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Specific Absorption Rate Calculation Model in Case of Exposure to Microwaves Sources

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Abstract. Technology is a revolution that allows humans to use several apparatus. The radiations emitted by these apparatus have a negative effect on human health, but until now these effects remains suspected only. The determination of the level of the radiation exposure remains important by elaborating the specific absorption rate models that may determine the level of exposure to several sources because all studies are focused on one source of radiation. This model will allow to verify if the level of exposure is under the requirement in case of several radiations sources, mainly with significant apparatus that surround the human even if each radiation of the apparatus is required under strict norms.
The goal of this paper is to develop the specific absorption rate calculation model according to the number of radiation sources that can co-exist in a geographical area, this model will be validated by the comparison between the simulated values of this model and the measurements achieved et Ibn Tofail by EM radiation meters.

Key-words: *The Specific Absorption rate* (SAR). Electrical Field. Biological Effects. Path Losses. Base station. Smartphone. Frequency band. Power density. Electromagnetic radiations.

1. Introduction

Technology is token as the first solution for several sectors, then smart devices are spread everywhere, even our children make acquaintance absolutely how to use them easily, in spite of our knowledge of the damaging effects of their radiances on the health. Those effects due to the absorbed dose of the human body were higher for children than for adults according to experimental studies.

For a total coverage of network, telecommunication provides install their base stations everywhere, these stations are installed under the particular norms of radiations required by the *International Non Ionizing Radiation Protection* (ICNIRP) committee. In fact, according to the results of deep research from major laboratories, they are unveiled that these radiation have danger and they may destroy the human biological organism, even if the level the exposure is under norms required SAR= 0.08 [W/Kg] for whole body and 1.6 [W/Kg] for the head [1]. Indeed, one source of EMF radiation could affect negatively the human biological system, especially the barrier of brain of blood. The study performed in Sweden, which proved that people who use the mobile phone for ten years or more are affected by an augmented risk of acoustic neuroma [2].

The high frequency waves have the possibility of changing the molecule of DNA [2]; other researchers conclude that those fields could appear a cataract induction or in other sense the formation of opacity of the lens of the eye [2]. Because of exposure, the pregnant woman would be possible to have the risk of a miscarriage [1].

To analyze these effects the previous studies are focused on the specific absorption rate, which is based on the received electrical field that is measured by probes, and on spectrum analyzers. Software systems are also used to simulate the dose absorbed by the human body with good accuracy, based on the finite-difference time-domain method.

The more influencing parameters that increase the specific absorption rate in humans are the distance between the radiation sources and the exposed person and the operating frequency band. The simulation results in [3] show that the SAR values are 0.8105 [W/Kg], 1.020 [W/Kg], 1.239 [W/Kg], 1.657 [W/Kg], 2.258 [W/Kg] and 3.128 [W/Kg] according to the gap distances of 1.0 [cm], 0.8 [cm], 0.6 [cm], 0.4 [cm], 0.2 and 0 [cm] respectively at the frequency 900 MHz. The exposure in the skin for 1800 MHz was found higher than that for 900 MHz.

The simulation of spherical layers of the head, with a mobile phone put of 20 [mm] of the head, the obtained values from CST MWS by the study [4] shows that the SAR_g and SAR_{10g} are all under the SAR limit of 1.6 [W/Kg] for the 1g head tissue (according to FCC standard) and 2.0 [W/Kg] for the 10g head tissue (according to ICNIRP standard) for the practical mobile phone applications.

The study [5] had evaluated the specific absorption rate distribution on the horizontal cross-section of the human head where the highest values are obtained in the region of the skin near the antenna. At 900 MHz, SAR was found 0.823 [W/Kg]; at 1800 MHz SAR was 1.187 [W/Kg]. This evaluation is depended on the frequency band of radiations source and the dielectric properties of human tissues. In case of exposition in N aerials at the same time, the study [6] with the support of the software SEMCAD X, they simulate two aerials as that of the mobile phone which operate on 2140 MHz. They illustrate the SAR distributions for the three pre-known relative phases between antennas, for 0; 90 and 180 degree, withthe maximum value of SAR= 1[W/Kg] was for the phase of 180 degree.

The paper [7] succeeded to determine exposure of the human tissues skin, fat and muscle that are exposed to the antenna of base station operating in 915 MHz and 2450 MHz. The incident electric field intensity amplitude of the antenna was adjusted at 10.23 [V/m] by using the PSPICE simulator. According to the electric field data obtained, [7] plots the specific absorption rate values at different points of each tissue layer with an accuracy of 0.001. The maximum average SAR of 350 [W/Kg] was found in the skin for 2.4 GHz frequency band, while SAR=100 [W/Kg] for 915 MHz. The values were lower in other tissues.

According to previous simulation studies the authors notice that the specific absorption rate values are below the limits, therefore they need to review the studies carried out by the probes of the radiations. An examples of the evaluation was in Turkey [8] near to a base station, where the measurements were taken during four months in the same point, whereas the measured values of the electrical field were analyzed for one day, where the average value of electrical field was 1.66

[V/m] corresponding to SAR =0.0033 [W/ Kg] on the skin. For one week the average electrical field value was 1.58 [V/m] with SAR=0.0031 [W/Kg]; the whole period of the study the average electrical field value was 1.52 [V/m] with SAR= 0.0029 [W/Kg] with 0.20 standard deviation.

The average electric field strength values for nine measuring points were below 2[V/m], with the maximum average value $E_{max} = 1.86$ [V/m] corresponding to $SAR_{max} = 0.0023$ [W/Kg] in the skin [9]. For the measurements in [10], carried out in Romania, the authors chose to interpolate the electrical field measurement values by fuzzy systems, in order to estimate the weighted value of the electric field in each measurements point and the weighted specific absorption rate value. The authors in the paper [11] have estimated the electrical field and the specific absorption rate for the whole geographical area by applying Sugeno systems to have the weighted values of the level of exposure for the whole area.

The interest of this paper is to implement a method to evaluate the level of exposure to radiations for a real case taking into account the path losses and all radiations sources. Therefore, the authors implement the specific absorption rate calculation model that includes all radiation sources regardless of their type; their frequency bands; and their environments of propagations. This calculation model will allow to test if the level of exposure in any point it is under the norms. As a validation the model the authors use the EM radiation meter that allows them to measure the level of the electrical field; the electromagnetic and the power density get from several sources that coexist in Ibn Tofail University.

2. Theoretical aspects

a. *The specific absorption rate on the human tissues.*

All the new technology devices are connected by their antennas and communicate using electromagnetic radiations.

The specific absorption rate value is the rate of the electromagnetic wave energy absorbed by the human tissues and it is integrated either over the whole body, or over a small sample volume typically 1 g of tissue specified as local SAR or average SAR of 10 gram of tissue [12]. The specific absorption rate is related to the electrical field at any point of the dielectric representing the human tissues; it is calculated by Eq. 1 [13].

$$SAR = \frac{\sigma}{\rho}|E|^2 \quad \left[{}^{W}/_{Kg}\right] \tag{1}$$

E represents the electric field in [V/m], σ the electrical conductivity in [S/m] and ρ which clarifies the mass density in [Kg/m^3]. Those parameters are depended respectively on the proprieties of the human tissues. Therefore, the human tissues are split into several layers; for more precision the researchers split them into 5 or 6 layers. The dielectric proprieties as presented in Table 1.

Table 1. Dielectric parameters of human tissues [14]

Dielectric parameters		Skin	Fat	Brest	Muscle	Bone
$\sigma\ [\frac{S}{m}]$	900 MHz	0.87	0.11	0.05	0.94	0.14
	1800 MHz	1.18	0.19	0.09	1.34	0.28
	2.4 GHz	1.46	0.27	0.14	1.74	0.39
$\rho[Kg/m^3]$		1100	916	928	1041	1990

The specific absorption rate distribution in the z-direction has a simple exponential decay for a variety of homogeneous materials; it depends on the x-y distribution and the z-distribution over a volume of the organ or the body as will be presented in Eq. 2, where SAR(x, y,z_s) is the SAR in the x-y plane measured at the distance z=z_s from the skin surface and δ=-10.7*f [GHz] +40.4 [15] is the penetration depth:

$$SAR\,(x,y,z) = SAR(x,y,z_s)e^{\frac{-2(z-z_s)}{\delta}} \tag{2}$$

The estimated SAR_v for an organ of volume v is calculated by integrating Eq. 2 as in Eq. 3 [15].

$$\begin{aligned} SAR_v &= \frac{1}{V_{tot}} \iiint SAR\ (x,y,z_s)\,dx\ dy\ dz \\ &= \frac{1}{V_{tot}} \iint dx\ dy\ SAR(x,y,z_s) \int_0^z e^{\frac{-2(z-z_s)}{\delta}} \\ &= \frac{1}{V_{tot}} \iint dx\ dy\ SAR\ (x,y,z_s)\,\frac{\delta}{2} e^{\frac{2z_s}{\delta}} (1 - e^{\frac{2z}{\delta}}) \end{aligned} \tag{3}$$

The authors express the local specific absorption rate and the average specific absorption rate according to the ratio between the SAR_V and the peak SAR ICNIRP basic restriction: $R_{(V/1g)}$ and $R_{(V/10g)}$ depend on the frequency range then the peak SAR_{1g} and SAR_{10g} , as defined in Eq. 4 [16].

$$SAR_{1g,10g} = \frac{1}{R_{1g,10g}} \frac{SAR_V}{SAR_V^{limit}} SAR_{1g,10g}^{limit} \qquad [W/Kg] \tag{4}$$

a. *The electric field for the different cases of exposure.*

The electric field for near fields

The specific absorption rate takes into account the distributions of the close antennas, as the ones of mobile phones, the WiFi routers and all devices used by the humans to join the network. The electrical filed distribution arrived to the human body is computed as a function of the transmitted power P_t of the equipment; D - the directivity of the antenna equipment; the impedance of the antenna and R - the distance between the head or the human tissues referred and the radiation source; specifically one applies Eq. 5 [17]:

$$E = \sqrt{\frac{P_t * D * \eta}{2 * \pi * R^2}} \ [V/m] \tag{5}$$

The above formula is valuable in case where the human use the equipment in standby mode or connected mode but for vocal communication, where the phone emits more power in order to achieve the communication, the authors need to recalculate the received electrical field to human tissue. Then the received electric field is the sum of the electrical field emitted by the antenna phone and the one of the base station. As known, the propagation of EM waves has losses because of the path of propagation and the obstacles. Therefore, many propagation models are developed to help the operators to install their infrastructure, but the problematic of the current propagation model are assigned to 1Km as a minimum distance. However, in the current study, the base stations are closed to the points of measurements. Then, the authors chose to apply the two-ray model [18] to calculate the received power of the exposure (downlink power):

$$P_r = P_t * \left[\frac{\lambda}{4\pi}\right]^2 \left|\frac{\sqrt{G_t G_r}}{l} + \frac{\Gamma\sqrt{G_t G_r}\, e^{j\Delta\phi}}{r + r'}\right|^2 \ [W] \tag{6}$$

G_t; G_r transmitter and received antenna gain, Γ the reflection coefficient into ground, l the direct ray between the transmitter and the receiver. r and r′ are the rays determine the length of the transmitter and the receiver; it is demonstrated by the values of h_t height of base station, h_r that presents the height of the receiver; by following function:

$$r + r' - l = \sqrt{(h_t + h_r)^2 + d^2} - \sqrt{(h_t - h_r)^2 + d^2} \ [m]$$

For $\Delta\phi = 2\pi(r + r' - l)/\lambda$[rad] is the phase difference between two received signal components. Then the authors deduce the received power density [19] by the following Eq.7:

$$P_D = \frac{P_r}{4\pi l^2} \quad [W/m^2] \tag{7}$$

In addition to the energy getting out from the base station, there is also an accumulated electric field mainly when using the mobile phone as this equation shows:

$$E_{accu} = E_{up} + E_{dow} \tag{8}$$

However, the density of the electric field of the uplink for an antenna that radiates in all directions is given by the Eq. 9[20]:

$$E_{up\ dB} = P_{t\ dBw} - 20\log(d) - 45.2 \quad [V/m] \tag{9}$$

$P_{t\ dBW}$ in [W] the transmitted power by the mobile phone; d is the distance between the human head and the mobile phone in [mm]. The propagation inside the buildings [21] is influenced by internal materials such as metal, concrete, drywall etc.; then, the loss is calculated by Eq. 10.

$$Pl = (20 * \log(f)) + (N * \log(d) + L_f(n) - 28 \tag{10}$$

where N is the distance power loss coefficient, f is the frequency on MHz, d is the distance separation between the cell phone and the base station $(d > 1m)L_f$, the penetration loss factor, n is the number of walls stand between the base station and the receiver space. The received power [22] to the exposed person takes place inside the building is:

$$P_{rdB} = P_{tdB} + G_{tdB} + G_{rdB} - Pl \quad [W] \tag{11}$$

The bases stations are classified into three types: Macro for a large area coverage, micro to enhance the coverage inside cities, pico which tends to be as a solution for any congestion of network. The propagation of the signals emitted by the antennas is shown in Fig. 1, the blue line shows the intensity of the electrical field E, whereas the red shows the antenna radiation pattern.

Fig. 1. Radiation of base station.

For far fields, the power density is calculated as in Eq. 12 [23]:

$$P_D(R, \theta, \emptyset) = \frac{(1 + |\Gamma|)^2 * P * G_{max} * F(\theta, \phi)}{4 * \pi * R^2} \quad [W/m2] \tag{12}$$

P is the power supplied to the antenna; G_{max}; is the maximum gain of the antenna; $|\Gamma|$ is the modulus of the reflection coefficient taking into consideration the wave reflected by the ground; and R is the distance between the antenna and the reference point, $F(\theta, \phi)$ is the antenna pattern that is expressed [24]:

$$F(\theta, \phi) = \begin{cases} \left[\frac{\sin[c \ \sin(\theta-\alpha)]}{c \ \sin(\theta-\alpha)} \right]^2 & Main\ Lobe \\ A_{sl} & Side\ Lobe \end{cases}$$

where $\frac{1.392}{\sin(\frac{\theta_{bw}}{2})}$ and θ_{bw} or θ three decibel angle of main lobe. Following the Maxwell equations, the authors may determine the power density according the electrical field E and the magnetic field H respectively [25], as the Eq. 13 presents:

$$\vec{P_D} = \Re \left\{ \vec{E_i} * \vec{H_i^*} \right\} \tag{13}$$

The impedance of plane waves emitted by the base stations and smartphones, propagating in the free space, is defined as $Z = {}^{E}/_{H}$

The transmitted electrical is written as function of the power density P_D, the incidence impedance Z_i and the transmission coefficient $t = \frac{2}{1+\sqrt{\epsilon_r}}$ where ϵ_r is relative complex permittivity,

$$|E_i|^2 = Z_i \, |t|^2 \, P_D \ \ [V/m] \tag{14}$$

3. The scenario of the study

The study was in Ibn Tofail university of Kenitra in three points, the first one was at the faculty of science whereby the other both points were at the National School of Applied Sciences because of their nearness to certain base stations. For the distances between the bases stations and the points of measurements, they are calculated with the support of the department architecture of the university.

Fig. 2. The geographical study Area [26].

The first point was in the garden of the faculty of sciences. In National School o Applied Sciences, The authors have taken the measurement in the professors building which is present by the point 2 in the Fig. 2 and researches laboratory is figured by point 3. Concerning the radiations source let be bases stations or smartphones, their radiations parameters are presented in the Tables 2 and 3 [27].

Table 2. The base station's parameters of study points

Radiations parameters	900 MHz	1800 MHz	2100
P_t [W]	500	250	250
G_{max} [dB]	15.5	17.8	18.3
Γ	1	1	1
h_b [m]	25	25	25

The parameters that determine the energy and radiation aspects of connected smartphones during transmission and reception are presented in Table 3 [28]:

Table 3. The smartphones parameters

Radiations parameters	900 MHz	1800 MHz	2100
P_t [W]	1.097	1.181	
$\eta[\Omega]$	377		
Directivity [dB]	1.86	3.8	1.17

4. Algorithm of the specific absorption rate calculation models

The diagram above presents the SAR calculation model of the exposed human to several radiation sources in a point. Then they become identified by their frequency band that allows to determine the electrical conductivity, according to the chosen tissue. Each source is identified also by its power of radiance compared to 2[W], then the simulator makes the choice on which equation will implement to calculate the electrical received field. the choice of 2[W] for comparison was not haphazardly made, because our calculation articulates on two types of fields, close fields as smartphones, router wifi their power of radiance does not exceed 2[W] in all their modes of functioning. The far-fields radiate with a power between 250 [W] and 500 [W].

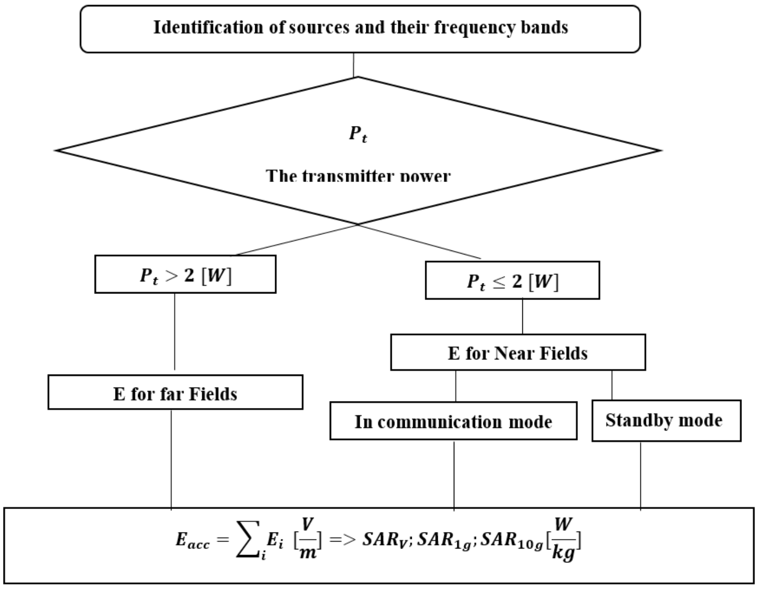

Fig. 3. Diagram for Specific Absorption Rate Calculation Model.

For the accumulated electrical field by all sources of radiance, the authors chose to make it of a direct way of making that the phase between fields equal 0.

5. Simulations and measurements results

By simulating the algorithm of our SAR calculation model and data, using Matlab software. The authors have been able to calculate specific absorption rate regardless of the numbers of radiation sources and the geographies point.

a. Simulated result

Laboratory in National School of Applied Sciences:

As figured in section 3 the first point of the study was in the laboratory, then it is surrounded by four base stations with distances 164 [m]; 180 [m]; 250 [m], and 224 [m] respectively. The authors have simulated the accumulated electrical field by the all base stations and for the smartphones, as presented in Table 4; also the specific absorption rate (SAR) for the whole body, the peak SAR_{1g} and peak SAR_{10g} are shown.

Table 4. The simulated SAR according to sources

Frequency band	The accumulated electrical field E_{acc}[V/m]				SAR_g [W/Kg]	SAR_{10g} [W/Kg]	SAR Whole body [W/Kg]
Base station							
900 MHz	1.5	3.1	3.9	4.7	0.6	0.3	0.018
1800 MHz	1.3	2.7	3.6	4.6	0.58	0.29	0.017
Base station and 3 smartphones							
1800 MHz	5.15				0.7	0.35	0.02

Professor's offices:

Concerning the second point, which is in the professor's office, it is located with respect to the four base stations at the distances: 171.5 [m]; 174.5 [m]; 190 [m] and 269.6 [m] respectively. In this case, assuming that the human exposed also communicates on a smartphone, the simulated results are shown in Table 5.

Table 5. The simulated SAR according to sources

Frequency band	The accumulated electrical field E_{acc}[V/m]				SAR_g [W/Kg]	SAR_{10g} [W/Kg]	SAR Whole body [W/Kg]
Base station							
900 MHz	1.3	2.6	3.8	5.1	0.5	0.25	0.015
1800 MHz	1.3	2.7	3.9	4.7	0.61	0.3	0.018
Base station and smartphones in communication							
1800 MHz	4.79				0.6	0.3	0.018

Faculty of science:

In the garden of the faculty of sciences where the students take break, each one may be surrounded by more than 5 smartphones, then in the simulation the authors have chosen 7 smartphones in addition to bases stations that are located in the distances 151.77 [m]; 144 [m]; 287.06 [m] and 301[m], according to the results figured in Table 6 the authors notice an augmentation of the electrical field and the peak SAR.

Table 6. The simulated SAR according to sources

Frequency band	The accumulated electrical field E_{acc}[V/m]				SAR_g [W/Kg]	$_{10g}$ [W/Kg]	SAR Whole body [W/Kg]
Base station							
900 MHz	1.4	2.2	3.8	4.5	0.4	0.2	0.012
1800 MHz	1.5	3.1	3.9	4.7	0.6	0.3	0.018
Base station more than 7 smartphones							
1800 MHz	6.20				1.02	0.51	0.03

b. Measurements results

As a validation of the specific absorption rate calculation model, the authors have chosen to carry out the measurements in the same studies points of simulation. The study lasted for 20 days using the EM Radiation meters as equipment of measure. They have taken the measurement every three minutes, after three successive measurements they shut down the equipment for 5 min, this operation is repeated three times for each measure and each point.

Prior to validate our SAR calculation model by comparing the simulated values and measurements, the authors have analyzed the influence of the number of sources on the electrical field and SAR received to the exposed human.

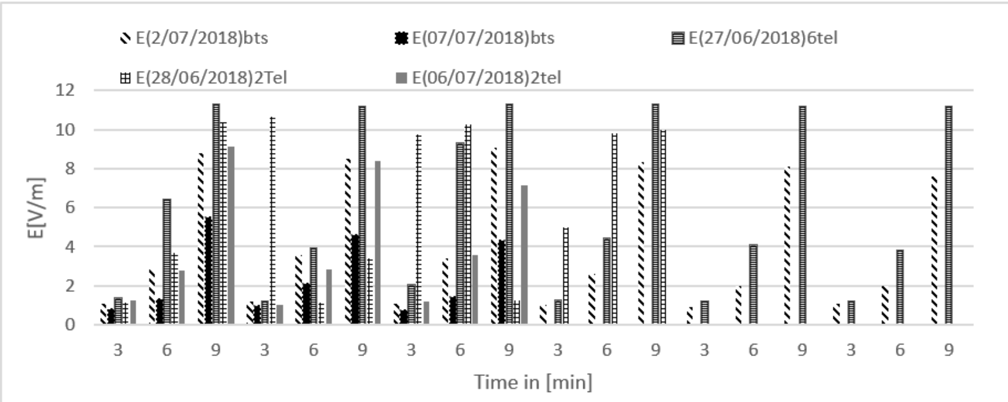

Fig. 4. The field measurements at the laboratory.

According to the Fig. 4, the maximum electrical value was for the case of the six smartphones and bases stations well on.

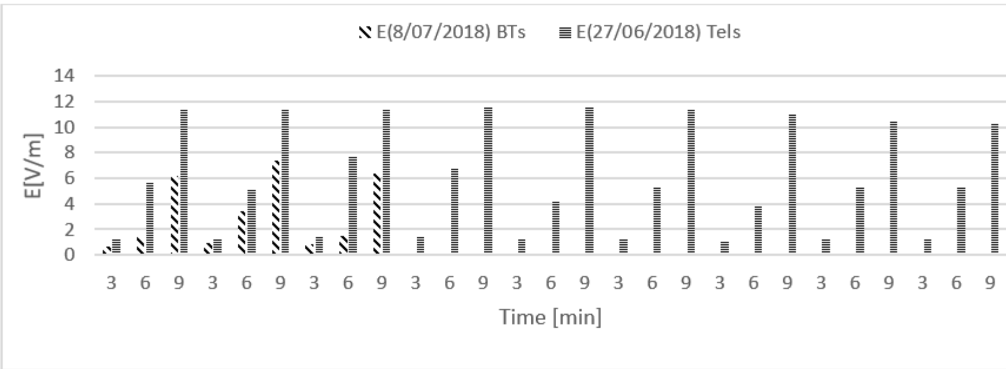

Fig. 5. The field measurements at faculty of science.

The Fig. 5 shows that, at the first three minutes, the electrical field values converge in case of base stations also with the smartphones, and they diverge for the 6 min and the 9 min.

Since the authors made several measurements for twenty days, they notice that the values are non-linear; then, they interpolated the values using a fuzzy system method, in order to deduce the weighted value of the electrical field at each point.

The applied Fuzzy System

The fuzzy system has membership function as in Eq. 15 [29], based on the maximum; minimum and the average values of the each day,

$$(E) = \begin{cases} \frac{E-E_{min}}{E_{average}-E_{min}} & E_{min} \leq E < E_{average} \\ \frac{1-(E-E_{average}\ )}{E_{average}-E_{Max}} & E_{average}\ \leq\ E <\ E_{Max} \\ 0 & else \end{cases} \tag{15}$$

The weighted values of the received electrical field by a human exposed to each point are obtained by Eq. 16 [30], for the union of membership functions for each day,

$$E_{weighted} = \frac{\sum E * \mu_{\cup whole\ period}\,(E)}{\sum \mu_{\cup whole\ period}\,(E)} \tag{16}$$

Measurement's results at Professors office

Table 7. The weighted values of the electrical field received to the body exposed to bases

Sources	4 Base stations
The weighted value of the electrical field	5,259 [V/m]
SAR for Whole body	0.022 [W/Kg]
SAR_g	0.73 [W/Kg]
SAR_{10g}	0.36 [W/Kg]

Interpolating the measured electrical field at the professors office position by the fuzzy system, following Eq. 15, the authors noticed that the weighted value of the electrical field is 5.25 [V/m] in case of the exposure to bases stations only. As a comparison with the measured values, the simulated values by our model are 5.1 [V/m] for 900 MHz and 4.7 [V/m] for 1800 MHz.

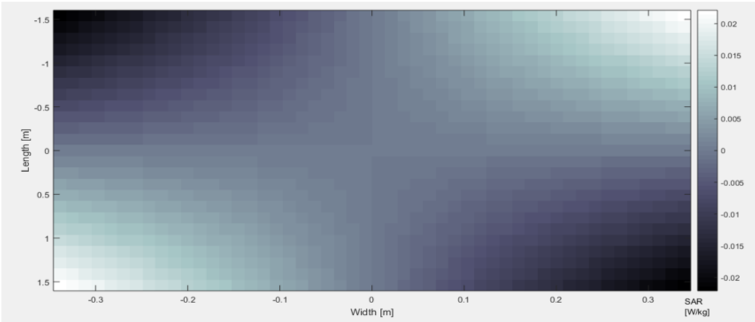

Fig. 6. The SAR distribution in whole body exposure to base stations at professor's office.

The Fig.6 presents the specific absorption rate distribution over the whole body surface, the peak SAR is 0.022 [W/Kg], where the electrical conductivity has chosen is 1.18 [S/m], which is specified to 1800 MHz frequency band as a median frequency of the microwave spectrum desired for our model.

Table 8. The weighted values of the electrical field received to the body by base station and 1 smartphone in communication

Sources	4 Base stations + 1 smathphone
The weighted value of the electrical field	4.01 [V/m]
SAR for Whole body	0.012 [W/Kg]
SAR_g	0.42 [W/Kg]
SAR_{10g}	0.21 [W/Kg]

Table 8 and Fig. 7 reflect the weighted values of the electric field and the SAR as well as the distribution on a surface, the authors include the case of communication in phone; the weighted value of the measured electrical field is 4.01 [V/m] and the simulated one is 4.79 [V /m].

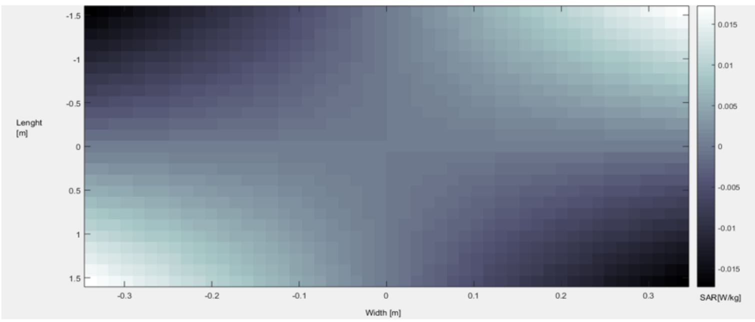

Fig. 7. The SAR distribution in whole body exposure to base stations and a smartphone in communication at professor's office.

Measurement's results at Laboratory

In the laboratory may exist 3 to 4 smartphones in standby mode; then, according to the fuzzy system applied for the interpolation, the electrical elds values in the laboratory throughout the duration is 5.80 [V/m], including the bases stations and smartphones, as presented in Table 10.

Table 9. The weighted values of the electrical field received to the body by base station at laboratory

Sources	4 Base stations
The weighted value of the electrical field	4.35 [V/m]
SAR for Whole body	0.015 [W/Kg]
SAR_g	0.50 [W/Kg]
SAR_{10g}	0.25 [W/Kg]

Table 9 presents the weighted values for the case of exposure only to base stations, the electrical field and SAR levels belong augment with the presence of other sources than base stations.

Table 10. The weighted values of the electrical field received to the body by base station and smartphones at laboratory

Sources	4 Base stations + 3 smarthphones
The weighted value of the electrical field	5.80 [V/m]
SAR for Whole body	0.027 [W/Kg]
SAR_g	0.89 [W/Kg]
SAR_{10g}	0.44 [W/Kg]

Measurement's results at faculty of sciences

Table 11. The weighted values of the Electrical field received to the body by base station at faculty of sciences

Sources	4 Base stations
The weighted value of the electrical field	4.087 [V/m]
SAR for Whole body	0.013 [W/Kg]
SAR_g	0.44 [W/Kg]
SAR_{10g}	0.22 [W/Kg]

The choice of the garden of the faculty of science for the study is not random, but because at this point can exist more than 8 smartphones close to each student; it is a good example of evaluating the influence the number of sources on the electrical field level.

Table 12. The weighted values of the electrical field received by the body from base station at the Faculty of sciences

Sources	4 Base stations + 6 smarthphones
The weighted value of the electrical field	6.17 [V/m]
SAR for Whole body	0.03 [W/Kg]
SAR_g	1.01 [W/Kg]
SAR_{10g}	0.50 [W/Kg]

Comparing the level of the electrical field in Table 12, due to base stations, when it is 4.087 [V/m], with more than seven smartphones in different modes, the level increased to 6.17 [V/m].

6. Discussion

According to simulated results and measurements results for every point, they are converged, where the accumulated electrical field values by the radiance issued by base stations in the laboratory are between 4.6 [V/m] and 4.7 [V/m], while the weighted value of the measurements is 4.35 [V/m]. Concerning the professors office, the margin of the accumulated electrical field is between 4.7 [V/m] and 5.1 [V/m] and the weighted value of the measurement is 5.25 [V/m]. In the faculty of science, the accumulated electrical fields by bases stations with our model is between 4.5 [V/m] and 4.7 [V/m], the weighted measured value is 4.08 [V/m].

The simulated values and the weighted one of measurements allow to make the differentiation of the parameters that influence the received electrical field to the exposed human, the authors point out an increase of the electrical field with the existence of smartphones. The weighted value of the electrical field with the existence of more than three smartphones, it is increased to 5.80 [V/m] and the simulated value to 5.15 [V/m] in the laboratory. The specific absorption rate increases with the augmentation of the electrical field and with the frequency band, as the specific absorption rate calculation model has proved for the peak SAR; SARg and SAR10g.

The measurements results show that several parameters influence on the received electrical field to the human body. The authors take into account that the exposed human that communicate in the phone, the weighted level of the electrical field measurements is 4.01 [V/m], and the simulated value of the model is 4.78 [V/m]. But, it is necessary to note that the measurements are taken in the evening and the morning of cloudy and sunny climate, of this fact the authors notice that climate has an influence on the received power then it will influence also the specific absorption rate of the exposed human.

Besides the distance, the frequency band of operation of source and climate, according to measurements, the authors conclude that the time of the exposure is an important parameter. for the first three minutes of measurements in every point of the field are similar for every measurement regardless of the number of sources, after six minutes, they note the increase of the electrical fields according to it numbers of existent sources.

The interest of our model is to specify the specific absorption rate level according to the sources of radiations of different frequencies that exist in geographic point without needing to perform measurements, in order to assess if the level is under the norms of the radiation exposure. In the garden of faculty of sciences, the level of SAR whole body attains 0.03 [W/Kg] for 7 smartphones. The question is what it will be the level of the case of 30 persons, or more in the same class.

7. 7. Conclusions

In this paper the authors worked on three levels to implement the model of calculation of SAR for a human exposed on several sources of radiance in a point. Firstly they had based on theoretical part concerning equations that allow them to calculate the received electrical field to the exposed body. They are focalized on the two rays model because of the base stations at the present study are much closed. From theory, the authors have elaborated an algorithm, which allows us to calculate SAR in case of the exposure to several sources of radiation according to their transmit power and their frequency band after the authors have simulated the algorithm. As a valuation of the SAR model, the authors have compared the simulated values with the measurement ones that they have taken from the same studies points, then they notice a convergence between the simulated values and weighted values of the measurements, by interpolating the measurements applying the fuzzy system.

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