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Design of Rectangular Microstrip Patch Antenna to Detect Cancer Cells in Thyroid Gland

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Abstract - *The rectangular microstrip patch antenna (24.413mm x 15.769mm) is designed using FR-4 substrate material with a permittivity of 4.4 to detect cancer cells in the thyroid gland. The thyroid gland model is placed below the proposed antenna to detect cancer cells. The proposed rectangular microstrip patch antenna (MPA) is operating in ISM band with the resonant frequency of 5.73GHz. It is simulated using Ansys 2023 R2 HFSS software. The thyroid gland model with cancer cells has different properties because cancer cells have more water content. The parameters of rectangular MPA such as return loss, voltage standing wave ratio (VSWR) are varied with and without cancer cells in the thyroid gland. By using these parameters cancer cells are detected in the thyroid gland. The return loss value of proposed rectangular MPA is below -10dB for thyroid gland model with and without cancer cells.*

Key Words: Thyroid gland model, tumor (cancer cells), VSWR, return loss, gain.

1.INTRODUCTION

The thyroid is a butterfly-shaped gland located at the base of the neck, just below the Adam's apple. Hormones that control blood pressure, body temperature, heart rate, and weight are produced by the thyroid. Cells begin to proliferate in the thyroid and eventually become thyroid cancer. At initially, thyroid cancer may not show any signs. However, when it gets bigger, it might produce symptoms and indicators such neck swelling, voice changes, and swallowing difficulties. When DNA alterations occur in thyroid cells, thyroid cancer results. A cell's DNA contains instructions that tell it what to do. The alterations, known to scientists as mutations, instruct the cells to proliferate and expand quickly. When healthy cells would naturally perish, the cells continue to exist. A tumor is a mass formed by the cells that are accumulating. The tumor has the potential to develop, infiltrate surrounding tissue, and travel (metastasize) to the neck lymph nodes. Occasionally, cancer cells have the ability to travel to other areas of the body, including the lungs, bones, and neck. Tumor is detected using proposed MPA by placing thyroid gland model below antenna [1].

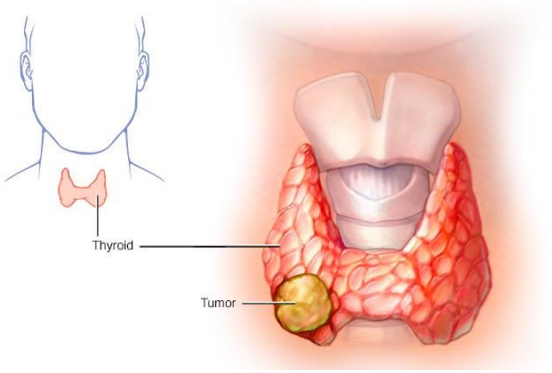


Fig -1: Thyroid gland with tumor (cancer cells)

The radio spectrum or group of radio bands known as the industrial, scientific, and medical radio band (ISM band) is set aside worldwide for the use of radio frequency (RF) energy for industrial, scientific, and medical purposes only, not for communication. 5.725 – 5.875GHz is one of the ISM bands and the proposed rectangular MPA is operating in this band.

A 3D electromagnetic (EM) simulation program called Ansys HFSS is used to design and simulate high-frequency electronic products, including printed circuit boards, antenna arrays, RF and microwave components, high-speed interconnects, filters, and connectors.

2.RECTANGULAR MICROSTRIP PATCH ANTENNA DESIGN

1.1 Equations for microstrip patch antenna design

Width of the rectangular MPA patch,

$$Wph = \frac{C}{2Frt\sqrt{\frac{\varepsilon re+1}{2}}} \quad \text{->(1)}$$

Length of the rectangular MPA patch,

$$Lph = \frac{C}{2Frt\sqrt{\varepsilon ef}} - 0.824Hs\frac{(\varepsilon ef+0.3)\left(\frac{Wph}{Hs}+0.264\right)}{(\varepsilon ef-0.258)\left(\frac{Wph}{Hs}+0.8\right)} \quad \text{->(2)}$$

Length of the microstrip patch antenna substrate,

$Ls = 2Lph$ ->(3)

Width of the microstrip patch antenna substrate,

$Ws = 2Wph$ ->(4)

where *C* denotes the velocity of light,

Frt denotes resonant frequency,

εre denotes relative permittivity,

εef denotes effective relative permittivity and

Hs denotes height of the substrate [2].

1.2 Calculations for microstrip patch antenna design

- By using equation (1),
  Width of the rectangular MPA patch,
  Wph = 15.769 mm is calculated.
- By using equation (2),
  Length of the rectangular MPA patch,
  Lph = 24.413 mm is calculated.
- By using equation (3),
  Length of the substrate,
  Ls = 48.826 mm is calculated.
- By using equation (4),
  Width of the substrate,
  Ws = 31.538 mm is calculated.
- Width of the feedline,
  W_f = 3 mm is calculated.
- Length of the feedline,
  L_f = 12.2065 mm is calculated.

Table -1: Design parameters and its value of rectangular microstrip patch antenna

Parameters	Values
Wph	15.769 mm
Lph	24.413 mm
Ls	48.826 mm
Ws	31.538 mm
W_f	3 mm
L_f	12.2065 mm
Hs	1.6 mm
εre	4.4
Frt E	5.73GHz

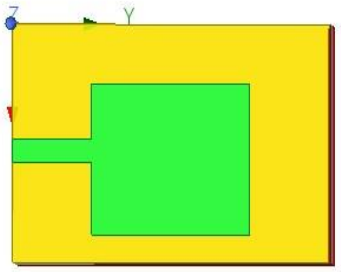


Fig -2: Top view of rectangular MPA

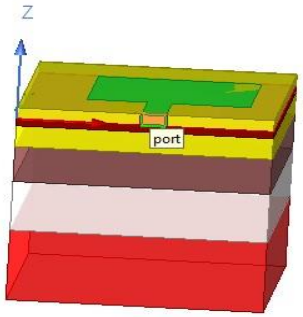


Fig -3: Front view of rectangular MPA with thyroid model

Fig-2 shows top view rectangular microstrip patch antenna which is designed with values mentioned in Table-1. Fig-3 shows Front view of rectangular MPA with thyroid model.

3.DESIGN OF THYROID MODEL

The thyroid model consists of five layers such as skin, fat, muscle, bone and thyroid gland. With tumor, it has six layers.

Table -2: Thyroid gland model design parameters and its values

Layers	Relative permittivity	Dielectric Loss Tangent	Mass Density (kg/m)	Thickness (mm)
Skin	1.5	0.35	1100	1
Fat	0.1	0.05	920	3
Muscle	0.7	0.3	1060	5
Bone	0.3	0.2	1800	7
Thyroid	1.7	0.1	1100	10
Tumor	3.5	1.2	1000	17

Fig -4: Side view of thyroid gland model

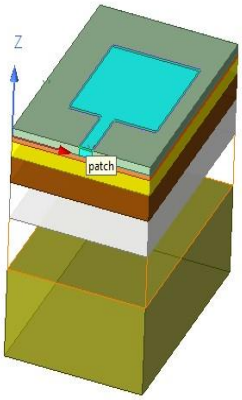


Fig -5: Thyroid gland model with MPA

Fig-4 and Fig-5 show Side view of thyroid gland model and Thyroid gland model with MPA respectively which are designed using values in Table 2.

4.RECTANGULAR MICROSTRIP PATCH ANTENNA WITH THYROID MODEL

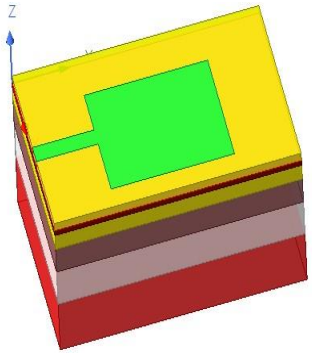


Fig -6: Rectangular MPA without tumor thyroid gland model

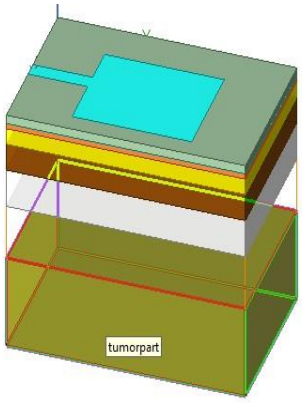


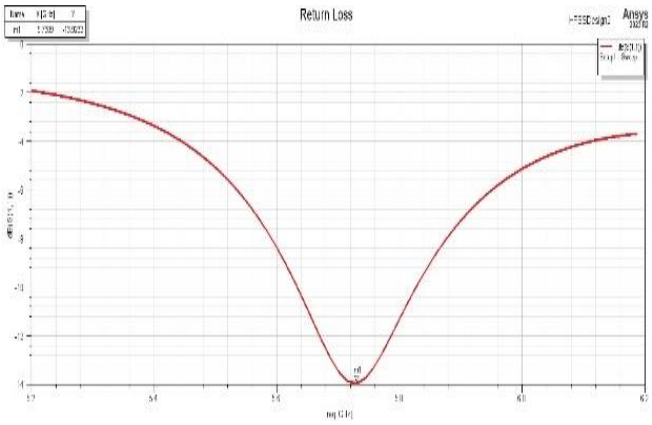
Fig -7: Rectangular MPA with tumor thyroid gland model

Fig-6 and Fig-7 shows rectangular microstrip patch antenna without tumor (cancer cells) thyroid gland model and rectangular microstrip patch antenna with tumor (cancer cells) thyroid gland model respectively [3].

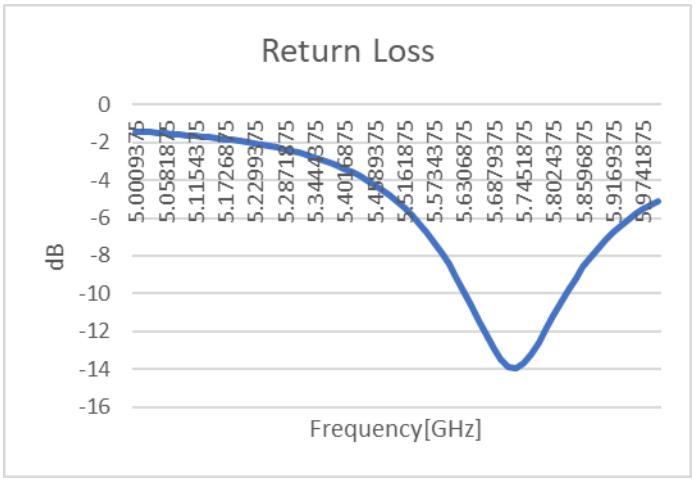
5.RESULTS OF RECTANGULAR MICROSTRIP PATCH ANTENNA FOR THYROID MODEL WITHOUT AND WITH TUMOR

Fig-8(a), (b) and Fig-9(a), (b) shows the return loss plot of proposed rectangular MPA in Ansys HFSS software and in line chart plot. At 5.73GHz, the proposed rectangular MPA gives return loss of -13.93dB and -12.97dB without and with tumor respectively.

Return loss below -10dB is obtained in this proposed antenna. Insertion loss is minimum when return loss below -10dB.

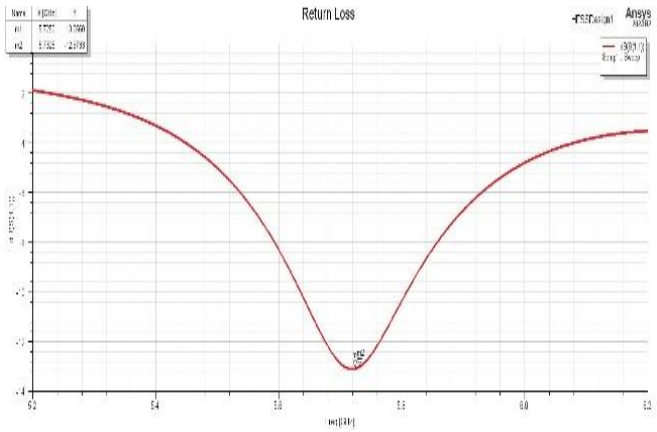


(a)

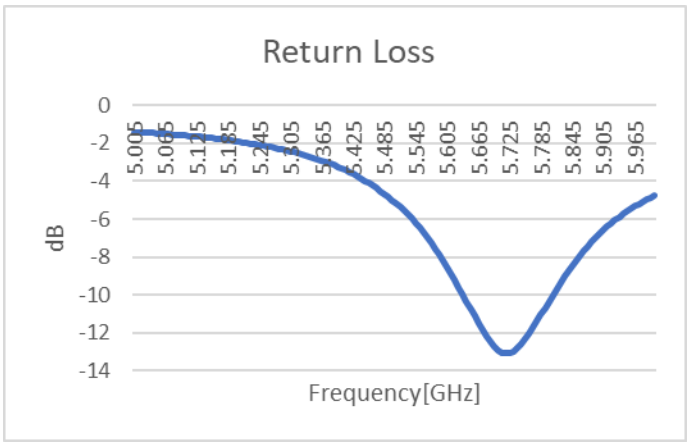


(b)

Fig -8: Return Loss of MPA for thyroid model without tumor



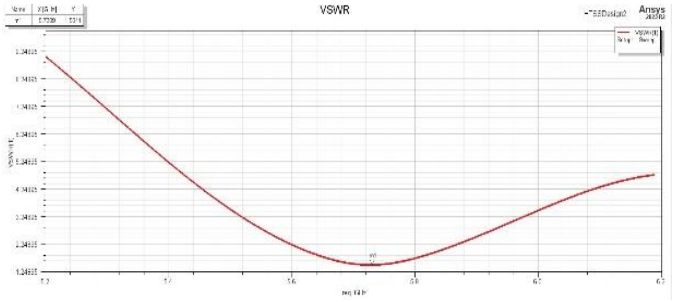
(a)



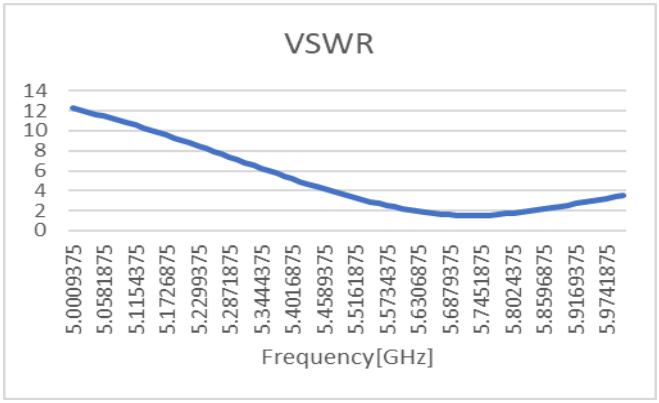
(b)

Fig -9: Return Loss of MPA for thyroid model with tumor

Fig-10 (a), (b)shows the VSWR plot of proposed rectangular MPA in Ansys HFSS software and in line chart plot. At 5.73GHz, the proposed rectangular MPA gives VSWR of 1.50 without tumor. Fig-11(a), (b) shows the VSWR plot of proposed rectangular MPA in Ansys HFSS software and in line chart plot. At 5.73GHz, the proposed rectangular MPA gives VSWR of 1.57 with tumor.

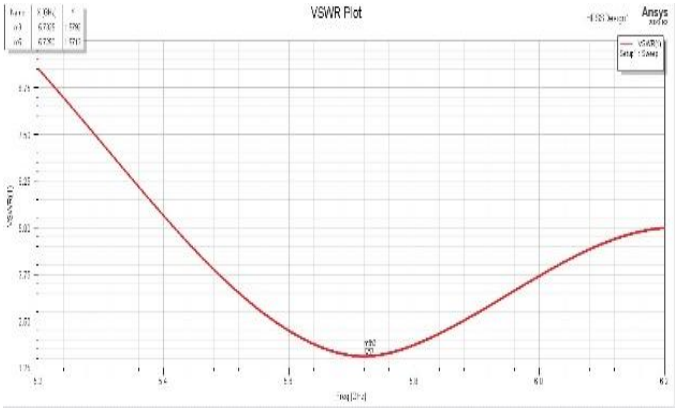


(a)

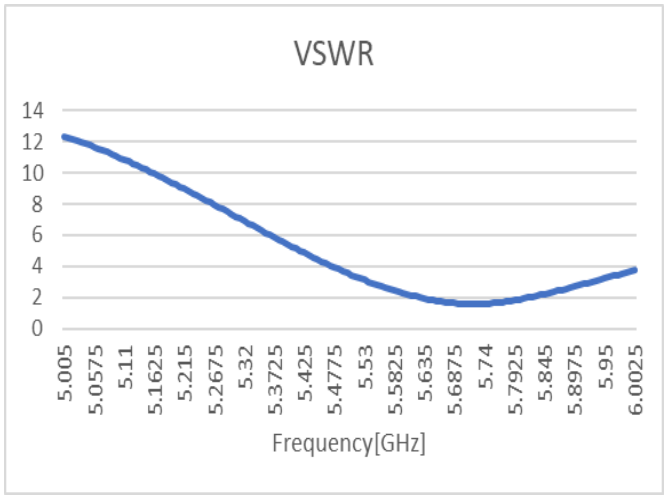


(b)

Fig -10: VSWR of MPA for thyroid model without tumor



(a)



(b)

Fig -11: VSWR of MPA for thyroid model with tumor

Fig-12 and Fig-13 shows the gain of proposed rectangular MPA. The proposed rectangular MPA gives maximum gain of 2.32 dB and 2.96 dB without and with tumor respectively.

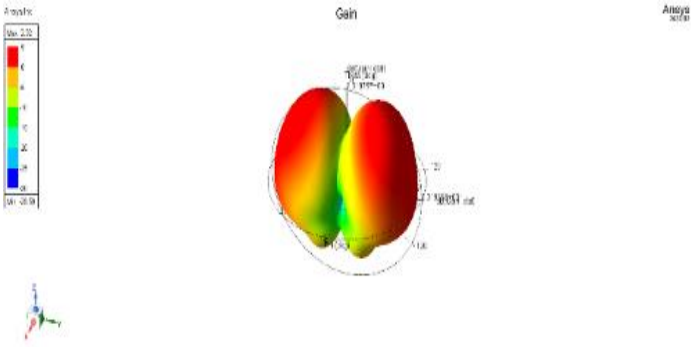


Fig -12: Gain of MPA for thyroid model without tumor

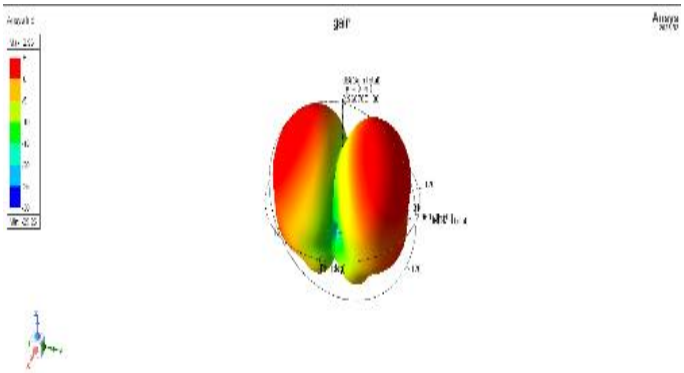


Fig -13: Gain of MPA for thyroid model with tumor

6.CONCLUSION

The proposed rectangular microstrip patch antenna has different return loss, gain, and VSWR values for thyroid gland with and without tumor. The variations in these parameters helps to detect the cancer cells in the thyroid gland. The proposed antenna uses edge feeding technique and it is easy to design. The proposed rectangular MPA has low profile and low cost. The proposed rectangular MPA with various frequencies will be designed to detect cancer cells at some earlier stages in future.

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