A New FDTD Perfectly Matched Layer (PML) Model Constructed by the Machine Learning

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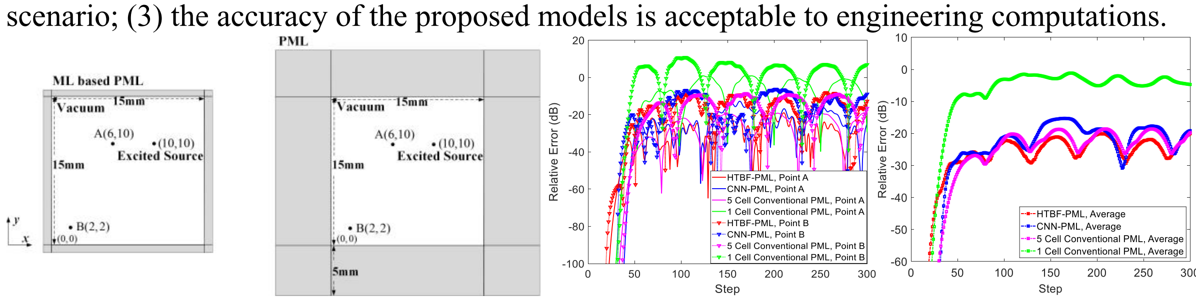
Perfectly matched layer (PML) utilizes analytical layers to absorb the electromagnetic waves. It aims at truncating the computational domain and minimizing reflections at boundary interfaces for finite difference time domain (FDTD) method on numerical simulations of electromagnetic waves. However, the size of PML has to be increased in order to reduce the residue error to obtain better absorption performance over a wide range of angles and frequency of electromagnetic waves. Hence, the enlarged size means the increased computational domain and complexity.

Recently, machine learning has numerous attractive applications in handling the computation complexity in engineering and science. Machine learning approaches aim to extract the potential mapping disciplinarian from the training data with the same pattern, then predict new output. As to the computation process involving PML, it can be seen as repeatively obtaining local field based on local and neighbouring fields in the current and previous step. Hence, this typical process of repeated computation makes machine learning approaches adaptable to replace the computation process of conventional PML.

In this paper, we propose a novel machine learning (ML) based absorbing boundary condition (ABC) models to replace the conventional PML. Based on the electromagnetic field data at the interface between the object domain and the first layer of the conventional PML, machine learning model based on the hyperbolic tangent basis function neural network (HTBFNN) and convolution neural network (CNN), called HTBF-PML and CNN-PML, can be established by training. The trained HTBF-PML and CNN-PML can replace conventional multi-layer PML to reduce the computation complexity of FDTD. Compared to the conventional approach, the proposed HTBF-PML and CNN-PML greatly lowers the computation complexity and the size of computation domain of FDTD because they only involve the one-cell boundary layer. The proposed ML based PML model and representative performances are in Fig.1. The advantages of the proposed method are: (1) the novel HTBF and CNN based PML models can greatly reduce computation complexity and the size of computation domain for FDTD ABC; (2) the proposed PML models are very flexible and can be conveniently utilized in different FDTD application scenario; (3) the accuracy of the proposed models is acceptable to engineering computations.



(a) (b) (c) (d)

Figure 1. The FDTD grid geometry on the 15mm×15mm area with one excited source and with two probes at points A and B. (a) Machine learning based PML. (b) Conventional PML with the size of 5 cell. Comparison of relative error between HTBF-PML, CNN-PML, 1 cell conventional PML and 5 cell conventional PML. (c) Relative error at Point A and Point B. (c) Average relative error of the entire 15×15 square.