



UWB printed monopole antenna with a notch frequency for coexistence with IEEE 802.11a WLAN devices

Rakhesh Singh Kshetrimayum, *Member, IEEE*, Jyoti Ranjan Panda and Ramu Pillalamarri
Radio Systems Laboratory, Department of Electronics and Communication Engineering,
Indian Institute of Technology, Guwahati, India, 781039. Email: krs@iitg.ernet.in

Abstract- In this paper, we have investigated a printed modified circular disc monopole antenna with cross-shaped slot in radiating patch for UWB applications. The proposed antenna covers the entire UWB band (i.e., 3.1GHz to 10.6GHz) except the frequency band of IEEE 802.11a (i.e., from 5.15GHz to 5.83GHz). This UWB antenna will be of use in environments where IEEE 802.11a WLAN devices are already in operation, such UWB antenna could coexist with IEEE 802.11a devices without any interference. Simple rectangular microstrip line is used for feeding the printed monopole antenna. We have simulated modified circular disk monopole antenna with cross-shaped slot using Zeland IE3D software and it has been observed that the notch frequency response of the antenna can be adjusted by the changing the position of the cross-shaped slot in the radiating patch.

I INTRODUCTION

In order to coexist with the IEEE 802.11a WLAN devices [1-2], which operate in the frequency region 5.150-5.825GHz, we will design an UWB antenna with a notch frequency response in the above said frequency range. In antenna engineer's terminology, this basically means that we will design an antenna which has a return loss less than -10dB throughout the UWB frequency 3.10-10.6GHz except at the frequency region 5.150-5.825GHz where the return loss should be greater than -10dB. Such antenna will allow both the UWB devices and IEEE 802.11a WLAN devices to coexist without any interference.

Research works along this direction is not new, many researchers across the globe has proposed many UWB antennas with the notch frequency for such applications [3-27]. In just a short span of 5 years, 2003-2008, there is a lot research works carried out in this area across the globe revealing that this is one of the bottlenecks for wide spread use of UWB technology. Seeing the gravity of the situation, we have come up with a new proposal for such UWB antenna with notch frequency for UWB radio applications for coexistence with IEEE 802.11a devices. Our UWB printed monopole antenna is compact, efficient and is a different structure from the existing notch frequency response UWB antennas. Besides it is less fragile and planar since the whole antenna structure is printed on FR4 board.

In this paper, we have investigated and proposed a modified circular disc with cross-shaped slot UWB antenna having a notch frequency response for cooperative radio applications. This proposed UWB antenna covers the entire UWB band except the frequency band of IEEE 802.11a to avoid interference or to coexist with IEEE 802.11a WLAN devices. It has been observed that the notch frequency can be adjusted by changing the position of the cross-shaped slot in the radiating patch and the antenna impedance can be adjusted by the feed gap between the radiating patch and the ground plane. This antenna has two bands of frequencies or bandwidths (BW1 and BW2). After an extensive simulation study, the final dimensions are determined and various parameters of antennas are tabulated. The UWB antenna is designed on FR4 substrate with dielectric constant of 4.4 and thickness of 1.6mm. In this modified circular UWB antenna with cross-shaped slot, the notch frequency can be adjusted by the position of the cross-shape slot accurately. The paper is structured in the following way. First we will investigate in depth the various antenna parameters based on the physical structure of modified circular disk printed monopole antenna as shown Fig. 1. We have used conventional rectangular microstrip lines as feed lines for printed UWB antennas which are properly matched to the antenna impedance. Zeland IE3D simulation software [28] has been employed for obtaining the simulation results.

II. GEOMETRY AND SIMULATION RESULTS OF UWB MONOPOLE ANTENNA WITH NOTCH FREQUENCY RESPONSE

The modified circular disc UWB antenna is designed on a FR4 substrate with 4.4 relative permittivity and 1.6 mm thickness. The final structure and dimensions (in mm) of the UWB antenna are shown in Fig. 1. At the particular value of g (at $g=1\text{mm}$), the antenna impedance, two band of frequencies i.e., BW1 ($f_{\text{low}1}$ and $f_{\text{high}1}$) and BW2 ($f_{\text{low}2}$ and $f_{\text{high}2}$), here the f_{low} is the lower start frequency of the antenna BW and the f_{high} is the higher end frequency of the antenna BW, and radiation efficiency are tabulated in table I. It has been observed that the gap (g) between the radiating patch and the ground plane below is the most crucial parameter for getting a broad BW as well as

proper impedance matching to maximize the antenna radiation efficiency. The optimized value of g is 1.0mm.

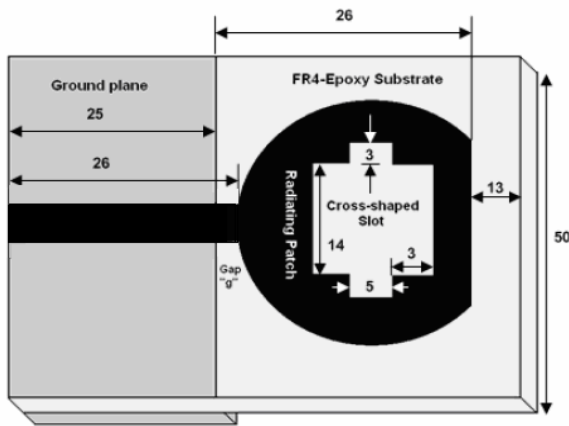


Fig. 1 Geometry of the modified circular disc UWB monopole antenna

As we can see clearly from return loss and VSWR vs frequency plots of the patch antenna in Fig. 2, the bandwidth of UWB antenna is from 2.1GHz to 11.26GHz including notch frequency response. The notch frequency response is from 5.05GHz to 5.81GHz. Due to this notch frequency response, there are two bandwidth of the UWB antenna. Lower frequency bandwidth (BW1) is starting from 2.1GHz to 5.05GHz and the upper frequency bandwidth (BW2) is starting from 5.81GHz to 11.26GHz. Note that the solution frequency was chosen as 8.5GHz for the simulation result of Fig. 2.

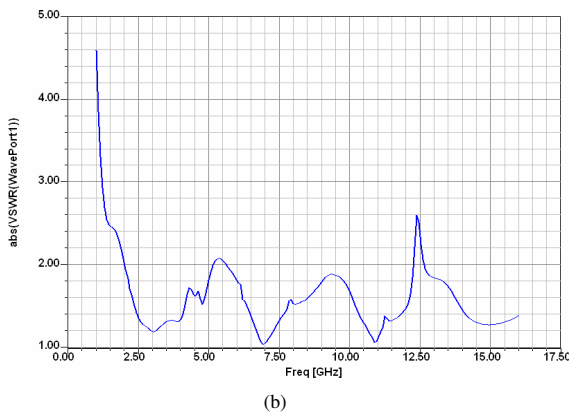
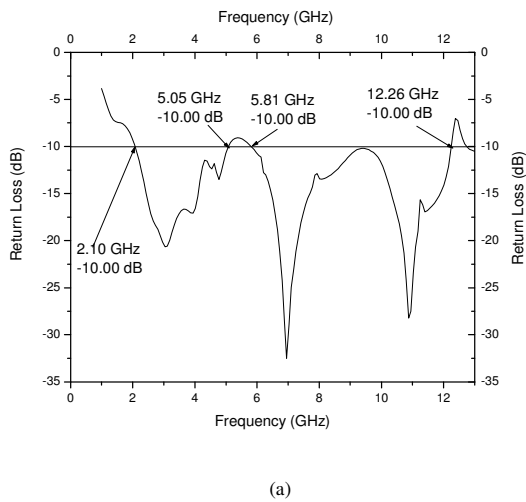


Fig. 2 (a) s_{11} and (b) VSWR versus frequency plot of the modified circular disc UWB monopole antenna (BW is from 2.1GHz to 12.4 GHz)

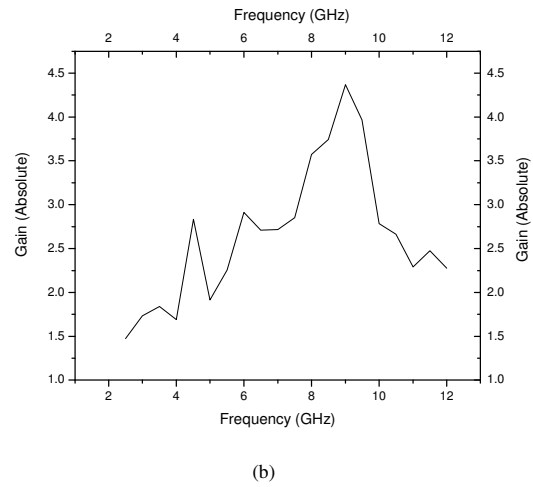
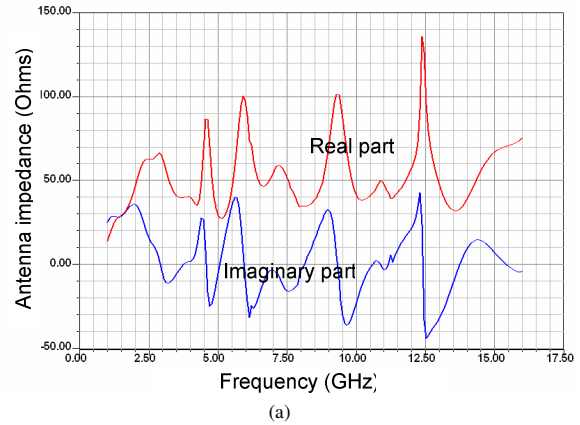


Fig. 3 (a) Antenna impedance and (b) gain (absolute) versus frequency of the modified circular disc UWB monopole antenna

TABLE-I Antenna bandwidth of the circular disc UWB monopole antenna vs solution frequency

Solution Frequency (GHz)	f_{low1}	f_{high1}	f_{low2}	f_{high2}
4.50	2.20	4.62	6.10	12.08
6.00	2.66	5.15	6.02	11.58
7.00	2.21	5.50	6.01	13.30
8.50	2.10	5.05	5.81	12.26
10.60	4.26	5.08	5.91	12.66



TABLE-II Antenna parameters of the circular disc UWB monopole antenna vs solution frequency

Antenna Parameters	Solution Frequency (GHz)				
	4.5	6.0	7.0	8.5	10.6
Max U (W/Sr)	0.20969	0.19936	0.19770	0.28078	0.18680
Peak Directivity	3.42750	3.31540	3.04640	4.63610	3.14460
Peak Gain	2.84520	2.76920	2.49220	3.74400	2.38030
Peak Realized Gain	2.63510	2.50530	2.48450	3.52850	2.34740
Radiated Power (W)	0.76881	0.75564	0.81554	0.76110	0.74648
Accepted Power (W)	0.92696	0.90471	0.99688	0.94246	0.98618
Incident Power (W)	1.00000	1.00000	1.00000	1.00000	1.00000
Radiation Efficiency	0.83010	0.83523	0.81810	0.80757	0.75694

obtained from the commercial software, depending on how you choose the simulation parameters; results can vary to some extent. So a fabrication and testing of such UWB notched antennas is inevitable. We have the facilities to fabricate such antennas and we have done a lot of experiments on them also. The reason why we have not fabricated and tested this particular antenna is because our Network Analyzer could give return loss plot vs frequency up to 6 GHz only. We are in the process of getting a new Network Analyzer which can work in the UWB frequency region. Once we have those facilities, we will fabricate and test this antenna to confirm our simulation results. It has also been observed that there is some changes in the various antenna parameters vs frequency as tabulated in Table II.

The question is what the best solution frequency for simulation is. In our opinion, the best solution frequency is usually the center frequency of bandwidth of the patch antenna under consideration. In that case for UWB antenna this frequency should be $(3.10+10.6)/2=6.85\text{GHz}$. Ours is a notched UWB antenna, hence, there are two bandwidths: lower bandwidth (3.1-5.150GHz) and upper bandwidth (5.825-10.6GHz). The center frequencies for the lower and upper bandwidths are 4.125GHz and 8.2125GHz respectively. But we can have only one solution frequency in the software. So which one to choose? Should the solution frequency be either 4.125GHz or 8.2125GHz? 8.2125GHz is the right choice because at higher frequency the wavelength is shorter. Number of discretizations (cells) required per wavelength is usually around 10. So at higher frequency we can have discretization steps smaller and higher accuracy in the simulation results. So from Table I and II, 8.5GHz is the nearest choice of 8.2125GHz, so, the simulation frequency we have chosen is good enough to give accurate results.

Final antenna impedance is exactly 50 Ohms at the designed frequency and the efficiency of the antenna is 80.7%. We have also seen that the ground plane size especially the width of the ground plane and the gap between the radiating patch and ground plane are also important factors in the proper matching of antenna impedance and consequently the strength of BW of the printed monopole antenna. The adjustment of notch frequency is done by varying the position of the cross-shaped slot. The first resonant frequency of the monopole antenna is determined by the diameter of the circular disc which is 26mm. It behaves like a quarter wave monopole antenna. The real part of antenna impedance is exactly 50 Ω at many frequencies within the UWB (at 3.2GHz and 7.8GHz) where the imaginary part of the antenna impedance equals zero as depicted in Fig. 3 (b). So the antenna is multi-resonant within the bandwidth. Throughout the bandwidth of the UWB antenna, the real part of the antenna impedance varies from 30 Ω to 90 Ω whereas the imaginary part of the antenna impedance is in the range -30 Ω to +30 Ω that is not a major variation of the antenna impedance. The gain vs frequency plot in Fig. 3(b) shows that the antenna gain is varying with frequency and maximum gain is achieved around 8.5GHz.

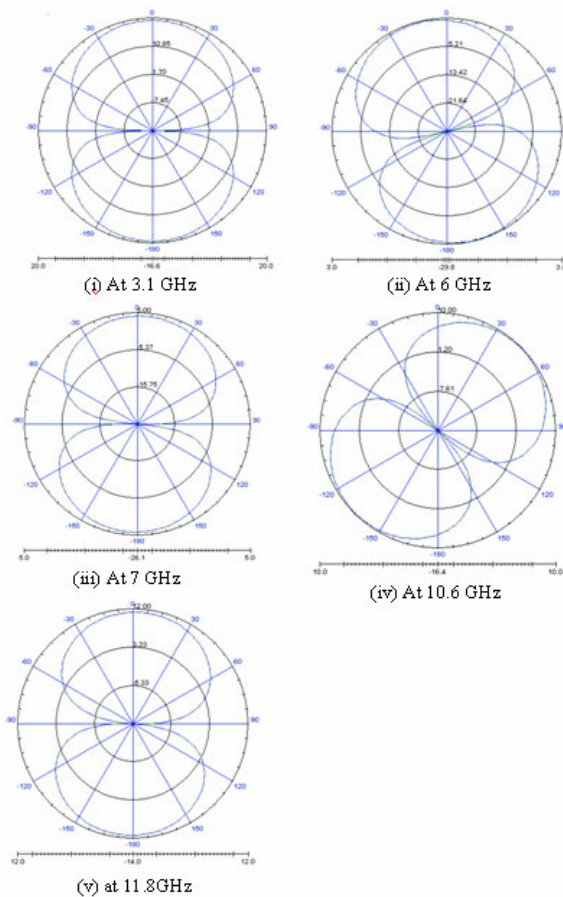


Fig. 4 E-plane radiation patterns of the modified circular disc UWB monopole antenna at different frequencies

We have observed that the return loss versus frequency plot slightly changes with different solution frequency (refer to Table I), although for the ideal case, this should not be like this. Such an observation reveals that we should be careful with the simulation results

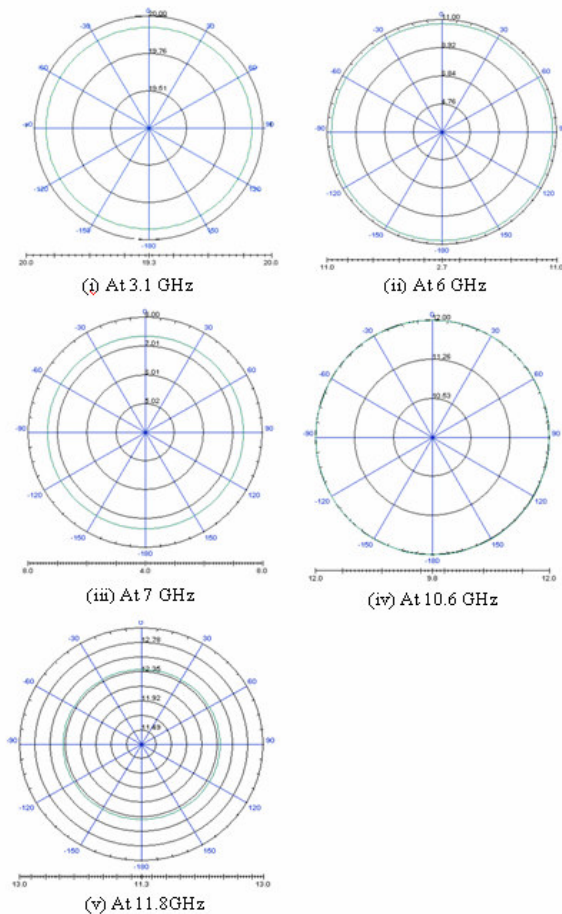


Fig. 5 H-plane radiation patterns of the modified circular disc UWB monopole antenna at different frequencies

The E-plane and H-plane radiation patterns of the modified circular disc UWB monopole antenna at 3.1, 6, 7, 10.6 and 11.8 GHz are shown in Fig. 4 and Fig. 5 respectively. It can be observed that the E-plane radiation pattern is in the shape of 8 throughout the UWB. It has maximum directivity at -15° and -180° at 3.1GHz and at the frequency 7.2GHz; it has been tilted to 10° and -175° . The H-plane radiation pattern on the other hand is purely omnidirectional pattern at 3.1GHz and as frequency increases it is slightly tilted from 5° to 10° .

III. CONCLUSION

In this paper, we have investigated printed modified circular disc UWB monopole antenna with cross-shaped slot in radiating patch for UWB applications. It has been observed that such UWB antennas have a notch frequency function in frequency band of IEEE 802.11a. We can adjust the notch frequency response by varying the position of the slot in the radiating patch. Printed UWB monopole antennas are less fragile, planar and can be integrated with the

integrated circuits unlike other conventional monopole antennas which have non-planar or protruded structures above the ground plane. The E-plane radiation of the printed UWB monopole antenna is in the form of 8 shape and it is slightly tilted to 5° - 10° at different frequencies within the bandwidth of the antenna. The H-plane radiation pattern has omni-directional patterns. It has been observed that such monopole antennas are suitable for UWB operations except the IEEE 802.11a frequency band from the IE3D simulation results. In fact it is an advantage for UWB communications environment where the IEEE 802.11a WLAN devices are already in existence. Both the UWB and IEEE 802.11a WLAN devices could coexist without any interference.

REFERENCES

- [1] Z. N. Chen, Antennas for portable devices, John Wiley & Sons Ltd, 2007.
- [2] B. Allen, M. Dohler, E. E. Okon, W. Q. Malik, A. K. Brown, D. J. Edwards "Ultra-Wideband Antennas and Propagation for Communications, Radar and Imaging", John Wiley & Sons, 2007.
- [3] X. L. Bao and M. J. Ammann, "Printed UWB Antenna with Coupled Slotted Element for Notch-Frequency Function," International Journal of Antennas and Propagation, 2008, 1-7.
- [4] T.-G. Ma and S.-J. Wu, "Ultrawideband Band-Notched Folded Strip Monopole Antenna," IEEE Trans. Ant. Propagat., vol. 55, no. 9, Sep 2007, pp 2473-2479.
- [5] W.-J. Lui, C.-H. Cheng and H.-B. Zhu, "Improved Frequency Notched Ultrawideband Slot Antenna Using Square Ring Resonator," IEEE Trans. Ant. Propagat., vol. 55, no. 9, Sep 2007, pp 2445-2450.
- [6] M. Ding, R. Jin, and J. Geng, "A Frequency Notched Inverted-trapezoid UWB Antenna," PIERS, Vol. 3, No. 7, 2007, pp. 980-983.
- [7] Y.-J. Cho, K.-H. Kim, D.-H. Choi, S.-S. Lee, and S.-O. Park, "A miniature UWB planar monopole antenna with 5-GHz band-rejection filter and the time-domain characteristics," IEEE Trans. Antennas Propag., vol. 54, May 2006, pp. 1453-1460.
- [8] W.-C. Liu and P.-C. Kao, "CPW-fed triangular antenna with a frequency-band notch function for ultra-wide band application," Microwave and Optical Technology Letters, vol. 48, no. 6, 2006, pp. 1032-1035.
- [9] S. W. Qu, J. L. Li, and Q. Xue, "A band-notched ultrawideband printed monopole antenna," IEEE Antennas and Wireless Propagation Letters, vol. 5, no. 1, 2006, pp. 495-498.
- [10] W. J. Lui, C. H. Cheng, and H. B. Zhu, "Compact frequency notched ultrawideband fractal printed slot antenna," IEEE Microw. Wireless Compon. Lett., vol. 16, no. 4, Apr. 2006, pp. 224-226.
- [11] J. N. Lee, J. K. Park and H. W. Song, "A Trapezoidal Ultra-Wideband Antenna Having a Notch Function", International Journal of Microwave and Optical Technology, Vol. 1, No. 2, August 2006.
- [12] J. Kim, C. S. Cho, and J. W. Lee, "5.2 GHz notched ultrawideband antenna using slot-type SRR," Electron. Lett., vol. 42, no. 6, Mar. 2006, pp. 315-316.
- [13] W. S. Lee, D. Z. Kim and K. J. Kim, "Multiple frequency notched planar monopole antenna for multi-band wireless systems," The European Conference on Wireless Technology, 535, Oct., 2005.
- [14] W. S. Lee, W. G. Lim and J. W. Yu, "Multiple band-notched planar monopole antenna for multiband wireless systems," IEEE Microw. Wireless Compon. Lett., vol. 15, Sep. 2005, pp. 576-578.
- [15] W. J. Lui, C. H. Cheng, Y. Cheng and H. Zhu, "Frequency notched ultra-wideband micro-strip slot antenna with fractal tuning stub," Electronics Letters, vol. 41, no. 6, 2005, pp. 294-296.
- [16] K. Chung, J. Kim, and J. Choi, "Wideband microstrip-fed monopole antenna having frequency band-notch function," IEEE



- Microwave and Wireless Components Letters*, vol. 15, no. 11, 2005, pp. 766–768.
- [17] S. H. Lee, J. K. Park and J. N. Lee, "A novel CPW-fed ultra-wideband antenna design," *Microwave Opt. Tech. Lett.*, vol.44, no.5, March 2005, pp.393-396.
- [18] J. Qiu, Z. Du and J. Lu, "A band-notched UWB antenna," *Microwave and Optical Technology Letters*, Vol. 45, No. 2, 2005.
- [19] S.-W. Su, K.-L. Wong, and F.-S. Chang, "Compact printed ultra-wideband slot antenna with a band notched operation," *Microw. Opt. Technol. Lett.*, vol. 45, no. 2, Apr. 2005, pp. 128–130.
- [20] K. H. Kim, Y. J. Cho, S. H. Hwang, and S.-O. Park, "Band notch UWB planar monopole with two parasitic patches," *Electron. Lett.*, vol. 41, no. 14, Jul. 2005, pp 783–785.
- [21] J. Choi, K. Chung and Y. Roh, "Parametric analysis of a band-rejection antenna for UWB application," *Microw. Opt. Technol. Lett.*, vol. 47, no. 3, Nov. 2005, pp. 287–290.
- [22] H. Yoon, H. Kim, K. Chang, Y. J. Yoon and Y. H. Kim, "A study on the UWB antenna with band rejection characteristic," *Proc. IEEE Antennas Propagation Society Int. Symp. Dig.*, 2004, vol. 2, pp. 1784-1787.
- [23] W.-S. Lee and J.-W. Yu, "Frequency-notched wideband planar monopole antenna with a L-shape ground plane", *KJJC-AP/EMC/EMT*, Nov 2004, pp. 49-52.
- [24] A. Kerkhoff and H. Ling, "A parametric study of band-notched UWB planar monopole antenna", *IEEE Antennas and Propagation Society Symposium*, June 2004, vol. 2, pp. 20-25.
- [25] Y. Kim and D. H. Kwon, "CPW-fed planar ultra wideband antenna having a frequency band notch function," *Electronics Letters*, vol. 40, no. 7, April 2004, pp. 403-405.
- [26] A. Kerkhoff and H. Ling, "Design of a planar monopole antenna for use with ultrawideband (UWB) having a band notched characteristic," *Proc. IEEE Antennas Propagation Society Int. Symp. Dig.*, Columbus, OH, USA, 2003, vol. 1, pp. 830-833.
- [27] H. G. Schantz, G. Wolynec and E. M. Myszka, "Frequency notched uwb antennas", *IEEE Conference on Ultra Wideband Systems and Technologies*, Nov. 2003, pp. 214-218.
- [28] IE3D version 10.2, Zeland Corp., Freemont, CA, USA.