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"Structural timbre"

Characteristic Effect for Proximal Stochastic Digital Narrow-band Noises

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ABSTRACT

We have got model component having a uniform randomness, from time-dependent changes which cannot be Fourier-transformed. And we have succeeded to extract the characteristics of structured timbers of sine waves that exist densely in close proximity, which cannot be recognized independently and conventionally ("Discovery of Structural timbre"). Similar to the "structural colour" in the visual, now it is able to treat the component which corresponds to the "brilliancy" in the sound independently, and is intended to give a new basic knowledge in music construction regardless of Ensemble or Solo.

1. Line spectrum and band noise.

Conventionally, it was a major problem in the sound study, how much ratio of the harmonic component obtained as a line spectrum should be. Analog synthesizers are using these setting parameters to make certain timbres, from this point of view. With the digitalization of audio processing techniques, timbre handling made more freely.

For example, morphing to connect between the different timbres "naturally", e.g. from violin to clarinet, became the main topic. It is obvious that the emphasized point is on how to control the coefficients of harmonic spectrum, since those instruments with a clear harmonic spectrum are selected, e.g. from violin as an initial state to clarinet as a final state. Vocoding technology have played an exceptional role from this background. While analog vocoder is mimicking the voice by band noise processed by a filter varies largely in time, digital vocoder became possible to use a more diverse ways.

For organisms, at basement membrane on the cochlea tract within inner ear, hair cells are arranged densely as detector corresponding to sound waves of each frequency of the audible range. Then, when the hair cell reacts to the sound wave for a certain frequency, the impulse of neuronal firing is sent to the brain through the inner ear nerve. Thus, it can be examined individually which range of hair cells can react to the test signal by the band noise of a specific frequency range. Decomposition and recomposition with sinusoidal model of spoken language [1] are established on the basis of this principle, our group has also obtained the results using the same [2]. However, fundamental considerations connecting the voice and timbres, in terms of music, have been left consistently since the 1950s. The music framework dealing with them systematically have been sought.

2. From Mesoscopic system of solid state physics … Bridge between Discrete spectra and Continuum

One of the authors was inspired from solid-state physics, e.g. for semi-conductor LSI. Here we describe in short. For Microscopic level, a single atom has discrete energy level. On the contrary, for Macroscopic level, cristale has several energy bands and gaps. However for Mesoscopic level, few-body system has in-between characteristics from discrete to continuum, which are proximate and dense discrete energy levels.

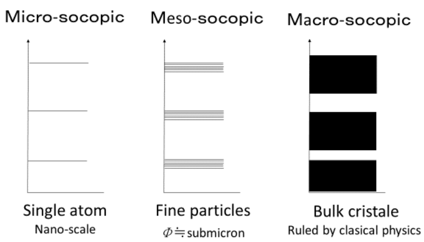


Figure 1. Schematic views of electron energy spectra
in single atom (left) bulk cristale (right) and fine particles (middles)

3. perception threshold and signal density

Human hearing is conducted frequency degradation by parallel processing in the cochlea duct, cochlear nerve is sending nerve firing impulse of upward to the brain as a signal of each frequency band. There appears difference depending on bands, depending on individuals also, assume that this resolution is Δ as model. If step-wise series of signals with shorter gaps than human cognitive resolution limit is less than Δ, human auditory cognition cannot recognize its discrete, and will listen as continuum (Fig. 2).

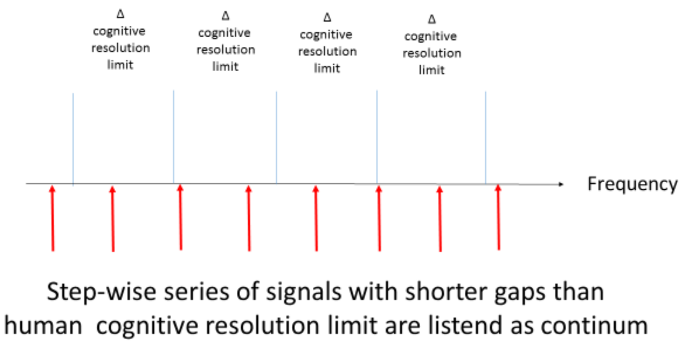


Figure. 2

Thus, we are able to make a series of appropriate test signals fundamentally, by selecting appropriate parameters, to make discrete digital spikes of signal but can be heard continuous enough.

4. "Cognitive Digital Noise" generated as a series of sine waves

Consider that realizing such a stimulation sequence as a sine wave series in proximity with the "Super Narrow Band". In reality, it is possible to make similar sound samples by narrow band noises with a extremely-high-Q-value band pass filter, to limit the range of the noises. When generating a band noise, assuming that both amplitude and phase spectrum is random, we can produce a signal source, while temporally changing in the short term but uniformly distributed in the long term. Let such a narrowband noise conveniently be called as Stochastic Narrow Band Noise (SNB Noise). This is a naming similar to "band noise", but it is indistinguishable by the real ear from the analog noise of continuous spectrum. Let's note that this noise is created as a collection of sine waves, in fact.

5. Stochastic Digital Narrow Band Noise and Uniform Digital Narrow Band Noise

Let us show the example of Stochastic Digital Narrowband Noise (SDN Noise). （Fig. 3, 4） This example is for the bandwidth of 1010 Hz ~ 1024 Hz, distributed in about 0.2Hz interval, with random amplitude.

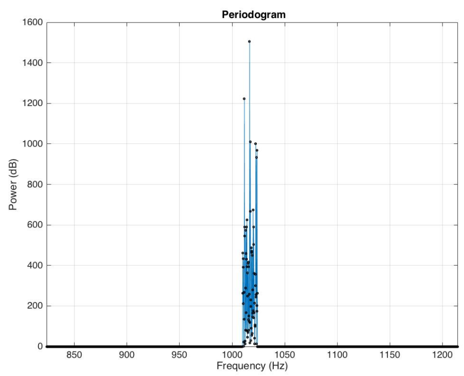


Figure.3. Super Narrow-band Digital Probability Noise between 1010 Hz and 1024 Hz

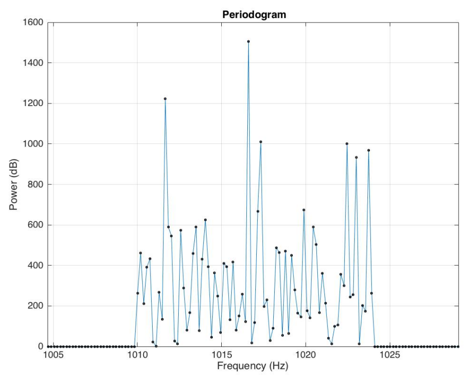


Figure.4. Zoom Up of Figure.1. (Left)

For contrast, we generated narrowband noise of uniform amplitudes by superimposed sine waves. (Fig. 5-7)

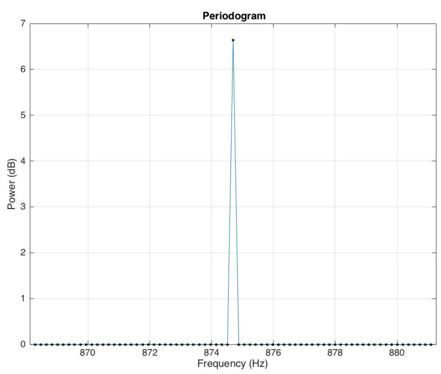


Figure.5. Zoom Up of Single Sine Wave (874.7 Hz) as Narrow-band Noise between 874.5 Hz and 874.9 Hz

It was devised the following points from the band noise to create such a "sine wave". For example, in case of sampling rate: $fs = 96000\ Hz$, we have selected $duration\ (of\ test\ sound) = {2^{19}}/{fs}$, to make ω_0 (basis of Fourier Transform) smaller enough. As a matter of cource, this can be done by using sine waves simply. （Fig. 6, 7） However we succeeded to make so-called “Uniform Noises” by adding sine waves of several frequencies, since we can now use this needle-like sine wave.

In distinction from noise with a random amplitude spectrum, we call these Uniform Digital Narrowband Noises (UDN Noises). Both narrowband noises present dense to a particular frequency range can be created as test sound sources.

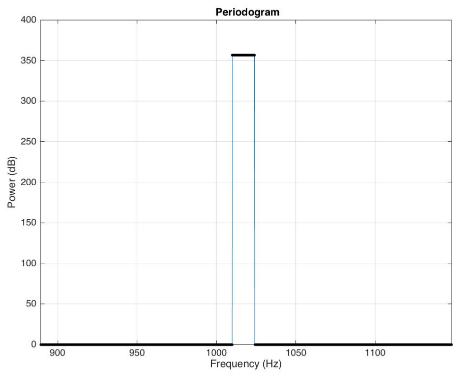


Figure.6. Super Narrow-band Digital Uniform Noise between 1010 Hz and 1024 Hz

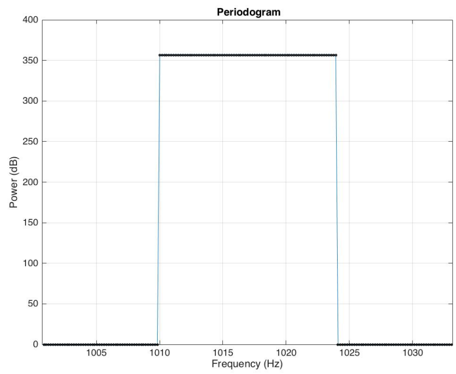


Figure.7. Zoom Up of Figure.4. (Left)

6. "Structural Timbre": Stationary and Random Component (Kolmogorov Component)

We mainly discuss on SDN Noises below. Suppose starting from a single sine wave to several sine waves to expand the bandwidth for the SDN noise, as starting from a single atom to metal particle little by little.

We can hear interference of beats from some neighboring sine waves. So, it is not "pitch" but "dynamics" of changing intensity of sounds for change in frequency or spread of the frequency distribution.

When spreading the frequency distribution little by little (unable to catch the pitch difference by human ears), SDN noise narrower than "half tone" can generate the texture of specific Brilliancy".

These SDN noises have "structural" characteristics since these noises are obtained by dense sine waves within proximate frequencies for audible range. Now, we can imagine about "structural colour" in visual.

"Structural colour" is a color that has a characteristic of the "brilliancy" by multiple scattering on the surface of the molecular layer, unlike the color obtained by such as flame reaction of the metal atoms. It can be seen well on the body of insects.

Distinctive shine can be seen on the body of morphoes and jewel beetles. It is known that the "Structural Colour" can show the scatter response characteristic for not only the sunlight but also various incident lights.

Figure. 8 “Structural Colors” from a) Morphoes and b) Jewel beetles

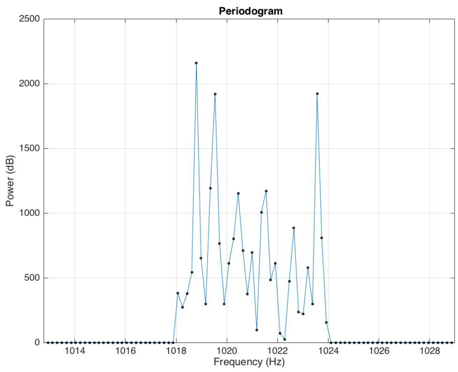


Figure.9. Super Narrow-band Digital Stochastic Noise
between 1018 Hz and 1024 Hz
Deviation in Amplitudes

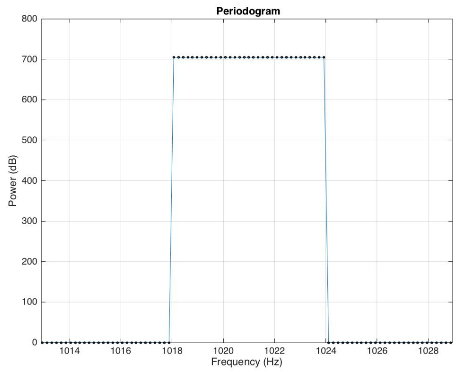
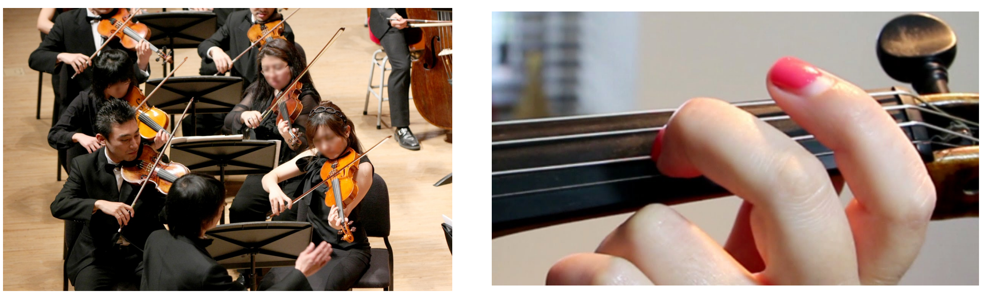


Figure.10. Super Narrow-band Digital Uniform Noise
between 1018 Hz and 1024 Hz
Without Deviation in Amplitudes

Temporally steady tone component have been the basis of tone quest by Fourier Component. In addition, the time variation of the Fourier components would be able called Laplace components. What we tried to extract here is not Fourier, not Laplace, but ever changing with uniform in long-term average. We identify this Stationary and Random Component as Kolmogorov Component, and will continue to examine its characterstics.

7. Example of Stationary-Random Timbre:
Possibility of “Structural Timbre” in Tutti of Strings or Chorus.

Kolmogorov configuration is just one of the models, and do not necessarily always match the real music audio. However, we can handle from a completely new perspective to the problem, "Unison" in the ensemble, as example of sounds in dense in a narrowband, and long-term average is uniform, by Kolmogorov configuration.



Reference:

[1] Takeyuki, HIDA, "White Noise: An Infinite Dimensional Calculus", Springer Science & Business Media, 1993