A Null Zone Reduction for HF-band RFID by Diversity Combining of Loop Antennas

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1. Introduction

Nowadays, the market of an RFID tag is rapidly growing. Particularly, the RFID tag using HF band (13.56MHz) is widely equipped in cellular phones or credit cards. They are being commodities as electronic wallets or electronic tickets for public transportation systems.

However, it is known that there exists a null zone in which the RFID tag does not respond although the RFID tag is in the closed vicinity to the reader/writer (R/W). Since consumers suffer inconvenience from such a null zone, it is desired to avoid an occurrence of the null zone.

Many investigations to improve an RFID performance are reported [1]-[3]. On the other hands, null zone has been kept off by expanding an antenna size, which occupies larger space. In this paper, we propose a method to overcome null zone by splitting antennas and combining antenna outputs, without enlarging antenna size. As combining circuit, three circuits are considered and compared. We have found by an FDTD simulation that the proposed method increases received power by 13.9 dB at the position of deepest null.

2. Mechanism of null zone

2.1 Simulation model

At first, to elucidate a mechanism of null zone, an FDTD simulation is demonstrated. Figure 1 shows a calculation model. One-turn loop antennas were modeled as transmitting (TX) and receiving (RX) antennas. The feeding gap was 1mm, and the width of the loop was 0.4mm. Capacitance of 1400pF was loaded at the gap so as to resonate at 13.56MHz. The TX antenna was excited with 0 dBm. The received power was calculated with varying the offset distance and the height between TX and RX antennas.

Electro-magnetic fields play a role in RFID system not only as information transmission but also as supplying power to drive RFID chips. In an actual implementation of RFID R/W, signals are received by detecting mutual impedance. In this paper, we are focusing on the received power from a viewpoint of power supply.

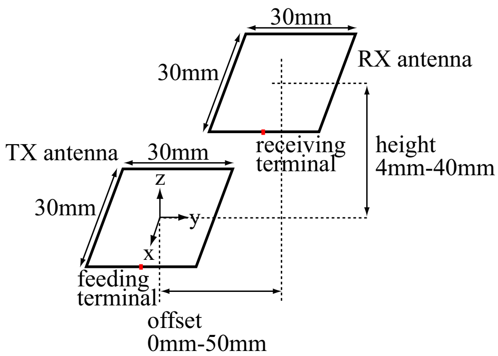


Figure 1: Simulation model

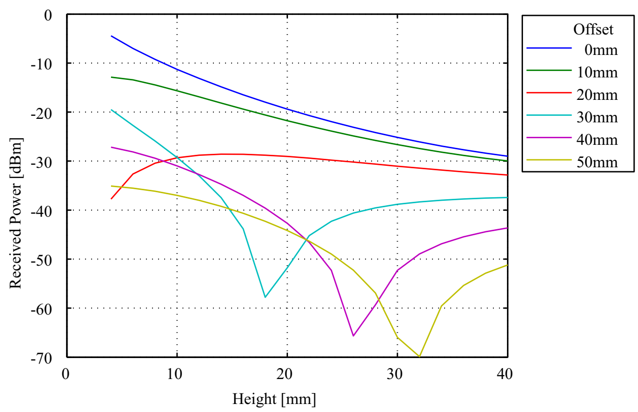


Figure 2: Received power

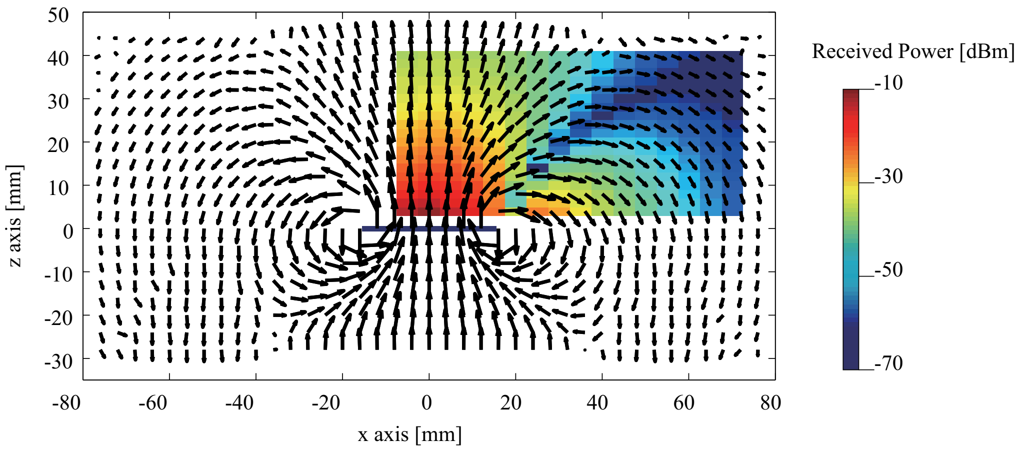


Figure 3: Magnetic field distribution

2.2 Consideration

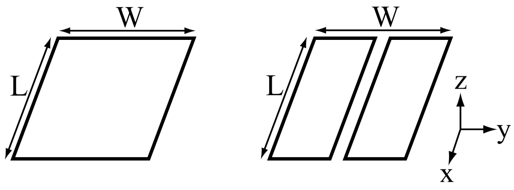
Figure 2 shows the calculated received power. In the cases of offset of 0 and 10 mm, received power increases monotonically when the RX antenna moves toward the TX antenna. On the other hands, for another offset cases, there are regions in which the received power decreases although the RX antenna is closing to the TX antenna.

To investigate the cause of these null zones, magnetic field vector distribution is illustrated in Fig. 3. The arrows show the magnetic field strengths and directions when RX antenna does not exist. The colour shows the received power when the center of the antenna is located at the point with the colour. From this figure, we can understand that the null occurs when the magnetic field vector becomes parallel to the RX antenna. In this situation, the magnetic fields are canceled over the loop surface to occur null zone, because magnetic fields penetrate upwards and downwards on the identical surface of the loop antenna.

3. Reduction method for null zone

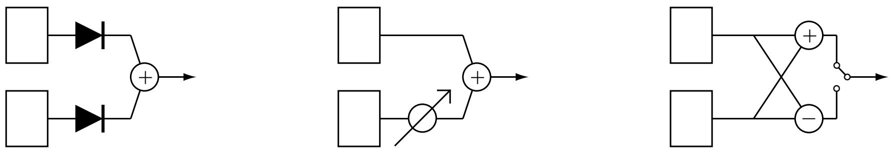
3.1 The proposed scheme

Considering the previously proved mechanism, it is suggested that by splitting the loop antenna, canceling magnetic field can be avoided. The proposed structure of the loop antenna is shown in Fig.4. The output powers of each antenna are combined by a combining circuit. In this paper, three types of combining circuit are suggested.



(a) Conventional (b) Proposed

Figure 4: Proposed structure



(a) Power combining (b) Equal gain combining (c) Selective diversity

Figure 5: Antenna combining circuits

The first circuit is power combining shown in Fig. 5(a). This circuit is simplest in the circuits considered. Let V_1 and V_2 be output complex voltages of each antenna. Z_l shows load impedance. The obtained power of this circuit P_a is calculated as

$$P_a = \frac{|V_1|^2}{Z_l} + \frac{|V_2|^2}{Z_l}. \tag{1}$$

Next, equal gain combining is suggested shown in Fig. 5(b). To obtain maximum power, equal gain combining is better than maximum ratio combining. This circuit becomes most complex because of a phase shifter. The obtained power P_b is

$$P_b = \frac{(|V_1| + |V_2|)^2}{Z_l}. \tag{2}$$

Finally, selective diversity is suggested shown in Fig. 5(c). The outputs of the antennas are added or substituted, and then the stronger is selected. This circuit can be easily implemented by using switches to invert polarity of one antenna. Since the null zone is occurred because of cancellation of the magnetic fields over loop surface, it is expected that this scheme is effective by adding antenna outputs in opposite phase when the null occurs. The obtained power is the stronger of P_{c1} and P_{c2}:

$$P_{c1} = \frac{|V_1 + V_2|^2}{Z_l} \tag{3}$$

$$P_{c2} = \frac{|V_1 - V_2|^2}{Z_l}. \tag{4}$$

3.2 Simulation result

An FDTD simulation is carried out to verify the usefulness of the proposed method. Figure 6 shows the geometry. The output voltages of two antennas were calculated, and then the combined powers by the proposed method were obtained by Eq. (1)-(4). The calculation result for the offset of 35mm is shown in Fig. 7. Improvement of received power by using the proposed method is up to 11 dB for the power combining and 13.9 dB for the equal gain combining and the selective diversity.

The equal gain combining and the selective diversity show identical received power because of the following reason. A phase difference caused by a direction of magnetic field is 0° or 180°. When these signals are blended with any ratio, resultant phase difference is also 0° or 180°. Thus, it is considered that the best combining circuit for the proposed method is the selective diversity because of its simply implementation and large effectiveness.

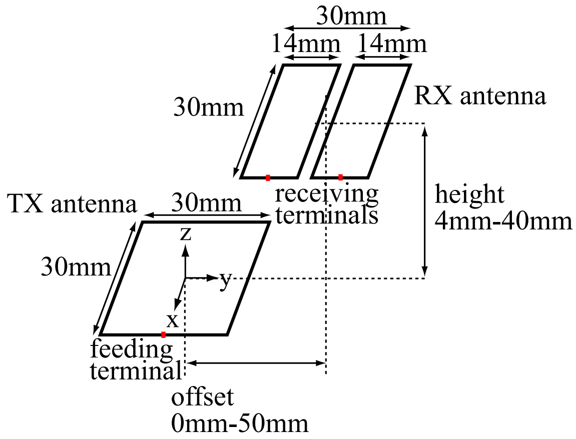


Figure 6: Simulation model of the proposed method

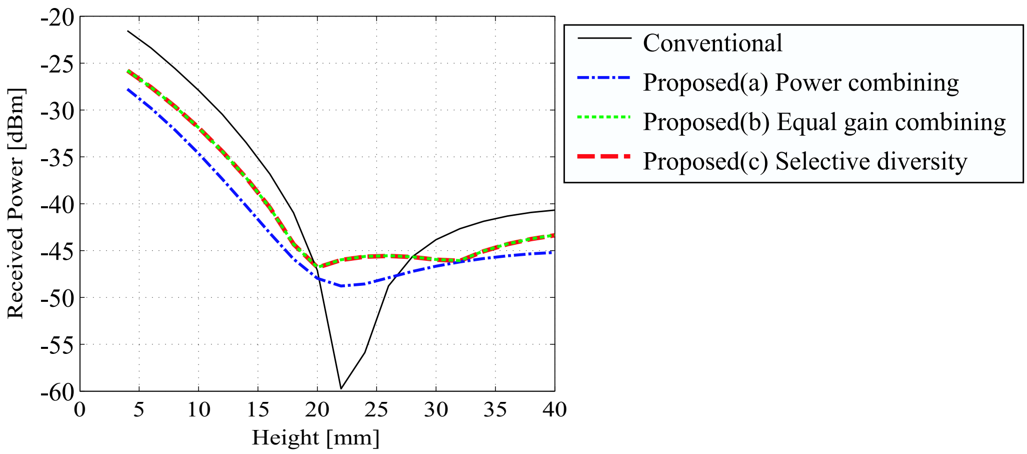


Figure 7: Received power of the proposed method

4. Conclusion

We have proposed a method to avoid null zone for HF-band RFID tag using diversity combining without expanding antenna size. The FDTD simulation shows that the proposed method enlarges received power by 13.9 dB at the position of deepest null. On the other hands, for the regions where null does not happen, received power reduced by 4.2 dB for the worst case because the element antenna becomes smaller.

In this paper, the diversity antenna is used as RX antenna. Considering the reciprocity of electromagnetic field, diversity is effective for both transmitting and receiving when only R/W is equipped with the proposed antenna.

Evaluation by bit error rate for ASK modulation is further study.

References

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