Antenna for Lung Cancer Detection Using Electric Properties of Lung Tissues

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Abstract – **The paper is devoted to analysis, design and implementation of patch antenna for lung cancer detection. It presents the patch antenna of overall dimension of 3.5×3.5cm^2. The antenna is fabricated on Roger material of relative permittivity and thickness of 3.66 and 1.524mm respectively. The loss tangent of the dielectric is 0.004. A lung model is presented comprising the lung tissues and the pleura. Dielectric properties of the lung tissues are, relative permittivity, ε_r of 20.4768 and conductivity, $_\sigma$ of 0.804 S/m, while those for the pleura are 42.035 and 1.67 S/m respectively. The return loss are simulated on CST microwave studio for the antenna located on the lung structure. It is shown that there is a resonance frequency shift between the simulated return loss of the normal lung tissues and those of the infected lung tissues by tumor cells for different stages.**

I. INTRODUCTION

Throughout time humans' health has enhanced with the help of massive researches, and rapid advances in technology. It was found that some patients need constant monitoring for their health. Other patients would benefit from early detection. So the basic idea of implanting medical device is to facilitate patient's life and trying to offer them a better care [1-4].

Many researchers investigated implanted antennas to detect cancer like Breast cancer [5], spiral implanted antenna in brain [6, 7] .

Lung cancer is the most common cause of death due to cancer in both men and women throughout the world statics from the American Cancer Society estimated that about 228,000 new cases of lung cancer in the U.S. will be diagnosed in 2013 [8].

This article presents the design, analysis, and fabrication of patch antenna on lung to detect lung cancer in several stages.

II. LUNG ANATOMY AND LUNG CANCER FACTS

Lungs are a pair of respiratory organs situated in a thoracic cavity. Right and left lung are separated by mediastinum of average 1cm. Each lung is about 30cm height, 12.5cm width, and the total air volume of the lungs is about 4 to 6 liters and varies with a person's size, age, gender [9]. The dielectric properties of the inflated lung is ε_r = 20.757009 and $_\sigma$ = 0.804 S/m. Pleura is one of the two membranes around the lungs. These two membranes are called the visceral and partial pleura [10]. In this work we concern the visceral pleura of average thickness 0.3mm. Its dielectric properties are ε_r = 42.561703 and $_\sigma$ = 1.443083 S/m.

There are two major types of lung cancer; non-small cell lung cancer (NSCLC) which is the common type of the lung cancer. About 85% of lung cancers are NSCLC [11], and small cell lung cancer (SCLC) which spreads quickly. About 10% to 15% of lung cancers are SCLC [11].

The system used to describe the growth and spread of NSCLC is the American Joint Committee on Cancer (AJCC) **TNM** staging system. The **TNM** system is based on 3 key pieces of information [12]:

- **T** indicates the size of the main **T**umor and whether it has grown into nearby areas.
- **N** describes the spread of cancer to nearby **N**odes. Lymph nodes are small bean-shaped collections of immune system cells to which cancers often spread before going to other parts of the body.
- **M** indicates whether the cancer has spread (**M**etastasized) to other organs of the body.

In this work the authors try different **TNM** as shown as in table 1.

Table 1: Stage grouping of lung cancer

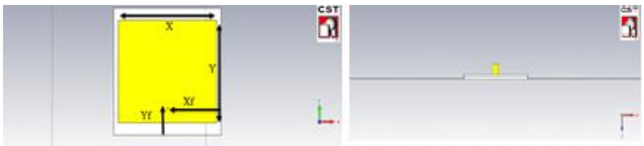
Stage:	Description:
Stage 0:	The cancer is found only in the air filling between the two lungs and it has not invaded into the lungs and has not spread to distant sites.
Stage IA:	The cancer is about 3 cm across, has not reached the pleura that surrounds the lungs. The cancer has not spread to distant sites.
Stage IB:	The main tumor is about 5 cm across. And the tumor grown into the pleura.
Stage IIB:	The main tumor is about 7 cm across. And the tumor has grown to the pleura.
Stage IIIA:	The main tumor is larger than 7 cm.
Stage IIIB:	The main tumor is any size has grown into the space between the lungs
Stage IV:	The cancer spread in the two lungs with any size.

III. ANTENNA DESIGN

The patch antenna is fabricated on a Roger 4530b substrate layer of thickness 1.524, and ε_r = 3.66. The overall dimension of antenna are 35×35 mm^2 while the patch are 32×28mm^2. Table 2 depicts the other dimensions of the antenna structure. The antenna is simulated using CST microwave studio. The simulated antenna is shown in figure 1 while figure 2 depicts the fabricated antenna.

Table 4.1 Patch antenna dimensions

Patch antenna dimensions	Length in mm
X	32
Y	28
Xf	15
Yf	5



(a) Front view (b) Side view

Figure1: Simulated patch antenna

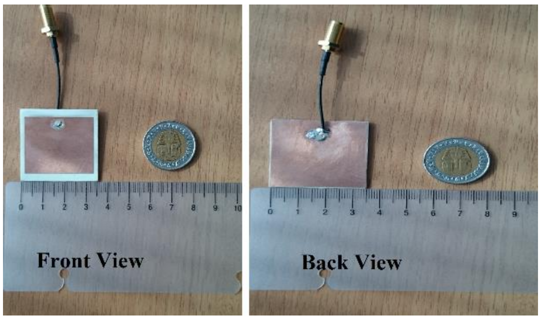


Figure 2: Fabricated antenna

IV. SIMULATIONS AND MEASUREMENTS

Figure 3 illustrates the configuration of the simulated lung model. The average dimensions of the model are 300×125×133mm^3. Figure 4 illustrates the simulation model for the implanted patch antenna on pleura and lungs.

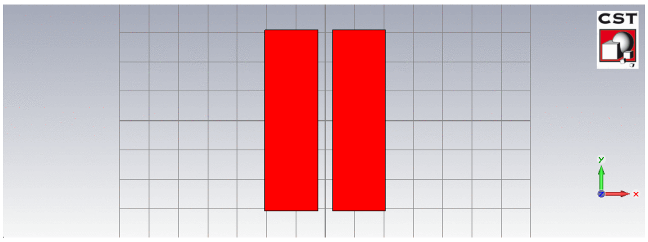


Figure3: Lungs model

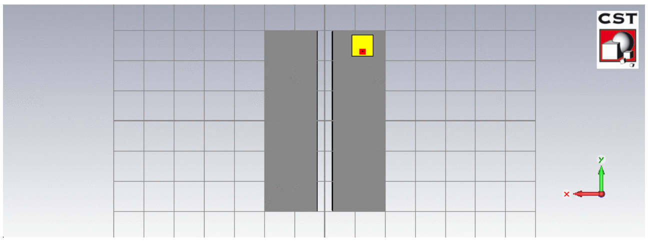


Figure 4: Patch antenna implanted on pleura and lungs

Figure 5 shows the simulated return loss of the patch antenna implanted on pleura and lungs for normal tissues which resonates on 2.3734 GHz and its bandwidth is 119.29 MHz.

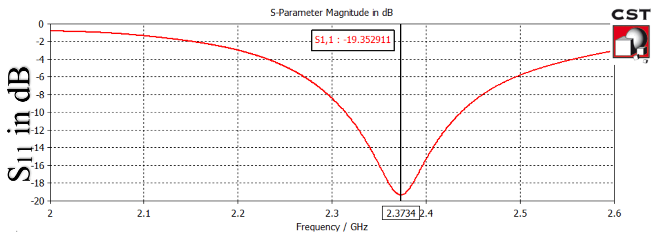


Figure 5: Simulated return loss of patch antenna implanted on pleura and lungs

The surface current and the 3D, E-Plane, and H-plane radiation patterns of patch antenna are shown in figures 6, 7, 8 and 9 at 2.37 GHz. The antenna directivity is 6.99 dB.

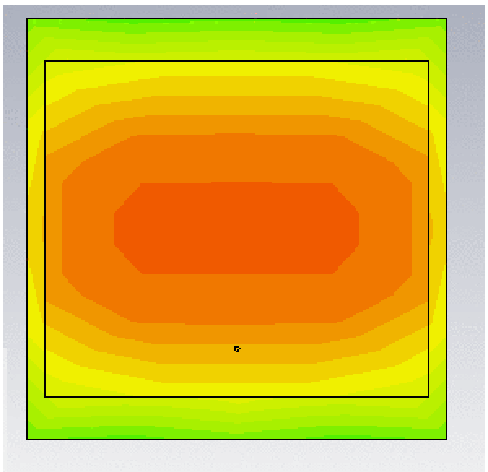


Figure 6: Surface current of patch antenna.

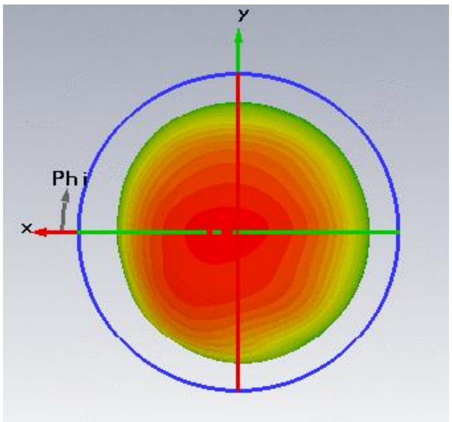


Figure 7: 3D radiation pattern of patch antenna.

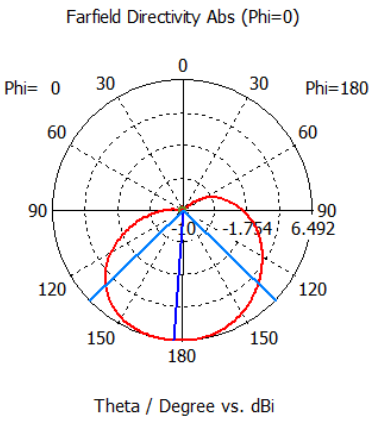


Figure 8: E-Plane pattern

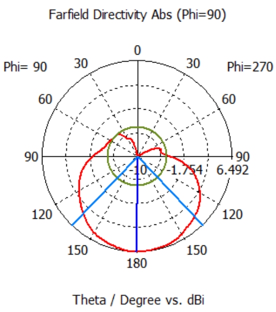


Figure 9: H-Plane pattern

To assure the fabrication process the antenna is placed in free space to compare between the simulation and measured return loss as shown in figure 10. It should be pointed out that the antenna is not well matched at the resonance frequency 2.68 GHz because our concern is the resonance of the antenna on lung structure for lung cancer detection.

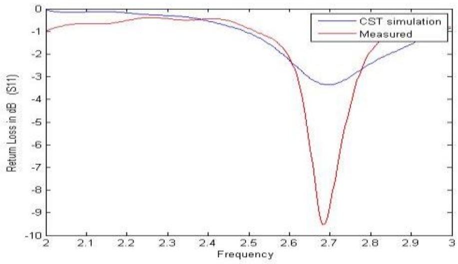


Figure 10: Simulated and measured return loss of patch antenna in free space.

The simulated model of stage 0 cancer cell is shown in figure 11. It is found only in the air filling between the two lungs. It has not invaded into the lungs, and has not spread to distant sites. Figure 12 illustrates the simulated return loss of the antenna implanted on pleura and lungs for the case stage 0 tumor with a sphere of radius 12 mm. Dielectric properties of the cancer cell are, relative permittivity of 54.77 and conductivity of 1.99 S/m. The structure resonates at 2.3443 GHz with bandwidth 126.43 MHz. It conducts a frequency shift of 29 MHz relative to the case of normal tissues.

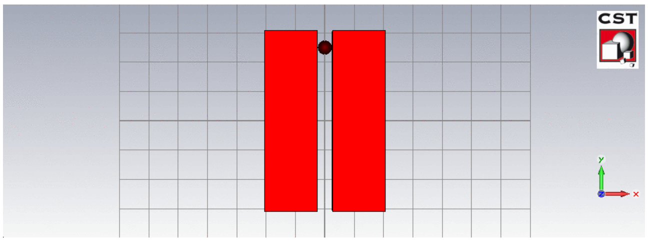


Figure 11: Stage 0 of lung cancer

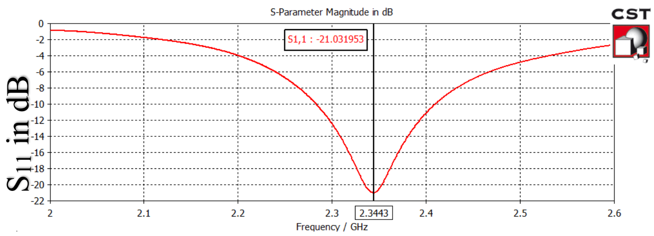


Figure 12: The simulated return loss of the antenna implanted on pleura and lungs for the case stage 0 tumors

Similarly the model for the other stages of lung tumors as well as their simulated return loss are depicted in figures 13 to 24. The resonance frequency associated with the bandwidth are depicted on the figures. Table 3 summaries the simulated resonance frequency for the antenna implanted on pleura and lungs for both normal and infected different stages.

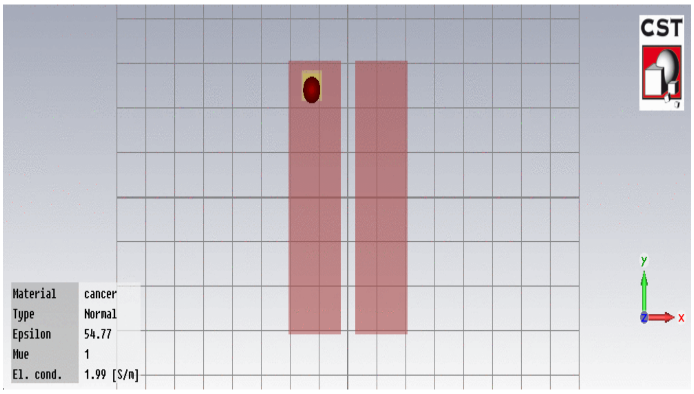


Figure 13: Stage IA

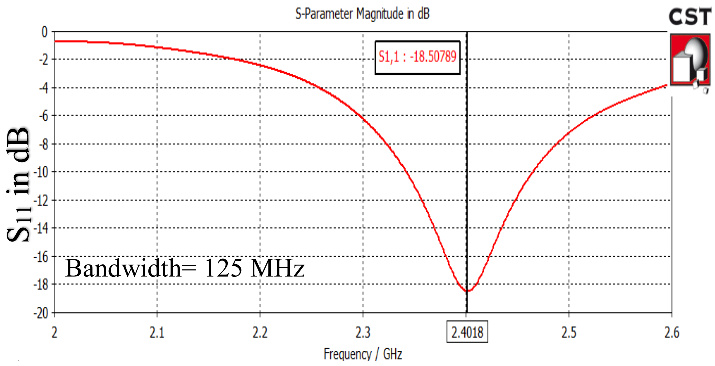


Figure 14: The simulated return loss of the antenna implanted on pleura and lungs for the case stage IA tumors

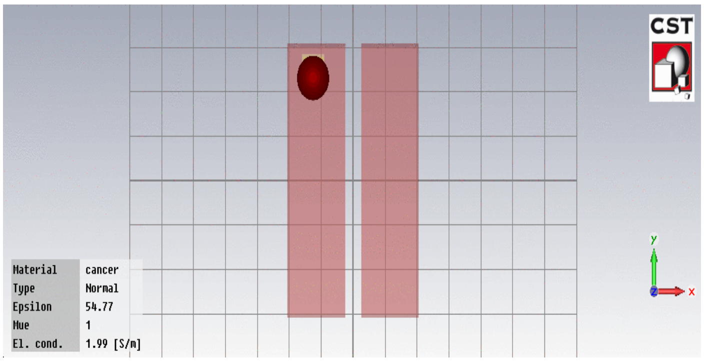


Figure 15: Stage IB

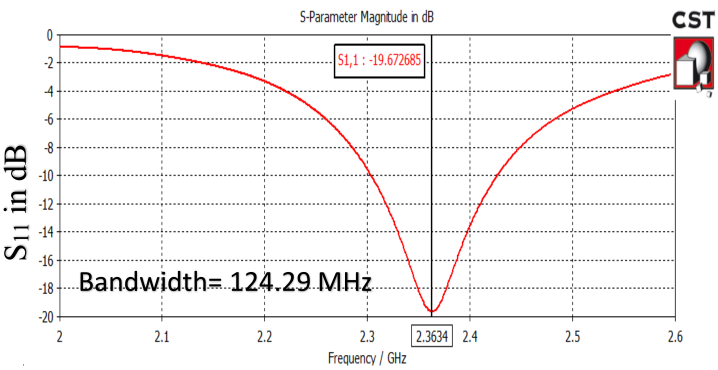


Figure 16: The simulated return loss of the antenna implanted on pleura and lungs for the case stage IB tumors

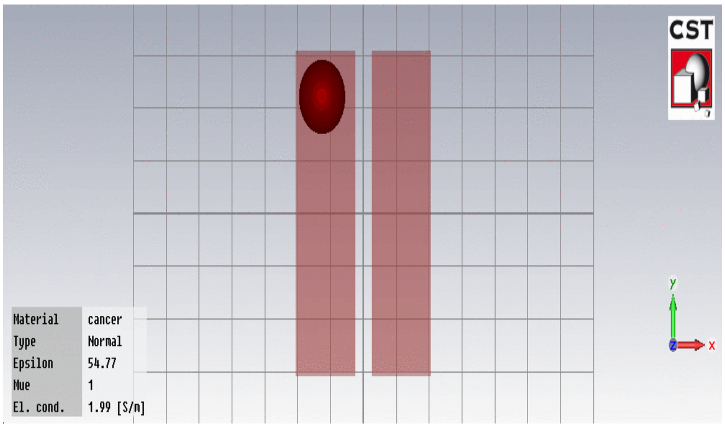


Figure 17: Stage IIB

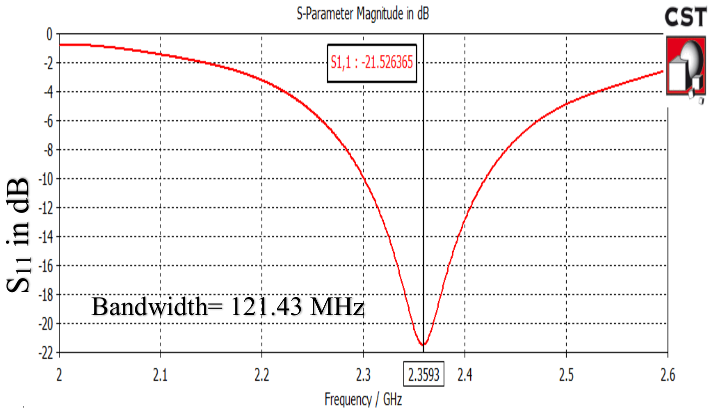


Figure 18: The simulated return loss of the antenna implanted on pleura and lungs for the case stage IIB tumors

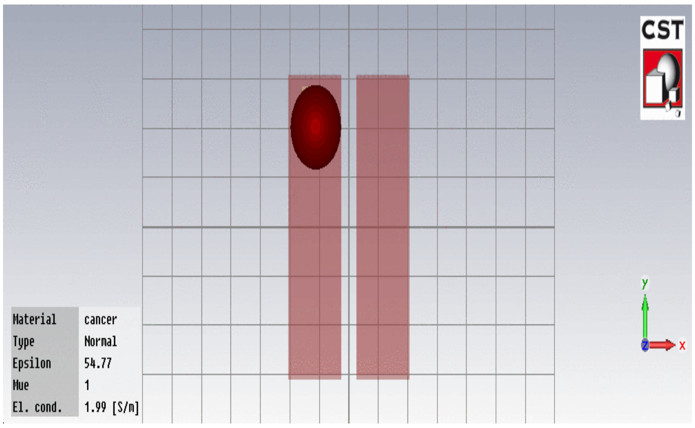


Figure 19: Stage IIIA

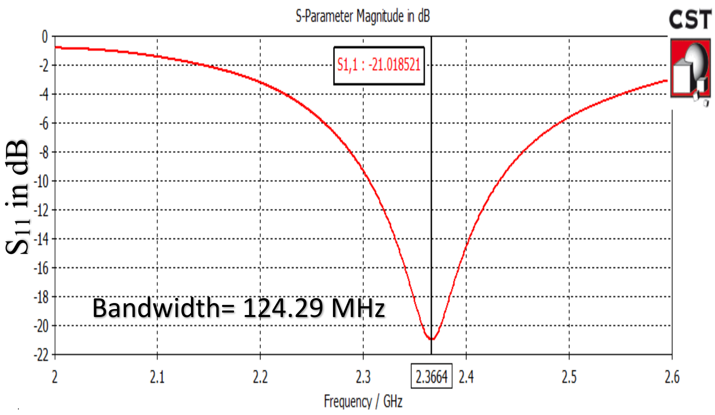


Figure 20: The simulated return loss of the antenna implanted on pleura and lungs for the case stage IIIA tumors

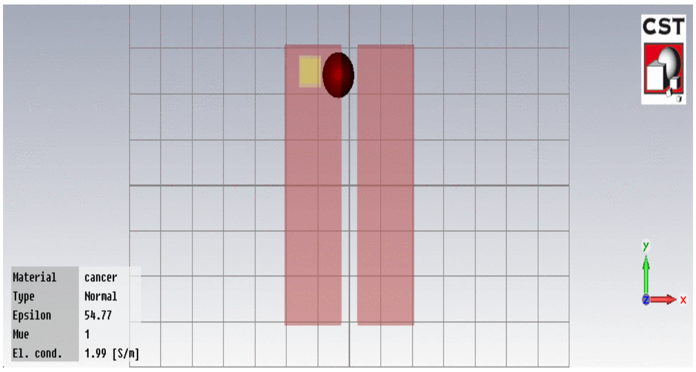


Figure 21: Stage IIIB

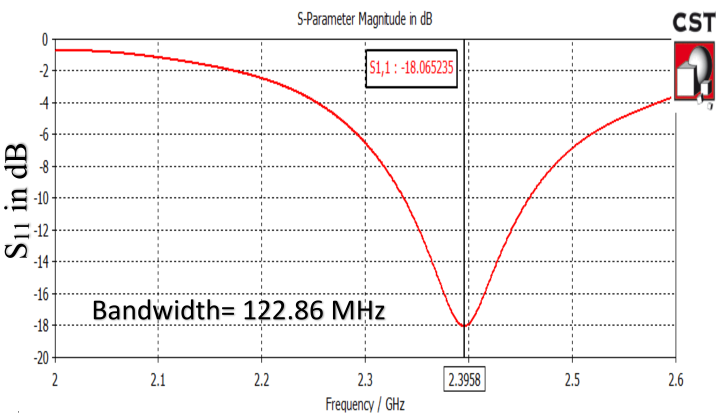


Figure 22: The simulated return loss of the antenna implanted on pleura and lungs for the case stage IIIB tumors

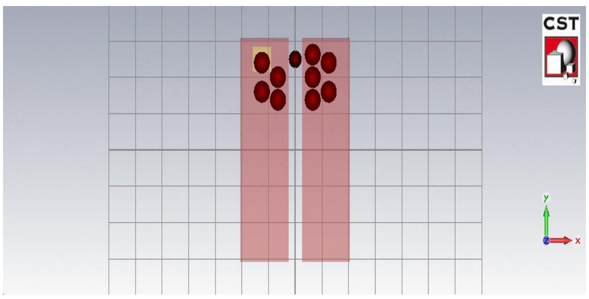


Figure 23: Stage IV

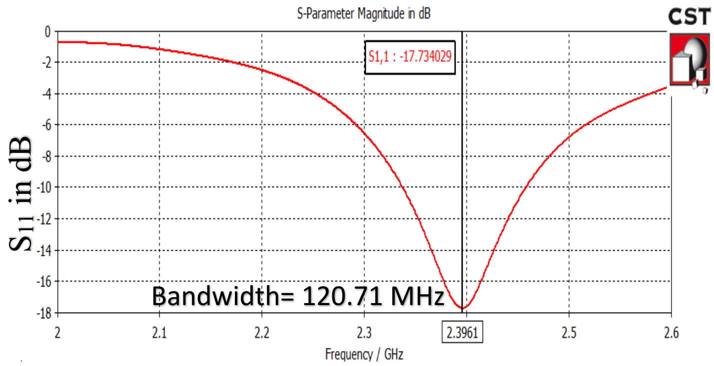


Figure 24: The simulated return loss of the antenna implanted on pleura and lungs for the case stage IV tumors

Table 3: The simulated resonance frequency of different stages of Lung cancer.

Stage:	F (GHz):
Stage 0:	2.3443
Stage IA:	2.4018
Stage IB:	2.3634
Stage IIB:	2.3593
Stage IIIA:	2.3664
Stage IIIB:	2.3958
Stage IV:	2.3961
The normal Lung:	2.3734

It is very important to point out that the electrical properties of the lung tissues and Pleura are obtained from the websites:

1- http://transition.fcc.gov/oet/rfsafety/dielectric.html
2- http://www.itis.ethz.ch/itis-for-health/tissue-properties/database/dielectric-properties/

V. CONCLUSION

Patch antenna is designed and implemented for lung cancer detection. The overall dimension of $3.5 \times 3.5 cm^2$. It is fabricated on Roger material of relative permittivity and thickness of 3.66 and 1.524mm respectively. The return loss are simulated on CST microwave studio for the antenna located on the lung structure. There is a resonance frequency shift between the simulated return loss of the normal lung tissues and those of the infected lung tissues by tumor cells up to 30 MHz depending on the stage of the infected tissues. This fact can be considered as a preliminary factor to judge the existence of tumor lung cancers in early stages.

ACKNOLEDGEMENT

I would like to express my deepest gratitude to my supervisor Prof. Dr. Abdelmegid Allam for all his support.

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