SAR Calculation in a Simulant Human Body which is between the Transmitter and Receiver of the Wireless Power Transmission System

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Abstract

Self-resonance wireless power delivery systems operating at 128 kHz and 13.56 MHz were designed. SAR (Specific Absorption Rate) of homogeneous human body between the transmitter and the receiver and resonance frequency of the wireless system were calculated.

Keywords : SAR Calculation Simulant Human Body Wireless Transmitter System

1. Introduction

Although wireless power transfer technology was suggested by Nikola Tesla, it has not been deeply studied until self-resonance technique was announced by Marin Soljačić in 2007[1]. Usually wireless power transfer is performed by applying magnetic field and its facilities are installed where people resides, so evaluation of human body effect by the magnetic field became very important.

Self-resonance wireless power transfer system was designed at 128 kHz and 13.56 MHz, and homogenous numerical human body was installed between the transmitter and the receiver.

The reasons of 128 kHz and 13.56 MHz for wireless power transfer system are that 128 kHz is used for MFAN(Magnetic Field Area Network)[2] and 13.56 MHz is in a ISM band which has variables usage including RFID and NFC(Near Field Communication).

2. Self-Resonant Wireless Transmitter System

Fig. 1 shows schematic diagram of self-resonance wireless power transfer system[1]. This system is more efficient than the other systems at near distance applying the resonating auxiliary coils.



Figure 1: Self-resonance wireless power transfer system using the resonance coils.

3. Reference Values of Human Body Protection of Electromagnetic Fields

Because of the possibility that electromagnetic fields can affect human health, many national and international EMF protection guidelines were provided. Table 1 shows basic restrictions of SAR values for frequencies up to 10 GHz[3].

Point SAR value is defined as absorption power per unit mass of the human body at a point.

 $\begin{aligned} SAR(x, y, z) &= \sigma(x, y, z) |\overline{E}(x, y, z)|^2 / 2\rho(x, y, z) \end{aligned} \tag{1} \\ \sigma(x, y, z) &= \text{Conductivity of the medium at } (x, y, z) \text{ including dielectric loss } (\omega \epsilon_0 \epsilon_r^{''}). \\ \overline{E}(x, y, z) &= \text{Vector phasor of E-field at } (x, y, z). \\ \rho(x, y, z) &= \text{Mass density of the material where SAR value is to be evaluated.} \end{aligned}$

Exposure Characteristics	Frequency Range	Whole-body Average SAR (W/kg)	Localized 10 gram SAR (Head and Trunk) (W/kg)	Localized 10 gram SAR (Limbs) (W/kg)
Occupational Exposure	100 kHz~	0.4	10	20
General Public Exposure	10 GHz	0.08	2	4

Table 1: Basic restrictions of 10 gram SAR values of ICNIRP for time-varying electric and magnetic fields[3].

4. Modelling of Human Body

Homogeneous human body in IEC62233 was modelled for numerical SAR calculation at resonance frequency[4]. The material of homogeneous human body is wet-skin and Table 2 shows dielectric properties of wet-skin at 128 kHz and 13.56 MHz[5].

Table 2 : Dielectric properties of wet-skin.

Frequency	Relative Permittivity $(\boldsymbol{\varepsilon}_{r}^{'})$	Loss factor ($\boldsymbol{\varepsilon}_{r}^{''}$)	Conductivity $(S/m)(\omega \varepsilon_0 \epsilon_r'')$
128 kHz	14,434	10,628	0.0744
13.56 MHz	171	570	0.46

5. SAR Calculation of Self-Resonant Wireless Power Transfer System

5.1 SAR Calculation of 128 kHz System

128 kHz system is suggested in Fig. 2. Distance between the transmitter and the receiver is 0.5 m, and their radii are 0.3 m each. Source or load coils and resonance coils of Fig. 2 are in the same plane. Source coil is fed 1 W by power source and source and load coils have 50 Ω port impedance each in the simulation tool of Ansoft HFSS 12.



Figure 2: Schematic of 128 kHz system.



Figure 3: S-parameters of 128 kHz system.

Fig. 3 shows s-parameters of 128 kHz system in Fig. 2. S_{21} is -4.7 dB at resonance. Fig. 4 shows homogenous human body of wet-skin at the middle of the transmitter and the receiver of Fig. 2. Fig. 5 shows s-parameters of Fig. 4. Resonance frequency and S_{21} remain almost the same without reference to the insertion of human body because of the very long wavelength of the magnetic field.





Figure 4: 128 kHz system with human body.

Figure 5: S-parameters of Fig. 4 with human body.

10 gram average SAR distribution in homogeneous human body at 128 kHz system is shown in the Fig. 6 and Fig. 7. Its spatial peak value and guideline value are in Table 3. When plotting the

average SAR, for each mesh point on the plot, HFSS reports the SAR averaged over a volume that surrounds that point.

SAR Field[W/kg]



Figure 6: 10 g SAR on x-z plane of Fig. 4.



Figure 7: 10 g SAR on y-z plane of Fig. 4.

5.2 SAR Calculation of Wireless Power Transfer System at 13.56 MHz

Fig. 8 shows schematic diagram of 13.56 MHz and Fig. 9 shows its s-parameters. Maximum S_{21} is -4.8 dB at resonance. Fig. 10 shows homogenous human body at the middle of the transmitter and the receiver of Fig. 8. Fig. 11 shows s-parameters of Fig. 10. Resonance frequency was moved from 13.6 MHz to 13.8 MHz in Fig. 11 due to the human body insertion at middle. Both S_{21} and S_{11} were increased to -3.5 dB and -12.2 dB respectively, which means less radiation to outside by the high dielectric constant of wet-skin.



Figure 8: 13.56 MHz power delivery system.



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KY Plot



Figure 10: 12.56 MHz system with human body.

Figure 11: S-parameters with human body.

10 gram average SAR values are shown in Fig. 12 and Fig. 13 on x-z plane and on y-z plane of Fig. 10. Their spatial peak SAR values and peak E-field on the skin are shown in Table 3 and 4.

Table 3: Spatial peak 10 gram SAR values of self-resonance wireless power transfer system and the guideline[3].

	General Public Guidelines of	Calculated SAR [W/kg] _{rms}	
	ICNIRP [W/kg] _{rms}	128 kHz	13.56 MHz
Spatial peak 10 gram SAR in Head and Trunk	2	1.140 x 10 ⁻⁵	0.0149

Table 4 : Spatial peak E-fields in the human body of self-resonance wireless power transfer system[6].

	Frequency	Basic Restriction Values [V/m] _{rms}	Calculated E-field Maximum [V/m] _{peak}
Spatial peak E-field	128 kHz	17.3	0.378
in the body	13.56 MHz	1,830	7.04





Figure 12: 10 g SAR on x-z plane of Fig. 10.

Figure 13: 10 g SAR on y-z plane of Fig. 10.

6. Conclusions

Self-resonance wireless power transfer systems operating at 128 kHz and 13.56 MHz were designed and SAR calculations in homogeneous human body between the transmitter and the receiver were performed. Resonance frequency and insertion loss at resonance of 128 kHz system change little, but they varied in 13.56 MHz system with regard to the human body insertion.

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