Review of Methods for Quantifying Tonalness in Noise

TC 2.6 Hot Topic
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Quantifying Tonalness

- ANSI S1.13-2005 "Measuring Sound Pressure Levels in Air"
  - Annex A "Identification and Evaluation of Prominent Discrete Tones"
    - Tone-to-Noise Ratio
    - Prominence Ratio
- Also in other standards
  - ANSI S12.10, ISO 7779, ECMA 74

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Tone-to-Noise Ratio (TNR)

- Ratio of power contained in the tone to power contained in the critical band centered on the tone but not including the tone
- Concerned with masking effects within the critical band
- See Fig. 1 from standard

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Prominence Ratio (PR)

- Ratio of the power in the critical band centered on the tone to the average power contained in the two adjacent critical bands (above and below)
- Concerned with relative loudness of critical bands
- See Fig. 2 from standard

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Critical Bandwidth

- Represents the ear's resolving power for simultaneous tones or partials
- Roughly 100 Hz for low frequencies (<500 Hz)
- Similar to 1/3 octave bandwidth for higher frequencies (~0.2*f_c)

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Round Robin Test

- A round robin test compared TNR and PR (Balant et al. 1999, Hellweg and Nobile 2002)
- For broadband noise with a single prominent tone, the two metrics correlate well with each other and also with the degree of tonalness perception
- Agreement much poorer for complex tones (multiple tones, harmonics, etc.)

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Round Robin Test

- Led to new limits for perceived prominence in ANSI S1.13-2005
  - Previously TNR>6 dB and PR>7 dB
  - Overall, limits increased, more greatly at lower frequencies
- See plot from Hellweg and Nobile or ANSI standard

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dBA Penalties?

- ISO Standard 1996-2 (2007) "Measurement and Assessment of Environmental Noise – Part 2: Determination of Environmental Noise Levels"
  - Annex C "Objective Method for Assessing the Audibility of Tones in Noise – Reference Method"
  - Tone-to-Noise Ratios linked to decibel adjustments, applied to measured L_{Aeq}
  - Penalties range from 0 to +6 dB

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Other Quantifiers

- Annex D of ISO 1996-2 also suggests simplified 1/3 octave band analysis
  - Tone is prominent if the level of the 1/3 octave band with the tone exceeds both adjacent bands by:
    - 15 dB (for 25 Hz to 125 Hz)
    - 8 dB (for 160 Hz to 400 Hz)
    - 5 dB (for 500 Hz to 10 kHz)

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Other Quantifiers

- Aures' Tonalness Metric (1985)
  - Uses weighting functions to account for
    - Frequency
    - Bandwidth of tone compared to critical band
    - Prominence
    - Loudness of tone compared to overall signal

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Other Quantifiers

- Tonal Audibility – Joint Nordic Method
  - Compares loudness of all tones in a critical bandwidth to the remaining signal
  - Tones defined to be local maxima with 3 dB bandwidth less than 10% of critical bandwidth

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Assorted Issues

- How to deal with complex tones?
  - Multiple tones in the same critical band
  - Harmonic series of tones
  - Time-varying tones
- Some research done to date
  (Hellman 1985; Hastings et al. 2003, Lee et al. 2004, 2005)

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