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Analysis of Plane Circuit Using CNNs

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1. Introduction

Recently, the operational speed of the integrated circuits are increasing rapidly. The increase of the operational speed causes many complicated phenomena, such as the transmission delay, the power/signal integrity or the power distribution. In designing the high speed systems, analyzing the power distribution of the multi-layer printed circuit bords is very important. Most of the analysis method of the power distributions are based on the finite element method. In the finite element method, obtaining the accrate solution, the number of element become very large. It is very time consuming task that calculate the solution by conventional digital computers. Hence, in this paper, we simulate the voltage propagation on the plane using two-layer Cellular Ceural Networks, which are high speed analog signal processing systems.

2. Plane Circuit

Analysis methods of the power distribution can be classified into three classes by its model accuracy, full-wave electromagnetic model, modified nodal model and lumped circuit model. In our research, we adapt the partial-element equivalent circuit (PEEC) method.

In PEEC aproach, the plane is discretized spatially and modeled by linear elements, R, L, G and C. Fig.1. shows the equaivalent circuit of the plane. The parameters of linear elements are determined by the physical property of the plane and the discritization size.

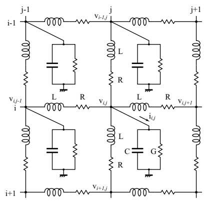


Fig. 1. Plane circuit.

The state equations of the PEEC model are given as follows;

$$\begin{cases} \dfrac{dv_{i,j}}{d\tau} = -G\sqrt{\dfrac{L}{C}}v_{i,j} + \sqrt{\dfrac{L}{C}}i_{i,j}, \\ \dfrac{di_{i,j}}{d\tau} = -R\sqrt{\dfrac{C}{L}}i_{i,j} + \sqrt{\dfrac{C}{L}}(v_{i-1,j} + v_{i+1,j} \\ \qquad\qquad + v_{i,j-1} + v_{i,j+1} - 4v_{ij}). \end{cases} \quad (1)$$

If we discretize the plane into $n \times n$ small elements, we have to calculate $2n^2$ differential equations.

3. Cellular Neural Networks

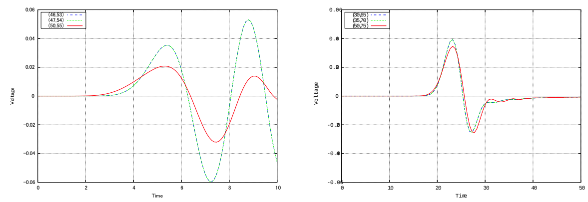
Cellular Neural Networks (CNNs) have the array structure of the fundamental elements, called *cell*, which is composed of simple analog circuit. CNNs have been developed as the analysis method of the partial differential equations and adapted for simulate spatio-temporal phenomena, such as traveling waves. The concept of the multi-layer CNNs has been proposed and reported its high processing abilities. The state equations of the two-layer CNNs are given by as follow;

$$\begin{cases} \dfrac{dx_{1ij}}{dt} = -x_{1ij} + \sum_{C(k,l)\in N_r(i,j)} A_1(i,j;k,l)y_{1kl} \\ \quad + \sum_{C(k,l)\in N_r(i,j)} B_1(i,j;k,l)u_{1kl} \\ \quad + \sum_{C(k,l)\in N_r(i,j)} C_1(i,j;k,l)y_{2kl} + I_1, \\ \dfrac{dx_{2ij}}{dt} = -x_{i,j} + \sum_{C(k,l)\in N_r(i,j)} A_2(i,j;k,l)y_{2kl} \\ \quad + \sum_{C(k,l)\in N_r(i,j)} B_2(i,j;k,l)u_{2kl} \\ \quad + \sum_{C(k,l)\in N_r(i,j)} C_2(i,j;k,l)y_{1kl} + I_2. \end{cases} \quad (2)$$

The behavior of CNNs is defined by the coefficients, called *cloning templates*. By comparing two system of equations, PEEC and CNNs, we can find that both equations have local connectivity. Hence, we can simulate the phenomena on the plane using two-layer CNNs.

4. Simulation

Confirming the accuracy of the PEEC model, we measure the voltage at some points whose distance from an arbitrary point in Euclidean space is the same. We compare two cases, in the first case, we discretize the plane $w = 2.0$[mm] and assume the impulse voltage as a point, while another case, we discretize $w = 0.4$[mm] and assume the impulse voltage as an area.



(a) $w = 2.0$[mm]. (b) $w = 0.4$[mm].

Fig. 2. Dirrection difference.

As shown in Fig.2, observed phenomena are different. This difference is resulted in the lattice-like structure of the plane circuit. Obtaining the accurate results, we have to discretize the plane smaller and to assume the voltage as an area, not as a point.

5. Conclusion

In this paper, we showed that the power distribution of the printed circuit board can be analyzed by two-layer CNNs. Although our research is only the simulation, CNNs will provide for a solution with higher speed than any oter known methods.