Title	外有毛細胞も出るの機能に着目した非線形蝸牛モデルの入出力特性の検討
Author(s)	村上，泰樹
Citation	
Issue Date	2007-03
Type	Thesis or Dissertation
Text version	author
URL	http://hdl.handle.net/10119/3622
Rights	
Description	Supervisor:鵜木　祐史，情報科学研究科，修士

A study on the input-output function of a nonlinear cochlear model based on a function of outer hair cell models

Yasuki Murakami (510102)

School of Information Science,
Japan Advanced Institute of Science and Technology

February 8, 2007

Keywords: outer hair cell models, nonlinear cochlear model, input-output function, compression.

From physiological and psychological experiments, it was known that the input-output (IO) function of the basilar membrane (BM) of the cochlea is linear at low and high sound pressure levels and is compressive (slope of the IO function is less than one dB /dB) at moderate sound pressure level. Is was also known that the nonlinear IO functions of the BM are disappeared by a damage of the outer hair cells (OHC). Therefore, nonlinear IO function of the BM is caused by a function of the OHCs. However, It is not unclear how OHCs affects the nonlinear IO function of the BM because physiological experiment is difficult to investigate a function of the OHC in the cochlea.

The aim of this paper is to demonstrate how the OHCs produce the nonlinear IO function of the BM using a computational model. This paper proposes a nonlinear cochlear model that embedded an OHC model modeled a physiological function. This paper carries out simulation with the proposed nonlinear cochlear model. The result shows the nonlinear IO function of the BM model caused by the OHC model and how the OHC model affects the IO function of the BM model. Then, the proposed model suggests how the OHC affects the nonlinear IO function of the BM.

This paper focus on a force produced by an elongation and contraction of the OHC.The elongation and contraction of the OHC is evoked by deflection of a stereocilia bundle. To model this motion, deflection of the stereocilia bundle affected by the BM vibration is considered. The elongation and contraction of the OHC as a function of angle of the stereocilia bundle is modeled.

First, this paper considers how the BM vibration affects the stereocilia bundle. The OHC supported by a supporting cell is on the BM. A tectrial membrane covers the OHC. The stereocilia bundle sticks a surface of the tectrial membrane. The BM vibration affects the tectrial membrane through the stereocilia. The tectrial membrane vibration and the BM vibration produce a shear stimulus to the stereocilia bundle. This paper considers this motion using a previously proposed model. The result show a phase of an angle of the stereocilia bundle model lags a phase of a displacement of the BM model by $\pi/2$ at the characteristic frequency. Therefore, a phase of an angle of the stereocilia bundle model is an opposite phase of a velocity of the BM model at the characteristic frequency.

Second, the elongation and contraction of the OHC caused by deflection of a stereocilia bundle is modeled. A force produced by the elongation and contraction of the OHC feed back to a BM. This paper divide this feedback process into five processes and investigate the each process. The result show that the elongation and contraction of the OHC depends on the change in the mechanical channel probability because of the deflection of stereocilia bundle. The changes in the mechanical channel probability is approximated by second order Boltzmann function. A force produced by the OHC is approximated by second order Boltzmann function as a function of angle of a stereocilia bundle. From the consideration of the motion of the tectrial membrane and stereocilia bundle models, a phase of an angle of the stereocilia bundle model is an opposite phase of a velocity of the BM. This paper proposes a nonlinear cochlear model that embedded a OHC model based on a force produced by the elongation and contraciton of the OHC.

The model simulation show that IO function of the BM model close to results of both physiological and psychological experiments. Furthermore, slopes of the IO function of the BM model are calculated over the input range 30 dB SPL - 80 dB SPL to investigate compression. The slopes of the IO function of the BM model are from 0.2 to 0.4. This results close to results of both physiological and psychological experiments. Those results come from (a) the force produced by the OHC models is linear at low signal levels (b) the force produced by the OHC models is compressive because of compressed the mechanical channel probability at moderate signal levels (c) the force produced by the OHC models is saturated at high signal levels and the force produced by the lymph fluid model is dominant.

To demonstrate how the OHCs produce the nonlinear IO function of the BM, this paper proposes the nonlinear cochlear model with the OHC model based on a force produced by the elongation and contraction of the OHC. The proposed OHC model is based on the elongation and contraction of the OHC caused by the deflection of stereocilia. The deflection of the stereocilia because of the BM and the tectrial membrane vibration is investigated using the earlier proposed model. The proposed OHC model depends on the mechanical channel probability as function of the angle of stereocilia. The result shows that the IO function of the BM model affected by the OHC models close to result of both physiological and psychological experiments. The result suggests that the saturation of the elongation and contraction of OHC because of the saturation of the mechanical channel probability at the stereocilia causes the nonlinear IO function of the BM.