Diyala Journal of Engineering Sciences

ISSN 1999-8716
Printed in Iraq

Second Engineering Scientific Conference
College of Engineering –University of Diyala
16-17 December. 2015, pp. 589-598

THREE ANTENNAS DESIGN USED BY ULTRA-WIDEBAND WIRELESS SYSTEMS

[1] RASHID A. FAYADH, [2] MASHAEL MATTI FARJO
[1, 2] Middle Technical University, College of Electrical & Electronic Engineering
Email: [1] r_rashid47@yahoo.com , [2] MMFFarjo@yahoo.com

ABSTRACT: - As there are many challenges in indoor and outdoor wireless propagation, high gain and sensitive antenna design plays crucial role in ultra wideband (UWB) small size systems. In this work, a design of UWB printed microstrip antennas that fed by microstrip transmission line were presented and printed on a substrate Taconic TLY-5 material with relative dielectric constant of 2.2. The proposed antennas were designed to cover the area of UWB frequency range (7.5 GHz) to be suitable for applications of wireless communication systems. The antennas of printed patch shapes are; rectangular patch, circular patch, and as-shaped patch designs with the same dimensions of feeder and ground plane. The proposed antennas were simulated using a package of Computer Simulation Test (CST) microwave studio software through range of 2 to 12 GHz operating frequency. Simulation results and comparison for reflection coefficient (S_{11}), radiation patterns, were presented and discussed over the UWB frequency. These results make the designs are very useful for UWB technology future applications because of the small size low cost.

Keywords: Rectangular patch antenna, ultra-wideband wireless systems, omni-directional radiation pattern, reflection coefficient.

1. INTRODUCTION

As the acceptance of using UWB technology was reported in [1] by the Federal Communication Commission (FCC) in the USA of frequency range between 3.1 and 10.6 GHz, the small size and low cost are the main research goals in military and commercial applications. The UWB technology for wireless systems makes the users free from wires and enables the wireless connections of multiple devices and several users in transmission and reception. Now a day, the requirement of using wireless systems is increasing with high capacity rate transfer at low power consumption (-41.3 dBm/MHz). The size of these systems was reduced
for reliability usage, so, small UWB antenna should be designed to be comfortable with the wireless devices. A design of T-slotted patch UWB antenna was designed by Yusnita Rahayu with large substrate material [2] getting evaluated results to cover the required frequency range.

A circular disc of one and two microstrip lines in the feeder part was produced by [3] for three bands from 1.8 GHz to 8.12 GHz of the third generation mobile and UWB systems. Rectangular shaped patch antenna with two concave and convex circulated corners at the bottom part of the radiator was designed in [4] to cover the UWB operation dynamic range and the results cleared the effect of these corners on the impedance matching of the feeder and radiator. Other several published samples of UWB antennas such as large rectangular patch antennas of 47 mm x 36 mm dimensions [5] use RF-4 substrate material and of 36 mm x 46 mm dimensions using FR-4 epoxy substrate material [6]. A diamond patch shape of 30 x

26 mm^2 in [7] was simulated and printed on FR4 substrate to cover 95 % of UWB starting from 3.39 GHz and has not got omni-directional radiation patterns. Also another antenna scheme of multiple fractal slots was implemented in [8] of 45 mm x 25 mm dimensions with unstable radiation patterns. In addition, a compact microstrip patch antenna was proposed in [9] with total size of 40 x 35 x 1.575 mm^3 and from the simulation results, the gain reduces at higher frequencies due to increasing the losses in the feed line.

The remainder of the paper is organized as, Section II shows the parametric study and the dimensions of the design parameters. Sections III detailed the simulated results and discussions for antenna parameters. Section IV presents radiation patterns for antenna shapes, while section V concentrates with conclusions.

2. ANTENNA DESIGN SHAPES

The UWB digital wireless communication systems operate with narrow pulses that lead to low power and high capacity of bit rate [10]. The requirements of UWB printed antenna designs are satisfied in Fig. 1, which demonstrate the antenna design shape methodology. These antennas were designed to develop the conventional rectangular patch antenna as shown in Fig. (2-a). All the conventional and proposed antennas are printed on Tacanic TLY-5 substrate of thickness 1.575 mm and relative dielectric constant ($\boldsymbol{\varepsilon}_r$) of 2.2 and loss tangent of 0.0009.

The dimensions of the patch are excited using a 50 Ω input impedance of the microstrip line. The printed patches are made of copper of 0.035 mm thickness (t) and the dimensions of the ground plane are same for all shapes as shown in Fig. (2-b). The gap between ground plane and radiating patch is 1 mm for all simulated antennas. The circular patch antenna of Fig. (3-a) was designed having radius 8 mm and it is fed by a feeder of 4.8 x 12 mm^2 in dimension. The patch and feeder are printed on substrate of 30 x 28 mm^2 in dimension. The proposed as-shaped patch antenna is shown in fig. (3-b) with all dimensions in mm and printed on substrate material of 30 x 28 mm^2. The conventional rectangular patch area is printed on PCB by using copper of 0.035 mm and this area is decreased by reducing the copper area in the proposed circular and as-shaped antenna designs. This modification is applied to extend the covering frequency range and increasing the surface current distribution. The idea of this design approach is to increase the antenna activity in cellular area communications and single-chip radar transceiver.

The rectangular shape of the microstrip patch has been designed as a radiator for UWB radiation. There are two degrees of freedom (length and width) for controlling a rectangular microstrip antenna, so that the order of changing the mode can be done by varying the relative dimensions of the width and length of the patch based on resonant frequency. The patch dimensions of W_p x L_p can be determined according to the following procedure at a resonant frequency (f_r) and a dielectric constant (ε_r) for used substrate material [11].

$$W_p = \frac{c}{2 f_r}\sqrt{\frac{2}{\varepsilon_r + 1}}, \qquad \text{…………(1)}$$

Where, c is the speed of the light in free space (3×10^8 m/s), and W_p is the width of the patch. The actual length of the patch (L_p) can be calculated by applying the following equations:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2\sqrt{1 + (\frac{12h}{W})}}$$

$$\lambda_{reff} = \frac{\lambda_r}{\sqrt{\varepsilon_{reff}}} \qquad \text{……………. (3)}$$

$$L_p = \frac{\lambda_{reff}}{2} - 2\Delta L , \qquad \text{……………..(4)}$$

where λ_r is the resonant wavelength (λ_r = c/f_r), ε_r is the relative dielectric constant, ε_{reff} is the relative effective dielectric constant, λ_{reff} is the relative effective wavelength of the patch, h is the substrate material thickness, W is the substrate material width. The extended length of the patch (ΔL) can be calculated as:

$$\Delta L = 0.412h \frac{(\varepsilon_{reff} + 0.3)(\frac{W_p}{h} + 0.264)}{(\varepsilon_{reff} - 0.258)(\frac{w_p}{h} + 0.8)} \qquad \text{…………….(5)}$$

$$R_{in}(L_s = value) = R_{in}(L_s = 0)\cos^2(\frac{\pi}{L_p} L_s) \qquad \text{…………….(6)}$$

Where R_{in} (L_s = value) is the input resistance at the inset feed point length (L_s) and can be taken as 50 Ω. R_{in}(L_s = 0) is the input resistance at the lower edge of the patch radiator. At simulation run, the 50 Ω input resistance should be kept at the top edge of the patch.

The proposed circular-shape and as-shaped antennas are designed to obtain the best reflection coefficient or return loss (S_{11}) at lower frequency band and omni-directional radiation patterns. These parameters make the antennas useful for indoor and outdoor mobile phones, all directions indoor propagation, and remote sensing devices applications.

3. SIMULATED ANTENNA RADIATION PATTRENS

To present the radiation patterns for rectangular antenna, Fig. (4-a) shows the two dimensional simulated radiation patterns were taken at resonant frequency of 8.5 GHz in E-plane when Phi = 45^o and Phi = 90^o. Fig. (4-b) shows the radiation patterns in H-plane when Theta = 45^o and Theta = 90^o. Fig. 5 illustrates the simulated H-plane and E-plane radiation patterns at resonant frequency of 8.5 GHz for circular antenna. However, the analysis of these patterns results shows that the proposed microstrip antennas are characterized by omni-directional radiation patterns in both planes.

Fig. 6 and Fig. 7 show the simulated radiation patterns of the Tacanic TLY-5 material proposed ax-shaped patch antenna that overcome whole the UWB bandwidth. For this printed monopole antenna, the simulation results for radiation patterns are shown in Fig. 5 and Fig. 6 which have been performed at 2 GHz to 12 GHz in the simulation process. These radiation patterns were simulated at frequencies of 5 GHz and 9 GHz, elevation angle (Phi = 0^o, 90^o), and azimuth angle (Theta = 0^o,90^o) which depict antenna's omni-directional patterns along the UWB frequency range. When the phi and theta are equal to 0^o, the radiation patterns are slightly better than those when phi and theta are equal to 90^o in covering omni-directional area.

4. SIMULATED S_{11} RESULTS AND DISCUSSIONS

The Computer Simulation Test (CST) microwave studio software was used in simulation run to calculate the results of reflection coefficient (S_{11}) in frequency domain. Fig. 8 shows the simulated S_{11} less than -10 dB in the whole UWB bandwidth for rectangular patch and circular patch antennas. Rectangular-shaped antenna provides improved performance that is covering all the UWB bandwidth compared with circular shaped-antenna. There are two resonance frequencies for rectangular antenna at 4.3 GHz and 8.5 GHz when S_{11} is less than -20 dB and there is one resonance frequency for circular antenna at 4 GHz with value of S_{11} below -22 dB. For rectangular-shaped antenna, the starting frequency at nearly 4 GHz and the best value of S_{11} below -25 dB at 8.5 GHz as a resonance frequency. In circular-shaped antenna, the starting S_{11} less than -10 dB characteristics are the same as that for rectangular antenna. The simulation was run again to display the impedance bandwidth across the UWB range for ax-shaped patch antenna. To reduce the conventional overall antenna size, parametric study was carried out to get the optimized dimension for antenna parameters. Essentially, the antenna performance was affected by the geometrical shape and after that three parameters were proposed to achieve the optimal design.

Firstly, the feed gap size and its effect is illustrated in Fig. 9 and the wider bandwidth can be shown at gap of 0.5 mm but the best resonance frequency of 8.7 GHz is applied at gap of 0.75 mm. Secondly, the effect of the lower slot depth is shown in Fig. 10 of three different values of the depth to have better matching impedance over the required bandwidth. The studying of this parameter is to present the best depth size for frequency range.

The entire band is provided when the lower slot depth in the patch is 1mm and the band is highly affected when the depth is 2 mm. Next, the effects of upper slot width are shown in Fig. 11 for three values of 3 mm, 4 mm, and 5 mm. Better impedance matching at W_s = 3 mm while no change when the width value increases to 4 or 5 mm but getting extended impedance bandwidth to cover most of UWB range. In general all the above parameters introduce the effects on antenna performance in order to optimize the proposed antenna patch shape for wireless UWB applications.

5. CONCLUSIONS

This paper presents three different patch shapes of UWB antennas with the same substrate material, feed transmission line, and planar ground plane dimensions. These antennas are suitable for small size of wireless UWB technology and narrow band systems because of their attractive characteristics, such as, small size, low cost, impedance bandwidth, omni-directional radiation, easy fabrication, and light in weight substrate material. The circular-shaped and as-shaped patch shapes antennas have a good performance compared with the conventional rectangular-shaped patch antenna by covering most of the UWB frequency range. So, they are more suitable in operation for multiband systems through the wideband applications. In addition, radiation patterns are provided omni-directional patterns in E-plane and H-plane over the required band to be used in wireless indoor propagation.

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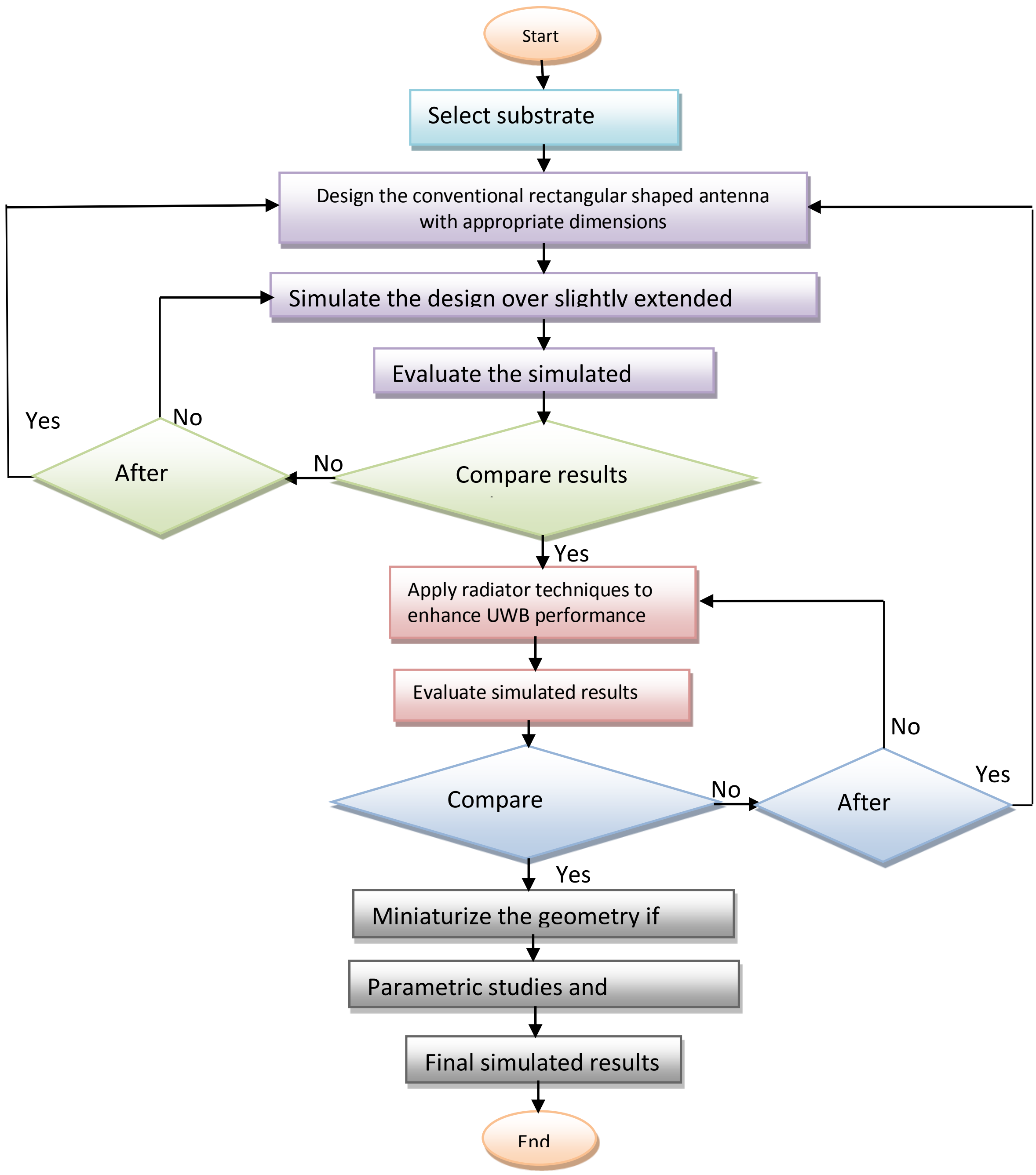
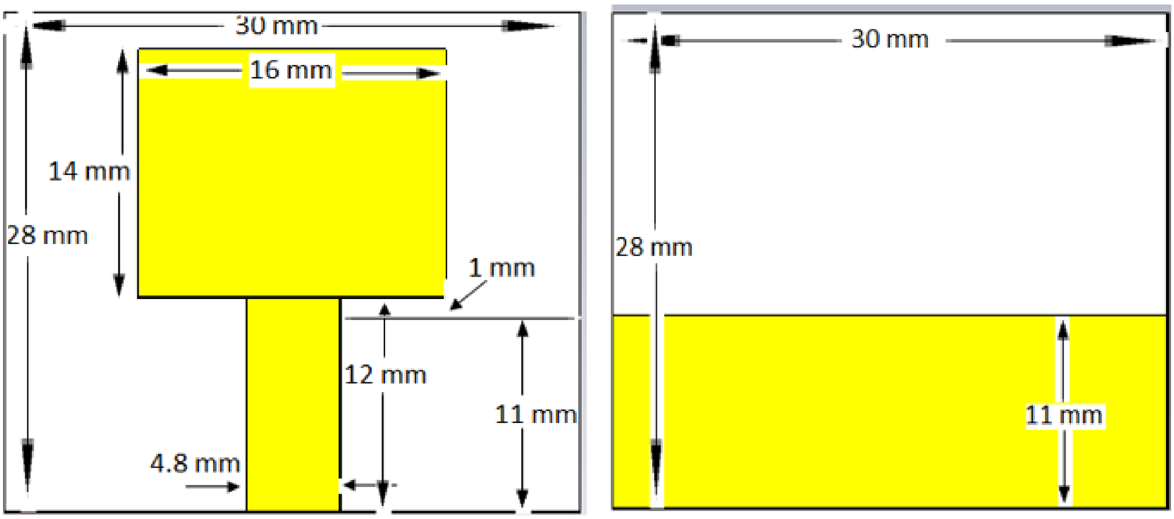


Figure (1): The proposed antennas design methodology.



(a) (b)

Figure (2): Conventional rectangular-shaped antenna (a) front view, (b) back view.

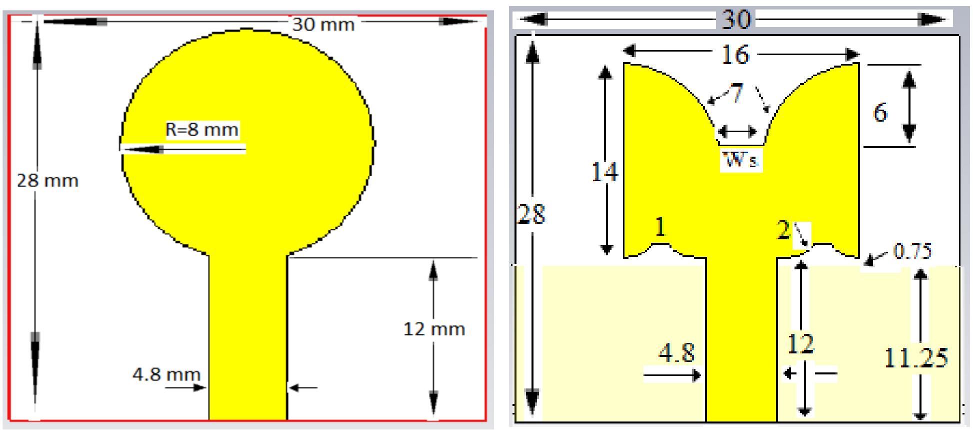
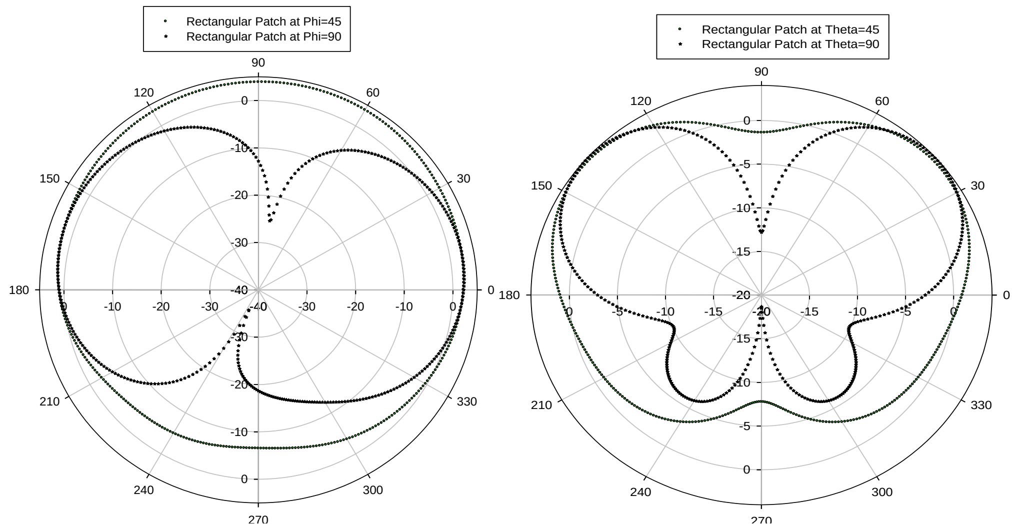
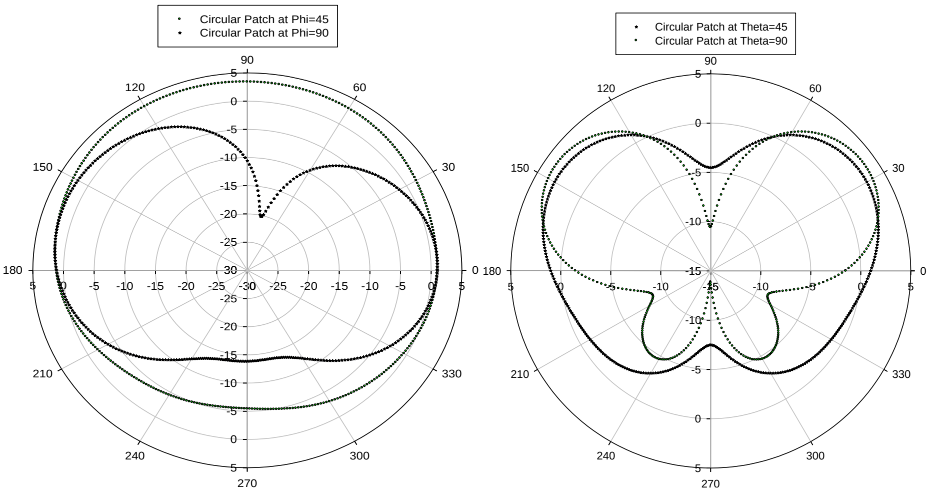


Figure (3): The proposed antenna shapes, (a) circular-shaped patch antenna, (b) as-shaped patch antenna.



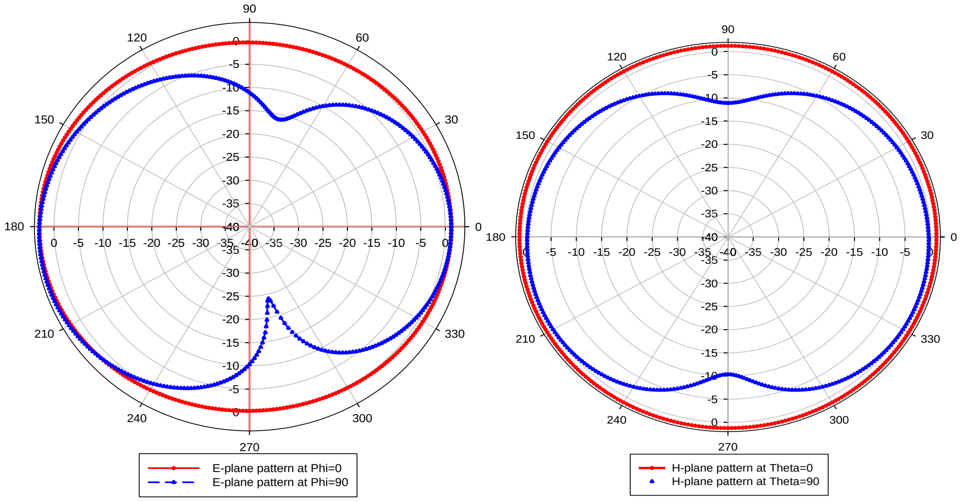
(a) (b)

Figure (4): Simulated radiation patterns for Rectangular Patch shape at 8.5 GHz, (a) E-plane, (b) H-plane.



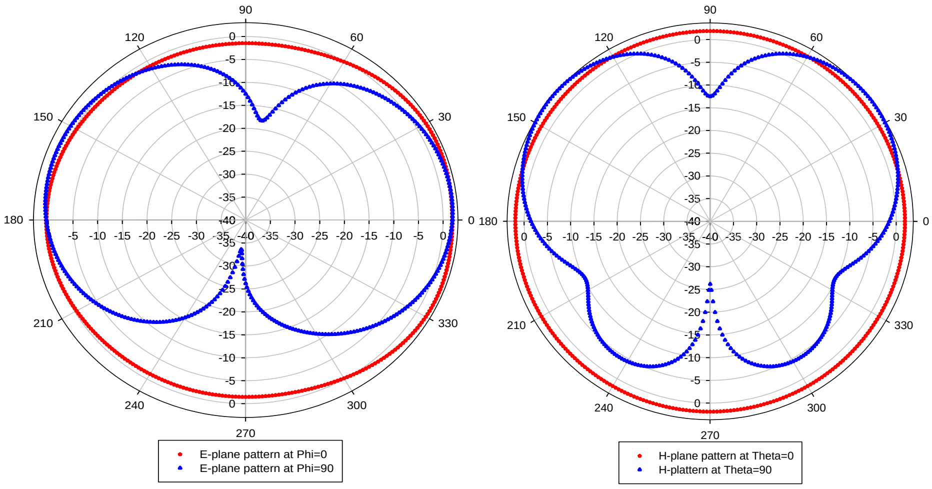
(a) (b)

Figure (5): Simulated radiation patterns for circular patch form at 8.5 GHz, (a) E-plane and (b) H-plane.



(a) (b)

Figure (6): Simulated radiation patterns for ax-shaped antenna at resonance frequency of 5 GHz with Phi and Theta equal to 0° and 90° (a) E-plane, (b) H-plane.



(a) (b)

Figure (7): Simulated radiation patterns for ax-shaped antenna at resonance frequency of 9 GHz with Phi and Theta equal to 0° and 90° (a) E-plane, (b) H-plane.

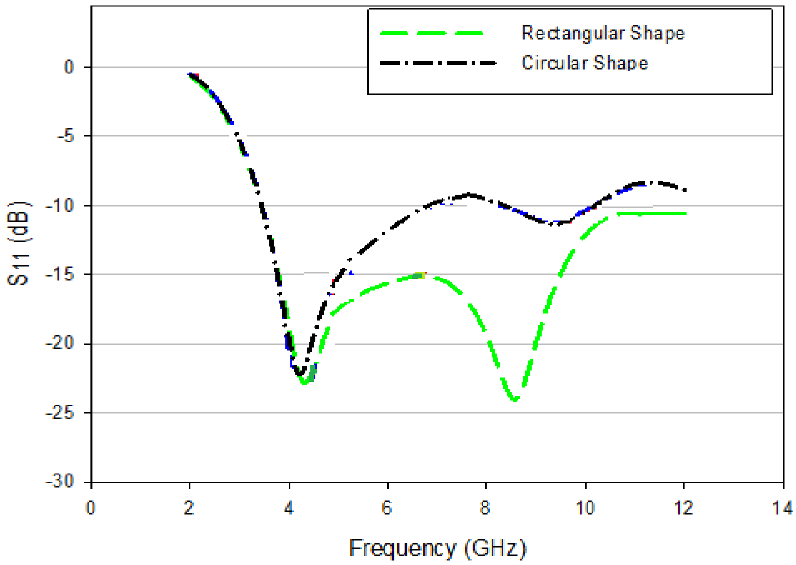


Figure (8): The reflection coefficient for rectangular and circular forms antennas.

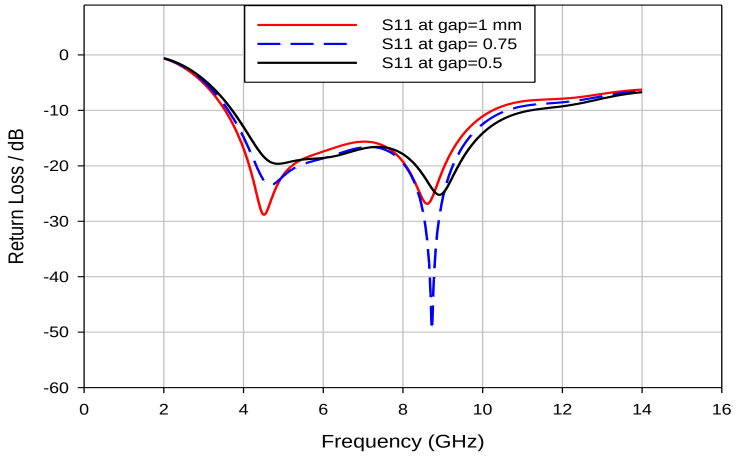


Figure (9): Effects of feed gap on S_{11} for ax-shaped patch antenna.

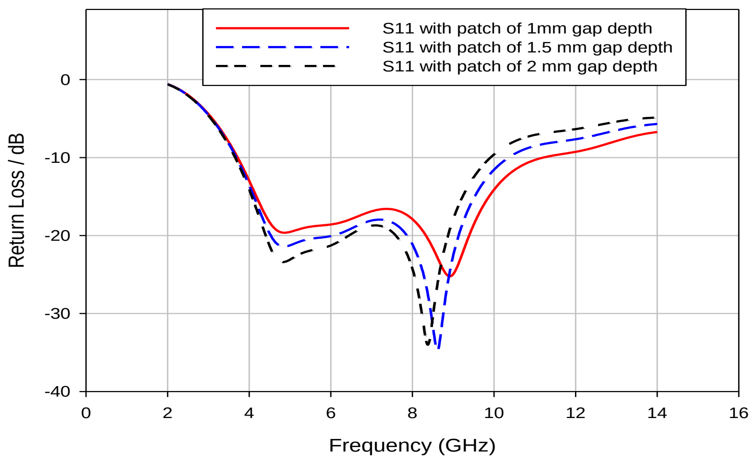


Figure (10): Effects of lower slot depth on S_{11} for ax-shaped patch antenna.

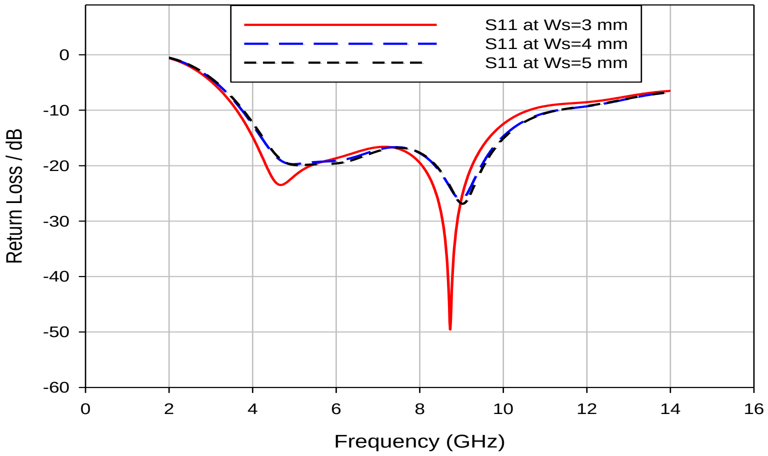


Figure (11): Effects of upper slot width on matching impedance bandwidth for ax-shaped patch antenna.

ثلاثة تصاميم لهوائيات مستخدمة في انظمة النطاق الواسع اللاسلكية

راشد علي فياض و مشاعل متي فرجو
الجامعة التقنية ألوسطى / كلية هندسة التقنيات الكهربائية والالكترونية

الخلاصة:

كما أن هناك العديد من التحديات في نشر البث اللاسلكي في الأماكن المغلقة والهواء الطلق لكثرة الانعكاسات ، ونظرا لتصغير حجم الاجهزة اللاسلكية مستقبلا لذا يتطلب تصميم هوائيات حساسة وصغيرة الحجم تستخدم في تقنيات النطاق العريض جدا . في هذا العمل، تكاونك هي المادة المستخدمة في تصميم الهوائيات وذات معامل عزل كهربائي قليل لتكون مناسبة للأجهزة المستقبلية. TLY–5 في التنفيذ لفحص كفاءة الهوائيات من خلال معامل الانعكاس ونموذج الاشعاع على (CST) استخدام برمجيات اختبار محاكاة الحاسبة طول النطاق الترددي. ومن خلال النتائج النظرية تبين ان هذه التصاميم كفوءة في تطبيقات تقنية النطاق العريض جدا للمنظومات اللاسلكية.