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Original Article

Parametric Study of the Modified Ground Plane on Co-Planar Waveguide-Fed Printed Monopole Antenna for Ultra-Wideband Technology

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Abstract *- Ultra-wideband (UWB) printed antenna having a disc-shaped radiator fed with a co-planar waveguide (CPW) is shown in this paper. A modified ground plane is initiated to observe the behavior of UWB bandwidth. The dimension of the proposed antenna is 20 X 25 X 1. 6mm^3. Comparing the prototype conventional printed antenna with reducing the ground plane in both length and breadth of the ground plane one by one. From the graph of return loss, voltage standing wave ratio (VSWR), radiation pattern that is best suited for optimized dimension can able be detected. The best parameters for UWB antenna are the fractional bandwidth which should be more than 85%, and VSWR, another parameter. The range of bandwidth of UWB must be below 2 for the best and most effective way of printing monopole antenna. Results show that the length and width of the ground plane are 15.9 mm and 11.4mm, which is most appropriate for UWB since it gives a return loss of -41.86 dB, a fractional bandwidth of about 89% and VSWR of below 2 within the frequency bandwidth. A fair radiation pattern which is omni-directional in nature, is observed in this modified prototype antenna.*

Keywords *- Ultra wideband, Printed antenna, Voltage standing wave ratio, Return loss, Fractional bandwidth.*

1. Introduction

With the challenges in ultra-wideband technology, the progress of printed antennas is increasing daily. The biggest advantages of printed antennas are that the radiation pattern is omnidirectional and has a great throughput. In 2002, a commercial bandwidth of 7.5GHz was assigned by the federal communication commission (FCC) for ultra-wideband technology [1]. Modifying the ground plane in a small slot printed antenna results in a wideband and narrowband resonance property. The dimension of the antenna is lowered by 70% in contrast to the standard antenna.

Meanwhile, a good radiation pattern having proper gain stability can be seen in this antenna. It covers almost all wireless communication bands such as WiMAX, INSAT, Wi-Fi/WLAN, UMTS 3G expansion band and microwave S-band [2]. In[28], a Sinc model printed monopole antenna is designed, which is meant for wireless communication. It is observed that a good performance in multiple resonance frequencies is seen in the sinc patch structure. With this antenna, it can capture a particular compact region, having a proper radiation pattern. It is appropriate for wireless devices operating at microwave range—printed antenna with patch structure of triangular in nature feeding with a meander line T model divider.

It can boost up the fractional bandwidth of about 185%, which is best matched for UWB (Ultra-wideband).[3] With the introduction of Split ring resonators, further bandwidth can be enhanced, as well as far-field radiation patterns that cover mostly the Ultra wideband, usually L and S bands [4]. CPW-fed monopole antenna having a disc-shaped radiator with a split ring resonator slot is meant for the dual bandwidth of 1.06 GHz, 4.5 GHz, while rejecting the bandwidth for WLAN/WiMAX, usually from 5GHz to 6GHz.Changing the dimensions of the ground plane can give more advanced bandwidth and radiation[5]. Two different types of band-notched (single and double notched) for UWB technology can be performed by inserting an L-model slot with the appropriate dimension and location in the reduced ground plane. Improvement of about 130% can be accomplished with this antenna model. It can reduce the lower cut-off frequency up to 0.8GHz[8]. A U-shaped ground plane with E-cut in the patch is used in [9] to accomplish dual band-notch function. UWB FSS with a unit cell dimension of 0.2 that is formed by numerous asymmetric rectangular radiators with disc model notched is implanted. The FSS covers a wide band of frequencies of bandwidth of 10GHz, with a gain of 4.5 dBi [29]. The antenna has a frequency range of up to 10 GHz. However, its operational bandwidth is limited due to low radiation at extreme frequencies. By using split ring resonators, it presented a CDM antenna with dimensions of 50 X 50 X 1.575 mm^3 that can give a frequency spectrum of up to 10.8 GHz [11].

Making a zigzag incision in the patch [12] improves bandwidth with an E-structure printed antenna of about 29.8%. Kaur et al. [30] developed a U-shaped slot-loaded inverted disc antenna with a maximum bandwidth of 24.2 percent. Similarly, a slot, fractal, or metamaterial can be used to create an ultra-wideband antenna. Various UWB antenna layouts have been published [14] –[15], with disc patch radiators having concentric-filled CPW-fed antenna for UWB uses. It can promote the frequency quality of the UWB antenna with the establishment of a defective ground structure [16] – [20].

2. Antenna Design

Eqn (1) gives the design detail having a circular patch [16].

$$R_1 = \frac{R_{ef}}{\sqrt{1+\frac{2h}{\pi\varepsilon_r R_{ef}}\left[ln\left(\frac{1.57R_{ef}}{h}\right)+1.78\right]}} \quad (1)$$

$$R_{ef} = \frac{8.79\times10^9}{f_{rr}\sqrt{\varepsilon_r}} \quad (2)$$

Where h = substrate's height in mm, ε_r = substrate's relative permittivity, f_{rr}=solution frequency.

The lower -3dB frequency of antennas is estimated from a basic cylindrical monopole antenna[21]–[26]. For an antenna with a planar prototype and monopole nature, these equations are valid. The lower -3dB frequency is plotted in [21]–[25]; Eqn (2) gives the formula of lower -3dB frequency where H is the height of the cylindrical monopole antenna, and r represents the effective radius.

$$f_{bef} = \frac{c}{\lambda_l} = \frac{7.2}{(H+R_{ef}+f_l)} GHz \quad (3)$$

When compared to microstrip antennas with circular patches having dielectric as substrate, the properties will remain the same with cylindrical monopole antennae. f_l represents feed length which is one of the most important parameters in impedance matching. The dielectric substrate will provide a more fringing effect, which in turn leads to strengthening the antenna's effective height, thus reducing the lower -3dB frequency. As a result, a better equation for the lower -3dB frequency is as follows:

$$f_{bef} = \frac{c}{\lambda_l} = \frac{7.2}{(H+R_{ef}+f_l)k} GHz \quad (4)$$

In Fig1. A model of the proposed antenna is shown. It has a substrate made of FR-4 epoxy with the following dimensions: L_{sub} = 30 mm, W_{sub} = 35 mm, h = 1.6 mm, ε_r = 4.4. A disc radiator of radius R_1 = 8.5mm is installed on the

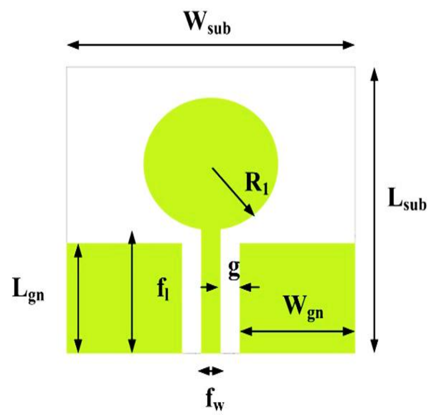

Fig. 1 Conventional printed antenna

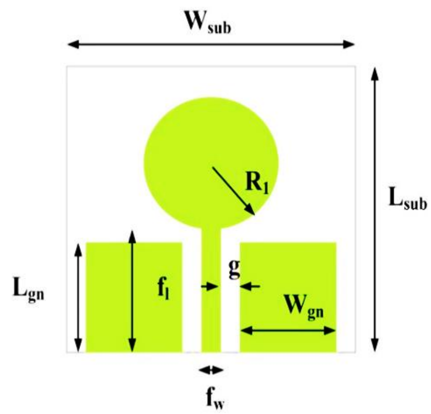

Fig. 2 Proposed printed antenna

substrate's surface and supplies a 50Ω CPW fed line. Stripline dimensions are f_l=18mm, and f_w = 1.6 mm, respectively. On the top portion of the substrate material, the modified ground structure is taken into consideration to increase the bandwidth, L_{gn}=19.5mm and W_{gn} =11.4mm, as shown in Figure 2.

3. Result and Discussion

Return loss, VSWR, gain, bandwidth, cross and co-polarization are the important parameters of the antenna. A variation in ground plane dimensions can improve such parameters, especially for the printed antenna. Fig3. demonstrate the impact of ground structure on center frequency when the simulation is run for various ground plane dimensions. Table 1 shows the variation of resonating frequencies, fractional bandwidth, and return loss for all the ground plane dimensions. It is noticed that the conventional prototype proposed antenna of length and width (L_{gn} =15.9 mm, W_{gn}=11.4mm) results in a maximum impedance bandwidth reaching a frequency up to 13.6 GHz and the fractional bandwidth of 89%, which exceeds 10GHz that satisfies the condition of UWB on its initial solution frequency, f_{cen1}=6GHz. However, on its second resonance frequency, it does not satisfy the criteria for UWB. Modifying the ground plane with variation in length and width, bandwidth can be improved, as well as return loss and VSWR. All the dimension of the modified ground plane satisfies the UWB, but the best one is at W_{gn}=11.4mm.

Table 1. Effect of Return loss (S_{11})dB on the ground dimension

Ground plane dimension	Operating Centre frequency(GHz)	$\|S_{11}\|$dB	-10dB Bandwidth(GHz)	Fractional Bandwidth(GHz)
L_{gn} = 15.9mm W_{gn} = 13.4mm	f_{cen1} = 7.4 f_{cen2} = 15.4	-25.30 -17.97	(5.1-12.9) (14.2-19)	86.6 28.9
L_{gn} = 15.9mm W_{gn} = 12.4mm	f_{cen1} = 6 f_{cen2} = 16	-27.69 -31.90	(5.2-12.8) (14.0-18.0)	84 25
L_{gn} = 15.9mm W_{gn} = 11.4mm	f_{cen1} = 6 f_{cen2} = 16	-41.86 -39.91	(5.2-13.6) (14.1-18.2)	89 25
L_{gn} = 15.9mm W_{gn} = 10.4mm	f_{cen1} = 6 f_{cen2} = 17.4	-41.58 -26.68	(5.3-13.5) (14.4-19.7)	87 29.5
L_{gn} = 15.9mm W_{gn} = 9.4mm	f_{cen1} = 6 f_{cen2} = 15.8	-21.97 -21.97	(5.4-13.4) (14.6-17.0)	85 15
L_{gn} = 14.9mm W_{gn} = 12.4mm	f_{cen1} = 6.4 f_{cen2} = 9.6	-19.32 -34.44	(5.4-13.5) (8.2-13.4)	85.9 48
L_{gn} = 14.9mm W_{gn} = 11.4mm	f_{cen1} = 6.4 f_{cen2} = 9.6	-16.12 -40.38	(5.4-8.0) (8.3-13.6)	38 49
L_{gn} = 14.9mm W_{gn} = 10.4mm	f_{cen1} = 6.2 f_{cen2} = 9.6	-17.32 -24.44	(5.4-7.2) (8.2-13.5)	33 48

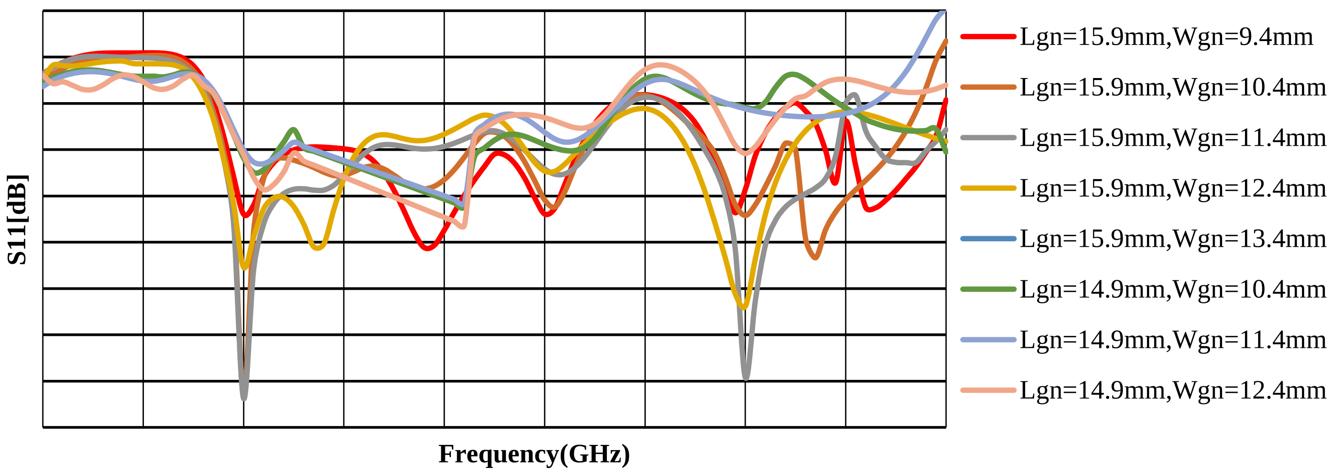

Fig. 3 Return loss vs frequency

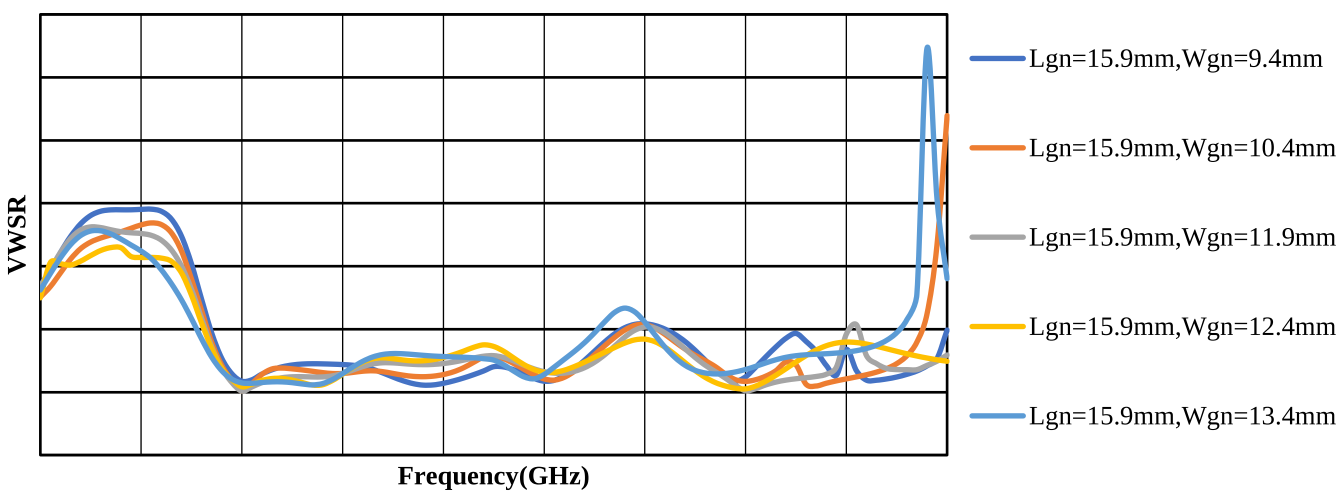

Fig. 4 VSWR vs Frequency response

Ground size related to the patch plays a crucial role in improving the bandwidth; Figure 3. and Table.1 clearly show that the lesser the gap, the more the bandwidth. Hence, the optimized length of the ground plane L_{gn}=15.9mm, but decreasing the width of the ground plane leads to increased bandwidth and return loss.

Further decreased width provides a poor bandwidth; therefore, the optimized dimension of the ground plane width (W_{gn}=11.4mm). When L_{gn}=15.9mm and W_{gn}=11.4mm, it gives a bandwidth exceeding 10GHz, reflection co-efficient of -41.86dB and fractional bandwidth of 89%, which satisfies the criteria for UWB.

Fig 4. gives the details of VSWR frequency response; VSWR parameters give the idea of the amount of radiation that takes the plane and its returning wave. Its value should be minimum as possible in order to promote maximum radiation. When the resistive parts of impedance are matched to 50Ω of the CPW fed line keeping the imaginary part of impedance as the lowest value. In the graph, it is seen that for the optimized dimension of the ground plane(L_{gn}=15.9mm, W_{gn}=11.4mm), a good result of VSWR whose value is less than 2 within the bandwidth range

The variation of gain from 5GHz to 10 GHz is shown in Fig 5. the highest gain of more than 8dBi is observed in the optimized ground plane for the second solution frequency. Better gain is seen in the modified ground plane. Fig 4. gives the details of VSWR frequency response; VSWR parameters give the idea of the amount of radiation that takes the plane and its returning wave. Its value should be minimum as possible in order to promote maximum radiation. When the resistive impedance is matched to 50Ω of the CPW fed line keeping the imaginary part of impedance as the lowest value. The graph shows that for the optimized dimension of the ground plane(L_{gn}=15.9mm, W_{gn}=11.4mm), a good result of VSWR whose value is less than 2 within the bandwidth range.

Fig 5. describe the behaviour of Co and Cross polarization radiation pattern for different ground dimensions; it is observed to show an omnidirectional pattern.

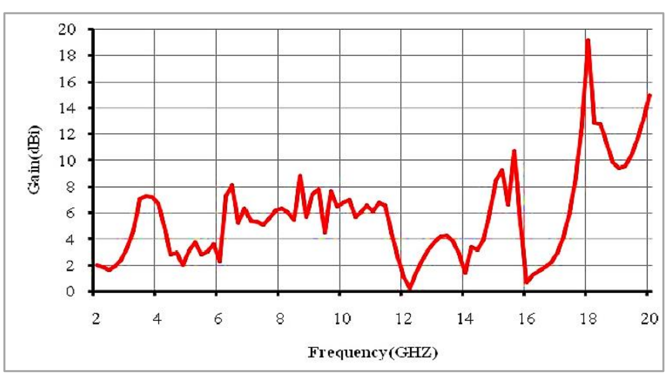

Fig. 5 Gain(dBi) vs frequency

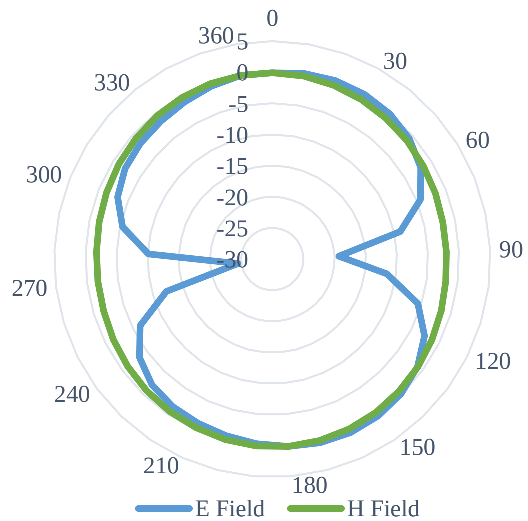

Fig. 6 Radiation pattern of the proposed antenna

Table 2. Literature survey of various printed monopole antenna

Ref	Size (mm)	Frequency Range (GHz)	Maximum Gain (dBi)
[16]	60 x 56 x 1.6	1.3 to12	7
[17]	50 x 50 x 1.575	2.6 to10.8	4
[18]	50 x 50 x 1.575	2.2 to11	4
[19]	42 x 42 x 1.5	2.6 to10.6	7
Proposed antenna	30 x 35 x 1.6	5.2 to13.6	8.77

Table 2. gives the details of various printed antennae for ultra-wideband applications. Comparing the various antenna, the size of the antenna is minimum, and a better bandwidth and gain can be seen in this proposed antenna.

4. Conclusion

A CPW-fed printed antenna which is appropriate for UWB applications with an impedance bandwidth of more than 10GHz. Reducing the ground plane dimension, impedance bandwidth keeps on increasing as well as return loss; if it is still reducing, a stage will come it will start decreasing the bandwidth. The ground dimension at which the bandwidth is reduced is the optimized dimension of the ground plane. In contrast with a conventional prototype antenna, a modified ground plane gives an effective way of enhancing the bandwidth. The Co and Cross polarization radiation pattern looks exactly like an omnidirectional field pattern. From this, it can be concluded that it is radiated uniformly in all directions, which is fair enough for a printed monopole antenna.

References

[1] FCC Report and Order on Ultra Wideband Technology, *Federal Communication Commission*, Washington, DC, USA, 2002.

[2] Sudipta Das, Partha Pratim Sarkar, and Santosh Kumar Chowdhury, "Compact Modified Ground Plane (MGP) Microstrip Antenna with Narrowband and Wideband Resonance Characteristics," *International Journal of Signal Processing, Image Processing and Pattern Recognition*, vol. 10, no. 2 , pp.13-26, 2017. *Crossref*, http://doi.org/10.14257/ijsip.2017.10.2.02

[3] S. A. Arunmozhi, and V. Benita Esther Jemmima, "A High Gain Ultra-Wideband Array Antenna for Wireless Communication," *International Journal of Recent Engineering Science*, vol. 7, no. 6, pp. 31-34, 2020. *Crossref*, http://doi.org/10.14445/23497157/IJRES-V7I6P105

[4] Mohammad Alibakhshikenari et al., "Wideband Printed Monopole Antenna for Application in Wireless Communication Systems," *IET Microwave and Antennas Propagation*, vol. 12 no 7, pp. 1222-1230, 2018. *Crossref*, http://doi.org/10.1049/iet-map.2017.0894

[5] R. Boopathi Rani, and S.K. Pandey, "A CPW -Fed Circular Patch Antenna Inspired by Reduced Ground Plane and CSRR Slot for UWB Applications with Notch Band," *Microwave and Optical Technology Letters*, vol. 59, no. 4, pp. 745-749, 2017. *Crossref*, http://doi.org/10.1002/mop.30386

[6] Neelaveni Ammal Murugan et al., "Printed Planar Monopole Antenna Design for Ultra-Wideband Communication," *Radio Electronics and Communication System*, vol. 61, no. 3, pp. 267-273, 2018. *Crossref*, http://doi.org/10.3103/S0735272718060055

[7] R. Azim, M.T. Islam, and N. Misran, "Ground Modified Double-Sided Printed Compact UWB Antenna," *Electronics Letters*, vol. 47, no. 1, pp. 9-11, 2011. *Crossref*, http://doi.org/10.1049/el.2010.3160

[8] Reza Zaker, Changiz Ghobadi, and Javad Nourinia, "Bandwidth Enhancement of Novel Compact Single and Dual Band-Notched Printed Monopole Antenna with a Pair of L-Shaped Slots," *IEEE Transactions on Antennas and Propagation*, vol. 57, no. 12, pp. 3978-3983, 2009. *Crossref*, http://doi.org/10.1109/TAP.2009.2023475

[9] J Liu et al., "Compact Printed Ultra-Wideband Monopole Antenna with Dual Band-Notch Characteristic," *Electronics Letter*, vol. 44, no. 12, pp. 710-711, 2008. *Crossref*, http://doi.org/10.1049/el:20080931

[10] Sudhanshu Belwal , Ahmad Rafiquee, and Vibhor Bangwal, "Modified UWB Antenna for Cognitive Radio Applications," *SSRG International Journal of Industrial Engineering*, vol. 5, no. 3, pp. 15-18, 2018. *Crossref*, https://doi.org/10.14445/23499362/IJIE-V5I3P103

[11] Jawad Y. Siddiqui, Chinmoy Saha, and Yahia M. M. Antar, "Compact Dual-SRR-Loaded UWB Monopole Antenna with Dual Frequency and Wideband Notch Characteristics," *IEEE Antennas Wireless Propag Letters*, vol. 14, pp. 100-103, 2014. *Crossref*, http://doi.org/10.1109/LAWP.2014.2356135

[12] D. Caratelli et al., "A Perturbed e-Shaped Patch Antenna for Wideband WLAN Applications," *IEEE Transaction Antennas Propagation*, vol. 54, no. 6, pp. 1871-1874, 2006. *Crossref*, http://doi.org/10.1109/TAP.2006.874364

[13] Divya Soundharya et al., "Design of Ultra Wide Band Antenna," *SSRG International Journal of Electronics and Communication Engineering*, vol. 5, no. 6, pp. 7-10, 2018. *Crossref*, https://doi.org/10.14445/23488549/IJECE-V5I6P102

[14] Gangadhara Mishra, and Sudhakar Sahu, "Compact Circular Patch UWB Antenna with WLAN Band Notch Characteristics," *Microwave Optical Technology Letters*, vol. 58, no. 5, pp. 1068–1073, 2016. *Crossref*, https://doi.org/10.1002/mop.29727

[15] Chia-Shan Li, and Chien-Wen Chiu, "A CPW-Fed Band-Notched Slot Antenna for UWB Applications," *Microwave Optical Technology Letters*, vol. 51, no. 6, pp. 1–4, 2008. *Crossref*, https://doi.org/10.1109/APS.2008.4620005

[16] Constantine A. Balanis, *Antenna Theory: Analysis and Design*, 3rd Edition, Wiley, New York, 2005.

[17] Samom Jayananda Singh, Rajesh Kumar, and M M Dixit, "Printed Monopole Antenna Design with CPW Fed for Ultra Wideband Application," *Journal of Physics: Conference Series*, vol. 2236, no. 1, p. 012010, 2022. *Crossref*, https://doi.org/10.1088/1742-6596/2236/1/012010.

[18] Somen Bhattacharjee, Rakhesh S. Kshetrimayum, and Ratnajit Bhattacharjee, "Bandwidth Enhancement of Printed Monopole Antennas using Magnetodielectric Cover," *IEEE Applied Electromagnetics Conference (AEMC)*, 2015. *Crossref*, https://doi.org/10.1109/AEMC.2015.7509113

[19] Kamalaveni Ayyadurai, and M. Ganesh Madhan, "Bandwidth Enhancement of Capacitive Fed Monopole Antenna Using Parasitic Patches," *International Journal of Microwave and Wireless Technologies*, vol. 1, no. 2, pp. 1-7, 2015. *Crossref*, https://doi.org/10.1017/S1759078714001597

[20] Yangjun Zhang, Tomonori Nakata, and Toyokatsu Miyashita, "A Minature Cirular Disc Monopole UWB Antenna with a Tapered Feed Line and a Circular Ground," *IEEE China-Japan Joint Microwave, Shanghai, China*, pp. 411-414, 2008. *Crossref*, https://doi.org/10.1109/CJMW.2008.4772457

[21] K.P. Ray, S.S. Thakur, and S.S. Kakatkar, "Bandwidth Enhancement Techniques for Printed Rectangular Monopole Antenna," *IETE Journal of Research*, vol.60, no. 3, pp. 249–256, 2014. *Crossref*, https://doi.org/10.1080/03772063.2014.914700

[22] Pritam S. Bakariya, Santanu Dwari, and Manas Sarkar, "Triple Band Notch UWB Printed Monopole Antenna with Enhanced Bandwidth," *International Journal of Electronics and Communication*, vol. 69, no. 1, pp. 26–30, 2015. *Crossref*, https://doi.org/10.1016/j.aeue.2014.07.023

[23] Surajit Kundu, "Experiment Study of a Printed Ultra -Wideband Modified Circular Monopole Antenna," *Microwave Optical Technology Letter*, vol. 61, no. 5, pp. 1388-1393, 2019. *Crossref*, https://doi.org/10.1002/mop.31736

[24] H. Kimouche et al., "Bandwidth Enhancement of Rectangular Monopole Antenna Using Modified Semi-Elliptical Ground Plane and Slots," *Microwave and Optical Technology Letters*, vol. 52, no. 1, pp. 54–58, 2010. *Crossref*, https://doi.org/10.1002/mop.24830

[25] Surajit Kundu, and Sanjay Kumar Jana, "Leaf-Shaped CPW-Fed UWB Antenna with Triple Notch Bands for Ground Penetrating Radar Applications," *Microwave and Optical Technology Letters*, vol. 60, no. 4, pp. 930-936, 2018. *Crossref*, https://doi.org/10.1002/mop.31075

[26] N K Saxena et al., "Study of Linear Array of Microstrip Hexagonal Patch Antenna Printed on LiTi Ferrite under External Magnetic Biasing," *International Journal of Engineering Trends and Technology*, vol. 48, no. 6, pp. 291-295, 2017. *Crossref*, https://doi.org/10.14445/22315381/IJETT-V48P251

[27] Jayananda Singh et al., "Study Analysis of Printed Monopole Antenna for C and X Band Application," *Proceeding of CECNet*, IOS Press, pp. 112-118, 2022.

[28] Ritesh Kumar Badhai, and Nisha Gupta, "Parametric Study of Sinc Shaped Monopole Antenna for Wireless Devices," *Applied Computational Electromagnectics Society*, vol. 30, no. 1, pp. 123-131, 2015.

[29] Priyanka Das, and Kaushik Mandal, "Modelling of Ultra-Wide Stopband Frequency-Selective Surface to Enhance the Gain of a UWB Antenna," *IET Microwaves, Antennas & Propagation*, vol. 13, no. 3, pp. 269-277, 2019. *Crossref*, https://doi.org/10.1049/iet-map.2018.5426

[30] Preet Kaur, S. K. aggarwal, and Asok De, "Reconfigurable Inverted Circular Patch Antenna for Wireless Applications," *International Journal of Advanced Science and Technology*, vol. 70, pp. 55-64, 2014. *Crossref*, https://doi.org/10.14257/ijast.2014.70.06