Abstract
論文の内容の要旨

論文題目　Study of finite-difference time-domain analysis on sound fields with porous materials
（多孔質材料を有する音場の時間領域有限差分解析に関する研究）

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In this dissertation, a finite-difference time-domain algorithm based on the equivalent fluid model (EF-FDTD algorithm) is developed to study the sound fields containing porous material.

In the porous material with rigid flame, the mechanism for the sound attenuated in the porous material is by the viscous losses and thermal losses in the porous material. In the frequency-domain equations based on the equivalent fluid model, the effective bulk modulus corresponds to the thermal effects in the porous material, and the effective density corresponds to the viscous effects in the porous material. In the porous material, the effective density and the effective bulk modulus are frequency dependent, which are designed in the form of the IIR filter. By applying the Z-transform theory, the whole wave equations (containing add operation, multiplication operation and frequency dependent parameters) are transformed to Z domain, avoiding the complex convolution operation in time domain. In Z domain, the add operation and the multiplication operation are not changed. New parameters are defined, which greatly simplified the equations in Z domain. The simplified equations and the defined parameters can

be easily transformed to time domain, and formulations of the EF-FDTD algorithm are obtained. In EF-FDTD algorithm, the thermal effects in the porous material are reflected by the parameters of the designed IIR filters of the effective bulk modulus. The viscous effects in the porous material are reflected by the parameters of the designed IIR filters the effective density. Once the IIR filters are designed, there is no need to design them again if the discrete time interval in the FDTD analysis is changed.

The formulations for the 1-dimensional EF-FDTD algorithm, 2-dimensional EF-FDTD algorithm and 3-dimensional EF-FDTD algorithm are presented in this dissertation. The stability conditions for the EF-FDTD algorithm are discussed.

The 1-dimensional EF-FDTD algorithm is validated under the normal incidence of the sound by comparing the numerical analysis and the experiment. In the simulation, the boundary conditions (the boundary between air and the porous material, the boundary between different porous materials) are mainly discussed. The arithmetic averaged density at the boundary is used. The calculated sound absorption coefficients of the constructed multi-layered porous material agree well to the measured values.

The 2-dimensional EF-FDTDT algorithm is validated under the oblique incidence of the sound by comparing the numerical analysis and the theoretical values. 4 regular cases of the common relative position of the porous material and the air are simulated. The methods for calculating the surface impedance for each case are discussed. The calculated surface impedances of the multi-layered porous material are very close to the theoretical values in broad frequency range.

The shaped porous material is simulated by using staircase approximation. In 2-dimensional sound field, the errors caused by using the staircase approximation are discussed. The smaller the discrete space interval is, the smaller the error introduced by the staircase approximation is.

The 2-dimensional EF-FDTDT algorithm is contrasted with the exiting Rayleigh method. The 2-dimensional EF-FDTD method is accurate in broad frequency range either at small

incident angle or big incident angle. For the Rayleigh method, the errors between the calculated absorption coefficients and the theoretical values are very large.

Porous materials are commonly used to construct absorbing wedges in anechoic chambers. The method for predicting the absorption coefficient of the wedges by using 2-dimensioal EF-FDTD algorithm is discussed. For the 4 kinds of designed wedges, the calculated absorption coefficient is very close to the measured values.