TECNIACUSTICA VALLADOLID·2013

44º CONGRESO ESPAÑOL DE ACÚSTICA
ENCUENTRO IBÉRICO DE ACÚSTICA
EAA EUROPEAN SYMPOSIUM ON ENVIRONMENTAL ACOUSTICS AND NOISE MAPPING

THE MUSIC FROM XX-XXI CENTURY AND ITS IMPLICATIONS AND CONSEQUENCES IN THE ACOUSTICS IN THE AUDITORIO 400 OF JEAN NOUVEL AT THE NATIONAL MUSEUM REINA SOFIA CENTER OF MADRID

PACS: 43.75.Cd

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ABSTRACT.

The Reina Sofia Museum in Madrid, has an auditorium designed by French architect Jean Nouvel, where the Spanish Culture Ministry focuses its season of concerts dedicated to the music of XX-XXI century.
This article will explain the special dedication of the museum and its musical center, analyzing electronic music composed and/or performed at this site, as well as the breakdown of specialized patches to apply concepts of space, special effects and digital signal processing to various sound sources.
The article will revise also, acoustic and architectural implications of this type of music inside a concert hall as the Auditorio400 in Madrid.

RESUMEN.

El Museo Reina Sofía de Madrid, tiene un auditorio diseñado por el arquitecto francés Jean Nouvel, donde el Ministerio de Cultura español celebra la temporada de conciertos dedicada a la música del siglo XX y XXI.
El artículo explicará la dedicación del museo, en concreto su centro musical, analizando la música electrónica compuesta y/o interpretada en este espacio, así como el desglose de "patches" especializados para aplicar conceptos de espacio, tratamiento digital y efectos especiales a diversas fuentes sonoras.
El artículo también revisará, las implicaciones acústicas y arquitectónicas de este tipo de músicas en una sala de conciertos como el Auditorio 400 en Madrid.

1. INTRODUCTION.

The avant-garde and contemporary music of the twentieth and twenty first centuries has some special characteristics and it needs of specific spaces for listening and production. However, most of the time is presented in spaces designed as theaters and auditoriums in an Italian style, intended as concert halls for classical and romantic music, derived from the eighteenth, the nineteenth and the early twentieth centuries.

The type of music appeared in recent years has produced a significant change in the central European musical traditions, which has led to the creation of new structures, sounds and ways of listening.
The twentieth century has also brought the development of a new branch of physics, known as psychoacoustics that enables the identification of problems associated with human brain responses to different sound impulses. This discipline can provide guidelines for understanding acoustic phenomena: masking properties of the physical fact and changing the characteristics of sound propagation in a certain space with defined architectural characteristics.
In this paper, it will be presented the characteristics of significant musical styles framed in contemporary and avant-garde music, most notably electronic music and computer music, explaining their acoustic implications in the Auditorio 400.

2. MUSIC IN THE AUDITORIO 400 AND ITS ACOUSTIC IMPLICATIONS

The big break in the Western musical tradition has been a change in the rules of classic music, and this break down has caused the apparition of some new parameters that must be considered in the design of concert hall for new music. These parameters are: dissonance, extreme dynamics, extended techniques in instruments and, computer and electronic processing of sound sources. All this has led to concert halls, designed for a certain type of music, have been overwhelmed with sounds for which perhaps were not prepared [1]. This is evident in the problems that this kind of music produces at the Auditorio 400.

2.1 Features and musical parameters.

The dissemination of music has to take into account the parameters derived from classical physics associated with musical acoustics.
Two basic parameters are the frequency and sound pressure level: the frequency can be associated with the musical concept of pitch that leads to melody, and the sound pressure level associated with the term dynamic in a score.
In the same sense, other musical characteristics with its physical equivalent can be cited as:

- Resonance, both from the instrument and from the room.
- Texture that produces sharp definition of ranges and listening lines.
- Harmony and harmonic clarity, as a mixture of sounds, avoiding possible effects of filtering sources in order to have a good definition of the spectrum.
- Spatiality, as a source of provenance and sound localization.
- Musical clarity, clarity of speech, dynamic contrasts, etc. as essential for clean sound.
- Clarity of timbre, which means that there is an adequate attenuation and amplification of frequencies and spectrum.

These new aspects of music have been introduced in avant-garde movements, which now have appropriate relevance and must have a correct sound diffusion in a concert hall. Among such movements can be highlighted: twelve-tone music, serialism, minimalism, random music, improvisation, electronic music, new complexity, new simplicity, computer music, postmodernism, spectralism, etc.

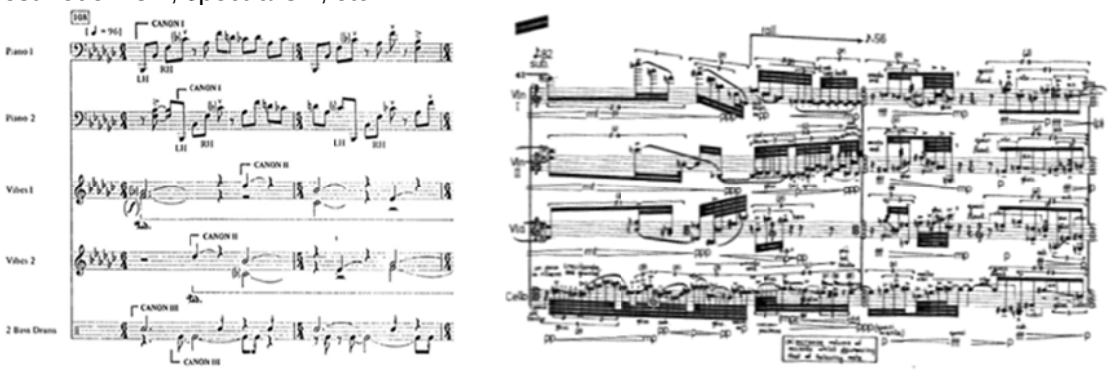


Figure 1.Examples of works of avant-garde and contemporary music of the twentieth and the twenty-first century. On the left a fragment of a work by Steve Reich, "Sextet" [2] and on the right a fragment of a work by Brian Ferneyhough, "String quartet number 3" [3].

Figure 1 shows a pair of works from these new styles, the first example is a work by Steve Reich, "Sextet" [2], framed within the minimalism and the second example is a sample of the new complexity, "String quartet number 3" by Brian Ferneyhough [3]. This figure is a sample of the new parameters cited above, that causes listening problems in a standard auditorium, as the one studied and analyzed in this paper.

Along with the proliferation of styles have appeared a number of performers and groups specializing in new techniques (extended techniques) that have expanded production methods and sound generation. The new technical virtuosity and extended techniques have caused that traditional instruments have expanded its usual limits of sound production and are now able to generate sounds in new forms and concepts.

Moreover, as discussed above, most of the concerts of new music are performed in traditional venues, where often the new sonorities are lost. All these styles have been produced and are being presented in the Auditorio 400 of Madrid. The characteristics of these styles cause that the acoustical problems at the auditorium become more pronounced. These problems are related to the high reverberation time of the enclosure and its inadequate distribution in frequency and the inhomogeneous distribution of sound pressure level in the room [4].

- The average reverberation time measured in the Auditorio 400 is 1,84s. This value is too high according its volume (about 4000m^3) and especially if the hall is used for chamber music concerts and for lectures.
- The distribution of reverberation time vs frequency is not adequate. It does not follow the flat graphic profile recommended. The measured graphic at Auditorio 400 has a medium frequency enhancement; in fact, at 2 kHz the reverberation time values 2,36s. This implies some problems with the parameter of warmth inside the place.
- The sound pressure levels are not homogenous over the hall, mainly at low frequencies; it has been measured differences of 10dBs between the maximum and the minimum values.

These aspects (reverberation time and sound pressure level) involve specific problems of loudness, clarity, masking etc. In this way, it should be noted that the auditorium designed by Jean Nouvel, is particularly sensitive to changes in texture and movement of sound masses, both in instrumental and in electronic music. These aspects are valid with natural acoustic sound and with electronic dissemination through speakers.

Besides objective measures presented in other article in Evora 2012, the authors have lead several subjective tests, with listeners in front of different music situation and with the composition of a poll, from a model obtained from IRCAM, which was sent to people with different background.

To better understand subjective information collected on sound conditions of Auditorio 400 of the Museo Reina Sofia in Madrid, the information is structured in a series of tables.

All the data showed below have been collected from:

- Professional opinions of people intimately related to the activities on the premises.
- Several visits to the room in order to analyzed different events offered in it.
- A poll about the acoustics of the hall drawn up with people of different occupations with varied activities.

The first set of tables, table 1, intended to assess clarity of the sound in the room to the different families of instruments and voice, The analysis is based on instrumental register, low, mid and high frequencies, and the speed of execution, fast or slow, indicating in which situations there are problems with clarity.

	Register	Speed	Clarity
STRINGS	low	slow	problems
		fast	----
	mid	slow	----
		fast	----
	high	slow	----
		fast	problems

	Register	Speed	Clarity
WINDS WOOD METAL	low	slow	problems
		fast	----
	mid	slow	----
		fast	----
	high	slow	----
		fast	----

	Register	Speed	Clarity
TUNED PERCUSSION	low	slow	problems
		fast	----
	mid	slow	----
		fast	problems
	high	slow	----
		fast	problems

	Register	Speed	Clarity
VOICE	low	slow	problems
		fast	-----
	mid	slow	-----
		fast	problems
	high	slow	-----
		fast	problems

Table 1. Assessment of the sound clarity of different types of musical instruments according to the register and the speed.

Table 2 indicates several problems identified in the Auditorio 400, depending on the configuration and arrangement of the different instruments and a possible amplification. It has a color associated with each type of problem and the instrument or combination of instruments that may appear reflected this problem, thus it can be analyzed the results in a faster and more intuitive way.

MASKING PROBLEMS IN INSTRUMENTS		
Piano	Low register	Masking of strings
	Slow speed	Problems in high frequencies
Flute /Clarinet		Masking of strings
Instrument in the same register		----
Instrument in different register		Register Masking
PROBLEMS IN INSTRUMENTAL GROUPS		
Chamber music		
Instruments together		Absence of clarity
Solo instruments		-----
Instrument in the same register		-----
Instrument in different register		Register Masking
TYPE OF ARTICULATION	Continuous sounds	Absence of clarity and spatiality
	Stacatto sounds	-----
PROBLEMS WITH THE AMPLIFICATION		
Amplification	Instrumental music	Vibrations problems in string
		Problems of phase and spatiality
		Problems of phase and spatiality
	Voice	Problems of resonance
		Problems of phase and spatiality

Table 2. Different problems at Auditorio 400 depending on the instruments configuration.

3. ELECTRONIC AND COMPUTER MUSIC

One of the most interesting aspects of the Auditorio 400 is the important addition of electronic music and the music performed, processed and treated with computer. In electronic music and computer music, the control over sound parameters is absolute, and the accuracy of frequencies, sound levels, reverberation, effects, etc. can be calculated, recorded and expressed in precise mathematical formulation.

3.1 Software processing.

Electronic and computer signal processing produces a transformation of sound that changes the production, propagation and listening of sound sources. An audio file can be organized into various modules: pre-processing the signal input, introduction of effects, directional distribution, equalization of the output signal etc.
An important consequence of electronic and computer music in the concert hall has been the introduction of the exhibition space simulation. In this aspect IRCAM has pioneered the development of programs to generate different sound paths.
The figure 2 shows a patch from Open Music to develop a score with the parameter space inside its characteristics. The application Open Music developed in the IRCAM, by people like Tristan Murail, Gerald Grisey and others. It is a Computer Aided Composition (CAC) and it is very helpful as an algorithm for composing music and for writing scores.

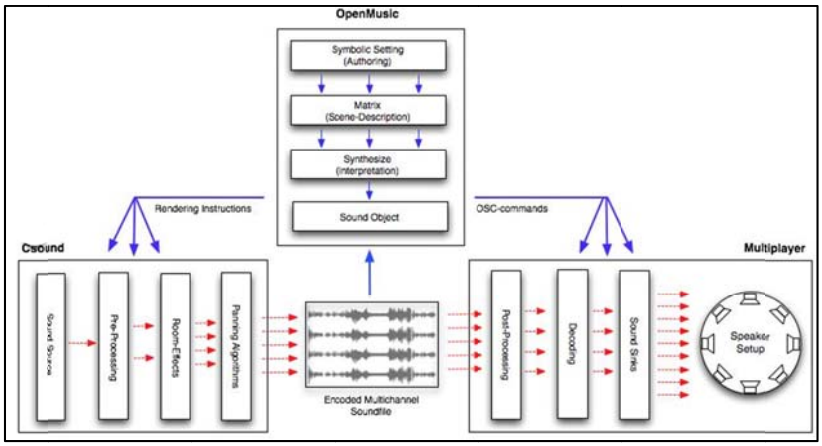


Figure 2. Patch from Open Music [5].

One of the possibilities with this software is the fact that exists several ways to connect with other programs. The best plugin is called OMAX, and link the out of Open Music with MAX-MSP. Inside MAX-MSP there is an application called Spatialisateur, which allows working in real time the space parameters to control spatiality as simulation in concert hall situation. IID; IIT, Delay, Reverberation, etc.

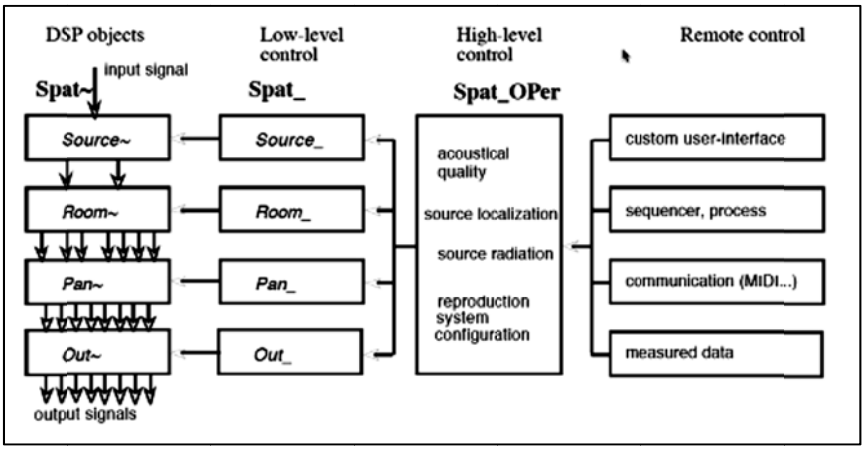


Figure 3. Schema of Spatialisateur [6]

3.2 Patches and examples of space music.

There are several pieces developed as spatial sonority. In this paper it has been presented two representations among the most important in electronic and computer music:

- "Oktophonie", Stockhausen, 1991.
- "Dialogue de l´ombre double", Boulez, 1985.

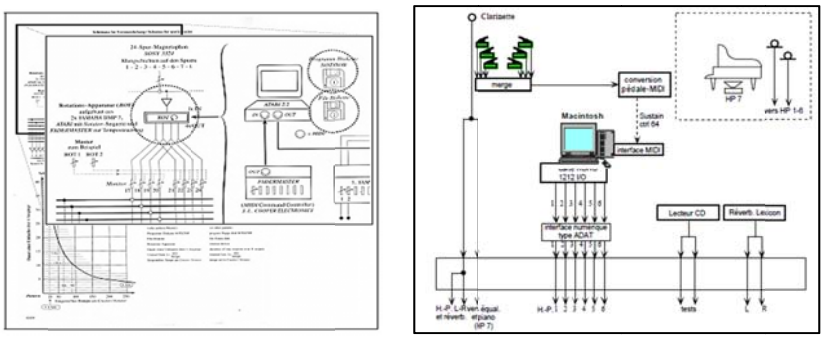


Figure 4. Examples of works of electronic and computer music*. On the left a work by Karlheinz Stockhausen, "Oktophonie" [7] and on the right a work by Pierre Boulez, "Dialogue de l´ombre double" [8].*

In the schemes above, it is possible to see how the works and how the composition develops the concept of spatial simulation. In Stockhausen´s work, the entire piece was pre-recorded and the composer or sound technician is in charge of sound distribution over speakers. There are a recording of 24 tracks. Spatialization was facilitated by the use of a QUEG (Quadrophonic Effect Generator), a device manufactured by EMS in the early 1970s. In Boulez´s Dialoguie, there is a live instrument (Clarinet) with different sound files that are played in different moments of the piece, with several real time processes. In this work the electronic was the first developed with MAX-MSP that was created at IRCAM. In both pieces the sound is distributed over speakers around the audience

3.3 Music and spatialization at LIEM-Auditorio 400.

The spatiality was one of the capital premises in the design of the Auditorio 400 sound reinforcement. The CDMC, Dissemination Center for Contemporary Music, and LIEM, the Laboratory of Computer and Electronic Music from the National Museum Reina Sofia Art Center, opted for the possibility of providing a sound reinforcement system that will not only serve to amplify the signal, but also that at the same time, it could be used for concepts derived from electronic music and computer music. This system is called Acousmonium.

Acousmonium is a suitable system to disseminate electronic music, both pre-recorded and live processed in real time. The system Acousmonium has 32 loudspeakers system, a specialized mixer and several DSP, allowing amplification and spatial distribution for the type of music played. This option is controlled by the LIEM, and is independent of the control system and sound amplification that depends on the service and audiovisual department of the Reina Sofia Museum.

The Auditorio 400 has a special dedication to this type of music, and this institution has an entire festival, at the end of June dedicated to this kind of music JIEM (Sessions of Computer and Electronic Music), a festival for Electronic and Computer Music.

The schemas presented in figure 5 are from two pieces in which the musical is distributed through speakers that simulate movements and diverse locations. These works have been performed in the auditorium.

"On the stillness of the water" by Emiliano del Cerro was a commission of Spanish Public Radio and Television, and was premiered in Madrid over Public Radio Station, as broadcast of a live concert. It is a work that is spread over a set of several eight speakers setting, disseminated with random program over eight speakers that surrounding the audience. The piece has been performed several times, and it was chosen by the group GRM to present Spanish music at the Auditorio 400. The composition was presented with sixteen speakers with the basic material, eight speakers with the English text, and eight speakers with the special mix down of the work.

"Koch space" by Julian Avila is a work conceived and written from a spatial vision of sound. It is a piece for tenor, saxophone and live electronics. The room space is organized as a big

topographic filter which spatialized sound through the light of the performer. The score is divided into three pages located in three stands, positioned in a semicircle around the interpreter. The work plays with dark room and it is the interpreter that illuminates the staff who is playing with a head lantern switched on throughout the play. The light is captured by photocells that allow electronic spatialization using MAX-MSP, as if it were the result of the lighting.

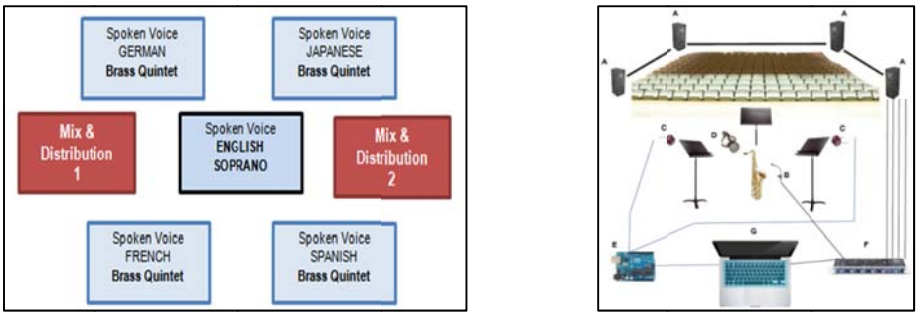
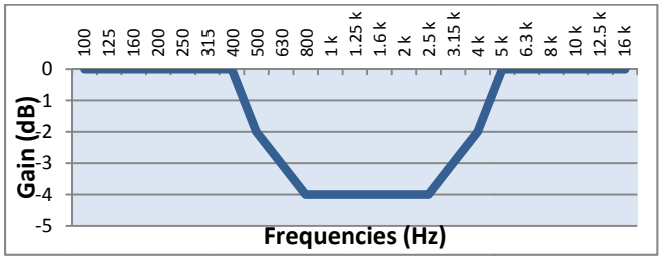


Figure 5. Examples of works of electronic and computer music perform at Auditorio 400. On the left a work by Emiliano del Cerro, "On the stillness on the water" [9] and on the right a work by Julian Avila, "Koch´s space" [10].

The Auditorio 400 has a number of problems associated with its particular geometry and design. In the dissemination of electroacoustic works, there are shadows and sound reinforcement areas. This has created a need for movable speakers in the middle of the room and along the side of the hall and central separation. The room produces a bass reinforcement and treble loss that needs to be treated specially with a good equalization and proper tuning of the sound reinforcement system. It should be counteract the effects of the high values of the reverberation, especially at medium frequencies, by equalizing the signal, i.e. it should be attenuate the signal somewhat localized at the center frequencies of the audible spectrum as shown in the graph 1.



Graph 1. Signal Equalization to counteract the high reverberation, mainly at mid frequencies, at Auditorio 400.

Finally note that to solve acoustic deficiencies mainly located in the center of the room it could be placed in this problematic area special speakers developed at IRCAM [11], figure 6.

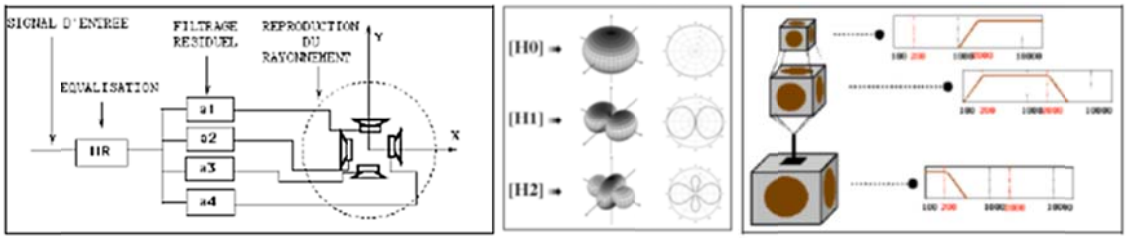


Figure 6. Speakers system developed by IRCAM [11].

The speaker system, showed in Figure 6, allows varying the signal sent to each of the four speakers that appear in the cube where are mounted, through an adequate sound processing system and appropriate transfer functions. The directivity of the speaker array can be modified by adjusting it to the needs of each use of the room. This setting produces different directivity diagrams: cardioid, bidirectional, omnidirectional, etc., as seen in the central image of the previous figure. The versatility in the performance of these speakers would be very useful in the Auditorio 400, both to allow more direct sound level at the center of the room and to enter multiple effects that require many of the works that are interpreted or reproduced inside.

4. CONCLUSIONS

New music from the twentieth and twenty first century have brought a new way of writing and producing instrumental and electronic music, all of this leads to a new mode of listening that causes a novel way to deal with the acoustic design of a hall. This implies the design of new spaces devoted almost exclusively to this type of music. However, a space dedicates only and exclusively for this kind of music could generate economic and logistical problems. Consequently, the music must be presented at venues already designed for other types of music and in spaces that must adapt to new requirements.

The music produced by electronic means requires very high quality speakers. Beside, in music that combines instruments and amplification, the difference of sound fidelity should be minimal. Sound pressure levels on stage sources and sound pressure levels sources through speakers should be appropriate.

As discussed in this paper, the music of recent years is characterized by extreme dissonance, very sharp sound planes, high complicated rhythms, with clear and haunting sequences, specific resonances, and a new way to produce sound even with traditional instruments. Specifically, in electronic music all of these aspects are present; in consequence the acoustic quality of the concert hall should be maximum for a perfect musical clarity and definition.

The Auditorio 400, object of this paper, presents different types of events. It has different problems depending on the class of message offered on it. To solve these difficulties, a first option would be a good equalization of the signal and the use of loudspeakers with variable directivity. Although the best option would come from the facilities that variable acoustic offers to us. This allows changing the acoustic parameters of the hall, adapting the hall to the type of act developed inside it.

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