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Design and Analysis of Double-Band Printed Corrugated Circular Patch Antenna for Wireless Communication Applications

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Abstract

In this paper, a novel structure of a circular patch microstrip antenna based on external corrugations is designed, simulated, and measured to operate in S and C-bands applications. The parameters of this antenna structure, such as input impedance, bandwidth, gain, surface currents, and radiation patterns were studied and improved. This antenna design includes modifying the shape of the radiating patch by cutting seven parts of the tip patch as semi-oval with a diameter and depth of 2 mm between each part, 45^0 angles. The antenna ground plane was reduced to the size of 40×13 mm^2. The insulating substrate has dimensions of $50\times40\times1.6$ mm^3. The obtained results showed a good improvement of the antenna performance with resonant frequencies of 3.1 GHz, 7.1 GHz, and fractional bandwidth of 40.8%, 12.4% respectively. This design is simulated using Ansoft High-Frequency Structure Simulator (HFSS), and it is compared with the obtained measurement data. Interestingly, the comparison results are in good agreement. The antenna design is helpful for many services operations at these bands of frequencies and their applications.

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1. Introduction

Communication systems are rapidly growing due to the engineering revolution in the field of antennas and materials technology [1], The microstrip antenna (MSA) is considered the most common type of antenna due to its specifications commensurate with the spread of wireless communication technology in terms of lightweight, low cost, and ease of manufacture [2]. The concept of a microstrip patch antenna was first proposed by Deschamps in 1953 [3]. Gutton and Baissinot presented a patent in the microstrip in 1955[4]. No commercially available printed circuit boards with controlled dielectric constants were developed during this period of time. So this antenna didn't become practical till 1970 when it was developed by Robert E. Munson [5]. MSAs are used in applications of broadly and increasingly in a wide range of microwave systems from navigation, telemetry, radars, mobile, satellite communications, global positioning systems for remote sensing, biomedical systems, missile systems, etc. [6].

The performance requirements may dictate the use of substrate materials whose dielectric constants can be greater than four. For example, various types of substrates have been developed that have an extensive range of dielectric constant and loss tangent values[7-8], there are two types of excitation for the antenna, either directly through direct contact with the patch and the base, and it is in two ways, the coaxial transmission method or the strip transmission method, or the feeding is indirectly through electrical induction, despite the widespread use of This type Because of its small size, it suffers from some weaknesses such as narrow bandwidth and reduced gain[9]. Many researchers focused on improving the antenna's efficiency, the most important of which is the change in the shape of the patch, which is what happened. To work on it in the current study. To improve the bandwidth of the ribbon antenna, there are several ways, including increasing the thickness of the insulating layer, but it did not work because the thick dielectric layer helps the presence of surface waves that lead to distortion of the radiation pattern, which leads to a decrease in the efficiency of the antenna [10-11], or by making slots in the shape of the patch. In recent years, dual-band or multi-band antennas with wireless communication capabilities have received widespread attention. Early researches on multi-band antennas are focused on wireless applications WLAN/WiMAX [12]. Such multi-band antennas represent the facility to integrate various communication standards within a one antenna design. To meet the objective of high gain operation within a single antenna design without affecting the other antenna parameters [13]. Adopting any of the techniques or hybrid of these techniques can construct the base of the design evolution of multi-band antennas for covering wireless communication applications [14]. Implementation of etching slot techniques in antenna design obtains additional resonating bands since slots are responsible for creating electric current perturbation; presently, multi-resonance antennas with frequency band configurability characteristics have gained more attention for wireless communication systems [16]. Among various protocols, wireless local area network (WLAN) and worldwide interoperability for microwave access (Wi-MAX) are current and potential future candidates for this application [17]. Compact mobile devices are popular in the market and therefore produce demands for miniaturized antennas. By using meandered metal strip structure, it can offer WLAN connectivity in a compact footprint [18], For Wi-MAX, the most common licensed bands are 2.5 ~ 2.7 GHz and 3.4 ~ 3.7 GHz [19]. This paper proposes microstrip antenna designs that covers WLAN and Wi-MAX at 2.5 ~ 5.1 GHz and at 6.6 ~7.5 GHz [20].

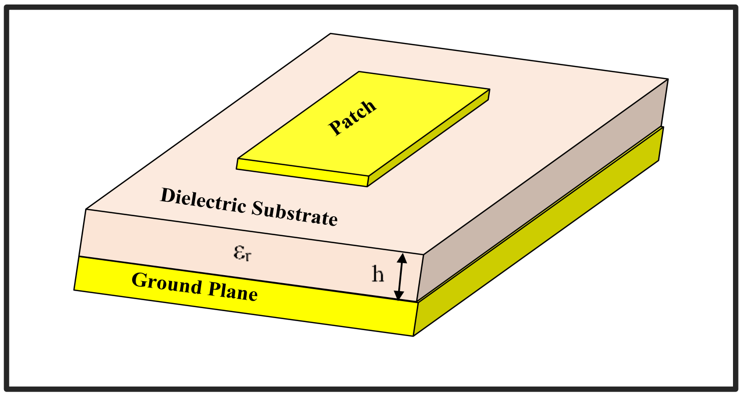


Fig. 1: The Basic Structure of Microstrip Antenna

2. Design of Antenna

HFSS software was used to simulate the proposed antenna Pattern [21]. a circular microstrip antenna was designed with dimensions of 50×40×1.6mm^3 and using the direct microstrip feed technique (microstrip line) and the insulating material used is epoxy with dielectric constant (ε_r = 4.4), substrate thickness $h = 1.6\ mm$. to obtain a radius (R=12mm) value of

$$R = \frac{\chi_{mn}\, C}{2\pi\, f\, \sqrt{\varepsilon_r}} \quad \text{-------} \quad (1)$$

Where , C is light speed (C = 3 ×10^8 m/s) , χ_{mn} is function's Bessel at TM_{11} (χ_{mn} = 1.84118), f is frequency (1~8 GHz) , After substituting the values into a function (1). we get:

$$R = \frac{0.419 \times 10^8}{f} \quad \text{------} \quad (2)$$

Radiating patch is the main part of the antenna affecting antenna performance through changing impedance matching bandwidth, and radiation pattern, as well as surface current distribution. Different shapes of patch antennas are used to improve the conducting patch performance in antennas. However, we attempted to find more effective and simple ways to achieve desired results. Next, we have modified the shape of the patch by cutting seven parts of the tip patch as semi-oval with the same previous diameter and depth, but with a 45-degree angle. The ground plane of the antenna was reduced to be 40×13mm^2. While the insulating substrate was fixed with the same dimensions during the two experiments. After testing some dimensions by changing their values, as we will show in the results, we got the final shape shown in Figure .2. , and Table (1) show the optimized proposed antenna parameters. Then the microstrip antenna was manufactured using the chemical method, by imprinting the shape of the radioactive after design on a copper layer and then placing it inside a chlorine solution so that the copper material is corroded outside the print. The SJF (VNA) (PLANAR 804/1) is used to measure the reflection coefficient of the fabricated antenna, as shown in Fig .3.

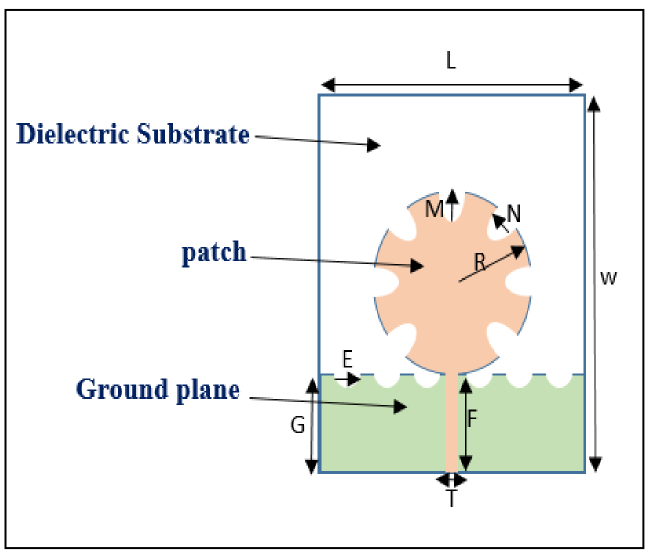


Fig. 2: Geometrical of the designed antenna: HFSS

Table: Dimensions of the designed antenna

Parameters	Values (mm)
W	50
L	40
R	12.3
M	2
N	2
F	12.7
T	2
E	2
G	13

Fig. 3: Geometrical of the designed antenna: manufacturer

3. Parametric study of the designed antenna

Since a novel design of feeding is utilized, a parametric analysis becomes important to provide information to antenna designers about the different components and dimensions of the antenna and how they affect the antenna results. Here, we have analyzed mainly the effect of R, M and G using the HFSS simulation. The variation of the return loss curve for different values of R is shown in Fig. 4. It is noted that M plays a significant role to improve the antenna bandwidth is shown in Figs. 5&6.

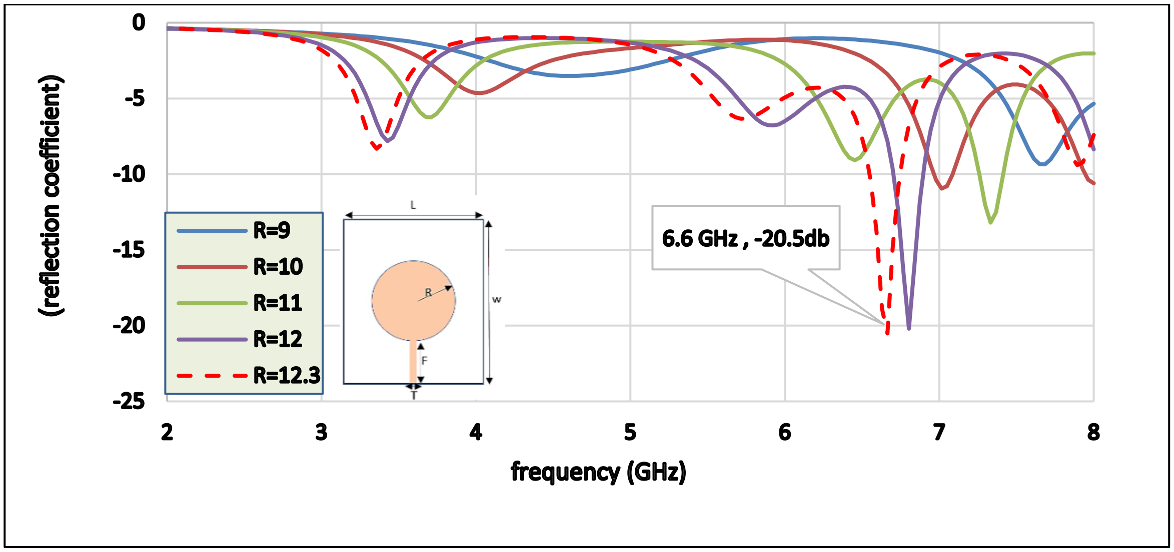


Fig. 4. Variation of return loss against frequency for different values of 'R'

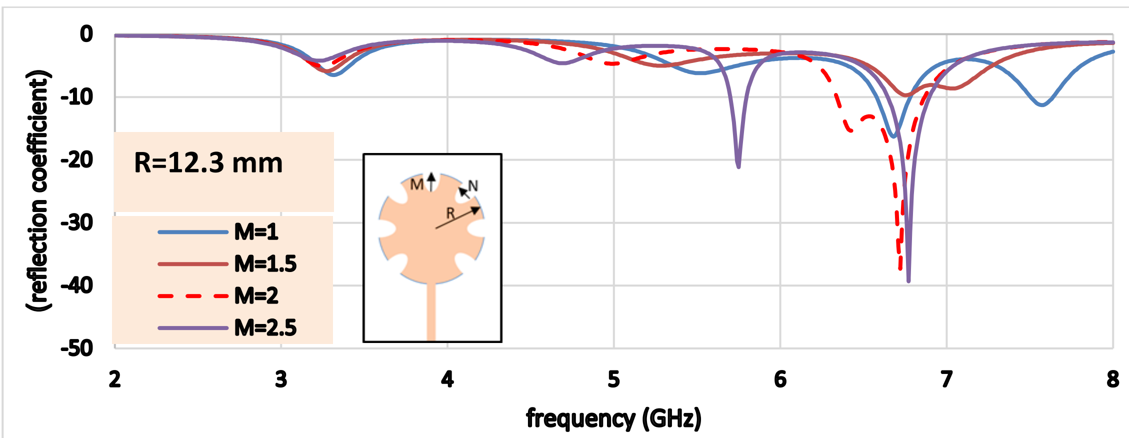


Fig. 5: Variation of return loss against frequency for different values of 'M'

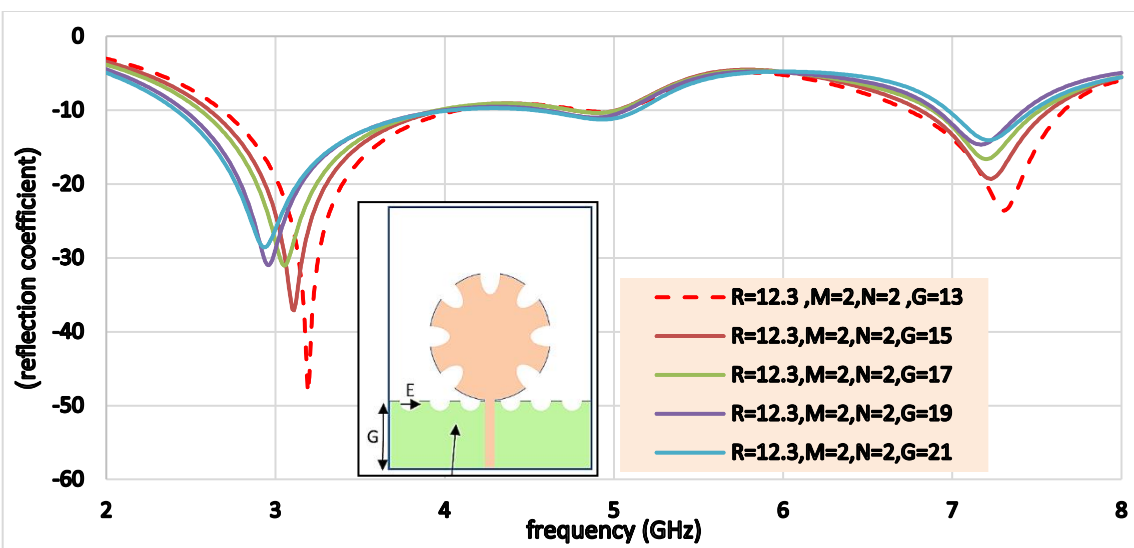


Fig. 6: Variation of return loss against frequency for different values of 'G'

4. Results and Discussion

Return loss (S_{11}) represents the decrease in the amplitude of the reflected energy from the energy emitted, the value of the resonance frequency within which the antenna operates is determined in front of the value of (-10 dB). Fig. 7. illustrates the comparison of simulated and measured results. the measured −10 dB bandwidth is 78.1% from 2.3 GHz to 5.25 GHz, 16.5% from 6.6 GHz to 7.8 GHz, which is in good agreement with the simulation result. Slight discrepancies between measurement and simulation results may be caused by fabrication precision, interface error, and test environment.

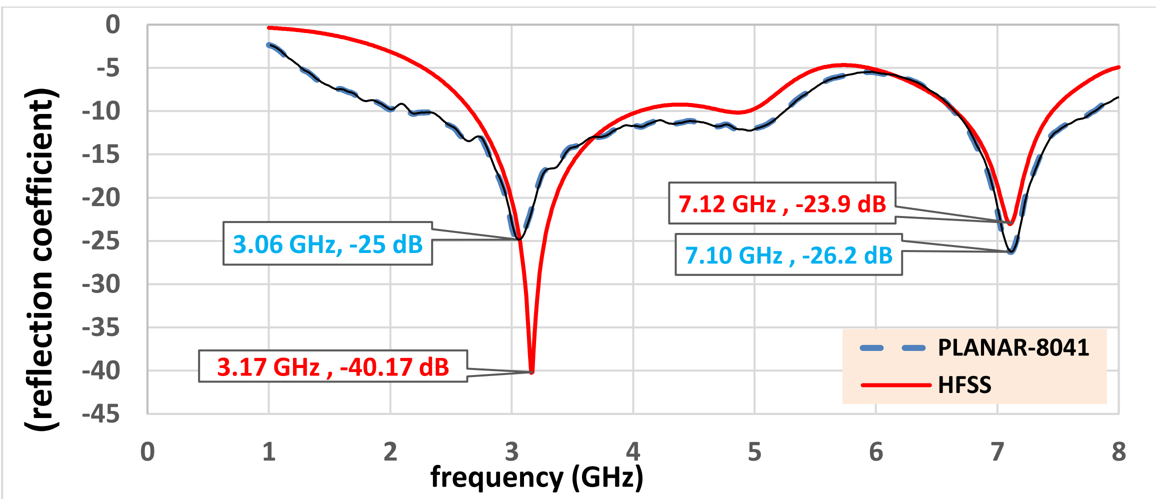


Fig. 7: The comparison of simulated and measured S11

The voltage standing wave ratio (VSWR) is a designation of the quantum of mismatch between an antenna and the feed line connecting to it. The values for VSWR start from 1 as an ideal case to ∞. A VSWR value under 2 is deemed suitable for most antenna applications. Consequently, the antenna can be described as having a good match [23] was 1.14 at 3.1 GHz and 1.11 at 7.1GHz, is shown in figure (8)

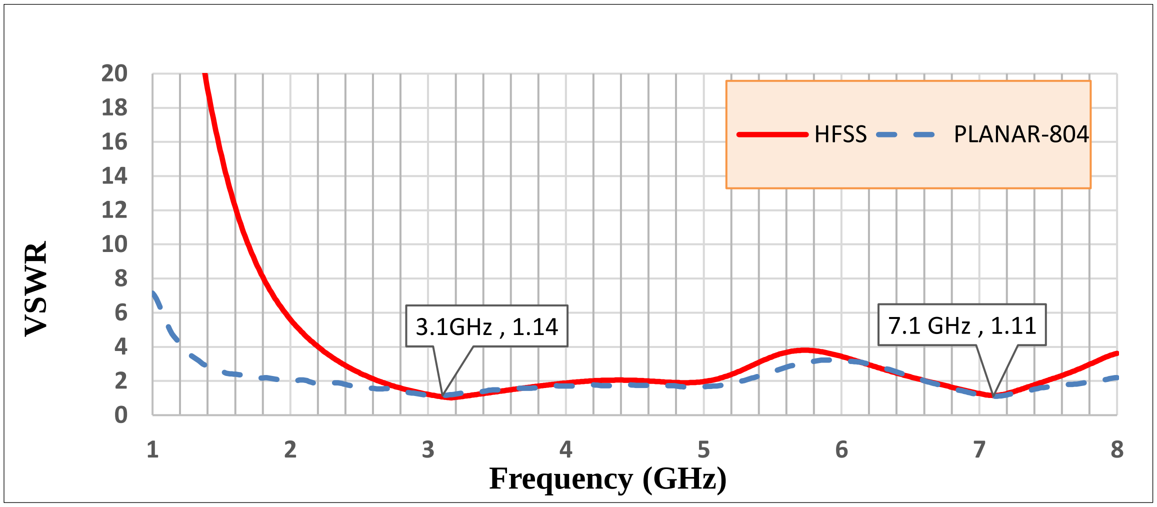


Fig. 8. Measured and simulated VSWR of the proposed antenna

The value of the input impedance of the circular band antenna after the second adjustment by (50.8Ω) at the frequency (3.16 GHz) and (42.4Ω) at the frequency (7.11GHz), as shown in Fig.6.

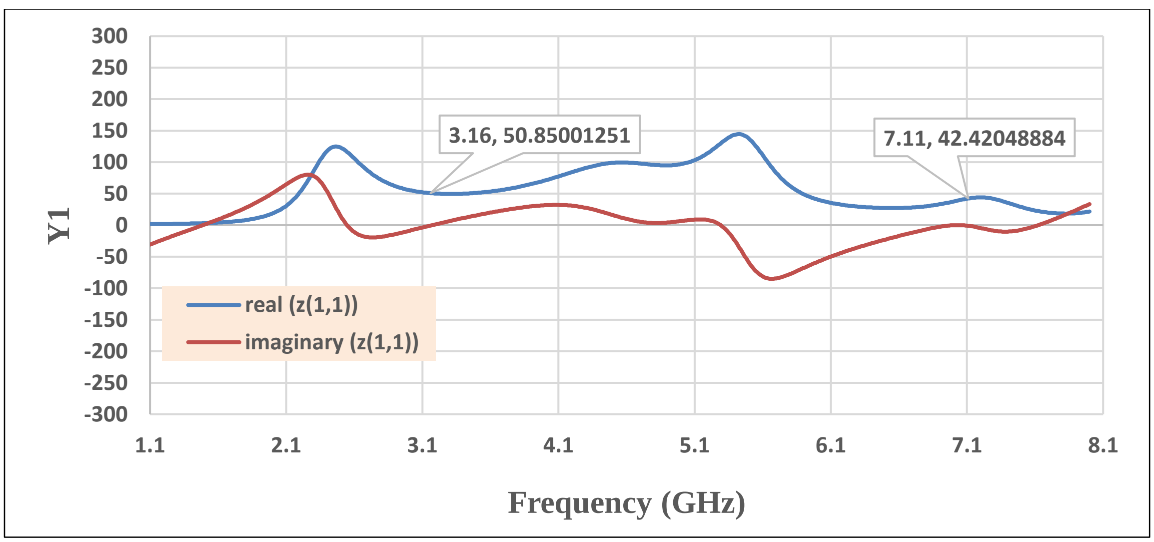


Fig. 9: Input impedance plot for the proposed antenna

The gain factor is defined as the ratio between the power produced by the antenna source (far-field) towards the target. The final results of the final design showed that the amount of gain (2.54

dB) and (5.54 dB) at the resonant frequencies (3.1GHz) and (7.1GHz), respectively. The gain versus frequency graph for antenna 1 is shown in Fig. 10.

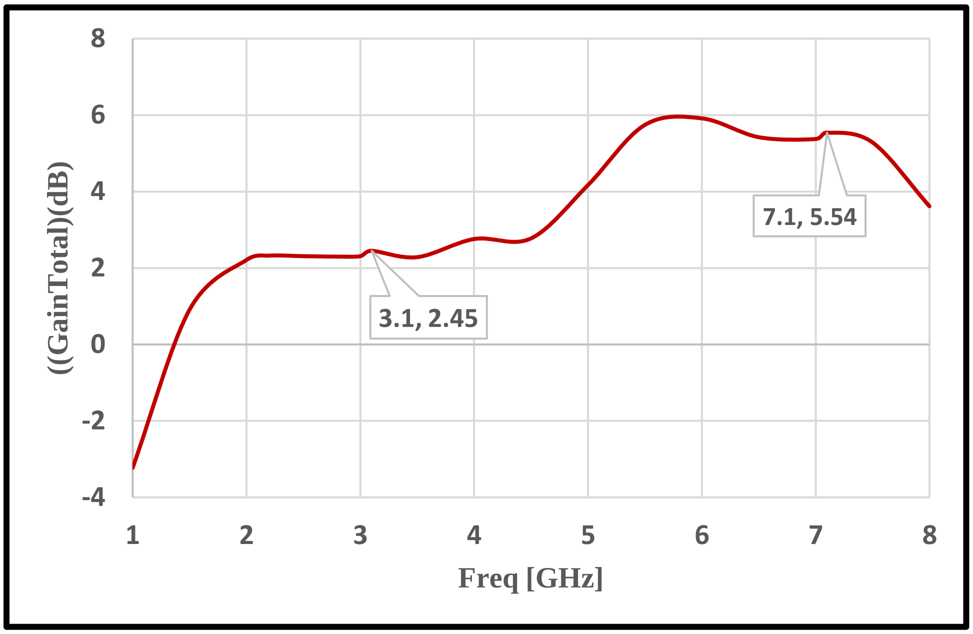


Fig. 10: Gain versus Frequency Graph.

After the final change, In contrast, Figures (11, 12) represent the radial structure of the ribbon antenna after the final modification. Fig. (10) shows that the radiation pattern is an omnidirectional.

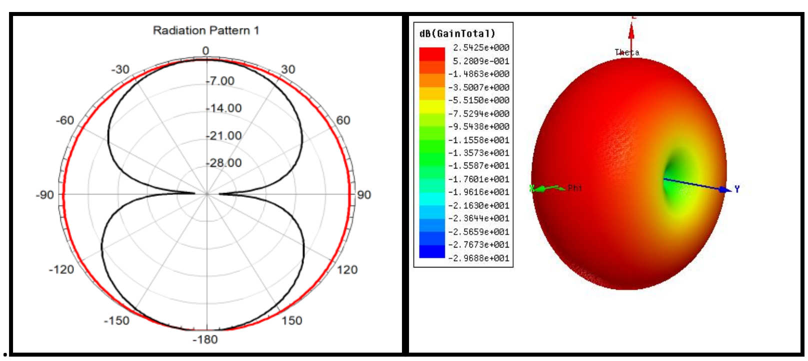


Fig. 11: Radiation patterns (3D) and (2D) at the first resonant frequency 3.1GHz. H-plane (red line) and E-plane (black line)

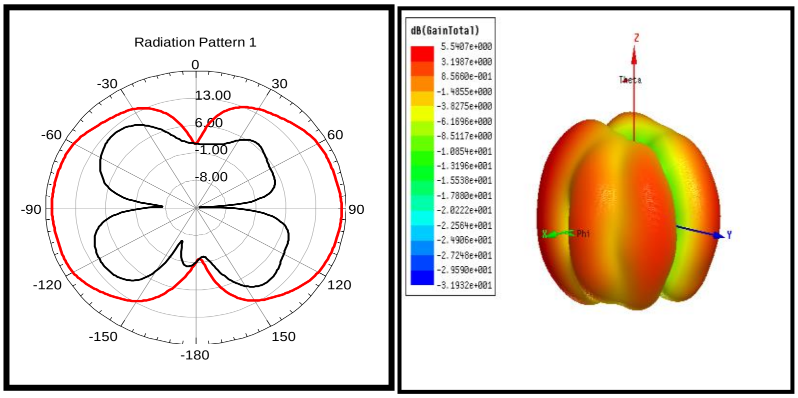
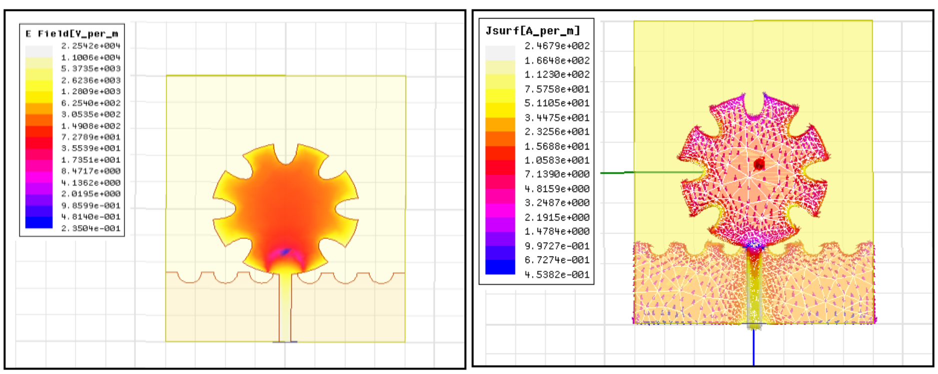


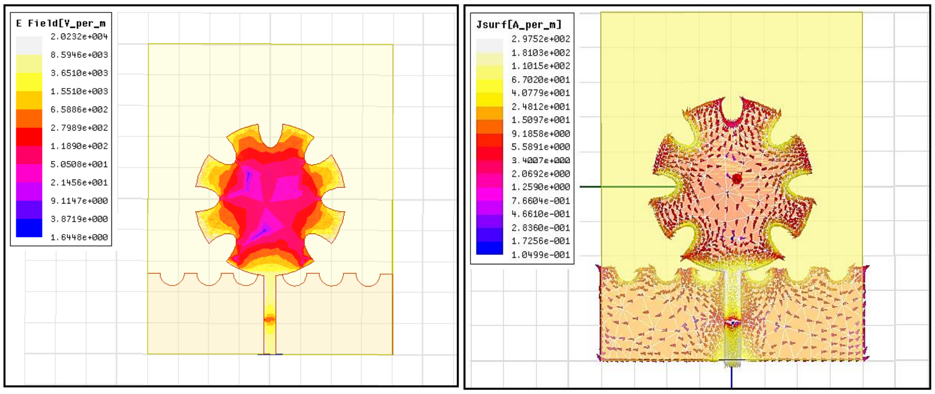
Fig. 12: Radiation patterns (3D) and (2D) at the second resonant frequency 7.1GHz. H-plane (red line) and E-plane (black line)

In contrast, Figs 13&14 represent the distributions of the electric field and surface currents around the patch. These figures illustrate that the surface currents are concentrated at the edges of the proposed antenna.



(b) Electric field (a) Surface currents

Fig.13. Surface currents and electric fields on the patch of proposed antenna. (3.1 GHz)



(b) Electric field (a) Surface currents

Fig.14: Surface currents and electric fields on the patch of proposed antenna (7.1 GHz)

5. Conclusions

The influence of the dielectric thickness change during the processing on the performance of the antenna cannot be ignored. The connection method of SMA between the feeder and the signal is solder connection. The solder increases the thickness of the dielectric board, which has a certain impact on the test results. The error is within the allowable range. At all frequency bands, the proposed antenna features stable radiation performance indicating that it can be a good candidate for LTE 42/43, WiMAX , and WLAN (802.11a/n) applications.

References

[1] C.G. Christodoulou, P.F. Wahid, Fundamentals of antennas: concepts and applications, SPIE, Bellingham, Washington USA, 2001.

[2] Y. Huang and, K. Boyle, Antennas: from theory to practice, John Wiley & Sons Ltd, 1st Ed.,(2008)184.

[3] M.G. Douglas, Antennas for Personal Communication Systems, Dissertation, University of Victoria (1998) 8 .

[4] G.A. Deschamps, "Microstrip microwave antennas," presented at The 3rd USAF Symposium on Antennas, 1(2003) 191-192 .

[5] R.E. Munson, Microstrip Phased Array Antenna, 2nd Annual USAF Antenna Symposium,(1972).

[6] W.A.G Al-Tumah, R.M. Shaaban, A. Tahir, Design, simulation and measurement of triple band annular ring microstrip antenna based on shape of crescent moon, AEU- *Technium.,* 117, (2020) 153-133.

[7] R.E. Malallah, R.M. Shaaban, W.A.G Al-Tumah, dual band star-shaped fractal slot antenna: Design, measuremen, AEU- *Technium.* 127(2020)153-473

[8] W.A.G. Al-Tumah, R.M. Shaaban , Z.A. Ahmed, A modified E-shaped microstrip patch antenna for dual band in x-and ku-bands applications, J Phys: Conf. Series., 1234 (2019) 012028.

[9] A. Mehta, Microstrip antenna Int.J. Sci., 17 (2020)1216-1216.

[11] R.A. Mutashar, W.A.G. Al-Tumah, A. Tahir,S, Design and Simulation of Triple Band Circular Patch Microstrip Antenna Based on Shape of Ring and Rectangular Slots, Eng. Sci. Technolo. Int. J., 3(2020) 245-252.

[12]T.S. Rappaport, J. Zhang , Overview of Millimeter Wave Communications for Fifth-Generation (5G) Wireless Networks-With a Focus on Propagation Models, IEEE Trans. Antennas Propag., 65 (2017) 6213 .

[13] R.M. Shaaban, Z.A. Ahmed, W.A. Godaymi, Design and analysis for circular microstrip antenna loaded by two annular rings, Global J. Pure Appl. Sci.,17(2017) .

[14] E.C.L. Chan, M. Kumar, L. Tharani, Introduction to wireless localization, first published, ohn Wiley & Sons Singapore Pte. Ltd., 2012

[15] R.M. Shaaban, Z.A. Ahmed, and W.A. Godaymi, Radiation patterns account of a circularmicrostrip antenna loaded two annular, J. Nat. Sci., l6 (2016) 71-81

[16] R.K. Saraswat and M. Kumar, A metamaterial loaded hybrid fractal multiband antenna for wireless applications with frequency band configurability characteristics, Frequenz.74(2020) 401-416.

[17] Y.F. Lin, C.H. Lin, H.M. Chen, J.Y. Jan and W.S Chen, Design of ceramic chip antenna for 2.4/5 GHz WLAN applications, Antennas and Propagation Society International Symposium, (2006) 985-988

[18] D.V. Chamkur, Dr.C.R. Byrareddy, 4G Shaped Wide band Patch Antenna for Wireless Applications, IEEE, ICCES, (2018) 323.

[19] J.G. Andrews, A. Ghosh and R. Muhamed, Fundamentals of WiMAX: understanding broadband wireless networking, Pearson Education (2007).

[20] S. Sandeep and K.K Tripathi, Design and analysis of microstrip antenna using HFSS software, International Journal of Computer Science and Communication. Int. J. Comput. Games Technol. 3 (2012) 119-124

[21] W. J. Krzysztofik , riangular microstrip antenna loaded by slots for GPS application, Nice, France,10(2006) 126

تصميم وتحليل هوائي شريطي دائري مموج مزدوج النطاق ليستخدم للاتصالات اللاسلكية

جاسم كيطان شديخ و رائد مسلم شعبان
قسم الفيزياء، كلية العلوم/،جامعة البصرة، البصرة، العراق

المستخلص

البحث عبارة عن تحليل وتصميم جديد لهوائي شريطي دائري معدل ذو ابعاد (50 × 40 × 1.6 مم^3) باستخدام برنامج المحاكاة (HFSS) و تصنيعه عملياً يعمل ضمن الحزمة الترددية (S-band ,C-band), تمت دراسة تحسين عرض النطاق الترددي و رفع كفاءة عمل الهوائي ، بعد تعديل شكل المشع من خلال قطع سبعة أجزاء من حافة المشع على شكل شبه بيضاوي بقطر وعمق 2 مم لتصبح الدائرة بشكل مموج . كما تم تصغير قاعدة الهوائي لتصبح بأبعاد 40 × 13 مم^2 ، أظهرت النتائج التي تم الحصول عليها تحسنًا جيدًا في أداء الهوائي مع تردد الرنين (3.1 GHz و 7.1) وعرض النطاق الترددي (40.8%, 12.4%) على التوالي .