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Radiation effect of M-slot patch antenna for wireless application

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ABSTRACT

Today, the specific absorption rate has become an important and necessary measurement when designing and implementing any type of antenna. In recent years, various devices have appeared that use different frequencies for wireless communication systems, which are a source of electromagnetic radiation. The M-slot antenna is designed in this paper to operate in multi-band frequencies for wireless communications using computer simulation technology (CST) software 2020. The radiation effect for this antenna is calculated for tissue mass of the human fingertips, which consists of three layers (skin, meat, and bone), over a mass of 1 g and 10 g according to the IEEE and International Commission on Non-Ionizing Radiation Protection (ICNIRP) organization. The results are shown three applications in the communication system, which are Wi-Fi, worldwide interoperability for microwave access (Wi-Max) and, satellite X-band and, the value of specific absorption rate (SAR) increase with increased frequency.

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1. INTRODUCTION

As the effect of the huge evolution in the wireless broadband communication besides the emergence of different types of devices that use antennas radiating electromagnetic waves, anxiety has increased among humans because of the radiation emitted from these devices and the health implications of that [1]-[10]. International organizations such as the World Health Organization and the Federal Communications Commission have developed regulatory guidelines for electromagnetic energy around the world to protect against non-ionizing radiation emitted from these devices. In addition, there is a group of countries that have set their own guidelines for the permissible amount of electromagnetic energy. All of these tributes are designed to protect humans and living things such as plants and flowers from the effects of radiation [11]-[15]. There are a lot of institutes that have developed a standard for measuring the electromagnetic energy radiate absorbed by human tissue, known as the specific absorption rate (SAR) such as International Commission on Non-Ionizing Radiation Protection (ICNIRP) and IEEE. SAR can be calculated for all human body or for part of it and (1) is represented this [16]-[20].

$$SAR = \frac{d}{dt}\left(\frac{dw}{\rho dm}\right) \tag{1}$$

where, dw=absorbing energy
dm=change in mass
ρ=density

According to (1), the unit of SAR is (W/Kg) or (mm/g). In addition, SAR can be calculated as an electric field and can be seen in (2).

$$SAR = \sigma E^2/\rho \tag{2}$$

where σ=conductivity for biological tissue in (S/m)
ρ=density for biological tissue in (Kg/m^3)

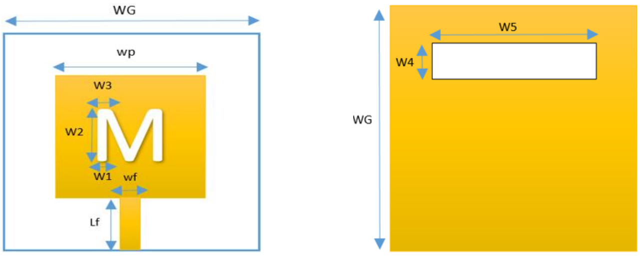
The ICNIRP and the IEEE has determined the amount of electromagnetic radiation that an organism is allowed to absorb without any negative impact on it. The specific absorbing rate is set at 2 watt/kilogram and 1.6 watt/kilogram for 10 gram and 1 gram of human tissues according to IEEE and ICNIRP respectively. There are many studies have been focused on the topic, two types of antennas are designed and compared, one is a dipole and the other is a square patch antenna. The SAR rate for both is calculated for human head tissue placed at a distance of 5 cm [2]. The square microstrip antenna is designed at 2.4 GHz and the radiation effect of the human head is simulated at distance of 5 cm. Different sizes are taken from the human head (child, young, and adult) [3].

The absorption rate of the fingers of an adult human being is calculated through the radiation sent from a Fractal Sierpinski Square patch antenna at 1.575 GHz [4]. While in [7] SAR is calculated for head tissues placed near fractal sausage minkowski at 1.575 GHz also. The absorption rate of the cylindrical patch antenna with a frequency 6.7 GHz of the human head is calculated according to ICNIRP [8].

In this paper, the specific absorbing rate for fingers tissues, which are consist of skin, meat, and bone, is calculated for the M-slot patch antenna. The proposed antenna is operated at multiband frequencies.

2. ANTENNA DESIGN

In the last two decades and the tremendous development in wireless communications, essentially in applications of antenna that need a frequency of 1-10 GHz, like Wi-Fi, worldwide interoperability for microwave access (Wi-Max), and global positioning system (GPS). The patch antenna is one of the famous types of antenna that is used because of having particular specifications in terms of size and weight [21]-[25]. The patch antenna consists of three main layers, ground, dielectric, and patch layers. In order to design the antenna with better efficiency and greater bandwidth, the length of the radiating layer should be less than half the wavelength, and the dielectric layer should be thick and with a relatively low isolation coefficient [26]-[29]. In this paper, the thickness of two radiate layers (patch & ground) is (t=0.035) mm, made of copper material, while the thickness of dielectric layer (substrate) is (h=1.5) mm, made of FR-4 epoxy material which is the relative permittivity of 4.3. Figures 1(a) to (b) and Table 1 are shown propose antenna dimensions with 50 Ω matching impedance [30].



(a) (b)

Figure 1 M-slot antenna (a) front view and (b) back view

Table 1. Proposed antenna dimensions

Parameters	Values (mm)
LG	60
lg	38
w1	2
w2	4
w3	3
w4	10
w5	32
wf	3.7
lf	11

3. RESULTS AND DISCUSSION

M-slot antenna is simulated, designed using computer simulation technology (CST) software 2020. Table 2 records all the characteristics of proposed antenna [30]. Figure 2 shows, the reflection coefficient for M-slot patch antenna. In addition, there are 6 bands of operating frequency (f_1=2.4, f_2=4.55, f_3=7.8, f_4=8.3, f_5=9, and f_6=9.9) GHz. notice it is operated at multi band wireless application.

Table 2. Specific parameters of antenna

Specifics	F1	F2	F3	F4	F5	F6
RC dB	-32	-21	-28	-15	-16_-14	-31
Gain dBi	4.97	5.95	9.24	5.56	8.15	7.23
Directivity dBi	6.35	6.44	9.78	6.1	8.5	7.62
SWR	1.01	1.18	1.07	1.2	1.4	1.06
BW MHz	55	85	78	71	510	170
Zo	50	48.99	49	48	48	50

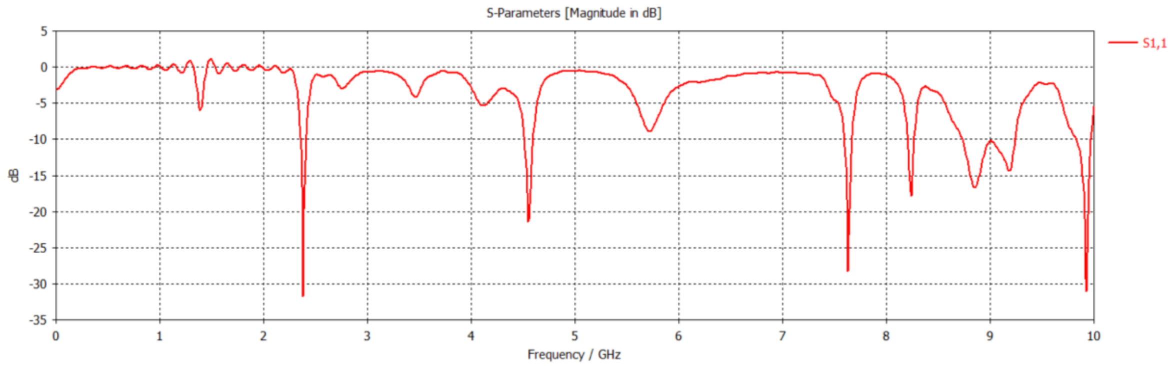
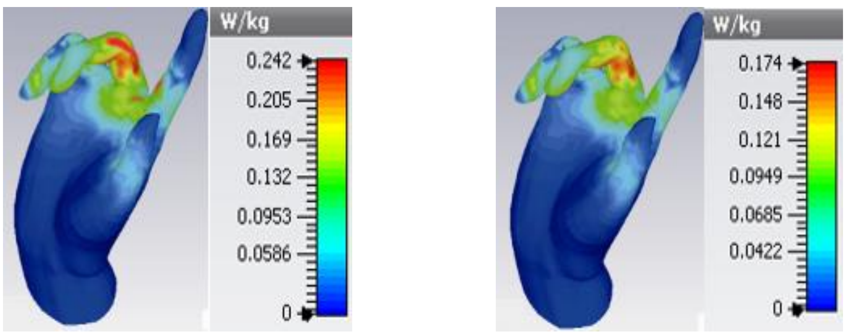


Figure 2. Reflection coefficient of antenna

From the Table 2, it can be seen that the characteristic parameters of proposed antenna recorded good values for all the frequencies. In this paper, the SAR values for the hand tissues are simulated using CST 2020 software. The SAR calculation is obtained for ICNIRP and IEEE world standard. The hand tissues consist of three layers: skin, meat, and bone. The SAR values is recorded for four band frequencies: 2.4, 4.55, 7.8, and 8.3 GHz.

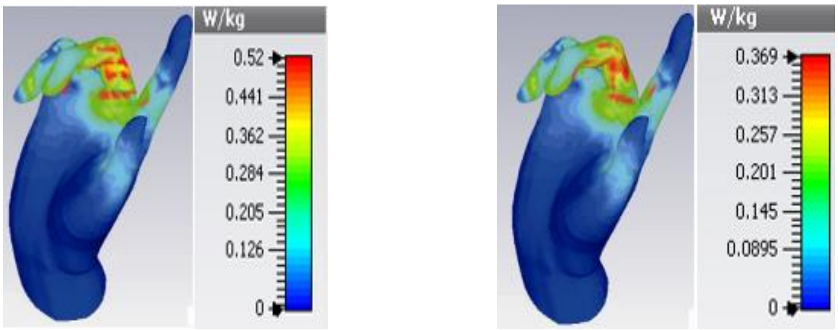
Figures 3(a) and (b), Figures 4(a) and (b), Figures 5(a) and (b), Figures 6(a) and (b), show the SAR levels for two standards ICNIPR and IEEE. It is observed that the values of SAR at 10 g are smaller than 1 g, this is due to the increased mass of tissues exposed to radiation. In addition, the level of SAR values is directly proportional to the frequency for both standards.

From Table 3, it appears the results of radiation levels at 10 g and 1 g for 4 band frequencies. At 1 g recorded (0.242, 0.52, 0.553, and 0.785) w/kg and 10 g (0.174, 0.369. 0.391, and 0.558) w/kg. All SAR values are recorded within acceptable levels with low radiation ratios for both standards and all frequencies.



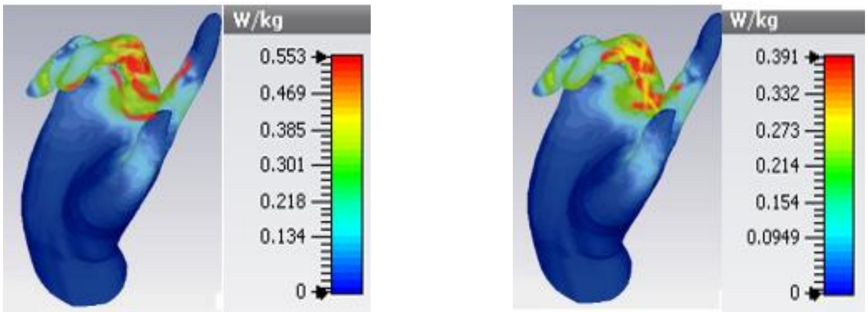
(a) (b)

Figure 3. Radiation effect of the antenna at f1 (a) 1 gram and (b) 10 grams



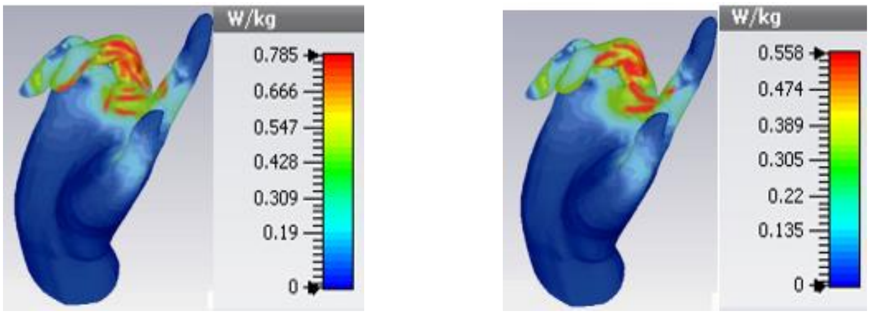
(a) (b)

Figure 4. Radiation effect of the antenna at f2 (a) 1 gram and (b) 10 grams



(a) (b)

Figure 5. Radiation effect of the antenna at f3 (a) 1 gram and (b) 10 grams



(a) (b)

Figure 6. Radiation effect of the antenna at f_4 (a) 1 gram and (b) 10 grams

Table 3. SAR levels for proposed antenna

SAR level	f_1	f_2	f_3	f_4
1 g	0.242	0.52	0.553	0.785
10 g	0.174	0.369	0.391	0.553

4. CONCLUSION

In recent years, there has been a strong demand in the global market to design a single antenna operating at multi bands frequencies in wireless communication applications. In this paper, M-slot antenna is measured and designed for main 4 band frequencies, 2.4, 4.5, 7.8, and 8.3 GHz. In addition, SAR is calculated over figure tissues according to IEEE and ICNIPR standards. The values of SAR for IEEE standard is smaller than ICNIPR standard.

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