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EVALUATION OF 5G SYSTEMS MICROSTRIP ANTENNAS PERFORMANCE AND APPROACHES FOR SAR REDUCTION OF HUMAN HEAD AT THE FREQUENCY 38 GHz

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Abstract. 5G systems have many interesting advantages, that's why their popularity around the world is growing rapidly. However, it is necessary to evaluate the potential negative impact of electromagnetic radiation from devices of these systems on human tissue in order to ensure the safety of the health of the human body. The present study was aimed at assessing the degree of exposure of the human head to electromagnetic radiation from a microstrip antenna at millimeter wave frequencies and improving the performance of this antenna to ensure human health safety. During the study, using the CST Studio Suite 2021 software package, the following was done: a microstrip antenna emitting at the frequency of 38 GHz was simulated; the efficiency and performance of the simulated antenna for 5G system devices was assessed; the layers of the human head were designed and simulated to analyze the impact of the simulated antenna radiation on it; the absorption specific rate of radiation energy from the simulated antenna by each layer of the human head was estimated. Based on the results of the study, approaches to reducing the SAR value of the human head were proposed and theoretically justified. These approaches consist of adding various materials to the microstrip antenna as protective barriers.

Keywords: microstrip antenna, electromagnetic waves, specific absorption rate, human head.

Conflict of interests. The authors declare no conflict of interests.

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ОЦЕНКА ПРОИЗВОДИТЕЛЬНОСТИ МИКРОПОЛОСКОВЫХ АНТЕНН СИСТЕМ 5G И ПОДХОДЫ К СНИЖЕНИЮ КОЭФФИЦИЕНТА УДЕЛЬНОГО ПОГЛОЩЕНИЯ ГОЛОВОЙ ЧЕЛОВЕКА ЭЛЕКТРОМАГНИТНОГО ИЗЛУЧЕНИЯ НА ЧАСТОТЕ 38 ГГц

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Аннотация. Системы 5G обладают множеством преимуществ, поэтому их популярность в мире стремительно растет. Однако необходимо оценить потенциальное негативное воздействие электромагнитного излучения устройств этих систем на ткани человека, чтобы обеспечить безопасность здоровья человеческого организма. Представляемое исследование было направлено на оценку степени воздействия электромагнитного излучения микрополосковой антенны на голову человека на частотах миллиметровых волн и улучшение характеристик этой антенны для обеспечения безопасности здоровья человека. В ходе проведения исследования с помощью программного комплекса CST Studio Suite 2021 выполнено следующее: смоделирована микрополосковая антенна, излучающая на частоте 38 ГГц; оценены эффективность и производительность смоделированной антенны для устройств систем 5G; спроектированы и смоделированы слои головы человека для анализа воздействия на нее излучения смоделированной антенны; оценена удельная скорость поглощения энергии излучения антенны каждым слоем головы человека. По результатам исследования предложены и теоретически обоснованы подходы к снижению значения удельной скорости поглощения электромагнитного излучения верхними слоями головы человека. Эти подходы состоят в добавлении в микрополосковую антенну различных материалов в качестве защитных барьеров.

Ключевые слова: микрополосковая антенна, электромагнитные волны, удельный коэффициент поглощения, голова человека.

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Introduction

An antenna is defined as a metal device used as a means of radiating and receiving electromagnetic waves, that is, the antenna is the crossing interface between free space and communication devices. The antenna has many applications and types, the most important of which is the Microstrip antenna used in mobile phones[1, 2]. It is a piece of conductive material on an insulating surface, and the insulating surface is installed at ground level so that it supports the entire structure [3]. Microstrip antennas are characterized by their small size, ease of fabrication and analysis, and cheap price [1, 2]. In addition to their radiation properties, they provide greater directivity, higher gain, and greater transmission range with less interference [3]. The electromagnetic waves sent by the antenna are a form of energy that is produced when the electrical charges that make up an atom vibrate. This radiation consists of electrical and magnetic waves that travel at the speed of light. Electromagnetic waves are divided into two types: ionizing waves and non-ionizing waves. The radiated waves emanating from a mobile phone are known as non-ionizing waves (radio), and these radiations show side effects depending on the energy and frequency of these waves [4]. Among these effects is its negative impact on the human body if it is exposed to a high percentage of it, as it penetrates the body's tissues. These harmful effects are classified into short-term and long-term effects [5]. The rate at which radiation is absorbed by body tissues is measured by the specific absorption rate (SAR), which is the time derivative of the energy dissipated per unit mass within the body generated by electromagnetic fields. They are averaged over a sample size as small as 1 or 10 grams of tissue [2, 6, 7].

Experiment method

The project includes several stages, including designing an antenna operating at a frequency of 38 GHz [8–11], evaluating its performance and enhancing it to ensure optimal performance of 5G networks. To design a small rectangular strip antenna, determine the antenna dimensions: antenna width *W* and antenna length *L*. In this design, an operating frequency of 38 GHz is used, and the substrate material used is RT/Duriod 5870, which has an dielectrical permittivity (ε_r) of 2.33 and a thickness (*h*) of 0.127 mm. It also has a loss tangent (tanδ) of 0.0005. The configuration and dimensions of the designed antenna are presented in Fig. 1. The parameters of the designed antenna are shown in Tab. 1.

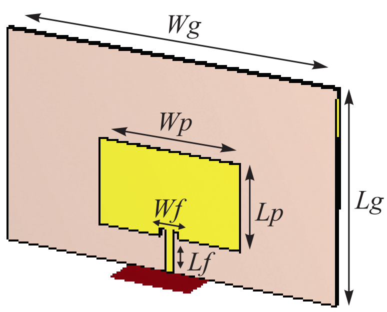

Fig. 1. The configuration and dimensions of the designed antenna

Table 1. The parameters of the designed antenna

Parameter		Value, mm
Ground	*Lg*	3.2866
	Wg	3.8211
Patch	*Lp*	2.5246
	Wp	3.0591
Feed line	*Lf*	1.4093
	Wf	0.3772
Thinks of substrate	*h*	0.1270
Thinks of copper	*t*	0.0350

Antenna characteristics [12, 13] were measured to ensure its working quality at a frequency of 38 GHz (Tab. 2).

Table 2. The characteristics of the designed antenna

Frequency, GHz	*S*-parameter	Voltage standing wave ratio	Directivity, dB	Realized gain, dB	Total efficiency, dB	Radiation efficiency, dB
37.996	–46.042	1.01	8.18	7.268	–0.9148	–0.8806

In addition, the four layers of the human head have been designed [14] and the SAR has been calculated based on the position and dimensions of the head relative to the antenna layers (Fig. 2) and according to the characteristics listed in Tab. 3.

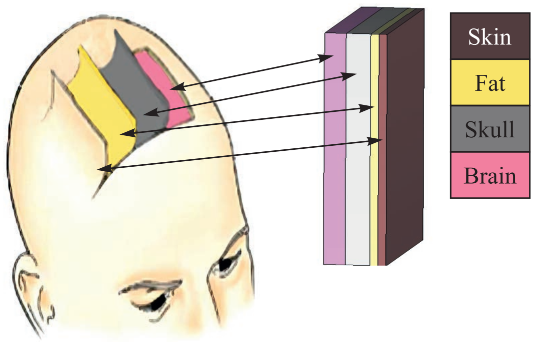

Fig. 2. The designed layers of the human head

Table 3. Characteristics of the designed layers of the human head

Layer	ε_r	σ, S/m	*w / m / k*	*w / m*^{2} */ k*	ρ, kg/m^2	Thickness, mm
Skin	12.3	31.0	0.42	9100	1109	1.5
Fat	5.33	6.36	0.25	520	911	1.5
Skull	4.52	5.86	0.40	1000	1908	4.5
Brain	15.10	33.5	0.54	3500	1046	4.0

The antenna has been placed in two ways:
1) the antenna patch to be directly in front of the human head;
2) the ground layer for antenna to be directly in front of the head.

Then the SAR is calculated in the two locations and at different dimensions, which is 0, 5.0, 15.0, 25.0 mm to know which of the two locations is the least harmful to human health. The final step involves studying the methods for reducing the SAR of the human head. These methods have been based on incorporating different types of absorbing materials as a shield for the high-frequency antenna design (Tab. 4). The SAR was measured to study the extent to which human head absorbs the electromagnetic waves generated by the antenna (per 1 and 10 g of human head tissue). Antenna parameters were measured at each stage to ensure that the antenna was working as required.

Table 4. Properties of the used absorbent materials

Absorbent material	Condictivity, S/m	Relative permittivity	Mass density, kg/m^3
Glass	0	5.5	2500
Air	0	1.0006	1.1614
Aluminium	38 000 000	1.0	2689

Results and its discussion

Results of the SAR calculation for a human head model are presented in Fig. 3, 4.

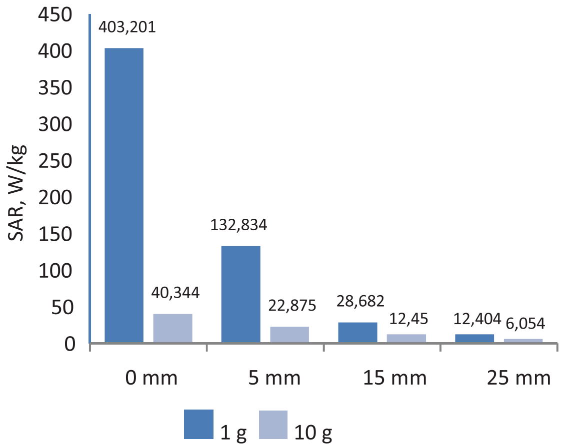

Fig. 3. The SAR percents with antenna patch in front of human head

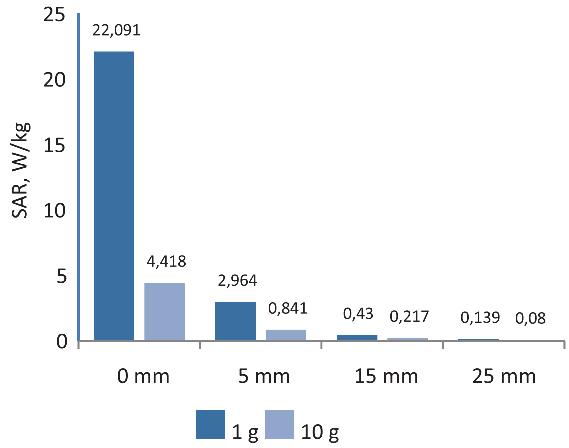

Fig. 4. The SAR percents with antenna ground in front of human head

Therefore, the layer of absorbent material will be added to the ground layer to reduce the rate of absorption of electromagnetic waves by the human head. Accordingly, three absorbent materials (air, glass, aluminium) were chosen and compared between themselves, and then choose the material largest absorption rate of electromagnetic waves. The rate at which the human head absorbes electromagnetic waves decreases. The Tab. 3 shows the properties of the added absorbent materials. The results of the SAR calculation for a human head model after adding the absorbent material to the antenna are presented in Fig. 5, 6.

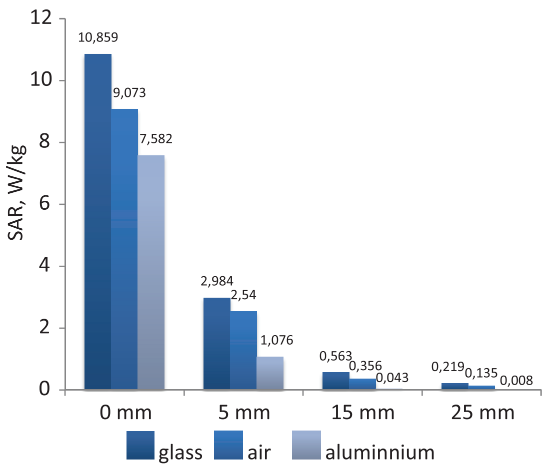

Fig. 5. The SAR percents with absorbent material for 1 g

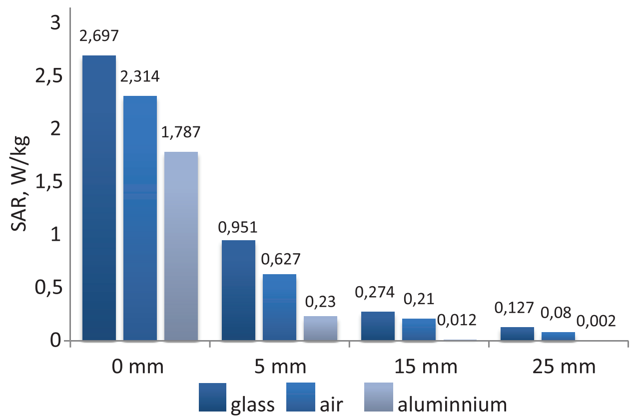

Fig. 6. The SAR percents with absorbent material for 10 g

Conclusion

1. The microstrip antenna is designed to work perfectly at the frequency 38 GHz. As for the SAR values for a mass of 1 and 10 g they depend on the location and dimensions of the human head in relation to the antenna. When the patch is directly front of the human head, the SAR value is higher compared to when the antenna's ground layer is directly front of the human head.

2. Furthermore, when the antenna's ground layer is directly in front of the human head, the SAR values decrease as the distance between the antenna and the human head increases.

3. The SAR values per 1 g of human head decrease by 86.58, 85.49 and 67.67 % when the distance increases from 0 to 5 mm, from 5 to 15 mm, and from 15 to 25 mm, respectively.

4. The SAR values per 10 g of human head decrease by 80.96, 74.19 and 63.13 % when the distance increases from 0 to 5 mm, from 5 to 15 mm, and from 15 to 25 mm, respectively.

5. When adding absorbent materials (air, glass or aluminum) as shields to the front of ground layer of antenna, the SAR values per 1 and 10 g of human head decrease. The simulation results have showed that aluminum has the best reduction in SAR values compared to air and glass. The SAR values decreased at a very significant rate. The SAR rate per 1 g of human head decreased after adding aluminum by 65.67 % at a distance of 0 mm, by 63.69 % at a distance of 5.0 mm, by 90 % at a distance of 15.0 mm, and by 94.2 % at a distance of 25.0 mm.

6. The SAR rate per 10 g of human head decreased after adding aluminum by 59.55 % at a distance of 0 mm, by 72.65 % at a distance of 5.0 mm, by 94.47 % at a distance of 15.0 mm, and by 97.5 % at a distance of 25.0 mm.

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Authors' contribution

The authors contributed equally to the writing of the article.

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