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DESIGN OF RECTANGULAR MICROSTRIP PATCH ANTENNA FOR WIRELESS COMMUNICATION SYSTEMS

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Abstract: In this paper a new rectangular microstrip patch antenna for wireless communication systems is designed and tested practically. The rectangular patch is modified by changing the basic parameters, adding triangular pieces to the bottom patch ,making L slots in the edge of the patch and etching rectangular slot in the ground plane .The optimized antenna (final modification) give a band of (2.26-20) GHz in which the return loss S11 is less than -10dB and a gain of (0.8-8) dBi . The slotted rectangular antenna is fabricated on FR4 having relative dielectric constant of €r=4.3 and loss tangent of 0.02.The dimension of the patch is (42×40×1.6)mm^3 .The slotted rectangular patch is tested practically using the Vector Spectrum Analyser (VNA) for insertion loss (S11),voltage standing ratio(VSWR), and input impedance . It is found that the simulation results agrees (mostly) with the practical results. The antenna is fed by 50Ω transmission line.

Keyword: *Microstrip patch antenna, Return loss (S11), Voltage standing wave ratio (VSWR), Slotted rectangular antenna*

تصميم هوائي الرقعة المستطيله لانظمة الاتصالات اللاسلكية

الخلاصة: يتضمن البحث تصميم هوائي الرقعة المستطيلة الشكل مناسب لانظمة الاتصالات اللاسلكية. تم تطويرالهوائي المستطيل المقترح بتغييرالمعاملات الاساسية , اضافة قطعة مثلثة الى اسفل الرقعة, عمل شقوق في الرقعة المستطيلة. عمل حفرة مستطيلة في المستوى الارضي . الهوائي المفترح يعطي عرض حزمة (20-2.26) جيجاهيرتزوتم تحسين الربح للهوائي بعمل عدة شقوق في الرقعة المستطيلة ليصبح (8-0.8) ديسبيل . وقد تم تصنيع الهوائي المحسن وفحصه عمليا بأستخدام محلل الشبكة الاتجاهي لمعامل الانعكاس, نسبة الموجة الواقفة والمقاومة الداخلية واتضح ان النتائج العملية ونتائج المحاكاة متقاربه وان ابعاد اللوحة هو (40×42×1.6) ملم3 ويتم تغذية الهوائي بواسطة خط ارسال مقاومته (50) اوم .

1. Introduction

An antenna is an element used for transmitting or receiving electromagnetic wave. The antenna is available in several different size and shapes, and they all operate according to the same basic principles of electromagnetics. Many types of portable electronic devices, such as cellular phones, GPS receivers, pagers, palm electronic devices, telematics unit in vehicles and laptop computers, need an efficient and effective antenna for communicating wirelessly with other fixed or mobile communication units. A microstrip patch antenna is a type of antennas that advance a low profile, i.e. thin and easy to fabricate, which provides a great advantage over traditional antennas [1,2]. Patch antennas are planar antennas used in wireless links and other microwave applications. Microstrip can be fabricated using photolithography

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techniques. It is easily fabricated into linear or planar arrays and readily integrated with microwave integrated circuits. There are several techniques to feed microstrip antenna. These techniques are divided into two groups contacting and non-contacting. The contacting feed technique such as coaxial cable and microstrip line, while the non-contacting such as proximity coupling and aperture coupling [3,4,5].

When using transmission line model to design of rectangular microstrip patch antenna, we have to first identify the operating resonant frequency 'f', the relative dielectric constant 'ε_r' and the height of the substrate (thickness) 'h'. The width 'W' of the patch can be calculated from [6,7].

$$W = \frac{c}{2f}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad (1)$$

Where 'c' is the free-space velocity of light. After calculating the width, the effective dielectric constant value 'εreff' is calculated by using the equation (2) [8]

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{w}\right]^{-1/2} \quad (2)$$

Now the calculation of extension in length of the patch 'ΔL' is required which can be done by

$$\Delta L = h \times 0.412\,\frac{(\varepsilon_{reff}+0.3)\left(\frac{w}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{w}{h}+0.8\right)} \qquad (3)$$

The length of the patch 'L' can be calculated by subtracting the extension in length on both sides of the patch. The pictorial representation of the extension in length 'ΔL' is shown in figure (1)

$$L = \frac{c}{2f} - 2\Delta L \qquad (4)$$

2. The Proposed Rectangular Patch Antenna

The antenna is fed by a 50Ω microstrip feed line on a substrate of size ($W_s \times L_s$). The substrate used with a thickness h= 1.6 mm and relative dielectric constant $\boldsymbol{\varepsilon}_r$= 4.3 with loss tangent tan δ= 0.02. The rectangular radiation patch which fed by microstrip feed line printed on one side of substrate and the ground plane printed on reverse side. The rectangular patch with the initial parameters is shown in fig. 1.

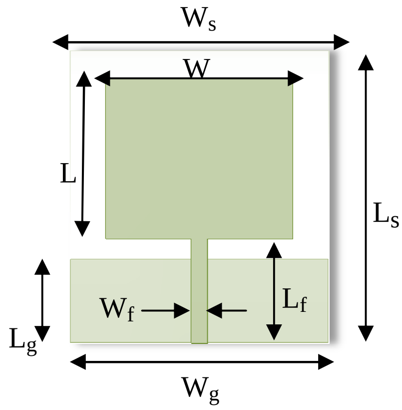


Figure 1: Proposed antenna with initial parameter

The parameters L, W, L_f, W_f, L_g and W_g affect the antenna characteristics and are optimized for wideband response. Let us study the effect of each parameter when all the other parameters are fixed.

2.1 The effect of patch length (L)

The first parameter is length of the rectangular patch which shown in fig. 2. It is observed that L=23mm give better impedance bandwidth, with the values of other parameters W=29mm, L_f=15mm, W_f=2.5mm, L_g=12mm and W_g=40mm. It gives dual band (2.5-3.8) GHz and (8.15-9.5) GHz

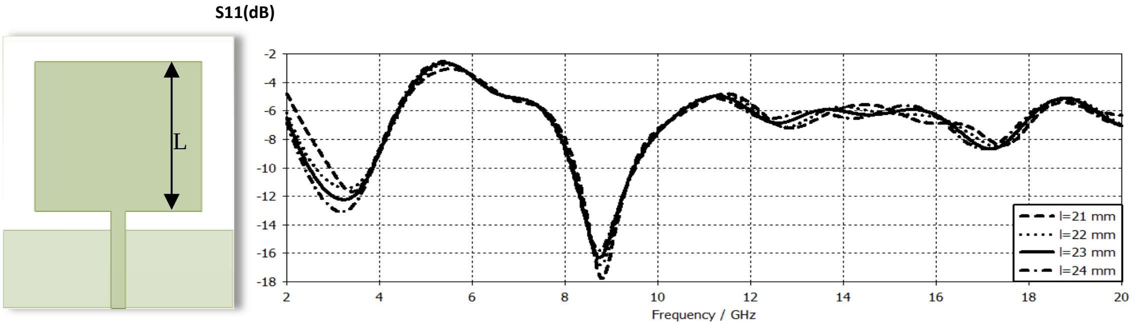


Figure 2: Simulated the return losses as a function of frequency at varying L.

2.2 The effect of patch width (W)

Fig.3 shows the simulated reflection coefficients of the antenna with the varying the width of the rectangular patch. It is clear that the best result at w=30mm with the values of other parameters L=23mm, L_f=15mm, W_f=2.5mm, L_g=12mm and W_g=40mm. also dual band (2.5-3.7) GHz and (8-9.35) GHz is obtained .

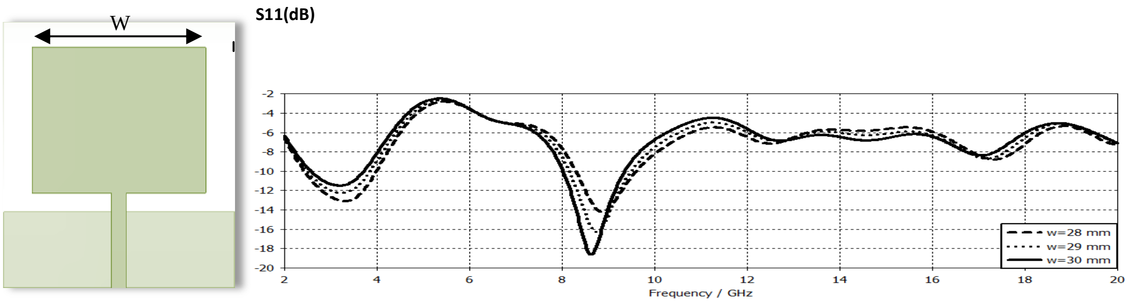


Figure 3: Simulated the return losses as a function of frequency at varying W.

2.3 The effect of feeder length (L_f)

The effect of varying the feeder length on the return losses is shown in fig.4. It is observed from the figure that the feeder length give best resultat L_f=15mmwith the values of other parameters are L=23mm, W=30mm, W_f=2.5mm, L_g=12mm and W_g= 40mm. Also it gives dual bands as before .

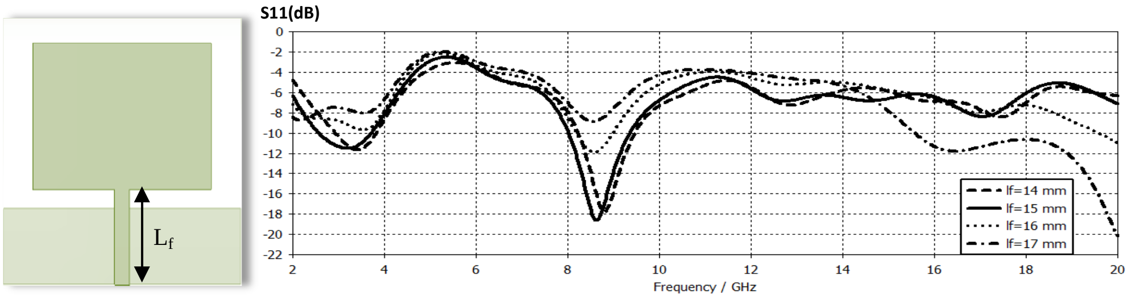


Figure 4: Simulated return losses versus frequency at varying Lf

2.4 *The effect of feeder width* (W_f)

The effect of the width of the feeder is clear in fig.5. It is observed that when decrease feeder width to W_f=2.2 mm with the values of other parameters are L=23mm, W=30mm, L_f=15mm, L_g=12mm and W_g=40mm. It gives dual bands (2.9-3.7) GHz and (7.8-9.3) GH in which S11< -10dB.

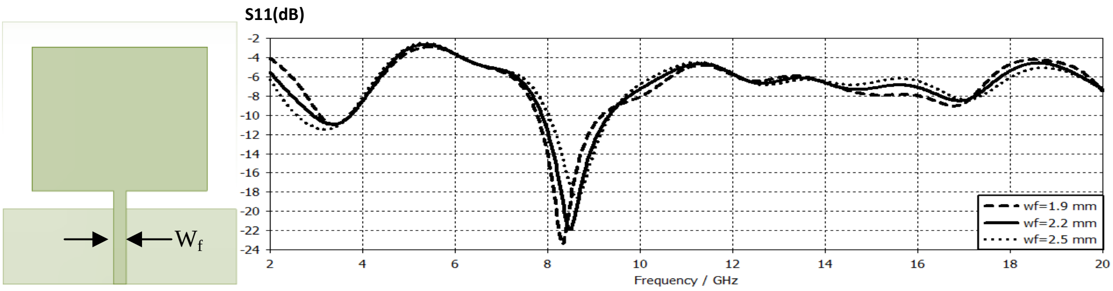


Figure 5: Simulated return losses versus frequency at varying Wf

2.5 *The effect of addition of triangular pieceto the Patch*

Fig. 6 shows add triangular shape to the bottom rectangular patch. At fixed parameters atL=23mm, W=30mm, L_f=15mm, W_f=2.2mm, L_g=12mm and W_g=40mmIt gives four bands, they are (2.6-4.5)GHz, (9.1-10.8)GHz, (14.3-15.7)GHz and (17.4-19.5)GHz.

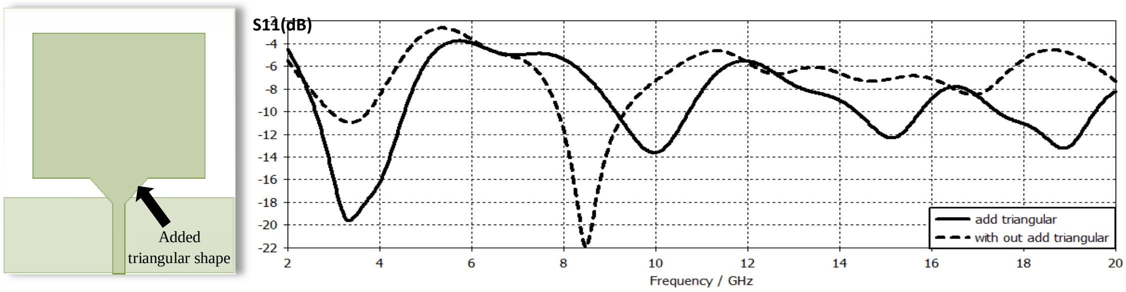


Figure 6: Simulated return losses versus frequency at adding triangular and without addition of triangular piece

2.6 *The effect of ground plane length* (L_g)

The effect of varying the length of the ground plane is shown in fig.7. It is clear that decreasing the ground plane width to L_g=11mm,(with the values of other parameters are L=23mm, W=30mm, L_f=15mm, W_f=2.2 mm and W_g= 40mm), leads to g triple bands (2.5-4.3) GHz, (8.4-11) GHz and (13.4-19.4)GHz.

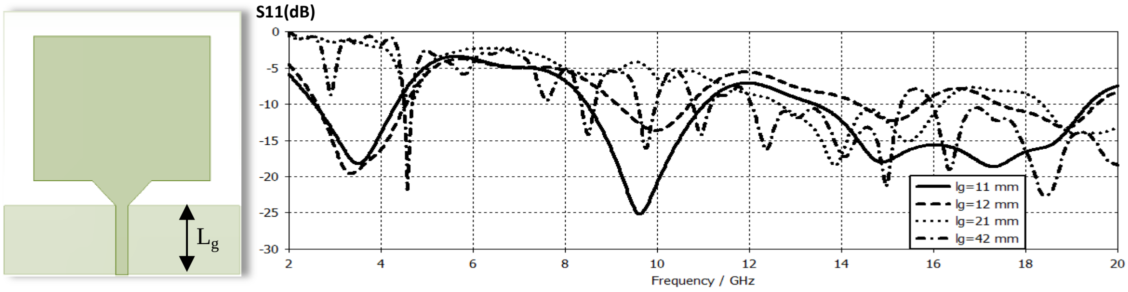


Figure 7: Simulated return losses versus frequency at varying Lg

2.7 The effect of ground plane width (W_g)

The effect of varying the width of the ground plane is shown in fig.8. It is observed that for W_g=14mm,(with the values of other parameters are L=23mm, W=30 mm, L_f=15 mm, W_f=2.2 mm and L_g=11mm), leads to triple bands (2.3-5.4) GHz, (8.3-12.4)GHz and (14.5-19)GHz.

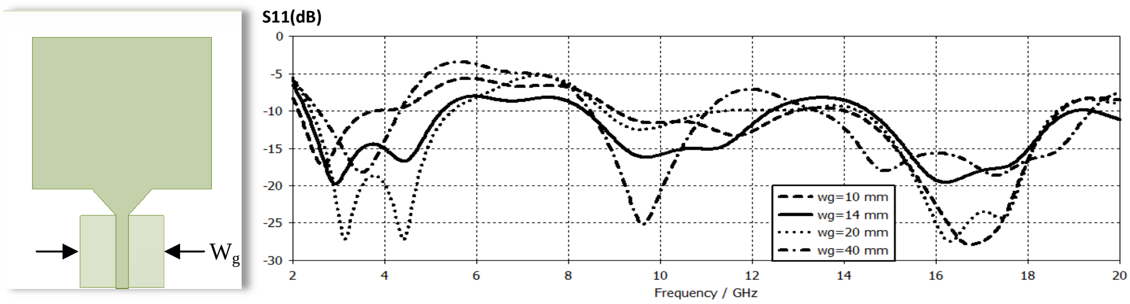


Figure 8: Simulated return losses relation to frequency at varying Wg.

2.8 Cuts on the Patch and Ground

It is observed that when a cut of L shape is made in the rectangular edges this will lead to triple bands (2.3-5.5) GHz, (6.4-10.6) GHz and (12.7-20) GHz as shown in Fig.9 .

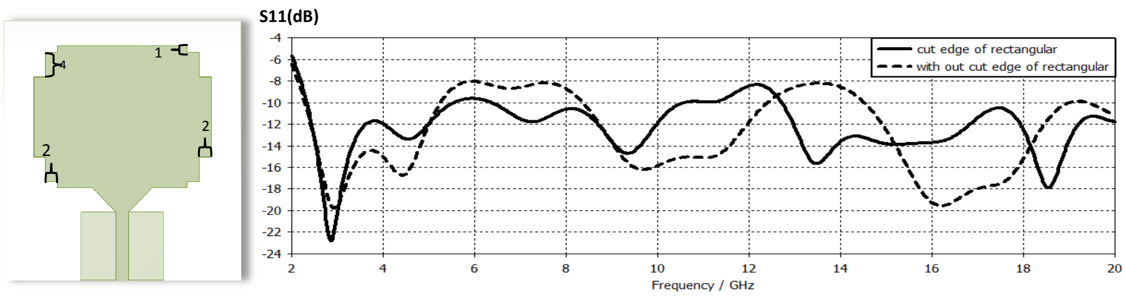


Figure9: Show simulated result of cut edge of rectangular and without cut rectangular edge

To increase the bandwidth of antenna we cut step in the triangular part of the patch as shown in fig.10, which results in dual bands (2.3-11.9) GHz and (12.3-20) GHz.

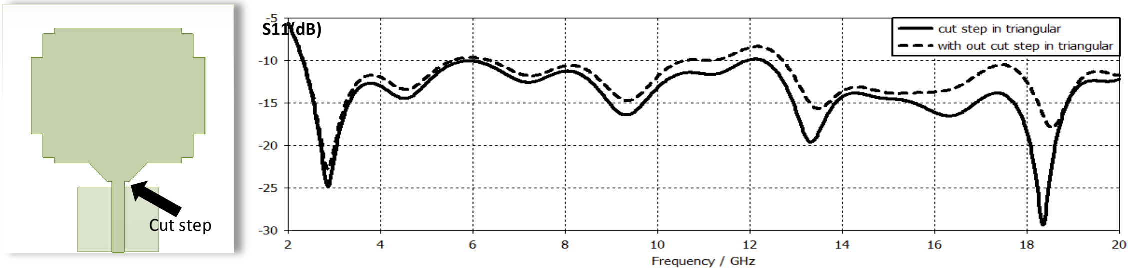


Figure 10: Show simulated result of cut step in triangular and without cut

In cutting the rectangular slot in the ground plane. It can be observed that this will increase the bandwidth of the antenna and the final characteristics is shown in fig. 11 which shows that it gives only a single transmission band (2.26-20) GHz.

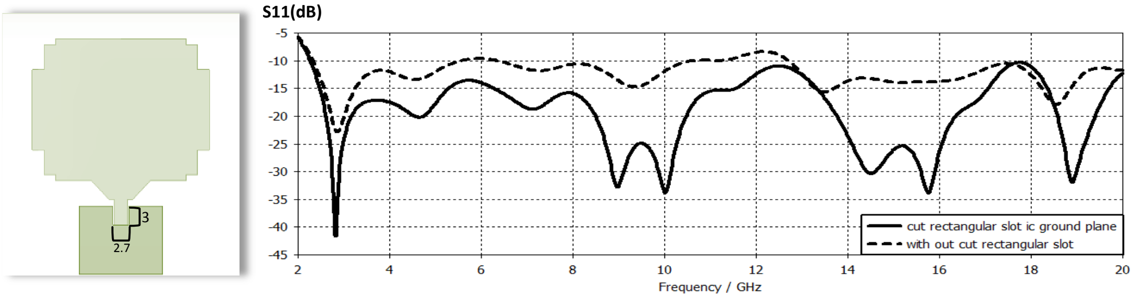


Figure 11: Show simulated result of cut rectangular slot and without cut

3. The Performance of the Proposed Antenna

The performance of proposed antenna in terms of reflection coefficient, gain, current distribution and far field radiation pattern are discussed.

The parameters of the optimized antenna design that give better performance (i.e better reflection coefficient) are shown in table 1.

Table 1: optimal deign dimensions of the proposed rectangular antenna.

Parameter	*Description*	*Value*
L_s	Substrate length	42mm
W_s	Substrate width	40mm
L	Rectangular patch length	23mm
W	Rectangular patch width	30mm
L_f	Feeder length	15mm
W_f	Feeder width	2.2mm
L_g	Ground plane length	11mm
W_g	Ground plane width	14mm

The gain of the proposed antenna is shown in fig.12, which shows the gain variation in the range of (-8.4-10.5) dBi.

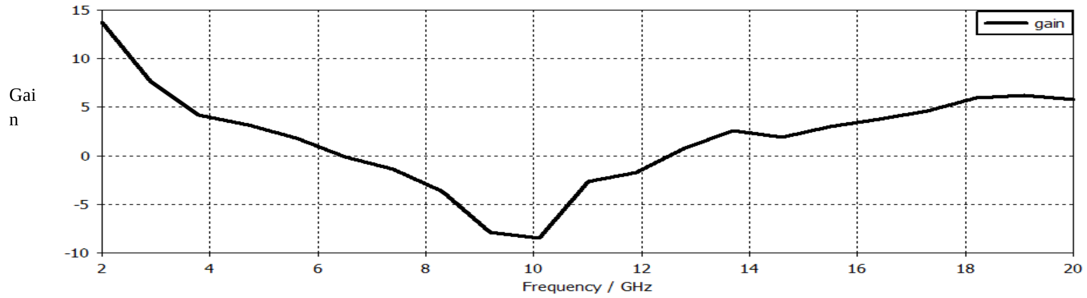


Figure 12: Simulated the gain of the modified antenna

To improve the gain characteristics, many slots are added with different shapes and size to the patch as shown in fig.13. The new gain is in the range (0.8-8) dBi as shown in fig.14.

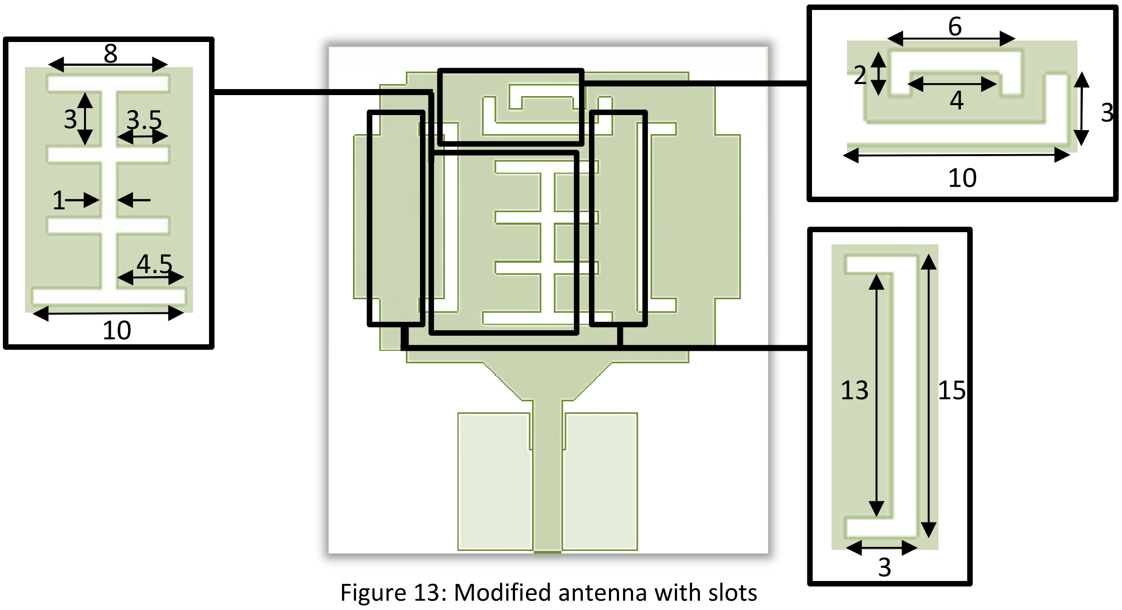


Figure 13: Modified antenna with slots

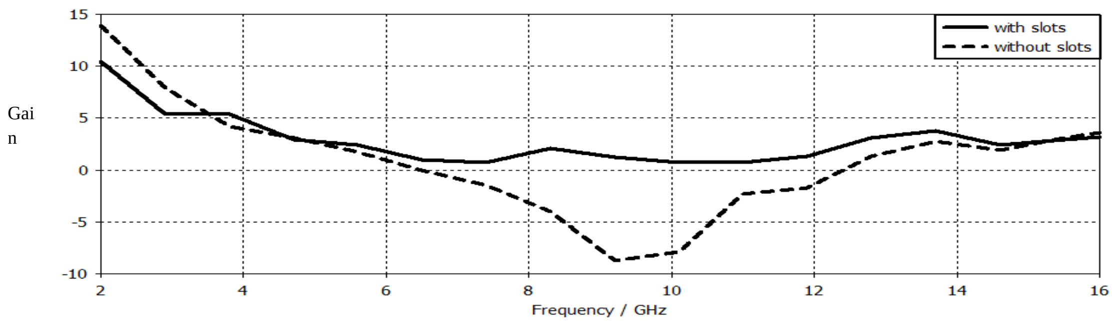


Figure 14: Simulated gain of antenna with slots and without slots

The rectangular antenna with slots is fabricated and tested. Photograph of the fabricated antenna is shown in fig. 15. The reflection coefficient is measured using VNA. The simulation results and measured results are compared as shown in figs. 16,17,18 respectively.

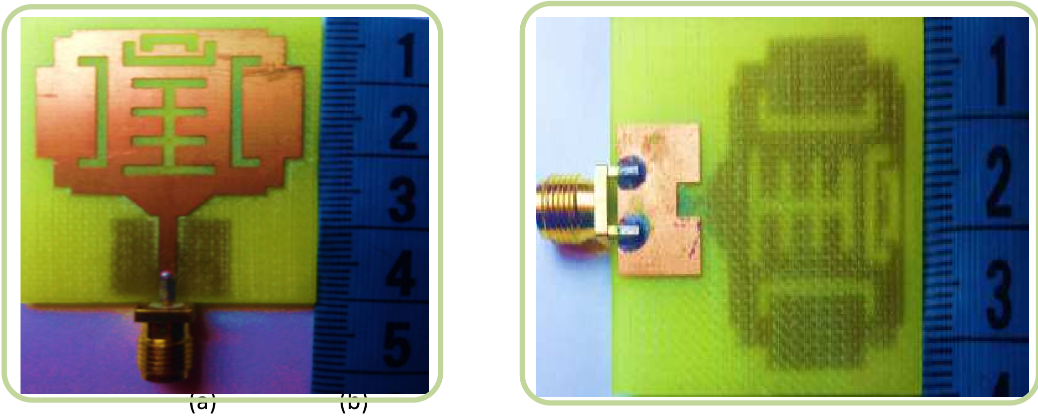


Figure 15: Photograph of the fabricated antenna, (a) Top view, (b) Bottom view

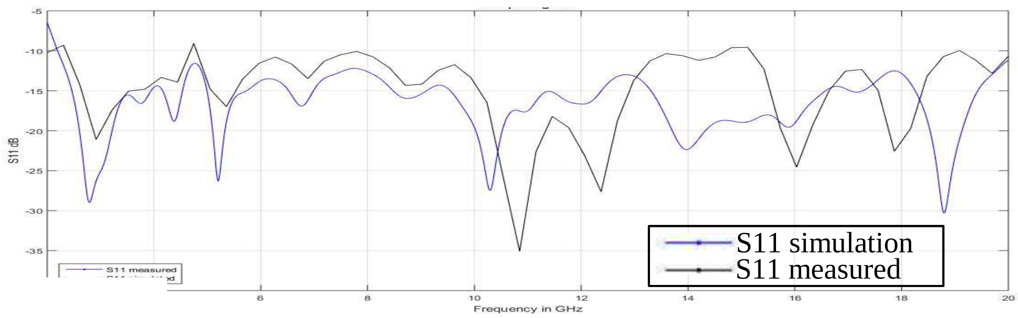


Figure 16: Simulation and measured S11 versus frequency for the final modified antenna.

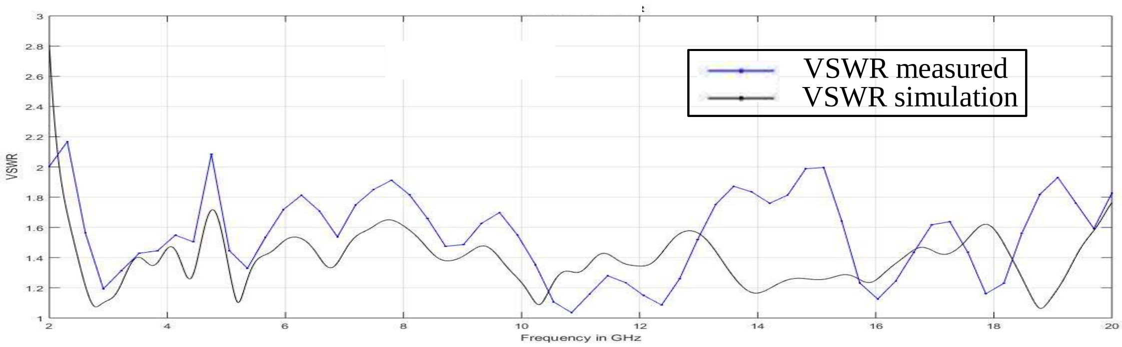
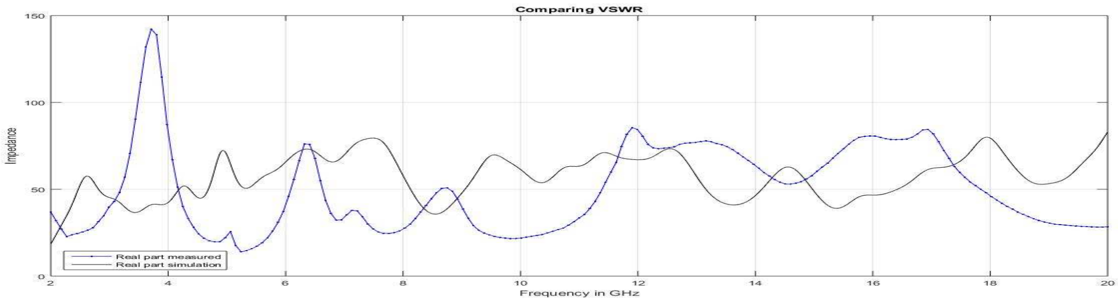


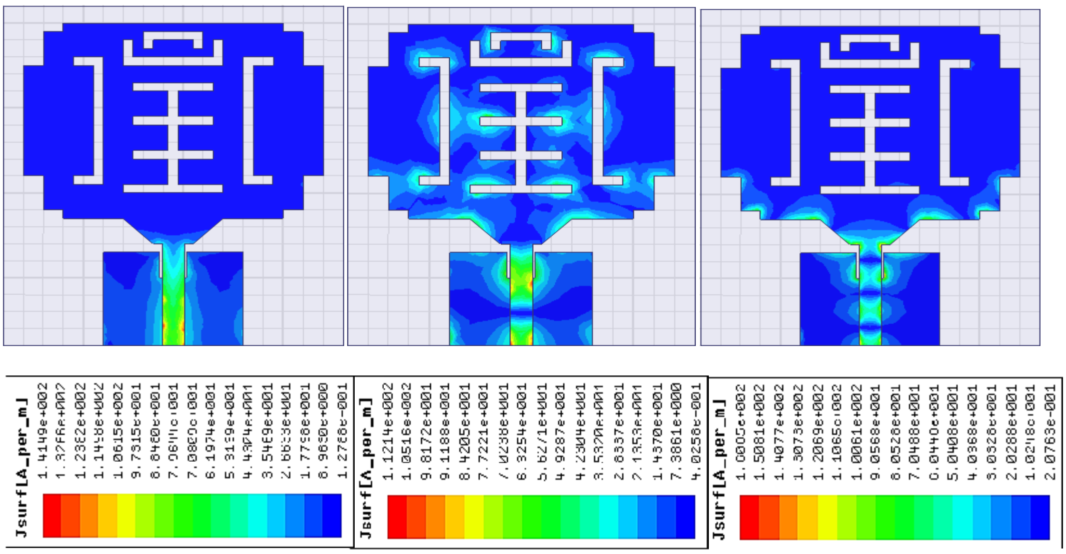
Figure 17: Simulation and measured VSWR versus frequency for the slotted antenna



(a)

(b)

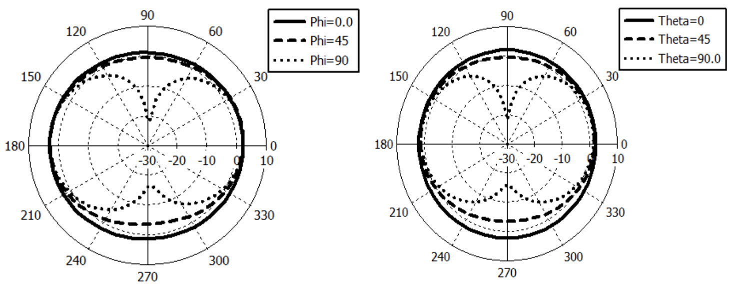
The current distribution of the proposed antenna is shown in fig.19, the current is not distributed equally in structure. Fig.19(a) shows the current distribution at frequency 3.2 GHz. The maximum current is 141.4 A/m, from the figure we observe that the most current concentrations in the feedline. In fig.19(b), the current distribution at frequency 10.35 GHz. the maximum current is 112.14 A/m, from figure observe that the most concentrations current in feedline and around the slots in the patch. Fig.19(c), the current distribution at frequency 18.9 GHz, The maximum current is 160.8 A/m, from the figure we observe that the most current concentrations is in the lower edges of the patch.



(a) (b) (c)

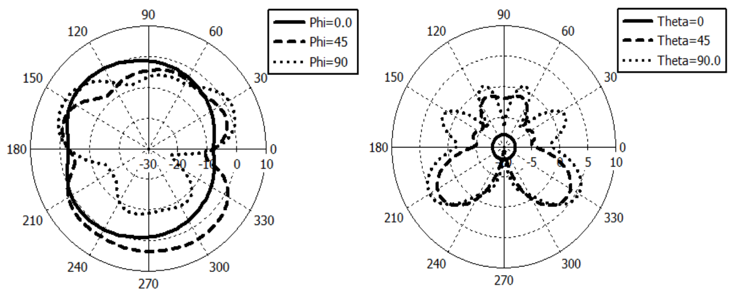
Figure 19: Currents distribution in the optimized antenna, (a) f=3.2GHz, (b) f=10.35GHz and (c) f=18.9GHz

The radiation characteristics of the final modified antenna as a function of space coordinate show in fig.20. For a linearly polarized antenna, performance is often described in terms of the E and H plane patterns. The E-plane is the plane that containing vector of the electric field and the directions of maximum radiation while the H-plane is the plane that contain the magnetic field vector and the direction of maximum radiation [9] .



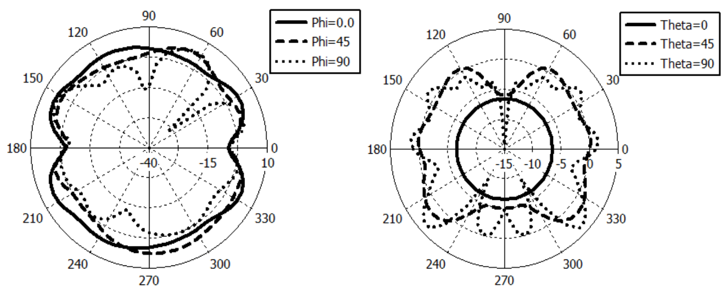
E-plane H-plane

(a)



E-plane H-plane

(b)



E-plane H-plane

(c)

Figure 20: Radiation pattern of the optimal proposed antenna at, (a) f=3.2GHz, (b) f=10.35GHz and f=18.9GHz

The elevation plane x-z plane with some certain azimuth angle (ϕ) is the principle E-plane while for the azimuth plane x-y plane with some certain elevation angle θ is the principle of H-plane[10]. The two dimensional E-plane and H-plane are simulated at three frequencies as shown in fig.20. In the E-plane, the value of ϕ is (0°, 45° and 90°) while in H-plane, the take value of θ is (0°, 45°and 90°). Three frequencies within pass band that utilized for radiation plot, which are at the lower bound 3.2GHz, 10.35GHz at the middle bound and 18.9 GHz at the upper bound.

The simulation far field 3-D radiation patterns of the final modified antenna at various frequencies 3.2GHz, 10.35GHz and 18.9GHz is shown in fig.21. These figures show the directivity over the phi and theta angles for the antenna. For the frequencies, 3.2GHz the maximum directivity is 2.96dBi, 10.35GHz the maximum directivity is 5.39dBi and 18.9GHz the maximum directivity is 4.63dBi.

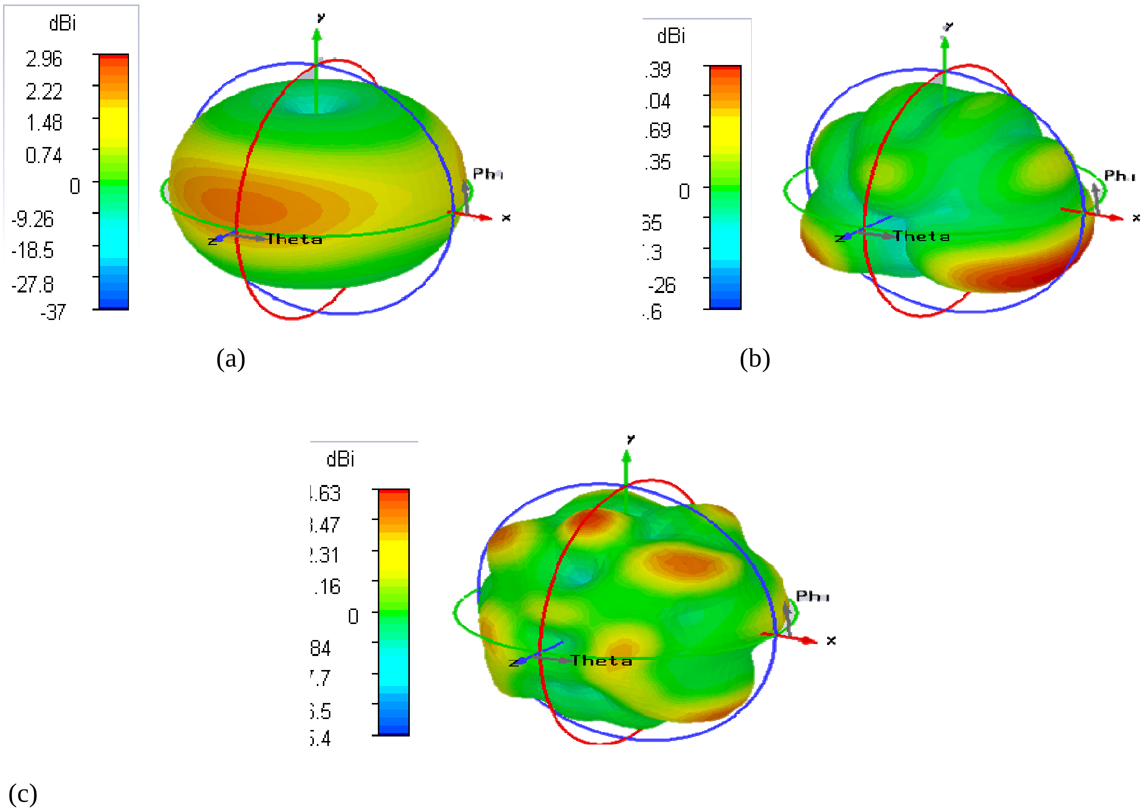


Figure 21: Simulated far field 3-D radiation patterns for the optimal proposed antenna at; (a) f=3.2GHz, (b) f=10.35GHz and (c) f=18.9GHz.

4. Conclusions

A rectangular antenna is designed and tested practically. It is found that the modified antenna give good pass band (i.e $S11 \leq -10$dB) is (2.25-20)GHz. The performance of the antenna is improved by adding many slots to the rectangular patch so that the gain is improved to(0.8 –8)dBi. The optimized antenna is fabricated and tested practically using the vector network analyzer (VNA) and the results of S11, VSWR and input impedance are compared with the simulation results. It is found that the results agrees (mostly) with simulation results and the slight difference is attributed to fabrication error. This leads to the suitability of the antenna for the frequency band (2.2-20)GHz wireless communication applications.

5. References

1. C.A. Balanis(2008)," Antenna Theory:Analysis and Design", 2nd edition.Wiely .
2. P.Bhartia,I.J.Bahl,(1980)"Microstrip Antennas", Artech House .
3. L.Boccia,andG.D.Massa,G.Amendola,(2005)" Shorted Elliptical Patch Antennas with Reduced Surface Waves on Two Frequency Bands",IEEE Transaction on Antenna and propagation.Vol.53,pp.1946-1956.
4. W.L.Stutzman and G.A.Thiele,(1988)"Antenna Theory and Design",JohnWiely&Sons.
5. Z.N. andM.Y.W.Chia Chen,(2006)"Broadband Planar Antenna Design and Applications", JhonWiely& sons.

6. Y.E.Mansour, (2014)"SingleSlot Dualband Microstrip Antenna for WIMAX Applications", Atilm University.
7. Gai.S, Y.B.Yang, C.Y.Li ,and J.G.Gong,(2010)"Design of a Novel Microstrip-Fed Dual-Band Slot Antenna for WLAN Applications", Prog.InElectr.Res. Vol.13 ,pp75-81..
8. Constantine A. Balanis,(1989)"Advanced Engineering Electromagnetic",NewYork,Wiely.
9. Gray Breed,(2005)" A summary of FCC rules for Ultra Wideband ".
10. I.BandA.I ,(2001)"Microstrip Antenna Design Handbook ", Artech House.