MEASUREMENT OF MAGNETIC ANTENNA FACTOR OF SHIELDED LOOP ANTENNA BY 3-ANTENNA METHOD.

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1. Introduction

It is important to exactly measure the radiating magnetic field for EMS (electromagnetic susceptibility) and EMI (electromagnetic interference) measurement. Receiving loop antennas, whose antenna factor is accurately estimated, is necessary for the measurement of the magnetic field. When the measurement is carried out in the frequency range below 30 MHz, loop antennas behave as small antennas in such a low frequency range. So far some various methods for evaluating the antenna factors of small loop antennas were proposed and investigated. In this paper, we show and discuss the results using the "3-Antenna Method" by averaged magnetic field.

2. 3-antenna method for loop antennas by averaged magnetic field

The magnetic antenna factor of a loop antenna is defined as the ratio of the incident plane magnetic field strength to the output voltage of the matched load. However, it is difficult to apply the actual plane wave to a loop antenna or obtain even a quasi far-field condition at the low frequency (The frequency range is less than 30 MHz.). Therefore the averaged magnetic field over the area of the receiving loop antenna in receiving mode is generally used instead of the plane magnetic field assumption [1]. The 3-antenna method defined by the averaged magnetic field [2] is expressed as (1).

$$F_m(\omega) = \sqrt{\frac{-A_{32}}{A_{21}A_{13}} \frac{\alpha_{21}\alpha_{13}}{\alpha_{32}}} \qquad [S/m], \qquad \cdots \qquad (1)$$

where

$$\alpha_{ij} = \frac{\sqrt{1+k^2R_{ij}^2}}{j\omega\mu_0\pi Z_0 R_{ij}^3}\left\{1+\frac{15(r_j r_i)^2}{8R_{ij}^4}+\frac{315}{64}\frac{(r_j r_i)^4}{R_{ij}^8}\right\}, \qquad R_{ij} = \sqrt{d^2+r_i^2+r_j^2},$$

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F_m : magnetic antenna factor, k : wave number ($= 2\pi / \lambda$), A_{32}, A_{21}, A_{13} : transmission S-parameters between antennas, ω : angular frequency, μ_0 : permeability of free-space, Z_0 : load matched to the line impedance, r_1, r_2, r_3 : radiuses of loop antennas and d : distance between these two loops.

3. Shielded Loop Antenna

In order to evaluate the previous "3-Antenna Method", we make a comparison between an experiment and a numerical simulation for a shielded loop antenna. The structure of the shielded loop antenna is shown in Fig.1. The diameter of the loop is 10 cm. The diameter of the antenna element is 3.7 mm because a semi-rigid cable is used.

In the simulation, the equivalent circuit drawn as shown in Fig.2-(a) is used for two shielded loop antennas. This equivalent circuit is re-drawn as Fig.2-(b) using the S-parameter concept. Finally, the total S-parameters between port #1 and #2 is obtain as shown in Fig.2-(c). In this figure, Z_{l1} and Z_{l2} are the matched-loads to the line impedance (50 Ω), l_1, l_2, l_1' and l_2' are the half length of each loop, Z_{r1} and Z_{r2} are loads at the ends of the supplementary circuits (short / 0 Ω), $[S_1]$ and $[S_2]$ are S-parameter matrixes of the transmission lines, $[S_{r1}]$ and $[S_{r2}]$ are S-parameter matrixes of the supplementary circuits, $[S_{MoM}]$ is the S-parameter matrix between only elements of the two loop antennas and, $[S_{Total}]$ is the total S-parameter matrix between port #1 and #2. Therefore the magnetic antenna factor of a shielded loop antenna is obtained by the $[S_{Total}]$ and (1) in the numerical simulation. The $[S_{MoM}]$ is calculated by a method of moment (MoM). In this MoM process, the delta-gap model and the piecewise sinusoidal functions are adopted as the source modeling and the expansion and weighting functions, respectively. The frequency range is from 150 kHz to 30 MHz. In the same way as the simulation, the experimental result is obtained by (1) and the measured total S-parameters. The S-parameters are measured by a vector network analyzer.

The both of results are compared as shown in Fig.3. The difference of these values is closed up to evaluate in detail the difference between the simulation and experiment. The difference is shown in Fig.4. The maximum difference is about 0.26 dB.

4. Conclusion

We applied a "three-antenna method" to a loop antenna measurement by using the averaged magnetic field over the area of the loop antenna. To evaluate the performance of the method, the comparison was made between the numerical simulation and the experiment. In the simulation, we calculate the total S-parameters including the transmission between two shielded loop antennas and the transmission lines in the loop antennas. In the experiment, the "3-Antenna Method" by averaged magnetic field was performed for the shielded loop antenna. The frequency range was from 150 kHz to 30 MHz. Consequently, the difference between these antenna factors obtained by numerical simulation and experiment was within 0.26 dB. It is shown the measurement method can be adequately used for the evaluation of the antenna factor of loop antennas.

In future works, this "3-Antenna Method" should be further compared with other measurement methods to be practically used.

References

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[2] M. Ishii and K. Komiyama, "A Measurement Method for Magnetic Antenna Factor of Small Circular Loop Antenna by 3-Antenna Method", URSI. North American Radio Science Meeting (Columbus), pp.458, July (2003)

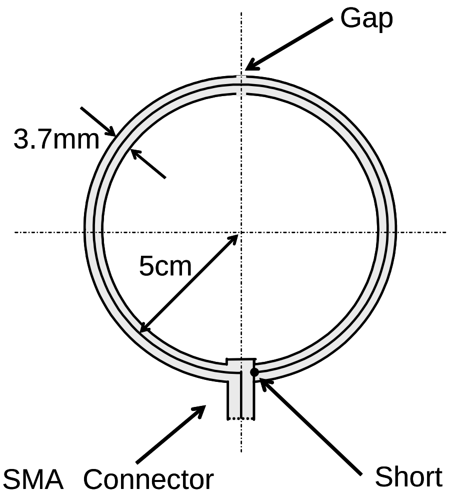

Fig.1 The structure of the shielded loop antenna.

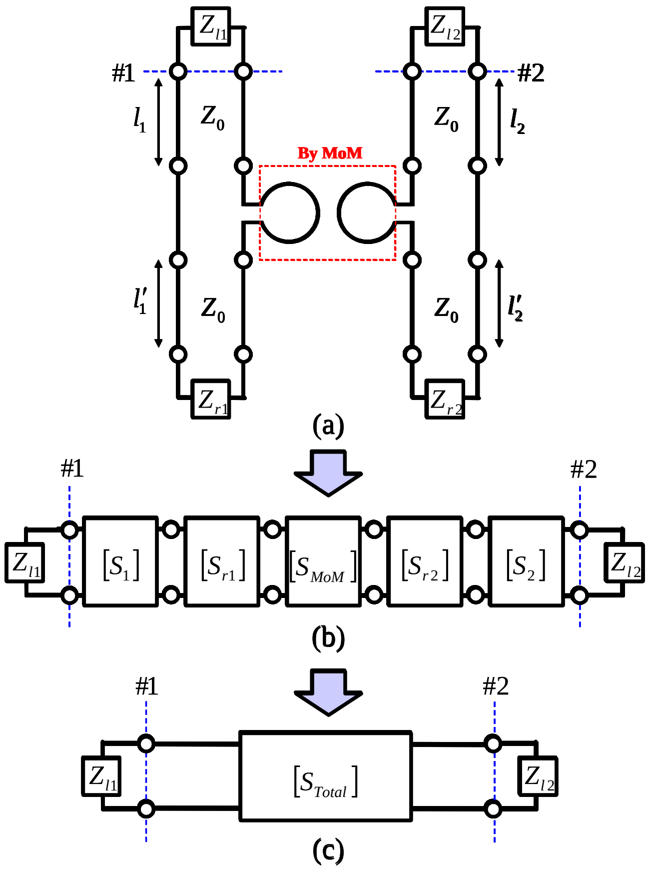

Fig.2 The equivalent circuit for two shielded loop antennas.

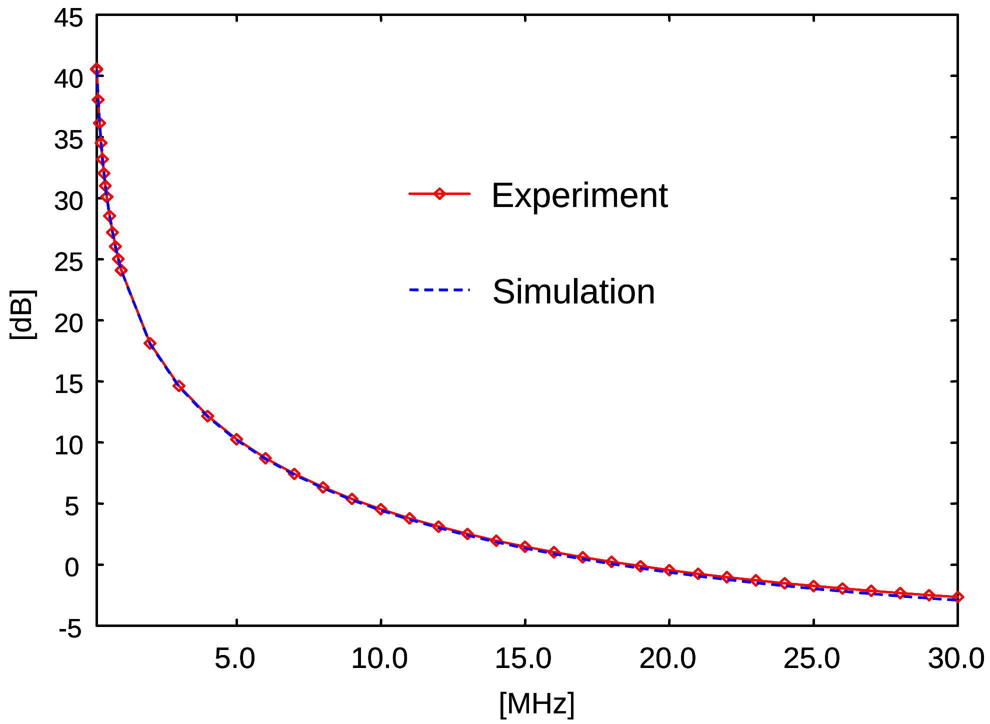

Fig.3 Magnetic antenna factors of the shield loop antenna (Experiment and Simulation).

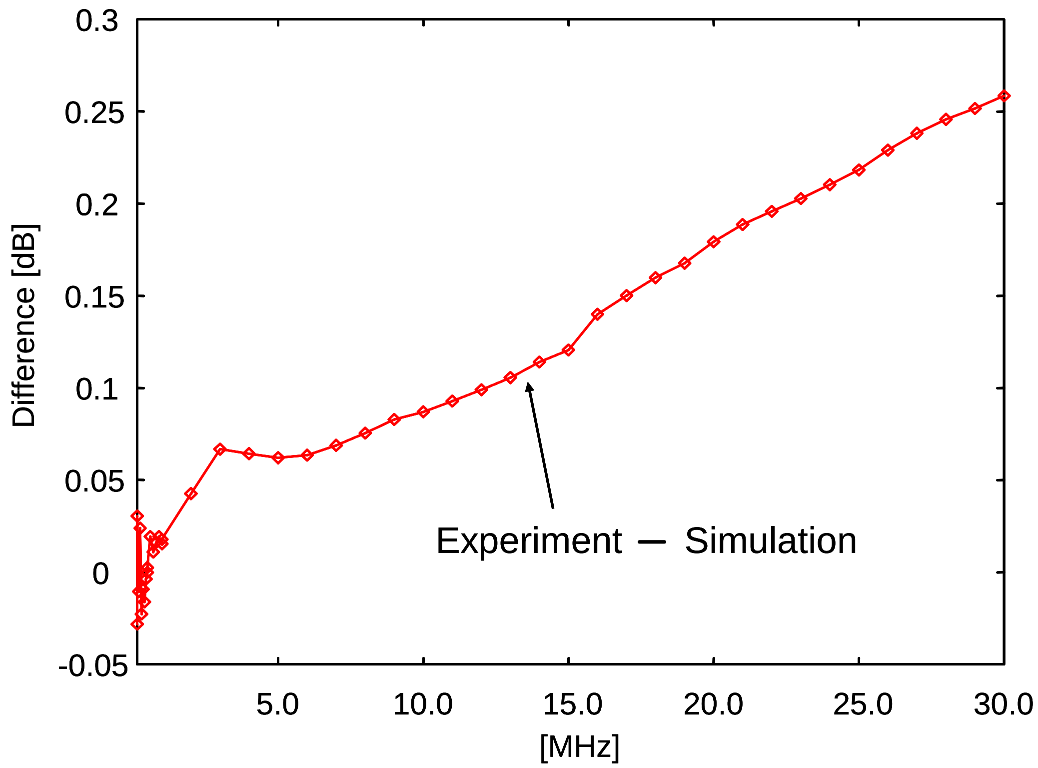

Fig.4 The difference between the experiment and the simulation.