Improved parameters and expanded simulation options for a model of the auditory periphery

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ABSTRACT

A phenomenological model of the auditory periphery in cats was previously developed by Zilany and colleagues (JASA, 2005) to examine the detailed transformation of acoustic signals into the auditory nerve (AN) representation. In this study, a few issues arising from the responses of the previous version have been addressed. The parameters of the synaptic model have been refined to build better simulated reported discharge rates at saturation for higher characteristic frequencies (CFs). This modification also corrects the responses of higher-CF model fibers to low-frequency tones that were erroneously much higher than the responses of low-CF model fibers in the previous version. Some new simulation options are also described. First, the possibility of incorporating frozen fractional Gaussian noise in the model of the synapse has been detailed. Second, an analytical method has been implemented to compute instantaneous mean rate and variance from the model’s synapse output that takes into account the effects of refractoriness. Finally, a version of the model with some parameters derived from the human auditory system is described. The revised model is more suitable to study and model psychophysical experiments with normal and impaired human listeners.

DESCRIPTION OF THE MODEL

A. Model of the Auditory-periphery

- The auditory-periphery model (Zilany and Bruce, 2008; Zilany et al., 2009) has most of the non-linearities seen in AN responses (e.g., nonlinear tuning, compression, suppression, level-dependent phase responses, shift in the best frequency as a function of sound level, adaptation, high level nonlinearities such as component-1/2 component-2 transition and peak-splitting).
- Classical models of neurotransmitter vesicle release in the inner-hair-cell (IHC)-AN synapse have the same double-exponential adaptation at both onset and offset. However, experimental data has different dynamics in the onset and offset response. Thus, these models fail to account for responses in the stimulus offset, as well as other long-term response properties in the AN.
- To address the different dynamics seen in the AN onset and offset responses, the synaptic model has exponential adaptation followed by power-law dynamics of adaptation (Zilany et al., 2009). This model can account for responses in the stimulus offset, long-term response properties, as well as adaptation to increments and decrements in the amplitude of an ongoing stimulus.

B. Power-Law Synapse Model

- The suppressive effects, δ(t), are accumulated with power-law dynamics (Drew and Abbott, 2008).
- The much longer tail on the power-law function produces a longer memory for past responses than does exponential adaptation.

C. Estimation of instantaneous mean rate and variance from synapse output

- Vannucci and Teich (1978) derived a general expression for the dead-time (absolute refractory period) modified mean and variance for a counting process when the rate of input is an arbitrarily instantaneous mean rate. $R(t)$ is the mean discharge rate as a function of time. $S_{out}(t)$ is the model synaptic output, and $r$ is the absolute refractory period (0.75 ms).

$$V(t) = S_{out}(t)/(1 + r S_{out}(t))^3$$

DISCUSSION

- A revised phenomenological model of the auditory periphery is presented here.
- The changes made to the previous version (Zilany et al., 2009) corrected the model saturation rates as a function of CF without adversely affecting other response properties. The forward-making properties were affected to a small degree, as could be expected after modifying synaptic adaptation.
- To avoid the stochastic nature of the synaptic output, the model included an option to simulate responses with a fixed FGN.
- The revised model also included a set of parameters that describes the middle-ear transfer function and peripheral tuning in human.
- The model is now a better candidate to examine realistic neural-encoding hypotheses, especially those involving higher CFs.

References


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