Local specific absorption rate reduction method for 1.2-GHz band handheld transceiver with a reflector

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Abstract: As the allowable antenna power of amateur stations is higher than that of smartphones, the specific absorption rate (SAR) is expected to increase. However, to date, there has been limited research on handheld FM transceivers and SAR for amateur stations. Therefore, this study focuses on the 1.2-GHz band, which is the highest frequency of all commercially available handheld FM transceivers, and proposes a monopole antenna with a reflector to reduce SAR. The finite-difference time-domain method was employed to conduct simulations using a brain-equivalent simple model and a real numerical human body model. It is confirmed that by installing a reflector, SAR can be reduced without significantly changing the antenna characteristics.

Keywords: amateur radio, SAR, FDTD, reflector, transceiver

Classification: Antennas and Propagation

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1 Introduction

Japan is prone to natural disasters, such as earthquakes, volcanoes, typhoons, and floods, which often disrupt the country’s communication infrastructure. In such emergency situations, the amateur station transceiver is used not only for training and technical research in wireless technologies but also as an emergency communication medium [1]. Communication terminals, such as the handheld transceivers used by amateur stations, are operated at close proximity to the human head; therefore, the human body is exposed to electromagnetic waves. As amateur stations have a larger allowable antenna power than other typically used communication terminals (smartphones), it is essential to determine the levels of electromagnetic wave exposure. The specific absorption rate (SAR) defined using Eq. (1) is a guideline value for evaluating electromagnetic wave exposure.

$$\text{SAR} = \frac{\sigma}{\rho} E^2 \text{ [W/kg]} \quad (1)$$

where E [V/m] is the effective value of the electric field, σ [S/m] is the conductivity of the living tissue, and ρ [kg/m³] is the density of the living tissue. In Japan, for groups receiving occupational exposure from wireless terminals (in a controlled environment), the local average value (SAR_{10g}) of any 10 g of living tissue is specified to be 10 W/kg or less. However, it is difficult to take preventive measures or to avoid/minimize exposure in general environments where many people of different ages and health conditions may gather; in these situations, SAR with a five-fold safety margin is prescribed [2]. Although one research example [3] exists of a handheld transceiver used in the commercial radio-frequency band, there are few reports regarding commercial handheld FM transceivers for use in amateur stations. This type of commercially available FM handheld transceiver operates at three frequency bands of 144 and 430 MHz, and 1.2 GHz. However, there is limited research available on other frequency bands. Additionally, as people other than those with amateur station licenses may gather in disaster areas, it is desirable to use a handheld transceiver with a low SAR value. Consequently, the focus of this study is the 1.2-GHz band, which is expected to have a shorter wavelength and higher local SAR than the 144 and 430-MHz bands. By applying an antenna element with a reflector [4], which reduces the strength of the magnetic field, to a 1.2-GHz band handheld transceiver, it is proposed that the SAR can be reduced when the human body is in close proximity without any degradation of the antenna characteristics.

2 Building a simulation model

An antenna model simulating the DJ-G7 (ALINCO) [5] is presented in Fig. 1(a) ANT1 refers to the antenna comprising a monopole antenna mounted on a metal housing, while ANT2 refers to the antenna comprising a monopole antenna and a reflector mounted on a metal housing. The monopole antenna and reflector were modeled by thin line approximation. Fig. 1(b) contains a simulation model of the antenna and the human body. To determine the worst SAR value, a brain-equivalent simple model with a side length of 200 mm was used. The electrical constants were set for relative permittivity $\epsilon_r = 51.56$, conductivity $\sigma = 1.076$ S/m, density $\rho = 1030$ kg/m³, and 1.2 GHz [6]. Additionally, the study used the real numerical human body model [7] from the National Institute of Information and Communications Technology due to its higher definition than the simple model, which allowed an analysis that was closer to actual conditions. The real model has a heterogeneous structure with a resolution of 2 mm³, and the electric constants are set according to each tissues, and the electric constants are almost the same as

Fig. 1. (a) Antenna models. (b) Simulation models and distance d .

published in IFAC [6]. The straight-line distance from the antenna's feeding point to the surface of the central part of the simple model and to the tip of the nose of the real model was defined as d [mm]. A commercially available finite-difference time-domain method simulator (XFDTD: ver.7.8.0) was used for the analysis of the models. Assuming a simulation in free space, the absorption boundary was defined by seven levels of perfectly matched layers, and the analysis area was restricted to the head.

3 Simulation results of specific absorption rate and antenna characteristics

Fig. 2 presents the change in the peak SAR_{10g} value with distance d [8]. The minimum distance between the human body and the terminal was set to 25 mm, and the DJ-G7 transmission power in the 1.2-GHz band was standardized with an allowable value of 1 W. Using both the simple model and ANT1, it was found that $SAR_{10g} \leq 2$ W/kg is not satisfied at $d = 25$ –30 mm. Furthermore, the worst SAR_{10g} value was confirmed to be about 2.5 W/kg ($d = 25$ mm). The peak value of ANT2

Fig. 2. Change of peak of SAR_{10g} by distance d [8].

(b) z - y plane

(c) x - y plane

Fig. 3. Antenna characteristics analysis. (a) Change of S_{11} by distance d [8]. (b) The z - y plane radiation pattern [8]. (c) The x - y plane radiation pattern [8].

was found to be smaller than that of ANT1 at all distances, and $SAR_{10g} \leq 2$ W/kg was realized for both the simple and real models, i.e., it was confirmed that ANT2 is a SAR_{10g} value that can be applied to a general environment, and that the regulation value can be satisfied, even in a location that is densely crowded with people from the general population, such as a disaster area.

The change of S_{11} with the distance d is shown in Fig. 3(a) [8]. In the case of the simple model, ANT2 has better impedance matching with the power supply line than ANT1 after $d = 28$ mm, and the reflection coefficient decreases. Similarly, in the case of the real model, the reflection coefficient of ANT2 is smaller than that of ANT1 at all distances. Additionally, $S_{11} \leq -10$ dB was satisfied by both ANT1 and ANT2 at any distance, and efficient radio wave radiation was confirmed in both models.

Figs. 3(b, c) show the radiation patterns of ANT1 and ANT2 in the case of $d = 25$ mm, respectively. The radiation patterns of ANT1 and ANT2 in the free space where the human body does not exist are also added for comparison. For the simple model, a change in both ANT1 and ANT2 results in an increase in gain to a maximum change of about 5 dBi. For the real model, the change in the radiation pattern due to the presence or absence of the reflector is minimal in both cases up to a maximum of about 1.5 dBi. From these findings, it is confirmed that a reduction in SAR without deterioration of antenna characteristics can be realized by mounting the proposed reflector.

4 Conclusions

This paper evaluated the SAR and various antenna characteristics when a monopole antenna with a housing equipped with a reflector was placed near the human body model. The findings confirmed that it is possible to achieve a lower SAR compared with conventional handheld transceivers. The proposed method reduced SAR by a maximum of 33% by installing a reflector; the reflection coefficient is less than -10 dB, and there is minimal change in radiation directivity. Therefore, the approach is considered to be effective for reducing SAR. A future research objective would be to clarify the SAR and various antenna characteristics under conditions of human body deformation.

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