

Time-domain model of the inner ear to study nonlinear responses

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Introduction: The ear doesn't solely listen but it also speaks. Sounds formed in the inner ear which are measurable in the outer ear are called Otoacoustic emissions (OAEs). Some claim these are produced by the outer hair cells (OHCs), the amplifiers in the inner ear. Our hypothesis is that the OHCs only amplify distortion products (DPs) but do not produce them.

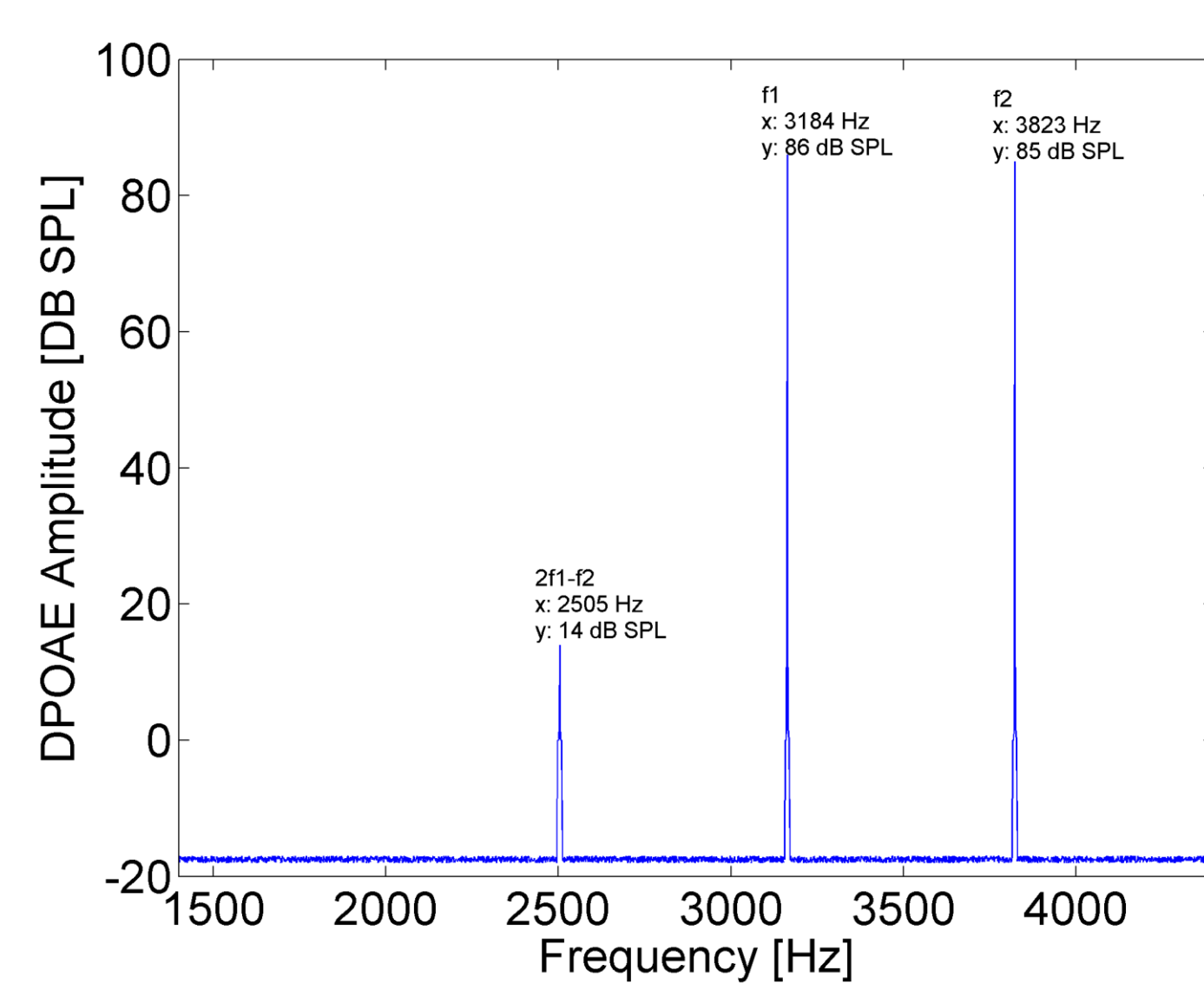


Figure 1. Example measurement of OAE¹

Computational Methods: A simple box model of the cochlea is used. The applied physics interface is *acoustic shell interaction (acsh)*. The basilar membrane (BM) and round window (RW) are modeled as shells. The oval window (OW) supplies an oscillatory pressure at two different frequencies. Firstly, solutions are calculated in the frequency domain, which are then passed on as a superposition to the time domain as initial values.

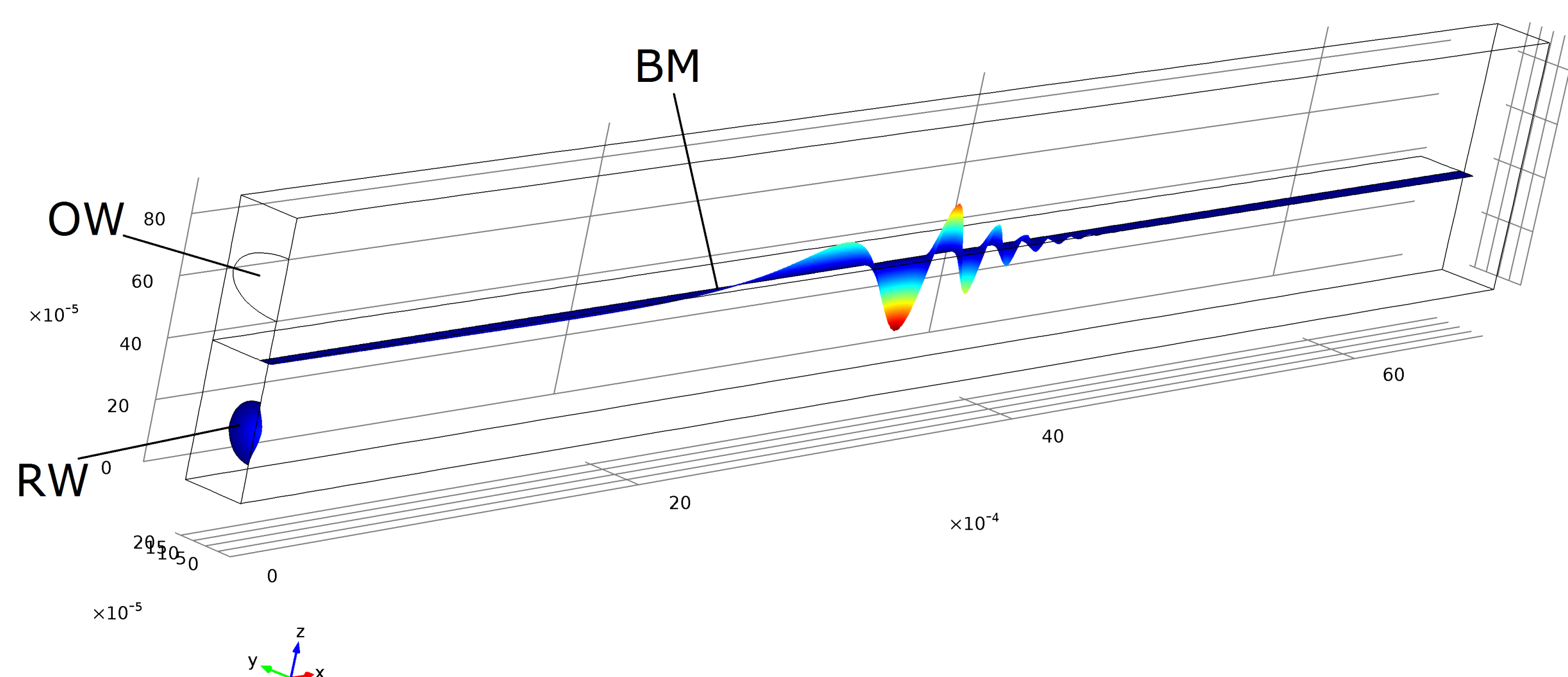


Figure 2. Geometry

Results: Possible DPs $f_{dp} = f_2 + n(f_2 - f_1)$ are calculated. After 16 periods of the lowest frequency stimulation, a spectrum of the vertical movement is shown (fig 6). These contain additional frequency spikes but no convergence of the results was obtained.

n	f _{DP} [kHz]	n	f _{DP} [kHz]
-6	2	-2	14
-5	5	-1	17
-4	8	0	20
-3	11	1	23

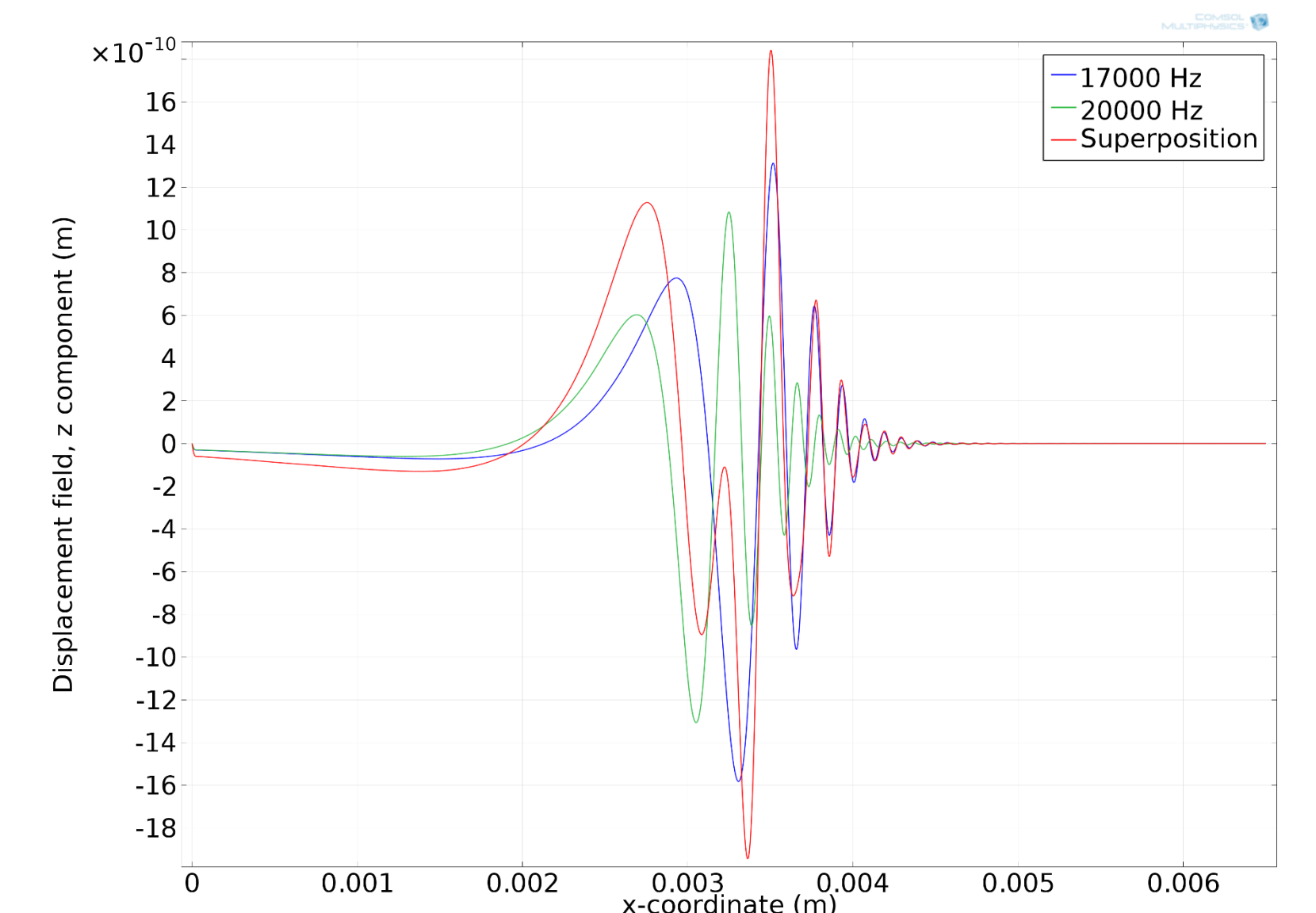


Table 1. Possible DPs (input frequencies in red)

Figure 5. membrane displacement

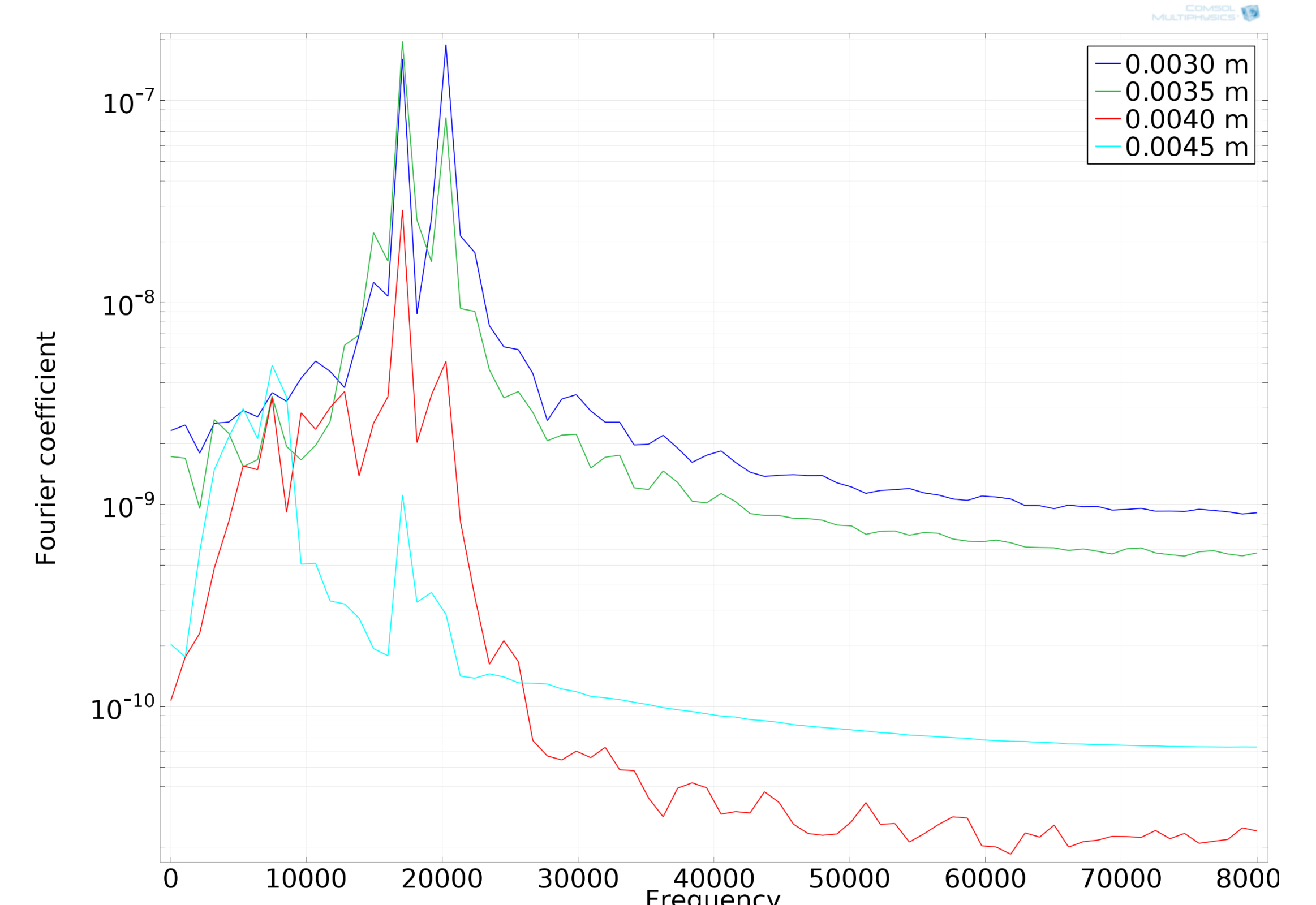


Figure 3. Spectrum of motion for several distances from base

Conclusions: Though the results looked promising, no conclusions about the distortion products can be made without convergence. Further investigation using this method is needed. Elsewise the usage of a ramp is an optional alternative.

References:

1. R., LONSBURY-MARTIN, B.L., MARTIN, G.K., 'A review of otoacoustic emissions' J Acoust Soc Am, Volume 88 (1991), p.2027-2067.