# Towards a metric to quantify information transmission by cochlear-implant coding strategies


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## I. Introduction

Cochlear-implant (CI) processing strategies aim to faithfully transmit information from the acoustic input signal to the auditory nerve via electrical pulsatile sequences. Many studies still observe important behavioral gaps between CI and normal hearing listeners due to suboptimal encoding of acoustic cues. Our aim is to develop computational models of CI outcomes to easily compare coding strategies and assess the potential benefit they could provide to individual CI listeners. While many models already exist for normal-hearing listeners to predict performance from the acoustic stimulus (e.g. speech intelligibility, binaural hearing, pitch and loudness discrimination …), equivalent models for CI listeners need to be developed.

## II. Description of the project

**Long-term goal:** To predict psychophysical outcomes for individual CI users from 1) a given coding strategy, and 2) listener-specific characteristics (current spread, neural survival, facilitation, etc...)

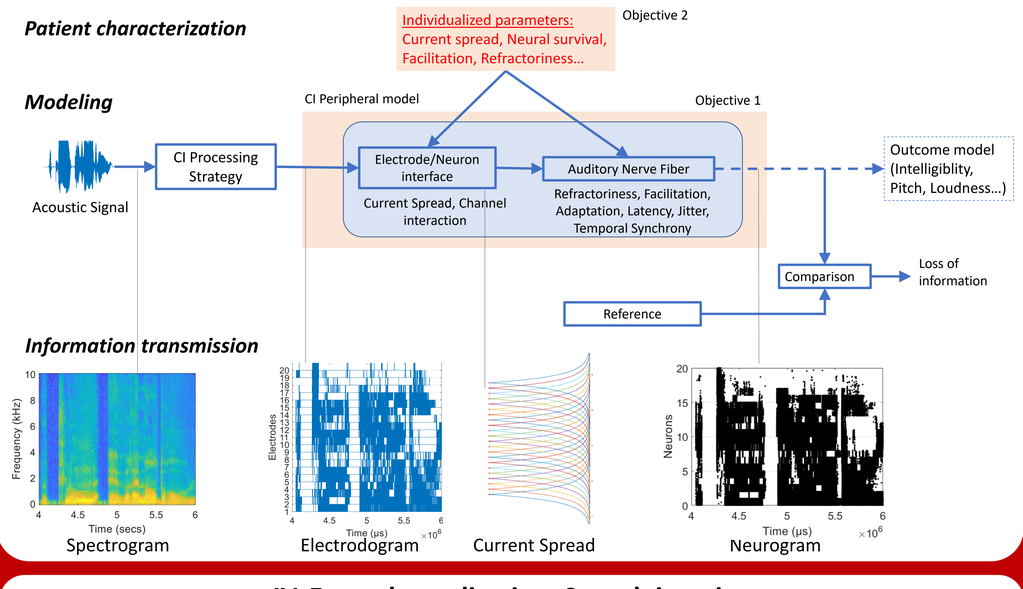
1. **Develop 'generic' computational models of CI outcomes**
2. Individualize predictions based on fitted parameters
3. Simplify the model to make it useful for clinical applications

**Assumption**: All of the information is encoded in the spike times of the auditory nerve.

***Patient characterization***

***Modeling***

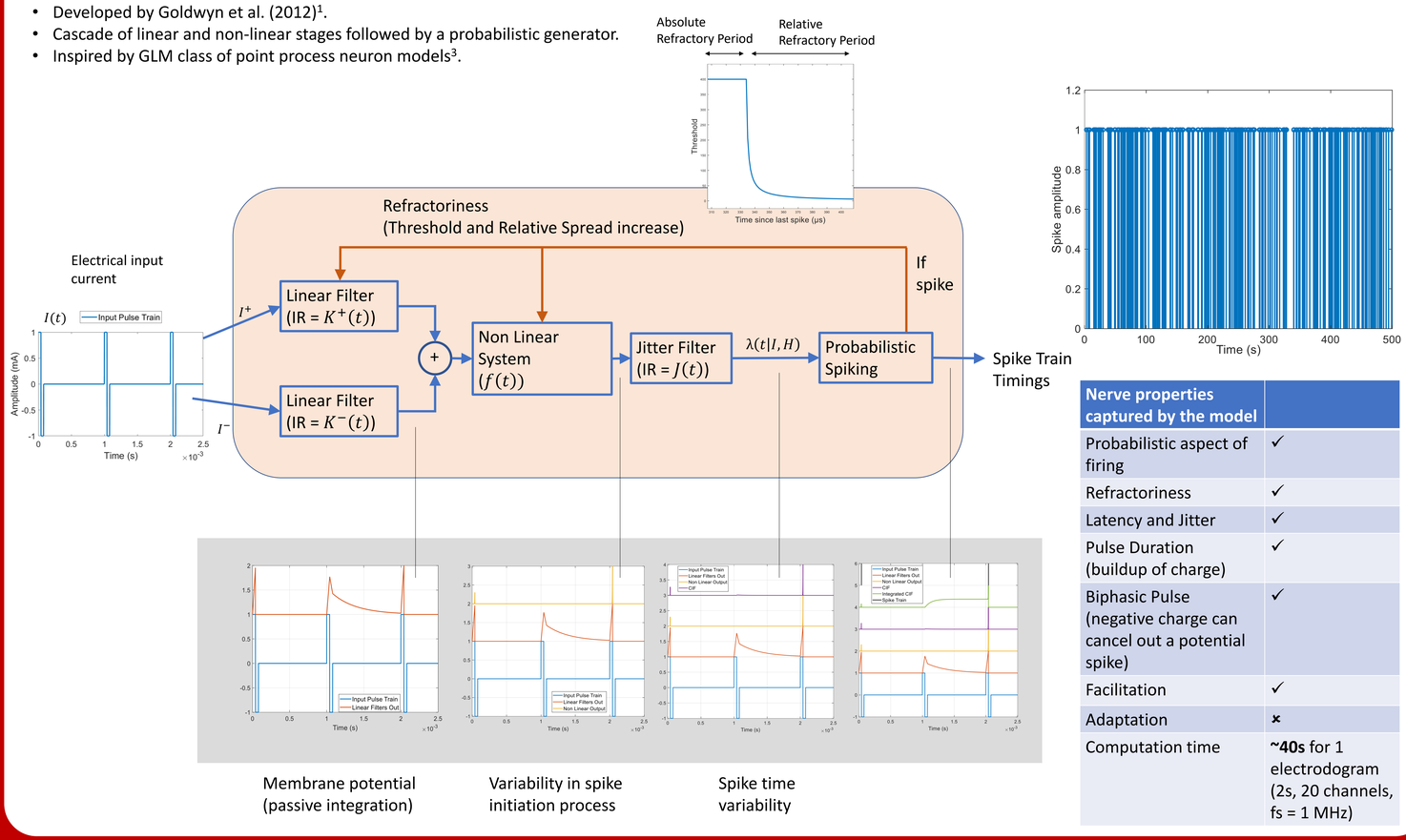
***Information transmission***




## III. Description of candidate auditory nerve model for electrical stimulation

**Model Description**

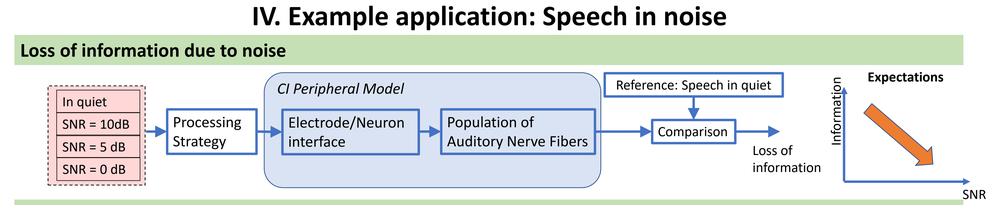
- Developed by Goldwyn et al. (2012)[1].
- Cascade of linear and non-linear stages followed by a probabilistic generator.
- Inspired by GLM class of point process neuron models[3].



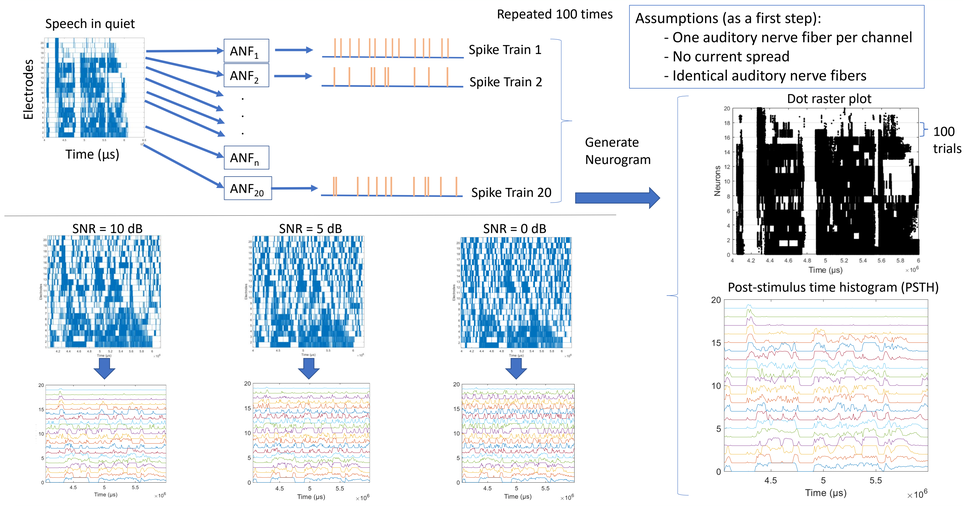

| Nerve properties captured by the model | |
|---|---|
| Probabilistic aspect of firing | ✓ |
| Refractoriness | ✓ |
| Latency and Jitter | ✓ |
| Pulse Duration (buildup of charge) | ✓ |
| Biphasic Pulse (negative charge can cancel out a potential spike) | ✓ |
| Facilitation | ✓ |
| Adaptation | ✖ |
| Computation time | **~40s** for 1 electrodogram (2s, 20 channels, fs = 1 MHz) |

## IV. Example application: Speech in noise

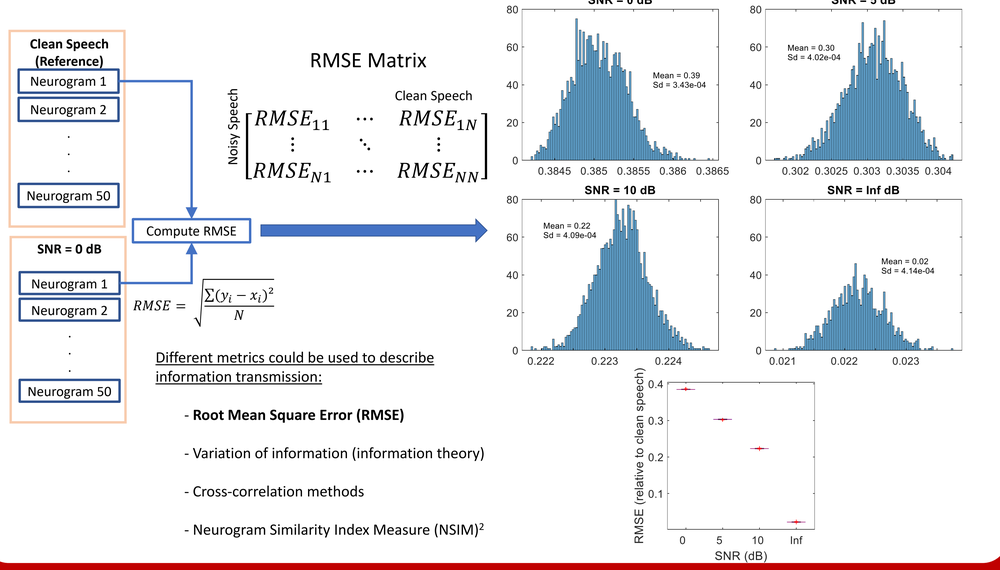
**Loss of information due to noise**




**Generate spike trains for a sentence at different SNRs**




**Quantify the amount of information at the neural level**



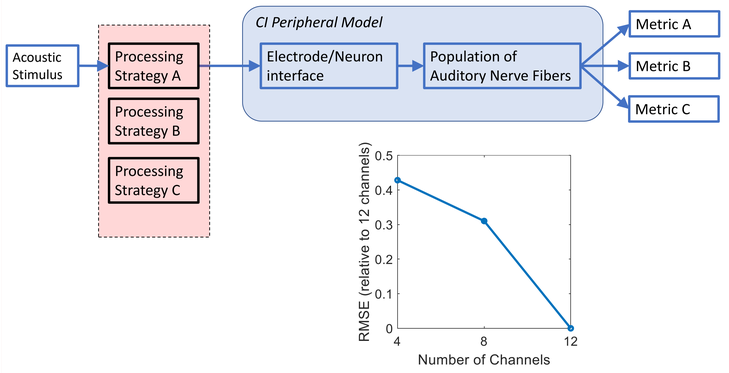

Different metrics could be used to describe information transmission:

- **Root Mean Square Error (RMSE)**
- Variation of information (information theory)
- Cross-correlation methods
- Neurogram Similarity Index Measure (NSIM)[2]

## V. Further directions and open questions

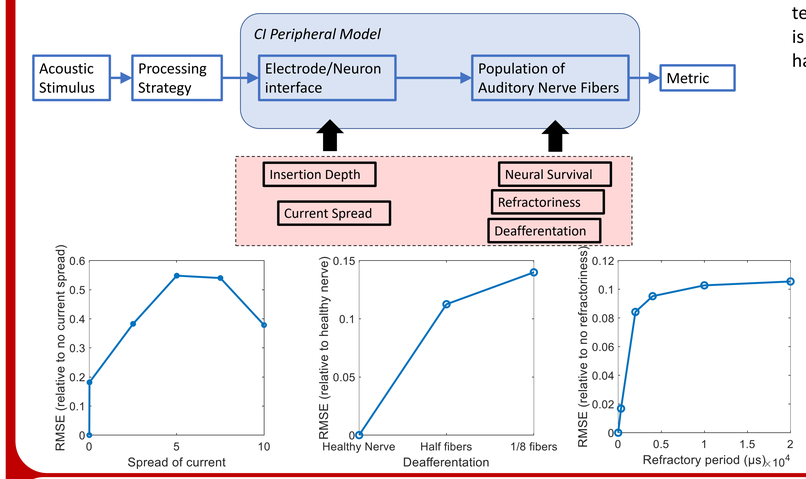
**What strategy transmits the most information to a given listener?**

Compare different coding strategies (eg CIS or any in-development strategy)




**How do different pathologies affect information transmission?**

Individualized predictions by characterizing physiological factors in each patient (eg insertion depth, neural survival, refractoriness, facilitation, etc…)

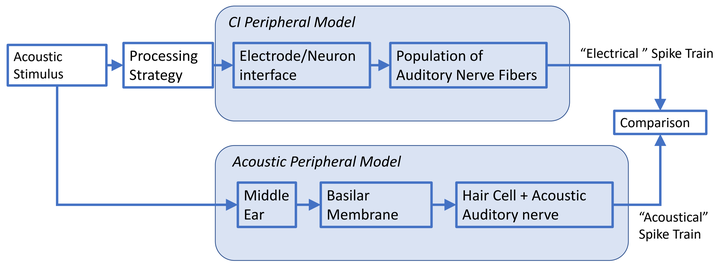



**Question of the reference**

So far the assessment of information loss in a given neurogram is being performed relative to a reference neurogram, where the reference is assumed to contain the maximum information accessible to an ideal (human) listener. Therefore the choise of reference is important and multiple alternatives will be considered.

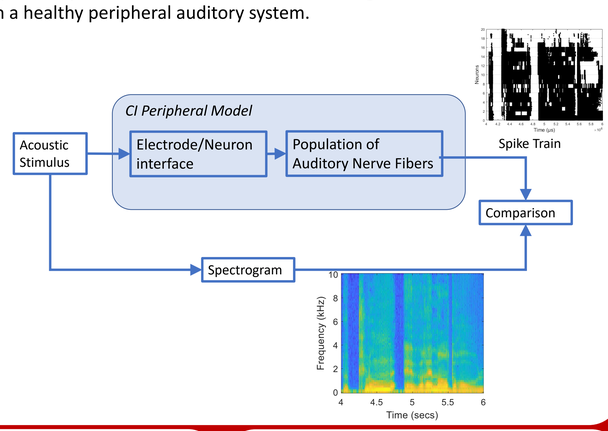
**Compare electrical and acoustical neurograms**

One reference could be the neurogram resulting from a normal-hearing auditory pathway. The metric then quantifies the loss of information relative to the "perfect" transmission.




**Compare electrical neurogram with spectrogram**

The spectogram could also be regarded as the best representation possible of the temporal and spectral information contained in any audio stimulus. Here the idea is to quantify/identify what information is transmitted, regardless of what would happen with a healthy peripheral auditory system.




## References


1. Goldwyn, J. H., Rubinstein, J. T., and Shea-Brown, E. (**2012**). "A point process framework for modeling electrical stimulation of the auditory nerve," J. Neurophysiol., **108**, 1430-1452
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3. Truccolo, W., Eden, U. T., Fellows, M. R., Donoghue, J. P., and Brown, E. N. (**2005**). "A Point Process Framework for Relating Neural Spiking Activity to Spiking History, Neural Ensemble, and Extrinsic Covariate Effects," J. Neurophysiol., **93**, 1074–1089.


## Acknowledgments


Work supported by Oticon Medical and the Oticon Foundation.