SAR Dependence on Phantom Dimensions in WPT Exposure Assessment

Andrey S. Andrenko, Jerdvisanop Chakarothai, Kanako Wake and Teruo Onishi*

National Institute of Information and Communications Technology (NICT)

4-2-1 Nukui-Kitamachi, Koganei, Tokyo 184-8795
Japan

URSI GASS 2020 presentation

Outline:

- Brief review of inductive-coupling wireless power transfer (WPT) technology and related applications
- Example of spiral coil-type WPT system and its frequency dependence of power transmission efficiency
- SAR calculation and measurement for human exposure assessment
- Numerical study of the effect of phantom size variation on calculated SAR values
- Increase of SAR values when the phantom dimension becomes close to the inductive coil size
- Conclusions

Research and Technology Background

In recent years, R&D on wireless power transfer (WPT) systems for practical applications has attracted much attention

First WPT system proposed by MIT *[1]

Applications

Electric car charge

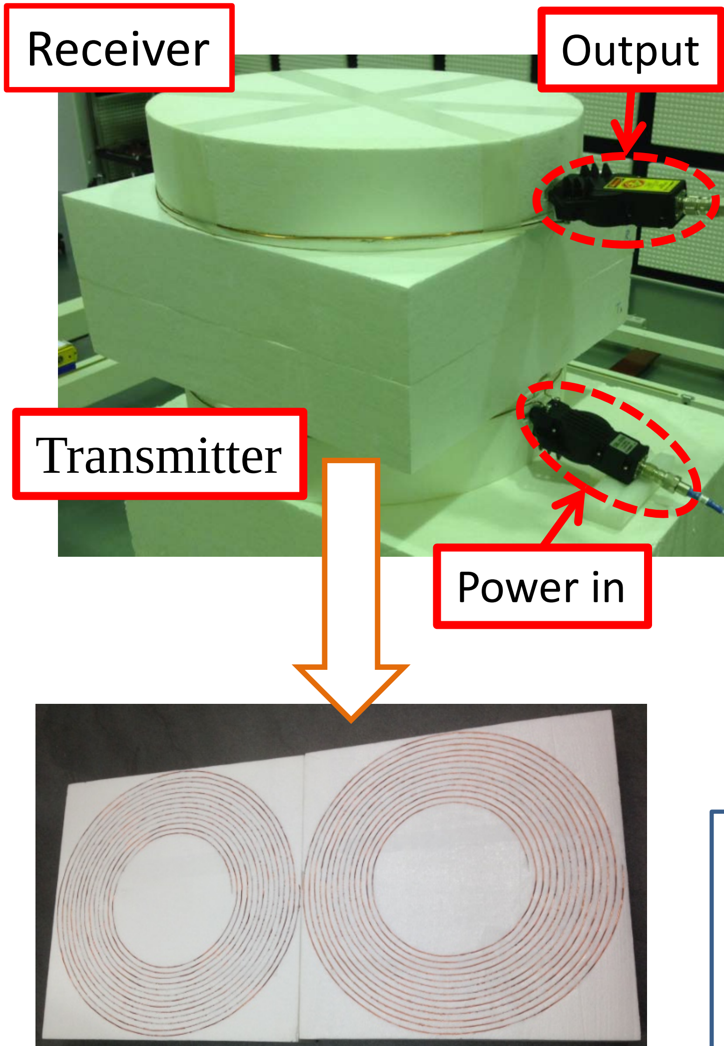
Appliances charge

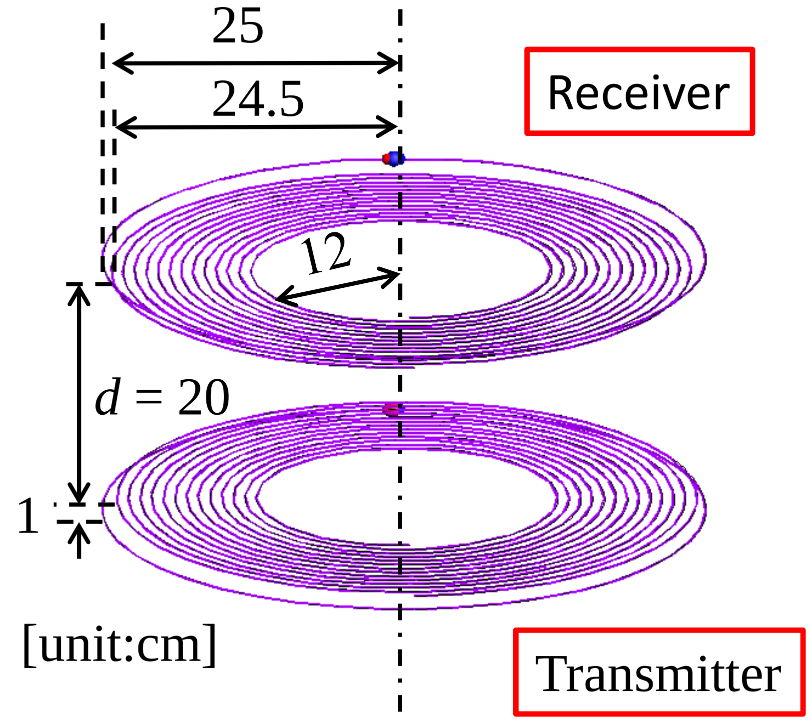
Because a strong EM field is generated near the WPT system, it is necessary to evaluate human exposure

In this study, we focus on MHz-band WPT system

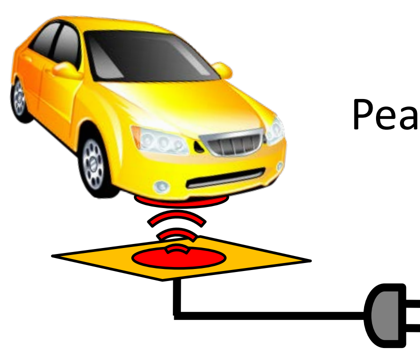
*[1] A. Kurs, et al.,"Wireless power transfer via strongly coupled magnetic resonances," *Sci.*,vol. 317, pp. 83-86, 2007

Example: Spiral type WPT system





EV WPT System



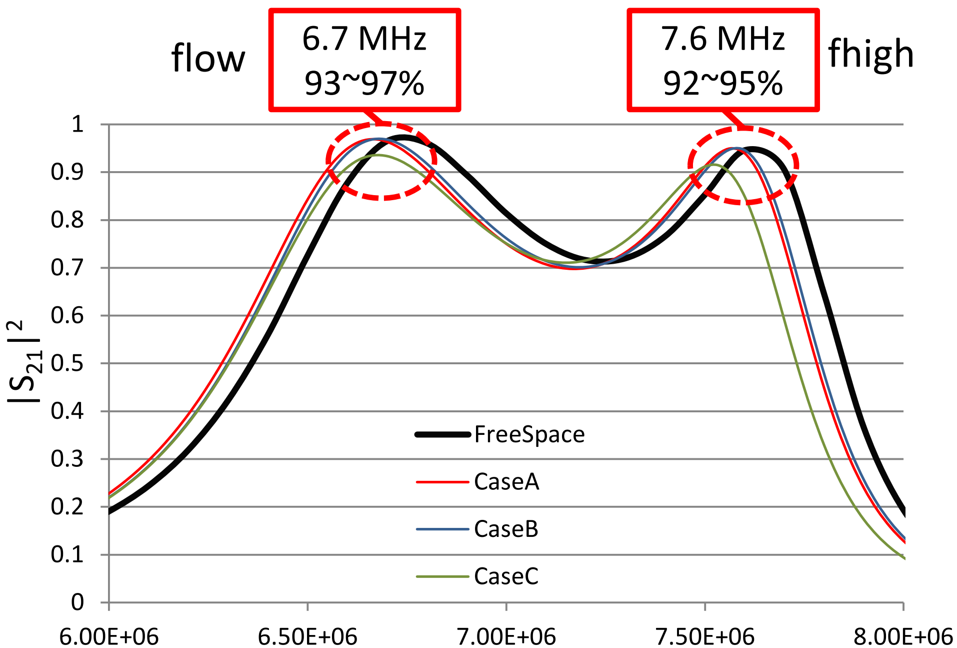
Very high power

Peak input power: 7.7kW (proposed)

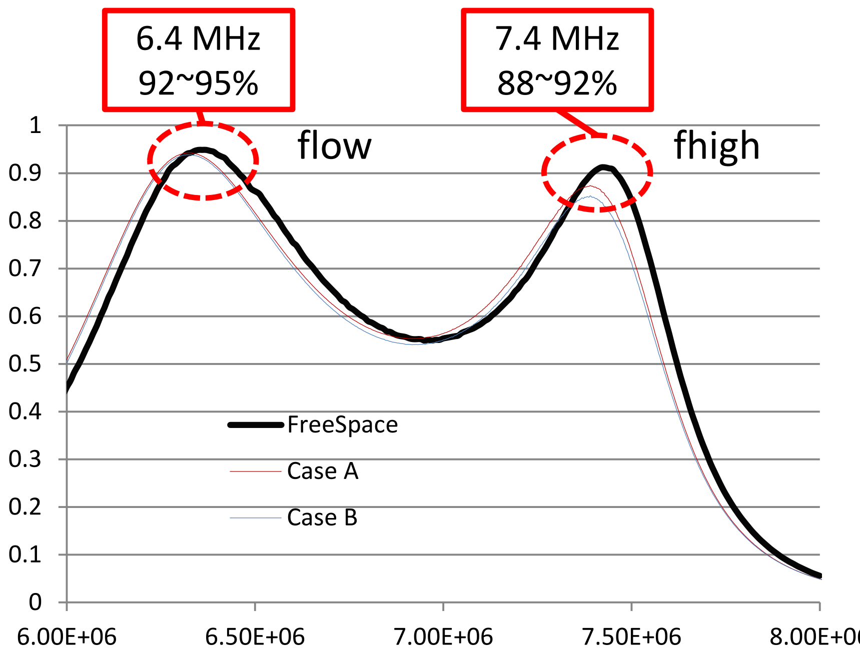
(compared with hundreds of mW for wireless communication devices)

Typical Frequency Dependence of Power Transmission Efficiency

Transmission efficiency between input-output loop |S21| is measured and calculated by FEKO software



EM simulation



Measured by *3

- Resonance frequency and efficiency are constant regardless of the arrangement of dielectrics
- About 5% deviation in measured/calculated resonance frequency

⇛ Manufacturing error

*3 Agilent Technology Network Analyzer E5071C

Specific Absorption Rate (SAR) Definition Used for Human Exposure Assessment

SAR: Power absorbed by unit mass of human body

$$\mathrm{SAR} = \frac{\sigma |E|^2}{\rho} \ [\mathrm{W/kg}]$$

σ : conductivity of human body (phantom) [S/m]

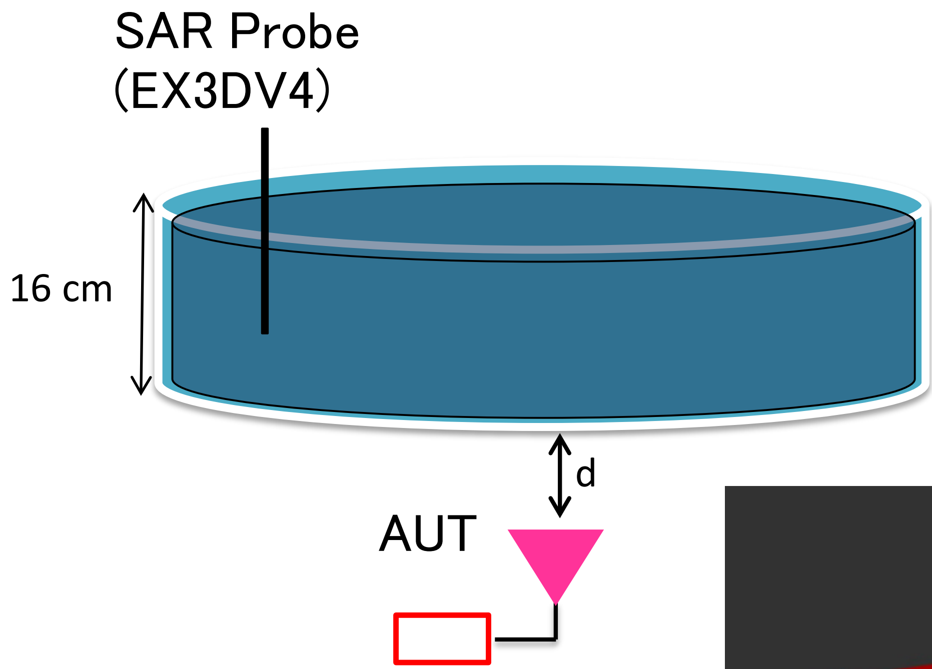
$\boldsymbol{E}$: E-field inside human body (phantom) [V/m]

ρ : human body density [$\mathrm{kg/m^3}$]

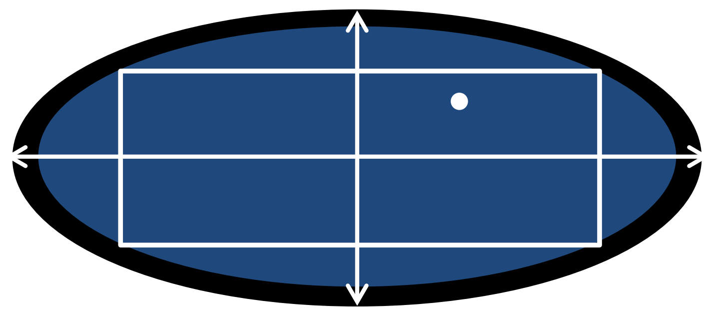
Local SAR	10-g average SAR value (1-g average by FCC)
Whole body average SAR	The average value of SAR in the whole human body

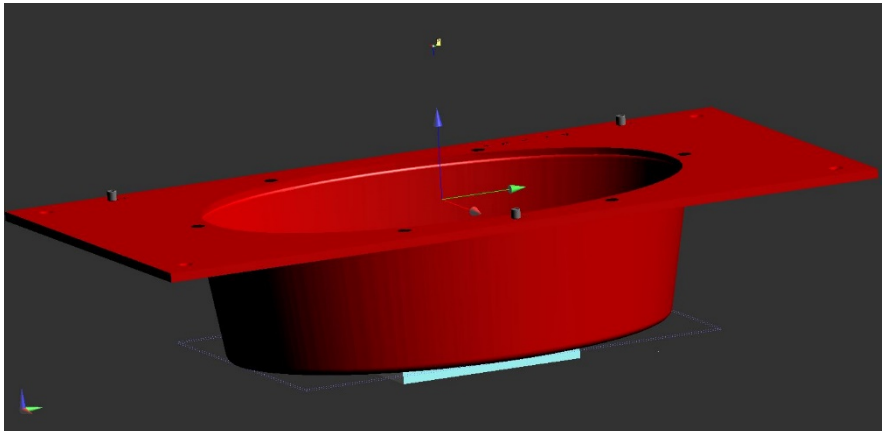
Liquid Phantom SAR Measurement Setup

Flat phantom according to IEC 62209-2 Standard



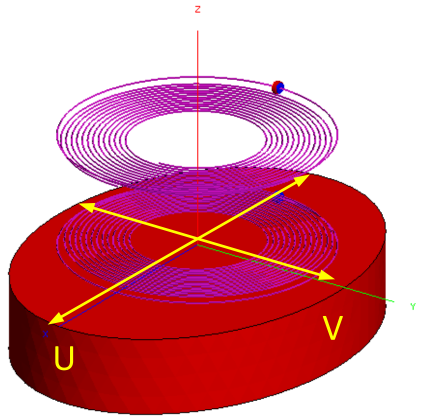
Phantom dimensions:
60 cm × 40 cm, 30 liters



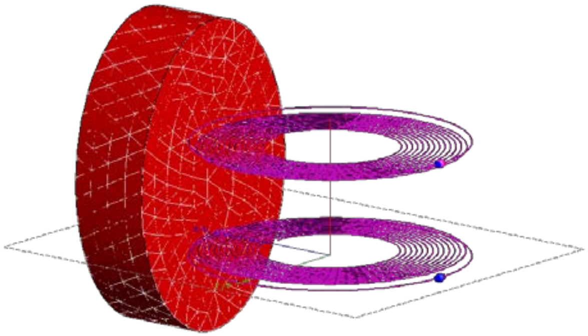


Effect of Phantom Size Variation on SAR Values

EM simulations of inductive coupling WPT coils operating close to the elliptical and rectangular phantoms with varying dimensions

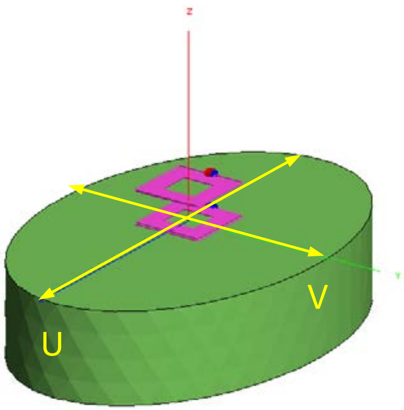


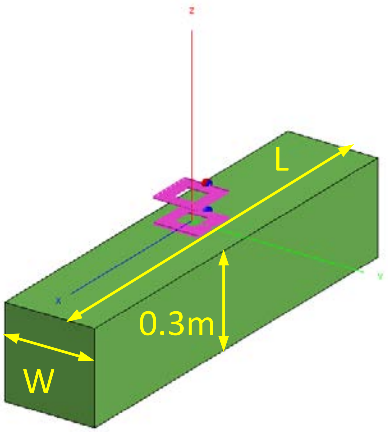
U/V=1.5



Case 1: large coils parallel to elli phantom

Case 2: large coils normal to elli phantom



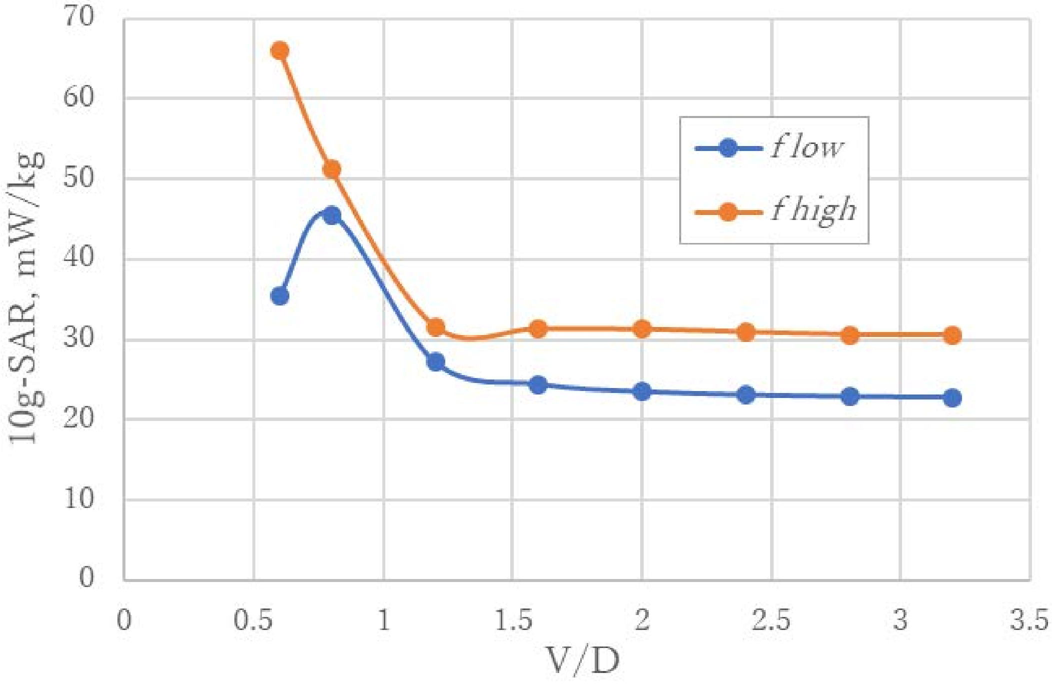


Case 3: small squared coils (10cm X 10cm) parallel to elli phantom

Case 4: small squared coils (10cm X 10cm) parallel to rectangular phantom

Case 1: 10g-SAR versus the smaller axis of elliptical phantom V normalized by coil diameter D

flow = 6.14 MHz, fhigh = 7.18 MHz, 1W excitation ports

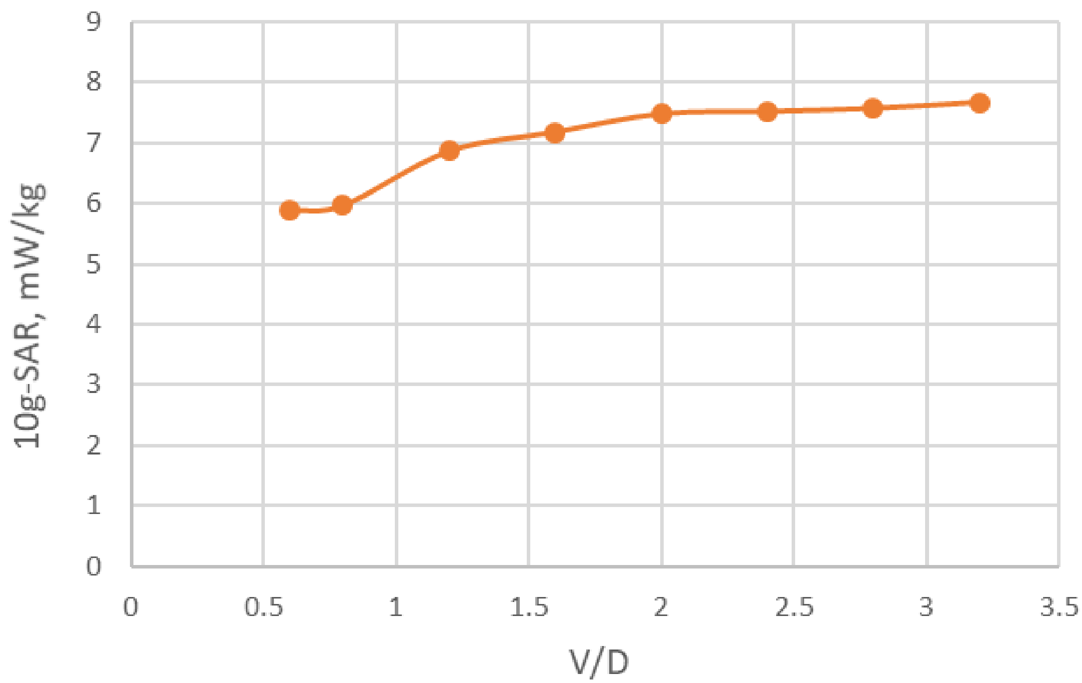


D =50 cm

phantom height is fixed (15 cm)

Case 2: 10g-SAR versus the smaller axis of elliptical phantom V normalized by coil diameter D @fhigh

flow = 6.64 MHz, fhigh = 7.54 MHz

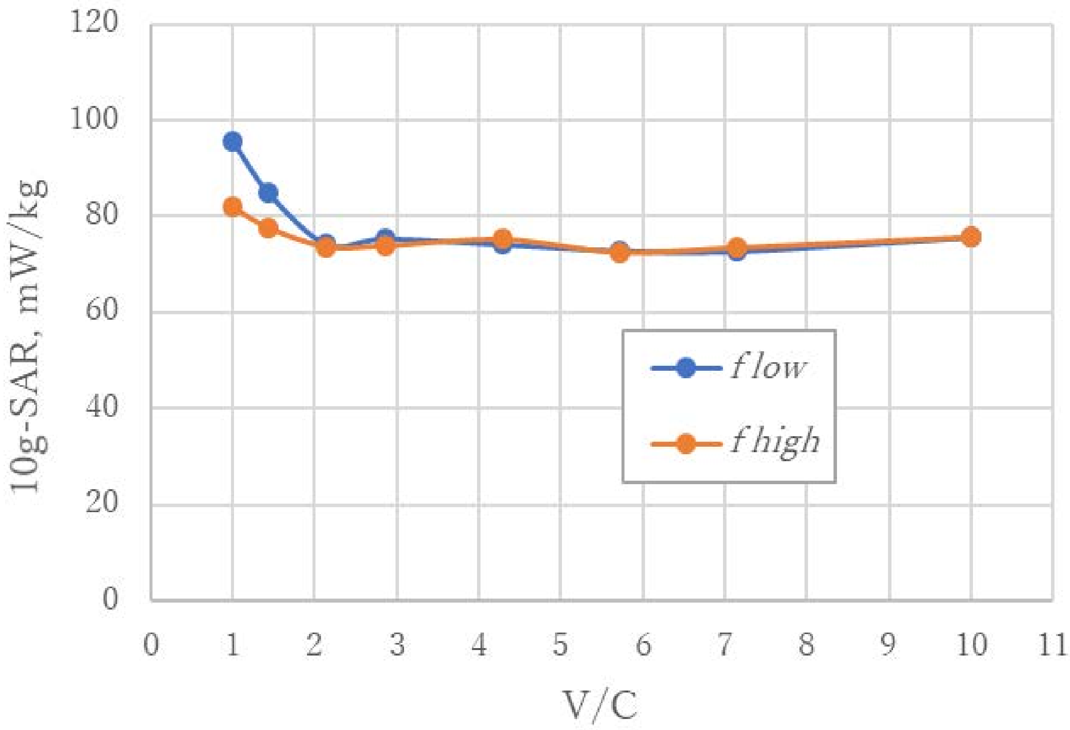


D =50 cm

phantom height is fixed (15 cm)

Case 3: 10g-SAR versus the smaller axis of elliptical phantom V normalized by square coil diagonal C

flow = 6.6 MHz, fhigh = 7.64 MHz, 1W excitation ports

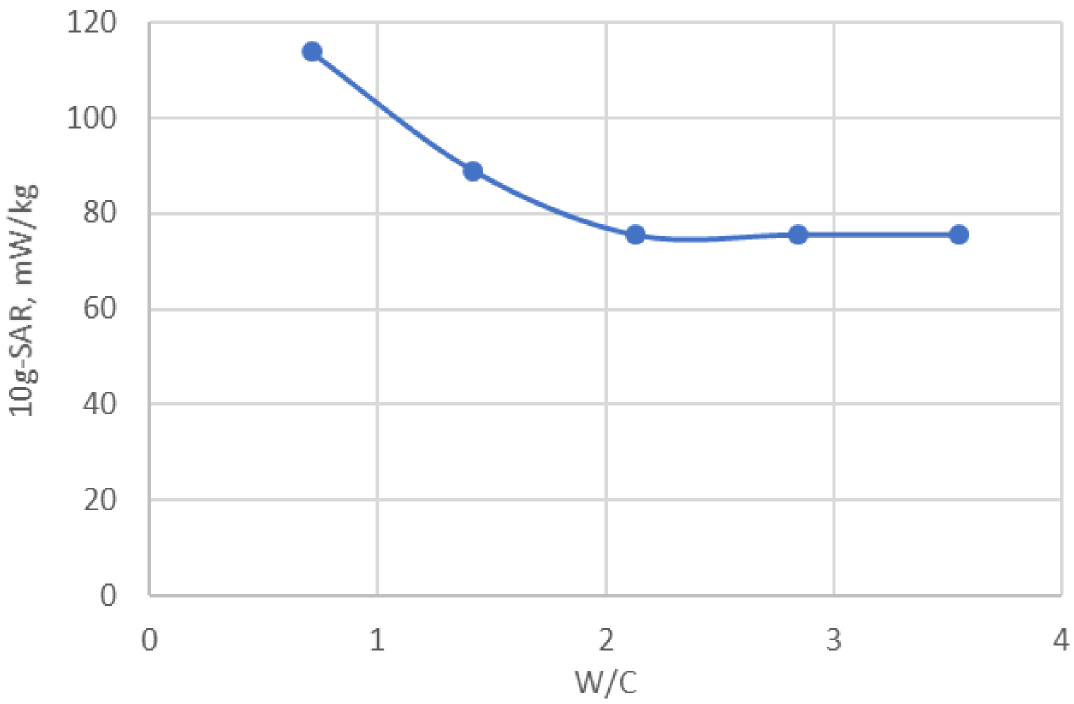


50 cm X 10 cm coils

phantom height is fixed (15 cm)

Case 4: 10g-SAR versus the width W of rectangular phantom normalized by square coil diagonal C @flow

flow = 6.59 MHz, 1W excitation ports



L =90 cm

Conclusions:

- In case of circular spiral coils placed parallel to elli phantom, SAR increases substantially (with a factor of 2) with the decrease of the phantom dimensions. 10g-SAR reaches maximum when the coil diameter is comparable to the length of elliptical smaller axis.
- Such an effect is not observed when spiral coils are placed normal to the elli phantom. SAR level remains much lower than in Case 1 with the small decrease as the phantom dimensions decrease. The difference is attributed to the different orientations of E-field vectors with respect to the phantom surface.
- In case of small squared coils parallel to elli phantom, similar effect is obtained. 10g-SAR reaches maximum when the coils size becomes comparable to the elli dimensions. The SAR factor increase is somewhat smaller.
- In case of small squared coils placed parallel to the rectangular phantom, SAR increases with the decrease of the phantom width. When the phantom length is fixed, SAR is increased substantially when the phantom width becomes equal to the coil size. However, the maximum SAR value in case if a narrow phantom is obtained at the certain phantom length (L=1.2m).
- The results obtained should be considered for selecting the phantoms with proper dimensions in the SAR measurements and human exposure assessment of WPT systems.

Acknowledgements:

- This work was supported by the Ministry of Internal Affairs and Communications of Japan.

Thank you for your attention !