Transmission Characteristics of RFID Antennas in a Closed Space

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***Abstract* - Radio-frequency identification (RFID) systems have been employed for managing items in the closed spaces of construction machinery. In this paper, two horizontal polarization antennas, including a loop antenna and monopole antenna, are employed in an RFID system to investigate the radio transmission characteristics in a closed space.**

***Index Terms* — RFID, monopole antenna, loop antenna, engine room, closed space.**

1. Introduction

Nowadays, the number of electronic devices that are equipped on construction machinery is increasing rapidly. Hence, it will become necessary to eliminate the wire harness. Radio-frequency identification (RFID) technology is an optimal option for managing these devices. However, multiple reflection phenomena cause problems for the wireless transmission of the RFID system. To solve problems of wireless propagation in a closed space in a vehicle, the propagation characteristics in closed spaces within vehicles have been investigated [1], [2]. In addition, the electric field distributions inside a cabin with a 1/3-scale car model have been clarified [3]. Moreover, the electric field distributions in a simplified model of an engine room have been analyzed for the UHF antenna of an RFID reader [4], suggesting that this type of antenna with horizontal polarization is suitable for the RFID system inside a closed space. In this paper, two horizontally polarized antennas are used for investigating the effects of the metallic wall surrounding the environment on the propagation line of an RFID system in a closed space.

2. Analytical Model

Configuration of the closed space is assumed to be simplified to a rectangular box with dimensions as shown in Fig. 1. Two horizontal polarization antennas with an operating frequency of 920 MHz are employed. A loop antenna is placed in the area of the RFID item and a monopole antenna is mounted in the area of the RFID reader. Additionally, the position of the feed point is also changed to four different positions corresponding to α angles of 0°, 90°, 180°, and 270° for investigating the wireless transmission characteristics in the closed space structure. However, because the radiation pattern of a loop antenna on the *xy* horizontal plane is shaped as a figure eight and its maximum radiation direction is in the direction of the feed point, a good wireless propagation line can exist between the two antennas with α angles of 0° and 180°. In the next section, we will consider the transmission characteristics for open- and closed -space structures in the case of an α angle of 0°.

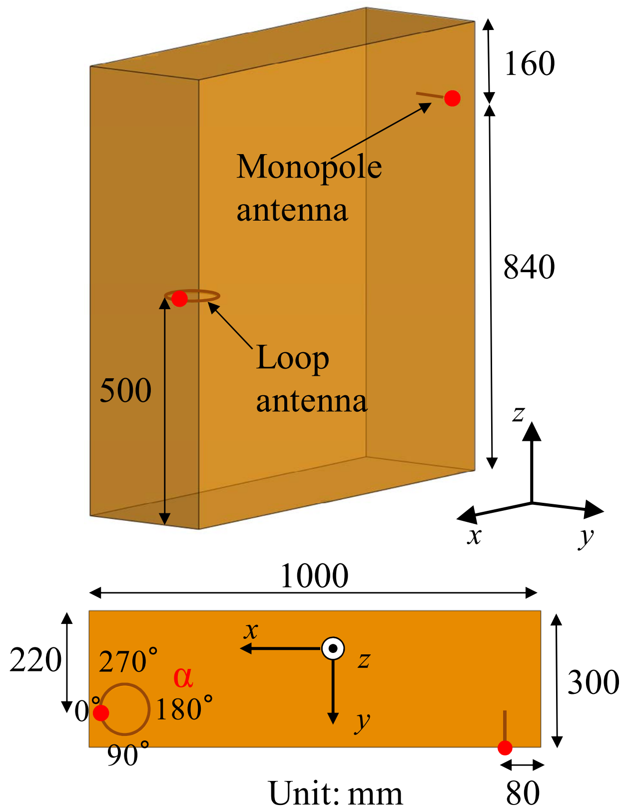

Fig. 1. Propagation model in closed space.

3. Analytical Results

(1) Open Structure with Five Metal Walls

Before starting to consider the transmission characteristic for the closed-space structure, it is better to examine the influences of each metal wall on the wireless propagation in an open space of this structure. In this part, an open structure is presented as a typical case that is created by removing a metal wall that is opposite the monopole antenna.

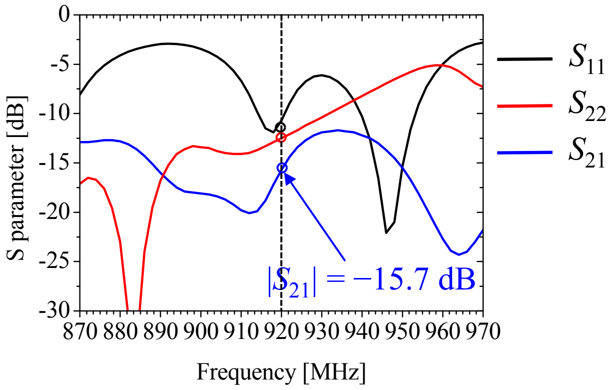

Fig. 2. Transmission characteristics for an open space.

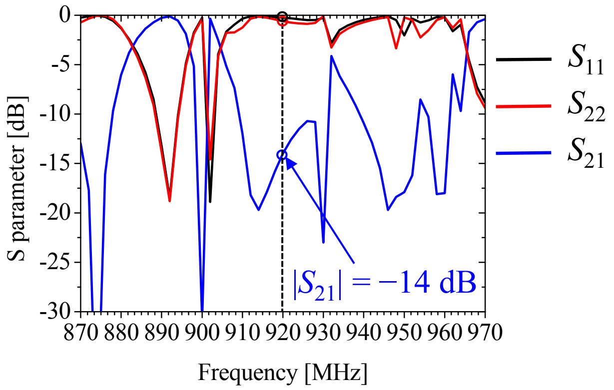

Fig. 3. Transmission characteristics for a closed space.

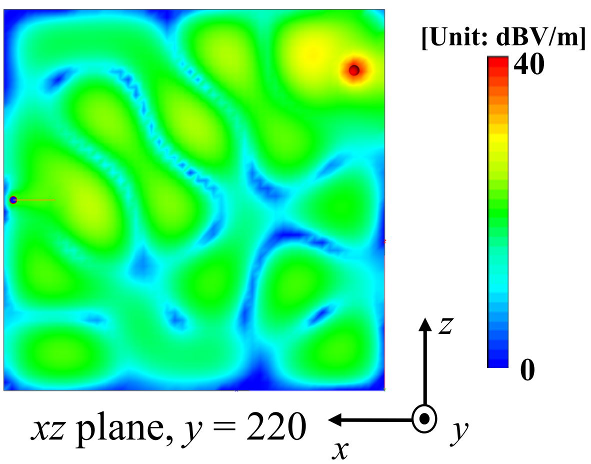

Fig. 4. Electric field distribution for an open space.

After that, the radiation pattern of the loop antenna is oriented in the maximum direction with an α angle of 0°; the results of the transmission characteristics are shown by the *S* parameters as illustrated in Fig. 2.

It is clear from Fig. 2 that the transmission coefficient S_{21} between the two antennas can attain approximately −16 dB, and the reflection coefficients of both antennas are smaller than −10 dB at a frequency of 920 MHz. Moreover, the distribution of near electric field intensity inside the open structure is weak, as shown in Fig. 4. This indicates that most

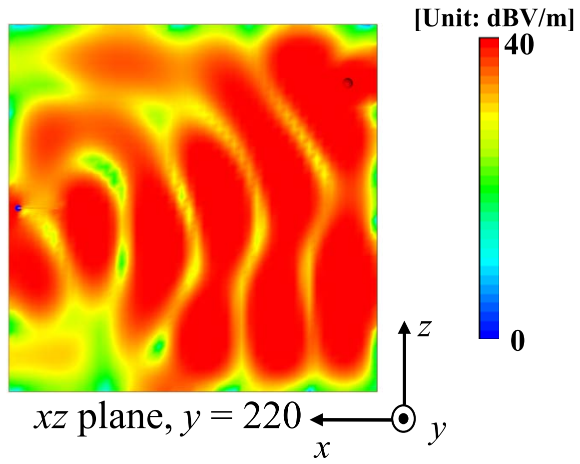

Fig. 5. Electric field distribution for a closed space.

of the energy is radiated into free space and only a part of the energy is kept within the open structure.

(2) Closed Space with Six Metal Walls

In the case of a closed space, the wireless propagation between the two antennas becomes more complicated as shown in Fig. 3. The obtained result indicates that the metallic wall surrounding the closed space has affected the electric current distribution on the body of the antennas, causing a change in their input impedance. As a result, the reflection coefficients of both antennas are almost equal to 0 dB at 920 MHz. Furthermore, in comparison with the electric field distribution of the open space structure, the near electric field intensity is strong as shown in Fig. 5. Moreover, we can see from Fig. 5 that six antinodes are formed between the two antennas, and the distance between two adjacent antinodes is approximately 166 mm (close to $\lambda/2$). This can be explained by the multiple reflection phenomena of the electromagnetic waves when they are reflected between the metal walls inside the closed space.

4. Conclusion

In this study, the transmission characteristics of RFID antennas were investigated for an open structure as well as a closed-space structure. We can confirm that the case of a closed space with the surrounding metal walls such as an engine room has a serious influence on the input impedance of both antennas, resulting in an impedance mismatch at the operating frequency of 920 MHz.

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