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A Study on Optimization of Loaded Magnetic Materials for Antenna Miniaturization

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1. Introduction

With the recent rapid progress in handsets, the downsizing of their antennas is acquiring great importance. Generally, these antennas have been downsized by changing a configuration of the antennas or utilizing materials such as dielectric materials and magnetic materials. Until now, we have investigated a downsizing technique of antennas for handsets by utilizing magnetic materials [1]. It was found that the magnetic materials have an effect on lowering resonance frequency of a planar inverted-F antenna (PIFA) instead of changing the radiation characteristics at both 900[MHz] and 2[GHz] bands. In addition, the effective configuration and arrangement of the magnetic materials have been investigated on the basis of the current distribution of PIFA. But this configuration and arrangement is not necessarily the optimal material distribution, so we used the Topology Optimization to find the optimal material distribution in our previous study [2].

The Topology Optimization has significantly been expanded to many optimization problems. We used the Topology Optimization to optimize the configuration and arrangement of the magnetic materials, which were inserted in PIFA on an infinite ground plane. In this optimization, the finite-difference time-domain (FDTD) method and the adjoint variable method (AVM) [3] were used, and design parameters were permittivity and permeability of the materials. As a result, it was found that the resonance frequency was effectively lowered by utilizing the optimal configuration of the magnetic materials. In this paper, we apply the Topology Optimization to PIFA on a finite ground plane, which is used in practice, and confirm its validity as compared with the results calculated by other simulator.

2. The analytical model and analytical method

A flowchart of adopted Optimization algorithm is shown in Fig.1. To start with, initial value of design parameters are set in each divided infinitesimal design cell. In the first step, FDTD simulation is executed. And the object function value is obtained. In this calculation, the object function is the value of the reflect power from antenna and this algorithm attempt a reduction of that. If the value becomes to converge, the optimal structure is determined. If not, the second step is to analyze the design sensitivity, which is the gradient in the objection function, by the AVM. The final step is to update the design parameter by sequential liner programming (SLP). This procedure is repeated until the object function value converged.

Fig.2 shows the analytical model. The PIFA is installed on the perfect conducting box. The resonance frequency, which can be adjusted by changing the size of the PIFA, is $3.2[\mathrm{GHz}]$. The magnetic materials can make the resonance frequency decrease instead of changing the size of the PIFA. The design domain is set between the PIFA and the conducting box. In the design domain, the values of permittivity and permeability are set at each infinitesimal cells of the FDTD method. The Topology Optimization is used to determine the optimal structure of the magnetic materials by using these values as design parameter. In order to confirm the validity of the Topology Optimization, the model approximate to the PIFA with the optimal magnetic structure obtained by

the Topology Optimization is analyzed with the electromagnetic simulator based on the Finite Element Method (FEM), and the results are compared with those of the Topology Optimization.

3. The result of analysis

The optimal structure of the magnetic materials given by using the Topology Optimization is shown in Fig.3. The PIFA and conducting box are not showed in this figure. Its structure has a shape such as wrapping a short pin and forming a loop. Fig.4 shows the VSWR characteristics. 'With material' indicates VSWR of the PIFA loaded with the optimal magnetic materials. When the PIFA was loaded with the optimal magnetic materials, the resonance frequency was shifted from 3.2[GHz] to 2.1[GHz]. 'No material' indicates VSWR of the PIFA without the magnetic materials, the size of this PIFA is adjusted to the resonance frequency of the PIFA of 'With material', that is 2.1[GHz]. VSWR of 'With material' is in good agreement with that of 'No material'. From the comparison in the volume of these PIFAs, it is concluded that miniaturization of about 36% is achieved. VSWR characteristic calculated by the FEM simulator is shown in Fig.5. 'With material (FEM)' indicates VSWR of the PIFA loaded with the optimal magnetic materials calculated by the Topology Optimization. 'No material (FEM)', as in the case of the Topology Optimization, indicates VSWR of the PIFA without the magnetic materials. The results similar to those by the Topology Optimization are obtained.

4. Conclusion

We applied the Topology Optimization to the PIFA on the conducting box to optimize the structure of the magnetic materials. As a result, utilizing the magnetic materials lowers the resonance frequency, and the miniaturization of about 36% is achieved. As compared with the results calculated by other simulator, the validity of this optimization is confirmed.

References

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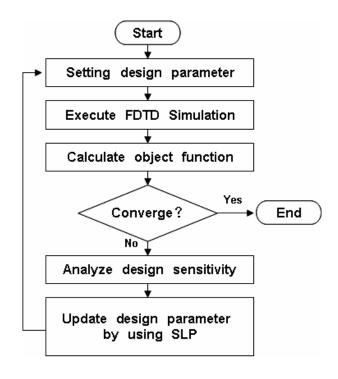


Fig.1 Flowchart of optimization algorithm

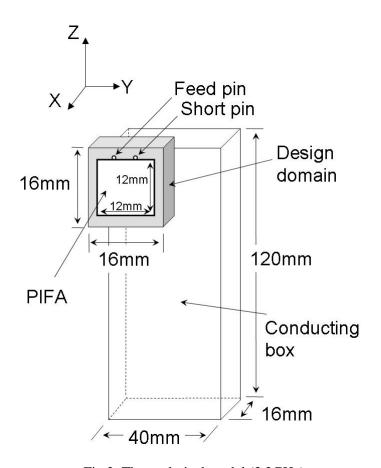


Fig.2 The analytical model (3.2GHz)

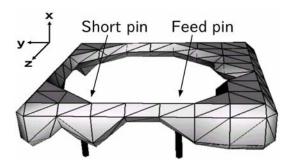


Fig.3 The optimal structure of magnetic material

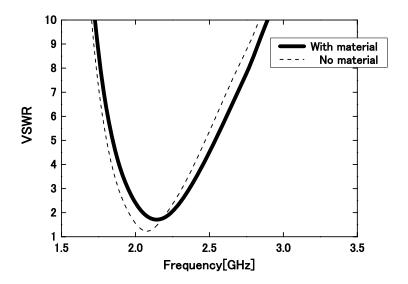


Fig.4 VSWR characteristics by the Topology Optimization

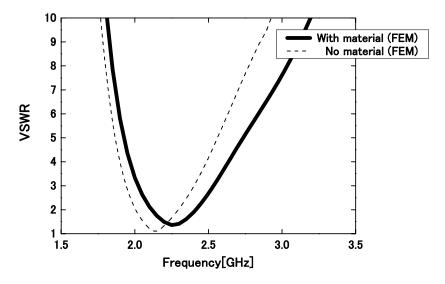


Fig.5 VSWR characteristics by the FEM simulator