# Antenna Performance of Push-to-Talk Transceiver in VHF and UHF Bands Considering Impedance Matching

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***Abstract*—The push-to-talk communication line for broadcasting services is used in the VHF band (165 MHz) and UHF band (460 MHz) in Japan. It is used for communication between staff during news gathering, television and radio program production, and so on. We designed a helical antenna with a metallic case as a handheld type transceiver and calculated the characteristics of the antenna with a numerical model of the human body. To investigate the effect of the human body on the performance of the antenna and the specific absorption rate on the human body, we calculated the antenna gain, radiation patterns and SAR when the antenna is in close proximity to the face. From these results, we propose using push-to-talk transceivers at a distance "*d*" that is more than 100 mm from the view point of antenna gain and SAR.**

## I. INTRODUCTION

Push-to-talk radio communication lines for broadcasting services are often used for communications during the production of a variety of programs [1]. They provide an effective communication means that enables accurate and also reliable transmission, particularly during a disaster or the like. The transceivers can be handheld or vehicle-mounted, but handheld walkie-talkies are the most commonly used. With a handheld transceiver, though, the transmission antenna is used in close proximity to the human body, so there is concern that the body could have an effect on the antenna gain and radiation pattern, affecting the radiation characteristic of the antenna by itself.

Previous reports relating to the effects of the human body on VHF-band and UHF-band transceivers include those which deal with study examples in which the human body is replaced by an elliptical cylinder [2], examples of studies using numerical human-body models, and examples in which VHF-band and UHF-band antennas are placed in the vicinity of the face [4]. However, a single posture is evaluated in each of those examples, and there is no comparison or evaluation of conditions that take operating configuration into consideration, such as the actual installation position of the antenna and the posture of the human.

In this paper, we compare and evaluate antenna gain, radiation pattern, and specific absorption rate with different distances of the antenna from the human body and different human postures, with the objective of clarifying the radiation characteristics and amount of electromagnetic exposure when a handheld transceiver for push-to-talk communication lines for broadcasting services is in operation. The frequencies we studied were those currently in use for push-to-talk communication lines, namely 165 MHz in the VHF band and 460 MHz in the UHF band. In this study, we use a numerical human-body model of an adult male having the average body type of a Japanese person and used computer simulation to analyze various cases in which the posture of the numerical human-body model is changed.

## II. CALCULATION MODEL

### A. Antenna Model

The configurations of the antennas for the VHF band and UHF band used in the study of this paper are shown in Fig. 1. The configurations of antennas are listed in Table A. We modelled the transceiver cases and antennas shown in Fig. 1 with reference to transceivers that are currently used with push-to-talk communication lines for broadcasting services. We modelled them so the dimensions of the cases are the same and only the antenna configurations are different. The configuration of the antennas is helical, and they operate in normal mode at 165 MHz and 460 MHz.

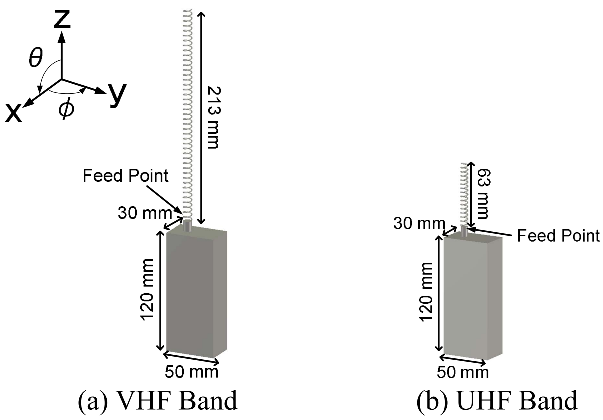
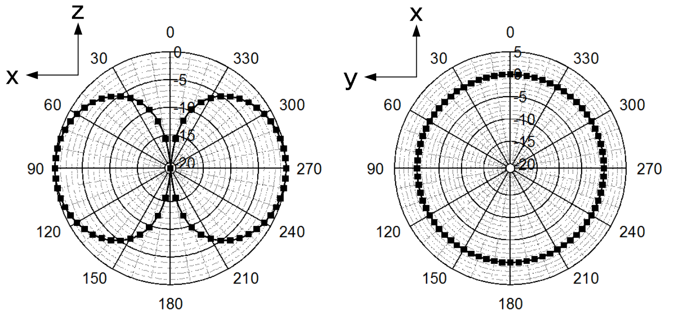



Fig.1 Antenna Configuration

TABLE A
ANTENNA CONFIGURATIONS

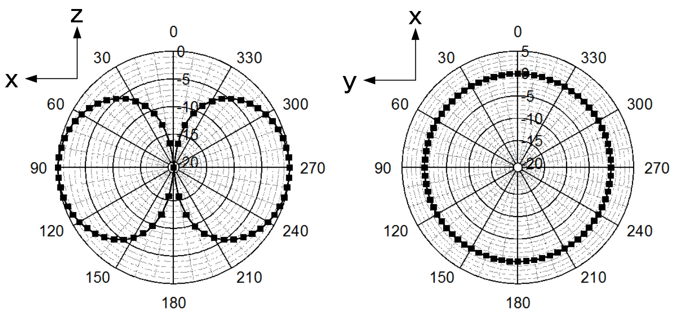
| Frequency Band | VHF Band | UHF Band |
|---|---|---|
| Antenna Shape | Helical Antenna | |
| Antenna Length | 213 mm | 63 mm |
| Wire Diameter | 1 mm | 1.35 mm |
| Helix Radius | 8.35 mm | 8 mm |
| Number of Turns | 43 | 15 |
| Case Dimension | 50 x 30 x 120 mm | |
| Material | Perfect Electric Conductor (PEC) | |

The results of calculating the radiation patterns in free space of the antenna of Fig. 1(a) at 165 MHz are shown in Fig. 2, and those for the antenna of Fig. 1(b) at 460 MHz are shown in Fig. 3. In Figs. 2 and 3, the amplitudes have each been normalized by the maximum value.



(a) $E_\theta$ (b) $E_\phi$

Fig.2 Radiation Pattern (165MHz)



(a) $E_\theta$ (b) $E_\phi$

Fig.3 Radiation Pattern (460MHz)

From Figs. 2 and 3, we can confirm that the helical antennas of Fig. 1 are operating in normal mode.

*B. Analysis Model*

When it came to calculating the antenna gain and radiation pattern when each antenna described in the previous section was placed in close proximity to the human face, we used a numerical human-body model as the human-body model for the analysis [5]. The analysis model studied in this paper is shown in Fig. 4. In the analysis of this study, we set the electrical constants for 165 MHz and 460 MHz individually for each type of body tissue [6].

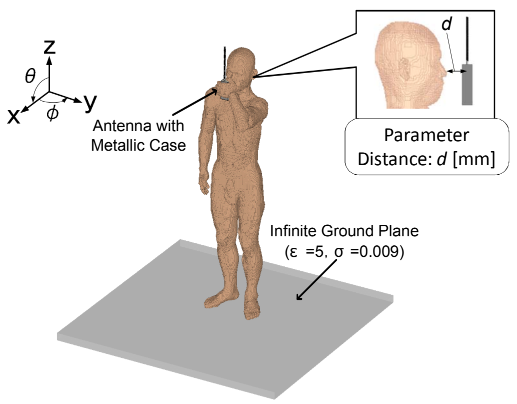
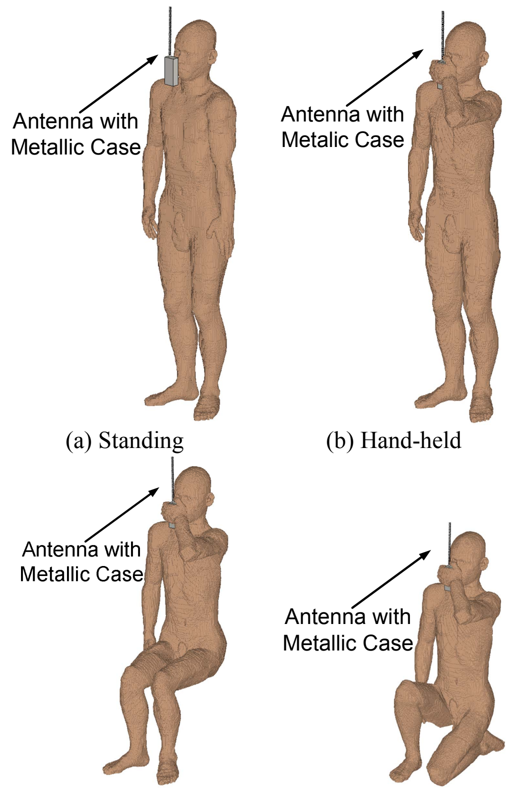


Fig.4 Analysis Model

In the analysis, we assumed that the distance between the tip of the nose and the antenna was "*d*" and used the parameters used during evaluation, as shown in Fig. 4. We also assumed that the ground was concrete, and set an infinite ground plane with a relative permittivity of 5 and conductivity of 0.009 [S/m]. In this analysis model, we consider the four human posture patterns shown in Fig. 5.



(a) Standing (b) Hand-held

(c) Sitting (d) Crouching

Fig.5 Antenna Position and Human Posture

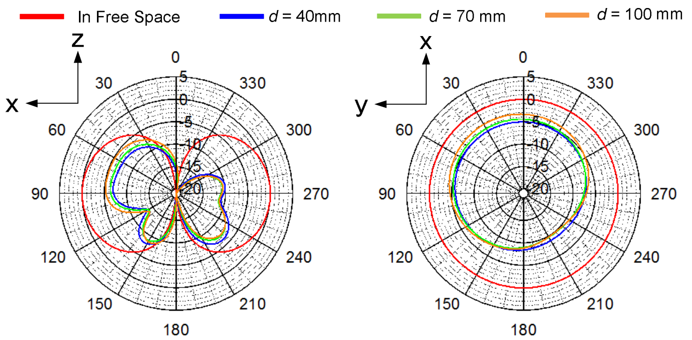
Since standard handheld push-to-talk communications devices have the transmission button on the left side of the case, we assumed postures in which the transceiver is held in the left hand and the installation position of the antenna is such that the distance from the tip of the nose to the antenna center is 40 mm. We compare and evaluate the antenna gain and radiation pattern for the VHF and UHF bands under four sets of conditions from a case in which the arm is not considered (Fig. 5(a)) to cases in which the posture is modified by considering the arm (Figs. 5(b) to 5(d)). When we evaluated the amount of electromagnetic exposure, we did so under the conditions shown in Fig. 5(a).

We set each of the electrical constants for each configuration of the numerical human-body model at 165 MHz and 460 MHz from Reference [6]. Considering the impedance matching of the antenna in our calculations of radiation pattern, and amount of electromagnetic exposure, we compared and evaluated by operating gain and specific absorption rate (SAR).

## III. Comparison of Radiation Patterns at Different Distance

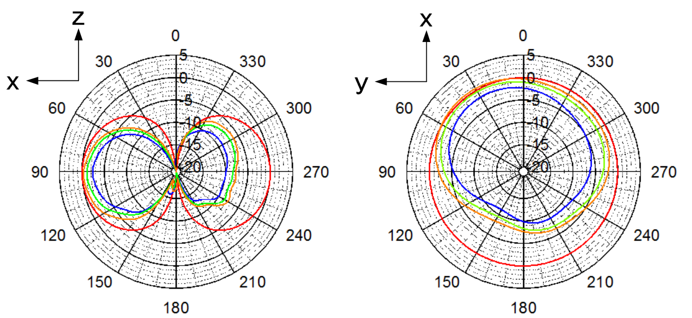
Based on the antenna gain and radiation pattern of each antenna by itself, as shown in Figs. 2 and 3, we study the effect of distance $d$ on antenna gain and radiation pattern when the antenna is placed in close proximity to the human body.

With the posture shown in Fig. 5(b) and the distance $d$ set to 40 mm, 70 mm, and 100 mm, the radiation patterns for 165 MHz are shown in Fig. 6 and those for 460 MHz are shown in Fig. 7. The values of amplitude were normalized by the maximum value of antenna gain for the antenna by itself, with the radiation pattern of the antenna by itself being is shown by dotted lines in the figures for comparison.




(a) z-x plane (b) x-y plane

Fig.6 Radiation Pattern vs. Distance "*d*" (VHF Band)




(a) z-x plane (b) x-y plane

Fig.7 Radiation Pattern vs. Distance "*d*" (UHF Band)

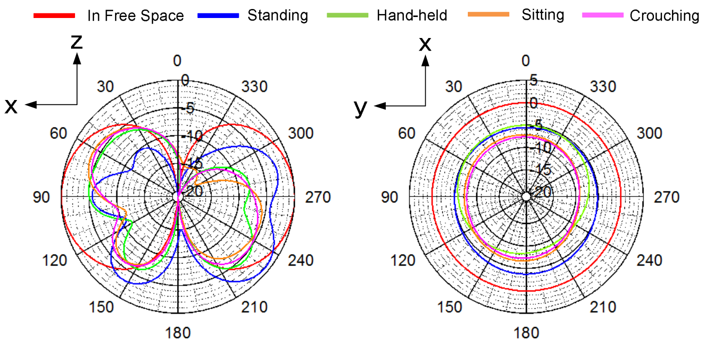
From Fig. 6, we see that the effect of the human body on antenna gain decreases as the distance $d$ increases, and thus the antenna gain increases. Looking at $\phi$ in the x-y plane in the 0-degree direction in either frequency band, we see that the antenna gain can be improved by approximately 2 dB by setting the distance $d$ to between 40 mm and 100 mm.

If we look at the radiation pattern, on the other hand, whereas $\theta$ tends to peak in the 60 degree direction in front of the body in the z-x plane with the VHF band, with the UHF band, where directionality is free space, we do not see so much change.

When impedance matching of the antenna is not considered, the wavelengths in the UHF band are shorter than that in the VHF band, so the effects of shielding by the body become larger and radiation to the rear of the body becomes less. However, we found that if impedance matching is considered, the VHF band is more susceptible to the effects of impedance matching, so shielding losses to the rear of the body are substantially the same with the VHF band and the UHF band.

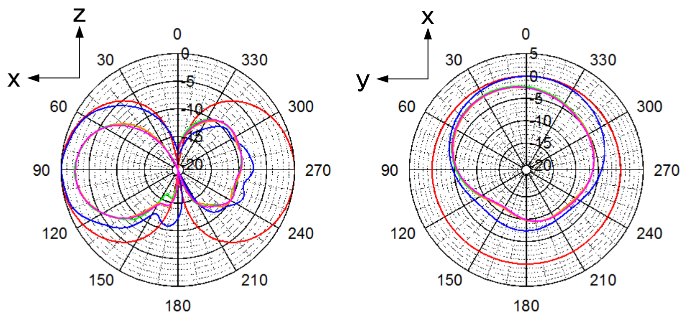
## IV. Comparison of Radiation Patterns with Different Postures

In a similar manner to Section III, we consider the effect of the posture of the human body on the antenna gain and radiation pattern. We studied the radiation patterns when the distance $d$ was fixed at 40 mm in each of the four postures shown in Fig. 5, with the results for 165 MHz shown in Fig. 8 and the results for 460 MHz shown in Figs. 9. The values of amplitude were normalized by the maximum value of antenna gain for the antenna by itself, with the radiation pattern of the antenna by itself being is shown by dotted lines in the figures for comparison.




(a) z-x plane (b) x-y plane

Fig.8 Radiation Pattern vs. Posture (VHF Band)




(a) z-x plane (b) x-y plane

Fig.9 Radiation Pattern vs. Posture (UHF Band)

If we compare the radiation patterns for the standing posture and hand-held posture, we see differences in radiation pattern due to the effect of the arm with both the VHF and UHF bands. In particular, we see from Fig. 8 that there are large differences in radiation pattern to the rear of the human body in the VHF band, and a comparison of standing and hand-held postures in Fig. 8(b) shows that $\phi$ has a difference in antenna gain of approximately 5 dB in the 210 degree direction, due to the effect of the left arm in the x-y plane, so the radiation pattern becomes laterally asymmetric. From Fig. 9, the effect of the hand is large and the antenna gain in front of the body is approximately 2 dB less with the hand-held posture than the standing posture in UHF band.

If we focus on differences in radiation pattern due to changes in posture, large differences in radiation pattern are seen in the z-x plane with the VHF band due to changes in posture, but with the UHF band we found there are not such large differences and the effects of the arm were more prominent than those of posture. In contrast to the VHF band where the wavelength is substantially the same length as the height of the numerical human-body model (approximately 170 cm), the UHF band has a wavelength that is about 1/3 of the body height, so it is thought that posture has a larger effect with the VHF band.

## V. Comparison of Amounts of Electromagnetic Exposure with Different Values of Distance d

Since values of SAR based on Equation (1) are used internationally [7], we based the calculations for evaluating the amount of electromagnetic exposure on the human body on Equation (1) in this paper.

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

In this case, $\sigma$ is the conductivity of body tissue [S/m], $\rho$ is the density of body tissue [kg/m3], and $E$ is the effective value of the field strength [V/m]. Note that evaluation of SAR is done by evaluating the 10-g average local SAR which is averaged over any 10 g of the human body [8]. In the electromagnetic protection guidelines of the Ministry of Internal Affairs and Communications, the guideline value for the 10-g average local SAR in a “managed environment” such as that of a push-to-talk communication line is set to 10 W/kg or less.

In this case, since the output of a handheld push-to-talk communications device is generally 5 W, we compare and evaluate the 10-g average local SAR when the output is 5 W, within a range of distance $d$ of 30 to 100 mm. The results are shown in Fig. 10.

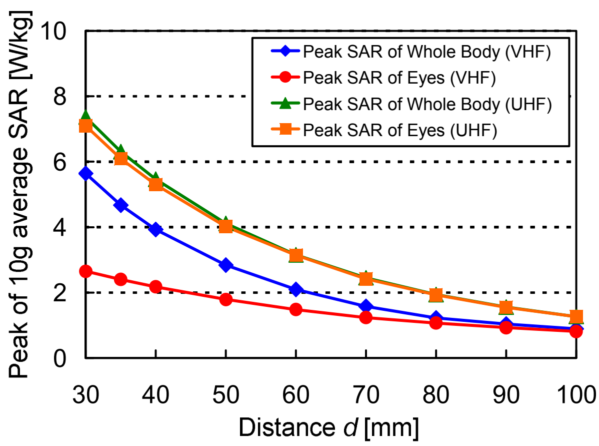



Fig. 10 10-g average local SAR when distance *d* was varied

From Fig. 10, we see that the 10-g average local SAR decreases with increasing distance *d*, in either of the VHF and UHF frequency bands. In either frequency band, the 10-g average local SAR also decreases in comparison to when impedance matching is not considered. In particular, we found that 10-g average local SAR was greater with the UHF band, whereas when impedance matching has not been considered, it was greater with the VHF band than the UHF band.

From these results, we found that the 10-g average local SAR can be reduced to 1 W/kg with either frequency band, by setting the distance *d* to about 100 mm, which can be smaller even than the guideline value (2 W/kg) for the general environment in the electromagnetic protection guidelines.

## VI. Conclusion

In this paper, we considered the operation of push-to-talk communications devices for broadcasting services and studied the effect that the human body has on the radiation pattern of the transceiver, as well as the amount of electromagnetic exposure.

We confirmed that differences in antenna gain due to angle are on the order of 2 to 5 dB for both of the VHF and UHF bands, by taking the effects of the arm into consideration, and at the same time found that the effects of posture were large in the VHF band but small in the UHF band. We also found that antenna gain can be improved by approximately 2 dB by making the distance between the human body and the antenna about 100 mm.

With the amount of electromagnetic exposure, we found that the 10-g average local SAR can be reduced by increasing the distance *d*. In particular, we found that the amount can be reduced to a value close to that of a mobile phone by use at a distance on the order of 100 mm.

From the above, we consider that it is valid to use push-to-talk communication lines at a distance *d* of about 100 mm, for effective and safe operation.

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