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Abstract— **This paper is all about to design an antenna for brain tumor detection using a novel material Kapton polyimide. A brain tumor, which has the potential to spread throughout the body and result in cancer, is one of the worst disorders. Using a novel material and observing variation in the S1,1 parameter to spot brain cancers is the main objective of this paper. An on-body microstrip patch antenna constructed in the K band and a three-size brain tumor in a brain phantom model were employed to identify the existence of brain tumor. This antenna can operate between 4 and 14 GHz. The resonance frequency of the proposed antenna was discovered to be 12.96 GHz in free space. A VSWR of 1.00 and -92.06 dB S1,1 was also measured in this area. S1,1 is -49.93 dB at 8.58 GHz in the Normal Brain and -40.51 dB at 11.87 GHz in the Tumor Affected Brain.**

Keywords— Brain tumor antenna, Brain Tumor Detection Patch Antenna, Tumor Affected Brain, Kapton Polyimide, Biomedical Antenna

I. INTRODUCTION

Due to its impact on the most important organ in the human body, brain cancer is one of the major public health issues that exists globally. For example, in the case, there are 16,700 and 23,800 patients in the USA approximate deaths from brain cancer in 2017 [1]

More than 120 different types of brain tumors exist. The majority of them are successfully treatable. There are two main categories of brain tumors. Primary brain tumors, which begin in brain tissue and frequently remain there, are the first. Secondary brain tumors, which are more frequent, are the second. These cancers develop in other parts of the body before spreading to the brain. Brain tumors can contain or lack cancer cells. [2]

Because tumors are so invasive, brain cancer has a high death rate. This is a result of the disease's serious nature. But it is encouraging that the cure rate can be raised by accurately diagnosing it in the early stages, as early cancer treatment is more effective and efficient than late cancer treatment. Magnetic resonance imaging (MRI) scanning, X-ray screening, computed tomography (CT) scans, positron emission tomography (PET), and ultrasound imaging are common imaging modalities used to detect cancer. [3-4]

Since it provides a quick, inexpensive, noninvasive, safe, and highly accurate system solution using nonionizing radiation, the potential for microwave imaging technology for brain cancer detection has grown recently. A noninvasive active wave-based imaging technique is microwave imaging. Microwave signals contain nonionizing electromagnetic waves that can pass through human tissue without endangering health. [5-6]

The average total tumor size, as reported online by the British Journal of Cancer, was 7.5 centimeters, or almost 3 inches. The median survival time for patients with total tumor diameters in this range was 9.5 months. The median survival time increased by 30% to 12.6 months for patients with overall dimensions under 7.5 centimeters. [7]

According to this study, a miniature micro strip antenna could be used to find brain tumors. This suggested antenna was built and recreated using computer simulation technologies (CST). When the suggested antenna is tested on a brain phantom with and without a tumor, as well as in different sizes and positions, the variations in S1,1, VSWR, Far-field, and Directivity in the presence of the tumor serve as evidence of the effectiveness of the antenna.

II. STRUCTURE AND DESIGN

This article describes the design of a 20 mm by 15 mm microstrip patch antenna. The three parts of this antenna are the ground, substrate, and patch. The patch is made of Kapton Polyimide, whereas the ground is made of pure copper. The substrate is Rogers RO3003 (lossy). The total thickness of this antenna is 1.82 mm (0.55mm + 0.72mm + 0.55mm). Ground is 0.55 mm, Patch is 0.55 mm, and Substrate is 0.72 mm thick. The antenna was created using CST Studio. To test the antenna on the human brain, a phantom model of the human head was also made.

Fig. 1 shows the size of the antenna patch. In Fig. 2, the waveguide port, patch, substrate, and antenna ground are all displayed together. TABLE I then displays the designed antenna's geometrical values. Every value in this is in the millimetre range.

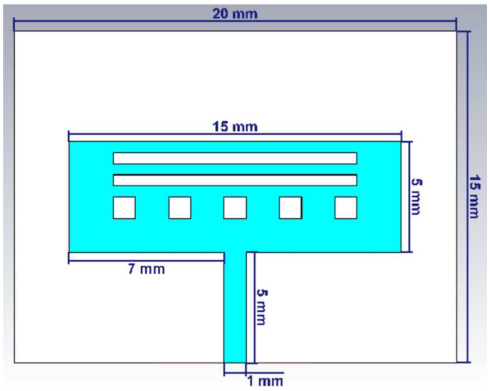

Fig. 1. Designed antenna's geometric dimensions.

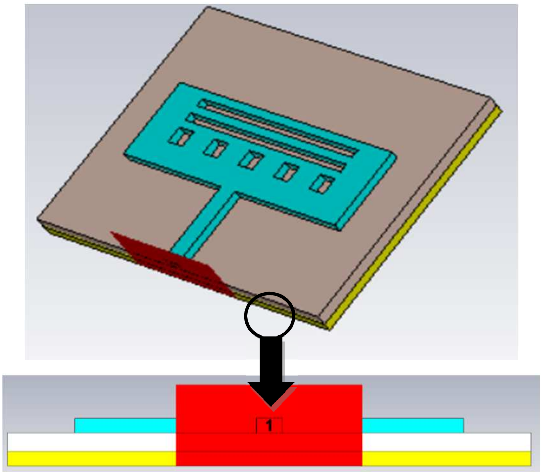

Fig. 2. Parts of the designed antenna.

TABLE I. ANTENNA SIZE PARAMETER

Name of The Parameter	Size(mm)
Ground Length (Gl)	**20**
Ground Width (Gw)	**25**
Ground Thickness (Gt)	**0.55**
Substrate Thickness (St)	**0.72**
Patch Thickness (Pt)	**0.55**
Fade line width (S)	**1**

Antenna size parameter

A. Equations to Design of Microstrip Patch Antenna

Different parameters for designing the antenna were calculated using this equation.

Width,

$$W = \frac{c}{2f_0\sqrt{\frac{\epsilon_R + 1}{2}}}$$

$$L = \frac{c}{2f_0\sqrt{\epsilon_{eff}}} - 0.824h\left(\frac{(\epsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\epsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.8\right)}\right)$$

Here,

$W = \textit{width of the microstrip patch antenna}$

$L = \textit{length of the microstrip patch antenna}$

$\epsilon_R = \textit{dielectric constant}$

$$\epsilon_{eff} = \frac{\epsilon_R + 1}{2} + \frac{\epsilon_R - 1}{2}\left[\frac{1}{\sqrt{1 + 12\left(\frac{h}{W}\right)}}\right]$$

By calculating, Length, L=5.968 mm and Width, W=7.798 mm. The ratio is adjusted for the desired frequency in order to arrive at our destination.

B. Design Metholodology

After the creation of the basic antenna, a human brain phantom model and a tumor inside the brain model were constructed. After the initial output was seen, a tumor was added to the brain model in CST Studio with three different places with same sizes in order to test the antenna. There has been created a 10 mm air gap layer since this antenna is an on-body patch. Next, three uniform layers of skin, bone and brain were created in CST Studio, as shown in Fig 3. The radius of these layers was 60 mm, 55mm and 50 mm.

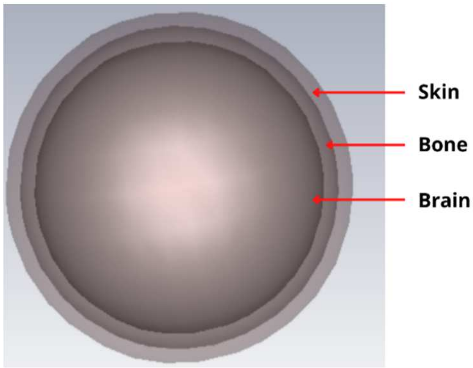

Fig. 3. Human Normal Brain model.

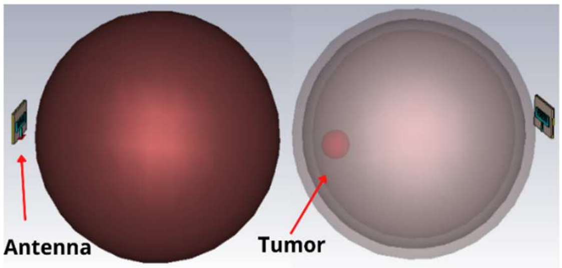

Fig. 4. Antenna placed on the brain models with and without tumors.

A minor tumor then developed within the brain layer, as shown in Fig. 4. Then, three different tumor sizes for the brain model were created: 3 mm, 5 mm, and 7 mm. The three tumors were shown in Fig. 5 in within the brain model.

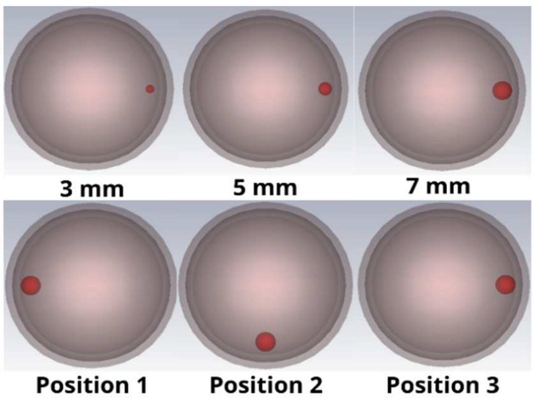

Fig. 5. Brain tumour phantom model with various positions and sizes.

III. Analysis of Antenna Characteristics

A brain model with and without a tumor is used to simulate the antenna in free space. The following images depict simulations of the fundamental parameters.

A. S-parameter.

To determine how much power is transmitted or reflected from an antenna, it must know its reflection coefficient, sometimes refer to as the S1,1 parameter. [8] The return loss and frequency were measured after the intended antenna was inserted into a model of a brain. The frequency is shown on the X-axis in Gegahertz in Fig. 6, and the return loss is shown on the Y-axis in dB. The observed resonance frequency is 12.96 GHz, and the proposed antenna's free-space return loss is -92.06 dB. The proposed antenna's operating frequency is 4 to 14 GHz. The antenna is suitable for usage due to its operating frequency, and enhanced efficiency is shown by the return loss, which also reveals the antenna's maximum radiation. [9]

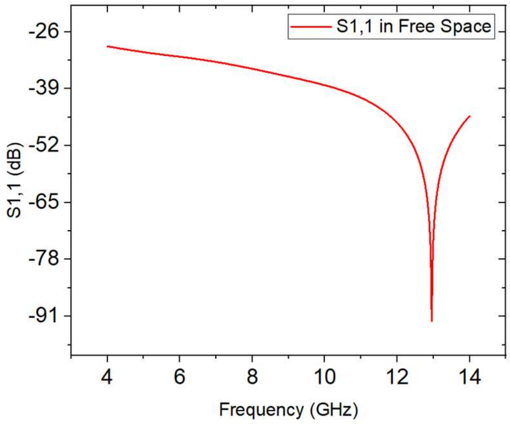

Fig. 6. S1,1 in free space at 12.96 GHz frequency is -92.06 dB

Fig. 7 depicts the S1,1 parameter for the Normal Brain model, which is -49.93 dB at 8.58 GHz..

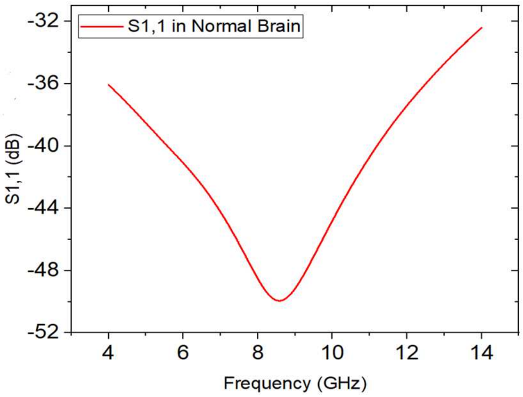

Fig. 7. S1,1 -49.93 dB at 8.58 GHz in the model of the normal brain.

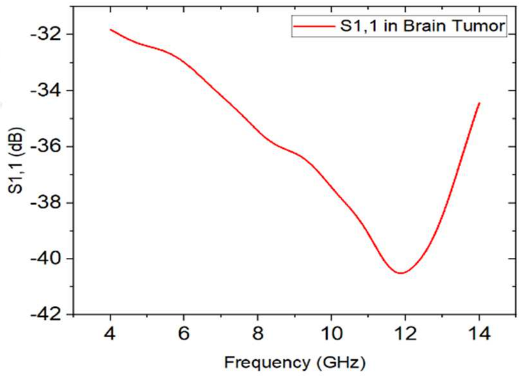

Fig. 8. Brain tumor S1,1 -40.50 dB at 11.87 GHz frequency.

Fig. 8 shows the brain tumor model's S1,1 parameter, which is -40.50 dB at 11.87 GHz. Fig. 9 and TABLE II shows all three tumor positions with the same size S1,1 value in a single graph and table. The resonant frequencies for the tumors in positions 1, 2, and 3 are respectively -40.06 dB in 11.73 GHz, -58.32 dB in 9.13 GHz, and -40.50 dB in 11.87 GHz.

TABLE II. Return Loss Analysis of Antenna in Three Different Position's Tumor

	Resonant Frequency	S1,1 (dB)
Position 1	11.73	-40.06
Position 2	9.13	-58.32
Position 3	11.87	-40.51

S1,1 & resonant frequency for three different position of tumor

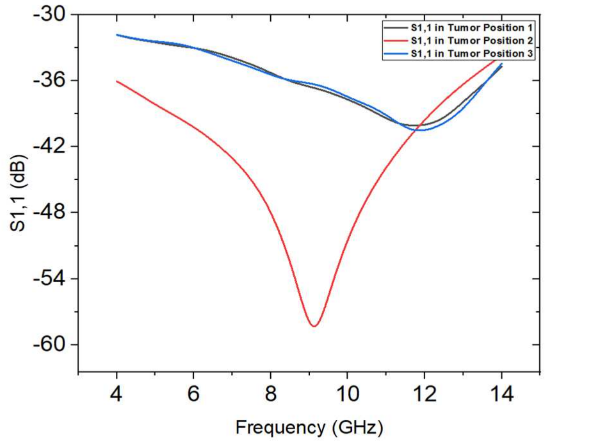

Fig. 9. S1,1: -40.06 dB in 11.73 GHz for position 1, -58.32 dB in 9.13 GHz for position 2, and -40.50 dB in 11.87 GHz for position 3.

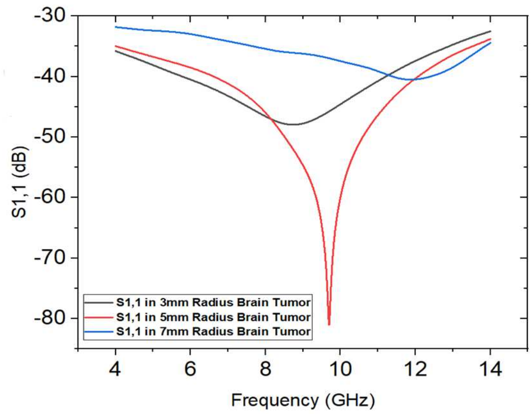

Fig. 10. S1,1: -40.50 dB in 11.87 GHz for a 7 mm radious tumor, -47.96 dB in 8.74 GHz for 3 mm, and -81.01 dB in 9.7 GHz for 5 mm.

TABLE III. Return Loss Analysis of Antenna in Three Different Sizes Tumor

	Resonant Frequency	S1,1 (dB)
3 mm radius	8.74	-47.96
5 mm radius	9.7	-81.01
7 mm radius	11.87	-40.50

S1,1 & resonant frequency for three different sizes of tumor

Fig. 10 and TABLE III depicted the S1,1 value for three different-sized radius tumors, measuring 3 mm, 5 mm, and 7 mm. For 3 mm radius tumors, 5 mm radius tumors, and 7 mm radius tumors, respectively, S1,1 -47.96 dB in 8.74 GHz, -81.01 dB in 9.7 GHz, and -40.50 dB in 11.87 were found.

B. Far-field Radiation Pattern

The far field area affects the antenna's radiation pattern. It is the one that is most remote from the antenna. The radiation pattern's form in this area is not significantly influenced by distance. Radiated fields are likewise prevalent in this region, with orthogonal E-field and H-fields and propagation axes that are similar to those of plane waves. [10]

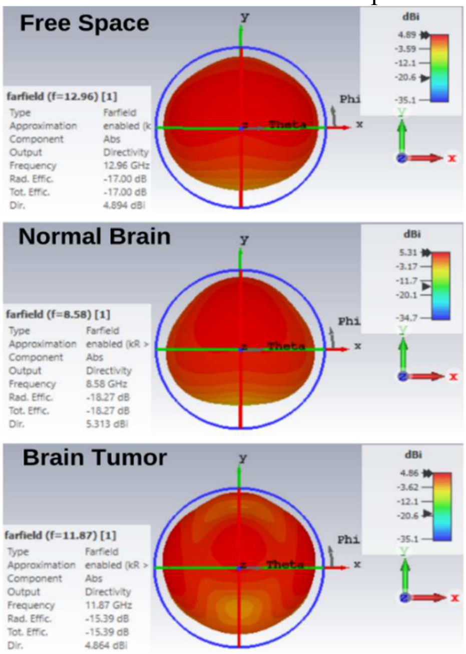

Fig. 11. Far-field radiation pattern (3D) of the designed antenna on free space, normal brain and brain tumor.

Fig. 11 shows that the total efficiency is -17.00 dB and that the directivity in free space is 4.89 dBi. In a normal brain, directivity is 5.31 dBi and overall efficiency is -18.27 dB. For brain tumors, the directivity is 4.86 dBi and the overall efficiency is -15.39 dB.

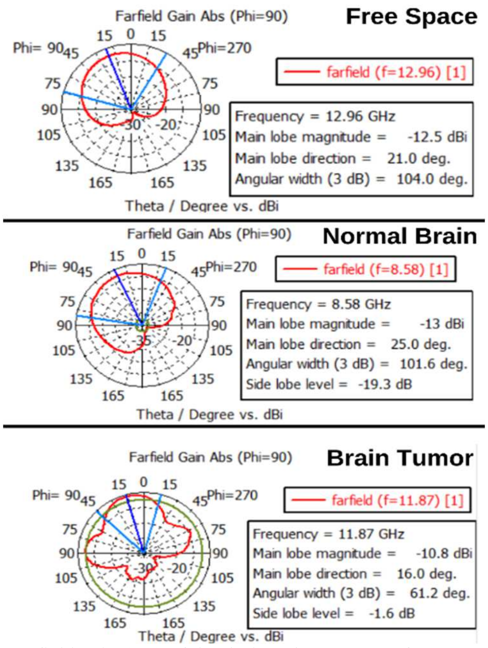

Fig. 12. Far-field gain (2D) of the designed antenna on free space, normal brain and brain tumor.

In Fig. 12, the farfield gain of the antennas is displayed in a 2D view. The main lobe in this instance has a magnitude of -12.5 dBi and a 21-degree free-space direction. A normal brain has a main lobe that is -13 dBi in magnitude and 25 degrees in direction. The primary lobe of the brain tumor has an angle of 16 degrees and a magnitude of -10.8 dBi.

C. VSWR Calculation

An antenna's impedance and the transmission line to which it is attached are matched by the VSWR, which is a measurement of the antenna's impedance.[11] A biocompatible antenna should have a VSWR of no more than 2. [9] According to Fig. 13, the proposed antenna's VSWR is 1.00 in free space, 1.00 in a model of a healthy brain, and 1.02 in a model of a brain with tumors.

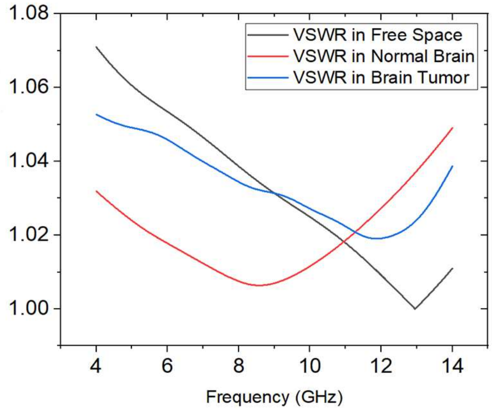

Fig. 13. The proposed antenna's VSWR is 1.00 in free space, 1.00 in a model of a healthy brain, and 1.02 in a model of a brain tumor.

D. Specific Absorption Rate

A method for estimating how much radiation is being absorbed by surrounding tissue is the specific absorption ratio (SAR). [12] SAR is a vital safety precaution. To increase safety, the FCC advises that SAR be less than 2 W/Kg for 10gm tissue. [13–14] According to Fig. 14, the maximum SAR of the proposed antenna for a point sample of tissue at resonance frequency is 3.868e-13 W/kg.

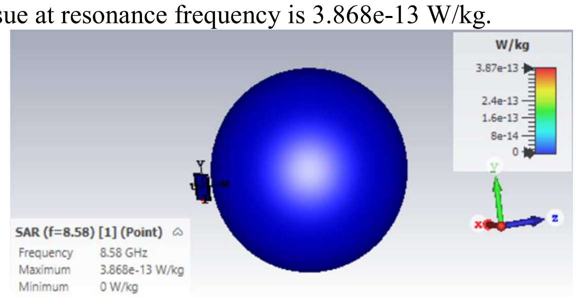

Fig. 14. SAR plot for tumor affected brain model.

IV. PERFORMANCE ANALYSIS

TABLE IV. PERFORMANCE ANALYSIS OF ANTENNA OVER DIFFERENT ENVIRONMENT

	Resonant Frequency	S1,1 (dB)	VSWR
Free Space	12.96	-92.06	1.00
Normal Brain	8.58	-49.93	1.00
Brain Tumor	11.87	-40.51	1.02

Performance analysis in different environment

TABLE IV and Fig. 15 present the antenna analysis results from various conditions. The environment can affect both the return loss and the resonant frequency. The antenna's high performance and capacity to detect brain tumors are ensured by different outcomes in various environments.

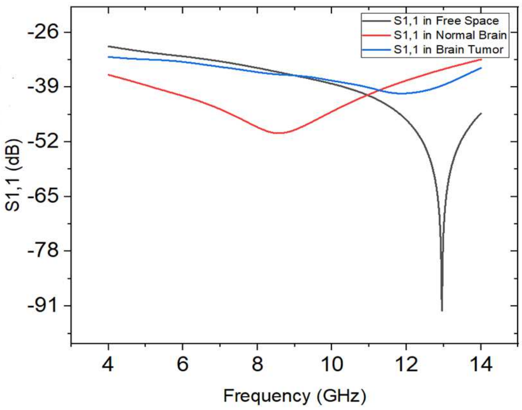

Fig 15. Free space S1,1 is -92.06 dB at 12.96 GHz, normal brain S1,1 is -49.93 dB at 8.58 GHz, and brain tumor S1,1 is -40.51 dB at resonant frequency at 11.87 GHz.

V. Comparison Analysis

TABLE IV and Fig. 15 display the antenna analysis findings from various environments. TABLE V compares the patch material, size, operating frequency, and return loss of the proposed antenna to those of the existing antenna.

TABLE V. COMPARATIVE STUDY

Patch Material	Size	S1,1	Resonant Frequency (GHz)	Ref.
Graphene	32.7×44×5	-25.26	5.28	15
Silver	60×60×2	-23.5	2.48	16
MWCNT	30×30	-19.5	2.32	17
Copper	35×35×1.52	-19.35	2.27	18
Kapton	20×15×1.82	-92.06	12.96	**Proposed antenna**

Comaprision with excisting antenna

Numerous earlier research investigations have focused on a variety of antenna parameters, such as Return Loss (S1,1), gain, bandwidth, efficiency, and a resonant frequency. In compared to the other reference paper stated in Table, a superior S1,1 parameter was achieved after running the simulation on CST at 12.96 GHz. The table shows that our antenna is superior, which we can expect.

VI. Conclusion

In this study, we suggested a brain tumor detection antenna that operates in the K band (12–40 GHz), has a resonance frequency of 12.96 GHz, and can identify brain tumors. Through design and modeling, all antenna parameters, such as operating frequency, bandwidth, return loss, VSWR, and radiation patterns, have been examined. All of the simulations are carried out in CST Microwave Studio, and the outcomes are analyzed. The Kapton Polyimide used to build the antenna. All of these antennas have adequate specifications and satisfy the standards needed to deliver improved outcomes when utilized with new materials. These antennas can be used inside the human body without harming it because its SAR values are so low.

References

[1] R. L. Siegel, K. D. Miller, and A. Jemal, "Cancer statistics, 2017,"CA: A Cancer Journal for Clinicians, vol. 67, no. 1, pp. 7–30, 2017.

[2] M.T. Islam, Md.Z. Mahmud, N. Misran, J.I. Takada, "Microwave Breast Phantom Measurement System with Compact Side Slotted Directional Antenna," IEEE access, vol. 5, pp. 5321-5330, May 2017.

[3] B. J. Mohammed, A. M. Abbosh, S. Mustafa, and D. Ireland, "Microwave system for head imaging," IEEE Transactions on Instrumentation and Measurement, vol. 63, no. 1, pp. 117–123,2014.

[4] R. Inum, Md. M. Rana, K. N. Shushama, and Md. A. Quader, "EBG Based Microstrip Patch Antenna for Brain Tumor Detection via Scattering Parameters in Microwave Imaging System," Int. J. Biomed. Imaging, vol. 2018, pp. 1–12, 2018, doi: 10.1155/2018/8241438.

[5] M.Ostadrahimi, P.Mojabi, S.Noghanian, L. Shafai, S. Pistorius,and J. Lovetri, "A novel microwave tomography system based on the scattering probe technique," IEEE Transactions on Instrumentation and Measurement, vol. 61, no. 2, pp. 379–390, 2012.

[6] F. S. G. B. Barnes, Handbook of Biological Effects of Electromagnetic Fields, CRC/Taylor & Francis, Boca Raton, Fl, USA, 2007.

[7] D E Gerber, S E Dahlberg, A B Sandler, D H Ahn, J H Schiller, J R Brahmer, D H Johnson. Baseline tumour measurements predict survival in advanced non-small cell lung cancer. British Journal of Cancer, 2013; DOI: 10.1038/bjc.2013.472

[8] T. Hasnat, S. A. Islam, S. H. Eshan, R. R. Hasan, J. Islam, and Md. A. Rahman, "SWCNT Based On-Body Antenna For Detecting COVID-19 Affected Lung Using 5G-Band," in *2022 International Conference on Advancement in Electrical and Electronic Engineering (ICAEEE)*, Gazipur, Bangladesh, Feb. 2022, pp. 1–6. doi: 10.1109/ICAEEE54957.2022.9836476

[9] M. Islam, R. Hasan, M. Haque, S. Ahmad, K. Mazed and M. Islam, "In-body Antenna for Wireless Capsule Endoscopy at MICS Band", in Computing Conference 2018, London, United Kingdom, 2018, pp.1002-1005

[10] A. C. Design, E. P. Systems, and T. Systems, Handbook of Antenna Technologies. Singapore: Springer Singapore, 2016.

[11] VSWR-Antenna Theory ''http://www.antennatheory.com/definitions/vswr.php'' [last accesed at 11- NOV,2021]

[12] Nasim Al Islam, Farhadur Arifin, "Performance analysis of a miniaturized implantable PIFA antenna for WBAN at ISM band," 3rd International Conference on Electrical Engineering and Information Communication Technology (ICEEICT), 2016.

[13] Safety, E., Committee, S. C., Radiation, N., & Board, I. S. (2008). IEEE Recommended Practice for Measurements and Computations of Radio Frequency Electromagnetic Fields With Respect to Human Exposure to Such Fields , 100 kHz –300 GHz. Measurement (Vol. 2002).

[14] ICNIRP, "Guidelines for limiting exposure to timevarying electric, magnetic, and electromagnetic fields," Health Phys., vol. 74, pp. 494–5229, 19..

[15] Av, E. A Novel Flexible Microstrip Patch Antenna with Different Conductive Materials For Telemedicine and Mobile Biomedical Imaging Systems. 2021.

[16] Ramli, M. R.; Ibrahim, S.; Ahmad, Z.; Abidin, I. S. Z.; Ain, M. F. Stretchable Conductive Ink Based on Polysiloxane-Silver Composite and Its Application as a Frequency Reconfigurable Patch Antenna for Wearable Electronics. ACS Appl. Mater. Interfaces 2019, 11 (31), 28033–28042. https://doi.org/10.1021/acsami.9b07671.

[17] Elwi, T. A.; Al-Rizzo, H. M.; Rucker, D. G.; Dervishi, E.; Li, Z.; Biris, A. S. Multi-Walled Carbon Nanotube-Based RF Antennas. Nanotechnology 2010, 21 (4), 045301. https://doi.org/10.1088/0957-4484/21/4/045301.

[18] El-bahii, M. M. Antenna for Lung Cancer Detection Using Electric Properties of Lung Tissues. 2013, 9 (9).