Using Method Moments to study the Properties the Octagonal Microstrip Antenna

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Abstract.

Simulation of octagonal microstrip antenna with 2.4 GHz resonant frequency was achieved using the microwave office 2000 program (MWO2000), which is depending on the method of moments (MOM). It has been found that the proposed antenna bandwidth was 4.95%. When the proposed antenna is modified and designed inside the circumference of a circle that its equation $r = ae^{b\theta}$ .This method led to the design of another shape of the original antenna it is found that the increase in bandwidth has increased 10.13%. The last modifying is made a rectangular slot in the patch of the antenna; it is found that the increase in bandwidth has increased to 11.61%. In this study, was used Polyethylene with dielectric constant ε_r=2.25, used foam with dielectric ε_r=1.07 , and also the center of the resonant frequency was shifted to a new value.

Keyword: Octagonal microstrip antenna, Bandwidth, Input impedance, Return loss, Method of Moments

الملخص

في هذا البحث تم تصميم هوائي شريطي ثماني الشكل باستخدام برنامج المحاكاة مايكرويف اوفس *(MWO 2000)* المبين بالشكل (٢) ، استخدامت المادة العازلة (*Polyethylene*) ثابت عزلها $\varepsilon_r = 2.25$ و المادة العازلة (*foam*) ثابت عزلها $\varepsilon_r = 1.07$ ، تم احتساب النواتج باستخدام طريقة العزوم *(MoM)* ، في البدء حصلنا على عرض النطاق الترددي للهوائي المقترح *4.95%* ، و لأجل تحسين عرض النطاق ، قمنا بتعديل الشكل الاصلي كما بالشكل (٥) ، ادى هذا التعديل الى زيادة عرض الحزمة الى *10.13%* . بعدها أيضا تم اجراء تعديل اخر

على الهوائي المقترح وذلك بعمل شق مستطيل الشكل على رقعة الهوائي كما بين بالشكل (٨) ، لوحظ زيادة بعرض النطاق الترددي فاصبح بمقدار *11.61%* .

الكلمات المفتاحية : هوائي شريطي ثماني الشكل ، عرض الحزمة ، ممانعة الادخال ،عامل الفقد العكسي ، نظرية العزوم

Introduction

The primary objective of any antenna's design is to transmit electromagnetic waves from a transmission line into space or to receive those waves via a receiver from space into a transmission line. The transmitting antenna is a device that converts electromagnetic waves deployed on the transmission line in order to spread free-space waves. The antenna is a part of an electrical circuit, while the other side is available at the interface with the spread of the planar wave. Hence, these antennas are devices used to transmit as well as receive radiation power. So, the antenna is considered a linking unit between transmission lines and space [1]. Microstrip Patch Antenna (MPA) is commonly used because of its low profile, low cost, and ease of manufacturing. A patch antenna is made by etching metal on one side of the dielectric substrate, where on the opposite side, there is a continuous metal layer of the substrate, which forms a ground plane [2]. These antennas can be integrated with printed strip-line feed networks and active devices. This is a relatively new area of antenna engineering. The radiation properties of microstrip structures have been known since the mid-1950s [3]. Frequency (GHz–2.9 GHz) applied to Bluetooth, TD-SCDMA, WCDMA, CDMA2000 and LTE33-41 . TD-SCDMA is a 3G format of choice for the national standard of 3G mobile telecommunication in China, CDMA is a third-generation (3G) wireless standard which allows use of both voice and data and offers data speeds of up to 384 Kbps. Europe and Asia - 2100MHz, North America -

1900MHz and 850MHz, CDMA2000 is a family of 3G mobile technology standards for sending voice, data,and signaling data between mobile phones and cell sites.

Theoretical Part

The method of moments is one of the most accurate methods of solving electromagnetic problems, but the difficulty is to calculate the Green function [4].

$$\mathbf{e_z} \times [\mathbf{E^e}(\mathrm{r}) + \mathbf{E^s}(\mathrm{r})] = \mathrm{Z_s}[\mathbf{e_z} \,\mathrm{x}\, \mathbf{J_s}(\mathrm{r})] \qquad (\boldsymbol{r} \in \boldsymbol{So}) \qquad (\mathbf{1})$$

If we assume that the surface current on the surface of a radiated antenna is j_s and that the irritating area is E^e, there is the field that will be scattering E^s so that these quantities are related to the relationship [5].

Where Z_s represents the impedance and depends on the type of material made from the radiator and e_z the vector unit on the vertical surface.

The scattering field is calculated from the vector magnetic voltage A (r) and the voltage V (r) where the magnetic voltage is given by the relationship [6].

$$\boldsymbol{A}(\boldsymbol{r}) = \int_{s} \boldsymbol{GA}(\boldsymbol{r}|\boldsymbol{r}') \cdot \boldsymbol{Js}(\boldsymbol{r}')\boldsymbol{dS}' \qquad (\mathbf{2})$$

And that the voltage is given by the relationship (3).

$$\boldsymbol{V}(\boldsymbol{r}) = \int_{s} \boldsymbol{G_V}(\boldsymbol{r}|\boldsymbol{r}') \cdot \boldsymbol{\rho_s}(\boldsymbol{r}')\boldsymbol{dS}' \qquad (\mathbf{3})$$

Where $\boldsymbol{G_A}(\boldsymbol{r}|\boldsymbol{r}')$,$\boldsymbol{G_V}(\boldsymbol{r}|\boldsymbol{r}')$ The function of the diatyc Green and the function of the numerical Green respectively, and ρ_s (r ') the current density. When the point of the field is very close to the source point in a material with a μ_0 permeability and an electrical permittivity $\varepsilon = \varepsilon_r \varepsilon_0$ where ε_r is the relative permittivity, the two Green functions may be given in relation.

$$\boldsymbol{GA}(\boldsymbol{r}|\boldsymbol{r}') = \frac{\boldsymbol{\mu_0}}{\boldsymbol{4\pi|r - r_0|}} \qquad (\boldsymbol{4})$$

$$\boldsymbol{G_V}(\boldsymbol{r}|\boldsymbol{r}') = \frac{\boldsymbol{1}}{\boldsymbol{2\pi(\varepsilon_r + 1)|r - r_0|}} \qquad (\boldsymbol{5})$$

The purpose of solving the problem is to calculate both J_s and ρ_s Since the above integration requires knowledge of J_s and ρ_s, numerical methods are used in the calculation of integration, where used moment of the method [4].

The solution is performed in the moment of the method, dividing the patch into rectangles a × b called the charged cells. Both the current and current density are defined as follows [6].

$$\boldsymbol{J_{sx}} = \frac{\boldsymbol{1}}{\boldsymbol{b}} \sum_{\boldsymbol{i=1}}^{\boldsymbol{M}} \boldsymbol{I_{ix}}\, \boldsymbol{T_x}(\boldsymbol{r} - \boldsymbol{r_{xi}}) \qquad (\boldsymbol{6})$$

$$\boldsymbol{J_{sy}} = \frac{\boldsymbol{1}}{\boldsymbol{a}} \sum_{\boldsymbol{i=1}}^{\boldsymbol{N}} \boldsymbol{I_{iy}}\, \boldsymbol{T_y}(\boldsymbol{r} - \boldsymbol{r_{yi}}) \qquad (\boldsymbol{7})$$

$$\boldsymbol{\rho_s} = \frac{\boldsymbol{1}}{\boldsymbol{j\omega ab}} \left(\sum_{\boldsymbol{i=1}}^{\boldsymbol{M}} \boldsymbol{I_{ix}} \left[\boldsymbol{P}(\boldsymbol{r} - \boldsymbol{r_{xi}^{+}}) - \boldsymbol{P}(\boldsymbol{r} - \boldsymbol{r_{xi}^{-}})\right] + \sum_{\boldsymbol{i=1}}^{\boldsymbol{N}} \boldsymbol{I_{iy}} \left[\boldsymbol{P}(\boldsymbol{r} - \boldsymbol{r_{yi}^{+}}) - \boldsymbol{P}(\boldsymbol{r} - \boldsymbol{r_{yi}^{-}})\right] \right) \qquad (\boldsymbol{8})$$

Where

$$T_x(r)\begin{cases}1-\dfrac{|x|}{a} & |x|<a, |y|<\dfrac{b}{2}\\ 0 & elsewhere\end{cases}$$

$$P(r)\begin{cases}1 & |x|<\dfrac{a}{2}, |y|<\dfrac{b}{2}\\ 0 & elsewhere\end{cases}$$

After making the simplifications, we get the following equation

$$\begin{pmatrix}\boldsymbol{C^{xx}} & \boldsymbol{C^{yx}}\\ \boldsymbol{C^{xy}} & \boldsymbol{C^{yy}}\end{pmatrix} = \frac{\mathbf{1}}{\boldsymbol{jZ_0}}\begin{pmatrix}\boldsymbol{V_x^{(e)}}\\ \boldsymbol{V_y^{(e)}}\end{pmatrix} \qquad (\mathbf{9})$$

Whereas

$$\boldsymbol{C_{ij}^{xx}} = \frac{\mathbf{1}}{\boldsymbol{k_0^2ab}}\left[-\boldsymbol{\Gamma}_{\mathrm{V}}(\boldsymbol{r_{xi}^+}|\boldsymbol{r_{xj}^-}) - \boldsymbol{\Gamma}_{\mathrm{V}}(\boldsymbol{r_{xi}^-}|\boldsymbol{r_{xj}^+}) + \boldsymbol{\Gamma}_{\mathrm{V}}(\boldsymbol{r_{xi}^+}|\boldsymbol{r_{xj}^+}) + \boldsymbol{\Gamma}_{\mathrm{V}}(\boldsymbol{r_{xi}^-}|\boldsymbol{r_{xj}^-})\right] - \frac{\mathbf{1}}{\boldsymbol{k_0b}}\int_{\boldsymbol{c_{xi}}}\boldsymbol{\Gamma}_{\mathrm{A}}(\boldsymbol{r}|\boldsymbol{r_{xj}^-})\boldsymbol{k_0dx} + \boldsymbol{j}\frac{\boldsymbol{Z_s}}{\boldsymbol{Z_0}}\frac{\boldsymbol{a}}{\boldsymbol{b}}\boldsymbol{\delta_{ij}} \qquad (\mathbf{10})$$

$$\boldsymbol{C_{ij}^{xy}} = \frac{\mathbf{1}}{\boldsymbol{k_0^2ab}}\left[-\boldsymbol{\Gamma}_{\mathrm{V}}(\boldsymbol{r_{xi}^+}|\boldsymbol{r_{yj}^-}) - \boldsymbol{\Gamma}_{\mathrm{V}}(\boldsymbol{r_{xi}^-}|\boldsymbol{r_{yj}^+}) + \boldsymbol{\Gamma}_{\mathrm{V}}(\boldsymbol{r_{xi}^+}|\boldsymbol{r_{yj}^+}) + \boldsymbol{\Gamma}_{\mathrm{V}}(\boldsymbol{r_{xi}^-}|\boldsymbol{r_{yj}^-})\right] \qquad (\mathbf{11})$$

Where

$$\boldsymbol{\Gamma}_{\mathrm{V}}(\boldsymbol{r}|\boldsymbol{r_{0j}}) = \int\frac{\boldsymbol{\varepsilon_0}}{\boldsymbol{k_0}}\boldsymbol{G_V}(\boldsymbol{r}|\boldsymbol{r'})\boldsymbol{P}(\boldsymbol{r'} - \boldsymbol{r_{0j}})(\boldsymbol{k_0^2dS'}) \qquad (\mathbf{12})$$

$$\Gamma_{A}^{xx}(r|r_{0j}) = \int \frac{1}{\mu_0 k_0} G_{A}^{xx}(r|r')T(r' - r_{xj})(k_0^2 dS') \qquad (13)$$

And $Z_S$represent the resistance of the patch and Z_O = 50Ω represents the impedance of the wire and $V^e$the excitation voltage is calculated according to the formula of [7] where we used the central feeder to control the amount of input impedance [8].

The values of r_{xi}^{+} , r_{xi}^{-}, r_{yi}^{+}, r_{yi}^{-} are illustrated in figure 1

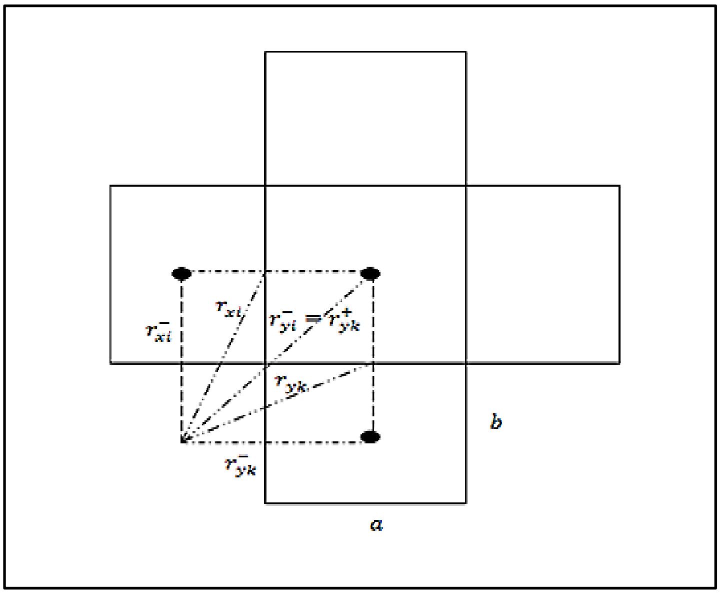

Figure (1) shows the values

3-Discussion of results

There are several ways to expand the bandwidth, and these methods are a simple change in the patch shape. There are a lot of researchers who have developed the basic idea of this technology, and the creation of a two-slit when the radioactive edges of the patch, as these slits, do not affect the resonant frequency and radiation structures, while providing another resonance frequency with similar radiation characteristics that are significantly affected by the length of the incision [9]. This is what we have done in this research and to show the amount of change that happened in the package shows as we see it, where using microwave office 2000 program to analysis the result in this study.

3-1 Octagonal Microstrip Antenna

We initially selected an octagonal microstrip antenna which side length (a= 18.2 mm) it and the coaxial feed position at the point (r_f), as shown in figure 2.

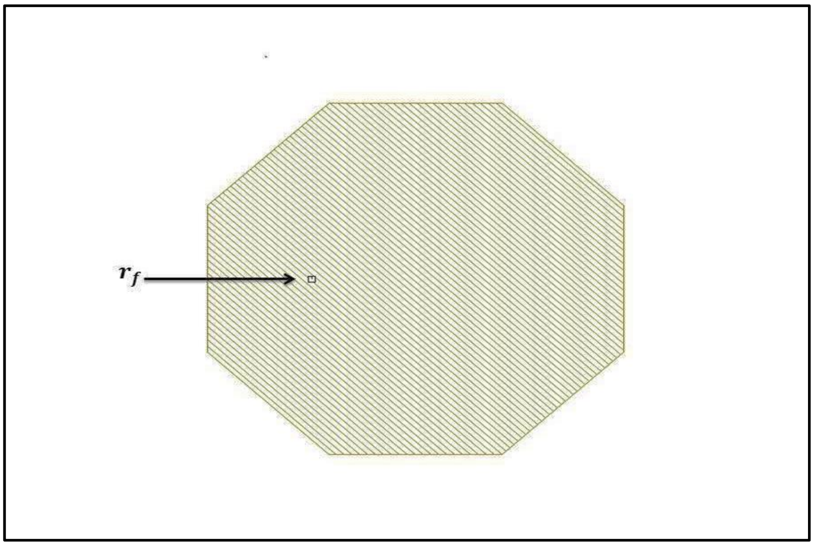

Figure (2) octagonal microstrip antenna

$$a = 18.2mm \ , h = 1.59mm \ \ \varepsilon_r = 2.25.$$

The resonant frequency (f_0) was determined by the intersecting point with the X-axis and the return loss s_{11} was calculated in Figure 3, the bandwidth is calculated from the following relationship [10]. Determined when ($s_{11} = -10dB$) was the bandwidth of the proposed antenna is ($BW = 4.95\%$)

$$\boldsymbol{BW} = \frac{2(f_u - f_l)}{(f_u + f_l)} \times \mathbf{100}\% \qquad (14)$$

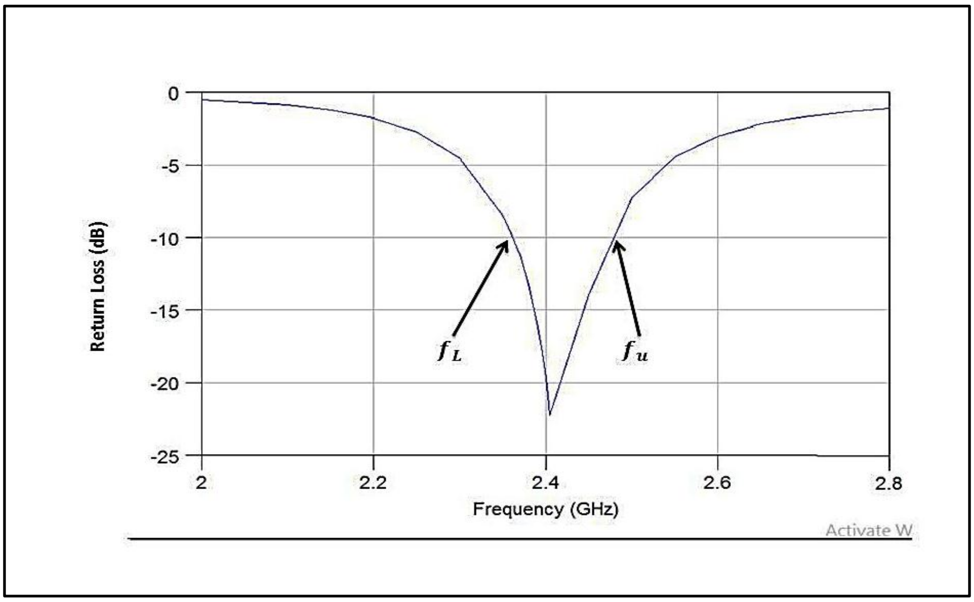

Figure (3) Return loss s_{11} of the octagonal microstrip antenna

$f_l = 2.36GHz$, $f_u = 2.48\ GHz$, $f_0 = 2.4GHz$ $h = 1.59mm$ $\varepsilon_r = 2.25$

The above results were obtained when the input impedance of the proposed antenna **(50Ω)** as shown in figure 4.

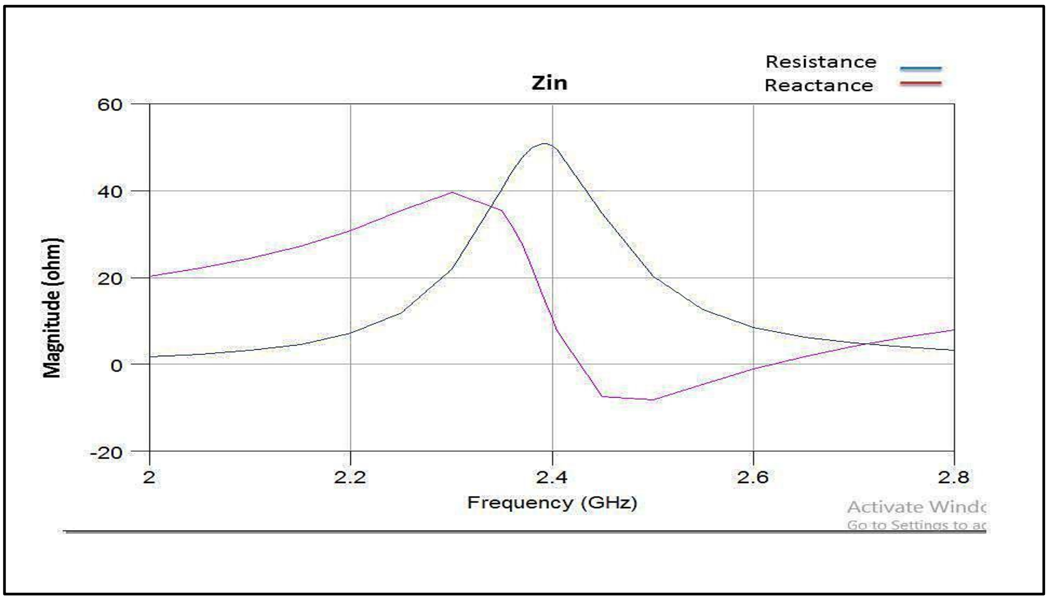

Figure (4) Input impedance of the octagonal microstrip antenna $f_0 = 2.4GHz$ $h = 1.59mm$ $\varepsilon_r = 2.25$

3-2 Modified Shape of Octagonal Microstrip Antenna

The aim of this work is to enhance the bandwidth of the octagonal microstrip antenna by changing the shape of the patch; since the octagonal shape can be designed inside the circumference of a circle that its equation $r = a$, we modified the originally proposed antenna by placing the vertices of modifying octagonal inside the modified circle perimeter, its equation $r = ae^{b\theta}$. This method led to the design of another shape of the original antenna [11]. As show in figure 5.

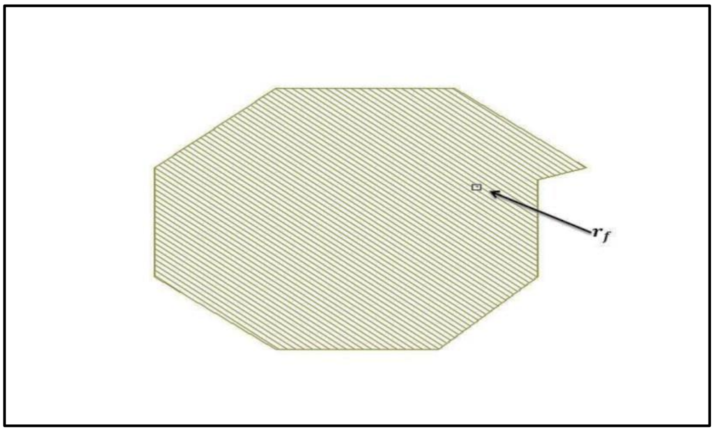

Figure (5) modifying octagonal microstrip antenna
$a = 18.2mm$, $h = 1.59mm$ $\varepsilon_r = 2.25$

After making this modification to the proposed antenna, the expansion of the amount of bandwidth has become (10.13%). The return loss and the input impedance of the modifying octagonal microstrip antenna were shown in figure 6, 7.

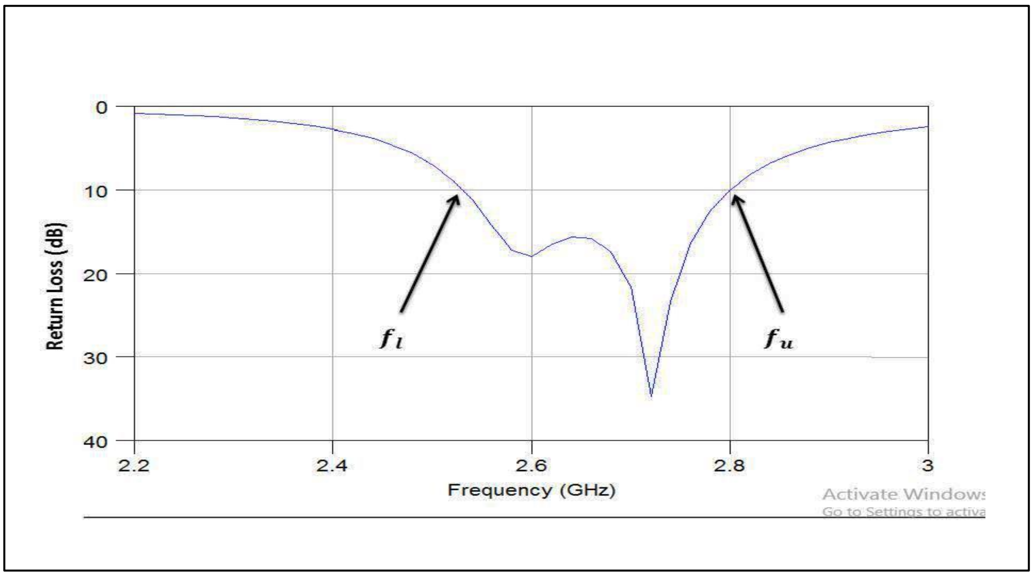

Figure (6) Return loss s_{11} of the octagonal microstrip antenna $f_l = 2.53GHz$, $f_u = 2.8\,GHz$, $f_0 = 2.4GHz$ $h = 1.59mm$ $\varepsilon_r = 2.25$

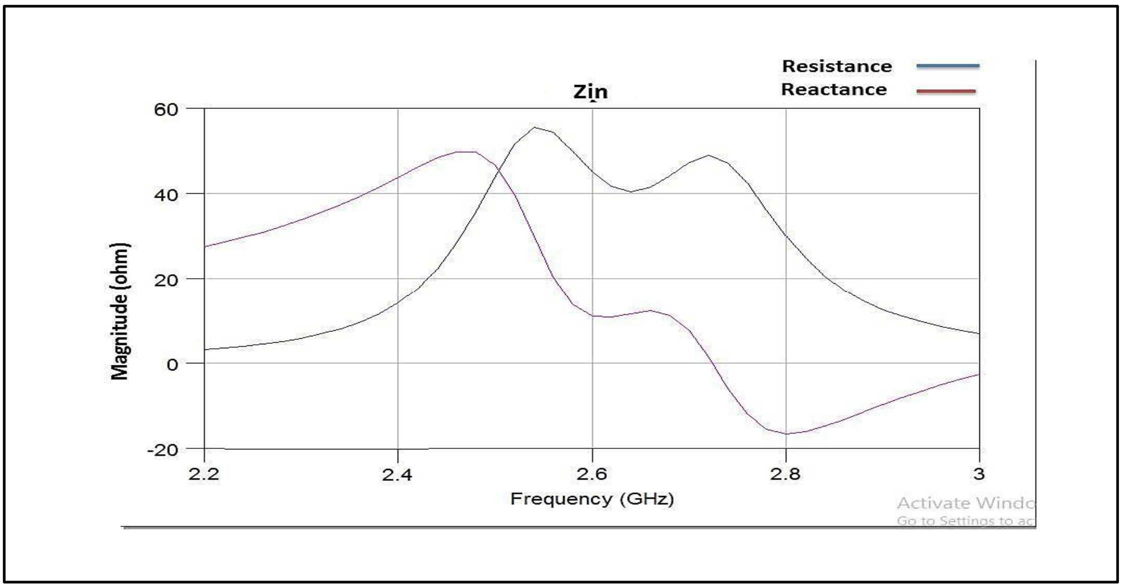

Figure (7) Input impedance of the modifying octagonal microstrip antenna $f_0 = 2.4GHz$ $h = 1.59mm$ $\varepsilon_r = 2.25$

3-3 Slot Octagonal Microstrip Antenna

In order to obtain an expansion of the proposed antenna bandwidth, we made a rectangular slot on one of the ribs edges in the patch, as in figure 8, where the dimensions of the rectangular space (9.635,1.927).

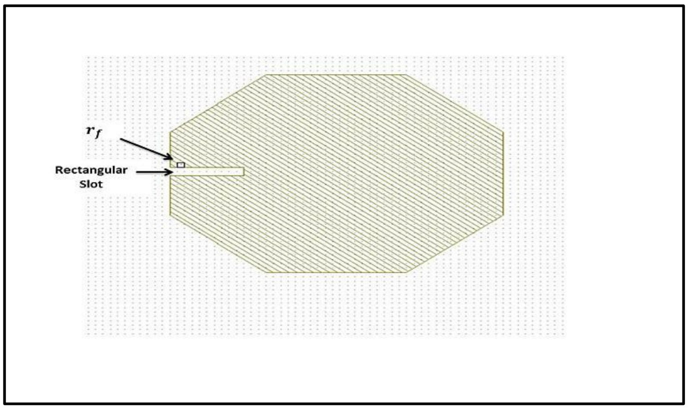

Figure (8) slot octagonal microstrip antenna
$a_1 = 18.2mm$, $h = 1.59mm$ $\varepsilon_r = 2.25$

After making this modification to the proposed antenna, the expansion of the amount of bandwidth has become (11.61%).

The return loss and the input impedance of the slot octagonal microstrip antenna were shown in figure 9, 10.

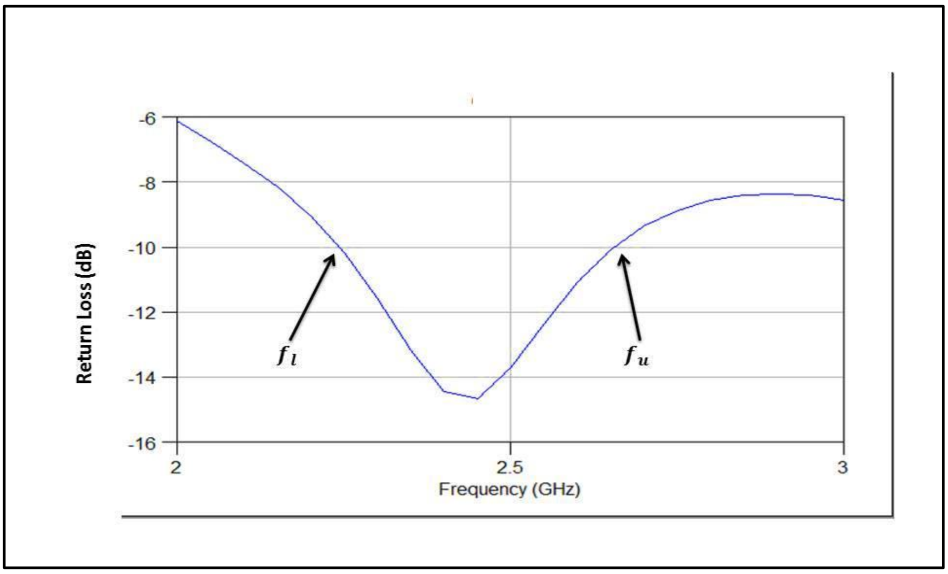

Figure (9) Return loss s_{11} of the slot octagonal microstrip antenna

$f_l = 2.27GHz, f_u = 2.55\ GHz,\ f_0 = 2.4GHz\ h = 1.59mm\ \ \varepsilon_r = 2.25$

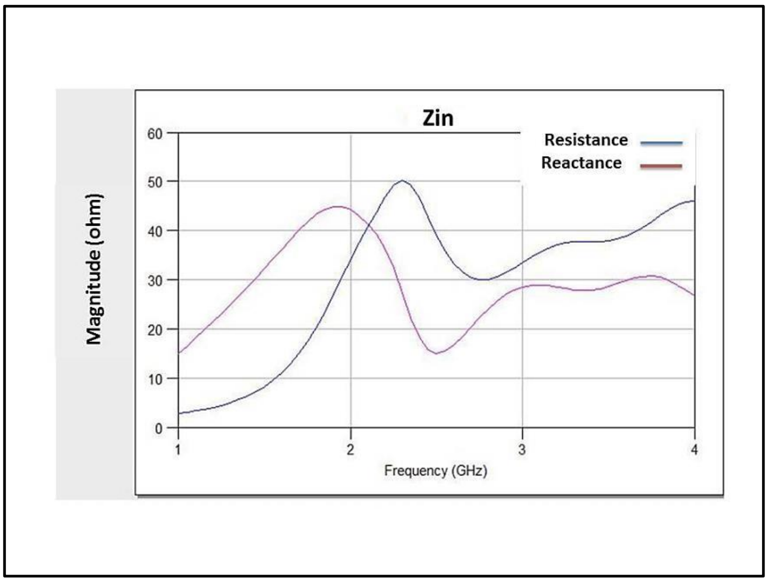

Figure (10) Input impedance of the slot octagonal microstrip antenna $f_0 = 2.4GHz\ h = 1.59mm\ \ \varepsilon_r = 2.25$

To ensure that the method is generally applicable and effective, we have applied it to antennas with a different dielectric material (foam, $\boldsymbol{\varepsilon_r = 1.07}$) with the center of the resonant frequency was shifted to a new high value ($\boldsymbol{f_0 = 3.5GHz}$), As shown in the following table.

Table (1) The Bandwidth and Resonant Frequency for Proposed Antenna

Dielectric constant value	Resonant frequency	Octagonal microstrip	Modified Octagonal	Slot Octagonal
		Bandwidth	Bandwidth	Bandwidth
2.25	2.4GHz	4.95%	10.13%	11.61%
1.07	3.5GHz	8.11%	12.07%	13.25%

Conclusions

When designing an octagonal microstrip antenna, its bandwidth (٤.95%) was calculated at a resonant frequency (2.4 GHz) and input impedance 50Ω. In order to increase the bandwidth of the proposed antenna, the following was done:

1- Modifying of octagonal microstrip antenna and designed inside circumference of a circle that its equation $r = ae^{b\theta}$ .This method led to the design of another shape of the original antenna it is found that the increase in bandwidth has increased by 10.13%.
2- A rectangular slot was made on one of the ribs edges in the patch for the proposed antenna. This modification increased the bandwidth to (11.61%).
3- When the proposed antenna was applied to another resonant frequency and different dielectric, there was a significant increase in bandwidth, where the bandwidth values in the proposed antenna are increased the lower the dielectric constant of the insulating material.

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References

[1] G. J. Foschini, "Layered space-time architecture for wireless communication in a fading environment when using multi-element antennas," *Bell Labs Tech. J.*, 1996, doi: 10.1002/bltj.2015.

[2] kaittan Shadkh, Jasim, Raed M. Shaaban, and Ra'ed Malallah. "Design and Analysis of Double Band Printed Corrugated Circular Patch Antenna for Wireless Communication Applications." *Basrah Journal of Science* 39.3 (2021): 432-445..

[3] Al-Tumah, W.A.G., Shaaban, R.M. and Ahmed, Z.A. "Designing a Microstrip Patch Antenna in Part of Ultra-Wideband Applications" Baghdad Science Journal, 17(4), pp.1216-1216. 2020..

[4] R. A. Kipp and C. H. Chan, "A Numerically Efficient Technique for the Method of Moments Solution for Planar Periodic Structures in Layered Media," *IEEE Trans. Microw. Theory Tech.*, 1994, doi: 10.1109/22.285070.

[5] B. Borden, "Mathematical problems in radar inverse scattering," *Inverse Problems*. 2002, doi: 10.1088/0266-5611/18/1/201.

[6] T. Srivastava *et al.*, "Large-Voltage Tuning of Dzyaloshinskii-Moriya Interactions: A Route toward Dynamic Control of Skyrmion Chirality," *Nano Lett.*, 2018, doi: 10.1021/acs.nanolett.8b01502.

[7] J. B. Patton and D. Curtice, "Analysis of utility protection problems associated with small wind turbine interconnections," *IEEE Trans. Power Appar. Syst.*, 1982, doi: 10.1109/TPAS.1982.317073.

[8] M. Svanda and M. Polivka, "Matching Technique for an On-Body Low-Profile Coupled-Patches UHF RFID Tag and for Sensor Antennas," *IEEE Trans. Antennas Propag.*, 2015, doi: 10.1109/TAP.2015.2403399.

[9] P. Y. Qin, A. R. Weily, Y. J. Guo, and C. H. Liang, "Polarization reconfigurable U-slot patch antenna," *IEEE Trans. Antennas Propag.*, 2010, doi: 10.1109/TAP.2010.2055808.

[10] B. Henin and A. Abbosh, "Design of compact planar crossover using Sierpinski carpet microstrip patch," *IET Microwaves, Antennas Propag.*, 2013, doi: 10.1049/iet-map.2012.0262.

[11] C. Y. Gan, K. S. M. Sahari, and C. S. Tan, "Numerical investigation on Coanda flow over a logarithmic surface," *J. Mech. Sci. Technol.*, 2015, doi: 10.1007/s12206-015-0615-y.