Design And Development of a Low Profile IOT Based Frequency Controlled Reconfigurable Antenna for Wireless Applications

Surendra Loya, SK. Nayeem Basha, A.Sai Naveen, K. Roopchand, E. Subhash
Department of ECE, Usha Rama College of Engineering and Technology, Telaprolu,521109 JNTUK, Kakinada, A.P.

Abstract-This white paper describes the design and analysis of antennas for WIMAX, ISM (industrial, scientific and medical) band and X-band microwave sensor applications. The design antenna is built on a polyamide substrate with a restricted ground plane with compact dimensions of 27.5 x 8 x 0.6 mm. The product antenna captures microwave signals applicable to WIMAX, ISM, &WALN, and X-band in adjustable frequency ranges of 3.2-3.9, 5.1-6.5, and 8.2-12 GHz respectively. The proposed antenna has excellent impedance matching, high gain and omnidirectional radiation pattern.

Index Terms CDAC. IoT. Reconfigurable antenna, PIN diode.

1.INTRODUCTION

An antenna is a device that is designed to transmit or receive electromagnetic waves. It is a key component of any wireless communication system and is responsible for converting electrical signals into electromagnetic waves and vice versa. Antennas can come in various shapes and sizes, depending on the application and frequency range they are designed to operate in. Some common antenna types include dipole antennas, patch antennas, horn antennas, parabolic reflector antennas, and helical antennas, to name a few. Antennas can be used for a wide range of applications, including wireless communication, television and radio broadcasting, radar systems, remote sensing, satellite communication, and even medical devices. The performance of an antenna depends on several factors, including its gain, bandwidth, radiation pattern, and impedance matching. Antenna designers must carefully consider these factors to optimize the performance of the antenna for its intended use. Overall, antennas play a critical role in wireless communication systems, and their design and optimization are essential for achieving reliable and efficient communication.

2.ANTENNA GEOMETRY

2.1 Basic antenna

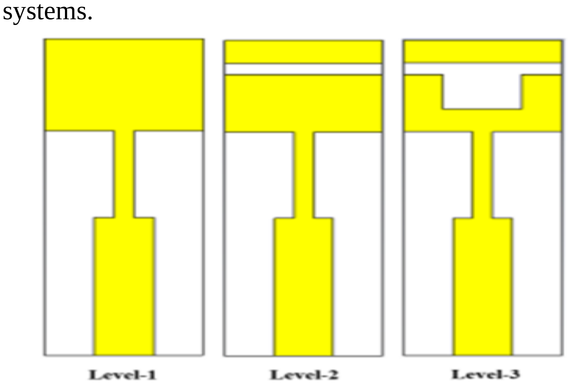
Construction of the proposed antenna geometry layout started with a square structure with a partial ground plane (plane 1 in corresponding reflection coefficient is shown in Fig. 2. In the next level (level-2), the design is modified by inserting a horizontal rectangular slot in the square patch, and this results in the upper strip got separated from the remaining segment of the patch. By inspiring the features of beveled structure such as impedance matching and reduction of return loss, further, level-2 is modified by removing another rectangular portion in the lower segment of the radiating patch. The entire slot structure is looking like bevelling with asymmetric dimensions. This is implemented, expecting that the beveled slotted structure could provide proper impedance matching as in by minimizing the reflections of the surface currents. The geometry of the proposed antenna is presented in Fig. 1(b). The antenna design consists of a 27.5x8x0.6 mm^3 substrate and square-shaped patch with a partial ground plane. The antenna's dimensional characteristics are shown in Table 1. The polyimide substrate is used in antenna design. This substrate material has the exceptional combination of thermal stability ([500>C}), mechanical toughness, chemical resistance, lower coefficient of thermal expansion; also, it ensures the antenna with a small form factor useful for easier integration into compact IoT modules.

The proposed antenna is simulated using the CST Microwave Studio 2019 full-wave electromagnetic solver. The simulated reflection coefficient of the proposed antenna with its designed evolutions (Level-1, Level-2, and Proposed antenna) is shown in Fig. 2. In level-1, the reflection loss across the frequency sweep is high, whereas, in level-2, the horizontal slot etching in the radiating patch introduced an operating band between 7–9.5 GHz. Further, the beveled slot has added to an additional operating band near 3.8, 5.9 GHz, and the initial band (of level-2) shifted to the 9–12 GHz region.

2.2 Reconfigurable antenna

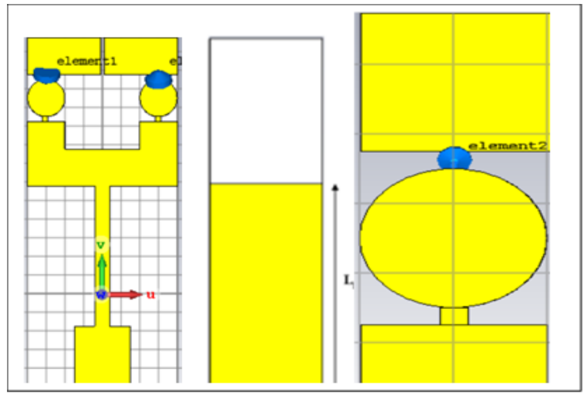
A frequency reconfigurable antenna (FRA) is an antenna that is designed to operate over a wide frequency range and can be dynamically adjusted to operate at specific frequencies within that range. These antennas can adjust their resonant frequency by changing their physical dimensions or by using electronic means, such as by altering the capacitance or inductance of the antenna. Frequency reconfigurable antennas are becoming increasingly important in modern wireless communication systems as they provide the ability to adapt to changing frequency bands and optimize the performance of the antenna for specific applications. These antennas can be used in a wide range of applications such as wireless communication, military systems, satellite communication, radar systems, and medical devices. One of the key advantages of FRA is their ability to switch between frequency bands without the need for multiple antennas, which can reduce the cost and complexity of a system. Additionally, FRA can be designed to have low profile and conformal shapes, making them suitable for integration into compact and portable devices.

Overall, frequency reconfigurable antennas offer a flexible and adaptable solution for a wide range of wireless communication applications, and their importance is expected to grow with the increasing demand for high-performance and versatile wireless systems.



(a)

Fig. 1 a Antenna



(b)

Fig. 1 (a) Antenna Iterations (b) Proposed antenna front and back view

Iterations Proposed antenna front and back view

The whole structure of the reconfigurable antenna, which is integrated with PIN diodes, is shown in Fig. 3(a). The PIN diode equivalent circuit is shown in Fig. 3(b). The structure is composed of one RF-Port, and two diodes D1, D2 are placed at suitable locations between the gaps existing in the parasitic rectangular strip and the arms of the beveled slotted patch. The frequency reconfigurability is accomplished by using the PIN diodes' switching state, and thus, without increasing the antenna size, multi-functional features are expected to be obtained. To achieve frequency reconfigurability, two BAR64-02v numbered PIN diodes are used as switching elements. A 2.1 X resistor is used in forward biased conditions, as per the datasheet, and a 3.9 killo ohm resistor and 0.13 pF capacitor are used in parallel in the reverse bias as per the equivalent circuit shown in Fig. 3(b). The magnitude of the reflection coefficient of the reconfigurable antenna S11 parameters.

parameters	Dimensions(mm)
Length of substrate	27.5
Width of substrate	8
length of Feedback	12
Width of feedback	3
Length of patch	27.5
Substrate length	16.5
Circle length	2
Circle width	2
Height of antenna	27.5

Table 1: Antenna dimensional characteristics in mm

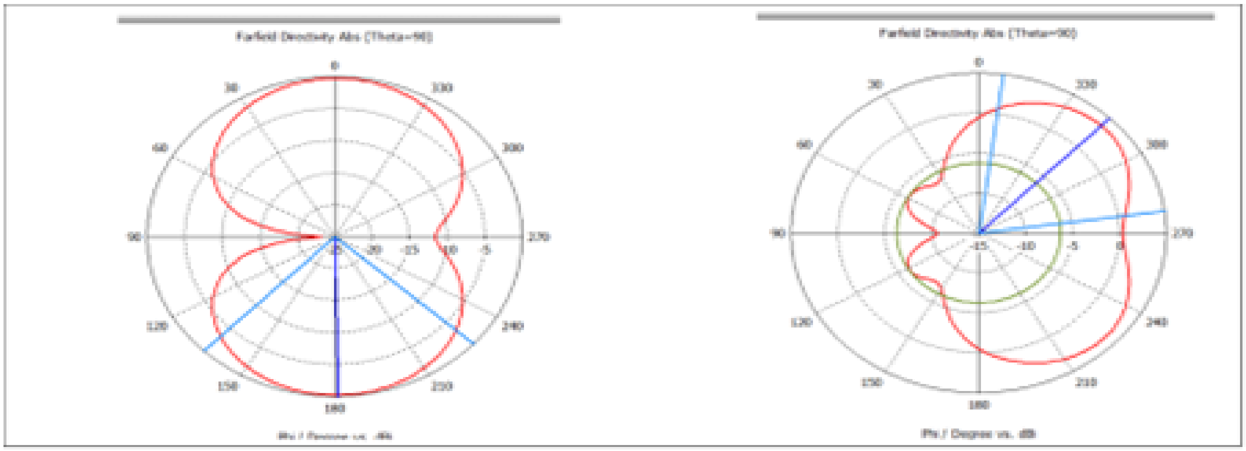
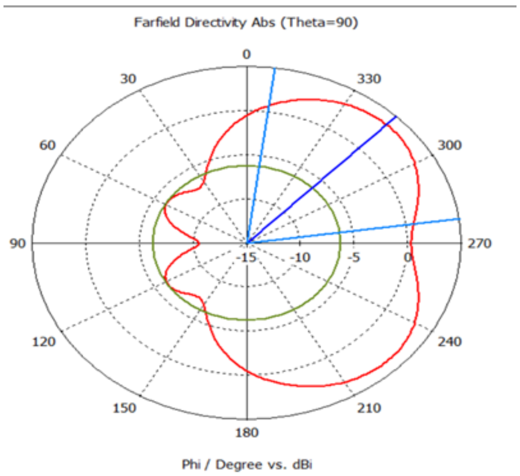


Fig.2 The far filed regions of the antenna for both



simulated and measured at (F=1), (F=6.5) and(F=12) GHZ

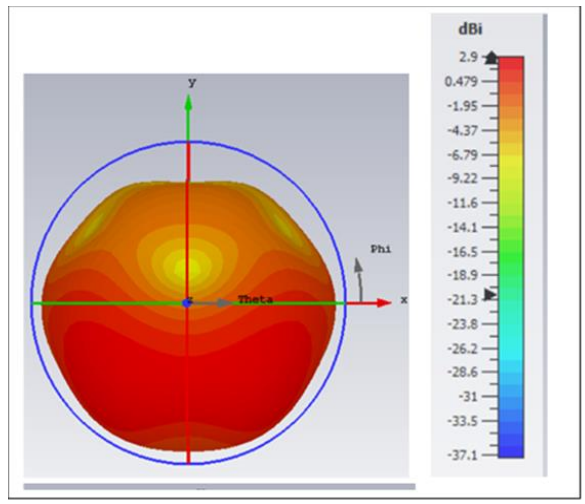
3.Far-Field Regions

The region furthest from the antenna is dominated by radiated electromagnetic fields and is called the far-field region or the Fraunhofer region. This region is immediate to the radiative near-field region

The far-field region can be defined by the following equation:

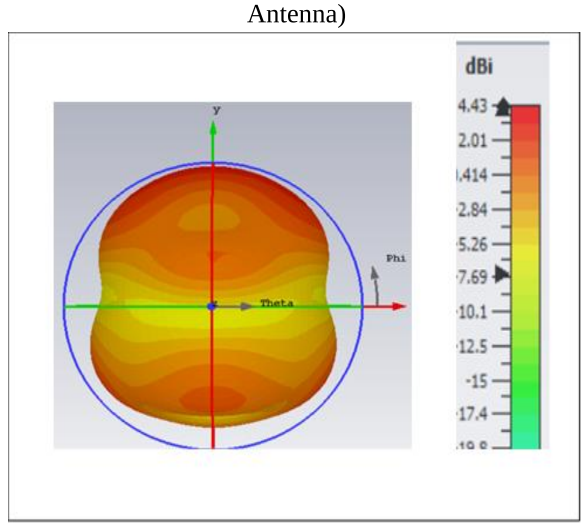
$$\text{Far-field exists at a region} > \frac{2D^2}{\lambda}$$

In this region, the radiation pattern of an antenna is independent of the distance from the antenna. The radiation effect is greater in the far-field region, as the electric and magnetic fields are orthogonal to each other and the direction of propagation is similar to plane waves.



(a)

Fig 3 (a): 6.5GHz resonant frequency (Gain of the Antenna)



(b)

Fig.3(b): 12 GHz resonant frequency (Gain of the Antenna

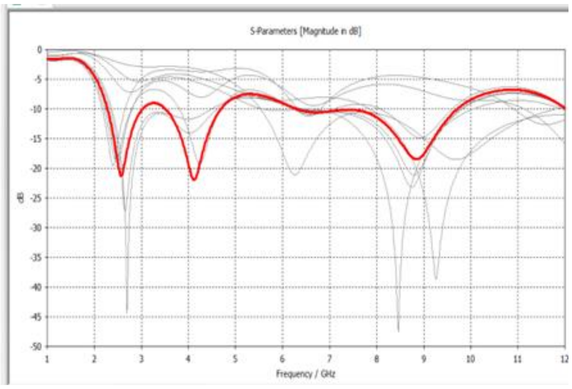


Fig.4 simulated and measured reflection coefficient

As we design a triple band antenna, we occur three different bands at 2.5,4.08,8.8GHz along with -21.0db, -21.7db and -18.51db.

The antenna is design by using Cst micro wave studio in the first frame we take ground and we attached the patch to the antenna. After we simulating results and we import the pin diodes for the antenna which is above mention. finally, we again simulated the antenna under different conditions various on off conditions.

5.HARDWARE RESULTS

In this we seen the fabrication antenna using polyamide substrate why we used this polyimide substrate because of the substrate have the high stability (>500) because it can be used in different temperatures conditions

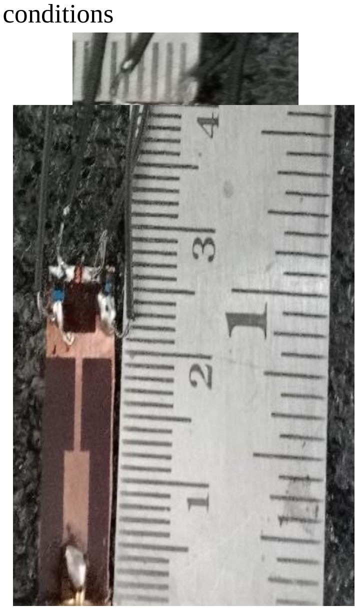


Fig 5(a) Fabrication of antenna

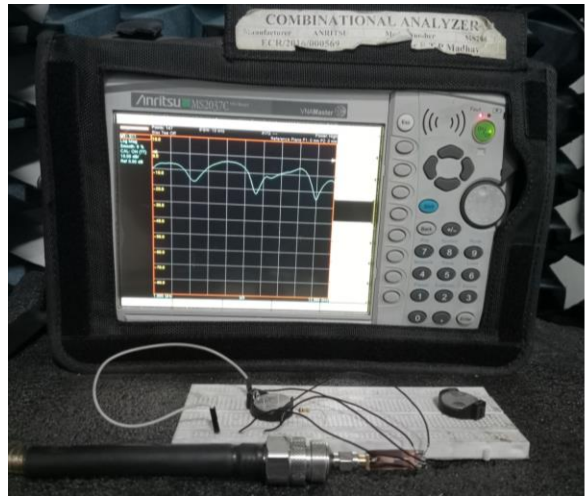


Fig 5(b) Reflection coefficient of fabrication antenna(s11)

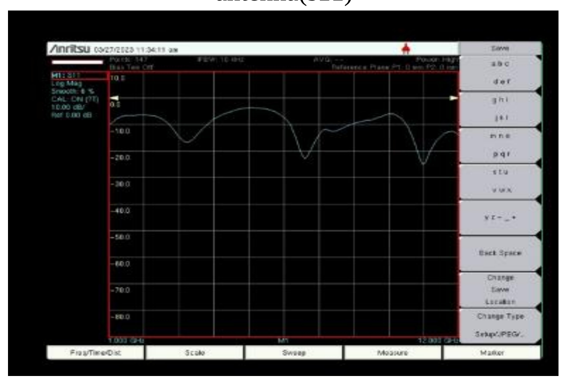


Fig 6 (a) D1-OFF-D2-OFF

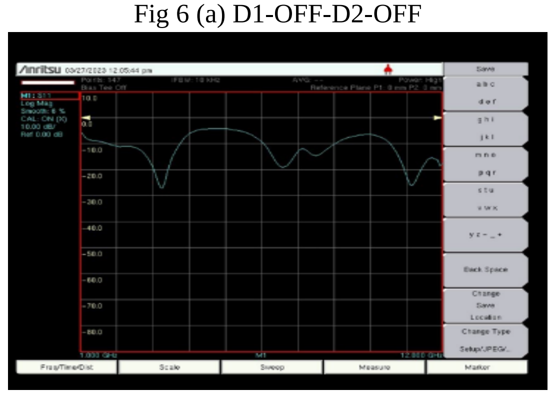


Fig.6(b) D1-ON-D2-OFF

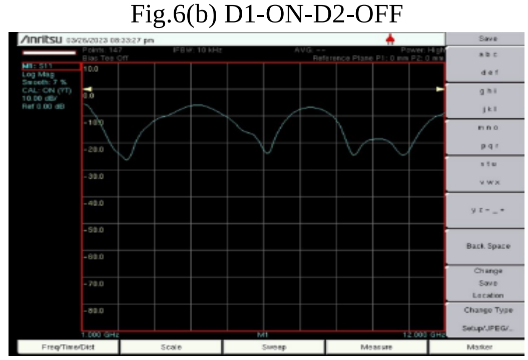


Fig.6(C) D1-ON-D2-ON

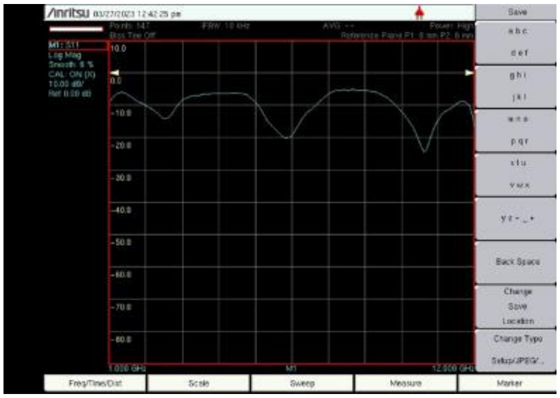


Fig.6(D) D1-OFF-D2-ON

Fig .6 (a-d) The reflection coefficient of the antenna for both simulated and measured in four biasing case of pin diodes

In this way we have four different conditions in these conditions we have shifts the frequency according to the didoes on/of conditions on all cases we occur the good radiation pattern and high gain & VSWR.

CONCLUSION

A frequency reconfigurable antenna is presented. This antenna has very good performance in terms of VSWR, gain and radiation pattern. This is shown above.

REFERENCE

[1] Ren, W. (2008). Compact dual-band slot antenna for 2.4/5GHz WLAN applications. Progress in Electromagnetics Research, 8, 319–327.

[2] Tiang, J. J., Islam, M. T., Misran, N., & Singh, M. (2011). Circular microstrip slot antenna for dual-frequency RFID application. Progress In Electromagnetics Research, 120, 499–512.

[3] Alhegazi, A., Zakaria, Z., Shairi, N. A., Ibrahim, I. M., & Ahmed, S. (2017). A novel reconfigurable UWB filtering-antenna with dual sharp band notches using double split-ring resonators. Progress In Electromagnetics Research, 79, 185–198.

[4] Li, T., Zhai, H., Wang, X., Li, L., & Liang, C. (2014). Frequency reconfigurable bow-tie antenna for Bluetooth, WiMAX, and WLAN applications. IEEE Antennas and Wireless Propagation Letters, 14, 171–174.

[5] Nazir, I., Rana, I. E., Mir, N. U. A., & Afreen, K. (2016). Design and analysis of a frequency reconfigurable microstrip patch antenna switching between four frequency bands. Progress In Electromagnetics Research, 68, 179–191.

[6] Saravanan, M., & Rangachar, M. J. S. (2018). Circular ringshaped polarization reconfigurable antenna for wireless communications. Progress in Electromagnetics Research, 74, 105–113.

[7] Iqbal, A., Smida, A., Mallat, N. K., Ghayoula, R., Elfergani, I., Rodriguez, J., & Kim, S. (2019). Frequency and pattern reconfigurable antenna for emerging wireless communication systems. Electronics, 8(4), 407.

[8] Christodoulou, C. G., Tawk, Y., Lane, S. A., & Erwin, S. R. (2012). Reconfigurable antennas for wireless and space applications. Proceedings of the IEEE, 100(7), 2250–2261.

[9] Vamseekrishna, A., Madhav, B. T. P., Anilkumar, T., & Reddy, L. S. S. (2019). An IoT controlled octahedron frequency reconfigurable multiband antenna for microwave sensing applications. IEEE Sensors Letters, 3(10), 1–4.

[10] Yang, S., Zhang, C., Pan, H. K., Fathy, A. E., & Nair, V. K. (2009). Frequency-reconfigurable antennas for multiradio wireless platforms. IEEE microwave magazine, 10(1), 66–83.

[11] Beigi, P., Zehforoosh, Y., & Nourinia, J. (2019). Enhanced bandwidth reconfigurable single and dual band-notch antenna by using DGS for UWB and KU applications. Journal of Instrumentation, 14(02), P02006.

[12] Beigi, P., Zehforoosh, Y., Rezvani, M., & Nourinia, J. (2019). Evaluation of a compact triangular crinkle-shaped multiband antenna with circular polarized for ITU band based on MADM method. Circuit world., 45(4), 292–299.

[13] Beigi, P., Nourinia, J., & Zehforoosh, Y. (2018). Compact CPWfed spiral-patch monopole antenna with tuneable frequency for multiband applications. Journal of Instrumentation, 13(04), P04014.

[14] Ammann, M. J. (2001). Control of the impedance bandwidth of wideband planar monopole antennas using a beveling technique. Microwave and Optical Technology Letters, 30(4), 229–232.

[15] Shah, S. A. A., Khan, M. F., Ullah, S., & Flint, J. A. (2014). Design of a multi-band frequency reconfigurable planar monopole antenna using

truncated ground plane for Wi-Fi, WLAN, and WiMAX applications. In 2014 International Conference on Open-Source Systems and Technologies (pp. 151–155). IEEE

[16] Saikia, B., Dutta, P., & Borah, K. (2019). Design of a Frequency Reconfigurable Microstrip Patch Antenna for Multiband Applications. In Proceedings of the 5th International Conference on Computers and Management Skills (ICCM 2019) | North Eastern Regional Institute of Science and Technology (NERIST), Nirjuli, Arunachal Pradesh, India.

[17] Ullah, S., Hayat, S., Umar, A., Ali, U., Tahir, F. A., & Flint, J. A. (2017). Design, fabrication, and measurement of triple band frequency reconfigurable antennas for portable wireless communications. AEU-International Journal of Electronics and Communications, 81, 236–242.

[18] Iqbal, A., Ullah, S., Naeem, U., Basir, A., & Ali, U. (2017). Design, fabrication, and measurement of a compact, frequency reconfigurable, modified T-shape planar antenna for portable applications. Journal of Electrical Engineering and Technology, 12(4), 1611–1618.

[19] Ullah, S., Ahmad, I., Raheem, Y., Ullah, S., Ahmad, T., & Habib, U. (2020). Hexagonal shaped CPW feed-based frequency reconfigurable antenna for WLAN and sub-6 GHz 5G applications. In 2020 International Conference on Emerging Trends in Smart Technologies (ICETST) (pp. 1–4). IEEE.

[20] Shah, I. A., Hayat, S., Khan, I., Alam, I., Ullah, S., & Afridi, A. (2016). A compact, tri-band and 9-shape reconfigurable antenna for Wi-Fi, WiMAX, and WLAN applications. International Journal of Wireless and Microwave Technologies (IJWMT), 6(5), 45–53.

[21] Ullah, S., Shaheen, A., Khan, B. A., & Flint, J. A. (2018). A multi-band switchable antenna for Wi-Fi, 3G Advanced, WiMAX, and WLAN wireless applications. International Journal of Microwave and Wireless Technologies, 10(8), 991–997.

[22] Shah, S. A. A., Khan, M. F., Ullah, S., Basir, A., Ali, U., & Naeem, U. (2017). Design and measurement of planar monopole antennas for multi-band wireless applications. IETE Journal of Research, 63(2), 194–204.

[23] L. Ge, and K. M. Luk, “Frequency-Reconfigurable Low-Profile Circular Monopolar Patch Antenna,” IEEE Trans. on Antennas and Propagation, vol. 62, no. 7, pp. 3443-3449, Jul. 2014.

[24] D. Peroulis, K. Sarbandi and P. B. K. Katehi, “Design of reconfigurable slot antennas,” IEEE Trans. on Antennas and Propagation, vol. 53, no. 2, pp. 645- 654, Feb. 2005.

[25] S. V. Shynu, G. Augustin, C. K. Aanandan, P. Mohanan, and K. Vasudevan, “A reconfigurable dual frequency slot loaded microstrip antenna controlled by pin diodes,” Microwave and Optical Technology Letters; vol. 44, no. 4, pp. 374-376, Feb. 2005.

[26] Y. Cai, Y. J. Guo, and P. Y. Qin, “Frequency switchable printed Yagi Uda dipole sub-array for base station antennas,” IEEE Trans. on Antennas and Propagation, vol. 60, no. 3, 1639-1642, Mar. 2012.

[27] K. Behdad, and K. Sarabandi, “Dual-band reconfigur-able antenna with a very wide tenability range,” IEEE Trans. on Antennas and Propagation vol. 54, no. 2, pp. 409-416, Feb. 2006.

[28] Y. Tawk, j. Costantine, and C. G. Christodoulou, “A varactor-based reconfigurable filtenna,” Antennas and Wireless Propagation Letters, vol. 11, pp. 716- 719, jun. 2012.

[29] S.A.A. Shah, M. F. Khan, S. Ullah and J. A. Flint, “Design of a multiband frequency reconfigurable planar monopole antenna using truncated ground plane for Wi-Fi, WLAN and WiMAX applications,” 2014 In International Conference on Open-Source Systems and Technologies (ICOSST), pp. 151-155, DOI 10.1109/ICOSST.2014.7029336

[30] S. V. Shynu, G. Augustin, C. K. Aanandan, P. Mohanan, and K. Vasudevan, “Design of compact reconfigurable dual frequency microstrip antennas using varactor diodes,” Progress In Electromagnetics Research. vol. 60, pp. 197-205, 2006.

[31] F. Yang, and Y. R. Sami, “A reconfigurable patch antenna using switchable slots for circular polariza tion diversity,” Microwave and wireless components letters, vol. 12, no. 3 pp. 96-98, 2002.

[32] M. R. Aghda, M. R. Kamarudin and H. U. Iddi, "Mshape surrounded with ring patch wideband monopole printed antenna," Microwave and optical technology letters, vol. 54, no.2, pp. 482-486, 2012.

[33] S. H. Yeh, and K. L. Wong, "Dual-Band F-Shaped Monopole Antenna for 2.4/5.2GHz WLAN Application," IEEE Antenna and Propagation Society Symp, vol. 34, pp. 72-75, June 2004.