International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-2, July 2019

A Planar Antenna Reconfigured in Frequency for Wireless Services

Ros Marie C Cleetus, G Josemin Bala

Abstract*: *An antenna that exhibits reconfiguration in frequency is introduced in this paper that can act as an ultrawide band antenna as well as a narrow band antenna according to the switching status of the design. This antenna structure provides a wide band coverage from 3.02 to 9 GHz and narrow band coverage from 3.45 to 6.45 GHz, 5.04 to 7.65 GHz and 7.04 to 8.58 GHz corresponding to four switching configurations. The simulation software used is Ansoft High Frequency Structure Simulator (HFSS). The results from simulation and measurement are found to be matching. This design finds its applications in Worldwide Interoperability for Microwave Access, Wireless Local Area Network, Cognitive Radio, Satellites, etc.

Index Terms*: *Cognitive radio, patch antennas, reconfigurable antennas, ultra wideband antenna.

I. INTRODUCTION

The usage of communication systems is growing tremendously which in turn stimulated the requirement of devices that are having multiple functionalities at the same instant. Reconfiguration in antennas, thus evolved take part in meeting the requirements of wireless systems nowadays. While traditional systems are designed for working with fixed operating characteristics like resonant frequency, radiation pattern and polarization, reconfigurable antennas allow changes in any of these characteristics without affecting the other parameters. The reconfigurable antennas contribute significantly in the areas of mobile and satellite communication, radars, airplane, etc. by supporting a huge number of standards like Wi-Fi, WiMAX, Universal Mobile Telecommunications System (UMTS), Bluetooth, Dedicated Short Range Communication (DSRC), etc. Thus, a single reconfigurable antenna is becoming an alternative to many antennas with single functionality [1]. Out of various reconfiguration techniques, Frequency reconfigurable antennas have become more prominent allowing the devices to work in multiple standards, bands and services and ensure finest spectrum usage [2].

The researches in Frequency Reconfigurable Antennas describes the use of tunable structures or switches like, PIN diodes [3],[4], Micro Electro Mechanical Systems (MEMS) [5],[6], varactors [7],[8], Photoconductive switches [9],[10]. and Field Effect Transistors (FET) [11],[12]. Structural alteration with the radiating structures [13],[14] as well as some smart materials like liquid crystals, ferrites, etc. provide reconfigurability [15],[16].

A rectangular patch with four corner-cut slots acting as a frequency reconfigurable antenna is presented in this paper. The frequency reconfiguration is accomplished using six switches attached to the main feed line of the antenna. These switches allow the antenna operation in a wideband as well as a few narrow bands within the wideband. The work is presented as follows. Section II describes the Configural details of the antenna. The results and the associated discussions are elaborated in Section III and the work is concluded with Section IV.

II. ANTENNA CONFIGURATION

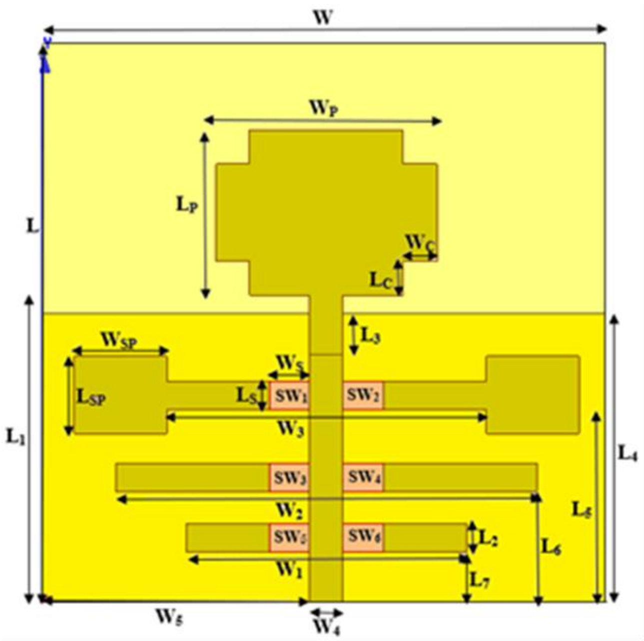
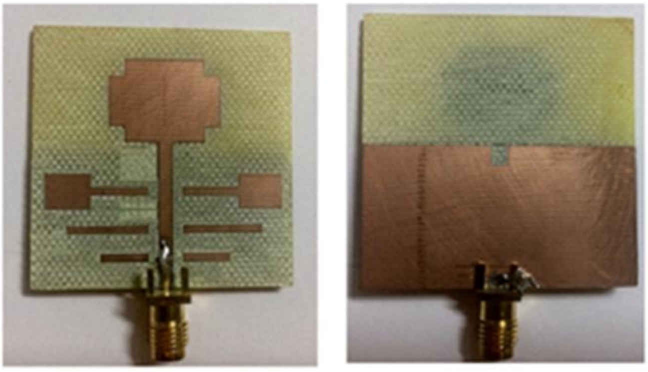


Fig. 1. Antenna design

The designing details of the antenna is illustrated in Fig. 1. The operating frequency of the rectangular patch in the design is 5.2 GHz. The substrate used is FR4-epoxy with dielectric constant 4.4, in the dimension 40 mm X 40 mm X 1.6 mm. Designing of the antenna is done based on procedural equations by Balanis [17]. The antenna dimensions are listed in Table 1. The defective ground plane with dimension 40 mm X 20.75 mm ensures the working of antenna in ultra wideband range. The defective ground is cut with a slot of dimension 2.36 mm X 2.9 mm in order to achieve impedance matching. The main transmission line is associated with six extended transmission lines.

Revised Manuscript Received on 30 July 2019.
* Correspondence Author
Ros Marie C Cleetus*, Department of Electronics & Communication Engineering, Karunya Institute of Technology and Sciences, Coimbatore, Sahrdaya College of Engineering and Technology, Kodakara, India.
G Josemin Bala, Department of Electronics & Communication Engineering, Karunya Institute of Technology and Sciences, Coimbatore, India.

These six transmission lines are either connected to or disconnected from the main line by six switches, SW1 to SW6. The switches can be either PIN diodes, MEMS or varactors. For the simulation purpose, conducting sheets are used as switches. Copper metallization with thickness 18 μm is used in the antenna as conducting sheets or planes. The sheets are inserted and removed to represent the states 'ON' and 'OFF' respectively. Figs. 2 (a), (b) shows up the front and back views of the fabricated antenna with all the switches OFF or no conducting sheets connecting main transmission line with the extended transmission lines.



(a) (b)

Fig. 2. Fabricated structure's views (a) Front (b) Back

Table. 1. The proposed antenna's dimensions in mm

L	L_1	L_2	L_3	L_4	L_5	L_6
40.0	22.07	1.40	2.90	20.75	14.0	8.16
L_7	L_p	L_{sp}	L_s	W	W_1	W_2
3.86	13.00	5.53	1.40	40.0	20.0	30.0
W_3	W_4	W_5	W_p	W_{sp}	W_s	L_c&W_c
22.75	2.36	19.0	17.50	6.61	2.50	2.50

III. RESULTS OBTAINED

A. The Reflection characteristics

Ansoft HFSS 19 is the software used to carry out the simulations. The presence of six switches in the design contributes a total of 64 switching configurations. The surface current distribution in each of these configurations is different and it leads to varying operating frequencies for them. The 64 configurations are analyzed in terms of their band of frequencies, bandwidth and corresponding return loss. Out of these, 4 configurations with better performances are selected and numbered as Configuration I to IV. The selected switching configurations of the design is shown in Table 2 and the corresponding simulated results of the configurations are listed in Table 3.

Table. 2. Switching configurations

Configuration	Switching States
I	All Switches OFF
II	SW_2 is ON, All other switches OFF
III	SW_4 is ON, All other switches OFF
IV	SW_5 is ON, All other switches OFF

Table. 3. Simulated results of the configurations

Configuration	Frequency Band (GHz)	Bandwidth (GHz)	Return Loss (dB)
I	3.02 to 9	5.98	< -10.00
II	3.45 to 6.45	3	-16.60
III	5.04 to 7.65	2.61	-22.50
IV	7.04 to 8.58	1.54	-20.80

The reflection characteristics of Configuration I, both measured and simulated, can be compared from Fig. 3 and are found to be matching. To measure the results, N9915A FieldFox Microwave Analyzer of Keysight Technologies is used. The simulated results of Configuration I indicate an ultrawide band response from 3.02 GHz to 9 GHz and the measured results also give responses in the range 3.13 GHz to 9 GHz. The bandwidth of simulated and measured results is found to be 5.98 GHz and 5.87 GHz respectively. The simulated reflection characteristics of Configuration II to IV is presented in Fig. 4. Narrow bands within the wide band of Configuration I is resulted, as per the simulated reflection coefficients of Configurations II to IV. The bandwidths of these narrow bands are found to be significant as they range from 1.54 GHz to 3 GHz.

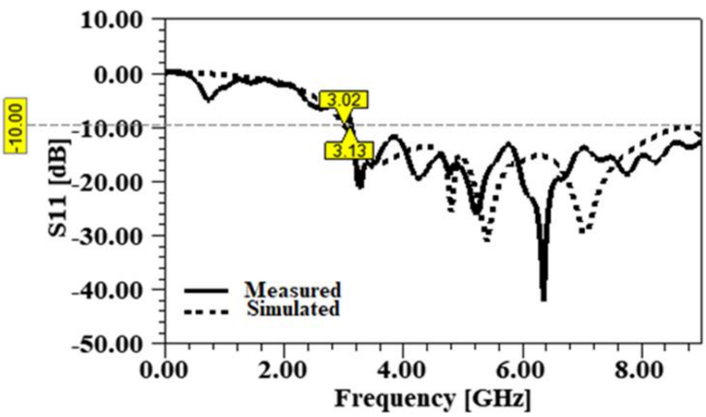


Fig. 3. Simulated and measured reflection characteristics of configuration I

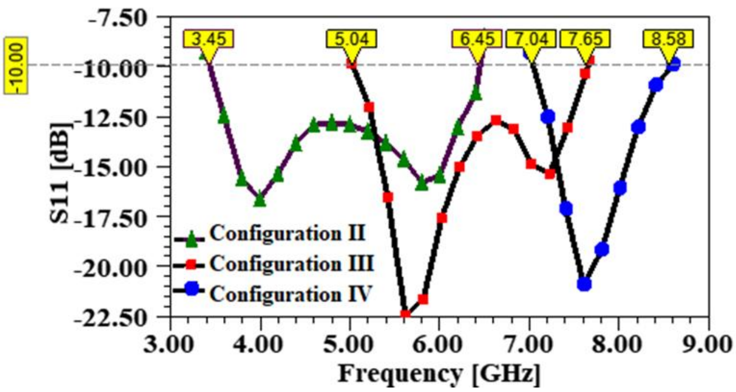


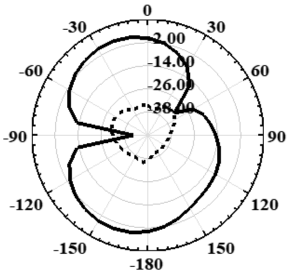
Fig. 4. Simulated reflection characteristics of configurations II to IV

Retrieval Number: B2714078219/19©BEIESP
DOI: 10.35940/ijrte.B2714.078219
Journal Website: www.ijrte.org

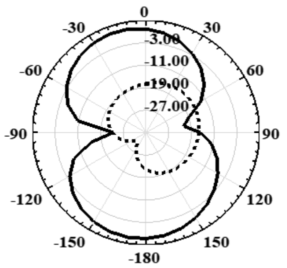
Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

The bands of frequencies covered by the antenna ensures its applicability in 5.2/5.8GHz (5.15–5.35 GHz/5.725–5.825 GHz) WLAN (Wireless Local Area Network) standards, Sub-6GHz 5G (3.50GHz) applications, Video PMSE (Video Program Making and Special Events) applications at 7 GHz (7.110-7.250 GHz and 7.300- 7.425 GHz), 3.5 GHz (3.3-3.7 GHz)/5.5 GHz (5.25–5.85 GHz) WiMAX (Worldwide Interoperability for Microwave Access) bands, Satellite allocations (5.925-8.5GHz) and Cognitive Radios.

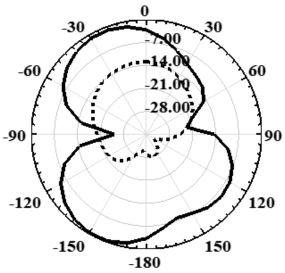
B. Pattern Characteristics



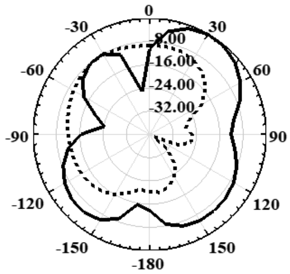
(a) Conf. I at 5.2 GHz



(b) Conf. II at 4 GHz



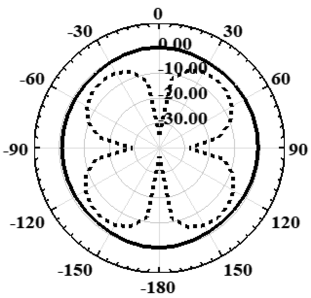
(c) Conf. III at 5.7 GHz



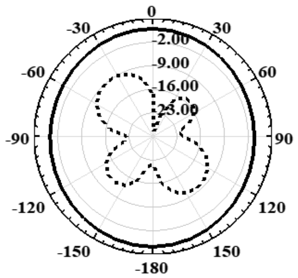
(d) Conf. IV at 7.6 GHz

Fig. 5. Co-polarization (solid line) and cross-polarization (dotted line) pattern in the E plane (a)-(d) Configurations I to IV

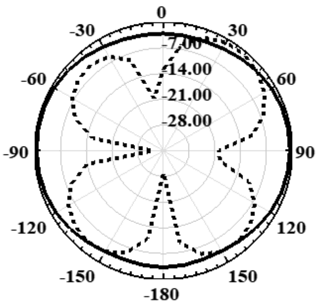
,



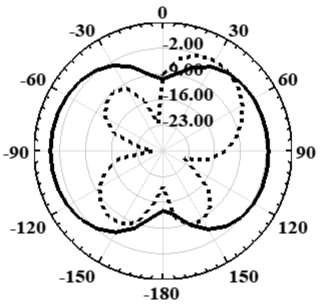
(a) Conf. I at 5.2 GHz



(b) Conf. II at 4 GHz



(c) Conf. III at 5.7 GHz



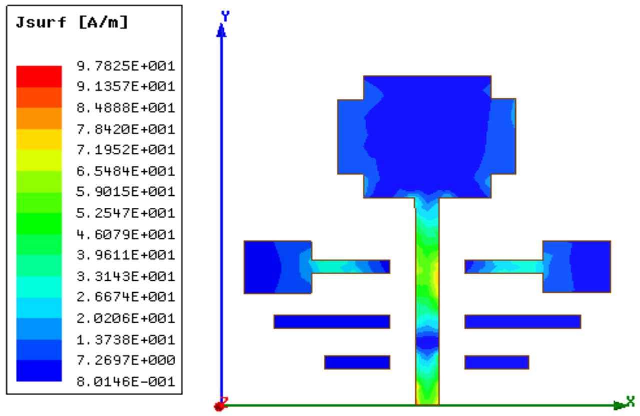
(d) Conf. IV at 7.6 GHz

Fig. 6. Co-polarization (solid line) and cross-polarization (dotted line) pattern in the H plane (a)-(d) Configurations I to IV

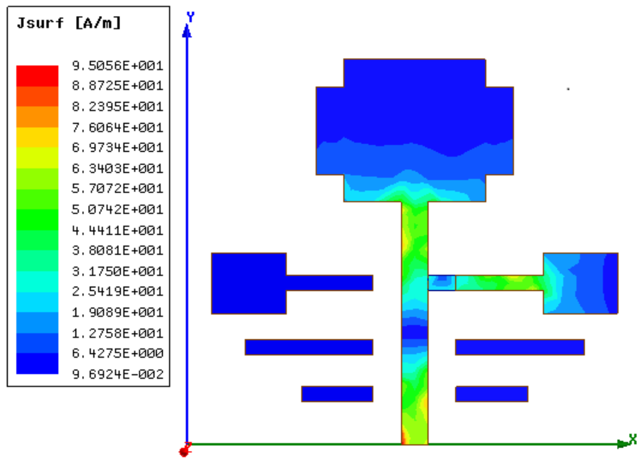
The simulated co-polarization and cross-polarization patterns for each configuration in the E plane are shown in Fig. 5 and that of the H plane are shown in Fig. 6. For each configuration, the pattern is decided based on the frequency with the lowest return loss or reflection characteristics. For Configurations I to IV, the operating frequencies are 5.2 GHz, 4 GHz, 5.7 GHz and 7.6 GHz respectively. As per Configuration I, the E-plane co-polarization pattern is of shape, 'Figure of 8' and H-plane co-polarization pattern is omnidirectional. The cross-polarizations are found out to be lower than that of co-polarization. The other configurations are having slightly varied patterns from that of Configuration I as they are unsymmetrical structurally.

C. Surface Current Distribution

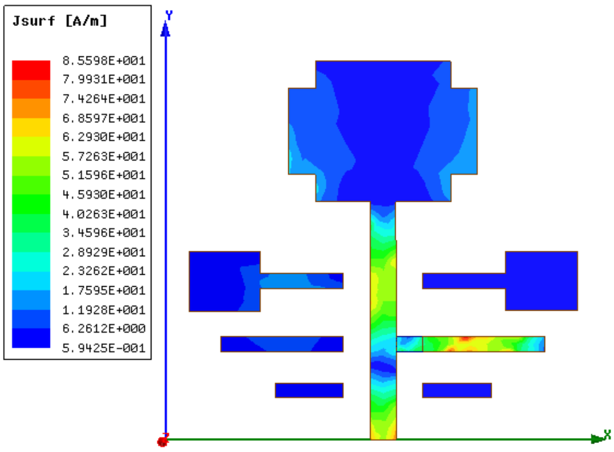
The distribution of surface current at the patch and ground plane surfaces of the configurations I to IV according to the resonance frequencies can be seen with Fig. 7 and Fig. 8. The current distribution is varied according to the switching status. In configuration I, main feed line is connected to no extended transmission lines. Hence the current is distributed over the main feed line alone. But in other configurations, main feed line is connected to extended transmission lines by means of switches, and the surface current seems to be distributed to the extensions also.



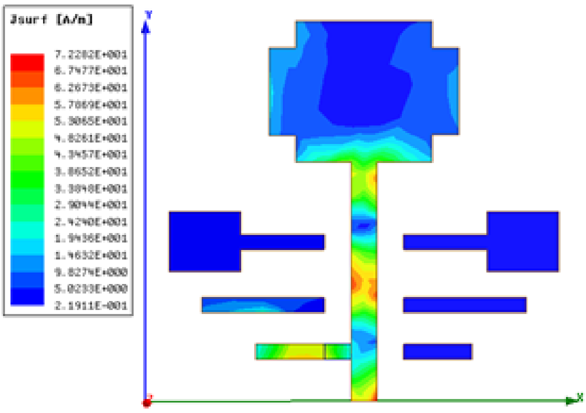
(a) Conf. I at 5.2 GHz



(b) Conf. II at 4 GHz

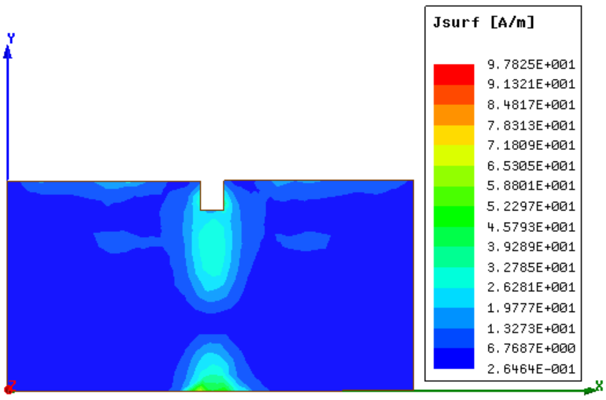


(c) Conf. III at 5.7 GHz

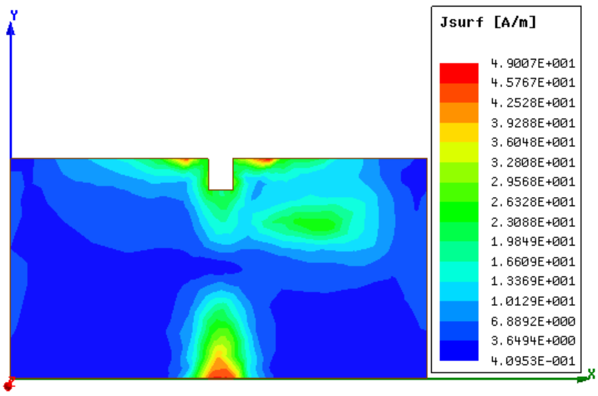


(d) Conf. IV at 7.6 GHz

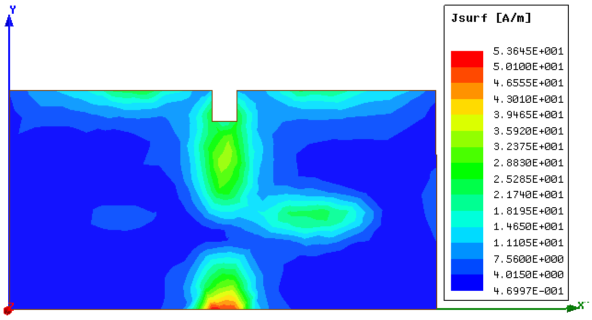
Fig. 7 (a)-(d). Surface current distribution at the patch surface of configurations I to IV.



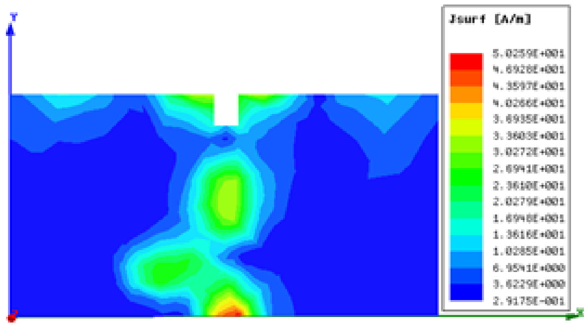
(a) Conf. I at 5.2 GHz



(b) Conf. II at 4 GHz



(c) Conf. III at 5.7 GHz



(d) Conf. IV at 7.6 GHz

Fig. 8 (a)-(d). Surface current distribution at ground plane of configurations I to IV.

IV. CONCLUSION

The reconfigurable antenna presented in this paper makes use of six conducting sheets as switches to ensure reconfigurability over various frequency bands. Out of sixty-four, four switching configurations result coverage in a wide band as well as three narrow bands. The first configuration makes the antenna to operate from 3.02 to 9 GHz, as per simulation and 3.13 to 9 GHz as per measurement. The other three configurations cover three narrow bands ranging from 3.45 to 8.58 GHz, altogether. The polarizations, both in desired and undesired directions in E-plane as well as H plane are discussed. The distribution of the surface current over the patch surface and the ground plane have been detailed for all the configurations. This makes the antenna a suitable candidate for applications in WLAN, WiMAX, PMSE, Sub-6GHz 5G applications, Cognitive Radio, Satellites, etc.

REFERENCES

1. N. Haider, D. Caratelli, and A. G. Yarovoy, “Recent developments in reconfigurable and multiband antenna technology,” in *Int. J. of Ant. and Propag.*, Article ID.869170, 2013, pp. 1-14.
2. C. G. Christodoulou, Y. Tawk, S. A. Lane and S. R. Erwin, "Reconfigurable antennas for wireless and space applications," *Proc. of the IEEE*, vol. 100, no. 7, Jul. 2012, pp. 2250-2261.
3. Y. I. Abdulraheem et al., "Design of frequency reconfigurable multiband compact antenna using two PIN diodes for WLAN/WiMAX applications," IET Microwaves, Ant.s & Propag., vol. 11, no. 8, 2017, pp. 1098-1105.
4. A. Romputtal and C. Phongcharoenpanich, "Frequency reconfigurable multiband antenna with embedded biasing network," IET Microwaves, Ant. & Propag., vol. 11, no. 10, 2017, pp. 1369-1378.
5. A. Gupta and P. Chawla, "RF MEMS technology with reconfigurable RF front end mobile terminals," in *Proc. of the 2nd Int. Conf. on Inventive Systems and Control*, India, 2018, pp. 408-412.

6. A. A. Ibrahim, A. Batmanov and E. P. Burte, "Design of reconfigurable antenna using RF MEMS switch for cognitive radio applications," in *Proc. of the Progress in Electromag. Research Symp. - Spring*, St. Petersburg, 2017, pp. 369-376.
7. J. M. Floc'h and I. Ben Trad, "Printed planar double inverted-F antenna with large frequency reconfigurability range," in *Proc. of the European Radar Conf.*, Nuremberg, 2017, pp. 441-444.
8. Z. Mahlaoui, E. Antonino-Daviu, M. Ferrando-Bataller, H. Benchakroun and A. Latif, "Frequency reconfigurable patch antenna with defected ground structure using varactor diodes," in *Proc. of the 11th European Conf. on Ant. and Propag.*, Paris, 2017, pp. 2217-2220.
9. Y. Tawk, A. R. Albrecht, S. Hemmady, G. Balakrishnan and C. G. Christodoulou, "Optically pumped frequency reconfigurable antenna design,' *IEEE Ant. and Wireless Propag. Lett*., vol. 9, 2010, pp. 280-283.
10. A. Andy, P. Alizadeh, K. Z. Rajab, T. Kreouzis and R. Donnan, "An optically-switched frequency reconfigurable antenna for cognitive radio applications," in *Proc. of the 10th European Conference on Ant. and Propag.*, Davos, 2016, pp. 1-4.
11. Y. Song et al., "An on-chip frequency-reconfigurable antenna for Q-band broadband applications," *IEEE Ant. and Wireless Propag. Lett*., vol. 16, 2017, pp. 2232-2235.
12. X. l. Yang, J. C. Lin, G. Chen and F. l. Kong, "Frequency reconfigurable antenna for wireless communications using GaAs FET switch," *IEEE Ant. and Wireless Propag. Lett.*, vol. 14, 2015, pp. 807-810.
13. P. Lotfi, M. Azarmanesh and S. Soltani, "Rotatable dual band-notched UWB/Triple-band WLAN reconfigurable antenna," *IEEE Ant. and Wireless Propag. Lett.*, vol. 12, 2013, pp. 104-107.
14. Y. Tawk, J. Costantine, K. Avery and C. G. Christodoulou, "Implementation of a cognitive radio front-end using rotatable controlled reconfigurable antennas," *IEEE Trans. on Ant. and Propag*., vol. 59, no. 5, 2011, pp. 1773-1778.
15. W. Farooq, M. Ur-Rehman, Q. H. Abbasi and K. Qaraqe, "A circular patch frequency reconfigurable antenna for wearable applications", in *Proc. of the IEEE 11th Int. Conf. on Wireless and Mobile Computing, Networking and Communications*, Abu Dhabi, 2015, pp. 103-106.
16. F.N. Ayoub, C. D. Woehrle, Y. Tawk, D. T. Doyle, C. G. Christodoulou and J. Costantine, "Frequency-tunable patch array using highly anisotropic liquid crystal", in *Proc. of the IEEE Ant. and Propag. Society Int. Symp.,* Memphis, 2014, pp. 1664-1665.
17. Constantine A. Balanis, *Antenna Theory: Analysis and Design*, Wiley-Interscience, 2005.

AUTHORS PROFILE

Ros Marie C Cleetus received the Bachelor's degree from M. G. University, Kottayam in 2010 and completed Masters from University of Calicut, Malappuram, in 2013 in Engineering. Presently she is a Research Scholar in the Dept. of ECE, KITS, Coimbatore. She is working in the Dept. of ECE at SCET, Kodakara. Her interests of research lie in Wireless Technologies of Communication, Reconfigurable Antennas, Cognitive Radio, etc.

G. Josemin Bala received her Bachelor's degree from Bharathidasan University, Tiruchirappalli, in 1996, and Master's degree the Master's degree from REC, Trichy, in 1999. She was honored with PhD from Anna University, Tamilnadu in 2008.Currently she is working in the Dept. of ECE, KITS, Coimbatore as a Professor. She is interested in researches on RF Systems and Communication Networks. Her works have been published in a number of proceedings and indexed journals. Recently, she was awarded for her excellence as woman educator by NFED in 2017 for her contributions and achievements in the field of Engineering.