並列SPM法による逆問題解析

Leakage magnetic field source searching by the correlative analysis

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Abstract

This paper describes a methodology of searching for the leakage magnetic field sources from the electronic devices by a correlative analysis. Previously, we have succeeded in searching for the magnetic field source from the measurement of local magnetic fields in biological systems. In the present paper, we now apply our method called the sampled pattern matching (SPM) method to the leakage magnetic field source searching problems. It is shown that a correlative analysis between the real and imaginary parts of magnetic field source yields an excellent result.

1.INTRODUCTION

With the development of modern digital computers, high frequency operation of the computers is essentially required in order to speed up the CPU and to realize the smaller size power supplies. This causes a problem so called the electromagnetic compatibility (EMC), i.e. the environmental effects caused by the electromagnetic fields leaking from the electronic devices. To remove this problem, at first, we have to find the leakage electromagnetic field source from the devices.

Previously, we have succeeded in searching for the magnetic field sources from the measurement of local magnetic fields in biological systems [1,2]. In the present paper, we now apply our method called the sampled pattern matching method to the EMC problems.

In most case, the electromagnetic wave can be represented in terms of the complex notation. This means that we have to independently searching for the real and imaginary parts of the leakage field source. Key idea of our approach is that both of the real and imaginary parts have to take the same path, thereby, a correlative analysis between the real and imaginary parts may yield the highly accurate result. Further, this removes a large amount of ambiguity associated with the sampled pattern matching solutions.

Thus, we have succeeded in searching for the leakage magnetic field source with high accuracy.

2. CORRELATIVE ANALYSIS OF THE LEAKAGE MAGNETIC FIELD SOURCE SEARCHING

2.1. Assumption

This paper assumes that the operating frequency of the target electronic devices is not so high. Moreover, it is assumed that the normal component of leakage magnetic fields is measured at a surface near to the target electronic devices. Thereby, the phase difference due to the space propagation time between the target and field measured points is assumed to be neglected. This assumption means that our problem is to searching for the low frequency alternating current density **J** distributions by measuring the local magnetic fields **H**.

2.2. Sampled Pattern Matching Method

The magnetic field **H** is related to the current density **J** by

$$\mathbf{H} = \nabla \times \int [\mathbf{J}/(4\pi|r|)]dv, \tag{1}$$

where r is a distance between the field **H** and source **J** points. In (1), the volume V containing the current density **J** is subdivided into a large number of subdivisions V_i, $i=1\sim m$. In this small volume V_i, $i=1\sim m$, each of current densities $\mathbf{J}_i$, $i=1\sim n$, takes a constant value. Also, the number of field measured points is denoted by n, then (1) reduces into

$$\mathbf{U} = \sum_{i=1}^{m} \alpha_i \mathbf{d}_i, \tag{2}$$

where

$$\mathbf{U} = [\mathbf{H}_1, \mathbf{H}_2, \cdots, \mathbf{H}_n]^T, \tag{3a}$$

$$\mathbf{d}_i = (1/4\pi)[\mathbf{n}\times\mathbf{a}_{1i}/r_{1i}^2, \mathbf{n}\times\mathbf{a}_{2i}/r_{2i}^2, \cdots, \mathbf{n}\times\mathbf{a}_{ni}/r_{ni}^2]^T, \tag{3b}$$

$$\alpha_i = J_i V_i, \quad i=1\sim m, \tag{3c}$$

$$m>>n. \tag{3d}$$

As shown in Fig.1, **n** is a unit vector in the direction of $\mathbf{J}_i$; $\mathbf{a}_{1i}, \mathbf{a}_{2i}, \cdot, \mathbf{a}_{ni}$ are the unit vectors from the source point i to the field points 1,2,·,n; $r_{1i}, r_{2i}, \cdot, r_{ni}$ are the distances from the source point i to the field points 1,2,···,n, respectively. Further, α_i, $i=1\sim m$, in (3c) is a magnitude of the current dipole $\mathbf{P}_i$ [1,3]. The condition m>>n in (3d) is always satisfied because the fields $\mathbf{H}_i$, $i=1\sim n$, can be measured on the limited surface but the field sources α_i, $i=1\sim m$, exist in the volume enclosed by the field measuring surface.

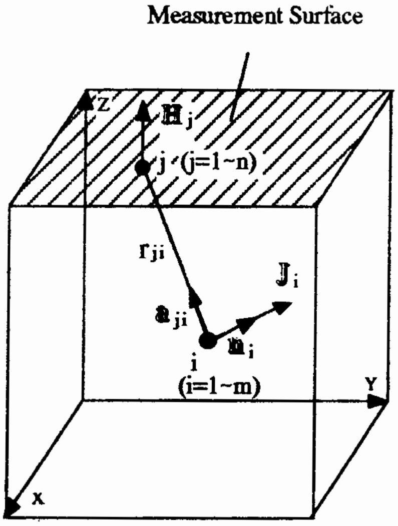


Figure 1. Relationship between the magnetic field and its source points.

Equation (2) means that the vector **U** is a linear combination of the vectors $\mathbf{d}_i$ ($i=1\sim m$). Thereby, (2) can be modified into

$$\mathbf{U} = \sum_{i=1}^{m} \{\beta_i \mathbf{d}_i + \sum_{j\neq i}^{m} \{\beta_{ij}(\mathbf{d}_i+\mathbf{d}_j) + \sum_{k\neq i,k\neq j}^{m} \{\beta_{ijk}(\mathbf{d}_i+\mathbf{d}_j+\mathbf{d}_k) + \cdots \}\}\}. \tag{4}$$

Each of the terms in (4) has its distinct field pattern. Namely, the 1st, 2nd and 3rd groups on the right give the one, two and three pairs of the north (N) and south (S) magnetic poles, respectively. This means that the pattern matching analysis should be applied only to the 1st solution group but also the other remaining solution groups. After carrying out this sampled pattern matching analysis to all of the groups in (4), summation of their results will yield a unique field source pattern. Thus, the obtained field source pattern corresponds to the normalized current distributions [1].

The 1st solution group in (4) is

$$[\mathbf{U}/|\mathbf{U}|]^T[\mathbf{d}_1/|\mathbf{d}_1|],\ [\mathbf{U}/|\mathbf{U}|]^T[\mathbf{d}_2/|\mathbf{d}_2|],\ \cdots,\ [\mathbf{U}/|\mathbf{U}|]^T[\mathbf{d}_h/|\mathbf{d}_h|],\ \cdots,[\mathbf{U}/|\mathbf{U}|]^T[\mathbf{d}_m/|\mathbf{d}_m|]. \qquad (5a)$$

If $[\mathbf{U}/|\mathbf{U}|]^T[\mathbf{d}_h/|\mathbf{d}_h|]$ takes the maximum in (5a), then 2nd solution group is

$$[\mathbf{U}/|\mathbf{U}|]^T[(\mathbf{d}_h+\mathbf{d}_1)/|\mathbf{d}_h+\mathbf{d}_1|],\ [\mathbf{U}/|\mathbf{U}|]^T[(\mathbf{d}_h+\mathbf{d}_2)/|\mathbf{d}_h+\mathbf{d}_2|],\ \cdots,\ 1,\ \cdots,[\mathbf{U}/|\mathbf{U}|]^T[(\mathbf{d}_h+\mathbf{d}_m)/|\mathbf{d}_h+\mathbf{d}_m|]. \qquad (5b)$$

Similar procedure is continued until a peak value of inner product can be obtained. Thereby, the normalized solutions of (2) are

$$\alpha_1[|\mathbf{d}_1|/|\mathbf{U}|] \simeq [\mathbf{U}/|\mathbf{U}|]^T\{[\mathbf{d}_1/|\mathbf{d}_1|]+[(\mathbf{d}_h+\mathbf{d}_1)/|\mathbf{d}_h+\mathbf{d}_1|]+\cdots\}, \qquad (6a)$$

$$\alpha_2[|\mathbf{d}_2|/|\mathbf{U}|] \simeq [\mathbf{U}/|\mathbf{U}|]^T\{[\mathbf{d}_2/|\mathbf{d}_2|]+[(\mathbf{d}_h+\mathbf{d}_2)/|\mathbf{d}_h+\mathbf{d}_2|]+\cdots\}, \qquad (6b)$$

....

$$\alpha_h[|\mathbf{d}_h|/|\mathbf{U}|] \simeq \{[\mathbf{U}/|\mathbf{U}|]^T[\mathbf{d}_h/|\mathbf{d}_h|]+1+1+\cdots\}, \qquad (6c)$$

....

$$\alpha_m[|\mathbf{d}_m|/|\mathbf{U}|] \simeq [\mathbf{U}/|\mathbf{U}|]^T\{[\mathbf{d}_m/|\mathbf{d}_m|]+[(\mathbf{d}_h+\mathbf{d}_m)/|\mathbf{d}_h+\mathbf{d}_m|]+\cdots\}. \qquad (6d)$$

Thus, it is possible to obtain the current dipole vectors from the magnetic field measurements. After obtaining the real and imaginary parts of the current dipole vectors independently, a correlation between them can be obtained by taking the inner product between the real and imaginary parts.

2.3. Example

Figure 2 shows a schematic diagram of a practically tested example [4]. The normal magnetic fields were measured at each of the grid points on the surface located 5cm above the target surface. The target device used in this experiment has a cross shape slit with 5mm width and includes a loop antenna located at the center of metallic box. The exciting frequency of the loop antenna is 1MHz. Therefore, the wave length is so long that the phase difference due to the space propagation time is negligibly small value.

In general, it may be considered that the position of target including the magnetic field source should be unknown. This means that we can measure the leakage magnetic fields but we do not know where they come from. Thereby, we assumed that the target having $40\times40\times12\text{cm}^3$ volume was located 5cm below the measurement surface. The target was subdivided into 153600 small rectangular prisms. Also, the angle in x-y surface is divided into 72 directions so that total number of unknowns m is 11059200 whereas the number of measured magnetic field n is 1681.

Figures 3(a) and 3(b) show the real and imaginary parts of the leakage magnetic field sources estimated by the sampled pattern matching method, respectively. They include a considerable ambiguity but a correlative analysis between them yields an excellent result as shown in Fig. 3(c).

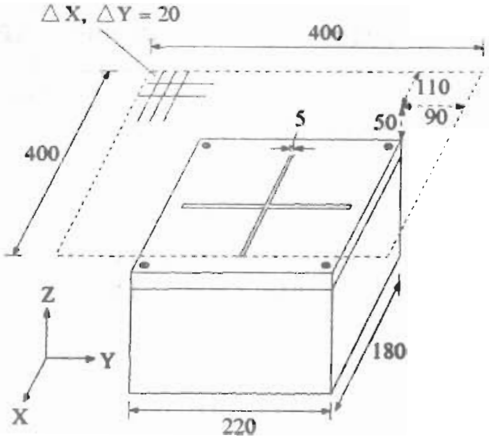
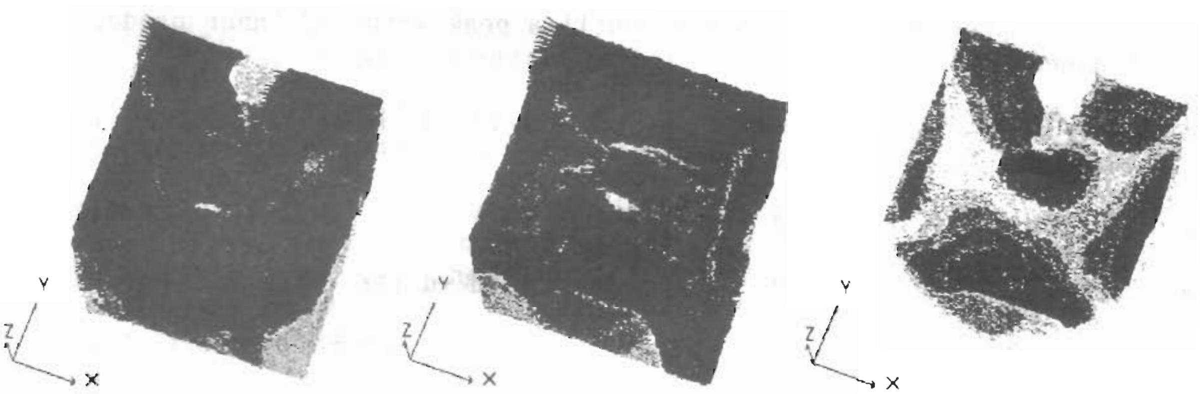


Figure 2. Schematic diagram of a practically tested example [unit mm].



(a) (b) (c)

Figure 3. Estimated leakage magnetic field source distributions. (a) real part, (b) imaginary part and (c) correlation.

3.CONCLUSION

As shown above, both of the real and imaginary parts include a considerable ambiguity but their correlation provides the reliable leakage magnetic field source distribution coincided with the results of previous work [4]. Thus, we have elucidated that our sampled pattern matching method can be available to solving for the EMC problems. Key idea to get the reliable results is similar to those of the space power distribution method [5].

4. REFERENCES

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