Planar Parasitic Monopole Antenna with a Circular Ground Plane for UWB Utility

Motahhare Farrokhfar[1], Seyyed Ali Hosseini[2], Mohammad Hossein Farrokhfar[3]
1- IRAN Meteorological Organization, Tehran, Iran
Email: m.farrokhfar67@gmail.com (Corresponding author)
2- Faculty of Technical and Engineering, Imam Hossein University, Tehran, Iran
Email: hosseini1364@gmail.com
3- Department of Electrical Engineering, Technical and Vocational University (TVU), Tehran, Iran
Email: Hfarrokhfar@gmail.com

ABSTRACT:
This paper proposes a monopole antenna with two-pair sleeves that is fed through a coplanar waveguide. The new structure is composed of a triangular radiator and sleeves in size of 40× 40×1.6 mm3. The suggested structure is constructed on an FR-4 PCB layer with a dielectric constant of ε r=4.3. The best results are obtained by parameters sweep study with the CST simulator. According to the results, the bandwidth range is 2.45-11 GHz, expressing that the compact design covers an ultrawide bandwidth. The optimized antenna is manufactured and the measurement outcome of the return loss is compared with the CST simulator results at various frequencies, representing a satisfactory consistency of simulation and measurement results.

KEYWORDS: Sleeve Antenna, Triangular Monopole, Coplanar Waveguide-Fed, Ultra-Wideband.

1. INTRODUCTION

Combining the traditional Ultra-wideband (UWB) antennas with modern integrated systems is not feasible due to the complicated systems and big dimensions. The low-profile planar antennas are a favorite in UWB applications. Therefore, the surface antennas are taken into consideration when they are fed by a coplanar waveguide based on their significant competencies e.g., broadband frequency ranges, compact size, simple matching with integrated circuits, and stable radiation patterns. Several structures of the monopole antenna have been studied in wideband applications including circular, square, elliptical, trapezoidal, rectangular, and mixed-shape structures [1]-[7]. Various approaches have been suggested to improve the antenna bandwidth. Printing parasitic elements around the main monopole antenna can increase the bandwidth of the planar antenna [8]-[12]. The triangular monopole antenna in previous studies had a good impedance bandwidth but needs to be enhanced to achieve better performance [13]-[14]. Another way to improve the antenna bandwidth is to shape the ground plane. In [16], the slots are cut from the circular monopole antenna and ground plane. A trapezoid monopole antenna with a sleeve and slots embedded in the ground plate to increase the bandwidth was presented in [17].

This work introduces a new triangular radiator with two-pair sleeves ranging from 2.45-11 GHz. Finally, the ground plane of the suggested antenna is modified circularly.

2. ANTENNA STRUCTURE

Fig. 1 presents the suggested antenna. As shown, the ground plate is truncated and parasitic elements are extensions of ground planes as sleeves. The substrate is FR-4 with ε_r=4.3. The two-pair sleeves are parallel to the monopole radiator and have grown out of the ground plane. The printed-strip sleeve lengths and spacing are denoted as L_{S1}, L_{S2}, W_{S1}, and W_{S2}, respectively. The variables include the monopole height (h_m), sleeves lengths (L_{S1}, L_{S2}), monopole, sleeves flare angle (θ), sleeves widths (W_{S1}, W_{S2}), and spacing between the sleeves and the monopole (S_1, S_2).

Paper type: Research paper
DOI: 10.30486/MJTD.1402.901845
Received: 16 November 2023; revised: 22 December 2023; accepted: 19 January 2024; published: 1 March 2024
How to cite this paper: M. Farrokhfar, S. A. Hosseini, and M. H. Farrokhfar, **"Planar Parasitic Monopole Antenna with a Circular Ground Plane for UWB Utility"**, *Majlesi Journal of Telecommunication Devices*, Vol. 13, No. 1, pp. 17-25, 2024.

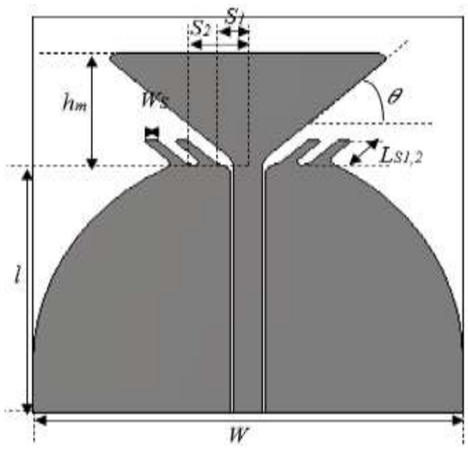


Fig. 1. Geometry of proposed triangular sleeves monopole antenna.

3. ANALYSIS AND SIMULATION

The appropriate structure of the antenna is designed and simulated with the genetic algorithm (GA) optimizer at the CST simulator. The aim of the optimization process was to determine the antenna dimensions which resulted in a return loss of less than -10dB. The GA is a method of random search; thus, it is not accurate. Therefore, the results of the model were improved by Sweep parameters. The strip and gap width are set to 2.6 mm and 0.28 mm respectively to reach the 50ohm CPW feed. The optimal selected parameters are shown in Table 1.

Table 1. The best parameters of the antenna.

parameters	Value(mm)
h_m	10.8
L_S	2.8
W_S	1.3
l	25
S_1	1.2
S_2	4
θ	0.72(rad)
W	40

As displayed in Fig. 2, the antenna bandwidth is 2.5-5.1 GHz without the sleeves, which denotes a relatively small bandwidth. Through adding two-pair sleeves to the printed triangular radiator, the bandwidth is improved, covering the 2.5-7.5 GHz range (return loss ≤ -10 dB), however, two-pair sleeves sound more efficient because of the wide impedance bandwidth from 2.45 to 11 GHz. Furthermore, we study three pair sleeves surrounding the monopole antenna, which leads to increased antenna size, without improving the bandwidth.

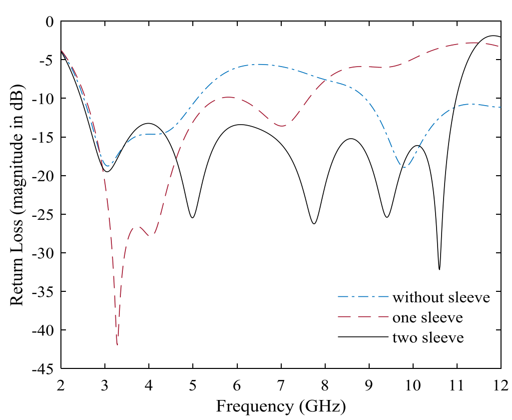


Fig. 2. The results of the simulation of the S_{11} of the designed antenna without the sleeve, with one and two-pair sleeves.

4. PARAMETRIC STUDY AND DISCUSSION

Fig. 3 shows the simulations of the current distributions from the suggested structure at the frequencies of 5.5, 7.5, and 9.5 GHz respectively. It represents a strong current distribution around the sleeves and curved ground.

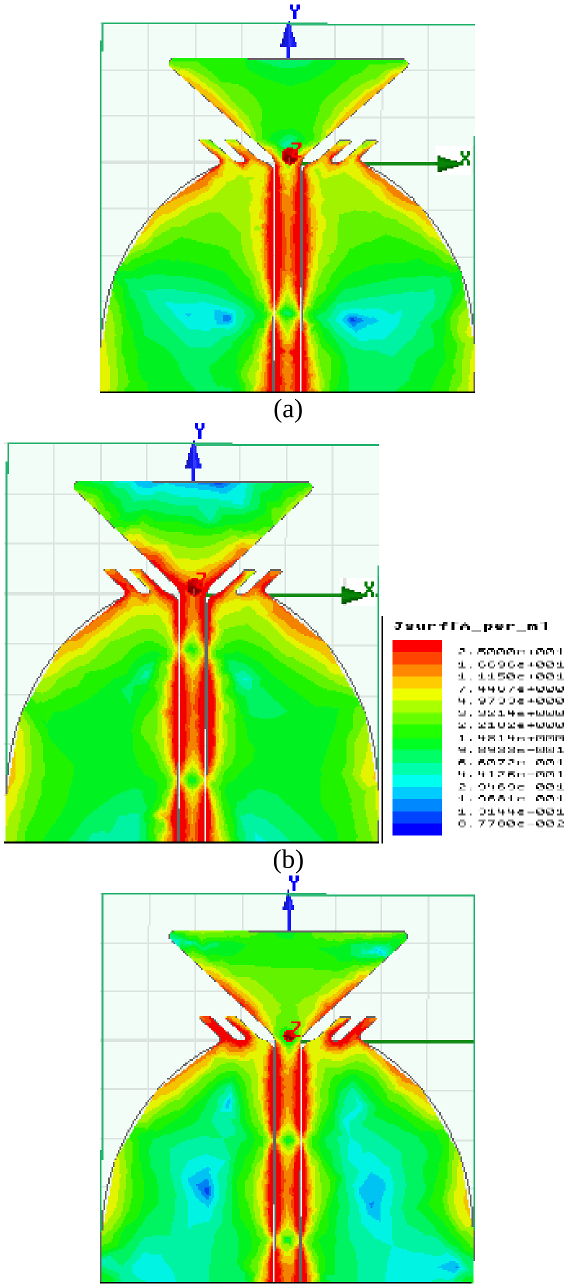


Fig. 3. Simulation of the current distributions for the suggested structure at, a) 5.5 GHz, b) 7.5 GHz, c) 9.5 GHz.

Fig. 4 presents the effect of flare angle (θ) on the return loss. It is a main parameter at the return loss of the structure. The optimum return loss for flare angle is about θ =0.72 rad.

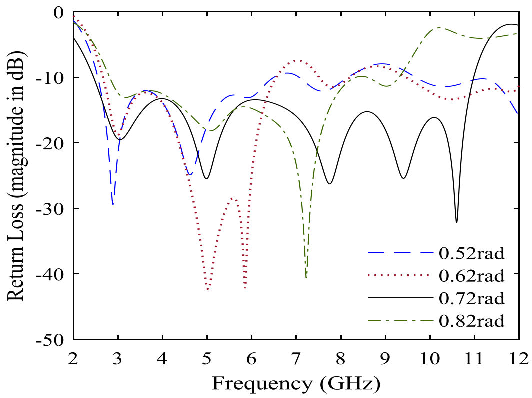


Fig. 4. Simulation results of the return loss for several flare angles (θ).

The return loss curves shown in Fig. 5 are derived through simulations of various monopole heights. The monopole height affects lower frequencies of bandwidth. The optimum return loss is about h_m=10.8 mm for monopole height.

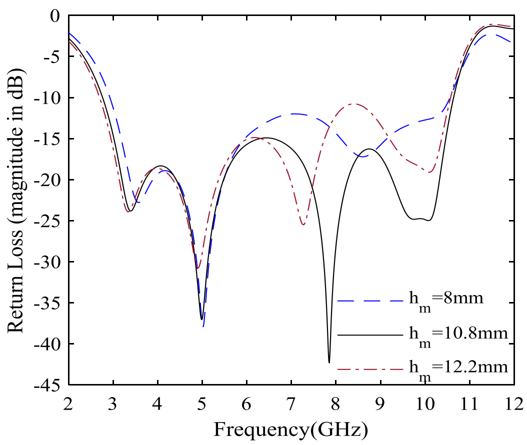
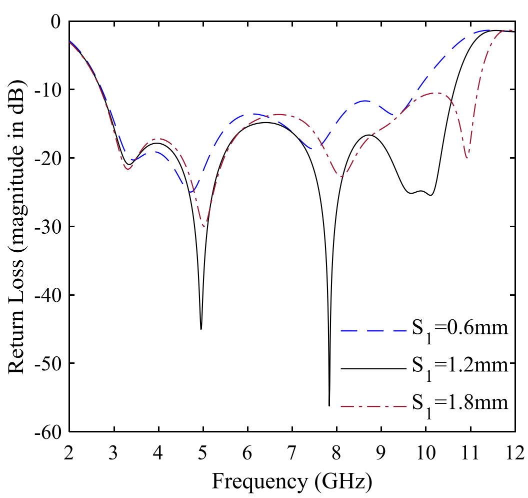
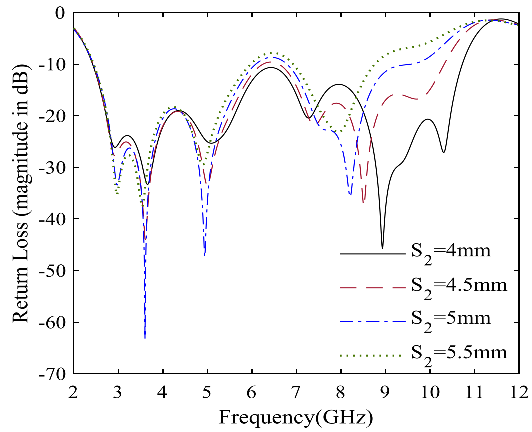


Fig. 5. Simulated return loss for several monopole heights (h_m).

The spacing between sleeves and the main radiator effect the higher frequency of bandwidth, as shown in Fig. 6. The best results are obtained for S_1 (spacing between the main radiator and the near sleeve) = 1.2 mm and S_2 (spacing between the main radiator and farther sleeve) = 4 mm.



(a)



(b)

Fig. 6. The results of the simulation of the S_{11} for several values of spacing between the main radiator and sleeves; a) the near sleeves (S_1), b) the farther sleeves (S_2).

Fig. 7 illustrates the simulation of the return loss for several sleeve-length L_S. The sleeve length affects all over the bandwidth, as observed. L_S=2.8 mm has the best bandwidth.

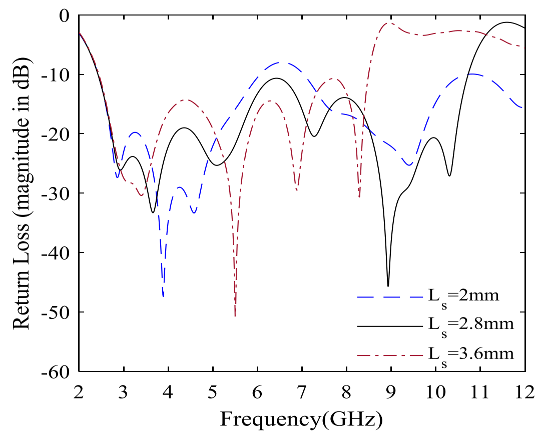


Fig. 7. The Simulation results of the S_{11} for several values of sleeves length (L_s).

The simulation results of the S_{11} for various amounts of sleeve width are plotted in Fig. 8. All of the values control good bandwidth, but W_S =1.3mm holds the better result.

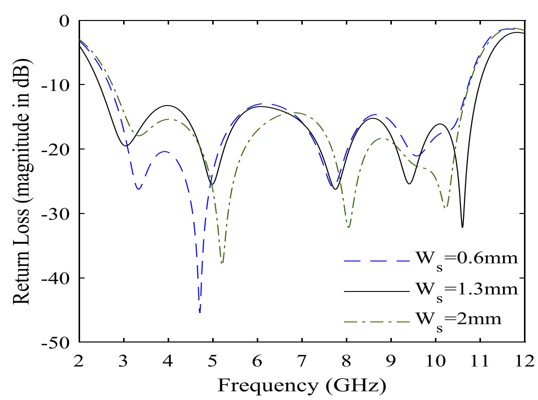


Fig. 8. The Simulation results of S_{11} for sleeves width (W_S).

Fig. 9 displays the peak gain of the suggested sleeve structure. The peak gain is almost 6.8 dBi at 10.7 GHz frequency.

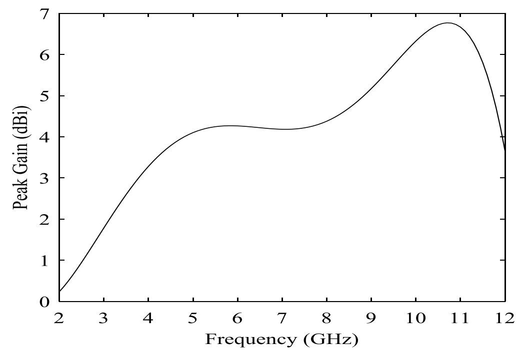


Fig. 9. The peak gain of the suggested sleeve monopole antenna.

5. FABRICATION AND MEASUREMENTS

An experimental evaluation of the optimized antenna was conducted by implementing and testing the proposed antenna. For this purpose, the printed sleeves monopole antenna is manufactured on an FR-4 PCB substrate. Fig. 10 shows the manufactured proposed antenna.

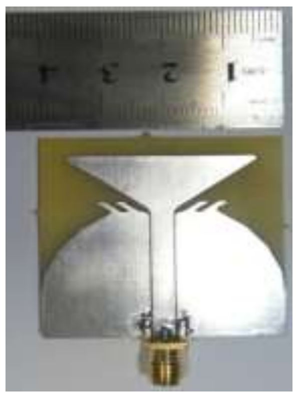


Fig. 10. The manufactured sleeves monopole antenna.

The return loss curves of the measuring and simulation results of the designed structure are plotted in Fig. 11. The 10-dB bandwidth reaches 2.45 - 11 GHz to meet the requirements of the UWB application. According to equations 1 and 2, the bandwidth efficiency is 127.14%.

$$BW(\%) = \frac{f_H - f_L}{f_C} \quad (1)$$

$$f_C = \frac{f_H + f_L}{2} \quad (2)$$

Where f_H, f_L, f_C are the operation band's upper, lower, and center frequency, respectively. The simulation corresponds to measurement fairly.

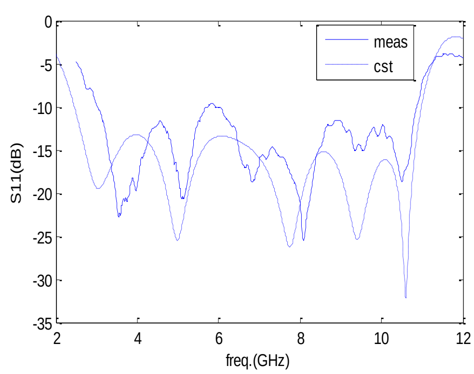
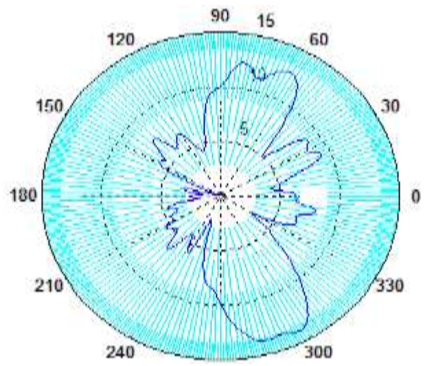
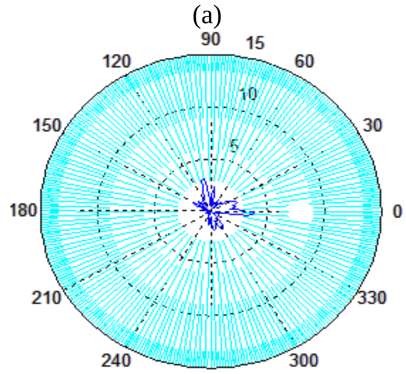


Fig. 11. Results of simulation and measuring of return loss.

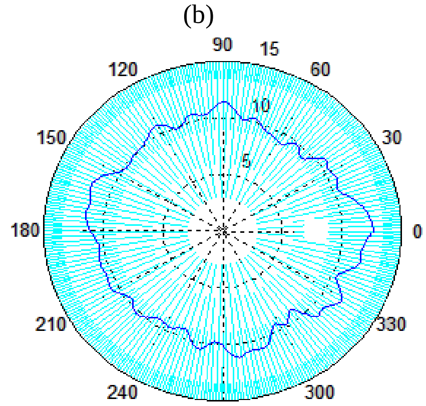
The radiation profiles measured in the x-y E and H planes at 5.5 GHz are shown in Fig. 12.



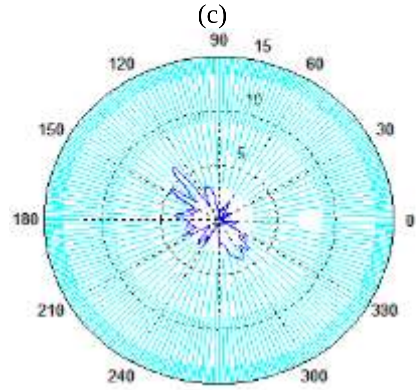
(a)



(b)



(c)



(d)

Fig. 12. The measuring results of the radiation patterns from the designed structure at 5.5 GHz; a) Co polarization in E-Plane, b) Cross polarization in E-Plane, c) Co polarization in H-Plane, d) Cross polarization in H-Plane.

Finally, a comparison proposed antenna with recent monopole antennas are in Table 2. This table verifies the improvement in the bandwidth of our proposed antenna.

Table 2. Comparison between monopole antennas

Reference	Frequency range (GHz)	Bandwidth (%)	Dimensions (mm^3)
[18]	0.24-0.95	119.3	30×30×320
[19]	3.92-7.52	62.94	30×32×1.6
[20]	2.87-11.44	119.7	22×18×1.6
[21]	0.47-0.9	63	185×45×1.6
[22]	0.2-0.51	86	530×150×50
[23]	2.4-7.6	104	40.5×30.5×1.6
Proposed antenna	2.45-11	127.14	40×40×1.6

6. CONCLUSION

The printed sleeve triangular monopole antenna was proposed. The CPW-fed characteristics, circular ground plane, and loading two-pair sleeves are tuned to the input impedance matching. The low profile of the designed structure is appropriate for integrated systems. The proposed structure has achieved an ultra-wide bandwidth. The accuracy of the result has been verified by the agreement between the simulation and measurement results. Also, the measurement results of the radiation patterns of the designed structure show the omnidirectional antenna. This design is a potential alternative for future UWB devices based on the results.

REFERENCES

[1] Y. W. Y. Z. a. H. Z. S. Hu, **"Design of a CPW-Fed Ultra-Wide Band Antenna,"** *Open Journal of Antennas and Propagation*, vol. 1, no. 2, pp. 18-22, Sep. 2013.

[2] G. K. K. R. N.P. Agrawall, **"Wide-band Planar Monopole Antennas,"** *IEEE Trans. Antennas Propag*., vol. 46, no. 2, pp. 294-295, Feb. 1998.

[3] M. C. F. M. F. B. A. V. N. E. A. Daviu, **"Wideband Double-fed Planar Monopole Antennas,"** *Electron*. Lett., vol. 39, no. 23, pp. 1635-1636, Nov. 2003.

[4] H. Chen, H.M. Chen and W.S. Chen, **"Planar CPW-fed sleeve monopole antenna for ultra-wideband operation,"** *IEE PROCEEDINGS MICROWAVES ANTENNAS AND PROPAGATION*, vol. 152, no. 6, p. 491, Dec. 2005.

[5] H. Chen, **"Compact broadband microstrip-line-fed sleeve monopole antenna for DTV application and ground plane effect,"** *IEEE Antennas and Wireless Propagation Letters*, vol. 7, pp. 497-500, Aug. 2008.

[6] P. Ramanujam, P. R. Venkatesan, Ch. Arumugam and M. Ponnusamy, **"Design of miniaturized super wideband printed monopole antenna operating from 0.7 to 18.5 GHz,"** *AEU-International Journal of Electronics and Communications*, vol. 123, p. 153273, 2020.

[7] B. Bag, S. Biswas and P. P. Sarkar, **"A wide circularly polarized dual- band isosceles trapezoidal monopole antenna with modified ground plane,"** *International Journal of Communication Systems*, vol. 35, no. 3, p. 5037, 2022.

[8] M. Rahman, M. A. Stuchly and M. Okoniewski, **"Dual-Band Strip-Sleeve Monopole for Handheld Telephone,"** *Microwave Opt. Technol. Lett.*, vol. 21, no. 2, pp. 79-82, Apr. 1999.

[9] H. D. Chen, H. M. Chen and W.-S. Chen, **"Planar CPW-fed Sleeve Monopole Antenna for Ultra-Wideband Operation,"** *IEE Proc.-Microw. Antenna Porpaga*., vol. 152, no. 6, pp. 491-494, Dec. 2005.

[10] S. B. Chen, Y. C. Jioa, W. Wang, and Q.-Z. Liu, **"Wideband CPW-fed Unipla-nar Sleeveshaped Monopole Antenna,"** *Microwave Opt. Technol. Lett*., vol. 47, no. 3, pp. 245-247, Nov. 2005.

[11] N. G, D.S, and U. S, **"Sleeve Monopole Antenna for WiMAX Applications,"** *India Conference (INDICON)*, 2012 Annual IEEE., pp. 588-591, 2012.

[12] Y. Zimu, L. Jiangang, Z. Dailiang, and Y. Aishuai, **"Compact Monopole Sleeve Antenna Reaches 11.8 GHz,"** *Microwaves & RF*., vol. 51, no. 7, Jul. 2012.

[13] G. Brown and O.M. Woodward, **"Experimentally Determined Radiation Characteristics of Conical and Triangular Antennas,"** *RCA Rev*., vol. 13, no. 4, pp. 425-452, Dec. 1952.

[14] K. L. Wong and Y. F. Lin, **"Stripline-fed Printed Triangular Monopole,"** *Electron. Lett.*, vol. 33, pp. 1428-1429, Aug. 1997.

[15] C.-C. Lin, K.-Y. Kan and H.-R. Chuang, **"A 3-8-GHz Broadband Planar Triangular Sleeve Monopole Antenna for UWB Communication,"** *in Proc. IEEE Antennas Propagat. Society International Symposium*, pp. 5741-5744, June 2007.

[16] A. De, B. Roy and A. K. Bhattacharjee, **"Design and investigations on a compact, UWB, monopole antenna with reconfigurable band notches for 5.2/5.8 GHz WLAN and 5.5 GHz Wi- MAX bands,"** *International Journal of communication systems*, vol. 33, no. 7, p. 4323, 2020.

[17] B. Bag, S. Biswas and P.P. Sarkar, **"A wide circularly polarized dual- band isosceles trapezoidal monopole antenna with the modified ground plane,"** *International Journal of Communication Systems*, vol. 35, no. 3, p. 5037, 2022.

[18] X. H. Zhang, X. W. Dai, W. Sun, H. Jin and G. Q. Luo, **"Sleeve monopole antenna with choke structure for broadband application,"** *IEEE Antennas and Wireless Propagation Letters*, vol. 20, no. 7, pp. 1230-1233, 2021.

[19] M. Midya, Sh. Bhattacharjee and M. Mitra, **"Broadband circularly polarized planar monopole antenna with G-shaped parasitic strip,"** *IEEE Antennas and Wireless Propagation Letters*, vol. 18, no. 4, pp. 581-585, 2019.

[20] T. Gayatri, N. Anveshkumar and V. K. Sharma, **"A compact planar UWB antenna for spectrum sensing in cognitive radio,"** *In 2020 International Conference on Emerging Trends in Information Technology and Engineering (ic-ETITE) IEEE*, pp. 1-5, 2020.

[21] J. Owusu, M. R. B. Hamid, S. T.-Koduah and S. Afoakwa, **"Omnidirectional antenna with modified ground plane for wideband DVB in handheld devices,"** *Scientific African*, vol. 13, p. e00872, 2021.

[22] D. Qin and B. Sun, **"VHF/UHF wideband slim monopole antenna with distributed matching structures,"** *International Journal of Antennas and Propagation 2022*, 2022.

[23] A. P. Acharya, T. K. Das, and T. Shaw, **"Design and analysis of compact flower-shaped wideband slotted monopole antenna for RFID reader applications,"** *AEU-International Journal of Electronics and Communications*, vol. 169, p. 154718, 2023.