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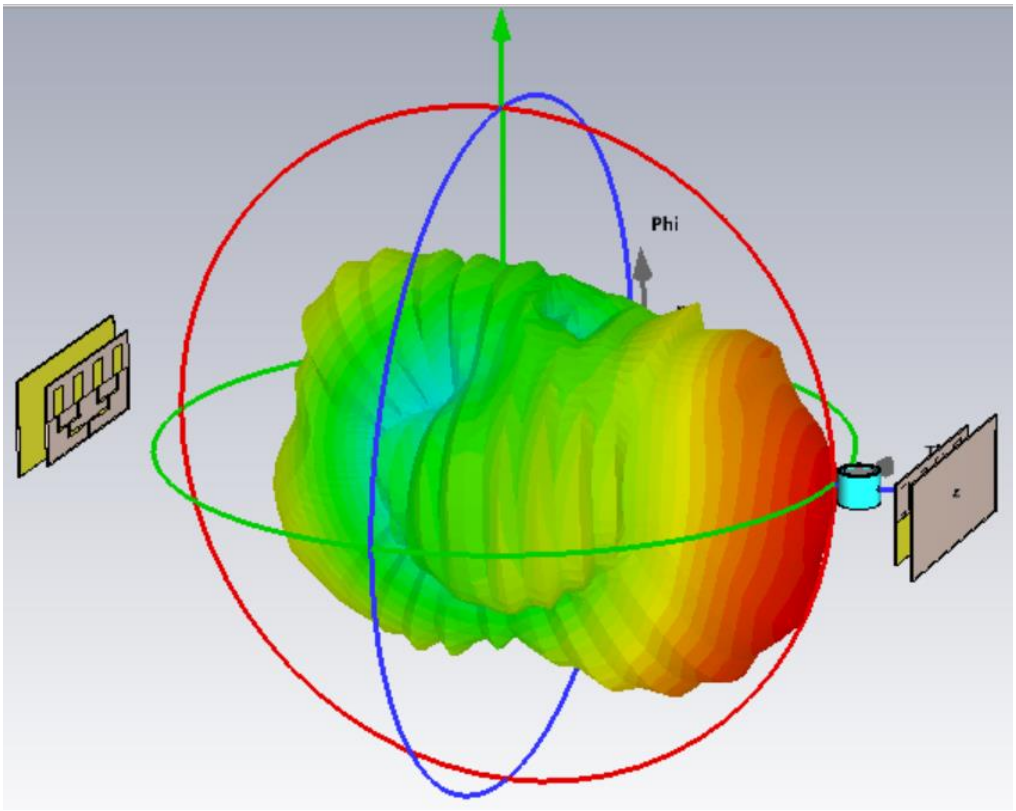
Antenna theory project



Detection of skin tumor using S-band and C-band microwave Frequency

by

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B220054, 3rd yr ETC

UWB and high gain Microstrip Antenna for detecting the presence of tumor in human skin using S-band and C-band microwave frequency

Introduction

A skin tumor refers to an abnormal growth of cells in the skin that can be benign (non-cancerous) or malignant (cancerous). Skin tumors can arise from various cell types in the skin, including the epidermis, dermis, or specialized skin structures such as hair follicles, sweat glands, or sebaceous glands.

Benign skin tumors, such as moles, cysts, or warts, are typically localized and do not spread to other parts of the body. They may not require immediate medical intervention unless they cause discomfort or cosmetic concerns.

On the other hand, malignant skin tumors, known as skin cancer, can invade nearby tissues and, if left untreated, can metastasize to other organs. The most common types of skin cancer are basal cell carcinoma (BCC), squamous cell carcinoma (SCC), and melanoma. BCC and SCC are usually caused by prolonged exposure to ultraviolet (UV) radiation from the sun or tanning beds, while melanoma is often associated with genetic factors and intense UV exposure.

Early detection and treatment of skin tumors are crucial to prevent their progression and potential complications. Regular self-examinations and professional skin checks can help identify any suspicious lesions or changes in existing moles, such as irregular borders, color variations, asymmetry, or growth.

Treatment options for skin tumors depend on their type, size, location, and stage. They may include surgical excision, cryotherapy (freezing), radiation therapy, topical medications, or systemic therapies like chemotherapy or immunotherapy. The prognosis for skin tumors varies, with early detection and treatment significantly improving the chances of successful outcomes.

Properties of Skin Tumour

The electrical properties of skin tumors can provide valuable information about their composition, structure, and behavior. Here are some key electrical properties associated with skin tumors:

1. Electrical Conductivity: Electrical conductivity refers to the ability of a material to conduct an electric current. Skin tumors often exhibit different conductivity compared to normal skin tissue due to variations in their cellular composition and moisture content. Conductivity measurements can be used to differentiate between healthy and tumor tissues, aiding in the diagnosis and monitoring of skin tumors.

2. Dielectric Properties: Dielectric properties describe how a material responds to an electric field. Skin tumors typically have different dielectric properties compared to healthy skin. Dielectric spectroscopy, which involves measuring the electrical response of tissues to different frequencies of electromagnetic waves, can be used to characterize skin tumors. These measurements can provide insights into the tumor's cellular structure, water content, and cellular membrane properties.

3. Impedance: Impedance is the opposition of a material to the flow of an alternating current. Skin tumors can exhibit altered impedance compared to surrounding healthy tissue. Impedance spectroscopy can be used to assess the electrical impedance of skin tumors at different frequencies. This technique can help differentiate between benign and malignant tumors and provide information about their growth patterns.

4. Electrical Resistance: Electrical resistance is the property that hinders the flow of electric current through a material. Skin tumors may have different resistance values compared to normal skin due to changes in cellular density, blood flow, and tissue composition. Resistance measurements can be used to assess tumor characteristics and aid in the development of non-invasive diagnostic techniques.

Understanding the electrical properties of skin tumors can contribute to the development of electrical-based imaging techniques, such as electrical impedance tomography or bioimpedance measurements, which may complement existing diagnostic methods and improve the accuracy of tumor detection and characterization. However, further research is needed to fully explore and utilize the electrical properties of skin tumors for clinical applications.

Detection Methods

Microwave frequency-based techniques have shown promise in the detection and characterization of skin tumors. Here are some commonly used methods for detecting skin tumors using microwave frequencies:

1. Microwave Imaging: Microwave imaging techniques, such as microwave radar or microwave tomography, utilize the interaction of microwaves with skin tissues to create images of the internal structures. These techniques can provide information about the size, shape, and location of skin tumors. By analysing the differences in microwave scattering or reflection between healthy and tumor tissues, microwave imaging can aid in the detection and localization of skin tumors.

2. Microwave Thermography: Microwave thermography measures the temperature distribution of the skin using microwave radiation. Tumors often have different metabolic rates and blood flow compared to healthy tissue, resulting in variations in temperature. By detecting these temperature differences, microwave thermography can help identify the presence of skin tumors and differentiate between benign and malignant lesions.

3. Microwave Doppler Imaging: Microwave Doppler imaging is based on the principle of Doppler effect, which measures the frequency shift of reflected microwaves caused by the movement of blood within tissues. Skin tumors can alter the blood flow patterns in the surrounding tissue. By analyzing the

Doppler frequency shifts, microwave Doppler imaging can provide information about the vascularity and blood flow characteristics of skin tumors.

4. Microwave Spectroscopy: Microwave spectroscopy involves analysing the interaction between microwaves and skin tissues at different frequencies. This technique can provide information about the dielectric properties, electrical conductivity, and tissue composition of skin tumors. By comparing the microwave response of healthy and tumor tissues, microwave spectroscopy can aid in the identification and characterization of skin tumors.

It's worth noting that while microwave-based techniques have shown promise, further research is needed to refine and validate their diagnostic capabilities for skin tumor detection. These methods are still under development and are not yet widely used in clinical practice. Nevertheless, they hold potential for non-invasive, radiation-free, and real-time imaging of skin tumors, which could complement existing diagnostic methods and improve early detection and treatment outcomes.

Antenna requirements for microwave imaging

When it comes to detecting tumors in the skin using microwave frequencies, the choice and design of antennas play a crucial role in achieving accurate and reliable results. Here are some considerations for antenna requirements in skin tumor detection:

1. Frequency Range: Selecting an appropriate frequency range is important for optimal tumor detection. The choice of frequency depends on factors such as the size and depth of the tumor and the desired resolution. Generally, microwave frequencies in the range of several hundred MHz to a few GHz are commonly used for skin tumor detection.

2. Antenna Type: Various antenna types can be used for skin tumor detection, including patch antennas, dipole antennas, microstrip antennas, or antenna arrays. The specific antenna type depends on factors such as the desired

radiation pattern, antenna size, and operating frequency range. Compact and conformal antennas are often preferred for skin tumor detection to ensure close proximity to the skin surface.

3. Polarization: The polarization of the antenna should be considered based on the expected polarization of the tumor response. Linear polarizations, such as horizontal or vertical, are commonly used, although circular polarization may also be utilized depending on the application requirements.

4. Antenna Placement: The antenna should be positioned appropriately to achieve optimal coupling with the skin tissue and ensure efficient transmission and reception of microwave signals. Close proximity to the skin surface is desired to improve the detection sensitivity. In some cases, the antenna may be placed in direct contact with the skin or incorporated into wearable devices for better skin-tumor interaction.

5. Radiation Pattern: The radiation pattern of the antenna should be well-defined and focused towards the skin tissue to maximize the interaction with the target area. Narrow beamwidth or directional antennas may be preferred to enhance the spatial resolution and reduce interference from surrounding tissues.

6. Sensitivity and Signal-to-Noise Ratio: Antennas used for skin tumor detection should exhibit high sensitivity to detect weak tumor responses and minimize noise. Design considerations, such as optimizing the antenna's gain, efficiency, and impedance matching, are crucial to ensure reliable tumor detection signals.

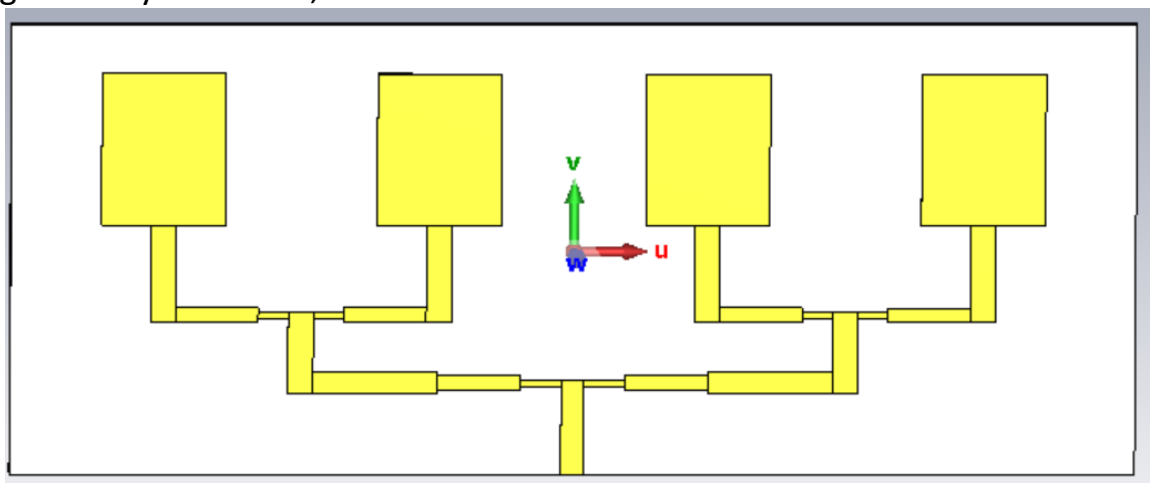
7. Safety Considerations: It is important to ensure that the power levels used for skin tumor detection remain within safe limits to avoid any adverse effects on the skin or underlying tissues. Compliance with relevant safety regulations and guidelines is essential.

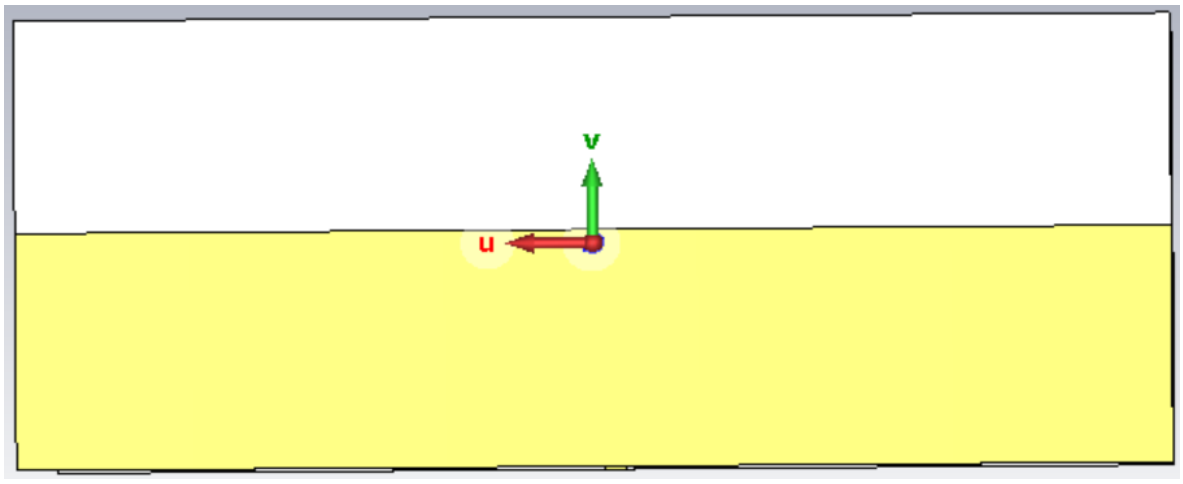
Overall, the choice of antennas for skin tumor detection depends on specific application requirements, such as frequency range, resolution, and desired depth of penetration. Designing antennas that offer good coupling, sensitivity, and suitable radiation patterns is crucial for accurate and effective detection of skin tumors using microwave frequencies.

Antenna Design

1) 1x4 Array Antenna

This antenna's main purpose was to give high gain and ultra-wideband and also significantly decent s1,1 value.





Farfield distance = $2D^2/\lambda$

D= maximum dimension of antenna,

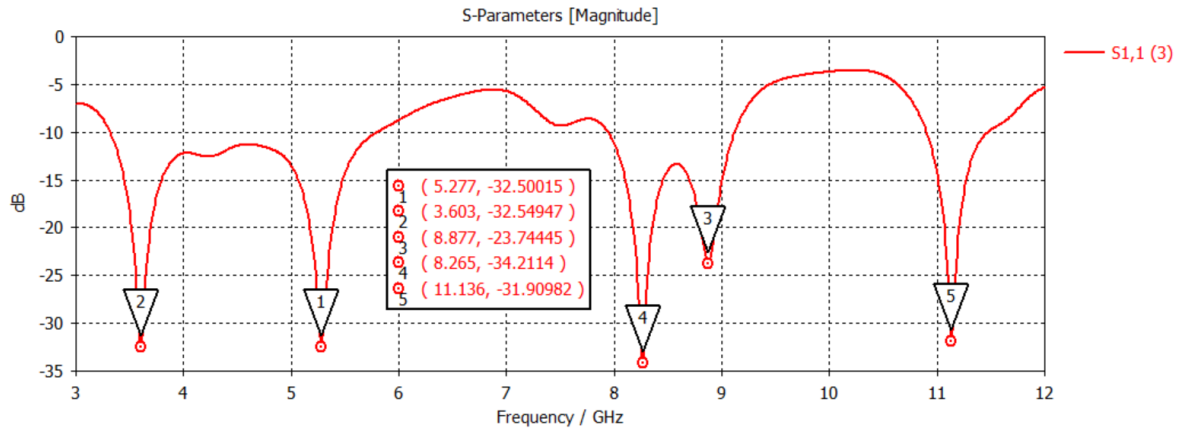
λ= wavelength

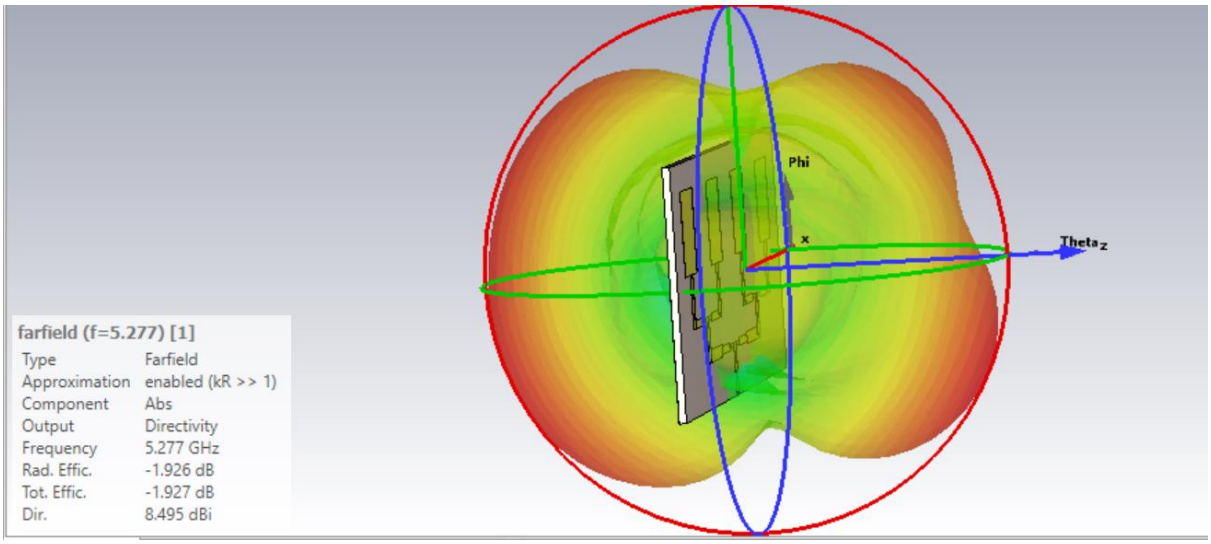
Parameter values

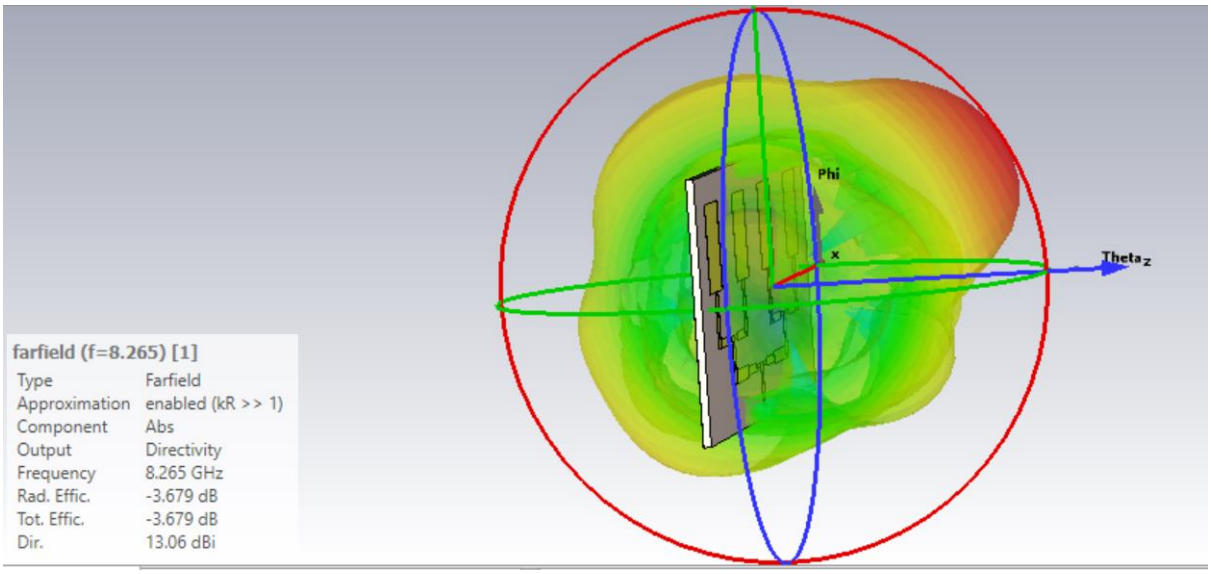
Parameter List

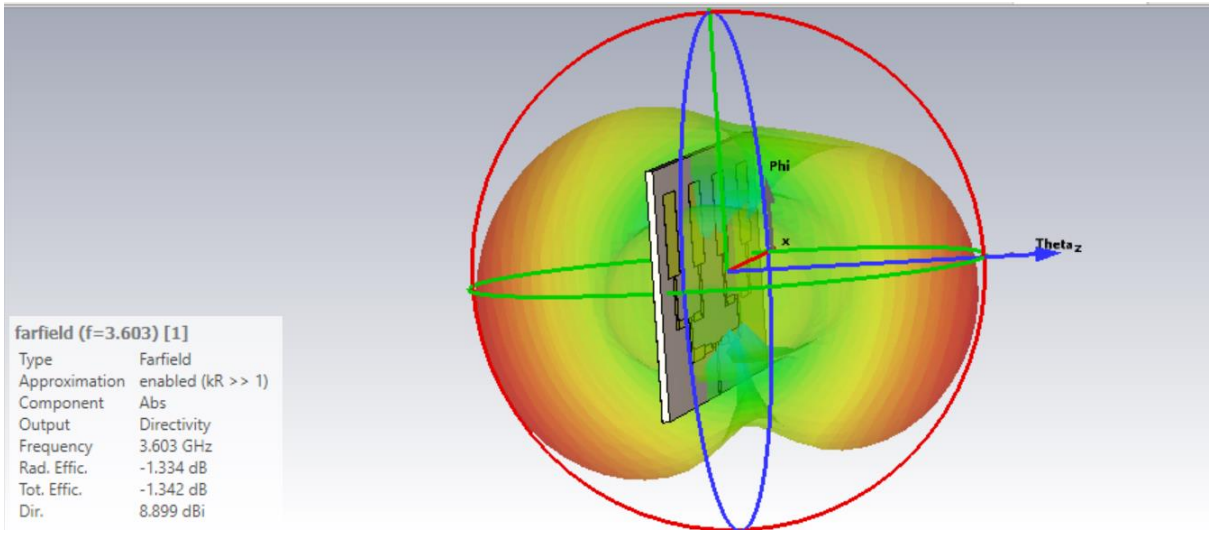
Name	Expression	Value	Description
sw	= 136	136	width of substrate
sl	= 55	55	length of substrate
sh	= 1.6	1.6	height of substrate
lg	= 29	29	length of ground
ph	= 0.035	0.035	height of patch and ground
pw	= 15	15	width of patch
x_shift	= 16.2248	16.2248	shift of x center of patch
pl	= 18.5	18.5	length of patch
y_shift	= 12.2375	12.2375	shift of y center of patch
patch_dist	= 100/3	33.3333333333333	distance between 2 patches of single array
fw	= 3.038	3.038	feedline/50 ohm line width
fl	= 11.84	11.84	feedline lengTh
qtrl	= 10	10	quater wave length
qtrw	= 1.79	1.79	quaterwave thickness
hl	= 5	5	100 ohm length
hw	= 0.79	0.79	100 ohm thickness
div_len	= 10.04	10.04	
dw	= 3.038	3.038	
con_len	= 15	15	
con_width	= 2.745	2.745	

s1,1









Due to decent radiation pattern and high penetration power (i.e., high skin depth) 3.6GHz frequency is chosen for our experiment and simulation.

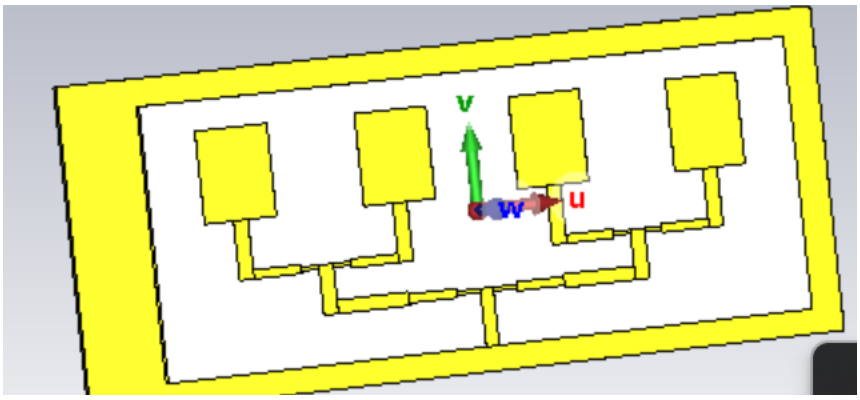
Here, at 3.6GHz we can observe that the radiation pattern has a significant back lobe. To overcome this, a reflector was introduced to reflect the back lobes.

2) 1x4 Array with 2nd substrate and Ground as a Reflector

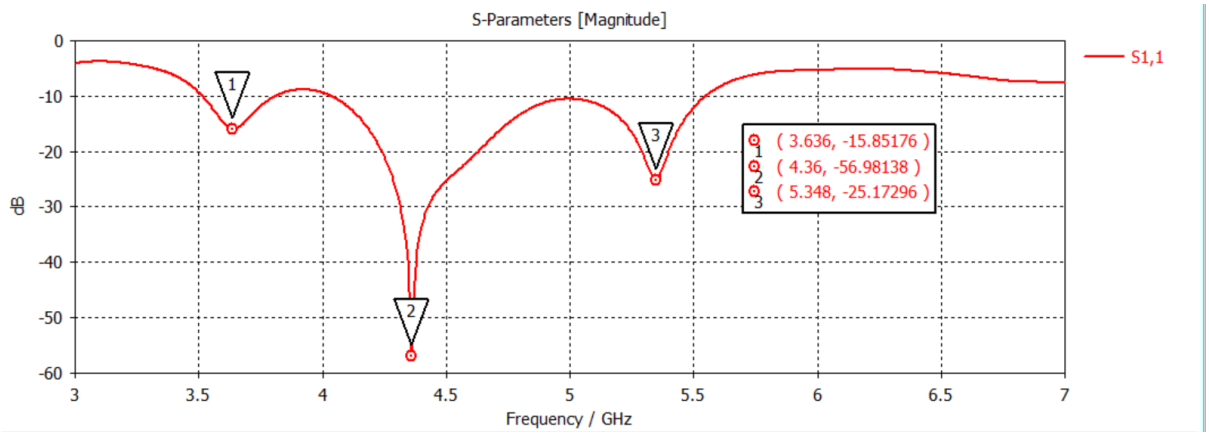
We used another ground placed on top of a substrate, dimensions of 160mm X 66mm, to increase the Gain and to reduce the back lobes.

And the gap between ground plane and reflector ground is 13.85mm.

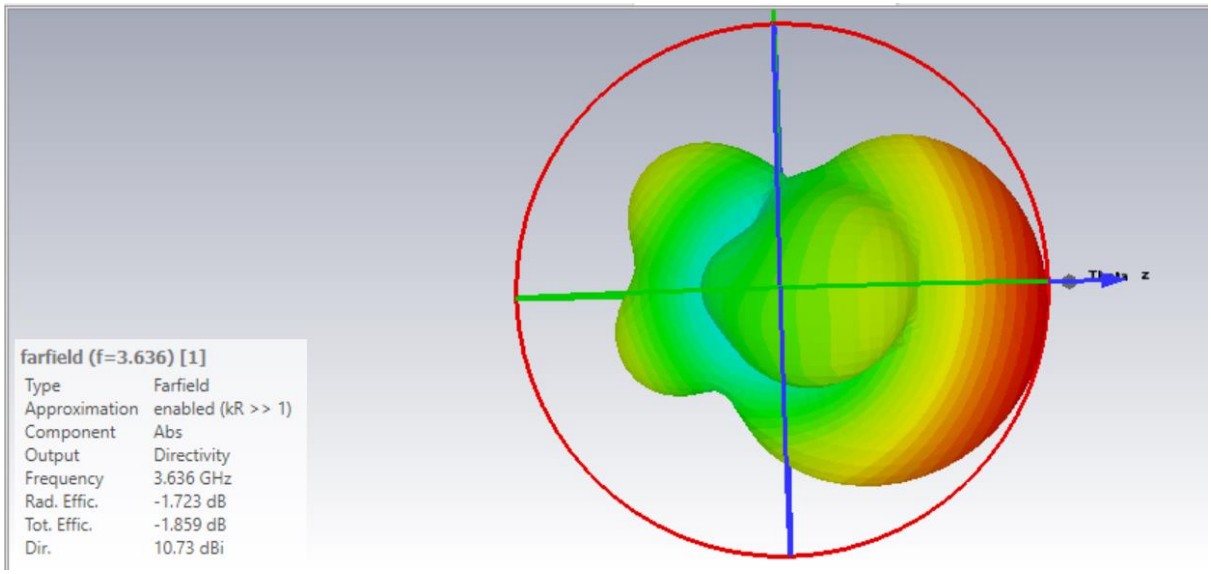
Structure



S1,1



Farfield

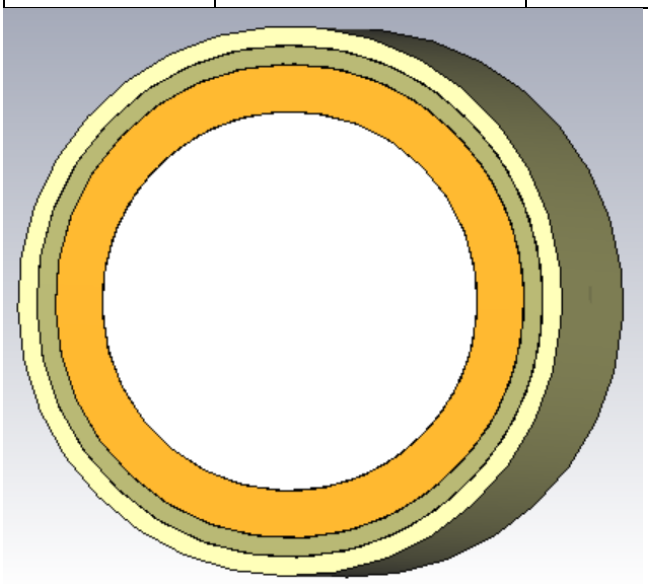


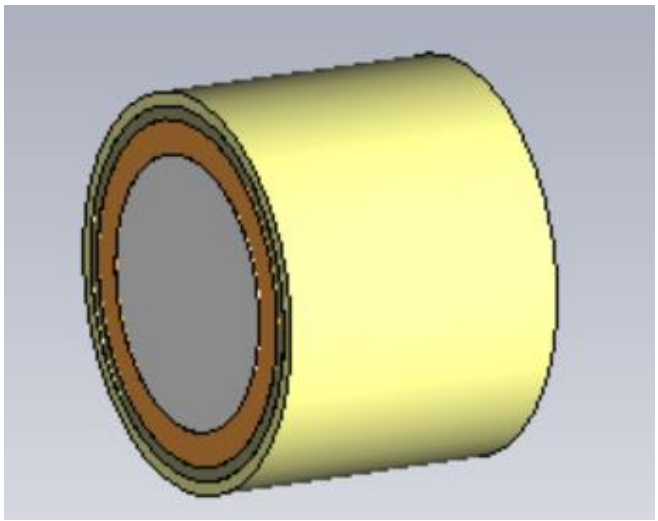
Here we can observe that we achieved a unidirectional beam/radiation pattern, which was required for tumor detection.

3) Phantom Model

A phantom model of human hand was designed at approximately 3.6GHz, with following parameters,

Tissue	Permittivity(Ɛr)	Conductivity(σ) Sm^{-1}	Density(ρ) Kgm^{-3}	Dimension (thickness)
Bone	11	6.4	1800	10mm
Glandular	44	2.65	1040	2.5mm
Fat	7	0.36	900	1mm
Skin	36	2.09	1100	1mm
Tumor	67	4	1040	2mm

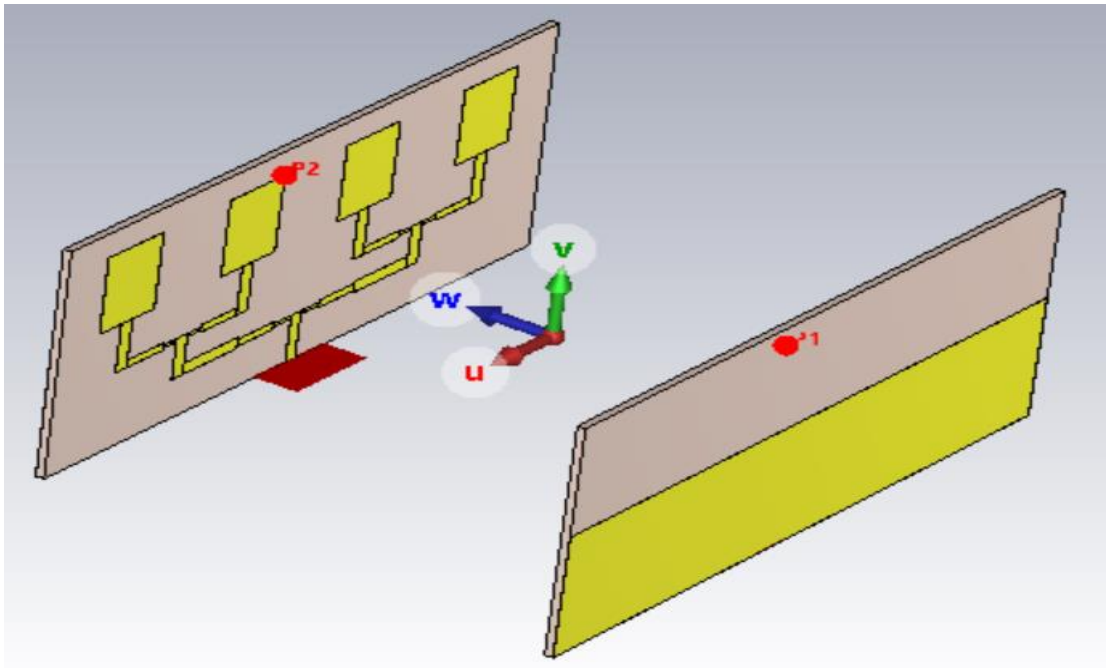


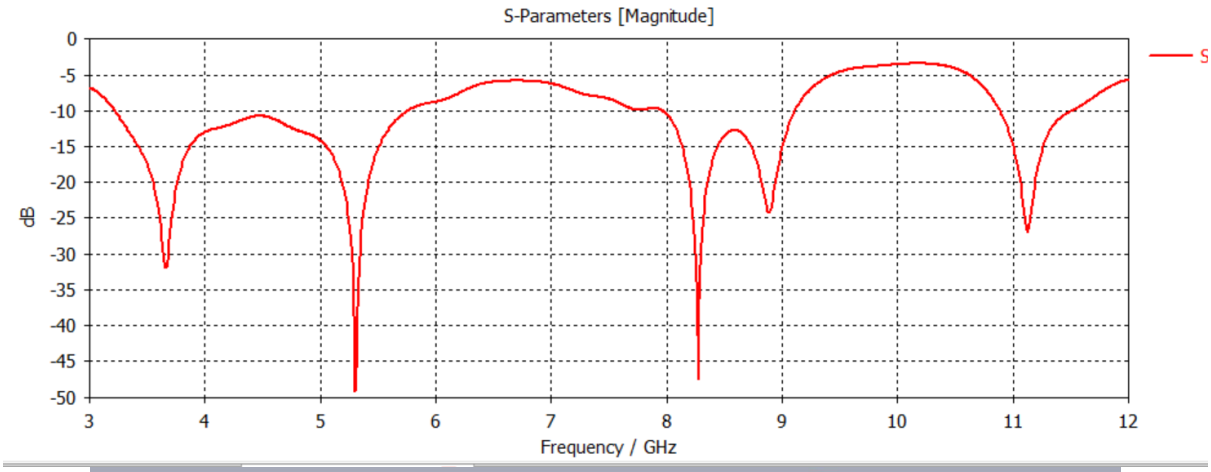


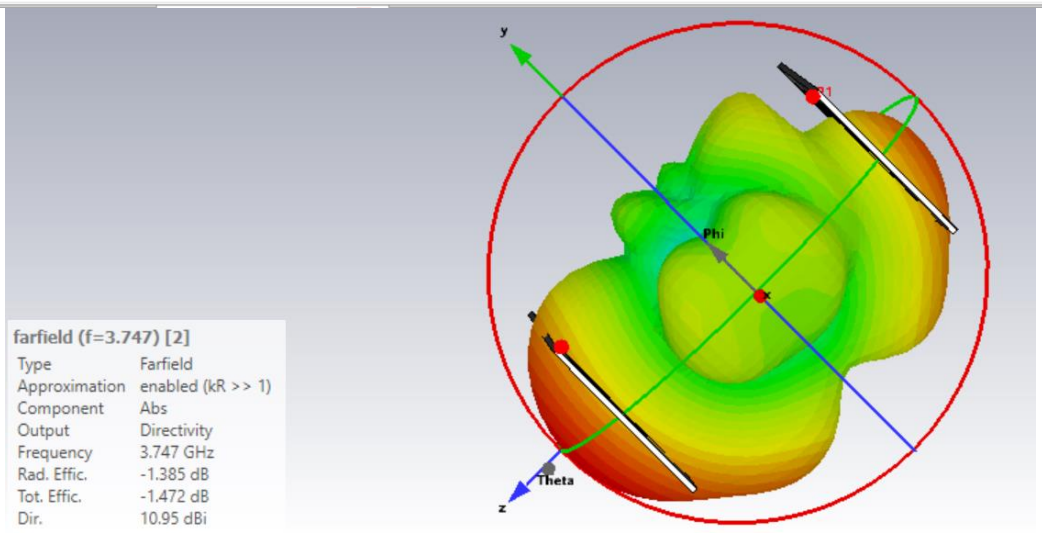
White is bone, Orange is glandular, Grey is fat, Golden yellow is skin

Phantom length is user choice. Here, it has been considered as around 1 inch(25mm).

4) Two 1x4 Array setup as transmitter and receiver model







The separation between 2 antennas is kept as 100mm

Simulation and study of phantom with 2 types of designed antenna by comparing the plotted S2,1 parameter

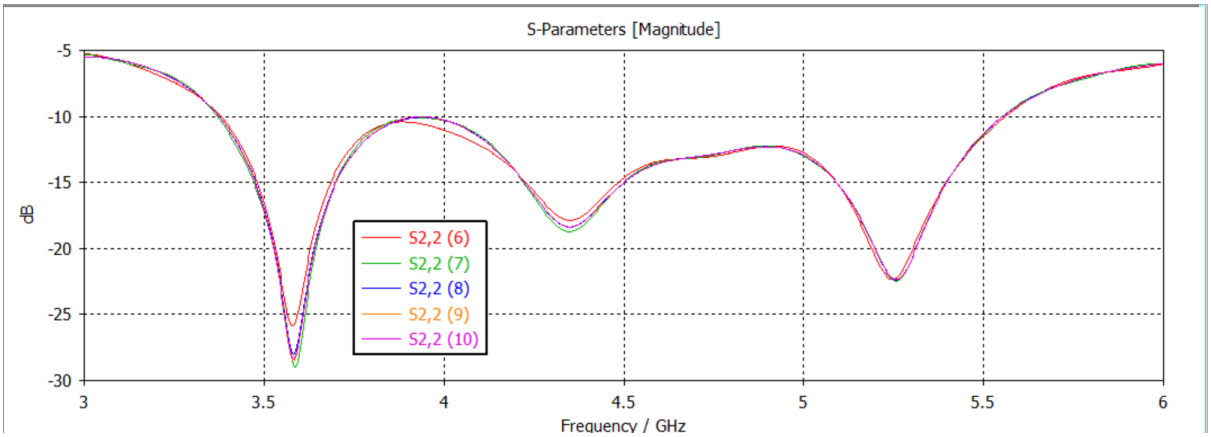
NOTE: in every simulation the tumor is always placed if front of transmitting antenna

1) Model 1 mid-point between 2 antennas

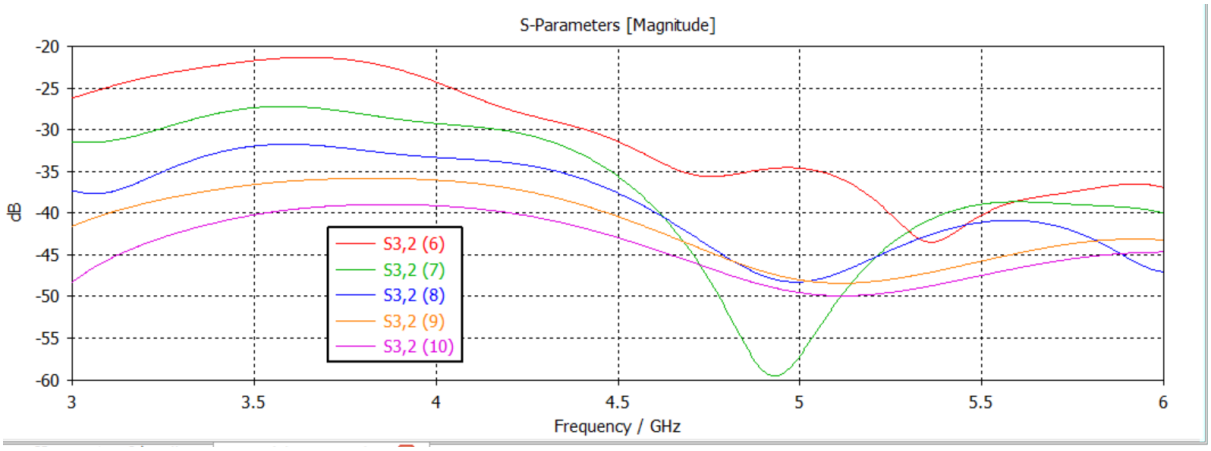
The phantom is kept, exactly at the mid-point of both antennas, while the gap between the antennas is being varied from 200mm to 400mm to 600 mm to 800mm to 1000mm.

Without Tumor

S1,1



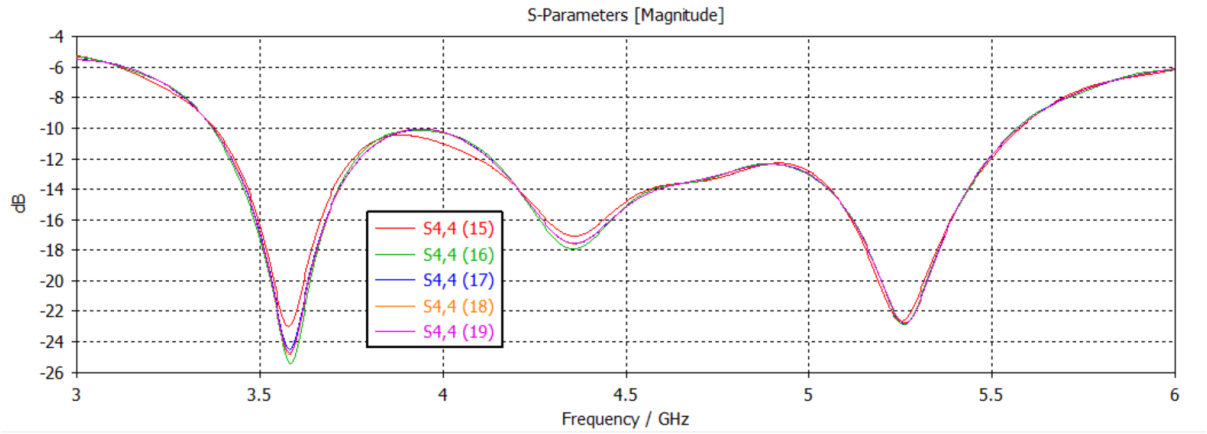
S2,1



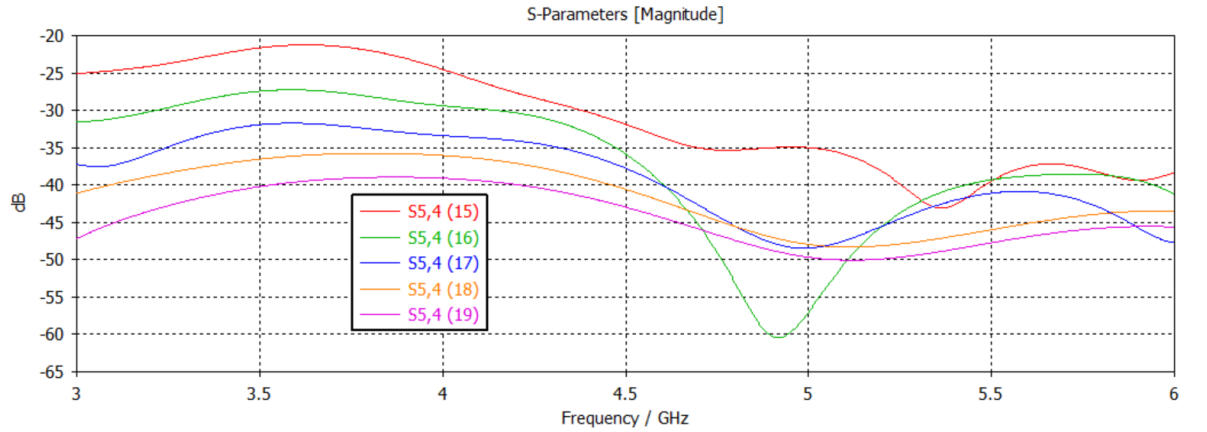
Red = 200mm, Green = 400mm, Blue = 600mm, Yellow =800mm, Purple = 1000mm

With tumor

S1,1



S2,1



Result

From the s11 graph of with and without tumor it has been found that, by introducing the tumor the quality of s11 decreases at 3.6GHz, that is

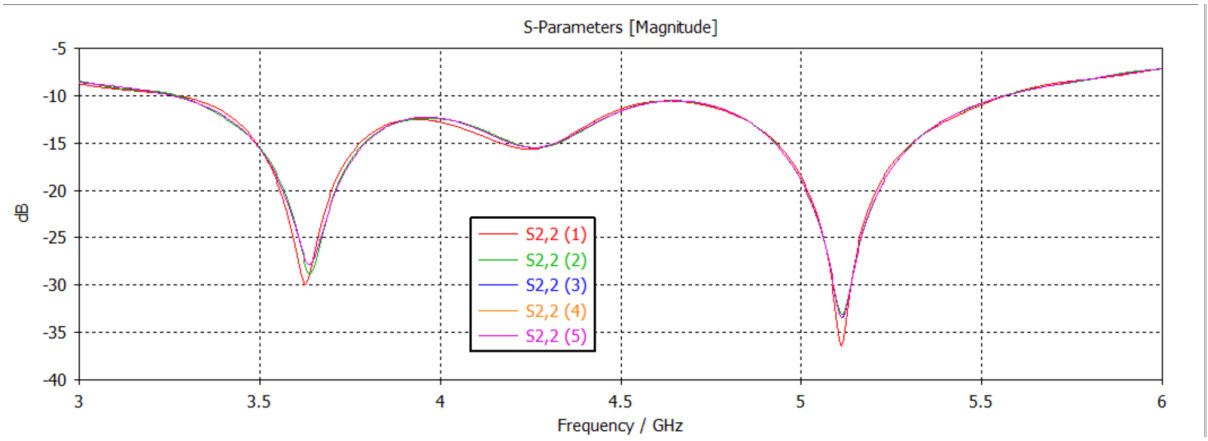
Separation(mm)	S11 Without tumor(dB)	S11 with tumor(dB)
200	-29	-25
400	-26	-23
600	-28	-24.5
800	-28.5	-24.66
1000	-28.5	-24.66

From the s21 graph of with and without tumor it has been found that, only for antenna separation of 200 mm there is a significant change in the s21 graph for frequency band of 5.5-6GHz. And for rest other antenna separations there is no significant or quantitative variation in the s21 graph.

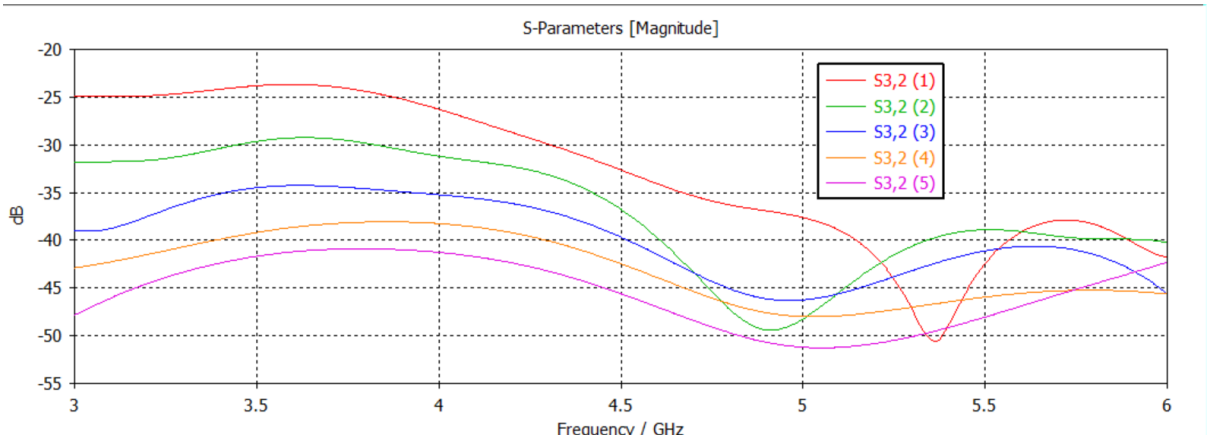
2) Model 2, keeping the phantom 5 mm away from the receiving antenna.

Without Tumor

S1,1

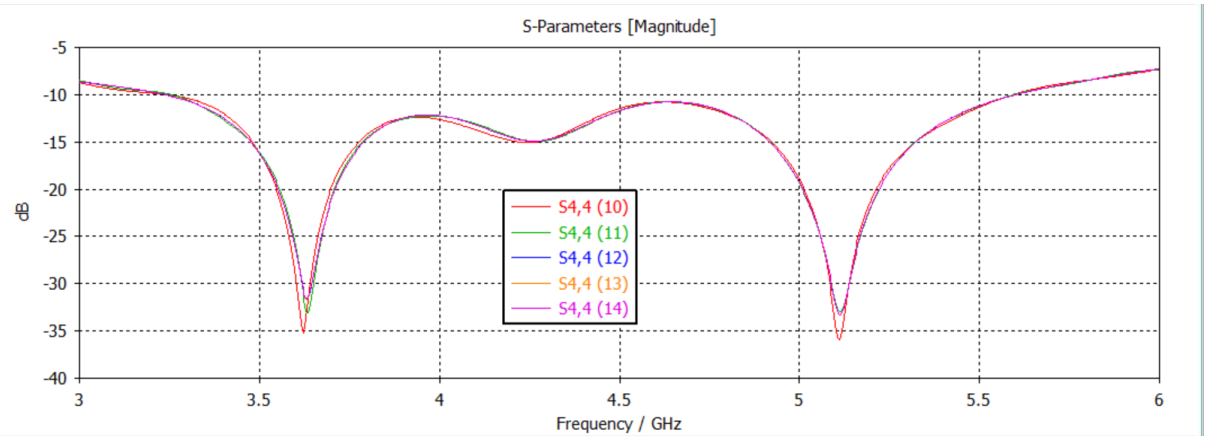


S2,1

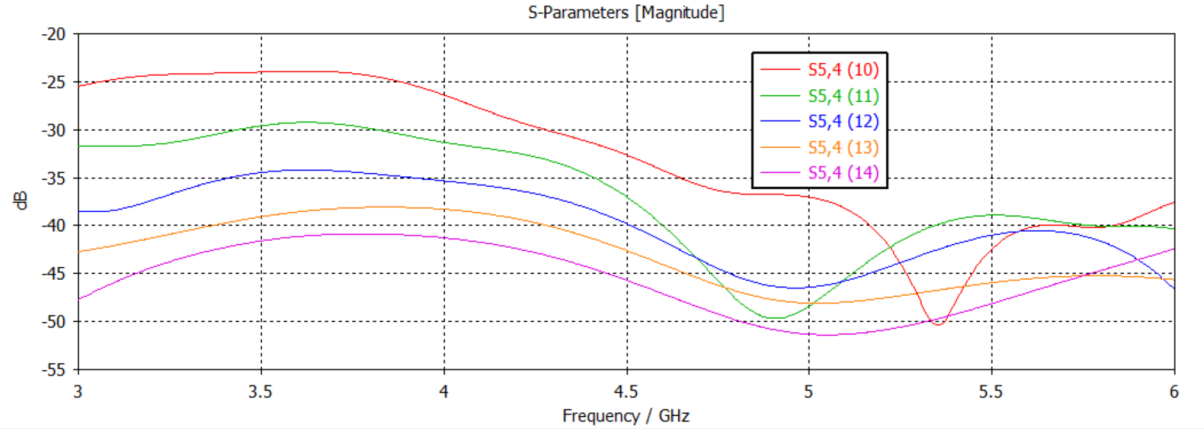


With Tumor

S1,1



S2, 1



Results

From s11 graph it is observed that by introducing the tumor inside the phantom, the s11 is improved by a significant amount.

Separation(mm)	S11 Without tumor(dB)	S11 with tumor(dB)
200	-30	-35.05
400	-28.8	-33
600	-27.5	-31.
800	-27.5	-31
1000	-27.5	-31

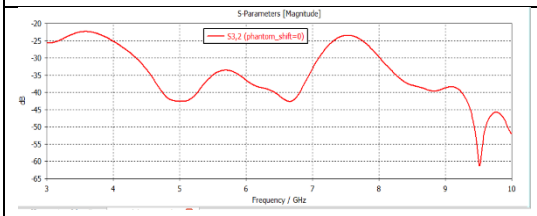
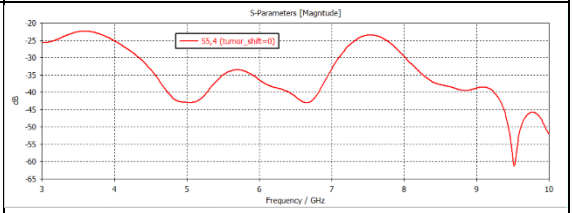
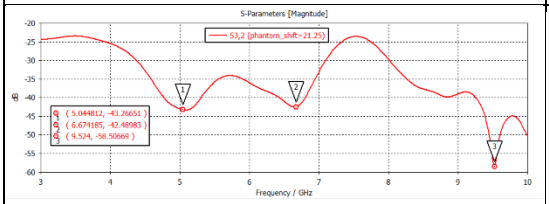
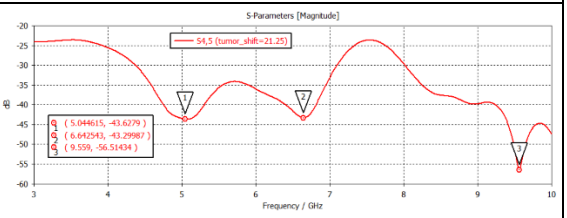
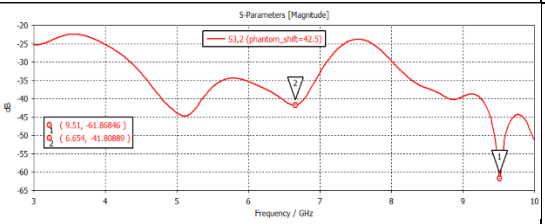
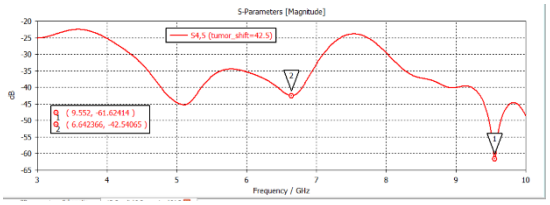
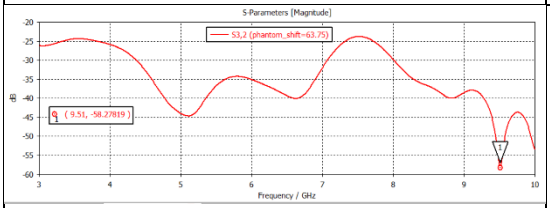
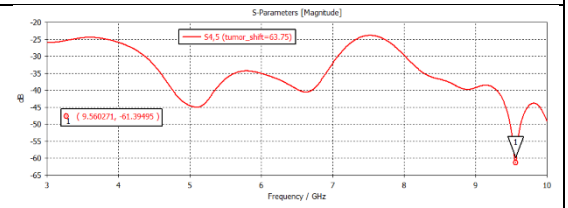
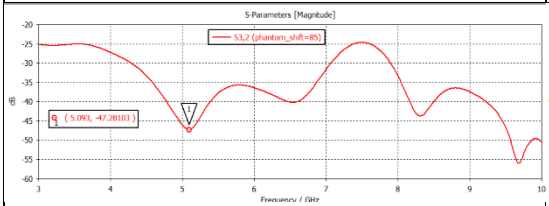
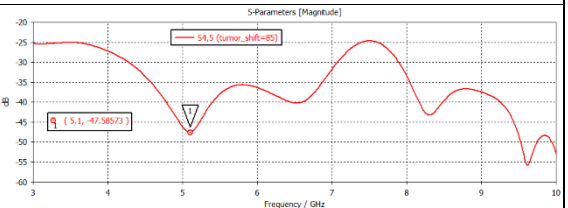
From s21 plot it was concluded that only significant variation was observed for antenna separation of 200mm from frequency band of 5.15-6GHz.

3) Model 3

Keeping antenna separation as 200mm and varying from mid-point to 5mm near of receiver antenna

Distances from transmitting antenna to phantom are, 100mm, 121.25mm, 142.5mm, 163.75mm, 185mm

S2,1

Without tumor	With tumor
	
	
	
	
	

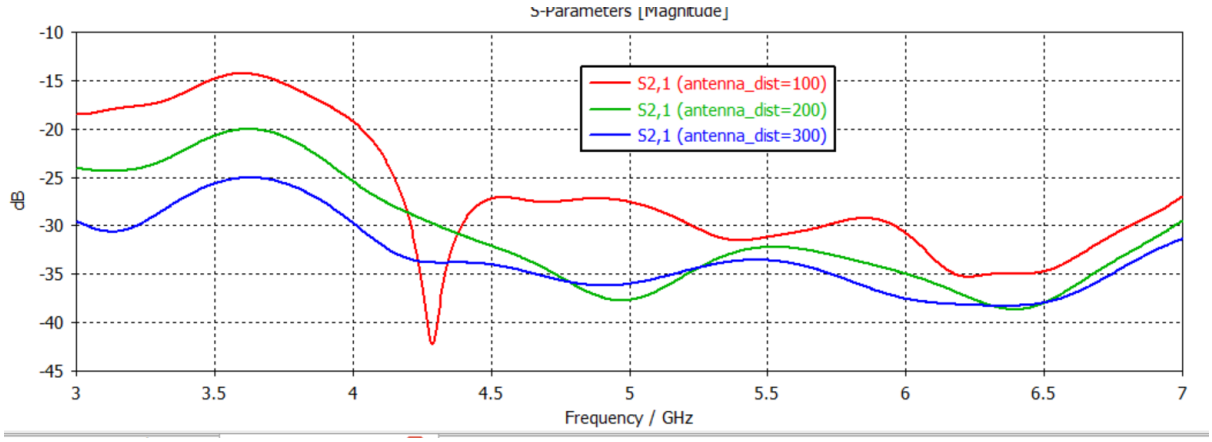
Results

By varying the phantom to various position, very minute forward shift of frequency was observed for 9.5GHz. Therefore, by using the doppler shift

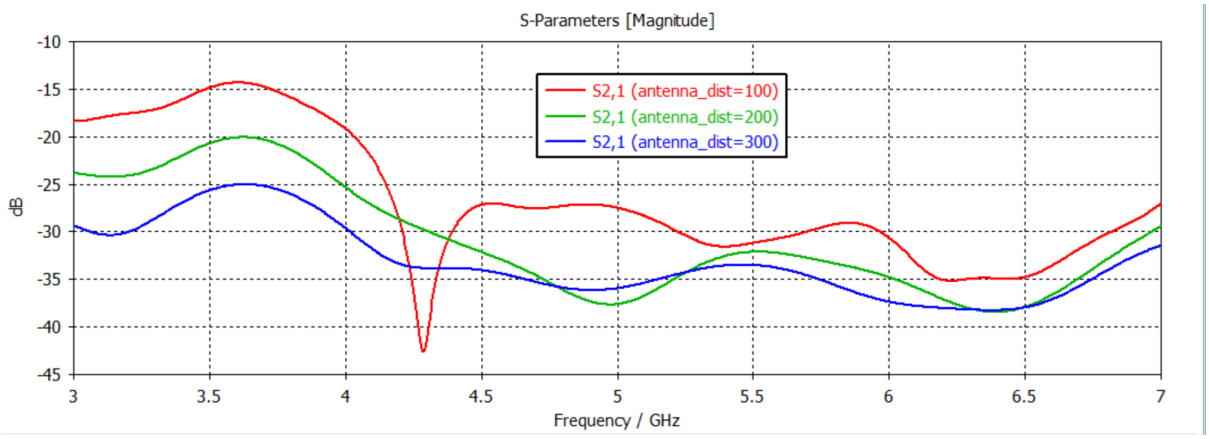
phenomena further calculations can be carried out for locating the tumor and defining the property of the tumor

4) Model 4 (using antennas with reflector plate)

S21 without tumor



S21 with tumor



Result

There is no visible difference between 2 s21 plots.

From intuition this may be due to high gain/directivity, due to which there is no quantitative transmission loss due to tumor introduced in the path.

Simulation and study of phantom with 2 types of designed antenna by Power loss density or SAR value

NOTE: a) For SAR calculation only 1 antenna has been considered

b) and the tumor is directly placed in front of the antenna

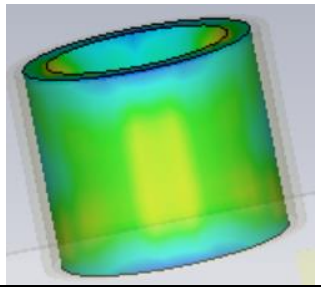
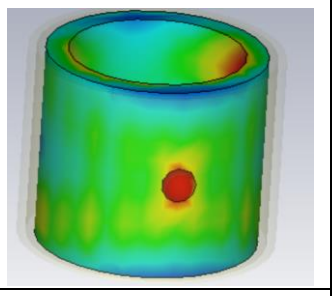
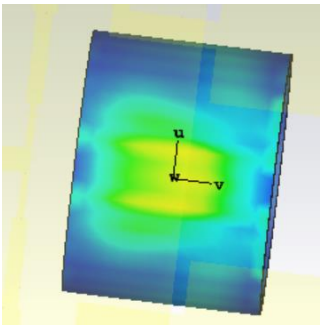
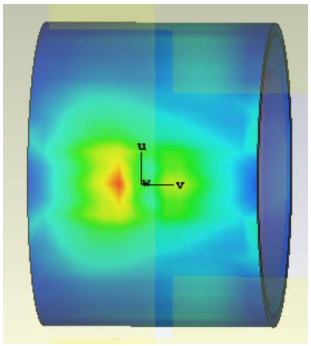
The Specific Absorption Rate (SAR) is defined as the time derivative of the incremental energy (*dW*) absorbed by (dissipated in) an incremental mass (*dm*) contained in a volume element (*dV*) of a given mass density (r).

$$SAR = \frac{\mathrm{d}}{\mathrm{d}t}\left(\frac{dW}{dm}\right) = \frac{\mathrm{d}}{\mathrm{d}t}\left(\frac{dW}{\rho \cdot dV}\right)$$

$$PLD = \frac{\mathrm{d}}{\mathrm{d}t}\left(\frac{dW}{dV}\right)$$

The SAR value is expressed in units of watts per kilogram (W/kg). The Power Loss Density (PLD) value is expressed in units of watts per cubic meter (W/m^3).

1) Normal 1x4 antenna

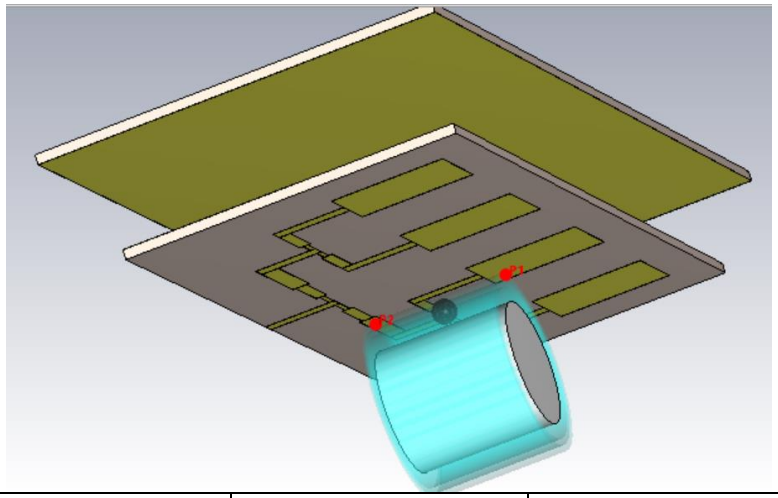
Distance from antenna	Power loss density (Wm^{-3})	Without tumor	With tumor
5mm	800 (Upper limit)		
185mm	16267 (Upper limit)		

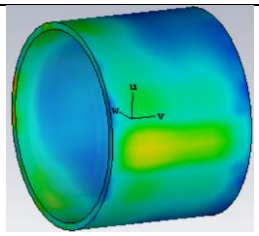
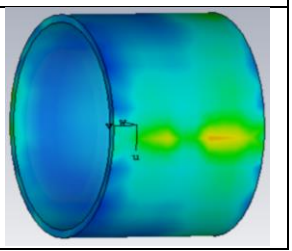
Results

In 1st case we have taken the power loss graph of glandular tissue. There we can observe that when tumour is introduced, it gets heated and starts to radiate. Therefore, we can locate the presence and position of tumour

In 2nd case, power loss graph of skin tissue is mapped. There we can observe that where the tumor is located, the surrounding area absorbs more power than, rest of the area.

2) 1x4 Antenna with Reflector plates



Distance from antenna	Power loss density (Wm^{-3})	Without tumor	With tumor
100mm	2013 (Upper limit)		

Result

When tumour is introduced the skin phantom shows power absorption relatively more at the position of tumour rather than normal healthy skin. Through this variation we can detect the presence and position of tumor.

Conclusion

By selecting a UWB range of 3.2-5.75GHz, 8-9.1GHz and 10.85-11.5GHz, frequency of 3.60GHz has been used for detection of tumor inside skin, muscle, and fat. S21 method of detection was efficient for normal 1x4 Array antenna where as SAR method was more suitable for 1x4 Array antenna with reflector, for detection of tumor. Keeping in mind of real-life scenario max tumor length of 2mm where as skin phantom of 25mm was used to get more accurate genuine results.

Therefore, it is advised to use Microwave Spectroscopy to detect the change in s11, s21 and the slightest frequency shift of s11 and s21 values of the above experimental setup.