ISSN 2321-807X
Volume 12 Number22
Journal of Advances in chemistry

Coplanar Waveguide Fed Hexagonal Shaped Slot Antenna for Breast Tumor Detection

V. Dinesh[1], Dr. G. Murugesan[2]
[1]Assistant Professor, [2] Professor,
[1,2]Department of Electronics and Communication Engineering,
[1,2]Kongu Engineering College,Perundurai,Erode,TamilNadu,India
[1]vdinesh.phd@gmail.com, [2]murugesanece@gmail.com

ABSTRACT

Breast cancer diagnosis is the second most mortal diseases for women in the worldwide. Recently microwave imaging has been the diagnostic techniques applied for the detection of breast cancer, heart stroke detection, brain cancer detection. A microwave imaging system requires an antenna which operates in an ultra wide band frequency range of 3.1 – 10.6 GHz and resonates at single and multiple frequencies. A novel coplanar waveguide fed micro-strip patch antenna is designed for the breast tumor detection based microwave imaging system which is the major objective presented in this paper. The design consists of coplanar waveguide fed hexagon shaped slotted patch antenna with dimension of 25x25x1mm3 and FR4 substrate of dielectric constant 4.4. Parametric analysis is performed and it provides a wide band of 2.3 GHz – 10.7 GHz and a fractional bandwidth of 129%. The design is very suitable for breast tumor detection. It provides a reflection loss of -49.8dB at 7GHz and VSWR <2 over 2.3 GHz – 10.7GHz.

Indexing terms/Keywords

UWB microstrip antenna, VSWR, Return loss, Breast Cancer, slot antenna.

1. INTRODUCTION

Microwave imaging and non-invasive testing of biological structures erstwhile of interest for many years. In recent times microwave imaging has been applied for the detection of breast cancer, heart stroke detection, brain cancer detection. Breast cancer is the most common cancer among American women, except for skin cancers. In survey among the American women 1 in 8 has the invasive breast cancer during their lifetime [1, 2]. As per the survey around 231,840 new cases of invasive breast cancer will be diagnosed in women estimated by the American Cancer Society, USA [3].

Breast cancer diagnosis is the second most mortal diseases for women in the worldwide. Regular mammograms can often required to identify the breast cancer at an early stage, when treatment is most probable to be successful. Breast changes can be found by mammogram testing to know possibility of cancer, years before physical symptoms develop. Identification of cancer for countless decades of research clearly show that women who undergoes regular mammograms are most likely to have breast cancer found early, less likely required an aggressive treatment (like surgery to remove the entire breast [mastectomy] and chemotherapy), and more likely to be cured. Mammograms are not perfect, they miss some cancers and sometimes more tests will be needed to find out if something found on a mammogram is or is not a cancer. There's also a small possibility of organism diagnosed along with cancer that in no way would have caused any problems had it not been found during screening. It's essential that women getting mammograms know what to expect and understand the benefits and limitations of screening. MRI is the another method of screening breast cancer, but there's no evidence right now that MRI is an effective screening tool for women at usual risk. While MRI is more sensitive than mammograms, it also has a higher false positive rate [1,18]. In lieu of X-ray and Mammography, Microwave detection of the breast cancer will be the best diagnostic method for earlier detection of breast cancer. Malignant tumors will have a high dielectric constant as a result of higher water content than the normal tissue. Electromagnetic waves get scattered when it is transmitted over the malignant tumor tissue, these scattered signal is back propagated and analyzed in order to find the location and size of the tumor.

The evaluation of microwave techniques in the screening and diagnosis of breast cancer and in the medical field are discussed [2, 15]. A new algorithm based on Huygens principle is presented which removes the need of solving inverse problems for UWB microwave imaging [7]. A stepped slot at bottom of the substrate is designed to resonate at different frequencies with a open ended feed line at the top of the antenna results in an omni directional pattern [8]. A rectangular microstrip antenna is designed to resonate at 2.45GHz with flexible copper substrate (Pyralux FR9151 CU CLAD) and is examined over breast model, where the designed antennas fractional bandwidth is less than 20% [9]. An UWB differential fed antenna is designed which improves the radiation patterns of the antenna at high frequency [10]. An antipodal planar tapered slot antenna is designed over a Rogers RO4003 substrate, in addition a resistive layer is placed behind its conductive layers in order to minimize the backward radiation [11]. A self complementary Bow Tie antenna is designed for UWB application results in a wider frequency band than the traditional bow tie antenna, but the obtained radiation pattern is not suitable for imaging applications [12]. A Microstrip-Fed "Dark Eyes" Antenna for Near-Field Microwave Sensing was designed with a dual layer planar structure where the feed and radiating element are embedded between the two dielectric layers, results with an increase in thickness of the antenna and reduces the radiation pattern [13]. A CPW fed tapered square monopole antenna and the slot antenna is designed to operate in a lossy coupling medium for breast cancer detection results in an unacceptable return loss over the UWB frequency [14 and 15]. In microwave imaging a new technique of limiting the location of buried object prior to the implementation of the genetic algorithm is proposed using the S11 parameter of the radiating bow tie antenna [16]. A cylindrical array antenna is presented with ultra wideband impulse for beamforming application which decreases the side lobe levels as the function of array elements [17]. A space-time beamforming method for imaging backscattered microwave energy is proposed and demonstrated for detecting millimeter-sized malignant tumors in the breast [18]. A fractal structure is introduced to improve the impedance bandwidth [19].

The breast tumor detection using non ionizing microwave radiation is a non invasive technique in medical diagnosis. Regular screening for tumor detection can able to identify the breast tumor at an early stage[20]. The various types UWB antenna design are discussed [21, 22]. A novel hexagonal shaped Coplanar Waveguide (CPW) fed ultra wideband microstrip patch antenna with circular slot is designed for the breast tumor detection. The hexagonal patch antenna with dimension 25x25x1 mm^3 is designed on the FR4 substrate with dielectric constant of 4.4. It resonates at the 7 GHz and has a fractional bandwidth of 129%. The operating frequency of the designed antenna is better suitable for breast cancer detection and it provides reflection loss of -49 dB at 7 GHz.

2. ANTENNA CONFIGURATION

2.1 Geometry of Hexagonal patch

The simple hexagonal patch antenna geometry is shown in Figure 1. The antenna is printed on the FR4 substrate with the thickness of h = 1mm and relative permittivity of εr = 4.4. The dimensions of the UWB patch antenna are L=25mm, W=25mm, feed length L_f= 8mm, feed width W_f = 3mm, gap= 0.5 mm and the dimensions of the top ground are Gx = 10.5mm, Gy = 7mm respectively. Coplanar waveguide feeding is used in the proposed hexagonal structure to results in a good impedance matching over the UWB system.

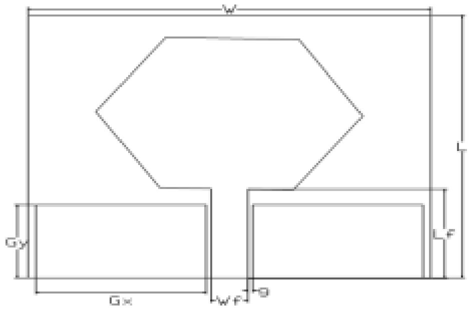


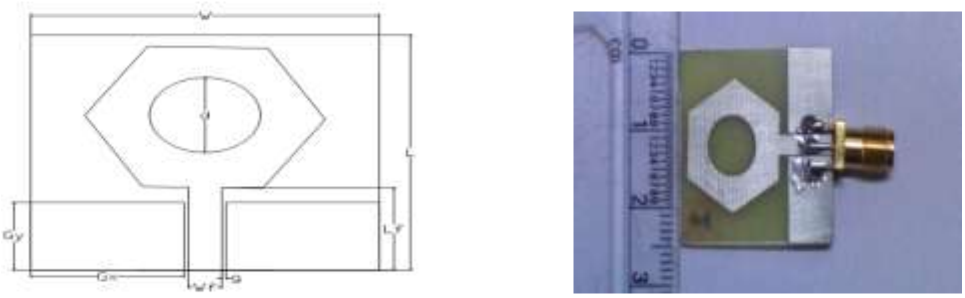
Fig. 1: CPW fed hexagonal patch antenna.

The antenna which operates in a bandwidth more than 500MHz or having a fractional bandwidth > 20% is named as UWB antenna. The proposed antenna is satisfying the UWB antenna requirements of Federal Communications Commission (FCC) standard.

$$\text{Fractional bandwidth} = 2\,\frac{f_h - f_l}{f_h + f_l} \qquad (1)$$

2.2 Geometry of a modified UWB slotted hexagonal patch

The design of the slotted hexagonal patch antenna with design parameters is shown in Figure 2. The proposed antenna comprises of a hexagonal radiator and the coplanar waveguide feed structure as elements. A hexagon patch is printed on the top side of the substrate material and ground plane is printed on either side of the feed line which acts as the CPW fed. The dimensional parameters of the FR4 substrate is L and W, the gap between the coplanar waveguide feed line and the side arm ground plane is g on both the sides, L_f and W_f are the length and width of the coplanar waveguide feed line, G_x and G_y are the ground plane dimensions of the antenna. Miniaturization is the major concern in the design of radio frequency components, regard to this the selection of CPW feeding technique in the design is better suited for integration with MMIC devices and components. A circular slot is introduced in the center of the hexagonal antenna which improves the impedance bandwidth results in a better return loss of about -49dB at the resonance frequency of 7GHz.



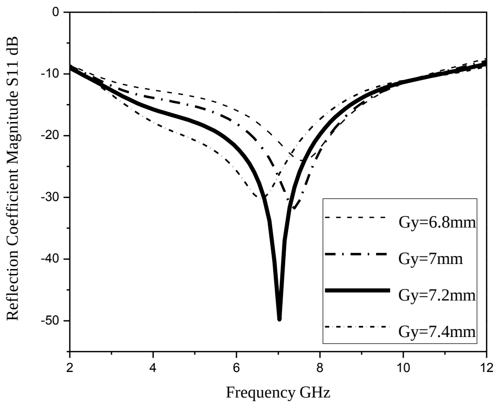
a **b**

Fig. 2(a): Optimized CPW fed hexagonal patch antenna with circular slot.

2(b): Fabricated CPW fed hexagonal patch antenna

2.3 Parametric study of the ground plane optimization

Proper method of feeding technique and ground plane selection gives an improved impedance matching and operational bandwidth. By the invention of surface mounted devices and components, CPW feeding techniques results in an excellent integration with the circuits. The optimized parameters are Gx = 11mm and Gy = 7.2 mm which results in a good performance of the antenna radiator with better return loss at 7 GHz shown in figure 3a and 3b. Several antennas are being designed in the recent years in order to operate in an ultra wide band range [6-14]. The selection of ground plane dimensions will improves the operating bandwidth of the UWB antenna. The parametric study shows that an excellent UWB response is achieved for a certain ground size, beyond which the response starts to degrade.



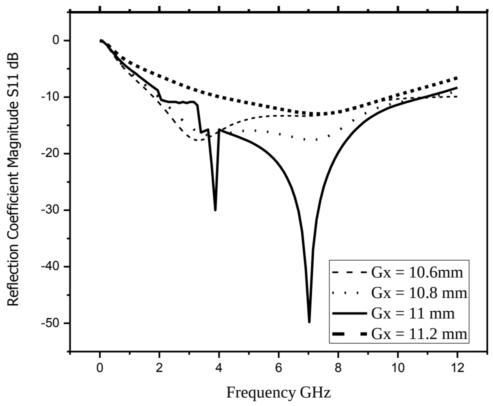


Fig. 3(a): Optimization of ground plane Gy. 3(b): Optimization of ground plane Gx.

2.4 Parametric study of Circular slot

A circular slot of radius is introduced at the center of the hexagonal patch results in an improved impedance bandwidth. The variation of the antenna radius changes current distribution over the patch which results in a better impedance matching over the UWB range. This optimization of the radius of the circular slot on the patch obtains a sharp resonance at 7 GHz and also there is a shift in the resonance at low frequency which is better than simple hexagon patch to cover the entire UWB range shown in figure 4.

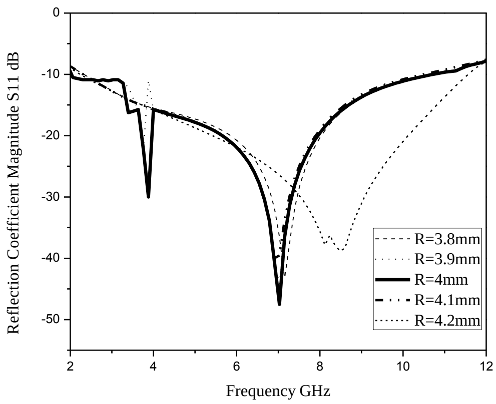


Fig. 4: Optimization of Circular Slot radius R

3. RESULT AND DISCUSSION

The optimizations of the various parameters such as feed width, length and width of the ground plane and slot radius were carried out using HFSS simulation. The hexagonal patch without slot resonates in the UWB range with a fractional bandwidth which satisfies the FCC standard but operates only between 3.1 to 8 GHz obtains a return loss of -30 dB. To improve the operational bandwidth a modified hexagonal patch with slot on the patch is introduced to cover the entire UWB frequency range. By optimization of the antenna slot radius, width of the feed, ground plane length and width obtains a fractional bandwidth of 129% over the operational band of 2.3 to 10.7 GHz shown in figure 5. The modified patch antenna resonates at both lower and higher frequencies so it is suitable for detecting the malignant tumor in the breast. A circular slot is included at the top of the hexagon patch which improves impedance matching of the antenna and obtains a VSWR of less than 2 over UWB band shown in figure 6. The Co and Cross polarization radiation pattern of the antenna at various frequencies and its current distribution of the modified patch are simulated and shown in figure 7 and figure 8.

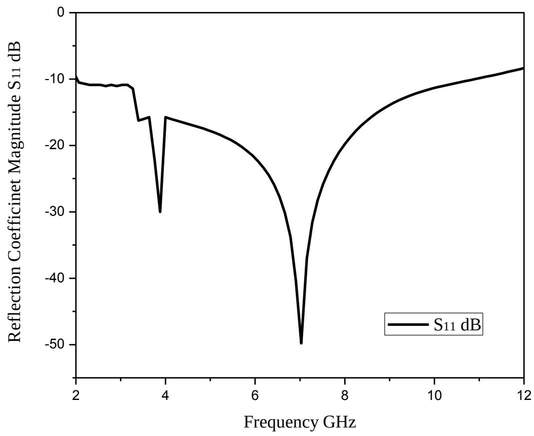


Fig.5: Simulated return loss of Antenna II CPW Hexagonal patch antenna with circular slot of radius R=4mm.

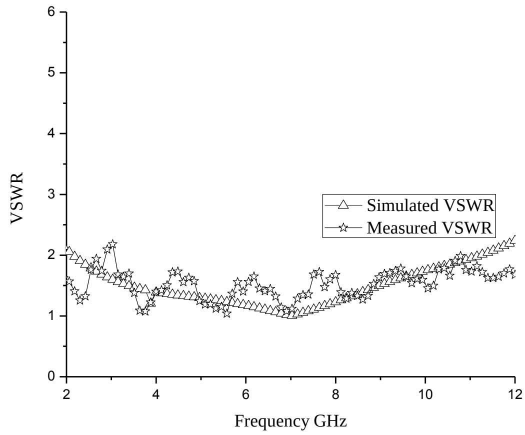
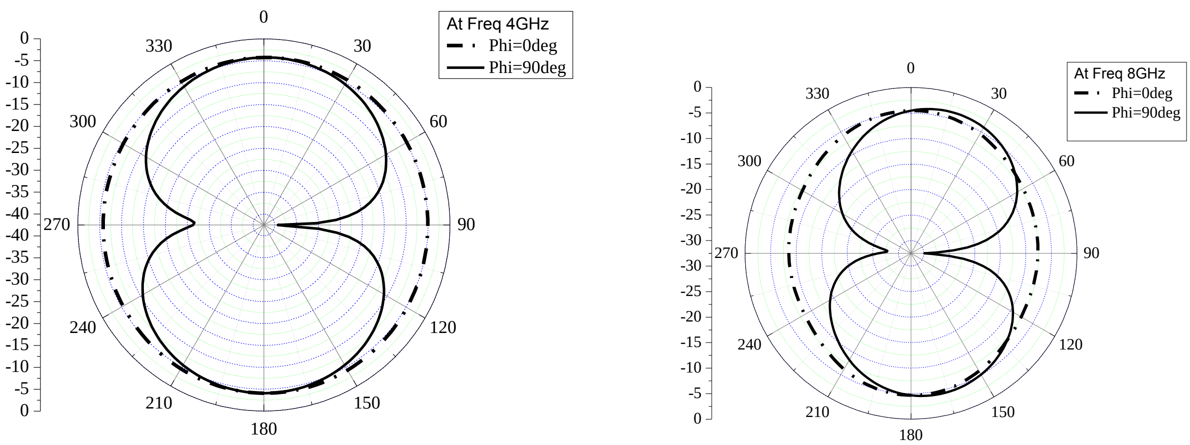
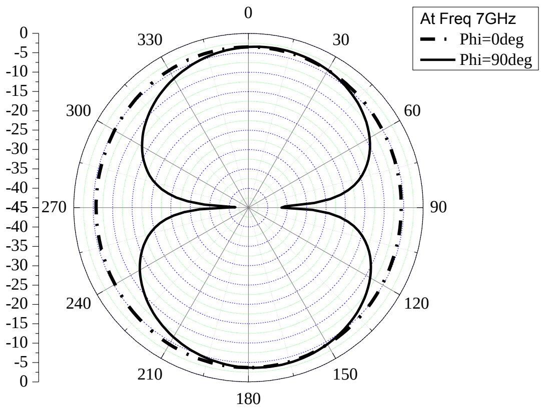


Fig. 6: Simulated VSWR vs Frequency.



a

b



c

Fig 7: Co and Cross polarization radiation pattern of the antenna at resonant frequencies

a.4 GHz b. 7 GHz and c. 8 GHz

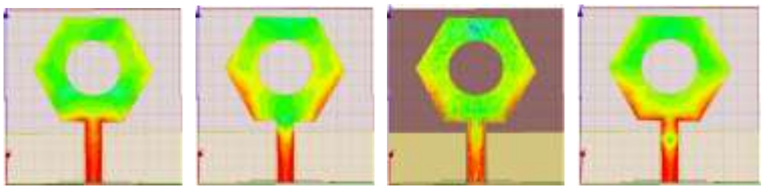


Fig. 8: Current distribution of patch antenna at 4 GHz, 6 GHz, 7GHz and 8 GHz respectively.

The figure 7(a) to 7(c) shows that the Co polarization level is greater than the cross polarization level of linear polarization. The current distributions shown in the figure 8 of the patch antenna shows the maximum current distribution at each frequency of excitation results in maximum radiated power over the frequency range of 2.3 GHz to 10.7 GHz. The VSWR value is 1 at 7GHz and over the operating bandwidth, its VSWR value is less than 2.

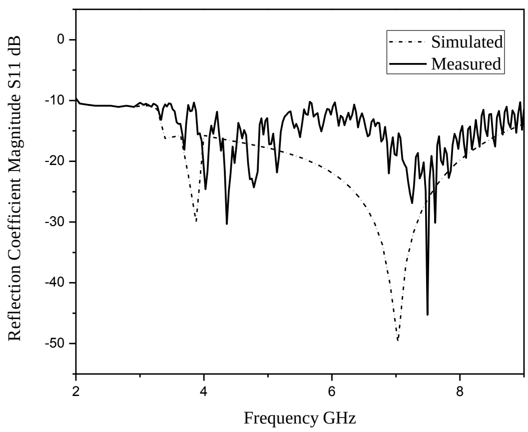


Fig. 9: The simulated and measured result of S11 in dB.

The modified hexagonal patch antenna is simulated using the HFSS software and it is fabricated and tested using the Agilent VNA. The S-parameters S11 plot for the simulated and the measured results is shown in figure 9 where the resonating frequency of the fabricated patch antenna is shifted to 7.5GHz with an S11 of -46.2 dB instead of resonating at 7GHz in simulation. The shift in the frequency is due to the mismatch in the soldering of the SMA connector, substrate thickness and the slight variation in the dielectric constant of the FR4 substrate. The patch antenna is designed for UWB frequency range of 2.3 GHz to 10.7 GHz so the shift in the resonating frequency will not affect the performance of the antenna on the microwave imaging application.

4. CONCLUSION

A novel and very compact size Hexagonal shaped circular slot patch antenna, fed by CPW 50 ohm feed line, is designed for UWB application. The designed patch antenna size is 25x25x1mm3 which is fabricated over the FR4 substrate is better suitable for microwave imaging application. The size of the antenna is very compact and it achieves an impedance bandwidth of 2.3 to 10.7 GHz for the S11 of -10 dB. The E plane and the H plane radiation pattern of the antenna show the antenna is linearly polarized and it has very low cross polarization patterns. The important features of the antenna are most suitable for any UWB applications.

REFERENCES

1. “Breast Cancer Prevention and Early Detection” American cancer society [acs 2014].
2. http://www.breastcancer.org/symptoms/understand_bc/statistics
3. “Breast Cancer,” American Cancer Society 2014.
4. Lazebnik, M., L. McCartney, D. Popovic, C. B. Watkins, M. J. Lindstorm, J. Harter, S. Sewall, A. Magliocco, J. H. Brooske, M. Okoniewski, and S. C. Hagness, “A large-scale study of the ultrawideband microwave dielectric properties of normal, benign and malignant breast tissues obtained from cancer surgeries," Phys. Med. Biol., Vol. 52, No. 20, 6093-6115, Oct. 2007.
5. Larsen, L. E. and J. H. Jacobi, “Medical Applications of Microwave Imaging,” IEEE Press, New York, 1986.
6. Pedersen, P. C., C. C. Johnson, C. H. Durney, and D. G. Bragg, “Microwave reflection and transmission measurements for pulmonary diagnosis and monitoring," IEEE Trans. Biomed. Eng., Vol. 25, No. 1, 40{48, Jan. 1978.
7. Gianluigi Tiberi , Navid Ghavami , David J. Edwards , and Agostino Monorchio, “Novel Techniques for UWB Microwave Imaging of Objects with Canonical Shape,” PIERS Proceedings, Marrakesh, MOROCCO, March 20–23, 2011.
8. M. Gopikrishna, Deepti Das Krishna, C. K. Aanandan, P. Mohanan, and K. Vasudevan, “DESIGN OF A MICROSTIP FED STEP SLOT ANTENNA FOR UWB COMMUNICATION,” Microwave and Optical Technology Letters, vol. 5. no. 4 April 2009.
9. Sudhir Shrestha, Mangilal Agarwal, Joshua Reid, and Kody Varahramyan, “Microstrip Antennas for Direct Human Skin Placement for Biomedical Applications,” PIERS Proceedings, Cambridge, USA, July 5–8, 2010.
10. J. H. Wang and Y.-Z. Yin, **“**Ultra-Wideband (UWB) Differential-Fed Antenna with Improved Radiation Patterns,” PIER C, Vol. 53, pages 1-10, 2014.
11. Amin M. Abbosh, “ Directive Antenna for Ultrawideband Medical Imaging Systems,” International Journal of Antennas and Propagation, Hindawi Publishing Corporation Volume 2008
12. Khalil H. Sayidmarie, Yasser A. Fadhel, “ A PLANAR SELF-COMPLEMENTARY BOW-TIE ANTENNA FOR UWB APPLICATIONS,” PIER C, Vol. 35, 253–267, 2013
13. Houssam Kanj, and Milica Popovic, “Miniaturized Microstrip-Fed “Dark Eyes” Antenna for Near-Field Microwave Sensing,” IEEE ANTENNAS AND WIRELESS PROPAGATION LETTERS, VOL. 4, 2005.
14. Hamed M. Jafari, M. Jamal Deen, Steve Hranilovic, and Natalia K. Nikolova, “A Study of Ultrawideband Antennas for Near-Field Imaging,” IEEE Transactions On Antennas And Propagation, vol. 55, no. 4, April 2007.
15. Abbosh, A. M., H. K. Kan, and M. E. Bialkowski, “Compact ultra-wideband planar tapered slot antenna for use in a microwave imaging system," Microwave Opt. Technol. Lett., Vol. 48, No. 11, 2212{2216, Nov. 2006.
16. F. Li, X. Chen, and K.-M. Huang, **“** Microwave Imaging a Buried Object by The GA and Using the S11 Parameter,” PIER, vol 85, pp. 289-302 .
17. Malek G. M. Hussain, “Theory and Analysis of Adaptive Cylindrical Array Antenna for Ultrawideband Wireless Communications,” IEEE Transactions On Wireless Communications, vol. 4, no. 6, November 2005.
18. Essex J. Bond, Xu Li, Susan C. Hagness, and Barry D. Van Veen, “Microwave Imaging via Space-Time Beamforming for Early Detection of Breast Cancer,” IEEE Transactions on Antennas and Propagation, vol. 51, no. 8, August 2003.
19. Hojjatollah Fallahi and Zahra Atlasbaf, “Study of a Class of UWB CPW-Fed Monopole Antenna With Fractal Elements,” IEEE ANTENNAS AND WIRELESS PROPAGATION LETTERS, VOL. 12, 2013, page 1484 – 1487.
20. Larsen, L. E. and J. H. Jacobi, “Medical Applications of Microwave Imaging,” IEEE Press, New York, 1986.
21. S. K. Rajagopal and S. K. Sharma, “Investigations on ultrawideband pentagon shape microstrip slot antenna for wireless communications,” IEEE Trans. Antennas Propag., vol. 57, no. 5, pp. 1353-1359, May 2009.
22. “Microstrip antenna design handbook,“ by Ramesh Garg, Prakash Bhartia and Inder Bhal, Artech House, 2001.