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Measurement of Human Body Absorption Cross Section from 1 GHz to 18 GHz in Reverberation Chamber

Xiaotian Zhang, Martin Robinson, Ian Flintoft

Department of Electronics, UNIVERSITY of York

Introduction

The electromagnetic radiation dosimetry study on human body is of great interest today, not only because of the safety exposure problems, but also because of its applications to communications such as the indoor radio channel modelling.
It is clear that morphology determines the electromagnetic power absorption. This research focuses on the inverse problem, which is inferring morphology from absorption cross section, especially parameters such as body surface area and average fat layer thickness.

ACS and morphology

Absorption cross section (ACS): ACS equals to the ratio of power losses in an object to the power density of a plane wave incident from a specific direction (θ, ϕ).

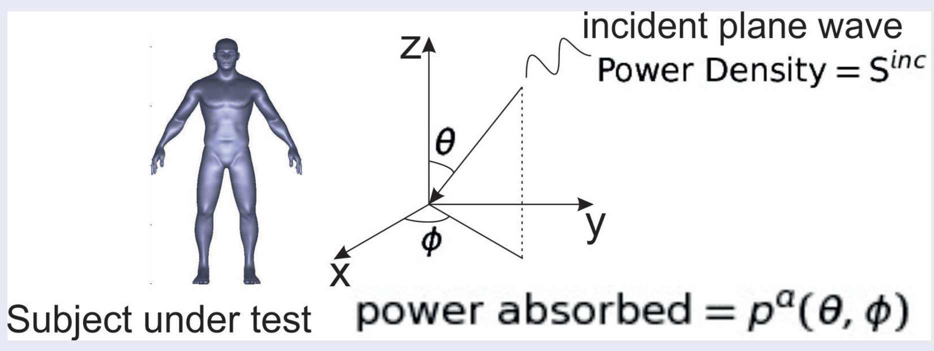

Figure : Definition of ACS

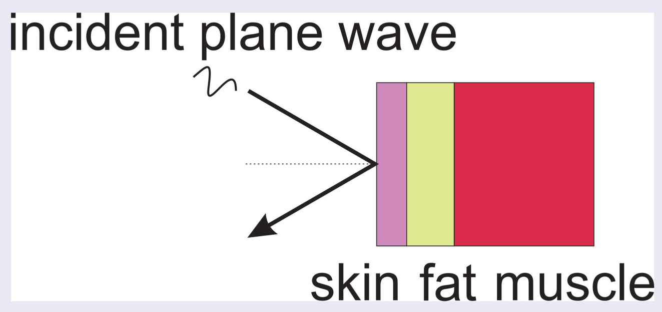

Figure : Power absorbed by a three layer model

$$\sigma^a(\theta, \phi) = \frac{p^a(\theta, \phi)}{S^{inc}} \quad (1)$$

$$< \psi^a > = < \sigma^a > / < g > \quad (2)$$

where $< \psi^a >$ is the averaged absorption efficiency; $< \sigma^a >$ is the ACS averaged all different angles; $< g >$ is the averaged silhouette area of subject over all directions. The surface structure of the lossy object can make a huge difference to the absorption efficiency.

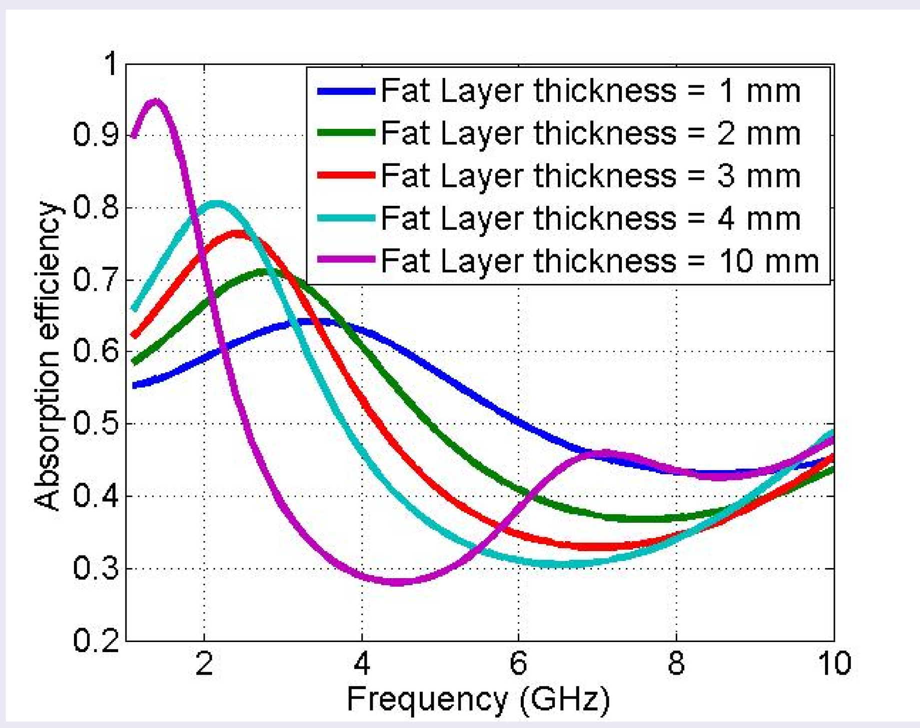

Figure : Absorption efficiency of a three layer sphere phantom

Measurement of ACS in the reveberation chamber

Reverberation Chamber (RC): The reverberation chamber is a cavity loaded with a moving stirrer which creates a stochastic field configuration inside. The object inside the reverberation chamber is illuminated by plane wave coming from all directions.

Chamber time constant τ : The charged reverberation chamber would lose stored energy experientially. The higher the loss inside the chamber is, the quicker the energy decays. The chamber time constant is the time for a reverberation chamber to lose its stored energy to $1/e$ of the initial level when the input power is cut off.

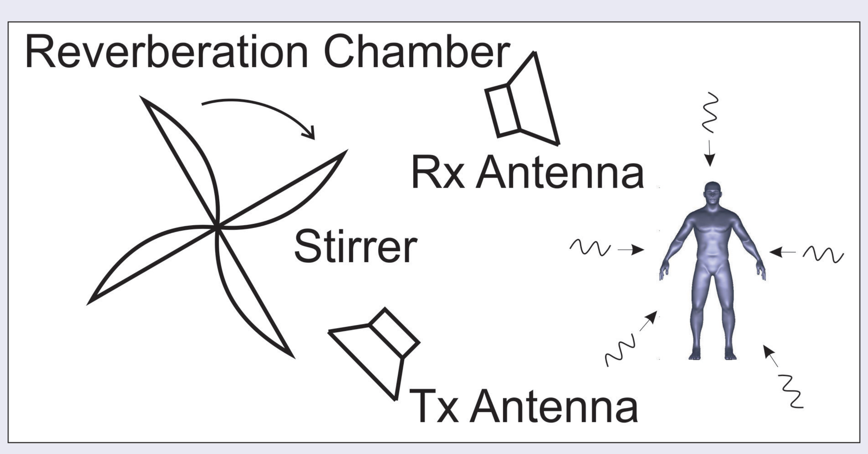

Figure : RC setup

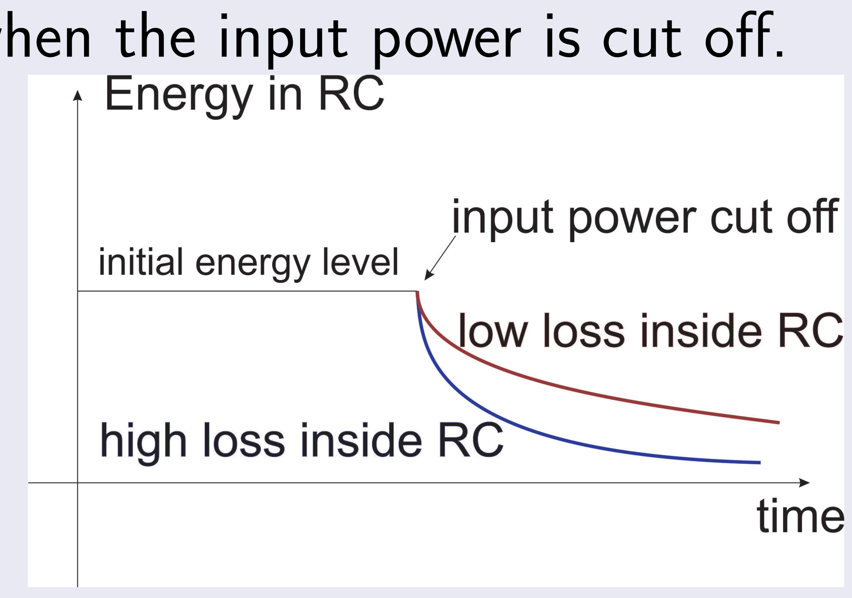

Figure : Energy loss in reverberation chamber (high loss and low loss)

Formula for calculating averaged ACS

$$< \sigma > = \frac{V}{c_0} \left(\frac{1}{\tau_{loaded}} - \frac{1}{\tau_{empty}} \right) \quad (3)$$

V: chamber volume; $< \sigma >$: Averaged ACS

Measurement validation with spherical phantom

ACS measurement of spherical phantom A spherical phantom filled with deionized water was put insider the reverberation for ACS measurement.

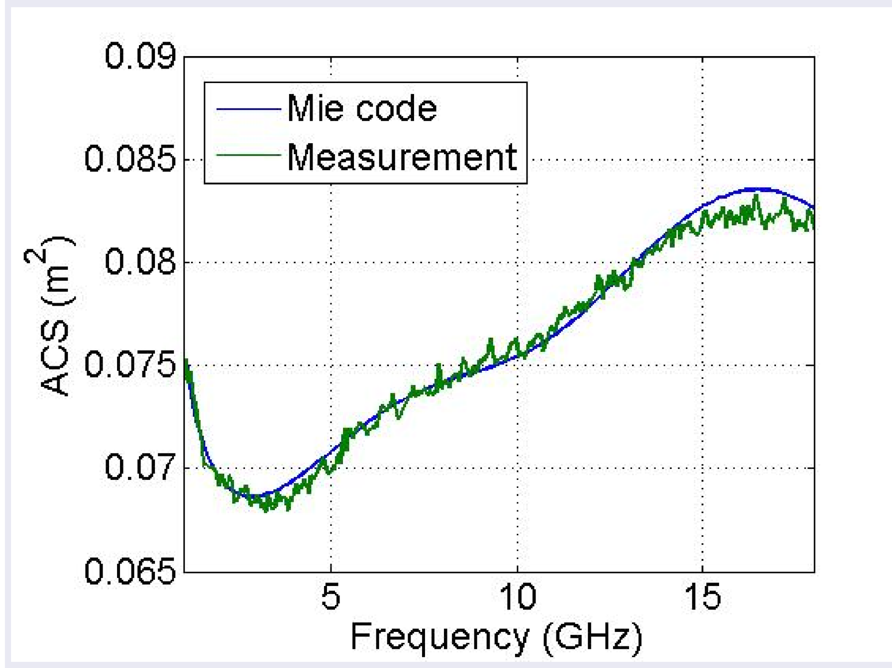

Figure : ACS of the spherical phantom

Figure : the ACS measurement in reverberation chamber

The measured average ACS was compared to the prediction of an analytic model based on Mie Theory [1]. Very good agreement was found within the uncertainties of the input parameters.

Results

Human study: A preliminary study on the ACS of 18 Human subjects has been conducted. The participants laid on a 60 cm high polystyrene block (2 times of the wave-length at 1 GHz). The morphology data, including the age, sex, height, weight, skin fold thickness are recorded.

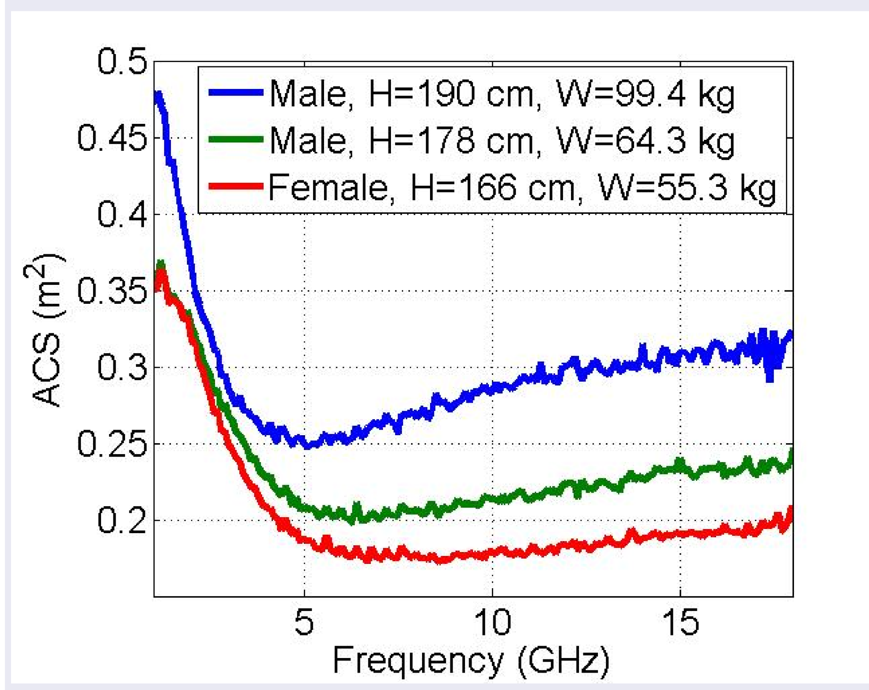

Figure : Human body ACS of three subjects as example

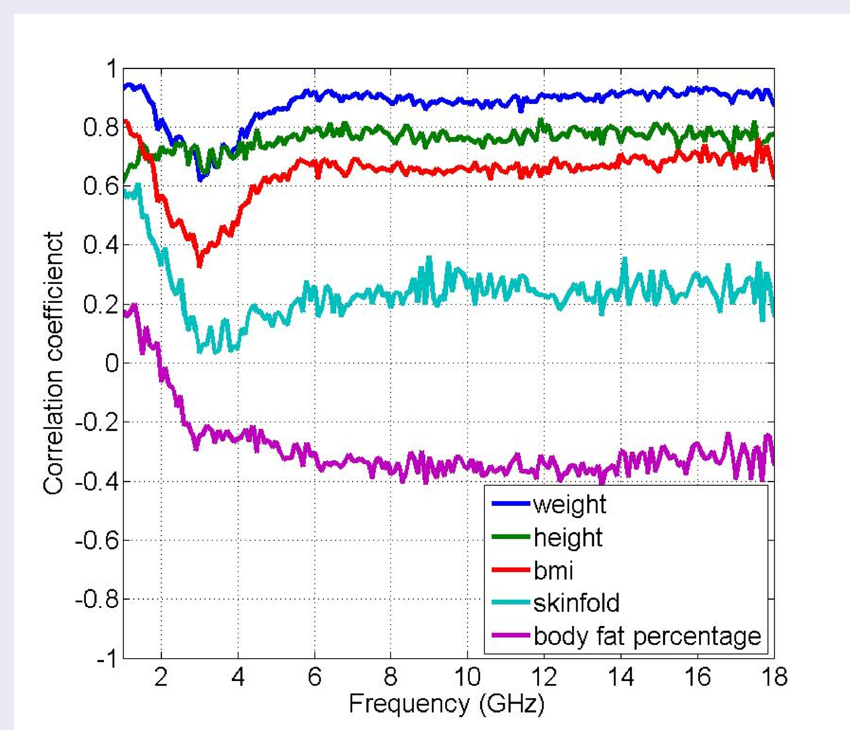

Figure : Correlation coefficient between ACS and morphological parameters

The body fat percentage of each subject is calculated using the formula given by J. Durnin and J. Womersley[2]

Conclusions

The ACS measurement of a single participant can be achieved in 10 minutes. A Preliminary study shows a close correlation between ACS and height above 6 GHz, but below 6 GHz, the correlation between ACS and morphology parameters is weaker.
More subjects will be collected for a full statistical study, and an optimizer is being designed to enable the reverse mapping of ACS to morphological parameters.

references

- E. Le Ru and P. Etchegoin, "Splac package v1. 0 guide and supplementary information," 2008.
- J. Durnin and J. Womersley, "Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged from 16 to 72 years," *British journal of nutrition*, vol. 32, no. 01, pp. 77–97, 1974.

Email: martin.robinson@york.ac.uk, ian.flintoft@york.ac.uk, xz1148@york.ac.uk