Different Shape Printed Monopole Antennas for UWB Applications

Nor-elhouda MEHENNI[1], Yamina TEGHILT[2], Asma SLIMANI[3], Rania Ibtissam BENMELOUKA[1], Djamel SAYAD[4]

[1]Laboratoire d'Electronique de Puissance et Commande Industrielle (LEPCI), Department of Electronics, University of Ferhat Abbas, Sétif 1, Algeria
[2]Laboratoire d'Instrumentation Scientifique (LIS), Department of Electronics University of Ferhat Abbas, Sétif 1, Algeria
[3] Laboratoire de modelisation des dispositifs a énergies renouvelables et nanométrique MoDERNa University of Frers Mentouri 1, Constantine, Algeria
[4] Laboratoire d'Electronique de skikda Industrielle (LES), Dept of Elecctrical Engineering University 20 Aout 1955-Skikda Skikda 21000, Algeria.

E-mail: norelhouda.mehenni@univ-setif.dz

Abstract - in this work, three printed monopole antennas of different shapes were proposed for UWB applications. The whole dimensions of these structures are $25 \times 30 \times 1.575\ \mathrm{mm}^3$ fabricated on a Rogers RT5880 type dielectric substrate material with a dielectric constant of 2.2 with 0.0009 loss tangent. The first proposed antenna is a circular patch with a partial ground plane; this antenna achieves the UWB requirement bandwidth calculated for S11<-10 dB with frequency range from 3.43 to 11.48 GHz. However, the FCC band witch spreads from 3.1 to 10.6 GHz is not achieved. In the aim of a low frequencies shifting, a hexagonal printed monopole antenna is proposed. The partial bandwidth of the second antenna is from 3.41 to 17.75 GHz. An important high frequencies shifting is achieved by this antenna with an insignificant shifting for the low frequencies. The FCC band is realized with a total bandwidth spreading from 2.54 to 18.70 GHz after some modifications made to the hexagonal patch which meets the requirements of both ultra-wideband and FCC applications. For the three proposed antennas the realized maximum gain and efficiency are respectively greater than 4.5 dBi and 70%. Simulation was carried out using a commercially available microwave studio simulator CST.

Keywords - CST software, FCC band, Printed monopole antenna, Ultra wide Bande (UWB).

I. INTRODUCTION

In wireless communication systems, monopole printed antennas have found extensive application in ultra-wideband (UWB) scenarios, consistently meeting the evolving demands of compact antenna technology [1]and that due to their attractive features such as simple design, small size, low profile, lightweight construction, constant gain and the stability of their radiation pattern in addition is easy to fabricate it [2-3]. Planar and printed monopole antennas are the best solution candidate for the use in UWB wireless technology due to their important characteristics mentioned above [4].

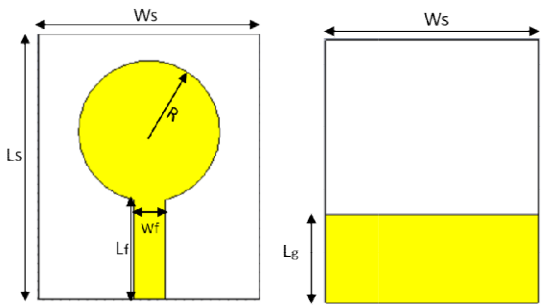
UWB antennas have been widely used in the field of wireless communication technology. According to the US Federal Communications Commission (FCC). [5-6] the UWB allocated for wireless communications ranges is from 3.1 GHz to 10.6 GHz [7-8]. Many antennas have been developed for UWB applications with a lot of shapes that can be used to design microstrip patch antenna to provide this applications such as bipolar, square, rectangular, triangular; Elliptical, circular, ring, hexagonal and pentagonal loop antennas. [9-12].

In this paper, three simple and compact micro strip patch antennas for UWB applications were proposed. The main points of this article are as follows. The first part describes the basic design model of the proposed antenna.

In the second part, the concept of hexagonal antenna is presented and the third part considers modifications of hexagonal antenna that meet the requirements of UWB systems and FFC band applications. The article ends by comparing the results obtained from the CST software for each level of steps.

II. CIRCULAR PRINTED MONOPOLE ANTENNA

In order to achieve a satisfactory UWB and the FCC band applications, three different antennas are proposed. The geometry of the first proposed antenna is illustrated in Fig. 1.



(a) (b)

Fig. 1. Geometry of Circular printed monopole antenna (CPMA); (a) Top view and (b) Side view with design parameters.

To enhance the bandwith defected ground structure (DGS) is considered on the bottom side of the substrate materiel as shown in Fig. 1 (b). The cylindrical antenna is having dimensions of substrat (Rogers RT5880) dielectric substrate material length LS = 30, width Ws=25 mm, and h=1.575 mm with $\boldsymbol{\varepsilon}_r$= 2.2, and loss of tangent (tan $\boldsymbol{\delta}$) is 0.0009. A circular patch antenna having radius R = 8 mm is mounted on a surface of the substrate, and providing 50 Ω microstrip feed line is depected in Figure1. The radius R (Eq. (2)) of the circular patch is calculated by using effective radius R_{reff} [13].

$$R_{eff} = \frac{8.79\times10^{9}}{f_{res}\sqrt{\varepsilon_r}} \quad (1)$$

$$R = \frac{R_{eff}}{\left(1+\frac{2h_{sub}}{\pi\varepsilon_r R_{eff}}\left[ln\left(\frac{1.57R_{eff}}{h_{sub}}\right)+1.78\right]\right)^{\frac{1}{2}}} \quad (2)$$

Where f_{res} is the first resonant frequency, $\boldsymbol{\varepsilon}_r$ is the dielectric constant of the substrate materiel; the other design parameters of this antenna are summarized in table 1.

Table 1. Designed antenna parameters in mm.

Substrat	Ls = 30 , Ws = 25 , hsub = 1.575
Patch	R = 8
Feed ligne	Lf = 11.5, Wf = 3.5
Defected ground	Lg = 10

This section describes the simulated properties of the proposed antenna, such as reflection coefficient, gain, and the efficiency respectively. The Reflection coefficient properties of the proposed antenna are presented in Figure2. We can observe from this figure that the proposed antenna covers the bandwidth 3.43 GHz to 11.48 GHz, optimal frequency Impedance matching between transmissions line and antennas. We find that the resonant frequency occurs at 4.21 GHz. We found this (>3.1 GHz) the FCC band is not achieved

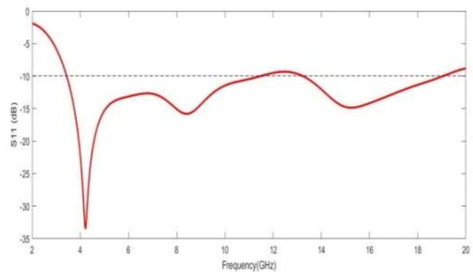


Fig. 2. Simulated reflection coefficient curve of the proposed antenna

Figure 3 shows the gain and efficiency obtained of the first designed antenna. The Gain values were observed is between 1.3 and 4.1 dBi, and the corresponding efficiency ranges from over 69% to 86% for the entire operating range.

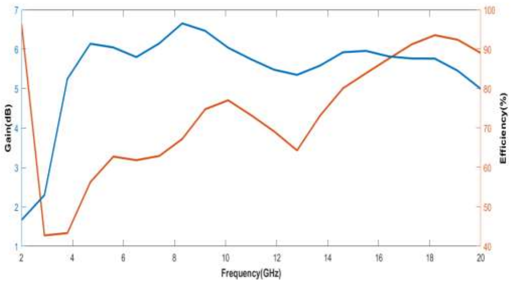
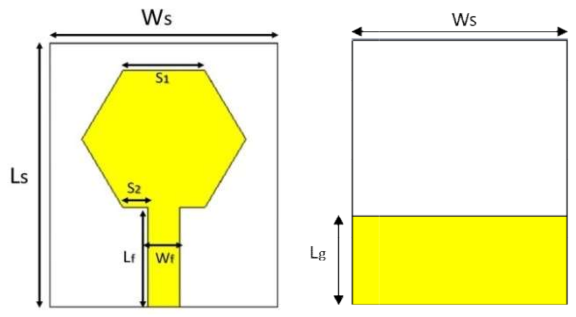


Fig. 3. Simulated gains and efficiency of the circular printed monopole antenna

III. Hexagonal Printed Monopole Antenna

In order to achieve the FCC band, hexagonal printed monopole antenna (HPMA) is proposed .The patch integration is shown in Figure4. The antenna consists of a microstrip line with dimensions Lf = 11.5 and
Wp =3.5 mm, and the ground plane is also partial. Other dimensions of the antenna are Ls = 30, Ws = 25, Lg = 10, S1 = 9 and S2 = 2.75 mm. The antenna is fabricated on a Rogers RT5880 substrate with a dielectric constant of 2.2, tangent loss (tan $\boldsymbol{\delta}$) of 0.0009, and a thickness of 1.575 mm.



(a) (b)

Fig. 4. Geometry of Hexagonal printed monopole antenna, (a) Top view (b) side view.

Figure 5 shows the reflection coefficient of the hexagonal proposed antenna. It is observed that enhanced band for this antenna it covers the bandwidth 3.41 GHz to 17.75 GHz, an important high frequencies shifting is achieved by this antenna with an insignificant shifting for the low frequencies.

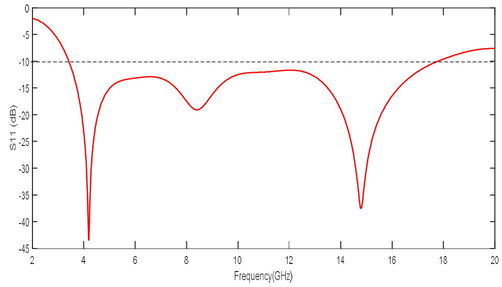


Fig. 5. Reflection coefficients (S11) for two different antennas

The gain and efficiency variation plot of the HPMA is shown in figure6 respectively. It is noticed that gain increases as the frequency increases and it is observed that the maxi-mum gain 5.8 dB occurs at 17.75 GHz.The corresponding efficiency ranged from over 71% to 83% for the entire operating band.

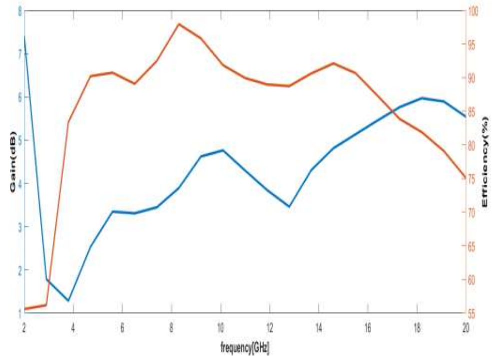
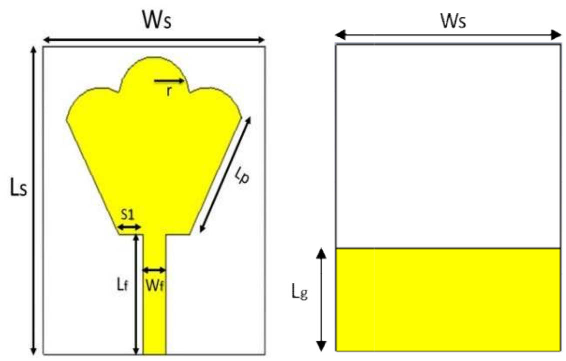


Fig. 6. Simulated gains and efficiency of the hexagonal printed monopole antenna

IV. Modifed Hexagonal Printed Monopole Antenna

After several modifications of hexagonal shaped patch antenna this MHPMA has achieved significant base frequency deflection and meets the requirements of ultra-wideband and FCC applications. Figure 7 shows the shape and configuration of MHPMA grown on Rogers RT5880 substrate with a thickness of 1.575 mm, a relative dielectric constant of 2.2, and a loss factor of 0.0009. The proposed antenna includes a patch. Powered by microstrips and printed on a Rogers RT5880 substrate measuring 25 mm × 30 mm, and other design parameters of this antenna are summarized in Table 2.



(a) (b)

Fig. 7. Geometry of our proposed antenna,
(a) Top view (b) Side view.

Table1. Designed antenna parameters in mm.

Substrat	$ls = 30 , Ws = 25 , hsub = 1.575$
Patch	$Lp = 12.6 , r = 4 , s1 = 2.7$
Feed line	$Lf = 11.5, Wf = 3.5$
Defected ground	$Lg = 10$

The reflection coefficient of the proposed antenna is shown in Fig 8. The -10dB frequency response can cover the wide frequency band of 2.54~18.70GHz, that is, 152.16%, which meets the requirements of both ultra-wideband and FCC applications [3.1~10.6GHz]. Simulation of S11 as a function of frequency in the [2.54, 18.70] GHz band shows that the structure has two resonant frequencies: f_1 = 3.15 GHz and f_2 = 11.59 GHz.

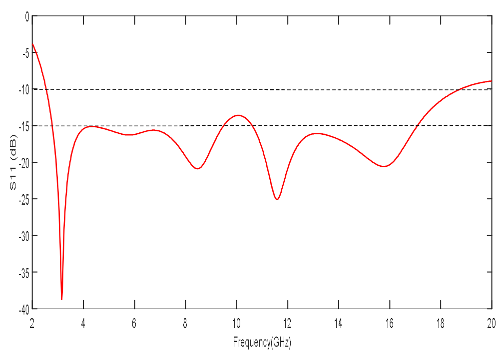


Fig. 8. Parameter |S11| of MHPMA via CST

Figure 9 illustrates the antenna gain and the efficiency as a function of frequency. We see that the gain increases as the frequency increases. The gain reaches a value of about 5 dB at frequencies 11 GHz and 17 GHz. Normal gain varies between 2.92 and 5.05 dB over the frequency band [2.54 to 18.70 GHz]. At 17 GHz, the maximum observed gain is 5.05 dB. In terms of efficiency, it ranges between 77% and 95% across the entire operating range.

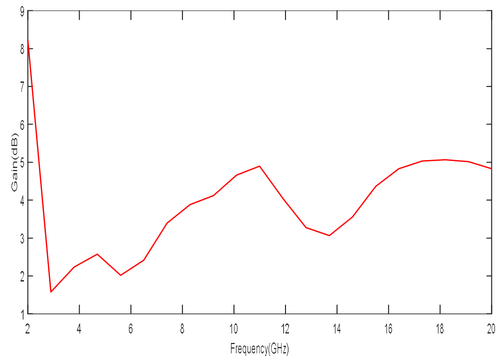


Fig. 9. Simulated gain of proposed antenna

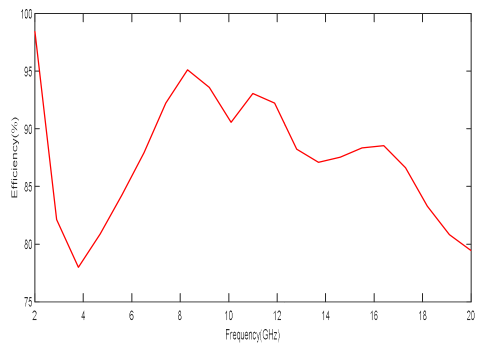


Fig. 10. Simulated efficiency of proposed antenna

V. RESULTS COMPARISON

Figures 11, 12, and 13 illustrate reflection coefficient, gain and efficiency respectively obtained for the three antennas. The third structure (MHPMA) presents the largest impedance bandwidth with 152.16 % and efficiency greater than 77 % over the overall frequency band. The results obtained for impedance bandwidth and percentage in GHz, maximum efficiency, and maximum gain are summarized in Table 2.

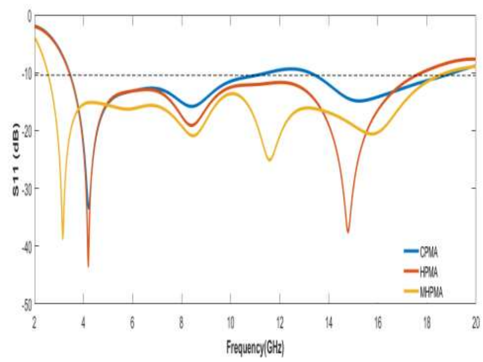


Fig. 11. Comparisons of Reflection coefficients for the three antennas proposed (CPMA, HPMA and MHPMA).

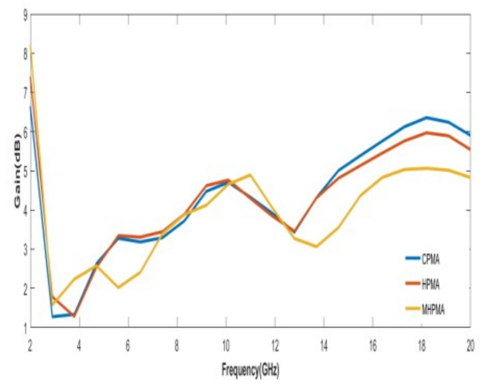


Fig. 12. Comparison of the gain for the three antennas proposed (CPMA, HPMA and MHPMA).

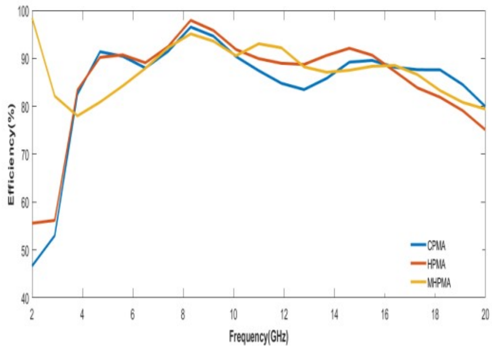


Fig. 13. Comparison of the efficiency for the three antennas proposed (CPMA, HPMA and MHPMA).

Table 2. Comparison of impedance bandwidth, and maximum gain, efficiency range for the three antennas proposed.

Antenna	Impedance bandwidth (GHz) %	Gmax dB	Efficiency %
CPMA	3.43 -11.48 / 107,98	4.7	70 - 96.4
HPMA	3.41 -17.75 /135,53	5.8	70 - 96.4
MHPM	2.54 -18.70 /152.16	4.85	77 - 95.2

VI. CONCLUSION

In this work, a circular, hexagonal and a modified hexagonal printed monopole antennas are proposed. The three antennas achieve an impedance bandwidth of more than 100% and a maximum gain and efficiency greater than 4.5dB and 70% respectively. The third antenna meets the requirements of both ultra-wideband and FCC applications.

VII. REFERENCES

[1] Rizvi, Syed Naheel Raza, et al. "A Compact Size Antenna for Extended UWB with WLAN Notch Band Stub." Applied Sciences 13.7 (2023): 4271.

[2] Stutzman, Warren L., and Gary A. Thiele. Antenna theory and design.John Wiley & Sons, 2012.

[3] Mazhar, W., et al. "Compact microstrip patch antenna for ultra-wideband applications." PIERS Proceedings, Stockholm, Sweden (2013).

[4] Ray, Kamala Prasan. "Design aspects of printed monopole antennas for ultra-wide band applications." International journal of antennas and propagation 2008 (2008).

[5] Hossain, M. J., M. R. I. Faruque, and M. T. Islam. "Design of a patch antenna for ultra-wide band applications." Microwave and Optical Technology Letters 58.9 (2016): 2152-2156.

[6] Yadav, Rohit, and Leeladhar Malviya. "UWB antenna and MIMO antennas with bandwidth, band-notched, and isolation properties for high-speed data rate wireless communication: A review." International Journal of RF and Microwave Computer-Aided Engineering 30.2 (2020): e22033

[7] Anusudha, K., and M. Karmugil. "Design of circular microstip patch antenna for ultra-wide band applications." 2016 International Conference on Control, Instrumentation, Communication and Computational Technologies (ICCICCT). IEEE, 2016.

[8] Gopi, Dattatreya, Appala Raju Vadaboyina, and JRK Kumar Dabbakuti. "DGS based monopole circular-shaped patch antenna for UWB applications." SN Applied Sciences 3.2 (2021): 198.

[9] Shakib, Mohammed Nazmus, Mohammad Tariqul Islam, and Norbahiah Misran. "Stacked patch antenna with folded patch feed for ultra-wideband application." IET microwaves, antennas & propagation 4.10 (2010): 1456-1461.

[10] Ezhumalai, Aravindraj, Nagarajan Ganesan, and Ramanathan Palaniappan. "Koch Snowflake Fractal Embedded Octagonal Patch Antenna with Hexagonal Split Ring for Ultra-Wide Band and 5G Applications." Progress In Electromagnetics Research C 135 (2023): 95-106.

[11] Azim, Rezaul, Mohammad Tariqul Islam, and Norbahiah Misran. "Microstrip line-fed printed planar monopole antenna for UWB applications." Arabian Journal for Science and Engineering 38 (2013): 2415-2422.

[12] Li, Dong, Shaohui Quan, and Zhengpeng Wang. "A printed ultra-wideband hexagon monopole antenna with WLAN band-notched designs for wireless communication." Microwave and Optical Technology Letters 51.4 (2009).

[13] Murali Krishna, Ch, P. Krishna Kanth Varma, and P. James Vijay. "Bandwidth enhancement of circular ring fractal antenna for wireless applications." Microelectronics, Electromagnetics and Telecommunications: Proceedings of the Fourth ICMEET 2018. Springer Singapore, 2019.