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On Methods of Analysing Sonoristic Music in the Context of Musical Sonology of Józef M. Chomiński

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I.

The concept of musical sonoristics has a permanent place in Polish musicological literature. It is virtually a reflex action to employ this category in situations where one finds particular fascination with timbre in the music being investigated. The concept originated with the Polish musicologist Józef Michał Chomiński, who introduced its adjectival form — "sonoristic" as early as 1956[1]. The phenomena included under the heading of sonoristics concerned the main tendency in the musical output of the 1950s and 1960s, which was to shape a composition through transformations of the sound mass and using "unconventional" sounds, while at the same time limiting the significance of, or even eliminating altogether, traditional and primary elements of a musical composition, such as melody, harmony and rhythm. This fascination with timbre was the consequence of assigning equal value to sounds of a particular pitch and to noise, sounds produced by traditional musical instruments in new articulations, and those generated using electroacoustic apparatus.

Although the concept of sonoristics, together with its numerous variants, is widely used in the language of Polish theory of music and musical criticism, there is still an ongoing discussion about its true meaning. There is a clear danger of it being used as a direct equivalent of tone-colour qualities, and that goes too far in narrowing its meaning. On the other hand, the meaning of sonoristics should not be reduced to cataloguing unconventional sound effects, since widening the boundaries of the world of sound had its significant consequences not only for the hierarchy of musical elements, but also for musical notation, for the relationship between technique and form, and finally for the psycho-acoustic sphere, fundamentally changing the manner of perception, during which the chain of cause and effect, guaranteed by the logic of the functional system, is broken.

In the process of creation, the point of departure for Chomiński was the postulate of treating a musical composition as an actual sound event, and taking into account the means of performance during its analysis. Since sonoristic values were regarded as the result of the evolution of the aspect of tone-colour, expressed in the nineteenth century through instrumentation, the concept of sonoristics was initially associated not only with twentieth-century music, but also with all earlier attempts at emphasising the timbre qualities of a musical work. In his book *Muzyka Polski Ludowej* published in 1968, Chomiński formulated the full designation of sonoristic technique, and it was then that he narrowed the issue to the developments taking place in the compositional techniques of Polish composers after 1956 (so-called "Polish school of composition" of the 1960s.). These involved "moving to the fore the sound itself as the main means of expression and thereby a factor of construction""[2].

This, however, does not mean that the category of sonoristics is not useful in other contexts of the history of music of the last century. It corresponds ideally with the tendency, indicated by many compositional techniques at the beginning of the 1960s, towards overcoming the serial crisis. At more or less the same time as Penderecki's *Threnody to the Victims of Hiroshima*, *Anaklasis*, or *I String Quartet* (1960) were becoming known in the world, with their style which operated through subtle nuances of slowly evolving sound masses instead of dramatic contrasts and thematic development, a number of somewhat analogous concepts were appearing in European music as a response to this aesthetic problem which, as György Ligeti put it "was in the air"[3]. The idea of "static sound-spaces" , regulated through gradual internal transformation of musical texture, where colour and timbre complexity function as determinants of the form, appeared as a response to the total dispersion of musical development characteristic of the Darmstadt school. One critic referred to the phenomena present in the scores of Ligeti, Penderecki or Xenakis directly as the school "of multiple-divisi orchestral textures"[4]. Western musicological literature uses such terms as the English *sound-mass music* and *texture music*, or the German *Klangkomposition* and *Klangfläschenmusik* in relation to techniqual transformations of this kind.

Of enormous significance for the expansion of the issue of sound in new twentieth-century music was the rapid development of the technology of producing and transforming sound, which began as early as the 1940s. It brought not only an enrichment of the sound palette of the compositions currently being written, but also gave rise to theoretical reflection on the subject of classification and analysis of new sound phenomena, particularly those which were impossible to describe using traditional categories. Chomiński also constructed an extended theoretical system called the theory of musical sonology around the concept which he created. Unfortunately, this theory is not widely known even in Poland, and all references to it are associated mainly with a rudimentary version of Chomiński's concept, published in the first volume of his monumental publication *Formy muzyczne*[5]. Therefore, the aim of this article is to review what appear to be the most important theoretical concepts relating to the problem of sound in twentieth-century music (§II), and also to place within their context the theory of Józef M. Chomiński, which was fully formulated towards the end of the 1970s[6] (§III). Finally, an attempt will be made to evaluate the true cognitive values of the theory of sonology, and to indicate prospects for its further development (§IV).

II.

In the history of the debate about timbre in twentieth-century music, the repertory which demanded most urgent intervention was electroacoustic music, which existed without conventional score recording. First attempts at notation became at the same time attempts at its analytic deconstruction. One of these was the so-called performance score of electronic music, for instance such as was produced by Karlheinz Stockhausen for his *Kontakte*, in which the actual musical course was reflected by a sequence of invented signs. One of the first concepts in researching the timbre of electroacoustic music was put forward by Pierre Schaeffer[7]. In response to the problems generated by *musique concrète* he formulated a theory which dealt with terminological and methodological problems resulting from basing the fundamental term "sound object" (*objet sonore*) on the concept of "reduced listening" (*écoute réduite*), freed from any associations with the source of the sound, emotions or value judgments[8]. After a series of listening experiments he proposed a typology dependent on morphological criteria and created a kind of solfeggio of musical objects. Schaeffer's morphological typology is based on a pair of formal-substantial criteria. The substance of a sound is that which we would hear if we could "freeze" a sound, while form refers to the evolution of this substance through time. Schaeffer's criteria result from focusing on material, form, timbre and changeability. Analysis is conducted on four stages: types (*types*) which correspond to typology (*typologie*), classes (*classes*) which correspond to morphology (*morphologie*), genres (*genres*) which correspond to caracterology (*caracterologie*) and species (*especes*) which correspond to musical analysis (*analyse musicale*). Moreover, there are seven morphological criteria related to various dimensions of perception which emerge from 'écoute réduite': *masse* related to perception of pitch (e.g. range from sound-noise to a pitched object) and later correlated with its spectral distribution (spectral width and spectral brightness); *grain*, or roughness defined as the microstructure of sound matter; *dynamique* related to the shape of the envelope of the amplitude (sound object's energy articulation); *allure* corresponding to the undulating movement or characteristic fluctuation found in the sustained part of sound objects and traced in the pitch dimension, in the dynamic dimension or in the spectrum of the sound object. Also *timbre harmonique* and *profile mélodique* and *profile de masse*.

Schaeffer's treatise turned out to be a strong stimulant for producing further theoretical-analytical ideas about electroacoustic music. Development of these ideas was aided by compositional achievements in this field, and it is that area of twentieth-century compositional activity which was, and is even today, subject to most frequent attempts at theoretical conceptualisation. As far back as the 1960s, an interesting attempt at creating a descriptive language for electroacoustic music was undertaken by Brian Fennely[9], who proposed a method based on the characteristics of the musical continuum in respect of three categories: timbre, envelope and enhancement. Each of these categories contains different classes of descriptive parameters and particular graphical symbols. The basis of Fennely's descriptive language of analysis

"is a formula whose terms separately represent the components of a sound in rank of their perceptual importance: first timbre, with means of describing spectrum adjustments, then the envelope controls the attack type and dynamic curie. A third term would be useful for designating any further defining characteristics, as beating, amplitude oscillations of certain spectrum components, or use of reverberation. These last features collectively will be given the generous title "enhancement""[10].

A specific symbolism was employed for analytical purposes, in which X_S designates type of colour X and S, Y_C attack Y and continuation C and enhancement, designated by symbol E. Hence the general formula for describing any sound is $\mathrm{X}_S\mathrm{Y}_C\mathrm{E}$. For additional characterisation of sound quality one can also use superscripts and other subscripts, which extends the formula to take the form $\mathrm{X}^t_{Sr}\mathrm{Y}^i_{Cd}\mathrm{E}$. Fennely emphasised that the descriptive language proposed by him

"as an analytic tool [...] is capable of clearly indicating relations between events as well as suggesting relations that might not be readily noticed under other systems"[11].

Another reformulation and expansion of Schaeffer's theory, which preserved some features of the original morphology and topology, was introduced by the New Zealand composer Dennis Smalley[12]. He introduced into the theory of music the concept of spectro-morphology, which he defined as

"an approach to sound materials and musical structures which concentrates on the spectrum of sound materials and their shaping in time (...) Spectro-morphology is a way of perceiving and conceiving these new values resulting from a chain of influences which has accelerated since the turn of the century. As such it is an heir to Western musical tradition at the same time changes musical criteria and demands new perceptions".[13].

Smalley developed a whole system of abstract terms describing the spectral properties of sound in their temporal course (spectrum, temporal morphology and space). His spectral typology stresses the differentiation between a note and its spectrum, the node, in which identification of pitch is not possible (e.g. percussion sounds) and noise. Graphical signs reflect both the morphology of a sound, and the course of its various entanglements. The developmental process through time is dealt with using a number of purely descriptive terms (centric, reciprocal, linear and curvilinear, unidirectional, bi-directional and multi-directional).

Lasse Thoresen also developed his own notational system for electronic music, based on Schaeffer's typomorphology[14]. The basis of the procedure consists in distinguishing temporal fields, from which develop musically important qualities, and their mutual relations are marked using an extended system of graphic signs. One of the most important categories in Thoresen's system are velocity and duration types, differentiated into gestural time, ambient time, flutter time and an intermediate region called ripple time. Pulse categories refer to phenomena such as regularity and irregularity and changes of tempo, such as accelerando and ritardando. Thoresen's *The Aural Sonology Project*, being developed since the 1970s, was designed to support analysis of music in which there is no simple correspondence between the score and the listening event (late Romantic, impressionistic and contemporary music), and thus not only electroacoustic music. The author seeks to conceptualise and represent graphically the syntactic sense of the music being heard. His approach combines phenomenological perspective with pragmatic use of selected structuralist techniques. The result is a terminology correlated with structural relations which is based on the listening experience. The key concept here is one of isotopes — a term adopted from structural semantics and referring to "a consistent strand of aural gestalts perceived to contain features essential for the organization of long stretches of the musical discourse"[15].

Proposals for analysing and interpreting electroacoustic music evolved in direct proportion to the development of modern research tools. Experiments with electronic and computer technology, development of new musical instruments and the expansion of the sound qualities of traditional instruments through digital processing of the signal — in a word, all the attributes of the era of information technology in music, — have placed demanding tasks before musical theory and analysis, but have also opened new perspectives of analytical visualisation of the musical signal[16]. The basic form in this area are the so-called sonograms or spectrograms, a kind of graphical, quantitative representation of a musical composition and documentation of its musical structure usually calculated on the basis of the algorithm known as Fast Fourier Transform. The first known sonogram was the *de facto* "score" of Karlheinz Stockhausen's *Elektronische Studie II* from 1956. The model sonogram is a construct built in two-dimensional space between the axis of time (axis X, unit: second) and the axis of frequency (axis Y, unit: Hz). The pitch of sounds of given duration is preserved as horizontal lines — systems of component tones lying above the line which defines the basic tone. Frequency bands correspond to the growing layers of sonogram bands, and the evolution of the sound mass is shown as changing shapes. Components with greater energy (amplitude) are usually indicated on the diagram by the colour which contrasts most with the background.

Although the main direction of using spectral images in musical analysis is undoubtedly linked to electroacoustic repertory, the proposals for using them in analysing other kind of repertory, which is traditionally notated, appeared relatively early. Spectrum photos of musical compositions were the object of interest of Robert Cogan[17], who came to the conclusion that they can serve to analyse music from various historical periods and cultural areas, written for a variety of media: vocal and instrumental music, music for large vocal-instrumental ensembles and music for tape. According to him,

> "photographs of the spectral formation of musical works provide a bridge that makes a new understanding of sound and music, sound in music possible. (...) They are the first to reveal the underlying spectral, sonic detail not of isolated sounds (...) but rather of entire musical works (...) in a kind of X-ray or electron photographic display. They reveal a structural aspect of musical shapes and forms that until now has remained hidden"[18].

The interrelationships between various sound morphologies reflected in the spectrum photo are interpreted within Cogan's system using a series of sound oppositions. The technique of their analytical interpretation comes from linguistic theories[19]; the borrowed categories have been modified for the needs of musical analysis and provide the following repertory: grave/acute, centered/extreme, narrow /wide, compact/affuse, non-spaced/spaced, sparse/rich, soft/loud, level/oblique, no-attack/ attack, steady /wavering, sustained/clipped, beatless/beating, slow beats/fast beats. The segments of a composition distinguished during the first stage of analysis thus possess unique sound characteristics expressed in categories of positive (+), negative (-), mixed (+/-) or neutral (0) values. The results of analytical observations are juxtaposed in tables of oppositions, and then

> "by comparing the complete sonic profile of characteristic moments of a musical works, we can observe the design of the entire context in terms of the largest oppositions: the poles of negative and positive sonic character, and those of constancy and change"[20].

Without a doubt Cogan has convincingly demonstrated the possibility of using spectral images of sounds in the analysis of all kinds and genres of music; however, electroacoustic music has remained the main area in which they are used. The sonogram as the model of three-dimensional visualisation of that music is, for example, the basis of analytical ideas of Mary Helmuth[21]. Analysis here includes five levels of representation: text description, event groupings, pitch, amplitude and sonogram (alias sound spectrogram). The first level concerns all those elements which have not been taken into account at other levels, such as sections, detailed descriptions of sound colour. The second level indicates the initial and final points of sections using square brackets, and uses arches for internal "phrases" or segments heard as continuous sections. In such analyses there may even be a number of levels of arches indicating superordinate elements and all kinds of subsections. The most important pitch events are notated at the third level, using conventional staff notation. The fourth level of analysis is an amplitude diagram. The sonogram provides the fifth level and it charts the frequency content through time[22].

A concise approach to analysing electroacoustic music using sonograms has also been presented by Martha Brech[23]. In the area of acoustic parameters she has defined the spectral range and width of the sound mass, the general character of the relationship between the fundamental and harmonics, the kind of timbre course and the envelope. Her system of analytical notation based on the sonogram consists of horizontal and vertical elements. Within the horizontal layer there are parts (*Teil*) and segments (*Abschnitt*), recorded in diagrams which include vertical contexts. These are: time (recorded absolutely and relatively as *Zeit* and *Dauer*). Using appropriate symbols one is also able to notate all the timbre layers (*Klangschichten*), as a continuous sound (*kontinuierlicher Klang*), overlapping layers (*überlappender Klangschichten*), broken layers (*unterbrochene Schicht oder Klangreihung*) and separate development of one layer (*Auseinanderentwicklung einer Klangschicht*), dynamics (*Dynamik*), space (*Raum*) and tensions, or directions of musical movement (*Spannung*).

The significance of visualisation of the sound signal in the latest ideas about analysing electroacoustic music is clearly demonstrated by the fact that the majority of articles collected in the volume *Analytical Methods of Electroacoustic Music*[24] published in 2006 is based on the spectrogram as the basic form of presenting and explaining formal-sound problems of this type of repertory. Although sonograms are the dominant research tool here, they are not the only one, and the main idea behind that collection of analytical texts is to demonstrate the multidimensional perspectives for conducting research into electroacoustic repertory using the most varied methods and their syntheses. For example, the editor of the volume[25] presented an analysis of Paul Lansky's composition for a string trio and computer entitled *As If*, using both spectrograms and temporal representation of the musical signal, and also, last but not least, pitch-class set theory.

The literature of the subject does, of course, include proposals for analytical approach to the problem of sound in twentieth-century music which offer alternatives to the idea of the spectrogram. As a rule they concentrate on investigating sound colour as the most significant component of the sonorous dimension of a composition. Among ideas formed in isolation from the listening experience and concentrated around investigating score notation, one should mention the proposal of Joseph Giovinazzo[26]. This involves analysing sound colour on the basis of premises built on the mathematical sets theory. The object of analysis is the "timbral object", whose properties result from the general nature of sets and the particular nature of "timbral sets". Each set is identified through defining the manner of its “instrumentation” witin the framework of the superordinate category of “timbral classes.” These classes, in turn, are identified using the concept of powerset. If we designate a particular set as set A, then powerset A (P(A)) is a separate set containing all possible subsets of set A. Thus, if A = (1,2,3) then P(A) = (1; 1,2; 1,2,3; 1,3; 2; 2,3; 3; empty set). Another element of Giovinazzo’s analytical system involves relations between sets. Timbral stasis is the antithesis of contrast and indicates lack of change. However, two timbral sets which do not have common elements create strong timbral contrast based on the relationship of complementation. Other forms of contrast are also possible, when two timbral sets have some shared elements and enter into various forms of interdependencies of set-subset type. Investigation of the functioning of timbral sets in an actual musical course involves defining timbral relationships, timbral syntax and, as a consequence, the degree of timbre unity of the composition.

Another idea for analysing colour is adopted by Danuta Mirka[27]. She has separated the problem of sound colour from the acoustic level and moved it to the level of sound generation. This allowed her to reconstruct the so-called timbral system of Krzysztof Penderecki, which is an integral part of a full sonoristic system. Using research into the possibility of sound generation by two physical bodies (vibrator and inciter), Mirka deduced a system of pairs of material categories based on elements of construction materials of the traditional symphony orchestra: metal, wood, leather, felt and hair. At the morphological level of the system the basic unit is a segment, and analysis of the timbral system’s syntax involves analysis of the sequence of timbre segments through categories of timbre opposition and mediation. Temporal sequences of particular segments may be shaped by succession, overlapping or imposition. Organisation of three other parameters of sound perception, i.e. pitch, time, and loudness is subordinated to the basic system, complementary to the timbral system. Its morphology is based on a system of binary oppositions involving intensity, register and continuity and movement in time and space, according to which the timbre segments are organised.

“Opposition between spatial continuity and discontinuity denotes here a relation between bands and individually discernible points on the perceptual axis of pitches. Temporal continuity vs. discontinuity is an opposition between lasting sounds and momentary impulses as, respectively, sections and points on the temporal axis. Spatial mobility means a perception of pitch change, and temporal mobility is tantamount to rhythm in traditional musical terminology. To understand the way in which these categories operate within the system, it is necessary to examine their inner logical structure"

— explains the author[28]. The sequence of segments is again regulated through opposition or its mediatisation, hence the possible ways of articulating are: positive term (+), negative term (-), neutral term (0), transition (→) and border-zone term (*). Abstract invariants — segments classified as sets defined by particular features of binary oppositions — represent in Mirka's proposal the level of "language" proper to the particular linguistic system. The level of "parole" includes actual variants of these segments which appear in individual cases generated by the system[29]. The reconstruction of Penderecki's sonoristic system is thus subordinated to the basic indices of semiotic-linguistic categories.

Yet another proposal for investigating timbre can be found in the work of Tomasz Kienik[30], who has analysed the relationship between the parameters of pitch and timbre in the compositions of Kazimierz Serocki. His analysis was carried out on the basis of calculating "empirical distributions of the discrete feature of pitch in the timbre function", their maxims and minims and the empirical area of changeability which is a number equal to the difference between the maximum and the minimum defined for a given instrumental part or a particular piano register. As a result he came to the conclusion that certain pitch values may create kinds of quantitative timbral centres, and the distribution of chromatic material within the range of designated timbral sets in Serocki's compositions is regulated using logical principles. This is emphasised by the graphical shapes of distribution charts, clearly visible points of concentration and avoidance of particular pitch values, symmetries and the existence of quantitatively privileged pitch values[31]. In this way, the author demonstrated that the functions of timbre and pitch elements are strongly correlated.

The great majority of methodological conceptions of analysing timbre phenomena in the heritage of twentieth-century music which were discussed above makes use in an organised way of findings from psychology of music, and in particular the psychology of perception. The reason for this is that the object of analysis is not sign-symbolic code of the score, but timbre as a physical-acoustic phenomenon involved in a listening experience. However, there exists in Polish theoretical literature the concept of analysing actual sound and implicit sound colour through categories based on cognitive psychology[32], but it is not supported by any experimental investigation of sound matter. Such a proposal is the system of analysis of the music of Igor Stravinsky created by Alicja Jarzębska[33]. Its creation was aided mainly by findings from psychology concerning cognitive schemata, perceptual invariances[34], mechanisms of grouping acoustic information and differentiating simultaneous signals into "background and figure"[35]. The hierarchisation of sound systems in Stravinsky's music modelled on this basis makes use of an elementary perceptual unit called parton, which is determined by the pitch, metrorhythmics and timbre structure. The timbre parton has the most complex nature in view of the interrelationship between the kinds of means of performance, their articulation, register, tempo of changes of sound impulses and the interval structure. However, the actual analysis of the timbral structure of a composition, consists, according to Jarzębska, in the description of the structure of the partons invariant, a discussion of the ways in which they can be modified and combined into formal wholes of a higher order, and graphic exposition (linked to the syntagmatic-paradigmatic model of analysis) of those relationships in which on the horizontal axis there are letter symbols of the repeated parton, and on the vertical axis the partons being used in a given fragment of a composition.

III.

Within the context of methodological conceptions discussed above, theory of musical sonology occupies a place of its own. Firstly, it is one of the few theories which proposes a highly universal conceptual apparatus, including all the interdependent elements of a musical composition and taking into account the indices of the so-called timbre technology, which can be applied both to music generated by electroacoustic equipment and compositions created for traditional instruments. Chomiński distinguished five basic functions which are included in the sonoristically regulated formation process. These are:

- making use of new ways of articulation and inciting timbre in traditional instruments;
- generating sound material using electroacoustic and electronic equipment;
- processing existing material using electroacoustic and electronic equipment;
- juxtaposing instruments and electroacoustic and electronic equipment;
- combining material from instruments and other sources with material obtained using electronic generators.

Depending on the manner of selection and use of sound material, there are thus three kinds of sonoristically regulated compositions: those making use of the possibilities offered by traditional instruments; those formed exclusively using electroacoustic and electronic apparatus; and mixed ones, which juxtapose instrumental and electronic sounds[36].

The systematics of sonoristic phenomena introduced by Chomiński included the following issues:

Equivalence of sound material

The essence of sonological regulation is equivalent treatment given to the material obtained from traditional generators and to that obtained using modern technical equipment. At the same time sonology indicates the perspectives for creating new systems of temperation, independent of twelve-tone equal temperament and constructed on the basis of freely chosen frequency coefficient. An important part in the process of modification of twelve-tone equal-tempered system is played by the "colouring" role of microintervals, which enables the construction of two kinds of sound: diastematic and glissando[37]. Sonologically conditioned criteria of choosing sound material are based on the differences in frequency relationships between very low and very high sounds[38]. Of importance is also the use of a swelling sound, which is the noise coefficient of the sound of melodic instruments and the noises themselves, which are characterised by pitch, density, width and intensity[39]. The author of the theory has also emphasised the possibility of electroacoustic apparatus, which allows one to extract or separate from each other noise and pitch parts of a sound and record particular segments on tape for further processing.

The dimensions of time and speed

Technical manipulations in the area of the speed of moving tape which change the frequency and character of the sound, from selective sound signal to uniform sound stop, and the phenomenon of sound pulses perform, according to Chomiński, a function which supplements the traditionally understood ways of regulating time defined by metre and rhythm. In sonoristic music there are metrically established and non-established sound courses, and particular intermediate states, which are ascribed to two superordinate categories of mono- and polychronic regulation[40]. Monochrony which operates with established time proportions includes conventional means of regulation: modal, mensural and bar rhythm. Polychrony, being an expression of changeability and freedom in the movement of sound signals, causes sounds which are the same in terms of pitch to achieve various rhythmic shapes and appropriate colouring through swelling and sustain[41].

According to Chomiński, modal rhythmic ordering of serial character has particularly important potential. It hides a variety of constructional possibilities through the use of numerical series (e.g. arithmetical, geometrical or binomial), causing loss of cohesion of rhythmic movement or its significant increase[42]. Various shapings of the rhythm (e.g. rhythmic fragmentation or stable sounds) influence the creation of various sonoristic values from the same point of departure in terms of pitch and timbre[43]. Further modification of the structure of sound can be achieved by two basic means of expression: silence and isolated sounds[44].

States of density and dilution of sound

The processes of densification and dilution of sound concern sound phenomena both in the horizontal and vertical course, and the whole of achievable sound material may be involved in them, including noises and sounds of indefinite pitch.

In sonoristic technique, the density of sound depends on the kind of instruments, articulation, and a number of other factors associated with the acoustic conditions of interiors. The problem of sound density combines, according to Chomiński, the question of harmony, counterpoint and instrumentation, which are considered from the sonological point of view[45]. One of the important ways of increasing sound density is the so-called delayed repetition[46]. This produces a new timbre-rhythm continuum with an increased and more dense number of signals, whose difference can be further intensified through using diminution and retrograde motion or a variety of rows of serial regulation. Transposition in time increases the degree of rhythm density, and diminution brings additional effects, causing acceleration of signals in the instruments themselves. When speed of 16 signals per second is exceeded, there is an increase in density and a change of pitch. The extreme form of dilution is juxtaposition of high and low registers and sounds with contrasting colour. Vertical dilution is then accompanied by horizontal dilution and differentiation of levels of loudness and sustain effects.

States of density and dilution of sound are influenced by changes in instrumentation. Its homogenisation favours creating compact sounds and convenient grounds for increasing density, while polygenising processes work in the reverse direction. Wide range and variety of pitch and articulation parameters makes homogenising processes more difficult. They are easy to obtain only in percussion instruments characterised by high noise coefficient and narrow frequency band[47].

The character of relationships between synchronised sounds is determined by three areas of frequency: baryphonic from 16 to 110 Hz (A), mezophonic from 119 to 2093 Hz (c^4) and oxyphonic above 2093 Hz[48]. Synchrony of sound of a particular pitch does not preclude the use of traditional harmonic and polyphonic devices, only widens their range. However, the higher the coefficient of dilution or densification of sound, the weaker is the influence of traditional harmonics[49].

The degree of density or dilution of sound is, moreover, the basis of the systematics of interval structure of chords in sonological regulation proposed by Chomiński[50]. Interval inversions represent a separate sonoristic value and becomes the source of the sound becoming more shrill. State of density is directly proportional to the number of notes making up a chord, and the state of dilution is inversely proportional to their number. Even more detailed systematics can be obtained on the basis of the parameters of instrumentation, articulation, frequency bands, selection of chords and dynamics. As a consequence one obtains uniform or varied sounds in all the parameters or only in some[51].

The highest degree of density of sound is represented by clusters (chords created out of small intervals, from the quarter tone to the whole tone). Types of clusters classified by Chomiński include the following structures[52]:

- narrow and wide;
- totally stable;
- changing pitch while preserving the same width;
- ascending, descending — combining both these directions;
- changing states of density through overlaying intervals, from the quarter tone to the whole tone, or by removing the smallest intervals.

Clusters undergo rhythm differentiation — they may be indefinite or serially ordered in this respect. Their most plastic form is a profiled centre in a binomial series. It is also possible to have mensural or periodic regulation[53].

Of particular interest sonoristically are structures which accumulating various kinds of clusters which undergo counterpoint regulation. In such situations, instead of voices the construction factors are sounds of layer which create various internal relationships. The following are the basic models of contrapuntal cluster play[54]:

- synchronic with elevation and deposition in the same direction and in the opposite direction;
- diachronic;

- with fluctuation between uniform stop and two-layer structure;
- with monophonic interpolations.

In the sonoristic system there are two basic kinds of vertical sounds[55]: those made up of only one kind of intervals in one scale, and those made up of various intervals and various scales. Depending on the quantity and quality of intervals, various states of density arise, and they can also appear together as a ready simultative creation, or arise successively.

The most diluted interval is the octave, and the multioctave space between the baryphonic C_1 and oxyphonic c^4, although it has no harmonic value, has significant sonoristic benefits. There are the following kinds of vertical diluted sounds [56]:

- including the whole space of all scales;
- making use of only some scales;
- limited to one kind of interval;
- constructed out of various interval which are relatively equivalent;
- with a particular interval being dominant;
- intermediate structures.

A device deriving from vertical sounds is that of figurations understood as special forms of densification of sound, whose structural value consists in the fact that within them take place processes of transforming sounds diluted by means of intervals into dense sounds as a result of increased rhythmic movement. The figurations are regulated according to diastematic and scale criteria. They can be constructed out of material from one or more scales, or brought about by synchronising various rhythms[57].

Qualitatively new structures are obtained through the interaction of melodic and percussion instruments. In the case of interaction of percussion and clusters, two- and multi-layered structures and a figuration, one does not obtain a separate sound layer; percussion instruments support the melodic ones, assimilate with them and prolong their sounding through the sustain effects. It is also possible to enhance the pulse character of sounds isolated by the percussion instruments. Moreover, interaction between instruments and human voice can create uniform structures, which produce an indivisible sound stop and differentiation, in which an instrument or a group of instruments at some moment become the priority source of sound[58].

Sonoristic modulation

Chomiński used the term "sonoristic modulation" with a meaning close to the original one, from the definition of music given by St Augustine: *scientia bene modulandi*[59]. This knowledge about modulation in musical sonology concerns mainly transformation activities. A synonym of "sonoristic modulation" is "metabolic regulation", defined as "processing the sound material, its consistency, i.e., the spectrum and shape of the sound wave"[60].

Metabolic modulation/transformation of timbre takes place using two kinds of equipment: simple (microphones and tapes) and complex (synthesizers). In microphone modulation the most important aspect is "polymicrophony", which consists in amplifying only some instruments or groups of instruments by having an appropriate system of microphones and thus influencing the transformation of the original orchestral sound. A tape enables further improvement of multi-layered systems, as it creates itself, apart from the instrumental layer, one of the sound layers of a work. There are single and multi-tape systems, which undergo synchronisation regulated mono- or polychronically[61]. On the other hand, in the classification of differentiated kinds of modulated sounds, Chomiński proposed using the criterion of sound source, which allows for differentiating group or layer sound structures resulting from the synchronisation processes[62].

The most basic and plastic form of sonoristic modulation is dynamisation of a stable sound with a definite pitch. It takes two forms: simple, when it intensifies and reaches the limit at the moment of the greatest relative intensity, and parabolic, which falls after reaching a particular degree of intensity. The basis of such shaping is the binomial series, which provides the possibility of central profiling, emphasising the pitch stability of a sound. It may be subjected to three kinds of time regulation: original, mensural and serial. Even the most complex forms of sonoristic modulation are subject to regulation on the basis of the criteria of time and states of density and dilution of sound[63].

Problems of form

The formation of a musical work involves four main activities which decide its kind, genre, structure and construction. In Chomiński's system, the general systematics of the shape of musical works is subordinated to the criterion of the source of sound material. On that basis kinds are created, and sonology contributes to their manifold enrichment, providing a wide spectrum of compositions: instrumental, vocal, vocal-instrumental, instrumental modified by processing equipment, vocal treated analogously to instrumental, vocal with the participation of voice acting, electronically pure, electronic-instrumental, electronic-vocal, electronic-vocal-instrumental, electronic with voice acting, electronic-vocal-instrumental with voice acting. Further differentiation includes: works performed live, works recorded and mixed works[64].

The ways of distributing sound material, depending on its quantity, quality, content and differentiation in terms of kind, provide in the theory of sonology the basis for the classification of musical genres. Quantitative cast determines whether a work belongs to the chamber, orchestral, choral including miniatures, symphonic or vocal-instrumental genre. The differentiating role of the content depends on the manner in which it is transmitted by the text, using theatrical devices, stage-setting arrangements and actors' performance, and through pantomime and dance. The remaining criteria of division of genres are their function and general distribution[65]. Even using traditional instrumentation acquires quantitative-qualitative proportions in sonological formation. The most radical changes take place in chamber music with extensive participation of percussion. Modification of even greater degree than in chamber music take place in the area of orchestral genres. Sonological formation, and in particular obtaining new qualities through the use of electronic equipment, deepens the multi-layered structure of an orchestral work[66].

The dynamic character of the form, according to Chomiński, consists in the processes of extracting new and absorbing previously existing formal values. In his search for the origin and essence of formal changes, Chomiński turned his attention to the significance of sound systems, whose transformations and mutual relationship lead to a considerable enrichment of genres and kinds of musical works. The new shape of the world of sound has consequences for the psychological sphere, since it presupposes intensification of the expressive power of the new means on a scale much larger than previously. All these factors lead to the emergence of a differentiated set of genres, consisting of:

- traditional genres enriched through the use of new sound systems;
- genres which change the prevailing manner of perception of a musical work;
- mixed genres, which unite both types previously referred to[67].

Structure as a category of the formation process, is a system "whose elements remain in a definite relationship to each other"[68] and which determine the integrity of a work. Structural investigations make it possible to establish the role of sonoristic regulation in musical composition, and help to establish the position of particular sound phenomena in the formal perspective[69].

Sound phenomena characteristic of sonoristic technique create in the formal perspective new structural systems associated with particular groups of means of expression. Formal structuring presupposes simultaneity of interaction of all the sound phenomena described in the systematic part, and various types of structure depend on the selection, hierarchy and proportion and manner of treating these elements. Within the framework of static homogeneous structures, new ways of articulation (e.g. using resonance boards of the chordophone and the piano) make it possible to, for instance, to create complex systems from mutually supplementary chordophonic and percussion sounds of strictly defined and approximate pitch. The essence of assimilation procedures consists thus in blurring the boundary between tuned instruments and percussion, and in creating a smooth transition between them as a result of freeing and intensifying noise effects. The shape of these various states of sound structure is also influenced by differentiated rhythmic regulation[70].

Dynamic homogeneous systems are much more highly differentiated than static systems. Formal dynamism is achieved through changes in the movement, sound systems and the resulting horizontal and vertical interval structures, loudness, volume and penetration of sound, and the colour dependent on all these factors[71].

Polygeneous structures are syntheses of homogeneous sounds, and their definition includes also old systems, such as orchestra, in which particular groups may represent homogeneous sounds. Within them takes place the maximal enrichment of sound, achieved through emphasis on the separateness of components. While in homogeneous structures various articulation means freed assimilation processes and aided the merging of sound, in polygeneous structures elements do not interprenetrate, but stand out through their individual sound. In order to eliminate absorption of elements, a selection of formation means is required which moves in the following directions[72]:

- selection of instruments and their articulation;
- interaction of principles which regulate the course of sound impulses;
- interaction of various modal systems and sound material with indefinite pitch;
- interaction of various states of sound material in their horizontal course and vertical section;
- irregular interaction with dominance of one or two elements.

These actions do not constitute autonomic systems, but together form a multimember superordinate synchronic structure.

Chomiński observed that traditional and elementary coefficients of form (motifs, phrases, periods) are also subject to transformation under the influence of sonological regulation. It breaks through the normative limitations of earlier music, putting in the first place the principles designed to extract the "purely sonorous" properties of structures. The range of distances is widened, from microintervals to macrointervals running through many octaves, which causes changes in the merging and selectivity of timbre. In the area of tempo of movement, rhythmic mensural norms are replaced by indivisible sound stops, or standing sound and silence. At the same time there may exist phrases arising out of melodic activity, derived from the music of the past. Generally, however, according to Chomiński, the "purely sonorous" technique creates coefficients of form which have nothing in common with the old concepts[73].

Mechanical systems are "structures obtained using generators and processing equipment"[74]. The superabundance of existing means of expression causes problems in their structuring, since the theory provides such a wide spectrum of possibilities that compositional practice is unable to adapt them fully. What is most important, the extent of structural possibilities allows for the use of various orderings of the material, based on exact mathematical operations, and in this way whole new constellations of sound systems come to be created.

Combining instrumental and vocal timbres with material obtained using electroacoustic equipment leads to different kinds of syntheses, e.g. successive or synchronic juxtapositions of instrumental and vocal structures with electromechanical ones, or polystructures — multilayered synchronic systems whose elements may successively appear and disappear or interact simultaneously[75].

The final element of Chomiński's sonological conception of form is constituted by constructions, meaning "a set of devices which are used to realise a structure, that is the construction of various coefficients of form"[76]. Constructions are the forming activity which is the easiest to grasp, involving only the external shape of the work. They are extremely durable, regardless of evolutionary and metabolic transformations. On the other hand, the internal shape of a work undergoes structural formation. Stable constructions are those which were taken over from tradition, while variable constructions display individual features under the influence of new technical devices. Stable constructions aid the creation of formal schemata, variable constructions safeguard form from becoming schematic. They supplement each other, creating an integral forming system which, according to Chomiński, is a "superordinate, timeless mechanism which works with uncommon precision"[77].

IV.

The aim of Chomiński's theory of sonology was to organise, order and systematise the sound phenomena observed in twentieth-century music. Undoubtedly the author realised his goal, creating a unique theoretical system, unprecedented in musical thought of the twentieth century. On the one hand, his sonoristic theory was an extremely sensitive barometer of changes taking place in contemporary compositional techniques; on the other hand, the theory itself opened up to composers perspectives of creating new sound systems, regulators of timbral qualities and new structural systems. Michał Bristiger's comment that sonoristics "is a mediating concepts, perhaps even a whole new field in musical thought, on the borderline between theory of music, compositional practice and psychology of hearing", seems particularly apt in this context[78].

The postulate to build up the "analytic sound structure based on the criterion of auditive reception from the acoustic and psychological aspects"[79], put forward in critical discussions of Chomiński's theory, has not been realised so far. Although in Poland it produced an intense reaction, attempts at investigating the "actual (real) sound" of a musical work undertaken in analytical studies remained exclusively within metaphorical categories. This follows from the fact that, in Chomiński's theory, the basis of research is that "auditive shape of the sound" for which the notated record is the projection of the creative intentions of the composer. Until now, questions of expanding traditional instrumentation, preparation of instruments, sounds generated electronically and new articulations, motoricity and range of rhythmic indefiniteness, percussion treatment of instruments, clusters and a-functional chords, sound bands, microtonic scales, dynamics effects and planes, space effects and untypical combinations of instruments were investigated exclusively on the basis of the written score, and not the real sound context in the shape of a sound recording[80].

The most important direction for the development of Chomiński's theory thus seems to be to overcome this paradox, and link research into the properties of "actual sound" with its empirical investigation. The most effective option in this respect seems to be the method of representing temporal-frequency features of musical signals on spectrograms, and thus making use of theoretical-technical achievements of electroacoustic music. However, one should remember that during translation of an acoustic message (sound recording) into sonograms the only thing which happens is that a new text has been produced as a subject for research. Graphic visualisation of musical signals is not their interpretation and needs further levels of explanation[81].

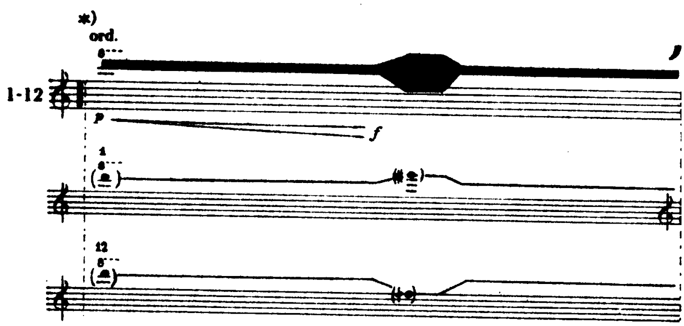
The question of notation continues to be closely related to the sonographic model of representation of the sound mass. As it was stated above, in

Chomiński's theory, research is carried out on works which use traditional orchestral apparatus, works formed exclusively with the use of electroacoustic and electronic equipment, and mixed works, which juxtapose instrumental and electronic sounds. Contemporary compositional practice and music theory have worked out a number of proposals in each of these categories which respond to the challenges of new music. The most bearable seems to be the systematics of Erhard Karkoschka, which distinguishes in this area attempts at creating revised versions of traditional notation by, on the one hand, introducing simplifications, and on the other expansion, supplementation or proposals of totally new systems of precise musical notation. Among them are: notation of approximate values (*notation ungefährer Werte*), action notation (*Aktionsschrift*), *Qualitative Notation*, tempered notation (*Temperierte Notation*), verbal notation (*Verbalpartituren*) and lastly musical graphics (*Musikalische Graphik*). Notating electronic music is of course a separate problem, and Karkoschka systematises it as: based on traditional methods but with new signs; a schematic sketch (*Schematische Skizze*) used by performer; verbal score (*Verbal Anweisung*) used for implementation and score as a chart of manner of tape perforation (*Lochstreifen-Aufzeichnung*) and verbal descriptions[82].

Research material in the case of works composed for traditional instruments or for traditional instruments with the participation of electronic devices will this be constituted by: score, a sound recording of the composition and the spectrogram generated on its basis. In the case of electroacoustic compositions, the basic material is the recording and the spectrogram, and the score is supplementary. The spectrogram is, as remarked by Martha Brech[83], a kind of quantitative representation of a musical composition which shows its "auditive materiality" devoid of any qualitative features, and during the process of analysis must each time be compared to the notational record if such exists.

Investigating aspects of the temporality of a work, such as its duration and tempo, the sphere of its loudness in the categories of dynamics understood as the effective acoustic power, the sphere of frequency and shape of sound spectrum and differentiation between timbral qualities leading indirectly to conclusions about its form, possible on the basis of the sonogram, should thus be supplemented by examination of details given in the score (e.g. those concerning precisely notated pitch) and the reverse: notational signs of the score (particularly those from the area of approximate notation, which often themselves should be the subject of analysis) are reflected in the spectrogram as phenomena functioning in their real, acoustic context.

These possibilities will be illustrated by two examples from the works of Krzysztof Penderecki. The first (see figure 6.1.) is a cluster used in the 14th number of the score of *Threnody*, of the type not classified by Chomiński, but which might be described as symmetric, centrally profiled and varying in width. Its score notation is precise (12 first violins *ordinario* in precisely defined high frequency band); however, the spectral image provides a unique chance of observing its evolution against the background of other elements of the sound mass at that particular moment in the score. It is created, to use Chomiński's terminology, by the contrapuntal play of clusters present also in the parts of 10 cellos and 8 double basses.



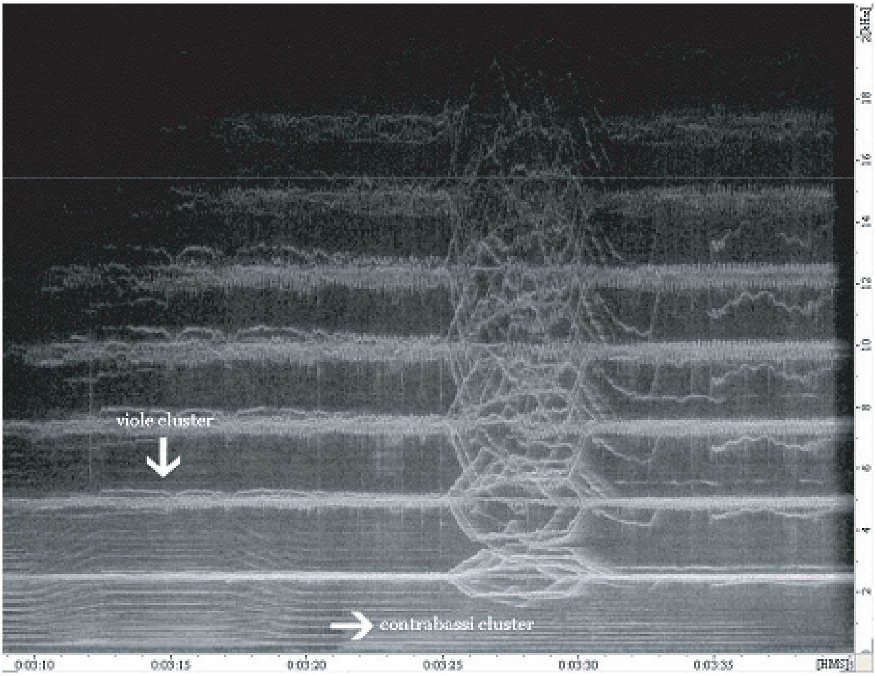


Fig. 6.1. K. Penderecki, *Threnody for the Victims of Hiroshima*, No. 14, score and sonogram.

The next example (see figure 6.2.) concerns the spectral image of approximate notation, concerning 37th and 38th of the 5-second segments of the score of Penderecki's *I String Quartet*. At this point there takes place the visualisation of auditive perception of a phenomenon designed by the composer as a kind of timbral canon, where counterpoint is provided by pairs of first violins and violas playing *arco* on strings E and A respectively between the tail-piece and the bridge in a very fast and unrhythmicised tremolo, and second violins and a cello playing *arco* and *sul ponticello* on the highest obtainable note.

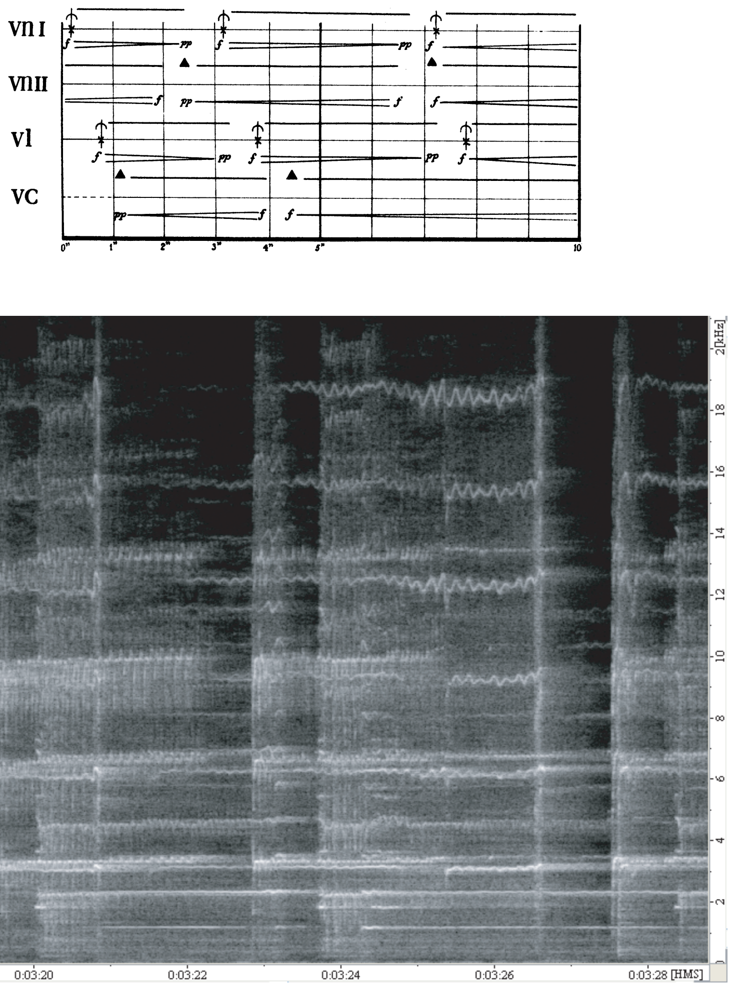


Fig. 6.2. K. Penderecki, *I String Quartet*, segment 37th and 38th, score and sonogram.

The interpretation of the results of the measurements and analytical observation of some of the features contained in the notational source of the composition has to be subjected to further description. It is possible to maintain in it, with some modifications, Chomiński's basic theoretical categories and concepts derived from his structural-dialectical conception of sound analysis as a network of relationships taking place between all the elements of a musical composition. An analysis of a sonoristic work based on the premises of Chomiński's theory of musical sonology should thus concern itself with the following issues:

- Sound material
  – traditional and electroacoustic sources of sound material;
  – twelve-tone equal-tempered system and open systems of musical temperament (including microintervals);
  – new scales;
  – intensification and noise effects;
- Regulation of time and speed
  – metre and rhythm;
  – selective sound signals and uniform sound stops;
  – rhythmic fragmentation and stable sounds;
  – silence and isolated sounds;
  – monochrony and polychrony;
- Densification and dilution of sound
  – homogenisation and heterogenisation of sound;
  – synchronisation of sounds in three frequency zones;
  – types of clusters;
  – types of rhythmic differentiation of clusters;
  – types of contrapuntal regulation of clusters;
  – types of vertical chords and vertical expanded chords;
  – types of figurative densifications and glissandi;
  – models of interaction between melodic instruments with percussion instruments and of interaction between instruments and human voice;
- Sonoristic modulation
  – activities processing the sound material using a differentiated set of technical apparatus;
  – characterisation of modulated sounds;

- Sonoristic transformation of form
  – kinds derived on the basis of sound source criterion;
  – genres dependent on the manner of distributing the sound material;
  – static and dynamic homogeneous structures;
  – heterogeneous structures as syntheses of homogeneous sounds;
  – sonoristic transformation of traditional coefficients of form;
  – mechanical systems;
  – syntheses of instrumental and vocal sounds with material obtained using electroacoustic equipment;
  – constructions;

The significance of Chomiński's theory of musical sonology lies in the fact that in its day it was unquestionably the fullest compendium of knowledge about the possibilities of sonoristic shaping of a musical work, but also in that still today it holds on to the qualities which made it such a breakthrough in the 1960s. However, the areas of discussion concerning electroacoustic music and its sonoristic potential stood the test of time somewhat less well. After all, they were formulated many years prior to the development of computers and digital synthesis of sound. One should also remember that Chomiński himself was aware of the inevitability of technological progress, and as early as the 1990s noted the presence in compositional technique of the phenomenon of "automatic steering of construction processes using computers", which "allows one entry into new, so far inaccessible to man, regions of sonological research." He also noted the necessity of creating a special research method in relation to works preserved on tapes, as "apart from the purely technical laboratory description at present there is nothing concrete that can be said about electronic music"[84]. This backlog has been successfully cleared by the theory of music at the beginning of the twenty-first century, as demonstrated by the already referred to publication edited by Mary Simoni.

The question thus remain as to the range of musical repertory which can be investigated within the sonological approach. The early phase of the reception of Chomiński's theory in Poland showed that its research potential can be regarded as very attractive, and the concept of sonoristics can be applied to research not only into the music of the last century, but also to all earlier attempts at emphasising the timbral qualities of a musical composition[85]. However, in view of the nature of the phenomena with which the mature interpretation of this theory is concerned, it is worthwhile to reserve this methodological potential for analysis of music of the second half of the twentieth century, with the centre of gravity placed within the post-serial repertory.

Notes

1 'Z zagadnień techniki kompozytorskiej XX wieku', *Muzyka*, No. 3, 1956.

2 *Muzyka Polski Ludowej*, Warszawa 1968, p. 127.

3 György Ligeti, 'A Viennese Exponent of Understatement: personal reflections on Friedrich Cerha', *Tempo*, No. 161/162, Jun.–Sep. 1987, p. 4.

4 Cf. Corey Field, review of*Netzwerk* and *Baal* by Friedrich Cerha published by UE (1981), in: *Notes*, vol. 39, No. 4, June 1983, p. 959.

5 Józef M. Chomiński, Krystyna Wilkowska-Chomińska, 'Podstawy sonologii muzycznej', in: *Formy muzyczne*, vol. I., Kraków 1983, pp. 126–153.

6 *Podstawy sonologii muzycznej*, typescript belonging to Theory and Aesthetics of Music Department of Musicology Institute, University of Warsaw: part I. [no subtitle], Falenica, 9 December 1976; part II. *Systematyka zjawisk dźwiękowych*, Falenica 1977.; part III. *Forma*, Falenica 1978.

7 *Traité des objects musicaux,* Paris 1966.

8 As Michel Chion put it: "The reduced listening is a listening attitude that consists in listening to the sound itself, as a sound object, while abstracting it from its real or supposed cause, as well as from the meaning it might carry. More precisely, it consists in turning this double curiosity for causes and meanings (both of which treat the sound as an intermediary between other objects towards which it directs the attention) towards the sound object itself..." Cf. *Guide des objets sonores*, INA, ed. Buchet/Castel 1983, p. 33.

9 'A Descriptive Language for the Analysis of Electronic Music', *Perspectives of New Music*, vol. 6, No. 1, 1967, p. 79–95.

10 Ibid., p. 82.

11 Ibid., p. 94.

12 'Spectro-morphology and Structuring Processes', in: *The Language of Electroacoustic Music*, Emmerson S. (ed.), London 1986 and 'Can Electro-Acoustic Music Be Analyzed?', in: eds. R. Dalmonte, M. Baroni, *Secondo Convegno Europeo di Analisi Musicale*, Trento 1992., pp. 423–434.
13 'Spectro-morphology and Structuring Process', op. cit., p. 61.
14 Lasse Thoresen 'Auditive Analysis of Musical Structures. A summary of analytical terms, graphical signs and definitions' in: *Proceedings from ICEM Conference on Electroacoustic Music Stockholm, Sweden, 25–27 September 1985*, Royal Swedish Academy of Music 1988.
15 *The Aural Sonology Project* at http://www.lassethoresen.com/research_sonology.htm.
16 Norman Adams gives this subject an exhaustive examination in 'Visualization of Musical Signals', in: *Analytical Metods of Electroacoustic Music*, ed. Mary Simoni, New York-London 2006, pp. 13–28.
17 Robert Cogan, *New Images of Musical Sound*, Cambridge MA 1984.
18 Ibid., p. 2–3.
19 The main source here is *The Sound Shape of Language* by Roman Jacobson and Linda Waugh, Bloomington 1979.
20 Ibid., p. 147–148.
21 'Multidimensional Representation of Electroacoustic Music', *Journal of New Music Research*, No. 25, 1996, pp. 77–104
22 See Mara Helmuth, 'Barry Truax's *Riverrun*', in: *Analytical Methods of Electroacoustic Music*, ed. Mary Simoni, New York-London 2006, pp. 187–238.
23 Martha Brech, *Analyse elektroakustischer Musik mit Hilfe von Sonagrammen*, Frankfurt am Main 1994.
24 Op. cit..
25 'Paul Lansky's *As If*', in: *Analytical Methods of Electroacustic Music*, op. cit., pp. 55–88.
26 Joseph Giovinazzo, 'Sets as a Model for Timbral Objects', *MikroPolyphonie,* 4, July 1997–December 1998, http://farben.latrobe.edu.au/mikropol/volume4/vol4-1.html.
27 *The sonoristic structuralism of Krzysztof Penderecki*, Katowice 1997.
28 'Texture in Penderecki's Sonoristic Style', *Music Theory Online*, vol. 6, No. 1, January 2000, §[3],
http://mto.societymusictheory.org/issues/mto.00.6.1/mto.00.6.1.mirka.html.
29 These levels correspond to the terminology of the Swiss linguist and semiologist Ferdinand de Saussure.
30 Tomasz Kienik, 'Związki między barwą a wysokością dźwięku w wybranych utworach Kazimierza Serockiego', *Muzyka*, No. 3, 2004, pp. 61–90.
31 Ibid., p. 89.
32 See John A. Sloboda *The Musical Mind. The Cognitive Psychology of Music*, Oxford 1993.
33 Alicja Jarzębska *Igor Strawiński. Myśli i muzyka*, Kraków 2002.
34 See, for instance Stewart H. Hulse, Annie H. Takeuchi, Richard F. Braaten 'Perceptual Invariances in the Comparative Psychology of Music', *Music Perception*, No. 2, 1992, pp. 151–184.
35 See Mary L. Serafine, 'Cognition in Music', *Cognition*, No. 14, 1983 , pp. 119–183.

36 See ‘Podstawy sonologii muzycznej’, in: J. M. Chomiński, K. Wilkowska-Chomińska, *Formy muzyczne*, vol. I., op. cit., p. 126.
37 *Podstawy sonologii muzycznej*, [typescript] part II. *Systematyka zjawisk dźwiękowych*, op. cit., pp. 13–14.
38 For example, frequency scale corresponding to diatonic scale g a h $c^1 d^1$ e^1 f^1 to 195, 220, 246, 261, 193, 329, 349 Hz, and the same scale dispersed among different registers as g^4 A_1 h^5 c d e^3 F corresponds to frequencies 3155, 55, 7902, 130, 146, 1318, 87 Hz. See ibidem, p. 10.
39 The pitch of noise depends on its position in the frequency band and on its width, since the narrower the width of the bands of a given noise, the more accurately can one determine its position. Noises whose boundary frequencies are not greater than the interval of the major third can be used to construct quasi-melodic courses. See ibidem, pp. 17–18.
40 Ibid., pp. 26–27.
41 Ibid., pp. 28–30.
42 Ibid., pp. 31–33.
43 Ibid., p. 34.
44 Isolated sounds are intermediate values between stationary sounds and impulses and function purely as a sonoristic value without melic connections. See ibidem, p. 35.
45 Ibid., p. 37.
46 Known as early as the Middle Ages as *repetitio diversae vocum in tempore diverso* (Johannes de Garlandia) . Cf. ibidem, p. 38.
47 Ibid., pp. 40–41.
48 Ibid., pp. 42–43. Analogous, register classification of sounds of particular pitch was conducted by Chomiński also in volume I of *Formy muzyczne*, op. cit., p. 109.
49 *Podstawy sonologii muzycznej*, part II. *Systematyka zjawisk dźwiękowych*, op. cit., p. 44.
50 Various kinds of chords are formed by the following groups: octave, fourth and fifth; thirds and sixths; major second, minor seventh and major ninth; triton, minor second, major seventh and minor ninth and microintervals. Cf. ibidem, p. 54.
51 Ibid., pp. 45–46.
52 Ibid., pp. 47–49.
53 Ibid., p. 50.
54 Ibid., pp. 51–53.
55 Ibid., p. 54–55.
56 Ibid., pp. 57–58.
57 Ibid., pp. 59–60.
58 Ibid., p. 61.
59 Ibid., p. 63.
60 Cf. ‘Metabolizm’, w: *Formy muzyczne*, vol.I., op. cit. p. 235.
61 *Podstawy sonologii muzycznej*, part II. *Systematyka zjawisk dźwiękowych*, op. cit., pp. 66–67.
62 Ibid., pp. 71–73.
63 Ibid., p. 74.
64 *Podstawy sonologii muzycznej*, [typescript], part III. *Forma*, op. cit., pp. s. 2–3.
65 Ibid., pp. 4–5.

66 Ibid., pp. 7–10.
67 Ibid., p. 19.
68 Ibidem.
69 Ibid., pp. 20–21.
70 Ibid., pp. 28–29.
71 Ibid., pp. 29–30.
72 Ibid., p. 32.
73 Ibid., pp. 34–38.
74 Ibid., p. 40.
75 Ibid., pp. 45–47. The systematics of the structures depends not only on the inventiveness of the theorist or the composer, but above all on the state of technological advancement which offers such possibilities, and which constantly undergoes powerful changes and quickly becomes outdated.
76 Cf. 'Kategorie procesu formującego', in Józef M. Chomiński, Krystyna Wilkowska-Chomińska, *Formy muzyczne*, vol. I., op. cit., p. 21.
77 *Podstawy sonologii muzycznej*, part III. , op. cit., pp. 48–50.
78 'Krytyka muzyczna a poetyka muzyki', in: *Współczesne problemy krytyki artystycznej. Materiały z sesji IS PAN*, Wrocław 1973, p. 109.
79 Elżbieta Dziębowska, Koncepcja realnego kształtu dzieła muzycznego, *Muzyka*, No. 4, 1979, p. 15.
80 See, for example, Hanna Kostrzewska, 'Zagadnienie sonoryzmu na przykładzie twórczości kompozytorów polskich', *Muzyka*, No. 1, 1991.
81 See on this subject Maciej Gołąb's *Spór o granice poznania dzieła muzycznego*, Wrocław 2003, p. 153.
82 Cf. E. Karkoschka, *Das Schriftbild der Neuen Musik*, Celle 1966, p. 5.
83 Martha Brech, *Analyse elektroakustischer Musik mit Hilfe von Sonogrammen*, op. cit., p. 47.
84 J. M. Chomiński, K. Wilkowska-Chomińska, *Historia muzyki*, part II., Kraków 1990, pp. 288–289.
85 For example, Antoni Prosnak ('Zagadnienia sonorystyki na podstawie etiud Chopina', *Muzyka*, No. 1–2, 1958) defined Chopin's sonoristics as "an aspect of musical structure freely developed in horizontal and vertical planes, which arises on the basis of the whole of the phenomena concerning the so-called colour of sound". Monika Gorczycka, on the other hand, drew attention to centralisation of timbre and planes and timbre "shadowlines" in the works of List (Nowatorstwo techniki dźwiękowej "Annèes de pélegrinage" Liszta, *Muzyka*, No. 4, 1961).