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Design and Performance of UWB Wide Slot Antenna to Detect the Breast Cancer in Women

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Abstract: ***Breast cancer is one of the fatal diseases that greatly contribute to the death of many women across the nations. Basically, breast cancer can be detected using a wide slot UWB antenna. In this paper the performance of both antennas like wide slot and stacked patch are used to compare the detection of breast cancer. The specific absorption rate of both antennas is calculated in a normal tissue and tumors tissue, the result is contrast. From this comparative study it's clear that wide slot UWB antenna has outstanding performance in this UWB frequency range and the size of the antenna is three times smaller when compared to the size of the stacked patch antenna. The performances of both the antennas were analyzed and the result suggests that the wide slot antenna performs better than the further antenna.***

Keywords : ***Breast cancer detection, microwave imaging, return loss, specific absorption rate, ultra-wideband antenna, VSWR.***

I. INTRODUCTION

Nowadays most of the women get affected by breast cancer. Prior detection of it increases the survival rate and can save lives [1]. Mammography is a popular screening method which produces digital X-rays [2]. Though it is the popular method in practice it has its own disadvantages. Increasing exposure can also increase the risk of producing new cancer cells [3], and also this method is very expensive. Microwave imaging is the alternative method used for detecting the breast cancer [3]. The application of microwave technology based on the electrical properties becomes essential in the corresponding field for diagnosing. After estimating the biological tissue using this technique the dielectric properties produce the assurance for non-destructive evaluation which is related to electrical properties of the breast tissue [4]. From this information we can identify the tissue with malignant tumor, which normally has higher level of water content than the other. Based on the level of scattering the tumor can be classified as malignant and benign [4]. Ultra-wideband radar imaging and Microwave tomography techniques are the two different approaches used for breast imaging. The unique technique Microwave tomography [5] offers the whole spatial mapping in the particular region of interest with the help of electrical properties. One of the many antennas that surround the RoI region transmits the signal and the rest of the antennas receive the reflected signal. The received signal is then compared with the simulated output of the particular region. Power transmission of the transmitter antenna, power dissipation as the signal passes through and the power received at the receiver antenna by the reflection from tumor tissue is predicted using a numerical model. In continuation of the increasing need of accuracy ultra-wideband radar imaging is proposed which is also called as confocal imaging [5]. Instead of using multiple antennas, this imaging method uses a single antenna. Two types of imaging can be done in this method [6]. In some cases, the pulses are broadcasted and received using the time delay is taken into account for geometrical computation assuming that the physical spacing between the elements of antenna array is known. The received signal is then computed to understand the magnitude of the scattering process which actually reduces the clutter ratio [5].

Designing an antenna that detects the breast cancer is the major challenge. To detect breast cancer high resolution images are very much essential. To obtain such images wide band propagation antenna has to be used. Normally for this scheme array of antennas are used. For this size is also an important factor. Lesser size is much preferable. The other disadvantages of such antennas are low efficiency and bandwidth. In order to improve bandwidth, we have used a wide slot antenna for the detection scheme. When comparing the size of wide slot and stacked patch, the stacked patch is bigger than the wide slot antenna. One of the promising technologies used in data transmission domain is LTRA Wide Band. Nowadays it is used in lot of medical imaging systems [17]. Basically, our focus is upon UWB imaging for detecting the breast cancer. The normal and cancerous tissues possess different electrical properties which can be identified at higher frequencies. In such cases at microwave frequencies the reflection of scattered signals was recorded to localize the tumor growth at an early stage [18-22]. Compared to the existing mammography, this technique is relatively low cost and provides greater resolution [23-25].

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The required parameters for an efficient detection using UWB antennas are high radiation efficiency and stability. There are several such antennas that can be used like Vivaldi and Bowtie antennas. [26-30].

The following sections of the paper give the details of the geometrical design of the wide slot antenna and stacked patch. The performance of the wide slot and stacked patch antenna are compared, and evaluating its results using FEKO software. These will include return loss, radiation pattern, bandwidth, SAR rate.

II. RELATED WORKS

The various types of antennas that are considered for the investigation are bowtie antenna, horn antenna and half oval patch antenna. The detailed description of antenna structures and its specifications are provided for the applications of breast cancer detection.

A. Bow-tie Antenna

The idea behind the bow tie antenna is to detect the breast cancer. This antenna is more superior to the slot line bowtie hybrid is put into operation in a dielectric medium [5]. Radar based ultra-wideband signal is adopted to attain full resolution lacking of extreme signal attenuation and this is put into operation by having appropriate sensor. An antenna is emitted through a pulse to scan the breast with the elevated fidelity among a range of frequency than the ultra-wide. To conquer power in excess of the antenna beam width is connected to the Bowtie plate which is shown in fig.1. The antenna is wrapped up in a dielectric material parallel to breast tissue to detect the cancer. The purpose of choosing the Bowtie design is that the cross polarization promotes to remove the backscatter owing to chest wall whereas unsymmetrical tumors be accepted. Bowtie antenna is capable of detecting 1.5 cm extensive elliptical tumor even if the depth is 1 cm. Microwave detection is realistic and sensitive to detect tumor of any size. In this structure tumors are measured in sub-centimeter which is not metastasized. After detecting the tumor, it is very critical to identify the life span whether those are associated with the cancer. When the return loss is calculated at 10 dB the bandwidth is from 2.5 – 10 GHz and when it is calculated at 5 dB the bandwidth is from 1–10 GHz. The size of the tumour diminishes when the depth is too far from the aperture i.e depths of 0, 1, 2, 3 and 4 cm [15].

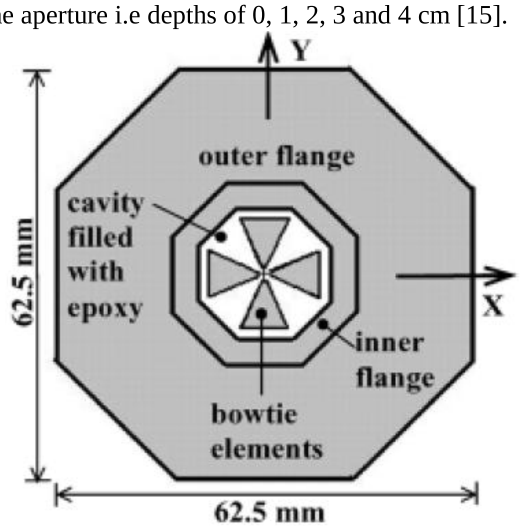

Fig. 1 Structure of bow-tie antenna [30]

B. Horn Antenna

Microwave imaging is to detect the cancer which is proposed by a novel horn antenna located over a solid dielectric medium [11]. The important design constraint is to pair the microwave energy with the tissue. The antenna accomplish this constraints by 1) All the power are radiated using the front aperture and 2) The electromagnetic intervention are blocked in the enclosed area using power absorbing sheets and copper sheets. The features of antenna are achieved by: 1) Antenna aperture with matching good impedance and 2) efficiency attained by good coupling. The breast is scanned using the microwave where the antenna and tissue are naturally wrapped up by means of a coupling liquid embedded with dielectric properties. This standard minimizes the indication happening at the skin boundary and amplifies the dispersion keen on the tissue. The complication and contamination are avoided through the coupling medium with the range of frequency from 3.1-10.6 GHz.

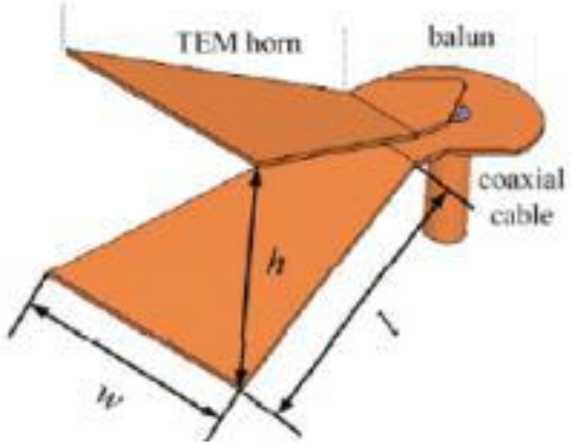

Fig. 2 Structure of horn antenna [30]

The size of the UWB TEM horn antenna is concerning with 75 mm which is depicted in fig.2. The antenna is covered by microwave absorbing sheet and copper sheet in the outer surface. All the sides are covered additionally by the copper sheets which results in increase in the size of the antenna. There are about 4-6 array antennas are used where the position of the tumors are not accurate and also the structure of the antenna is very expensive and complex.

C. Half oval patch antenna

To detect the cancer very actively simple half oval patch antenna is projected through a bandwidth as shown in fig. 3. In this technique patch antenna arrays are incorporated with cubic chamber [10]. The chambers exist with the corresponding dielectric medium. The features of the antenna must be lightweight, compact and compatible to get connected directly with the breast and the operating bandwidth required being of 2.7-5 GHz.

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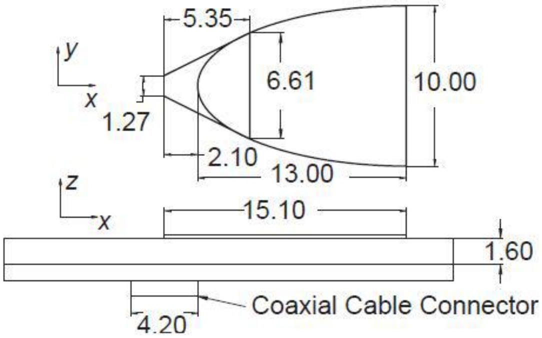

Fig. 3 Structure of half oval patch [30]

There are four cubic chambers available of which the antennas are mounted on it as shown in fig.4. The number of antennas accessible for each panel is same. Switching between the antennas one by one from the source to destination are reconstructed using the breast dielectric distribution. Scanning is done between the source and the destination using single antenna.

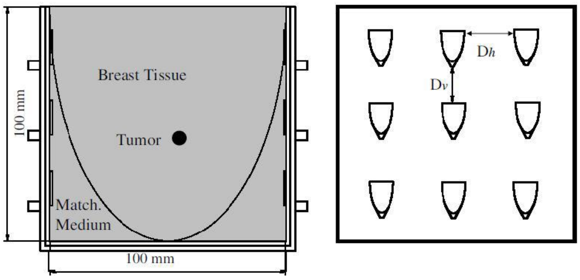

Fig. 4 Imaging cubic chamber [30]

The antenna contains more data imaging that can be obtained by every scanning results in which the coupling may be tough and the array turn out to be more expensive. The return loss of the antenna measured from less than -10 dB from 2.7 to 5 GHz.

III. ANTENNA DESIGN

The antennas used in this paper are: (i) A stacked patch antenna used to detect the breast cancer. (ii) A fork-fed wide slot antenna for this detection scheme. Both these antennas are constructed using substrate Roger duroid with permittivity 10.2. these antennas are engrossed in a similar medium, its dielectric properties like permittivity and conductivity are similar to normal breast tissue. To determine the specific absorption rate, the antenna is placed above tissue in order to determine how much amount of power is absorbed by the body.

A. Stacked Patch Antenna

The stacked patches are arranged using a microstrip line feeding slot which is depicted in fig.5. The stacked patch is the modification of the conventional patch antenna. The antenna's popularity is mainly due to its simple design. This stacked patch can obtain wider bandwidth than the traditional microstrip antennas.

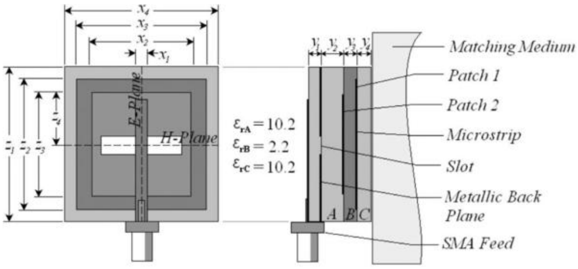

Fig. 5 Schematic view of stacked patch antenna [30]

This antenna contains three dielectric layer that are sandwiched between the patches. It has two patches upper and lower patches. The stacked patch antenna is shown in fig. 5 with dimensions being: x1 = .66, x2 = 6, x3 = 9, x4 =18, y1 = 0.64, y2 = 1.9, y3= 0.8, y4 = 1.27, z1 = 18, z2 = 6.5, z3 = 6, z4 =3. This is simulated using FEKO software.

B. Wide Slot Antenna

The view of the wide slot antenna infig.6 consists of two sides of which one of the sides is the wide square slot and another side is the fork-fed microstrip feed. The bandwidth of the antenna is increased using forked feed. The opposite side of the slot region is the wise slot positioned with the fork like fine-tuning stub.

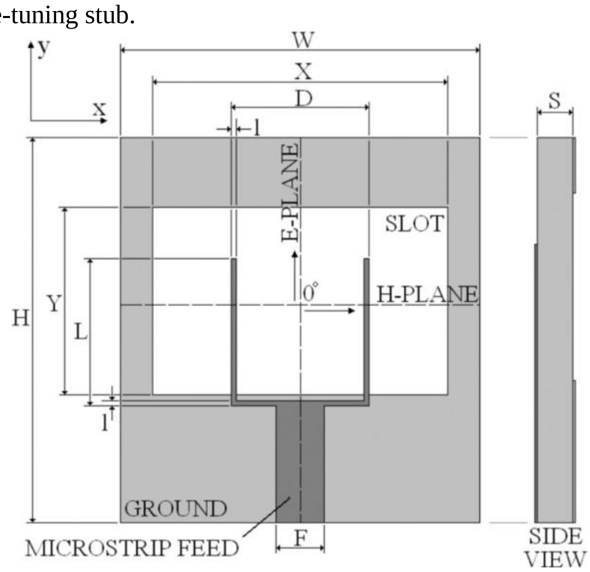

Fig. 6 Schematic view of wide slot antenna

The bandwidth is enhanced by coupling between the wide slot and the microstrip line where both are effectively controlled with the help of wide slot antenna. This method is called as fork like tuning stub due to the fork shape. The dimensions of the antenna are: H =14, Y =7, L = 6.5, D = 4, W = 13, X = 10, F = 1.25, S = 1.25, and l =2.

IV. RESULTS AND DISCUSSIONS

The performance of these antennas are evaluated using FEKO software. Comparing the value of return loss, SAR, bandwidth, electric field intensity, radiation pattern, directivity, VSWR, impedance, stray factor, and efficiency of both antennas.

A. Return Loss

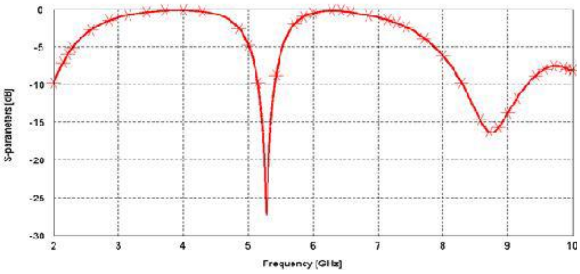

Fig. 7 Return loss of stacked patch antenna

The return loss or reflection coefficient depends on the amount of power reflected back from the antenna. It can be determined using the S-Parameter.

The S-parameter is expressed it as

$$\Gamma = (VSWR - 1) / (VSWR + 1) \quad (1)$$

$$\text{Return loss} = -10 \log (\Gamma) \quad (2)$$

Where, Γ represents reflection coefficient of antenna.

The return loss measurement of the stacked patch is shown in Fig.7 and the frequency range is at 5.25GHz and the manifestation of frequency dependents on the coefficient. When the coefficient decreases the frequency decreases and vice versa. At 7.2GHz the reflection coefficient begins to reduce and when the frequency increases the corresponding coefficient increased by 8.7GHz. As one of the features the graph works with dual band frequency. The evaluation of the return loss is about -27dB along with the stacked patch antenna proves with good matching impedance. The bandwidth determines the frequency range when the antenna emits or receives energy. The bandwidth for the stacked patch antenna acquires 6.51dB.

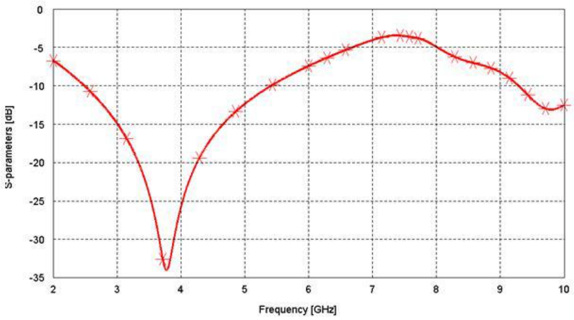

Fig. 8 Return loss of wide slot antenna

The return loss which resonates at 3.75 GHz belongs to wide slot antenna is shown in fig.8 and the reflection coefficient is increases with increasing frequency. The whole bandwidth is performing well because the reflection coefficient is less than -10dB for entire frequency range. Return loss is enhanced to -34.17 dB of the wide slot antenna. And also suggest good impedance matching. The bandwidth of the antenna is enhanced to 13dB for the fork like feed.

B. Specific Absorption Rate

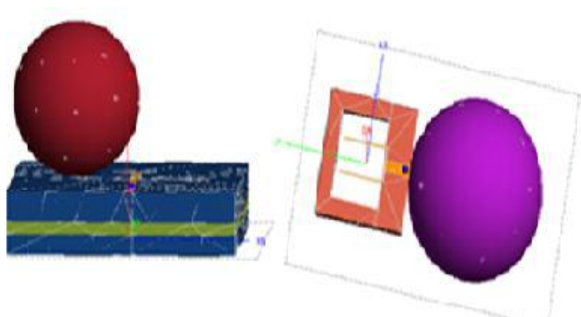

Fig. 9 Phantom model placed in stacked and wide slot antenna.

The SAR is to measure the power captivated by the average. The value of the SAR to detect the cancer is very limited [5]. The value is evaluated by the equation,

$$SAR = \frac{\sigma E^2}{\rho} \text{W/Kg} \quad (3)$$

Where E is the electric field intensity in V/m, σ is the conductivity of the material in S/m. When comparing the usual and impure tissue the value of the infected tissue is higher than the normal tissue which is executed by the electromagnetic power. To calculate the Specific Absorption Rate (SAR) value of the antenna is linked with phantom in processing the human tissue. On the top of the wide slot and stacked patch a phantom is attached as shown in fig.9 to measure the normal and abnormal tissues.

The permittivity between the normal and tumors are measured in the ratio of 1:5. To calculate the relative permittivity of normal tissue is ε_r=9, absorption rate, for tumor is ε_r =50, and the conductivity is σ = .4 S/m and for tumor is σ = 9 S/m.

Table 1 shows SAR calculation of normal and tumors tissues for stacked patch and wide slot antenna for frequency 2GHZ to 10GHZ. This assumes that SAR value of abnormal breast is higher than normal breast tissue, because that tumors tissue contains more water and blood content than normal tissue. The dielectric properties for tumors tissue are five times greater than normal tissue.

Table 1: SAR rate calculation of wide slot antenna and stacked patch

Frequency (GHz)	SAR rate (Normal tissue)		SAR rate (Tumors tissue)	
	Stacked patch	Wide slot	Stacked patch	Wide slot
2.00	0.0123	0.0221	0.0525	0.2216
3.14	0.0463	0.0460	0.0319	0.4933
4.28	0.0893	0.2924	0.1411	0.5667
5.14	0.1562	0.3194	0.7170	0.6532
6.00	0.1631	0.4812	1.0190	0.7234
7.14	0.2556	0.6213	1.0275	0.9743
8.00	0.3217	0.7110	1.1600	1.2130
9.14	0.4156	1.0920	1.3767	1.5250
10.00	0.5713	1.3120	2.5300	2.2100

C. Electric Field Intensity

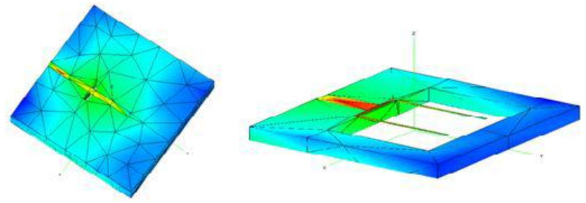

Fig. 10 E-field of (i) Stacked patch, and (ii) Wide slot antenna

The quantity of the electric energy accumulated in the area of the space per unit volume and the current is distributed to both the antennas equally as shown in the fig.10. Passing the electric energy into the antenna the frequency range is stable and the ports obtain maximum current at various regions. In figure the flow of current is utilized in the maximum is indicated by red color and if there exists no current is notified by blue color. When the current flows at the maximum range the frequency resonate at 5.25GHz for the stacked patch and at 3.5GHz for wide slot antenna.

D. Radiation Pattern

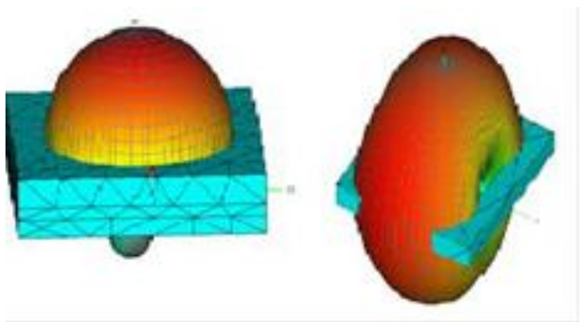

Fig. 11 Radiation pattern of (i) Stacked patch, and (ii) Wide slot antenna.

The properties of antenna depict the graphical representation of the radiation pattern. The 3D radiation pattern of both antennas is shown in the fig.3.For stacked patch antenna it has bidirectional radiation pattern whereas the wide slot antenna radiates power only in one direction. From this pattern in fig. 11(i) is clear that maximum radiation occurs in forward direction. For wide slot antenna pattern in fig. 11(ii) is an omni-directional pattern is obtained. It has a donut shape pattern.

V. COMPARATIVE PERFORMANCE ANALYSIS OF UWB WIDE SLOT AND STACKED PATCH ANTENNA

The antenna metrics for high band frequencies has been performed with the investigated results, to know about the antenna performance.

A. Beam Area

The total beam area Ω_A is consisting of main beam area Ω_M and minor beam area Ω_m.

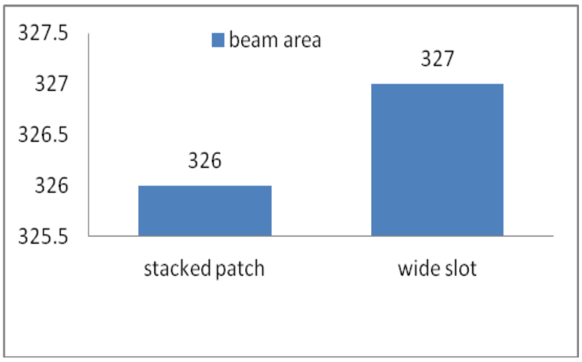

Fig. 12 Beam area of stacked patch and wide slot antenna

B. Bandwidth

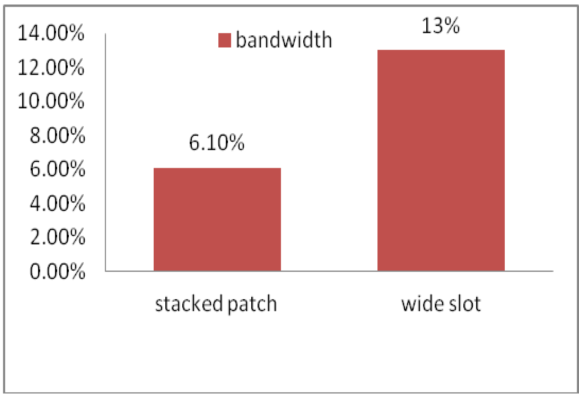

Fig. 13 Bandwidth of stacked patch and wide slot antenna.

The antennas are capable of operating or acquire energy using the bandwidth which in turn reflected at various frequencies. It is also the frequency on the either side of a centre frequency where the antenna characteristics are within the acceptable value. By using fork like tuning stub in wide slot antenna bandwidth is improved to 13%.

C. Stray Factor

The small unit of radiation known as the minor-lobe associated with the solid angle ratio Ω_m along with the total beam solid angle Ω_A is called the stray factor. The equation follows that $\Omega_M/\Omega_A + \Omega_m/\Omega_A = 1$. Using the minor-lobe, the antenna gain and the directivity are attained which is almost identical to stray factor.

$$\text{Stray factor} = \Omega_m / \Omega_A \quad (4)$$

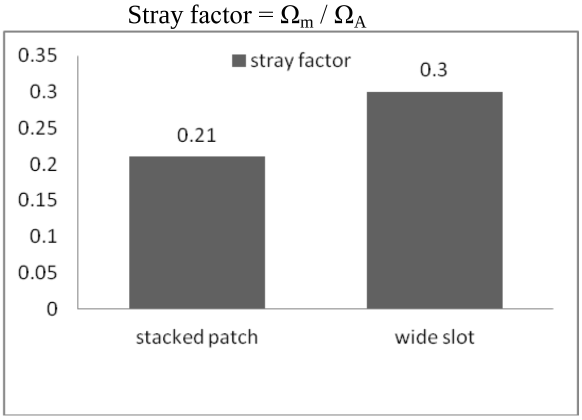

Fig. 14 Stray factor of stacked patch and wide slot antenna.

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D. Beam Efficiency

The beam efficiency is calculated using the ratio between the main beam and total beam.

$$\text{Beam efficiency} = \Sigma_M = \Omega_M / \Omega_A \quad (5)$$

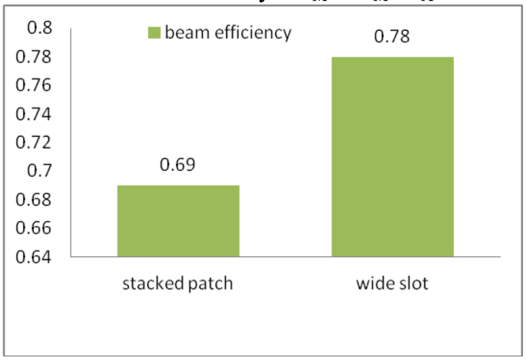


Fig. 15 Beam efficiency of stacked patch and wide slot antenna.

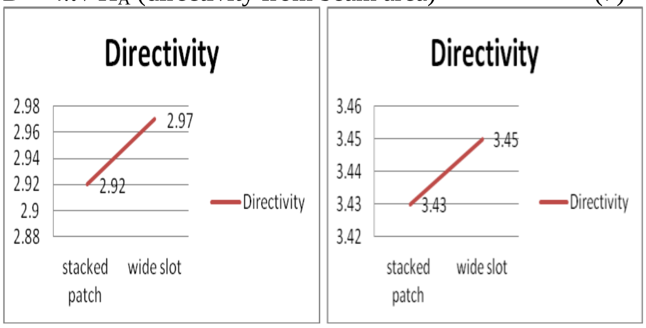
The upcoming session are simulated and measured results of designed antenna parameters like directivity, VSWR, impedance, admittance, and efficiency.

E. Directivity

The directivity is evaluated using the maximum power thickness $P(\theta,\phi)_{max}$ and the standard rate above a sphere are experimented in the remote ground of the antenna.

$D = P(\theta,\phi)_{max} / P(\theta,\phi)_{av}$ (directivity from pattern) (6)

$D = 4\pi / \Omega_A$ (directivity from beam area) (7)

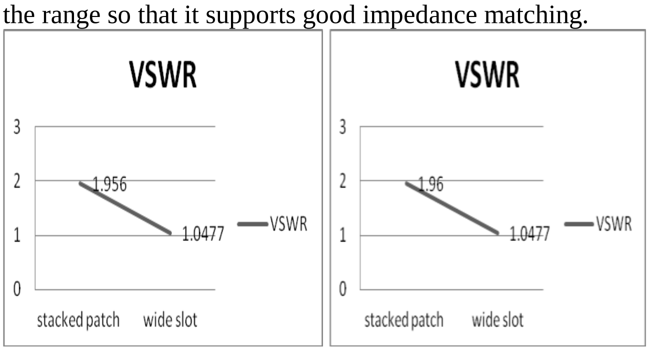


(i)Simulated (ii)Measured

Fig. 16 Directivity of stacked patch and wide slot antenna

F. VSWR

VSWR is a measure of impedance of RF components of antenna circuit. When the impedances are improper, there will be loss of signal power which results in weak transmissions and poor reception. Fig. 17 inferred that transmission and reception is efficient because the VSWR is acceptable within the range so that it supports good impedance matching.

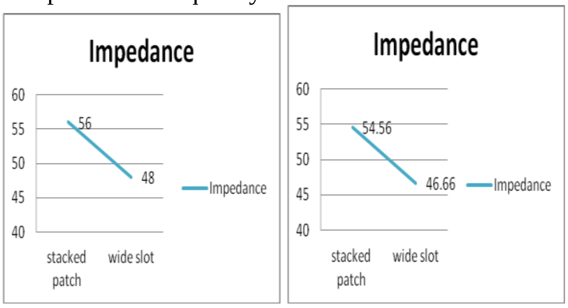


(i)Simulated (ii)Measured

Fig. 17 VSWR of stacked patch and wide slot antenna.

G. Impedance

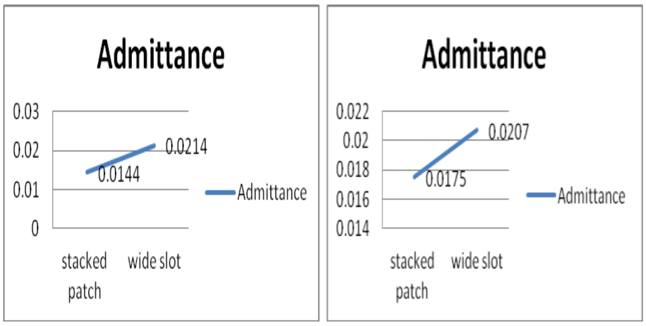
Maximum power coupling into the antenna can be done when the impedance 50 ohm matches the cable impedance. It is the voltage to current ratio for a single complex parameter at a particular frequency with a unit of resistance ohm.



(i)Simulated (ii)Measured

Fig. 18 Impedance of stacked patch and wide slot antenna

H. Admittance



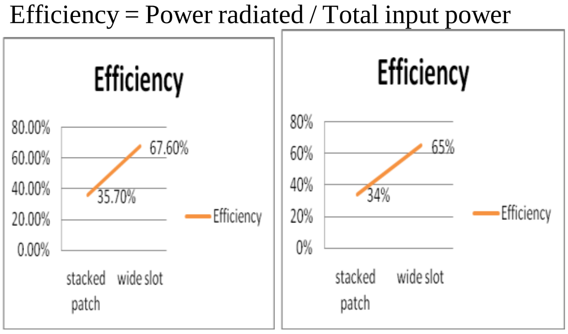
(i) Simulated (ii) measured

Fig. 19 Admittance of stacked patch and wide slot antenna.

I. Efficiency

To determine the efficiency of the antenna the total input power passed on to the antenna.

Efficiency = Power radiated / Total input power (8)



(i) simulated (ii) measured

Fig. 20 Efficiency of stacked patch and wide slot antenna

VI. SUMMARY AND CONCLUSION

The UWB radar system is to detect the cancer using stacked patch antenna is matched up to wide slot antenna. While comparing the performance of both antennas the return loss is improved to -34dB. By using fork like tuning stub in the wide slot its bandwidth is improved to 13%. The distribution of electric energy is uniform through the antenna. When the electric filed is above 0.02J then the tissue will be burn. The efficiency of stacked patch is 35% and it is improved to 67.9% for wide slot antenna.

From this comparative study it is clear that size of the stacked patch antenna is three times bigger than the wide slot. The Specific Absorption Rate (SAR) of normal and tumors tissue are compared. The cancerous tissue has higher SAR value in case of both antennas. Thus the wide slot antenna is the ideal choice for breast cancer detection.

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