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A Miniature BroadBand Microstrip Antenna for LTE, Wi-Fi and WiMAX Applications

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ABSTRACT

A Compact microstrip antenna with rectangular slotted radiating element has been developed. Four slots have been introduced on the radiating element with the use of a partial ground plane and a wideband response has been obtained. The bandwidth of the proposed antenna is 1.7 GHz with a percentage bandwidth of 71%. A low-cost dielectric (FR4_EPOXY) has been considered in the development of the proposed antenna. The obtained frequency band is from 1.9 GHz to 3.6 GHz. To investigate the robustness of our modelled antenna the simulation process has been carried out using two different solvers (Finite Element Method and Finite Integration Technique). In addition, the designed antenna was realized and these results were compared with those of the simulation. The proposed antenna is suitable for many LTE bands {1, 3, 7… 38, 40} broadly deployed in European, South American, Asian, and African countries, Wi-Fi (2.4 GHz), and WiMAX technology (3.5 GHz).

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1. INTRODUCTION

Microstrip patch antennas are widely used because of their intrinsic characteristics of small size, light weight, easiness of mass-production, etc. However, the usual microstrip patch antenna is less wide and small in term of bandwidth [1]. To enhance these characteristics different research works are issued to overcame the limitation of bandwidth, this is the main disadvantage of antennas that use microstrip technology. It was widely discussed in different research papers [2-6] that the multiple frequency bands can be obtained by using shaped antennas. Microstrip antenna is presently designed by the researchers [7-11] to fit in the broadband applications. However there gain is reduced with the enlargement of bandwidth. Currently, the major goal for researchers is to increase both the bandwidth and gain. The circular and rectangular antennas that use microstrip technology, have modest bandwidth response. By changing the structure of the ground plane or the radiating element, it has been improved [12-14].

The compact antenna manufactured using the microstrip technology and proposed in this paper was designed with modifing both the radiating element by introducing four slots and using a partial ground plane. Also a large bandwidth is achieved in the frequency band of interest (1.9 GHz- 3.6 GHz). The proposed antenna has been fabricated using a low-cost substrate (FR4_EPOXY) with $\varepsilon r=4.4$ as relative permittivity and 1.58 mm as thickness. The rest of the paper is arranged as follows: antenna design in Section 2, results and discussion in Section 3 and conclusion in Section 4.

2. ANTENNA STRUCTURE

In this section, emphasis will be placed on the systematic transition from the antenna structure 1 to the final adopted structure 3. As shown in Figure 1, a simple rectangular microstrip patch antenna (antenna 1) which radiates at a centre frequency of 2.4 GHz has been synthetized based on the work of Bhatia et al [15] who specifies the width of the conventional patch antenna as:

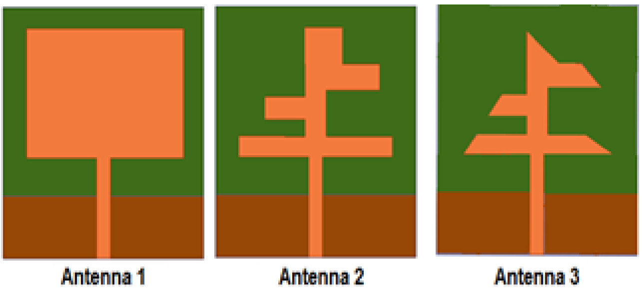

Figure 1. Evolution of the proposed antenna modelling

$$W = \frac{c}{2f_r\sqrt{\frac{\varepsilon_r+1}{2}}} \tag{1}$$

Where fr and εr are resonant frequency and relative dielectric constant of the substrate, one-to-one. Then, the effective dielectric is formulated by Gilb and Balanis [16] as:

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1+12\frac{h}{W}\right)^{-\frac{1}{2}} \tag{2}$$

Where h is the height or the thickness of the dielectric substrate used for the model of the studied antenna. [17] give the actual length of the patch antenna by this equation:

$$L = \frac{c}{2f_r\sqrt{\varepsilon_r}} - 2\Delta L \tag{3}$$

Where ΔL is the addition of the patch length on the ends of the microstrip antenna that is given by Hammerstad:

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{W}{h}+0.8)} \tag{4}$$

The whole ground plane length and width can be considered as:

$$\begin{cases} L_g = 6h + L\,, \\ W_g = 6h + W \end{cases} \tag{5}$$

Figure 2 shows 3D layout and image of the realized antenna. In addition, a ground defected structure (GDS) has been replaced by the classic full ground plane and its dimensions are calculated according to a parametric study for bandwidth enhancement. So, four open slots are introduced into the radiating element (Rectangular at the base), the dimensions of these slots (width, length) are optimized to have the widest bandwidth possible. Also, Kuo and Hsieh [18] achieved the CP using triangular shaped DGS coinciding with the corners of equilateral triangle. This technique has been integrated to the radiating element of the studied antenna (antenna structure 3), to achieve the circular polarization (CP) characteristics. The final Microstrip patch antenna (MPA) that has been adopted (Figure 3) consists of three layers: Partial ground, substrate and modified patch.

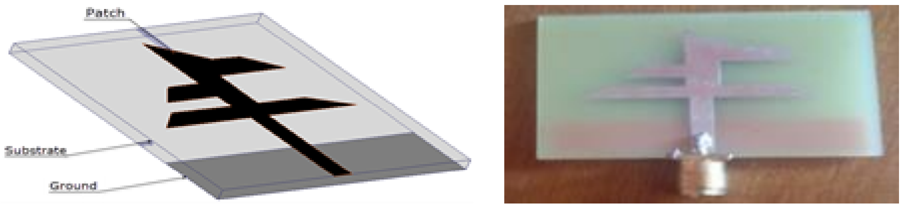

Figure 2. 3D layout and image of the realized antenna

The dielectric substrate used for the design of the proposed antenna is FR4_Epoxy of thickness 1.58 mm with a dielectric constant εr=4.4. It is commonly known in the literature that the use of substrates with a low thickness and permittivity makes it possible to reduce the size of the antennas [19]. Antenna feeding is performed by a microstrip line, this adapter is required to have 50 Ω at the input of the microstrip antenna.

The dimensions of the substrate are taken as 35 x 35 x 1.58 mm3 and the size of the partial ground plane is 8.75 x 35 mm2. Figure 4 shows the top and bottom layers of the final geometry of the studied antenna. All the optimal antenna parameters are summarized in Table 1.

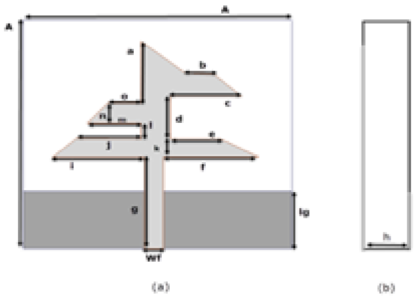

Figure 3. The geometry of the proposed antenna (not to scale), (a) front side view, (b) right side view

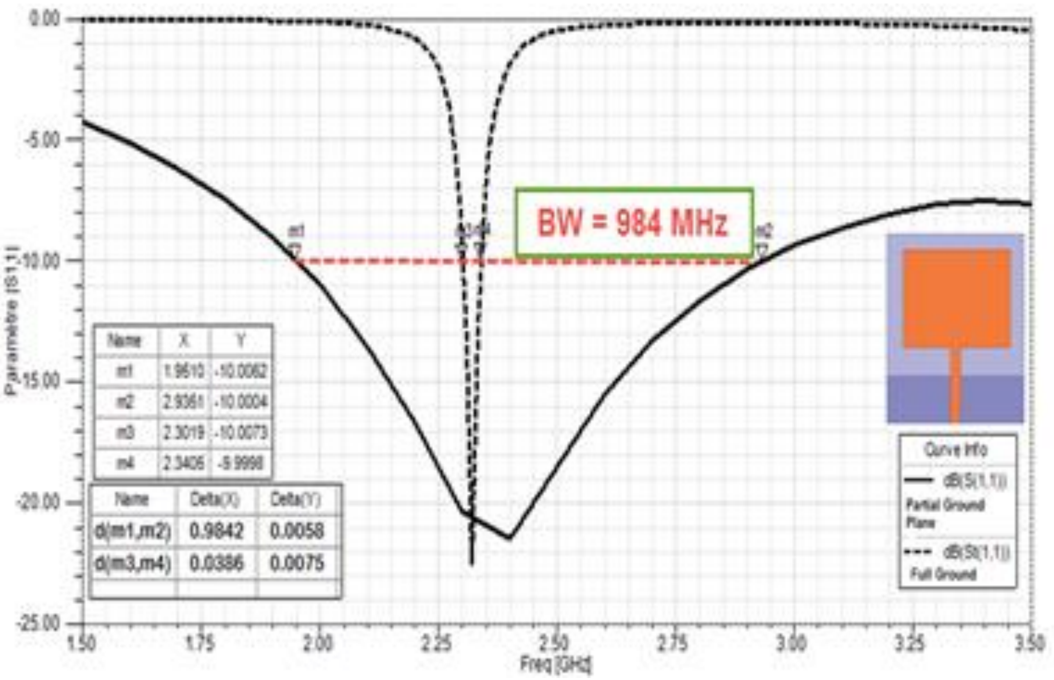

Figure 4. Comparison between the reflection coefficients S11 against frequency with a partial/full ground

Table 1. Specifications of the proposed Antenna

Parameter	Value (mm)
A	35
h	1.58
a	9.4
b	3.8
c	9.3
e,d	6.5
f	12.4
g	14
i	11.9
j	8.3
k	2.8
l	2.4
m	7
n	3.1
o	4.3
wf	2.5
lg	8.75

3. RESULTS AND DISCUSSIONS

To figure out the matching of an antenna, the S11-Parameter can be used. The plot of S11 Parameter against frequency shows that it is < -10 dB for the operational band as illustrated in Figures (4-6). Figure 4 indicates the different values of the reflection coefficient for our proposed antenna 1 model.

The S11 parameter versus frequency for the structure 1 is shown in figure 4. The first point was to estimate the effect of the ground plane on the enlargement of the bandwidth, a partial ground plane allowed us to enhance the bandwidth, narrow at origin with the use of a full ground plane. The partial ground plane shows better return loss compared to the full ground plane with an enhancement of 981 MHz compared to the 3 MHz bandwidth of a typical microstrip antenna. Next, four open slots where added to the radiating element. A parametric study was launched in the electromagnetic solver we fixed as input the dimensions of the four slots and as objective to further enhance the bandwidth of the antenna. It is clear that the bandwidth of the structure 2 against structure 1 is enhanced significantly due to introduction of slots as shown in Figure 5. Finally the edges of the antenna structure 2 have been sharpened, we note that a bandwidth of 100 MHz is acquired in the final structure 3 as shown in Figure 6.

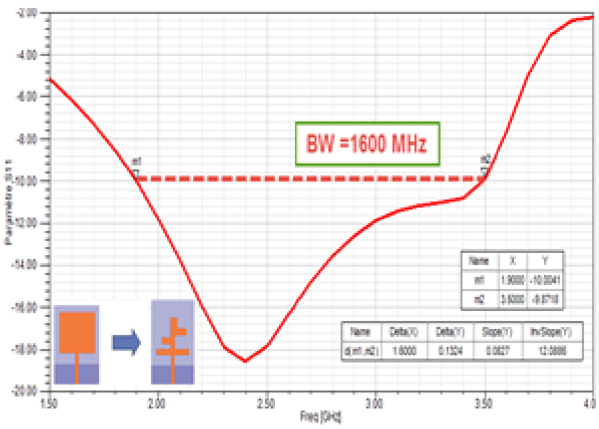

Figure 5. Comparison between the reflection coefficients S11 against frequency of the structures 1 and 2

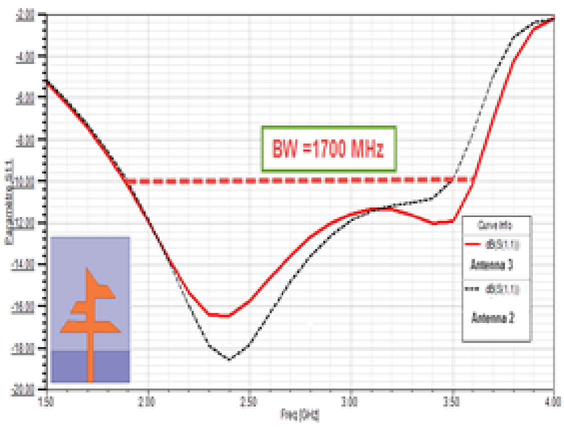

Figure 6. Comparison between the reflection coefficients S11 against frequency of the structures 2 and 3

The model of structure 3 have been simulated in two electromagnetic solvers and which use two methods of calculation, it can be noticed that there is a very good correlation between measurement and simulation results as illustrated in Figure 7.

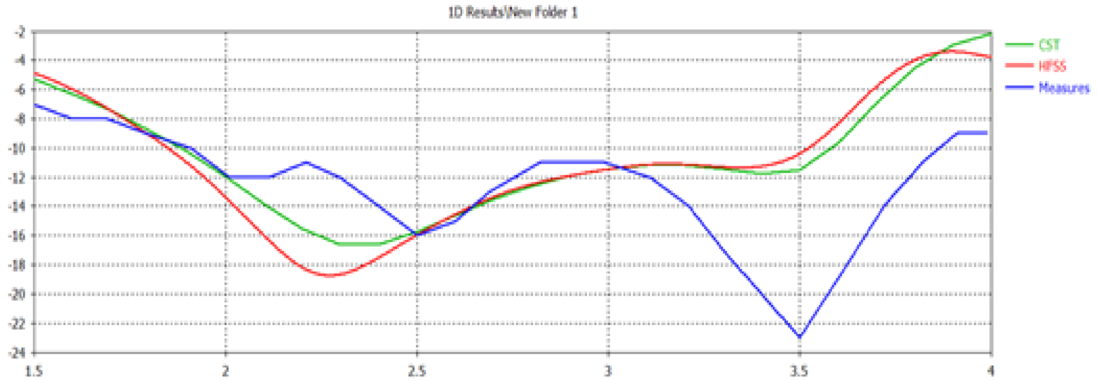

Figure 7. Comparison of simulated vs measured reflection coefficients

It was established that the antenna resonates in the desired frequency band as shown in Figure 7. Indeed, for |S11| < -10 dB: the band ranges from 1.9 GHz to 3.6 GHz with two resonant frequencies at 2.4 GHz and 3.5 GHz. The bandwidth is approximately 1700 MHz which usually suitable for many LTE bands {1, 3, 7… 38, 40} broadly deployed in European, South American, Asian, and African countries, Wi-Fi (2.4 GHz), and WiMAX technology (3.5 GHz) as described in Table 2.

Table 2: Current Major Spectrum Allocations for LTE, Wi-Fi and WiMAX Worldwide

Standard	Frequency Band (MHz)	World deployment
LTE Band 1	1920-2170	China, Japan, EU
LTE Band 2	1850-1990	North/South America
LTE Band 7	2500-2690	North/South America, Africa
LTE Band 33	1900-1920	-
LTE Band 34	2010-2025	China
LTE Band 35	1850-1910	-
LTE Band 36	1930-1990	-
LTE Band 37	1910-1930	-
LTE Band 38	2570-2620	EU
LTE Band 39	1880-1920	China
LTE Band 40	2300-2400	China, Asia
LTE Band 41	2496-2690	-
IEEE 802.11b/g/n (Wi-Fi)	2400-2500	Japan, EU, China, America.
WiMAX	2500, 3500	North/South America, EU, Africa, Asia, China

Figure 8 shows the field pattern in 2D of the proposed antenna at three frequencies: 1.9 GHz, 2.1 GHz and 3.5 GHz. The E (x-y plane) and H (y-z plane) fields in the figures shows that they have almost good Omni-directional radiation patterns. It may be noted that the typical radiation patterns are dominated at the three resonant frequencies: At 1.9 GHz (the inferior resonant frequency), the radiation pattern of the antenna is similar to that of a conventional monopole patch antenna in free space, with a so-called 'doughnut' shape. The radiation pattern at the higher functioning frequency becomes more irregular. For both cases, the shape of the partial ground plane and the slotted radiating element affects considerably the radiation patterns. The proposed antenna shows an acceptable Omni-directional radiation pattern even at lower and higher frequencies, it should be noted that the radiation is focused in both directions of the antenna which is required to receive data signals from all directions. Published work results in the literature with this work are regrouped and compared in Table 3.

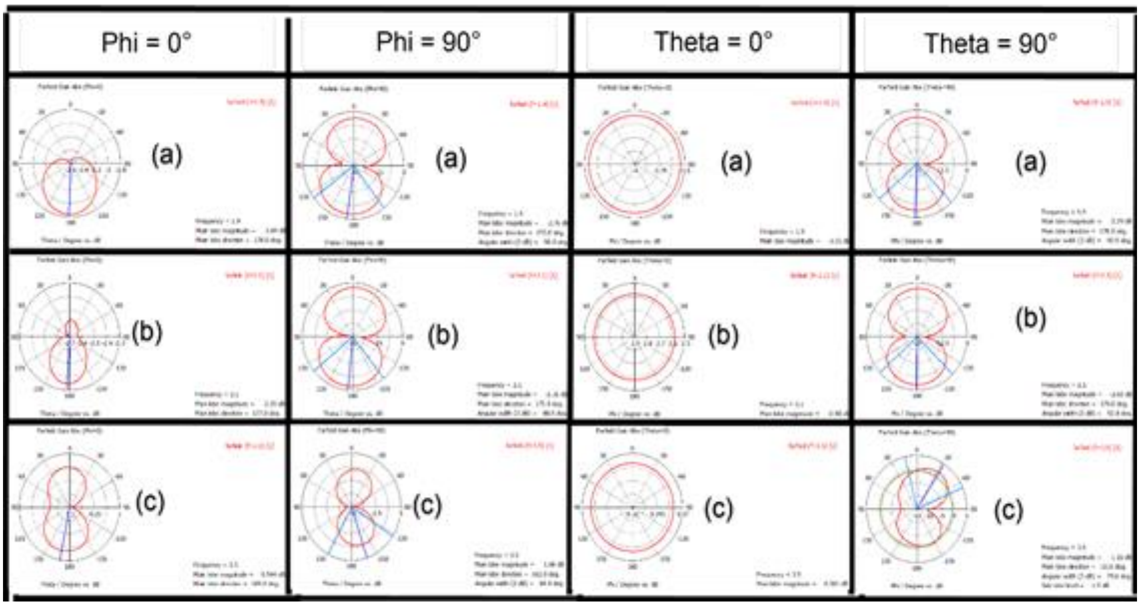

Figure 8. 2D radiation patterns of the proposed antenna at frequencies: (a) 1.9 GHz, (b) 2.1 GHz and (c) 3.6 GHz

Table 3. Results of All the References and our Work

Article No.	Bandwidth (GHz)	Dimensions (mm2)
Ref. [2]	1.5-2.1	19 X 28
Ref. [3]	5-6	18 X 37
Ref. [4]	1.9 -2.5	22 X 76
Ref. [5]	3.2-4.3	20 X 38.5
Ref. [6]	2.1-2.75	45 X 30
Ref. [11]	3.8-7.6	31 X 24.6
Ref. [12]	4.5-5.6	46 X38
Ref. [13]	1.93-3.74	60X50
Ref. [14]	1.93-3.6	55 X 15
This Work	1.9-3.6	35X35

4. CONCLUSION

In this paper, a miniature broadband microstrip antenna for LTE/Wi-Fi/WiMAX applications has been develpopped. The proposed antenna is simple to design and compact in size, it provides broadband impedance matching, stable omnidirectional radiation patterns and suitable gain characteristics for the LTE/Wi-Fi/WiMAX frequency region. The antenna has been designed on a typical FR4 substrate and can be realized with conventional Printed Circuit Board (PCB) techniques, therefore, this proposed antenna can be deployed more ubiquitously in much larger numbers.

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REFERENCES

[1] J. P. Gilb and C. A. Balanis, "Pulse distortion on multilayer coupled microstrip lines," *IEEE Transactions on Microwave Theory and Techniques,* Vol. 37, N°. 10, pp. 1620–1628, 1989.

[2] Kumar, S. and Tomar, R, "A dual-band compact printed monopole antenna using multiple rectangle-shaped defected ground structures and cross-shaped feed line". *Microw. Opt. Technol. Lett*., 57: 1810–1813, 2015. doi:10.1002/mop.29195

[3] H. Zhai, Z. Ma, Y. Han, and C. Liang, "A compact printed antenna for triple-band WLAN/WiMAX applications," *IEEE Antennas and Wireless Propagation Letters*, vol. 12, pp. 65–68, 2013

[4] Sambhe, V. K., Awale, R. N. and Wagh, A, "Dual band inverted L-shape monopole antenna for cellular phone applications". *Microw. Opt. Technol. Lett*., 56: 2751–2755, 2014. doi:10.1002/mop.28697

[5] Sim, C.-Y.-D., Chen, H.-D., Yeh, C.-H. and Lin, H.-L., "Small size tripleband monopole antenna with a parasitic element". *Microw. Opt. Technol. Lett*., 57: 342–348, 2015. doi:10.1002/mop.28837

[6] Sim, C.-Y.-D., Hsu, Y.-W. and Chao, C.-H., "Dual broadband slot antenna design for WLAN applications". *Microw. Opt. Technol. Lett*., 56: 983–988, 2014. doi:10.1002/mop.28207

[7] A. Singh et al. "Slots and Notches Loaded Microstrip Patch Antenna for Wireless Communication", *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 13, no. 3, pp. 584-594, March 2013.

[8] Ningsih Y K, Hadinegoro R. "Low Mutual Coupling Dualband MIMO Microstrip Antenna with Air Gap Parasitic", *TELKOMNIKA (Telekommunication Computing, Electronics and Control)*, vol. 12, no. 2, pp. 405-410, June 2014.

[9] Y. Rahayu, Jherino P. Putra "Design of Circular Patch with Double C-Shaped Slot Microstrip Antenna for LTE 1800 MHz ", *TELKOMNIKA (Telekommunication Computing, Electronics and Control)*, vol. 12, no 12, pp. 1079-1082, September 2017.

[10] S. Alam, et all "Design and Realization of Compact Microstrip Antenna Using Fractal Sierpenski Carpet For Wireless Fidelity Application", *Indonesian Journal of Electrical Engineering and Informatics (IJEEI)*, vol. 6, no 1, pp. 70-78, March 2018.

[11] Pandeeswari, R. and Raghavan, S., "Broadband monopole antenna with split ring resonator loaded substrate for good impedance matching". *Microw. Opt. Technol. Lett*., 56: 2388–2392, 2014. doi:10.1002/mop.28602

[12] Mandal, K., Sarkar, S. and Sarkar, P. P., "Bandwidth enhancement of microstrip antennas by staggering effect". *Microw. Opt. Technol. Lett*., 53: 2446–2447; 2011. doi:10.1002/mop.26299

[13] Saini, R. K. and Dwari, S., "CPW-fed broadband circularly polarized rectangular slot antenna with L-shaped feed line and parasitic elements". *Microw. Opt. Technol. Lett*., 57: 1788–1794; 2015. doi:10.1002/mop.29188

[14] Rautela, R. S. and Vishwakarma, D., "A ramp type planar monopole antenna for WLAN and WiMAX application". *Microw. Opt. Technol. Lett*., 57: 1485–1487, 2015. doi:10.1002/mop.29123

[15] P. Bhartia, I. Bahl, R. Garg, and A. Ittipiboon, "Microstrip Antenna Design Handbook", Artech House, Norwood, Mass, USA, 2000.

[16] J. P. Gilb and C. A. Balanis, "Pulse distortion on multilayer coupled microstrip lines," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 37, N°. 10, pp. 1620–1628, 1989.

[17] J.-B. Yan and J. T. Bernhard, "Design of a MIMO dielectric resonator antenna for LTE femtocell base stations," *IEEE Transactions on Antennas and Propagation*, Vol. 60, N°. 2, pp. 438–444, 2012.

[18] J.-S. Kuo and G.-B. Hsieh, "Gain enhancement of a circularly polarized equilateral-triangular microstrip antenna with a slotted ground plane," *IEEE Transactions on Antennas and Propagation*, vol. 51, no. 7, pp. 1652–1656, 2003.

[19] Mohamed Mahfoudh Harane, Hassan Ammor "A Compact Dual Band Elliptical Microstrip Antenna for Ku/K Band Satellite Applications" *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 8, no. 3, pp. 1596-1601, June 2018.