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Performance of a 5G MIMO Antenna for Detecting Damaged Lungs of Pneumonia Patients Related to Covid-19

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Abstract— Currently, world is facing COVID-19 pandemic where a huge number of people gets affected each day and dies. Various symptoms are visible in a COVID-19 affected patient. One of them is short and long-term effect on lung. Hence, in this situation conventionally people are using X-ray to detect lung affection. In this paper, the proposed antenna will help in faster detection of pneumonia affected lung due to COVID-19. In this paper, the proposed model inset fed multiple-input-multiple-output (MIMO) Microstrip patch antenna with a small size of mm is proposed for 38 GHz (Ka-band) which is in 5G frequency bands. The dimension of antenna is 3.561mm*2.449mm* 0.254mm and the main substrate of Rogers RT 5880 and a superstate of polyimide film. The antenna is placed on both normal lung phantom and affected lung phantom. Simulation results of S11, Directivity and SAR shows comparatively better values. Eventually, it can be said that the antenna has the potentiality to help in detection of affected lung.

Index Terms— Directivity, Gain, 5G, Lung- phantom, MIMO, SAR, S-parameter.

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1 Introduction

COVID-19 has been affecting individuals all over the world gradually, since it emerged in Wuhan, China on December 2019. There are several symptoms for COVID-19 affected patient such as dry cough, fever, pneumonia, and so on [1]. COVID-19 can cause short term and long-term lung complexions such as pneumonia, ARDS (acute respiratory distress syndrome). Usually, those sacs are filled in air in human lung but in pneumonia Inflamed lung filles with fluid which leads to difficulties in breathing, cough and many other lung diseases [2]. However, in this situation faster detection of affected lung is necessary. Normally, CT scan and x-ray machines are used in this respect so far [3]. In this paper, our objective to prepare an advanced antenna to help the detection of affected lung due to COVID-19 with a faster response and at cheaper cost. An affected lung phantom is designed to examine the performance of the designed antenna in that environment. The designed antenna is a one pair of multiple input multiple output antenna which operates at 5G technology as it provides higher quality wireless communications. Such as MIMO offers high performances with lower cost as well as it is functional in dusty and foggy environment [4]. New technology like 5G contains several bands with advantages and few disadvantages [5]. This contains higher capacity, data rate and larger bandwidth [6]. The working methodology is divided in few sections. First, designed antenna is tested in free space. Second, a normal lung phantom is designed and the designed antenna placed on it then tested. Eventually, an affected lung is designed and the proposed antenna is placed on it to test. All simulation results would be discussed and then will be concluded.

2. Design Of Mimo Antenna In Free Space

For enhanced performance, a multi slotted insert feed Microstrip MIMO antenna is designed to operate at 38 GHz. In a simulation environment, the maximum and minimum frequencies are first determined. The maximum and minimum frequency ranges are 40 GHz and 35 GHz, respectively. Then a Rogers RT5880 (lossy) substrate with a permittivity of 2.2 is chosen and polyimide is chosen as superstate. The geometric orientation of the proposed model in free space is depicted in Fig. 1.

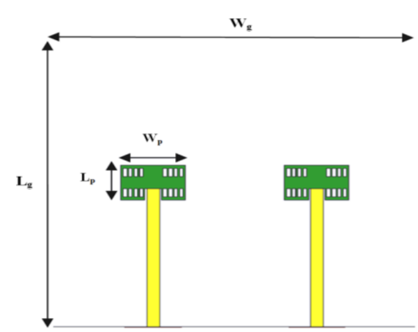

Fig. 1. Approached Microstrip Patch MIMO antenna's structure (in free space).

The width and length of the patch are computed using the calculations below [7].

$$\mathbf{W} = \frac{c_0}{2 f_r \sqrt{\frac{\varepsilon_r + 1}{2}}} \qquad (1)$$

International Journal of Scientific & Engineering Research Volume 12, Issue 7, July-2021
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Using this equation effective permittivity ε_{reff} is calculated.

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 2}{2}\left(1 + 12\frac{h}{w}\right)^{-0.5} \quad (2)$$

Effective Length, L_{eff} is calculated using this equation using previously determined effective permittivity value.

$$L_{eff} = \frac{c_0}{2f_r\sqrt{\varepsilon_{reff}}} \quad (3)$$

And then using the bellow equation length extension ΔL due to fringing field is calculated.

$$\Delta L = 0.412\frac{\left(\frac{w}{h} + 0.264\right)(\varepsilon_{reff} + 0.3)}{(\varepsilon_{reff} - 0.258)\left(\frac{w}{h} + 0.813\right)} \quad (4)$$

Using L_{eff} and ΔL actual length is calculated.

$$L = L_{eff} - 2\Delta L \quad (5)$$

TABLE I. PARAMETERS OF THE PROPOSED MODEL

Model's Parameters	*Model's Symbols*	*Dimensions (mm)*
Width of Patch	W_p	3.561
Length of Patch	L_p	2.449
Width of the Ground plane	W_g	20
Length of the Ground plane	L_g	20
Slot width	a	0.2
Slot length	b	0.3
Height of Substrate	h_s	0.254
Feedline width	f_t	0.695
Ground Thickness	h_t	0.035
The gap between the Patch and the Feedline	GW	0.1
Depth	d	0.8

3. Modeling Of MIMO Antenna In Normal And Damaged Lungs Phantom

The table below shows the required parameters and their values. The CST program was used to create and simulate the lungs phantom, which is made up of four layers. skin, fat, muscle, and lungs. The real human lung tissues and their dielectric characteristics were used to create the damaged lung phantom. Pneumonia, acute respiratory distress syndrome (ARDS), and severe cases are all possible side effects of COVID-19. Pneumonia sufferers experience breathing difficulties as their lungs filled with fluid [8]. For pneumonia patients, the alveoli are filled with pus and fluid [9]. The damaged lungs phantom was created using skin, fat, muscle, water, and a lung layer to analyze whether the MIMO antenna is operating effectively in fluid with the lung phantom or not. The characteristics permittivity, conductivity, density, thermal conductance, and others computed using references [10] and [11] are shown in the table below.

TABLE II. PARAMETER VALUES OF LUNG PHANTOMS FOR 38 GHz MEASUREMENT

Tissue / Properties	Skin	Fat	Muscle	Lung	Water
Permittivity	12.29	3.44	19.07	7.44	78
Conductivity (s/m)	31.04	2.14	41.82	14.839	1.59
Density (kg/m³)	1100	910	1041	1020	994
Thermal Conductance [W/K/KG]	0.50	0.24	0.56	0.48	0.60
Heat capacity [Kj/K/Kg]	3.5	2.5	3.7	3.8	4.2
Diffusivity [m2/s]	7.6e-08	8.8e-08	1.4e-07	1.7e-07	-
Blood flow[W/K/m3]	9100	1700	2700	9500	-
Metabolic rate [W/m3]	1620	300	480	1700	-
Size	1	3	25	15	1

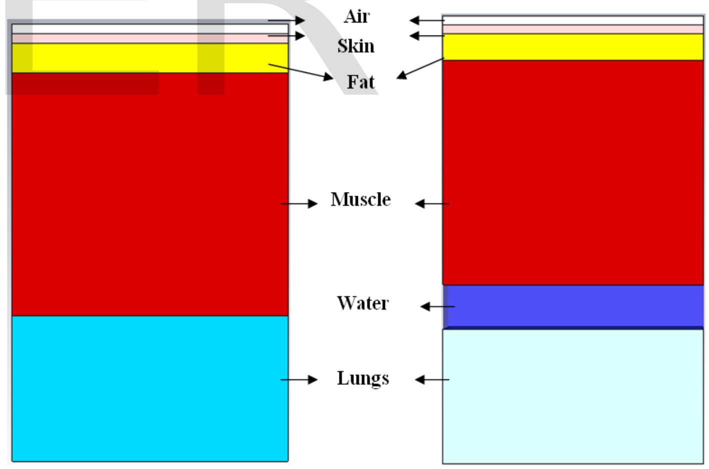
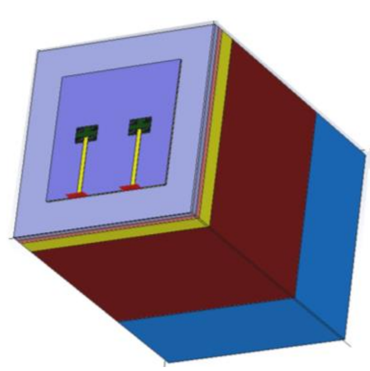


Fig.2. Normal lung model and Damaged lung model



International Journal of Scientific & Engineering Research Volume 12, Issue 7, July-2021
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Fig.3. Lung model with MIMO antenna

4. Result Analysis

Different MIMO antenna findings, such as reflection coefficient, directivity, specific absorption rate, and other characteristics, are presented and compared with normal and damaged lungs phantoms in this part.

4.1 Reflection coeffcient.

For MIMO antenna, after placing it in normal lungs phantom the value of S11 is -25.93 dB and S22 is -25.89 dB at resonance frequency 38.425 GHz. The value of S11 is -28.116dB at 38.375 GHz operating frequency in affected lung are shown in figure 4 and 5 sequentially. Return loss can be defined as the measurement of reflected power due to discontinuity of impedance and the limit for this value is greater than -10dB. [13].

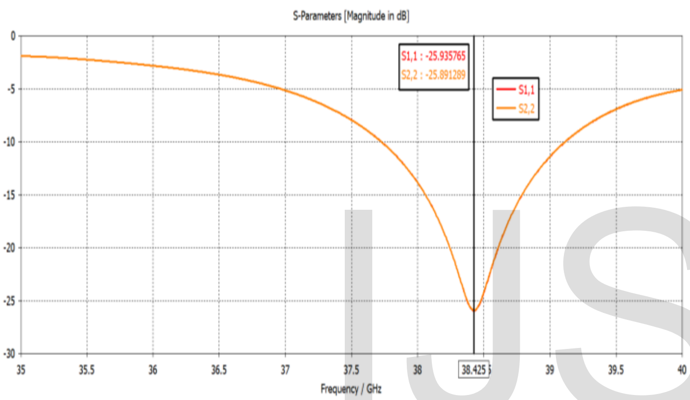

Fig.4. S11 and S22 parametrs in normal lungs phantom.

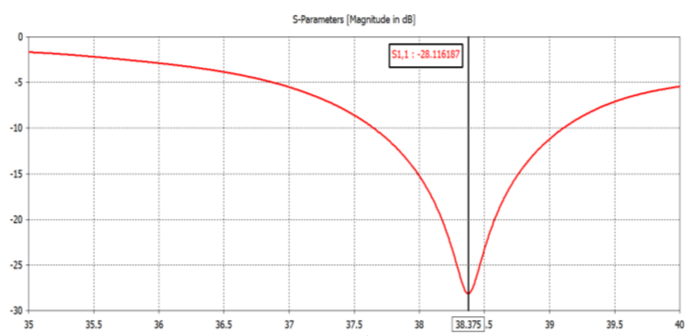

Fig.5. S11 parameter after placing antenna on damaged lungs phantom

4.2 Directivity.

Directivity gives idea about the radiation pattern of antenna. Gain, directivity and efficiency are closely related and help to understand the performance of antenna [8]. Here, values of directivity are 8.510 dBi in normal lung phantom and 8.443dBi for affected lung phantom, fig 6&7 respectively.

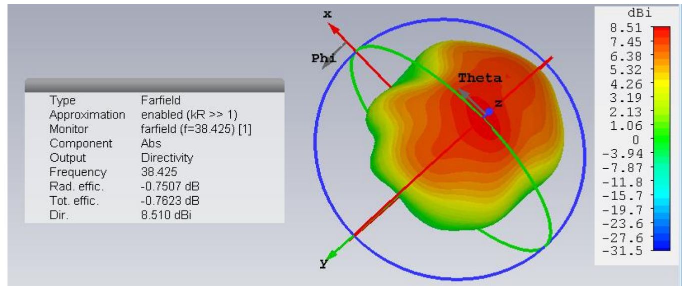

Fig. 6. directivity of normal lungs phantom

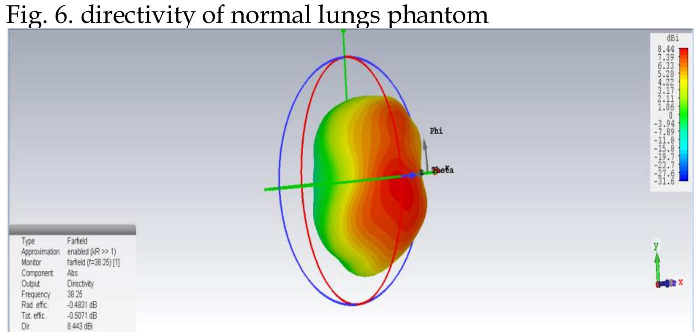

Fig.7. directivity of damaged lungs phantom

4.3 Specific Absorption Rate (SAR).

According to Federal Communications Commission (FCC) acceptable range for SAR is 1.6W/Kg for each 1 gm of tissue. Moreover, for 10gm of tissue the safe range of SAR is 2.0W/kg by International Commission on Non-Ionizing Radiation Protection (ICNIRP) [14-15]. In this proposed work, the value of SAR in normal long is 0.786W/Kg and 0.599 W/Kg in affected lung for 10 g of tissue, which is under safety limit shown in figure 8 and 9.

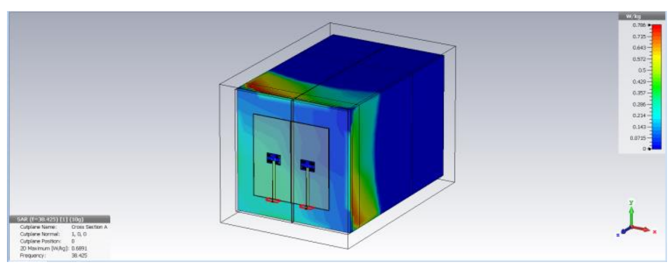

Fig.8. SAR calculation in normal lungs phantom

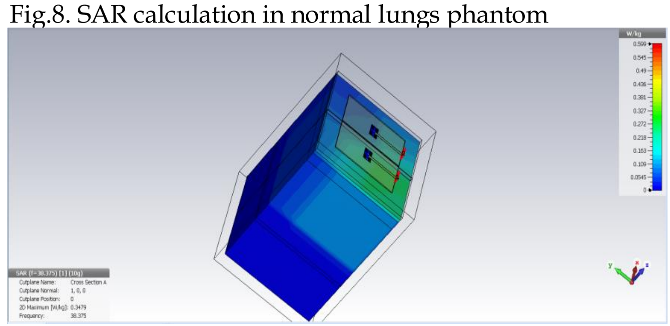

Fig.9. SAR calculation in damaged lungs phantom

The findings with different parameters and simulation output with lung and damaged lung phantom are summarized in the table below.

International Journal of Scientific & Engineering Research Volume 12, Issue 7, July-2021
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TABLE III. DIFFERENCE BETWEEN NORMAL AND DAMAGED LUNGS PHANTOM

Parameters	Lungs phantom	Damaged Lungs phantom
S11	-25.93 dB	-28.12 dB
Resonance Frequency	38.425 GHz	38.375 GHz
SAR	0.786 W/Kg	0.599 W/Kg

5. Comparative Study

The thickness of the water level has been changed in the table below, as well as the simulation output of S11, VSWR, Gain, directivity, and SAR value. According to the findings, when the water level in the damaged lung phantom increases, the resonance frequency decreases, the S11 value changes, the VSWR decreases, the directivity and gain changes, and the SAR value falls. The simulation output of the MIMO antenna works for the damaged lungs phantom, as shown in this table.

TABLE IV. DAMAGED LUNGS BY CHANGING WATER THICKNESS

Size (mm)	Resonant Frequency (GHz)	S11 (dB)	VSWR	Gain (dB)	Directivty (dBi)	SAR (W/Kg)
0.25	38.415	-28.204	1.0809	8.018	8.520	0.602
0.50	38.4	-28.182	1.0811	8.019	8.522	0.599
0.75	38.39	-28.139	1.081	8.015	8.519	0.599
1.00	38.375	-28.116	1.081	7.923	8.506	0.599
2.50	38.25	-22.25	1.157	7.960	8.443	0.588
5.00	38.125	-23.24	1.147	7.993	8.414	0.579

6. Conclusion

Covid-19 diagnosis has become a need for determining the appropriate number of COVID patients. As a result, a rapid and accurate technique has become highly essential. The RT-PCR method, which is sufficiently reliable and fast, antigen detection methods, filed-effect transistors (FET), and surface Plasmon resonance (SPR) method will also monitor molecular interacts between protein-protein, protein-DNA, and others are currently some of the COVID-19 diagnosis methods [16]. In this research, 5G MIMO antenna has been designed to detect the damaged lungs for pneumonia patients due to COVID-19. This article provides a precise simulation result while using this antenna on a normal lung phantom and a damaged lung phantom. The antenna has been tested in free space, then on normal lungs, and finally on damaged lungs. Parasitic or slot components were utilized to build a MIMO antenna, and both antennas are kept in the same direction with adequate distance between them to reduce mutual coupling. The SAR values for normal and damaged lungs are 0.786 W/Kg and 0.599 W/Kg, correspondingly, indicating that this MIMO antenna is safe for the human body. This research work will require more testing and analysis for the near future.

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