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PERFORMANCE ANALYSIS OF H-SHAPE MULTI-BAND WITH RECTANGULAR PATCH MICRO STRIP ANTENNA

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ABSTRACT

This paper introduces the design of rectangular multi-band H-shaped microstrip antenna with rectangular slot (RMSA). A special H-structure with constant substrate thickness was simulated for the proposed antenna, and the effects of different stub sizes on rectangular patch antenna performance were investigated. A balanced patch antenna has been designed and analyzed at frequencies of (1 to 6.5 GHz). COMSOL Multiphysics program was used for the simulation. The resonant frequencies and radiation characteristics were analysed. Different frequencies used for Radio Frequency Identification RFID, Worldwide Interoperability for Microwave Access (Wimax) and computer network applications were tackled.

تحليل الأداء للهوائي الشريطي المستطيل ذو الشكل H متعدد الحزم

الخلاصة

يهدف هذا البحث إلى تصميم هوائي شريطي متعدد الحزم على شكل H مستطيل ذو فتحة اخدود شريطية باستخدام (RMSA) ، وهو تركيب خاص على شكل H مع افتراض ثبات سمك الركيزة الشريطية للهوائيات المقترحة . اختبرت الهوائيات المصممة على النطاق ترددي (من 1 الى 6.5 كيكاهرتز) .تم التحقق من اداء الهوائيات المقترحة (بمختلف الابعاد) باستخدام برنامج COMSOL Multiphysics لمحاكاة الهوائي. تم تحليل الترددات الرنانة وخصائص الإشعاع لهذه الهوائيات .ومن خلال الهوائي المصمم تم الحصول على الترددات التي تستخدم في التطبيقات (ترددات الراديو لتحديد الهوية) RFID ، Wimax وتطبيقات شبكة الكمبيوتر .

الكلمات المفتاحية

COMSOL ، متعدد الحزم ، الهوائي الشريطي ، التردد الرنيني

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Introduction

Light weight, ease of fabrication, low cost and small size are the main reasons for adopting microstrip antenna in wireless systems [1-3]. It was used for various frequency bands such as Wimax and Wifi, GPS, GSM, WLAN and RFID. The evolution of design technology for planar patch antennas in past decades have achieved wider bandwidth, improved resonant frequency, mechanical robustness, better polarization patterns [2, 4-6].

There are many well-known methods for increasing bandwidth, the most common ways are increasing the thickness of the substrates and using substrate material with low dielectric constant. However, the size and bandwidth of an antenna are mutually conflicting properties, which means, degradation of one of the characteristics usually results in the improvement of the other [3].

Embedding a slot in the patch is one method to obtain multi-band in a microstrip antenna. Enhancement of the impedance bandwidth by embedded slots can also be used for a single band antenna [6].

Through this work, we have managed to achieve antennas with multi-band frequency by adding more rectangles to the original H-shaped antenna. Different resonant frequencies can be prepared by altering the dimensions of the H-shaped antenna.

In this paper, multiband microstrip antenna was established by changing the dimensions of the initial antenna. The proposed antennas can operate at (2, 2.1, 2.25, 2.4, 3.25, 3.7, 4.1, 4.5, 4.7, 4.75, 5, 5.1, 5.4, 5.6) GHz for $|S_{11}|$ = -8 dB or less. Moreover, the designed antennas have smaller sizes ranging from 80 × 80 mm^2 to 36 × 36 mm^2. Results were presented to show the usefulness of the proposed antenna for Radio Frequency Identification RFID, UWB and wireless computer network applications.

The rest of this paper is organized as follow. Section II describes the rectangular micro strip antenna design. The proposed antenna geometry is presented in Section III. Results and discussions are presented in Section IV. Section V demonstrates the conclusions of the whole work

Rectangular Micro strip Patch Antenna Design

One element of the rectangular Micro strip Antenna (MSA) is a rectangular metallic radiating patch. The patch dimensions width (W_P) and length (L_p) which is mounted on one side of a dielectric substrate which has a size of $L_s \times W_s$, thickness h and relative permittivity ε_r. On the other substrate side there is a metallic ground plane as shown in Figure (1). Many possible shapes can be taken as a radiating patch, as well as the feeding network, which could be implemented with different techniques and are usually photo etched on the dielectric substrate [8-13].

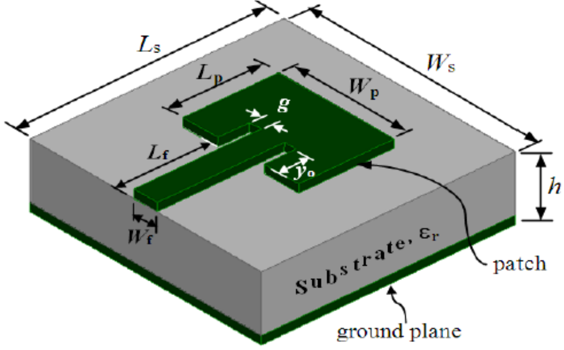

Figure (1) Basic structure of micro strip antenna

There are different substrates which can be used for the design of MSAs, and the dielectric constants are normally in the range of 2.2 < ε_r < 12. In this paper, two values were adopted for the dielectric constant.

The design of rectangular MSA can be described as follows [3, 5]:

For a resonant frequency f_r and a substrate with dielectric constant ($\boldsymbol{\varepsilon_r}$), the efficient radiation for patch Width (W) must be;

$$-\sqrt{-} \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where, c_o is the speed of light.

Due to wave propagation and fringing in the field line, an effective dielectric constant (ε_{reff}) can be determined by equation (2) [3, 9, 10]:

$$- \quad - \qquad -] \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where, h is the dielectric substrate height. The Effective Length ($\boldsymbol{L_{eff}}$) and the Length Extension ($\Delta\boldsymbol{L}$) for a given resonance frequency f_r are given in equations (3) and (4) [3, 9];

$$\frac{}{r\sqrt{\varepsilon}} \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

$$\frac{-}{-} \ldots\ldots\ldots\ldots\ldots\ldots(4)$$

So that, the actual length of patch should be;

$$\boldsymbol{L} \ldots\ldots\ldots\ldots\ldots\ldots(5)$$

and the bandwidth (BW)

$$\mathbf{77}\left(-\right)\left(-\right)\left(-\right) \quad \mathbf{100} \ldots\ldots\ldots\ldots\ldots\ldots(6)$$

Where, is the free space wavelength.

The feed points are calculated as in equations (7) and (8) when coaxial probe-fed technique is used [2];

$$\frac{}{2\sqrt{\varepsilon}} \ldots\ldots\ldots\ldots\ldots\ldots(7)$$

$$- \ldots\ldots\ldots\ldots\ldots\ldots(8)$$

Where, X_f and Y_f are the feed co-ordinates in the patch length and width respectively.

III. Proposed Antenna Geometry

The geometry of the proposed antennas is shown in Figure (2). The patch antenna is simulated using COMSOL program with a relative dielectric constant of 3.5 and 4.4. The x–y plane is used for the location of the antenna and the z–axis as the normal direction. It is made up of symmetrical H planar with added rectangles patch. It is to be noticed that, the feed line of the antenna is fed by a micro strip similar to many planar antennas with characteristic impedance of 50Ω.

In this work, the value of dielectric constant (ε_r) was initially selected to be (3.5, 4.4) and the substrate thickness (h) as

0.508mm. On the next dielectric substrate side, a ground plane is printed with the width W_s and length L_s under the micro strip feed line. The details of parameters for the proposed antenna are as shown in Table (1).

Initially the H-shaped patch was simulated (using COMSOL Multiphysics) and the resonant frequency was recorded as a base value for later comparison. Then, the dimensions of the patch were changed to try to get a better performance for the antenna, i.e. more suitable resonant frequency, better radiation patterns, less reflected loss and higher efficiency.

Table (1): Parameters of the proposed antennas for ε_r=3.5 or 4.4

Basic configuration	Sym.	Dimensions (mm)			
		Ant. 1	Ant. 2	Ant. 3	Ant. 4
Substrate	W	80	72	68	32
	L	80	72	68	32
Patch Ant.	L_1	40	36	34	16
	L_2	15	13.5	12.75	6
	L_3	12	10.8	10.2	4.8
	L_4	7	6.3	5.95	2.8
	W_1	40	36	34	16
	W_2	15	13.5	12.75	6
	W_3	5	4.5	4.25	2
	W_4	5	4.5	4.25	2
Subst. thickness	h	0.508	0.508	0.508	0.508

Results and Discussions

The H-shaped patch was first simulated using the finite element method in COMSOL as a reference case, as pointed out in table (1) column three, then the parameters of the patch and the substrate was changed. After an exhaustive efforts, the more suitable parameters to meet the required specifications for radio frequency identification RFID, Wimax and computer network applications. The final requirement is a better S-parameter and more frequency bands as compared to the reference case.

When figures (3-7) were compared, an improvement in the return loss (S_{11}) can be observed when the value of the dielectric constant was increased. On the other hand, an antenna with larger dimensions has more frequency bands as compared to the smaller size, which indicated a proportional relation between the size and number of frequency bands, while smaller dimensions showed an improvement in the S-parameter as compared to the larger size.

The electric field intensity was also drawn for selective resonant frequencies of various antenna dimensions and dielectric constants as in figures (8-12) to estimate the total energy density per cubic meter. Three dimensional radiation patterns for the proposed antenna were also included as well as those for the two dimensional which denotes the efficiency of the antenna as in Figures (13-30).

An observation of figures (3-7) shows that the best antennas are in figures (5) and (7), where the relative permittivity was equal to 3.5. The return loss reached values of -17dB, -16.5dB for resonant frequencies of 2.4 and 5.4 GHz respectively for the second antenna and the return loss values of -15dB, -18dB for resonant frequencies of 4 and 4.6 GHz respectively for the fourth antenna.

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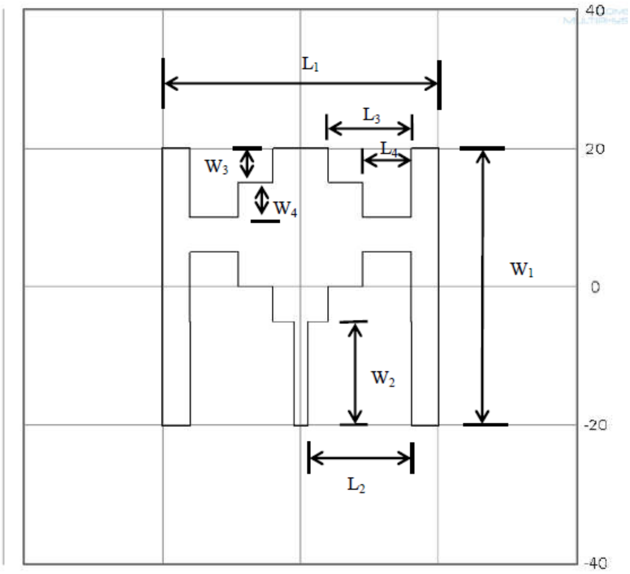

Figure (2) the photograph of the proposed fabricated antenna.

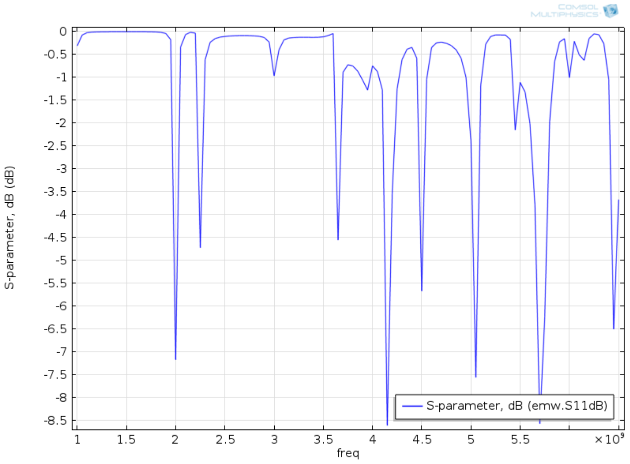

Figure (3) S-parameter (S_{11}) for the first antenna (Ant.1) prototype ε_r=3.5

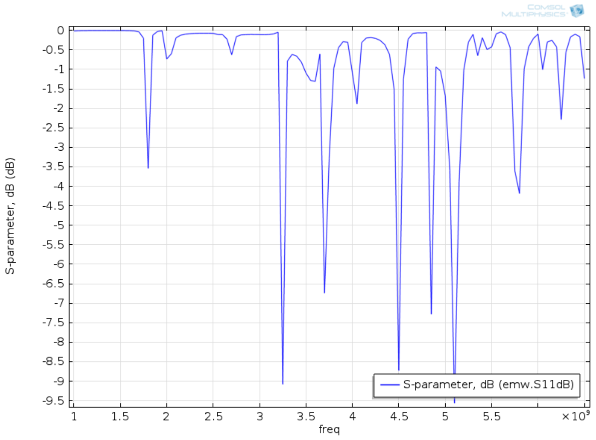

Figure (4) S-parameter (S_{11}) for the first antenna (Ant.1) prototype ε_r=4.4

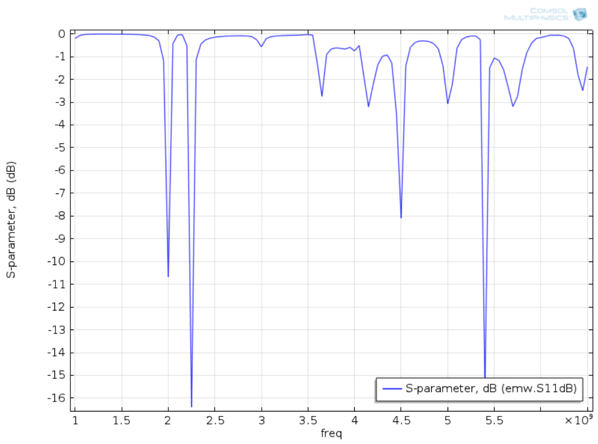

Figure (5) S-parameter (S_{11}) for the second antenna (Ant.2) prototype ε_r=3.5

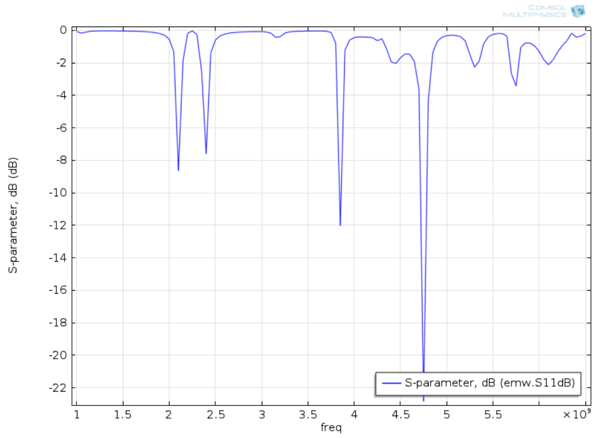

Figure (6) S-parameter (S_{11}) for the third antenna (Ant.3) prototype ε_r=3.5

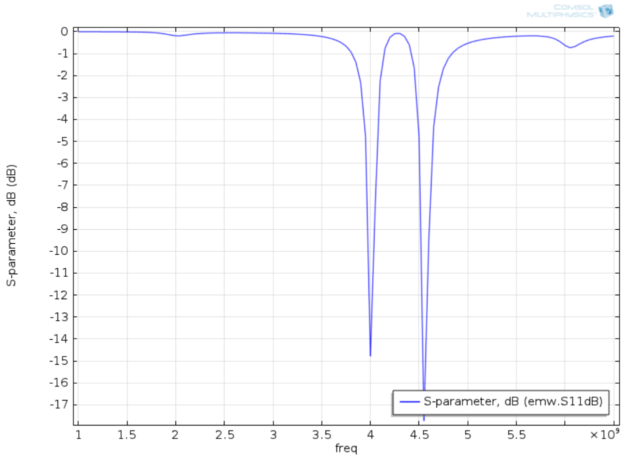

Figure (7) S-parameter (S_{11}) for the fourth antenna (Ant.4) prototype ε_r=3.5

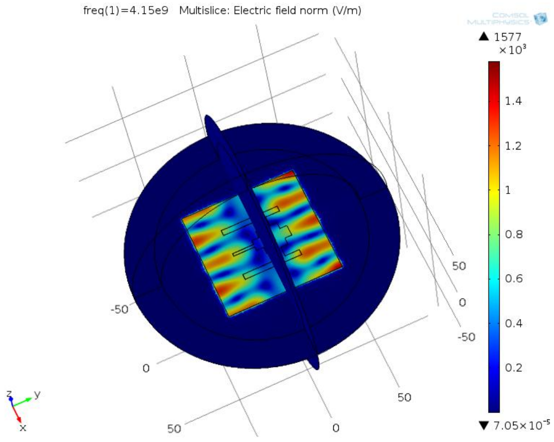

Figure (8) Electrical Field (emw) in (V/m) for first antenna (Ant.1) 4.15GHz ε_r=3.5

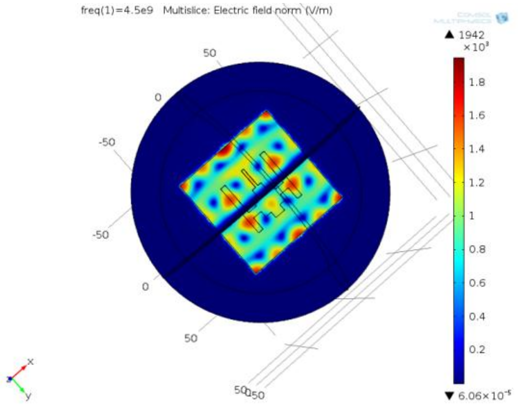

Figure (9) Electrical Field (emw) in (V/m) for first antenna (Ant.1) 4.5GHz ε_r=4.4

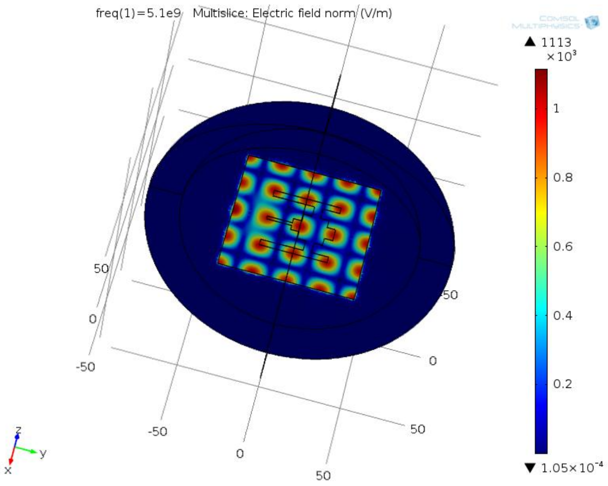

Figure (10) Electrical Field (emw) in (V/m) for first antenna (Ant.1) 5.1GHz ε_r=4.4

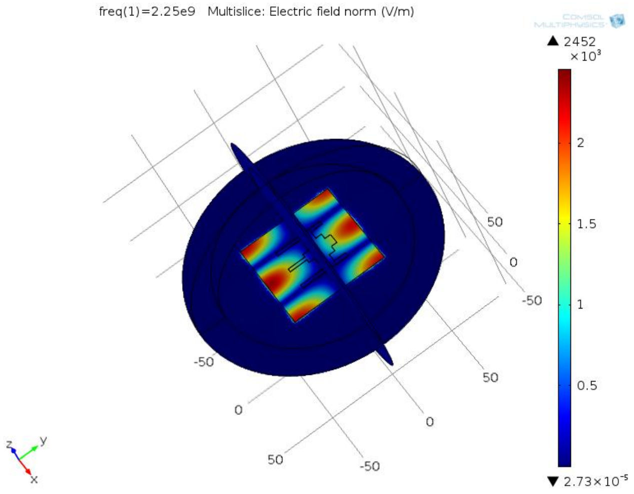

Figure (11) Electrical Field (emw) in (V/m) for second Antenna (2GHz , ε_r=3.5)

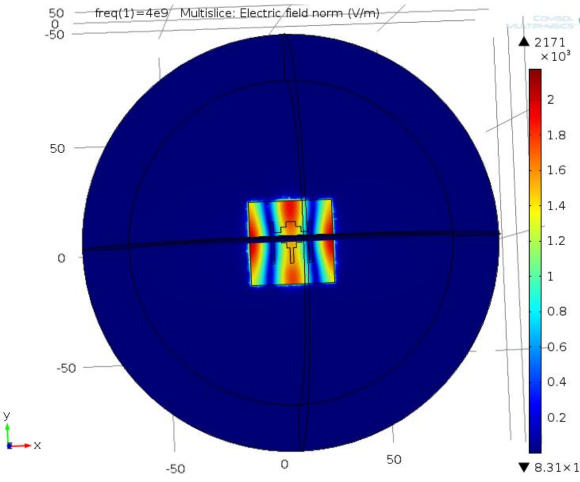

Figure (12) Electrical Field (emw) in (V/m) for fourth Antenna (Ant.4) (4GHz)

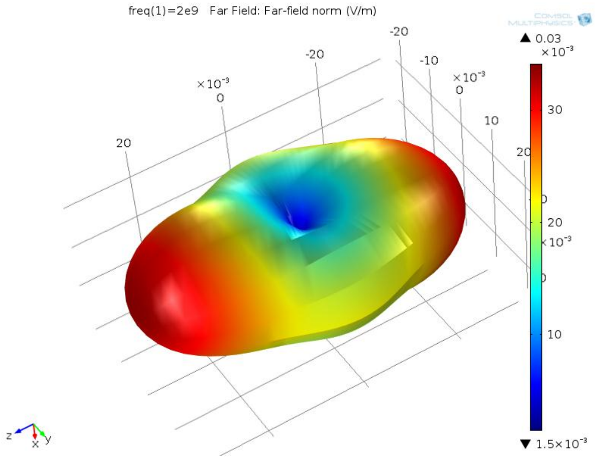

Figure (13) 3D radiation pattern for the first antenna prototype (2GHz) ε_r=3.5

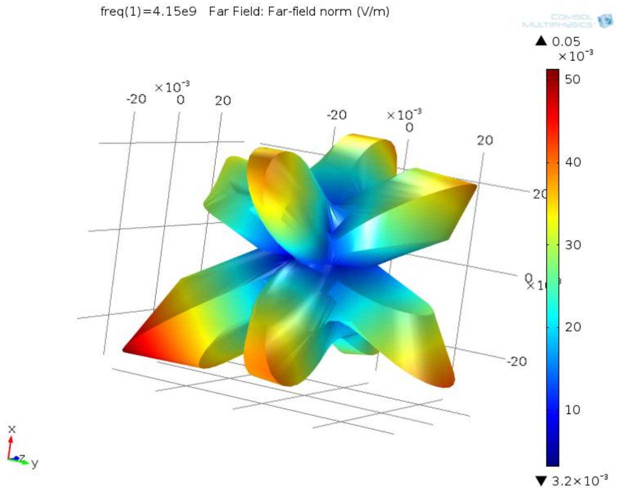

Figure (14) 3D radiation pattern for the first antenna prototype (4.15GHz) ε_r=3.5

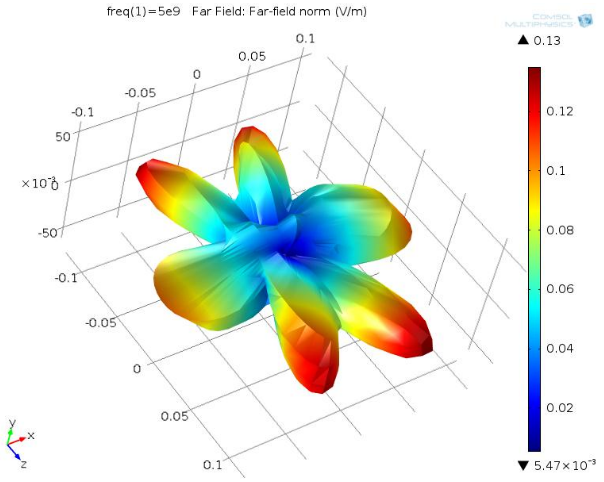

Figure (15) 3D radiation pattern for the first antenna prototype (5GHz) ε_r=3.5

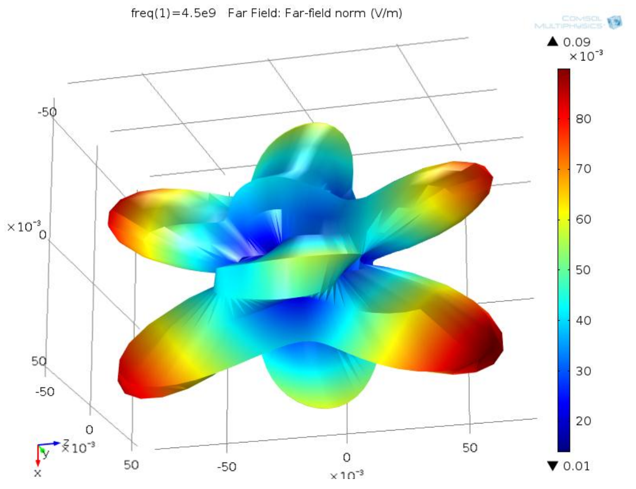

Figure (16) 3D radiation pattern for the first antenna prototype (4.5GHz) ε_r=4.4

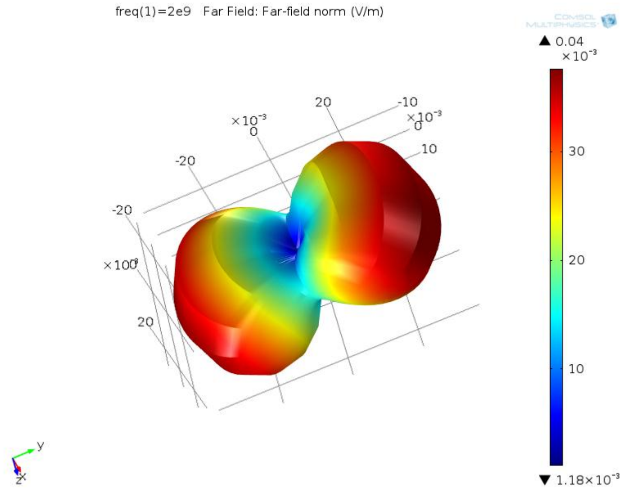

Figure (17) 3D radiation pattern for the second antenna prototype (2GHz) ε_r=3.5

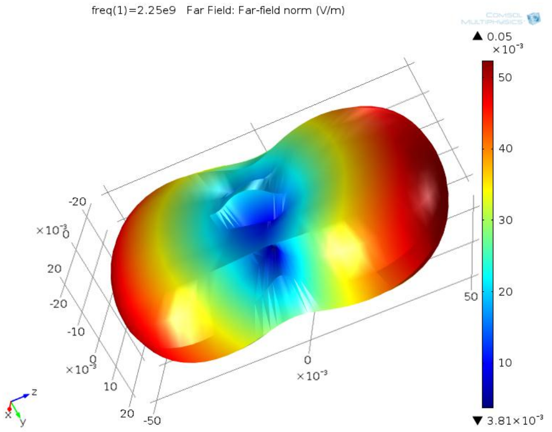

Figure (18) 2D radiation pattern for the second antenna (Ant.2) (2.25GHz) ε_r=3.5

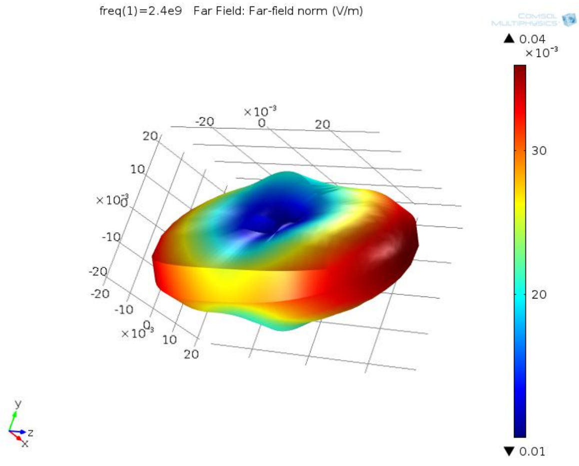

Figure (19) 3D radiation pattern for the third antenna (Ant.3) (2.4GHz) ε_r=3.5

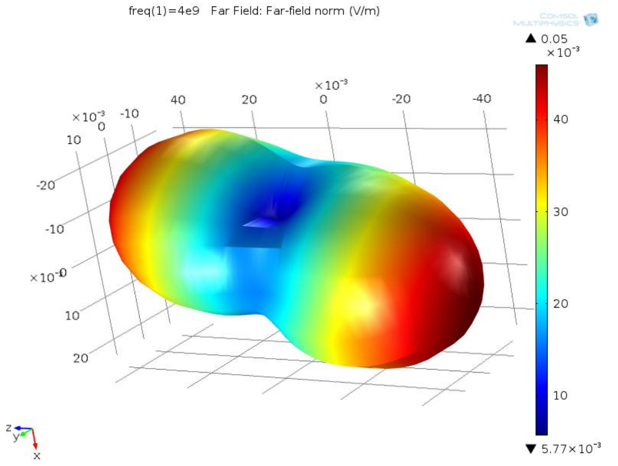

Figure (20) 3D radiation pattern for the fourth antenna (Ant.4) (4GHz) ε_r=3.5

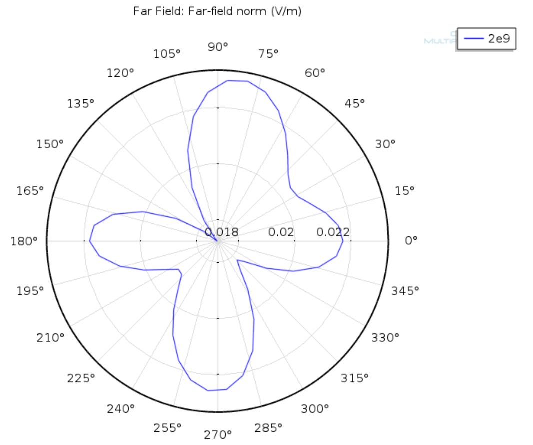

Figure (21) 2D radiation pattern for the first antenna (2GHz) ε_r=3.5

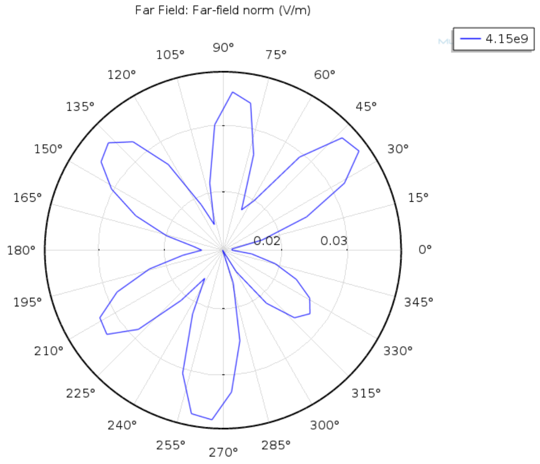

Figure (22) 2D radiation pattern for the first antenna (4.15GHz) ε_r=3.5

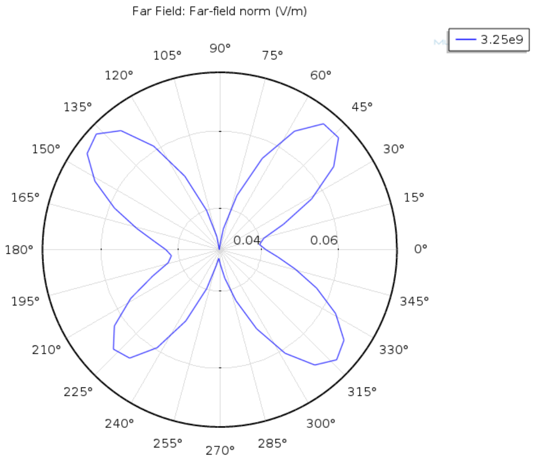

Figure (23) 2D radiation pattern for the first antenna (3.25GHz) ε_r=4.4

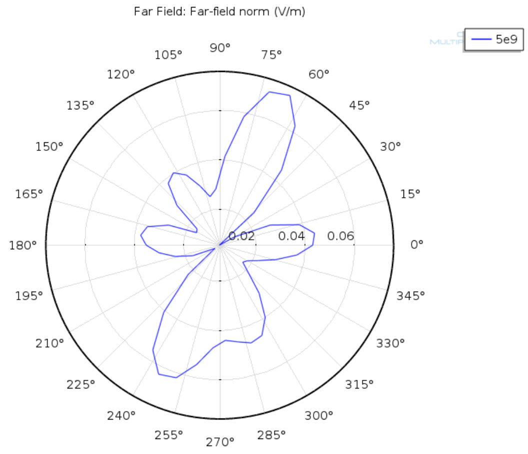

Figure (24) 2D radiation pattern for the first antenna (5GHz) ε_r=4.4

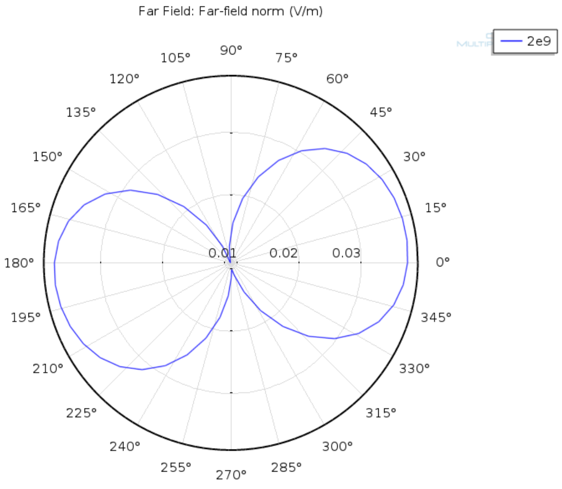

Figure (25) 2D radiation pattern for the second antenna (Ant.2) (2GHz) ε_r=3.5

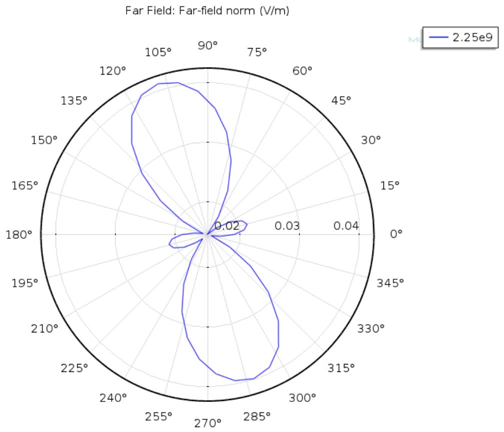

Figure (26) 2D radiation pattern for the second antenna (Ant.2) (2.25GHz) ε_r=3.5

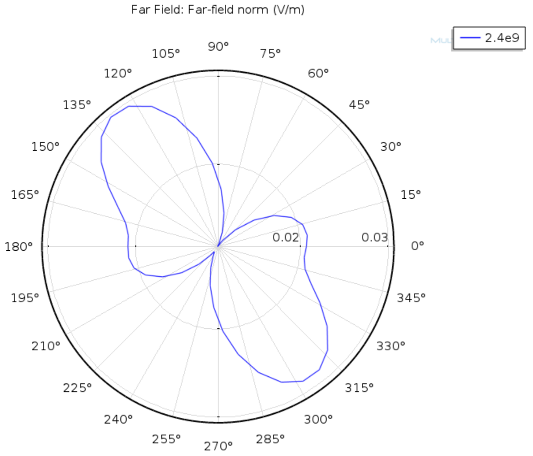

Figure (27) 2D radiation pattern for the third antenna (Ant.3) (2.4GHz) ε_r=3.5

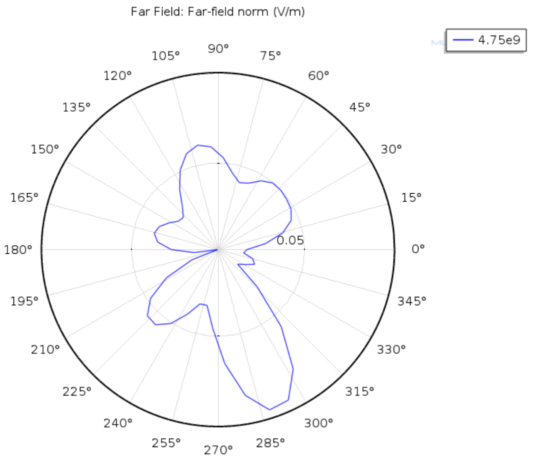

Figure (28) 2D radiation pattern for the third antenna (Ant.3) (4.75GHz) ε_r=3.5

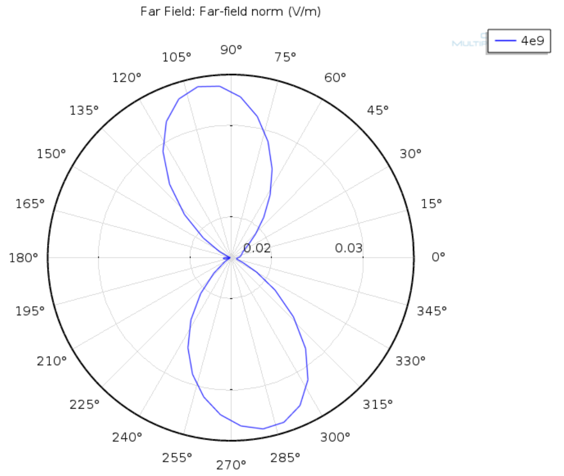

Figure (29) 2D radiation pattern for the fourth antenna (Ant.4) (4GHz) ε_r=3.5

Conclusions

In this paper H-shaped MSA has been designed and analyzed at frequencies of (1 to 6.5 GHz) using COMSOL Multiphysics finite element method. Four different structures of H-Shaped multi-band rectangular microstrip patch antenna are presented for different microwave applications. It was observed that larger patch configurations yield more frequency bands and less S-parameter, while increasing the dielectric constant does improve the S-parameter. Therefore combining these two facts can help in the design of an antenna with more frequency bands and better S-parameters.

Radiation characteristics of the antennas are investigated by numerical simulations. The proposed antenna configurations were analyzed to show that the antenna has achieved satisfactory parameters (resonant frequency and radiating properties).

References:

1. S. Dhar, R. Ghatak, B. Gupta, and Dipak Ranjan Poddar " A Wideband Minkowski Fractal Dielectric Resonator Antenna," IEEE Transctions on Antennas and Propagation, Vol. 61, No. 6, June 2013,pp.. 2895- 2903.

2. S. Kumar, G. Jagrawal and D. Billore, "E–Shaped Coaxial Feed Microstrip Patch Antenna for WLAN and WIMAX Applications," International Journal of Current Engineering and Technology, Vol.5, No.2 , 2015, pp. 874- 876.

3. K.V. Rop, D. B. O. Konditi, "Performance Analysis of a Rectangular Microstrip Patch Antenna on Different Dielectric Substrates," Innovative Systems Design and Engineering, Vol. 3, No 8, 2012, pp. 7-15.

4. P. Bansal and D. S. Sidhu ,"Design and Analysis of Balanced Doubled Feed Square Patch Antenna using Finite Element Method ," Int. Journal of Innovative Research in Electrical and Electronic, Instrumentation and control Eng., Vol. 2, Issue 7, July 2014, pp. 1666- 1669.

5.J. S. Sivia, M. Sinch, S. Rani and T. S. Kamal, "Design and Analysis of Triple band Rectangular Microstrip Patch Antenna Array," Proceedings of the 9th International Conference on Circuits, Systems, Signal and Telecommunications (CSST '15), February 22-24, 2015, pp. 97- 100.

6. P. Ramya , S. Gopalakrishnan and R. Pradeep, " Modified E-Shaped Microstrip Patch Antenna For Wimax Application," International Journal of Advanced Research in Computer and Communication Engineering Vol. 3, Issue 8, August 2014, pp. 7678- 7680.

7. J. Ghalibafan and A. R. Attari, " A New Dual-Band Microstrip Antenna with U-Shaped Slot," Progress In Electromagnetic Research C, Vol. 12, 2010, pp. 215-223.

8. I. Singh and V.S. Tripathi, "Micro strip Patch Antenna and its Applications: a Survey," International Journal of Computer Applications in Technology, Vol 2 (5), 2011, pp. 1595-1599.

9. E. K. I. Hamad, "Design and Implementation of Dual –Band of Dual Band Microstrip Antennas for RFID Reader Applications ," Ciencia e Tecnica Vitivinicola, Vol. 29, No. 9, 2014, pp. 2-10.

10. D. Rishishwar and L. Shrivastava, " Rectangular Microstrip Patch Antenna With FSS And Slotted Patch To Enhance Bandwidth At 2.4 GHz For WLAN Applications," International Journal of Technical Enhancements and Engineering Research, Vol. 2, Issue 4, 2014, pp.59-62.

11. B. Kasi, L. C. Ping and C. K. Chakrabarty, "A Compact Microstrip Antenna for Ultra Wideband Applications," European Journal of Scientific Research, Vol.67, No. 1, 2011, pp. 45-51.

12. P. Siddaiah, S. Nagakishore Bhavanam and V. Midasala, "Design of Dipole Antenna by Using COMSOL Multiphysics Software," Proceeding of International Conference on Innovations in Electronics and Communication Engineering (ICIECE 2014) 18th & 19th July 2014, pp. 25-27

13. A. H. Ahmad and B.K. Jar'alla, "Design and Simulation of Broadband Rectangular Microstrip Antenna," Journal of Engineering and Technology Journal .Vol.26, No1, 2008, pp. 1-15