A Study on measurement method of shielding effectiveness using loop antenna in low-frequency

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Abstract—This paper describes a measurement method of electromagnetic shielding effectiveness in low frequency. In order to measure the magnetic shielding effectiveness, loop antennas are usually used. When a type of shielding material is sheet or cloth, it is easily put up inside a loop antenna. Therefore, we propose a method to measure a magnetic shielding effectiveness of materials whose type is sheet or cloth.

Keywords—magnetic shielding effectiveness; loop antenna; low frequency

I. INTRODUCTION

In the fields of electromagnetic interference (EMI) and electromagnetic compatibility (EMC), it is important to evaluate a characteristic of an electromagnetic shielding material. Recently, various types of materials for electromagnetic shielding are proposed. As one of them, there is sheet type material. This type shielding material is used for shielding clothes, shielding windows, simple shielding rooms, and so on. In this paper, we propose a simple method to evaluate a shielding effectiveness of material whose types is sheet or cloth.

II. PRINCIPLE OF LOOP ANTENNA [1]

In general, the equivalent circuit of an antenna in a receiving mode is as shown in Fig. 1.

The output open voltage $V_o$ of the loop antenna element is expressed by Faraday’s law as

$$V_o = -j\omega \pi r_a^2 \mu_0 H$$

(2)

where $\omega$ is the angular frequency; $r_a$, the radius of the loop antenna; $\mu_0$, the permeability of free space; and $H$, the magnetic field strength of the incident plane wave. On the other hand, when $\Gamma_L$ is zero, the relationship between $V_a$ and $V_L$ is expressed from Fig. 1 as

$$V_L = \frac{Z_L}{Z_L + Z_{in}} V_a.$$  

(3)

In the case of an active loop antenna, an amplifier is inside antenna. The output voltage of loop antenna is amplified. However, the basic principle of active loop antenna is basically same.

III. PROPOSED MEASUREING METHOD OF SHIELDING EFFECTIVENESS

A. Principle

The loop antenna is dominated by Faraday’s law as mentioned before. This means that the sensitivity of loop antenna can be controlled by an amount of magnetic flux inside loop as

$$\Phi = \pi r_a^2 \mu_0 H.$$  

(4)

When the radius of loop antenna is constant, $\mu_0 H$ becomes main factor of the magnetic flux. This time, we hope to measure the shielding effect of sample materials whose types are meshed or cloth. In general, a shielding room with a window is necessary to measure the shielding effect of sample materials [2]. We propose a method without a shielding room as shown in Fig. 2.
In this proposed method, the sample material sheet or cloth is put up inside loop of a loop antenna. It is expected that the shielding characteristic of a sample material can be obtained by this method. A reference value of this method is measured without the sample material. A setup of experiment of Rx loop antenna is shown in Fig. 3. The sample material is cut in a circle whose diameter is approximately 30 cm, and it is stretched along the loop antenna element as a frame and fastened with adhesive tapes.

In Fig. 4, five results are shown. The results of 6027RxFix, 9027RxFix, and 13227RxFix are for only single sheet of sample. The results of 6027WRxFix and 13227WRxFix are for double sheet of sample, that is, two sheets of sample are put up inside loop of the loop antenna. It is found that the sample with narrow pitch of mesh has high shield effectiveness as expected. These results show a feasibility of the proposed method as a method to measure shielding effectiveness of the sheet or cloth type shielding materials.

In this experiment, Tx loop antenna is passive type and Rx loop antenna is active type. Their diameters are 30 cm, and the distance between Tx and Tx loop antennas is 60 cm. Generally, the size of loop antenna is regulated in [2] and Rx loop antenna is usually active type. It is expected that there is a change of input impedance of Rx loop antenna caused by the sample material. However, it is impossible that a variation of input impedance of this Rx loop antenna is measured because there is an amplifier inside this Rx loop antenna. Therefore, in the following experiment, a passive type whose diameter is 10 cm is used as the Tx and Rx loop antennas.
B. Evaluation of shielding effectiveness of sample materials

In this experiment, measurements of shielding effectiveness of a same sample material are performed by the both types of antenna orientation. Basically, it is expected that the obtained results by the both types of orientations should agree with each other.

As sample materials, three types of sample are prepared. They are sheet or meshed types. Two of three samples (9027 and 13227) are same ones in the previous experiments for the feasibility study. Moreover, one sample is added in this experiment. This sample isn’t a meshed type but the shielding material is printed on a vinyl sheet. We name this sample as Sumitomo in this paper. The frequency range is from 10 kHz to 1 MHz. The results of this experiment are shown in Fig. 8.

In Fig. 8, eight results are shown. The results of 9027 and 13227 are for only single sheet of sample. The results of Sumitomo are for both single and double sheets of sample. The “double sheets” means same two sheets of sample are put up inside loop of the loop antenna. This result shows that the obtained shielding effectiveness by the both types of orientation agree with each other below 1 MHz, and the
samples with narrow pitch of mesh or double sheets have high
shield effectiveness.

In Fig. 9, differences between the results of shielding
effectiveness by coplanar and coaxial antenna orientations are
shown. The frequency range is from 10 kHz to 10 MHz. It is
clear that the difference becomes obvious more than 1 MHz. In
this method, the positioning of the sample material might affect
the measurement result more than 1 MHz as the material is
close to feeding gap of loop antenna. Under the present
conditions, this method has restrictions on frequency band.

C. Variation of antenna impedance

It is supposed that the restriction of this method is caused
by a variation of antenna impedance. The variations of antenna
impedance by sample material are shown in Fig. 10 and 11.

When Fig. 10 and 11 are compared, they are very similar
results. It is found that these variations of antenna impedance
don’t depend on the antenna orientations. Therefore the
antenna distance and orientation don’t affect the measurement
results. The each difference from the antenna impedance of
“No Sample” is within several Ohms below 1 MHz. On the
other hand, the differences become more than 15 \( \Omega \) at 3 MHz.
However, it is very hard succeed in removing or compensating
this variation of antenna impedance in this experiment. In the
future work, we need to remove or compensate this variation of
antenna impedance caused by sample material.

Generally, in order to measure a shielding effectiveness of
material, a shielding room and antenna or special waveguide
are necessary. However, this proposed method needs only Tx
and Rx loop antennas, therefore it is expected that the
measurement of shielding effectiveness is realized at low cost
by this proposed method.

V. CONCLUSION

In this paper, we proposed a simple method to measure a
shielding effectiveness of material whose type is meshed or
cloth using loop antenna in low frequency band. In the
experiment, the relative tendencies of the result are appropriate.

The proposed method is simple and realized at low cost
because shielding room or special waveguide is not necessary.
Therefore, it is expect that the proposed method has
 possibilities and potentiality for measuring the shielding
effectiveness of materials simply and easily.

REFERENCES

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