Reconfigurable Antenna using PIN Diode for Future Wireless Communication

Bhakkiyalakshmi R, M. S. Vasanthi

Abstract- ***This paper discusses design and analysis of reconfigurable antenna for millimeter wave communication. The proposed antenna model resonates at frequencies between 25-34GHz using PIN diode. Return loss and voltage standing wave ratio achieved less than -10dB and 2 respectively. Resonating frequency changed by varying the bias of PIN diode switches. Antenna size is reduced using meander lines in the patch compared to the existing micro strip patch reconfigurable antennas. The proposed antenna is designed using Electromagnetic simulation software with appreciable gain.***

Keywords- ***Reconfigurable antenna, micro strip patch, meander line, PIN diode, 5G wireless communication***

I. INTRODUCTION

Modern wireless communication introduces many day-to-day life communication devices, which happen to be vital for human beings. All these devices operate in their own frequency of operation. Hence the need for single antenna operates in various frequency bands have been increased. The researchers are interested in developing a single antenna that resonates at multiple frequency bands. The solution for this is reconfigurable antennas. They facilitate reconfiguration in the radiation characteristics like radiation pattern, polarization and bandwidth that can serve at multiple frequency bands [2]. Reconfiguration techniques can be classified as mechanical, electrical, optical and structures using liquid crystals [3]. Mechanical reconfiguration uses stepper motors and other mechanical devices to control antenna. Electrical reconfiguration uses MEMS switches, Varactors, RF switches, and PIN diodes [5-7]. PIN diodes used widely compared to all other switches based on low insertion loss, good isolation, low power consumption and less cost [4]. Optical reconfiguration employs photoconductive switches whose electrical conductivity controlled by laser [10].

Introducing meander line can reduce size of antenna on the radiating patch. We present a meander line reconfigurable patch antenna using PIN diode to work at multiple frequency bands. It's frequency of operation can be controlled by biasing the diodes to ON and OFF state without making any further change in the size of meander line antenna[8]. Our proposed antenna resonates in multiple frequency bands from 25 to 34 GHz, can be used for future 5G wireless communication with Gbps transmission and millimeter wave communication.

Revised Manuscript Received on April 25, 2019.
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II. ANTENNA DESIGN

Proposed antenna designed with a micro strip patch. Vertical and horizontal lines are created with meander slits in the rectangular patch there by reducing the size of the antenna. The operating frequency of antenna with meander line depends on meander spacing and separation. Resonant frequency of meander line antenna decreases with increase in meander spacing and separation [1,15]. ROGER RO3006 is used as substrate with thickness h = 0.13mm, dielectric constant Ɛr = 6.50, dissipation Factor tanδ = 0.0020. Patch and ground are made up of copper with a patch dimension of 2mmx2.4mm. Then meander slits are done on the patch to obtain the proposed shape as shown in Figure 1, which is excited by 50Ω, feed line. Simulations are done in HFSS15.0 and simulation result of the designed antenna resonates at frequencies 25.3 GHz and 31.5 GHz with return loss of -29.8dB and - 10.6dB, VSWR of 1 and 2respectively and gain of 4.5dB is achieved as shown in Figure 2a, 2b and 2c.

To obtain reconfiguration of different frequencies single PIN diode and two PIN diodes are placed in the radiating element of the meander line as discussed in chapter 3 and 4.

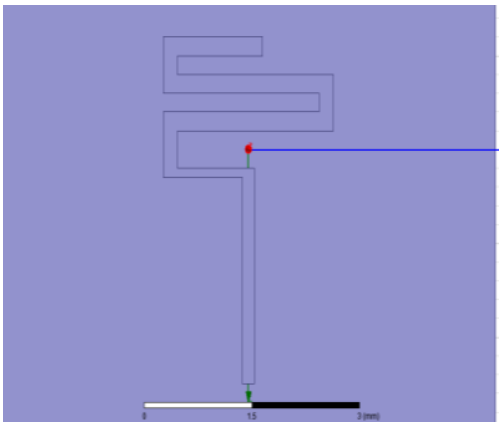


Figure 1. Meander line antenna

The feed line has dimension of height 2.3mm and width 0.13mm. Meander line has four horizontal lines from top to down and their lengths are 1.4mm, 2.4mm, 2.4mm and 1.284mm. Three vertical lines are having height of 0.6mm, 0.6mm and 0.8mm from top to down. The thickness of meander line is 0.2mm everywhere except down horizontal line, which is 0.1mm. Separation distance between first and second horizontal lines, second and third horizontal lines is 0.2mm and third and fourth horizontal lines are separated by 0.4mm.

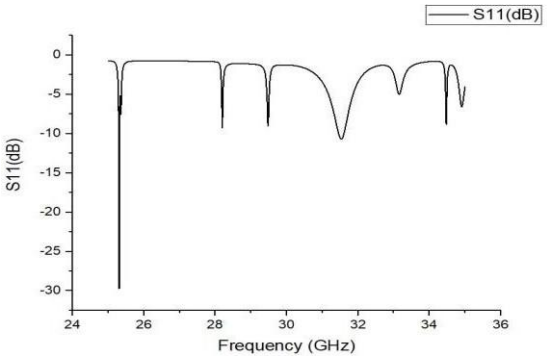


Figure 2a. Return loss of meander line antenna

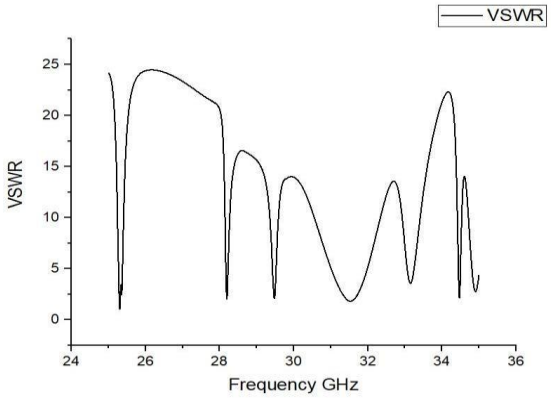


Figure 2b. VSWR of meander line antenna

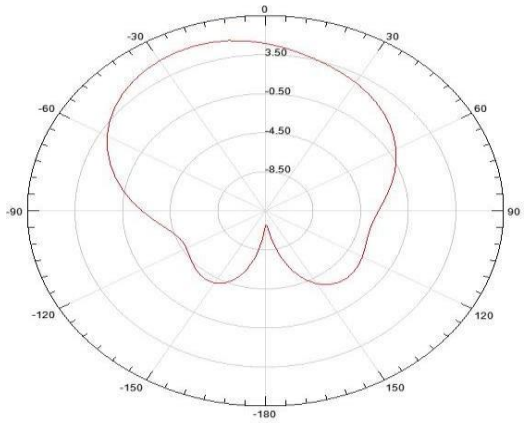


Figure 2c. Radiation pattern at 31.5GHz

III. RECONFIGURABLE ANTENNA WITH ONE PIN DIODE

Multiple frequency of operations achieved by introducing PIN diode BAP142LX, 315 equivalent circuit in the vertical axis of the antenna as in Figure 3. PIN diode is made ON and OFF using external bias to make it conduct or not. Diode is conducting for ON state and fails to conduct for OFF state. ON state is represented by series inductance Ls and resistance Rs. OFF state by Ls connected in series with parallel combination of resistance Rp and capacitance Cp as shown in Figure 3a and b. The equivalent circuit parameters given by the data sheet is mentioned in Table 1.

When diode is ON, antenna works at 25.45 GHz and 33.25 GHz with S11 of -22, -21dB as shown in figure 3(c) and 3(d). When it turned to OFF state, antenna resonates at three different frequencies 25.35GHz, 25.45GHz and 33.35GHz as shown in Figure 3(e) with return loss of -27dB, -20 dB and -15.8 dB respectively. VSWR performance of reconfigurable antenna for diode OFF state shown in Figure 3(f). Radiation pattern of reconfigurable antenna with ON and OFF states are shown in Figure 3(g) and 3(h) respectively.

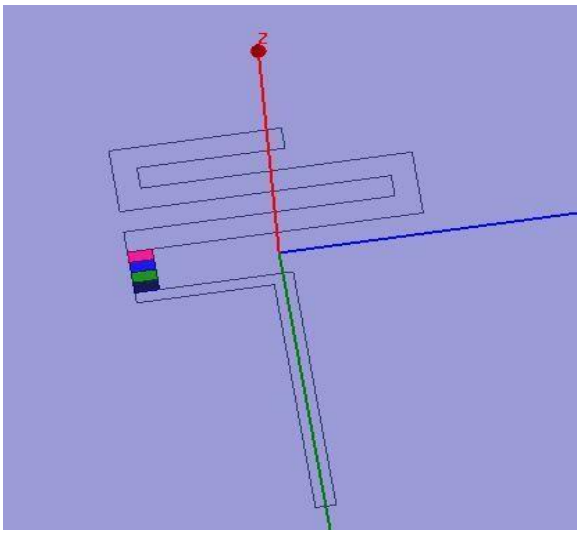


Figure 3. Antenna with one PIN switch

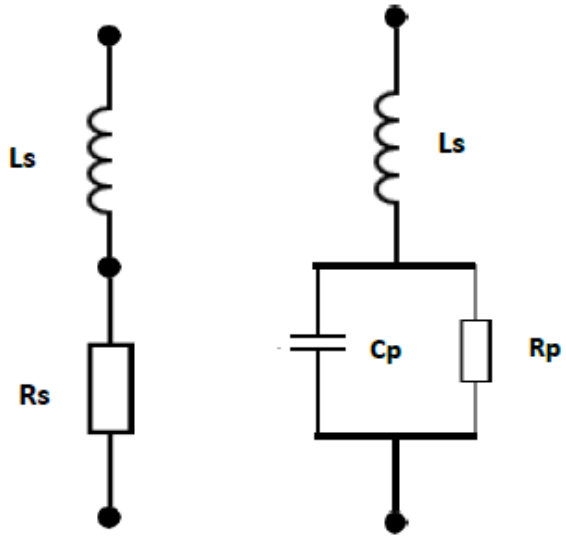


Figure 3.a) ON state b) OFF state equivalent circuit of PIN diode

Table 1. PIN diode equivalent circuit parameters

Parameters	Value
Ls	0.4nH
Rs	1.3Ω
Cp	0.26pF
Rp	20KΩ

The simulated results of reconfigurable antenna like frequency of operations, return loss, VSWR and gain for different diode states are listed in table 2. Antenna works at 25.3GHz and 31.5GHz without reconfiguration. At OFF state antenna resonates at three different bands. After reconfiguration, resonating frequency increased to 33.35GHz. Return loss is decent for all simulated cases within the appreciable limit. VSWR value is also maintained less than 2

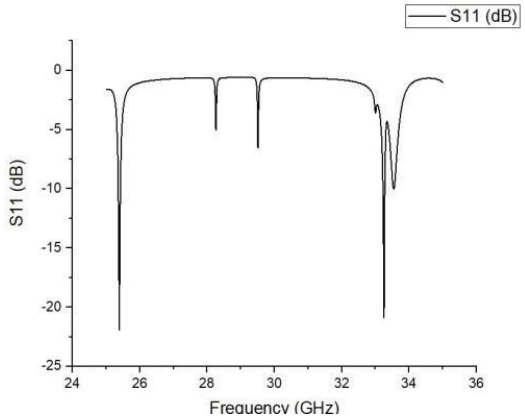


Figure 3c). Reflection coefficient for diode ON

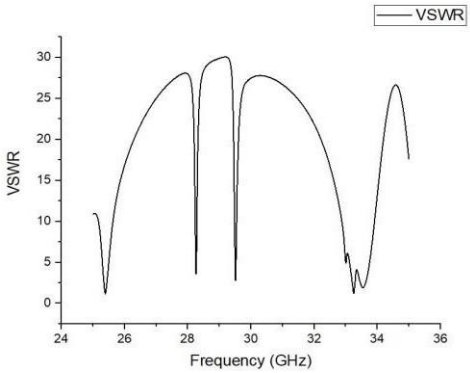


Figure 3d). VSWR of antenna for diode ON

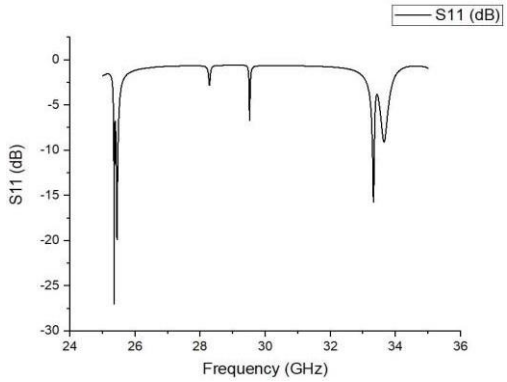


Figure 3e). Reflection coefficient for diode OFF

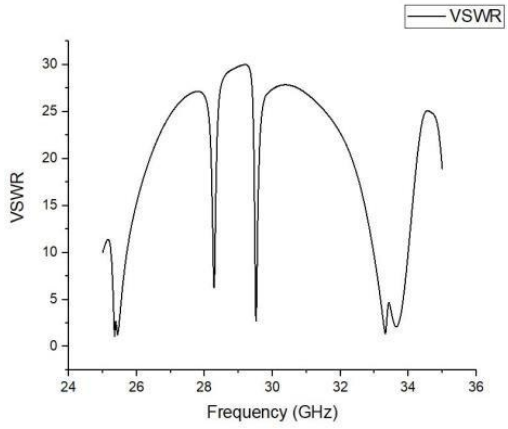


Figure 3f).VSWR of antenna for diode OFF

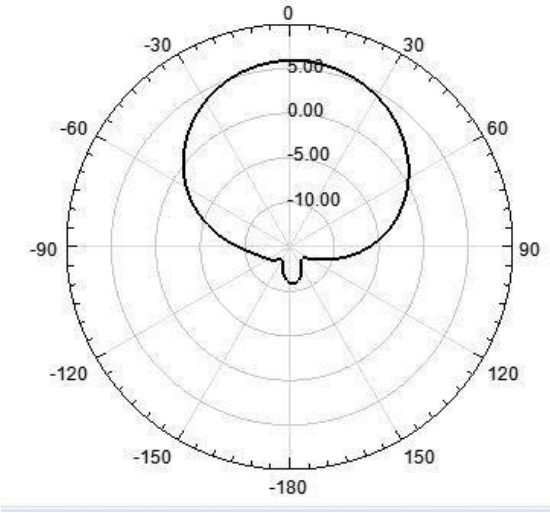
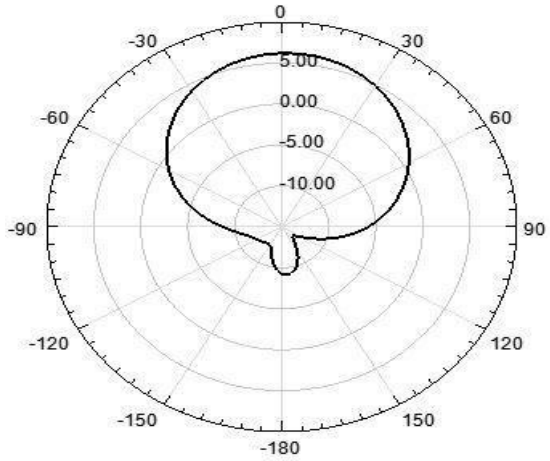


Figure 3g). Radiation pattern of antenna with PIN diode



ON state at 33.25GHz

Figure 3h). Radiation pattern of antenna with PIN diode OFF state at 33.35GHz

Table 2. Result with and without diode

Diode state	Frequency (GHz)	Return loss (dB)	VSWR	Max Gain (dB)
No Diode	25.3 31.5	-29.8 -10.6	1 2	4.5
ON	25.45 33.25	-22 -21	1 1	5.5
OFF	25.35 25.45 33.35	-27 -20 -15.8	1 1.2 1.4	5.8

IV. RECONFIGURABLE ANTENNA WITH TWO PIN DIODES

The PIN diodes of reconfigurable antenna are replaced by their equivalent circuit for simulation in HFSS as shown in Figure 4. First diode D1 placed on the left vertical line and D2 on the right vertical line. PIN diodes can be biased in four possible ways as shown in Table 3.

Table 3. Different biasing state of PIN diodes

Diode D1	Diode D2
OFF	OFF
OFF	ON
ON	OFF
ON	ON

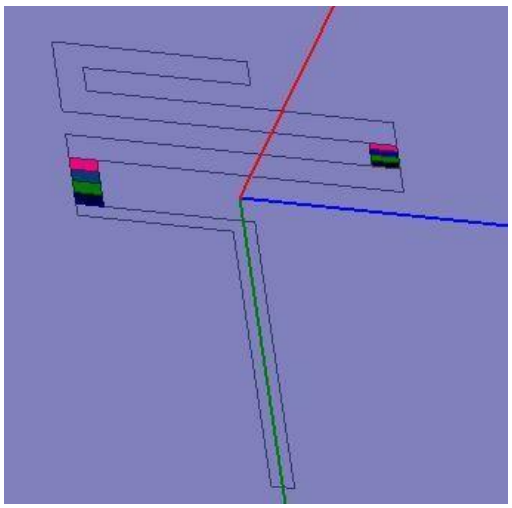


Figure 4. Antenna with two switches

Diodes are biased to different biasing states and replaced by its equivalent circuit to simulate ON and OFF states, parameters S11 and VSWR are measured for various resonating frequencies. Frequency vs. S11 and VSWR results are shown in Figure 4(a) and 4(b) for the state D1 ON and D2 OFF. Radiation pattern is shown in Figure 4(c) with maximum gain of 16dB. At ON state Diode D1 and D2 works at 28.25GHz and 34.8GHz respectively. Its return loss and VSWR graphs are shown in Figure 4(d) and 4(e).

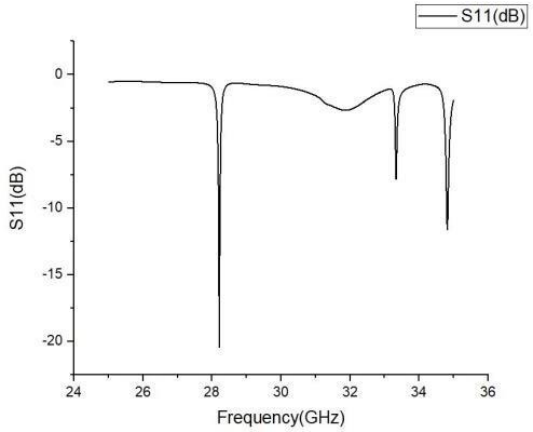


Figure 4a). Reflection coefficient for D1 ON and D2 OFF

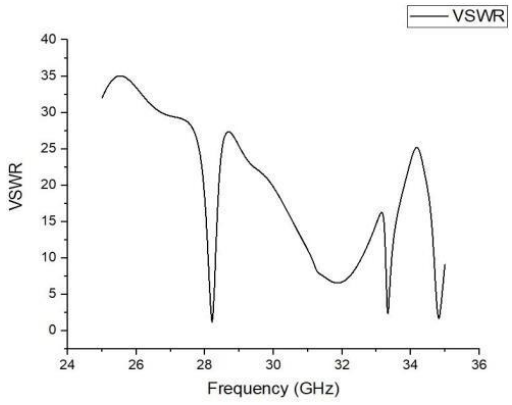


Figure 4b). VSWR of antenna for D1 ON and D2 OFF

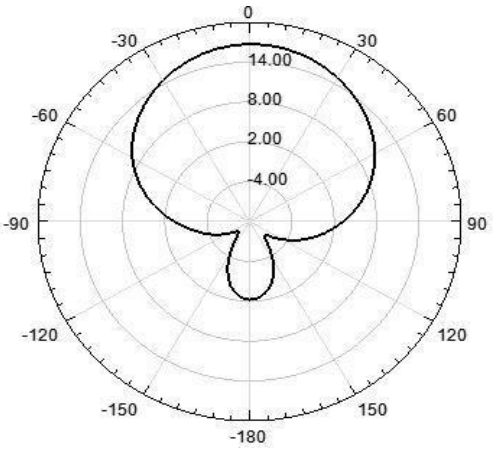


Figure 4c). Radiation pattern for D1 ON and D2 OFF at 34.8GHz

The results of reconfigurable antenna using two diodes are listed in Table 4 for various resonant frequencies, return loss, VSWR, and gain. The results are obtained for four different biasing states of two PIN diodes. This two switch reconfigurable antenna works in 28.2 GHz and 34.85 GHz with good VSWR less than 2 and return loss. Frequency of operation for all the states of diodes is not varying much but return loss varies much. Minimum return loss of -36.2dB is achieved for D1 OFF and D2 OFF. D1 ON and D2 OFF state gives maximum return loss of - 21.5dB. All S11 values found are less than -10dB. D1 and D2 OFF state shows good performance compared to all at 28.25GHz with S11 of -36.2dB , VSWR of 1 and maximum gain 16 dB.

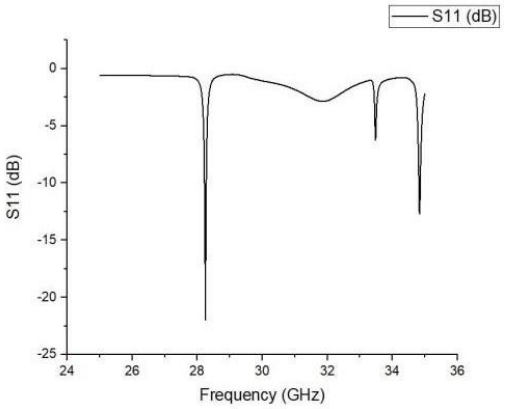


Figure 4d). Reflection coefficient for D1 ON and D2 ON

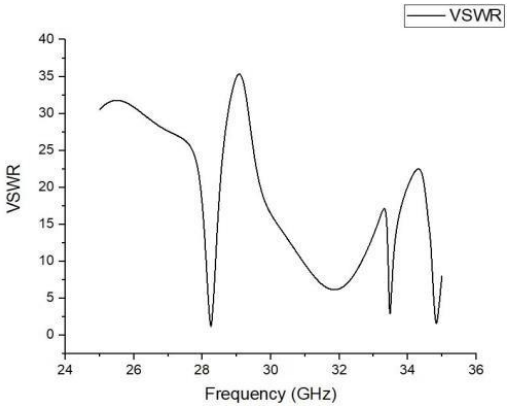


Figure 4e). VSWR of antenna for D1 ON and D2 ON

Table 4. Results of antenna with two PIN diodes

D1, D2 state	Frequency (GHz)	S11 (dB)	VSWR	Max gain (dB)
OFF, OFF	28.25 34.6	-36.25 -14.5	1 1.3	16
OFF, ON	28.2 34.8	-25 -11.5	1.3 1.8	16.5
ON , OFF	28.2 34.85	-20.5 -11.7	1.75 1.9	16.8
ON, ON	28.25 34.8	-22, -12.75	1.6 1.8	16.5

V. RESULT ANALYSIS

Design of antenna is done under three categories i).Antenna without switch ii).Reconfigurable with one switch iii).Reconfigurable with two switches. The designed meander line reconfigurable antennas resonating from 25.3GHz to 34.8GHz. Antennas can be chosen based on the frequency needs. The proposed reconfigurable antennas are designed to satisfy future wireless communication requirements.

VI. CONCLUSION

PIN diode switches are introduced to achieve frequency re-configurability. Designed antenna shows VSWR and Return losses are in the appreciable limits. It is well suitable for mm wave communication devices. Bias circuits are needed to operate PIN diodes in real time. It will leads to system complexity. Losses might happen because of lead terminals and it should be reduced for better performance. The optical reconfigurable antenna using photoconductive silicon switches are free from lead terminal noises and doesn't require external bias circuit[12]. Light can control the switching operation.

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