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A phenomenological model of the synapse between the inner hair cell and auditory nerve: Implications of limited neurotransmitter release sites

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Abstract

Peterson and Heil [Hear. Res., In Press] have argued that the statistics of spontaneous spiking in auditory nerve fibers (ANFs) can be best explained by a model with a limited number of synaptic vesicle docking (release) sites (~ 4) and a relatively-long average redocking time (~16–17 ms) for each of the sites. In this paper we demonstrate how their model can be: i) generalized to also describe sound-driven ANF responses and ii) incorporated into a well-established and widely-used model of the entire auditory periphery [Zilany et al., J. Acoust. Soc. Am. 135, 283–286, 2014]. The responses of the new model exhibit substantial improvement in several measures of ANF spiking statistics, and predicted physiological forward-masking and rate-level functions from the new model structure are shown to also better match published physiological data.

Keywords: Auditory model, Synapse, Neurotransmitter vesicle release, Spike timing statistics, Refractoriness, Renewal process

1. Introduction

In the mammalian ear, excitation of auditory nerve fibers (ANFs) is achieved via release of neurotransmitter contained in synaptic vesicles at the basolateral wall of inner hair cells (IHCs), as illustrated in Fig. 1. While this synapse shares many characteristics with other synapses in the mammalian nervous system, it also has some specializations that enable high firing rates and temporal precision in ANF spiking (see Safieddine et al., 2012, for a recent review). IHCs have specialized presynaptic zones with a presynaptic ribbon that helps traffic vesicles to the release sites. A number of proteins are thought to form the docking sites that facilitate exocytosis of the vesicles, although the exact location and form of the docking proteins in IHCs is still somewhat uncertain. The influx of calcium through voltage-dependent calcium channels provide the trigger for neurotransmitter release. The dynamics of this synaptic release process, along with

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