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工学　研究科　人工システム科学　専攻　メディカルシステムコース
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論文題名（外国語の場合は、その和訳を併記） Thesis Title（foreign language title must be accompanied by Japanese translation）
Evaluation of RF Exposure for Pregnant Woman from Wireless Radio Terminal （携帯無線端末による妊娠女性での電波ばく露量評価）

Abstract

1. Background

Recently, there has been rapid expansion in the use of portable telecommunications technology based on electromagnetic (EM) waves. For instance, mobile-cellular subscriptions are used by over 3.5 billion people in the world [1], and in Japan over 100 million people subscribe to them [1]. In particular, the new wireless radio terminals such as tablet computers with the data communication come into wide usage for various positions in proximity to the human body in different from conventional mobile phones intended to only voice communication. Consequently there has been growing interest in evaluating interactions between the human body and EM waves from such devices. In sum, it is necessary to evaluate the influence for the human body exposed to EM waves from antennas of wireless radio terminals and for the antenna characteristic close to the human body. In particular, this dissertation focused on the effect for the human body from wireless radio terminals.

Until now, evaluations of the radio-frequency (RF) exposure for the human body from wireless radio terminals have been studied in the world. These studies focused on exposure levels for the human head because mobile phones with the 2nd-generation (2G) wireless communication system are used close to the human head during calling. However, recent mobile phones with the data communication owing to 3rd- and 4th-generation wireless communication systems are used in various configurations, e.g., in the vicinity of the human abdomen.

There are deep concerns about the RF exposure for developing organs and tissues such as a fetus during the pregnancy. However, the studies of the RF exposure for pregnant women and their fetuses are insufficient in spite of the usage of the recent mobile phone in the vicinity of the abdomen (see in Fig. 1). The primary effect for the human body owing to microwaves using

wireless radio terminals is thermal heating. M. J. Edwards *et al*. [2] reported that the excessive temperature elevation effects to the health of the fetus. However, the safety guidelines of the RF exposure for the pregnant woman and fetus have not been established yet. Therefore, World Health Organization (WHO) announced the evaluation form the view of the EM safety for the pregnant woman and fetus is one of the priority research topic [3].

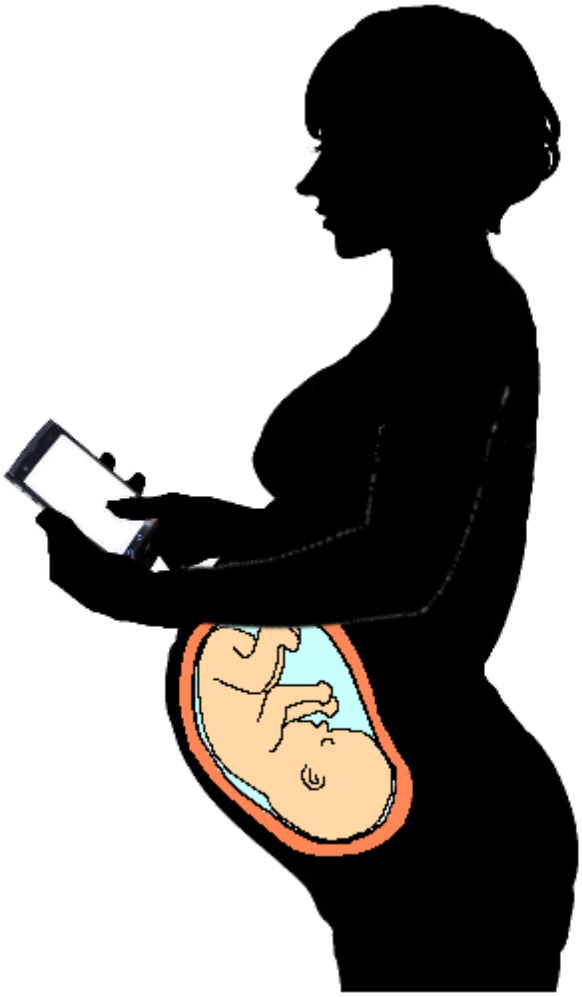

Fig. 1 Usage form of wireless radio terminal close to the abdomen of pregnant woman.

2. Effects of EM waves for human body

The effects of the EM waves for the human body depend on the frequency. In the case of higher frequency than the ultraviolet so-called the ionizing radiation, this EM waves makes bio molecules ionized. Therefore, the ionizing radiation directly causes the cancer and leukemic disease because it damages a gene in a cell. On the other hand, EM waves below the frequency of the ultraviolet are called the non-ionizing radiation.

In recent years, studies on the influence of the human body owing to various frequency bands, e.g., extremely low frequency (ELF) band including the commercial frequency bands of 50 Hz and 60 Hz, and ultra high frequency (UHF) band using wireless radio terminals. These frequencies are included in the non-ionizing radiation.

The primary effects for the human body owing to the non-ionizing radiation are altered around 100 kHz. Below 100 kHz such as the ELF band, the induced current because of the fluctuation of the magnetic field in the body tissues causes the stimulant effect for the human body. Whereas, above 100 kHz such as the UHF band, absorbed EM energy in the human tissues mainly contributes to the thermal effect because the human body performs as the lossy media for EM waves. Since the microwave band using wireless radio terminals is above 100 kHz, the thermal heating is dominant effect for the human body from wireless radio terminals. Up to now, the most recognized that RF exposure standards adopt the specific absorption rate (SAR) as the basic parameter. Therefore, the safety guidelines of EM waves from wireless radio terminals are based on the SAR [4], [5]. For reference, Fig. 2 shows the effects of EM waves for human body owing to different frequencies.

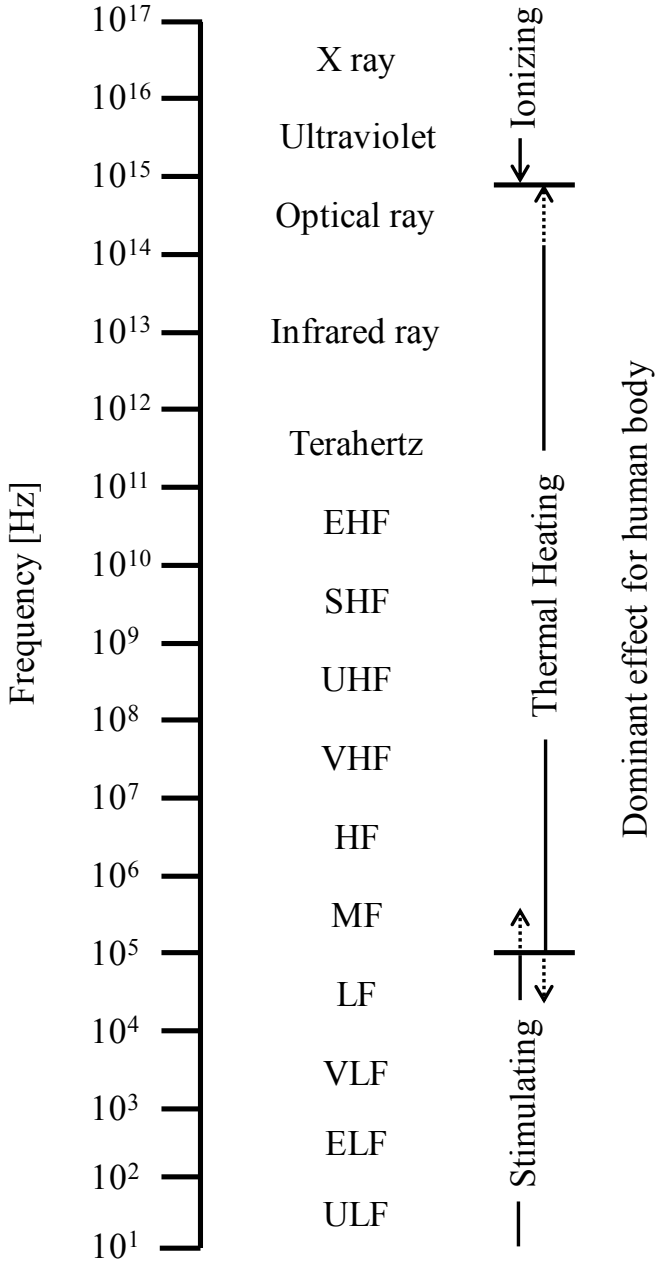

Fig. 2 Effects of EM waves for the human body owing to different frequencies.

3. Objectives of this study

This dissertation presents the evaluation of the RF exposure for the human body, in particular pregnant women and fetuses, from wireless radio terminals assumed the utilization close to the human abdomen.

For local exposure from antennas of wireless radio terminals, 10-g-averaged SAR, which is obtained by averaging SAR over a mass of 10-g at arbitrary body tissues, is often evaluated and compared with the safety guidelines. However, the safety guideline of the SAR for fetuses has not yet been set any limiting value. Therefore, it is important to evaluate temperature elevations for fetuses caused by the absorption of EM radiation; temperature elevations serve as the basis for setting SAR guidelines and the index of the threshold for thermal effects on fetuses. In light of the difficulty of evaluating 10-g-averaged SARs and temperature elevations for an actual human body by the measurement owing to ethical issues, the 10-g-averaged SARs and temperature elevations for the human body has been estimated by the computational calculation using a numerical model of the human body. Therefore, many numerical models with the anatomical structure of the human body to estimate the SAR by numerical calculations have been developed [6]-[9]. Moreover, studies on SARs for the human head radiated from the mobile phones have been conducted ever [10]-[15]. However, the recent wireless radio terminals are not used in the vicinity of only human head but also human abdomen, that is to say, pregnant women can use them in proximity to fetuses.

There are several papers reported about SAR evaluations for pregnant women and fetuses [16]-[1-22]. For the far-field exposure, Nagaoka *et al*. [16], Dimbylow [17], and Dimbylow *et al*. [18] reported the SAR evaluations owing to the plane wave for the pregnant woman and fetus. For the near-field exposure, Togashi *et al*. [19] have calculated whole-body-averaged SARs, which is estimated by averaging the SAR over a whole body, for a fetus at a 26th gestational weeks exposed to a half-wavelength dipole antenna and a planar inverted-F antenna (PIFA) with a metallic case operating at 900 MHz and 2 GHz; these are typical frequency bands of 3G communication systems. In addition, they did not deal with the 10-g-averaged SAR and

temperature elevation for pregnant woman and fetuses. Akimoto *et al*. [20] have calculated the 10-g-averaged SAR and temperature elevation for a fetus when a normal-mode helical antenna on a metallic box assumed the wireless radio terminal for the professional-use was placed at the sides of the abdomen of a female who was in the 26th gestational week of pregnancy. Body types and anatomical structures of the pregnant woman and fetus differ depending on the stage of fetal growth. Therefore, evaluations for various gestation ages are important, but in [19] and [20], those have not been reported. Moreover, the EM sources were simple structure. The development of realistic wireless radio terminals is also important because the RF exposure levels and situations may be different between simple and realistic wireless radio terminals. Consequently, this dissertation is expressly described as follows:

1. Evaluations of SARs and temperature elevation during pregnancy from simple EM sources operating at 900 MHz and 2 GHz using anatomical models with different gestational weeks.
2. Development of numerical models of realistic wireless radio terminals such as a flip phone and tablet computer for evaluations of RF exposure.
3. Evaluations of the EM safety for pregnant women and fetuses from the realistic wireless radio terminal models.

Finally, on the basis of the results of above investigations, this dissertation proposes one of a safety guideline for fetuses using the wireless radio terminals close to the human abdomen as a reference.

4. References

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