Localized electric field generating for rats head using a patch antenna in 26.5 GHz band

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Abstract: In this paper, two types of patch antenna that can be used for animal experiments are proposed. The proposed antenna can generate a localized electric field at the head of the rat. The operating frequency of the system is 26.5 GHz. This frequency is used the fifth generation of mobile communication (5G). The localization of the electric field is evaluated by the ratio between target area field and whole body field.

Keywords: patch antenna, reflection coefficient, SAR

Classification: Antennas and Propagation

1 Introduction

In recent years, the fifth generation of mobile communication (5G) has been actively developed. In this communication system, relatively higher frequency ranges such as 28 GHz will be used. On the other hand, while the mobile
communication device using, a part of electromagnetic energy is absorbed by the human body including the head. The guidelines [1] are provided to protect human safety. However, guidelines for higher than 10 GHz have not been provided, and animal experiments have not been conducted to evaluate the effects of health. In order to investigate the health effect, localized electric field should be realized for rat head to simulate human mobile device use. Then, it is necessary to develop an antenna for animal experiments. In this research, we develop two types of antennas to be used for animal experiments at 26.5 GHz. These antennas are designed by numerical simulation using the FDTD method.

2 Localized field generating by the patch antenna

In this animal experiment, the electromagnetic field should be concentrated on the rat head by the antenna. The patch antenna that satisfies both conditions is used in this research [2]. For further miniaturization, a shorted patch antenna is utilized. It is expected that shorted patch antenna is less affected to the reflected waves from the rat. In the antenna design, the inner conductor radius of the coaxial cable is considered for modeling realistic model. The antenna parameters are decided based on ref. [3]. Fig. 1(a) shows patch antenna, Fig. 1(b) shows a shorted patch antenna [3, 4]. The reflection characteristics of the antennas are calculated. In this calculation, the 8 weeks old rat model is placed near the antennas as shown in Fig. 1(c). The aim of this research is to generate localized electric field at the target area. In this paper, the target area is defined as shown in Fig. 1(c). The distance between the antennas and the target area is 4 to 5 mm. The radiating element size of the shorted patch antenna is about a quarter of the size of the normal patch antenna. Fig. 1(d) and Fig. 1(e) show the calculated reflection coefficients of the normal patch antenna and the shorted patch antenna, respectively. In these calculations, the antenna is placed above the rat and the distance \( H \) is 4 and 5 mm. In these results, both antennas satisfy \(-10 \text{ dB} \) at 26.5 GHz at any distance. As comparing with the normal patch antenna, the shorted patch antenna has less change in resonance frequency.

Next, the localization of the electric field in the rat is evaluated. The SAR (Specific Absorption Rate) is used to evaluate the localization.

\[
SAR = \frac{\sigma E^2}{\rho} \tag{1}
\]

The SAR is defined by eq. (1).

\[
Localization = \frac{SAR_{TA}}{SAR_{WB}} \tag{2}
\]

In this paper, the localization is defined by eq. (2).

In eq. (2), \( SAR_{TA} \) is SAR average of target area, \( SAR_{WB} \) is SAR average of whole body of the rat.

Figs. 2(a), (b), (c), (d) are projection views of the SAR when the distance \( H \) is 5 mm. The target areas are indicated as a circle in these figures. The electromagnetic waves are intensively exposed to the head in both antennas. Next, the localization and average SAR in the rat model is indicated in Table I. The input power of the antennas is 1 W. Regarding the value of SAR in target area, as distance \( H \) is
decreased, the value of $SAR_{\text{average}}$ increases both antennas. The localities of both antennas are a quite high value compared with other proposed antennas [5]. In these calculations, the localization of the shorted type patch antenna is lower than the normal patch antenna, however, the localization is high enough. Therefore, both antennas can be used for our purpose.

Fig. 1. Rat model, antenna parameters and reflection coefficient
3 Conclusion

In this research, two types of patch antenna that can be used for animal experiments are developed. The SAR and the localization are calculated by the simulation. The developed antennas can be generating localized field for rat head.

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### Table 1. Evaluation of electromagnetic field exposure

|                | SAR_{average} [W/kg] |
|----------------|---------------------|
|                | Patch antenna       | Shorted patch antenna |
|                | 4 mm                | 5 mm                  | 4 mm                | 5 mm                  |
| Fat            | 0.00627             | 0.00551               | 0.0126              | 0.0135                |
| Muscle         | 0.146               | 0.159                 | 0.178               | 0.187                 |
| Bone           | 2.54                | 2.37                  | 1.72                | 1.59                  |
| Organ          | 0.00699             | 0.00734               | 0.00400             | 0.00461               |
| Eye            | 67.9                | 64.9                  | 46.0                | 47.4                  |
| Brain          | 13.5                | 12.6                  | 8.05                | 7.57                  |
| Skin           | 13.7                | 13.4                  | 12.1                | 12.0                  |
| Target area    | 776                 | 631                   | 271                 | 254                   |
| Whole body     | 1.83                | 1.78                  | 1.59                | 1.58                  |
| Absorption rate [\%] | 0.54              | 0.53                  | 0.42                | 0.42                  |
| Localization [\%] | 425                | 354                   | 170                 | 161                   |

![Fig. 2. Projection views of the maximum value of SAR](image)