Analysis of cancer cell behaviour using Sub-THz excitation in COMSOL Multiphysics

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Abstract —**In this paper, analysis of cancer cells using Sub-THz technology have been studied. Sub-THz technique for cancer detection is a much reliable and safer technique as compared to conventional methods [1,2]. To study the behavior of cancer cells and normal cells using Sub-THz technology, a simulation model has been developed using COMSOL software [3]. In COMSOL Multiphysics, the 3D modeling of the cancer cell kept inside the waveguide has been designed using RF module. The waveguide taken in the simulation model is WR-10, with frequency range of 75 GHz to 110 GHz with step size 0.1 GHz, while the cancer cell is placed in center of waveguide. The difference in transmissive and reflective property of cancer cells and normal cells have been analyzed. The comparative analysis has been performed for these different cells by shining the sub-terahertz signal. The resultant S-parameter clearly depicts the difference in reflection and transmission parameter property of cells.**

Keywords— Terahertz, COMSOL, reflection, transmission, WR-10.

I. INTRODUCTION

Cancer is still one of the deadliest diseases in the world. Almost a 51% death rate occurred in 2020, which is almost equivalent to the survival rate of cancer patients [1]. Even during the COVID-19 outbreak, there has been a downfall in cancer testing and treatment technology due to measures and the economy shifted mainly towards coronavirus which led to a significant drop in cancer testing and treatment technology. Diagnosis of cancer at an early stage is necessary to reduce the symptoms, increase the life span and decrease the recurrence rate in cancer patients. Due to delays in cancer diagnosis, it leads to an increase in the risk of survival. There is a need for early-stage cancer diagnostic techniques [2].

Terahertz (THz) technology is being widely researched for diagnostics the of cancer cells. THz is one of the promising and emerging techniques in the world [3-6]. THz radiation lies between the electronics and photonics area in EM spectra. Worldwide efforts are being carried out in the field of relevant THz technologies [7-12]. Extensive studies have been done during the last 5 years and discussed related to imaging and THz spectroscopy of cancer [6]. Due to the non-ionizing property of radiation, it is a promising technology in the field of imaging cancer cells. The cancer cell and normal cells differentiate based on biomolecular, chemical properties and hydration power [13-15]. A comparative analysis has been performed to study the behavior of normal cells and cancer cells with the excitation of the sub-THz wave using a simulation model. The relevant technologies for the design and development of high-power sub-THz sources have been executed at CSIR-CEERI for the last five years.

Therefore, in this paper, a comparison has been studied between normal cells and cancer cells due to differences in biological and chemical constituents [16]. A simulation model has been designed at different angles to calculate the maximum transmittance value for cancer cells at different angles. The RF wave with a frequency range of 75 GHz to 110 GHz with a step size of 0.1 GHz has been shined on the cells. The resulting reflection and transmission values have been observed and compared for both cells. This gives a better understanding of the behaviour of cancer and normal cells in the THz regime.

II. SIMULATION MODEL

A 3-D simulation model has been designed and developed to perform the simulation in the w-band region (75 GHz to 110 GHz with step size 0.1 GHz) using COMSOL RF module 6.1. There has been a significant change in the electrical field due to the change in the electrical properties of materials. The reflected and transmitted signals have been calculated by estimation of S-parameters. Simulations have also been performed to analyze the transmitted power by positioning the receiving port at different angles. It will also help in positioning the detector in a futuristic experimental diagnostic setup. The overall simulation model will also lead to an estimation of the requirement of input power from the THz source.

The schematic view of a physical model of the rectangular metallic chamber with mast of cells containing normal skin cells or skin cancer cells in Fig. 1. The dimensions of the rectangular waveguide with port and cancer cell details are presented in Table I.

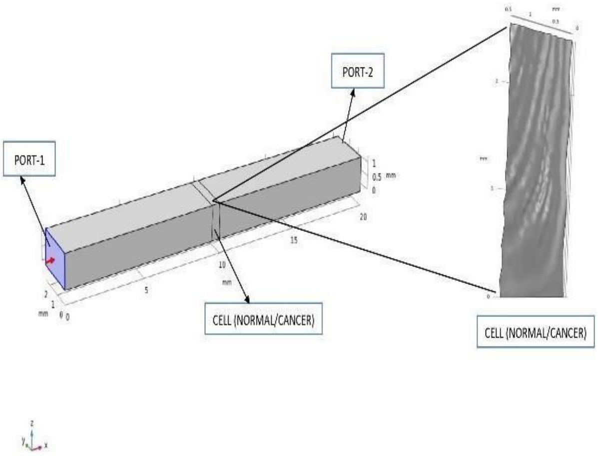

Fig. 1. 3D SCHEMATIC OF THz BASED SIMULATION MODEL CONTAINING NORMAL AND CANCER CELLS AT 0°.

TABLE I. DETAILS OF THE COMPONENT USED IN THE SIMULATION MODEL

Parameters	**Value**
Rectangular wave guide (w)	20 mm
Rectangular wave guide (b)	2.54 mm
Rectangular wave guide (h)	1.27 mm
Cancer cell size	1.5 mm width
Cancer cell shape	Irregular

The model comprised two different ports placed at opposite ends in a rectangular waveguide. The first input port (Port-1) excites the W-band signal. The W-band signal gets transmitted through the waveguide before getting exposed to cancer or normal cells and is finally collected by the receiving port (Port-2). The rectangular waveguide of WR-10 has been assigned in the physical model. The rectangular geometrical structure has depth (b = 2.54 mm). The length of drift space between the input and output port is (w= 20 mm) and the height (h = 1.27 mm). A tissue containing normal cells and cancer cells has been kept fixed at the central position of a hollow rectangular waveguide.

A cell has been placed at the center position of the simulation model. The normal and cancer cell has been designed in such a way as to mimic the specimen. The cells have been designed with surface roughness with the equation [16]:

x=(cos(s2*s1*20)*sin(s2*s1*7)+sin(s2*s1*43)+cos(s2*s1*15))/100 +(sin((s2-1)*(s1-1)*7)+cos((s2-1)*(s1-1)*7))/100

TABLE II. PROPERTY OF SKIN NORMAL CELL AND SKIN CANCER CELL [16]

S.NO.	**PROPERTY**	**NORMAL SKIN CELLS**	**SKIN CANCER CELL**
1	Relative Permittivity	5	8
2	Relative Permeability	1	1
3	Electrical Conductivity (S/m)	0	0

The electrical and biological properties have already been defined for normal cells and cancer cells. Relative permittivity, relative permeability, and electrical conductance parameters have been used for the cells as shown in Table II.

Changing the position of the detector at different angles is to check the maximum absorption and reflection peak at different directions. The shift of additional ports at different angles is to analyze the position of the detector to get maximum transmitted values. It is also useful in determining the distance between ports and cells and positioning the detector to calculate the higher intensity peak for reflection and transmission. It will also help in determining the maximum shift in the position of the detector from the central position in a line of the cancer cell. The simulation model has been presented for 15° in Figure 2. A comparative study has been performed to study the reflection and transmission properties of skin malignancy at different angles in Fig 1 and

Fig 2.

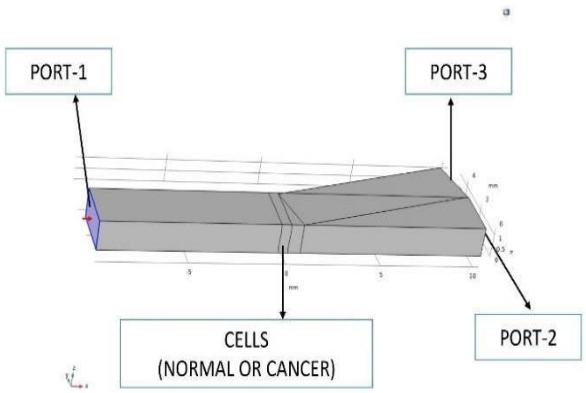

Fig. 2. 3D SCHEMATIC OF THz BASED SIMULATION MODEL CONTAINING NORMAL AND CANCER CELLS AT 15°.

III. RESULTS AND DISCUSSION

Using the simulation model, the transmittance of the W-band signal has been analyzed as shown in Fig. 3. There is a difference in negative peaks of frequency for normal and cancer cells. It will lead to differentiation between normal and cancer cells by exciting the W-band signal.

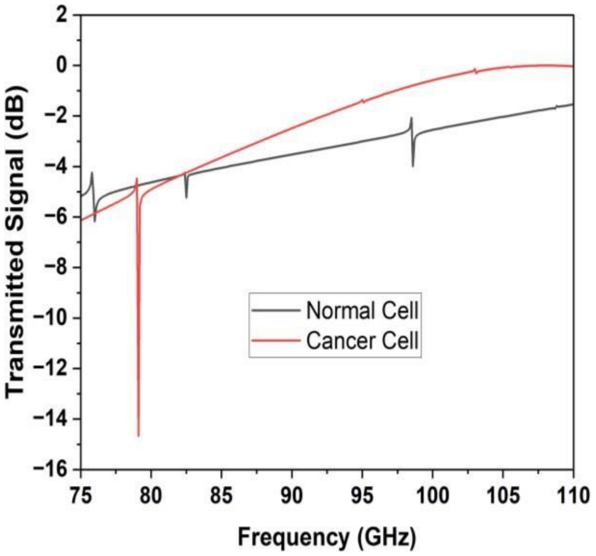

Fig. 3. COMPARISON OF TRANSMISSION PARAMETER IN NORMAL AND CANCER CELLS AT 0°.

The reflected, transmitted signals, for the detector placed at 0° and the detector placed at 15° has been developed using simulation model are shown in 4 and 5 for normal and cancer cell respectively. In Fig 4 there is the transmission of sub-THz signal for normal cells and cancer cells except at the frequency near about 0.1 THz. However, there is minimum reflection beyond 0.1 THz has been observed for cancer cells as normal cells.

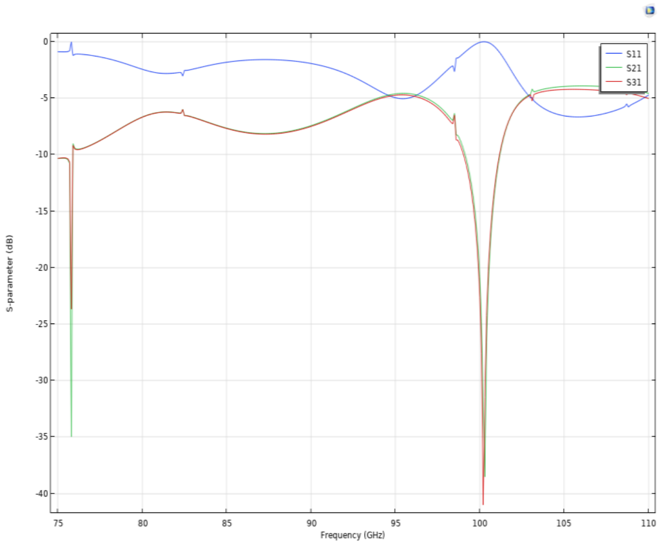

Fig. 4. REFLECTION AND TRANSMISSION PARAMETER IN NORMAL CELLS AT 15°.

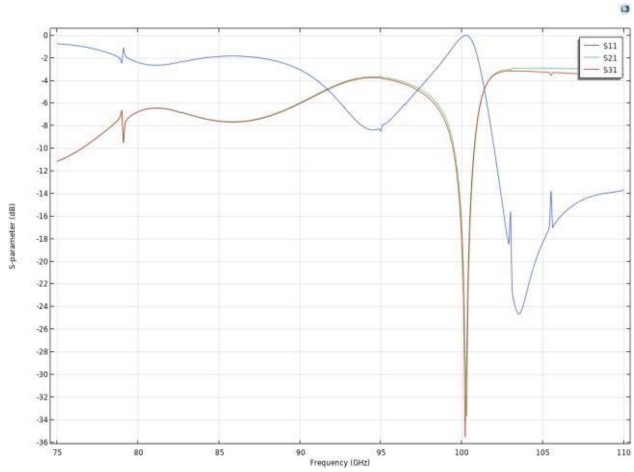

Fig. 5. REFLECTION AND TRANSMISSION PARAMETER IN CANCER CELLS AT 15°.

The electric field profile developed in the simulation model is shown in Fig. 6 there is a uniform periodic field pattern before the cancer cells are placed inside the simulation model. However, non-periodicity has been observed after cancer cells due to the absorption of the sub-THz signal.

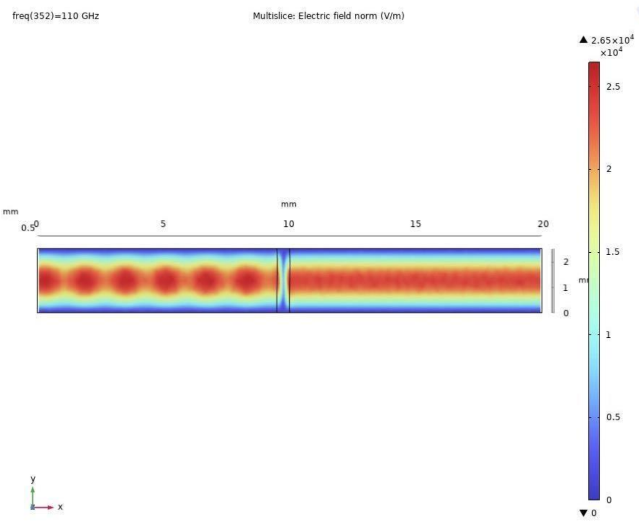

Fig.6. ELECTRIC FIELD PROPAGATION FOR CANCER CELLS AT 0°.

IV. *SUMMARY*

A comparative simulation study has been performed between skin normal cells and skin cancer cells with excitation of THz signal using COMSOL Multiphysics. The obtained simulation results demonstrate that there is a difference in absorption values for transmitted signals for the normal and cancer cell in the W-band regime. It has also been observed that the reflected power is very high at 0.1 THz for normal as well as cancer cell. There is low reflected power for the cancer cell as compared to the normal cell beyond 0. 1THz.These studies demonstrate different behavior of the cancer cells and normal cells in the W-band regime. It will be helpful for researchers in developing the Sub-THz-based early-stage cancer diagnostics system.

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