Design of Frequency Reconfigurable Antenna For Multi Standard Mobile Communication

Sonia Sharma and C.C.Tripathi

Abstract: The develpoment of smart antennas for mobile phones has recently recevied much interest due to compact size of multimode phones and requirements to keep the amount of RF power absorbed by a user below a certain level. In this paper a new Yagi Uda shaped frequency reconfigurable antenna for multimode mobile applications has been presented. The proposed fabricated antenna have return loss better than -10dB, VSWR below 2, radaiation efficiency greater than 60% and SAR below 2W/kg for all the frequency bands. The proposed antenna structure is compact in size, offer high isolation between eight transmitting bands. PIN diodes are used to switch the frequecny bands between WCDMA, FDMA, PDC, GPS (1.56-1.585 GHz), GSM1800 (1710-1880MHz), PCS1900 (1859-1990MHz), UMTS (1900-2170MHz), DCS1800, WLAN, Bluetooth, Wi-Fi etc.

Keywords: **Frequency Reconfigurable antenna, mobile antenna, SAR,Yagi Uda antenna, Patch antenna**

I. INTRODUCTION

With the ever increasing demand of the customers for access to large number of standards/ application with in single portable device; the field of mobile communication has advanced a lot but still need a lot of research for its culmination. This advancement in mobile communication has resulted in getting access to several application [1-2] such as GSM 900 (880-960MHz), GSM 1800 (1.71-1.88GHz), PCS 1900 (1.859-1.99 GHz) and UMTS (1.9-2.17 GHz) DCS 1800, WLAN, Bluetooth, Wi-Fi, 4G etc.

As antenna forms the backbone of every wireless communication system, so an extensive research has been carried out on an antenna which can work on all such standards/frequencies. From the designer's point of view, antennas having small size, light weight, low profile, flexibility and excellent rejection ratio in the transmitting band[3]. Also, with the change in operating standards/ frequencies, the size of the antenna changes accordingly, which need to be addressed strongly keeping the view of portability of mobile phones. Extensive research has been carried out in the last two decades to find ways of reducing the size of resonant antennas so that they will fit within a given volume inside a handset [3-5]. However, this gives rise to restrictions and compromise regarding polarization, radiation efficiency, bandwidth, and furthermore increases the sensitivity to manufacturing tolerances. Unfortunately, the performance requirements for the antenna are rarely relaxed with the demand for smaller size. Mobile phone antennas should have a return loss better than 6 dB. This corresponds to a VSWR of 3:1 and a reflected power of 25% and radiation efficiency greater than 50%, SAR less than 2W/kg.

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Since each communication protocol may operate in a distinctive frequency band, instead of using several antennas, it is highly desirable to have one broadband or multi-band antenna to meet the antenna needs of multiple systems. Most current multiband antenna designs used for mobile devices can be categorized into three types: planar inverted-F antenna (PIFAs), monopole antennas and slot-type antennas[7-16].

Among different antennas multiband, planar inverted-F antenna (PIFA) antenna are mostly used for mobile handset for multimode operation. Many methods are used to enchance the performance and the number of frequency bands for mobile phone antenna like by adding monopole antenna as a parasitic antenna, by etching differnt shaped slot antenna and shorting the patch with capacitive load etc. For example, Z. D. Liu et al. explained a dual resonance antenna structure for several frequency ranges which can be used as an internal antenna for mobile phone [7]. Lin and D.-B. et al. proposed compact quad-band PIFA by tuning the defected ground structure [8] while Saidatul et al. add fractal apertures to increase the resonant path and therefore reduce the antenna size [9]. Ciais et al. use shorted parasitic patches with capacitive loads and slots to achieve quad band and wideband operations[10]. Han, H.-T. Kim et al, inserts two long slots for dual band operation [11] while Anguera et al. inserts F-shaped and rectangular slots to accomplish dual mode resonance[12]. Lin and D.-B. et al. cut an open-ended slot on the ground to broaden the operational bandwidth[13]. Isohatala et al. proposed a planner antenna having low SAR value [14] while Song et al. presented a triple band PIFA [15]. So the PIFA antenna can provides several desirable properties but the main drawbacks of above described antenna are limited coverage of multiple standards, small opertional bandwidth and poor isolation among transmitting bands which degrade the signal quality and its 3D structure which may be challenging in fabrication [16]. Although size of these antenna are small but at the cost of other important antenna parameter like radiation efficiency, gain etc.

To access multimode communication we need such an antenna which has a wider input impedance bandwidth and can easily fabricated. Also to cover multiple bands, antenna should dynamically alter it's transmit and/or receive RF characteristics by keeping all antenna parameters in tolerable range. The challenge infront of antenna designer is not only create new designs of antenna structure which are capable of providing these facilities but also manage the interference among wireless standards which can limit their usefulness. Frequency reconfigurable patch antennas have attracted significant attention due to their ability to cover multiple frequency bands[17-23]. Alot of work has been carried out on frequency reconfigurable microstip patch antenna for mobile communication standards summerized in [20]. F. Yang and Y. Rahmat-Samii et al. reported the mechanism of switchable slot for dual band GPS and WLAN application [18]. P. Bhartia and I. J. Bahl presented a Frequency agile microstrip antennas for different mobile standards [19]. Compared with multi-band and wideband antennas, one of the merits of frequency reconfigurable antennas is that the antenna can provide rejection of interfering signals in the bands that are not in use so that the filter requirements of the front-end circuits can be greatly reduced [20]. Reconfigurable antennas have more advantages for example, saving energy; reducing the number of antennas thus reducing the mutual interferences between them as compared with conventional antennas [20].

In lietrature, there has been many reports on the design and implementation of reconfigurable antenna for the opertion of multiple bands. However, there is no single efforts to design an antenna which can be operted on multiple bands like WCDMA, FDMA, PDC, GPS, GSM, PCS, UMTS, WLAN, Bluetooth, Wi-Fi etc. without adding complexicity to the system on the account of minimizing interfence for the interpotibilty of multiple satndards. There for present work is focused on design of an frequency reconfigurable antenna structure consisting of number of parastic patches which can be made to resonate at desired frequency when operted in consonance with PIN diodes switches. This may results in reduction in number of antennas on wireless equipment hence saves the area and power requirement.

In this paper a noval frequency reconfigurable Yagi Uda shaped antenna which can switch its resonating frequency for different standards like GSM, DCS, PCS, UMTS, and IEEE 802.11a etc. with high isolation and within 2:1 voltage standing wave ratio (VSWR) has been proposed. SAR of the proposed antenna is below 2 W/kg. Good radiation characteristics are obtained over all frequency bands.

II. ANTENNA DESIGN

The geometry of the proposed frequency reconfigurable Yagi Uda shaped antenna for multimode wireless applications with optimized parameters is depicted in Fig.1. This antenna was printed on FR4 substrate with the dielectric constant of 4.4 and the substrate thickness of 1.57 mm. In this work, inset microstrip feeding technique is used. The location of inset cut point is adjusted to match with its input impedance (usually 50 ohm). 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.

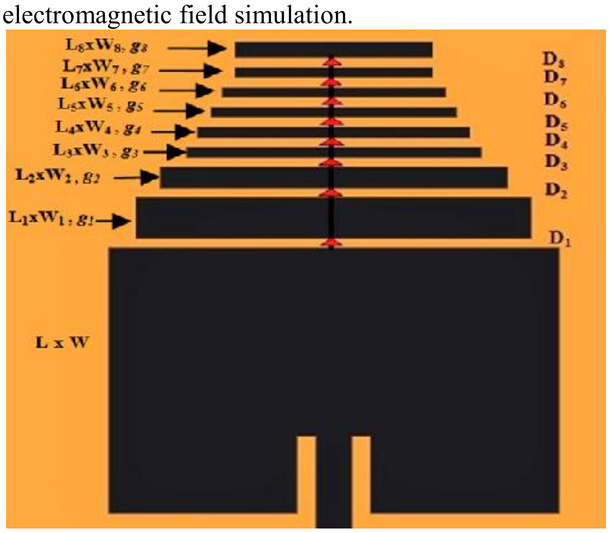

Fig.1 Yagi Uda shaped frequency Reconfigurable microstrip antenna

The optimized parameters of proposed antenna are: length= 36.48mm, width =26.4mm on a ground 80x60mm^2. The eight parasitic patches on the top patch metallization are properly placed and its length, width and gap were optimized for desired frequency range as shown in Table 1. Antenna is fed by micro strip transmission line with a metal strip of width 3 mm and length 30 mm.

Table 1: Geometry parameter of frequency reconfigurable yagi uda shaped antenna

Length (mm)	Width (mm)	Gap (mm)
L =36.48	W =26.4	--------
L_1 =32	W_1 =4	g_1 =1
L_2 =28	W_2 =2	g_2 =1
L_3 =24	W_3 =1	g_3 =1
L_4 =22	W_4 =1	g_4 =1
L_5 =20	W_5 =1	g_5 =1
L_6 =18	W_6 =1	g_6 =1
L_7 =16	W_7 =1	g_7 =1
L_8 =16	W_8 =1	g_8 =1

Eight PIN diode pairs are introduced in between the gap of parasitic patch to connect and disconnect them. According to the state of PIN diode; electrical length of the patch antenna can be altered so that resonating frequency of patch can be reconfigured. The proposed antenna can work on 8 different bands depending upon the state (ON/OFF) and number of PIN diode.

III. MODELLING OF PIN DIODE

The ON and OFF conditions of switches are realized by forward and reverse biasing of PIN diodes. Ideally, when a forward bias is applied to make the switch ON, the switch would have low impedance characteristic, acts as short and the current can flow through the diode. On the other hand, when a reverse bias is applied to make the switch OFF, the switch exhibits high impedance characteristic and acts as open circuit which implies that there is no connection. In order to explain the working of PIN diode; electrical circuit is shown in Fig.2 which consists of a DC block capacitor of 1µF, a RF choke coil 0.1µH. If diode is forward biased it can be modeled as a resistor of 1 ohm and if diode is in reverse biased it can be modeled as a parallel combination of 0.1µF capacitor and 25 Kohm resistor shown in Fig 3-4. The return loss and insertion loss under ON and OFF condition is shown in Fig 5 and 6.

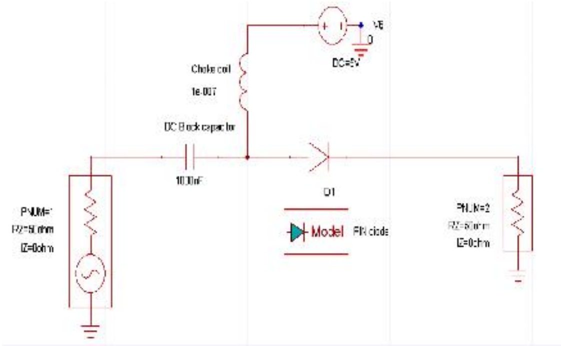

Fig.2 PIN diode circuit connection for model.

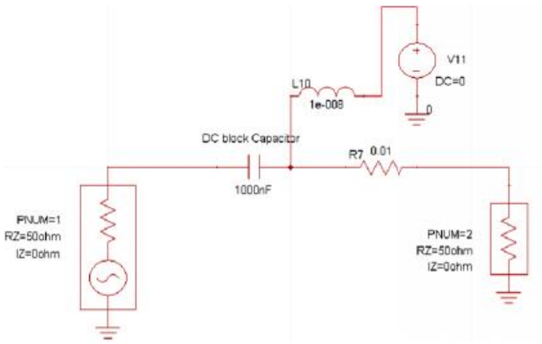

Fig.3 PIN diode model under forward biased condition.

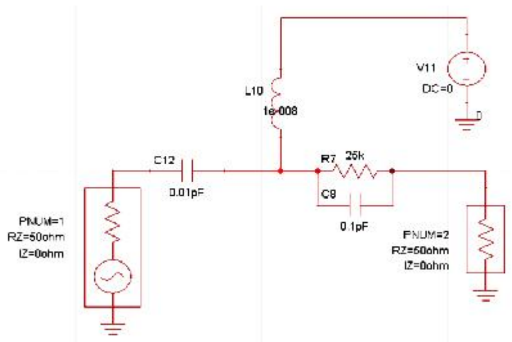

Fig.4 PIN diode model under Reverse biased condition.

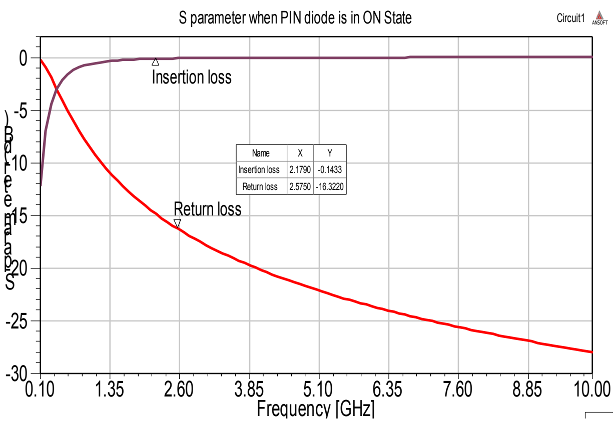

Fig.5 S parameter vs. frequency when PIN diode is forward biased.

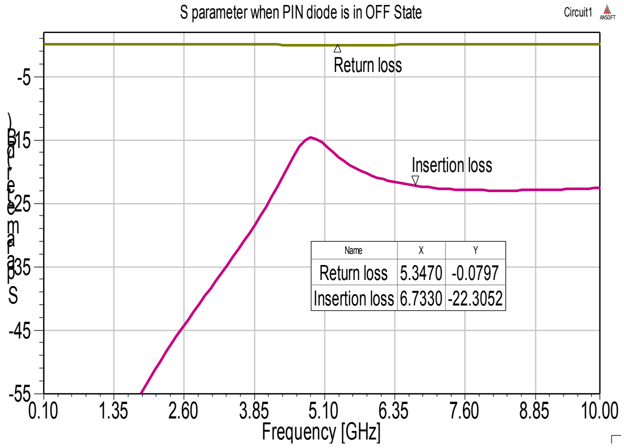

Fig.6. S parameter vs. frequency when PIN diode is Reverse biased.

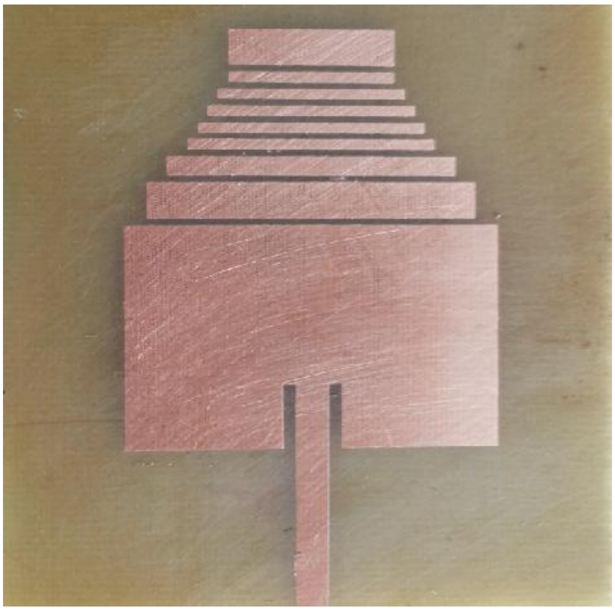

Fig.7 Fabricated Yagi Uda shaped frequency Reconfigurable microstrip antenna

IV. RESULT AND DISCUSSION

The performance of proposed antenna is characterized by a number of electrical properties, which include impedance, VSWR, bandwidth, gain (a function of directivity, efficiency, and mismatch loss), and polarization.

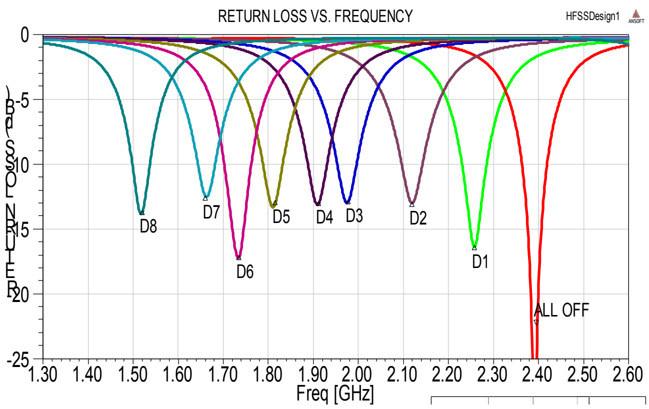

Fig.8 Return loss vs. frequency under all PIN diode condition

Fig.8 shows the simulated results for return loss of this antenna. The overall goal of the proposed antenna design is to achieve good performance in the return loss below -10dB. When no diode is switch ON antenna have first resonance in a frequency range of 2.36-2.41GHz (Blue-tooth802.15.1, WiFi, WLAN). As diode D1 is forward biased there is conducting path between parasitic patch Length L1 and main patch Length L hence the resonating frequency of the antenna is according to equivalent length of L1 and L and antenna have second resonance in a frequency range of 2.22-2.28 GHz [3G,

Diode state	Resonating Frequency (GHz)	Return Loss (dB)	Impedance (ohm)	VSWR
ALL OFF	2.4	-25.7264	43.27	1.0493
D1	2.26	-16.3009	42.9712	1.3588
D2	2.12	-12.9785	45.7776	1.589
D3	1.98	-12.7908	43.402	1.5889
D4	1.92	-12.8823	44.0075	1.5742
D5	1.8	-12.8772	44.091	1.5566
D6	1.73	-17.0671	52.0562	1.3213
D7	1.66	-12.5052	56.2575	1.6196
D8	1.52	-13.6291	50.3151	1.5127

ITM(1.885-2.2 GHz)]. Similarly when diode D2, D3, D4, D5, D6, D7, D8 is forward biased antenna will resonate in the frequency band 2.14-2.19 GHz [UMTS(1.92 -2.17GHz),WCDMA]; 1.95-1.99GHz[FDMA,PCS)]; 1.88-1.92GHz[PHS,CDMA]; 1.786-1.83GHz[DCS]; 1.7-1.76 GHz [FDMA,CDMA]; 1.64-1.68 GHz; 1.5-1.54 GHz [PDC, GPS (1.56-1.585 GHz)].

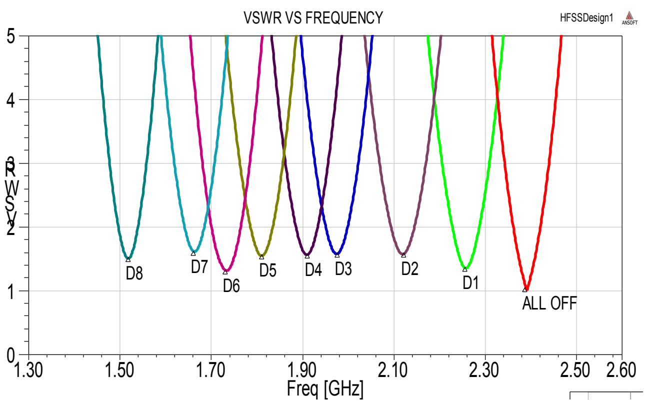

Fig.9 VSWR vs. frequency under all PIN diode condition

Fig.9 shows the simulated result of VSWR against frequency (GHz). The VSWR of the antenna is closely related to the return loss. VSWR value is below 2 for all the frequency bands.

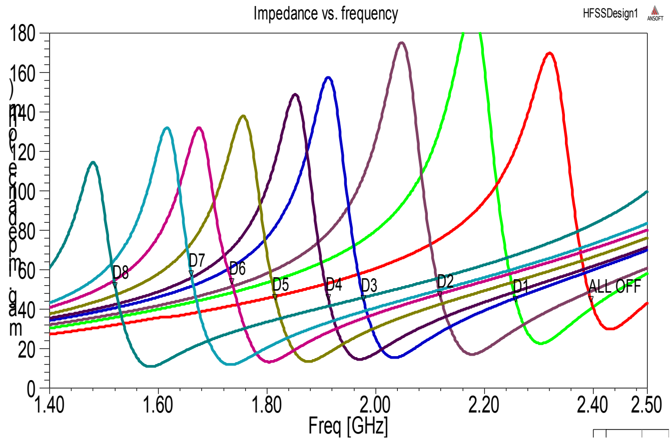

Fig.10 Impedance vs. frequency under all PIN diode condition.

Fig.10 shows the simulated result of magnitude of Impedance against frequency (GHz). Results shows that antenna is matched nearly to 50 ohm for all the frequency bands. Simulated value of return loss, VSWR, Impedance is given in Table 2.

Table 2 Simulated value of return loss, VSWR, Impedance

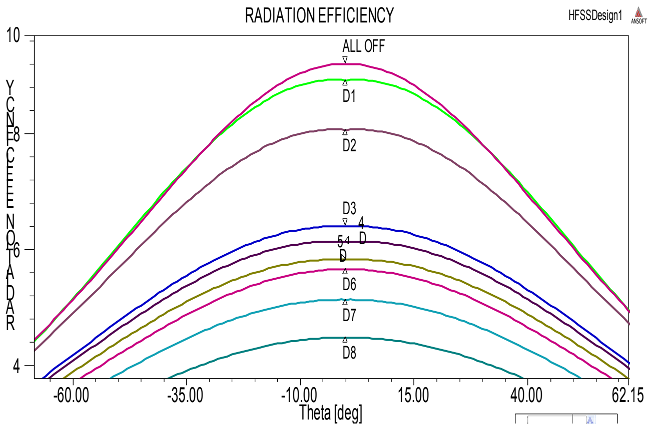

Fig.11 Radiation efficiency vs. angle (degree) under all PIN diode condition.

The antenna radiation efficiency is defined as the ratio of the total radiated power to the power accepted by the antenna at the input. Fig.11 shows the simulated radiation efficiency against angle (degree). From the result it can be conclude that radiation efficiency is greater than 50% in all frequency bands.

Diode state	Gain (dBm)	Directivity	Radiation Efficiency
ALL OFF	20.1507	1.0925	9.1999
D1	31.3278	3.4383	8.9175
D2	30.5739	3.1655	8.0616
D3	28.5809	2.2562	6.3999
D4	28.1902	2.1101	6.1301
D5	27.7314	1.9915	5.822
D6	27.3576	1.9594	5.6587
D7	26.6723	1.7366	5.1318
D8	25.4197	1.4764	4.4787

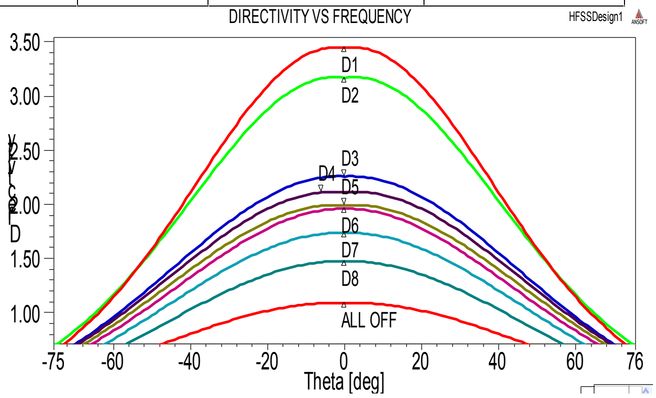

Fig.12 Directivity vs. angle (degree) under all PIN diode condition.

Directivity is the ability of an antenna to focus energy in a particular direction. Directivity (of an antenna) is the ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions. Directivity is always greater than one. Fig.12 shows the simulated directivity against angle(degree).From the result it can be conclude that directivity is greater than one in all frequency bands.

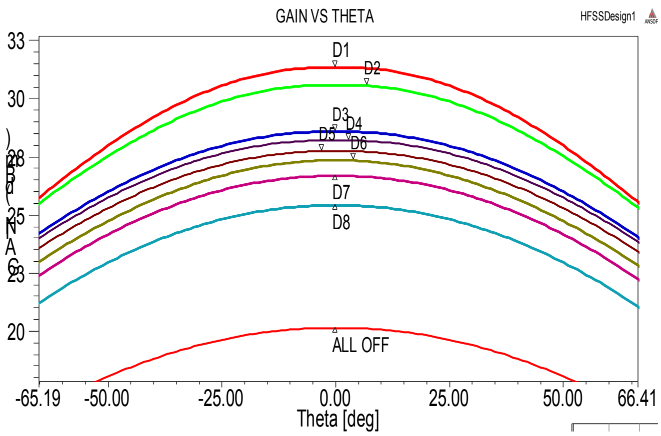

Fig.13 Gain vs. angle (degree) under all PIN diode condition.

Fig.13 shows the total gain of the proposed antenna. This figure shows that the proposed antenna's gain varies between 31dBm to 21dBm within all operating frequency band of the antenna.

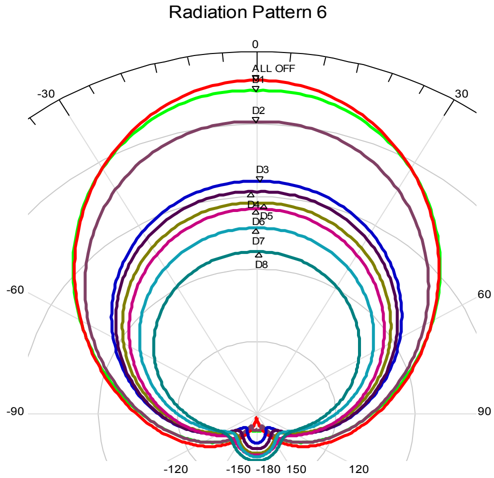

Fig.14 Radiation Pattern under all PIN diode condition

Table 3: Simulated value of Gain, Directivity, Radiation Efficiency

for $\varphi = 0^0$ plane or E plane pattern and for $\varphi = 90^0$ plane or H plane pattern is shown in Fig.15-16. It is observed from here that both the E plane and H plane radiation pattern are broad with no side lobes. The narrow patch broadens the H plane pattern while thinner substrate broadens the E plane pattern.

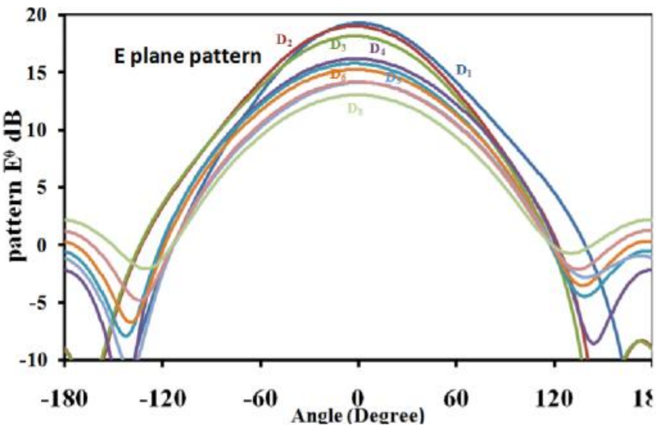

Fig.15. E plane pattern vs. angle (degree) under all PIN diode condition

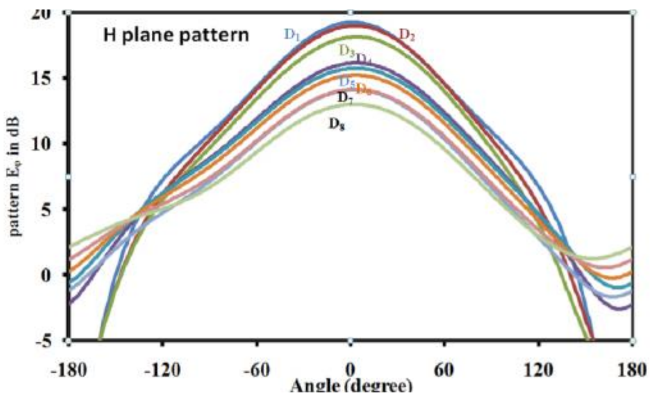

Fig.16 H plane pattern vs. angle (degree) under all PIN diode condition.

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

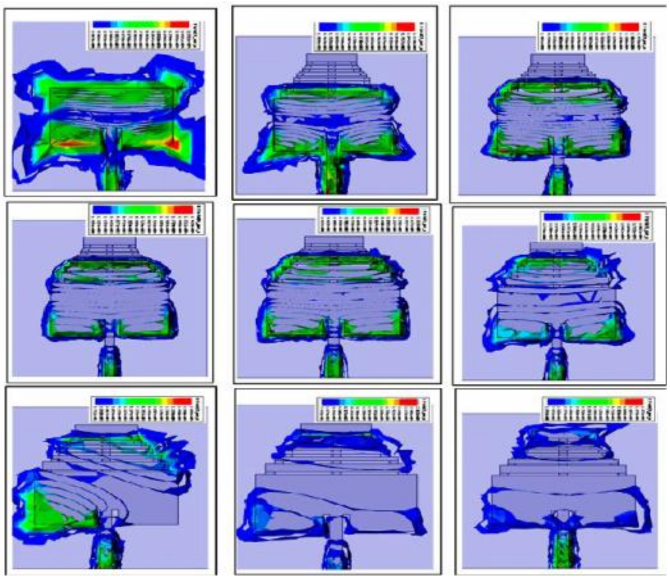

Fig.17 Electric field distribution under all PIN diode condition.

Specific absorption rate (SAR) is a measure of the rate at which energy is absorbed by the body when exposed to a radio frequency (RF) electromagnetic field. It is defined as the power absorbed per mass of tissue and has units of watts per kilogram (W/kg) [1,4,5]. When A handset placed alongside the user's body will deposit energy in the tissue penetrated by electromagnetic fields. To control the possibility of high local peaks, the maximum permitted SAR is specified as applying to any 1 g or 10 g of tissue [4,5]. It is important to distinguish between limits for exposure to electromagnetic fields and maximum permitted SAR levels. There is no single world-wide standard limit for SAR because The body is not electrically homogeneous – bone, brain, skin, and other tissues have different densities, dielectric constants, dielectric loss factors and complex shapes. The responsibility of the antenna designer is to ensure that the user is exposed to the lowest values of SAR consistent with the transmission of a radio signal with the power demanded by the work. The standard value of SAR in India is 2 W/Kg.

The SAR value for proposed antenna is calculated for each PIN diode condition. For all case maximum value is positioned at corner of patch antenna and at the location of PIN diode but this value is below 2W/kg as shown in Fig 18.

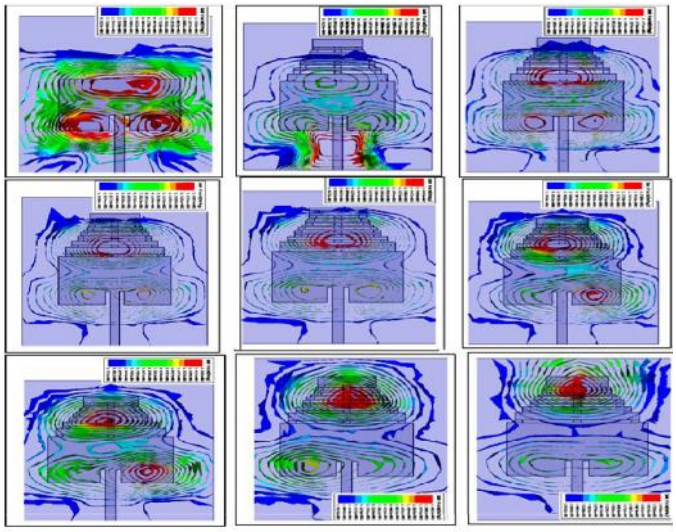

Fig.18 SAR distribution under all PIN diode condition.

V. CONCLUSION

In this paper frequency reconfigurable Yagi Uda shaped microstrip patch antenna for multimode mobile communication is presented. The proposed antenna can work on different wireless standards like WCDMA, FDMA, PDC, and GPS (1.56-1.585 GHz). GSM1800(1710-1880MHz), PCS1900(1859-1990MHz) and UMTS (1900-2170MHz) DCS1800, WLAN, Bluetooth, Wi-Fi, 4G etc. 8 PIN diode are used to switch the frequencu between different standards. The proposed structure is very simple to fabricated due to planner structure, small in size, have good radiation characteristics like Gain, radiation efficiency, return loss, VSWR over all frequency bands. SAR of the proposed antenna is below 2W/kg.

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