MECHANICAL PROPERTIES OF COUPLED HAIR BUNDLES

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We present numerical results concerning the stochastic dynamics of arrays of coupled hair bundles. Our findings indicate that elastic coupling of hair bundles could render spontaneous oscillations more coherent and improve signal detection properties.

1. Summary

Hair bundles from the sacculus of the bullfrog have been shown to amplify weak periodic stimuli in a frequency selective manner [1]. For stronger stimuli their response is marked by a region of non-linear compression [2]. They can also exhibit spontaneous oscillations [3].

These features are also recognized as signatures of the cochlear amplifier. But while e.g. the gain of the cochlear amplifier is about 1000 [4], the gain of a single hair bundle is about 10. Single hair bundle dynamics thus cannot account quantitatively for the performance of the cochlear amplifier.

However, in many inner ear organs hair bundles are attached to overlaying structures such as tectorial or otolithic membranes. And thus hair bundles are often elastically coupled to each other. Here we investigate what effect such a coupling could have on hair bundle dynamics. In a first approach we describe coupling by linear springs (see Fig. 1). We describe single hair bundle dynamics by means of a biophysical model that earlier has been shown to capture quantitatively the main features of stochastic hair bundle motility [5].

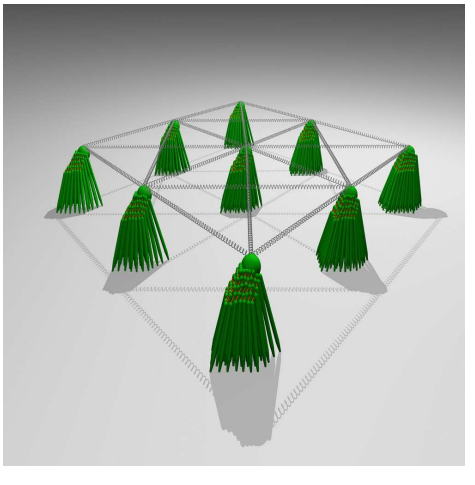

Fig. 1. Schematic view of a system of hair bundles coupled by springs.

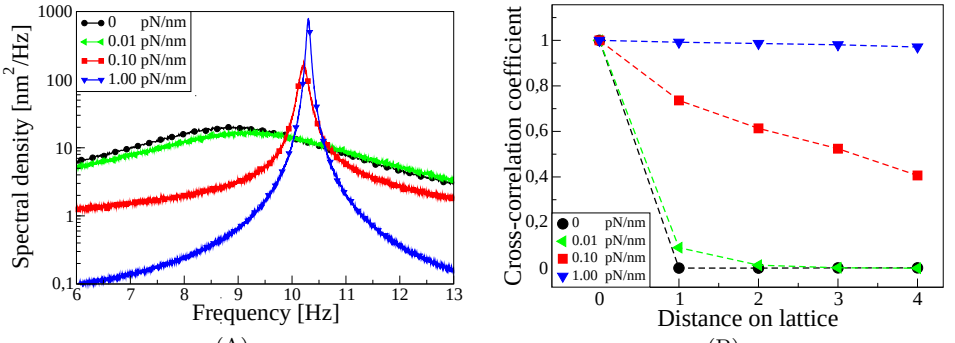

Fig. 2. (A) Various power spectra for the most central hair bundle in a 9x9 lattice for various coupling strengths. For increasing coupling strength the spectral peak sharpens. Also, there is a shift of the characteristic frequency of the oscillation. (B) Cross-correlation coefficient between the most central hair bundle in a 9x9 lattice and neighbouring hair bundles at various distances. Note that for a coupling of about 1 pN/nm hair bundle movements are synchronized.

Our simulations show that coupling could, indeed, alter the spectral characteristics of spontaneous movements, rendering stochastic oscillations more coherent (see Fig. 2A). Also, coupled hair bundles can synchronize (see Fig. 2B). As far as signal detection properties are concerned, we find that sensitivity to weak periodic driving is increased considerably when the strength of coupling is chosen in an appropriate way.

References

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