ISSN No.: 2455-6130
Volume 3, Issue 7, 2019, pp. 11-18

website: www.ijoetr.com

International Journal of Emerging Trends in Research

High Isolation with L Shaped Decoupling Structure UWB MIMO Antenna for Wireless Communications

Anchal Chauhan[1], Kapil Kumar[2], Shraddha Sood[3], Gaurav Saxsena[4], Neera Agrawal[5]

[1,3] *Department of ECE, HRIT Ghaziabad, India*

[2] *Department of ECE, Sanskar College of Engineering, Ghaziabad, India*

[4] *Department of ECE, Galgotia College of Engineering, Gr Noida, India*

[5] *Department of ECE, Bhartividyapeeth College of Engineering, New Delhi, India*

Abstract

In this article, a high isolation MIMO antenna is designed to achieve intended characteristics. Proposed antenna is tailored on FR-4 substrate with size of 41×30×1.6mm3. This antenna has semi circular patches which provides better radiation efficiency (>0.5) in the UWB-band (2.2 to 10.6 GHz). High isolation (-20dB) is achieved in entire bandwidth by using L shaped decoupling structure on the ground. Diversity performance of antenna is also judged by the various parameters like ECC, Diversity gain, which has the practically accepted values <0.004, >9.98dB, <0.3bits/sec/Hz and <-30dB correspondingly.

Keywords: Electromagnetic band gap (EBG), Multiple input multiple output (MIMO), Envelope correlation coefficient (ECC).

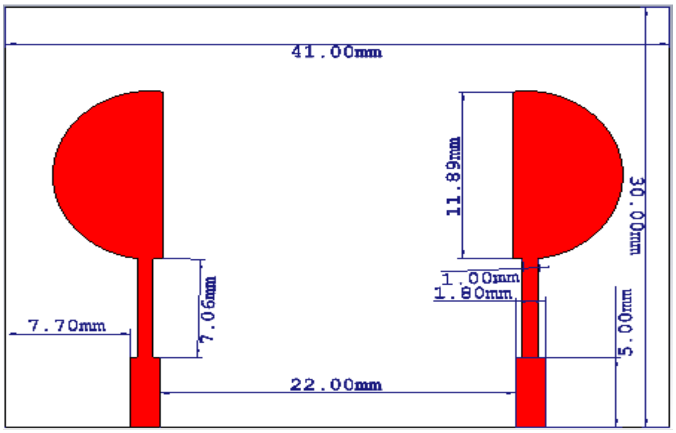
1. Introduction

Wireless communication have seen different generations from single input single output (SISO), multiple input single output (MISO) system to multiple input multiple output (MIMO) systems. In modern generation, bandwidth is considered as one of the dominant factors in wireless communication system for transmission of high data in digital communication services as i.e. voice, data and video. At the receiver end capacity directly manipulates the quality of these communication systems. MIMO (Multiple Input Multiple Output) system provides these features in a competitive and challenging world to provide high data bit rate with low channel capacity loss (CCL) and high signal to noise ratio (SNR). MIMO antennas are widely used in modern wireless RF communication system having improved diversity problem that SISO antenna have [1]. MIMO antenna consists of spatial diversity as well spatial multiplexing capability for a remarkable change in the reliability and data rate of system. The antenna consists of four planar Microstrip lines having open ended fed λ/4 slot to excite the fundamental radiating antenna mode over a prescribed frequency range for achieving enhance isolation between two radiating [2]. The method of Decoupling is introduced for the improvement in isolation between two radiating elements [3]. SRR (Split Ring Resonator) is used to improve the isolation between the two radiating patches [4]. Three open ended slots are used as a decoupling structure for enhancing the isolation between antenna elements [5]. U-shaped slot cut and embedded vertical slot are used to improve the impedance bandwidth [6]. Introduced H-shaped DGS should improve the impedance bandwidth with good isolation of referred antenna [7]. L–shaped decoupling structure in ground plane is extruded which improved the isolation in the MIMO antenna [8]. Electronic band gap (EBG) and co-design approach structures are used to improve isolation of antenna that offers better diversity performance [9-10].

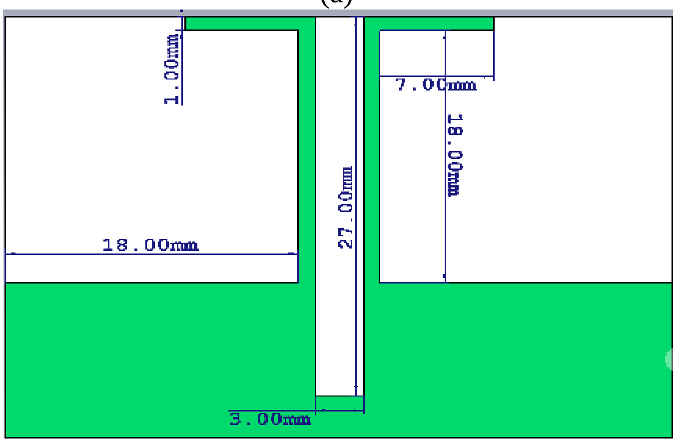
In this paper design EBG (Electronic Band Gap) antenna for isolation improvement in X-band range. Proposed antenna is design on FR-4 substrate with 1.6mm height (h). Section-II shows the antenna analysis and results of proposed MIMO antenna. Section-III shows the diversity performance of proposed MIMO antenna as ECC, DG, MEG, TARC and CCL. A conclusion of the proposed designing work is summarized in section-IV.

2. Antenna Analysis and Results

Front and bottom of patch antenna is presented in Fig.1 (a) including all dimensions of top and (b) dimensions of bottom of antenna.



(a)



(b)

Fig. 1 Proposed UWB-MIMO antenna structure (a) Front view (b) Bottom view.

The fundamental resonant frequency of MIMO antenna is given by Equation (1) [11]. Where, l1 and A1 are the length & area of ground plane, d2 and A2 are the diameter & area of radiating patch in that order.

$$f_r(\mathrm{GHz}) = \frac{144}{l_1 + d_2 + h + \frac{A_1}{2\pi\sqrt{\epsilon_r +1}} + \frac{A_2}{2\pi\sqrt{\epsilon_r +1}}} \quad (1)$$

The S-parameters is measured and the results obtained together with the results of simulation are shown in Fig. 8. The simulated and measured impedance bandwidth of the UWB-MIMO antenna is found to be from 2.2 to 10.6GHz. Thus, the designed antenna satisfied the FCC requirement for UWB band. From Fig.8, the measured S12 shows higher isolation than the simulation result, it is also clearly observed that the isolation between two antenna elements is better than −30dB for the entire UWB range. Measured and Simulated results return loss of proposed MIMO antenna is ≤ -

10dB in entire UWB bandwidth except notch band (WLAN Band). The impedance bandwidth of designed antenna is from 2.2 to 10.6GHz, which completely satisfies with the applications of UWB communications.

.

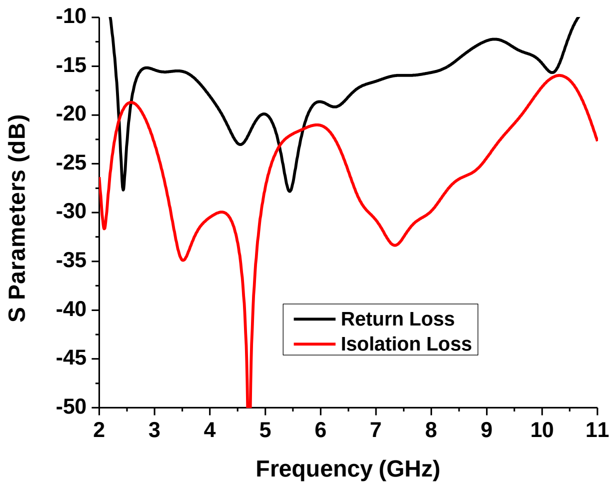
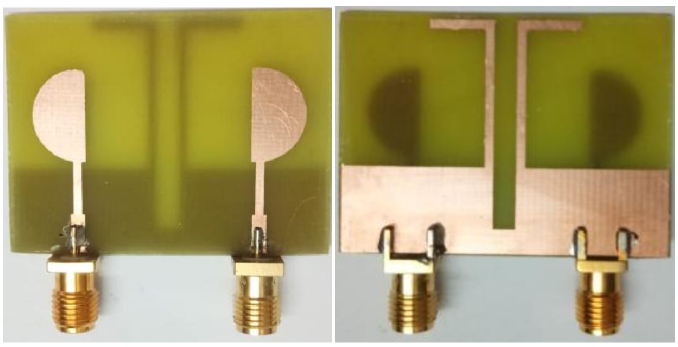


Fig. 2. Scattering parameter of designed MIMO Antenna.

Fig. 2 explained about the S-parameters of proposed MIMO radiator, the Return Loss is less than -10dB in entire UWB-band and Isolation between two antennas is below -20dB in entire band, which gives it a best fit in challenging environment. Fig. 3 (a) shows the fabricated MIMO antenna structure that provides better isolation (S21<-20dB) by using L Shaped decoupling structure on ground.



(a) (b)

Fig. 3 (a) Fabricated MIMO Antenna Front View (b) Fabricated MIMO Antenna bottom View

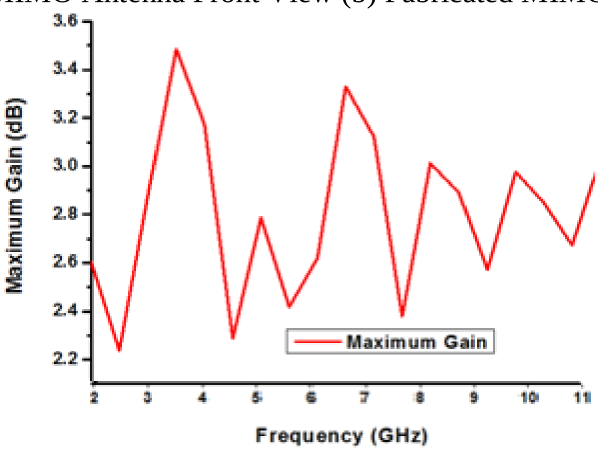
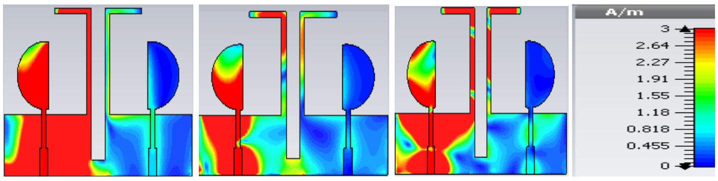


Fig. 4 Simulated maximum gain (MG) of MIMO antenna.



(b) (c)

Fig. 5. Current density of proposed antenna at (a) 2.4 (b) 6.5 (c) 10 GHz frequency when one port is energized and other port is terminated by 50Ω impedance.

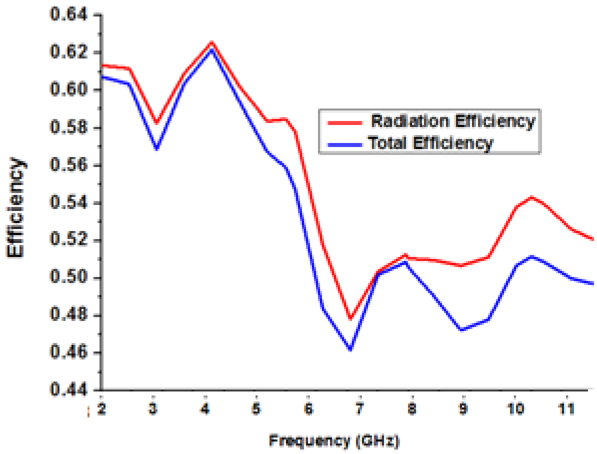
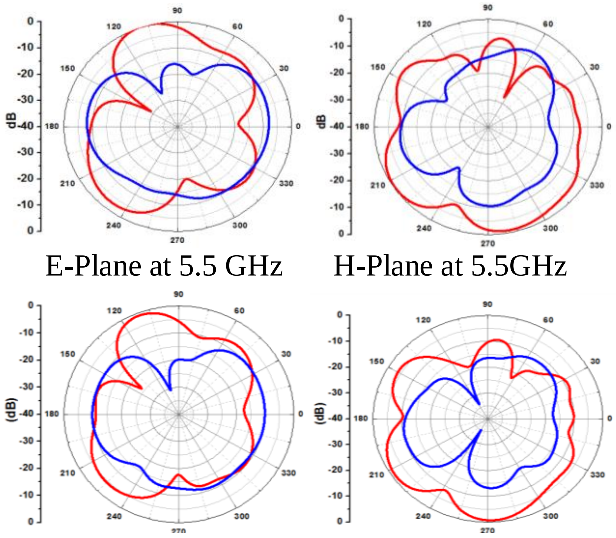


Fig. 6 Simulated radiated efficiency and total efficiency of proposed MIMO antenna in UWB-band.



E-Plane at 5.5 GHz H-Plane at 5.5GHz

E-Plane at 9.5 GHz H-Plane at 9.5GHz

------CO -----.CROSS

Fig.7. Polar plot of E & H-Plane CO-CROSS at 5.5 and 9.5GHz when one port is excited by external source and another port terminated by 50Ω.

The peak gain of proposed MIMO antenna is >2.2dB in the range of 2-11GHz shown in Fig. 4. Gain bandwidth product of antenna is constant if bandwidth goes high then gain should be low. So bandwidth is confined in UWB range. Percentage bandwidth of proposed MIMO antenna is 43.9%. Current density of proposed antenna at 2.4, 6.5 and 10.0GHz frequency is shown in Fig. 5. At this frequency charge does not accumulate because current density is low in the radiated patch therefore most of the power is radiated. Radiation as well total Efficiency of proposed

MIMO antenna is depicted in Fig. 6. Maximum radiation efficiency meets at 3.5-5.5GHz that is near to 62% and minimum radiation efficiency meets on 10GHz frequency that is near to 47%.

In Fig. 7 shows the 2D radiation pattern of E and H-planes at 5.5 and 9.5GHz frequency. In Co-polarization the radiation pattern is almost Omni-direction which radiates the power in all the directions but in the cross-polarization it is orthogonal to co-polarization thus becomes least radiated power which is depicted in Fig. 7 and the entire graph is stable for best fit in MIMO antenna.

Table-I: Comparison table of proposed antenna with existing reference.

Size(mm^2)	**Isolation (dB)**	**ECC**	**Reference**
140×120	15	<0.1	[2]
52.8×52.8	14	<0.25	[4]
77×79	20	-	[7]
54.98×76	12	<0.026	[12]
41×30	**20**	**<0.004**	**Proposed**

Above Table-I shows that proposed MIMO antenna provides better isolation and ECC above referred articles.

3. Diversity Performance of MIMO Antenna

Diversity performance of proposed MIMO antenna is judged by the ECC "Envelope Correlation Coefficient" and Mutual Coupling existing between two antennas. It is determined as the correlation factor of one antenna to another antenna and ECC is calculated by equation 2(a) under the assumption that the entire radiated field is uniformly distributed over the lossless antenna [12]. For the satisfactory performance of MIMO antenna, ECC should be <0.1 and the value of proposed MIMO antenna ECC and DG are less than 0.004 and >9.98dB respectively as shown in Fig. 8.

$$ECC = \frac{\left|S^*_{11}S_{12} + S^*_{21}S_{22}\right|^2}{\left(1-\left|S_{11}\right|^2 - \left|S_{21}\right|^2\right)\left(1-\left|S_{22}\right|^2 - \left|S_{12}\right|^2\right)} \quad 2(a)$$

Lossless antenna is a hypothetical term so we calculate the ECC in terms of radiated electric field by equation 2(b).

$$ECC = \frac{\left|\iint_{4\pi}\left[E_i(\theta,\phi) \times E_j(\theta,\phi)\right] d\Omega\right|^2}{\iint_{4\pi}\left|E_i(\theta,\phi)\right|^2 d\Omega \times \iint_{4\pi}\left|E_j(\theta,\phi)\right|^2 d\Omega} \quad 2(b)$$

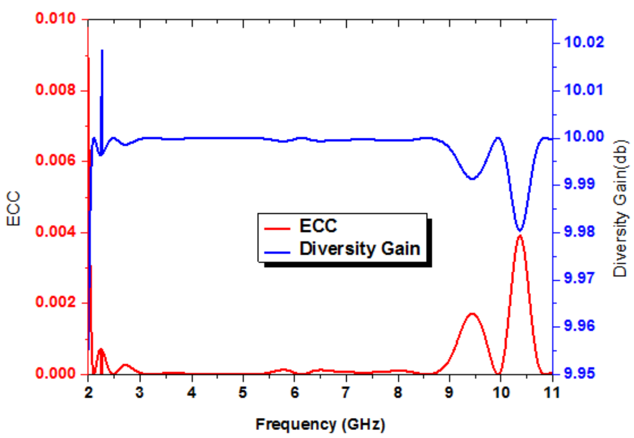


Fig.8. ECC and DG of proposed MIMO antenna.

DG (dB) = 10√1-(ECC)2, for ideally ECC = 0 and DG value should be 10dB. MEG ratio for proposed antenna lies between ±3dB. Mean effective gain is the "ratio of true mean effective received power (Prec.) to the mean effective incoming power (Pinc.)" to the antenna along the same random route. The MEG can be calculated by MEGi/j = εTotal/2.

E Total is the total efficiency associated with ith antenna, and $\varepsilon^{i}_{Total} = \varepsilon^{i}_{mis} \times \varepsilon^{i}_{rad}$, $\varepsilon^{i}_{mis} = 1 - \sum_{j=1}^{N} |S_{ij}|^2$, $\varepsilon^{i}_{rad} = \sum_{j=1}^{N} |S_{ij}|^2$ where, ε^{i}_{mis} implies mismatch efficiency and ε^{i}_{rad} radiation efficiency of ith antenna. Mismatch efficiency can be calculated by following terms. Mean effective gain calculation for outdoor XPR = 0dB and indoor XPR = 6dB at isotropic and Gaussian medium by equation (3) [12] and is shown in Fig. 9. Where XPR = cross-polarization ratio and Ω = beam area of the antenna.

$$MEG_i = \frac{P_{rec.}}{P_{inc.}} = \oiint \left[\frac{XPR \times G_{\theta i}(\Omega) + G_{\phi i}(\Omega) \times P_{\phi}(\Omega)}{1 + XPR} \right] d\Omega \quad (3)$$

TARC is also an imperative parameter for calculating the MIMO antenna diversity performance. TARC is calculated in terms of S parameters .TARC is defined as "the ratio of square root of total reflected power to the total incident power". It gives the information about apparent return loss of the antenna. The ideal value of TARC should be less than 0dB for MIMO antenna and it is calculated by equation (4) [8]. In this paper, the calculated value of designed antenna is less than -35dB, as depicted in Fig. 9.

$$TARC = \sqrt{\frac{(S_{11} + S_{12})^2 + (S_{22} + S_{21})^2}{2}} \quad (4)$$

At XPR = 0dB (isotropic) and 6dB (indoor) in an isotropic medium MEG should be -3.01dB throughout the UWB and -4.01 to -4.18dB for Gaussian medium -3.19 to -2.85dB and -4.8 to -5.18dB respectively, as revealed in Fig. 10.

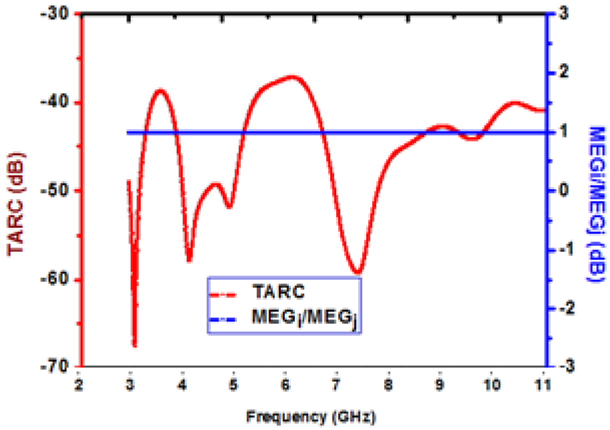


Fig. 9. TARC and MEG of proposed MIMO antenna.

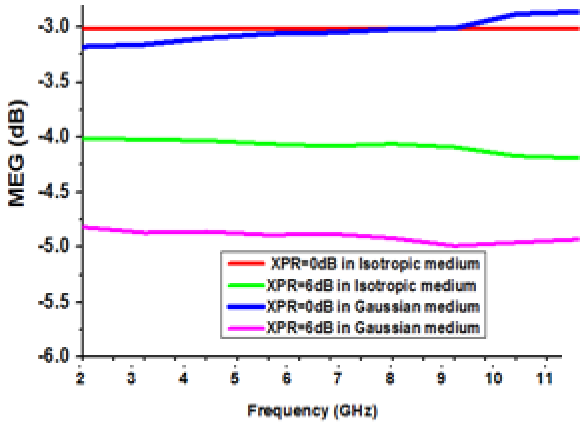


Fig.10. MEG calculation at XPR = 0 and 6dB in isotropic and Gaussian medium.

$$\text{CCL(dB)} = -\log_2 \text{Det}\left(\phi^P\right) \qquad (5)$$

Where, ϕ^P is the 1×2 correlation matrix in terms of S-parameter $\phi_{ii} = 1-|S_{ii}|^2-|S_{ij}|^2$, $\phi_{ij} = -\left(S_{ii} \times S_{ij} + S_{ji} \times S_{jj}\right)$.

Channel capacity loss should be determined by equation (5)[8].For MIMO antenna channel bandwidth should be improve but as well as channel capacity loss also increase for 1×2 proposed MIMO antenna, it should be less than 0.30bits/sec/Hz and CCL of proposed MIMO antenna is less than 0.30bits/sec/Hz which is made known in Fig.11.

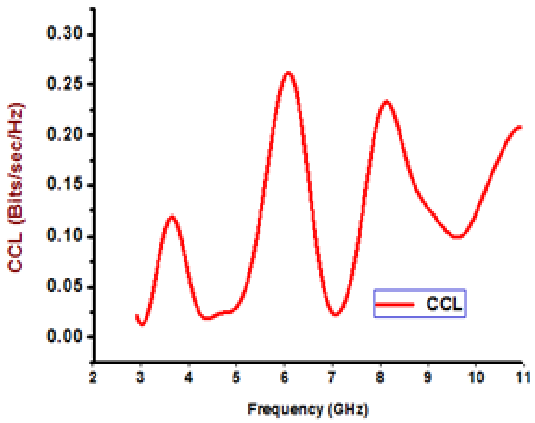


Fig.11. Simulated CCL of proposed MIMO antenna

4. Conclusion

MIMO antenna has been designed for UWB -band application with accepted isolation i.e. <-20dB, by using L-shape decoupling structure. The diversity performance has also been verified in terms of ECC, DG, TARC, CCL and MEG, which are having excellent acceptable limit for wireless communication and also provides better channel capacity with low channel capacity loss including high data rates with respect to SISO antenna. Consequently, the designed antenna is high-quality for future communications as for sea based X-band RADAR sbx-1 and UWB application.

References

[1] M. Sonkki, D. Pfeil, V. Hovinen, and K. R. Dandekar, "Wideband Planar Four-Element Linear Antenna Array," IEEE Antennas and Wireless Propagation Letters, vol. 13, pp. 1663-1666, 2014.

[2] A. MoradiKordalivand, T. A. Rahman, and M. Khalily, "Common Elements Wideband MIMO Antenna System for WiFi/LTE Access-Point Applications," IEEE Antennas and Wireless Propagation Letters, vol. 13, pp. 1601-1604, 2014.

[3] S. Soltani and R. D. Murch, "A Compact Planar Printed MIMO Antenna Design," IEEE Transactions on Antennas and Propagation, vol. 63, no. 3, pp. 1140-1149, 2015.

[4] R. Anitha, P. V. Vinesh, K. C. Prakash, P. Mohanan, and K. Vasudevan, "A Compact Quad Element Slotted Ground Wideband Antenna for MIMO Applications," IEEE Transactions on Antennas and Propagation, vol. 64, no. 10, pp. 4550-4553, 2016.

[5] S. Nandi and A. Mohan, "A Compact Dual-Band MIMO Slot Antenna for WLAN Applications," IEEE Antennas and Wireless Propagation Letters, vol. 16, pp. 2457-2460, 2017.

[6] H.-T. Hu, F.-C. Chen, and Q.-X. Chu, "A Wideband U-Shaped Slot Antenna and Its Application in MIMO Terminals," IEEE Antennas and Wireless Propagation Letters, vol. 15, pp. 508-511, 2016.

[7] L. Kong and X. Xu, "A Compact Dual-Band Dual-Polarized Microstrip Antenna Array for MIMO-SAR Applications," IEEE Transactions on Antennas and Propagation, vol. 66, no. 5, pp. 2374-2381, 2018.

[8] R. Chandel, A. K. Gautam, and K. Rambabu, "Design and Packaging of an Eye-Shaped Multiple-Input–Multiple-Output Antenna With High Isolation for Wireless UWB Applications," IEEE Transactions on Components, Packaging and Manufacturing Technology, vol. 8, no. 4, pp. 635-642, 2018.

[9] Q. Li, A. P. Feresidis, M. Mavridou, and P. S. Hall, "Miniaturized Double-Layer EBG Structures for Broadband Mutual Coupling Reduction Between UWB Monopoles," IEEE Transactions on Antennas and Propagation, vol. 63, no. 3, pp. 1168-1171, 2015.

[10] S. K. Dhar, M. S. Sharawi, O. Hammi, and F. M. Ghannouchi, "An Active Integrated Ultra-Wideband MIMO Antenna," IEEE Transactions on Antennas and Propagation, vol. 64, no. 4, pp. 1573-1578, 2016.

[11] N. Malekpour, M. Amin Honarvar, A. Dadgarpur, B. S. Virdee, and T. A. Denidni, "Compact UWB mimo antenna with band-notched characteristic," Microwave and Optical Technology Letters, vol. 59, no. 5, pp. 1037-1041, 2017.

[12] S. Chouhan, D. K. Panda, V. S. Kushwah, and P. K. Mishra, "Octagonal-shaped wideband MIMO antenna for human interface device and S-band application," International Journal of Microwave and Wireless Technologies, pp. 1-10, 2018.