ACOUSTICS2008/1009
Acoustic analysis of the vocal tract during vowel production by finite-difference time-domain method

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An acoustic simulator based on the finite-difference time-domain (FDTD) method was evaluated by acoustic measurements on solid models of the vocal tract. Three-dimensional vocal tract (3D VT) shapes for a male subject during production of the five Japanese vowels were measured by magnetic resonance imaging. Transfer functions of the 3D VT shapes were computed by the acoustic simulator. The accuracy of the finite-difference algorithm was second-order in time and fourth-order in space. From the same 3D VT shapes, solid models were made of epoxide resin by a stereo-lithographic technique, and their acoustic transfer functions were measured using a time-stretched pulse signal. The calculated and measured spectra were compared up to 8 kHz. Although locations of major poles and zeros were common between calculated and measured spectra, the calculated spectra showed a larger number of small zeros, possibly caused by underestimation of VT acoustic losses in the simulation. However, the lower four formants were simulated remarkably accurately, with a mean absolute error of only 2.2 % compared with the acoustic measurements. These facts indicated that the acoustic simulator can reasonably account for acoustic phenomena within the VT.