MICROWAVE IMAGING FOR EARLY BREAST TUMOUR DETECTION

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ABSTRACT:
In the field of women's health, after lung cancer, the second most common type of cancer affecting women globally and known to be one of the most lethal in women worldwide is breast cancer. The high number of women's deaths each year due to breast cancer is a cause for concern. Well-known techniques that aid in understanding this disease include X-ray, MRI, ultrasound, and biopsy. They also greatly facilitate the diagnosis of breast tumors in women. It is important to detect breast cancer at an early stage because it significantly affects treatment outcomes. To ensure the success of treatment, the exact site and volume of the tumor also need to be measured. While there are limitations to performing medical procedures on a human body, in this particular study, HFSS software has been used to design two types of breast phantoms in the shapes of a transmitting microstrip antenna and a receiving microstrip antenna, aiming more at tumor detection. The use of microwave imaging provides the potential to examine biological tissues without physical interaction, which is considered a better and safer alternative compared to the standard techniques in existence. Due to the variation in electrical properties, microwave frequencies have been considered suitable for locating tumors in breast tissue. The use of microstrip antennas also results in low energy absorption.
Keywords– Microstrip patch antenna, Breast Cancer, Ansys HFSS, S-Parameter Plot.

INTRODUCTION:
Within the world, a large population is suffering from different kinds of cancer, and breast cancer is the most common among women. Various factors such as diet, living surroundings, and mental pressure accelerate the causes of this disease. Current approaches used for the detection process are accurate but cause anxiety, depression, and dissatisfaction among patients. Tumor detection is very necessary in order to achieve faster recovery of patients, especially in the treatment of cancer. Antennas have been considered an effective tool for various applications like microwave engineering and tumor detection in the medical field as well. The recent advancements made in the antenna field help detect the tumors present inside the body through the conversion of radio signals to electromagnetic waves, then transmitting them after having some distinctive features like absorption and reflection, which are useful in medical-oriented applications. Microstrip patch antennas offer great merits such as being less expensive with reduced size, making them work better when compared with other antennas, like horn antennas with wide band performance, whereas dipole and monopole antennas demand more space.

LITERATURE REVIEW:
The demand for effective diagnostic tools for improving breast cancer treatment outcomes is sufficient to reveal the downsides of traditional practices like mammography, MRI, or ultrasound. Recently, microstrip antennas have become known for their efficiency at higher frequencies and reduced energy

absorption in biological tissues, regarded as a suitable replacement. Several studies have suggested various advantages of microstrip antennas such as efficient functioning at higher frequencies that reduce absorption of energy in biological tissues, thus providing safety. Simulation platforms like Ansys High-Frequency Structure Simulator have greatly helped in easing the workload of antenna modeling and optimization tasks along with breast phantoms. The model generally contains layers representing skin, fat, and fibroglandular tissues; simulated tumors are hemispherical with a comparatively higher dielectric constant. The difference in S-parameters and VSWR presented provides a basis for healthy versus malignant tissue differentiation. Studies have revealed tremendous differences in S-parameters and VSWR frequencies between normal tissue and the presence of tumors, highlighting how the properties of tumors can differ and how different these properties can be identified using microwave imaging methods. Comparative analyses also provide insight into how tumor size and location influence the imaging outcome while proposing the potential for more accurate diagnoses with better materials and design. There are, nevertheless, gaps concerning the detection of internal tumors and real-time imaging. Although promising advances have been made in the area regarding improvements in non-invasive and biocompatible microwave imaging systems concerning breast cancer diagnostics, safer yet lower-cost solutions remain to be developed for the early-stage detection of cancer.

MICROSTRIP PATCH ANTENNA DESIGN:

There are numerous types of antennas in communication systems to effectively achieve the broadcasting and receiving process. Microstrip patch antennas are one of the commonly used antennas for many applications. These antennas are constituted of a patch, dielectric material, and ground plane, ensuring ease of designing them. In addition, there is a connection between the feed lines to the edge of the patch whereby their antenna becomes compatible in the transmitter and receiver antennas. The shape of the patch is variable and can be circular, square, rectangular, or even some other various shapes, depending on the literature. The patch and ground plane layers are usually made from materials such as copper. Upon application of voltage between the conducting metal patch and ground plane, the activated patch above the dielectric substrate starts radiating after some small amount of time. The activate antenna emits radiation in the broadside direction without directing the radiation towards the substrate. A microstrip, or an electrical transmission line supporting microwave frequency signals, may be produced using several techniques. The increased popularity of microstrip patch antennas comes from their small size, low cost, and increased feasibility against other kinds of antenna designs. The construction process of these antennas is made easy by using software packages like HFSS, CST, etc.

i.PATCH ANTENNA SPECIFICATIONS :

TABLE 1 Antenna dimensions

AntennaParts	Length (mm)	Width (mm)	Height (mm)
Ground	2.35	2.35	0
Substrate	2.35	2.35	0.254
Patch	1.375	1.55	0
Feed line	0.4875	0.1	0

ii.ANSYS HFSS SOFTWARE:

Ansys HFSS is outstanding software for designing & simulating high-frequency products. It is reputed for its very efficient optimization and computation of transmission and reception of high-frequency EM waves. This makes Ansys HFSS a basic realization for engineers involved with designing electronic products. Together with its ensuing expansive global acceptance at the forefront of high-frequency

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electronic design,Ansys HFSS consitutes one of the most important tools with high potential and accurate solution of complex design problems. It is regarded as the gold standard in 3D electromagnetic simulation and provides the most complete spectrum of technologies and tools needed for antenna simulations. Its accuracy in antenna structure modeling rigging assessment quite closely to actual performance has secured its place in the industry. Antennas are central to surfacing technologies for different applications, ranging from handsets to self-driving vehicles.Reputation for dependability and excellence made this software a household name for antenna design across the globe. Besides, antenna performance evaluation, accurate results, and showing the effectiveness of the various techniques of signal processing have never had a better opportunity than roofing an antenna through Ansys HFSS. Simulations on different antennas, including dipole, horn, Yagi-Uda.

ANTENNA DESIGN AND METHODOLOGY:

i. **Design of Microstrip Patch Antenna**

The design of the patch antenna was developed using HFSS, as described below. The ground plane was generated using a rectangular sheet measuring 2.35 mm in YZ dimension. The antenna is designed for operation at 33 GHz. The substrate was formed from a rectangular solid box with dielectric material FR4 having a dielectric constant of 4.4, with dimensions of 2.35 mm in length and width and a substrate thickness of 0.254 mm. The rectangular patch is created over the generated substrate and is 1.375 mm by 1.55mm long. The feed line for feeding the excitation is formed from a rectangular conductor of dimensions 0.1mm × 0.4875 mm. The wave port is made as a rectangular structure with a length of 1.5 mm and width of 0.254mm. Being given the wave port, the port must be covered with a metallic conductor where the thickness varies from 0.05 mm to 0.1 mm. Figure 1 shows the finalized view of the patch antenna.

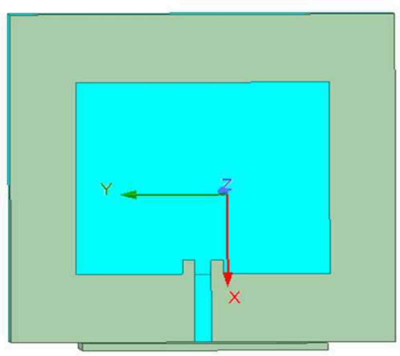

Fig. 1. Patch antenna

ii. DESIGN OF BREAST STRUCTURE:

The breast structure is modeled depending on the various parameters existing in the tissue. Breast fiber (hemi-circle) created with starting point 9mm x 0 mm x 0 mm in y-z plane. Construct the same dimension hemi-circle in x-y plane. Then sweep along the axis to get the three-dimensional hemisphere. Inside the breast tissue, there will be a tumour sphere of dimensions 0 mm x 0 mm x 0 mm for the non-cancerous breast phantom. It can be varied according to needs and during evaluation while analyzing. The permittivity of the breast fibre is 16. The design of Breast fat in the semi-circle with starting point 9.5 mm x 0 mm x 0 mm in y-z plane is completed. Construct the same dimension semi-circle in x-y plane. Then sweep along the axis for three-dimensional shape of the hemisphere. The permittivity of breast fat is 3.4. The Breast skin is designed in the outer layer of the hemi-circle shape as starting in the

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yz plane from 10 mm, 0 mm, to 0 mm being. Construct the same dimension hemi-circle in the xy plane. Then sweep along the axis to get a three-dimensional image of a hemisphere. The permittivity of breast skin is 17.7. The real breast structure thus formed is from the HFSS software. Each breast layer has a different conductivity and permittivity number. The designed breast structure with cancerous tissue is shown in Figure 2. The design characteristics of breast parameters are tabulated in Table 2.

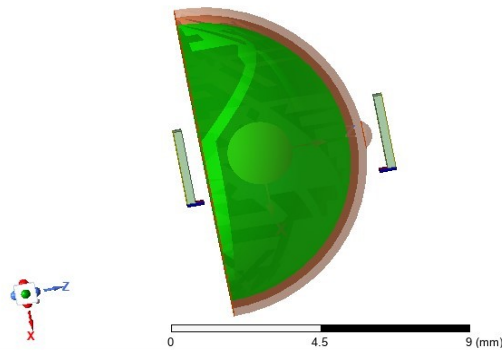

Fig. 2. Breast Structure with cancerous tissue

Table II Breast Design:

Tissue	**Permittivity**	**angentLoss**
Breastskin	17.7	0.93
Breastfiber	16	0.94
Breastfat	3.4	0.16
Tumour	18	1.05

iii. CANCEROUS TISSUE WITH TRANSMITTING AND RECEIVING ANTENNA:

The designed breast tissue structure is positioned between the basic patch antenna, which is used as both the transmitting and receiving antenna.

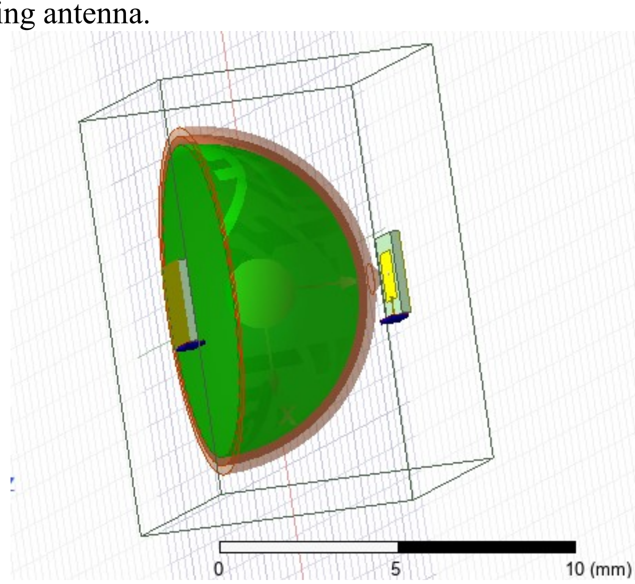

Fig. 3. Predection Model

The entire designed model is enclosed with radiation box. The use of radiation box in HFSS is to create the open model. The radius of tumour is varied by parametric setup available in HFSS. The prediction model is shown in Figure 3.

iv. COMPARISION OF CANCEROUS AND NON-CANCEROUS MODEL:

The principal dielectric parameters for describing microwave propagation in human body tissues due to electrical field interaction are permittivity and conductivity. The respective dielectric properties may account for the differences and variations in evaluation of the magnetic and electric fields based on the nature and structure of the buildings. The permittivity and conductivity define some electromagnetic fields upon a given structure. Such information is very paramount in distinguishing cancerous tissue.Upon the entry of the electromagnetic waves into the breast tissue, there may be some variation in S parameter that describes the linear relationship in electric circuits. By this, it can be identified by the VSWR graph plot, the Directivity plot, and the Gain plot. There seems to be considerable fluctuation of S parameter differences in breast structures with and without tumours. The electromagnetic field values into the breast structure alter to some extent with the different configurations of the antenna structure in place. Such variations make it possible to determine the presence of breast tissue with a tumour. Furthermore, switching antenna configurations produced a visible increase in changes in the results.

ANTENNA OPTIMIZATION:

The process of antenna optimization comprises two distinct parts, i.e., modification of the antenna design structure and the breast structure phantom model. The adjustments need to be fine, meant especially to depict the radius of the tumor and to simulate the tumor modeled alongside the specified antenna structures. An important facet in this optimization process entails a careful selection of a fitting substrate, thus replacing the conventional FR4 material with substances that significantly enhance the antenna's permittivity and radiation power.

The impact of tumor radius manipulation within this optimization drive is paramount, since these operational parameters directly affect the Voltage standing wave ratio curve, S parameters, directivity curve, and gain curve. The optimization procedure illustrates exactly how changes in the tumor radius have cascaded effects on these important metrics: With systematic variation in the radius and commensurate S-Parameter plotting, Figure 6 gives a general overview on such a wide span of radius variations from 0.75mm to 1mm. Through vigilant evaluation of these subtle results and their scrutiny for comparative purposes, tremendous insights are gleaned in the course of S-parameter analysis and comparison.

It is commonly observed in human medicine that breast tumors usually grow bigger than 7 cm. With this perspicacity in mind, the ingenious model developed from this thorough optimization approach stands as a primary tool for diagnosis of breast tumors. This optimally devised model plays a pivotal role in achieving successful diagnostics and prognostic research—by optimally coordinating adjustments in both antenna and tumor sizes. This synergy of tuning antenna parameters with appropriate tumor specifications epitomizes a remarkable advancement to deliver more accurate and efficient diagnosis.

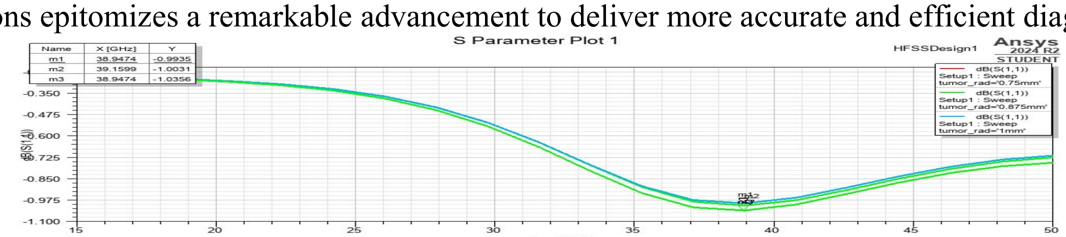

Fig. 4. S parameter plot with multiple radii

RESULTS AND ANALYSIS:

i.VSWR PLOT

The result of the designed antenna is analysed forthe cancerous breast tissue detection. Voltage Standing Wave Ratio (VSWR) is mentioned as the measurement of the designed antenna is matched with a transmission line. VSWR of the designed antenna model has been obtainedand for non-cancerous tissue and cancerous tissue is shown in Figure 5 and 6. It could also be described as the proportion of an antenna system's input voltage to output voltage. VSWR defines how efficiently the incident poweris transmitted from the source to the destination.

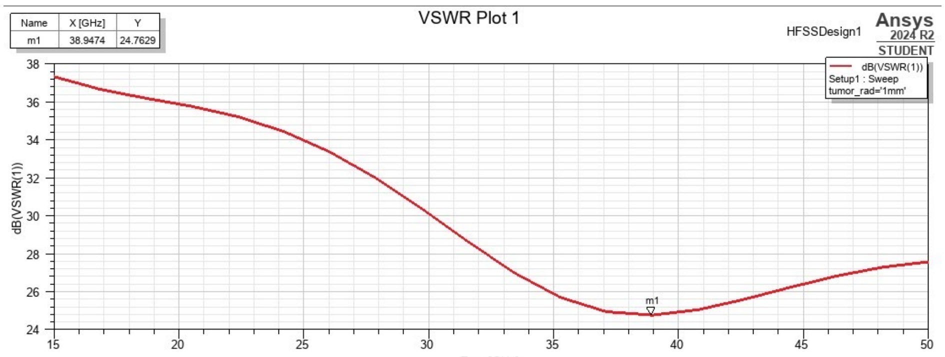

Fig. 5. VSWR plot for non-cancerous tissue

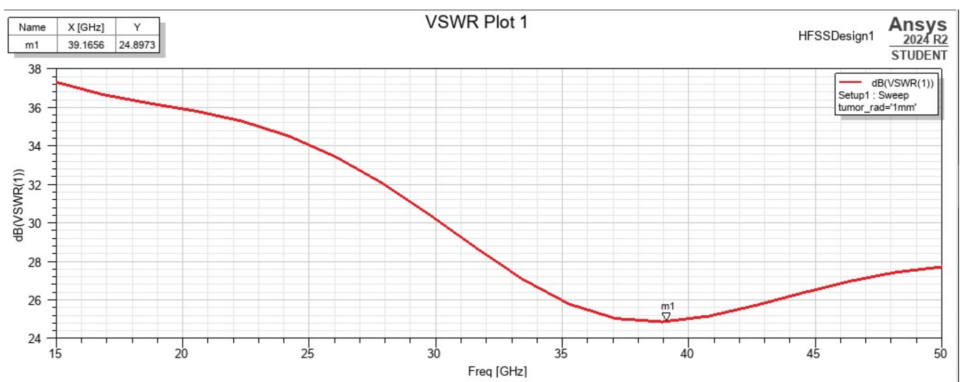

Fig. 6. VSWR plot for cancerous tissue

The obtained values of VSWR plot of non-cancerous breast tissue are resonating at frequencies of 38.9474GHz. The obtained values of VSWR plot of cancerous breast tissue are resonating at frequencies of 39.1656 GHz.

ii. S PARAMETER PLOT:

The S parameter in a transmitting antenna denotes the amount of reflected power by the load, which ideally should be minimal for optimal transmission quality. The power initially transmitted from the source is absorbed by the load on the receiving side, with any excess power being reflected back to the source, a phenomenon referred to as return loss, which should be kept to a minimum. The S parameter graphs for the breast phantom depicting non-cancerous and cancerous tissues are illustrated in Figures 7 and 8.

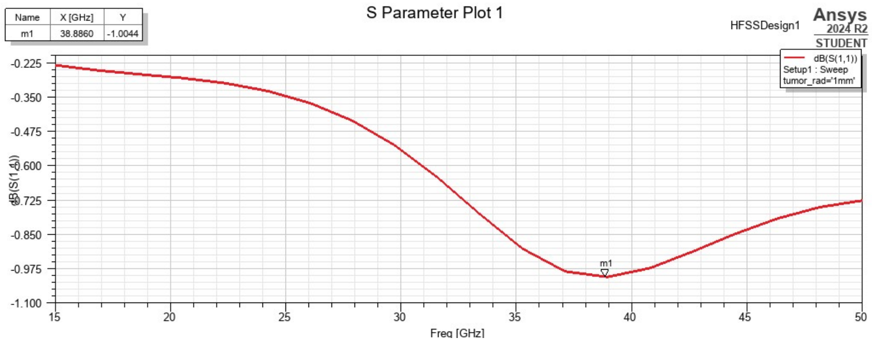

Fig. 7.S parameter plot for non-cancerous tissue

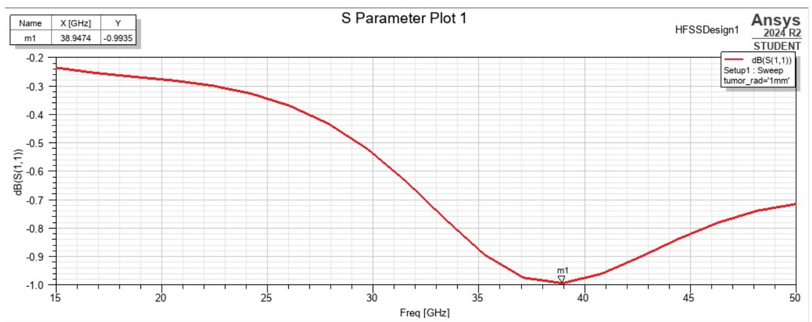

Fig. 8.S parameter plot for Cancerous tissue

The obtained values of S Parameter of non-cancerous breast tissue are resonated at frequencies 38.8860 GHz and withreturn lossorreflectionloss in yaxis are -1.0044dB. The obtained values of S Parameter of cancerous breast tissue are resonated at frequencies 38.9474 and with return loss or reflection loss in y axis are -0.9915dB.

iii.GAIN PLOT

The gainplotplaysa major role inthe detectionpart of cancerous tissue. The variations of the gain plot of non- cancerous tissue and cancerous tissue are analysed to perform the detection. Improvement in the gain of the designed antenna improves the performance of the antenna. The gain plot for the non-cancerous breast tissue and cancerous breast tissue is shown in Figure 9 and 10. Thegainplotwithnon-cancerousbreasttissueprovidesagain of 0.82 dB and with cancerous breast tissue the gain is marked as 0.87dB.

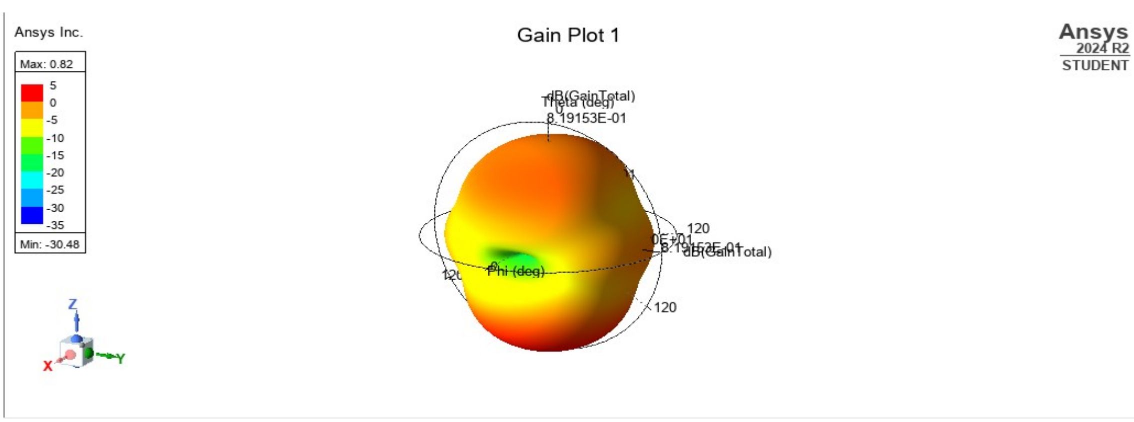

Fig. 9. Gain plot for non-cancerous tissue

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Vol-15, Issue-01, No.02, January: 2025

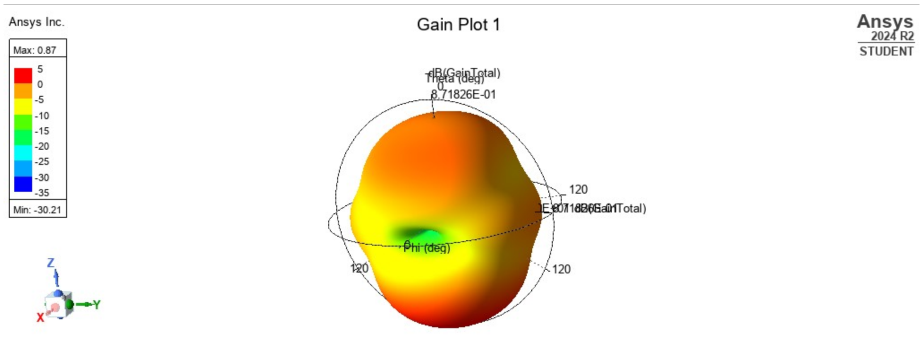

Fig. 10. Gain plot for cancerous tissue

iv. DIRECTIVITY PLOT :

The directivity indicates the direction of antenna radiation. The Microstrip antenna array structure can beused to increase directivity, but this increases the size and complexity of the structure. As a result, by slightly incrementing the dimensions of the patch antenna, the directivity of the Microstrip antenna shall be increased. The simulated antenna's directiveness plot for non-cancerous and cancerous breast tissue has been shown in Figure11 and 12.The directivity value for the antenna with non-cancerous breasttissueis3.89dBandwithcancerousbreasttissueis 3.92dB. The variations in the directivity values shall be determined for detection of tumour.

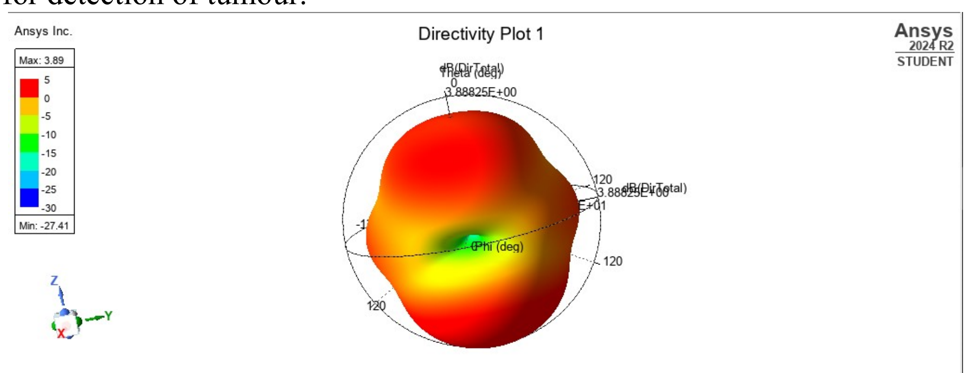

Fig. 11. Directivity plot for non-cancerous tissue

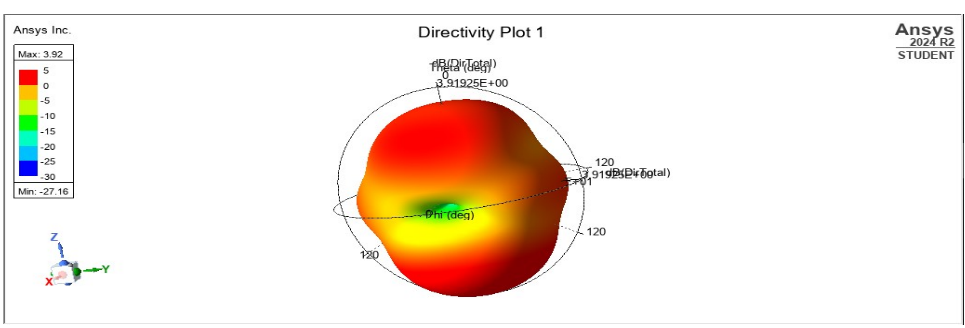

Fig. 12.Directivity plot for cancerous tissue

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Vol-15, Issue-01, No.02, January: 2025

CONCLUSION :

A microstrip patch antenna has been designed and simulated at a resonant frequency of 33MHz. This antenna is preferred because it is smaller than others and is bio-compatible. To assess the outcomes, two kinds of breast phantoms were constructed: with and without a tumor. The simulated breast phantoms were all based on various radii of the tumor. Thus, the different simulated results with tumor and without tumor were obtained. This study makes it clear that these results can detect or rule out malignant tumors. The antenna will pick up the reflected wave coming from this phantom. The phantom consists of both cancerous and non-malignant tissues. Therefore, the contrasting reflected powers will show the presence of a foreign body or tumor cell in the breast region. The reflectance coefficient changed significantly for the breast phantom model due to the presence of a tumor. The antenna could detect malignant tumors inside the designed virtual breast phantom. This antenna could potentially be used in applications that involve biomedicine, including microwave imaging. The implant is not designed for insertion under human skin, but it can be used in different implantation scenarios with flexible, conductive material in future implantation situations.

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