Study and Analysis of Microstrip Arrays ensemble with PN Diode Switches for Satellite Communication

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I. *Abstract*

This research work was conducted to examine and design different configurations of frequency reconfigurable antenna arrays for satellite communication. Different configurations of microstrip patch antenna arrays have been designed and simulated to attain a wide bandwidth and assortment in frequency radiations. RF PIN diodes were used as a switch for frequency hopping. Four different antenna arrays, which were conjunct by power dividers through port feed configuration were designed and simulated. Depending on the state of RF PIN diode, the frequency reconfigurable antenna arrays were capable of operating at different frequencies. Deprived of making any modification in the geometry, frequency hopping was examined by only changing the RF PIN diode switching state. By changing the switching conditions of switches, frequency reconfigurable antenna arrays can operate in single, dual and triple modes of band. All four frequency reconfigurable antenna arrays were examined and compared in terms of their microwave performance parameters such as frequency bandwidth, radiation patterns, VSWR, peak gain and return loss. From these configurations, considerably wide bandwidth was achieved in T-shaped metal stub patch and the preeminent frequency configurability achieved in the wheel-patch configuration.

***Index Terms*— Microstrip, Antenna Arrays, RF PIN diodes, frequency re-configurability.** *(key words)*

II. Introduction

In modern telecommunication, re-configurable antennas are vital because of their huge demand. Re-configurable antennas offer the aptitude to dynamically adjust their operating frequency and other antenna parameters such as radiation pattern, bandwidth and polarization. These antennas are particularly helpful where several communication systems converged and due to multiple antennas are required; in that case a single reconfigurable antenna can be used for getting optimum results to reduce space complexity. To make antenna reconfigurable, different techniques can be considering i.e. electrically by using RF PIN diodes, Varactor diode and RF MEMS.

Single element antenna outcomes are low gain and directivity. Single element antenna also gives the broad radiation pattern. Those systems in which high gain is on priority basis then array of radiating elements are used. Arrays are simply combination of two or more radiating elements so that they can enhance the effect to improve gain of antenna, directivity etc, which is not possible by using single element [1]. Microstrip patch antennas posses' small size, low cost, easy fabrication that is why they are immensely used in millimeter wave applications [2]. A rotatable antenna array, which also carries the properties of pattern and frequency reconfigurable has been designed. In this paper three 2-element arrays have been designed and to achieve high gain properties of quasi-yaggi antenna were follow. The designed arrays have 2.66GHz to 3.72GHz frequency-tunable band [3]. This paper proposed a capsule-conformal antenna array, which consist of two mirrored dual band element operating at frequencies 434MHz and 2.45GHz ISM. This antenna array is pattern and frequency reconfigurable, designed for bioelectronics to meet challenges of next generation in human body [4]. A bow-tie antenna, which is having the property of pattern re-configurability for imaging applications of functional brain has been proposed. For pattern re-configurability pin-diodes has been inserted to control the direction of main beam. The realized gain of bow-tie antenna is increased from 1.29dbi to 2.38dbi at operating frequency 3GHz, by using metasurface structure [5]. Polarization reconfigurable antenna array for wireless application as satellite communication and radar systems has been proposed. For polarization reconfigurable characteristics four pin diode are modeled into the ground slot. The scanning range of array is $\pm 40^{o}$ and $\pm 20^{o}$ in X- and Ku-band respectively [6]. In this paper a cube antenna system operating at frequency 5.8GHz (C-band) with characteristics of pattern reconfigurability for cognitive radio application has been presented. In center a reconfigurable feeding network is placed to control four radiating elements of antenna array. A microstrip line configuration with reflective SP8T switch is used which allows four output ports to produce eight radiation patterns [7]. There are many benefits of using reconfigurable antennas as they have ability to beer more than one wireless standard. They are cost vise low, reduce space complexity, and make integration more simple and low front end processing. Reconfigurable antennas can give narrow and wide bandwidths depending upon the designing [8]. A compact frequency reconfigurable antenna using six RF PIN Diodes with double slots has been addressed. This antenna was capable of operating at eleven different frequencies depending upon the switching condition of RF PIN diodes [9]. Design and analysis of reconfigurable microstrip patch antenna has been proposed. This antenna design is based on RF PIN diodes to get radiation at four different frequencies, different switching conditions gives results in different hoping of notch frequency [10]. A frequency reconfigurable microstrip circular patch antenna for wireless devices has been proposed. This antenna consists of circular patch and circular slot and two RF PIN diodes for switching [11]. A 4-element reconfigurable antenna array have been designed with the capability of switching using RF-pin diodes. Fabricated bandwidth of this antenna array 27.2 to 28.35 GHz was achieved [12]. Switching mechanism for reconfigurable antennas has been analyzed by means of electrical and mechanical also. Different techniques to make antenna reconfigurable has been reviewed like to make antenna reconfigurable electrically and mechanically

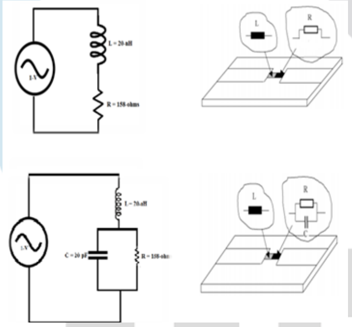
the options are varactor diode, micro electro mechanical switching and pin diode. Diode's equivalent circuit has been analyzed [13]. A compact reconfigurable monopole antenna design of size ($42*16mm^2$) has been proposed. This antenna was able to radiate in seven bands by using switching mechanism of PIN diode. The band in which this antenna radiates were 1.575GHz, 2.4GHz, 3.5GHz, 5GHz, 5.5GHz, 6GHz, 9.2GHz [14]. A frequency reconfigurable microstrip patch antenna has been modeled for Wireless Body Area Network (WBAN) applications. For frequency hopping PIN diode were used to obtain 2.45GHz frequency at ON state and 4.8 GHz frequency at OFF state [15]. In this paper several lately projected antennas for applications such as 4G/5G, multiple-input multiple-output (MIMO), Ultra-Wideband (UWB) has been reviewed. Different antennas and their reconfigurability mechanism are compared on the basis of their performances [16]. A hexagonal shape microstrip patch frequency reconfigurable antenna design has been addressed for multi-input multi-output (MIMO) applications. The frequency range of this modeled antenna design is from 1.3 to 2.6GHz [17].For wireless communication a multiband frequency reconfigurable monopole antenna has been designed. Liable to the switching conditions the proposed antenna works in single and dual mode of frequency [18]. In this paper frequency reconfigurable antennas have been reviewed. Three different configurations of antennas as slot antenna, planar monopole antenna and tunable electromagnetic band gap (EBG) are analyzed [19].
This paper comprises of detail study and analysis of four different designs of patch arrays with RF PIN Diode switches. The configurations were designed and optimized to achieve wide bandwidths and frequency reconfigurability and matched port networks in all arrays achieved maximum power transmission.

III. Design and Development Descriptions

Feed mechanism and switching circuits

To give feed, power dividing network which contains microstrip lines is designed. Firstly, a 50-ohm microstrip transmission line is divided into two 100-ohm microstrip lines. Calculated thickness of 100-ohm is very small when compared with 50-ohm line also conferring to network their length were designed. To join 100-ohm microstrip line with 50-ohm microstrip line quarter wave transformer is used with 70.7-ohm resistance. Due to curvature in microstrip line mitered microstrip line is used for providing compensation to the discontinuity. To match the impedance of wheel shape patch a quarter wave transformer is attached to 50-ohm transmission line. For changing the electrical dimensions of antenna arrays, RF PIN diodes were used as switches and switching is carried out by using forward and reversed biasing of equivalent RL and RLC circuits.

Fig1. Equivalent circuit and Implementation of forward and reverse biasing of PIN diode

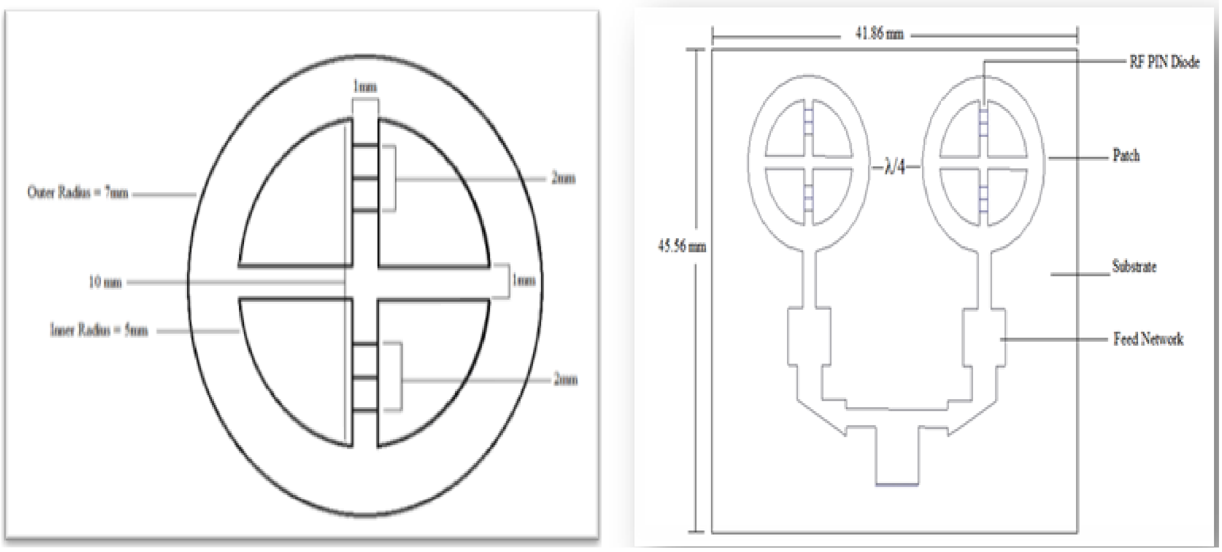


A1. Frequency Reconfigurable 2-Element Wheel Patch Slotted Array

i. Array Design

This modeled frequency reconfigurable 2-element array design comprises four RF PIN Diodes which are assembled in slotted wheel shape patch array. RF PIN Diodes are designed in between the slots to change the dimensions electrically, of array. The change in electrical dimensions would give frequency hopping. Elements of antenna array were kept at λ/4 and two switches were designed in each element. This array was designed for 10GHz frequency and for frequency hoping we use switches ON and OFF states. For ON state circuit is closed and for OFF state circuit condition is open.

Fig2. Geometry of Microstrip Slotted wheel with RF PIN diodes and Implemented design of 2-element array.



ii. Simulated Results and discussion

State 1 is designated to the switches in which all switches are in ON condition which depicts that switches are forward biased. In state 1 wheel patch antenna array radiates in X-band and Ku-band. Radiation in X-band is from 8.6GHz to 8.8GHz frequency. Radiation in Ku-band are 12GHz to 12.6GHz, 12.7GHz to 13.96GHz and 15.9GHz to 16.4GHz. State 2 is labelled to the switches in which all the switches are in OFF condition which shows that switches are reversed biased. In state 2 wheel patch antenna array radiates in Ku-band. Radiation in Ku-band are 12GHz to 12.6GHz and 12.7GHz to 14.2GHz.

Table 1. Performance Parameters with diode Switching state 1 and 2

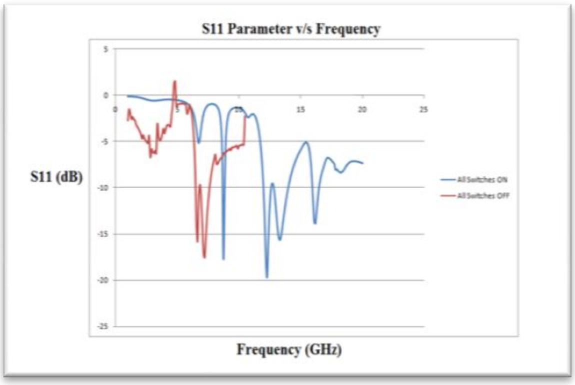
State 1 (All Switches On)						
Sr. No	**Frequency**	**Bandwidth**	**Parameter**			
	Ghz	**Mhz**	**Return Loss**	**VSWR**	**Reflection Coefficient**	**Mismatch Loss**
1	8.7	200	-17.69	1.30	0.13	0.07
2	12.2	580	-19.64	1.23	0.10	0.05
3	13.2	1170	-15.65	1.40	0.17	0.12
4	16.14	560	-13.79	1.51	0.20	0.19
State # 2 (All Switches Off)						
1	12.3	600	-15.6	1.40	0.17	0.12
2	13.2	1300	-17.3	1.32	0.14	0.08

State 3 is designated to the switches in which switch 1 and 2 are forward biased while switch 3 and 4 are in reverse biased mode. In this state wheel patch antenna array radiates in Ku-band and K-band. Radiation in Ku-band are 12GHz to 12.5GHz and 12.7GHz to 14GHz. Radiation in K-band is from 18.8GHz to 20GHz. State 4 is labelled to the switches in which switch 1 and 2 are reversed biased and switch 3 and 4 are forward biased. In this state wheel patch antenna array radiates in Ku-band. Radiations in Ku-band are 12GHz to 12.5GHz and 12.7GHz to 13.96GHz.

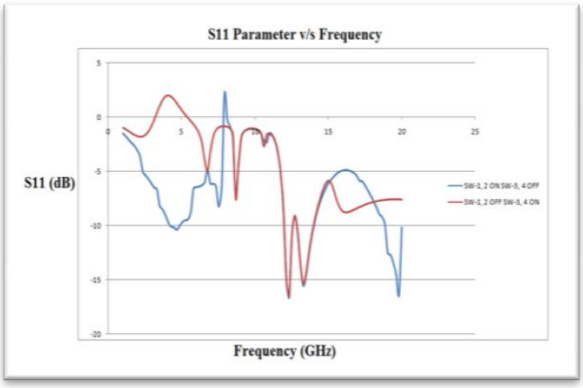
Table 2. Performance Parameters with diode Switching state 3 and 4

State # 3 (Sw-1,2 On Sw-3,4 Off)						
Sr. No	**Frequency**	**Bandwidth**	**Parameter**			
	GHz	**MHz**	**Return Loss**	**VSWR**	**Reflection Coefficient**	**Mismatch Loss**
1	12.2	500	-16.5	1.35	0.15	0.10
2	13.2	1300	-15.4	1.41	0.17	0.13
3	19.7	1200	-16.3	1.36	0.15	0.10
State # 4 (Sw-1, 2 Off Sw-3, 4 On)						
1	12.2	500	-16.5	1.35	0.15	0.10
2	13.2	1300	-15.4	1.41	0.17	0.13

Fig 3. Simulated return loss parameters (a) state. 1 and 2 (b) state 3 and state 4



(a)



(b)

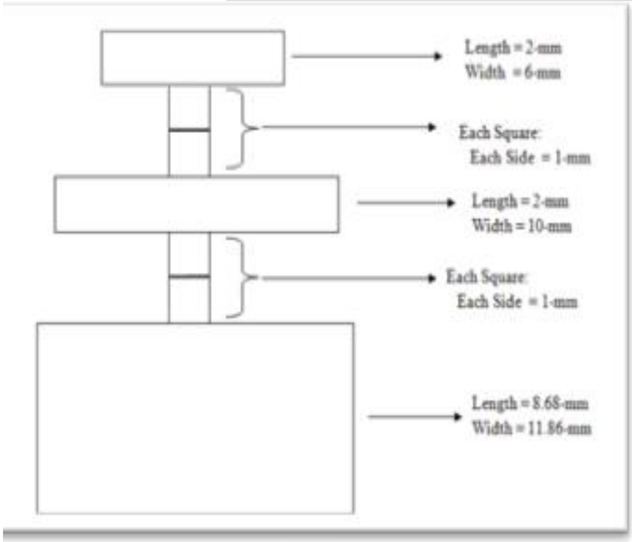
A2. Frequency Reconfigurable 2-Element Yagi-Uda Shape Patch Array

i. Array Design

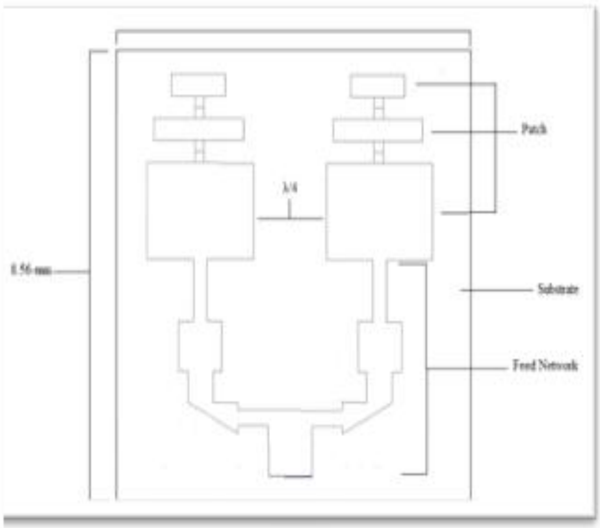
A frequency reconfigurable e-element microstrip patch antenna array is proposed. The shape of antenna array re

sembles with the shape of Yagi-Uda antenna shape. The main patch of microstrip patch is distributed into deputize patches. The designed deputize patches are diminutive in width as compared to the main microstrip patch. Connectivity between the main patch and deputized patch is only possible through RF PIN Diode. RF PIN Diode connectivity change the electrical dimensions of antenna array and thus yields frequency hopping. The ON state of RF PIN Diode allow current to flow in respective deputize patches, while the OFF state of RF PIN Diode cease the current. By applying different switching conditions to antenna array results the change of electrical dimension every time which gives frequency hopping. For forward biasing or ON state of RF PIN Diode the values of R, L and C are L= 20nH, R = 1000 ohms, C=0. For reverse biasing or OFF state of RF PIN Diode the values of R, L and C are L = 20nH, R = 1000 ohms, C = 20 pF.

Fig 4. a) single element design schematic of Yagi -Uda array Array b) Complete Geometry for 2-Element Array



a



b

ii. Simulated Results and Discussion

State 1 is labelled to the switches in which all 4 switches are in forward biased mode. In this state yaggi-uda shape antenna array radiates in X-band, Ku-band and K-band. Radiation in X-band is from 9.78GHz to 10.16GHz. Radiation in Ku-band is from 12.48GHz to 13.05GHz and 15.53GHz to 16.29GHz while radiation in K-band is 18.64GHz to 18.90GHz. State 2 is designated to switches in which all 4 switch are reversed biased. In this state yaggi-uda shape patch antenna array radiates in X-band and Ku-band. Radiation in X-band is 9.75GHz to 10.14GHz while radiation in Ku-band is 12.45GHz to 13.02GHz.

Table 3. Performance Parameters with diode Switching state 1 and 2

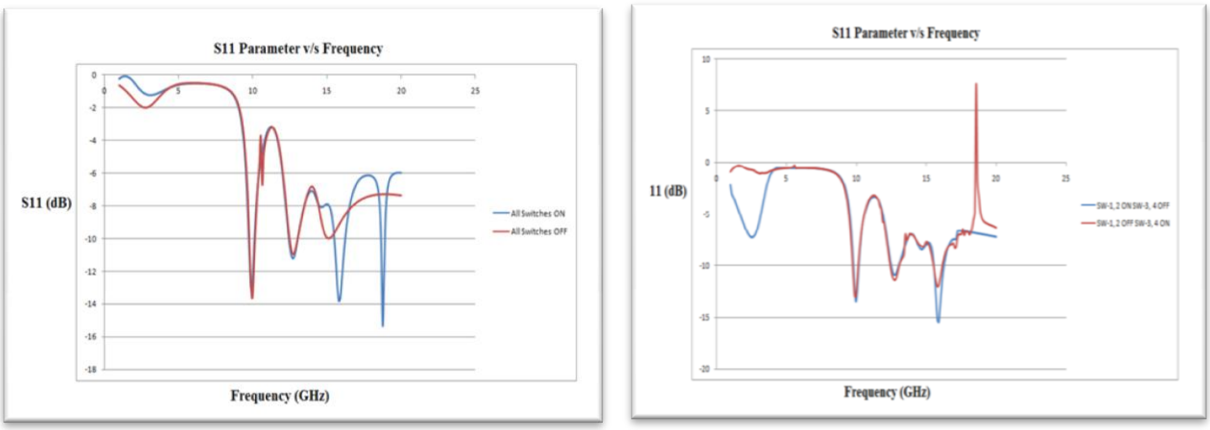
State # 1 (All Switches On)						
Sr. No	Frequency	Bandwidth	Parameter			
	GHz	MHz	Return Loss	VSWR	Reflection Coefficient	Mismatch Loss
1	10	400	-12.87	1.59	0.23	0.23
2	12.75	610	-11.13	1.77	0.28	0.35
3	15.82	720	-13.72	1.52	0.21	0.19
4	18.77	280	-15.29	1.42	0.17	0.13
State # 2 (All Switches Are Off)						
1	10	390	-13.59	1.53	0.21	0.19
2	12.75	579	-10.89	1.80	0.29	0.37

State 3 is designated to switches in which switch 1 and 2 are forward biased and rest are reversed biased. In this state yaggi-uda shape patch antenna array radiates in X-band and Ku-band. Radiation in X-band is from 9.76GHz to 10.15GHz and radiation in Ku-band is from 12.47GHz to 13.02GHz and from 15.52GHz to 16.25GHz. State 4 is labelled to switches in which switch 1 and 2 are reverse biased and rest are forward biased. In this state yaggi-uda shape patch antenna array also radiates in X-band and Ku-band. Radiation in X-band is from 9.76Ghz to 10.16GHz and radiation in Ku-band is from 12.45GHz to 13.02GHz and also from 15.61GHz to 16.18GHz.

Table 4. Performance Parameters with diode Switching state 3 and 4

STATE # 3 (SW-1, 2 ON SW-3, 4 OFF)						
SR. NO	FREQUENCY	BANDWIDTH	PARAMETER			
	GHZ	MHZ	RETURN LOSS	VSWR	REFLECTION COEFFICIENT	MISMATCH LOSS
1	10	400	-13.44	1.54	0.21	0.20
2	12.75	530	-10.85	1.80	0.29	0.37
3	15.82	730	-15.39	1.41	0.17	0.13
STATE # 4(SW-1, 2 OFF SW-3, 4 ON)						
1	10	400	-12.94	1.58	0.23	0.23
2	12.75	660	-11.34	1.74	0.27	0.33
3	15.82	640	-11.89	1.68	0.25	0.29

Fig 5. Simulated return loss parameters (a) state. 1 and 2 (b) state 3 and state 4



(a) (b)

A3. Frequency Reconfigurable 2-Element Polygon Shape Patch Array

i. Array Design

An eight sided polygon shaped microstrip patch antenna array is proposed. This shape is obtained by cutting the edges equally of rectangular microstrip patch. For the change in electrical dimension and frequency hopping a slot is introduced in patch. Four RF PIN diode are used two in each slot, there ON and OFF state ensures frequency hopping. For forward biasing or ON state of RF PIN Diode the values of R, L and C are L= 20nH, R = 1000 ohms, C=0. For reverse biasing or OFF state of RF PIN Diode the values of R, L and C are L = 20nH, R = 1000 ohms, C = 20 pF.

Fig 6. Geometry of single element polygon shape Microstrip antenna with RF PIN diodes and Complete geometry of 2 element polygon shape microstrip antenna array

ii. Simulated Results and Discussion

State 1 is assigned to switches in which all switches are in ON state and forward biased mode. In this state polygon shape patch antenna array radiates in X-band and Ku-band. Radiation in X-band is from 9.59GHz to 9.95GHz. Radiation in Ku-band is from 12.37GHz to 12.90GHz and 14.59GHz to 15.63GHz. State 2 is designated to switches in which all switches are in reverse biased mode. In this state polygon shape patch antenna array also radiates in X-band and Ku-band but with different bandwidths. Radiation in X-band is from 9.34GHz to 9.66GHz and from 10.88GHz to 10.93GHz. Radiation in Ku-band is from 14.40GHz to 14.30GHz and from 15.06GHz to 15.63GHz.

Table 5. Performance Parameters with diode Switching state 1 and 2

State # 1 (All Switches On)						
Sr. No	**Frequency**	**Bandwidth**	**Parameter**			
	GHz	**Mhz**	**Return Loss**	**VSWR**	**Reflection Coefficient**	**Mismatch Loss**
1	9.7	360	-12.80	1.59	0.23	0.23
2	12.60	530	-10.86	1.80	0.29	0.37
3	15	1040	-16.25	1.36	0.15	0.10
State # 2 (All Switches Off)						
1	9.49	320	-24.27	1.13	0.06	0.02
2	10.91	50	-12.17	1.65	0.25	0.27

3	14.61	530	-17.96	1.29	0.13	0.07
4	15.21	570	-12.90	1.59	0.23	0.23

State 3 is labelled to switches in which switch 1 and 2 are forward biased while switch 3 and 4 are reverse biased. In this state polygon shape patch antenna array radiates in X-band and Ku-band. Radiation in X-band is from 9.44GHz to 9.78GHz and radiation in Ku-band is from 12.35GHz to 14.97GHz. State 4 is assigned to switches in which switch 1 and 2 are reverse biased and rest are forward biased. In this state polygon shape antenna array also radiates in X-band and Ku-band with different bandwidths. Radiation in X-band is from 9.44GHz to 9.74GHz and radiation in Ku-band is from 12.37GHz to 12.90GHz.

Table 6. Performance Parameters with diode Switching state 3 and 4

State # 3 (Sw-1, 2 On Sw-3, 4 Off)						
Sr. No	**Frequency**	**Bandwidth**	**Parameter**			
	GHz	**MHz**	**Return Loss**	**VSWR**	**Reflection Coefficient**	**Mismatch Loss**
1	9.7	340	-15.6	1.40	0.17	0.12
2	12.98	2620	-13.10	1.57	0.22	0.22
State # 4 (Sw-1, 2 Off Sw-3, 4 On)						
1	9.61	300	-14.76	1.45	0.18	0.15
2	12.60	530	-10.77	1.81	0.29	0.38

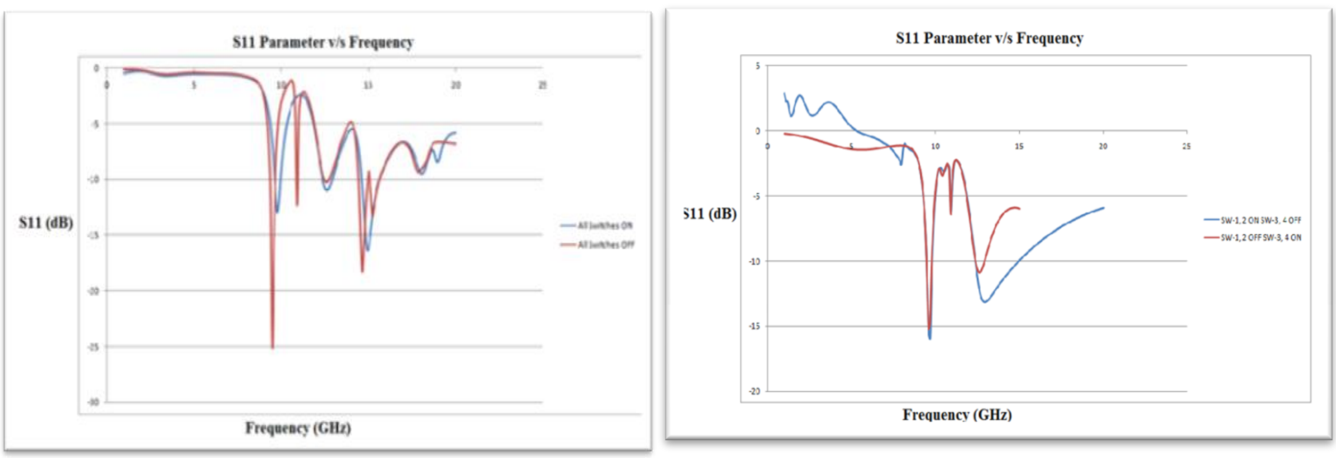
Fig 7. Simulated return loss parameters of (a) states 1 and 2 (b) state 3 and 4

. Frequency Reconfigurable 2-Element slotted T-Stub Patch Array

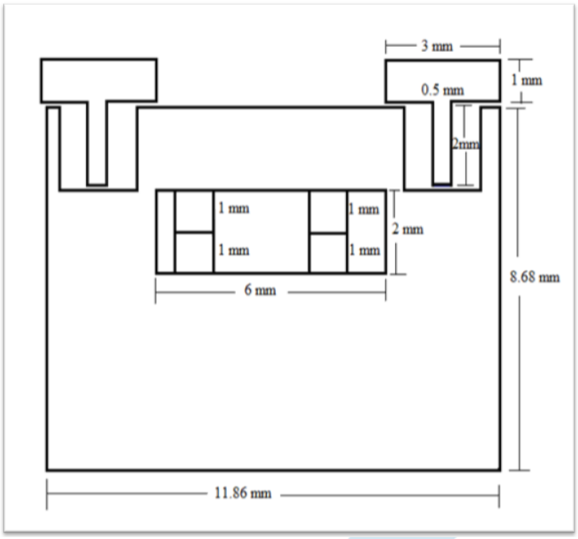
i. Array Design

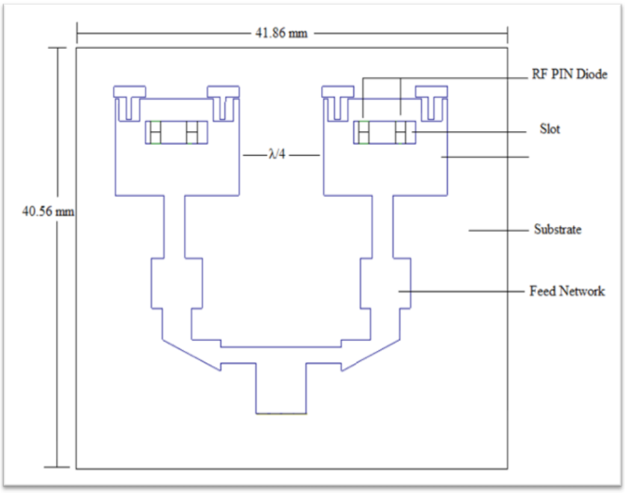
A slotted t-stub shape patch antenna array is proposed. In this design t-shape metal stub behaves like parallel plate capacitor, also t-stub is connected to main patch by electrical means. This type of configuration gives polarization diversity. For frequency hopping four RF PIN Diode is used in slot. Slot change the electrical dimension of array and for frequency reconfigurability ON and OFF state of RF PIN Diode is utilized. For forward biasing or ON state of RF PIN Diode the values of R, L and C are L= 20nH, R = 1000 ohms, C=0. For reverse biasing or OFF state of RF PIN Diode the values of R, L and C are L = 20nH, R = 1000 ohms, C = 20 pF.

Fig 8. Schematic of single element T stub microstrip patch antenna and complete geometry of 2 element T stub microstrip antenna array



(a) (b)





ii. Simulated Results and Discussions

State 1 is designated to switches in which all switches are in forward biased mode. In this state t-stub patch antenna array radiates in X-band and Ku-band. Radiation in X-band are from 8.70Ghz to 9.02GHz and then it radiates from 11.88GHz in X-band to 13.41GHz in Ku-band. Radiation in Ku-band is from 15.15GHz to 16.03GHz. State 2 is labelled to switches in which all 4 switches are reverse biased. In this state slotted t-stub patch antenna array radiates in X-band and Ku-band. Radiation in X-band is from 8.7GHz to 9.08GHz and radiation in Ku-band from 12.01GHz to 13.58GHz.

Table 7. Performance Parameters with diode Switching state 1 and 2

State # 1(All Switches On):						
Sr. No	Frequency	Bandwidth	Parameter			
	Ghz	Mhz	Return Loss	VSWR	Reflection Coefficient	Mismatch Loss
1	8.8	320	-19.40	1.24	0.11	0.05
2	12.73	1530	-21.39	1.19	0.09	0.03
3	15.5	870	-23.44	1.14	0.07	0.02
State # 2(All Switches Are Off)						
1	8.8	380	-31.66	1.05	0.03	0.00
2	12.58	1570	-20.33	1.21	0.10	0.04

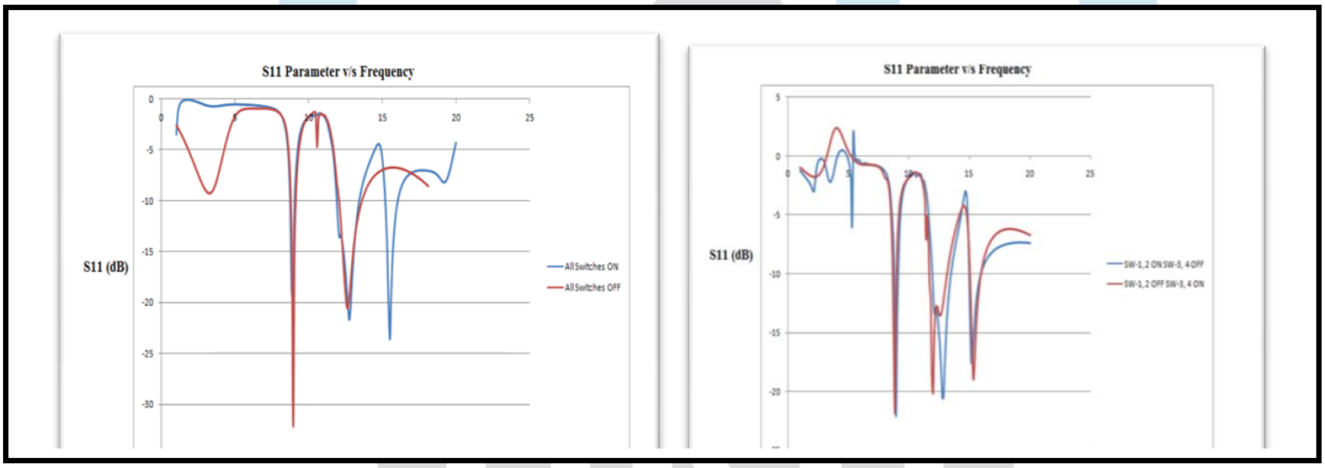
State 3 is designated to switches in which switch 1 and 2 are forward biased and switch 3 and 4 reverse biased. In this state slotted t-stub patch antenna array radiates in X-band and Ku-band. Radiation in X-band is from 8.7GHz to 9.08GHz and radiation from 11.88GHz in X-band to 13.54GHz in Ku-band. Radiation in Ku-band is from 14.93GHz to 15.93GHz. State 4 is labelled to switches in which switch 1 and 2 are reverse biased while rest are forward biased. In this state slotted t-stub patch antenna array also radiates in X-band and Ku-band with different bandwidths. Radiations in X-band is from 8.6GHz to 8.94GHz and from 11.65GHz in X-band to 13.13GHz in Ku-band. Radiation in Ku-band is from 15GHz to 15.93GHz.

Table 8. Performance Parameters with diode Switching state 3 and 4

State # 3 (Sw-1, 2 On Sw-3, 4 Off)						
Sr. No	**Frequency**	**Bandwidth**	**Parameter**			
	GHz	**MHz**	**Return Loss**	**Vswr**	**Reflection Coefficient**	**Mismatch Loss**

1	8.8	380	-21.87	1.18	0.08	0.03
2	12.75	1570	-20.41	1.21	0.10	0.04
3	15.14	1000	-17.41	1.31	0.13	0.08
State # 4(Sw-1, 2 Off Sw-3, 4 On)						
1	8.8	340	-21.47	1.18	0.08	0.03
2	11.94	1480	-19.94	1.22	0.10	0.04
3	15.29	930	-18.74	1.26	0.12	0.06

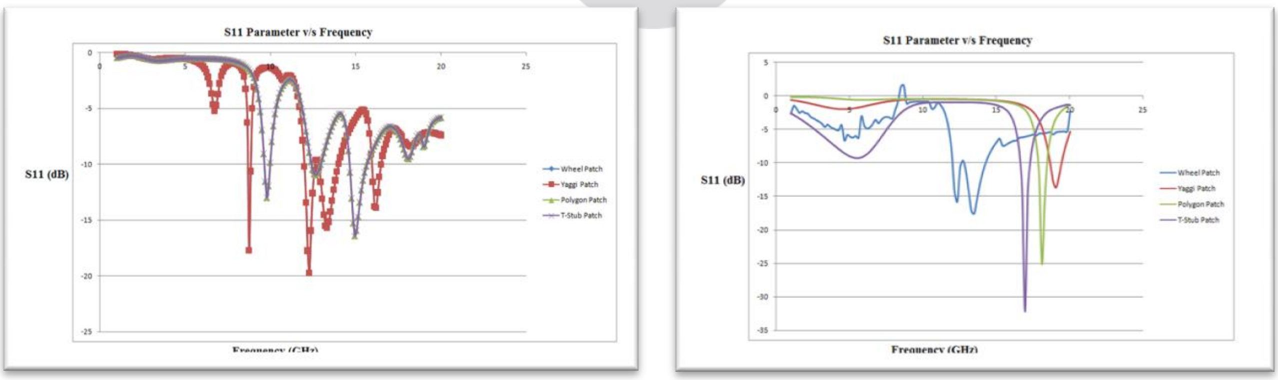
Fig 9. Simulated return loss parameters of (a) state 1 and 2 (b) state 3 and ig 10. Implemented design of arrays (a) Wheel patch antenna array (b) Yaggi-Uda shape patch antenna array (c) Polygon



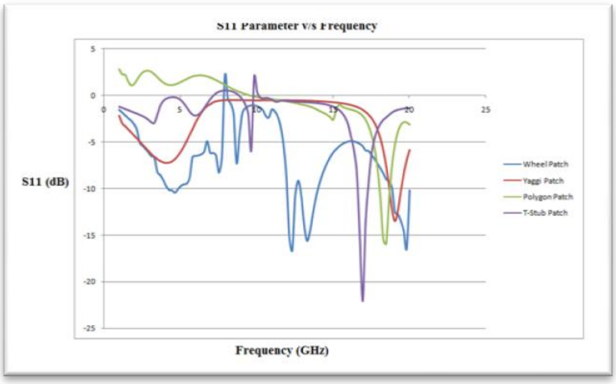
IV. Inter-Comparison of Frequency Ranges & Bandwidths

The comparative measurements of simulated return loss parameters of arrays has been carried out using four specified states of switching of PIN diodes. State 1 in which all four switches are ON, state 2 in which all switches kept OFF, state 3 in which SW-1 and SW-2 kept ON and SW-3 and SW-4 kept off and exact opposite switching of state 3 in state 4. The arrays are radiating at four different ranges of frequencies and optimized to ensures maximum power transfer.

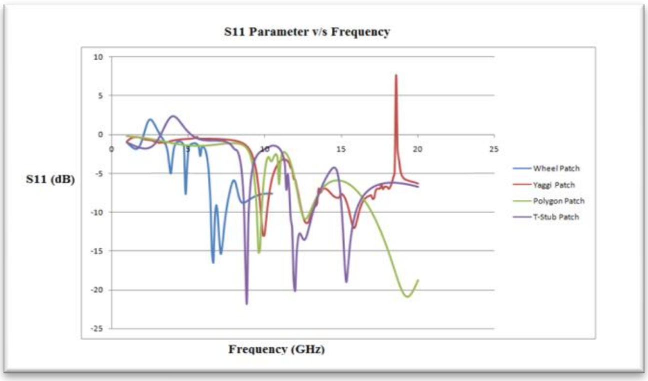
Fig 11. Simulated return loss of all reconfigurable microstrip patch antenna arrays combined in (a) state 1 (b) state 2 (c) state 3 (d) state 4.



(a)



(b)



Slotted wheel patch array, yaggi udda and t-stub patch arrays exhibits dual band operation while radiating in state 2, whereas in state 1, all configurations exhibits tri-band or tetra-band operations achieving minimum bandwidths. Similarly in state 3 and 4, all the arrays exhibit both dual and tri-band radiations with maximum bandwidth achieved in polygon shape antenna array i.e. 2620 MHz. For state 1 and 2 the maximum bandwidth achieved is 1570 MHz in the configuration of slotted t-stub patch antenna array and this configuration is compatible for Ku band applications.

Table 9. Bandwidths and range of frequencies of radiating arrays in state 1 and 2

Array	**frequency ranges**	**bandwidths**	**Frequency Ranges**	**Bandwidths**
	GHz	**MHz**	**Ghz**	**Mhz**
	State 1		**State 2**	
frequency reconfigurable slotted microstrip wheel patch antenna array	8.6-8.8 12-12.6 12.7-13.96 15.9-16.4	200 500 1170 560	12-12.6 12.7-14.2	600 1300
frequency reconfigurable yaggi udda shape patch antenna array	9.78-10.16 12.48-13.05 15.53-16.29 18.64-18.90	400 610 720 280	9.75-10.14 12.45-13.02	390 579
frequency reconfigurable slotted polygon shape patch antenna array	9.59-9.95 12.37-12.90 14.59-15.63	360 530 1040	9.34-9.66 10.88-10.93 14.40-14.30 15.06-15.63	320 50 530 570
frequency reconfigurable slotted t-stub patch antenna array	8.70-9.02 11.88-13.41 15.15-16.03	320 1530 870	8.7-9.08 12.01-13.58	380 1570

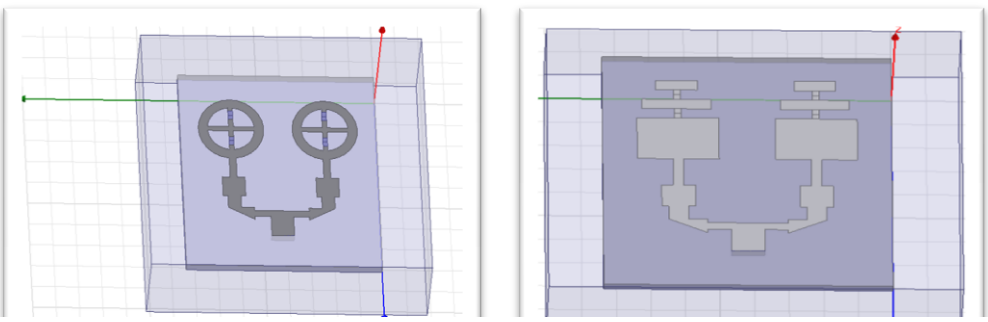


Table 10. Bandwidths and range of frequencies in which arrays radiate with state 3 and state 4

Array	Frequency Ranges	Bandwidths	Frequency Ranges	Bandwidths
	Ghz	Mhz	Ghz	Mhz
	State 3		State 4	
Frequency Reconfigurable Slotted Microstrip Wheel Patch Antenna Array	12-12.5 12.7-14 18.8-20	500 1300 1200	12-12.5 12.7-13.96	500 1300
Frequency Reconfigurable Yaggi Udda Shape Patch Antenna Array	9.76-10.15 12.47-13.02 15.52-16.25	400 530 730	9.76-10.16 12.45-13.02 15.61-16.18	400 660 640
Frequency Reconfigurable Slotted Polygon Shape Patch Antenna Array	9.44-9.78 12.35-14.97	340 2620	9.44-9.74 12.37-12.90	300 530
Frequency Reconfigurable Slotted T-Stub Patch Antenna Array	8.7-9.08 11.88-13.45 14.93-15.93	380 1570 1000	8.6-8.94 11.65-13.13 15-15.93	340 1480 930

IV. Conclusion

In this paper, four different configurations of microstrip patch antenna arrays are designed, simulated, frequency reconfigurability of all four arrays analyzed and obtained simulation results were compared. Frequency reconfigurable slotted microstrip wheel patch antenna array and frequency reconfigurable yagii udda shape patch antenna array was operating in x-band, ku-band and k-band by giving frequency of 10 GHz. Frequency reconfigurable slotted polygon shape patch antenna array and frequency reconfigurable slotted T-Stub patch antenna array was operating in x-band and ku-band by applying frequency of 10 GHz. Directivity and high gain is obtained from yaggi-udda shape array while wide bandwidths achieved from t-stub shape array. In wheel shape patch antenna array two characteristics are observed as reconfigurability of frequency and radiation pattern which shows non-uniformity of patches leads to the radiation pattern reconfiguration.

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