A Measurement Method for Magnetic Antenna Factor of Small Circular Loop Antenna by 3-Antenna Method

Masanori Ishii* Masanobu Hirose Koji Komiyama
National Institute of Advanced Industrial Science and Technology,
National Metrology Institute of Japan

Background:

In the field of electromagnetic interference and electromagnetic compatibility (EMI/EMC), it is important to exactly measure the radiating magnetic field. In order to measure the magnetic field strength, a receiving loop antenna's antenna factor must be exactly determined, too. In this paper, a measurement method for the magnetic antenna factor of a small circular loop antenna using a 3-antenna method is described. The frequency range is less than 30MHz. The result of the 3-antenna method on magnetic antenna factor is compared with a theoretical one and it is confirmed that these results agree with each other.

A proposed 3-antenna method:

A loop antenna behaves as a small antenna at the low frequency. The magnetic antenna factor 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 obtain a quasi far-field condition or apply the plane wave to the loop antenna at the low frequency. So the averaged magnetic field over the aria of the receiving loop is generally used instead of the plane magnetic field. (F. M. Greene, "The Near-Zone Magnetic Field of a Small Circular-Loop Antenna", J. of R. NBS-C, EI, Vol. 71C, No.4, Oct.-Dec. 1967.) A 3-antenna method defined by the averaged magnetic field is expressed as Equation (1).

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

where

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

F_m: magnetic antenna factor, k: wavelength constant ($=2\pi/\lambda$), 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 the two loops.

Comparison the result of a proposed 3-antenna method with theoretical one:

The input impedance of a small loop antenna (Z_{in}) is obtained theoretically. (J. E. Storer, "Impedance of Thin-wire Loop Antennas, AIEE. Trans. Vol. 75, Part1, No.27, pp.606-619, Nov. (1956)) It is possible to calculate the theoretical magnetic antenna factor of a small loop antenna from Z_{in} and Faraday's law. In Fig.1, the magnetic antenna factors by the proposed 3-antenna method simulation and the theory are exactly same. The frequency range is from 10kHz to 30MHz. The radius of the loop is 10cm. The diameter of the antenna element is 3mm. The distance of the two antennas is 2m. For this 3-antenna method, the transmission S-parameters are calculated by the moment method. The difference between these results is 0.13dB at the maximum. The result confirms that the proposed 3-antenna method is effective.

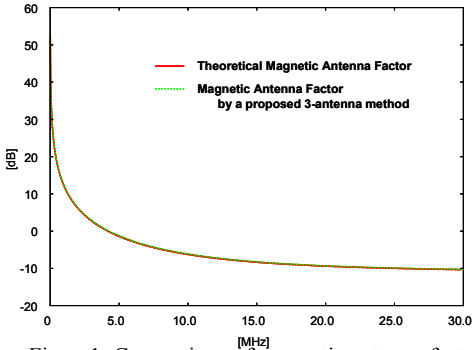

Figure1. Comparison of magnetic antenna factors