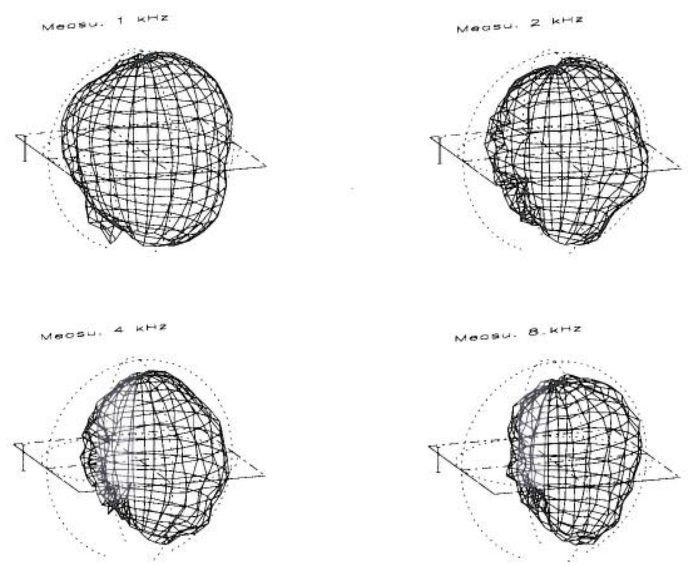

Figure 3.3.8: Directivity pattern of a human speaker at the frequencies 1 kHz, 2 kHz, 4 kHz and 8 kHz.

3.3.2.3 *Models*

Due to the relatively small size of the speaker sound source including the radiation from the mouth, the diffraction from the head and the small influence of the chest, it is assumed that the minimal phase approximation is sufficient to describe the phase of this source. When the monopole model algorithms are applied, a linear phase corresponding to the delay of propagation existing between the centre and the sphere of measurement is artificially added to the directivity factor filters. Using these modifications the procedure employed for modelling this source is very similar to the one described for the JBL loudspeaker in the preceding section. In the following only the main results of the modelling procedure are given.

> An estimation of the spatial Nyquist rate, which can be reached by using the preceding spatial resolution with $M = 385$ points, gives the order L = 14. The maximum extent of this source, measured from the mouth and comprising the chest of the speaker is approximately $r_s = 0.22$ m; the corresponding frequency which can be resolved is f = 3506 Hz.

Figure 3.3.9 shows the coefficients of the DSHT of the sound field up to the 15[th] order for the frequency $f = 3506$ Hz and the corresponding directivity gain; the right side of this figure gives the directivity gain, if only the coefficients of the DSHT up to the first order are

retained. They represent 94.6 % of the total radiated acoustic power. The mean relative level error of this model as compared to the original data is 1.49 dB.

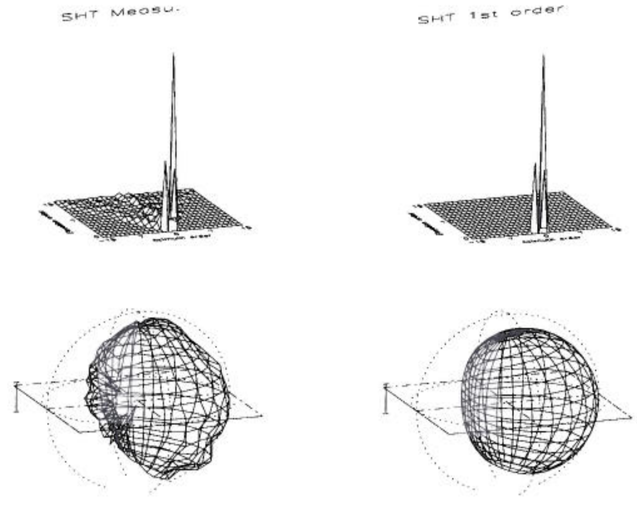

Figure 3.3.9: Modules of the DSHT coefficients up to the 15[th] order (upper left picture) and up to the 1[st] order (upper right picture) of the speaker radiation for the frequency 3506 Hz. The original directivity gain (lower left picture) and the ISHT model of first order (lower right picture) are also depicted.

To determine the monopole locations for this source, a variation is applied to the algorithm described in section 2.4.4. Since most of the radiation information is contained in the DSHT coefficients up to the first order (dipole radiation), some analytical relations have been derived from these coefficients to approximate the radiation from a monopole and a dipole oriented in a direction determined from the DHST coefficients of the first order (see Appendix A).

The corresponding first order approximation of the complex sound field is then subtracted from the original data and the difference is analysed by the classical algorithm to find the monopole locations modelling this difference. The amplitude of these monopoles is then determined by using the same algorithm employed in previous cases. Figure 3.3.10 gives the results of this model for six monopoles and the corresponding DSHT as compared to the original data. The back radiation is more accurate. By looking at the corresponding DSHT it becomes clear that this model also represents the main components of the fine structure of the DSHT for orders greater than one. However it only increases the total radiated acoustic power from 1.1 % to 95.7 %. The mean relative level error is reduced to 1.37 dB.

Remark: The criterion used to guarantee convergence in Newton's method is that the inverse of the Hessian matrix **H** is positive definite: $\mathbf{H}^{-1} > \mathbf{0}$. **H** is positive definite for strictly convex functions, but for general functions Newton's method may lead to direction diverging from the minimum of J. Some methods have been implemented to force the Hessian matrix to be positive definite. One of them, the singular value decomposition, is described in [Press, 1986].

Appendix D

Directivity characteristics of a male human speaker

This appendix contains some directivity characteristics of a male human speaker for the frequencies 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz and 8000 Hz in a similar format to those of [Marshall, 1983]. The reader is invited to compare the following figures with those of these authors in the corresponding article (p.132).

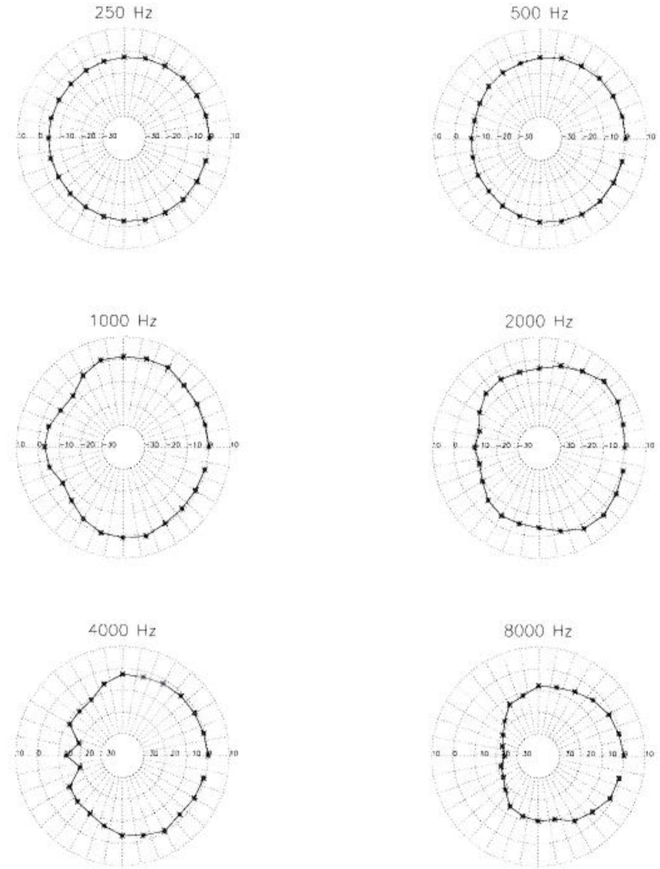

Figure D.1: Directivity of a male human speaker in the horizontal plane.