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Far-Field Effects with Human Head Evaluation of EM Emission

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Abstract: - This paper presents an assessment of radiation electromagnetic (EM) energy absorption by using far-field measurement system. Dipole radiator was applied for closed proximate Specific Anthropomorphic Mannequin (SAM) in order to measure EM energy, radiation pattern and Specific Absorption Rate (SAR). The evaluation of SAR values were taken from numerical analysis and experimental measurement. In this study, scattering and power absorption of SAM were evaluated by environmental measurement. To simplify the computational complication, uniform similar tissue liquids were used in this study for evaluation of EM radiation energy. The concept of Poynting vector was applied to derivate the degree of human head damage subjected to EM radiation energy that may be evaluated with the far-field.

Key-Words: - Radiation, Electromagnetic, Specific Absorption Rate, Scattering, Power Absorption, SAM

1 Introduction

Wireless communication devices are now more extensively used than the last decade. But it can cause electromagnetic (EM) energy radiation that will influence human health. Despite the convenience of any portable communication devices, assessment of EM energy effect on human head by measurement Specific Absorption Rate (SAR) should be done. Generally, the evaluation of SAR value uses numerical analysis and experiment measurement [1,2,3]. The SAR can be defined based on E-field measurements or temperature increase measurements [4,5]. The limit of SAR value by ANSI/IEEE standard is 1.6 W/kg average over cube 1-g tissue exposed to EM energy radiation in the duration of 6 minutes [6]. International Commission for Non-Ionizing Radiation Protection (ICNIRP) standard is 2 W/kg average over cube 10-g tissue exposed to EM energy radiation in the duration of 30 minutes [7].

In order to evaluate user' safety in using wireless communication devices, SAR values are thus critical in limiting the damage degree of human tissue under EM wave radiation energy. In practice, ways to find SAR values can be categorized into experiments and numerical method [2,3]. Experiments are performed in E-field probe and thermographic measurement method [8]. Numerical method using Finite-Difference Time-Domain (FDTD) and Method of Moment (MoM) are used in simulation software [9,10]. These two kinds of numerical methods can be applicable in Near- and Far-field [3].

This paper presents the assessment of absorbed EM radiation energy of SAM by far-field measurement and verified with numerical method.

2 Theory

Dipole radiator was operated in Global System for Mobile communications (GSM) 1900 MHz closed proximate SAM in order to measure radiation pattern, electromagnetic (EM) energy absorption. The SAR can be defined as the energy of E-field measured in human tissue as defined in Equation (1) [4,11] or based on temperature increase measurement as defined in Equation (2) [4,12].

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

where

σ is the electrical conductivity (s/m)

ρ is the density of tissue (kg/m^3)

E is the E-field intensity (v/m)

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$$SAR = c \frac{\Delta T}{\Delta t} \bigg|_{t=0} \quad (2)$$

where
ΔT is the change of temperature(℃)
Δt is exposure duration (s)
c is the specific heat (J/kg℃)

Here, with using far-field measurement, scattering and power absorption of SAM were also evaluated in measurement environment. Scattering can be determined as rate of different values of radiation loss in free space and without filling up similar tissue liquids mass [13]. Radiation absorption can be determined as rate of different values of radiation loss in free space with filling up similar tissue mass [14].

3 Measurement Method

Actually, human head is an inhomogeneous tissue. In order to reduce computation complication, uniform similar tissue liquid was used [15]. Table 1 and Table 2 show ingredients of similar tissue liquid of relative permittivity and conductivity referring to IEEE Std.1528-2003 ™ [4]. This study focuses at examining wireless communication safety; far-field measurement system for evaluation radiation energy of antenna was operated in GSM 1900 MHz. Fig.1 shows the experiment concept using Poynting vector, which can be derived from Maxwell's Equations as in (3) and (4) through (5) to (8).

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} \quad (3)$$

$$\nabla \times \vec{H} = \frac{\partial \vec{D}}{\partial t} + \vec{J} \quad (4)$$

$$\nabla \cdot \left(\vec{E} \times \vec{H}\right) = \vec{H} \cdot \left(\nabla \times \vec{E}\right) - \vec{E} \cdot \left(\nabla \times \vec{H}\right) \quad (5)$$

$$\nabla \cdot \left(\vec{E} \times \vec{H}\right) = -\vec{H} \cdot \frac{\partial \vec{B}}{\partial t} - \vec{E} \cdot \frac{\partial \vec{D}}{\partial t} - \vec{E} \cdot \vec{J} \quad (6)$$

$$\nabla \cdot \left(\vec{E} \times \vec{H}\right) = -\frac{\partial}{\partial t}\left(\frac{1}{2}\varepsilon E^2 + \frac{1}{2}\mu H^2\right) - \sigma E^2 \quad (7)$$

$$-\oint_S \left(\vec{E} \times \vec{H}\right) \cdot d\vec{s} = \frac{\partial}{\partial t}\int_V \left(\frac{1}{2}\varepsilon E^2 + \frac{1}{2}\mu H^2\right) dv + \int_V \sigma E^2 \quad (8)$$

In this study, dipole radiator was placed closed to SAM without filling up similar tissue liquid, then, with filling up similar tissue liquid. Using the above method, two different emitting values were obtained. Their difference is then divided by the mass of similar tissue liquid to obtain the Radio Frequency (RF) energy deposition on SAM. Finally, numerical analysis of Finite-Difference Time Domain (FDTD) [16] was used to compare with experiment results.

4 Result

Fig.2 shows the reflection loss of dipole antenna in free space. Fig.3 shows the reflection loss of dipole antenna, which was placed in SAM without filling up similar tissue liquids, vertical as well as horizontal polarization. These values would be used to compute scattering of loss medium. Fig.4 shows the reflection loss of dipole antenna, which was placed in SAM with filling up similar tissue liquids, vertical as well as horizontal polarization. These values would be used to compute EM energy absorption of similar human head. Fig.5 shows electromagnetic energy pattern of vertical and horizontal polarization by using dipole antenna placed in closed SAM with far-field measurement system. Various kinds of radiation patterns show EM energy affecting human head. Table 3 indicates the EM energy scattering and absorption degree without filling up similar tissue liquid. The listed Table 4 is EM energy absorption degree of filling similar tissue liquids. Above experimental result can be used to estimate EM energy absorption of human head. Table 5 listing summarized values of antenna impedance with and without SAM and EM emission energy by far-field experiment and FDTD numerical analysis. The differences are within 5 percents.

5 Conclusions

In this study, evaluation of EM energy emission absorbed in human head is proposed by using far-field measurement system with dipole radiator operated in GSM 1900 MHz. Because dipole antenna is a basic radiator with the H-plane of antenna radiation has omni-directional pattern, the radiation energy of using dipole antenna is somehow more serious than others. But from experimental measurement and the numerical analysis, the difference is negligible. Hence, the evaluation of EM energy absorption degree of SAM by far-field measurement is acceptable.

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Table 1 Ingredients of similar tissue liquid

Frequency(MHz)	Ingredients (weight %)
900	Water:49.20, Diacetin:49.20, NaCl:1.10, Bactericide:0.50
1800	Water:52.64, DGBE:47.00, NaCl:0.36
1800T	Water:65.30, DGBE:16.33,Triton:17.96, NaCl:0.41
1900	Water:54.90, NaCl:0.18, DGBE:44.94
1900	Water:55.36, NaCl:0.35, DGBE:13.84, Triton:30.45

Table 2 Relative permittivity and electrical conductivity of similar tissue medium

Frequency(MHz)	Relative permittivity (έr)	Conductivity (σ)(s/m)
835	41.5	0.90
900	41.5	0.97
1800-2000	40.0	1.40
2450	39.2	1.80

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Table 3 EM energy absorption degree of with and without filling up similar tissue liquid and scattering and power absorption under vertical and horizontal polarization

Vertical polarization	Frequency(MHz)	1900
Free space	Average Gain(dB)	-0.70
SAM (without filling up similar tissue liquid)	Average Gain(dB)	-1.33
SAM (with filling up similar tissue liquid)	Average Gain(dB)	-6.92
Scattering	(mW)	1.15
Power absorption	(mW)	5.32
Horizontal polarization	Frequency(MHz)	1900
Free space	Average Gain(dB)	-1.81
SAM (without filling up similar tissue liquid)	Average Gain(dB)	-4.54
SAM (with filling up similar tissue liquid)	Average Gain(dB)	-8.63
Scattering	(mW)	3.069
Power absorption	(mW)	2.14

Table 4 EM energy absorption level of SAM of vertical and horizontal polarization

Vertical polarization	Frequency (MHz)	1900
SAM (fill similar tissue liquid)	EM Radiation energy (mW/g)	1.3
Horizontal polarization	Frequency (MHz)	1900
SAM (fill similar tissue liquid)	EM Radiation energy (mW/g)	0.53

Table 5 Summarize values of impedance and EM emission energy both far-field experiment and FDTD numerical analysis.

Term	Far-Field measurement	FDTD numerical
Impedence[ohm] (free space)	67.73-j16.41	65.65-j15.63
Impedence[ohm] (with SAM)	51.12-j4.1	49.68-j3.08
EM Radiation energy (mW/g)	1.3	1.45

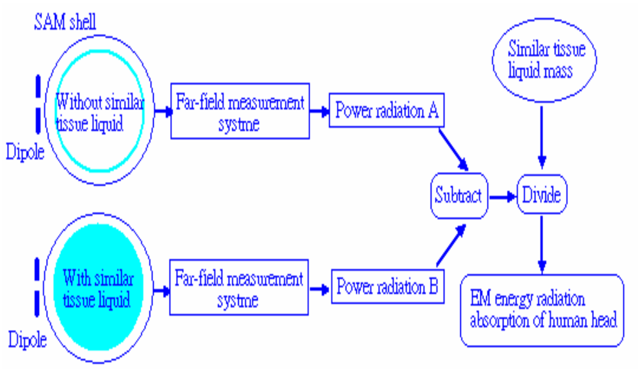


Fig.1 Evaluation EM energy absorption steps by far-field measurement system

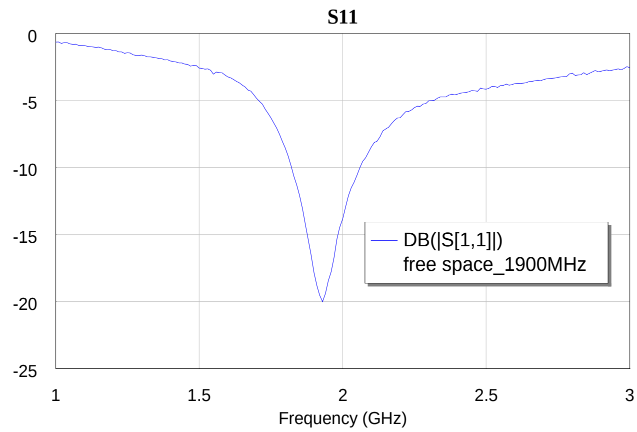


Fig.2 Reflection loss of dipole radiator in free space

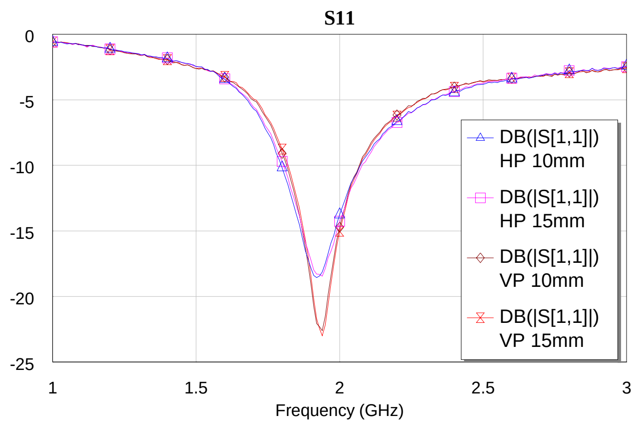


Fig.3 Reflection coefficient of Dipole antenna without filling up similar tissue liquid

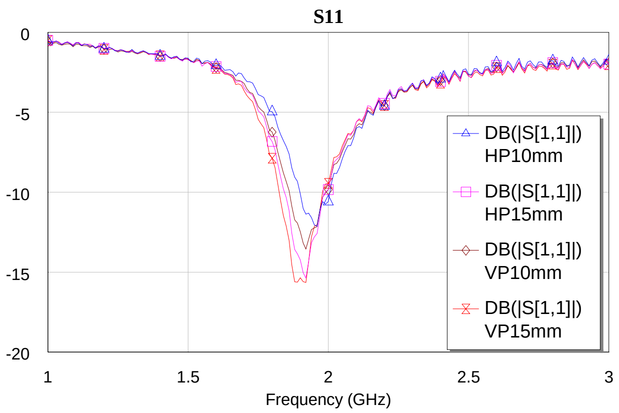
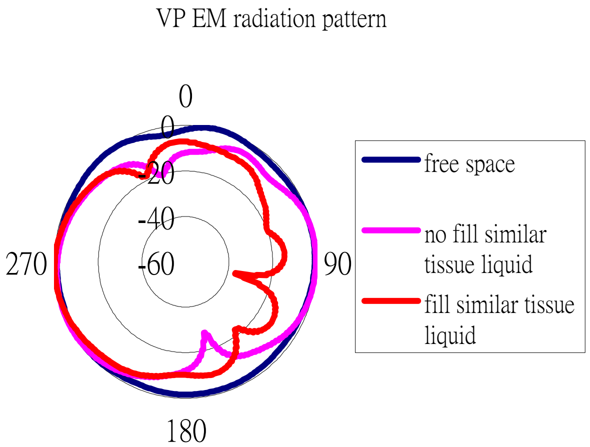


Fig.4 Reflection coefficient of dipole antenna with filling up similar tissue liquid



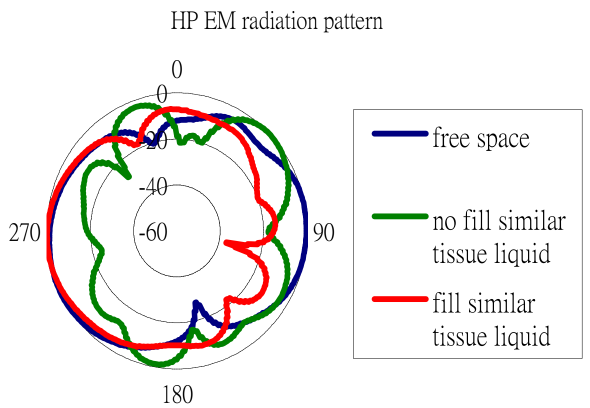


Fig.5 EM energy pattern of vertical polarization and horizontal polarization of dipole antenna by far-field measurement system