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A New Microstrip Planar Antenna with Super Wide Bandwidth

Mohamad AKBARI [1] Jafar KHALILPOUR [2] Mojtaba MIGHANI [3] Marjan MARBOUTI [4]

[1] Young Researchers and Elite club, Central Tehran Branch, Islamic Azad University, Tehran, Iran
[2] Faculty of Electrical Engineering, Aeronautical University of Science &Technology, Tehran, Iran
[3] Faculty of Electrical Engineering, Aeronautical University of Science &Technology, Tehran, Iran
[4] Young Researchers and Elite club, Central Tehran Branch, Islamic Azad University, Tehran, Iran

*Corresponding author:
E-mail: Akbari.telecom@gmail.com

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Abstract

A novel planar monopole antenna with Ultra-Wideband characteristics is proposed. The antenna has a very wide bandwidth that easily covers the requirements for Ultra Wideband applications. The radiation patterns results indicate that the proposed antenna has omni-directional radiation pattern in the H-plane while it is directional in the E-plane which across a major portion of its bandwidth.

Keywords: microstrip, monopole antenna, super wide band, very wide band.

INTRODUCTION

Since wireless communication applications need more and more bandwidth, there has been continued increase in demand for wideband antennas. Various wideband antennas have found important applications in both military and commercial systems. For examples, the Super Wideband (SWB) antenna is a key component of electronic counterwork equipment in the electronic information warfare; while the Ultra Wide Band (UWB) antenna is widely used in various radars and has attracted much attention for communication systems due to its high speed data rate and excellent immunity to multi–path interference. Since the Federal Communications Commission (FCC) allocated the frequency band from 3.1 to 10.6 GHz for UWB radio applications, there has been a good opportunity for antenna designers to overcome in one of the challenging tasks in these systems [1]. The Ultra Wide Band frequency range defined by FCC has a ratio bandwidth of 3.4:1, while the antenna with a ratio bandwidth not less than 10:1 is generally called the SWB antenna in antenna engineering. UWB antenna design has been studied much in recent years [2–15]. Microstrip patch antennas because of offering antennas with low cost, low profile, light weight and ease of fabrication are popular. In addition, compatibility with printed circuit board (PCB) technology making it possible to integrate the antenna with the RF circuits on the same board. These features make microstrip antennas very popular for wireless communications systems. However, a microstrip patch antenna has a limited bandwidth. To overcome this drawback, several techniques have been explored including slot monopole antenna [2–8], backed conduct resonator [9], partial ground plane [10]. Suitable UWB antennas must cover FCC definition for the indoor and handheld UWB applications, have electrically small size, and hold a reasonable impedance match and non-directional radiation patterns over the entire band. Our goal is to maximize the bandwidth of the antenna with a small size, simple configuration and low fabrication cost. The proposed antenna originates from conventional rectangular monopole and realized by adding slots for patch radiator, ground plane and feeding structure. A simple microstrip line is used to feed the proposed antenna. Techniques to expand the impedance bandwidth of a simple rectangular monopole antenna are given. In this design, the use of slots in feeding structure which cause to make a trident shape feed line, serves as an effective technique to obtain the super impedance bandwidth ranges (3 up to more than 40 GHz) for 10 dB return loss. Patterns in the FCC defined UWB band in both E–plane and H–plane have been measured and presented. The proposed antenna exhibits a nearly omnidirectional radiation characteristic over the most fractional bandwidth of interest. Both Ansoft high frequency simulation structure (HFSS) [17] and computer simulation technology (CST) [18] three-dimensional (3−D) electromagnetic (EM) simulators are used to optimize the proposed design. The proposed antenna was successfully implemented and the simulated results show reasonable agreement with the measured results.

Antenna structure and design

A new microstrip patch structure is proposed here which is based on the recent work in UWB antenna design [12]. The antenna herein has wider bandwidth and is (~ 12%) smaller than the antenna presented in Ref [12]. The broad aim of designing the proposed antenna is to operate at the FCC defined frequency range. Also we have insight to design antenna for higher frequencies above the FCC band which is used in various applications. For example, for fixed satellite service in the Ku band or the mobile satellite service receiver in the Ka band. The structure of the proposed antenna comprises of an octagonal patch attached to a small inverted triangle with two truncated slots that is subsequently connected to a 50 Ω connector through a simple microstrip line. On the other side of the dielectric substrate, a partial ground plane of width Lg1 and length Wsub is printed below the microstrip feed line. The antenna is located in x–y plane and the normal direction is parallel to z–axis. Configuration of the proposed antenna with optimal parameters is depicted in Figure 1. In order to maintain a 50Ω match the microstrip line of the feeding structure has a signal line width, W_{feed}, of 2mm and length, L_{feed}, of 10.5 mm. The total size (Wsub×Lsub) of the proposed antenna is 28 × 26 mm^2 which is fabricated on an inexpensive FR4 microwave substrate with a thickness (h) of 1.6 mm and relative dielectric constant of 4.4, loss tangent $\tan\delta = 0.02$. Modification is introduced on the patch radiator, feeding structure, and ground plane to improve its operating bandwidth. To achieve wider bandwidth corners of the rectangular patch radiator is removed and reshaped to the octagonal patch. On the other hand, the partially ground plane plays an important role in the band broadening characteristics of this antenna because it helps match the patch with the feed line in a wide range of frequencies. A small rectangular–shaped on the ground plane, under the feed line in the vicinity of the patch, is removed to enhance the bandwidth. Based on simulation, the rectangular–shaped notch is used to control the impedance bandwidth and return loss level by producing nearly pure resistive input impedance. The rectangular–shaped notch on the ground is 3 mm width (W_f) and 1.3 mm length (L_f). Also inserting two triangle slots on both corner side of microstrip feed line on the ground plane cause to achieve even more impedance bandwidth. Note that the maximum bandwidth is obtained using trident shape feeding structure. To design the UWB antenna, we have applied five techniques to the proposed antenna: the use of (i) octagonal patch, (ii) partially ground plane, (iii) a single rectangular notch on the ground plane, (iv) triangular slots on the ground plane, and (v) a trident shaped feeding structure which can lead to an excellent impedance matching. By properly selecting these parameters, the proposed antenna can create the super wide bandwidth and also can be tuned to operate in various frequency ranges. The final dimensions of the proposed antenna are presented in Table I. Figure 2 exhibit the top and the bottom view of the fabricated antenna. The fabricated antenna has a compact structure [12], and the total size is 28×26 mm^2.

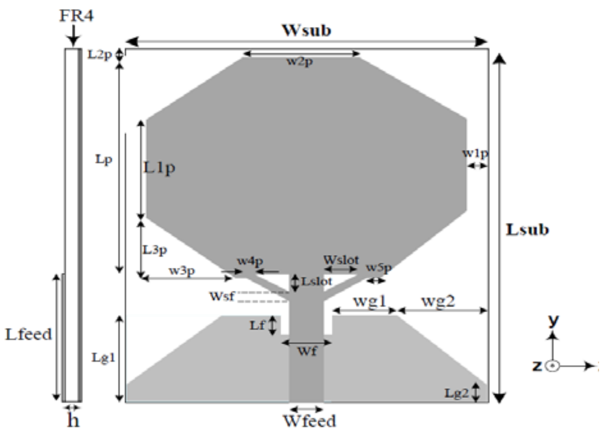

Fig. 1. The antenna geometry and its design parameters.

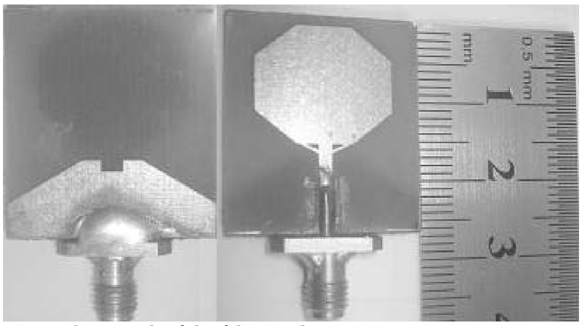

Fig. 2. Photograph of the fabricated antenna.

Table I. The optimal dimensions of the proposed antenna (unit: mm).

W_{sub}	L_{sub}	W_{sf}	W_{1p}	W_{2p}	W_{3p}	W_{4p}	W_{5p}
28	26	0.4	4	8	6	0.7	0.5
W_{slot}	L_{slot}	L_p	L_{1p}	L_{2p}	L_{3p}	W_{g1}	W_{g2}
1.8	0.6	14.5	6.5	1	4	2.5	10
W_f	W_{feed}	L_{feed}	L_f	L_{g1}	L_{g2}	h	
3	2	10.5	1.3	9	4	1.6	

MEASUREMENT RESULTS AND DISCUSSIONS

At the beginning of this section to obtain the optimum performance from the antenna, design procedure of the proposed monopole antenna with simulated return loss curves is studied. Note that the proposed structure was simulated using Ansoft HFSS solver. As will be shown below the performance of the proposed antenna is mainly affected by its geometrical parameters, i.e. radiator shape, ground plane structure and feeding structure. First, the effect of varying the radiated patch and feed line on the impedance bandwidth is studied. Figure 3 shows the structure of three antennas. The simulated return loss curves for rectangular patch, octagonal patch, and proposed antenna is shown in Figure 4. It can be seen that the antenna with rectangular patch is only able to achieve an impedance bandwidth with a lower and upper edge frequency of 3 GHz and 6.8 GHz, respectively. It is also observed that using the octagonal patch cannot cover frequency range from 13.2 to 15.8 GHz. It is therefore clear that the best performance is achieved by using a trident shaped feed line structure connecting to octagonal patch as displayed in Figure 3(c). As shown in Figure 4, covering more than FCC defined frequency range is obtained.

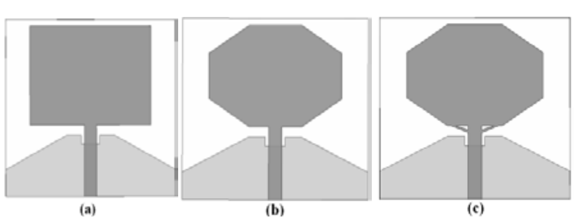

Fig. 3. (a) The antenna with rectangular patch (b) The antenna with octagonal patch (c) The proposed antenna.

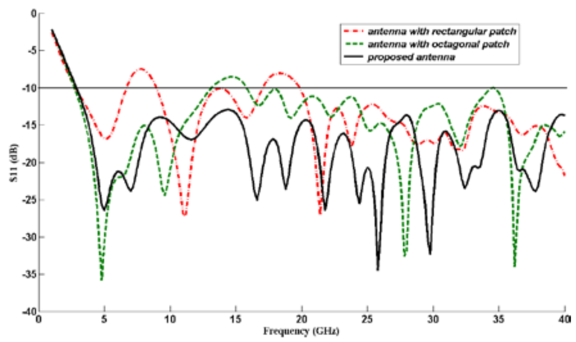

Fig. 4. Simulated return loss for the antennas shown in Fig.3.

On the other hand, current density distribution on the antenna was also computed to determine the location of the slots. Note that due to rectangular patch cannot cover frequency range from 6.8 up to 9 GHz; the current distribution is computed at 8 GHz to show the effect of the slots through investigating the RF currents. Three types of antennas which one has a rectangular patch and the two others have an octagonal patch with different feed lines are studied. Figure 5 shows the distribution of the current vectors over the patch radiator and feed line. The current distribution on the patch radiator suggests that the radiator patch has a significant effect on the antenna impedance bandwidth.

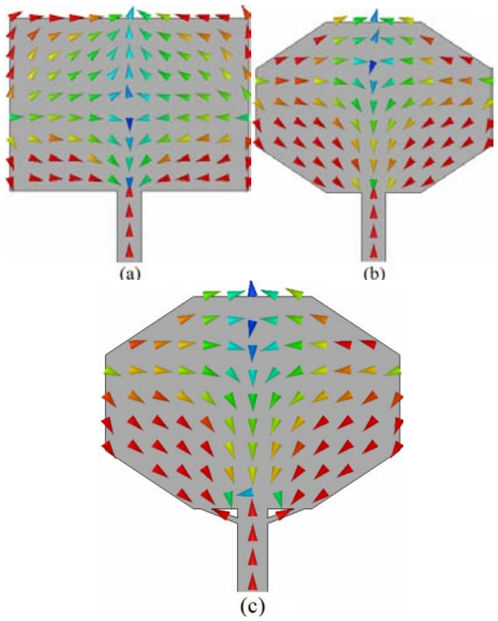

Fig. 5. Current distribution vectors over the antenna with: (a) rectangular patch (b) octagonal patch-single feed, (c) octagonal patch-trident shaped feed.

As shown in Figure 5(a), the current distribution on the patch is mostly concentrated around the upper and lower corners along the edges of the rectangular shaped patch which means directly affect the impedance matching. So cutting corners to the primary structure changes the current distributions on the radiator, and the electrical fields on the patch, which makes it easier to match the antenna in a very large frequency band. Therefore, the radiator patch is designed to have non–rectangular shape by cutting the upper and lower corners of the rectangular shape to create radiating element in the shape of an octagon. As mentioned above, the antenna with rectangular patch cannot cover more than 6.8 GHz. Figure 4 shows that with transforming the rectangular patch to octagonal patch covering more frequency range is obtained. As illustrated in Figure 5(c), it can be seen that compared to the case of the proposed antenna with single feed line (shown in Figure 5(b)), the major effect of the inserted slots in the feeding structure is to produce three different current paths, and thus seem to effectively excite more resonant modes. This clearly results in a bandwidth enhancement of the proposed antenna by overlapping these resonant modes [15]. To have a wider impedance bandwidth, the slots position needs to be well optimized. In next stage, to examine the effect of the ground plane shape on the antenna impedance matching performance, various ground plane shape is studied. Figure 6 shows the structure of three antennas with various ground plane structure. The characteristics of three designs, namely with notch and without any notch on the ground are compared to understand the function of the notch in the design. Figure 7 shows the return loss response of the antenna through the truncation of the ground plane notches. It can be seen that the impedance bandwidth of the antenna without any notch on the ground plane (shown in Figure 6(a)) is destroyed from 7.8 to 10.2 GHz and 14.2 to 16.7 GHz and cannot cover the UWB impedance bandwidth defined by FCC. Also it is seen in Figure 6(b) that for the antenna with rectangular notch on the ground plane from 8 to 9 GHz and 13.5 to 15.3 the matching became poor. Therefore, by tapering the upper sides of the truncated ground (shown in Figure 6(c)) the best performance is achieved. This is evident in Figure 7, which shows that more than the FCC UWB band is fully covered. To validate the design, the proposed antenna has been constructed based on dimensions presented in Table 1. The return loss of the antenna has been measured using an Agilent E8363B network analyzer in its full operational span (50 MHz–40 GHz). The antenna is fed through a sub miniature version A (SMA) connector. The simulated and measured return losses of the fabricated antenna are shown in Figure 8. The results show that the antenna impedance bandwidth extends from 3 to more than 40 GHz, exceeds 172%, covering more than FCC defined frequency band and confirm the antenna shows SWB characteristic. This behaviour almost was predicted from HFSS and CST simulations. As Figure 8 depicts, the antenna return loss curve has several resonance frequencies which are scattered widely over the entire frequency range and overlapping among them results in the antenna showing a super wide impedance matching. Reasonable agreement between simulated and measured results is observed and the difference between them may be from SMA connector effects and fabrication imperfections. It should be noted that the FR4 substrate is a lossy substrate that losses increase rapidly at high frequency especially over 15 GHz, which means that the difference between measure and simulation results over the band 15–40 GHz can be from this reason. The y–z plane and the x–z plane are selected to show the antenna radiation patterns referred to as E–plane and H–plane, respectively. Figure 9 show the antenna normalized radiation pattern at 5.3, 7, and 10 GHz. It is clear that in the UWB band the proposed antenna has an acceptable non-directional radiation pattern required to receive information signals from all directions.

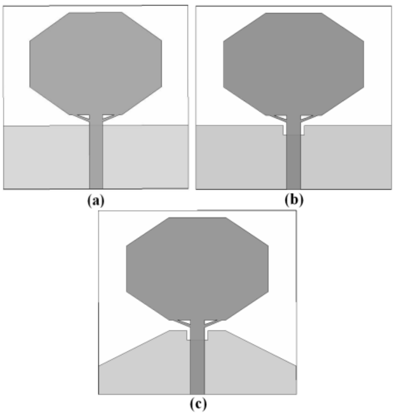

Fig. 6. Ground plane of (a) The antenna without notch (b) The antenna with rectangular notch (c) The proposed antenna.

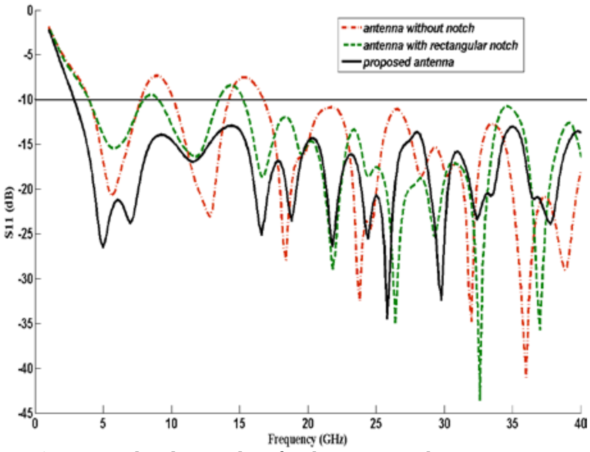

Fig. 7. Simulated return loss for the antennas shown in Fig.6.

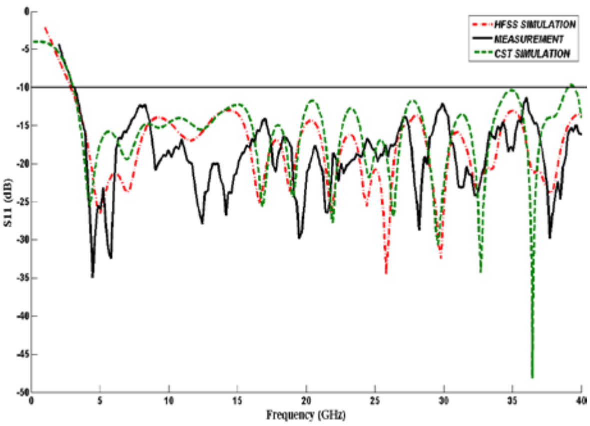

Fig. 8. Measured and simulated return loss of the fabricated antenna.

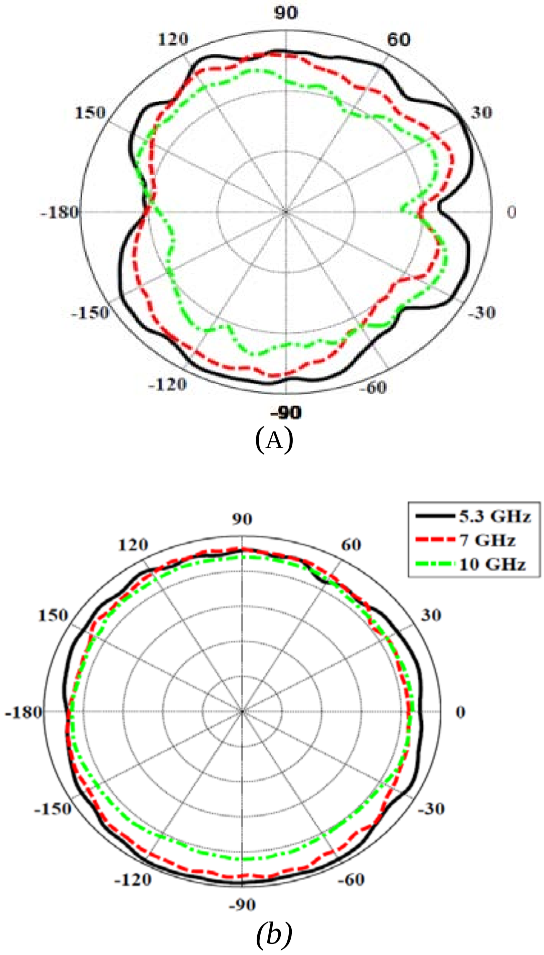

Fig. 9. Measured normalized radiation pattern of the antenna at (a) H-plane, (b) E-plane.

CONCLUSION

A new planar monopole antenna is proposed for UWB applications. The HFSS and CST‒B EM simulator is employed for design simulation. The antenna structure is simple and the total size is compact. Broad impedance bandwidth and stable radiation patterns is obtained. The results show that the return loss extends from 3 GHz to more than 40 GHz. This super wideband property is achieved by applying various impedance matching techniques of using partial ground plane and creating slots at the ground, radiator and feeding structure. The measured radiation patterns indicate that the antenna radiates non-directional in the H–plane and bidirectional in the E–plane through the UWB band defined by FCC. Compared with the recently proposed antennas, this antenna has advantages in super wide bandwidth, compact in size, low cost and easy fabrication. Accordingly, the proposed antenna is expected to find applications in future UWB communications and other UWB military systems.

REFERENCES

[1] Federal Communications Commission, First Report and Order on Ultra-Wideband Technology, FCC 02-48, Washington, DC, 22nd April, 2002.

[2] Sadat, S., M. Fardis, F. Geran, and G. Dadashzadeh, "A compact microstrip square-ring slot antenna for UWB applications," Progress In Electromagnetics Research, PIER 67, 173–179, 2007.

[3] Kharakhili, F. G., M. Fardis, G. Dadashzadeh, A. Ahmadi, andN. Hojjat, "Circular slot with a novel circular microstrip open endedmicrostrip feed for UWB applications," Progress In Electromagnetics Research, PIER 68, 161–167, 2007.

[4] M. Koohestani, M. Golpour, 'Compact rectangular slot antenna with a novel coplanar waveguide fed diamond patch for ultra wideband applications', Microw. Opt. Tech. Lett., Vol. 52, no.2, pp. 331–334, 2010.

[5] Zhang, G.-M.,J.-S. Hong,and B.-Z. Wang,"Tw o novel bandnotched UWB slot antennas fed by microstrip line," Progress In Electromagnetics Research,PIER 78,209–218,2008.

[6] Fallahi, R. ,A.-A. Kalteh,and M. G. Roozbahani,"A novel UWB elliptical slot antenna with band-notched characteristics," Progress In Electromagnetics Research,PIER 82,127–136,2008.

[7] Shi-Wei Qu, Chengli Ruan and Bing-Zhong Wang., 'Bandwidth Enhancement of Wide-Slot Antenna Fed by CPW and Microstrip Line'. IEEE Antennas and Wirel. Propag. Lett. Vol. 5, pp. 15–17, 2006.

[8] Jin-Sen Chen., 'Studies of CPW–Fed Equilateral Triangular–Ring Slot Antennas and Triangular–Ring Slot Coupled Patch Antennas'. IEEE Trans. on Antennas and Propag., Vol. 53, pp. 2208–2211, 2005.

[9] R. Zaker, C. Ghobadi, J. Nourinia, 'Novel modified UWB plannar monopole antenna with variable frequency bandwidth function,' IEEE antennas wirel. Propag. Lett., Vol. 7, pp.112–114, 2008.

[10] M.N. Moghadasi, M. Koohestani, R.A. Sadeghzadeh, 'Compact microstrip–fed ultra–wideband antenna with novel radiating element', Microw. Opt. Tech. Lett., Vol. 52, pp. 2267–2269, 2009.

[11] W. Jian Liu, Q.X. Chu, 'Planar Disc Super Wide Band Antennas with C-like Slots'. IEEE ICMMT proceeding, pp. 1901–1904, 2010.

[12] M. N. Moghadasi, G. R. Dadashzadeh, M. Abdolahvand, Y. Zehforoosh and B. S. Virdee, 'Planar triangular monopole antenna with multioctave bandwidth', Microw. Opt. Tech. Lett., Vol. 53, no.1, pp. 10–14, 2011.

[13] M. Koohestani, M. Golpour, 'U–shaped microstrip patch antenna with novel parasitic tuning stubs for ultra wideband applications,' IET Microw. Antennas Propag., Vol. 4, pp.938–946, 2010.

[14] Kyungho Chung, Jaemoung Kim and Jaehoon Choi., 'Wideband Microstrip–Fed Monopole Antenna Having Frequency Band- Notch Function'. IEEE Microw. and Wirel. Comp. Lett., Vol. 15, pp. 766–768, 2005.

[15] B.L. Ooi, G. Zhaho, M.S. Leong, K.M. Chua, C.W. Lu Albert, 'Wideband LTCC CPW–fed two–layered monopole antenna', Electron. Lett., Vol. 41, no. 16, pp.9–10, 2005.

[16]P. Li, J. Liang and X. Chen, 'Study of printed elliptical/circular slot antennas for ultra wideband applications,' IEEE Trans. on Antennas Propag., vol. 54, no.6, pp.1670-1675, 2006.

[17] Ansoft HFSS User's manual. Ansoft Corporation, Beta Release 11, 2007.

[18] CST Microwave Studio, ver. 2008, Computer Simulation Technology, Framingham, MA, 2008.