Prediction of masking thresholds for Schroeder phase maskers: masker level effect

Václav Vencovský[1]

[1] Musical Acoustics Research Center, Academy of Performing Arts in Prague, 118 00 Prague, Czech Republic

Email: vaclav.vencovsky@gmail.com

Abstract

Schroeder phase maskers are harmonic complex tones with starting phases of individual harmonics given by an equation proposed by Schroeder [1]. Relative phase between the harmonics may affect masking thresholds. This masker phase effect depends on the masker level: difference between masking thresholds increases with increasing level. This study used four auditory models to predict masking thresholds for Schroeder phase maskers of various levels. The models contained different algorithms simulating response of the basilar membrane (BM): dual resonance nonlinear (DRNL) filterbank of Lopez-Poveda and Meddis [2]; a transmission line model of Verhulst *et al.* [3]; a transmission line model of Baumgarte [4]; and a hydrodynamic model of Nobili *et al.* [5]. The algorithms were extended by an inner hair cell model and a decision device. The DRNL filterbank model predicted the same masker phase effect for the lowest and highest masker level. Transmission line models showed the opposite dependence: the masker phase effect decreased with increasing level. The hydrodynamic model for some of the maskers predicted thresholds with qualitative agreement with behavioral data.

Introduction

Schroeder phase maskers used in this study were harmonic complex tones whose spectral components have equal amplitudes and starting phases are given by

$$\theta_n = C\pi n(n+1)/N, \tag{1}$$

where n is the nth spectral component and N is the overall number of spectral components. The complexes with starting phases calculated for $C = +1$ are called "positive Schroeder phase" and for $C = -1$ "negative Schroeder phase" complexes. Behavioral studies (e.g. [6]) showed that although the positive and negative Schroeder phase complexes have approximately same, flat temporal envelope, they may produce different masking thresholds (differences up to 20 dB). These masker phase effects depend also on the masker level [7, 8]. All these effects can be accounted for on a peripheral level and since many of cochlear models cannot predict the masker phase effects, the stimuli put a strong constraint on their function [9].

This study uses four different cochlear models to predict the effects of level on masking thresholds. Since also the parameters of the cochlear models and the used method of prediction affect the predicted thresholds, the study is not aimed to prove any of the used modeling approaches as wrong. Instead, the aim is to compare the predicted masking thresholds for different types of cochlear models with given parameters.

Cochlear models

Nobili et al. model

The cochlear model proposed by Nobili *et al.* [5] approximates the BM as an array of damped oscillators (with mass and stiffness). The oscillators are coupled through the incompressible fluids in the cochlea. The coupling is modeled by the method of Green's functions. The active function of the cochlea is modeled by a feedback force which undamps the oscillators. This study uses the Nobili et al. model proposed with parameters and dimensions of the human cochlea [5]. I have changed the damping of the oscillators in order to increase the frequency selectivity of the model. Table 1 shows equivalent rectangular bandwidths (ERB) of the simulated cochlear filters measured in six discrete outputs of the model (with characteristic frequency (CF) of 0.125, 0.25, 0.5, 1, 2 and 4 kHz). The values of ERB_{GM} are ERB estimated from behavioral data [10]. Responses of the model are nonlinear and the model can simulate otoacoustic emissions [5].

Table 1: Nobili et al. model: equivalent rectangular bandwidths (ERB) of the simulated cochlear filters. ERB_{GM}: behavioral data [10]

level	characteristic frequency (kHz)					
(dB SPL)	0.125	0.25	0.5	1	2	4
20	43	62	89	141	225	390
40	43	62	90	148	245	521
60	43	70	122	201	337	818
80	54	98	168	307	528	1107
ERB_{GM}	38	52	79	133	241	456

Table 2: DRNL model: ERB of the simulated cochlear filters. ERB_{GM}: behavioral data [10].

level	characteristic frequency (kHz)					
(dB SPL)	0.125	0.25	0.5	1	2	4
20	37	48	73	117	204	303
40	37	48	73	156	272	403
60	37	49	99	172	287	418
80	47	77	130	245	391	541
ERB_{GM}	38	52	79	133	241	456