A Study on Metal-Insensitive Antenna for Closed Space Wireless Communications

Y.Nakagawa, S.Tanaka, T.Toba, T.Kimura, K.Shirasu
Transmission Technology Research Department
Yazaki Research & Technology Center, Yazaki Corporation
3-1 Hikari-no-oka, Yokosuka, 239-0847, Japan
yuta.nakagawa@jp.yazaki.com

T. Oki, N.Nishiyama, H.Morishita
Department of Electrical & Electronic Engineering
National Defense Academy
1-10-20 Hashirimizu, Yokosuka, 239-0811, Japan
morisita@nda.ac.jp

***Abstract*— In order to obtain metal-insensitive antenna for closed-space wireless communications, the impedance characteristics of U-shaped folded monopole antenna is investigated in detail. The simulated and measured results show that the proposed higher impedance model has stronger metal-insensitiveness than the conventional middle impedance model. The simulated results show that the antenna gains of higher impedance models are 3dB greater than those of middle impedance models.**

Keywords—metal-insensitive anenna; robust antenna against metal; closed space wireless communications

I. Introduction

The research and development activities on wireless communication technologies are rapidly growing, not only for open space applications, but also for closed space applications [1]-[3]. The propagations and distributions of electric fields in closed space are more complicated than those in open space, but it is expected that those research and development will pioneer novel application fields on wireless communications.

However, the problems for closed space wireless communications are not only electric field propagations, but also antenna characteristics. It is known that the antenna impedances are strongly influenced by the near object (especially metal), so the metal-insensitive antennas are strongly required for closed space wireless communications [4]-[5].

In this article, therefore, we introduce fundamental study on metal-insensitive antenna, by employing U-shaped folded monopole antenna (UFMA) with ground plane (GP) [6]. UFMA is a modified folded monopole antenna, so the basic impedance characteristics are depends on step up ratio (SUR) [7]-[8]. The impedance characteristics of UFMAs are investigated in detail when metal object approaches and SUR is controlled in order to enhance metal-insensitive characteristics. In addition to simulated results [9], measured results will be shown and compared.

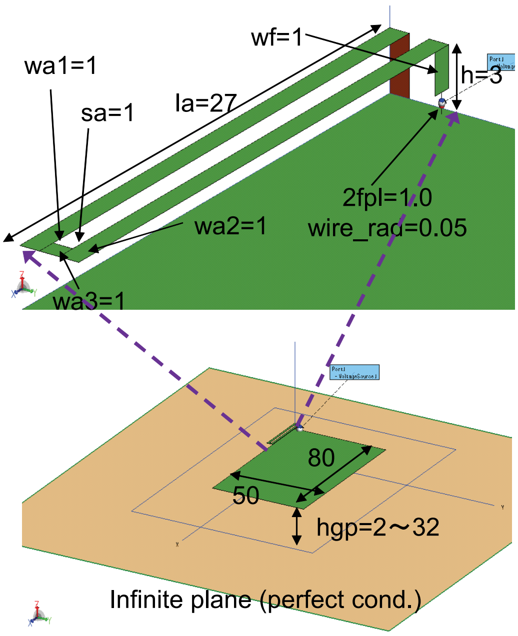

Fig.1. Antenna structure and parameters of UFMA.

II. Antenna Structures

The structure of investigated UFMA is shown in Fig.1. The antenna element is composed of two parallel metal strips with widths wa1 and wa2. Two strips are short-connected by metal strips with width wa3 and length sa, at one side. At the other side, one strip with width wa1 is connected to GP and the other strip with width wa2 is connected to feed point. The total length of two metal strips is la + h, and they are folded to keep low profile antenna with height h. The antenna impedance can be changed by SUR (wa1:wa2). The parameter values shown in Fig.1 is selected in order to obtain S11≤0.5 (VSWR≤3 or S11≤ -6dB) at 2.4GHz with bandwidth 10MHz, when there is no infinite plane (it means hgp in Fig.1 is ∞).

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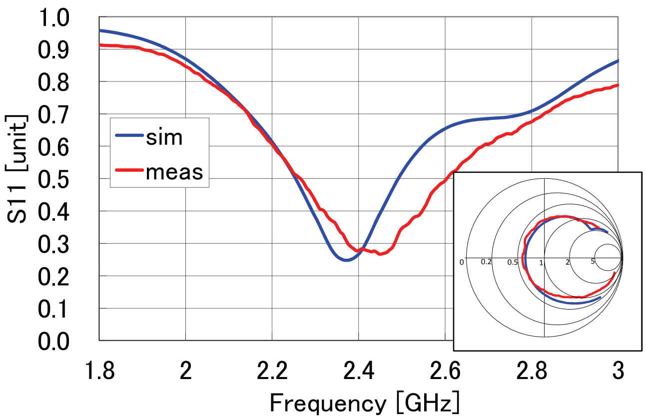
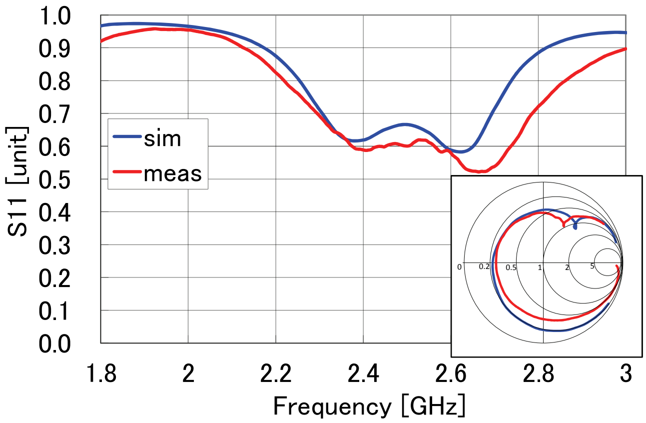
The antenna element is placed on the GP (50 x 80 mm), which models printed circuit board of electronic control unit. The infinite plane (perfect conductor), which models metal wall of closed space, is located in parallel to GP. The distance between GP and infinite plane is defined as hgp, and changed in order to investigate the metal-insensitive characteristics of the antenna.

III. Impedance Characteristics

The impedance characteristics of the UFMA are investigated in this chapter, when hgp values are changed. The simulated results using FEKO simulation, based on method of moment and measured results are shown and compared. For the measurement, Cu plane with size 400 mm x 635 mm is placed near the antenna, instead of infinite plane for simulation.



(a) hgp=16



(b) hgp=4

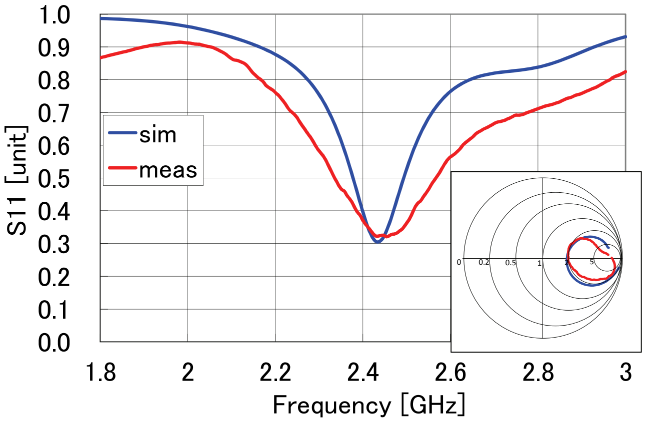
Fig.2. Simulated and measured S11s of middle impedance model.

A. *UFMA (Middle Impedance Model)*

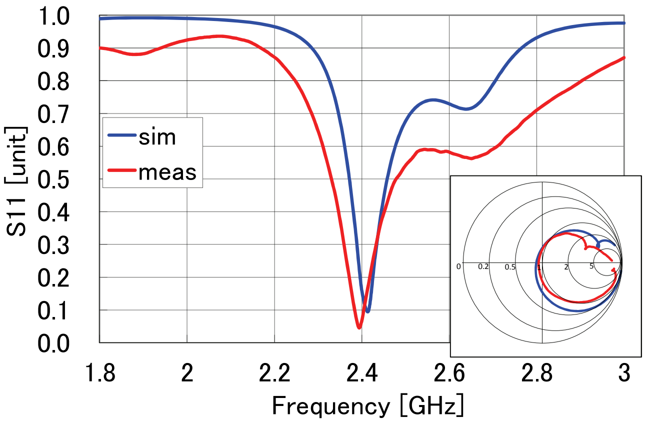
The UFMA with parameter values shown in Fig.1 is referred to as middle impedance model, as it is designed to obtain 50 ohms when there is no infinite plane (hgp=∞). The simulated and measured S11s of middle impedance model are shown in Fig.2. Linear scale for S11 is selected, in order to evaluate results both in high and low reflection regions. The relevant Smith Charts are also shown inside. Fig.2(a) shows that S11≤0.5 is satisfied when hgp=16mm. However, as are shown in Fig.2(b), S11≤0.5 cannot be satisfied when hgp=4mm. We can say that the measured S11 values agree well with simulated S11 values.

The Smith Charts in Figs.2(a) and (b) indicate that the larger S11s with hgp=4mm is caused by lower impedance than those with hgp=16mm, so we can say that this is the influence of nearby metal. Therefore, we expect that, if we can obtain higher antenna impedance by adjusting SUR, the antenna will be more metal-insensitive than middle impedance model.

B. *UFMA (Higher Impedance Model)*



(a) hgp=16



(b) hgp=4

Fig.3. Simulated and measured S11s of higher impedance model.

In order to obtain higher antenna impedance, we changed parameters shown in Fig.1. wa1=2 and wa2=0.2 are selected to obtain higher SUR. la=26 is selected for frequency adjustment, but other parameters are not changed from Fig.1, and the antenna is referred to as higher impedance model. Fig.3 shows the simulated and measured S11s of higher impedance model. Fig.3(a) shows that the antenna impedance of higher impedance model is higher than that of middle impedance model, but S11≤0.5 is satisfied when hgp=16mm. Fig.3(b) shows that antenna impedance with hgp=4mm is lower than that with hgp=16mm, as are observed in Fig.2. However, due to higher impedance with hgp=∞, S11≤0.5 is satisfied even when hgp=4mm.

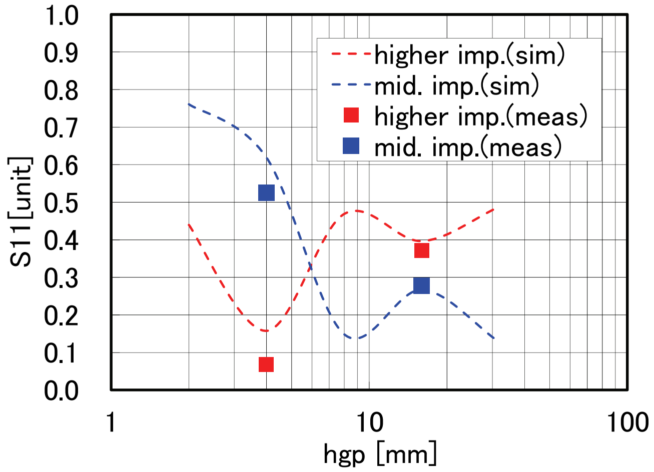
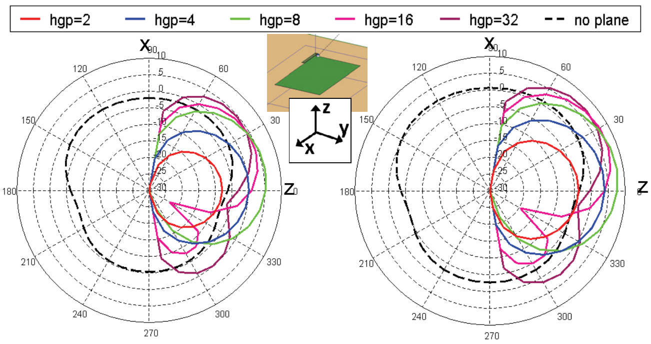


Fig.4. Simulated and measured S11 values vs. hgp values at 2.4GHz.



(a) middle impedance model (b) higher impedance model

Fig.5. Simulated radiation patterns of UFMAs in x-z plane for various hgp values at 2.4GHz.

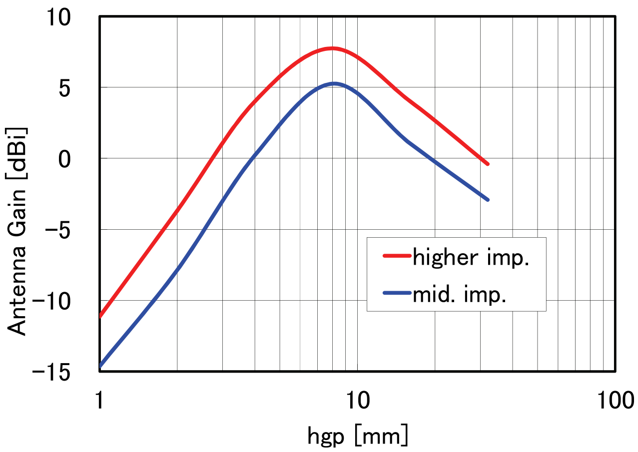


Fig.6. Simulated antenna gains of UFMAs toward z axis vs. hgp values at 2.4GHz.

The simulated S11 values vs. hgp values at 2.4GHz are summarized in Fig.4. The measured values shown in Figs.2 and 3 are also plotted in Fig.4. We can say that, in order to obtain S11≤0.5, hgp≥5mm is necessary for middle impedance model, however, hgp≥2mm is acceptable for higher impedance model. Higher impedance model is more robust against nearby metal than middle impedance model.

IV. Radiation Characteristics

The simulated radiation patterns of UFMAs in x-z plane at 2.4GHz when hgp values change are shown in Fig.5. Fig.5(a) is for middle impedance model and Fig.5(b) is for higher impedance model, respectively. The definitions of x/y/z axes are shown inside, and maximum radiation is observed toward z axis.

Fig.6 shows the simulated antenna gains toward z axis vs. hgp values at 2.4GHz. We can say that the antenna gain of higher impedance model is greater than that of middle impedance model. The difference of antenna gain between middle impedance model and higher impedance model is constant to 3dB for different hgp values. The physical mechanism of this difference will be clarified in the next step. The measurement will be done also in order to verify the simulated result.

V Conclusions

We investigated impedance characteristics of UFMA (U-shaped folded monopole antenna), in order to obtain metal-insensitive antenna for closed-space wireless communications. The simulated and measured results show that the antenna impedance changes to small value when metal plane approaches. To encounter this issue, we proposed higher impedance model by selecting SUR (step up ratio). The limitation value of hgp (distance between antenna and metal plane) in order to obtain S11≤0.5 (VSWR≤3 or S11≤ -6dB) is 5 mm for the conventional middle impedance model and 2 mm for the proposed higher impedance model, respectively. The simulated results show that the antenna gains of higher impedance models are 3dB greater than those of middle impedance models. The physical mechanism of this gain improvement will be investigated in the next step.

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