The evaluation of the magnetic field below 30 MHz in an open area test site

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Abstract: Photovoltaic generation systems and power line communication systems radiate EM-waves below 30 MHz. In this situation, measurement sites for the EM-waves are required. However, evaluation methods of the site below 30 MHz are not established yet. In this paper, we measure the magnetic behavior below 30 MHz in a OATS (Open Area Test Site), and also simulate with a moment method. As the results, the deviation between the measurement and calculation data became within 2.5 dB. Therefore, we confirm that this paper’s method of measurement can be used to evaluate the measurement site in below 30 MHz.

Keywords: EM-wave, magnetic field, OATS, method of moment

Classification: Electronic instrumentation and control

References

1 Introduction

Measurement sites for EM-waves below 30 MHz are required because photovoltaic generation and power line communication systems emit the RF energy [1, 2]. On the other hand, generally the anechoic chamber is used as a measurement site for EM-fields above 30 MHz. However, it is not yet confirmed whether the anechoic chamber can be used also as the measurement site below 30 MHz.

In [3], for simulating the EM-emission from a solar cell, they have used a dipole antenna instead of a solar cell module, which is on the tip of a twist line linked to a balun on the ground. In [4], the result of simulating EM-emission by a moment method in substituting the solar cell module with the loop is not reported because the modeling of twist line and balun below 30 MHz is difficult. The loop was a grounded large U-shaped wire having an electrical image below the ground plane for increasing the strength of the magnetic field as much as possible. In these reports, the performance of an anechoic chamber is measured with this device and showed that the measured value in the anechoic chamber and the calculated value assumed to be a semi-infinite space were in agreement within 5 dB.

However, the anechoic chamber is not the semi-infinite space because it has reflection from the walls and ceiling. Therefore, in this paper, we measure the magnetic field behavior below 30 MHz in an open area test site (OATS), which has no reflection from the walls and ceiling, and also simulate with a moment method. We evaluate this measurement method below 30 MHz by comparison of these results.

2 Method of measurement and calculation

2.1 Measurement method

A transmitting antenna is manufactured, as shown in Fig. 1 (a). It is a balance-fed loop antenna, using electric image below ground plane. The antenna is formed with a U-shaped copper wire and a metal plate. The loop size was set to 1.25 m because this size was maximum possible on the turntable of 1.5 m diameter [4]. The loop size agreed with the setting of reference [4] though the loop size had to be originally unrestricted because the utility evaluation of the anechoic chamber was a purpose of this paper.

A measurement system and a coordinate system are shown in Fig. 1 (b). The measurement is carried out in the OATS (Kashima No. 3 site of Intertek Japan). A receiving antenna is a commercial loop antenna (HFH2-Z2 R&S) calibrated with standard electric field method. The receiving antenna is set at 1.28 m high, and is 3 or 10 m away from the transmitting antenna. Each component of magnetic fields is measured by changing the direction of the receiving antenna’s axis to X, Y, and Z. Furthermore, the magnetic field transition when the aperture direction of transmitting loop antenna turned in X and Y direction is also measured.
2.2 Calculation method

For comparison with the measurement result, the magnetic field in the semi-infinite space on the metal ground plane, which imitates the OATS, is calculated with a moment method software (Numerical Electromagnetic Code Ver. 2; NEC2).

It was assumed that the voltage source of the same voltage as the measurement is connected with transmitting antenna which consisted of U-shape copper wire (0.6 mm in diameter) and metal plate. Using this calculation model, each component of the magnetic field is calculated at the center position of the loop of the receiving antenna.

3 Measurement and calculation results on OATS

3.1 Characteristics of EM-wave on transmitting loop antenna

To investigate the influence of insufficient ground plane, the magnetic fields under three conditions of the transmitting antenna are calculated. In the first condition, U-shape wire exists in the free space. As for other two, U-shape
wire is constructed on infinite ground plane or finite ground plane.

Fig. 2 (a) shows the result of calculating the ratio of the orthogonal electric field and magnetic field each other. Here, the \(|H|\) and \(|E|\) are the strength of the magnetic and electric field, respectively. As a calculation result, if ground plane exists, the impact which the plane size gives to the ratio of the electric and magnetic field is small. This suggests that EM-wave radiating from this antenna is intended magnetic-wave even if the grounding of the copper plate to the OATS's floor is insufficient. Furthermore, Fig. 2 (b) shows current distributions along the wire of the loop antenna on the model of the U-shaped wire with an infinite ground plate. In this figure, feed point

![Graphical representation of current distributions along the wire of the loop antenna on the model of the U-shaped wire with an infinite ground plate.](image-url)

**Fig. 2.** Analysis of transmitting loop antenna and conductivity of turn table edge: (a) Characteristics of EM-wave from transmitting antenna; (b) Current distribution in transmitting antenna; (c) Difference of results depending on conductivity of turn table edge; (d) Improvement of conductivity of turn table edge
is assumed to be an origin point (= 0 m) of loop. Although the current distribution along the wire is almost constant until 10 MHz, it is not constant around 30 MHz. Since the length of the loop antenna including the virtual image becomes a half of the wavelength at 30 MHz, the maximum point of the current amplitude on loop element becomes the position at 2.5 m. Therefore, as for the frequency above 10 MHz, this antenna has an unsymmetrical current distribution.

### 3.2 Improvement of conductivity of turn table edge

The floor of the OATS has a clearance gap around a turn table because the turn table must rotate. The result indicates irregular vibrations of about 3 dBμA/m in 5 to 20 MHz, as shown at a red line in Fig. 2 (c). To improve this, the gap is covered by conductive sheets as shown in Fig. 2 (d). Covering to the gap eliminates the irregular vibration, as shown at a black line in Fig. 2 (c).

### 3.3 Comparison between calculation and measurement

The grounding situation for transmitting loop antenna is evaluated by the comparison between the measured and calculated radiation magnetic field strength. If grounding is insufficient, it is assumed that the actual measurement radiation magnetic field is near to the radiation magnetic field from U-shaped wire with a finite-size ground plane. On the other hand, if grounding is perfect, the measurement radiation magnetic field is assumed to be approximate to the radiation magnetic field by U-shaped wire with an infinite ground plane.

The comparison result is shown in Fig. 3 (a). In this graph, the distance between transmitting and receiving antenna is set to 3 m. The transmitting antenna is directed toward the X direction. In both of the measurement and the calculation of the “U-shaped wire with an infinite ground plate” are within 1.0 dB. As a result, it is thought that the transmitting loop antenna grounding is sufficient in measurement.

Fig. 3 (b) shows the comparison between the measurement and the calculated radiation magnetic field when transmitting-antenna is turned toward the X or Y direction. Moreover, the radiation magnetic field comparison at different transmitting and receiving antenna intervals (3 m and 10 m) are shown. In this graph, the dots such as ‘○’ and ‘△’ etc. show calculated values, and the lines show measured data. As a result, both data of the measurement and calculation are within 2.5 dB. These results show the validity of the measurement method and calculation method of this paper.

Furthermore, the comparison between the measurement and the calculation data of all components of the magnetic field are shown in Fig. 3 (c). Transmitting and receiving antenna interval is set to 3 m, and transmitting antenna is turned toward the X-direction. In this graph, HX is X-component of magnetic field strength, HY is Y-component, and HZ is Z-component. Ideally, the difference between angle of the transmitting antenna axis and the
receiving antenna axis is 0 degree. However, it is difficult in actual measurement. Therefore, when antenna axis difference angle $\theta$ is $\theta = 1$ and 2 deg., magnetic field are also calculated. These calculations are imitating Fig. 3.

(a) Measured 
Calculated : an infinite-size Cu plate
Calculated : a finite-size Cu plate 1x2m

(b) Measured 
Calculated : an infinite-size Cu plate
Calculated : a finite-size Cu plate 1x2m

(c) Measured 
Calculated : an infinite-size Cu plate
Calculated : a finite-size Cu plate 1x2m

**Fig. 3.** Measurement and calculation result: (a) Difference of the magnetic field by the size of a copper plate; (b) Comparison of measured values and calculated values; (c) Difference of the magnetic field by the setting accuracy of antenna positions
the realistic arrangement of antennas. This result is also shown in Fig. 3 (c).

As for HX and HZ, the calculated and the measured data are same, within 1.5 dB. On these components of magnetic field, the influence by the difference of antenna axis angle is less than 0.1 dB.

Next, HY component of magnetic field is investigated. Since the current distribution in a loop is not uniform as shown in Fig. 2 (b), HY component exists. As for the frequency band of 10 MHz or more, the calculated values and the measured values are same, within 1.5 dB. However, regarding HY component below 10 MHz, there is a large difference between the measured data and the calculated data under $\theta = 0$ deg.

HY components increase with the angle $\theta$ of the transmitting antenna. On the other hand, under the $\theta = 2$ deg. condition, the difference between measured data and the calculated one become within 1.5 dB. As a result, although each component of magnetic field is greatly influenced by the setting accuracy of antenna positions, the magnitude of magnetic field is not influenced by it.

4 Conclusion

In this paper, we measured the magnetic performance below 30 MHz in an OATS, and also simulated with a moment method. As the results, the value of measurement and calculation was agreement within 2.5 dB in all frequencies. Therefore, we confirmed that this paper’s method of measurement can be used to evaluate a measurement site in below 30 MHz.