Speech Chain

Homework 11

Solutions

\[a\]

<table>
<thead>
<tr>
<th>x</th>
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<th>3</th>
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<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
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<td>52</td>
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<td>65</td>
<td>58</td>
<td>53</td>
<td>58</td>
<td>65</td>
<td>75</td>
<td>45</td>
<td>22</td>
<td>10</td>
<td>3</td>
</tr>
</tbody>
</table>

\[b\]

\[s_d\] 0.4 3.5 4.2 20 10 14 34 17 12 17 34 95 42 7/4 3/0 3/0

8000Hz 6000Hz 4000Hz 2000Hz

Peak Peak Peak Peak

Notice
- 2000Hz tone is encoded over many frequencies, including harmonics of 2000Hz.

The acoustic pure tone has no energy at 4000Hz, 6000Hz, ... These components are created in the ear by nonlinearities in the basilar membrane.

\[c\] \[R = \sum_{x=0}^{31} \left( \frac{\text{# neuron fibers}}{\text{mm}} \right) \times \left( \frac{\text{# pulses/sec}}{\text{fiber}} \right) \]

= Total # \(\frac{\text{pulses}}{\text{second}}\) on auditory nerve

\[\approx 265,500 \ \frac{\text{pulses}}{\text{second}}\]

\[d\] 265k pulses/sec \(\Rightarrow 77\) dB SPL
the equal-loudness curves dip slightly between 1800 and 6000 Hz, so a 75 dB tone at 2000 Hz is slightly louder than a 75 dB tone at 1000 Hz. Perhaps equal in loudness to a 77 dB tone at 1000 Hz. Using Stevens' terminology, a 75 dB tone at 2 kHz has a loudness of 77 “phons.”

With a 70 dB masker, the only place on the BM that senses the tone is \( x = 11 \text{ mm} \), with stimulus level \( \alpha = 5 \text{ dB} \). Assume that, for negative \( \alpha \), \( S(\alpha) \approx 0 \).

\[
S(5 \text{ dB}) = 0.015
\]

\[
R = \sum_{x=0}^{31} n \cdot S(\alpha(x)) = 1000 \cdot 0.015 = 15
\]

meaning the tone increases total spike count on the auditory nerve (all neurons) by only 15 spikes/second.

From Fig. 15, 15 spikes/second \( \Rightarrow \) 0 phons so the tone is right at the boundary between audible and inaudible.