The “Relative Approach” for Direct Measurement of Noise Patterns

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A/B listening comparisons and acoustic and psychoacoustic measures are frequently used to evaluate sounds. Their accuracy is compromised if time or tonal structure, recognized by listeners as ‘patterns,’ are present in one or more of the sounds. The “Relative Approach” is a new measurement procedure that can be used to obtain valid results in cases that defy conventional techniques.

Conventional and psychoacoustic measurements and A/B listening comparisons are frequently employed to link subjective impressions of sounds with objective quantifications. The presence of pattern information creates problems in obtaining subjectively-valid results from typical conventional or psychoacoustic measurements. A similar problem arises in performing immediate A/B comparison tests where patterns are present. In an immediate comparison, human hearing can detect small differences between two sound events in terms of loudness or A-weighted sound pressure level. But with a relatively long lapse of time between presentations, the human ear can only determine if the patterns are different.

Listening judgments in “everyday life” occur without A/B comparison. A listener forms a sound quality evaluation within a single sound situation without immediate comparison to other sound situations. If pattern information is present, it draws the attention and dominates the judgment. In such cases immediate A/B comparisons are counterproductive because they bring into play the acoustic short-term memory and draw attention to absolute magnitude differences at the transition between any two sound examples. A quick transition itself is registered as a change, drawing specific attention. The true pattern-related perception, which dominates an isolated presentation, is then disturbed. In experiencing a patterned situation, the absolute level or loudness is almost completely without significance.

As an adaptive receiver, human hearing is highly sensitive to patterns in time and/or tonal structure. It creates for its automatic recognition process a running reference sound “comparison file” or “anchored” signal against which it classifies tonal or temporal pattern information moment-by-moment. It evaluates the difference between the instantaneous pattern in both time and frequency and the ‘smooth’ or less-structured content in similar time and frequency ranges. In the presence of pattern information, the pattern rather than the absolute values dominates the subjective evaluation, even though the magnitude in the temporal, tonal or combined pattern may be much lower than in ‘smooth’ or pseudostationary components of the same situation.

When the magnitude of ‘unpatterned’ energy rises in the same time/frequency region relative to a time or frequency pattern, perceived pattern magnitude decreases. If, for example, a vehicle is driven faster and the higher road and wind noise make a rattle less noticeable, the sensation will be of a lower quality in the temporal, tonal or combined pattern. Perceived pattern magnitude decreases. If, for example, the same Relative Approach tool with different settings can be used as preprocessing for the Relative Approach:

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- In an immediate comparison, human hearing can detect small differences between two sound events in terms of loudness or A-weighted sound pressure level.
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time-sensitive and frequency-sensitive regression procedures, with adjustable priority weighting between the two and independent settings choices for each. In this way both time and frequency patterns in a sound situation may be displayed in the same measurement result. Although developed to model the pattern-sensitive evaluation of human hearing, the method has wider engineering applicability in quantifying patterns in noise and potentially also patterns in vibration.

The Relative Approach algorithm objectivizes pattern(s) in accordance with perception by resolving, or extracting, them while largely rejecting pseudostationary energy. At the same time, it considers the context of the relative difference of the ‘patterned’ and ‘non-patterned’ magnitudes.

Due to measurement of relative instead of absolute magnitudes, Relative Approach results are largely insensitive to the absolute magnitude of the entire signal. If the relationship of a detected pattern to the surrounding average remains unchanged, the analysis output (the relative signal) will also remain unchanged over a wide range of overall magnitudes. A pattern that has the same relationship to its surrounding continuum may be detected and judged as essentially the same over a wide range of overall objective magnitudes. Similarly, lowering the level of a complete signal without altering the pattern relationship is likely to result in the same subjective evaluation as before. If a time-data file exhibits no temporal or spectral pattern(s), a Relative Approach measurement will yield a null output. The adaptation of the Relative Approach is similar to that of hearing. Relativity-sensitive analysis suggests application to hitherto-intractable situations.

In addition to providing aurally-accurate objective results, the Relative Approach offers a realistic answer for unattended screening of products and processes whose operation creates or may create time- and/or frequency-patterns. The method has already been applied to automated brake-squeal detection and several other end-of-line tests.

**Typical Applications**

The windshield wiper example shown in Figure 1 compares absolute-value measurements with adaptive relative-value (pattern-sensitive) quantifications. An example of squeak quantification is shown in Figure 2.

Figure 1. Windshield wiper, two cycles. Upper graph – conventional FFT spectrum vs. time with best choice of block size for resolving both tonal and ‘thump’ patterns. Lower graph – Relative Approach, with variation analysis optimized for sensitivity to both temporal and tonal patterns. Time scale is horizontal, frequency vertical; color indicates magnitude.

Figure 2. Squeak quantification – the upper graph is a specific loudness vs. time measurement (ISO 532B filter method) of a squeak situation in a car driven at highway speed. The lower graph is a Relative Approach measurement.
Wind gusting heard in a vehicle interior is another clearly audible and annoying pattern extremely difficult to quantify via absolute measures (see Figures 3 and 4). This includes conventional metrics such as levels and spectra versus time, or psychoacoustic metrics, such as specific loudness, roughness or fluctuation strength versus time. Relative Approach analyses clearly detect all gusts individually according to human perception as shown in Figure 5.

The example in Figure 6 shows the application of the Relative Approach for the evaluation of patterned sounds with the addition of random noise to reduce pattern strength. The “added noise” situation is perceived as quieter than the original engine noise.

Information Technology (IT) manufacturers deal with a potpourri of tonal and temporal patterns, often simultaneously. Figure 7 shows a Relative Approach 3D analysis of a PC workstation performing a hard disk access.

An unusual application in architectural/musical acoustics has been found, quantifying perceived time/frequency patterns in the decay of a concert room’s reverberant field. Figure 8 shows that a relative structure may be seen over a considerable time interval far into the absolute magnitude decline, in good accordance with the perceived structure of musical reverberant decays.

References
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