

Development of VHF-band Antenna Mounted on the Helmet

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Abstract- Recently, the VHF band attracts attention for mobile use. For example, around 150 MHz is used in fire fighting and police radio et al. The microwave in VHF-band is especially useful for the communication network construction under the environment with a lot of obstacles. However, a present transceiver's antenna that sticks out long has the possibility to obstruct the user's activity. To solve this problem, we decided to use wearable antenna. In this paper, we propose the inverted-L antenna mounted on a helmet as a wearable antenna.

I. INTRODUCTION

Recently, the development of the wearable wireless device is being paid attention with the progress of the human centric communication technology. Many of them show the tendency to concentrate on the development of RF device intended for high frequency uses though the capacity restriction for the wearable wireless device is more generous than the portable wireless device [1]-[3]. On the other hand, the wireless system that uses a lower frequency band is more advantageous than the system that uses the ISM band concerning the propagation loss or multiple reflection influence. Especially, the VHF-band wireless system used for the police, fire fighting or a military communication is robust for interception with barriers. However, it is thought that the development of the wearable antenna that can be used in this frequency band (for instance, 146-156MHz in Japan) is a considerably challenging problem. For this problem, the development of the antenna that was able to use the wireless system hands-free and was able to exclude the communication interception with system user's body was set to the goal. Additionally, the design for the antenna mounting method that is able to suppress the microwave exposure to users than a present VHF-band transceiver was also included.

For the above-mentioned requirements, when the antenna is mounted on the metallic helmet often used in the police, fire fighting or the army, etc., antenna's radiation and input property are described in this report. Concretely, the antenna radiation and the input property when PIFA is mounted on a metallic helmet are shown in Chapter 2. The antenna feature when PIFA is transformed to improve its performance is also shown. In next Chapter 3, to emphasize bandwidth than PIFA, the performance of helmet antenna that adopts PILA (Planar Inverse L-shape Antenna) is described. Moreover, to

emphasize bandwidth additionally, the antenna performance of PILA that adds a parasitic element is also described.

II. BASIC STRUCTURE OF HELMET ANTENNA BASED ON A PIFA

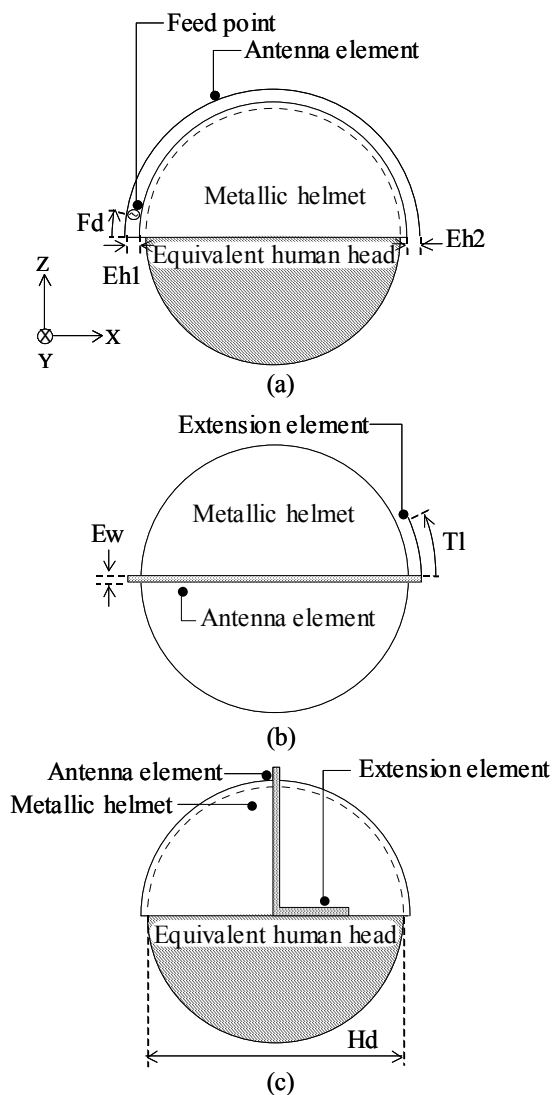


Figure 1. Basic structure of helmet antenna based on a PIFA. (a) Side view of antenna. (b) Bird's eye view of antenna. (c) Antenna back side.

Figure 1 shows the antenna configuration when PIFA is adopted as the element to evaluate the possibility of the helmet antenna that can be used in VHF-band. The each parts of antenna dimension are shown in Table I collectively.

TABLE I THE EACH PARTS OF ANTENNA DIMENSION. UNIT [mm]

Fb	5	Ew	5
Eh1	10	TI	75
Eh2	10	Hd	200

In the helmet antenna shown in Fig. 1, PIFA of a round element is composed on a metallic hemispherical shell as a ground plane.

Figure 2 shows the result of simulating the antenna input property in the helmet antenna loading on the equivalent human head. Because the helmet antenna is used near the human head, it is necessary to simulate the human head effect for the antenna design. In the analysis FDTD method is used [4]. The cell size is set to 2 mm in X, Y and Z directions. The time step is 3.85ps based on the Curant condition. As the absorbing boundary condition, an 8-layered Berenger's PML is used. To evaluate the worst case with the antenna input property, the equivalent human head is modeled with the homogeneous brain tissue (relative permittivity $\epsilon_r = 60.19$, conductivity $\sigma = 0.479$ S/m [5]).

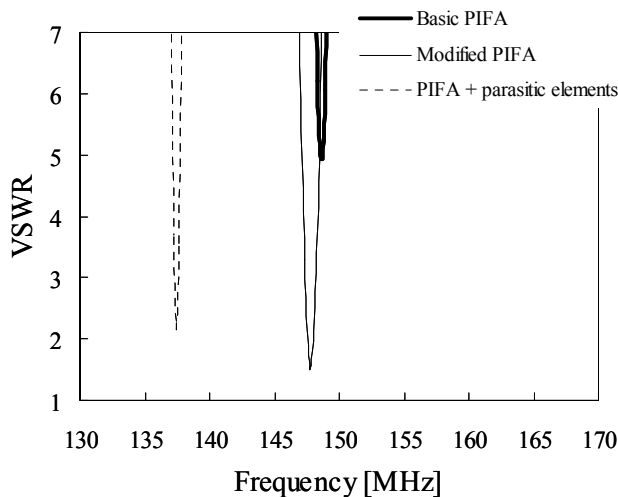


Figure 2. Input property of helmet antenna based on a PIFA

The antenna resonates around 150 MHz by adding extension element like the tail because the gap of the element and ground plane is free space. However, antenna bandwidth is so narrow to use for mobile communication system. Also, VSWR is not satisfied to use. On the other hand, it is proven to be able to construct the antenna that can be used in VHF-band with loading the serviceable size element on the helmet. Hence, the above-mentioned antenna is modified for the practical improvement as follows.

- (1) The space of the element and ground plane is filled with dielectric spacer.
- (2) The edge of the element of PIFA is expanded (Eh1 is maintained, and only Eh2 is expanded).
- (3) Parasitic elements are loaded to PIFA.

Figure 3 shows configuration of the antenna which adopts the modification of (1) and (2). In addition, the antenna configuration that adopts the modification until (3) is shown in Figure 4.

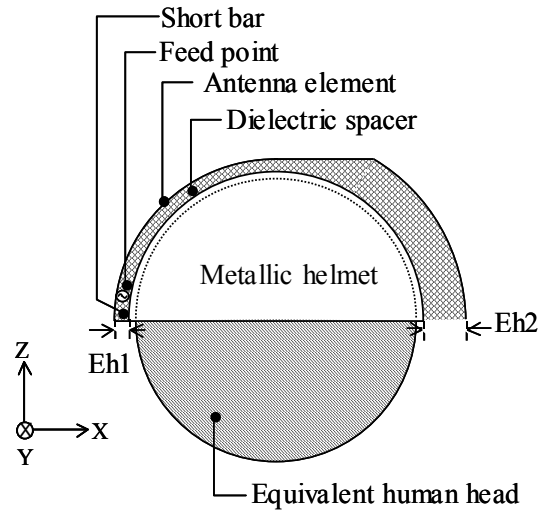


Figure 3. The configuration of modified PIFA with dielectric spacer.

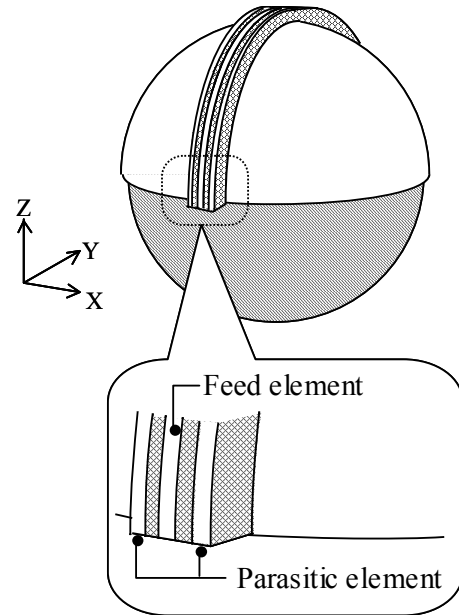


Figure 4. The configuration of modified PIFA with parasitic elements.

Figure 2 shows VSWR as the function of the frequency for the modified PIFA that expanded the PIFA element edge (only Eh2 is expanded in Figure 3). The impedance matching is achieved by the loadings of dielectric spacer ($\epsilon_r = 4.0$, conductivity $\sigma = 0.0005$ S/m) around 150MHz though there is

no extension element. Moreover, because the height of PIFA on opposite side of feed point is increased, bandwidth and VSWR are improved. However, it turned out not effective of the bandwidth emphasis though the effect of the resonance frequency reduction appeared to a further loadings of parasitic elements (see Figure 2). In the case of PIFA, the radiation element is coupled with the ground plane strongly. Accordingly, it is assumed that an electromagnetic coupling between the radiation element and parasitic elements becomes unremarkable. In other words, the parasitic elements effect is assumed to be demonstrated in the antenna which does not strongly couple with ground plane.

III. BASIC STRUCTURE OF WEARABLE ANTENNA BASED ON A INVERTED-L ANTENNA WITH PARASITIC ELEMENTS

In this chapter, PILA (Planar Inverse L-shape Antenna) is adopted as an antenna that is able to use the parasitic elements effect. Because PILA does not have short bar like PIFA, the radiation elements are not strongly coupled with ground plane. Therefore, it is expected that the effect of parasitic elements be demonstrated. Moreover, the improvement technique of bandwidth and VSWR for PIFA in the previous chapter can be applied to PILA.

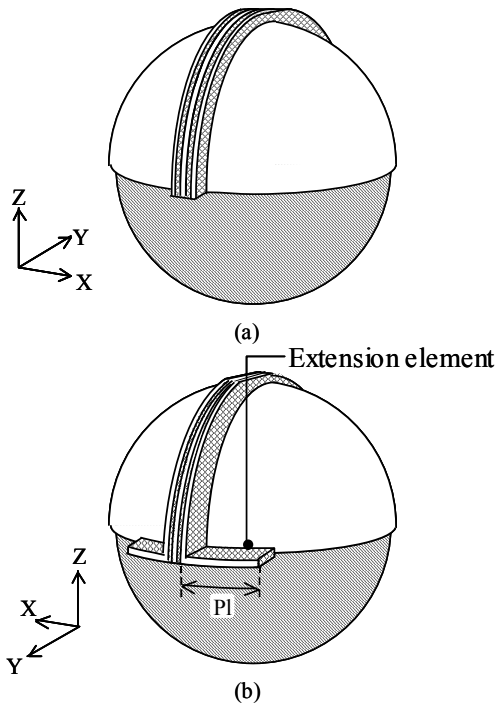


Figure 5. The configuration of PILA with parasitic elements. (a) Front view of PILA with parasitic elements. (b) Antenna back view.

Figure 5 shows the outline of PIFA with parasitic elements. The structure of PILA is almost same as the antenna shown in Fig. 3. However, there is no short bar other than the feed point. Also, the extended element for parasitic elements has been added as shown in Figure 5(b). The parasitic elements are

short-circuited to ground plane at the same position of feed point. As for PIFA, the miniaturization is easy, and the extension element for parasitic elements is unnecessary though antenna bandwidth is narrow. On the other hand, the influence of ground plane decreases in PILA, and coupling between parasitic elements and the radiation element comes to stand out though the antenna miniaturization is difficult.

Figure 6 shows the input property of the antenna shown in Figure 5. Because coupling between the parasitic and the radiation elements strengthened, bandwidth has been greatly expanded. Furthermore, the resonance frequency can be controlled only by extending parasitic elements with the radiation element fixed. The resonance frequency transition by extension parasitic element's length ('Pl' in Figure 6) as the parameter is also shown in Figure 6. This is thought to be a feature profitable to design the antenna. As the result of Figure 6, the effect on the VSWR improvement is low though parameter 'Pl' is effective for the resonance frequency control. It is attempted to move the parasitic elements short-circuited position from the bottom to the upper side in Figure 5(a) as VSWR improvement technique. The result is shown in Figure 6 as explanatory note of 'Pl=11cm+short offset'. It is found that the antenna input property is rapidly improved by this technique.

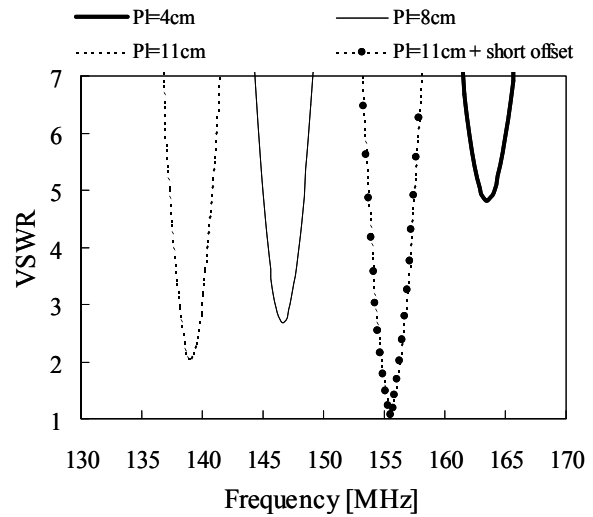


Figure 6. Input property of PILA with parasitic element.

IV. COMPARISON BETWEEN THE PRESENT TRANSEIVER ANTENNA AND PROPOSAL ANTENNA

In this chapter, the comparison result concerning the radiation performance of a proposal helmet antenna and a present transceiver is described. The radiation gain and the radiation efficiency in VHF-band of both antennas are compared for the radiation performance evaluation.

An actual situation that uses present transceiver near the human torso and the numerical model to analyze those situations are shown in Fig. 7. The dimension of human torso and the transceiver model is noticed to Table 2. Transceiver is

composed of metal box and normal mode helical antenna. The gap between transceiver and human torso model is set to 10mm. The mixture tissue such as the fat, muscles and bones are adopted as an averaged electric property of human torso. They roughly correspond to 2/3 of muscular tissue's electric properties (relative permittivity $\epsilon_r = 41.78$, conductivity $\sigma = 0.45$ S/m [5]).

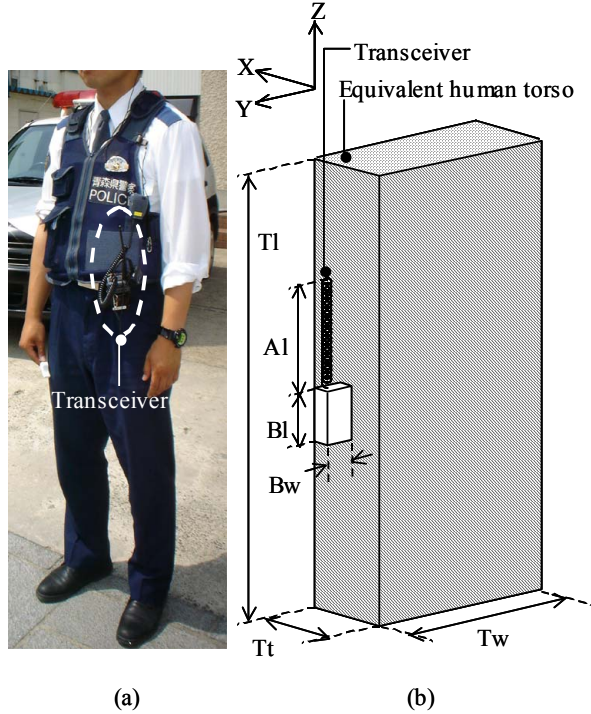


Figure 7. The present transceiver's uses situation and the numerical model configuration. (a) An actual uses situation of present transceiver by policeman. (b) The canonical model configuration for numerical analysis.

TABLE II THE DIMENSION OF HUMAN TORSO AND THE TRANSCEIVER MODEL.. UNIT [mm]

Tl	700	Al	205
Tt	200	Bl	95
Tw	270	Bw	60

Figure 8 shows the simulated comparison results about the radiation properties of proposal helmet antenna and present transceiver. Figure 8(a) shows the vertical-polarization radiation pattern comparison result between the normal mode helical antenna and helmet antenna on X-Y plane. The transceiver's radiation in opposite direction toward torso is about 6dB superior compared with the helmet antenna. However, there is deflection of 14.5dB in the transceiver's radiation though the radiation deflection by helmet antenna is settled to about 8dB on X-Y plane. On the other hand, the comparison of the horizontal-polarization radiation pattern in Z-X plane with the proposal antenna and transceiver is shown in Figure 8(b). The proposal antenna's radiation is more

greatly than transceiver's superior in Z-X plane. The maximum radiation gain of proposal antenna is about -4dBi, and this is about 4dB more superior to the transceiver's maximum gain. Moreover, the helmet antenna's radiation efficiency is around 74 %, though transceiver's radiation efficiency is 28 %. Accordingly, it is thought that the proposal antenna has the advantage for present transceiver in the radiation property.

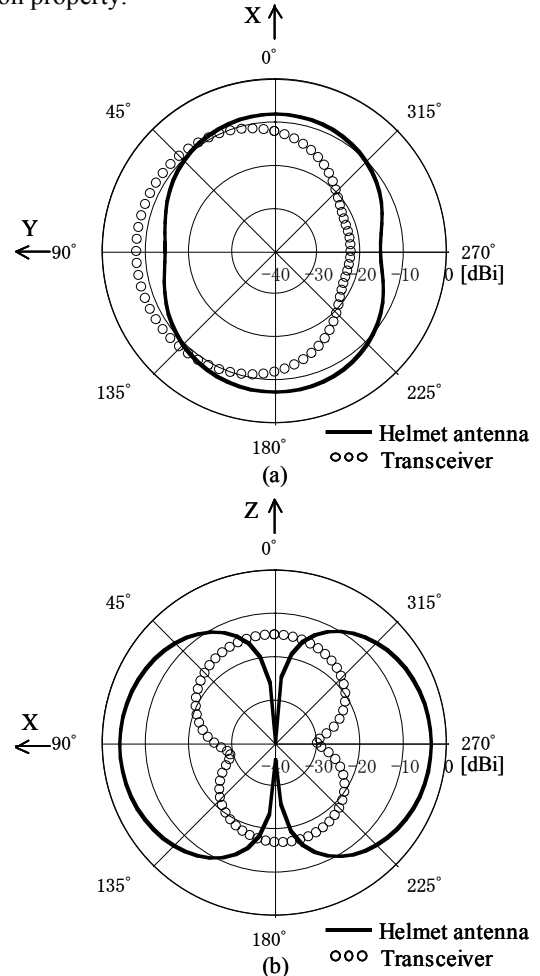


Figure 8. Radiation property comparison between helmet antenna and present transceiver. (a) Vertical-polarization radiation pattern on X-Y plane @155 MHz. (b) Horizontal-polarization radiation pattern in Z-X plane @155 MHz.

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