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**Factors Concerning Frequency Ranges and Durational Values of Tone Bursts with
Accompanying Silences**
Observed Through Work Completed by Scoot Wyatt
(with the assistance of research assistant Jim Kilbourne)

Based upon our preliminary investigation, we found:

- the location of sustained tones with durations longer than 2 seconds were difficult to perceive.
- the location of a sine wave tone (short or long duration) with a frequency lower than 60 Hz or higher than 10,000 Hz was extremely difficult to perceive.
- the initial attack point or transient of a tone lasting shorter than .08 seconds caused the tone to have a perceived multiple frequency component click at the beginning point of a sound creating a false observation concerning the locatable sustained frequency parameter. Attack points of a tone lasting longer than .1 seconds significantly reduced the ability of an observer to identify the sound's location.

Over a six week period, a two-channel DAT test tape was assembled by recording a series of sine wave tone bursts, each with an attack of .08 seconds. Two pitch class sets were used: C and G. The sine waves were controlled by a sequencing program used to generate control data to drive a Kurzweil K2000 synthesizer that generated the sine wave tone bursts. Therefore, octave designations were according to the Yamaha/MIDI octave register labeling system, i.e., A3 = 440 Hertz and C3 = 261.63 Hertz (middle C). Tone frequencies ranged from G1 (98 Hz) to G7 (6271.92 Hz), and from C2 (130.8 Hz) to C8 (8372.02 Hz). They were recorded at a constant amplitude level. The sine wave bursts were presented in varying repeating patterns of duration and silence. These patterns began at the lowest frequency and ascended by octave.

The tones were played through the audio system at a constant 75 dB sound pressure level (spl) - measured at the distance of one meter from the speaker - and registered 64 dB (spl) at the listening point. Sound pressure level measurements were taken with a commercially available sound level meter using C weighting (C weighting has C-curve [flat] frequency characteristics. This setting causes the meter to respond mainly to frequencies in the 32 to 10,000 Hertz range). The listener was located between the front left (FL) and front right (FR) speakers at a distance of 3.37 meters. The tones were projected from one, then the other speaker in a random order. The listener attempted to determine the location of the tones, i.e., from which speaker the tones were projected.

The purpose of listening to this test tape through the sound system was to verify the perceptibility of specific frequencies and their corresponding patterns of length of duration and silence for simulating stationary and moving sound sources within a multi-channel audio playback environment. Specific patterns used were as follows:

The sequencer file was set to a constant tempo of one quarter note per second. Each pattern was sixteen seconds long, and was divided into four measure groups. The patterns were eighth notes divided by eighth rests - an eighth note lasting .5 seconds; sixteenth notes divided by sixteenth rests - a sixteenth notes lasting .25 seconds; thirty-second notes divided by thirty-second rests - a thirty-second note lasting .125 seconds; sixty-fourth notes divided by sixty-fourth rests - sixty-fourth notes lasting .0625

seconds; sixteenth notes divided by eighth rests; thirty-second notes divided by sixteenth rests; sixty-fourth notes divided by thirty-second rests; thirty-second notes divided by dotted thirty-second rests; sixty-fourth notes divided by dotted sixty-fourth rests; thirty-second notes divided by eighth rests; and sixty-fourth notes divided by sixteenth rests.

The criteria for a frequency and rhythmic pattern's source location perceptibility included:

- 1) could the location of the sound source - which speaker - be positively determined
- 2) whether or not location of the tones needed to be determined by repositioning the head (a head turn, abbreviated to H.T.)
- 3) the length of time the location of the tones could be determined before interference confused the source location.

Terms used to describe the perception of each pattern's location were: Not Usable (NU), Poor Perception (PP), Fair Perception (FP) and Good Perception (GP).

Three observers listened to the tape individually. The following are conclusions made from the composite observations:

Both the length of durations as well as the length of dividing silences determined whether or not the location of tones from G1 to C3 (98.0 to 261.63 Hz) was perceptible. It was found that within this frequency range tones longer than .5 seconds in duration were not usable even if followed by an equal length of silence. However, when the duration of the tones was shortened to .25 seconds and followed by .5 seconds of silence, tones from this range could be used. For the discrete location of tones from this range to be perceptible, the minimum length of dividing silences was found to be .5 seconds. Shorter durations inevitably lead to ambiguity of sound location due to developing reflective interference.

Successive tones (frequencies ranging from 98 to 8372.02 Hz) and silences having like durations of .125 seconds or shorter were difficult to perceive and were considered not usable.

The location of successive tone bursts from G3 to C6 (392.0 to 2,093.0 Hz) with durations and silences longer than .125 seconds (and being no longer than .5 seconds each) were easily perceived. This suggests that sounds from this range are applicable for simulating stationary and moving sound sources within a multi-channel audio playback environment. The perceived location of successive tone bursts from G6 to C7 (3,315.96 to 4,186.01 Hz) having similar durations was generally found to be fair to good.

The perceived location of successive tone bursts from G7 to C8 (6271.92 to 8372.02 Hz) having durations between .125 and .5 seconds (inclusive) with alternating silences having durations between .25 and .5 seconds (inclusive) was generally found to be good (with occasional ambiguities).