Reconfigurable Antenna Parameters with the Change in the Position of Switches

Shafqat Hussain[1], Muhammad Usman Ali Khan[2], Muhammad Rizwan Anjum[3]
Department of Electronics Engineering
The Islamia University Bahawalpur
Pakistan
shafqathn@yahoo.com[1],usman.ali@iub.edu.pk[2], engr.muhammadrizwan@gmail.com[3]

ABSTRACT: *In this paper the reconfigurable dual band micro strip patch antenna with resonant frequencies 1102MHz and 912MHz is analyzed with the change in position of internal two switches which are connecting the four antenna patches. It is showed that reconfigurable antenna changes the basic parameters with the change in the position of the switches which are being used to connect the antenna structure. A micro strip patch antenna of dimension (width 100mm, length 100mm and height 30.4mm) is designed. The dual frequency band reconfigurable antenna is achieved by using two copper tapes for connecting the antenna internal elements. The reconfigurable antenna consists of a FR4 substrate containing the four copper annealed patches which are connected by two copper switches. The software CST MW studio is used for simulation. The results show the variation of the re-configurability of the antenna with the change of position of the internal switches of the reconfigurable antenna. The change in the antenna parameters like Return loss, resonant frequency, bandwidth and directivity are described for both frequency bands. With the change in the position of the switches of reconfigurable antenna the return loss is improved, resonant frequency is being changed, Bandwidth of the antenna is changed and the radiation pattern remains same. The idea to change the basic parameters of the reconfigurable antenna by only changing the position of the reconfigurable antenna switches can provide another simple approach to make an antenna reconfigurable in frequency agility. The future work for researchers is recommended to use diode switches in the place of copper tapes. The position of the switches is changed simultaneously and some more results can be extracted while changing the position of one switch and keeping the position of second switch fixed.*

Keywords: Return losses, resonant frequency, bandwidth directivity, FR4, Substrate

Received: 28 May 2016, Revised 29 June 2016, Accepted 5 July 2016

1. Introduction

The changes in the physical geometry of the antenna by any means that convert it reconfigurable antennas. The reconfigurable antenna can change the polarization, operating frequency and the radiation patterns of the antenna. The reconfigurable antenna has very effective use in multi communication system. in order to avoid interference by directing the nulls of antenna in the direction of interference and subscribers can get noise free communication. For any communication system requirements or any change in the communicating channels, the reconfigurable antennas is able to adjust the changes itself [1], [2]. Two or more fixed antennas required for in communication system are replaced by a single reconfigurable antenna because the reconfigurable antenna adjust itself with the change in its internal structure and no need of external system.

The reconfigurable antenna behaves in better results than a fixed antenna [3]. The reconfigurable antennas are getting popularity because of its simple, easy and cost effective design and implementation.

In the past, many researches are working a lot to convert an antenna into reconfigurable antenna by applying many techniques which are changing the antenna's internal structure. One technique is to use the internal switches which connect/disconnect the internal parts of the antenna. These switching components are PIN diodes [4], or photo conductive switches [5] which reduces the losses of PIN diodes, packaged [6] or integrated [7], FETs and MEMs [8] to attach the internal parts of the antenna to redistribute the current. These techniques showed that an antenna can operate in a multiband reconfigurable antenna by the different positions of the switches. The antenna showing the frequency agility is achieved by switches 1and 2 [9], switching of plasma [10]. A very good method to turn an antenna into reconfigurable is performed by variations in the of ground plane of the antenna [11]. Switch feed and switched grouped techniques is used for antenna reconfigurable [12].

In this paper, a different approach is adopted where shift in the operating frequency of the dual band reconfigurable antenna is observed when the position of switches is changed while keeping the materials and dimensions of the antenna unchanged. The switches connect the internal elements of the reconfigurable antenna. The effects of antenna's parameters like return loss, resonant frequency, bandwidth and directivity of the dual band frequency reconfigurable antenna with the change in the position of two coppers tapes switches which connect the four patches are described. The directivity of the both bands of the reconfigurable antenna remains same against all the positions of the switches.

The work is classified as, in section-II the Antenna operating in a GSM frequency band is implemented which having the omnidirectional radiation pattern. The section III presents the design of reconfigurable antenna by using switches S1 and S2. Here four copper patches and two copper tapes which are used to connect the patches. A micro strip antenna is selected. The micro strip patch antenna is preferred because it is simple in structure and, light weight in size for [13]. The section-IV describes the simulation results of reconfigurable antenna by changing the switches positions. The antenna parameters like S11, Resonant Frequency, Bandwidth and directivity are discussed. In section-IV conclusions are described and effects on the antenna parameters when the switches position is changed while keeping the other constituent of antenna fixed.

2. Related Work & Single Band Antenna Design

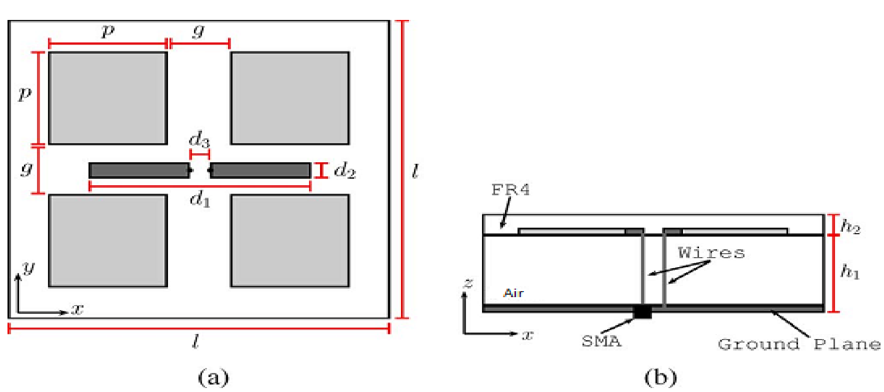

Figure 1. Antenna Structure (a) Top view (b) Side View

In 2012, Leonardo Lizzi, Member, IEEE, Fabien Ferrero, Member, IEEE, Jean-Marc Ribero, and Robert Staraj designed a "Light and Low-Profile GSM Omnidirectional Antenna" [14]. The operating band of this antenna is 890 MHz to 960 MHz with central frequency 925 MHz The radiation pattern of this antenna is omnidirectional. The beauty of the antenna is it is light in weight. Authors suggested the future work to convert it multiband antenna. The Antenna is implemented and enhanced by making it reconfigurable where two bands of operating frequencies 912 MHz and 1102 MHz are achieved. In the designed antenna, there are four patches of equal length and width "p" and one dipole of length "d1". The two wires of diameter 1 mm are passes through the structure. One wire connects the one arm of the dipole to SMA connector and other wire is connected with ground directly. The antenna structure is presented in Fig. 1.

The antenna is implemented in CST by using the values of different parameters as given in Table 1.

Parameters	**Value (mm)**	**Parameters**	**Values (mm)**
l	100	g	9
d1	71.5	p	38.5
d2	2	h1	0.4
d3	5	h2	33

Table 1.Gsm Antenna Parameters Values

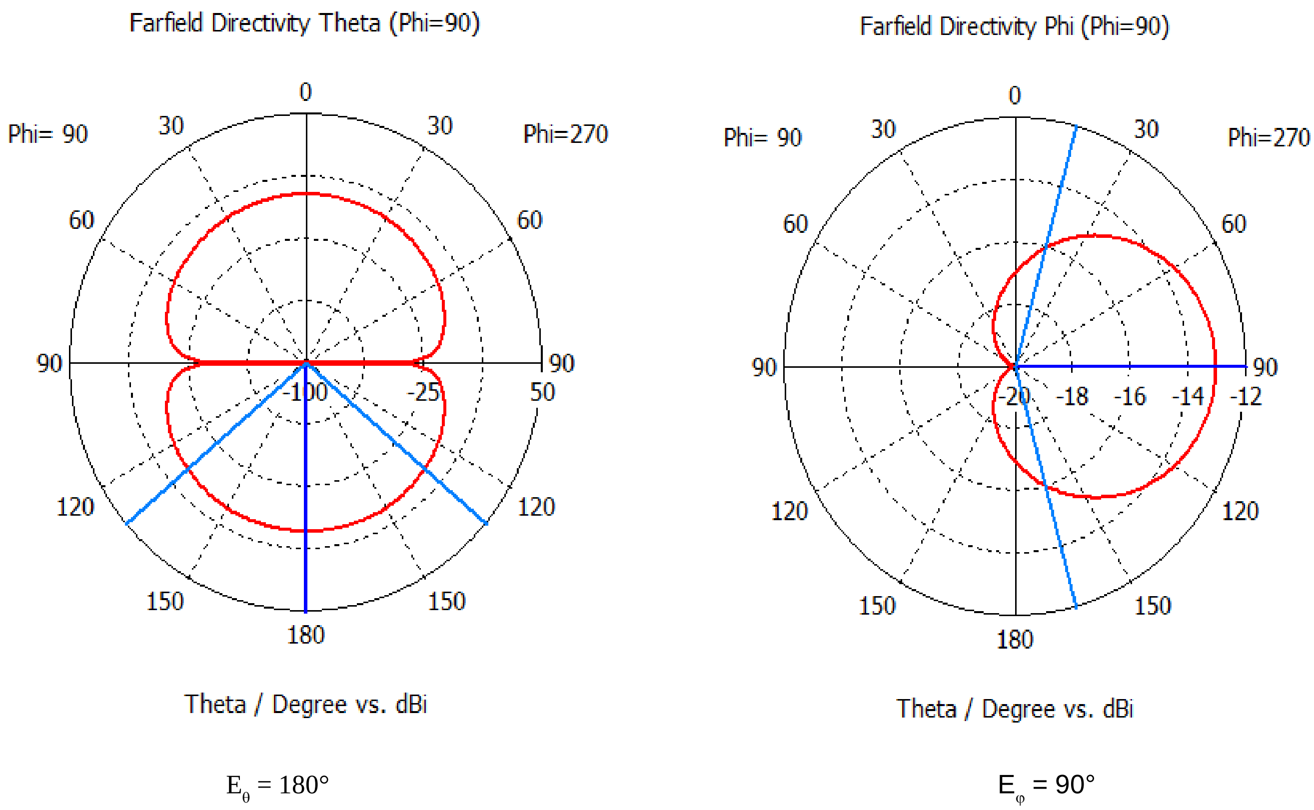

Figure 2. Radiation pattern of maximum beam for single band antenna

3. Multiband Reconfigurable Antenna Design

In order to make antenna reconfigurable the two copper tapes are used to connect the four patches. The width of each copper tape switch is 1 mm and placed between the of the patches. The copper tapes switches are represented by S1 and S2 as shown in Fig. 3.

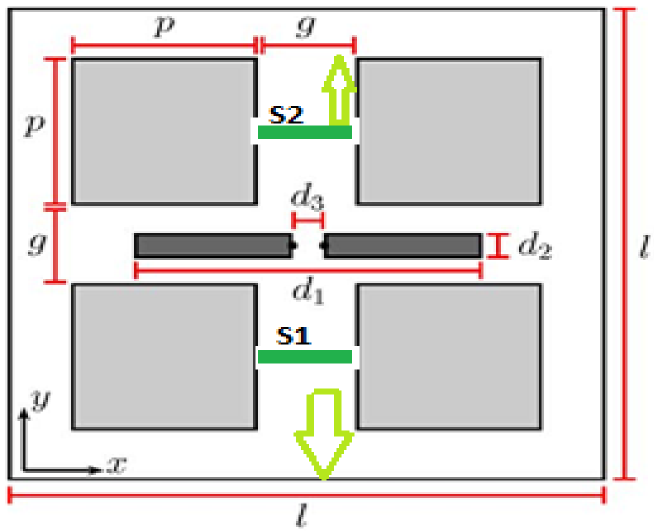

Figure 3. Geometry of Reconfigurable Dual Band Antenna

The designed single band Antenna is operating with two frequency bands when one of the switches S1 and S2 is connected with the patches. The Fig. 4 shows the return loss for both of the frequency bands. The return loss of the first frequency band is good than that of the second frequency band.

In Fig. 5, the S11 parameters are described where two frequency bands are shown at central frequencies 912 MHz and 1102 MHz when both switches S1 and S2 are connected with the patches. The return loss of second band is better in this case.

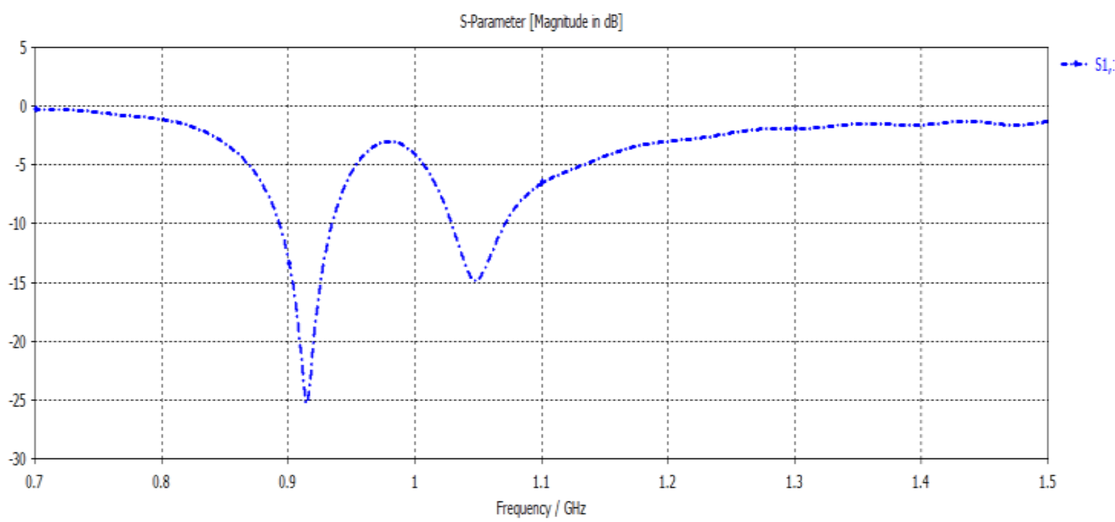

Figure 4. S11 Parameters (One of switches S1 and S2 is ON)

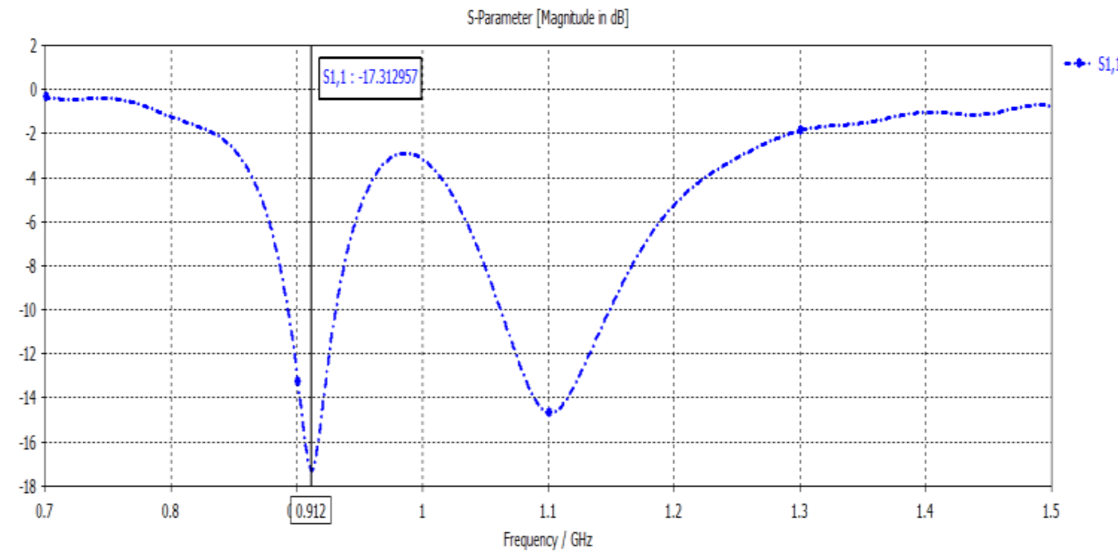

Figure 5. S11 Parameters (S1=ON, S2=ON)

4. Simulation Results of Dual Band Antenna For Change In The Position of Switches

The dual frequency band antenna is designed and simulated using the CST MW Studio from frequency range 0.5 GHz to 1.5 GHz. The second frequency band is achieved only when one of the both switches or both switches are connected with the patches as shown in Fig. 3. The return loss for both frequency bands is better when both switches are connected. The effect on the antenna parameters by the change in the position of the switches are studied when both switches are in contact.

4.1. First Frequency Band of Reconfigurable Antenna

The simulation results for 1st frequency band of reconfigurable antenna are presented in this section. From Fig. 6 it is clear that as the switches move towards the center of the center of the dipole the return loss is getting improved accordingly.

1) Return Loss of the 1st Frequency Band

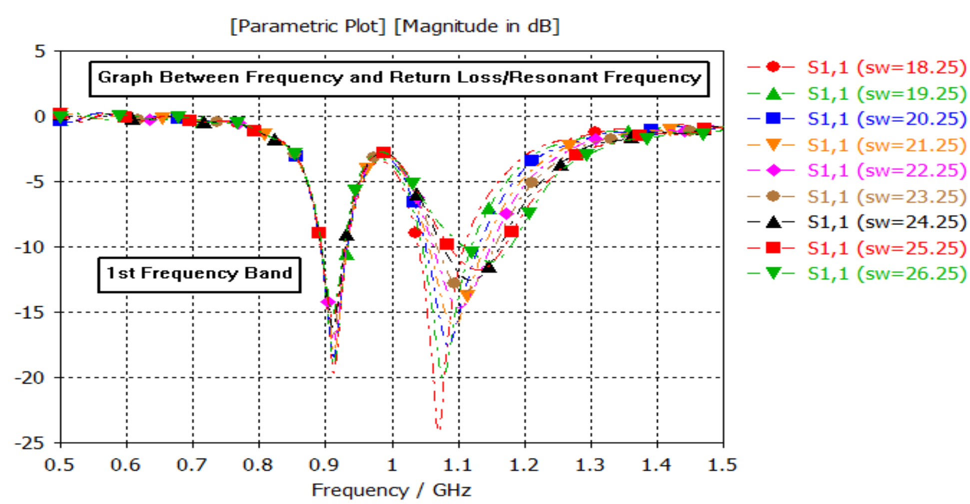

Figure 6. S11 Parameters (S1=ON, S2=ON) at different position of S1 and S2

From Table 2, the return loss is varying from -19.67 to -15.52 when the both switches move away from the center of the dipole. The return loss of the first frequency band is better for the switches position at 18.75mm from the center of the dipole. The return loss can be varied by changing the switches position.

Position of S1 and S2 from the center of dipole (mm)	S11
18.75	-19.66811
19.75	-19.042946
20.75	-18.413954
21.75	-18.092899
22.75	-17.312957
23.75	-16.796998
25.75	-15.518912
26.75	-15.1328

Table 2. Switches Position And Return Loss (1^{ST} Frequency Band)

2) Resonant Frequency of 1^{st} frequency Band: From the
Table III, in the first frequency band operational frequency is being changed with the change in the position of switches. The resonant frequency varies from 910 MHz to 913 MHz as switches move away from the center of the dipole.

3) Bandwidth of 1^{st} frequency Band
From the Table IV, for the first frequency band of the reconfigurable antenna the bandwidth is being changed with different positions of the switches. The antenna bandwidth of the antenna can be designed to meet the requirement of any communication system. The antenna bandwidth is 72.23MHz when the switches are at 18.75mm distance from the center of the dipole.

Position of S1 and S2 from the center of dipole (mm)	Resonant Frequency (MHz)
18.75	912
19.75	912
20.75	912
21.75	913
22.75	912
23.75	911
25.75	910
26.75	911

Table 3. Switches Position And Resonant Frequency

Position of S1 and S2 from the center of dipole (mm)	Bandwidth (MHz)
18.75	72.237
19.75	71.579
20.75	71.025
21.75	70.276
22.75	68.635
23.75	67.688
25.75	65.541
26.75	63.137

Table 4. Switches Position And Bandwidth (1st Frequency Band)

4) Directivity of 1st frequency Band

The directivity of the antenna is very important parameters. From the directivity it can be seen that how much antenna power is being radiated in any particular direction. From Table V, it is clear that the value of directivity remains same for first frequency band of reconfigurable antenna where ever the both switches are placed between the patches at equal distance from the center of the dipole. Fig 7 is showing the polar graph of the directivity against at the different positions of the switches.

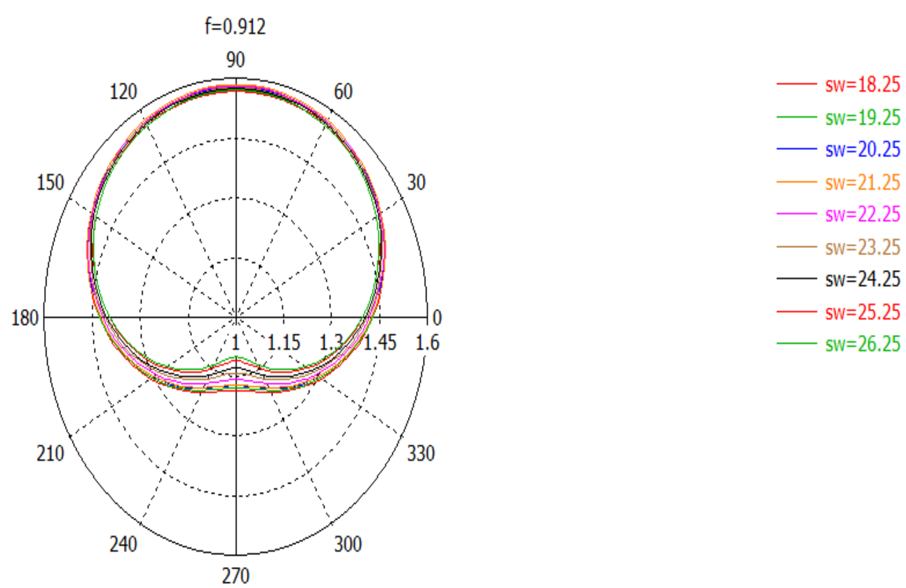

Figure 7. Directivity values at different position of S1 and S2 (1st Band)

Position of S1 and S2 from the center of dipole (mm)	Directivity (dBi)
18.75	1.575
19.75	1.576
20.75	1.577
21.75	1.58
22.75	1.58
23.75	1.58
25.75	1.577
26.75	1.575

Table 5. Position of switches and Directivity (1st Frequency Band)

4.2 Second Frequency Band of Reconfigurable Antenna

In this section, the simulation results of 2nd frequency band are described.

1) Return Loss of the 2nd Frequency Band

From Fig. 8, the return loss of the 2nd frequency band of the reconfigurable antenna is better than that of the first frequency band as shown in Fig. 6. The return loss of the 2nd band of the antenna is improving further if the position of switches is near to the center of the dipole.

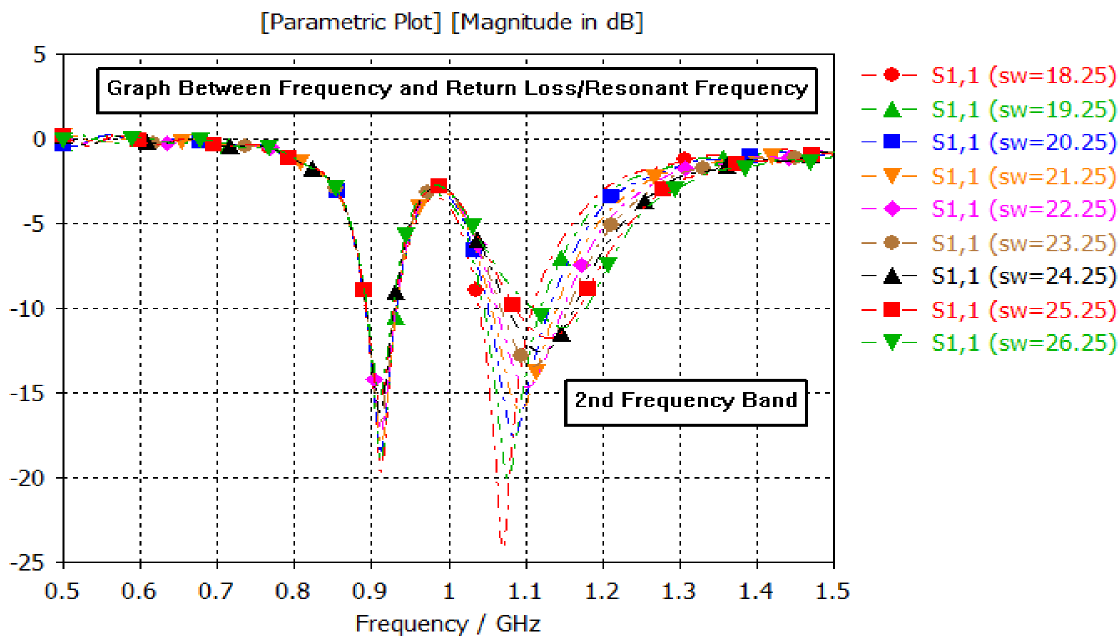

Figure 8. S11 Parameters (S1=ON, S2=ON) at different position of S1 and S2

The Table 6, shows that return loss of the second frequency band is -20.12 when the switches are at distance of 19.75mm from the center of the dipole. S11 parameter is improved with placing of switches between the patches.

Position of S1 and S2 from the center of dipole (mm)	S11
19.75	-20.125903
20.75	-17.602658
21.75	-16.071021
22.75	-14.689099
25.75	-11.77686
26.75	-11.15413
27.75	-10.91411
28.75	-10.750713

Table 6. Switches Position And Return Loss (2nd Frequency Band)

2) Resonant Frequency of 2nd frequency Band

From the Table 7, in the second frequency band operational frequency is being changed with the change in the position of switches. The resonant frequency varies from 1.077MHz to 1.1691MHz as switches move away from the center of the dipole.

Position of S1 and S2 from the center of dipole (mm)	Resonant Frequency (MHz)
19.75	1.077
20.75	1.085
21.75	1.0925
22.75	1.102
25.75	1.131
26.75	1.149
27.75	1.1606
28.75	1.1691

Table 7. Switches Position And Resonant Frequency (2nd Band)

3) Bandwidth of 2nd frequency Band

From the Table 7 for the second frequency band of the reconfigurable antenna the bandwidth is being changed with different positions of the switches. The antenna bandwidth of the antenna can be designed to meet the requirement of any communication system by just changing the switch positions. For second frequency band the antenna bandwidth is 133.85MHz to 188.7MHz when the switches are at 19.75mm and 28.75MHz distance respectively from the center of the dipole. For comparison, the bandwidth of the second frequency band is higher than that of the first frequency band.

Position of S1 and S2 from the center of dipole (mm)	Bandwidth (MHz)
19.75	133.85
20.75	141.4
21.75	147.79
22.75	154.13
25.75	176.58
26.75	183.9
27.75	188.7
28.75	192.88

Table 8. Position of switches and Bandwidth (2nd Frequency Band)

4) Directivity of 2nd frequency Band

The directivity of 2nd frequency band is shown in Fig. 9. It is showing the polar graph of the directivity against at the different positions of the switches. The directivity is almost same at different positions of the switches.

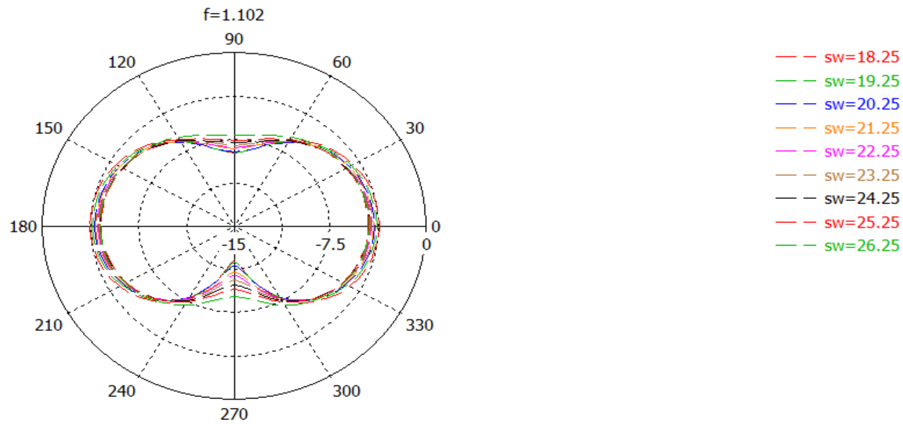

Figure 9. Directivity values at different position of S1 and S2 (2nd Band)

5. Conclusions

A unique and different approach is implemented in which the position of switches which connect the antenna internal elements of a reconfigurable antenna is changed and subsequently the shift in the operating frequencies for both bands is observed.

The return loss for both bands is also improved by changing the switches position. Bandwidth for both frequency bands also enhanced at different position of the switches. The directivity remains same for each band irrespective of the position of the switches.

The future work for researchers is recommended to use diode switches in the place of copper tapes. In this paper the position of switches is changed simultaneously and some more results can be extracted while changing the position of one switch and keeping the position of second switch fixed

Acknowledgement

My parents provided me the moral and financial support throughout my academic career. I am thankful them for their countless efforts to support me. Mr. Abid Javed (HOD Electronics Engineering Department IUB, Pakistan), Muhammad Ajmal (Ph.D. Scholar) and Mr. Abdul Aziz (Ph.D. Scholar) supported and shared their knowledge to complete this work

References

[1] Cetiner, B. A., Jafarkhani, H., Qian, J.-Y., Yoo, H. J Grau, A. De Flaviis, F. (2004). Multifunctional reconfigurable MEMS integrated antennas for adaptive MIMO systems, *Communications Magazine, IEEE*, vol. 42, p. 62-70, 2004.

[2] Eslami, H. Sukumar, C. P. Rodrigo, D. Mopidevi, S. Eltawil, A. M. Jofre, L.(2010). Reduced overhead training for multi reconfigurable antennas with beam-tilting capability, *Wireless Communications, IEEE Transactions on*, vol. 9, p. 3810-3821, 2010.

[3] Roach, T. L. Huff, G. Bernhard, J. (2007). A comparative study of diversity gain and spatial coverage: fixed versus reconfigurable antennas for portable devices, Microwave and Optical Technology Letters, 49, 535-539.

[4] Nikolaou, S., Bairavasubramanian, R. Lugo C. Jr, . Carrasquillo, I., Thompson, D. C. Ponchak, G. E. (2006). Pattern and frequency reconfigurable annular slot antenna using PIN diodes, *Antennas and Propagation, IEEE Transactions on*, V. 54, p. 439-448, 2006.

[5] Panagamuwa, C. J. Chauraya, A.Vardaxoglou, J. (2006). Frequency and beam reconfigurable antenna using photoconducting switches, *Antennas and Propagation, IEEE Transactions on*, V. 54, p. 449-454.

[6] Huff , G. H.and Bernhard, J. T. (2006). Integration of packaged RF MEMS switches with radiation pattern reconfigurable square spiral microstrip antennas, *Antennas and Propagation, IEEE Transactions on,* p (ANOVA)V. 54, p. 464-469.

[7] Jung, C. W. Lee, M.-j. Li, G. De Flaviis, F. (2006). Reconfigurable scan-beam single-arm spiral antenna integrated with RF-MEMS switches, *Antennas and Propagation, IEEE Transactions on*, V. 54, p. 455-463.

[8] Wang, C.-J., Tsai, W.-T. (2005). A slot antenna module for switchable radiation patterns, Antennas and Wireless Propagation Letters, IEEE, V. 4, p. 202-204.

[9] Nguyen V. T. Jung, C. W. (2016). Radiation-Pattern Reconfigurable Antenna for Medical Implants in MedRadio Band, *IEEE Antennas and Wireless Propagation Letters,* V. 15, p. 106-109.

[10] Barro, O. A. Himdi, M. . Lafond, O (2016).Reconfigurable Patch Antenna Radiations Using Plasma Faraday Shield Effect, *IEEE Antennas and Wireless Propagation Letters*, vol. 15, p. 726-729.

[11] Sabapathy, T.Jusoh, M., Ahmad, R. B . Kamarudin, M. R., Soh, P. J. (2016). A Ground-Plane-Truncated, Broadly Steerable Yagi–Uda Patch Array Antenna, *IEEE Antennas and Wireless Propagation Letters*, vol. 15, p. 1069-1072.

[12] Mak, A. C. Rowell, C. R.. Murch, R. D Mak, C.-L.(2007). Reconfigurable multiband antenna designs for wireless communication devices, *Antennas and Propagation, IEEE Transactions on,* V 55, p. 1919-1928, 2007.

[13] Valizade, A., Rezaei, P., Orouji, A. A. (2014). A new design of dual-port active integrated antenna for 2.4/5.2 GHz WLAN applications, *Progress In Electromagnetics Research B,* V. 58, p. 83-94, 2014.

[14]Lizzi, L. Ferrero, F Ribero, .J.-M. Staraj, R. (2012). Light and low-profile GSM omnidirectional antenna, *IEEE Antennas and Wireless Propagation Letters,* p. 1146-1149.