Exploring the Interrelationship between Spontaneous and Low-Level Stimulus-Frequency Otoacoustic Emissions

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Motivation

- Some healthy cochleas produce spontaneous otoacoustic emissions (SOAEs), however their use in evaluating cochlear status is limited.

- Evoked emissions are more commonly measured and have significant clinical value; traditionally distortion product and transient-evoked OAEs (DPOAEs, TEOAEs) have been used, but their generation is complex.

- Stimulus-frequency otoacoustic emissions (SFOAEs), evoked using a single stimulus tone, may be a better option.

- However, controversy over interpretation of SFOAEs has limited their use.

- Previous research has suggested that SFOAEs (Talmadge et al., 2007) and SOAEs (Shea, 2003) arise from place-like reflection sources: cochlear perturbations or roughness.

- Linear coherent reflection model (Shea, 2003) further hypothesizes that SOAEs and low-level SFOAEs have a common origin.

- Model predictions suggest that this relationship is strongest at levels closest to threshold.

- However, previous studies considering SOAE level have typically not used probe tones lower than 40 dB SPL.

Methods

- Subjects: 7 normal-hearing (thresholds ≤35 dB HL) females 20-39 yr old, 15 ears; only left ears used.

- Frequency region investigated for presence of SOAEs: 205-6600 Hz; SOAE presence confirmed with 40 dB SPL suppressor tone presented =100-200 Hz below each SOAE frequency.

- SFOAEs measured with off-frequency suppression paradigm (suppressor 400 Hz above probe), 20 dB SPL probe level, 35 dB SPL suppressor level.

- SFOAE amplitude and phase measured at 1 kHz frequency resolution, except one ear that was tested at 1 kHz resolution.

- Linear interpolation used to approximate phase values at specific frequencies.

- SFOAE measurements focused around frequency regions of known SOAE presence (beginning =2200 Hz below lowest frequency of SOAE and ending =2200 Hz above highest-frequency SOAE).

Questions

- How do SFOAEs evoked with low-probe tone levels (20 dB SPL) compare to the results of similar studies using higher levels?

- What data support predictions made by linear coherent reflection model?

Results

Relating SFOAE Amplitude and Phase to SOAE Frequency

- A common trend across subjects is the correspondence of SOAE frequencies to peaks in SFOAE amplitude.

- There is variability in SFOAE amplitude and overall shape among different subjects. As illustrated below some subjects displayed relatively broad SFOAE responses (Subject 3), while other responses were more confined to areas around SOAEs (Subject 4).

- The variability in SFOAEs varies with respect to frequency, and the overall shape appears to be steeper at 20 dB SPL as compared to higher levels, 40-70 dB SPL.

- SOAEs are measured at low levels using the same stimulus tone, which may be the reason.

- Subjects: 7 normal-hearing (thresholds ≤35 dB HL) females 20-39 yr old, 15 ears; only left ears used.

SOAE Phase Accumulation between Adjacent SOAE Peaks

- Due to a common source, the differences in SFOAE phase between those frequencies of adjacent SOAE peaks are predicted to be integer numbers.

- Calculating these phase differences is another reason to test our data with coherency reflection model which hypothesizes correlation between SOAE and SFOAE generation.

- Data tend to cluster around integer values, although several non-integer values are observed. This may be due to poor phase unwrapping or phase shifts that are indicative of mechanical perturbations.

- SOAEs were measured with off-frequency suppression paradigm (suppressor 400 Hz above probe), 20 dB SPL probe level, 35 dB SPL suppressor level.

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Discussion

- Regardless of the validity of the linear coherent reflection model, our results indicate a clear interrelationship between SOAEs and SFOAEs observed both in magnitude and phase characteristics.

- The relationship between SOAEs and SFOAEs is readily apparent when stimulation is at low levels.

- Presumably, because generation of SOAEs and low stimulus level SFOAEs is confined to a more focused region of the basilar membrane, this limits the interference from other sources, such as nonlinear distortion.

- The present data are broadly consistent with linear coherent reflection model, both with increased SFOAE amplitudes about SOAE frequencies, and SOAE phase behavior demonstrating a degree of correlation regarding SOAE peak spacing.

- At low levels, responses may be more affected by individual threshold differences. Could stimulation at sensation level provide less variability results across subjects?

- One normal-hearing subject with middle-ear pathology suggests different effects of middle ear on SOAEs and SFOAEs. It may be that SOAEs are "one-way", while SFOAEs are a "two-way" process. Can a simple middle ear model account for such differences?

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References

