# Psychoacoustikcs

8th lesson

Harmony

# Theory of Harmony

- Harmonia, Greek: composition
- Music:
  - Theory of chord shapes
  - Theory of chord progressions
- Concept has changed through the development of polyphony.

# Period Tunings

- Tunings where all thirds and fifths are just can not exist mathematically, therefore are tunings are compromises:
  - Just-intonation tuning
  - Pythagorean tuning
  - Mean-tone tuning
  - Werckmeister
  - Valotti and many more

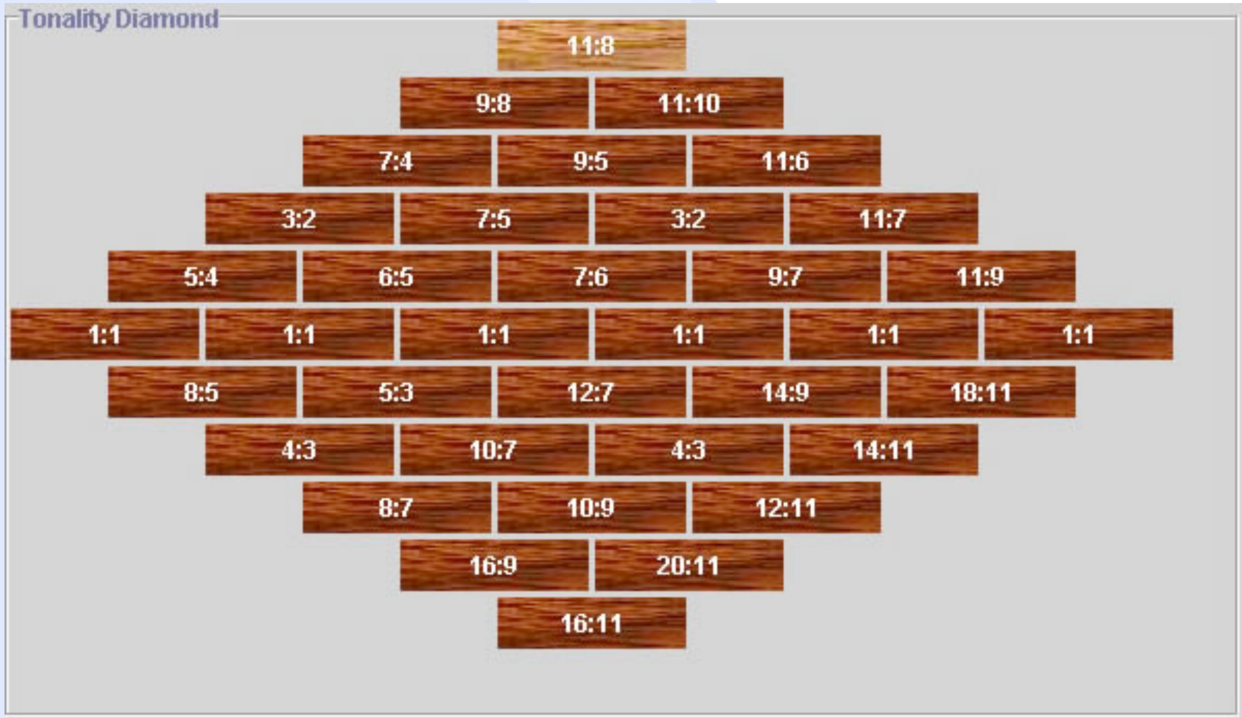
# Example for mean-tone tuning: Froberger Capriccio (FbWV 506)

# Microtonality

The term microtonality refers to the systematic exploration of tonal relationships that can not be derived from our tempered or quasi-tempered tuning. By comparison with the steps of the 12-tone tempered tuning (also called 12TET = "12-tone equal temperament"), in microtonal tunings deviations are smaller than 100 cents are common. Hence the term microtonality.

There are two schools of thought:

1. Just Intonation: The representatives of this movement, established by American composer Harry Partch ("Genesis of a Music"), focus on the intervals that can be derived from the overtone series and their inversion (undertone series). In the process, rather unusual intervals such as 11/7 or 7/3 come to the center of attention.



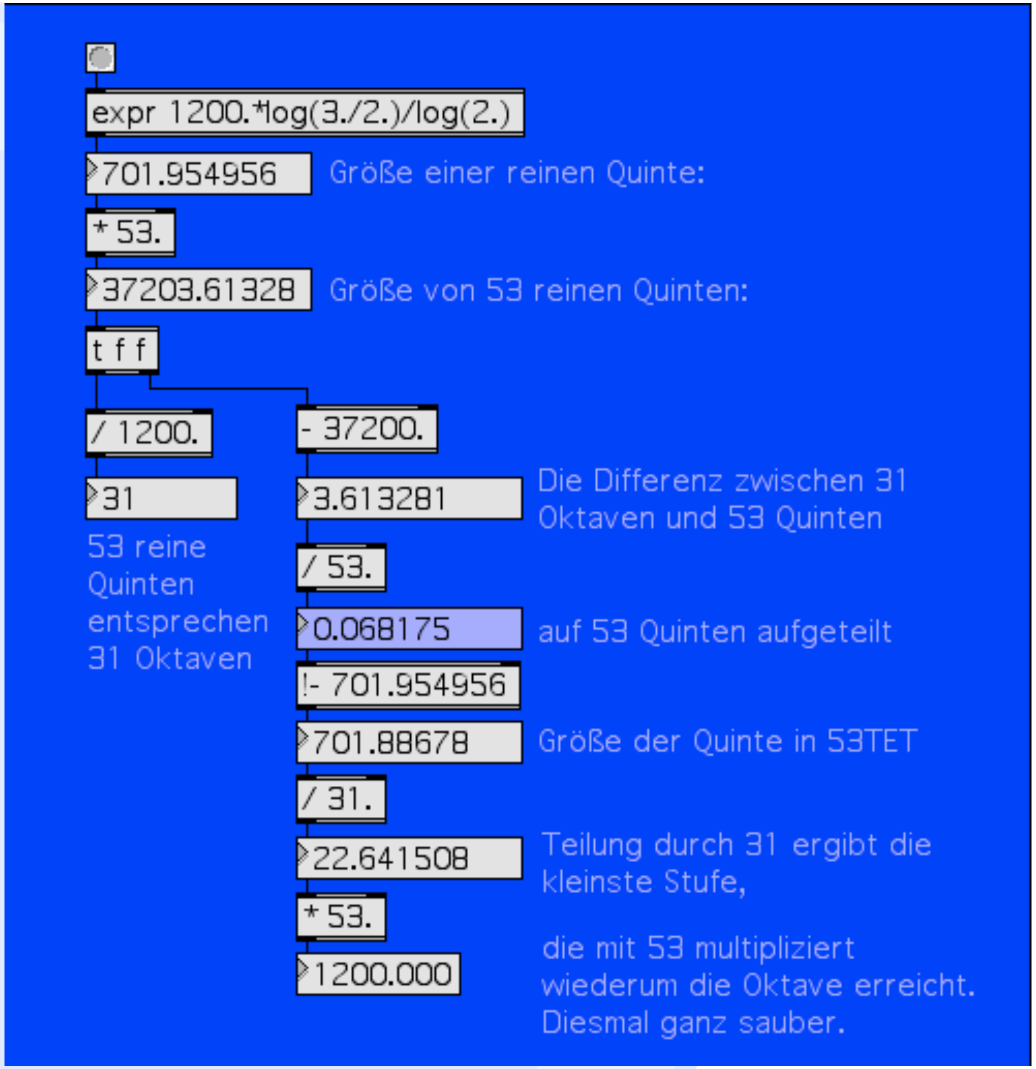

Arrangement of wooden bars in Harry Partch's marimba in just intonation (11-limit)

2. Equal Temperament: The need for small subdivisions of the whole tone into four (24TET) and six (36TET) was already theorized and practiced at the beginning of the 20th Century (Busoni, Haba, Wishnegradsky, Ives). The Mexican composer Julian Carrillo patented in 1940 a piano with 16th notes (96TET). The 72-level, ekmelic tuning closely approximates most of the harmonic overtones, while 53TET is derived from the layering of 53 fifths. 53 fifths correspond to 31 octaves in a very good approximation (see next slide). Interesting are also tuning systems in which a diatonic tone set exists, such as at 17TET, 19TET, 22TET, 31TET (mean-tone tuning) and 41TET.

These systems obey the following rule: $5 * m * s + 2 * n * s = 1200$, where s is the step size of the system, and m and n are the integer factors with which s must be multiplied by to achieve a whole tone or semitone, resp.

This also applies: $5 * m + 2 * n$ = number of steps in the tuning.
The following condition should also be met: 694 cents <$(3 * m + n) * s$ <710 cents.

For 12TET: $m = 2$ and $n = 1$,
For 17TET: $m = 3$ and $n = 1$,
For 19TET: $m = 3$ and $n = 2$,
For 22TET: $m = 4$ and $n = 1$,
For 31TET: $m = 5$ and $n = 3$,
For 41TET: $m = 7$ and $n = 3$.

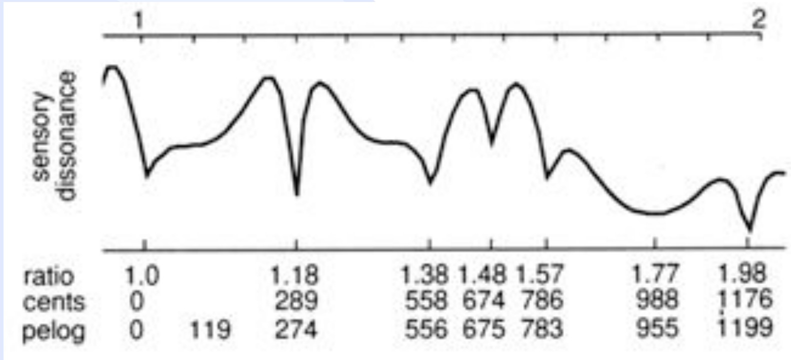



Calculation of the 53-step equidistant tuning in Max

In addition to the octave, of course, other intervals can be divided. An example is the Bohlen-Pierce scale, which was discovered and described in 1978 by engineer Heinz Bohlen. This scale divides the just twelfth (3: 1) into thirteen equal steps and has a tone set containing a striking number of intervals of odd ratios such as 5: 3, 7: 5, 7: 3, 9: 7 and 9: 5 , These intervals are also included in the spectrum of the clarinet, which is one of the few wind instruments that blow over at the twelfth. What could be more appropriate than developing a clarinet with the Bohlen-Pierce tuning? http://www.sfoxclarinets.com/bpclar.html.

| Stufe | Reine Stimmung | | | Gleichschwebend temperierte Stimmung | | |
|---|---|---|---|---|---|---|
| n | $f_n/f_0$ | cent | hekt | $f_n/f_0$ | cent | hekt |
| 0 | 1/1 | 0 | 0 | 1,0000 | 0 | 0 |
| 1 | 27/25 | 133 | 91 | 1,0882 | 146 | 100 |
| 2 | 25/21 | 302 | 206 | 1,1841 | 293 | 200 |
| 3 | 9/7 | 435 | 297 | 1,2886 | 439 | 300 |
| 4 | 7/5 | 583 | 398 | 1,4022 | 585 | 400 |
| 5 | 75/49 | 737 | 504 | 1,5258 | 732 | 500 |
| 6 | 5/3 | 884 | 604 | 1,6604 | 878 | 600 |
| 7 | 9/5 | 1018 | 696 | 1,8068 | 1024 | 700 |
| 8 | 49/25 | 1165 | 796 | 1,9661 | 1170 | 800 |
| 9 | 15/7 | 1319 | 902 | 2,1395 | 1317 | 900 |
| 10 | 7/3 | 1467 | 1003 | 2,3282 | 1463 | 1000 |
| 11 | 63/25 | 1600 | 1094 | 2,5335 | 1609 | 1100 |
| 12 | 25/9 | 1769 | 1209 | 2,7569 | 1756 | 1200 |
| 13 | 3/1 | 1902 | 1300 | 3,0000 | 1902 | 1300 |

3. Another class of tunings can not be classified into one group or the other. This includes the Indonesian pelog (gamelan music), which has a set of 5 small and 2 large unequal intervals, of which only 5 are used. It is likely that these tunings follows the need to minimize the sensory dissonance of the mainly inharmonic sounds of the gamelan orchestra. (The other scale commonly used in gamelan music, Slendro, is characterized by a quasi-equidistant 5-tone scale.)



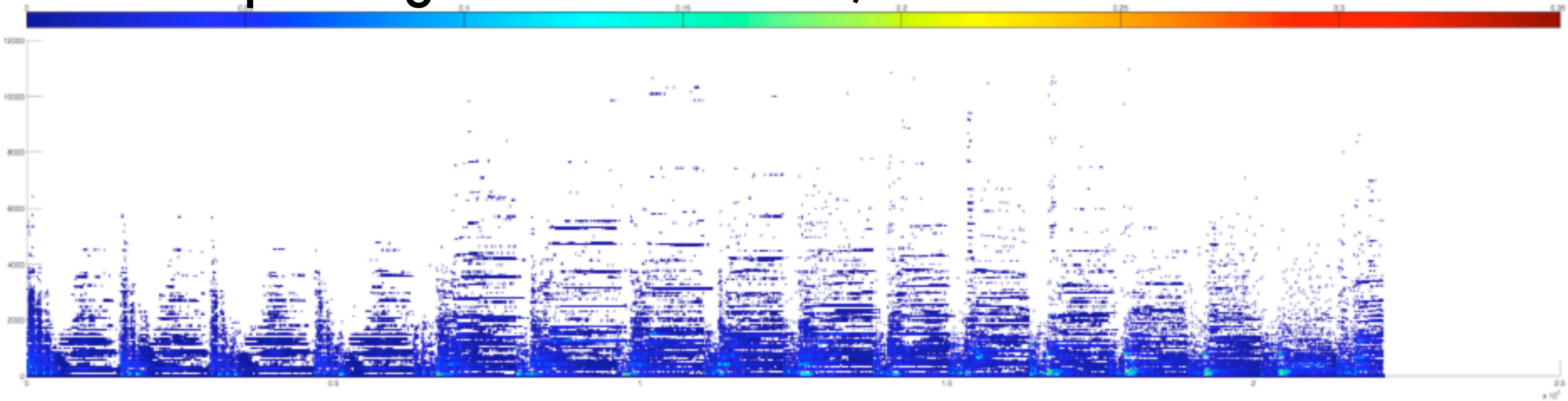

Sensory dissonance curve for a gamelan instrument. The minima are in good agreement with the pelog scale.

# Harmony in the 20th/21st centuries

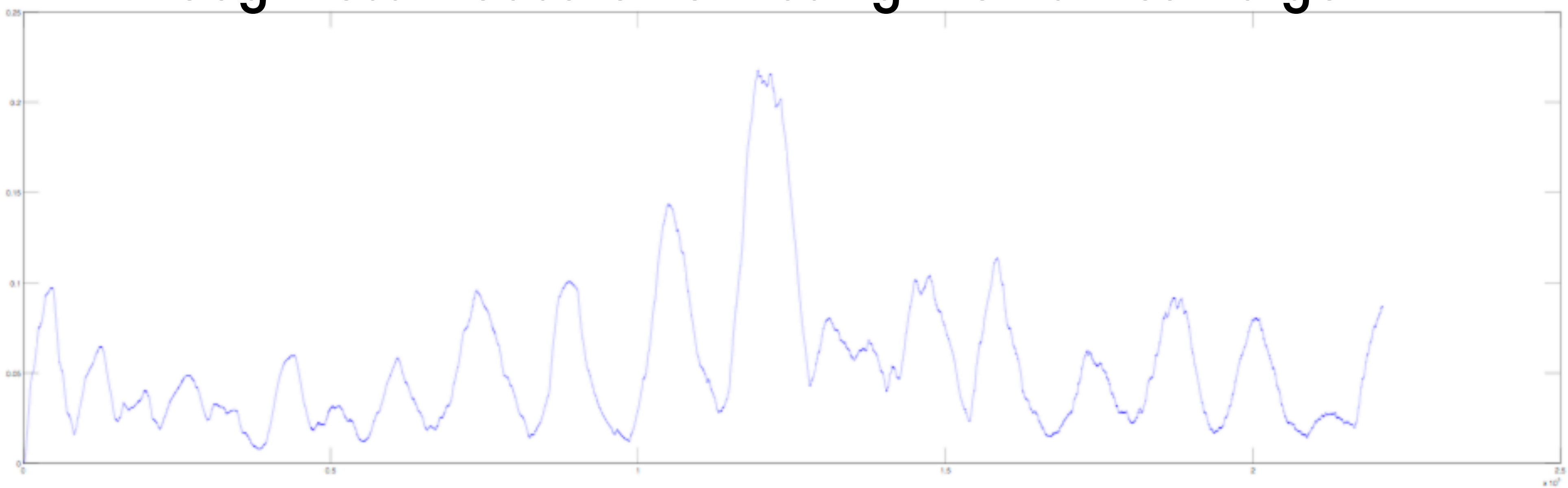
- Tension and relaxation as the driving force of harmonic progressions
- Leveling of harmonic tension in the works of the serialists
- New approaches by spectralists, among others:
- K. Saariaho: Degree of Silence (Timbre and harmony: interpolations of timbral structures). Example: Nymphea for string quartet and electronics.
- Gérard Grisey: Relationships between harmonicity and inharmonicity of spectra.

# Grisey: Partiels

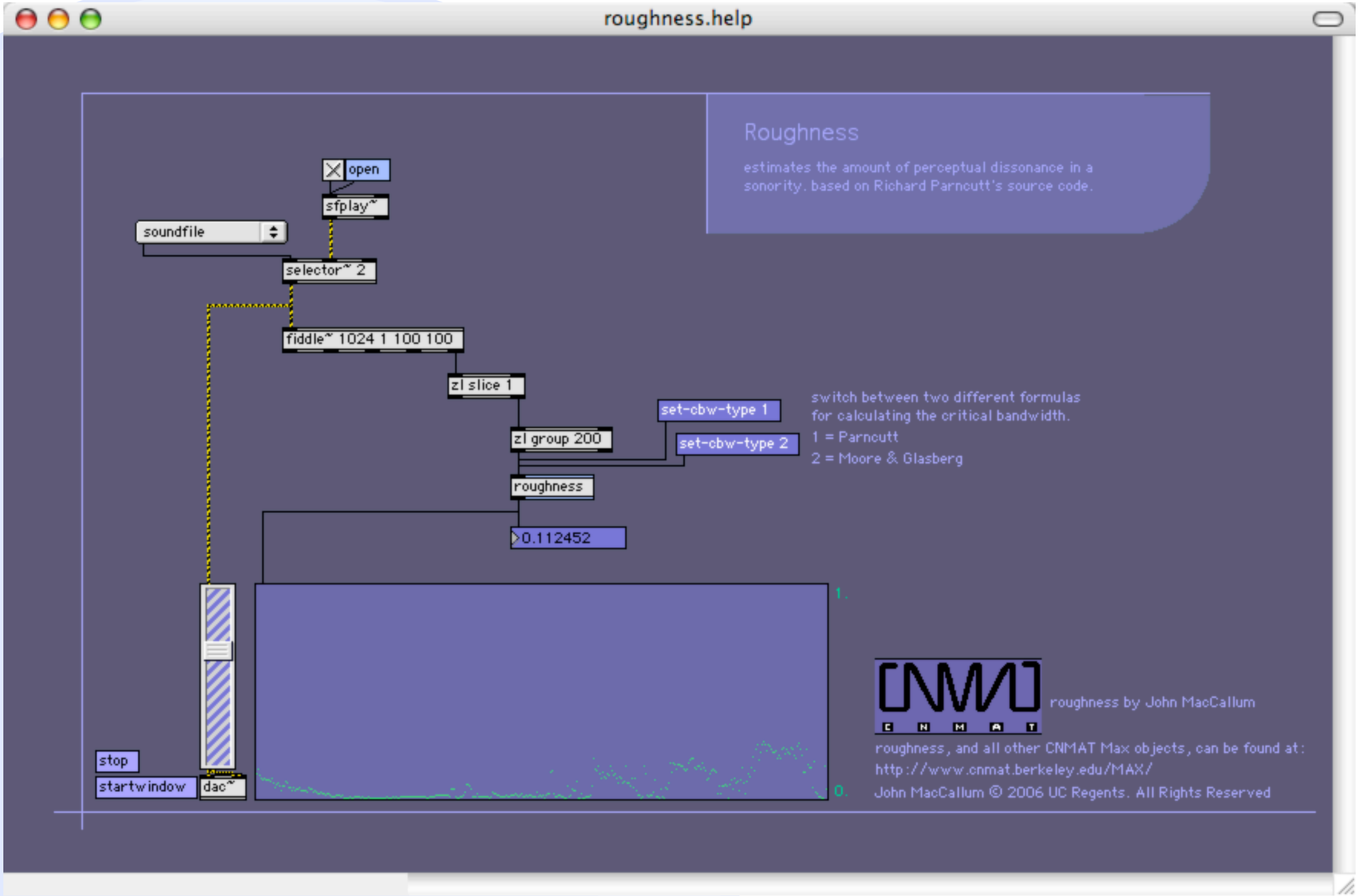
Spectrogram of the first 2,5 minuts



Roughness measurement using the Parncutt algorithm



# Roughness Estimation in Max



# Convergence of harmony and timbre

The work of the spectralists raises interesting questions. When tension / relaxation is created by manipulations of partials, what exactly is the difference between harmony and timbre?