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Designing a Microstrip Patch Antenna in Part of Ultra-Wideband Applications

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Abstract:

In this work, a simulated study was carried out for designing a novel spiral rectangular patch of microstrip antenna that is used in ultra-wideband applications by using a high frequency structure simulator software (HFSS). A substrate with dielectric constant of 4.4 and height 2.10 mm (commercial substrate height available is about 0.8-1.575 mm) has been used for the design of the proposed antenna. The design basis for enhancing bandwidth in the frequency range 6.63 - 10.93 GHz is based on increasing the edge areas that positively affect the antenna's efficiency. This design makes the designed antenna cost less by reducing the area of the patch. It has been noticed that the bandwidth of the antenna under this study is increasing to 4.30 GHz or 61% compared with 3.6% for the standard rectangular microstrip antenna with the same dimensions of the proposed antenna. The antenna also maintains the voltage standing wave ratio of 1.09 at resonant frequency 7.07 GHz, return loss -27.07 dB, and the amount of impedance in real and imaginary parts 51.5Ω and 3.3Ω, respectively.

Key words: Bandwidth Impedance, HFSS, Microstrip Antenna, Return Loss, Ultra-Wideband

Introduction:

In the microwave frequency range, one of the most widely used types of antennas for wireless systems and radio frequency applications are the microstrip antennas (MSAs) due to their low cost and compact design (1,2). Basically, MSAs are composed of a radiating conductive patch located on the top of the dielectric substrate layer with thickness h. This substrate layer is fixed on a good conductor of ground plane. The dielectric substrate has relative permittivity and permeability ϵ_r and μ_r, respectively, as shown in Fig. 1 (3).
Generally, the metallic material such as gold or copper is used to formulate the conducting patch. The metallic patch may be of various shapes, the most common shapes are rectangular and circular (4). MSAs have attracted much interest in satellite applications and wireless mobile communication, because of their small size, low profile, low cost on mass production, light weight, and easy integration with the other types of components (5,6). However, this kind of antennas has narrow bandwidth where the typical impedance bandwidth is less than 1%, which represents the main serious limitations of MSAs. Also, the typical gain of an individual MSA is about 6 dB. Importantly, to increase the bandwidth of the MSA, there are many approaches that can be implemented. One of these approaches has been used by perturbing the mode of higher order using interpolating surface modification into the geometry of patch (7,8).

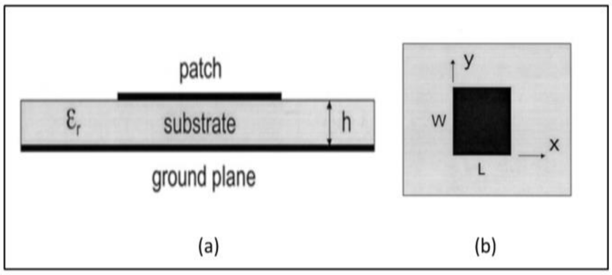


Figure 1. Geometry of MSA: (a) side view and (b) top view (3).

The wireless transmission scheme that occupies more than 500 MHz or over 20% of absolute bandwidth is defined as ultra-wideband (UWB) system. UWB is a relatively new technology which is capable of high-speed data transmission, as well as achieving high-resolution ranging (9). Since the first UWB Report which is adopted and ordered on February 14, 2002 from

United States Federal Communications Commission (FCC), the interest from academics and the market place has increased basically in UWB technology. The expectation from this interest will solve the shortage of the available frequency resources by using the UWB. Also, the higher data throughput can represents potential by UWB (10). In 2002, the FCC of the United State released the spectrum frequency of UWB 3.1 to10.6 GHz (11). The radio systems of UWB are attractive for scientists and engineers, because these radio systems have many attractive features like flexibility, extremely high data-rate, high mobility etc. (12,13).

A comprehensive review of the design and analysis of wideband and UWB antennas concerning the materials, the geometry, the numerical methods, and manufacturing technologies has been introduced for wireless applications (14). An innovative dual band-notch monopole antenna has been studied for UWB applications. This antenna reveals 3.0-12.5 GHz of the frequency bandwidth (15).The designing of UWB antenna attracted more researchers to study the elimination of any interference from narrowband wireless applications. For this purpose, they have used multi-patches, multi-layered and differently shapes of slot in the ground plane, feed and patch (16–20). In particular, a compact design for multiband in UWB frequency spectrum has been designed and it gave reasonable gain with good radiation characteristics (21). A novel UWB miniaturized integrated antenna has been designed based on implementing the new capacitive and inductive components to provide good radiation properties, bandwidth extension and size reduction (22). Bakariya et al. presented a rectangular patch with two bevels in UWB applications with a stable gain and omnidirectional radiation pattern (23). Further, a triple-notch UWB monopole antenna is presented using Koch structure and T-shaped stub (24). In addition, a microstrip line-fed UWB antenna was designed using a truncated ground plates and a slot to achieve 117% of the fractional bandwidth (25). A wide impedance bandwidth of a MSA has been simulated based on a novel design with multi-forked patch, with Arlon AD320A (tm) dielectric. Also, the resonance frequency was10.31 GHz and 114% of impedance bandwidth value, and this bandwidth is quite useful for X-band applications in fields of satellite, mobile, radio location, etc. (26).

In this paper, a spiral shape is proposed as a new patch of MSA to be a candidate for use in UWB applications at resonant frequency 7.07 GHz and matched with 51.5 Ω. In addition, this study was carried out to optimize the dimensions of the proposed antenna in UWB frequency spectrum.

Antenna Design:

In this work, the authors have presented radiation due to the proposed antenna that is simulated and designed using the software of high frequency structure simulator (HFSS). This software is used for solving problems of engineering and mathematical physics based on the finite element method and method of moment based on integral equation solver (27). In fact, the present paper shows that the antenna design is useful for UWB applications.

The very common technique used for feeding MSAs is a coaxial feed. To get the input impedance matching in this excitation technique, the desired location of the coaxial feed can be obtained by placing this feeder at any position inside the patch, and this is the main advantage of a coaxial feed (28). Therefore, the coaxial feed is used for feeding this designed antenna. The point of the feed location and the dimensions for the proposed antenna has been optimized so as to get the better possible impedance match to the antenna. The feed location was selected for a $51.5\ \Omega$ typical impedance, based on the matching process, to be $\mathrm{x_f} = 4.2\ \mathrm{mm}$ and $\mathrm{y_f} = 0.25\ \mathrm{mm}$. The radii of the outer and inner of the coaxial probe are $\mathrm{r_o} = 2.5\ \mathrm{mm}$ and $\mathrm{r_i} = 0.5\ \mathrm{mm}$, respectively.

The process design of a new patch of MSA included the dimensions of the length and width of the patch, new spiral shape patch and location of the feed point, as illustrated in Table 1.

Table 1. Dimensional parameters of the proposed spiral patch.

Parameters	Dimensions (mm)
L_1	18.0
L_2	15.0
L_3	14.0
L_4	10.5
L_5	10.0
L_6	6.0
L_7	5.5
L_8	2.0
T	2.5

The design of rectangular MSA with the standard dimensions is calculating the width (W_s) and length (L_s) for a resonant frequency (f_o) in GHz as (29):

$$W_s = \frac{c}{2f_o} \times \left(\frac{2}{\varepsilon_r + 1}\right)^{-1} \qquad \dots \quad 1$$

$$L_s = \frac{c}{2f_o}\left(\varepsilon_{eff}\right)^{-1/2} - 2\Delta L_s \qquad \dots \quad 2$$

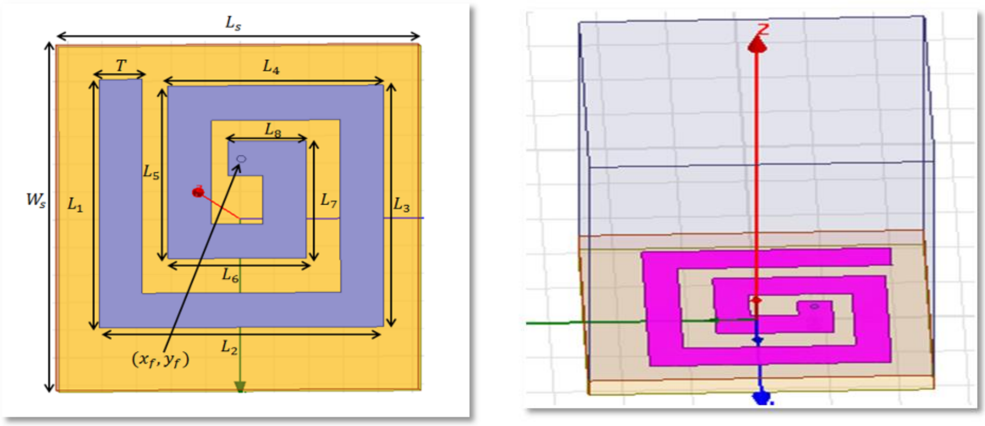
The values of effective dielectric constant (ε_{eff}) and length extension have been calculated using:

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{(\varepsilon_r - 1)\left(1 + 12\frac{h}{W_s}\right)^{-1/2}}{2} \quad \ldots\ 3$$

$$\Delta L_s = 0.41h\left(\left(\varepsilon_{eff} + 0.3\right)\left(\varepsilon_{eff} - 0.258\right)^{-1}\right) * \left(\left(\frac{W_s}{h} + 0.264\right)\left(\frac{W_s}{h} + 0.8\right)^{-1}\right) \quad \ldots\ 4$$

where c is the light velocity. The dimensions of the ground plane conductor are similar to the dielectric substrate dimensions. The dielectric substrate has the thickness of $h = 2.10$ mm, a dielectric constant is $\varepsilon_r = 4.4$, and the length and width of the substrate are $L_s = 21.00$ mm and $W_s = 25.00$ mm, respectively.

The new shape of the patch consists of eight parts in the form of a rectangular with dimensions (T, L_n) and they are connected to each other, where n=1,2,…,8. Figure 2a illustrates the antenna structure from the top, while Fig. 2b describes the side view of the proposed antenna. The dimensions of the patch of this antenna are illustrating in Table 1 at operating frequency 7.07 GHz.



(a) **(b)**

Figure 2. Geometric design and dimensions of the proposed antenna: (a) top view and (b) side view.

Results and Discussion:

This paper presents the simulated results of the proposed antenna that is obtained by using HFSS software 13.0, its development and performance are based on these simulated results. The results of the parameters of the proposed antenna at operating frequency 7.07 GHz are return loss -27.07 dB, impedance bandwidth 4.30 GHz or 61%, and voltage standing wave ratio (VSWR) 1.09 as shown in Figs. 3 and 4, respectively. Therefore, the designed antenna is helpful for many services processes at C- and X-band frequency applications.

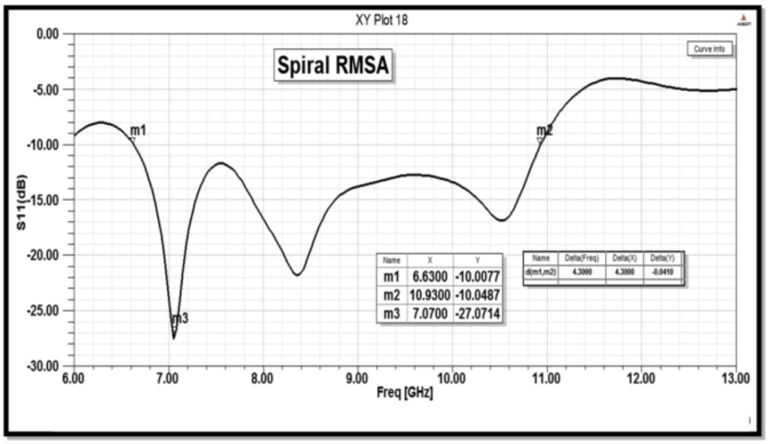


Figure 3. Simulated return loss of proposed antenna.

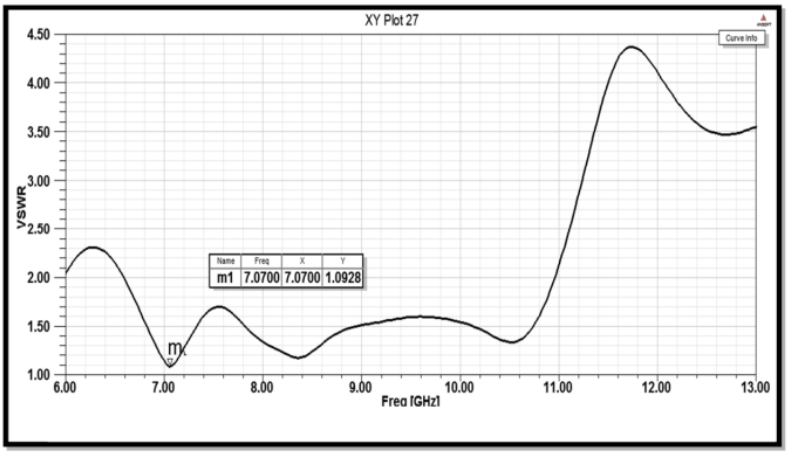


Figure 4. VSWR simulation of the proposed antenna.

However, Fig. 5 shows that the impedance bandwidth of the standard rectangular microstrip antenna (RMSA) is 3.6% with the same antenna dimensions (i.e. rectangular patch instead of a spiral rectangular patch). Therefore, this antenna is suitable for 6.63 -10.93 GHz band. In Fig. 6, the simulated input impedance is showed, which consists of resistance and reactance, at the operation frequency the input impedance of this antenna shows 51.5 Ω and 3.3 Ω as real and imaginary parts, respectively. By comparing the results of Figs. 3 and 5, the impedance bandwidth of the proposed antenna is 57.4% more than the impedance bandwidth of standard RMSA with the same antenna dimensions.

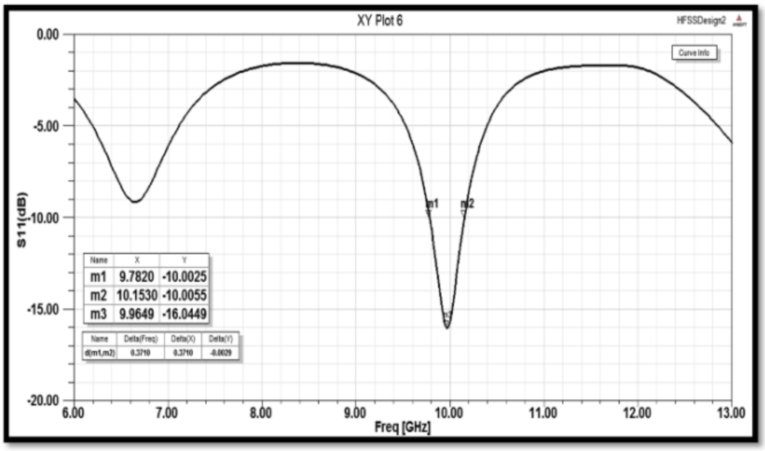


Figure 5. Simulated return loss of RMSA.

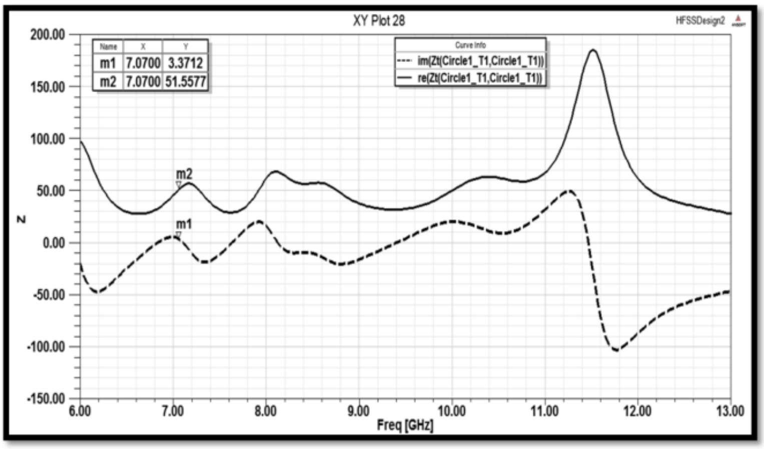


Figure 6. Simulated input impedance of the proposed antenna.

Figure 7 shows the radiation patterns in three dimensions of the proposed antenna, for lower, resonance, and upper frequencies, respectively. The properties of the radiation patterns, over the working frequency bandwidth, are reasonably constant of the proposed antenna. Figure 8 shows the electric and magnetic fields distribution on the proposed antenna at resonance frequency 7.07 GHz.

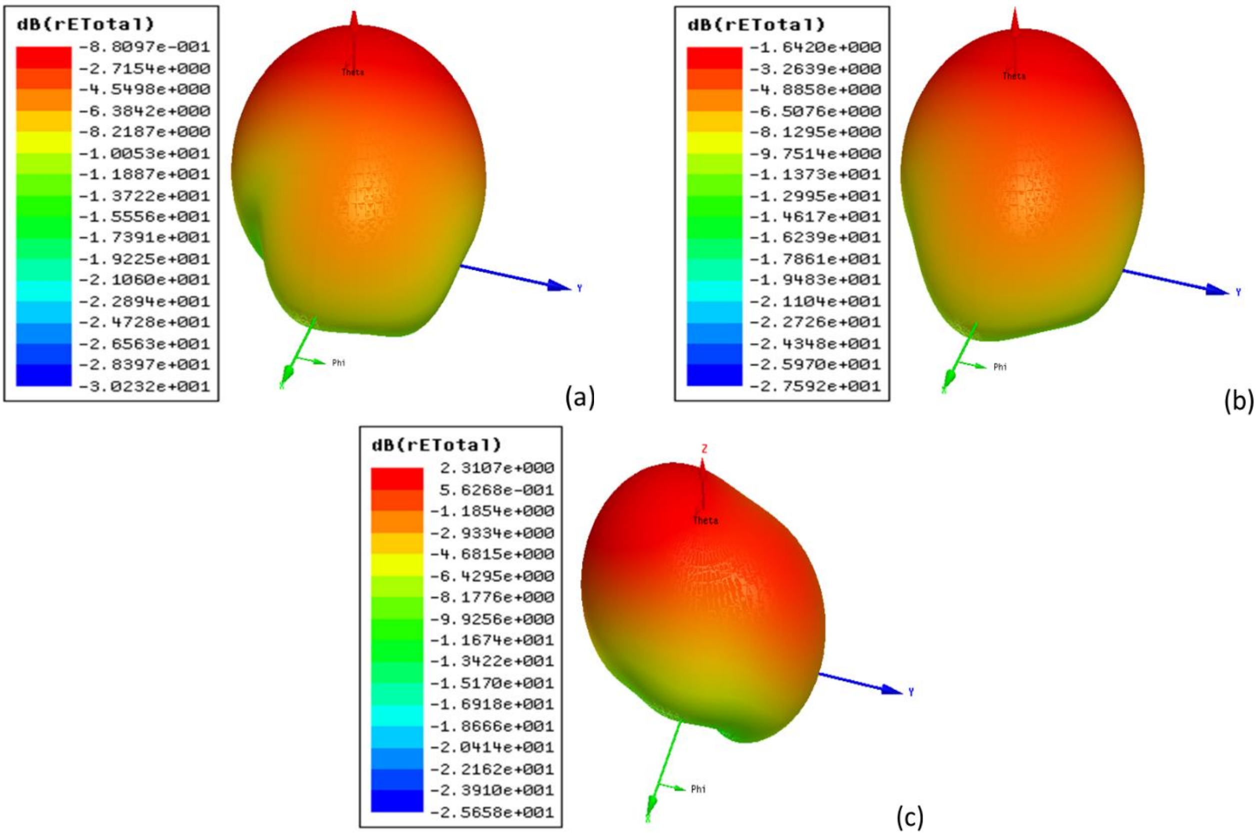


Figure 7. Radiation patterns of designed antenna in 3D: (a) f=6.63 GHz, (b) f=7.07 GHz, and, (c) f=10.93 GHz.

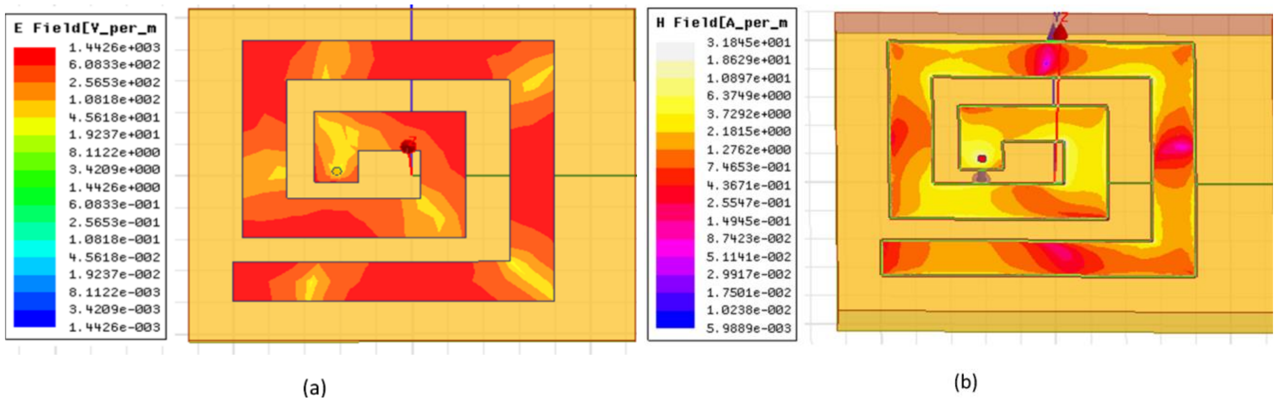


Figure 8. Simulated (a) electric, and (b) magnetic fields distribution on the proposed antenna.

Conclusion:

It can be concluded that the use of a spiral shape as a new patch of MSA makes the proposed antenna suitable for operating in UWB applications with frequency range 6.63 -10.93 GHz. The parameters of the designed antenna at operating frequency 7.07 GHz are -27.07 dB of return loss, 61% of impedance bandwidth, and 1.09 of VSWR. This design makes the antenna cost less by reducing the area of the patch. The proposed antenna has wide impedance bandwidth that is located within C- and X-band. C-band is particularly used for satellite communications, weather radars and full-time satellite TV networks or raw satellite feeds. However, X-band MSAs are widely used for point-to-point like as industrial scientific medical, imaging radar satellite communication, on air traffic.

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Authors' declaration:
- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are mine ours. Besides, the Figures and images, which are not mine ours, have been given the permission for re-publication attached with the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee in University of Basrah.

References:
1. Garg R, Bhartia P, Bahl IJ, Ittipiboon A. Microstrip antenna design handbook. London, Artech House Inc., 2001.
2. Balanis CA. Antenna theory: analysis and design. New Jersey: John Wiley & Sons Inc., 2016.
3. Bansal R. Fundamentals of Engineering Electromagnetics. Boca Raton: Taylor and Francis Group, LLC, 2006.
4. Godaymi Al-Tumah WA, Mohammed AK, Ahmed ZA. Determination of Surface Currents on Circular Microstrip Antennas. J electromagn Eng Sci. 2012 ;12(4):260-70.
5. Richie JE, Ababei C. Optimization of patch antennas via multithreaded simulated annealing based design exploration J Comput Des Eng. 2017;4(4):249-255.
6. Godaymi Al-Tumah WA, Shaaban RM, Tahir AS. Design, simulation and measurement of triple band annular ring microstrip antenna based on shape of crescent moon. AEU Int J Electron C. 2020 Feb; 15:153133.
7. Mudgal R, Shrivastava L. Microstrip V Slot Patch Antenna Using An H–Slot Defected Ground Structure (DGS). IJTEEE. 2014; 2(2):21-24.
8. Shaaban RM, Ahmed ZA, Godaymi Al-Tumah WA. Design and analysis for circular microstrip antenna loaded by two annular rings. GJCST. 2017 ;17(1):30-35.
9. Nguyen C, Miao M. Design of CMOS RFIC ultra-wideband impulse transmitters and receivers. Springer; 2017.
10. Yang T, Suh SY, Nealy R, Davis WA, Stutzman WL. Compact antennas for UWB applications. Aero El Sys Mag. 2004; 19(5):16-20.
11. Djaiz A, Habib MA, Nedil M, Denidni TA. Design of UWB filter-antenna with notched band at 5.8 GHz. In2009 IEEE Antennas and Propagation Society International Symposium 2009 Jun 1 (pp. 1-4). IEEE.
12. Kumar H, Upadhayay MD. Design of UWB filter with WLAN notch. Int J Antenn Propag. 2012 ;3(1):45-47.
13. Shameena VA, Mridula S, Pradeep A, Jacob S, Lindo AO, Mohanan P. A compact CPW fed slot antenna for ultrawide band applications. AEU Int J Electron C. 2012 ;66(3):189-194.
14. Cicchetti R, Miozzi E, Testa O. Wideband and UWB antennas for wireless applications: A comprehensive review. Int J Antenn Propag. 2017; 2017:1-45.
15. Azarm B, Nourinia J, Ghobadi C, Karamirad M. Novel Design of Dual Band-Notched Rectangular Monopole Antenna with Bandwidth Enhancement for UWB Applications. In Electrical Engineering (ICEE), Iranian Conference on 2018 May 8 (pp. 567-571). IEEE.
16. Choi J, Chung K, Roh Y. Parametric analysis of a band rejection antenna for UWB application. Microw Opt Techn Let. 2005;47(3):287-290.
17. Ahmed O, Sebak AR. A compact UWB butterfly shaped planar monopole antenna with bandstop characteristic. In 2009 13th International Symposium on Antenna Technology and Applied Electromagnetics and the Canadian Radio Science Meeting. IEEE. 2009 Feb 15 (pp. 1-3)..
18. Eshtiaghi R, Zaker R, Nouronia J, Ghobadi C. UWB semi-elliptical printed monopole antenna with subband rejection filter. Aeu Int J Electron C. 2010 ;64(2):133-141.
19. Li L, Zhou ZI, Hong JS, Wang BZ. Compact ultra-wideband printed monopole antenna. Electron lett. 2011;47(16):894-896.
20. Ali JK, Yassen MT, Hussan MR, Hasan MF. A new compact ultra wideband printed monopole antenna with reduced ground plane and band notch characterization. PIER. 2012 Mar 27;1531-1536.
21. Mark R, Mishra N, Mandal K, Sarkar PP, Das S. Hexagonal ring fractal antenna with dumb bell shaped defected ground structure for multiband wireless applications. Aeu Int J Electron C. 2018 ;94(2):42-50.
22. Alibakhshi-Kenari M, Naser-Moghadasi M. Novel UWB miniaturized integrated antenna based on CRLH metamaterial transmission lines. Aeu Int J Electron C. 2015; 69(8):1143-1149.
23. Bakariya PS, Dwari S, Sarkar M. Triple band notch UWB printed monopole antenna with enhanced bandwidth. Aeu Int J Electron C. 2015 ;69(1):26-30.
24. Zarrabi FB, Mansouri Z, Gandji NP, Kuhestani H. Triple-notch UWB monopole antenna with fractal Koch and T-shaped stub. Aeu Int J Electron C 2016 ;70(1):64-69.
25. Jayasinghe JW, Saraereh OA. Bandwidth optimization of an ultra-wide band microstrip antenna. Proceedings of the International Conference on Information, Communication, Instrumentation and Control, Indore, India, 2017 ;(pp. 1-4).
26. Godaymi Al-Tumah WA, Shaaban RM, Tahir AS, Ahmed ZA. Multi-forked microstrip patch antenna for broadband application. J. Phys. Conf 2019 Jul (Vol. 1279, No. 1, p. 012025). IOP Publishing.
27. Hati K, Sabbar N, El Hajjaji A, Asselman H. A Novel Multiband Patch Antenna Array for Satellite Applications. Procedia Eng. 2017 Jan 1; 181:496-502.
28. Fanat BN, Prabhakar NM. Quad Band Microstrip Antenna for Mobile and GNSS application. IJRITCC. 2017; 5(4):226-228.

29. Godaymi Al-Tumah WA, Shaaban RM, Ahmed ZA. A modified E-shaped microstrip patch antenna for dual band in x-and ku-bands applications. J Phys Conf Ser. 2019 Jul (Vol. 1234, No. 1, p. 012028).

تصميم هوائي شريطي مشع لتطبيقات النطاق الترددي العريض الفائق

وائل عبد اللطيف كديمي الطعمه **رائد مسلم شعبان** **زكي عبد الله احمد**

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الخلاصة:

في هذه الدراسة، أجريت دراسة محاكاة لتصميم هوائي شريطي مع رقعة مستطيلة لولبية جديدة والذي يُستخدم في تطبيقات النطاق الترددي العريض الفائق وباستخدام برنامج محاكاة التراكيب عالية التردد (high frequency structure simulator software (HFSS)). تم استخدام شريحة عازلة بقيمة ثابت عزل يساوي 4.4 وارتفاع 2.10 ملم لتصميم الهوائي المقترح. أن أساس التصميم يستند على زيادة عرض النطاق الترددي ضمن الحزمة الترددية 6.63 - 10.93 كيكاهرتز من خلال زيادة مناطق الحافة للمشع والتي تؤثر إيجابًا على كفاءة الهوائي. أن هذا التصميم يجعل تكلفة تصميم الهوائي اقل من خلال تقليل مساحة المشع. لاحظنا أن عرض النطاق الترددي للهوائي في هذه الدراسة يزداد إلى 4.30 كيكاهرتز أو ما يعادل 61٪ مقارنةً بالنسبة 3.6٪ الناتجة عن الهوائي الشريطي المستطيل القياسي مع نفس أبعاد الهوائي المقترح. أن الهوائي المقترح حافظ على نسبة موجة الفولتية القياسية الواقفة (voltage standing wave ratio) وهي 1.09 عند التردد الرنيني 7.7 كيكاهيرتز، وعامل الفقد 27.07 ديسبل، وان قيمة الجزء الحقيقي والخيالي للممانعة هي 51.5 أوم و 3.3 أوم ، على الترتيب.

الكلمات المفتاحية HFSS ، عرض نطاق الممانعة، الهوائي الشريطي، عامل الفقد، النطاق العريض الفائق.