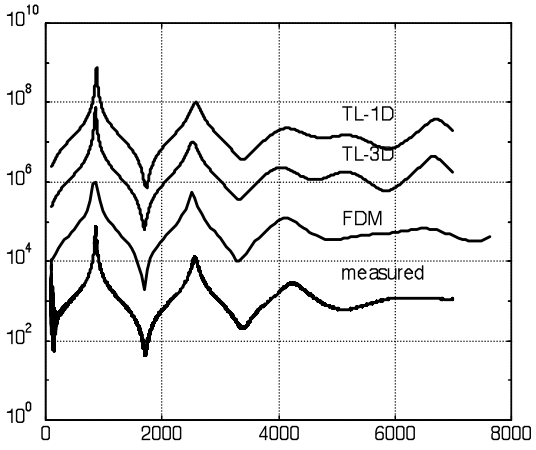

Figure 10. Absolute value of imput impedance of a cylinder with a short cone

Table 2. First resonance peak for a cylinder with a short conical horn

Method	TL-1D	TL-3D	FDM	Measured
1st peak, Hz	865	850	855	859
Difference	+ 0.7%	– 1 %	– 0.5%	

An end correction to the cylinder can be calculated (Figure 12). As can be seen the behaviour is only varying slightly below 5 kHz. Above that frequency the length correction suddenly decreases.

4. DISCUSSION

The position of the first resonance peak of the impedance spectrum is best predicted by TL-3D. The value found with TL-1D can be too high. The short conical horn can be described as a length correction, in a way comparable to that of a flange, provided the frequency is not too high. At higher frequencies the FDM results correspond much better with the measurements than the TL methods. TL methods are fast and conveniently applied. The FDM is cumbersome, a program must be written, there are limitations to the choice of the dimensions.

5. CONCLUSIONS

Since the investigations are still in progress, conclusions are preliminary. For calculating the input impedance of an arbitrary pipe, we conclude that

1. The well-known 1D-TL method is useful for pipes flaring not too much.
2. For horns flaring more than 10% a correction for transverse flow, leading to the so-called 3D-TL method is useful for low frequencies.
3. For higher frequencies, where cross-dimensions are no longer small with respect to the wavelength, the FDM gives better results. This method, however, is cumbersome.
4. Berenger's PML absorbing boundary can be implemented easily in a FDM calculation scheme.

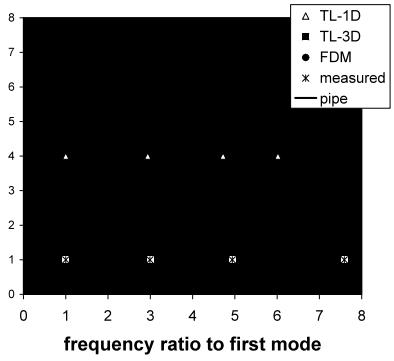

Figure 11. Relative positions of modes in a cylinder with a short cone

6. ACKOWLEDGEMENTS

I thank Alex de Bruijn and Jean-Pierre Dalmont for many stimulating discussions, the latter for valuable assistence with measuring the impedance.

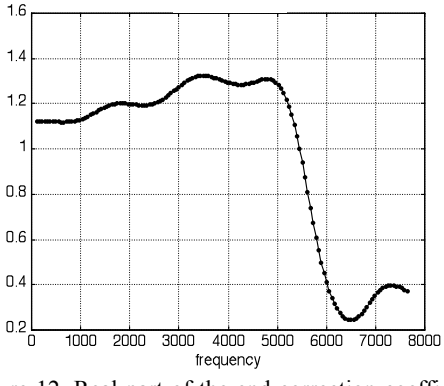

Figure 12. Real part of the end correction coefficient δ/a to the cylinder for the short cone, obtained by FDM.

7. REFERENCES

[1] Nederveen, C.J. Acoustical Aspects of woodwind instruments, 2nd edition. Northern Illinois University Press, De Kalb, Ill. 1998.

[2] Nederveen, C.J., Dalmont, J.-P. Corrections to the Plane-Wave Approximation in Rapidly Flaring Horns, Acta Acustica/Acustica, Vol. 94 (2008) 461–473

[3] Dalmont, J.-P., Nederveen, C.J., Joly, N. Radiation impedance of tubes with different flanges: numerical and experimental investigations. J. Sound and Vibration Vol. 244 (2001) 505–534.

[4] Berenger, J.P., A perfectly matched layer for the absorption of electromagnetic waves, J. Computational Physics, Vol. 114 (1994) 185–200

[5] Taflove, A., Hagness, S.C., Computational Electrodynamics, Artech House, Norwood 2005

[6] Yuan, X., Borup, D, Wiskin, J.W., Berggren, M., Eidend, R., Johnson, S.A., Formulation and validation of Berenger's PML absorbing boundary for the FDTD simulation of acoustic scattering. IEEE Transactions on ultrasonics, ferroelectrics, and frequency control, Vol. 44, (1997) 816–822.