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Frequency Reconfigurable Antenna for Multistandard Applications

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Abstract: ***A reconfigurable yagi uda shaped microstrip antenna with switchable frequency is proposed. The proposed antenna has a simple structure, consisting of a square radiating patch and parasitic conductors of rectangular shape. This antenna is designed for multiband like WIMAX, GSM, GPS, FDMA and PCS. PIN diodes are used to switch frequencies between different bands depending on the state of the PIN diode switch. The antenna structure proposed have return loss better than -10dB and VSWR below 3. TheAnsoft HFSS 14software is used to model and simulate the proposed antenna.***

Keywords: Microstrip patch antenna, Frequency Reconfigurable antenna, Return loss, VSWR, PIN diode.

1. Introduction

Antennas can necessary and critical components of communication and radar systems. Arguably antennas are categorized into nine different types. Each category of antenna possesses its own inherent benefits and demerits that make them more or less suitable for particular applications. The antenna characteristics are fixed so there will be restrictions on system performance. Making antenna reconfigurable so that their behavior can adapt with changing system requirements. Antenna can be reconfigured by changing its frequency, polarization or radiation characteristics by making use of some kind of switching mechanism like pin diodes, RF MEMS, Varactor diodes etc. Microstrip antennas are widely used to provide reconfigurability due to their advantages of low profile, light weight, low fabrication cost, and ease of integration with RF devices. Frequency reconfigurability can be achieved by adjusting the resonant frequency by changing the shape of the radiating element. Switches are used to achieve frequency selectivity by controlling the state of the switches, switches can be pin diode, varactor diode or RF MEMS.

A simple frequency reconfigurable antenna which function at UMTS/IMT 2000 and ISM Band using the principle of controlling the antenna resonant frequency by PIN diodes switches [4].The selection of different modes in [6] was achieved by using either feed or ground switching. For example, by using feed switching, the antenna can cover global system for mobile communications (GSM) standard, which are GSM850 and GSM900 for lower band and digital cellular service (DCS) for upper band in mode 0. Furthermore, GSM900 was covered for lower band while for upper band, personal communication system (PCS) and universal mobile telecommunications system (UMTS) was covered in mode 1. Reconfigurable multiband slot dipole antenna that can select a separate frequency bands is proposed [7]. It can switch to single, dual or triple band modes by using hard - wire switches. Switches are located in the slot of the antenna which can control the arms of the dipole either switch in and out from the slot edges. An open-end straight slot line and the PIN diodes to achieve frequency reconfigurable capability is proposed in [8]. The PIN diodes along with DC bias network are located at specific positions to create short circuit or open circuit across the slot. By carefully controlling these diodes, the antenna operates as the conventional $\lambda/4$ slot antenna. The design of a combined frequency- and polarization reconfigurable antenna is presented in [9]. Shorting posts around the patch are used to enable the antenna to radiate three polarizations, and varactor diodes are employed to achieve independent frequency tuning for each polarization state.A compact Planar Inverted-F Antenna (PIFA) suitable for cellular telephone applications is presented in [10]. The quarter-wavelength antenna combines the use of a slot, shorted parasitic patches and capacitive loads to achieve multiband operation. The antenna operates from 880 to 960 MHz and 1710 to 2170 MHz covering GSM, DCS, PCS, and UMTS standards.A compact five-band planar inverted-F antenna (PIFA) for mobile phones using helical feeding and shorting lines, wide folded patch, and two long slots is presented in [11]. The antenna showed wide band characteristics covering DCN(824-894 MHz), GSM (880-960 MHz), DCS (1710-1880 MHz), USPCS (1850-1990MHz), and WCDMA (1920-2170 MHz) within 3.0:1 VSWR. And controlling the two slots showed that the antenna's low/high resonant frequencies can be independently obtained.HFSS is a commercial finite element method solver for electromagnetic structures. The software includes a linearcircuit simulator with integrated optimetrics for input andmatching network design. HFSS solver incorporates apowerful, automated solution process, so we need only tospecify geometry, material properties and the desired output.From there, HFSS automatically generates an appropriate, efficient and accurate mesh for solving the problem using the selected solution technology [13].

In this paper presents a yagi Uda shaped microstrip frequency reconfigurable antenna. This antenna employs PIN diodes to switch its resonating frequency for different standards like WIMAX, GSM, PCS, FDMA and GPS with return loss below -10dB and VSWR below 3.The software used to model and simulate the proposed antenna was Ansoft HFSS 14.

2. Reconfigurable Antenna Design

The proposed reconfigurable antenna is designed using the FR4 substrate with the dielectric constant of 4.4 and the substrate thickness of 1.6mm on a ground dimension of 60x35mm^2 .

Antenna is fed by microstrip transmission line feed technique with transmission line width of 3mm and length 21.5mm. The optimal dimension of the proposed antenna is shown in table 1.

Table 1:The optimal dimensions of the proposed antenna

Width (mm)	*Length (mm)*	*Gap (mm)*
w=26.08	h=20	-----
w1=24	h1=4	g1=2
w2=22	h2=2	g2=1
w3=20	h3=2	g3=1
w4=18	h4=2	g4=1

The proposed antenna has square radiating patch along with four parasitic patches. Frequency reconfigurability is achieved by varying the electrical length of patch antenna depending on the state of the PIN diodes. The geometry of the proposed antenna is shown in figure 1.

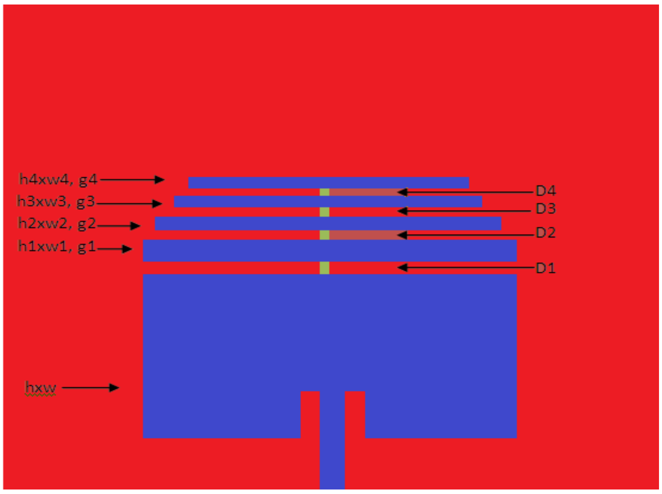

Figure 1: Geometry of the proposed reconfigurable antenna

By properly biasing the PIN diode, ON and OFF state of the PIN diode is realised. For ON state, PIN diode is forward biased which provide low impedance and acts as short. For OFF state, PIN diode is reverse biased which provide high impedance and acts as opencircuit. The equivalent circuit of pin corresponds to an inductance L in series with a resistance *R*sfor the ON state and an inductance L in series with the parallel connection of a capacitor *C*t and a resistance *R*pfor the OFF state. According to the manufacturer, the diode parameters are L=0.6 nH, *R*s =1.2Ω, *R*p= 15 kΩ and Ct=0.3 pF. The equivalent circuit of pin diode is shown in figure 2.

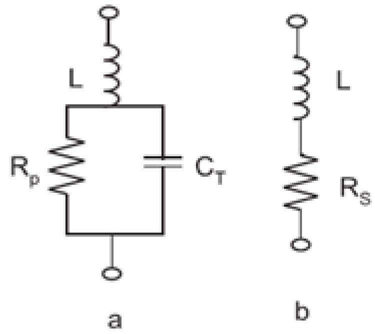

Figure 2: PIN diode equivalent circuits: (a) OFF state, (b) ON state.

The software used to model and simulate the proposed antenna was Ansoft HFSS 14, which is an industry-standard simulation tool for 3D full-wave electromagnetic field simulation.

3. Simulated Antenna Performance

The performance of the proposed antenna is characterized by its electrical properties such as bandwidth, VSWR and return loss.

Return loss is way of expressing the mismatch in transmission line. It is the loss of signal power resulting from the reflection caused at a discontinuity in a transmission line. The return loss of the proposed antenna is below -10dB. VSWR measures the relative size of the reflection. It is closely related to the return loss. VSWR of the proposed antenna is below 2dB. Bandwidth of an antenna is the range of frequency over which the antenna can operate correctly.

When all the PIN diodes are OFF only square radiating patch will radiate. It operates in the 3.5 GHz band with the return loss of -19.5dB, VSWR of 1.84 and bandwidth of90MHz. Fig.3.and Fig.4.shows simulated results for Return loss and VSWR when all the diodes are OFF of the proposed antenna.

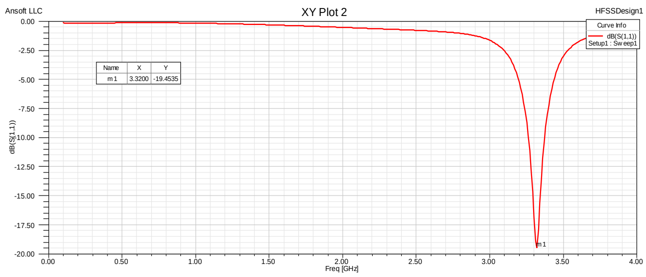

Figure 3: Return loss when all the diodes are OFF.

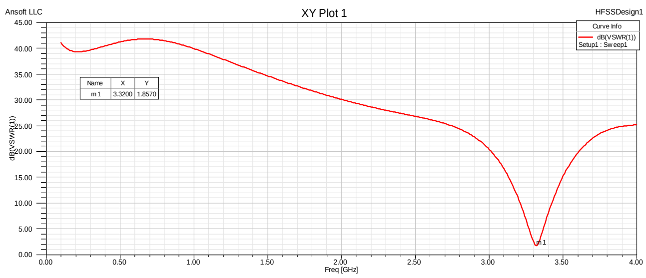

Figure 4: VSWR when all the diodes are OFF.

When PIN diode D1 is ON square radiating patch and parasitic patch h1*w1 will be a single antenna and radiate. It

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operates in the 1.8GHz band with the return loss of -27.77dB, VSWR of 1.09 and bandwidth of 91MHz. Fig.5.and Fig.6.shows simulated results for Return loss and VSWR when diode D1 is ON of the proposed antenna.

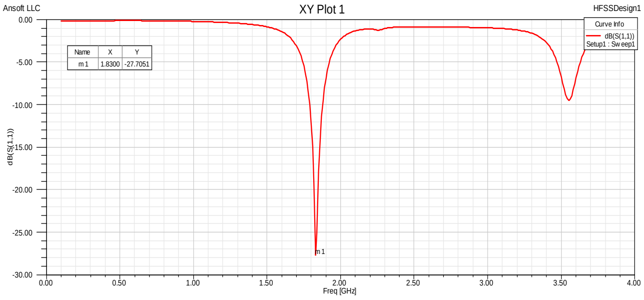

Figure 5: Return loss when diode D1 is ON.

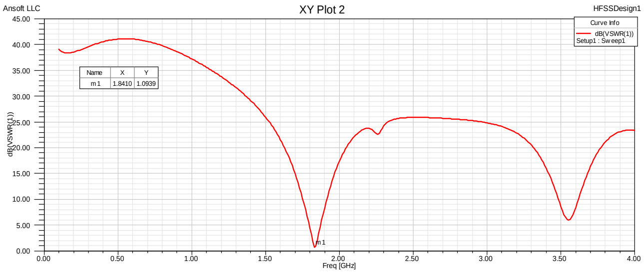

Figure 6: VSWR when diode D1 is ON.

Similarly Fig 7 to Fig 12 shows return loss and VSWR simulated results when diode D1and D2 are ON which operates in 1.6GHz band with return loss of -23.04 dB, VSWR of 1.23 and bandwidth 77MHz, when diode D1, D2 and D3 are ON which operates in 1.4GHz band with return loss of -23.84dB, VSWR of 1.35 of and bandwidth of 91MHz and when all the diodes are ON which operates in 1.3GHz band with return loss of -19.74, VSWR of 1.796 and bandwidth of 73MHz.

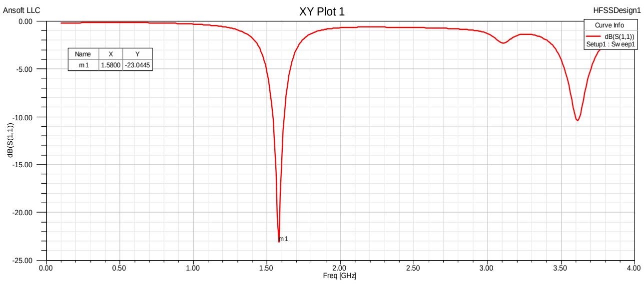

Figure 7: Return loss when diodes D1 and D2 are ON.

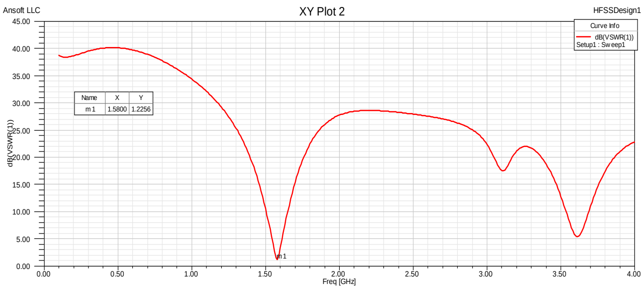

Figure 8: VSWR when diodes D1 and D2 are ON.

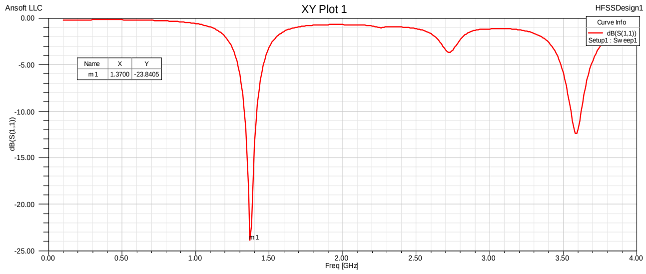

Figure 9: Return loss when diodes D1, D2 and D3 are ON.

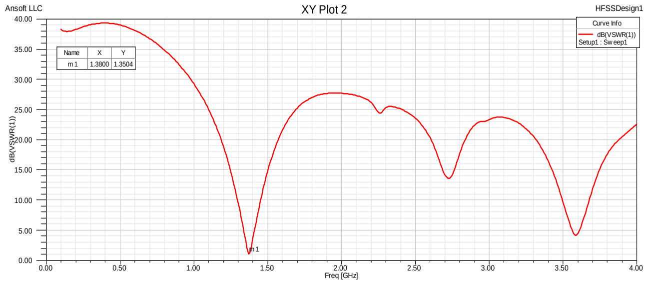

Figure 10:VSWR when diodes D1, D2 and D3 are ON.

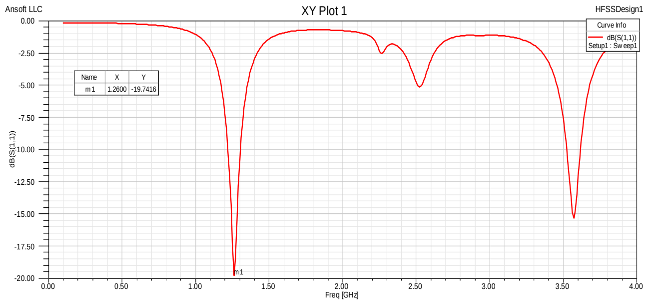

Figure 11: Return loss when all the diodes are ON.

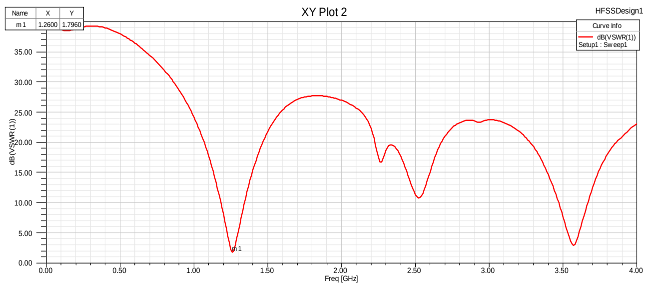

Figure 12: VSWR when all the diodes are ON.

Electric field distribution for each PIN diode condition is Shown in Fig 13 to Fig 17. It can be concluded that as the PIN diode ON electric field distribute over the parasitic patch hence electrical length of the patch increases hence the resonating frequency decreases.

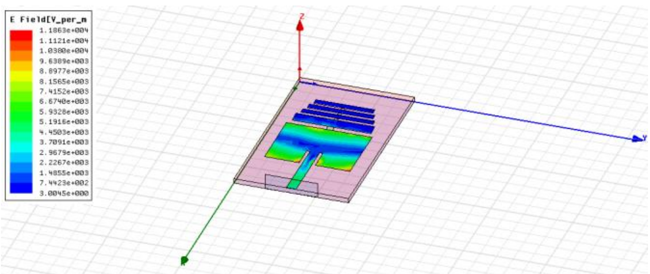

Figure 13: Electric field distribution when all diodes are OFF.

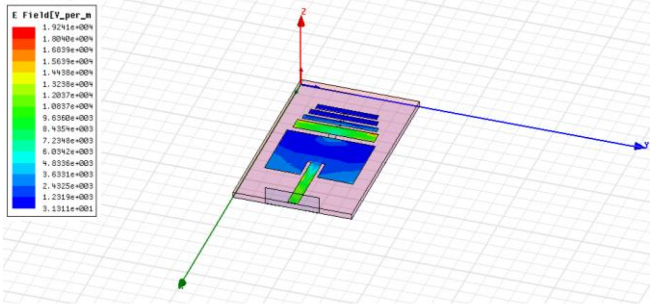

Figure 14: Electric field distribution when diode D1 is ON.

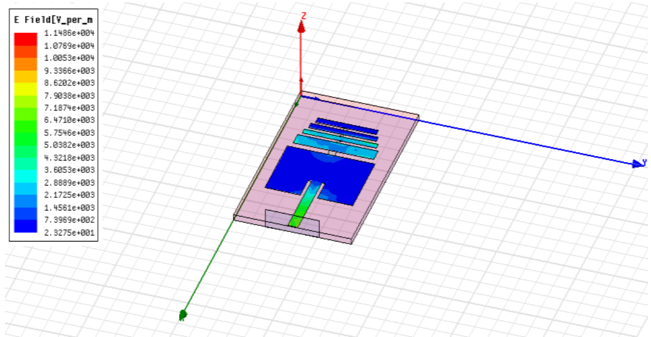

Figure 15: Electric field distribution when diodes D1 and D2 are ON.

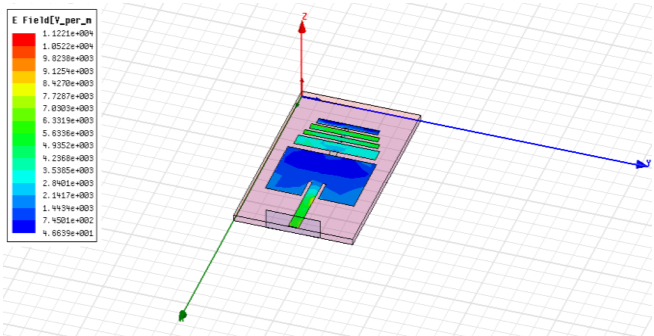

Figure 16: Electric field distribution when diodes D1, D2 and D3 are ON.

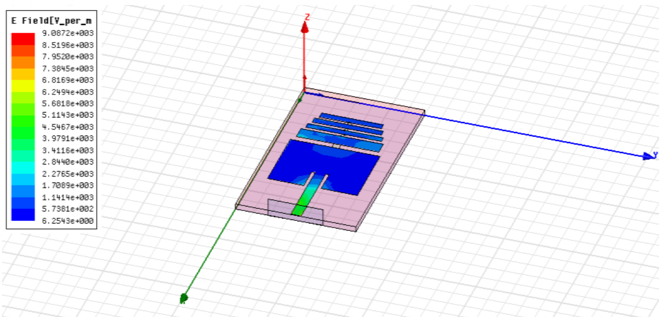

Figure 17: Electric field distribution when all diodes are ON.

Simulations are performed using commercially available package Ansoft HFSS 14,which is anindustry-standard simulation tool for 3D full-wave electromagnetic field simulation. The Pin-diode was modelled by the RFequivalent circuit in order to take into account the non-ideal behavior of the diodes.

The simulated results of the proposed antenna are shown in table 2.

Table 2: The simulated results of the proposed antenna

Switch condition	*Frequency (GHz)*	*Return loss (dB)*	*VSWR*	*Bandwidth (MHz)*
All OFF	3.5	-19.45	1.84	90
D1 ON	1.8	-27.77	1.09	91
D1, D2 ON	1.6	-23.04	1.23	77
D1, D2, D3 ON	1.4	-23.84	1.35	91
All ON	1.3	-19.74	1.796	73

4. Conclusion

The proposed antenna achieves its goals of obtaining frequency selectivity by electronically varying the effective physical dimension of the microstrip antenna, thereby resonating at different frequency. The resonant frequency is tuned by changing the effective length of the antenna radiator controlled by PIN-diodes switches. The proposed antenna can work on different wireless standards like WIMAX, FDMA, GPS, PCS and GSM. The proposed antenna is a simple structure with good radiation characteristics like VSWR, return loss and bandwidth.

5. Acknowledgement

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