained is with the range of 1.39- 3.24 GHZ and the return loss obtained is -19.32 db. The gain obtained is measured as 1.97db.
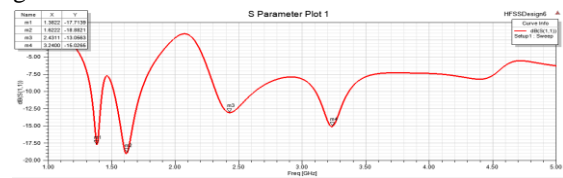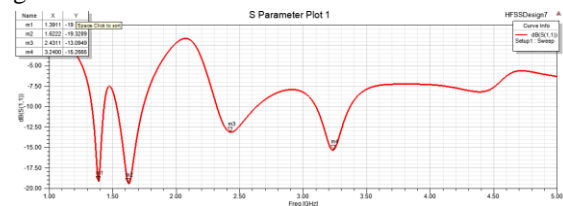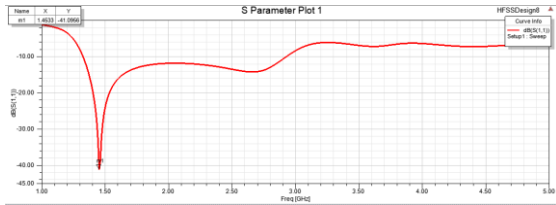

**Fig.10 S-parameter for 7th condition**

H. D1 is OFF, D2 is ON, D3 is OFF Condition:

When the diode D1, D2 are in OFF condition (i.e) reverse bias and D2 is in ON condition (i.e) forward bias ,the frequency reconfiguration attained is with the range of 1.45 GHZ and the return loss obtained is -41.09 db. The gain obtained is measured as 1.98 db.

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Fig.11 S-parameter for 8th condition

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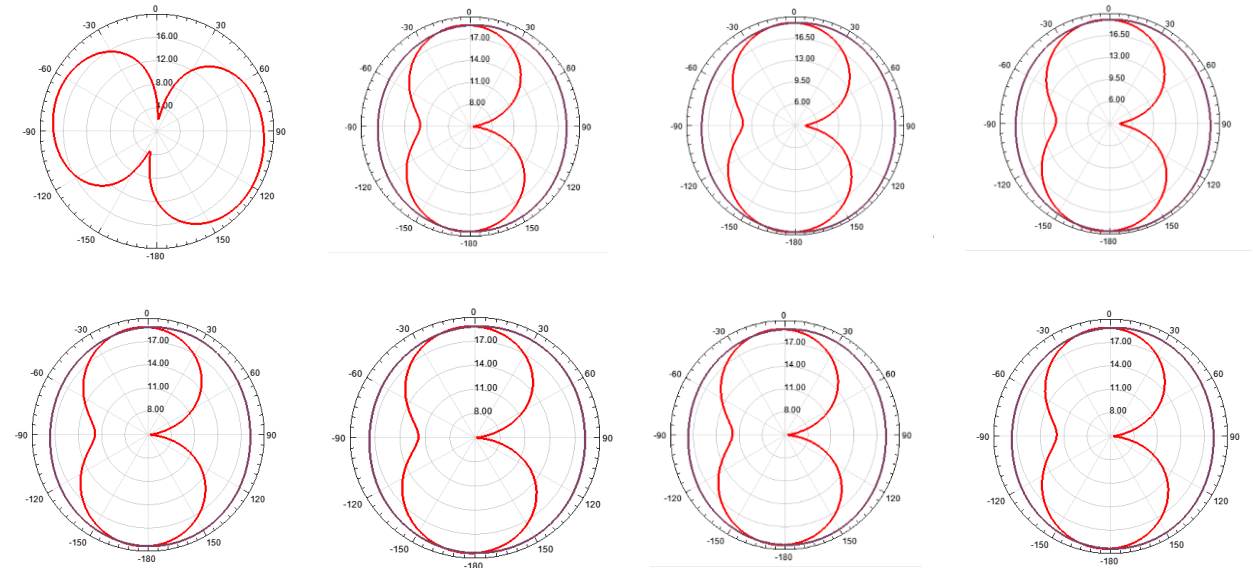
Fig.12 Radiation pattern for all 8 conditions.

V. CONCLUSION

The frequency reconfigurable antenna is designed, analysed and simulated. The antenna designed is analysed with 2,45GHZ . The substrate used is FR4 epoxy with thickness of 1.6mm. The reconfiguration is attained using BAR 64 – 02V switching conditions. The ON and OFF condition applied to the diode go well with the designed antenna. The obtained results show that the frequency reconfiguration is attained within the range of 1.38GHZ to 3.14GHZ with return loss, VSWR and Gain. The software tool used is ANSYS HFSS. The frequency switched range can be applicable for LTE, WIFI and other applications.

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