International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-12, October 2019

A Metamaterial Inspired UWB Circular Antenna as Superstrate for Gain and Directivity Improvement's

Mourad Elhabchi, Mohamed Nabil Srifi, Raja Touahni

Abstract: *A Near Zero refractive Index (NZIM) metamaterial inspired UWB circular antenna as a superstrate for gain and directivity improvement's is presented and investigated in this work. The frequency range with S_{11} less than -10dB is from 4.5GHz to 12.5GHz. The permeability and permittivity of the (NZIM) has an extraordinary property that could be optimized to synchronously approach zero and have an effective wave impedance matching with air and near-zero index simultaneously, this feature of metamaterial gives the NZIM the ability to collimates the incident bending waves and gather it's towards the normal direction. Hence the antenna performances in term of the gain and directivity will be enhanced. The studied metamaterial design is optimized and analyzed using CST microwave. Obviously, the antenna gain and directivity are enhanced by 4.8 and 4.89 respectively. The simulation of this developed metamaterial antenna has been optimized and performed by using Computer Simulation Technology-Microwave Studio (CST) and Ansof High Frequency Structure Simulator (HFSS).*

Keywords: *Near Zero Index Metamaterial, Gain, Directivity, UWB circular antenna.*

I. INTRODUCTION

In recent years, several metamaterials inspired the microwave device have been developed and used to improve their performance especially antennas [1],[2] .In 2002, Enoch et al, investigated the metamaterial and found that using the near zero index (NZIMs) as a superstrate could achieve the directive emission on antenna. Backward Cerenkov radiation, simultaneously negative permeability and permittivity, negative index, backward wave, and so on are the most attractive extraordinary properties of metamaterials [3]. The near-zero index metamaterials (NZIM) have a kind property that can control the antenna radiation wave and gather it to be in a normal direction, to more clarify the principle procedure, we will use the Snell's law, when the ray is incident from inside the NZIM into free space, the angle of refraction will be normal to the interface because the refracted rays will be controlled and closed to near zero. As a result, the metamaterial will improve the antenna performance in terms of gain and directivity [4].

To extract the S-parameters from CST to MATLAB software's, the computation method using Nicolson Ross algorithm was used for retrieving the permeability, permittivity and refraction index of metamaterial.

Some metamaterial antennas have been implemented and studied [5], an anisotropic ZIML was theoretically presented with proper design 2016, A near-zero index metamaterial lens as superstrate and an Artificial Magnetic Conductor (AMC) substrate are used respectively to improve the antenna directivity and to reduce the height of a low profile antenna. An improved gain with good impedance matching based on ZIMLS of Vivaldi The antenna is studied in [6]. The gain of bow-tie antenna is increased by The ZIMLS property used the split ring resonator (SRR) array is presented in [7]. A Fabry-Perot resonant cavity (FPRC) is another technique to increase the antenna gain, it is obtained using a frequency selective surface (FSS) or an electromagnetic band-gap (EBG). A metamaterial using the frequency selective surfaces (FSSs) superstrate on the top side of a metallic ground plane containing a compact antenna are also used and implemented.

In this paper, an UWB circular compact monopole antenna [8] which is suffering from a low directivity and gain is inspired as superstrate with a one layer metamaterial unit cell near zero refractive-index layer (NZIM). From the obtained results, both the gain and directivity of the proposed design are effectively increased respectively by 4.8dB and 4.89dB using the mentioned technique based on metamaterial. Finally, an antenna performance comparison between the conventional small circular UWB antenna the modified proposed loaded metamaterial UWB circular antenna is presented as well as a comparison with recently similar works[9].

II. ANTENNA DESIGN PROCEDURE

The design geometry together with dimensions of the reference low gain circular UWB antenna without MTM superstrate is illuminated in Fig. 1.

Revised Manuscript Received on October 30, 2019.
* Correspondence Author

Mourad Elhabchi*, LASTID Laboratory, Department of physics, Faculty of Sciences, Ibn Tofail University ,Kenitra, Morocco .Email mouradelhabchi@hotmail.fr

Mohamed Nabil Srifi, Electronics and Telecommunication Systems Research Group, National School of Applied Sciences (ENSA), Ibn Tofail University, kenitra, Morocco. Email srifimn@ieee.org

Raja Touahni, LASTID Laboratory, Department of physics, Faculty of Sciences, Ibn Tofail University ,Kenitra, Morocco .

The substrate FR4 with 4.3 and 0.025 of the permittivity and the loss tangent respectively is chosen for antenna conception. 50 ohm impedance adaptation is achieved with a selected dimension of the microstrip line in Wf=2mm and Lf=9.6mm for the width and the length respectively.

The configuration of the metamaterial NZIM unit-cell which is consists on a Rogers R04350B with a 0.0031 of the loss tangent , 0.762mm of thickness and 3.48 of the dielectric permittivity is illuminated in Fig. 2.it is designed to be smaller than the normal wavelength. The NZIM is composed on 5x5 elements with a 0.75mm of spacing. The distance between the UWB circular antenna and the NZIM is hm=16mm.

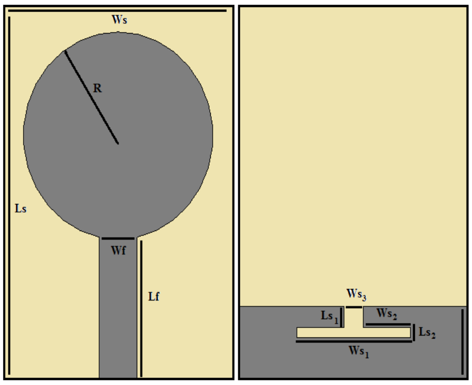
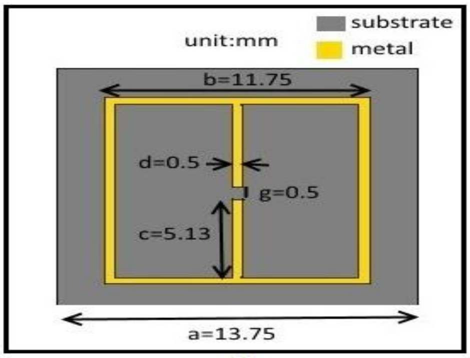
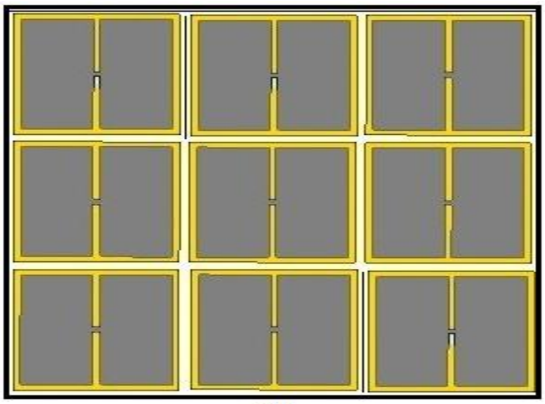


Fig. 1. The reference low gain circular UWB antenna toghether with it’s dimensions (mm) : Ls=18 ,Ws=12 , R=5 , Wf=2, Lf=7 , Ws1= 6 , Ws2=1 ,Ws3= 1 , Ls1= , Ls2=1 ,



(a)



(b)

Fig. 2. (a) The geometry of single metamaterial near zero-index , (b) near zero-index metamaterial (NZIM) 3x3 unit-cell.

III. SIMULATION RESULTS AND DISCUSSION

A. NZIM metamaterial

In order to understand the NZIM principle for antenna performance enhancement as mentioned above, it is very important to investigate the refractive index n as presented in fig.3, the results presented in this figure (fig.3 (a)) are obtained using the extracted data from CST to MATLAB software’s.

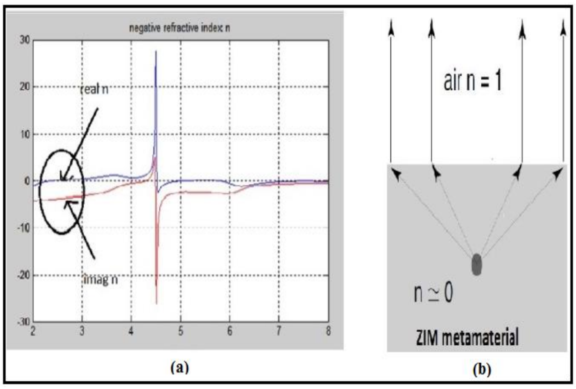


Fig. 3. (a) Zero refractive index , (b) NZIM effects of the incident waves.

B. Return loss, Gain and Radiation pattern Results

Fig.4 illuminates the S_{11} plots versus frequency of the presented circular NZIM metamaterial antenna using both CST and HFSS software’s, it is noted that from this traces the NZIM design is not affected by the superstrate metamaterial in the term of S11 and cover an UWB frequencies range from 4.5 GHz to 12.5GHz with better impedance adaptation ($S_{11} <$ -10dB).

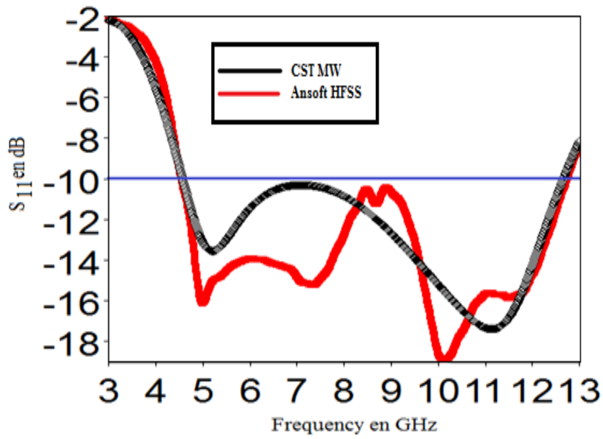


Fig. 4. Return loss comparison between CST Microwave and Ansoft HFSS

Fig.5 and fig.6 depicts the obtained simulated gain and directivity of the reference low gain circular UWB design and those of the proposed NZIN metamaterial structure. It is demonstrated that from the simulated results the gain and directivity of initial UWB design at 5.8 GHz (for WLAN upper band application) are 2.43dB and 2.75dB respectively, have been increased on the evaluated metamaterial antenna at the same frequency band (5.8 GHz) to 7.23 and 7.64dB. It is show that the design gain and directivity are improved by 4.8 and 4.89dB respectively.

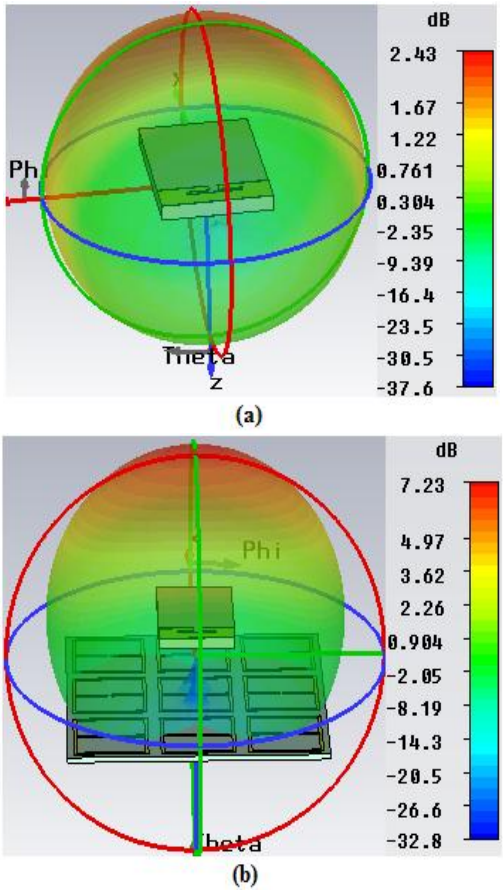


Fig. 5. The antenna gain at 5.8GHz. (a) reference low gain UWB antenna , (b) the presented NZIN MTM antenna.

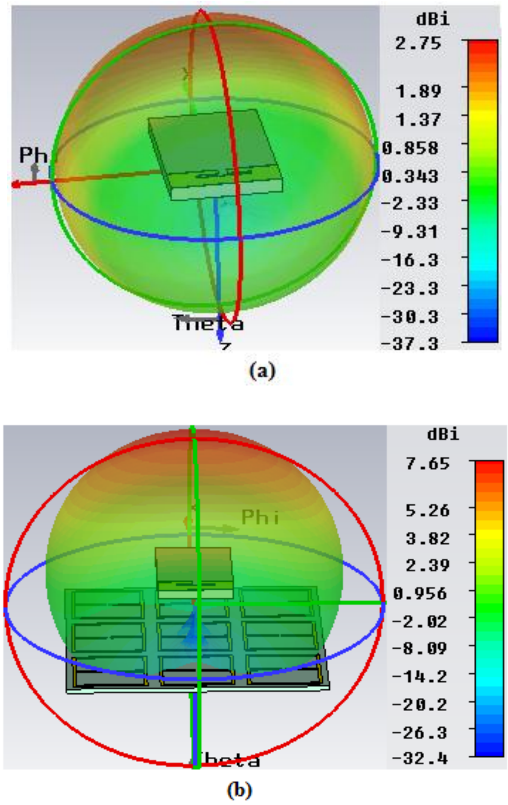


Fig. 6. The antenna directivity at 5.8GHz. (a) reference low gain UWB antenna , (b) the NZIN MTM antenna.

The obtained simulated radiation patterns both in CST and HFSS of the investigated design in E and H-planes with and without NZIM at upper WLAN band of 5.8GHz are illuminated in fig.7.

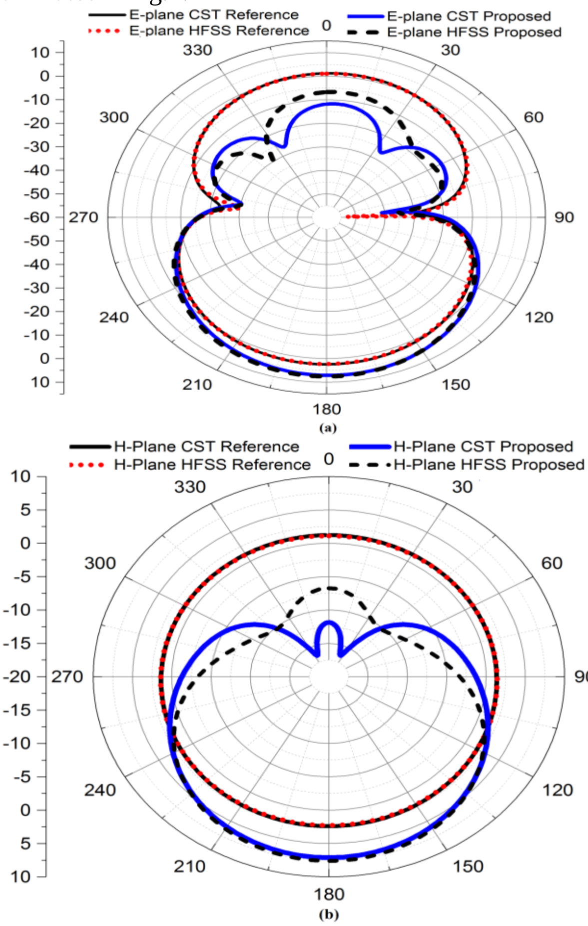


Fig. 7. The antenna radiation pattern at 5.8GHz. (a) E-plane , (b) H-plane

It is clear that the radiation beam pattern in E-plane are bi-directional without NZIN MTM and become more directional with the superstrate MTM, which is obviously becoming with high radiation pattern .

The radiation beam pattern in H-plane is omnidirectional because the energy is radiated in all directions (180) without NZIM and it's become directional with the NZIM metamaterial (about 75). As a summary, the mentioned design can be considered as a one of good candidate to challenge the antenna conceptions in the recent technology[10],[11],[12].

Fig. 8 depicts the gain evolution versus frequency for various NZIM h_m distance values. It is clearly noted that the gain is more affected while the separation between the initial low gain antenna and the MTM NZIM hm value changes from 11 to 14mm. The optimum separation value of h_m to obtain better enhanced antenna gain is 11mm.

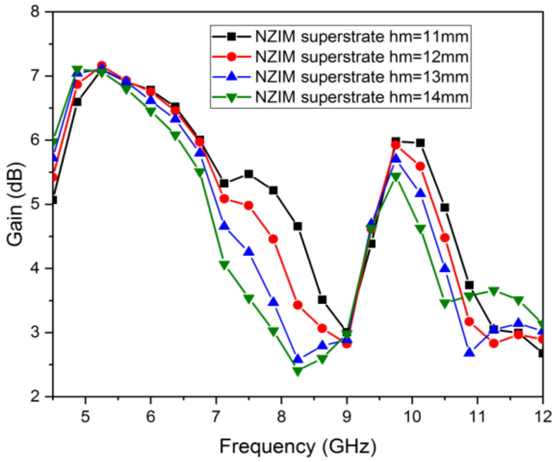


Fig. 8. Gain against frequency for various NZIM MTM separation values.

Fig .9 illustrates the antenna gain against frequency with and without NZIM metamaterial, it is observed that higher gain with a maximum value of 7.23 dB at the upper WLAN band of 5.8 is provided with the NZIM MTM over the frequency range,

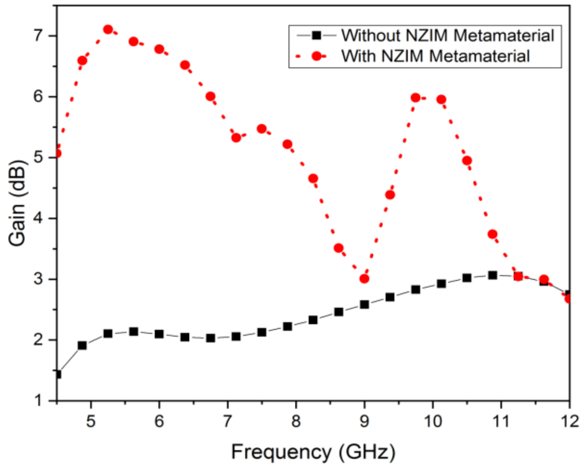


Fig. 9.The antenna gain comparison with and withot NZIM.

IV. COMPARISON WITH RECENTLY DEVELOPED DESIGNS

Finally, the mentioned loaded single layer NZIM metamaterial UWB circular design and the recently avaluated antennas cited in this work are summarized and compared in Table. I. In the term of frequency range, dimension and average gain. The geometry and dimensions the implemented structure of this letter is not only has an improved gain and directivity characteristics but also has a very compact miniaturized size[13].

Table- I: Comparison with developed published designs

Antennas	*Antennas Frequency*	*Technique used for the gain enhancement*	*Average enhanced Gain(dB)*
Ref [4]	3.39-12.9	frequency selective surfaces (FSSs) unit cell	About 3
Ref [5]	12.5-14	Electromagnetic Bandgap(EBG) Superstrate	2-3
Ref [7]	4-9	Split Ring Resonator (SRR) unit cells	4-5
This work	4.5-12.5	NZIM metamaterial loaded circular antenna as a superstrate	About 5

V. CONCLUSION

In this article, the gain and directivity of UWB circular antenna are increased using a NZIM shaped unit cell of 3x3 metamaterial superstrate. The presented single layer metamaterial has been implemented and analyzed in detail. This NZIM was designed to change the direction the radiation energy and gather in the defined closed direction to the normal direction of the proposed MTM structure. The simulated results in both the two mentioned software's shows that the S_{11} parameters are not influenced by the MTM and cover an UWB behavior with stable radiation pattern and enhanced gain and directivity (about 5dB).

REFERENCES.

1. Amanpreet. K , and Komalpreet. K, "A Compact Rectangular Microstrip Patch Antenna Loaded with Stubs and Defected Partial Ground Structure for UWB Systems," International Journal of Innovative Technology and Exploring Engineering (IJITEE), Vol-8(9S).2019 pp.155-160.
2. Elhabchi. M , Srifi, M.N and Touahni.R , "A novel dual-band antenna with L-slot defective Ground structure (DGS) and T-shaped strip for WIMAX /WLAN and ISM medical band applications,". International Journal of Microwave and Optical Technology. 12.2017. 440-446.
3. Navneet .K, Surbhi S., Jaswinder K. , " Concave Shape Microstrip Patch Antenna using SRR for 5G Applications ," International Journal of Innovative Technology and Exploring Engineering (IJITEE), Vol-8(9S).2019. pp.743-746.
4. Komalpreet. K and Amanpreet. K , " Ultra-Wideband Coplanar Waveguide Antenna with an Improved Gain using a Frequency Selective Surfaces (FSS) ," International Journal of Innovative Technology and Exploring Engineering (IJITEE), Vol-8(9S).2019. pp.145-149.
5. Pandey, G.K., Singh, H.S., Meshram, M.K., "EMeander-line-based inhomogeneous anisotropic artificial material for gain enhancement of UWB Vivaldi antenna,"Appl. Phys. A.2016., 122, pp. 122134.
6. Popescu A.-S., Bendoym, I. and Rexhepi, T and Crouse,D ,"Anisotropic Zero Index Material: a Method of Reducing the Footprint of Vivaldi Antennas in the UHF Range,"Progress In Electromagnetics Research C, 2016.Vol. 65, 33-43.
7. W. ,Cao, Zhang, B., Liu, A., et al ,"Gain enhancement for broadband periodic end-fire antenna by using split-ring resonator structures,"IEEE Trans. Antennas Propag., 60, (7), pp. 35133516.2012.
8. Lakrit, S and Ammor, H. ,"Design of ultra wideband small circular patch antenna for wireless communication,". Journal of Engineering and Applied Sciences. 10.2015.pp. 1762-1765.
9. Elhabchi. M , Srifi, M.N and Touahni.R, "A Novel Dual Band Hexagonal Antenna for Bluetooth and Uwb Applications With Single Band Notched,". Advanced Electromagnetics. Vol 7(5).2018.pp. 63-68.
10. Rakesh K. P. et al , " Design and Performance Analysis of Wideband Hexagonal Ring Antenna with Defected Ground Structure," International Journal of Innovative Technology and Exploring Engineering (IJITEE), Vol-8(7S).2019.pp.33-38.
11. Elhabchi. M , Srifi, M.N and Touahni.R ,"A novel circular fractal-like antenna for bluetooth/ WLAN and X-band applications," International Journal of Microwave and Optical Technology.2019, vol. 14,pp. 46–53.
12. Elhabchi. M , Srifi, M.N and Touahni.R ," A Novel CPW-Fed Semi-Circular Triangular Antenna with Modified Ground Plane for Super Ultra Wide Band (UWB) Applications," 2018 International Symposium on Advanced Electrical and Communication Technologies (ISAECT), Rabat, Morocco, pp. 1-5. Nov2018.
13. M. Elhabchi, M. N. Srifi and R. Touahni, "A Modified Hexagonal UWB Antenna Loaded with Multiple L-shaped Stubs for GPS Band Integration and Like Y-Shaped Slot for Single Band Rejection," 2019 International Conference on Wireless Technologies, Embedded and Intelligent Systems (WITS), Fez, Morocco, 2019, pp. 1-5.doi: 10.1109/WITS.2019.8723735.