JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

T slotted multiresonator microstrip antenna for breast cancer detection through SAR value

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***Abstract*:** Breast cancer is one of the most widespread invasive diseases for women around the world. Now a day, a greater number of women are being affected every year by breast cancer. There are main techniques used for breast tumor detection mammography, Biopsy, Computer Aided Detection, Magnetic Resonance Imaging as these techniques have their limitations. To overcome these limitations to use micro strip antenna is a wearable, convenient, planar, easy-to-fabricate antenna with some attractive attributes and features, as well as some distinct limitations. The wearable antenna has wearable bending in 2D, which shows flexibility for wearable electronic devices. Antenna working in ISM band is perfectly suitable for biomedical applications. As radiation patch provide antenna a wide working band 1.9-2.5GHz or 5.3-5.6GHz which is an ISM band used for wearable Biomedical Applications**.** In the proposed antenna silk substrate is chosen for implementation because of its low SAR (Specific Absorption Rate) and is placed on the breast to detect the breast cancer tumor. So a simple rectangular patch of dimension 46×56.56mm^2 is made with T slot loading on a jeans substrate is proposed and we got a triple band at 2.5,5.5 and 9.5 GHz resonant frequency with S_{11} values of -28,-20,-25dB at respective resonant frequency. Microstrip Patch Antenna were considered and analyzed within and without cancer-affected areas. Since cancer cells are more water content tissues, the gain and electrical conductivity performance were found to change. For this we have to use SAR value which is found to be 0.0541 W/Kg without tumor and 0.1561 W/Kg with tumor.

Introduction:

Cancer is a disease occurs due to the uncontrolled growth of abnormal cells that spread rapidly to the rest of body and damage healthy tissues. It started anywhere in the body usually forms a solid tumor. Breast cancer is one of the most wide spread invasive diseases for women around the world. Nowadays, a greater number of women are being affected every year by breast cancer[6]. Breast cancer can also lead to others serious complications in brain, lungs, liver, bones and also cause death. It is necessary to ensure critical, proper and effective treatment, early detection of tumors that leads to breast cancer is of most importance. Globally it is known that Breast cancer is the main prevalent type of cancer in the world, and the earlier it's been detected the better. Presently, the most common way for the detection is X-ray imaging, which is called the X-ray mammography. However, due to the limits in the X-ray mammography, researchers started to search for a new advanced device that will aid in the early detection of the Breast cancer [1]. For long time ago, microwaves were utilized for breast cancer detection, and the microwave imaging functions by using low power electromagnetic wave at microwave frequencies in order to illuminate the target, and then view its internal parts. Utilizing microwaves radiation into the breast in order to check and discover the existence of tumors is a popular method and it can be divided into two approaches the tomography and the radar- based. The antenna is a device that is made out of a conductive, metallic material and has the purpose of transmitting and receiving electromagnetic waves, usually radio waves is to communicate or signals. There are two basic types of antennas:

Transmitter antenna and Receiver antenna. The purpose of transmitting and receiving radio waves to communicate or broadcast information at the speed of light. In the first stage, tomography, one transmitter is used to radiate toward the breast, in the same time, around the breast several antennas are laid in order to receive scattered and diffracted waves [3].Based on the received data, some processes are done to get a 2-D or 3-D image of the breast[4]-[6].

The radar-based microwave imaging is another used method for breast cancer detection. This method requires a single ultra-wideband (UWB) antenna is used to transmit a short pulse to the breast and receive the scattered signal back, and the same thing is repeated in various locations around the breast [7]. If the strength of the scattering was high, it will indicate that there is a tumor. In this method extra detailed information are provided compared to the tomography microwave imaging method. However, the UWB antennas should authorize resolution level, which causes some limitations. Thus, the major characteristics that must be taken into consideration are large fractional bandwidth, low side-lobes and low mutual coupling [6]. In addition, to minimize the reflection between the free space and the breast surface, the metallic sensors must be placed in a matching medium that has almost the same permittivity of the breast tissue. However, in real life, the implementation of the matching medium around the patient's breast is hard. As we discussed above There are main techniques used for breast tumor detection mammography, Biopsy, Computer Aided Detection, Magnetic Resonance Imaging as these techniques have their limitations [8]. To overcome these techniques limitations an alternative method is Micro strip Patch Antenna (MSPA).

These parameters are sometimes also Properties of Antenna or Characteristics of Antenna:

- Radiation Intensity
- Directivity and Gain
- Input Impendence
- Effective Length
- Bandwidth
- Effective Aperture
- Antenna Polarization
- Radiation Efficiency
- Antenna Radiation Pattern

The early detection of breast cancer can be done via the microwave imaging. Due to the micro-strip patch antenna's features such as small size, lightweight, low profile, and low manufacturing cost, studies are done on the capability of micro-strip patch antenna in detecting the breast tumor [9]-[11]. Therefore, micro-strip patch antenna became active and useful for the imaging, as it will aid in the early detection of the cancer and it will help to locate the suspicious in the breast for a biopsy procedure. The technology of wearable devices is a technology of electronic and computer devices incorporated into clothes [12]. It can be worn on in everyday life. Those devices can be watches, glasses, earring, caps and fabrics. Those devices are capable to do various tasks; it can work normally like a mobile phone and computer but also can work as a sensor or a tracker or even work as a scanning device [13]. It is considered as a major step in the trend of pervasive computing where everybody can access information anywhere. In general, wearable devices have a very broad application. Before introducing, it the consumers those devices were used in military technology [14]-[16]. Microstrip Patch Antenna is more flexible for Biomedical Applications Performance. Antennas can be thought of as a “transducer” that converts radio waves into electrical currents and voltages and vice versa. More specifically, these are devices designed to radiate or receive electromagnetic energy efficiently in a prescribed manner [17]-[20].Micro-strip antennas recently are used in the medical field for the purpose of imaging, diagnosis, and treatment. In addition, the flexibility in the micro-strip antenna leads to the ability of contacting between the human body and the skin[21]-[23].MSPA these patches are capable to blend with - microwave circuits therefore very well suited for Biomedical Applications, Wireless Local Area Network Applications and Navigation Systems etc.

Design of proposed Antenna:

The proposed structure is designed on jeans substrate of dimension 60×60×1 mm^3 beneath a PEC ground plane of same length and breadth as substrate but has a thickness of 0.038mm and above it a patch whose dimension of 46×56.56mm^2 and has a same thickness as ground and then a T shaped slot is loading on patch which has vertical length of 16mm and horizontal length of 20mm and has 3 mm slotted dimension as shown in Figure 1 and is fabricated design is made which is depicted in Figure 2.The whole geometry is simulated on CST and its S_{11} vs Frequency curve has a multiband operation on 2.5GHz, 5.5GHz and 9.5GHz of -28dB, -20dB and -25dB return loss that has an application of breast cancer detection, WLAN, WiMax etc.

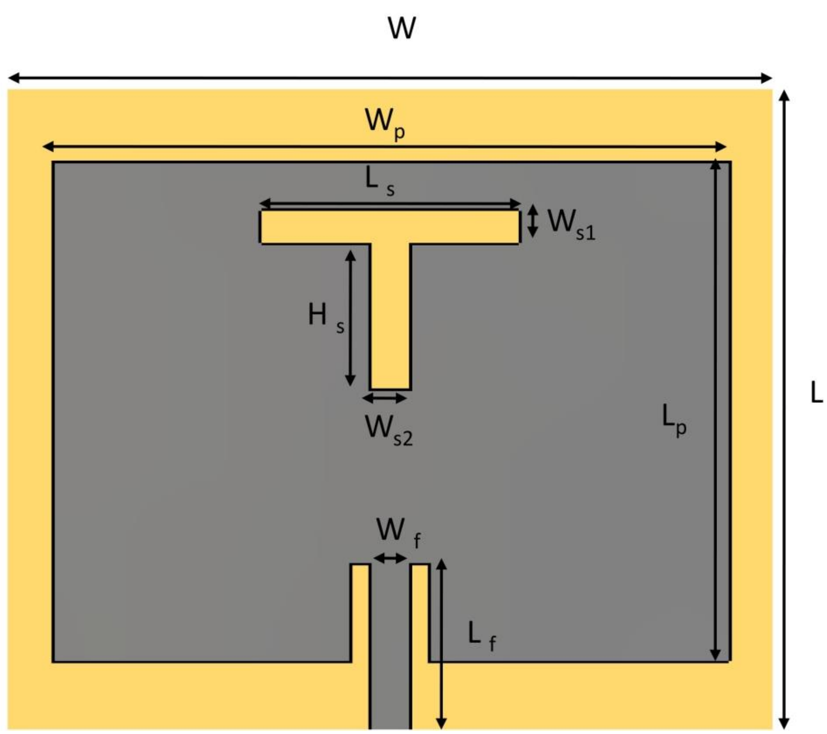


Figure 1: Layout of multi-resonator antenna with T slot

Table 1: Parameter with value in mm of multi-resonator antenna with T slot

Parameter	W	L	W_p	L_p	W_{s1}	W_{s2}	L_s	H_s	W_f	L_f
Value(mm)	60	60	56.56	46	2	3	20	16	3	10

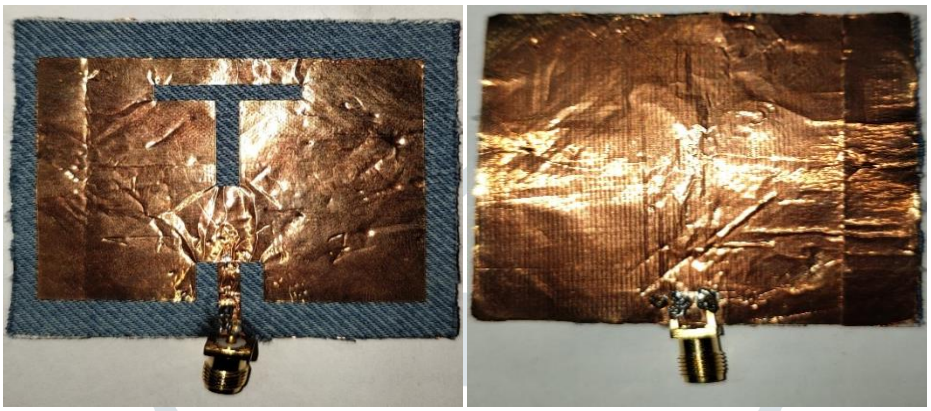


Figure 2: Fabricated proposed antenna

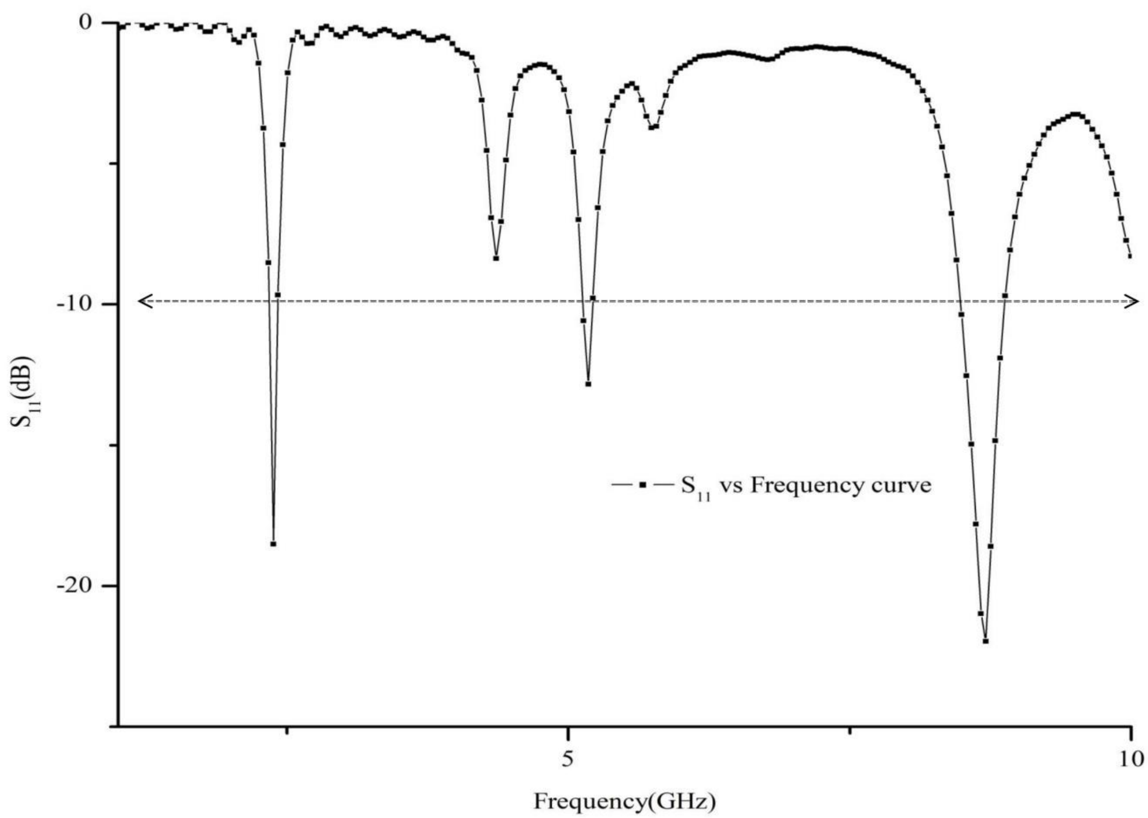


Figure 3: S_{11} parameter vs frequency curve of proposed structure

Parametric Analysis:

By varying the parameter like Width of the slot W_{s1} and W_{s2}, Length of the slot L_s, Height of the slot H_s and Width of the feed W_f , the return loss and resonant frequency changes.

On changing the width of the slot W_{s1}

On increasing the Width of the slot W_{s1}, the S_{11} of upper resonant frequency is decreases from -19dB to -28dB as shown in figure 4.

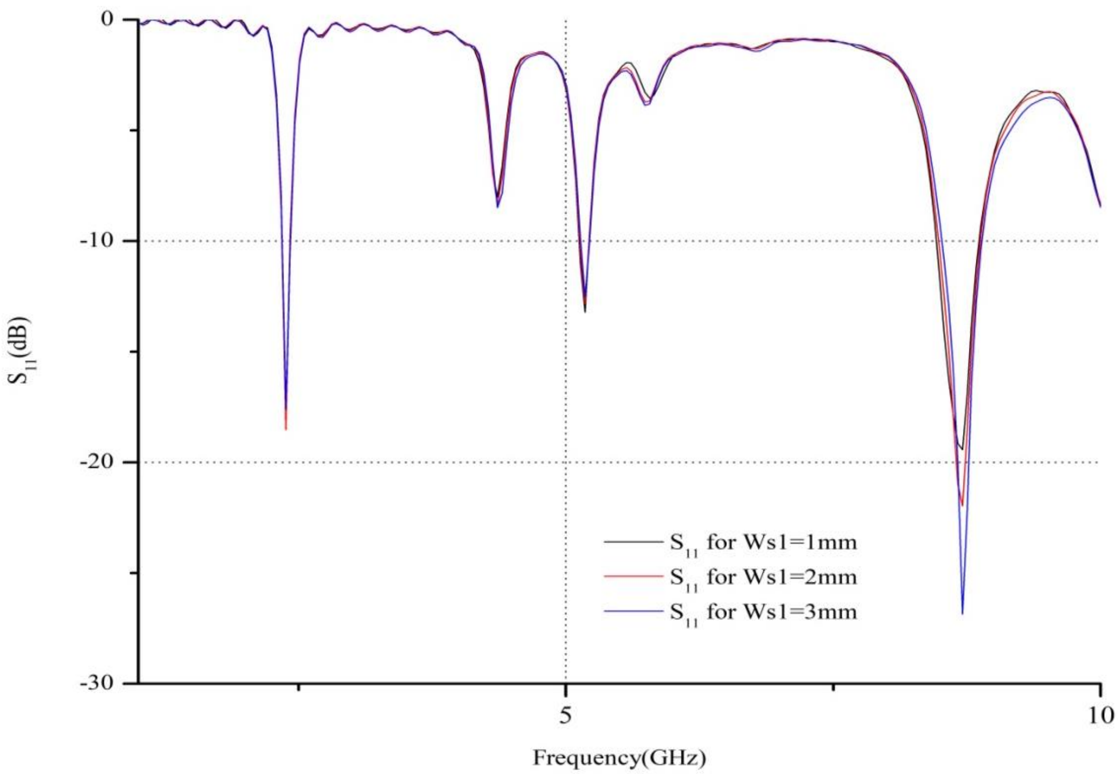


Figure 4: Effect of T slot width W_{s1} on S_{11} of proposed structure

On changing the width of the slot W_{s2}

The effect of decreasing the W_{s2} from 5mm to 1mm, the S_{11} of middle resonant frequency also decreases from -11dB to -14dB which is shown in Figure 5.

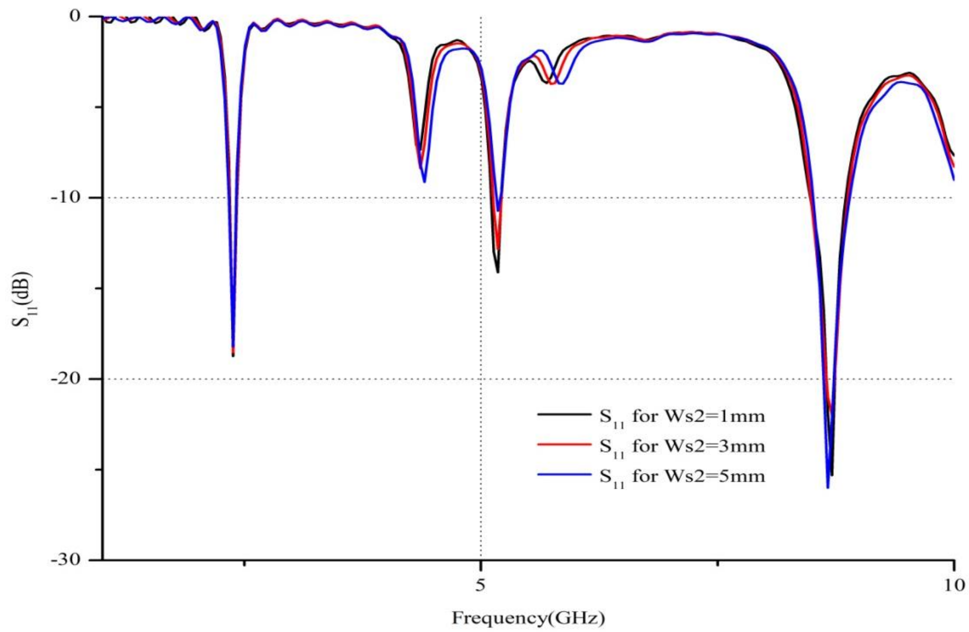


Figure 5: Effect of T slot width W_{s2} on S_{11} of proposed structure

On changing the Length of the slot L_s

On increasing the length of the T slot the lower and upper lower frequency decreases and also the upper frequency band increases from -24dB to -18dB as depicted in Figure 6.

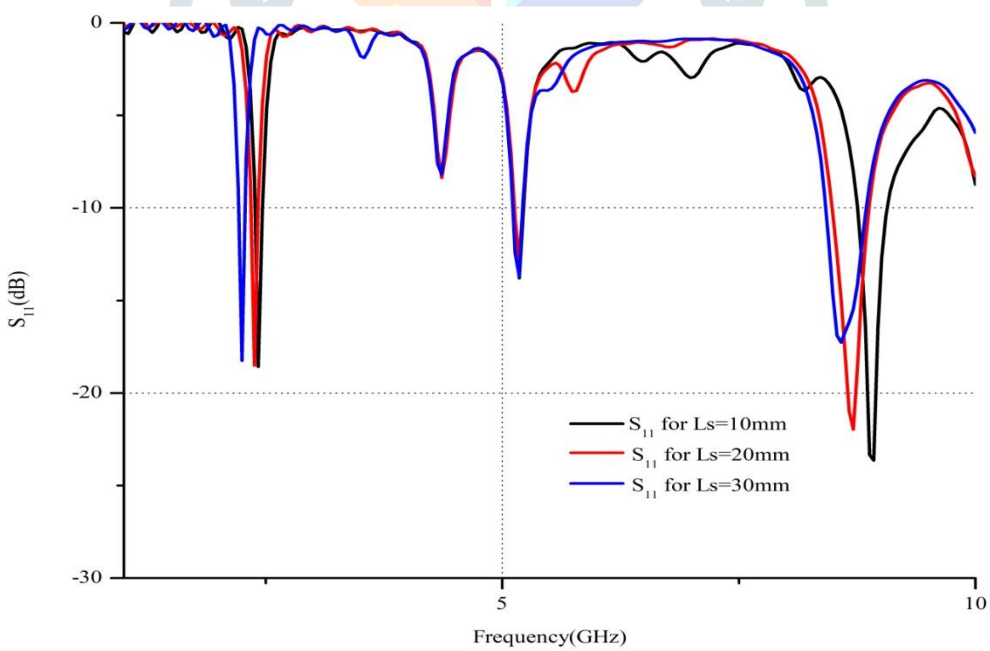


Figure 6: Effect of T slot length L_s on S_{11} of proposed structure

On changing the Height of the slot H_s

The slight change in the upper frequency band from-17dB to -22dB as height of the slot decreases which is shown in Figure 7.

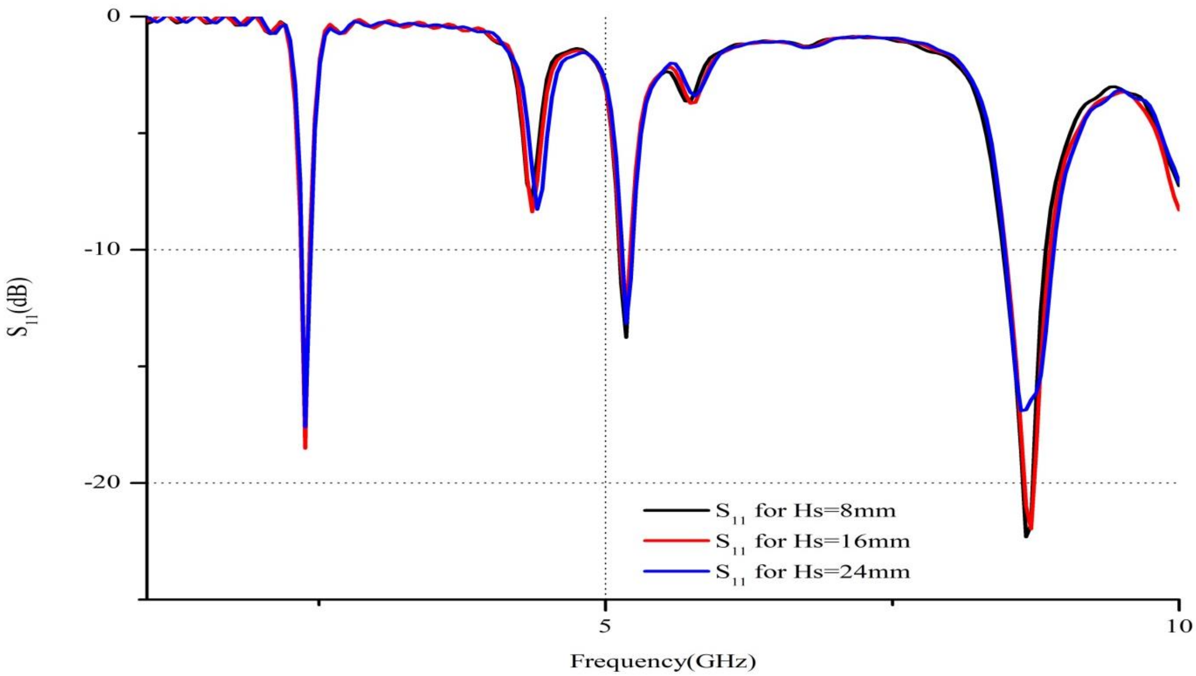


Figure 7: Effect of T slot height H_s on S_{11} of proposed structure

On changing the Width of the Feed W_f

The S_{11} value of lower and middle resonant frequency decrease when feed width increases but for upper resonant frequency the S11 value increases and resonant frequency decreases as shown in Figure 8.

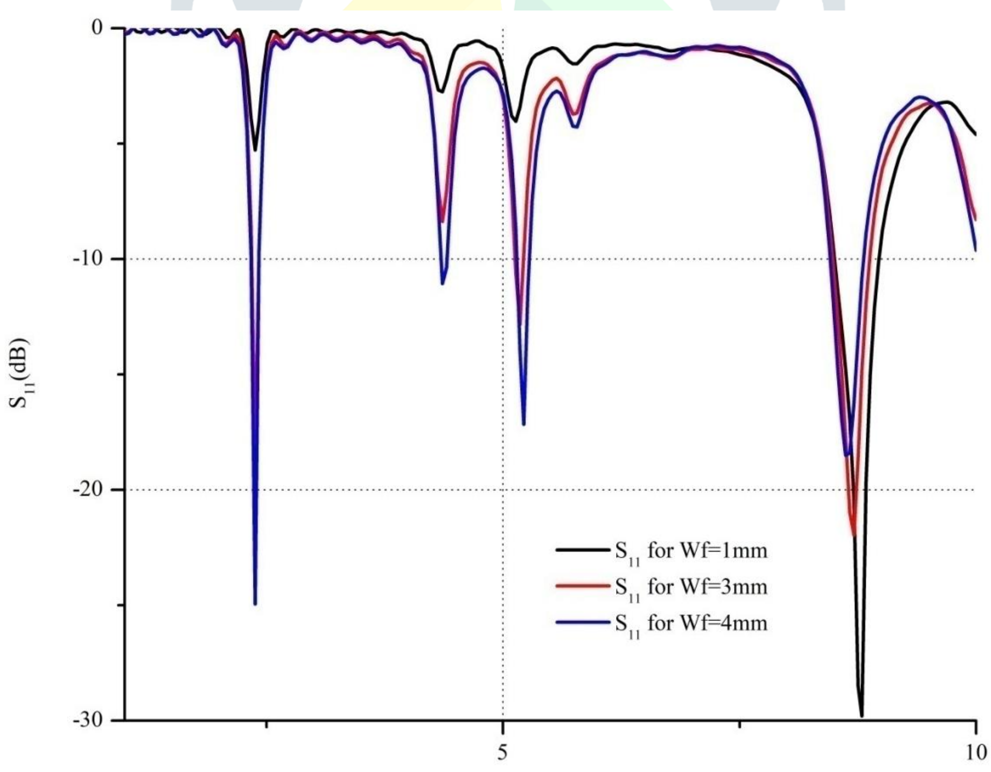


Figure 8: Effect of Feed Width W_f on S_{11} of proposed structure

Theoretical Analysis:

The proposed structure is well justified through theoretical formula and also its SAR value. The effective relative permittivity is found to be

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} - \frac{\varepsilon_r-1}{2}\left(1+12\frac{h}{w}\right)^{-\frac{1}{2}} \quad \text{..........(1)}$$

The change in Length due to effect is

$$\frac{\Delta L}{h} = 0.412\,\frac{(\varepsilon_{reff}+0.3)}{(\varepsilon_{reff}-0.258)}\,\frac{(\frac{W}{h}+0.264)}{(\frac{W}{h}+0.8)} \quad \text{..........(2)}$$

Effective length of patch is given as

$$L_{eff} = L + 2\,\Delta L \quad \text{..........(3)}$$

For dominant mode (TM_{010}) resonant frequency is given as

$$(f_{rc})_{010} = \frac{1}{2L_{eff}\sqrt{\varepsilon_{reff}}\sqrt{\mu_0\varepsilon_0}} = \frac{1}{2(L+2\Delta L)\sqrt{\varepsilon_{reff}}\sqrt{\mu_0\varepsilon_0}} = q\frac{1}{2L\sqrt{\varepsilon_r}\sqrt{\mu_0\varepsilon_0}}$$

$$= q\frac{v_0}{2L\sqrt{\varepsilon_r}} \qquad where\ q = \frac{(f_{rc})_{010}}{(f_r)_{010}} \quad \text{.......(4)}$$

q is referred as fringing factor (length reduction factor). As the substrate height increases, fringing increases and lead to larger separation between the radiating edges so resonant frequency decreases.

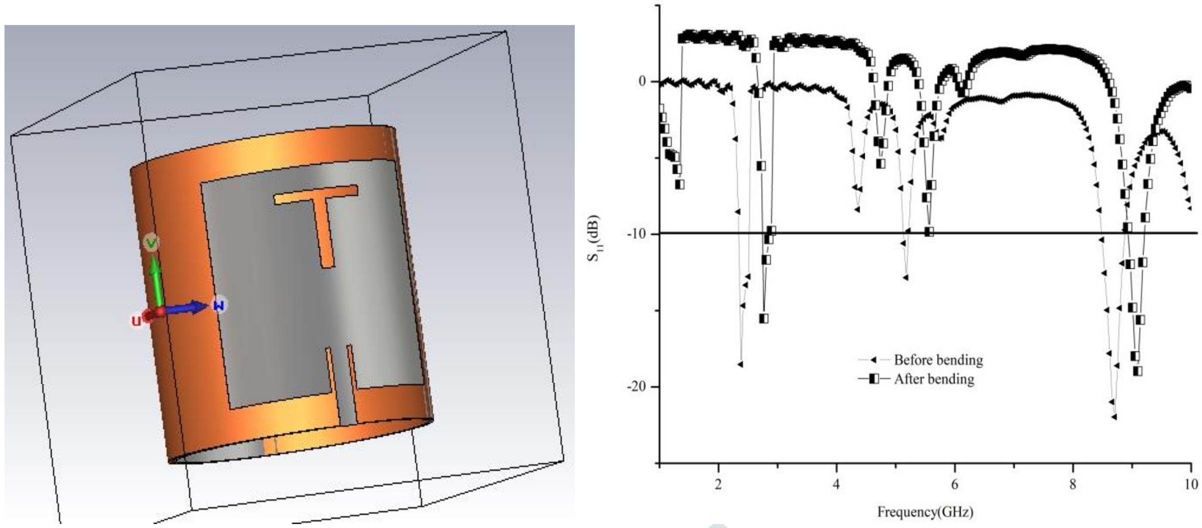
SAR is expressed mathematically through the following relationship.

$$SAR = \frac{\sigma E^2}{\rho} \quad \text{..........(5)}$$

σ =conductivity
ρ =resistivity
E =Electric field

Bending Analysis:

The Bending is usually used in wearable, flexible antenna to check the performance .On applying bending in proposed structure as shown in Figure 9(a), the S_{11} value is decreased and also there is a shifting towards upper band as depicted in Figure 9(b).

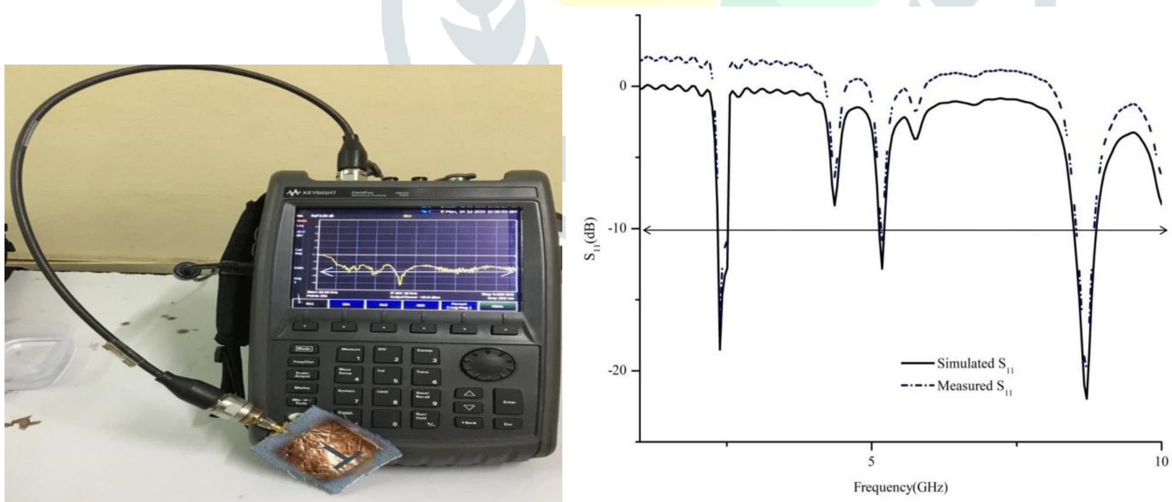


(a) (b)

Figure 9: (a) Bending of proposed structure in CST (b) Comparison of S_{11} value before and after bending

Results and Discussion:

Proposed antenna is measured through Vector network analyzer and the measured and simulated S_{11} value is observed in Figure 10a and 10b .We observed gain variation with and without tumor detection which is shown in Figure 11 and also the surface current distribution at 2.5GHz is shown on Figure 12 its clearly understand the working of proposed antenna on definite direction. But for confirm detection of Tumor we used SAR variation of proposed for that SAR variation of values with and without Tumor is found to have maximum value of .0541 W/kg without tumor and 0.182 W/kg with Tumor for 10 gm of Tissue at 2.5GHz which is depicted in Figure 13 and 14 respectively.



(a) (b)

Figure 10: (a) Measured Result through VNA (b) Comparison of simulated and measured S_{11} value

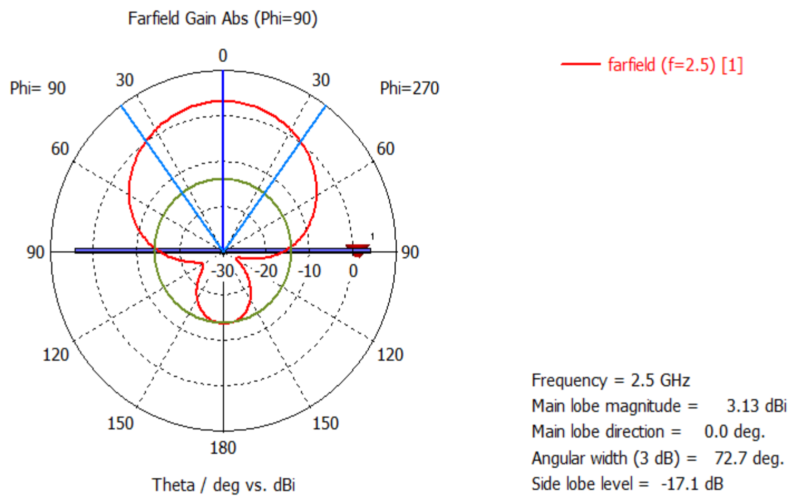


Figure 11: Gain of proposed structure in dB at 2.5GHz

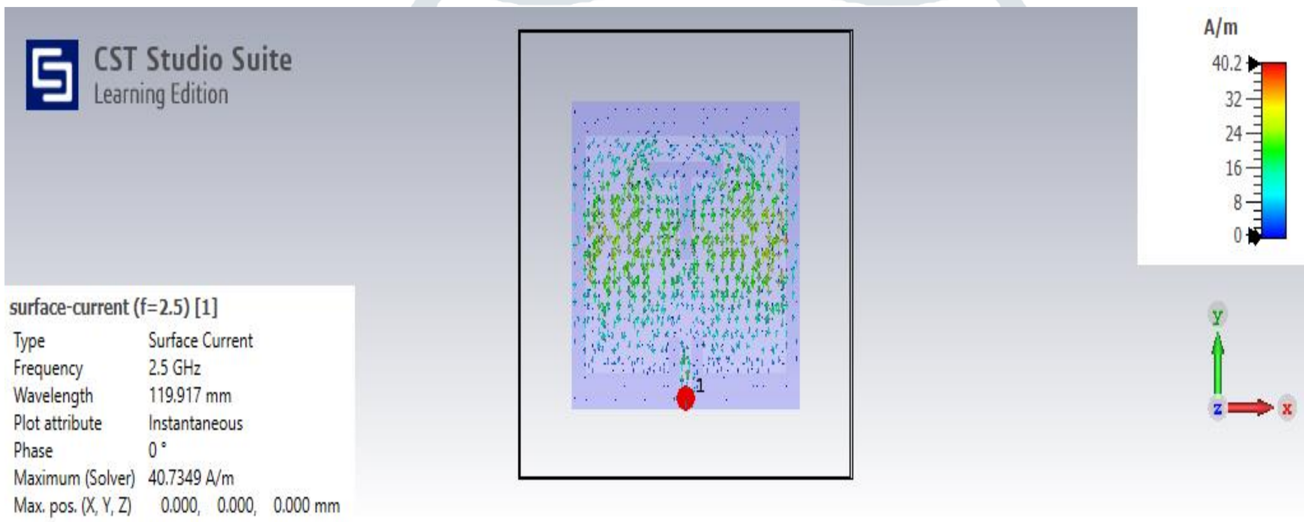


Figure 12: Surface current variation on proposed structure at 2.5GHz

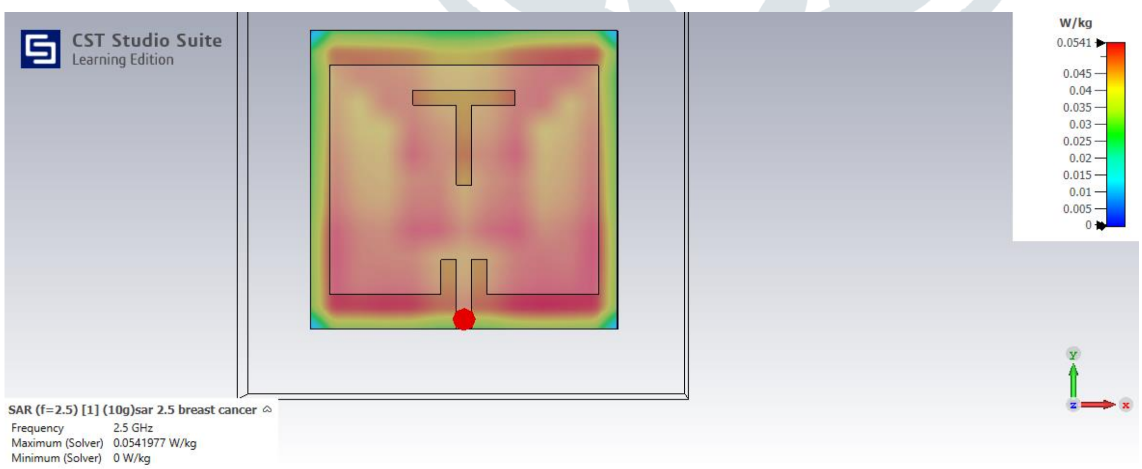


Figure 13: SAR at 2.5GHz without Tumor

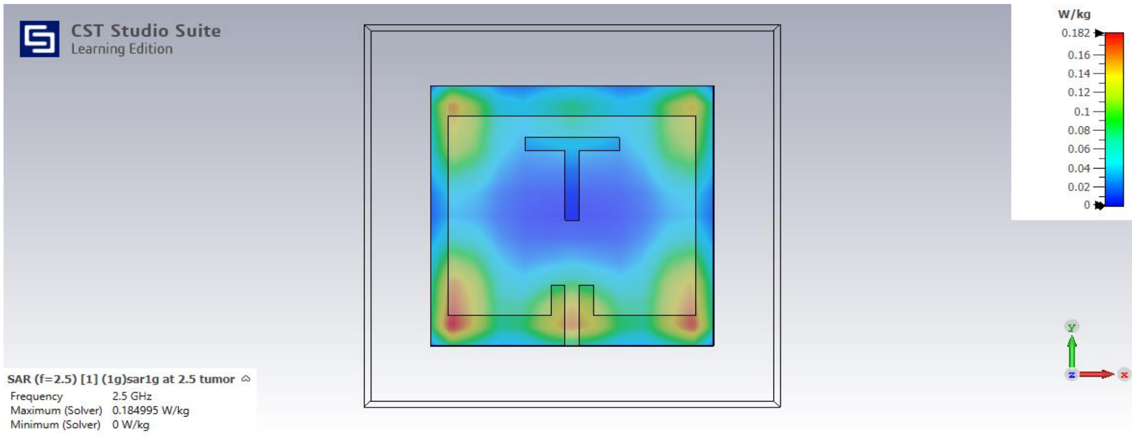


Figure 14: SAR at 2.5GHz with Tumor

Conclusion:

The overall working of antennas was understood. Design and Fabrication of Microstrip Patch Antenna for breast Cancer Tumor Detection was done at 2.5 GHz where SAR value without and with tumor is found to be 0.0541 and 0.156W/Kg. Difference between With and Without Tumor was shown in Figure 13 and 14. The major parameters (such as VSWR, Return Loss curves, Radiation Patterns, Directivity and Beam width) that affect design and applications were studied and their implications understood. The patch antenna was simulated (using CST) and the desired level of optimization was obtained. It was concluded that the software results we obtained matched the theoretically predicted results.

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