International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 7 (2018) pp. 4859-4864

Ultra Wideband Octagonal Fractal Antenna using Minkowski geometry for Wireless Applications

Vivek R[1]*, Yamuna G[2], Suganthi S[3]

[1]*Research Scholar, Dept. of ECE, Faculty of Engineering and Technology, Annamalai University, Chidambaram, India.*
[2]*Professor, Dept. of ECE, Faculty of Engineering and Technology, Annamalai University, Chidambaram, India.*
[3]*Professor, Dept. of ECE, Faculty of Engineering, Christ University, Bangalore, Karnataka, India.*
**Corresponding author*

Abstract

In this paper, an Octagonal monopole fractal antenna for Ultra wideband (UWB) applications is presented. It is observed that the self-similar structure of Minkowski like fractal geometry laterally with the basic Octagonal patch shape having modified ground structure provides the UWB operating bandwidth because of the multiple resonances. The proposed antenna was designed on an inexpensive FR4-epoxy substrate and simulated using the High Frequency Structure Simulator (HFSS). The Compact 35 mm x 31 mm x 1.6 mm antenna geometry having advantage of UWB impedance matching, appropriate gain and stable radiation pattern with respectable return loss of less than -9.54 dB which is equivalent to Voltage Standing Wave Ratio (VSWR) < 2 over its entire operating frequency range of 3.05-10.45 GHz and can be used in wireless UWB applications.

Keywords: Octagonal geometry, Minkowski fractal, Return loss, Gain, VSWR, UWB, HFSS.

INTRODUCTION

Wireless communication systems have perceived incredible developments in recent years. Federal Communications Commission (FCC) has released UWB to afford a competent use of bandwidth for unlicensed applications [1].The UWB antennas are gaining attention due to their potential of very high data transmission rate, smaller size, low power consumption, low cost with ease of fabrication and wide operating bandwidth[2].Hence, design a compact Wideband antenna is a tedious task. But several efforts have been investigated by the researchers to achieve this by means developing antennas using Fractal geometry. The idea of fractal geometry is applied in antenna design to discover miniaturized antenna without disturbing antenna performance and also to provide wide operating bandwidth [3].To achieve the desired antenna characteristics the space filling property of the fractal geometry is used in designing of antennas to increase the effective electrical path length of the antenna [4, 5].The different kinds of fractal structures such as Koch fractal [4], sierpinski triangle [5], hexagonal [3] and

Some other irregular structures [6, 7] are used to design the UWB antennas. Therefore, fractal antenna is an auspicious area to be inspected and developed.

In this paper, a Compact Octagonal UWB Fractal antenna (COUFA) is designed. The proposed antenna is simulated using HFSS. The Minkowski like fractal geometry is combined with the Octagonal structure [8] with modified ground plane configuration is proposed to achieve the desired UWB characteristics for wireless applications. The simulated reflection characteristics, radiation pattern and gain of the proposed antenna are presented in the succeeding sections.

ANTENNA DESIGN

Fig.1 shows the proposed COUFA designed using the concept of applying minkowski fractal structures with its second iteration in Octagonal shape [8] on an FR4 dielectric layer of length (L_s) of 35 mm and width (W_s) of 31 mm with an height (h_s) of 1.6 mm and relative permittivity (ε_r) of 4.4.The antenna is fed by 50 ohms microstrip feed line of width (W_f) of 4.3 mm and length (L_f) of 11.3 mm for better impedance matching. The antenna is mounted on partial ground plane having length (L_g) of 10.5 mm and width (W_g) of 20.7 mm in which second iterated minkowski like fractal structures are slotted in it to achieve the better impedance bandwidth characteristics.

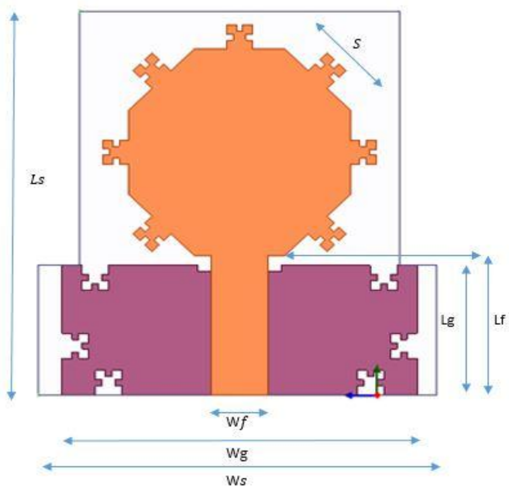


Figure1. Structure of Proposed COUFA

The resonant frequency of the octagonal antenna can be given by [8]

$$f_r = \frac{X_{mn}\, c}{2\pi\,(1.24\, S)\sqrt{\varepsilon_r}} \quad [1]$$

Where f_r is the resonant frequency, Xmn is 1.8411 for lowest order mode TM11 for producing linear polarization similar to square patch antenna, 'c' is the velocity of the electromagnetic wave in free space ($3x10^8$ meters/second) and ε_r is the relative permittivity of the dielectric medium. Initially the basic octagonal patch is designed for 'S' of 6.88 mm and resonant frequency of 4.91 GHz.

SIMULATION RESULTS AND DISCUSSION

The proposed COUFA is designed using HFSS in the sweep frequency range of 2-12 GHz using final optimized parameter values as mentioned in the previous section.

A. Return loss

As shown in the Fig.2, the simulated return loss S_{11} of the COUFA with slotted fractal perturbations in the ground plane clearly indicates that this proposed antenna is broadband and has an excellent UWB ranging from 3.05 – 10.45 GHz for -9.54 dB impedance bandwidth which is acceptable for practical considerations for better impedance matching[9].The proposed antenna has three resonant frequencies such as 3.45 GHz, 6.02 GHz and 9.05 GHz with return loss of -17.57 dB,-26.25 dB and -37.61 dB respectively. However the Octagonal antenna without fractal slots in the ground plane exhibits dual broadband in the range of 3.06 - 6.94 GHz and 7.50 – 10.01 GHz with notching from 6.94 - 7.50 GHz which is presented in the Fig.2. By comparing this with return loss with that COUFA, it is evident that operational bandwidth of the antenna is increased and the desired UWB bandwidth of almost 7.35 GHz is achieved.

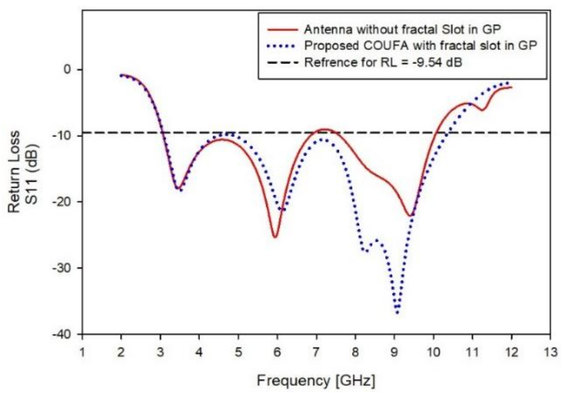


Figure 2. Simulated Return Loss against frequency for the proposed COUFA and Octagonal Fractal antenna without Fractal slots

B. VSWR

The simulated VSWR Characteristics of the Proposed COUFA is depicted in the Fig.3.It is clearly observed that the VSWR < 2 for the Proposed antenna in its entire operative bandwidth of 3.05- 10. 45 GHz when compared to the antenna without ground plane modifications. This evident that the proposed antenna has better impedance matching which is acceptable efficient use in practical considerations.

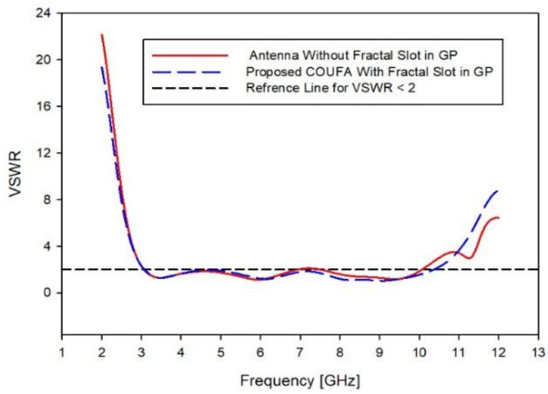
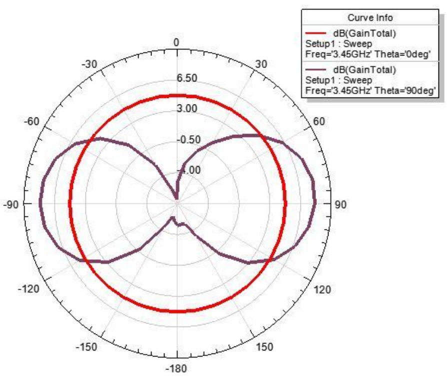


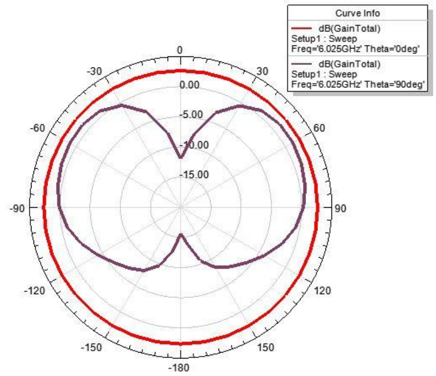
Figure 3. Simulated VSWR against frequency for the proposed COUFA and Octagonal Fractal antenna without Fractal slots

C. Radiation Pattern

The radiation assets of any antenna can be investigated to recognize the dispersal of power around the orientation. The simulated gain pattern of the proposed antenna can be deliberate at various resonant frequencies. The Fig.4 and Fig.5 represents the radiation pattern of the COUFA at 3.45 GHz, 6.02 GHz and 9.05 GHz for E plane and H plane patterns respectively. From these simulated radiation patterns is it observed that the antenna exhibits bidirectional and omnidirectional pattern.

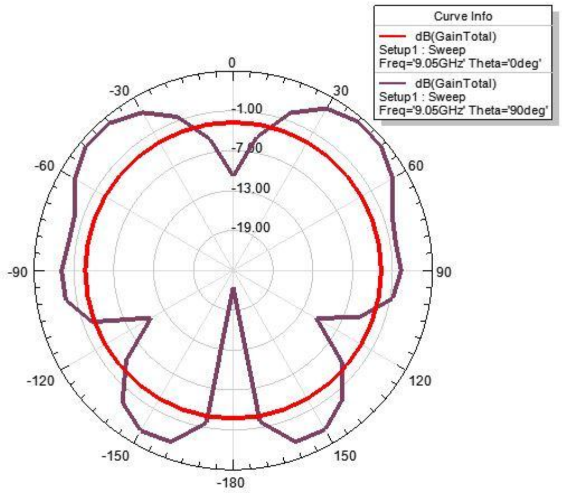


(a)



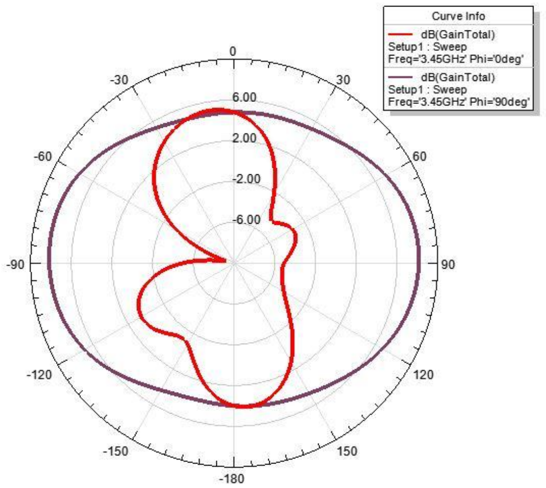
(b)

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 7 (2018) pp. 4859-4864

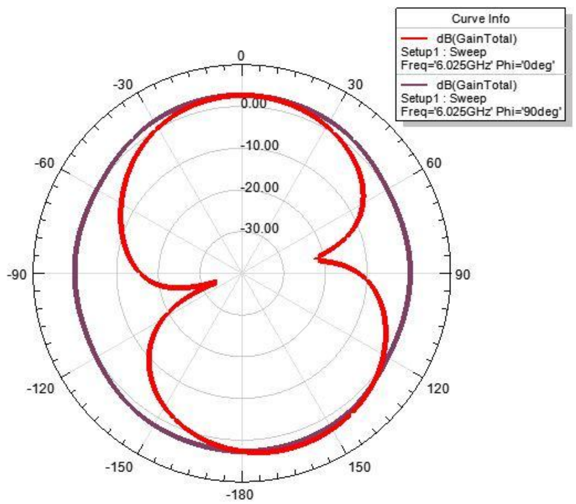


(c)

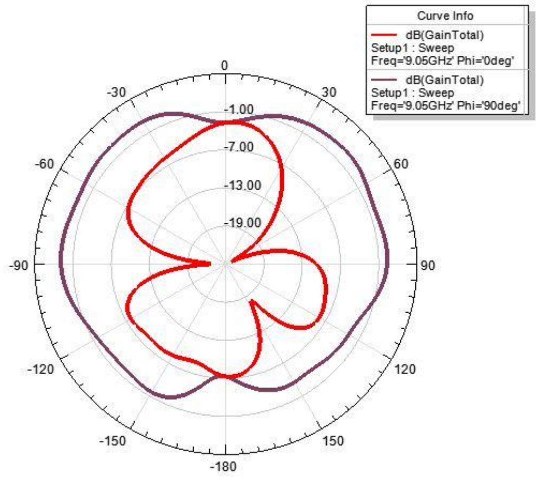
Figure 4. Simulated E Plane radiation pattern of COUFA for various resonant frequencies at (a) 3.45 GHz, (b) 6.02 GHz, (c) 9.05 GHz.



(a)



(b)

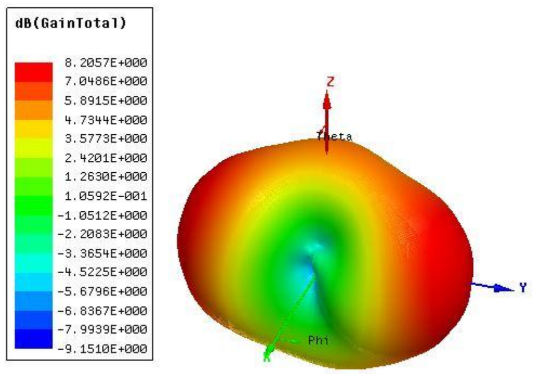


(c)

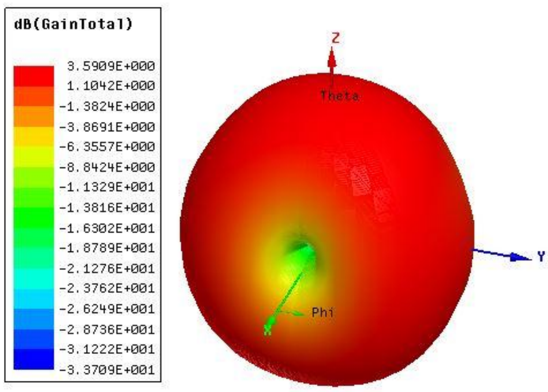
Figure 5. Simulated H Plane radiation pattern of COUFA for various resonant frequencies at (a) 3.45 GHz, (b) 6.02 GHz, (c) 9.05 GHz.

D. Gain

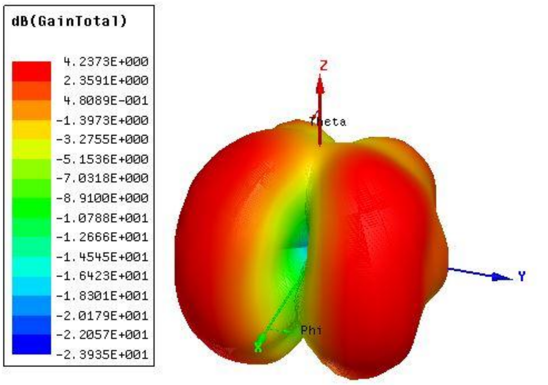
The 3D gain pattern of the proposed COUFA at various resonance frequencies are shown in the Fig. 6.



(a)



(b)



(c)

Figure 6. Simulated 3D gain pattern of COUFA for various resonant frequencies at (a) 3.45 GHz, (b) 6.02 GHz,

(c) 9.05 GHz.

The Table I provides the values of different antenna parameters obtained for the various resonance of COUFA.

From the above table it is inferred that the COUFA possess UWB operational bandwidth having multiple resonance with lowest return loss characteristics while maintaining the VSWR of 1:2 over the entire band. The gain and directivity are also worthy sufficient with significant efficiency. The Fig.7 represents the gain of the proposed COUFA over the entire frequency spectrum 3.05 to 10.6 GHz.

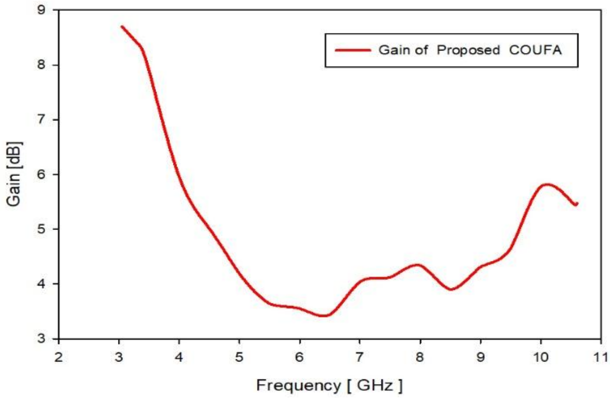


Figure 7. Gain of proposed COBFA

The gain of COUFA in the entire band varies between 3.44 dB and 8.7 dB and also it provides a gain of 3.44 dB at the lowest resonance point of 6.5 GHz whereas it increases to 8.7 dB at the 3.1 GHz resonance point.

The performance of the proposed antenna is compared with that of the antennas reported in the literature as shown in Table II. The proposed antenna possess the unique features such as appreciable gain, reduced return loss, Ultra wideband, simple feeding technique and ease of fabrication with readily available substrate material.

Table I. Performance of the Proposed COUFA

Antenna parameters	**COUFA**		
Resonance Frequency (GHz)	3.45	6.025	9.05
Bandwidth Range(GHz)	3.05 – 10.45		
Return Loss (dB)	-17.57	-26.25	-37.61
VSWR	1.45	1.14	1.03
Max radiation Intensity (mW/sr)	517.2	181.4	211.07
Gain (dB)	8.28	3.59	4.23
Radiated Power	2.11W	963.08 mW	965.26 mW
Accepted Power	982.5 mW	997.63 mW	999.82 mW
Incident Power (W)	1	1	1
Radiation Efficiency	2.15	0.96	0.96

Table II. Comparison Results of Proposed COUFA with the other antennas

Antennas	Antenna Size (L x W) mm^2 [substrate used]	Peak Resonance Frequency (GHz)	Return Loss (dB)	BW (GHz)	Gain at Resonance Frequency
[8]	24 x 21 FR4	5.6 , 10.73	-26.15, -32.80	4.5-8.3, 10-11	2.15dB, 10.22 dB
[12]	13.5 x 16.5 RT Duroid	4.1	-41	3.1 - 10.6	-3 dBi
[18]	30 x 30 FR4	3.84	-51	2.8 -4.9	3.3 dBi
[13]	45 x 60 FR4	1.9	-14	1.3 -5.6	- 3.3 dB
[14]	17.5 x 13.2 FR4	8.01	-40	7.85 -8.2	4 dB
Proposed COUFA	35x 31 FR4	3.45, 6.02, 9.05	-17.57, -26.25, -37.61	3.05-10.45	8.28dB 3.59dB 4.23dB

CONCLUSION

A novel compact UWB antenna is presented and its characteristics such as return loss, VSWR, gain and radiation pattern are simulated and investigated. The application of Minkowski fractal like geometry increases the effective electrical path length which aids to obtain the compact dimension of 35 x 31 mm^2. The Minkowski like fractal structure introduced at the edges of the ground plane helps to achieve the desired UWB frequency band 3.05 to 10.45 GHz. The simulated proposed antenna possess better return loss, VSWR and radiation characteristics and appreciable gain in its operating range and is appropriate for various UWB wireless applications.

REFERENCES

[1] M.R. Tripathy and Isha Chauchan, “CPW – fed Hexagonal shaped slot antenna for UWB Applications”, International Journal of Information and Communication Technology, Vol.3, pp.1135-1144, 2013.

[2] J.Guterman, A.A. Moreria and C.Peixeiro, “Microstrip fractal antennas for multistandard terminals”, IEEE Antennas Wireless Propagations Lett3 (2004), pp.351-354.

[3] D.H.Werner, R.L.Haupt, and P.L.Werner, “Fractal antenna engineering: The theory and design of fractal antenna arrays”, IEEE Antennas Propag Mag 41(1999), 37–58.

[4] J.Anguera, C.Puente, C.Borja, and J.Soler, “Fractal-shaped antennas: A review”, Wiley Encyclopedia of RF Microwave Eng. 2(2005), 1620–1635.

[5] C.Puente-Baliarda, J.Romeu, R.Pous, and A.Cardama,"On the behavior of the Sierpinski multiband fractal antenna", IEEE Trans Antennas Propag, 46 (1998), 517–524.

[6] A.K.Gautam, S.Yadav, and B.K.Kanaujia, “A CPW-Fed Compact UWB Microstrip Antenna”, IEEE Antennas Wireless Propag Lett. (2013), pp.151–154.

[7] N.Ojaroudi, M.Ojaroudi ,and N.Ghadimi,"Dual band-notched small monopole antenna with novel coupled inverted u-ring strip and novel fork- shaped slit for UWB applications, IEEE Antennas Wireless Propag Lett12(2013),182–185.

[8] Vivek, R., Yamuna, G., Suganthi, S. et al., “Performance Analysis of Novel Compact Octagonal Shaped Fractal Antenna for Broadband Wireless Applications”, Wireless Personal Communication (2018).

[9] Arya.A.k, Patnaik.A and Karthikeyan .M.V., “Microstrip patch antenna with Skew F shaped GS for Dual band Operation”, Progress in Electromagnetic Research, Vol.19.pp 147-160.

[10] P. Wang, G. J. Wen, Y. J. Huang, and Y. H. Sun, “Compact CPW fed planar monopole antenna with distinct triple bands for Wi-Fi/WiMAX applications”, Electron. Lett. vol. 48, pp. 357–359, 2012.

[11] W.J. Krzysztofik, “Fractal Geometry in Electromagnetics Applications-From Antenna to Metamaterils”, Microwave Review, ISSN 14505835, vol. 19, no. 2, pp. 3-14. Dec 2013.

[12] Shrivisha Tripathi, Akhilesh Mohan, and Sandeep Yadav, “A Multi Notched Octagonal Shaped UWB Antenna ” ,Microwave & Optical Technology Letters , vol.56,no.11,pp 2469-2473, Nov 2014.

[13] K. S. Chakradhar and B. Rama Rao, “Implementation of Octagonal and Hexagonal Strip Monopole Antennas for UWB Applications”, ARPN Journal of Engineering and Applied Sciences, vol.12, no. 22, Nov 2017.

[14] Swagatha .B. Sarkar, “Design and Analysis of Multiband Octagonal Microstrip patch Antenna with Different Annular Ring”, ICTACT Journal on Microelectronics, vol.2, no.2, Jul 2016.

[15] Vivek.R, Yamuna.G, Mahesh.N.Jivani and Kosta.Y.P, “A Novel Miniaturized Fractal patch antenna for Wireless applications”, IEEE proceedings on International Workshop on Antenna Innovations and Modern Technologies (iAIM-2015),Proceedings, Dec 2015.

[16] Anshika Khanna, Dinesh Kumar Srivastava and Jai Prakash Saini, “Bandwidth enhancement of modified square fractal microstrip patch antenna using gap-coupling”, Engineering Science and Technology, an International Journal, vol.18, iss. 2, pp. 286-293, Jun 2015.

[17] Inkwinder Singh Bangi and Jagtar Singh Sivia., “Minkowski and Hilbert Curves Based Hybrid Fractal Antenna for Wireless Applications”, AEU-International Journal of Electronics and Communications, Jan 2018.

[18] N.Gunavathy, R.Pandeswari and S.Raghavan, “A CPW Fed Octagon Shaped Aperture Antenna for Lower Band UWB Applications”, IEEE INDICON Proceedings, Dec 2009.

[19] Patel S.K., Argyropoulos C and Kosta Y.P, “Broadband compact microstrip patch antenna design loaded by multiple split ring resonator superstrate and substrate”, Waves in Random and Complex Media, vol. 27, no.1, pp. 92-102, 2017.

[20] R. Vivek, G. Yamuna, Y.P. Kosta, S. Suganthi and Mahesh. N. Jivani “Crown Shaped Broadband Monopole Fractal Antenna for 4G Wireless Applications”, IEEE WiSPNET 2017 Proceedings, pp.1099-1103, Mar 2017.

[21] David M. Pozar, "Microwave engineering", 4th edition, John Wiley& sons Inc. 2012, pp. 135-152.

[22] C.A. Balanis. "Antenna Theory", John Wiley & Sons Inc., 3rd edition 2005.