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Reducing the impact of electromagnetic radiation on the human head using a shielding chip for mobile phones.

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Abstract

According to the guidelines established by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) for electromagnetic radiation exposure, polyimide sheets have been shown to outperform other materials in mitigating radiation.In the present study, MATLAB simulation software was employed to model effectiveness of polyethylene sheet in shielding head tissues from radio frequency (RF) emitted by mobile phone. The study focused on a frequency of 5 GHz, which is commonly used in modern telecommunications. The selection of this frequency allows for the investigation of the effects of higher-frequency electromagnetic fields on biological tissues. The simulation results shown in table 3 provide insights into how electromagnetic radiation from mobile phones at various 5G frequencies is absorbed by different tissues in the head. Additionally, this study explores the potential role of protective materials, such as polyethylene and metamaterials, in reducing exposure to these radiation fields.

Key words: SAR-electromagnetic radiation- shielding- polyimide – Metamaterial- human head.

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تقليل تأثير الإشعاع الكهرومغناطيسي على رأس الإنسان باستخدام درع (شريحة) حماية للهواتف المحمولة.

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الملخص:

وفقًا للإرشادات التي وضعتها اللجنة الدولية لحماية الإشعاع غير المؤين (ICNIRP) للتعرض للإشعاع الكهرومغناطيسي، فقد أظهرت رقائق البوليميد تفوقها على المواد الأخرى في التخفيف من الإشعاع. في هذه الدراسة استخدام برنامج محاكاة ماتلاب لنمذجة فاعلية صفائح (شرائح) البولي ايثيلين في حماية أنسجة الرأس من الانبعاثات ذات الترددات الراديوية (RF) الصادرة عن الهواتف المحمولة. ركزت الدراسة على تردد 5 جيجا هيرتز، والذي يستخدم عادة في الإتصالات الحديثة. يسمح اختيار هذا التردد بدراسة تأثيرات المجالات الكهرومغناطيسية عالية التردد على الأنسجة البيولوجية. توفر نتائج المحاكاة الموضحة في الجدول 3 رؤى حول كيفية امتصاص الإشعاع الكهرومغناطيسي من الهواتف المحمولة على الترددات المختلفة لشبكات الجيل الخامس (G5) من قبل الأنسجة المختلفة في الرأس. بالإضافة إلى ذلك، تستكشف هذه الدراسة الدور المحتمل للمواد الواقية، مثل البولي إيثيلين والمواد الفائقة في تقليل التعرض لهذه الحقول الإشعاعية.

الكلمات المفتاحية: معدل الامتصـــاص النوعي –الإشـــعاع الكهرومغناطيســـي – درع حماية– البولي ايثيلين– المادة الفائقة – الرأس البشري.

I. Introduction

The radiation emitted from electronic devices causes biological damage to cells [1] as an example mobile phone which usage has become an integral part of our day today life. Where the more we use and the mobile phone the more we are prone to exposure to electromagnetic radiations [2]. The human body when introduced to a radiofrequency electromagnetic field absorbs radio repeat energy

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[3]. Specific absorption rate (SAR) is a measure of the rate at which electromagnetic energy is absorbed by the human body when exposed to radio frequency (RF) electromagnetic field, and the heating energy engrossed in the human body is defined as a specific absorption rate (SAR) measured in W/Kg [1]. Mobile phones can be shielded to comply with SAR standards and minimize radio frequency energy exposure to the human head. However, the effectiveness of different shielding materials in reducing SAR is uncertain [4]. It is important to note that the specific absorption rate depends greatly on the type of tissue that is exposed to radiation, as well as on the frequency of electromagnetic radiation and the distance from the radiation source [5].

In 2009, a study by Islam et al. on the reduction of Specific Absorption Rate (SAR) by attaching a ferrite sheet to the human head found that optimal placement and distance significantly reduced SAR by 57.75% [4]. SAR can be computed using two methods: computational modeling and measurements with anatomically structured phantoms, both thermal and electromagnetic. Numerous studies have employed various techniques to examine how radio waves from mobile phone antennas affect different human tissues [5]. In this study, we utilize the Finite Element Method (FEM). The non-ionizing effect of electromagnetic radiation on human tissues, influenced by source frequencies ranging from 100 kHz to 300 GHz, led to the concept of SAR. SAR quantifies the energy absorbed by human tissues within the RF spectrum, averaged over 1 g or 10 g of tissue [6]. It is a critical factor in assessing the risks associated with the use of wearable electronic devices [7]. Electromagnetic absorption in near-field exposure depends on the phone's frequency and distance from the source. Modern smartphones, used for SMS and video applications, expose the head and eyes to radiation from various angles and require different positions. Poorly constructed mobile phones, with low-quality components and performance, are available at lower prices, potentially impacting human health due to prolonged exposure [8], [9]. Studies have shown that the reduction of SAR levels in brain tissue is most effectively achieved through the use of nanomaterials [10]. Carbon-based nanomaterials, including single-walled carbon nanotubes (SWCNT), multi-walled carbon nanotubes (MWCNT), Graphene, and their composites such as magneto-dielectric nan composites (MDNC) and reduced

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Graphene oxide (rGO-5, rGO-10), have been proposed as shielding materials in conjunction with dipole radiating elements. Various studies have explored methods to reduce radiation effects on the human head, focusing on SAR variations with mobile phone frequencies and the exposure of both adult and child heads by replicating antennas [1]. In this study, we employ two materials—polyethylene and metamaterial sheets—to shield head tissues from the radiofrequency waves emitted by mobile phones.

II. Electromagnetic wave absorption performance of diverse materials

Metals, due to high electrical conductivity, are the most commonly used shielding materials. However, high density, susceptibility to corrosion and the fact that metals are easily exposed due to the reflection of the metallic gloss have motivated a pursuit of alternatives. Conductive polymers (CPs), with 'programmable' mechanical properties (e.g. flexibility or rigidity), low density and inexpensive costs of large-scale production, have been applied as the next-generation EMI shielding materials [16]. It is imperative to explore novel and highly efficient electromagnetic (EM) wave-absorbing and shielding materials to tackle this issue. Conventional EM wave absorbing and shielding (EMAS) materials, such as metals and ferrites, have been widely employed. Unfortunately, these materials have disadvantages such as high mass and poor chemical stability, which call for alternatives [17]. As representative dielectric dominant loss materials, carbon materials, including carbon nanotubes (CNTs), Graphene, and biomass-derived porous Carbon materials (BDPCMs) have attracted tremendous attention for use as excellent EMW-absorbing materials in view of their excellent electric conductivity, large specific surface area, and low density. However, due to the poor impedance-matching characteristics of carbon-based materials, which result from their excellent electrical conductivity, incident EM waves can easily be reflected rather than transmitted further into the absorbers [18]. There is a great opportunity for the development of EMAS materials that have multiple functions, where these materials with high thermal insulation capability allow for their use at high temperatures. These attractive properties indicate that An EM wave absorber can absorb EM waves and convert EM energy into thermal energy, thus blocking EM radiation. One of the key performance indicators is the reflection loss (RL) value, which is expressed in

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decibels (dB). For a material or device to be considered an effective absorber, it requires a RL value of less than -10 dB, which means that 90% of the EM waves are absorbed [17].

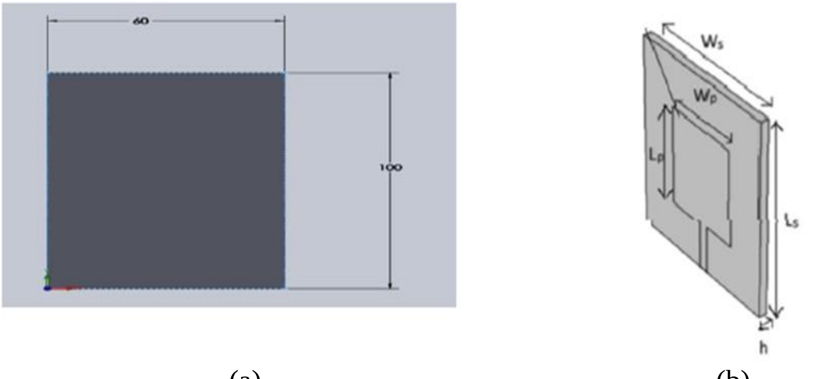
III. Model

Reducing the Specific Absorption Rate (SAR) in the human head from mobile phones using shielding materials is a complex process, but it can be approached in several ways. Shielding materials generally function by absorbing or reflecting electromagnetic fields (EMF) to prevent them from penetrating the human head. Previous studies have shown that polyimide sheets, as outlined in Table 1, effectively reduce local radiofrequency (RF) exposure and lower the SAR value over 10g of tissue, outperforming other materials.

Table.1 Polyurethane characteristic

Material	density(kg/m^3)	Thermal conductivity(w/m-k)	specific heat(j/kg-k)	emissivity	conductivity(s/m)
Polyurethane	65	0.035	1800	0.9	10^-15

The geometry of the shielding design includes a small chip, with the properties of the human head tissues detailed in Table 2. The dimensions of the mobile phone, along with those of the protective shield (a square shield), are specified in Figure 1 (a, b).



(a) (b)

Figure 1. (a) Dimensions of mobile phone model
(b) Dimensions of Rectangular patch antenna

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The type and characteristics of the materials used for protection polyethylene and metamaterials—are also identified. Additionally, the dimensions of the human head model were assumed to have the following tissue layer thicknesses: Skin: 0.07 cm, Fat: 0.16 cm, Bone: 2.05 cm, Dura: 0.05 cm, Cerebrospinal Fluid (CSF): 0.2 cm, and the brain, modeled as a circle with a radius of 6.47 cm. The mobile phone is placed 1 cm from the head, with its electromagnetic field directed toward the head. The electromagnetic source is a monopole antenna.

The tissues are modeled as concentric circles, as shown in Figure 2. And the properties of human head tissues are described in table2.

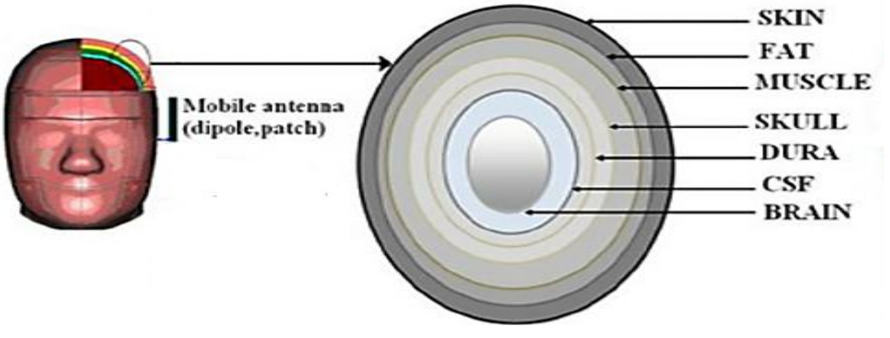

Figure 2. The model of a human head tissues

Table.2 the properties of human head tissues

Tissue	Density (kg/m^3)	Frequency (0.9 GHZ)		Frequency (1.8 GHZ)		Frequency (2.4 GHZ)		Frequency (3.35 GHZ)		Frequency (4.45 GHZ)	
		ε_r	$\sigma(\frac{S}{m})$	ε_r	$\sigma(\frac{S}{m})$	ε_r	$\sigma(\frac{S}{m})$	ε_r	$\sigma(\frac{S}{m})$	ε_r	$\sigma(\frac{S}{m})$
Skin	1100	41.4	0.87	38.9	0.87	38.1	1.44	37.1	1.93	36.18	2.68
Fat	920	5.46	0.05	5.34	0.05	5.29	0.102	5.18	0.14	5.076	0.21
Bone	1850	12.4	0.14	11.8	0.14	11. 4	0.38	10.8	0.5	10.28	0.84
Dura	1050	44.4	0.96	42.9	0.96	42.1	1.64	40.9	2.25	39.47	3.15
CSF	1060	68.7	2.41	67.2	2.41	66.3	3.41	64.8	4.39	62.85	5.87
Brain	1030	45.8	0.77	43.5	0.77	42.6	1.48	41.3	2.11	39.91	3.03

The total radius of the head is 9 cm, and the angle between the mobile phone and the head is 35°. The dimensions of the mobile phone are as follows: length = 14 cm, width = 6.5 cm, and thickness

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= 0.5 cm. The protective film has the same dimensions as the phone, except for the thickness, which is 0.2 cm.

To achieve optimal results using the Finite Element Method (FEM) for simulating the SAR in a human head due to electromagnetic radiation from a mobile phone, the tissue layers of the head and the mobile phone were carefully divided to distinguish each layer from the others.

Using the Finite Element Method, we divided the length of the mobile phone and the head into sections of 1 cm each and similarly divided the width into sections of 0.5 cm. The thickness of both the phone and the protective chip was also divided into corresponding sections. As a result, we obtained a mesh network of hexagonal elements for both the phone and the protective chip, with dimensions of 14×13×5 and 14×13×2, respectively. The final shape of the model is shown in Figure 3.

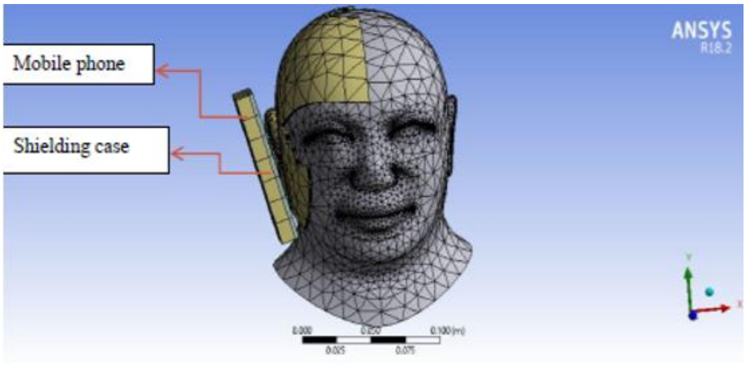

Figure3. Applying the finite element method to the model

IV. Simulation results

Figure 4 illustrates the varying levels of tissue absorption based on how their dielectric properties change with frequency. This is because the metamaterial effectively shields or absorbs electromagnetic energy before it reaches the tissues. We observe lower SAR values in tissues such as skin, bone, and fat (the SAR value for skin is zero). This suggests that, the metamaterial is highly effective at blocking or reducing electromagnetic radiation absorption in the skin tissue. However, CSF and brain tissue absorb

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more radiation at higher frequencies due to their higher permittivity and conductivity.

The absorption rate of tissues varies according to their electrical properties. However, as shown in Figure 5, the results clearly indicate a decrease in the specific absorption rate (SAR) values for head tissues, with fat and bone recording lower percentages compared to the unprotected case. The SAR values for polyethylene are higher compared to metamaterials, as polyethylene does not interact with electromagnetic waves as effectively as metamaterials, offering less shielding or attenuation.

Table 3. Values of SAR after using metamaterials and polyethylene slices.

Tissue	Frequency (0.9 GHZ)		Frequency (1.8 GHZ)		Frequency (2.4 GHZ)		Frequency (3.35 GHZ)		Frequency (4.45 GHZ)	
	Meta	Poly	Meta	Poly	Meta	Poly	Meta	Poly	Meta	Poly
Skin	0	.0034	0	.0034	0	.0034	0	.0034	0	.0034
Fat	0.0058	$5.6e^{-05}$	0.0057	$5.6e^{-05}$	0.0058	$5.6e^{-05}$	0.0058	$5.6e^{-05}$	0.0055	$5.6e^{-05}$
Bone	0.0064	$6.13e^{-05}$	0.0061	$6.13e^{-05}$	0.0058	$6.13e^{-05}$	0.0058	$6.13e^{-05}$	0.0055	$6.13e^{-05}$
Dura	0.04086	0.0004	0.04009	0.0004	0.03895	0.0004	0.03895	0.0004	0.0376	0.0004
CSF	0.0634	0.0006	0.06254	0.0006	0.06113	0.0006	0.06113	0.0006	0.05929	0.0006
Brain	0.04223	0.0004	0.04136	0.0004	0.04011	0.0004	0.04011	0.0004	0.0004	0.0004

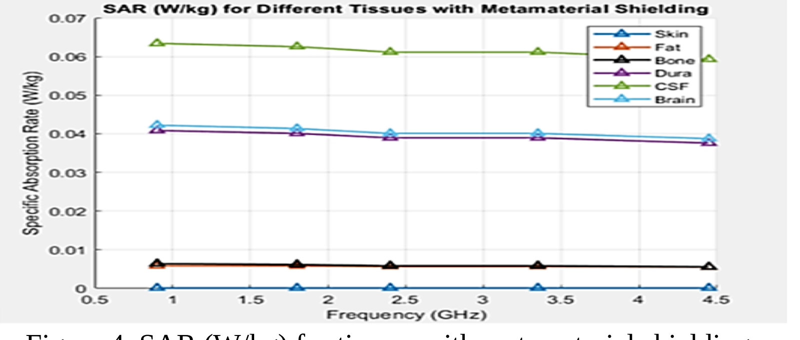

Figure 4. SAR (W/kg) for tissues with metamaterial shielding.

The absorption rate of tissues varies according to their electrical properties. However, as shown in Figure 5, the results clearly indicate a decrease in the specific absorption rate (SAR) values for head tissues, with fat and bone recording lower percentages compared to the unprotected case. The SAR values for polyethylene are higher compared to metamaterials, as polyethylene does not interact with the electromagnetic waves as effectively as metamaterials, offering less shielding or attenuation.

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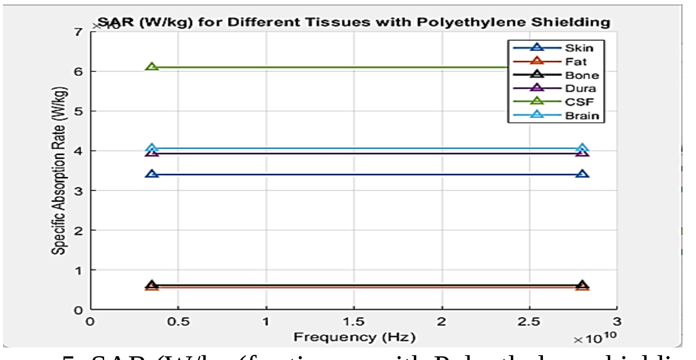

Figure 5. SAR (W/kg (for tissues with Polyethylene shielding

Upon reviewing the results presented in table 3, we observe that for the metamaterial, the absorption rate remains nearly constant, with slight variations due to frequency changes. Therefore, the most common value was selected. In contrast, for polyethylene, the specific absorption rate is constant across all frequencies, as shown in Figure 6. From the graphical results, we can see the superiority of ideal materials and their ability to interact effectively with electromagnetic waves, offering resistance to absorption and providing complete protection for certain tissues (e.g., skin). In comparison, the lowest absorption rate for polyethylene was measured at 3.5 W/kg, while the highest absorption value for the metamaterials was measured at 0.064 W/kg—more than fifty times lower than the lowest absorption rate recorded for polyethylene.

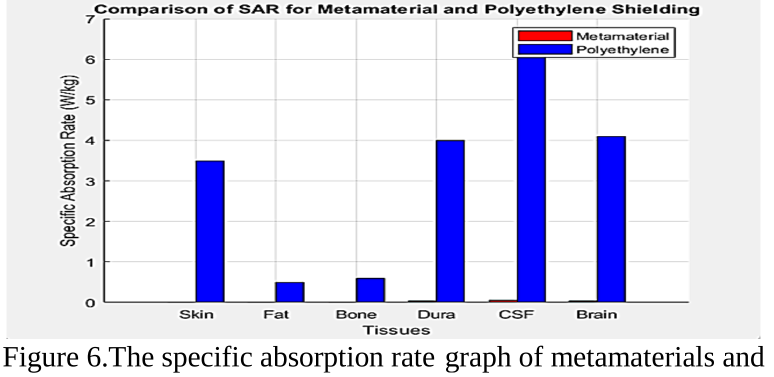

Figure 6.The specific absorption rate graph of metamaterials and polyethylene.

V. Conclusion

Metamaterials provide better shielding, especially for higher frequencies like 5G, due to their negative permittivity. They can refract, scatter, or absorb electromagnetic waves more efficiently

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than simple dielectric materials. The skin exhibits a lower SAR value compared to other tissues, indicating that the metamaterial has successfully reduced the energy absorbed by the skin tissue.

In contrast, polyethylene shields the head but is less effective at attenuating high-frequency waves. Metamaterials can be tuned to enhance absorption or shielding at specific frequencies, making them more effective against technologies like 5G. Polyethylene, however, offers a more consistent level of protection across the frequency range but lacks advanced wave-manipulating properties. Metamaterials, being frequency-specific, can be engineered to provide superior SAR reduction.

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