Magnetic Field Measurement Near Wireless Power Transfer Systems

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Abstract

Measurement method of magnetic field near a magnetic source is investigated. Frequencies of the magnetic field are 100 kHz and 6.78 MHz. As a result, even if magnetic sensor is placed nearest to the source, change of current flowing through the source is marginal in this study. When the sensor whose measuring area is 100 cm^2 is moved closer to the source, the difference between the actual strength of the magnetic field and that estimated using the sensor increases. At the source-sensor distance of 20 cm, the estimated strengths are 0.9 and 2.2% higher than the actual field strength. On the other hand, the estimated strengths are 10.0 and 10.2% higher at the frequencies of 100 kHz and 6.78 MHz, respectively, at the distance of 0 cm.

1. Introduction

Wireless power transfer systems that meet standards determined by the Wireless Power Consortium (WPC), Alliance for Wireless Power (A4WP), and so on have been recently investigated and commercialized [1, 2]. Since these systems are used near the human body, assessing the exposure to the human body is important. International Electrotechnical Commission (IEC) 62233 [3] is an example of a measurement method for human exposure at the measuring distance of 0 or 30 cm. On the other hand, the Ministry of Internal Affairs and Communications of Japan (MIC) published a guideline regarding human exposure to an electromagnetic field [4], and the guideline says that at the frequency of a magnetic field is lower than 300 MHz, the distance between the magnetic source and the sensor should be set to equal or greater than 20 cm; otherwise, measurement error may not be negligible. Therefore, in this study, measurement method of magnetic field is investigated by measurement and simulation for the source-sensor distance less than 20 cm.

2. Magnetic Field Measurement and Numerical Simulation

A magnetic field near a magnetic source is measured and simulated. Figure 1 shows the schematic explanation of an investigation model. The magnetic source is a loop coil with the radius (r) of 5 cm. Term i is the current flowing through the source. As a magnetic sensor, three mutually perpendicular concentric coils with a measuring area of 100 cm^2 covered with a radome is used. Method of Moment (MoM) is used as the simulation method, more specifically, the simulation software FEKO (EMSS, South Africa) is used. The frequencies considered are 100 kHz and 6.78 MHz assuming the WPC and A4WP. First, in order to confirm the validity of the simulation, only the magnetic source is modeled and magnetic field attenuation along the dotted line shown in Figure 1 is simulated and compared to the calculated value based on equation (1). As a result, the simulated magnetic field strengths are in agreement with the calculated values in the range of x≦20 cm at the frequencies of 100 kHz and 6.78 MHz.

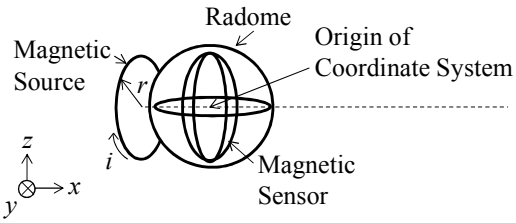

Figure 1. Schematic explanation of an investigation model

$$H(x) = \frac{ir^2}{2\left(r^2 + x^2\right)^{3/2}} \qquad \text{[A/m]...(1)}$$

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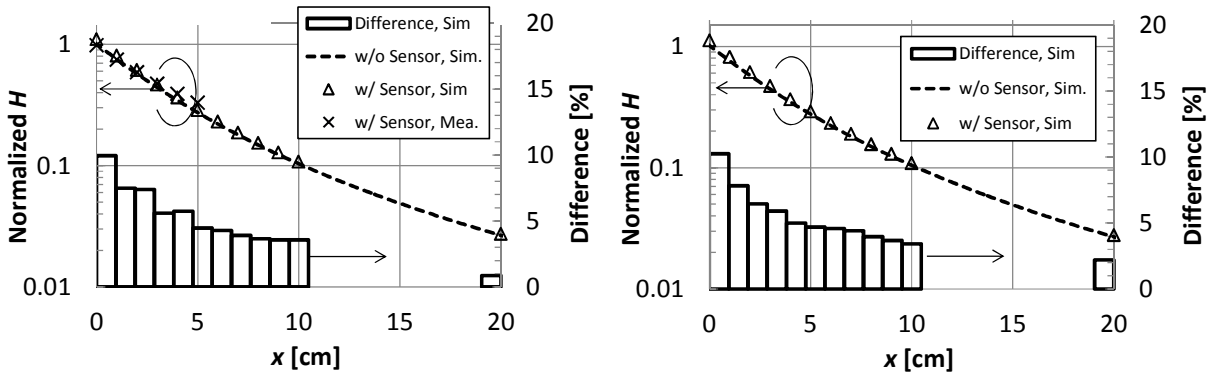
Second, the measured and simulated magnetic field strengths are compared. Figures 2(a) and 2(b) show the measured and simulated magnetic field strengths at the frequencies of 100 kHz and 6.78 MHz, respectively. In the figure, the labels of "w/o Sensor" and "w/ Sensor" represent the actual magnetic field strength and the magnetic field strength calculated from an induced voltage to the sensor at each x, respectively. They are normalized to the actual strength at $x = 0$. In the figure, "Difference" means the ratio of the difference between the "w/ and the w/o Sensor" values to the "w/ Sensor" values at each x. As shown in Figure 2(a), the simulated "w/ Sensor" values agree with the measured values at the frequency of 100 kHz. Therefore, the validity of the simulation employing the magnetic source and sensor models is verified. Because the upper limit frequency of the measurement instrument is 400 kHz, for 6.78 MHz, another instrument with sensor measuring area of 86.6 cm^2 is used for measurement and it is confirmed that the simulated "w/ Sensor" values are in agreement with the measured values.

In order to confirm the effect of the sensor on the magnetic source, the current flowing through the source is measured and simulated. Even if the sensor is placed nearest to the source ($x = 0$), change of the current flowing through the source is marginal. The effect of the sensor on the magnetic field strength is evaluated based on simulation. The "Difference" becomes larger when the distance between the source and sensor becomes shorter as shown in Figures 2 (a) and 2 (b). At the frequencies of 100 kHz and 6.78 MHz, the estimated field strengths at $x = 20$ cm are 0.9 and 2.2% higher than the actual strength, respectively. On the other hand, at the distance of 0 cm, the estimated field strengths are 10.0 and 10.2% higher than the actual values, respectively. The reason of this difference is local change of linkage magnetic field to the sensor.



(a) 100 kHz (b) 6.78 MHz

Figure 2. Measured and simulated magnetic field strength

3. Conclusion

Magnetic field measurement in the range of less than 20 cm from the magnetic source was investigated. The frequencies for the magnetic field are 100 kHz and 6.78 MHz. In this study, even if the sensor is placed nearest to the source, change of the current flowing through the source is marginal. When the sensor with the measuring area of 100 cm^2 is moved closer to the source, the difference between the actual and estimated magnetic field strengths increased. At the frequencies of 100 kHz and 6.78 MHz, the estimated field strengths are 0.9 and 2.2% higher than the actual strengths, respectively, at the source-sensor distance of 20 cm. On the other hand, at the distance of 0 cm, the estimated field strengths are 10.0 and 10.2% higher than the actual values, respectively.

4. References

1. Wireless Power Consortium (WPC), http://www.wirelesspowerconsortium.com/

2. Alliance for Wireless Power (A4WP), http://www.rezence.com/

3. International Electrotechnical Commission (IEC), IEC 62233 Ed. 1.0, 2005.

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