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NE360/HS361
Lab 3: Due 9-25-13

Abstract:

The purpose of this lab is to examine models of early auditory processing in the outer ear, inner ear, and basilar membrane (BM) in the cochlea. These models are then related back to the physiology of the early auditory system. To do this, the Auditory Image Model (AIM-MAT) toolbox in MATLAB is utilized. AIM-MAT is a graphical and/or code interface for computational models of audition.

Results:

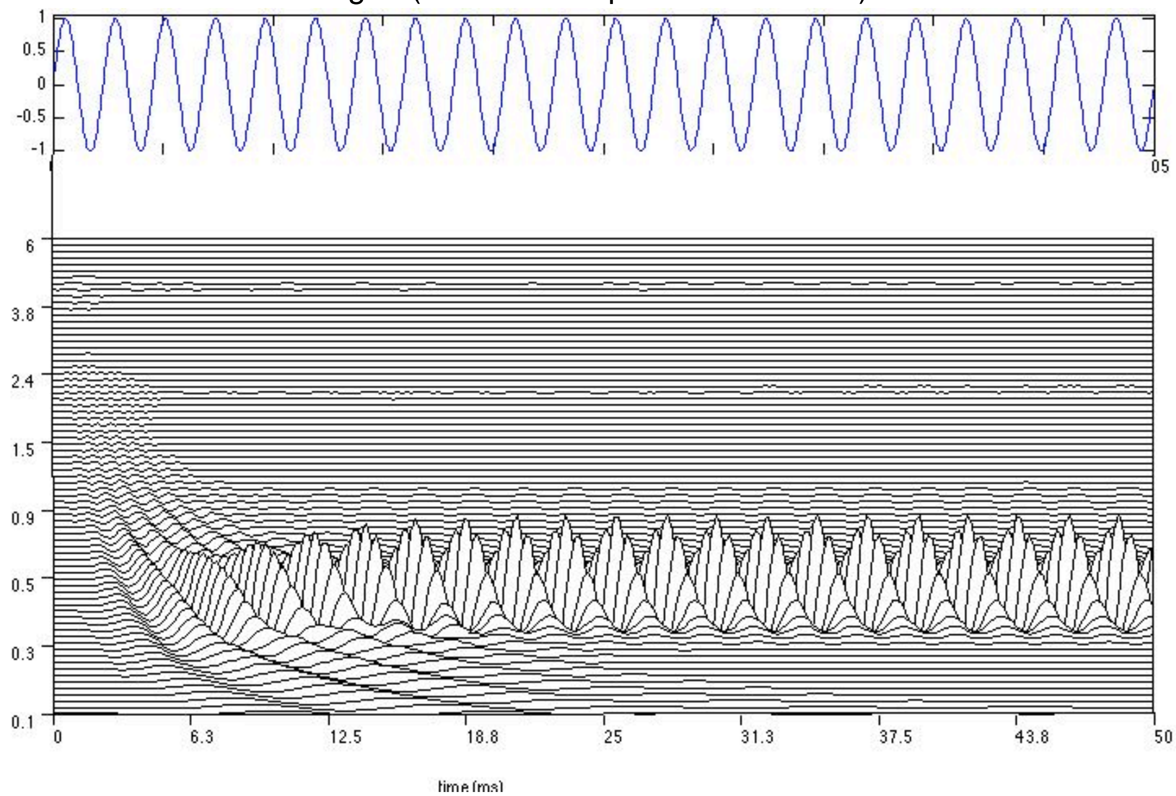
In the first part of the lab we modeled how the early auditory system processes different frequency tones. We looked at gamma-tone filters to model the BM and compared models where there was and was not pre-cochlear processing.

The filter functions are a computational model that describes the preferred frequencies at different points along the BM. Each line represents a different region of the BM. The amplitude of the lines show the relative strengths of the signals at different frequencies.

The importance of precochlear processing is that it amplifies the sound wave, and helps with localization. As it relates to this model, localization has little to no significance, since it does not come into play until postcochlear processing. Precochlear processing is made up of amplification of the sound wave by the difference in surface area between the eardrum and the footplate of the stapes. Since all preprocessing does is increase the amplitude of the sound wave, it can be modeled by a linear filter that increases the magnitude of the wave from before it reaches the ear, to the the point where it reaches the cochlea.

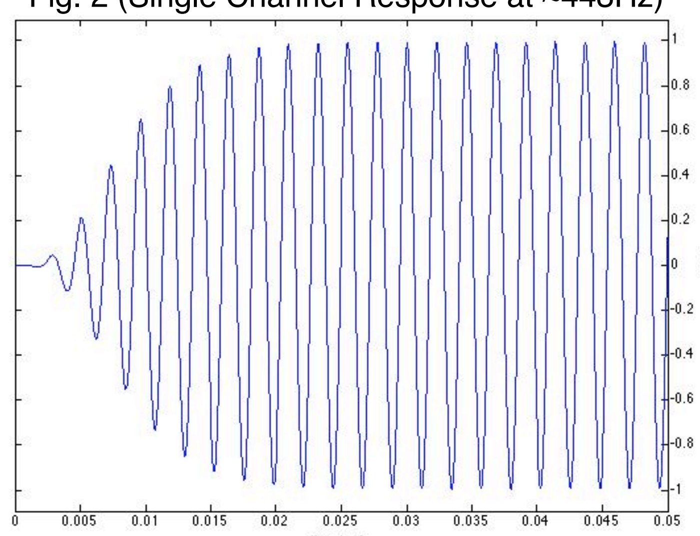
Each line on the graph represents a different position along the BM. There is a section that responds much more violently than the rest, when a 440Hz tone is applied. This shows that the preferred frequency of the BM at the position represented by this group of lines is 440Hz. Since within this group, the central most line responds the most to the tone, and since the amplitudes tapper off moving away from it, one can infer that the surrounding regions respond most to similar frequency tones. The other behavior of the graph that should be noted is the peak amplitude of these waves only increases for a short time, then levels off. This implies that there is a brief onset period before the BM fully responds to the tone.

Fig. 1 (Waterfall Graph at 440Hz Tone)



There is a quicker response to the tone at higher frequencies. This is because the regions of the BM that respond to higher frequencies are closer to the footplate of the stapes, and lower frequencies are picked up better closer to the apex of the cochlea. The larges amplitude is picked up by channel 19, and the magnitude falls to half that by channels 17 and 21. Channel 19 responds to 443.6819Hz, 17 to 392.2888Hz, and 21 to 499.3274Hz.

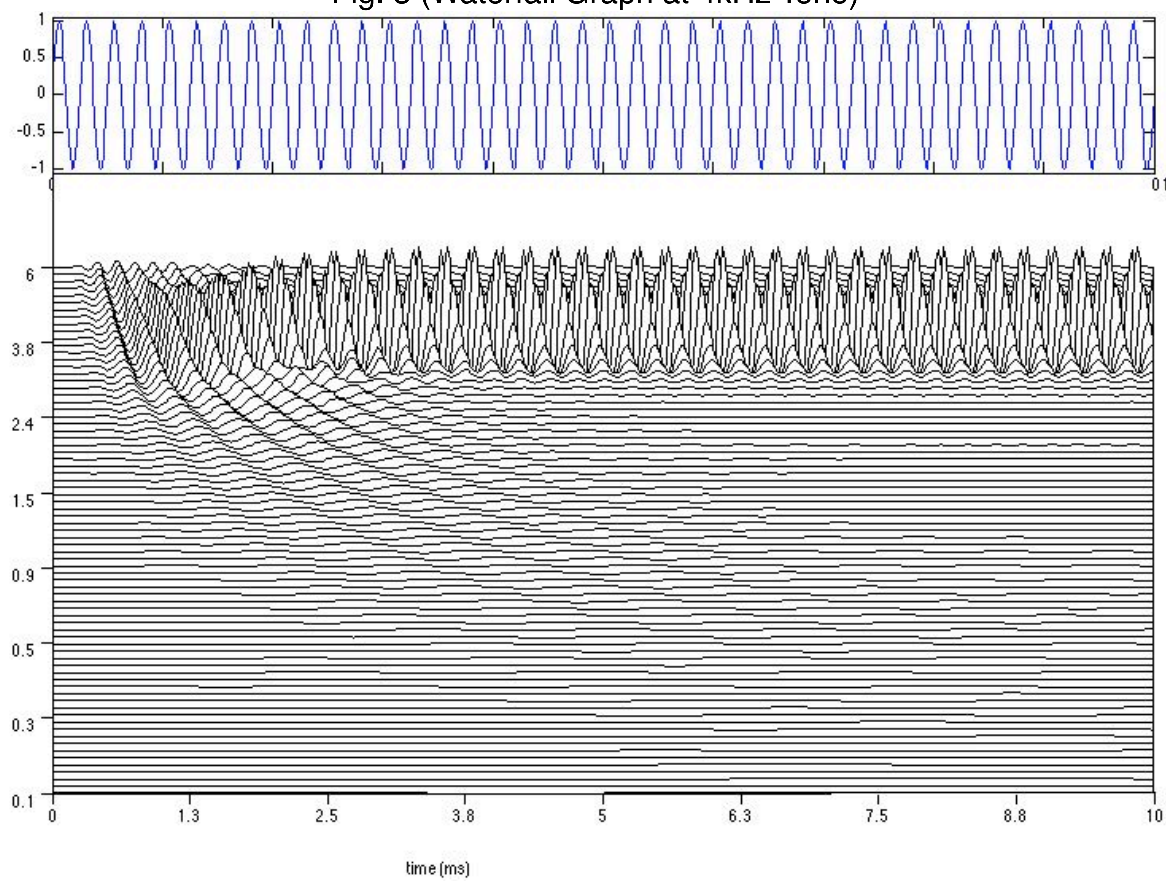
Fig. 2 (Single Channel Response at ~443Hz)



This analysis is then repeated for a tone at 4kHz.

The main differences in the graphs are the frequency of oscillation of the BM, and the channels that are picking up the tones. Since there sound is at a higher frequency the region closer to the footplate of the stapes responds most violently. The impact of the parameter changes is that the full waveform can be plotted since the highest possible frequency is increased, and the regions that are active can be more accurately represented by increasing the number of channels. The advantage to increasing the number of channels is a more precise rendering of the BM, but the draw back is that the graph is more clustered.

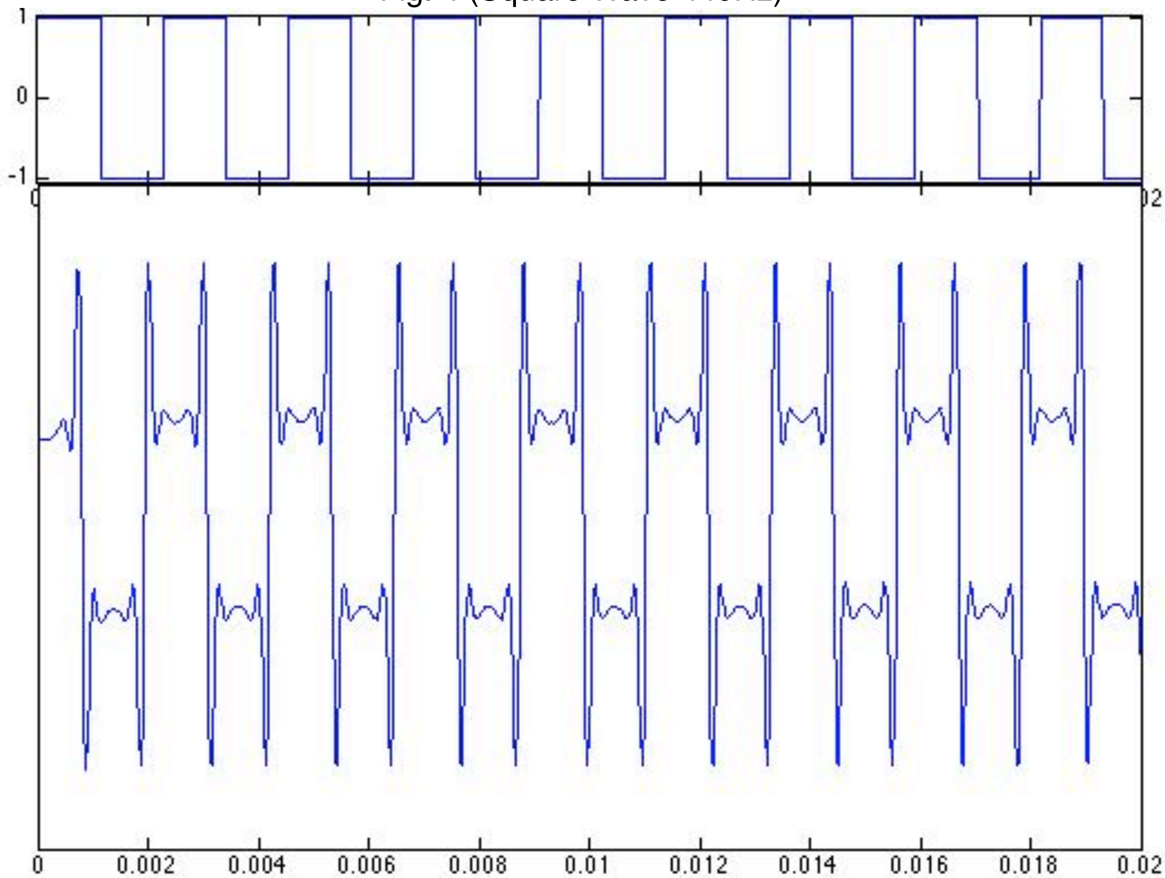
Fig. 3 (Waterfall Graph at 4kHz Tone)



In part two of the lab, a similar analysis was done with a square wave.

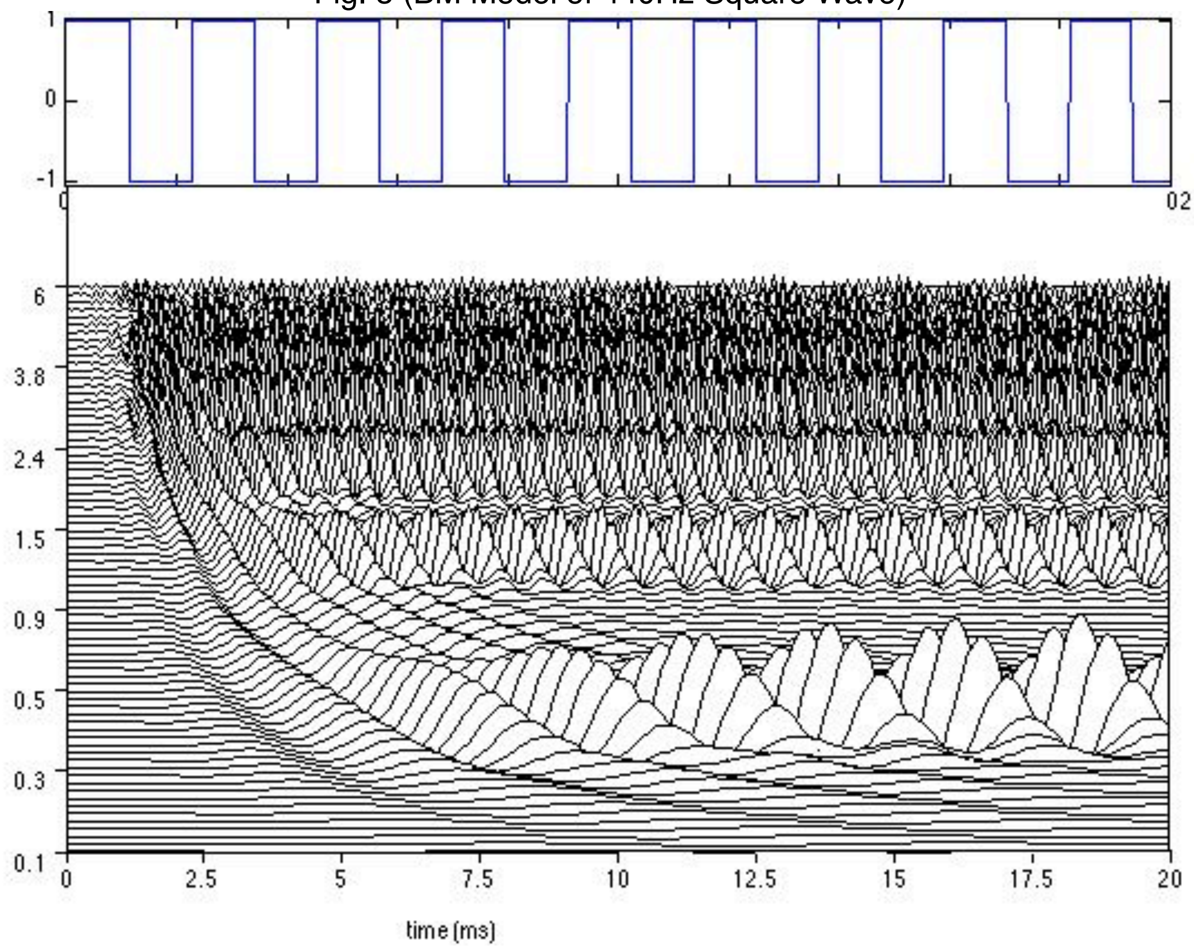
The effect the filter has on the square wave is a sharp reversal in the direction of the wave when there is a dramatic change in the frequency of the wave. This is a high frequency filter since the effected frequencies are the component frequencies that flatten the curves of the wave.

Fig. 4 (Square Wave 440Hz)



When this wave is run through the BM model, the component frequencies of the wave can be seen. The preferred frequencies of the channels that are active correspond to the spikes from the Fourier transform of the wave. The channel that responds the most is 19 at ~443Hz, this is the fundamental frequency of the wave.

Fig. 5 (BM Model of 440Hz Square Wave)



In part 3 of the lab, the effect of a broad amplitude spectrum tone of the model of the BM is explored. A click sound is played through AIM-MAT, since a click is made up of all frequencies.

The precochlear processing stretches out the time domain and moves it back in time. The purpose of this is to make it easier for the model to find the component frequencies of the waveform. The BM response is activity in almost all the channels, as would be expected by a broad amplitude spectrum, with a concentration of activity in the high frequency channels. The time delay for the activation of the low frequency channels is due to the time it takes for the sound wave to reach that part of the BM.

Fig. 6 (Precochlear Processing of a Click)

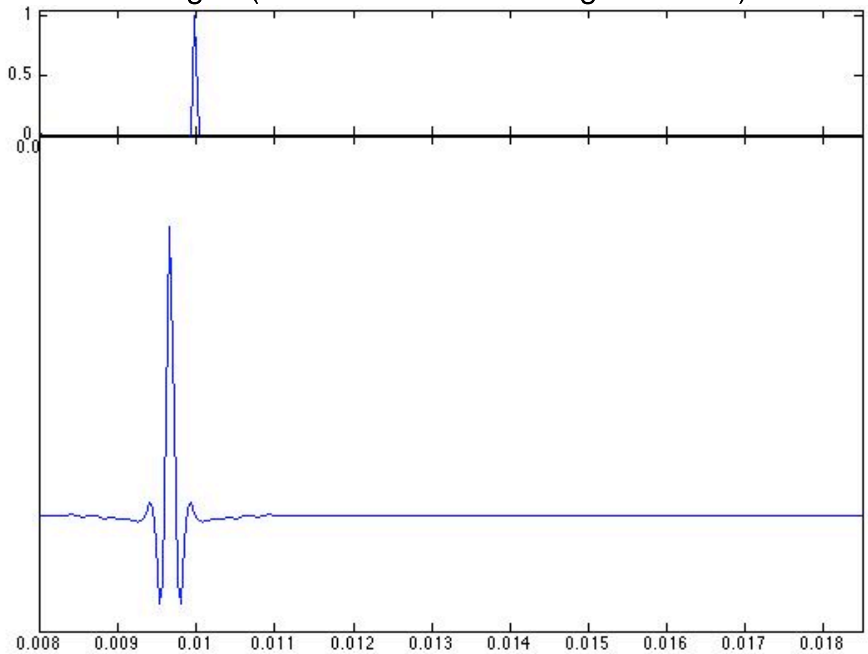
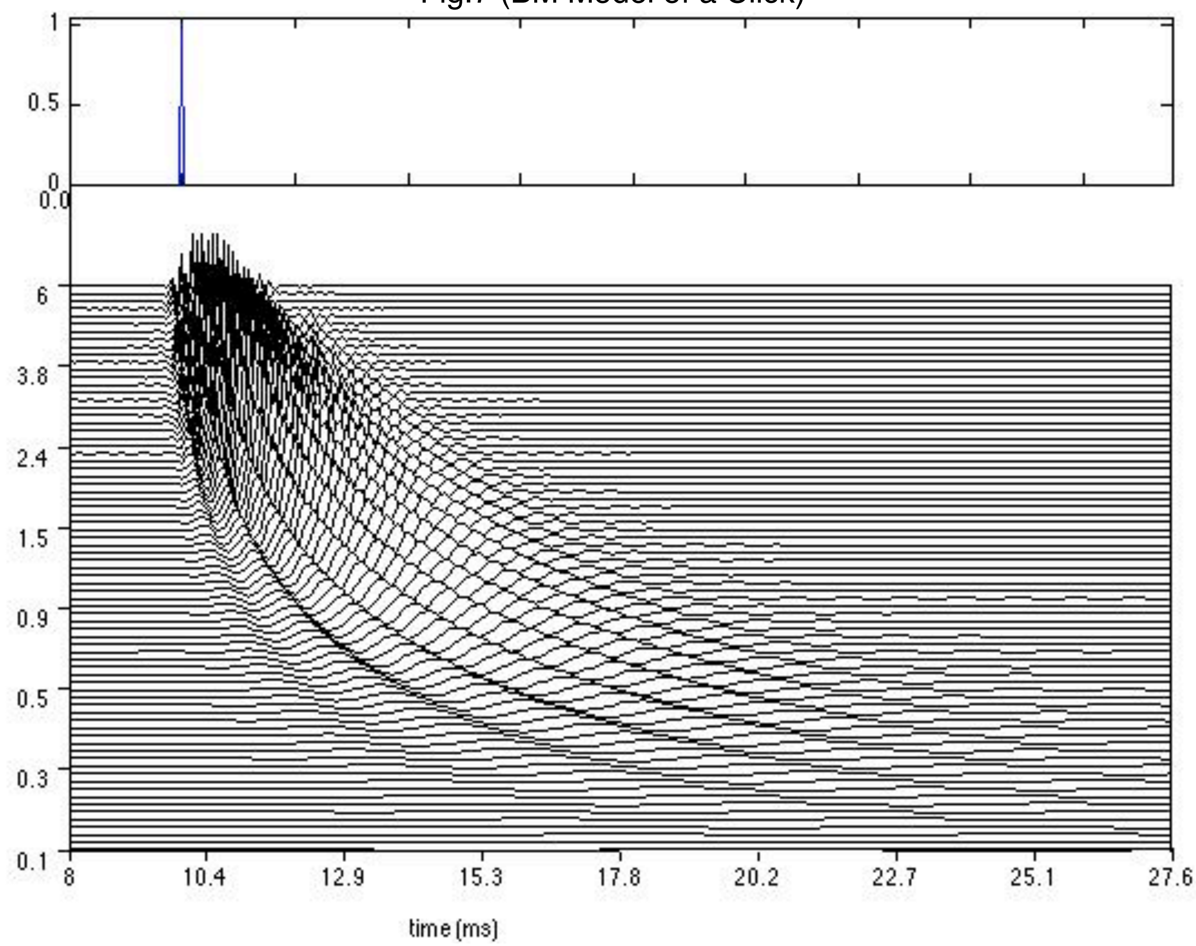


Fig.7 (BM Model of a Click)



As the wave travels from the base to the apex, the preferred frequency decreases. Because of this the time of the highest oscillation is greater as the frequency decreases.

Channel	Frequency (Hz)	Time (sec)
50	2077.0754	0.01156
52	2267.8719	0.01143
54	2474.4554	0.01129
56	2698.1322	0.01116
58	2940.3165	0.01102

Part 4: Problems

1) On next page
2) It will be a wave with 3 frequencies at 408.1028Hz, 1.8231kHz, and 6.7296kHz
3)

Frequency	Phase Shift
1000	0
200	5.02654825
125	π

Conclusion:

The lab provided an insight to modeling the activity of the BM, and precochlear processing. We examined the effects that different types of tones had on the BM, and extrapolated the reasons for these effects from the AIM-MAT produced graphs.