A modified Bow-Tie Antenna for Microwave Imaging Applications

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***Abstract*— Microwave imaging systems offer much promise for biomedical applications such as cancer detection because of their good penetration, non invasive and non ionizing nature and low cost. The resolution is one of the major problems faced in such systems, which can be improved by applying signal processing techniques. The key element for the microwave imaging system is the antenna. In this paper we have discussed about the characteristics of an antenna suitable for this purpose.**

Index Terms— Microwave imaging, dielectric contrast, bow-tie antenna.

I. INTRODUCTION

The application of microwave technology in the field of biomedical engineering is increasing both in diagnostic and therapeutic areas. Microwave imaging has a great potential in the area of diagnostics. This technique promises non destructive evaluation of biological medium based on the dielectric property variation. Changes in the dielectric properties of tissues can be related to their physiological condition. Therefore microwave imaging can be used as a diagnostic indicator. Several applications of microwave imaging have been proposed in the medical field and one of them is microwaves for breast cancer detection [1].

Breast cancer is the most common form of cancer found in woman. Early detection and timely treatment are key factors that affect long term survival. X-ray mammography is currently the popular screening method for breast cancer. Mammography has been proved to be quite sensitive to the presence of lesions in the breast. However, association of this diagnoses method with uncomfortable breast compression and exposure to ionizing radiation prevents patients to undergo early stage examination which is the best and effective phase for medical treatment [2]. These concerns provide motivation to develop a supplement to the existing technique.

Microwave imaging can be defined as seeing the internal structure of an object by illuminating the object with low power electromagnetic fields at microwave frequencies. An antenna is used to illuminate the object with microwaves which travels through the object and is then detected with the receiver antenna. Another technique is to use reflections which are detected with the same transmitter that is illuminating the object. The measured data can be processed using reconstruction algorithm to give information on the complex dielectric permittivity of the scattering object [3].

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Microwave imaging system relies on the fundamental property that malignant tumor has higher water content and hence have higher dielectric properties than normal breast tissues which have low water content. Therefore, strong scattering takes place at the boundary between normal tissues and lesions.

One of the key system components is the antenna, as it must effectively radiate and receive the signal from the object being imaged. Several UWB antenna designs have been proposed for use in medical imaging systems[4]. Some of the proposed antennas have non-planar structure while others have low gain and poor return loss. Majority of the compact UWB antenna presented in literature exhibit omnidirectional radiation patterns with relatively low gain[5-7]. These types of antennas are suitable for the short range indoor and outdoor communication. However, for radar systems, such as microwave imaging systems for detection of tumor in women's breast a moderate gain antenna is preferred. Amoung few alternatives, a microstrip antenna was chosen due to the ease in design and fabrication and can be used in a planar gap coupled array configuration for imaging applications.

A conformal broadband microstrip antenna is suitable for this kind of application. The conventional microstrip antenna suffers from a major disadvantage that it has a narrow bandwidth. Over the years, there have been several research efforts by various groups world wide aiming to increase the bandwidth of these antennas. A detailed survey on various techniques for bandwidth enhancement of microstrip antennas is given in [4]. These techniques include, but not limited to: i. increasing the substrate thickness ii. use antenna elements in a multilayer geometry or in a planar gap coupled elements configuration iii. cutting slots into the patch surface iv. use of frequency independent antenna concepts.

The main objective of the presented work is to design a microstrip bowtie antenna element with good return loss, unidirectional radiation pattern, and moderate gain which can be used in a planar array configuration.

II. ANTENNA DESIGN AND FABRICATION

Antenna is the key element in a Microwave Imaging system. Therfore for the effective reconstruction of the target images, the following factors are considered in the design of the antenna. First, the illuminating frequency of the microwave is based on the electrical and geometrical parameters of the sample that has to be tested. For using in the detection of breast cancer, we have selected the frequency of 5.8GHz, in view of the electrical parameters of the medium and optimization of signal attenuation and image resolution. Second, the antenna should be able to radiate the wave into the sample and to receive the scattered field from the target of small size. Third, the antenna should be compact enough to be mounted on to a scanning arrangement.

The rectangular patch was designed using the transmission line model and are adjusted to match 50 Ω at the input port of the antenna. This was simulated using a moment method based commercial EM simulator IE3D. The simulated frequency response of the input of the designed antenna yielded a return loss of -11.6dB and a gain of 3dBi at the desired frequency of operation. In order to improve

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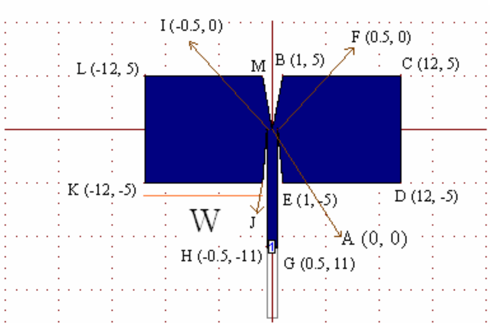
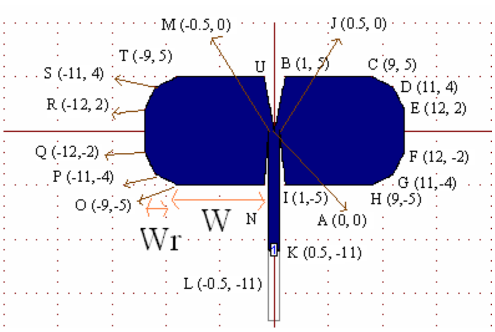
the return loss and the gain the rectangular geometry was modified at the ends to have a rounded shape instead of being flat. The configuration of the proposed antenna is shown in fig.1. The dimensions of the rounded antenna and the flat ended rectangular patch antenna are exactly the same except that in the rounded antenna, the rectangular patch is divided into two parts- one is a rectangle and another an arc. All other parameters such as the feed length, feed width and flare angle are optimised using the trial and error approach to satisfy the required characteristics(return loss <-10dB in the operating frequency, moderate gain and omni directional radiation pattern).



(a) Flat ended bow-tie



(b) Rounded bow-tie

Figure.1. Geometry of the antenna

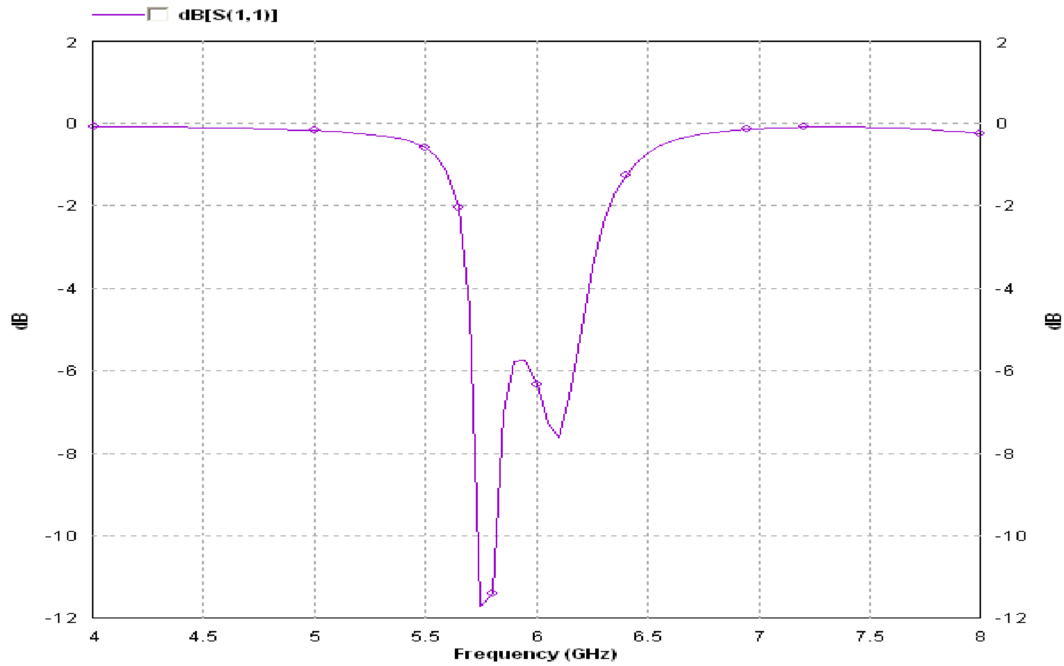
The rounded bow-tie antenna was fabricated on a FR4 substrate (ε_r = 4.28, tanδ = 0.001) of thickness 1.6mm. The return loss of this fabricated antenna is measured using an Agilent N5230A network analyzer.

Table.I. Dimensions of the fabricated modified bowtie antenna.

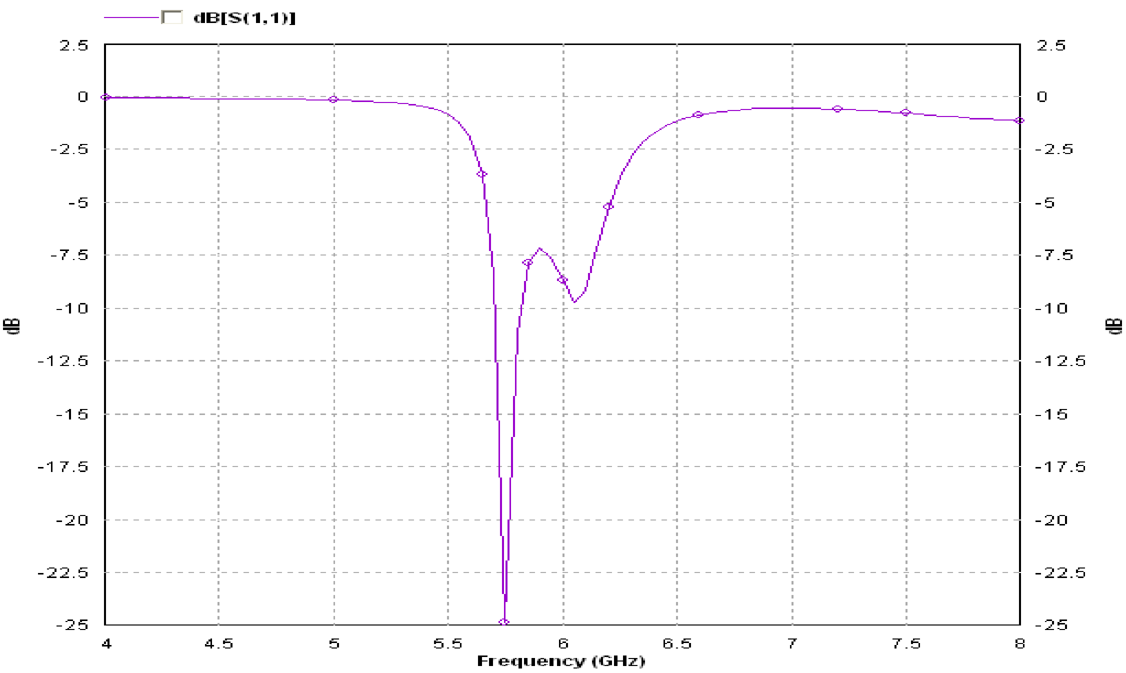
Dielectric constant of substrate (εr)	4.8
Thickness of substrate (mm)	1.6
Length of arm (mm)	10
Width of arm (mm)	11
Length of feed (mm)	11
Width of feed (mm)	1

III. RESULTS AND DISCUSSION

To characterize the performance of the antenna, the following measures are considered: 1. Return loss, 2. gain of the antenna, 3. Radiation pattern at the center frequency. First the return loss of the flat ended bow-tie antenna and that of the modified antenna is compared in figure.2. It is seen that there is an appreciable improvement in the return loss from -11.6dB to -25dB in the modified antenna. Based on this fact the rounded bow-tie antenna was considered for further simulation studies.



(a)



(b)

Figure.2. a) Return loss of flat ended bow-tie antenna b) Return loss of rounded bow-tie antenna

The feed length, feed width and the flare angle were also varied and the simulations show that the effect of changing these dimensions of the antenna have appreciable change in the resonant frequency and the return loss of the antenna as shown in fig.3.

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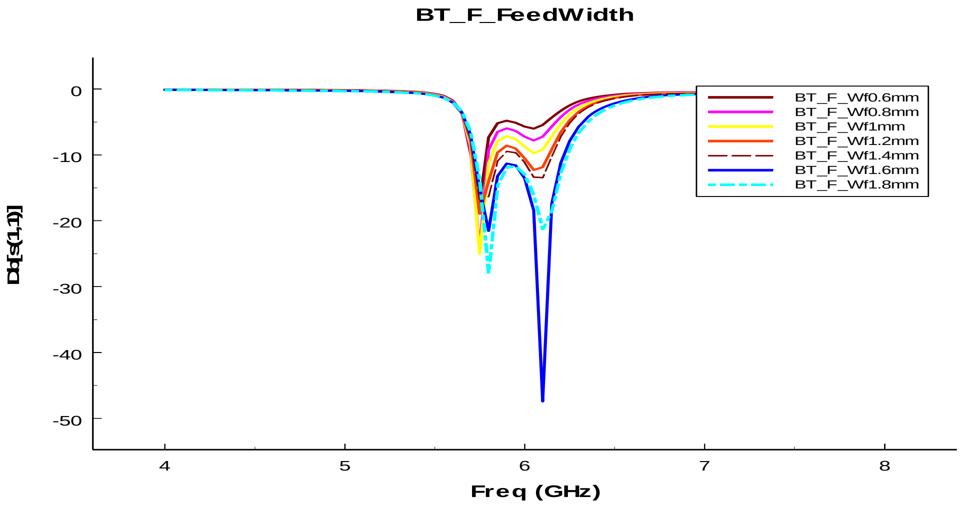

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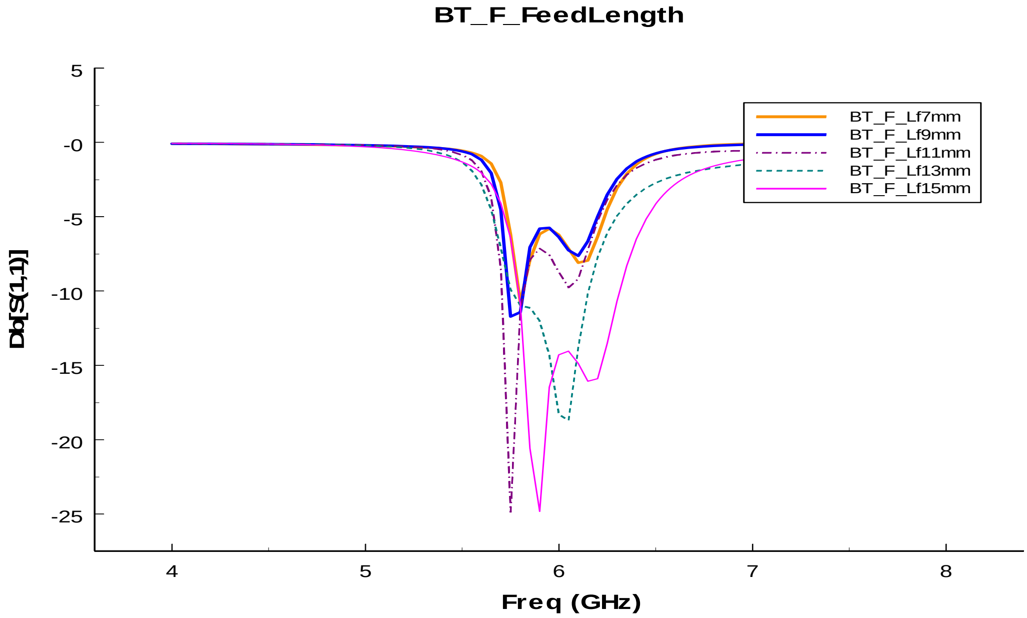

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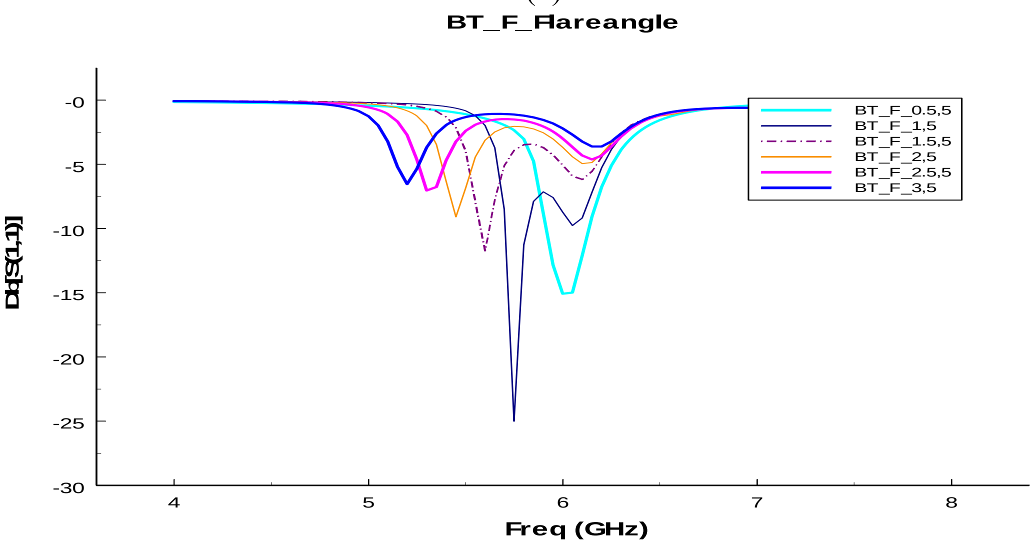

(c)

Figure.4. Effect of changing the a) feed length b) feed width, c) flare angle of the bow-tie antenna on resonant frequency and S_{11}.

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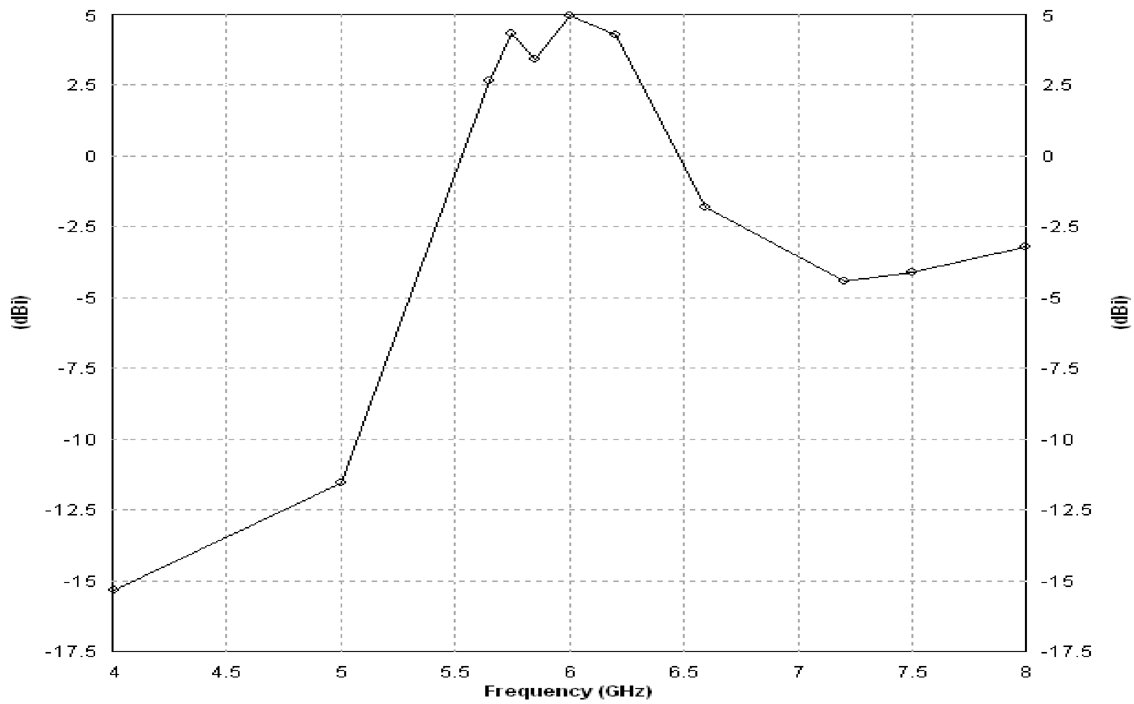
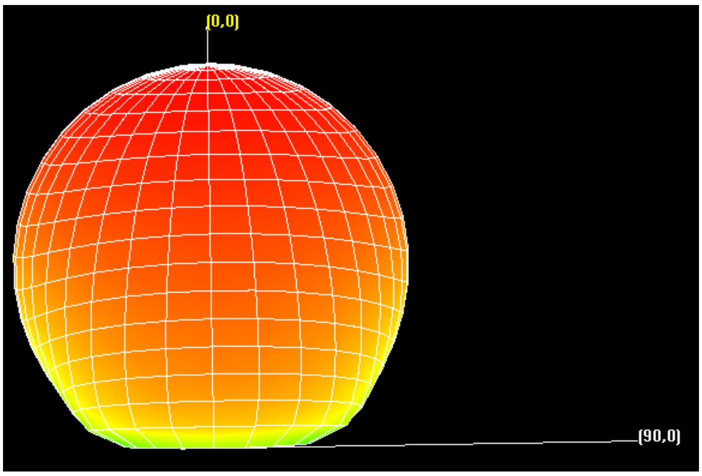
The gain of the antenna is nearly 5dBi at the resonant frequency, and the radiation pattern is omni directional as preferred for imaging applications as shown in fig.4.



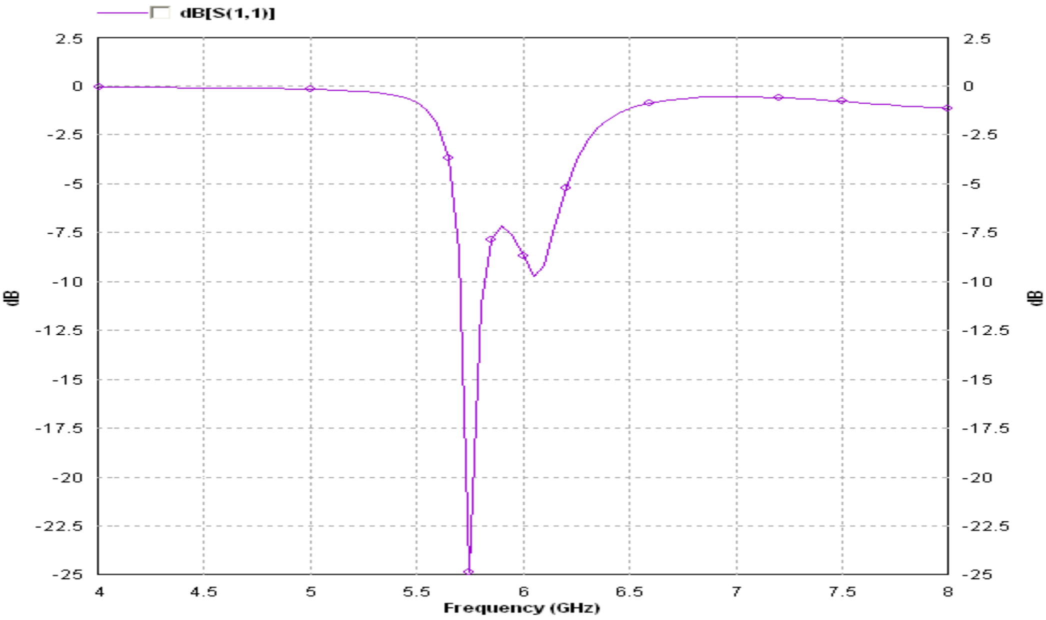
(a)



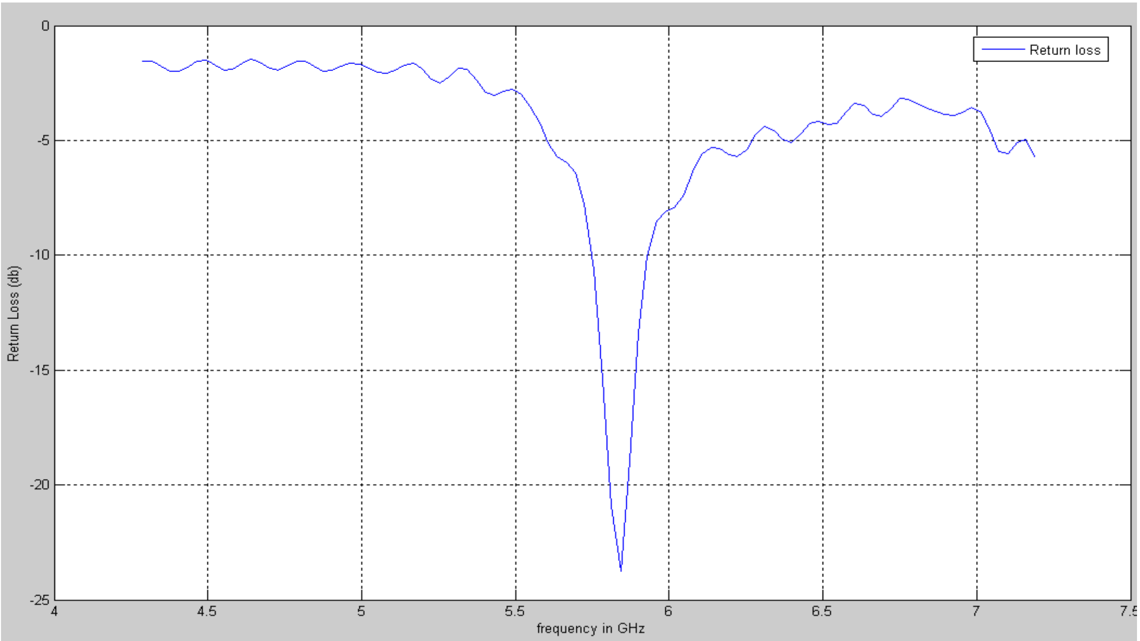
(b)

Figure.4.a) Gain of the bow-tie antenna (feed width = 1mm, feed length = 11mm, flare angle =165^0) b) radiation pattern at f=5.8GHz

The return loss of this fabricated modified bow-tie antenna is measured using an Agilent N5230A network analyzer. The simulated and the measured return loss of the antenna are shown in Figure.5a and b. The measurement results indicate that return loss is -24dB at 5.8GHz which is in good agreement with the simulation result.



(a)



(b)

Figure.5. a) Simulated return loss b) Measured return loss

IV. CONCLUSION

In this paper, a modified, compact bow-tie antenna was designed and fabricated and tested. The results show that the fabricated antenna provides a return loss of -24dB at 5.8GHz and is in good agreement with the simulation results. The simulation results also show that by varying the dimensions of the antenna, the resonant characteristics can be changed.

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The modified bowtie antenna proposed yields good return loss of -24dB, moderate gain of 5dBi and omni directional radiation pattern as desired for imaging applications.

REFERENCES

[1] E C Fear and M A Stuchly, "Microwave System for Breast Tumor Detector", *IEEE Microwave and Guided Wave Letters, Vol.9, No.11, pp. 470-472, Nov.1999.*

[2] E C Fear, S C Hagness, P m Meaney, M Okoniewski and M A stuchly, " Enhancing Breast Tumor detection with near field imaging", *IEEE Microwave Magazine,pp.48-56, March 2002.*

[3] Elise. C. Fear, Susan. C. Hagness, Maria. A. Stuchly and Xu Li, "Confocal Microwave Imaging for Breast Cancer Detection: Localization of Tumors in Three Dimensions", *IEEE transactions on Biomedical Engineering, Vol.49, No.8, pp.812-822, August, 2002.*

[4] Sanches-Hernandez.D, Robertson.I , " A Survey of broadband microstrip patch antennas," *Microwave Journal*, Sep, 1996.

[5] X.Yun, E.Fear and R.Johnson, "Broadband cross polarized bowtie antenna for breast cancer detection," *Proceedings of IEEE Antennas and Propagation International Society International Symposium*, Vol.3, pp.1091-1094, June. 2003.

[6] C.J.Shannon, E.C.Fear, and M. Okoniewski, "Dielectric filled slot line bowtie antenna for breast cancer detection," *Electronic Letters*, Vol 41, No.7, pp.388-390, March 2005.

[7] H.kanj and M.Popovic, "Miniaturized microstrip fed dark eyes antenna for near field microwave sensing," *IEEE Antennas and Wireless Propagation Letters*, Vol.4, pp.397-401, 2005.

[8] Tonny Ruback, Paul M Meany, Peter Meincke, Keith D Paulsen, "Nonlinear Microwave Imaging of breast cancer screening using Gauss Newton's method and the CGLS inversion algorithm", *IEEE transactions on Antenna and Propagation*, Vol.55, No.8, pp.2320-2331, August,2007.

[9] Ravi Kumar Joshi and Ayyangar Ranganath Harish, "A Modified Bow-Tie Antenna for Dual Band Applications", *IEEE Antennas and wireless propagation letters*, Vol.6, pp.468-471, 2007.

[10] David. A. Hill, "Near field detection of buried dielectric objects", *IEEE transactions on Geoscience and Remote sensing*, Vol.27, No.4, pp.364-368, July 1989.

[11] Jeff M Sill, Elise Fear," Tissue sensing adaptive radar for breast cancer detection-Experimental investigation of simple tumor models", *IEEE Transactions on Microwave theory and Techniques*, Vol.53, No.11, pp.3312-3319, Nov 2005.

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