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Invention of an Original Tetra-Generations Patch Antenna for the New Generation of Mobile Telephony and the Study of the Thermal Effect of GSM on the Human Hand

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Abstract

The present invention relates to a miniature original tetra-generations patch antenna with rectangular slots at low cost, and dedicated to the new generation of mobile telephony by covering the frequency bands of 900MHz, 1800MHz, 2100MHz and 2600MHz. The Modeling and simulation of the basic model are performed using the finite element method. This study allowed us to determine the reflection coefficient, the voltage standing wave ratio (VSWR), the omnidirectional radiation and the bandwidth. With this antenna, we obtained new results from the GSM thermal effect on the human hand. With this in mind, a new, simple and miniaturized quadri-band antenna in patch technology meeting the standards of dosimetry and temperature for mobile phone applications is designed and proposed.

Keywords: Quadri-band patch antenna, SAR, human hand, dosimetry, temperature rise.

I. INTRODUCTION

The patch antennas are in great demand in the fabrication of new generations of mobile phones due to their limited industrial costs and simple designs [1]. A broad and universal debate has been produced on the effects of mobile phone electromagnetic waves on human health as a result of the phenomenal increase in the use of wireless technologies [2].

The mobile phone is usually used with a habitual location very close to the human head and hand. As a result, the human head and hand absorbs some of the electromagnetic energy radiated by the cellular mobile phone [3]. To study this phenomenon scientifically, a modeling of the human hand is done via a concentric multilayer representation.

Subsequently, these scientific efforts have been complemented by the development of standards establishing safety limits for exposure to electromagnetic waves and recommendations from national and international organizations [4]. In order to quantify these impacts, the pioneers of radio frequency wave dosimetry introduced the Specific Absorption Rate (SAR), defined as the most appropriate measure for assessing the absorption phenomenon and warming up after exposure to RF waves [13][14].

The use of SAR represents a good contribution in the field of dosimetry, which studies the impacts of mobile phones on human health for two reasons. First, this rate allows confirmation of the choice and validation of the best brands and manufacturers of mobile phones in accordance with the standards. Secondly, we represent the distribution of SAR and temperature rise in all anatomical layers of the human head and this in a localized way. This is obviously a rich and effective database for determining the correlations and probable links between the thermal and non-thermal impacts of mobile phone RF waves on human health [6]. Our study constitutes the simulation and the realization of a new antenna tetra-generations patch for the new generation of the mobile telephony operating in the bands of frequencies of 900MHz, 1800MHz, 2100MHz and 2600MHz respecting the norms of the dosimetry and the temperature.

This work is based on simulations obtained on the Ansoft HFSS software basing on one anatomical model concerning human hand and represented by 4 layers. The simulations of the SAR distribution and temperature rise are performed at four frequency bands, for one antenna- hand distance during five exposure times, based on the tetra-generations patch antenna model.

II. METHOD

Modeling and Geometry of the Patch Antenna

The figure 1 represents a real realization of this original antenna. It is a new rectangular quadri-band patch antenna including technical slots [7]. The antenna is simulated and realized on a substrate FR4_epoxy with dimensions L×W= 45×42mm^2 and a dielectric constant εr = 4.4. The substrate thickness is h = 1.6 mm. The εr value is chosen so that it provides better efficiency and broader bandwidth. The antenna feed is provided via a coaxial feed adapted to 50Ω to improve the bandwidth and gain.

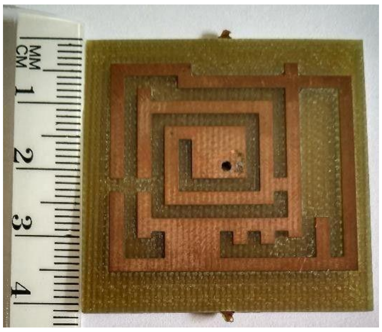

Fig. 1. Real realization of the patch antenna

II.I.I Comparison between real and simulation results of Return Loss

The figure 2 represents the real results of measuring of the reflection coefficient of the quadri-band patch antenna that confirm obviously the simulation results. We notice that the antenna operates at resonance frequencies values of 0.91GHz, 1,84GHz, 2.18GHz and 2.59GHz covering the GSM, DCS, PCS, UMTS and LTE standards.

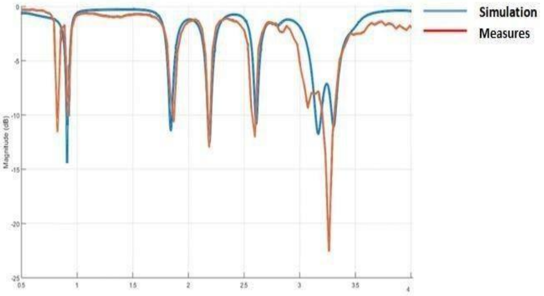

Fig. 2. Real and simulation results of patch antenna reflection coefficient

Distribution of SAR and Temperature Rise

The propagation of electromagnetic waves through a human tissue leads to an absorption of a portion of the transmitted electromagnetic energy. The specific absorption rate (SAR) describes the impact of electromagnetic fields on biological tissues. It represents for our case a rate that evaluates the level of the high frequency electromagnetic field in the human head after being emitted by a mobile telephone operating at maximum output power according to unfavorable circumstances.

The SAR unit is watts per kilogram (W/kg). The international institutions and organizations have recommended standards for the maximum SAR value that must not be exceeded to avoid health risks. This maximum value is 1.6 W/Kg averaged 1g of tissue or 2 W/Kg averaged 10g of tissue [8]. The SAR is represented by the following formula [9]:

$$SAR = \frac{\sigma}{2\rho}|E|^2 \qquad (1)$$

With σ the electric conductivity (S/m), ρ is the tissue density (Kg/m^3) and E is the peak value of the electric field (V/m). The absorption of electromagnetic waves causes temperature variation ΔT, in the case of a human body with a specific heat C, furthermore in thermal equilibrium with the environment, and exposed during the time Δt to these waves.

This correlation between the SAR and the temperature variation is given by the formula [10]:

$$SAR = C\frac{\Delta T}{\Delta t} \qquad (2)$$

The international institutions and organizations have recommended standards for the maximum temperature value that must not be exceeded to avoid health risks. This maximum value is 4.5 C° as an allowable limit which does not lead to any physiological damage of biological tissue [11].

Methodology and Modeling

The evaluation of the effects of radiation exposure on the human hand is made by determining the induced electromagnetic field and its spatial distribution. In our study, the source of the radiation field is represented by the new quadri-band patch antenna used for a mobile phone localized on a human hand according with a mobile-hand distance of 0 mm.

We used according to figure 3 an HFSS model of human hand multilayer with four types of tissues: skin, fat, muscle and bone and irradiated by our tetra-generations patch antenna.

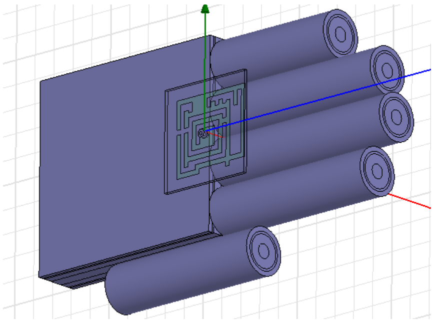

Fig. 3. HFSS model of the human hand irradiated by our tetra-generations patch antenna

The tables 1 and 2 show the numerical values of dielectric properties, specific heat and mass density of each layer. These values were taken from the scientific community literature data [12].

Table 1. Dielectric properties.

Layers	900 MHz		1800 MHz		2100 MHz		2600 MHz	
	Permittivity (ε_r)	Conductivity σ(S/m)	Permittivity (ε_r)	Conductivity σ(S/m)	Permittivity (ε_r)	Conductivity σ(S/m)	Permittivity (ε_r)	Conductivity σ(S/m)
Skin	43.8	0.86	43.9	1.23	43.9	1.23	42.9	1.59
Fat	11.3	0.11	11.0	0.19	11.0	0.19	10.82	0.26
Muscle	55.9	0.97	54.4	1.38	54.3	1.38	53.64	1.77
Bone	20.8	0.34	15.6	0.43	15.5	0.43	15.01	0.57

Table 2. Specific heat and mass density for each layer

Layer	Mass Density ρ (kg/m^3)	Specific Heat (J/g.C)
Skin	1100	3.6
Fat	1100	3.0
Muscle	1040	3.5
Bone	1850	3.1

III. RESULT

Maximal SAR results

The figure 4 represents the distribution of local SAR in the human hand at 900MHz, 1800MHz, 2100MHz and 2600MHz frequencies.

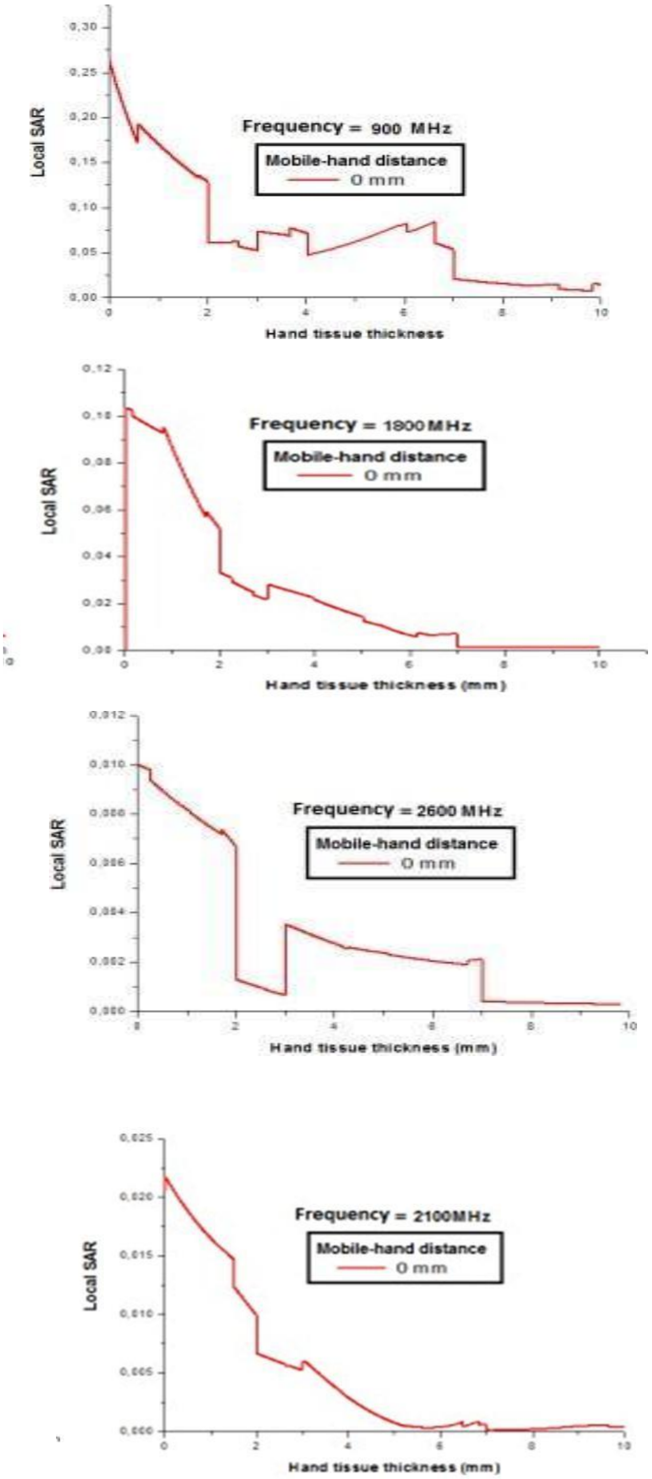

Fig. 4. Distribution of local SAR in the human hand.

Spatial distribution of temperature in the human hand

The figure 5 represents the spatial distribution of temperature in the human hand at 900MHz, 1800MHz, 2100MHz and 2600MHz frequencies during five times: 1 mn, 5 mn, 10 mn, 30 mn and 45 mn.

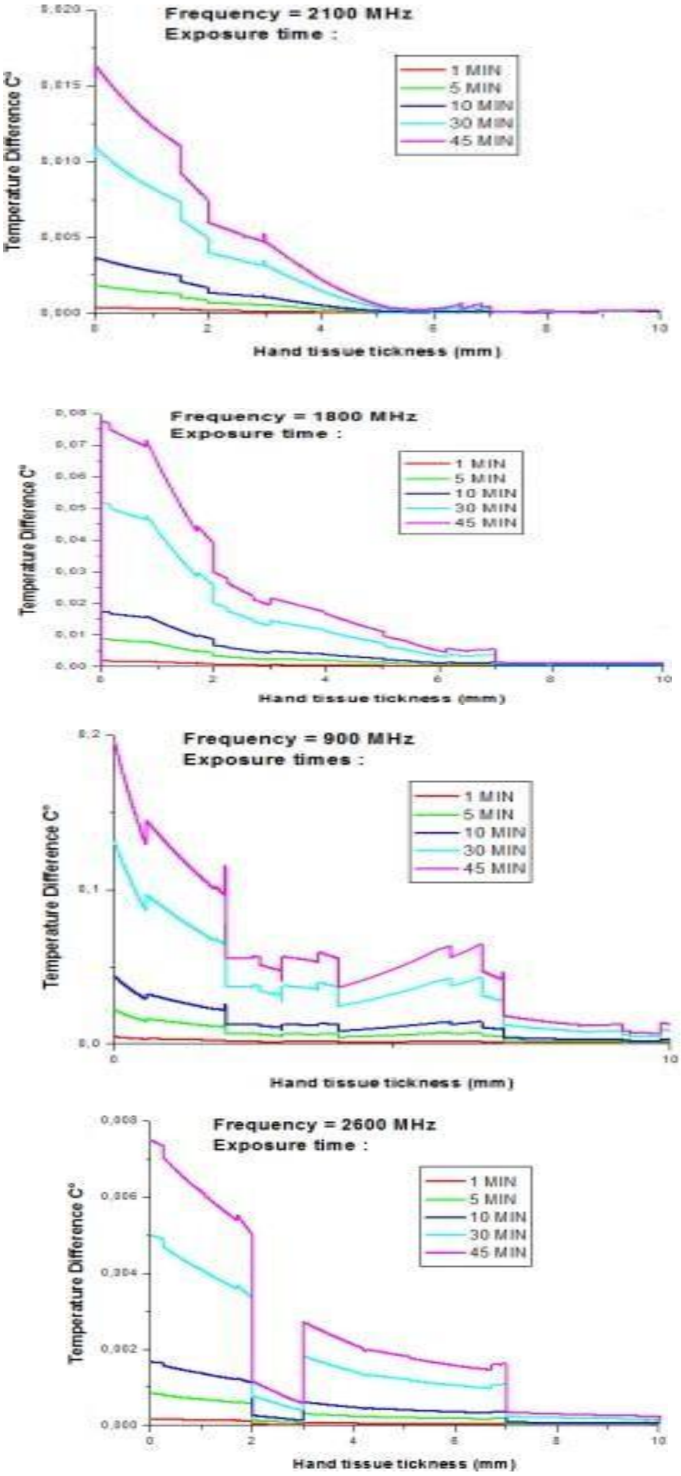

Fig. 5. Spatial distribution of temperature in the human hand.

Temperature rise study

The figure 6 represents the temperature rise in the two layers: skin and muscle at 900MHz, 1800MHz, 2100MHz and 2600MHz obtained by the using of the formula (2) and with various simulations on Ansoft HFSS software.

The two layers: skin and muscle correspond to two peaks of values of SAR and temperature spatial distribution.

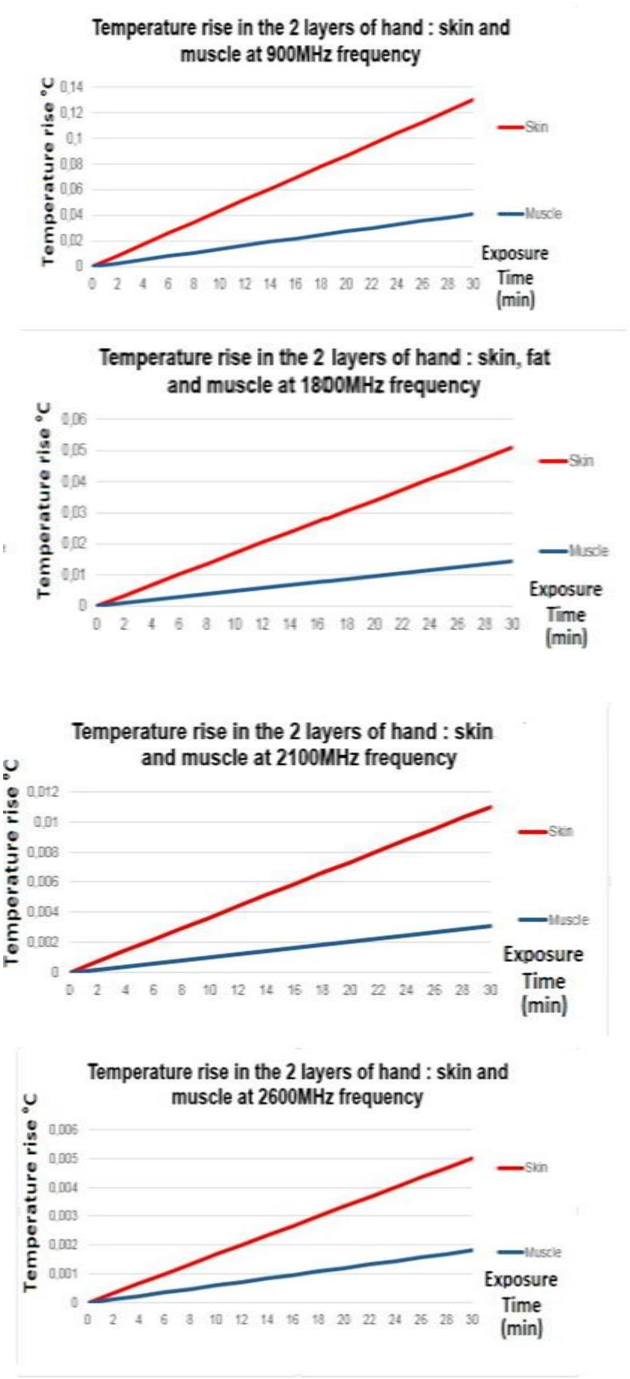

Fig. 6. Temperature rise simulation in the 2 layers: skin and muscle.

IV. DISCUSSION

Maximal SAR results

We find that the SAR curve has two peaks corresponding to the two layers: skin and muscle. The reason is that these layers contain more water, therefore more absorption of electromagnetic waves.

We notice that as long as the electromagnetic waves penetrate into the human hand, the SAR decreases. The two layers: skin and muscle absorb the majority of electromagnetic waves before that they arrive to the center of the bone. We notice that SAR values are maximal at 900MHz and minimal at 2600MHz. It justifies the migration of mobile phones operators to the recent standards of 3G and 4G by ensuring a minimization of SAR values.

If we compare our results of SAR shown in figure 4 with the maximum limits 1.6 W/Kg set by the standards, we find that our values for the different human hand layers at 900MHz, 1800MHz, 2100MHz and 2600MHz frequencies are less than 0.27 W/Kg. This confirms that our new quadri-band patch antenna meets the requirements of dosimetry standards.

Spatial distribution of temperature in the human hand

We notice that spatial distribution of the human hand temperature has two peaks corresponding to the two layers: skin and muscle. The reason is that two layers contain more quantity of water. We note the temperature increases as the mobile usage time advances. It explains that it is safety to use the phone during short time. Also, as the electromagnetic waves penetrate into the human hand, so that the temperature of each layer decreases. The two layers: skin and muscle absorb the majority of electromagnetic waves before they arrive to the center of bone. The maximal values of SAR and temperature rise concern the skin. Thus, the absorption of radiation by the skin is greater in comparison with the other layers. We find that the absorption of fat is less important with comparison with skin and muscle. The absorption of bone layer is less important with comparison with skin and muscle. The center of bone receives only very minimal values of SAR and temperature rise. Therefore, now we confirm that these layers offer a true natural defense for the bone center in front of the high values of SAR and temperature rise.

Temperature rise study

We find that the temperature increase has small values during low exposure times and significant values for long exposure times. This result is very consistent with the reality that the user of the mobile phone feels for a long time the sensation of heating at the exposed part of the body, especially the head and hands.

We find that the temperature increase for the same exposure time are significant at 900MHz and 1800MHz frequencies (with respectively antenna emission powers values of 1W and 0.5W) and less significant with 2100MHz and 2600MHz frequencies (with respectively antenna emission powers values of 0.25W and 0.1W). Then, the migration by mobile phone operators to recent 3G and 4G standards characterized by low antenna transmission power values is a very beneficial strategy and provides more safety for human health than 1G and 2G standards. With comparison of our results of the temperature rise represented in figure 6 with the maximum limits 4.5°C set by the standards, we notice that our results for the different human hand layers at 900MHz, 1800MHz, 2100MHz and 2600MHz frequencies are less than 1°C. This confirms that our new quadri-band patch antenna meets the requirements of temperature standards for human hand.

V. CONCLUSION

The intensity of the temperature rise has small values with little exposure time and significant for a long duration of exposure. The two layers: skin and muscle absorb most of the power emitted by the mobile phone. The study of the thermal effect of GSM on the human hand has given results for the SAR (<0.3 W / Kg) and for the temperature increase (<1°C) are significantly lower compared to the maximum limits (1.6 W / kg) [5] and (4.5°C) [6] set by international standards. Our study confirms that our tetra-generations patch antenna is compliant and meets the standards of dosimetry and temperature when it is used by the human hand.

VI. ACKNOWLEDGMENT

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