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Design of a Novel Microstrip Patch Antenna for Microwave Imaging Systems

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***Abstract*- A novel compact bowtie antenna is designed and optimized with rounded edge for microwave imaging applications such as cancer tissue detection. The proposed antenna is designed using FR4(ε_r=4.8) as a substrate material to operate in 5.8 GHz. The proposed microstrip patch antenna is a low profile, low cost and minimal weight that are capable to maintain its high performance over a wide range of frequencies. By designing such an antenna, it is possible to achieve a return loss of -29.62 dB at gain of 6.2dB and good radiation characteristics compared to conventional antennas. The parameters are optimized using ADS simulation software.**

***Index Terms*- Microstrip antenna, Return Loss, Radiation Pattern, Microwave Imaging.**

I. INTRODUCTION

Microwave Imaging in medical field is one of the important diagnosing mechanisms available. This technique uses non destructive evaluation of biological tissue based on the dielectric property changes. Therefore microwave imaging can be used as a diagnostic tool. Several applications of microwave imaging have been proposed in the medical field and one of them is microwaves for breast cancer detection.

Many women, especially young ones have radiographically dense breasts. Which means that the breast tissues contain more glands and ligaments resulting in dense breast tissue. Thus the diagnosis becomes very difficult. In order to exclude the difficulties encountered alternative techniques like magnetic resonance imaging with contrast enhancement and ultrasound imaging are used.

The fundamental basis of any imaging system lies in the contrast that exists between the properties of healthy and malignant tissues. Breast cancer detection with mammography basically utilizes a low dose X-ray as the initial diagnostic tool. Frequent exposures to X-rays of any kind are really not recommended for young people. Statistics in this field suggests that there is a false positive cases exists one in five cases in women.. Based on National Council on Radiation Protection (NCRP) and International Radiation Protection Association (IRPA) suggestions, human exposure at or below the permissible levels recommended by IEEE and other organizations is not harmful to human health. The experimental setup of microwave imaging is depicted in fig1.

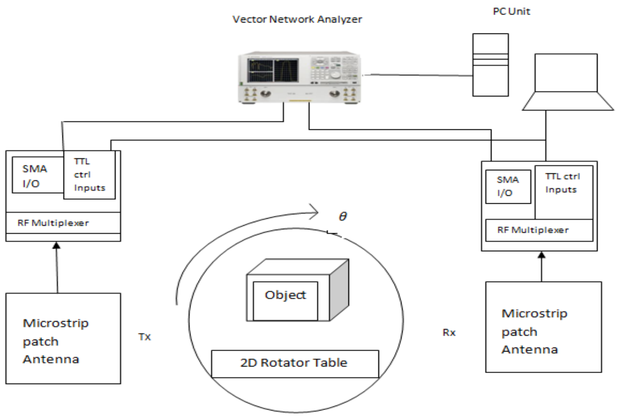

Figure 1: Experimental setup of Microwave Imaging System

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. 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. 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 Omni-directional radiation patterns with relatively low gain. 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. Among few alternatives, a microstrip antenna was chosen due to the low profile and ease of fabrication and can be used in a planar gap coupled array configuration for imaging applications. 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 worldwide aiming to increase the bandwidth of these antennas.

II. ANTENNA DESIGN

A. *Construction of Conventional Bowtie Antenna*

Microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate with a continuous metal

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layer bonded to the opposite side of the substrate which forms a ground plane. The patch is generally made of conducting material such as copper or gold and can take any possible shape(conventional types are square, rectangle, circle and triangle). A patch antenna is a narrowband, wide-beam antenna fabricated by photo etching the antenna element pattern in metal trace on the dielectric substrate[11]. The recent studies of microstrip patches revealed that the triangular patch has a radiation characteristic similar to a rectangular patch, but with reduced dimensions. The principle of transmission line model of triangular microstrip antenna is depicted in the fig 2.

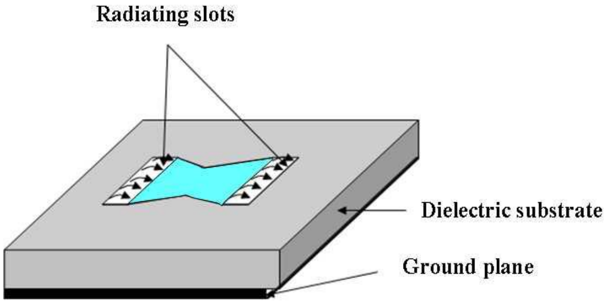

Figure 2: Principle of Transmission Line Model

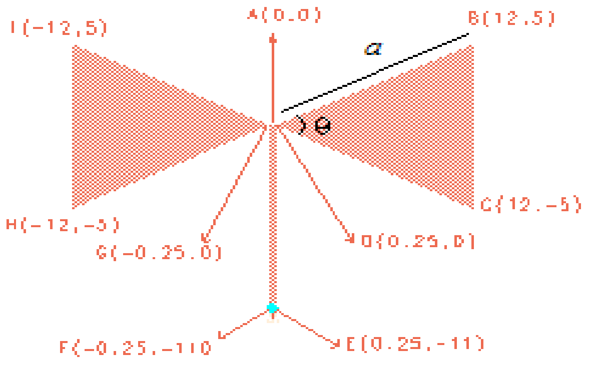

Figure 3: Construction of Conventional Triangular Bowtie Antenna

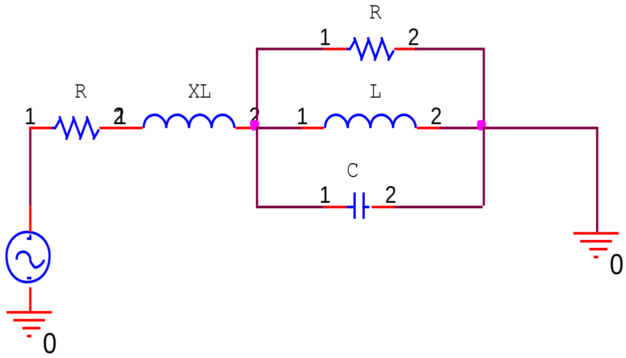

Figure 4: Electrical Model of Triangular Patch

Fig.3 shows the bowtie Antenna dimensions with coordinates. ‘a’ is the side length of the bowtie strip, ‘θ’ is the angle between the side lengths of the triangles. The value of ‘a’ can be calculated as follows

$$a = \frac{2c}{3 f_r \sqrt{\varepsilon_r}} \quad (1)$$

$$a_e = a + t(\varepsilon_r)^{-1/2} \quad (2)$$

Where
a- side length of Bowtie
a_e- Effective Side length of Bowtie
f_r - Resonance Frequency
ε_r- Dielectric Constant

Fig 4 shows the return loss of the conventional triangular bowtie antenna on FR4 substrate showing its deep in - 9.9dB with its center frequency as 6GHz

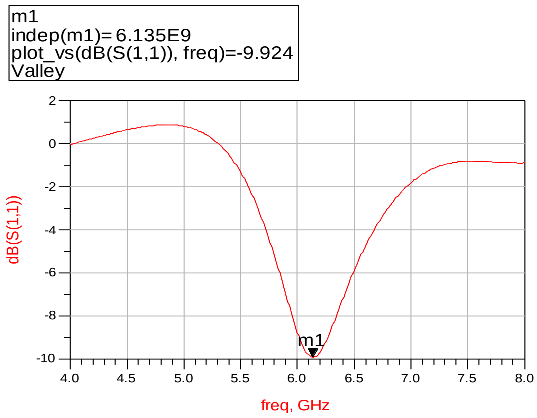

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Figure 5: Return Loss of conventional triangular structure

The Antenna parameters of the conventional triangular Bowtie Antenna is shown in table 1.

Antenna Parameters	Conventional Triangular Bowtie Antenna
Power Radiated(Watts)	2.48714e-07
Effective Angle(Steradians)	4.43402
Directivity(dB)	4.52412
Maximum Intensity(Watts/Steradian)	5.60922e-08
Angle of U max(Theta,phi)	(50,180)
E(Theta)max(mag,Phase)	(0.00538819,177.004)
E(Phi)max(mag,Phase)	(0.0036374,-90.0455)
E(x)max(mag,Phase)	(0.00346346,-2.99579)
E(y)max(mag,Phase)	(0.0036374,89.9545)
E(z)max(mag,Phase)	(0.00412759,-2.99759)
Return Loss(dB)	-9.94

Table 1:Parameters of conventional triangular Bowtie Antenna

B. Construction of Modified Square Bowtie Antenna

The modified Bowtie strip is square in shape instead of triangular structure A modified version of Conventional triangular Bowtie Antenna and its construction is shown in fog 6.

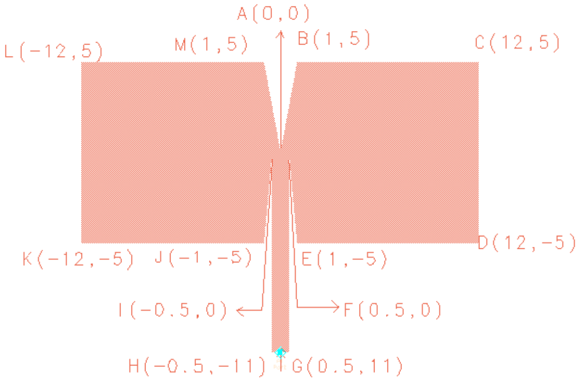

Figure 6: Modified Square Bowtie Antenna

The effective width of the Bowtie arm is given by[12],

$$W = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{2\varepsilon_r+1}} = \frac{v_0}{2f_r}\sqrt{\frac{2}{2\varepsilon_r+1}} \qquad (3)$$

The actual length is determined as follows:

$$L = \frac{1}{2f_r\sqrt{\varepsilon_{reff}}\sqrt{\mu_0\varepsilon_0}} - \Delta L \qquad (4)$$

The equation 5 can be used to determine the input impedance of the microstrip Patch

$$Z_{in} = \frac{R}{1+Q_T^2\left[\frac{f}{f_r} - \frac{f_r}{f}\right]} + j\left[X_L - \frac{RQ_T\left[\frac{f}{f_r} - \frac{f_r}{f}\right]}{1+Q_T^2\left[\frac{f}{f_r} - \frac{f_r}{f}\right]^2}\right] \qquad (5)$$

Where R is the resonant resistance of the resonant parallel RLC circuit, f_r is the resonant frequency, and Q_T is the total quality factor associated with the system losses including radiation, the loss due to heating in conducting elements and ground plane, and the loss due to heating in the dielectric medium.

The impedance of the air filled microstrip line is as follows

$$Z_{ao}(W) = Z_a(W, \varepsilon_r = 1) \qquad (6)$$

The return loss(-12.7dB) of modified square Bowtie Antenna shows its better performance compared to conventional triangular patch(fig .7).

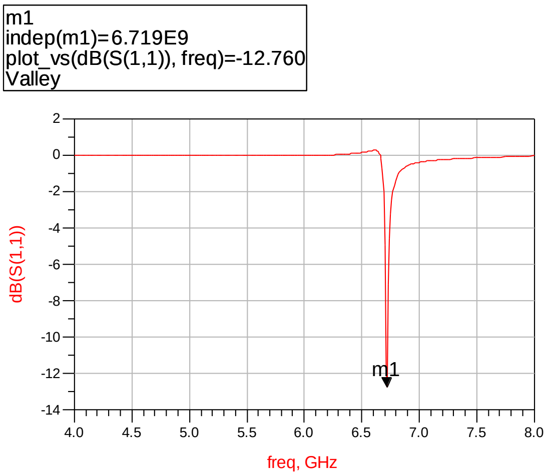

Figure 7: Return Loss of Modified square Bowtie structure

III. PROPOSED ANTENNA DESIGN

The conventional microstrip bow-tie antenna consists of two triangle patches disposed on the planar structure to form a shape of bowtie. The proposed system improves the performance of the conventional Bowtie Antenna by adding the rounded corners on the radiation surfaces.

The electrical model of the proposed bowtie structure is shown in fig 8.

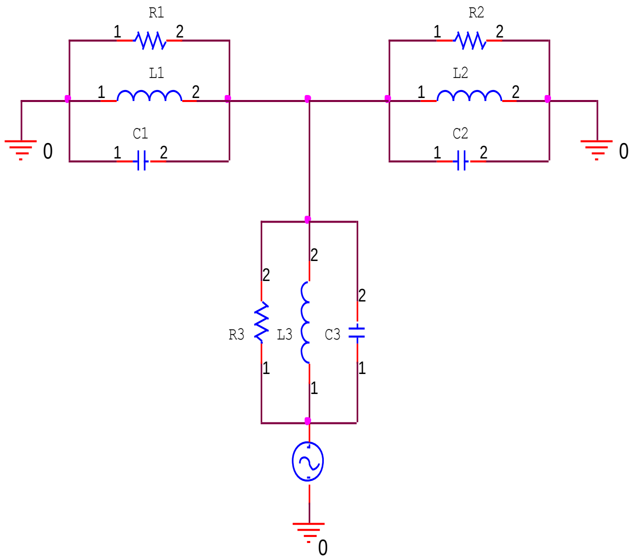

Figure 8: Electrical model of proposed structure

An electrical model was developed for analyzing this antenna which was inspired from the electrical model of the triangular patch described in [3].The transmission line was modeled by RLC circuit. The RLC parameters were determined by means of the formula developed in section 2.

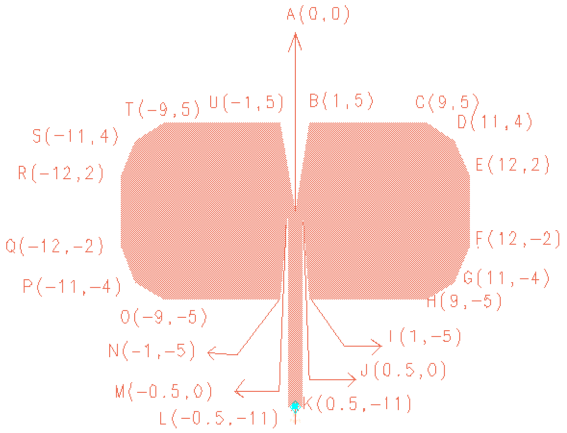

Figure 7: Modified rounded Bowtie Structure

IV. RESULTS AND DISCUSSION

The rounded bowtie Antenna was designed on a FR4 substrate of thickness 1.6mm. The Dimensions list is given in the below Table:

Dielectric constant of the substrate(ε_r)	4.8
Thickness of the substrate(mm)	1.6
Length of the Arm(mm)	10
Width of the Arm(mm)	11
Length of the feed(mm)	11
Width of the Feed(mm)	1

Table 2: Dimensions of the rounded bowtie Antenna

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

The return loss of rounded bowtie is -29.6dB which is very good compared to the previous designs at its center frequency. The S_{11} graph is seen in fig.8 and the radiation pattern is shown in fig.9.

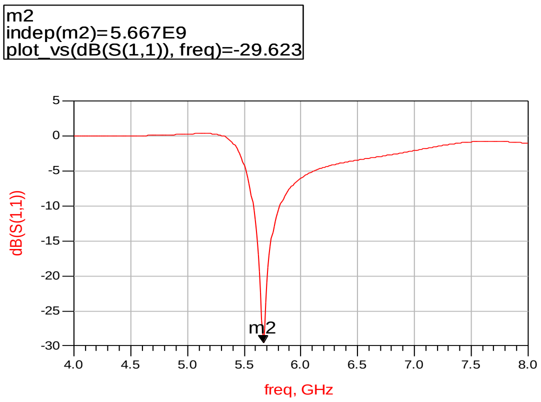

Figure 8: Return Loss of rounded bowtie Antenna

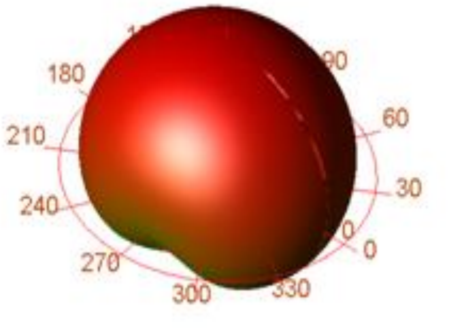

Figure 9: Radiation pattern of rounded bowtie

The Antenna parameters of two types types are distinguished below in table 2.

Table 3: Parameters of Modified Bowtie Antenna

Antenna Parameters	Modified Square Bowtie Antenna	Modified Rounded Bowtie Antenna
Power Radiated(Watts)	1.96117e-05	2.1405e-05
Effective Angle(Steradians)	2.95272	3.02569
Directivity(dB)	6.28988	6.18385
Maximum Intensity(Watts/Steradian)	6.64191e-06	7.07442e-06
Angle of U max(Theta,phi)	(0,0)	(0,0)
E(Theta)max(mag, Phase)	(0.0500189,82.1699)	(0.0595775,82.1148)
E(Phi)max(mag,Phase)	(0.0500253,82.1709)	(0.0421998,82.1669)
E(x)max(mag,Phase)	(4.57942e-06, -96.2711)	(0.0016702,-96.7948)
E(y)max(mag,Phase)	(0.0707419,82.17)	(0.0729898,82.1316)
E(z)max(mag,Phase)	(0,-180)	(0,-180)
Return Loss(dB)	-12.76	-29.623

V. CONCLUSION

In this Paper, a modified, compact bowtie antenna was designed and simulated and compared with the existing conventional patches. The results show that the proposed antenna provides a return loss of -29dB at 5.8GHz which would be best suited for microwave imaging systems.

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