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DESIGN OF H-SHAPE MICROSTRIP PATCH ANTENNA FOR WEARABLE APPLICATIONS TO DETECT THE THYROID GLAND CANCER CELLS

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Abstract

This paper presents the design of an H-shaped microstrip patch antenna to evaluate the SAR (Specific Absorption Rate) for thyroid gland cancer cell detection. This antenna is flexible and appropriate for wearable applications. The performance can be varied when the antenna is placed on the thyroid gland of humans. The parameters like return loss, gain, VSWR are measured. There are different varieties of the antenna but microstrip patch antenna provides low cost, low volume, lightweight etc. FR-4 (lossy) is used as a substrate to overcome low gain and high return loss. The patch conductor is made up of copper material to form a flexible antenna. The proposed antenna design provides a high SAR value of 0.0199W/Kg for 1g of tissue with a tumor. Since cancer cells contain more water content the performance of various parameters can be changed in the proposed antenna design. The gain value of the proposed antenna is 6.36 dB at 16.452GHz. The thyroid gland model of proposed H-shaped and H-shaped vertical slot antennas are designed using CST (Computer Simulation Technology) microwave studio tool.

Keywords:

Voltage Standing Wave Ratio, Return Loss, Gain, Specific Absorption Rate

1. INTRODUCTION

The Thyroid gland is found within the neck slightly below the larynx. This is also named as the voice box. The Thyroid gland contains two lobes called isthmus. It is a butterfly in shape. Thyroid cancer starts in the thyroid gland. It also starts when the healthy cells change and form a mass called tumor [1]. Thyroid gland cancer can spread easily over the neck and to entire parts of the body. Under microscope normal cells differ from thyroid cells [2]. Wearable microwave imaging device is used for cancer detection by the use of a flexible antenna [4]. The Metal Composite Embroidery Yarn (MCEY), which is a polyester substrate used to detect FM signals. The MCEY embroidered Multi Resonant Folded Dipole (MRFD) is fixed to a jacket which is a wearable antenna.

When the antenna is kept close to the human body the antenna efficiency and frequency are reduced because the human body has high permittivity [8]. Textile antenna obtain less return loss at lower frequency. Flexible foam is a protective cloth that provides excellent thickness, secure, constant value [9] [10]. Specific Absorption Rate (SAR) is the amount of power that can be absorbed by human tissue. To identify SAR value the antenna can be placed at the different positions [5]. SAR value can be evaluated over a sample volume (typically 1g or 10 g of tissue). SAR value can be calculated by the equation given below

$$SAR=(\sigma E^2)/(2\rho) \quad (1)$$

where, σ is the conductivity of tissue (S/m), E is the electric field strength of tissue (V/m) and ρ is the Mass density (Kg/m^3)

Antennas which are designed with polydimethylsiloxane that can be modified by dielectric permittivity and the sealed antennas are manufacture to integrate the substrate. The radiation feature are better because the antenna is soft and flexible [6].

Wearable antenna for the fabric substrate that can measure the dielectric constant by the use of microstrip patch radiator. Microstrip antenna is suitable for all the wearable applications. Multilayer weaving technique one of the wearable antenna based on a cotton substrate weaving consists of multiple layers which is yarn. The weaving was done and the thickness of skin, fat, muscle can be varied based on the different parts of the body [3].

2. LITERATURE REVIEW

Microstrip patch antenna with an inset feed technique is used to improve return loss and the antenna is placed on the thyroid gland to simulate the performance. This antenna operates under the ISM (Industrial, Scientific, and Medical) of frequency range at 2.45GHz. It provide the return loss of -14db at 2.45GHz [1].

The Z shape wearable patch antenna was designed with a frequency band of 2.5GHz. By using the silk substrate SAR value reduces. From the designed antenna the gain value is 1.67dB. The performance changes due to the presence or absence of thyroid cancer [2].

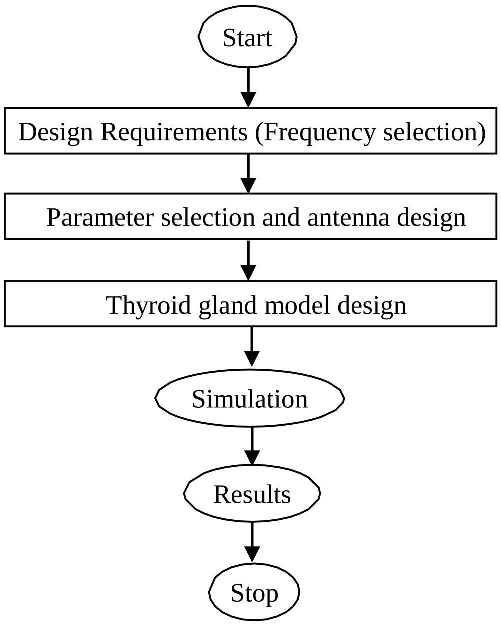

Fig.1. Data Flow Diagram

Multilayered weave textile with coaxial feeding for wearable applications designed at 2.45GHz. SAR value differs for different parts of the body. The simulated SAR at the arm is found as 0.0164W/Kg [3].

From the above literature review, it is found that the different wearable antenna operated at an ISM band, so our designed H-shaped microstrip patch antenna operated at a higher frequency band from 10.846GHz to 16.452GHz. FR-4 (Flame Retardant) is used as a substrate material.

This H-shaped microstrip patch antenna is designed to analyze the various antenna parameters performance such as the gain, VSWR, return loss, directivity, E-field, H-field and also the observation of specific absorption rate for the human thyroid gland (tissue).

The Fig.1 shows the data flow graph of a designed antenna and human thyroid gland model were designed using CST software. The designed antenna frequency range from 10.846GHz-16.452GHz.

3. THYROID GLAND MODEL DESIGN

The frequency value for the designed H-shaped microstrip patch antenna ranges from 10.846GHz to 16.452GHz. In this section, For the H-shape microstrip patch antenna the material copper (annealed) is used for the ground, patch, and the material FR-4 (Flame Retardant) is used for the substrate which consists of fiberglass and epoxy resin for the communication in between the ground and patch.

The patch is kept over the substrate which is designed using copper (annealed) material. The slots are marked then the portions are highlighted and cut away by the material nickel (lossy).

3.1 H-SHAPE MICROSTRIP PATCH ANTENNA

The H-shaped microstrip patch antenna is designed with ground, substrate, patch and the feed used in this antenna is microstrip line feed with the dimensions of width and length is 4mm and 17mm respectively. The width and length of the ground and substrate are usually designed with the same dimensions of 24mm and 30mm. The thickness for the ground used here is 0.05mm and the thickness for the substrate used in this antenna is 1.40mm.

The Fig.2 shows the H-shaped microstrip patch antenna. The H-shaped microstrip antenna is designed with 3 set of patches and their dimensions are given below,

- The width and length of the left patch are 22mm and 14mm and the thickness is 0.05mm.
- The width and length of the center patch are 6mm and 9mm and the thickness is 0.05mm.
- The width and length of the right patch are 22mm and 14mm, and the thickness is 0.05mm.

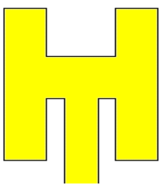

Fig.2. H-shape microstrip patch antenna

3.2 VERTICAL SLOT H-SHAPE MICROSTRIP PATCH ANTENNA

The H-shaped microstrip patch antenna with a vertical slot is designed with ground, substrate, patch, and feed with the same dimensions of the H-shaped microstrip patch antenna. The vertical H-shaped antenna consists of two vertical slots in the left and right patch which is made up of a material called nickel (lossy) to cut away a highlighted portions. The Fig.3 shows the vertical slot microstrip patch antenna

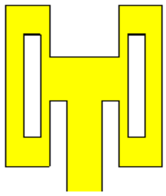

Fig.3. Vertical slot H-shape microstrip patch antenna

The slot 1 and slot 2 differ in positions only but has the same dimensions. The width, length, and thickness of the slot 1 and slot 2 is 14mm, 16mm, and 0.05mm.

3.3 THYROID GLAND MODEL DESIGN

Thyroid cancer affects the thyroid gland which is a small gland present at the base of the neck. Most of the thyroid cancers are curable. The designed H-shape wearable microstrip patch antenna was placed on the human thyroid gland to identify the parameter performance to check whether the cancer cells are present or not. While placing the antenna the SAR value should be high. This paper describes the human thyroid gland model which is designed with 6 layers (skin, fat, muscle, bone, thyroid and tumor). The amount of radiation absorbed by the human thyroid gland can be calculated as SAR. The SAR of the thyroid gland model can be calculated by with a tumor and without tumor.

The average mass density and conductivity of these layers are : skin (ρ = 1100; σ = 5.0138), fat (ρ = 1100; σ = 0.1), muscle (ρ = 1060; σ = 1.705), bone (ρ = 1810; σ = 0.32), thyroid (ρ = 1050; σ = 1.469) ,and tumor (ρ = 2050; σ = 6).The thickness of skin, fat, muscle, bone, thyroid, and tumor layers is 1mm, 4mm, 6mm, 9mm, 13mm, and 18mm respectively. The designed thyroid model is shown in Fig.4.

Fig.4. Human thyroid gland model

In this proposed work, the H-shape micro strip patch antenna and H-shape micro strip patch antenna with vertical slot are designed and its parameters such as gain, VSWR, return loss, and SAR value is evaluated for the thyroid gland model with and without tumor.

3.4 TUMOR DESIGN MODEL

The Fig.5 - Fig.8 shows the H-shape MPA without and with a tumor layer. The H-shape MPA is designed and then the six layers are kept 1mm away from the antenna.

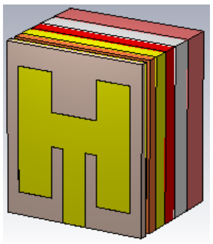

Fig.5. Without tumor layer

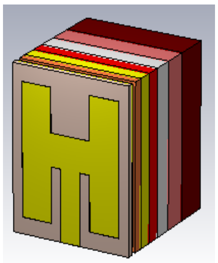

Fig.6. With tumor layer

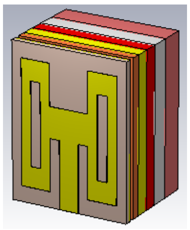

Fig.7. Without tumor layer

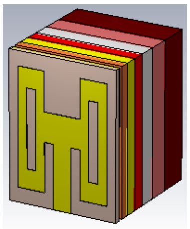

Fig.8. With tumor layer

4. RESULTS OF H-SHAPE MICROSTRIP PATCH ANTENNA

The return loss of the H-shape micro strip patch antenna with and without a tumor is shown below in Fig.9 and Fig.10. H-shape MPA without a tumor provides a return loss of -23.116dB at 12.278GHz. H-shape MPA with a tumor provides a return loss of 25.488dB at 12.139GHz.

The gain of H-shape micro strip patch antenna with and without a tumor is shown below in Fig.11-Fig.14 at different frequency. The Fig.11 and Fig.12 shows the H-shape MPA without a tumor of gain 2.09dB at 10.846GHz and 2.11dB at 16.452GHz. The Fig.13 and Fig.14 shows the H-shape MPA with a tumor of gain 1.9dB at 10.846GHz and 3.11dB at 16.452GHz.

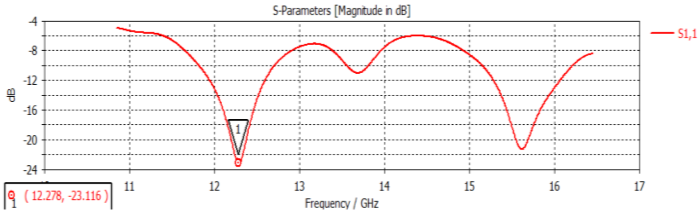

Fig.9. Return loss of H-shape MPA without a tumor

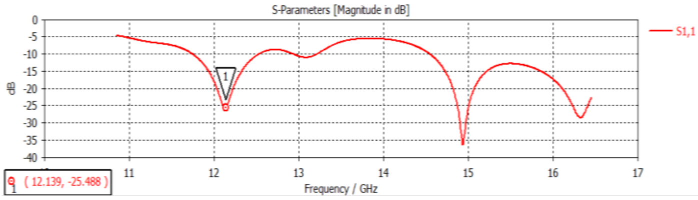

Fig.10. Return loss of H-shape MPA with a tumor

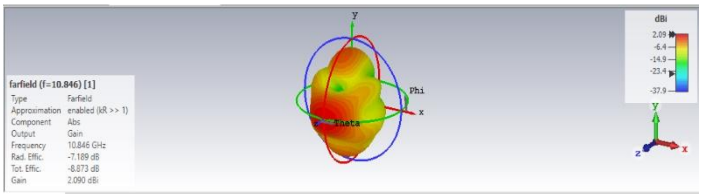

Fig.11. Gain for H-shape MPA without tumor at 10.846GHz

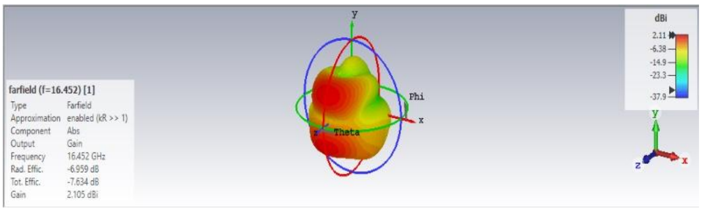

Fig.12. Gain for H-shape MPA without tumor at 16.452GHz

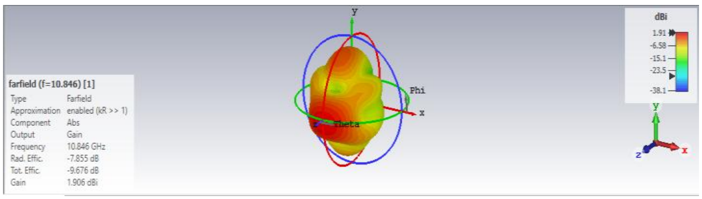

Fig.13. Gain for H-shape MPA with a tumor at 10.846GHz

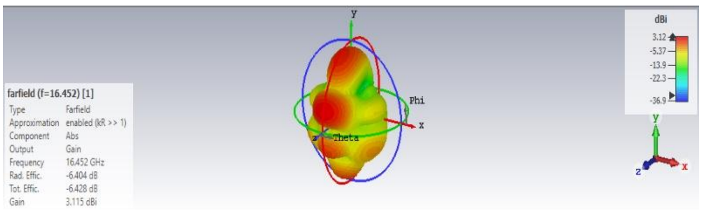

Fig.14. Gain for H-shape MPA with a tumor at 16.452GHz

H-shape MPA without a tumor provides VSWR of 1.1495 at 12.292GHz. H-shape MPA with a tumor provides VSWR of 1.1122 at 12.123GHz which is shown in Fig.15 and Fig.16.

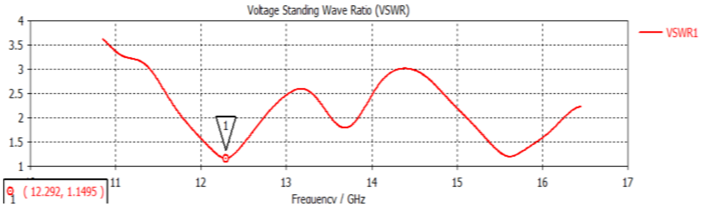

Fig.15.VSWR for H-shape MPA without a tumor

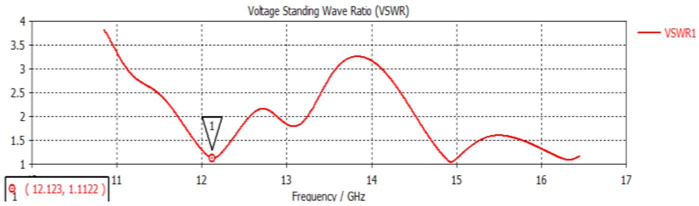

Fig.16. VSWR for H-shape MPA with a tumor

The SAR value for 1g of tissue for the H-shape microstrip patch antenna without a tumor for a frequency of 10.846GHz and 16.452GHz which provides the SAR value of 0.0102W/Kg at 10.846GHz and 0.00335W/Kg at 16.452GHz which is shown in Fig.17 and Fig.18.

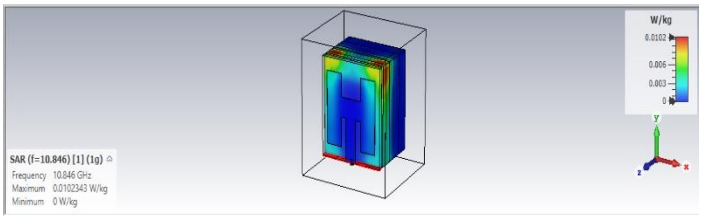

Fig.17. SAR for 1g of tissue without a tumor at 10.846GHz

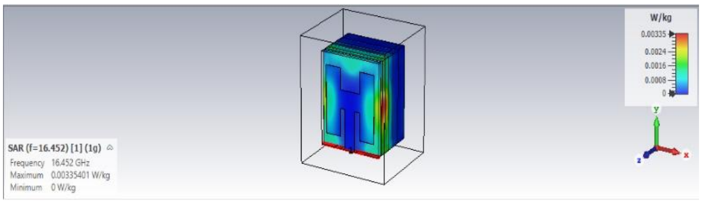

Fig.18. SAR for 1g of tissue without a tumor at 16.452GHz

The SAR value for 1g of tissue for the H-shape microstrip patch antenna with a tumor for a frequency of 10.846GHz and 16.452GHz which provides the SAR value of 0.0089W/Kg at 10.846GHz and 0.0062W/Kg at 16.452GHz which is shown in Fig.19 and Fig.20.

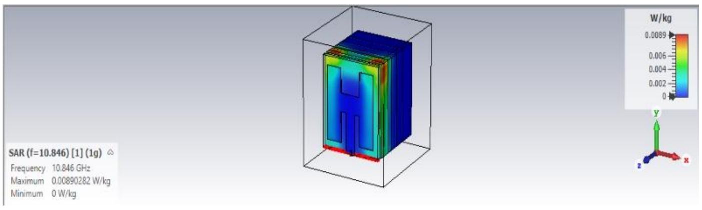

Fig.19. SAR for 1g of tissue with a tumor at 10.846GHz

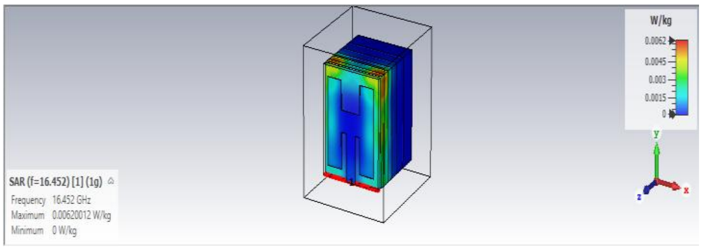

Fig.20. SAR for 1g of tissue with a tumor at 16.452GHz

4.1 H-SHAPE MICROSTRIP PATCH ANTENNA WITH VERTICAL SLOT

The return loss of H-shape micro strip patch antenna with a vertical slot with and without a tumor is shown below in Fig.21 and Fig.22. H-shape MPA with a vertical slot without a tumor provides a return loss of -26.68dB at 11.072GHz. H-shape MPA with a vertical slot with a tumor provides a return loss of -23.138dB at 11.528GHz.

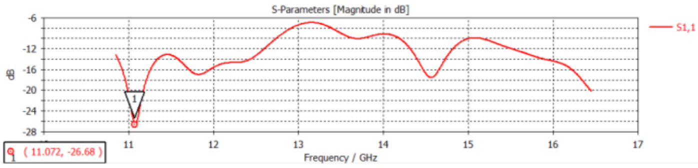

Fig.21. Return loss of H-shape MPA with a vertical slot without a tumor

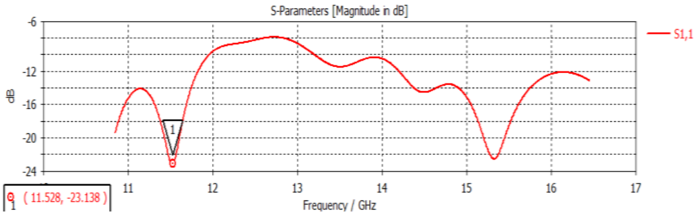

Fig.22. Return loss of H-shape MPA with a vertical slot with a tumor

The gain of H-shape micro strip patch antenna with a vertical slot with and without a tumor is shown below in Fig.23 - Fig.26 at different frequencies.

The Fig.23 and Fig.24 shows the H-shape MPA with a vertical slot without a tumor of gain 1.63dB at 10.846GHz and 3.35dB at 16.452GHz. The Fig.25 and Fig.26 shows the H-shape MPA with a vertical slot with a tumor of gain 4.43dB at 10.846GHz and 6.36dB at 16.452GHz.

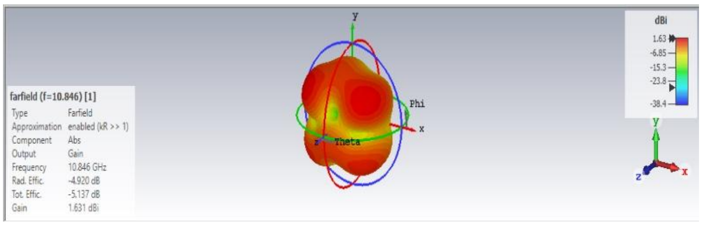

Fig.23. Gain for H-shape MPA with vertical slot without a tumor at 10.846GHz

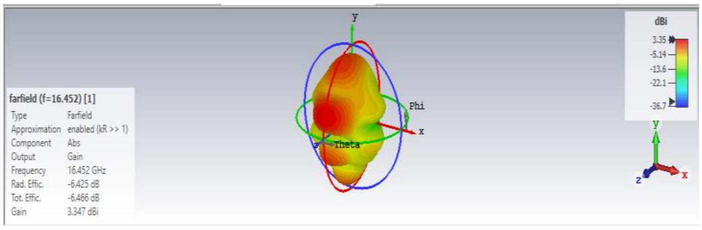

Fig.24. Gain for H-shape MPA with vertical slot without a tumor at 16.452GHz

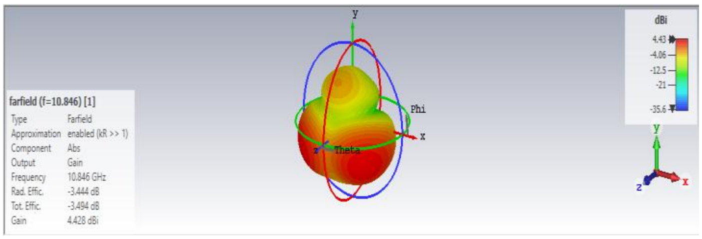

Fig.25. Gain for H-shape MPA with vertical slot with a tumor at 10.846GHz

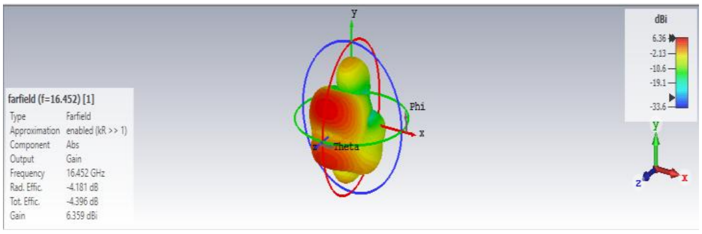

Fig.26. Gain for H-shape MPA with vertical slot with a tumor at 16.452GHz

The VSWR value for H-shape MPA with a vertical slot with and without a tumor is shown below in Fig.27 and Fig.28. H-shape MPA with a vertical slot without a tumor provides VSWR of 1.096 at 11.077GHz. H-shape MPA with a vertical slot with a tumor provides VSWR of 1.1497 at 11.513GHz.

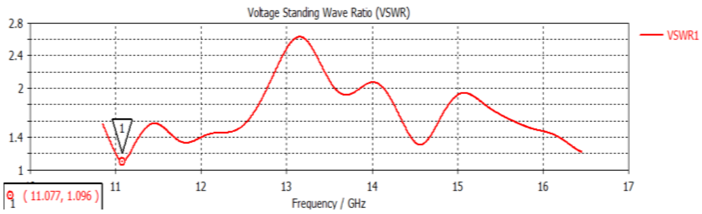

Fig.27. VSWR for H-shape MPA with vertical slot without a tumor

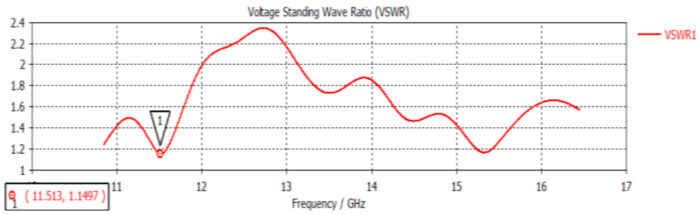

Fig.28. VSWR for H-shape MPA with vertical slot with a tumor

The SAR value for 1g of tissue for the H-shape MPA with a vertical slot without a tumor for a frequency of 10.846GHz and 16.452GHz which provides the SAR value of 0.0143W/Kg at 10.846GHz and 0.00499W/Kg at 16.452GHz which is shown in Fig.29 and Fig.30

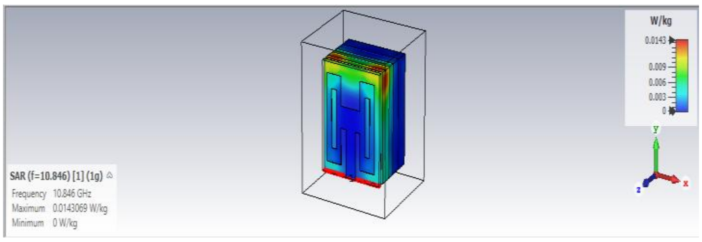

Fig.29. SAR for 1g of tissue without a tumor at 10.846GHz

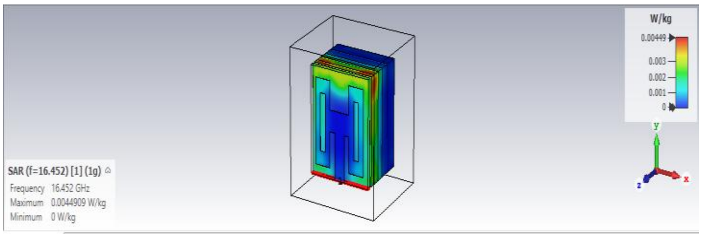

Fig.30. SAR for 1g of tissue without a tumor at 16.452GHz

The SAR value for 1g of tissue for the H-shape MPA with a vertical slot with a tumor for a frequency of 10.846GHz and 16.452GHz which provides the SAR value of 0.0199W/Kg at 10.846GHz and 0.000637W/Kg at 16.452GHz which is shown in Fig.31 and Fig.32.

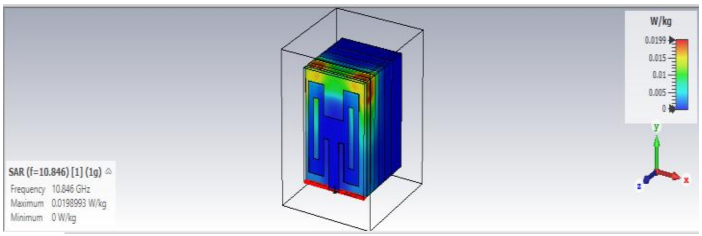

Fig.31. SAR for 1g of tissue with a tumor at 10.846GHz

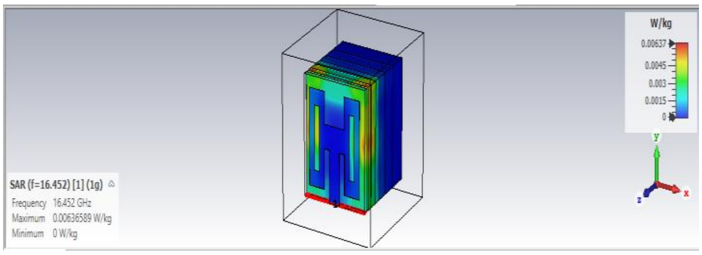

Fig.32. SAR for 1g of tissue with a tumor at 16.452GHz

Table.1. Results of the proposed antennas

Antennas	Return loss (dB)		VSWR	
	Without Tumor	**With Tumor**	**Without Tumor**	**With Tumor**
H-shape MPA	-23.116	-25.488	1.1495	1.1122
H-shape with vertical slot	-26.68	-23.138	1.096	1.1497

From Table.1, it is observed that the H-shape microstrip patch antenna with vertical slot provides less return loss of -26.68dB without a tumor and -23.138dB with a tumor. The H-shape microstrip patch antenna with vertical slot provides less VSWR 1.096 without a tumor and 1.1497 with a tumor.

From Table.2, and Table.3 H-shape microstrip patch antenna with a vertical slot provides a high gain of 6.36dB and high SAR of 0.0199W/Kg with a tumor.

Table.2. Results of the proposed antennas

Antennas	**Resonant frequency (GHz)**	**Gain (dB)**	
		Without Tumor	**With Tumor**
H-shape MPA	10.846	2.09	1.9
	16.452	2.11	3.11
H-shape with vertical slot	10.846	1.63	4.43
	16.452	3.35	6.36

Table.3. Specific Absorption Rates

Antennas	**Resonant frequency (GHz)**	**SAR (W/Kg)**	
		Without Tumor	**With Tumor**
H-shape MPA	10.846	0.0102	0.0089
	16.452	0.00335	0.0062
H-shape MPA with vertical slot	10.846	0.0143	0.0199
	16.452	0.00499	0.00637

5. CONCLUSION

In this paper H-shape micro strip patch antenna and H-shape micro strip patch antenna with vertical slot are designed to evaluate the SAR (Specific Absorption Rate) for thyroid gland cancer cells detection and it is simulated using CST tool. The H-shape MPA design has been implemented because the human thyroid gland is similar to H-shape. The human thyroid gland model is designed with six layers -skin, fat, muscle, bone, thyroid, and tumor. The performance can be varied by with and without tumor of the human thyroid gland.

The H-shape micro strip patch antenna with a vertical slot with a tumor provides a high gain of 6.36dB at 16.452GHz. The Specific Absorption Rate (SAR) is calculated for 1g of tissue for with and without tumor. The H-shape micro strip patch antenna with a vertical slot with a tumor provides a high SAR value of 0.0199W/Kg at 10.846GHz. In this proposed design H-shape with vertical slot with a tumor provides a better result compared to other designs. In the future, the proposed antenna may be developed to identify the tumor for different parts of the body and the antenna can be designed in different shape with various frequency to get a better performance.

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