A modified E-shaped microstrip patch antenna for dual band in x- and ku-bands applications

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A modified E-shaped microstrip patch antenna for dual band in x- and ku-bands applications

Wa'il A. Godaymi Al-Tumah*, Raed M. Shaaban, and Zeki A. Ahmed

Physics Department, Science College, Basrah University, Basrah, Iraq

*Corresponding author: Email: wail.godaymi@uobasrah.edu.iq

Abstract. In this paper, different shapes of an E-patch microstrip antenna designed and operating at x- and ku-bands by using High Frequency Structure Simulator (HFSS) software version 13. The finite element method used to solve electromagnetic values. The dielectric substrate material is Arlon AD320A (tm) with dielectric constant ($\varepsilon_r = 3.2$) and thickness h=1.79 mm used in this design. The new designs including modifying and slotting E-patch increased the gain of proposed antennas and provided a dual band frequency in x- and ku- bands. The return loss, voltage standing wave ratio (VSWR) and radiation patterns are evaluated.

Keywords. E-Shaped Microstrip Patch, Slot Antenna, x-band, Ku Band, Dual Band Antenna, High Frequency Structure Simulator HFSS.

1. Introduction

Microstrip antennas (MSAs) have various unique properties which make them experienced increased popularity since the last decade. Distinctive physical features like low cost, light weight, conformability, low profile, relatively compact, mechanically robust and other desirable features have made MSAs an attractive source for the researchers [1,2]. However, MSAs have narrow impedance bandwidth and low gain which represent the major weakness of these antennas. The significant study work has been presented till now many techniques for enhancing the bandwidth, increasing the gain and designing dual-band antennas [3-6]. Some of these techniques are employing a parasitic patches and stacked microstrip antennas to provide large bandwidth and high gain [7-10]. Also, the experimental study has been designed a rectangular patch antenna which electromagnetically coupled with a two dielectric substrates [11]. In 2007, Pedra et al. increased the bandwidth up to 32% using shorting pins and capacitive feeding for E-shaped patch antenna [12]. In particular, multi-frequency or wideband operation obtained by using various slotted which allowed reactively loaded and modified MSA structures. Different shape and size of microstrip antennas with different feeding technique have been developed. These various feeding mechanisms include coaxial, aperture coupled, offset feedings and the coupling slot which represents the most popular feeding technique [13-17]. It is observed that the capacitive feeding technique that obtained by etching a small circular slot on the patch can reduce the probe inductance to achieve 16% bandwidth [18]. The experimental and simulation results have been studied the coaxially fed U-slot rectangular patch antenna on a foam substrate to increase the bandwidth up to 30% [19]. Moreover, a novel equivalent circuit model has been analyzed and designed for MSA with the defected ground structure for Ku band applications. The results indicate that a 56.67% impedance bandwidth is achieved [20]. Previous researches have addressed different shape and size of slots incorporated into E-shaped MSAs for wideband applications. These various slots include two parallel slots and cutting a pair of tapered slots [21-24]. Recently, researchers have been used a new E-shaped patch antenna to improve through-wall radio tomographic imaging [25]. It was shown that the use of half structure techniques leads to extend the two U-slot patches to the edges and produce the E-shaped patch for wideband behavior. Additionally, this technique with shorting wall and pin of U-slot was applied to achieve dual band and wideband [26]. The L-shaped probe feeding techniques, H-slot patch and two parallel slots (E-shaped) of MSAs are investigated for increasing the impedance bandwidth [27].

2. Antenna Design

We have proposed new designs of E-patch MSAs with Arlon AD320A (tm) as a dielectric substrate material as shown in figure 1. This substrate has dielectric constant ($\varepsilon_r = 3.2$) and its dimensions are length (L_s=29mm), width (W_s=24mm) and thickness (h=1.79mm). The novelty of the antenna lies in its shape and the observed features. They have been made with the help of two different shapes of triangle, in addition to use circle and triangle slots. The version 13 of HFSS software was used to model these proposed antennas with an aim to achieve wideband and dual frequency operation in x- and Ku-bands. This achievement can be use in the aircraft, spacecraft and satellite based communication system applications.

In the design process, the parameters involved are dimensions of the triangles and circle slots, length and width of the patch and location of the feed point, as predicated in table 1.

The standard dimensions of rectangular MSA are design by calculating the width (W) and length (L) for a resonant frequency (f_o) in GHz as [28]:

$$W = \frac{c}{2f_o} \times \left(\frac{2}{\varepsilon_r + 1}\right)^{-1} \tag{1}$$

$$L = \frac{c}{2f_o} \left(\varepsilon_{eff}\right)^{-1/2} - 2\Delta L \tag{2}$$

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

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

$$\Delta L = 0.41h\left(\left(\varepsilon_{eff} + 0.3\right)\left(\varepsilon_{eff} - 0.258\right)^{-1}\right) * \left(\left(\frac{w}{h} + 0.264\right)\left(\frac{w}{h} + 0.8\right)^{-1}\right) \tag{4}$$

where c is the velocity of light. The dimensions of the ground plane are similar to the dielectric substrate dimensions. The proposed antenna is excited by a coaxial probe feed at position ($x_f = 0, y_f = 3.5mm$).

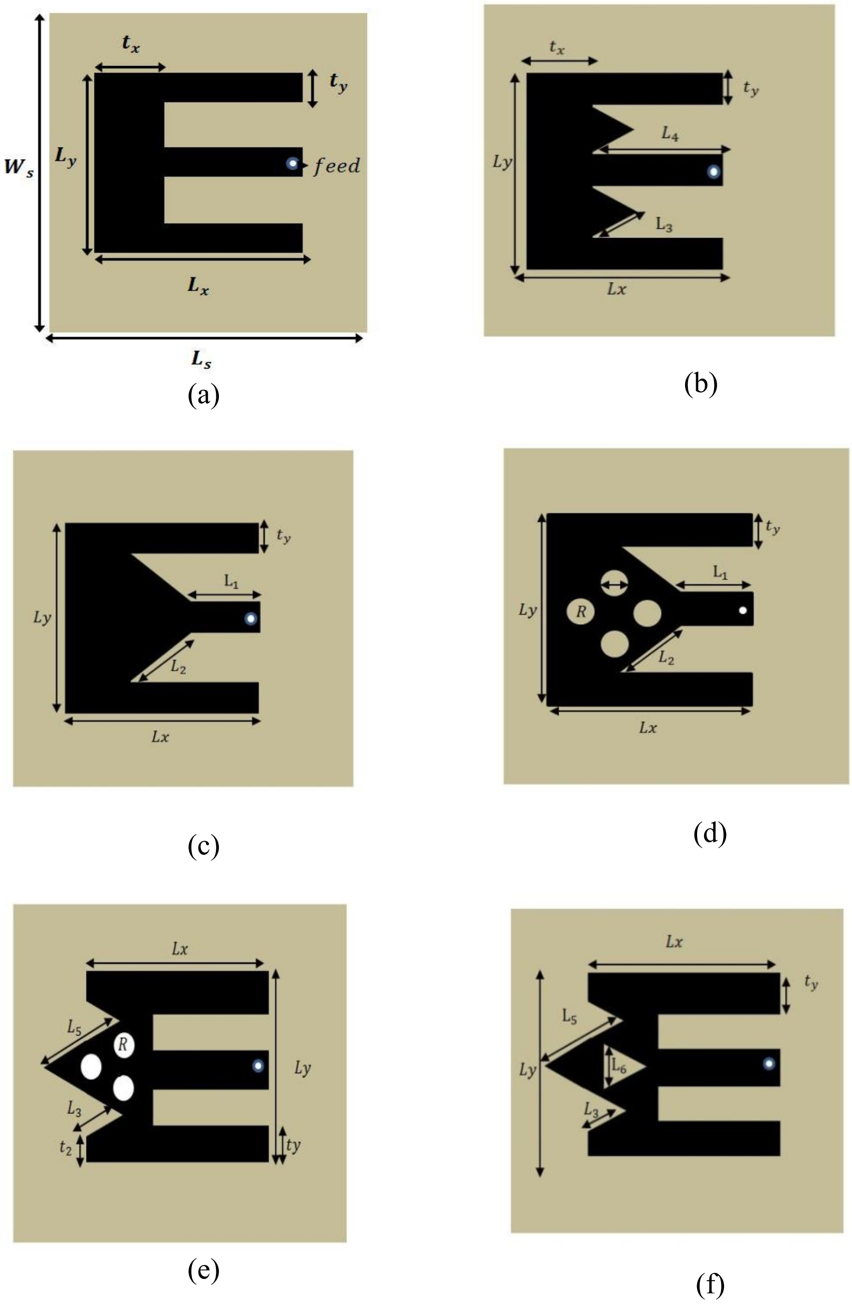

Figure 1. Designs of proposed E-patch microstrip antennas.

Table 1. Dimensions of the variables as shown in figure 1.

Label	Dimension (mm)
t_x	5.0
t_y	3.0
L_x	12.0
L_y	16.0
R	1.8
L_1	4.0
L_2	4.5
L_3	2.5
L_4	7.0
L_5	5.5
L_6	3.0
L_7	2.0

3. Results and Discussion

The proposed antennas in figure 1 are simulated by using Ansoft HFSS version 13, which based on the finite element method as a numerical analysis. The best performance of an antenna depends on the value of return loss (S11) and its value should be less than -10 dB. Figure 2 shows the comparison between the simulated S11 of the proposed antennas. This parameter values are between -15.7 dB and -46.5 dB, which make these antennas to be suitable for wireless communication application. Figure 3 shows VSWR for the proposed antennas. It can be concluded from this figure that the values of VSWR between (1.009 – 1.38). Therefore, the proposed antennas can be fabricated easily.

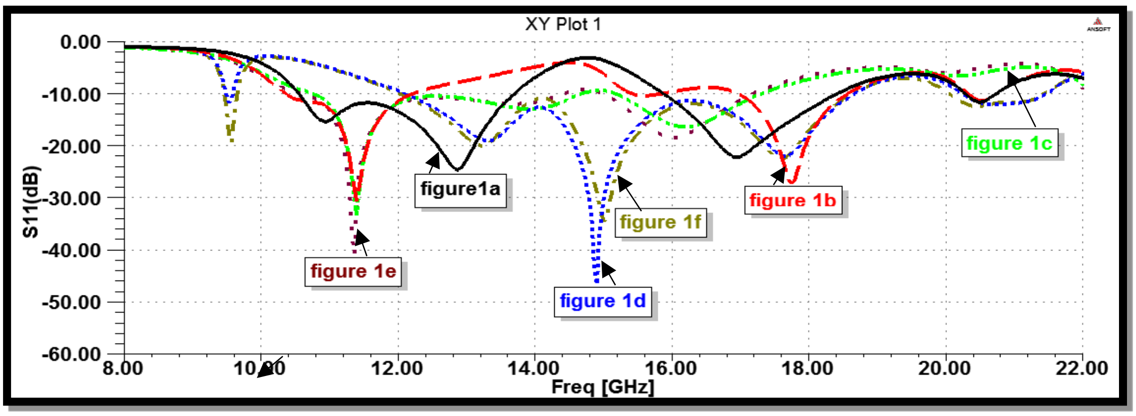

Figure 2. S_{11} plots of the proposed antennas.

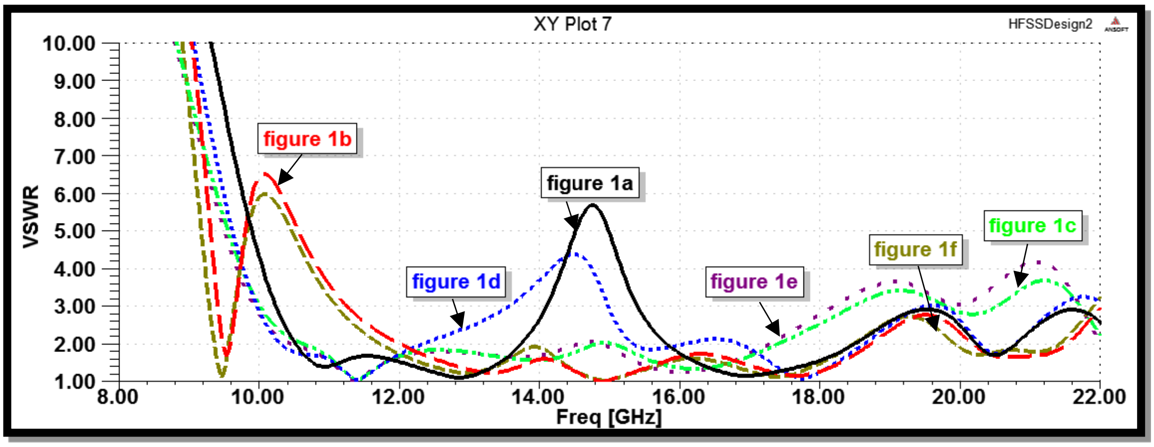

Figure 3. Plots of VSWR the proposed antennas.

Table 2 illustrates the values of resonant frequency, return loss, bandwidth, directivity and gain for the proposed antennas. The results of these parameters remain comparable also the little modified in the E-patch may be attributed to get the best values of these parameters. The proposed antennas in figure 1a, 1b, 1c and 1e have dual band frequency. This table illustrates that the proposed antenna in figure 1b has the maximum gain (7.48 dB) with return loss (-27.2 dB) and it has the highest value of directivity (7.53 dB) at resonant frequency 17.7 GHz. While the best value of S11 is -46.5 dB for the proposed antenna in figure 1d.

Table 2. Parameters values of the proposed antennas as shown in figure 1.

Figure	Operating frequency (GHz)		S_{11} (dB)		Bandwidth (%)		Directivity (dB)		Gain (dB)	
	1st Band	2nd Band	1st Band	2nd Band	1st Band	2nd Band	1st Band	2nd Band	1st Band	2nd Band
1a	12.98	16.94	-24.5	-22.7	24	15	6.90	3.80	6.80	3.72
1b	11.40	17.70	-30.5	-27.2	16	8.5	4.41	7.53	3.80	7.48
1c	10.90	16.40	-33.8	-15.7	14	9	3.14	7.45	3.14	7.38
1d	14.90	------	-46.5	------	43	------	6.69	------	6.64	------
1e	11.30	16.00	-40.8	-18.3	31	13	3.92	6.20	3.80	6.14
1f	15.10	------	-39.2	-39.2	41	------	4.55	------	4.49	------

The radiation patterns of the proposed antennas in three dimensions are simulated in the far field region, as shown in figure 4. This figure shows that the radiation pattern of the proposed antenna in figure 1b has only one main lobe whereas the side lobes are minimized. Figure 1b represents the optimum radiation pattern of the proposed antennas.

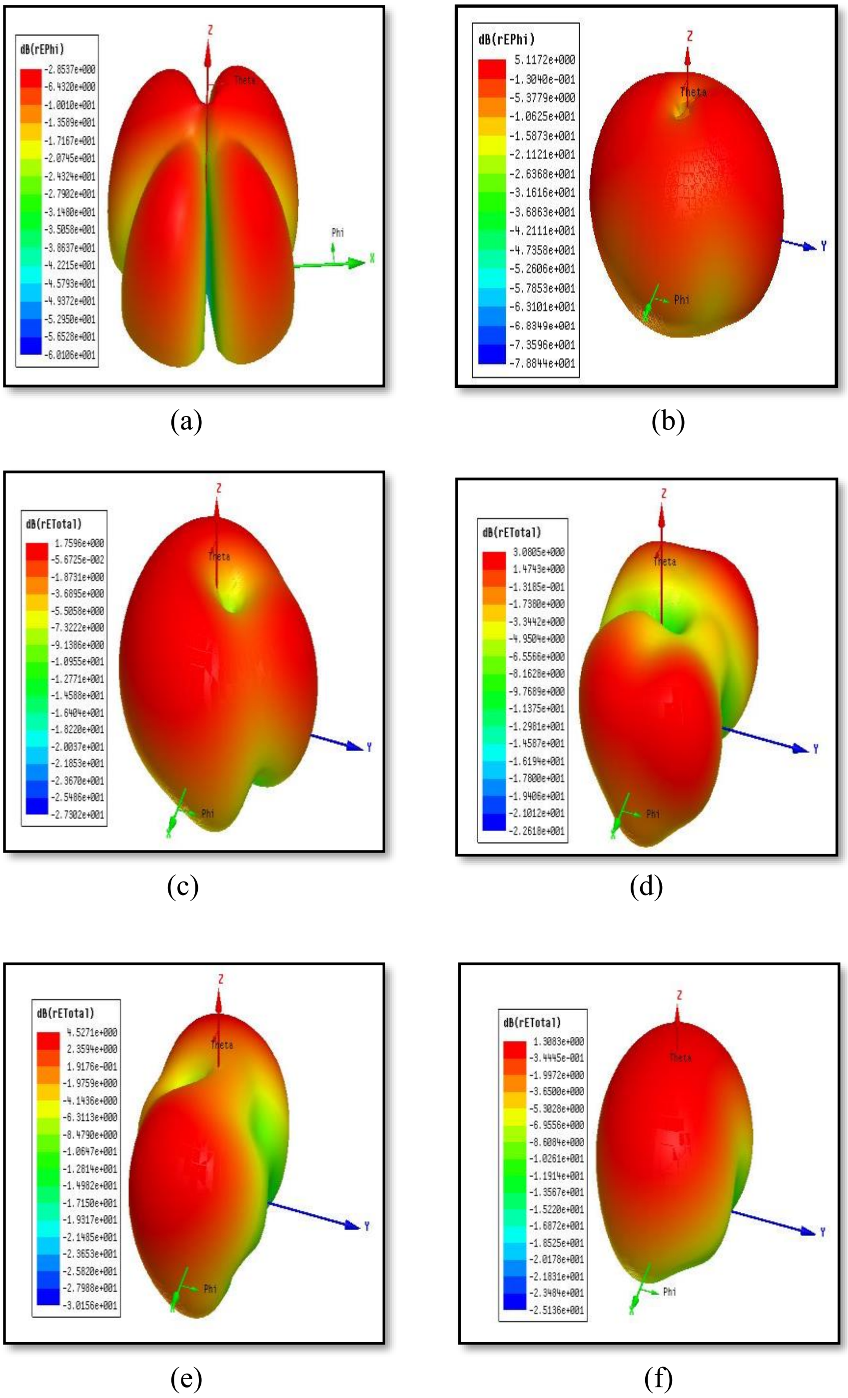

Figure 4. Radiation patterns for the proposed antennas in figure 1.

4. Conclusions

In this article, E-shaped MSAs were designed and simulated and their operating frequencies are in the X- and Ku-bands. The proposed antennas provide useful frequency, dual band and good radiation characteristics in terms of radiation patterns. The simulated results of a maximum gain and directivity are 7.48 dB and 7.53 dB, respectively, while the best value of S11 is -46.5 dB. These parameters are relatively good and can be improved by making an array of the proposed antennas. The simulated result values of return loss are between -15.7 dB and -46.5 dB, while the values of VSWR are between 1.009 and 1.38.Therefore, these results make proposed antennas to be suitable for radar, satellite and wireless communication application and can be fabricated easily.

References

[1] Kumar A, Kumar P and Deb A 2015 *Int. Conf. In Communications and Signal Processing (ICCSP)*An e-shaped microstrip antenna with unidirectional propagation *IEEE* p 274-276
[2] Mishra R, Mishra RG, Kuchhal P and Chaurasia RK 2016*Int. Conf. In Recent Advances and Innovations in Engineering (ICRAIE)*Optimization of the dimension of circular slotted rectangular Microstrip antenna for wide band wireless applications *IEEE* p 1-5
[3] Abd-Elrazzak MM and Al-Nomay IS 2010 A modified E-shaped microstrip antenna for ultra wideband and ISM band applications *International Journal of Computer Science and Network Security***10** p 179-183
[4] Shaaban RM, Ahmed ZA and Godaymi WA 2017 Design and analysis for circular microstrip antenna loaded by two annular rings *Global Journal of Computer Science and Technology: C* **17** p 31-35
[5] Kumar A, Gupta N and Gautam PC 2016 Gain and bandwidth enhancement techniques in microstrip patch antennas-A Review *International Journal of Computer Applications* **148** p 9-14
[6] Lakrit S 2018 Design of dual and wideband rectangular patch antenna for C and X bandapplications *Advanced Electromagnetics***7** p 145-150
[7] Shaaban RM, Ahmed ZA and Godaymi WA 2016 Radiation patterns account of a circularmicrostrip antenna loaded two annular *Journal of Natural Sciences Research***6** p 71-81
[8] Gomez-Tagle J and Christodoulou CG 1997 Extended cavity model analysis of stacked microstrip ring antennas *IEEE Transactions on Antennas and Propagation* **45**p 1626-1635
[9] Mahajan M, Khah SK and Chakravarty T 2006 Extended cavity model analysis of stacked circular disc *Progress In Electromagnetics Research* **65** p 287-308
[10] Trivedi RD and Dwivedi V 2012 *Int. Conf.In Communication Systems and Network Technologies (CSNT)* Stacked microstrip patch antenna: gain and bandwidth improvement, effect of patch rotation *IEEE***11** p 45-48
[11] Lee RQ, Lee KF and Bobinchak J 1987 Characteristics of a two-layer electromagnetically coupled rectangular patch antenna *Electronics letters***23** p 1070-1072
[12] Pedra AC, Bulla G, Serafini P, Fernandez CR, Monser G and de Salles AA 2007 *Int. Conf. In Microwave and Optoelectronics* Bandwidth and size optimisation of a wide-band E-shaped patch antenna *SBMO/IEEE MTT-S* p 422-426
[13] Hienonen S, Lehto A and Raisanen AV 1999*Int. Symp. In Antennas and Propagation Society*Simple broadband dual-polarized aperture-coupled microstrip antenna *IEEE***2** p 1228-1231
[14] Gao SC, Li LW, Leong MS and Yeo TS 2002 Wide-band microstrip antenna with an H- shaped coupling aperture *IEEE Transactions on vehicular technology* **51** p17-27
[15] Padhi SK, Karmakar NC, Law CL and Aditya S 2003 A dual polarized aperture coupled circular patch antenna using a C-shaped coupling slot *IEEE transactions on antennas and propagation* **51** p 3295-3298
[16] Chen ZN 2009 Aperture-coupled asymmetrical C-shaped slot microstrip antenna for circular polarisation *IET microwaves, antennas & propagation* **3** p 372-378
[17] Deb A, Roy JS and Gupta B 2011 Design of microstrip antennas using differential evolution algorithm *International Journal of Information Systems and Communication* **1** p 1-14

[18] Hall PS 1987 Probe compensation in thick microstrip patches *Electronics Letters* **23** p606-607
[19] Lee KF, Luk KM, Tong KF, Shum SM, Huynh T and Lee RQ 1997 Experimental and simulation studies of the coaxially fed U-slot rectangular patch antenna *IEE Proceedings-Microwaves, Antennas and Propagation* **144** p354-358
[20] Khandelwal MK, Kanaujia BK, Dwari S, Kumar S and Gautam AK 2014 Analysis and design of wide band Microstrip-line-fed antenna with defected ground structure for Ku band applications *AEU-International Journal of Electronics and Communications* **68** p951-957
[21] Yang F, Zhang XX, Ye X and Rahmat-Samii Y 2001 Wide-band E-shaped patch antennas for wireless communications *IEEE transactions on antennas and propagation* **49** p 1094-1100
[22] Deshmukh AA and Kumar G 2005 Compact broadband E-shaped microstrip antennas *Electronics Letters* **41** p 989-990
[23] Ang BK and Chung BK 2007 A wideband E-shaped microstrip patch antenna for 5-6 GHz wireless communications *Progress In Electromagnetics Research* **75** p 397-407
[24] Deshmukh V and Mishra A 2014 Analysis &designing of E-shape microstrip antenna with slot for Ism band *IMPACT: International Journal of Research in Engineering & Technology* **2** p 41-48
[25] Hillyard P, Qi C, Al-Husseiny A, Durgin GD and Patwari N 2017 *InRFID (RFID)Int. Conf.IEEE International Conference* Focusing through walls: An E-shaped patch antenna improves whole-home radio tomography *IEEE* p 174-181
[26] Chair R, Mak CL, Lee KF, Luk KM and Kishk AA 2005 Miniature wide-band half U-slot and half E-shaped patch antennas *IEEE transactions on antennas and propagation* **53** p 2645-2652
[27] Islam MT, Misran N, Shakib MN and Yatim B 2008 *Int. Conf. In Communication Systems ICCS Singapore* Analysis of L-probe fed slotted microstrip patch antenna *IEEE* p 380-383
[28] Balanis CA 2005 *Antenna Theory Analysis and Design* 3rd, Wiley