Indian Institute of Technology Kharagpur
Department of Electronics & Electrical Communication Engg.
EC60004: Neuronal Coding of Sensory Information
Project - I Writeup

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1 Question 1

1.1 Problem

By using the AN model as informed in class to generate the following: Use a high spontaneous rate auditory nerve fiber (ANF) with Best Frequency (BF) of 500 Hz kHz and 4 kHz and obtain their tuning curves (response rates as a function of frequency) at 10 different intensities: -10 dB SPL to 80 dB SPL (in steps of 10 dB). Use tone frequencies of 125 Hz to 16 kHz (a total of 7 octaves) with 8 frequencies in each octave (1/8th octave frequency difference). That is the tone frequencies will be $\texttt{125} * \texttt{2.}^{[\texttt{0:1/8:7}]}\texttt{Hz}$. Use a duration of 200 ms for each tone and modulate the tones with onset and offset ramps of 10 ms. Use 20 repetitions of each tone and obtain the average rates. Plot all the tuning curves of each ANF in one figure (use a logarithmic frequency axis, Figure 1 and Figure 2). Obtain the rate vs intensity function for BF tone of each ANF at the 10 intensities above and plot them (Figure 3). What are the observations?

1.2 Figures and observations

The Best Frequency (BF) of an Auditory Nerve Fiber (ANF) is the frequency at which the ANF exhibits the highest firing rate viz. it is the frequency of tone that an ANF is most sensitive to. The BF is specific to each ANF, which we define as a model parameter.

1.2.1 Expectations

1. Rate vs Frequency
   (a) The peak rate should be at the BF, by definition.
   (b) At lower intensities, the rate vs intensity functions have a smaller and flatter dynamic range and vice versa.
2. Rate vs Intensity

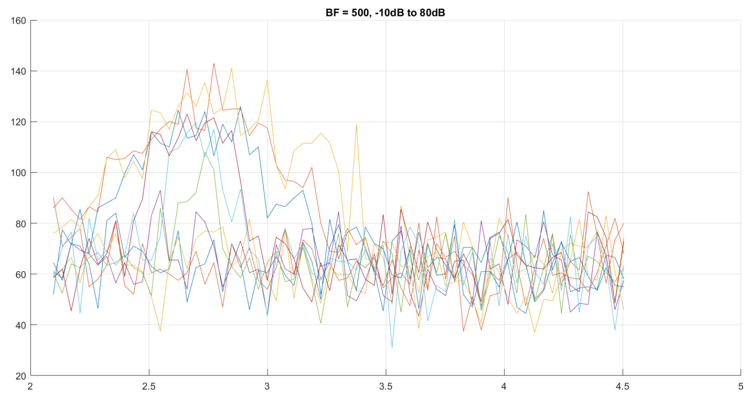

Figure 1: Rate vs Frequency, BF = 500Hz

(a) The graph should ideally look like a sigmoid curve.
(b) There should be a clear range of spontaneous activity.

1.2.2 Observations

1. Rate vs Frequency (Fig. 1, 2)
   (a) The peak rate for BF = $500Hz$ is around $x = 2.7$, so $F_{peak} \approx 10^{2.7} \approx 502Hz$
   (b) The peak rate for BF = $4000Hz$ is around $x = 3.6$, so $F_{peak} \approx 10^{3.6} \approx 3986Hz$
   (c) At lower intensities, the rate vs intensity functions have a smaller and flatter dynamic range and vice versa.
2. Rate vs Intensity (Fig. 3)
   (a) Since there is some randomization in the model, and the model is approximate, we observe somewhat different results for each run (despite the 20-iteration average).
   (b) The best runs look like sigmoids.
   (c) Some runs do not quite show a clear saturation region, but they do show a range of spontaneous activity.

2 Question 2

2.1 Problem

Now have a bank of ANFs starting with BF 125 Hz up to 8 kHz (a total of 6 octaves) with 16 ANFs in each octave spaced 1/16th octaves apart (like frequen-

Figure 2: Rate vs Frequency, BF = 4kHz

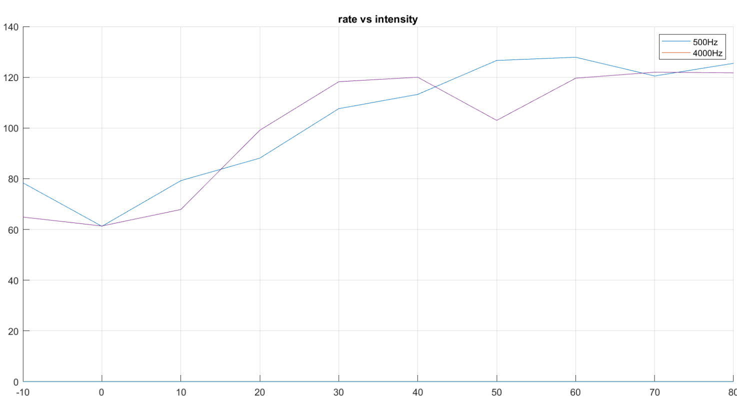

Figure 3: Rate vs Intensity

cies presented in Part 1; ANF BFs $125 * 2.^{[0:1/12:6]}$ Hz; a total of 72 different BFs of ANFs).

Fixing sound level: Use a steady state portion of the speech sound wavfile provided ("ah" part of b"a"sketball). Use the wavread or audioread function to read it into MATLAB. Separate the "ah" out from your speech signal waveform – by trial and hearing the segment. Use the root mean square value of the segment to calculate its dB SPL level [re 20×10^{-6}]. Use this steady state sound level and multiply the entire speech signal with appropriate factors to input in the ANFs (bank) for 3 different sound levels. Determine the 3 sound level as follows. Use the steady state portion and modify it with onset and offset ramps as in Part 1 and find the rate responses to the vowel "ah" of a 500 Hz BF ANF at -20 to 80 dB SPL in 5 dB steps, plot (Figure 4) the rate intensity function (comment by comparing it with the BF tone rate intensity function). Choose 3 sound levels one near (but above) threshold, one in the dynamic range and one in the saturation level close to the end of the dynamic range. After having determined the 3 sound levels generate the spike trains (50 repetitions each) of each ANF in the bank (72 fibers) to the entire speech signal at the 3 sound levels. Plot (Figure 5) the spectrogram of the speech signal with appropriate window size (25.6 ms hanning windows maybe used with overlap of successive windows by 50%, that is, a resolution of 12.8 ms). Now compare the spectrogram with the following: Represent the responses determined above from each ANF as an average rate (number of spikes per unit time) as a function of time. Use windows of 4 ms, 8 ms, 16 ms, 32, ms 64 ms and 128 ms (with overlap between successive windows by 50%, Figure 6A-F, 6 different window sizes). Plot the rate in an image in color with one axis as time (centre of each successive window) and the other axis as BF of the ANFs: It is akin to a spectrogram (cochleogram), only that now you have rate response instead of energy and BF instead of frequency.

2.2 Figures and Observations

Vowels are mainly defined by two fundamental frequencies, F_1 and F_2, called formants. For the "ah" vowel sound, which we will use, the formants are somewhere around $700Hz$ and $1100Hz$. We pass it through what is effectively a filter bank and visualize the response.

2.2.1 Expectations

1. Rate-Intensity Plot
   (a) The response will be similar to that of a single tone, viz. it will look like some sort of sigmoid function.
2. Spectrogram
   (a) The spectrogram should have a series of horizontal bands or "stripes" that correspond to the formants of the "ah" vowel sound.

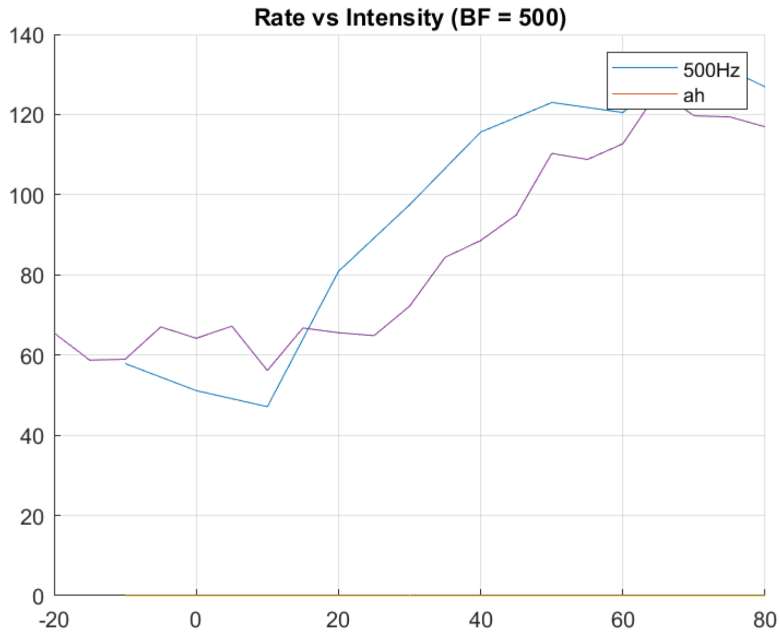

Figure 4: Rate vs Intensity for 'ah' compared with '500Hz'

(b) The first formant (F1) should be around 700 Hz.

(c) The second formant (F2) should be around 1100 Hz.

(d) There may be some other vestigial formants depending on the speaker's accent, voice, etc.

3. Windowing

   (a) It should resemble the spectrogram

2.2.2 Observations

1. The RMS dB SPL of the "ah" segment is 76.033dB

2. We choose 0dB, 40dB, 76dB as pre, within, post-active region respectively.

3. We use the 76dB spike train for the windowing method, since that is close to the actual level of the "ah".

4. Rate vs Intensity (Fig. 4) resembles a sigmoid, like the at-BF rate vs intensity curve for BF = 500.

5. Spectrogram (Fig. 5)

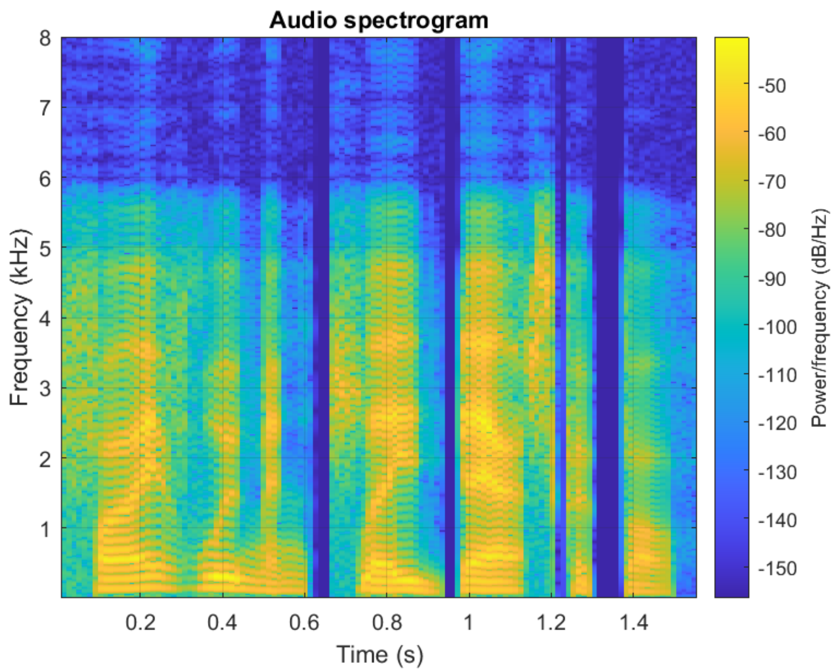

Figure 5: Spectrogram

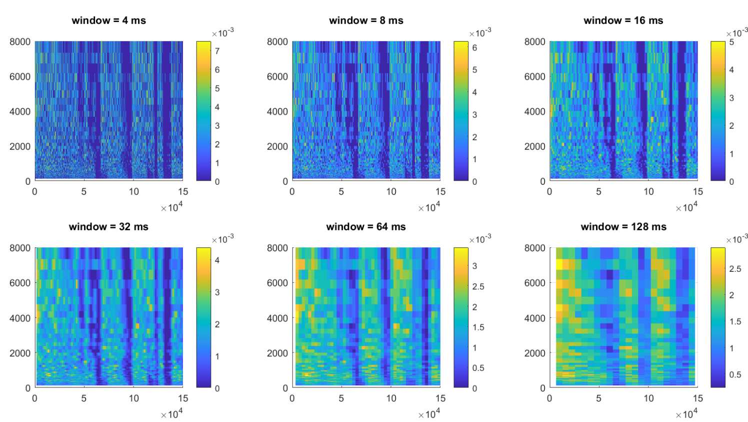

Figure 6: Varying the window length

(a) Rate highest at BF, other formants are filtered out.

6. PSTH Spectrogram Estimate (Fig. 6)

   (a) Looks like the spectrogram

   (b) Increasing the window loses resolution, but resembles (at a higher level) the spectrogram more

   (c) The time window averages out short-term variations in the signal, or higher frequency spike rates, and emphasizes longer-term patterns.

3 Question 3

3.1 Problem

Use the PSTHs from 50 repeats of the stimulus in every ANF, using a window size 0.1 ms or 100 microseconds. Consider the 12.8 ms long successive windows (50% overlap in successive windows) and get the discrete Fourier Transform (use the fft function) of the PSTH. This is an indirect way of looking at phase locking, that too relative amounts of locking to many different frequencies can be observed simultaneously. Find the frequency to which a fiber locks the most, that is, find the peak in the fft and its corresponding frequency which is the dominant frequency. Get the dominant frequency in each successive window. Mark the frequency and time location on top of the spectrogram (say with an asterisk). Do not use all the BFs of ANFs for this purpose. Use only BFs 1 octaves apart and only up to 4 kHz (0.125, 0.25, 0.5, 1, 2 and 4 kHz). So there will be total of 6 fibers, use 6 colors of asterisks and overlay them on the spectrogram at appropriate frequencies (dominant frequency) and time (Figure 7). In a separate figure (Figure 8) do the same for another 5 fibers with BFs at 1 octave intervals starting $\frac{1}{2}$ octave above 125 Hz and ending $\frac{1}{2}$ octave below 8 kHz (ie 0.177 to 5.657 kHz). Comment on your observations.

3.2 Figures and Observations

3.2.1 Expectations

1. Figure 7 should display centrality about the dominant frequency for 6 fibers with BFs at 1 octave intervals up to 4 kHz. These fibers should be represented by 6 different colors of asterisks overlaid on the spectrogram at appropriate frequencies and times.

2. Figure 8 should display centrality about the dominant frequency for another 5 fibers with BFs at 1 octave intervals starting $\frac{1}{2}$ octave above 125 Hz and ending $\frac{1}{2}$ octave below 8 kHz. However, the energy content should be lower, since they are not fundamental to the formants.

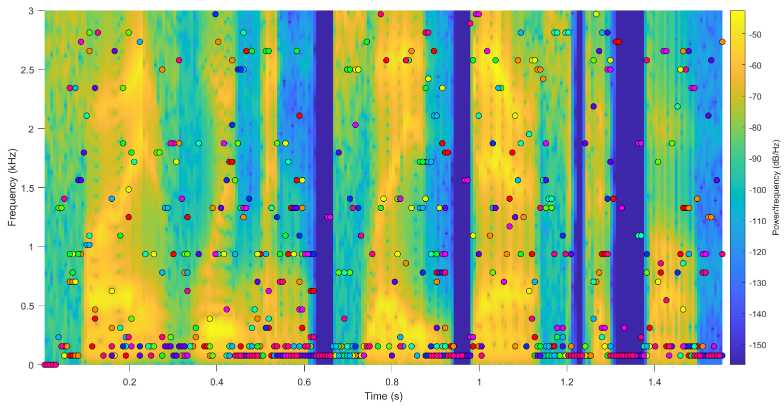

Figure 7: Octaves starting at 125Hz

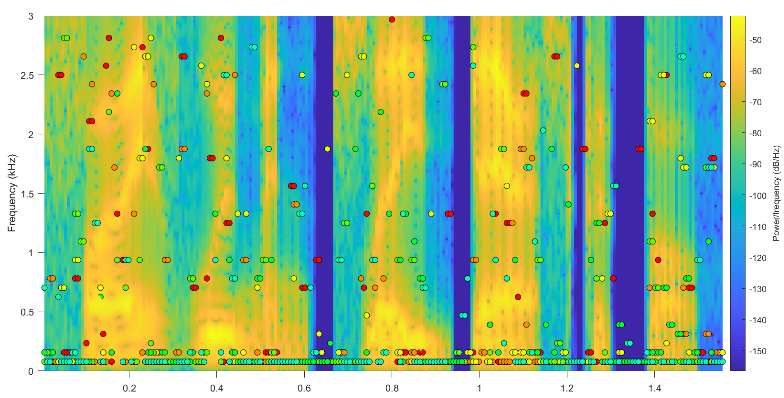

Figure 8: Octaves offset by $\frac{1}{2}$

3.2.2 Observations

We did not observe very good results for this experiment. However, especially for lower BFs, we see the frequencies from the FFT do cluster around the BF. The firing times seem to be somewhat shifted in Fig. 8, as well as a bit sparser for higher BFs, indicating consistent results.