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Design and Investigation of Ultra-Wide Band MIMO Antenna for ISM band/WiMAX/WLAN Applications

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Abstract: In today's era, miniaturized, low profile and easy in fabrication kind of antennas are preferred by the researchers. An Ultra-Wide Band (UWB) MIMO antenna model is designed, analyzed, demonstrated, and fabricated in this paper. The antenna resonates from 1.8 GHz to 11.6 GHz frequency range with moderate gain and efficiency over 80 %. The FR4 material is utilised to develop the cost effective antenna. The ground structure having partial conducting strip is utilized to receive the wide bandwidth. An isolating strip geometry with ground plane geometry is incorporated in the structure to shrink the inter element coupling effect among the radiating components of MIMO antenna. All necessary MIMO output parameters such as Mean Effective Gain (MEG), Channel Capacity Loss (CCL), and Envelop Correlation Coefficient (ECC) are analyzed and observed satisfactory. The design has been verified with the actual performance. The software generated results and the machine generated results are having a very good co-relation. The proposed antenna covers 2.4 GHz, 3.5 GHz and 5 GHz frequencies which are well suitable for ISM band, WiMAX, WLAN applications.

Keywords: *MIMO, wireless communications, UWB antenna*

1. Introduction:

Before two decades, Ultra-Wide Band (UWB) antenna was not investigated and presented due to unawareness regarding its advantages. However, since last 20 years, many researchers have paid their concentration in developing the designing the UWB antennas [1]. In today's era, to design any antenna, the data rate must be higher to fulfil current technology requirement. To improve the data rate, the Multiple radiators based antenna is the suitable candidate. In this antenna, more than one port could be effectively utilised to increase the data rate such as 2x2,4x4 and 8x8 etc. MIMO elements. Due to multiple ports, several ports are simultaneously used to transmit and receive the data [2-4]. The researchers have analysed MIMO techniques for UWB antenna designing. They have systematically explained certain conclusions with various types of MIMO for specific applications [5-8]. When more than one radiating component is involved in a structure, mutual coupling happens which reduce the antenna performance significantly. While designing the MIMO elements, it is highly required that sufficient isolation should be achieved between the radiating components. Minimum 15 dB isolation is acceptable for any geometry to receive optimum response. Various shapes and techniques were adopted to enhance the segregation level between inter radiators MIMO structure such as defective ground plane, parasitic geometries, diversity polarization, lines neutralization or metallic barriers. In [9], 2x2 MIMO antenna was presented with defective ground structure technique to receive the adequate isolation. Due to this, an isolation up to 30 dB was achieved. The projected antenna designed for the C band and X band communication applications. In [10], to increase the isolation above 30 dB, U-shaped geometry has been introduced between the two F-shaped radiators. This MIMO antenna operates for WLAN applications. A miniaturised UWB structure consists of a two orthogonal elements were discussed and presented in [11-14]. Here, to increase the isolation level, a fork-shaped slot was created in bottom layer. Due to this, the isolation is improved and reach up to 20 dB. In recent time, unique types of UWB antennas were proposed for achieving higher isolation between the internal ports. They have designed the structures with and without notch filters [15-25]. Despite of 15 dB seperation, it is advisable to achieve suitable isolation to receive the adequate MIMO response. Electronic circuits could also be implemented using conducting liquids [26,27].

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2. Antenna Geometry:

The proposed antenna has been developed by performing the systematic steps of antenna designing. The figure 1 illustrates the same. The development of two elements antenna model having defected ground plane is visible in figure 2 (a). The figure 1 (b) depicts the antenna view from backside. The slots are introduced in both the radiators to increase the fringing effect. The certain dimensions microstrip lines are provided to excite the antenna. The detailed dimensions are shown table 1. The substrate has been developed from low cost FR4 material. The partial ground plane was introduced to receive ultra-wide band which could cover wide range of frequencies. A simple microctrip line is added with the bottom layer geometry to expand the isolation level between the conducting ports.

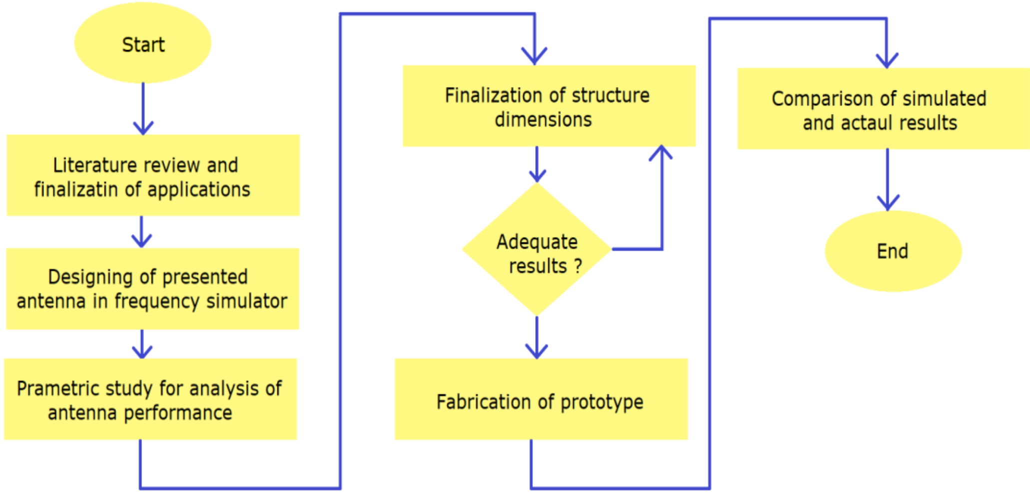
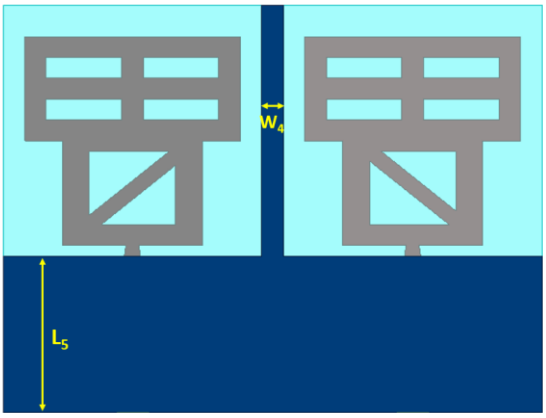


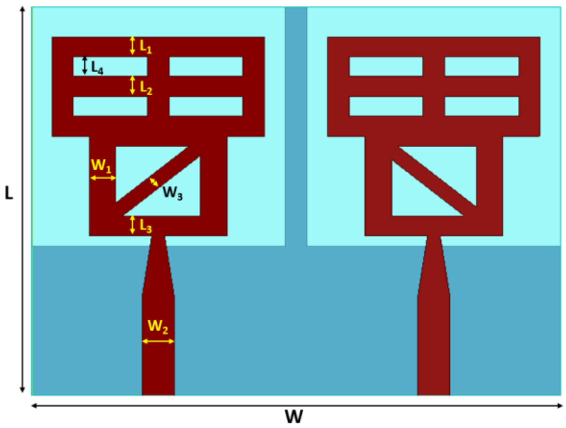
Fig 1. Systematic antenna designing

Table 2. Detailed measurements

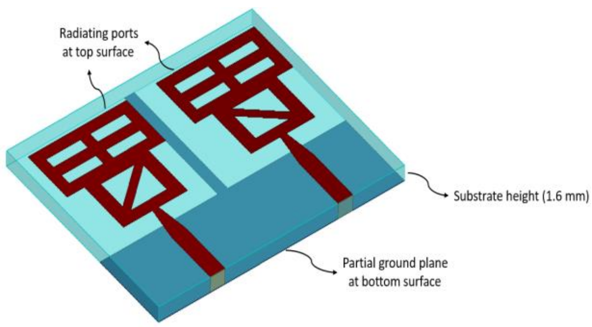
Parameters	Measurements (mm)	Parameters	Measurements (mm)
L1	2	W	50
L2	2	W1	2.5
L3	2	W2	3
L4	2	W3	1.45
L5	15	W4	2
L	39	-	-



(b) View from back

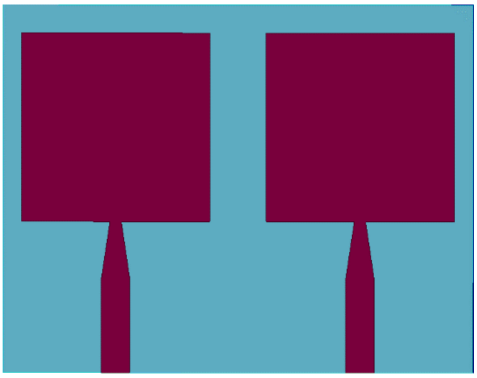


(a) View from top

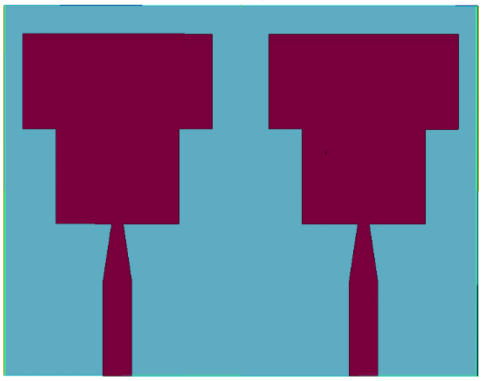


(c) Bird eye view

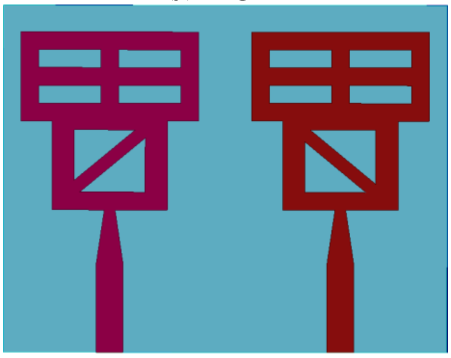
Fig 2. Antenna design



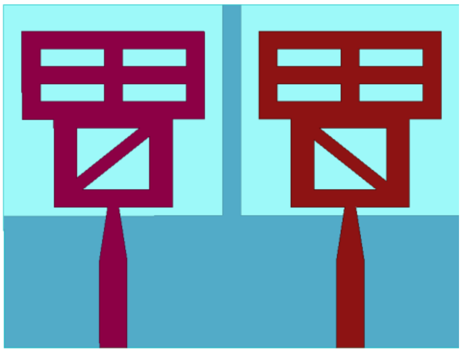
(x) Stage I



(y) Stage II



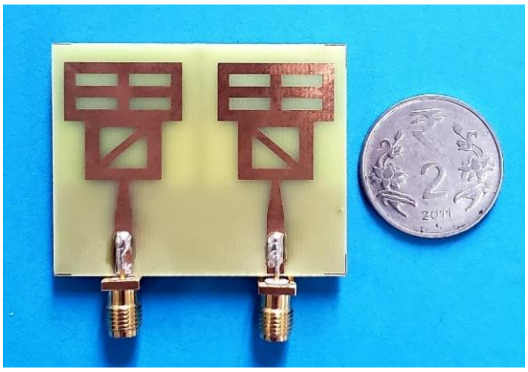
(z) Stage III



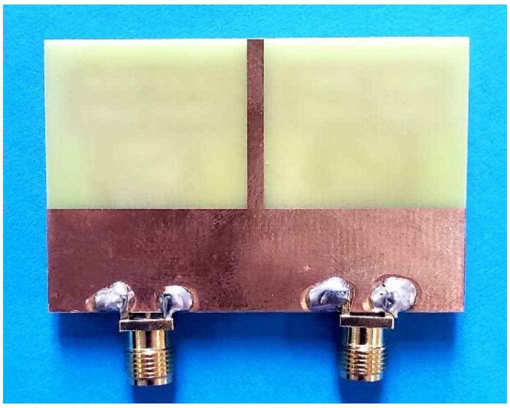
(w) Stage IV

Fig 3. Systematic MIMO antenna designing

The systematic antenna development is given by figure 3. After every designing iteration, the response has been recorded to analyse the particular design. The figure 2 (x), (y), (z) and (w) depict the stage I, II, III and IV respectively.



(w) Front view



(x) Rear view

Fig 4. Fabricated antenna model

The antenna view from top and from back of actual MIMO antenna model could be seen in figure 4 (a) and (b) respectively.

3. Result and Discussion:

The developed design is fabricated and measured. The design was first developed using frequency based simulation software. The software generated and actual return losses were compared for systematic analysis. The figure 5 represents the antenna responses from phase by phase antenna designing. It is noticed through comparison graph that having the projected antenna design, the response and promising. The figure 6 depicts the graph of comparison aforesaid comparison. The measured graph is having very good correlation with the simulated graph. Certain sets of experiments are performed to receive the adequate trade-off between the antenna size miniaturization and output parameters. It is seen from the graph of reflection coefficients that the MIMO antenna elements are having satisfactory isolation level. The MIMO structure radiates from 1.8 GHz to 11.6 GHz frequency band where all targeted resonances are covered for specific applications.

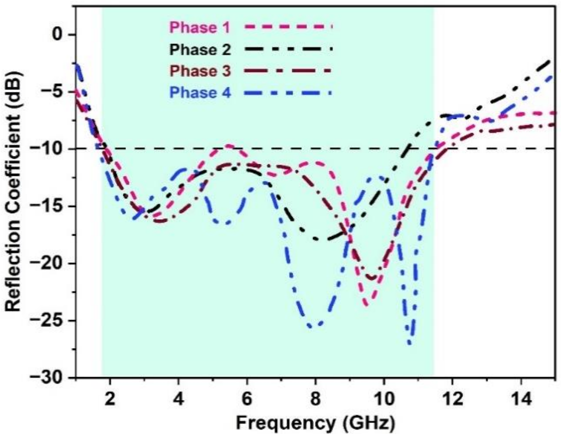


Fig 5. Reflection coefficient values of various antenna phases

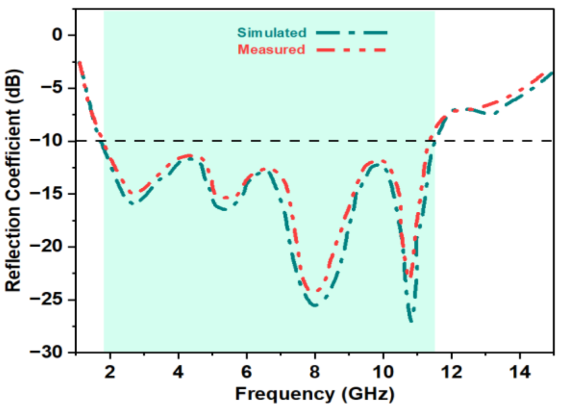
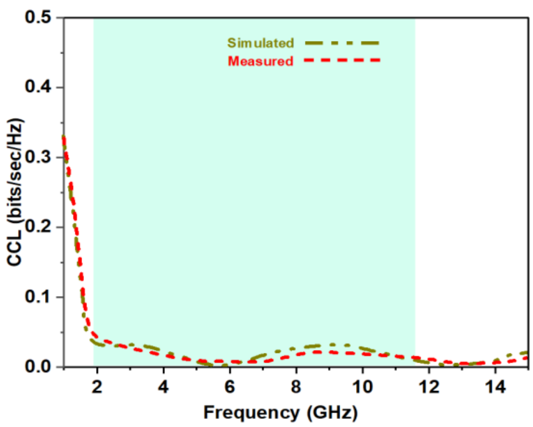


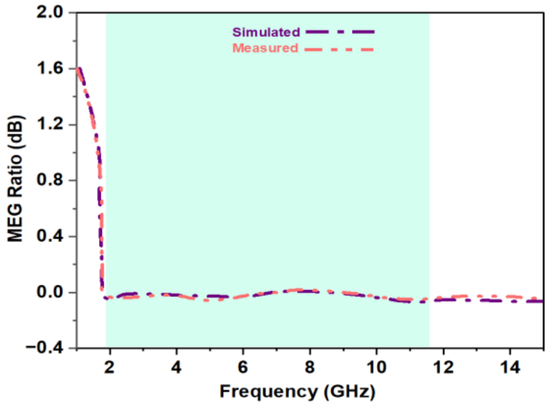
Fig 6. Graph of reflection coefficient Vs. Frequency

4. MIMO Diversity Characteristics:

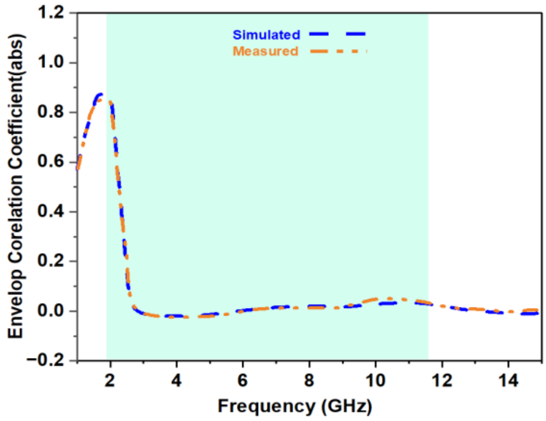
Necessary all diversity parameters of proposed MIMO structures are carried out and presented through figure 7. Mean Effective Gain (MEG), Channel Capacity Loss (CCL), and Envelop Correlation Coefficients (ECC) were carried out for resonating band. The threshold level of data transmission rates could be predicted by close observation of CCL. The depicted CCL values for targeted resonance are below 0.4 bits/sec/Hz. The MEG is nearer to the one for both adjacent and diagonal elements. The correlation factor could be depicted from Envelope Correlation Coefficient (ECC).



(i)



(ii)



(iii)

Fig 7. Received response from antenna (i) CCL (ii) MEG (iii) ECC

The figure 8 shows the graph of gain and efficiency against the resonating band. Despite of having ultra-wide band response the antenna exhibits moderate gain which is above 2 dBi. The proposed antenna structure is efficient and offers at least 80% efficiency for the targeted band.

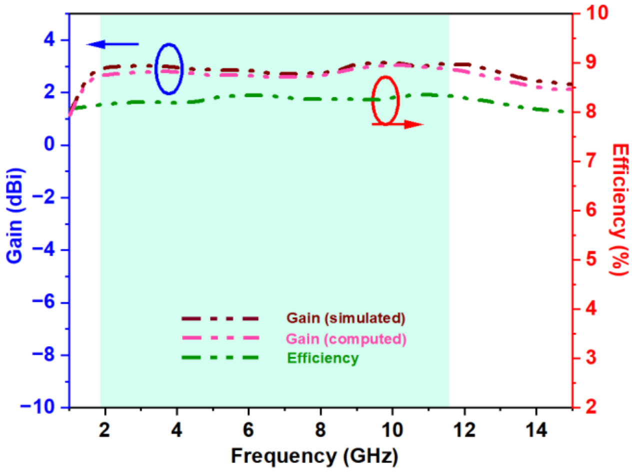


Fig 8. Gain Vs efficiency

The fabricated model has been fixed inside anechoic chamber to receive the actual accurate response. The anechoic chamber is having the dimension of 5m x 5m x 5m. One port is fixed with the anechoic chamber where the other port is connected with 50 Ω terminator. The setup is shown using figure 9.

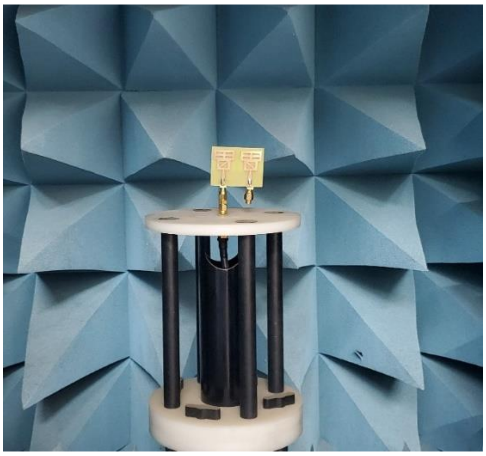
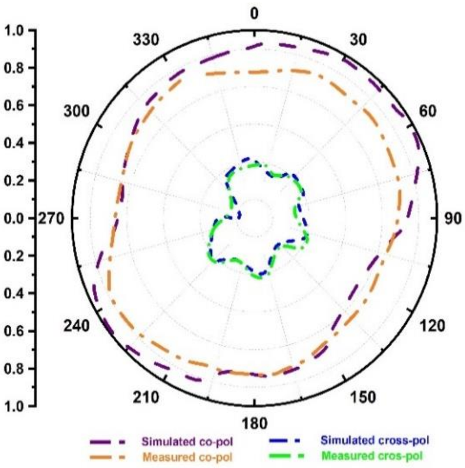
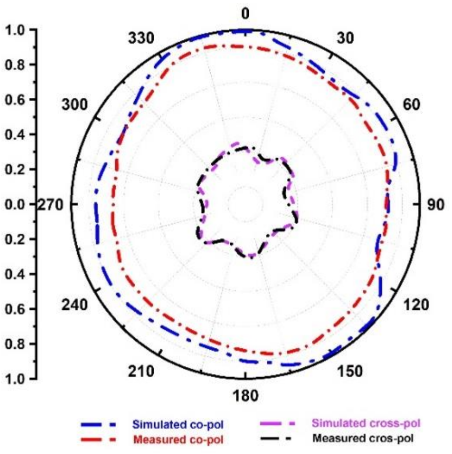


Fig 9. Antenna testing setup

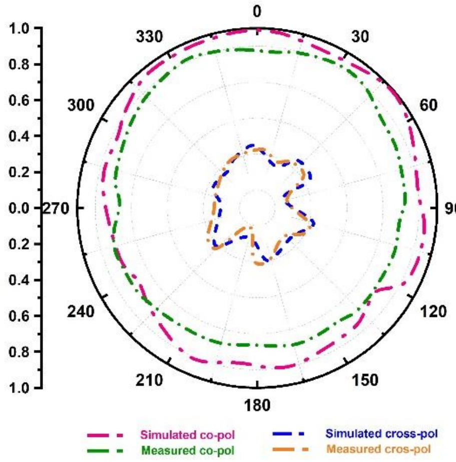
The figure 10 (p), (q) and (r) depicts the 2D radiation pattern for targeted frequencies. The figure illustrates the radiation in favourable direction and undesired direction graphs. The satisfactory isolation is received between the co-pol and cross polarization.



(p) 2.4 GHz



(q) 3.5 GHz



(r) 5 GHz

Fig 10. 2-D Radiation pattern

5. Conclusion:

An Ultra Wide-Band 2 x 2 MIMO was developed and proposed in this paper. To minimize the inter coupling effect amongst the conducting ports, a microstrip geometry is developed and united with ground structure. A limited ground plane is incorporated to receive the ultra -wide band which could cover several frequency bands. The flame retardant material makes the antenna design cost effective. The software generated reflection coefficient values were compared with actual results. There was a very close agreement between those values. Apart from return losses, other output parameters such as MEG, CCL, ECC, were also carried out found satisfactory. The presented antenna exhibits adequate response which includes for 2.4 GHz, 3.5 GHz and 5 GHz frequencies for ISM band, WiMAX and Wireless LAN applications.

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Conflicts of interest:

The authors declare no conflicts of interest.

References:

[1] Federal Communications Commission. (2002). Federal Communications Commission revision of Part 15 of the commission’s rules regarding ultra-wideband transmission systems. FCC, Washington, DC, First Report and Order FCC, 02. V48.

[2] Sturm, C., Porebska, M., Timmermann, J., & Wiesbeck, W.(2007, September). Investigations on the applicability of diversity techniques in ultra wideband radio. In 2007 International Conference on Electromagnetics in Advanced Applications (pp.899-902). IEEE.

[3] Rajagopalan, A., Gupta, G., Konanur, A. S., Hughes, B., & Lazzi,G. (2007). Increasing channel capacity of an ultra-wideband MIMO system using vector antennas. IEEE Transactions on Antennas and Propagation, 55(10), 2880–2887.

[4] Ben, I. M., Talbi, L., Nedil, M., & Hettak, K. (2012). MIMO-UWB channel characterization within an underground mine gallery. IEEE Transactions on Antennas and Propagation, 60(10), 4866–4874.

[5] Lee, J. M., Kim, K. B., Ryu, H. K., & Woo, J. M. (2012). A compact ultra-wideband MIMO antenna with WLAN band-re-jected operation for mobile devices. IEEE Antennas Wireless Propagation Letter, 11, 990–993.

[6] Hong, S., Chung, K., Lee, J., Jung, S., Lee, S. S., & Choi, J. (2008). Design of a diversity antenna with stubs for UWB applications. Microwave and Optical Technology Letters, 50(5), 1352–1356.

[7] Zhang, S., Ying, Z. N., Xiong, J., & He, S. L. (2009). Ultra wideband MIMO/diversity antennas with a tree-like structure to enhance wideband isolation. IEEE Antennas Wireless Propagation Letter, 8, 1279–1282.

[8] See, T. S. P., & Chen, Z. N. (2009). An ultra-wideband diversity antenna. IEEE Trans. Antennas Propagation., 57(6), 1597–1605.

[9] Pouyanfar, N., Ghobadi, C., Nourinia, J., Pedram, K., & Majid- zadeh, M. (2018). A compact multi-band MIMO antenna with high isolation for C and X bands using defected ground structure. Radio engineering, 27(3), 686–693.

[10] Liu, P., Sun, D., Wang, P., & Gao, P. (2018). Design of a dual-band MIMO antenna with high isolation for WLAN applications. Progress In Electromagnetics Research Letters, 74, 23–30.

[11] Tao, J. (2016). Quan yuan Feng, ‘‘Compact isolation-enhanced UWB MIMO antenna with band-notch character.’’ Journal of Electromagnetic Waves and Applications, 30(16), 2206–2214.

[12] Pandya, Aneri, Trushit K. Upadhyaya, and Killol Pandya. "Tri-band defected ground plane based planar monopole antenna for Wi-Fi/WiMAX/WLAN applications." Progress In Electromagnetics Research C 108 (2021): 127-136.

[13] Pandya, Aneri, Trushit K. Upadhyaya, and Killol Pandya. "Design of metamaterial based multilayer antenna for navigation/WiFi/satellite applications." Progress In Electromagnetics Research M 99 (2021): 103-113.

[14] Pandya, Killol Vishnuprasad. "Low Profile Meandered Printed Monopole WiMAX/WLAN Antenna for Laptop Computer Applications." Micromachines 13, no. 12 (2022): 2251.

[15] Jaglan, N., Gupta, S. D., Thakur, E., Kumar, D., Kanaujia, B. K.,& Srivastava, S. (2018). Triple band notched mushroom and uniplanar EBG structures based UWB MIMO/Diversity antenna with enhanced wide band isolation. AEU- International Journal of Electronics and Communications, 90, 36–44.

[16] Mewara, H. S., Jhanwar, D., Sharma, M. M., & Deegwal, J. K. (2018). A printed monopole ellipzoidal UWB antenna with four band rejection characteristics. AEU-International Journal ofElectronics and Communications, 83, 222–232.

[17] Sharma, M., Dhasarathan, V., & Pateld, S. K. (2020). Truong Khang Nguyenb’’,An ultra-compact four-port 494 superwide-band MIMO antenna including mitigation of dual notched bands characteristics designed for wireless network applications’’. AEU International Journal of Electronics and Communications. https://doi.org/10.1016/j.aeue.2020.153332,August

[18] Khorramizadeh, M., & Mohammad-Ali-Nezhad, S. (2021). Radar cross-section reduction of an UWB MIMO antenna using image theory and its equivalent circuit model. International Journal of RF and Microwave Computer-Aided Engineering. https://doi.org/10.1002/mmce.22563

[19] Abdulkawi, W. M., Malik, W. A., Rehman, S. U., Aziz, A., Sheta, A. F. A., & Alkanhal, M. A. (2021). Design of a compact dual- band MIMO antenna system with high-diversity gain performance in both frequency bands. Micromachines. https://doi.org/10.3390/mi12040383

[20] Ahmed, B. T., Olivares, P. S., Campos, J. L. M., & Vazquez, F.M. (2018). (3.1–20) GHz MIMO Antennas. AEU – International Journal of Electronics and Communications, 94, 348–358.

[21] Ahmed, B. T., Carreras, D. C., & Marin, E. G. (2021). Design and implementation of super wide band triple band-notched MIMO antennas. Wireless Personal Communications, 121, 2757–2778.

[22] Khalid, M., Naqvi, S. I., Hussain, N., Rahman, M., Mirjavadi, S.S., Khan, M. J., & Amin, Y. (2020). 4-Port MIMO antenna with defected ground structure for 5G millimeter wave applications. Electronics, 9, 71.

[23] Pandya, Killol V., Jeenal Barot, Trushit Upadhyaya, Upesh Patel, Rajat Pandey, and Aneri Pandya. "Design and Analysis of Low Profile E-shaped Slotted Triple-band Antenna for ISM band/WiMAX/WLAN Applications." International Journal of Computing and Digital Systems 13, no. 1 (2023): 59-67.

[24] Pandya, Killol Vishnuprasad, Trushit Upadhyaya, Aneri Pandya, Upesh Patel, and Poonam Thanki. "Design and Development of Slotted Ultra-Wide Band Antenna for WiMAX and WLAN

Applications." In 2023 IEEE Wireless Antenna and Microwave Symposium (WAMS), pp. 1-5. IEEE, 2023.

[25] Patel, Upesh, Trushit Upadhyaya, Arpan Desai, Rajat Pandey, Killol Pandya, and Brijesh Kundaliya. "3× 3 Split-Ring Resonators Array-Inspired Defected Ground Plane Antenna for 2.4/5.5 GHz Wireless LAN Applications." In Proceedings of International Conference on Communication and Artificial Intelligence: ICCAI 2021, pp. 3-12. Singapore: Springer Nature Singapore, 2022.

[26] Pandya, Killol. "Designing and Implementation of Liquid Electronic Circuits Using Implantable Material-First Step towards Human-circuit Interface." Am. J. Biomed. Sci 9, no. 4 (2017): 244-253.

[27] Pandya, Killol V., and ShivPrasad Kosta. "Synthetic Plasma Liquid Based Electronic Circuits Realization-A Novel Concept." International Journal of Biomedical Science: IJBS 12, no. 3 (2016): 79.