Journal of the International Society for Orthodox Church Music
Vol. 1 (2014), Section I: Peer-reviewed Articles, pp. 1-19
https://journal.fi/jisocm

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Spectral examination of Byzantine Chant archetype

In this article, a particular hypostasis of Byzantine chant was chosen to be spectrally examined, from the multitude of possible variants: a melodic structure accompanied by a simple bass drone called Ison, placed bellow the melody and sung by male choir. This model is referred to in this paper as *Byzantine chant archetype* and is further approached from the spectral listening perspective. Psychoacoustic analysis criteria were used, such as: holistic/analytic listening, sound fusion/fissioning, sensory consonance/dissonance, harmonic entropy, etc. The research is an attempt to demonstrate that Byzantine chant with Ison presents an ideal situation for *sound fusion perception and holistic listening*. The persistence of the fundamental pitch (Ison) over the melodic structure acts in favor of partials fusion of the two layers into *one perceptual enti*ty. Starting with Western medieval organum, polyphonic practice broke with the monolithic perceptual entity provided by the Ison by simply moving the bass line and later filling it in with chords resulting from the multipart structure. The perception mode shifted from *sound fusion* to *sound fissioning*. The way we hear the polyphonic texture is of an analytic nature (*analytic listening mode*). It appears that Western music culture developed a more analytic model of hearing while the Eastern one relied more on a holistic listening type.

Keywords: holistic listening, analytic listening, tonalness, inharmonicity, heterophony.

1. Spectral Description of Byzantine Chant archetype as a melodic structure accompanied by a bass drone (Ison)

Byzantine music is exclusively vocal. In order to understand the subtle link between a certain ethos and the underlying acoustic properties of the body that produces the sound, some aspects of the human voice are discussed from a psychoacoustic perspective.

1.1. Spectral Characteristics of the Human Voice

The human voice is regarded as having an *harmonic sound*. William A. Sethares refers to sounds produced by instruments with a harmonic spectrum, including the human voice, as *harmonic sounds* and their timbre as *harmonic timbre*.[1] The voice produces *harmonic sounds*, as well as having a *harmonic timbre*, along with most Western classical instruments such as strings or winds. *Harmonic sounds* are understood to be those sounds which, on the steady portion of vibration, have more spectral energy on the harmonic spectrum. The fundamental frequency of a harmonic spectrum is generally the strongest and is perceived as the sound's pitch, the other frequencies being integer multiples of the fundamental frequency (f, 2f, 3f, etc.). In certain conditions of sound emission, *inharmonic frequencies* are also produced that are not integer multiples of the fundamental (for example, f, 2,1f, etc.). Instruments (such as bells, cymbals, gongs) that have more spectral energy on the inharmonic spectrum produce *inharmonic sounds*; therefore, their

[1] See Sethares, William A. *Tuning, Timbre, Spectrum, Scale*. 2nd ed., London: Springer-Verlag 2005.

partials are not harmonically related. The human voice also produces inharmonic partials on the attack portion of the vibrations or by using nonconventional vocal techniques (for example, quasi-whispering or screaming). Timbre subtleties that embellish the sound quality could also be due to the presence of inharmonics. The harmonic spectrum coexists with the inharmonic spectrum in different proportions.

The complexity of the human voice spectrum could be better understood by analogy with certain instruments' spectra. In the case of a wind instrument, the vibration of the resonator—under the sound action generated by the air column—modulates the air vibration within the tube. The modulation level is very small, but the magnifying glass effect of aural perception grasps the change produced in the nature of the vibration.[2] Similarly, in the case of the human voice, the vibration of the different parts of the body that act as resonators—under the action of the sound generated by the vocal strings—influences the sound quality and therefore changes the nature of the vibration. In these circumstances, the vibration of the air cannot anymore be considered as an ideal vibration—where a single parameter (the amplitude) has sinusoidal variation. It should be treated as a 'parametrical vibration', where one or several parameters (considered as being constant in comparison with the ideal vibration) are *modulated* by the general vibration itself. Although the parameter of modulation is very small, the ear perceives it as a *timbral subtlety.* The aural system also translates into *timbral subtleties* some other details of the vocal vibration, such as: *vibrato* or *micro-tonal fluctuations.*

1.2. Vocal Timbre Characteristics of Byzantine Chant archetype as a melodic structure accompanied by a simple bass drone (Ison) sung by male choir

The vocal timbre of the Byzantine chant archetype chosen to be examined in this paper is the result of a combination of male voices. The melodic structure of Byzantine chant archetype we are examining is placed above the Ison and is sung, normally, by higher voices and the Ison by lower voices. The *Ison* is usually placed in a low register and is sung either in unison or in octaves. The general timbre quality of Byzantine Chant is also influenced by its *syntax, register setting, non-tempered intonation* and *specific vocal emission of the sounds.*

The heterophonic *syntax* provides a melodic structure of continuous character versus a large scale pedal point on the fundamental of the spectrum. The persistence of a low frequency is highly important for the general *timbre* quality. The voices of the basses and baritones singing the Ison introduce a large number of harmonics in the audible domain. These harmonics combine with the notes and harmonics of the melodic layer sung by the tenors (the upper voice). Where intonation is very precise, certain partials of the melodic layer coincide exactly with those of the Ison.

Byzantine chant with Ison sung by male choir uses, generally, a certain *register setting*. The bass drone could be situated in a very low register (i.e. D_2) and the melody is sometimes placed more than an octave above the Ison. If the distance between tenors and basses is very large, the interaction between partials becomes negligible because the amplitudes of the high partials of the Ison are increasingly low. Consequently, dissonant intervals are no longer perceived as such. The register setting of Byzantine chant creates conditions for an enhanced perception of *consonance*, related, in a very subtle way, to the perception of timbre. A more *fused timbre* is likely to be heard associated with consonance.[3] The male choir with an enhanced low register produces a significant *timbral fusion* perception.

The *non-tempered intonation*, closer to *just intonation*, is also an attribute in favour of tonal fusion and timbral fusion perception.

2 See Teodorescu-Ciocănea, Livia. *Timbrul muzical: Strategii de compoziţie*. Bucureşti: Editura Muzicală 2004.

3 See Teodorescu-Ciocănea, Livia. "Timbre versus spectralism", *Contemporary music review,* Vol. 22, Nos 1 and 2. 2003, 87-104.

1.3. Melodic Consonance/Dissonance Perception of Byzantine Chant archetype

Generally, *melodic structures* could be divided in two categories depending on the manner in which the pitches are intoned:

1. continuous melodic structures (continuous sequentiality on the frequencies axis);
2. discontinuous melodic structures (discrete sequentiality on the frequencies axis).

The human voice is capable of both types of melodic sequentiality. It is exceptionally suited for *legato* and *portato*, but also for instrumental-like intonation.

Byzantine chant archetype presents a high level of *continuous melodic sequentiality* by its smoothly character. This characteristic has significance for the perception of *melodic consonance/dissonance*, which depends, along with other factors, on the type of movement (smooth or abrupt) from one spectrum to another.

The aural system analyses the spectral components of each note of a melodic structure and the relationships between the notes. The notes of a melody we hear as pitches are only the fundamental frequencies of their spectra. The relationship between notes also represents the relationship between their spectra. When pitch shift from one note to another, a *spectral flux* arises within the partials domain.[4] A small interval step allows each overtone to continue along a flow line (a sequence of harmonics in close frequency). By contrast, a large step will break the continuity of the flow lines. If the interval is very small (slight variation in pitch), many harmonics on the flow lines could coincide exactly. If two consecutive spectra of tones have lots of coinciding harmonics or are close and in the same direction as the previous interval, then the spectral flux will have a smoother variation. A *melodic consonance* will be perceived. However, if two consecutive spectra of tones have few or no coinciding harmonics and move in opposite directions, then the spectral flux variation will be abrupt. A *melodic dissonance* will be perceived.[5]

The neuropsychological explanation of the melodic consonance/dissonance sensation is based on the continuity or discontinuity of the excitation regions of the basilar membrane.

According to Jared Anderson, melodic consonance is augmented in the following conditions: small intervals, so the spectral flux will move smoothly; movement in the same direction as the previous interval; the use of the notes of the scale, so the harmonics are well established; microtonal fluctuation, so the well-established harmonics coincide.[6] Examining only the melodic layer of Byzantine chant archetype, we could observe that it offers conditions to support a sensation of melodic consonance: the intonation of the melismatic formulas through glissando or quasi glissando (sliding pitch), that creates the smoothest variation of the spectral flux; the use of just intonation intervals, that increases the number of coinciding harmonics; the microtonal fluctuation of pitch; melodic continuity (continuous sequentiality).

1.4. Harmonic Consonance/Disonance Perception of Byzantine Chant archetype. Spectral implications of the Ison on the overall harmonic structure.

The overall consonance/dissonance perception of Byzantine chant accompanied by Ison depends greatly on the perception of the harmonic intervals (on the vertical axis) resulting from the superimposition of the melodic line on the pedal point.

Dissonant harmonic intervals are resolved at perfect and imperfect consonances. Pythagoras's assumption that the ear prefers small integer ratios is one of the explanations for consonance

[4] See Anderson, Jared E. "The perception of melodic consonance: an acoustical and neurophysiological explanation based on the overtone series", unpublished paper, Department of Music Mathematics, University of Pittsburgh, 2004, http://cogprints.org/3513/1/melcons.pdf. Accessed August-September 2008.

[5] Anderson 2004.

[6] Anderson 2004.

sensation. Thus, the intervals based on small integer ratios (such as 2:1, 3:2) are perceived as being more consonant than the others.[7]

The heterophonic structure of Byzantine chant introduces many unison or octaves that frequently resolve the tension generated by dissonant harmonic intervals. The overall perception of consonance is increased by the following factors: high degree of harmonic consonance (lots of moments on unison, octaves or fifth) high degree of melodic consonance (coinciding partials and smooth movement of the spectral flux); high degree of harmonic spectrum stability by the use of just intonation; high degree of timbral fusion; overall structural 'consonance' (in the case of one pedal point); high 'structural consonance' (in the case of several pedal points on large musical surfaces).

1.5. Sensory Consonance/Dissonance Perception of Byzantine Chant archetype

A closer look at the spectral characteristics of the Ison and/or the melodic line, if sung by more than one chanter, reveals the existence of inherent beats caused by the slightly out of tune unison. A perfect unison is quite impossible to achieve (either for the held bass note or for the melodic layer). A *sensory dissonance* is perceived in these circumstances, due to a phase shift and beats phenomenon.

The concept of *sensory consonance/dissonance* (Sethares) is equivalent to the *psycho-acoustic consonance/dissonance* concept known as CDC-5 (Tenney), and is based on Helmholtz's observations as later developed by Plomp & Levelt (1965).[8] The *sensory consonance/dissonance concept* focuses on the perceptual mechanisms of the auditory system and refers to the perceived *roughness* or *smoothness* of a single sound or combination of sounds. Sound *roughness* is a measure of sensory dissonance, caused by the beating phenomenon produced by partials that have very close frequencies. Sound *smoothness* reflects the absence of beats and produces the sensation of consonance. According to Sethares's *sensory consonance/dissonance concept*, sounds with more than one partial have an inherent sensory dissonance caused by interacting partials.[9] The consonance/dissonance sensation is not only caused by the relationship between tones, but depends also on the interaction of their spectra. When a high degree of roughness occurs because of beating partials, the interval is perceived as dissonant. The consonance/dissonance concepts are not absolute properties of sounds. They are perceived by the aural system on a continuum axis. 'CDC-5 recognises a *continuum* of possible gradations between consonance and dissonance.' [10]

The inherent *sensory dissonance* encountered in Byzantine Chant when sung collectively enriches its general sonority.

1.6 Other Perceptual Characteristics of Byzantine Chant archetype

Byzantine structures can also be examined according to other spectral phenomena, such as: *harmonicity, inharmonicity, tonalness, harmonic entropy, virtual pitch, spectral fusion and spectral listening.*

Harmonicity is a measure of the degree of periodicity of the sound components[i]**.** A high degree of harmonicity increases the stability of the oscillation regime.[11] When *just intervals* are used, the *harmonicity* measure is higher.

7 See Sethares 2005.

8 See Sethares 2005; Tenney, James. *History of 'consonance' and 'dissonance'*. New York: Excelsior Music Pub. 1988; Helmholtz, Hermann. *On the sensation of tones as a physiological basic for the theory of music*. Trans. By Alexander J. Ellis, New York: Dover, 1977/1954; Plomp, R. and Levelt, W.J.M., "Tonal consonance and critical bandwidth", *Journal of the Acoustical Society of America*, Vol. 38, Iss. 4. 1965, 548-560.

9 See Sethares 2005, 80.

10 Sethares 2005, 80.

11 See Teodorescu-Ciocănea 2004.

Byzantine chant archetype exhibits a high degree of harmonicity due to the following factors: the voice is an 'instrument' with harmonic spectrum; the basses and baritones singing the Ison have a great amount of harmonics that bring richness to the global sound and enhances the harmonicity; the harmonics of the upper voice are strengthened by the harmonics of the Ison, especially when the first three harmonics coincide (harmonicity is reinforced). Byzantine chant uses just intervals, consequently, the spectrum is more stable and the harmonicity degree is higher.

Inharmonicity is a measure of displacement of the partials from the harmonic template[ii]. It is a kind of dissonance within the harmonic spectrum. Inharmonicity arises also in the thick strings of the piano in the low register, because of their size and stiffness.[12] (Schneider, 2000). Frequency dispersion and phase shift also bring inharmonicity.

The vibrato of the held note (Ison) encompasses a critical band (the smallest band of frequencies around a given frequency, which activates the same part of the basilar membrane). In the low register, the use of vibrato produces a certain amount of frequency dispersion. The vibrato and intonation fluctuation of the Ison of Byzantine chant introduces a subtle degree of inharmonicity, reflected in the timbre perception. Inharmonicity as quasi 'noise elements' is also introduced while the sound of the Ison is re-attacked, after breathing. The pronunciation of the consonants of the text produces noise-like elements, too.

Tonalness is a factor of psychoacoustic consonance. As Sethares states, the concept of tonalness derived from the fundamental bass introduced by Rameau in his *Treatise on Harmony* (original edition *Traité de l'harmonie*, 1722) and extended to a psychoacoustic dimension by Terhardt (1984) and Parncutt (1989).[13] Generally, the concept of tonalness is understood as a degree of closeness of the partials to a harmonic series related to a fundamental. The aural system works out a complex sound trying to fit the components into a single or a small number of harmonic series. In a musical context, the fundamental is heard outright even when it is not present in the physical signal, or, if it is present, it provides an enhanced sense of the overall pitch, regarded as the root: 'As a component of consonance, the ease with which the ear/brain system can resolve the fundamental is known as *tonalness*' (Erlich).[14] In other words, tonalness is the sense of a root, whether present or not present in the acoustical signal. *Distonalness* is the degree of partials deviation from harmonicity.[15] It provides a weaker sense of the spectrum root (or tonal center).

Applying these concepts (tonalness/distonalness) to Byzantine chant archetype structure, it becomes obvious that the persistence of the Ison as the root of the whole chant offers condition for the highest degree of tonalness. The sense of a root is maintained and enhanced for the entire structure to which the pedal point is assigned.

'Harmonic entropy is a model of the degree of uncertainty in the perception of pitch. Tonalness is the inverse: A cluster of partials with high tonalness fits closely to a harmonic series and has low uncertainty of pitch and low entropy, and an ambiguous cluster with low tonalness has a high uncertainty and hence high entropy'.[16] A sound that displays greater tonalness, or smaller harmonic entropy, is perceived by the aural system as being more consonant than a sound with lesser tonalness and greater harmonic entropy.[17]

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12 See Schneider, Albrecht., Schneider, A. (2000). Inharmonic Sounds: Implications as to 'pitch', 'timbre' and 'consonance'. *Journal of New Music Research*, Vol 29, No 4. 2000, 275–301.

13 See Sethares 2005, 80; Terhardt, Ernst. "The concept of musical consonance: a link between music and psychoacoustics", *Music perception* Vol 1, No.2, Spring 1984, 27–295; Parncutt, Richard, *Harmony: a psychoacoustical approach*. Berlin; New York: Springer-Verlag 1989.

14 Erlich, P. "On harmonic entropy", in *Encyclopedia of tuning*, 2004, "On harmonic entropy" by Joe Monzo and Paul Erlich, http://sonic-arts.org/td/erlich/entropy.htm. Accessed February 2012.

15 See Sethares 2005, 80.

16 Sethares 2005, 91.

17 Sethares 2005, 101.

Byzantine chant archetype provides a small degree of *harmonic entropy*, due to the stability generated by the pedal point (Ison).

Virtual pitch is a neuro-acoustic phenomenon. It is a pitch generated in the brain, representing the fundamental of a complex waveform. Terhardt states that the pitch we hear when the fundamental is strong enough is of the *spectral pitch type* and is the pitch of a sine tone.[18] But, the pitch we hear is not always dependent on the fundamental frequency being audible, '…it is by the auditory system extracted from a range of the Fourier spectrum that extends above the fundamental. The latter type of pitch is termed *virtual pitch*.'[19] 'When there is no discernible fundamental, the ear will often create one.'[20]

Spectral pitch is the result of the sound wave exciting a place in the cochlea, while virtual pitch is processed by the brain. The brain assigns a pitch to a complex wave that corresponds to the fundamental frequency, even if its amplitude is zero. Thus, virtual pitch refers to a self-generated frequency (the fundamental) that is not present in the physical signal. This phenomenon occurs also when the fundamental frequency is present in the original waveform. The virtual pitch will be superimposed with the spectral pitch. The virtual pitch phenomenon is also an aspect of the *holistic listening perceptual mode*.

Difference tones are different from the virtual pitch, although similar in that both are absent in the physical signal.[21] Difference tones result from the difference between the existent frequencies, while virtual pitch seeks the fundamental frequency. Difference tones were described and used by Hindemith in explaining consonant and dissonant chords.[22]

The characteristics of Byzantine chant archetype with Ison provide special conditions for the phenomenon of *virtual pitch*. As mentioned before, the pitch of the Ison is generally the final of the mode, and the fundamental pitch of the spectrum. If the register allows, the pitch of the Ison could be very low and thus it will overlap with the virtual pitch. But, if the register of the voice does not allow for such a low sound, then the pitch of the Ison will correspond to the second harmonic of the overall spectrum. The brain will generate the virtual pitch an octave lower (that is the fundamental frequency). If the Ison is sung in octaves, then the virtual pitch will enhance the lowest tone.

Within Byzantine chant with Ison, the aural system is aware in any moment of the fundamental. The sense of the root is extremely well displayed. As for the pitches of the melodic layer, they will relate to the fundamental enhanced by the Ison.

Spectral fusion is the psychoacoustic aspect that integrates most of the spectral phenomena described above. Fusion is the sensation of the *unity* of the spectral components or different tones played together. It is the degree to which a sonic event is heard as a *single perceptual unit*.

One complex sound is perceived by the aural system as one perceptual entity if its spectral energy is balanced enough to allow the fundamental frequency to be heard as its pitch.[23] . The fusion of a complex waveform is enhanced when more partials are harmonically related, when it possesses high *harmonicity* and high *tonalness*. A high degree of tonalness provides a higher degree of *fusion perception*. A single sound is perceived more as being fused into one entity if its components are harmonically related. In the same way, when simultaneous sounds occur,

[18] Terhardt, Ernst, "Virtual pitch", (2000) http://www.mmk.ei.tum.de/persons/ter/top/virtualp.html. Accessed August-September 2008.

[19] Terhardt 2000.

[20] Sethares 2005, 34.

[21] See Sethares 2005, 83.

[22] See Hindemith, Paul. *The craft of musical composition*, trans. by Arthur Mendel, New York: Associated Music Publishers 1937/1945.

[23] Smalley, D. *Spectro-morphology and Structuring Processes*, in Emmerson, Simon. (ed.) *The Language of Electroacoustic Music*. London: Macmillan 1986, 61–93.

a unitary perception is more likely to be achieved if partials are close to one harmonic series, rather than to several harmonic series.[24]

Fusion is the 'goal' of the aural system when generating virtual pitches or difference tones, in order to relate the collection of partials to the nearest harmonic template and to provide a unitary perception of the complex waveform.

Timbral fusion is one of the goals pursued in orchestral playing or choir singing.[25] Concurrent different timbres are perceived as being more *fused* if the spectral centroid (the midpoint of the spectral distribution) is placed on lower frequencies.[26] Similar timbres (such as strings or voices) are perceived as more homogeneous in lower registers, at lower intensities and when there is simultaneity of attack.[27] Timbral fusion depends also on intensity. The spectral centroid position moves towards higher frequencies with increasing intensity. A higher centroid position on the frequencies axis provides more timbral identity therefore *timbral segregation* is achieved, as opposed to timbral fusion.[28] ***Consonance*** is also a matter of spectral fusion. Intervals are heard as more *consonant* when enough partials coincide, that is, when the spectral components of the concurrent tones present a high degree of *fusion.* In other words, the fusion of simultaneous sounds is the degree to which they become a single entity in our aural perception.

Tonal fusion was studied by Carl Stumpf and defined as the effect of hearing two tones not as the sum of the parts, but as a whole.[29] Stumpf found that the consonant intervals such as unison, octave or fifth have more tonal fusion than the increasingly dissonant intervals.[30] Tonal fusion is appropriate for homophonic structure, rather than polyphonic. A study of Bach's music (Huron, 1991) showed that he manipulated consonant intervals and tonal fusion in such a manner that polyphony could still be achieved.[31] Polyphonic structures should provide discernable separate melodic layers, so the degree of tonal fusion should be well measured in order not to compromise the segregation of independent voices.

Cultures respond differently to *spectral fusion* perception. Byzantine chant, as a monodic structure accompanied by a pedal point (Ison), is a remarkable example of spectral fusion, in many aspects. Its characteristics lead to high harmonicity, high tonalness, high consonance and high timbral fusion, all being aspects of the spectral fusion phenomenon. The presence of the Ison preserves the sense of a root, toward which all the notes of the melodic line - including their spectra - are organically related. An overall *tonal fusion* is achieved. This is the main attribute of the ethos of Byzantine chant, seen as the expression of the Orthodox Church rite[iii]**.**

Spectral listening is the way in which the auditory system perceives the complexity of the acoustic signal. When a single perceptual entity is depicted, due to the *fusion* property of the complex waveform, the type of spectral listening is called *holistic listening*.[32] In contrast to sound fusion, *fissioning of sound* occurs when components of a complex periodic waveform are heard. This corresponds to the *analytic listening* perceptual mode. Perception of chords in music is governed by the same factors as perception of a single pitch as a complex waveform.[33] For example, a major or minor triad could be heard either as one entity when listening holistically, or as superimposed different pitches when listening analytically.[34]

[24] See Sethares 2005.

[25] Teodorescu-Ciocănea 2003

[26] See Sandell, Gregory, "Roles of spectral centroid and other factors in determining blended instruments pairing in orchestration", *Music perception*, Vol. 13, No. 2. 1995, 209–246.

[27] Sandell 1995.

[28] Sandell 1995.

[29] See Stumpf, Carl, *Tonpsychologie*. 2 Vols, Leipzig: S. Hirzel 1883-1890/R.1939.

[30] See Loy, D. Gareth. Musimathics: the mathematical foundations of music, vol.1, Cambridge, MA and London: MIT Press 2006.

[31] Huron, David, "Tonal consonance versus tonal fusion in polyphonic sonorities," *Music perception,* Vol. 9, No. 2. 1991, 135-154.

[32] See Sethares 2005.

[33] See Parncutt 1989.

[34] See Cross, Ian, "Pitch schemata", in Deliège, Irène and Sloboda, John (eds), *Perception and cognition of music*, Hove:

Byzantine chant archetype engages the aural system in a *holistic listening type*. The later development of the Gregorian chant, which led to polyphonic structures such as *organum*, shifts towards the *analytic listening type*. The segregation of several voices and the resultant vertical chords are the expression of the *analytic listening* perceptual mode. The evolution of classical music based on the tonal system combines both *holistic* and *analytic listening* types.

As a conclusion of the examination of the spectral characteristics of Byzantine chant archetype, it is found that *spectral fusion* and the *holistic listening type* are the main psychoacoustic aspects that explain its powerful religious expression. The existence of the Ison is crucial for the achievement of unitary perception and sound fusion. It engages a *holistic perception* of the whole as an enlarged complex sound evolving in time.

Figure 2.1 – Byzantine chant *Impărate ceresc* by I. Popescu-Pasăre.

Psychology Press 1997, 353–386; Parncutt 1989.

2. Spectral Analysis of Selected Byzantine Chant

The above perceptual characteristics and type of spectral listening apply greatly to any Byzantine Chant from the general repertoire of male choirs that fit in this particular archetype: a melodic structure accompanied by Ison sung by male choir.

In order to illustrate the above psychoacoustic characteristics of Byzantine chant archetype, two examples are presented and analysed. The selected chants are entitled *Impărate ceresc (Celestial Emperor)* by Ion Popescu-Pasăre and *Axion la întâmpinarea Domnului* by (Macarie Hieromonk). Both chants were taken from the Romanian Anthology called *Cântările Sfintei liturghii și alte cântări bisericești (The Chants of the Divine Liturgy and other Sacred Chants)* published in 1999 (p. 345 and 224), which includes Byzantine chants sung in the Romanian Orthodox Church.

The first page of *Impărate ceresc* presented in Fig. 2.1 shows both Byzantine neumatic notation (above the staff) and Western linear notation simultaneously.

Figure 2.2 – Spectral layers reductional analysis of Byzantine chant Impărate ceresc by I. Popescu-Pasăre.

This chant is written in mode II plagal (chromatic). Figure 2.2 focuses only on a transcription of the first two melodic 'phrases' of *Impărate ceresc*. It is meant to show the correspondence between the overtone series of the Ison and the overtones series of each note of the melodic layer. At the same time, it displays reductional layers according to a *structural hearing* vision,[35] which results in a *spectral layers reductional analysis*. For analytical purposes, sounding pitches were preferred to the written pitches for the tenors, in order to provide the real frequency level.

The 6 staves (a, b, c, d, e, f) correspond to: a. the unfolding of the overtone series (first 12 harmonics, including the fundamental) of each note of the melodic structure; *the spectral flux* (discussed in section 1.3.) can be also observed on this layer, corresponding to the perception of melodic consonance/dissonance; b. the overtone series of the Ison (first 12 harmonics); c. melodic structure versus Ison (bass drone) with corresponding numbers of coinciding partials as a measure of perceived consonance; d. virtual pitch (in this case it coincides with and enhances the actual fundamental frequency); e. the first level of structural reduction (melodic structure reduction); the principal tones of the whole structure are represented by the tonic, the fourth, the fifth and the final of the mode. The forth of the mode corresponds to the last note of the first tetrachord and the fifth corresponds to the first note of the second tetrachord juxtaposed, as is shown at the beginning of the fifth stave (e); f. The second level of reduction (in this case equivalent to Schenker's *Ursatz* and structural hearing theory) displaying the harmonic prolongation of the fundamental, accompanied by the second and third harmonics, as the 'core' of the whole sonic structure.

Figure 2.3 presents the complex waveform corresponding to the first twenty seconds of a recording of *Imparate ceresc* Byzantine chant. The recording was made by protopsaltes Marian Moise[36] as soloist and male choir. The fragment is equivalent to that analysed in Fig. 2.2. The spectrogram was obtained using *Sonic Visualizer* software.

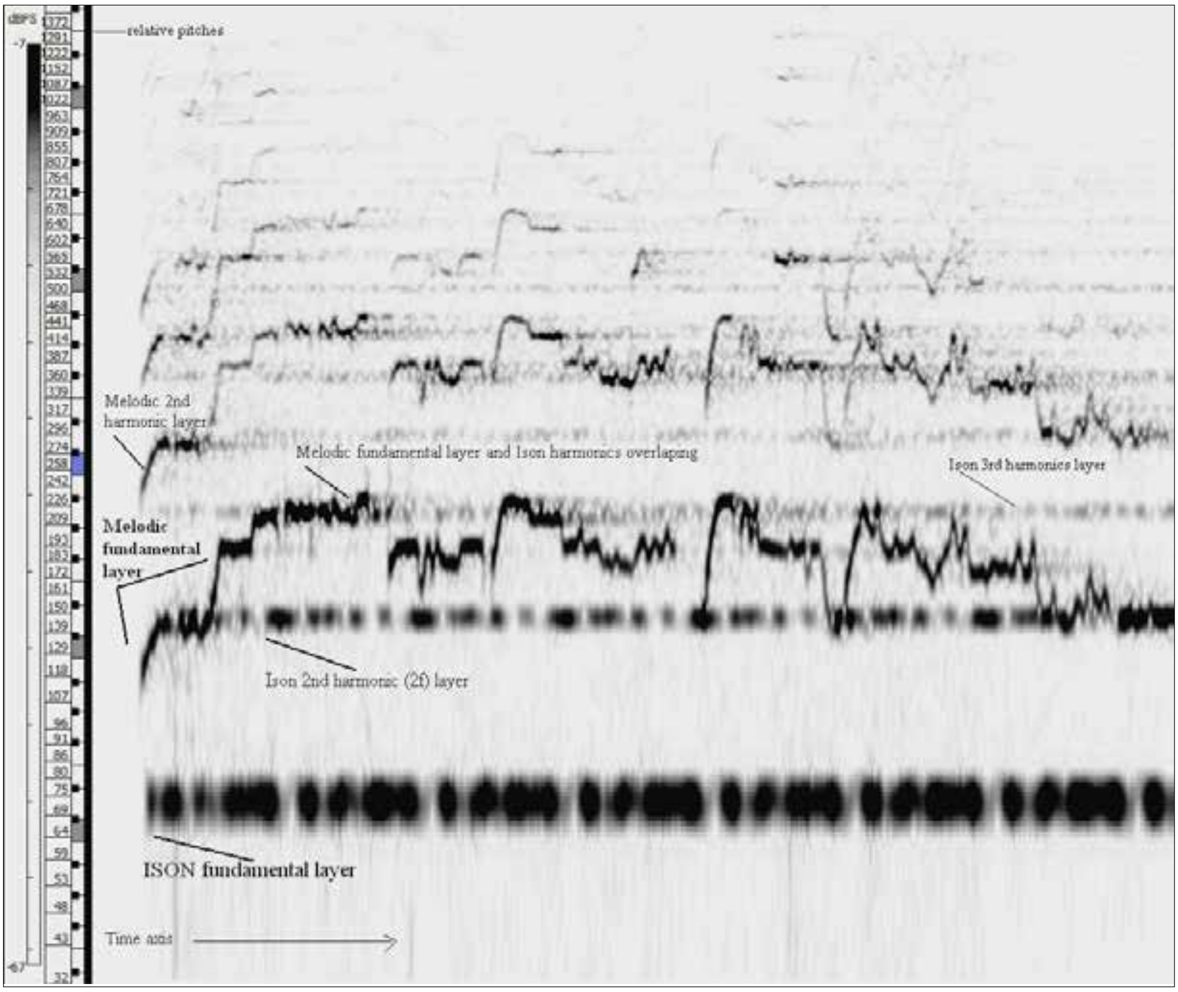
On the vertical axis of the spectrogram (Figures 2.3) there are indicators (from left to right) for loudness, frequency and relative pitches. Loudness is measured in dB and is represented by means of colours: loudness increases with brightness of colour (here, with the intensity of black). The frequency is measured in Hz and represented on the vertical axis from low frequency (at the bottom of the logarithmic scale) to high frequencies (on the top of the logarithmic scale). The frequency domain is from 59 Hz to 1388 Hz. The keyboard-like vertical bar indicates the corresponding relative pitches as 'notes' on a 12-tet scale. The grey keys are C notes, from C_1 to C_5. Note that, in this particular notation, the central C corresponds to C_3, as in MIDI Octave Designations). The time is measured on the horizontal axis, from left to right, from 0" – 20".

The thick and bright black horizontal band at the bottom of the Figure 2.3 corresponds to a very low D (approximately between 67-76 Hz) of the *Ison*. As one can see, it appears as a band of frequencies (critical band from approximately 65 Hz to 77 Hz that is between approx. D flat to approx. D sharp). This is caused by pitch fluctuation, by vibrato and by a slightly out of tune intonation. Frequency modulation and beats phenomena occur. While sustaining the Ison, noisy elements are also introduced caused by inhaling. All the superimposed parallel horizontal bands (from bottom to the top of the image) correspond to harmonic frequencies (2f, 3f, etc.) of the fundamental (Ison). The decreasing of black intensity indicates the decreasing of loudness of the corresponding harmonics, to the point where they disappear from the audible domain.

35 See Salzer, Felix, *Structural hearing: Tonal coherence in music*. 2 vols. New York: Dover 1962; Lerdahl, F. *Tonal pitch space*. Oxford: Oxford University Press 2001; Lerdahl, F and Jackendoff, R. *A Generative theory of tonal music.* Cambridge: MIT Press 1983.

36 Recording available at http://www.youtube.com/watch?v=Osg6sLFDH-U (from time 27"–47") and http://www.trilulilu.ro/muzica-diverse/marian-moise-imparate-ceresc (time 0"–20").

Figure 2.3 – Melodic Range Spectrogram of *Impărate ceresc* Byzantine chant recording.
Parallel lines (from bottom to top):
Ison and its harmonics layers. Broken parallel lines: melodic (from bottom to top):
Melodic structure and its harmonics layers.
Time axis: from left to right (0″-20″). Loudness (dB) and Frequency (Hz)
are represented on the vertical left axis. Relative pitches
are represented by the keyboard-like vertical drawn.



The *melodic structure* is represented by the irregular broken line that evolves between the second harmonic (2f) and the third harmonic (3f) of the Ison (note that, conventionally, the fundamental equals the first harmonic). From time to time, this broken line overlaps with both 2f and 3f. When notes of the melodic structure overlap with the second harmonic of the Ison, an octave is produced. These parallel octaves enhance the fundamental pitch, therefore the consonance and tonalness of the overall complex sound. A heterophonic - like structure is achieved. When notes of the melodic structure overlap with 3f (that is the fifth over the octave), the consonance and harmonicity of the overall complex sound is reinforced. As is known, the first 3 harmonics are more important for the perception of sound characteristics (pitch, timbre) because they are stronger and interfere with other sounds in the audible domain. The parallel broken lines (from the bottom to the top of the image) are harmonics layers of the melodic structure. They also interact with the upper harmonics of the Ison generating degrees of consonance, harmonicity and fusion perception.

The difference in color (from bright black to gray and white) shows the decrease of loudness (dB) of the corresponding harmonics. Singing the melodic layer, noisy elements are introduced not only while inhaling air but also while pronouncing the consonants of the text.

Alternatively, a different type of spectrogram was also obtained with Sonic Visualizer for the same fragment of *Imparate ceresc* recording. Figure 2.4 displays only the peak frequencies of the frequencies bands, resulting in a clearer visualization of the spectral lines. It was also chosen a less contrasting representation of the decrease of loudness with corresponding decrease of brightness, in order to observe more of the spectral components.

Figure 2.4 – Peak Frequency Spectrogram of Byzantine chant *Imparate ceresc* recording.

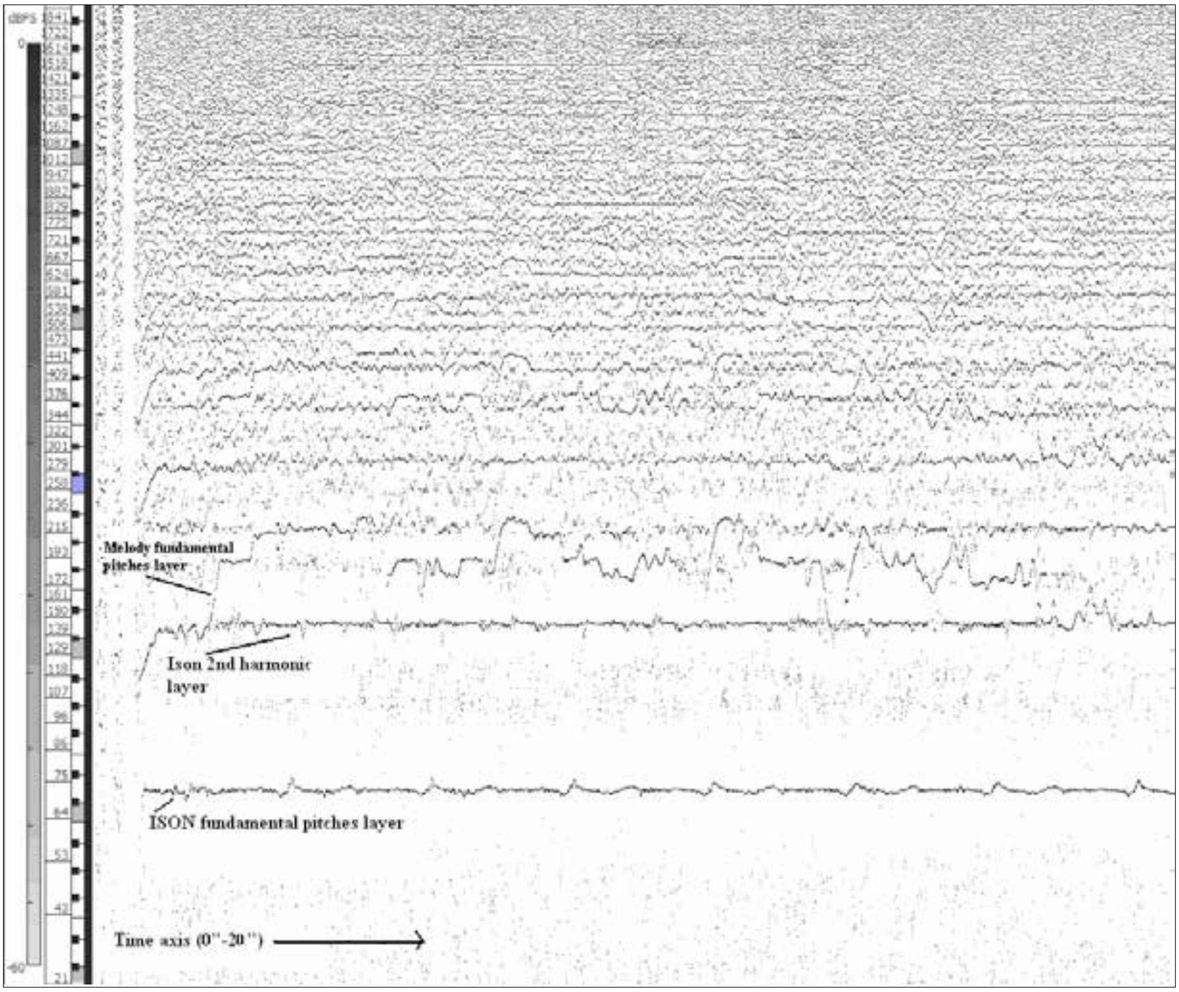


Figure 2.5 presents a fragment of the second Byzantine chant example, *Axion la întâmpinarea Domnului* by Macarie Hieromonk, extracted from the same Romanian Orthodox Church music anthology (1999), pag. 224. Both Byzantine and Western linear notation are simultaneously displayed. The chant is based on the III-rd mode enharmonic.

A spectral layers analysis is presented in the Figure 2.6 applied to a fragment of the second example, *Axion la intampinarea Domnului* by Macarie Hieromonk. The same 6 layers are superimposed, as explained above for Figure 2.2. This time, the overtone series goes up to the 14^{th} harmonic. The spectral flux of the melody and its correspondences with the Ison spectrum can be observed on the first layer. In the recording of this example, available from the Stavropoleos Choir Church in Bucharest[37] (founded by Gabriel Oprea and Nicolae Gheorghiță), the Ison is held on F_3. Thus, the F_2 corresponds to the *virtual pitch*.

[37] http://www.crestinortodox.ro/cantari-bisericesti-audio-mp3/axioane-praznicale-corul-stavropoleos-audio/axion-intampinarea-domnului-audio-3217.html

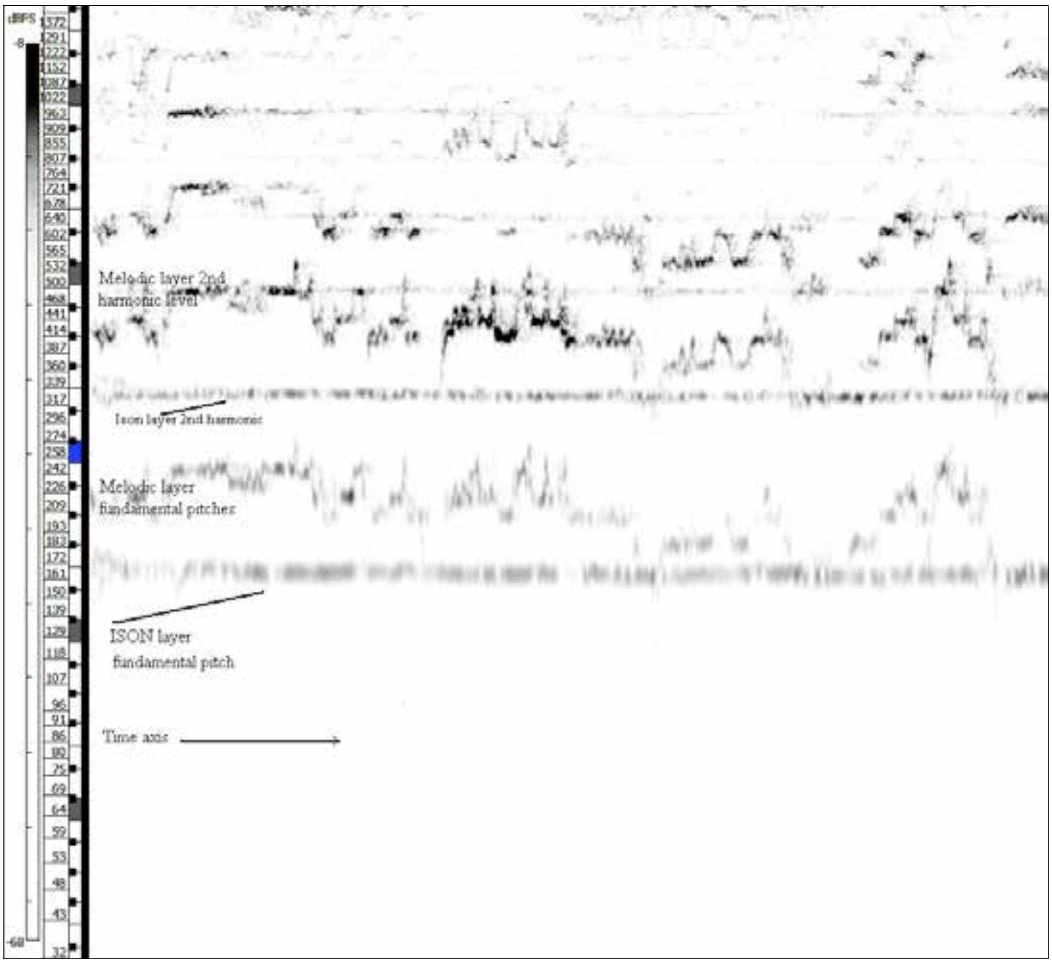
Figure 2.5 – Byzantine chant *Axion la întâmpinarea Domnului* by Macarie Hieromonk.

Figure 2.6 – Spectral layers analysis of Byzantine chant *Axion la întampinarea Domnului* by Macarie Hieromonk.

Figure 2.6 (continued)

Figure 2.7 displays loudness, frequency and time (0"-26"), in the same manner as figure 2.3. Loudness is represented by degrees of color intensity (dB), frequency by values in Hz on the vertical axis and time (in seconds) on the horizontal axis. The relative pitches are shown by the vertical keyboard-like scale.

Figure 2.7 – Melodic Range Spectrogram of Byzantine chant *Imparate ceresc* recording.



Alternatively, Figure 2.8 displays only the peak frequencies of the frequencies bands, showing clearer the spectral lines.

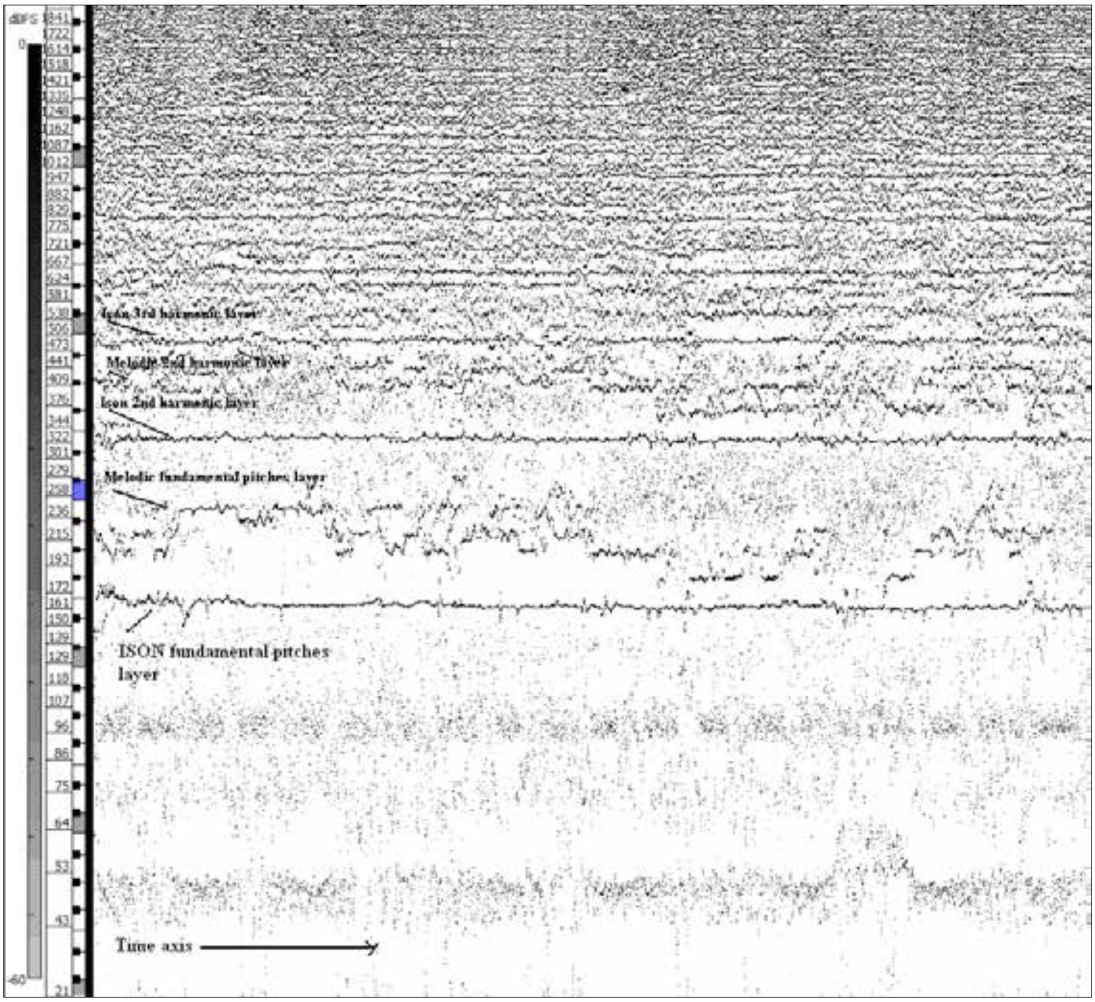


Figure 2.8 – Peak Frequency Spectrogram of Byzantine chant
Axion la întâmpinarea Domnului recording.

In this particular recording (Stavropoleos Choir) used for the spectrograms, the Ison is held not in a very low register, but in the second octave, F_2 below central C (note that in this notation, central C is indicated as C_3). It is interesting to observe that the second harmonic layer of the melody (first harmonic equals the fundamental) appears to be stronger than the fundamental, as it is colored in a brighter black. This happens due to a particularity of the sound emission, especially when nasality of timbre is intended (phenomenon encountered in some instruments spectrum, such as oboe or clarinet).

The spectrograms displayed by Sonic Visualizer software reveal clearly the spectral layers and their interaction of the two Byzantine Chants examples discussed in this paper: *Impărate ceresc* and *Axion la întâmpinarea Domnului.*

For both examples, the parallel horizontal lines represent the Ison and its harmonics layers (from the bottom of the image to the top, from thick to thin lines). The parallel broken lines represent the melodic structure with its harmonics layers (from bottom of the image to the top, from the thick to the thin ones).

It is important to note that any other recordings of these examples of Byzantine Chants displayed by Sonic Visualizer software will look very similar, if they provide the same type of voices and the same register setting. Similiarities will appear concerning the disposition of the layers (Ison represented by horizontal parallel lines and melodic structure represented by broken parallel lines) and the frequency domain or relative pitches (if the notes are exactly the same). The spectrograms will differ mostly on the loudness axis. Subtle differences could be also perceived concerning the general timbre of particular choirs.

One could also predict that any Byzantine Chant accompanied by Ison, with the same register setting and type of voices displayed by Sonic Visualizer software will look in a similar manner: parallel horizontal lines (Ison and its harmonics layers) interacting with parallel broken lines (melody and its harmonics layers). These spectrograms allow us to detect the degree of spectral fusion of the Byzantine Chants analyzed.

The more coinciding partials detected, the more fused sonority will be perceived.

The sound fusion perception and holistic listening type of hearing are applying for any Byzantine chant providing the same structural and acoustic conditions: melodic structure accompanied by a bass drone (Ison) sung by male choir.

Conclusion

The principal aim of this study has been to bring out the spectral characteristics of Byzantine chant archetype, as a melodic structure accompanied by a bass drone (Ison). Byzantine chant, with its composite origins, incorporates archaic features that reveal a certain approach to sound. It has a rather static character with a sense of *root*.

Byzantine chant archetype, as described in this paper, denotes correspondence with certain modern directions that reinvigorated and developed the archaic heterophonic style[38] (George Enescu, Ştefan Niculescu, György Ligeti, Pierre Boulez), accompanied by pedal points or a bass drone that originated in recto tono practice. We could expand discussion of the connections of the spectral characteristics of Byzantine chant archetype to modern 'spectralism', (Tristan Murail, Gérard Grisey, Octavian Nemescu) with regard to its underlying fundamental and the unfolding within one principal spectrum to which the 'notes' relate as partials. Early medieval European music could also be related to Byzantine chant's general *tonalness.* The later tonal system is the expression of the search for *fusion* and *tonalness*, connected to a single fundamental, but on a deeper level and a larger scale than Byzantine chant.

The results of this research may be summarised as follows: *sound fusion* and *holistic listening* are the main psycho-acoustic aspects of Byzantine chant that provide its unique ethos. Byzantine chant contrasts with early polyphonic Organum (Gregorian chant-based), whose perceptual characteristics could be defined as *sound fissioning* and *analytical spectral listening.* Western early polyphony "escaped" from the single note held by the bass (Ison) to a moving bass line that gave rise to a network of other related spectra with their own overtone series. Multivoiced counterpoint generated chords on the vertical axes. As mentioned before, from a spectral point of view, chords could be seen as the expression of the *sound fissioning*. Perceiving individual sounds within a chord denotes an *analytical listening* perceptual mode.

The *sound fusion* and *sound fissioning* aspects of music perception open new insights for composers and musicologists, offering a larger view of cultural differences and similarities. Cultural ethos appears also to be a matter of sound perception.

Acknowledgements

This article was written while Livia Teodorescu-Ciocănea was a visiting research fellow at Monash University (sponsored by the Australian Government through an Endeavour Award Postdoctoral Research Fellowship, between June and October, 2008), in collaboration with Dr Joel Crotty. We would also like to acknowledge the contribution of various members of the staff

[38] Niculescu, Ştefan, *Reflecţii despre muzică.* Bucureşti: Editura Muzicală 1980; Niculescu, Ştefan. *Reflecţii despre muzică.* Bucureşti: Editura Academiei Române 2006.

of the School of Music-Conservatorium, Monash University, to the realization of this article. Peter McIlwain (lecturer in composition) is a specialist in electronic music and provided the free version of the Sonic Visualizer software which helped with the spectral analysis process. Our discussions with him about spectral aspects of the sound were extremely fruitful and inspiring. Our thanks are due to Dr Kay Dreyfus, Dr Thomas Reiner (coordinator of composition and Head of School), and Paul Watt (research officer), for scholarly discussions and suggestions. Special thanks to Tamara Smolyar (coordinator of piano), Prof. Margaret Kartomi, Bronia Kornhauser and Dr Made Mantle Hood for their support.

Notes

i 'There are many indications that our sense of hearing is „tuned" to periodic vibrations' (Keidel, 1989).

ii The *inharmonic spectrum* is defined as being generated by noninteger multiples of the fundamental. The components of the inharmonic complex sounds produced by inharmonic instruments (usually idiophones like bells or cymbals) lack periodicity and prevent fundamental pitch perception. Ambiguity of pitch perception of inharmonic sounds occurs because (quasi) periodicity is more difficult to detect. 'Periodicity typically deteriorates with increasing inharmonicity of spectral components while it is maximum in perfectly harmonic spectra' (Schneider 2000, 275).

iii 'In order for the criterion of spectral fusion to operate within a culture it is necessary that the culture recognizes it as such, by attributing positive qualities to harmonic fusion against which all other kinds of spectral phenomena are placed in opposition' (Arom & Voisin 1997).

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