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THE ACOUSTICS OF ORTHODOX CHURCHES BETWEEN BYZANTINE TRADITION, LITURGICAL EXPERIENCE AND MUSICAL CHALLENGE

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SUMMARY. The study examines the acoustics of Orthodox churches as a constitutive dimension of the liturgical experience, at the intersection between Byzantine tradition, musical practice and contemporary architectural choices in Romania. Starting from the coexistence of two sonic traditions – psaltic (monodic) and choral (polyphonic) – the research shows how the parameters of space (dome, vaults, iconostasis, materials) shape the intelligibility of the text and the ethos of chant. The results suggest that psaltic chant 'flourishes' in ample reverberations with slow tempi and sustained *ison,* while choral chant requires a balance between resonance and clarity for the text and the verticality of harmony. It is proposed that acoustics be integrated from the earliest stages of design and restoration in order to optimize the relationship between timbral beauty and the intelligibility of the word. Conclusion: sacred space must also be thought of as sound space; acoustics, treated as a "sonic icon", enhances the catechetical, mystagogical, and communal function of liturgical chant.

Keywords: Orthodox church acoustics, byzantine chant, liturgical space, speech intelligibility, sacred architecture

1. Introduction

The Orthodox liturgical space is defined not only by iconography and architecture, but also by a specific sonorous dimension, in which church chant acquires spiritual and aesthetic power. While in the Byzantine tradition architecture and music developed in an organic connection, in Romania, the situation is unique due to the coexistence of two musical traditions: the psaltic

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and the choral. This diversity calls for careful research into how the liturgical space constructed, especially after 1990, shapes and conditions sung prayer.

Alongside the practical aspects of church music, recent years have also witnessed a growth in scientific research devoted to the acoustics of Orthodox churches.[2] While until recently the specialized literature on this topic was scarce, with Orthodox church acoustics often marginalized, more and more interdisciplinary studies have emerged. In Poland, for example, acousticians have measured the parameters of 20 historic Orthodox churches, noting features such as longer reverberation times at low frequencies due to the domes, but also a relative uniformity of musical clarity across most churches, indicating that Orthodox architecture ensures a certain implicit *acoustic standard.*[3] Other studies compare the acoustics of wooden versus masonry churches, or analyze the effect of the presence of worshippers, the absorption produced by the human body significantly reducing reverberation.[4]

Acoustics is an essential component of the Orthodox liturgical experience. Although church architecture has been analyzed from an artistic and historical point of view,[5] the acoustic dimension has often been overlooked by professors in the field of church music. In the context of Romania, where stylistic diversity abounds – from the wooden churches of Maramureș to monumental stone cathedrals – the study of acoustics becomes indispensable for understanding how sacred space supports and amplifies singing.

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[2] Carvalho A.P., Morgado A.E. (1997), *Relationships between speech intelligibility and objective acoustical parameters for architectural features in Catholic churches*, Journal of Acoustical Society of America, 101, 3051 - 3052; Elicio L., Martellotta F. (2015), *Acoustics as a cultural heritage: the case of Orthodox churches and of the "Russian church" in Bari*, Journal of Cultural Heritage, 16, 912–917; Lubman D., Wetherill E. (1985), *Acoustics of worship spaces*, American Institute of Physics, New York; Małecki P., Wiciak J. (2011), *Acoustic parameters of chosen orthodox churches overview and preliminary psychoacoustic tests using choral music*, Proceedings of 130th AES Convention, London, UK; Martellotta F., Cirillo E., Carbonari A., Ricciardi P. (2009), *Guidelines for acoustical measurements in churches*, Applied Acoustics, 70, pp. 378–388.

[3] Paweł Małecki, Jerzy wiciak, Damian Nowak, "Acoustics of Orthodox Churches in Poland" in: *Archives of Acoustic,* Vol. 42, No. 4, (2017), pp. 579–590.

[4] Mijic M., Sumarac-Pavlovic D. (2000), *Acoustical characteristics of old wooden churches in Serbia*, Journalof Acoustical Society of America, 108, 2648–2648. Rossing T. *Handbook of Acoustics,* Springer, Stanford, (2007).

[5] Marius Porumb, *Monumente istorice și de artă religioasă din Arhiepiscopia Vadului, Feleacului și Clujului*, (*Historical and Religious Art Monuments in the Archdiocese of Vad, Feleac, and Cluj*) Editura Arhiepiscopiei, Cluj-Napoca, 1982; Ene Braniște, *Liturgica generală cu noțiuni de artă bisericească, arhitectură și pictură creștină*, (*General Liturgics with Elements of Church Art, Architecture, and Christian Painting*) vol. I, II, Basilica, București, 2015; Nicolae Stoicescu, *Repertoriul bibliografic al monumentelor feudale din Bucureşti*, (*The Bibliographic Repertoire of Feudal Monuments in Bucharest*) Editura Basilica, 2017; Metropolitan Hilarion Alfeyev*, Orthodox Christianity Volume III: The Architecture, Icons, and Music of the Orthodox Church*, translated from the Russian by Andrei Tepper, St Vladimir Seminary Press, Yonkers, New York, 2008.

Based on the results of previous research, this paper aims to contribute to the understanding of the relationship between the architecture of contemporary churches in Romania and traditional Romanian ecclesiastical music, offering an analysis that combines theological, musicological and scientific perspectives.

The purpose of this work is to demonstrate that the acoustics of Orthodox churches in Romania form a constitutive dimension of the liturgical experience, directly influencing both the quality of chant and the way it is perceived by those present in places of worship. The study aims to emphasize that sacred space must also be considered as a sonic environment, and that acoustics should be integrated into the design, restoration and use of churches.

The objectives of the paper include analyzing the historical and theological foundations that have linked ecclesiastical chant to Byzantine and post-Byzantine architecture. To highlight the musicological particularities of the psaltic and choral tradition in Romania and their acoustic requirements. To examine the psychological and pastoral dimension of acoustics upon faithfulness. To formulate practical recommendations for the design of new churches and the restoration of historic ones.

The methodology adopted in this paper is interdisciplinary, combining several types of approaches: bibliographic documentation, the study of patristic, musicological and architectural sources, as well as international research on the acoustics of sacred spaces.

The importance of conducting a study on the acoustics of Orthodox churches in Romania lies in the fact that liturgical space cannot be understood solely in terms of its architectural or aesthetic dimensions, but also through the quality of its sonic environment. In Orthodox tradition, church chant constitutes an integral part of worship and a privileged means of communion with God, which is why its spiritual and aesthetic efficacy is deeply influenced by the acoustic conditions of the edifice. Acoustic analysis allows not only the enhancement of existing heritage and the foundation of restoration processes, but also the optimization of the design of contemporary churches, so that they meet the requirements of worship and the perceptive expectations of the ecclesial community.

2. Historical and theological foundations of the relationship between singing and liturgical space

In Byzantium, church singing was not conceived as a mere aesthetic addition to worship, but as a theological language and prayer through sound. As early as the 4th–5th centuries, church architecture was designed not only to illustrate the Kingdom of God iconographically, but also to create the

acoustic conditions necessary for the transmission of chant.[6] From the first Christian basilicas to the great modern Orthodox cathedrals, architects and clergy have observed that certain spatial configurations can amplify the unamplified voices of priests and cantors, allowing the sacred message to reach those present clearly. The high domes, harmonious proportions and volumetric distribution of the nave were designed to support Byzantine monody. The internal shape of the church, its dimensions and materials directly influence the way sound is propagated and perceived.

Studies on the acoustics of historic churches show that reverberation times vary from 1.5 seconds in small rural churches to 6 seconds in large urban cathedrals, which profoundly influences the perception of liturgical music. As reverberation increases, chant acquires beauty and depth, seeming to spring from the walls and domes, rather than merely from human voices.[7] This mystical and iconic quality of sound allows music to be perceived as the singing of saints and angels, thus integrating it into Orthodox liturgical theology. Therefore, the acoustics of the church are not merely an aesthetic element but fulfil the essential purpose of the sacred space and chant: to serve as a sonic icon of the Kingdom of God.[8]

In contemporary Orthodox tradition, ecclesiastical chant retains its value as an expression of faith and a means of communion, having a profound soteriological and mystical status. It is not a simple ornament intended to embellish worship, but constitutes the prayer raised by the entire community, a "theology in song" that renders audible the words of Scripture and Tradition. That is why psalmody often has a stronger impact on the soul than preaching, since music conveys the theological message in an affective, participatory form capable of mobilizing the entire being of the believer.[9]

For this function to be fully realized, the acoustics of the liturgical space play a fundamental role. The church is not merely a place of gathering, but also a resonant instrument designed to amplify prayer. Excessive reverberation can obscure textual intelligibility and create a sense of distance, whereas weak acoustics reduce the enveloping power and emotional intensity of chant. Only a harmonious acoustic balance allows both the clarity of the word and the richness of the melody, thus allowing the hymnographic message to

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[6] A. Papalexandrou. *Sacred sound and the reflective cornice. In Architecture and Visual Culture in the Late Antique and Medieval Mediterranean*. Brepols Publishers n. v., Turnhout, Belgium, 2020, p. 20.

[7] Andrew Gould, "Acoustical Considerations in Orthodox Church Design" in: *Orthodox Arts Journal,* nr 6, (2020).

[8] Egon Wellesz, *A History of Byzantine Music and Hymnography*. Oxford: Clarendon Press, 1949, Clarendon Press, 1961, p. 165.

[9] Alexander Lingas, "Performance Practice and the Politics of Transcribing Byzantine Chant." *Early Music History* 19 (2000): pp. 85–87.

be heard, understood and internalized by the community. An edifying example of how the liturgical space influences music is the Hagia Sophia Church in Constantinople.[10]

The Hagia Sophia Cathedral in Constantinople (Istanbul) is the most famous example of synergy between architecture and Byzantine chant. Inaugurated in 537, this monumental edifice astonished not only by its dimension and visual splendor, but also by its exceptional acoustics. Modern measurements reveal that the interior of Hagia Sophia has a reverberation time that can reach 12 seconds at low frequencies (250–500 Hz)[11] -an extraordinary value, indicating a very persistent echo in the lower register.[12] In fact, the acoustics of Hagia Sophia feature both long late reverberation and a relatively long early decay time (EDT), causing sound to 'float' in space, becoming spatially diffuse and difficult to localize, creating a unique auditory experience.[13]

This phenomenon results primarily from the reflective nature of the dome and the way in which the dome and marble surfaces diffuse sound in multiple directions. Basically, the sound produced under the magnificent dome (31 m in diameter) is sent to all corners, bouncing between the marble columns, clad walls and side vaults, generating large reverberations, cross echoes and amplification of certain frequencies.[14]

Within this impressive sound bath, the Byzantine chants composed for the cathedral, such as the Cherubic Hymn and the Chinonic, took on a

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[10] Pentcheva, Bissera V. *Hagia Sophia: Sound, Space, and Spirit in Byzantium*. University Park, PA: Penn State University Press, 2017, p. 22–30; Abel, Jonathan. "Simulating the Acoustics of Hagia Sophia." *Proceedings of the Acoustical Society of America* 2014, pp. 123–128.

[11] ISO 3382-1: RT, EDT, C50/C80, STI, G. ISO 3382-1 parameters (RT, EDT, C50/C80, STI, G) describe how sound decays, how clearly it is perceived, how intelligible speech remains, and how strong it feels within an architectural space — making them essential tools for evaluating and designing the acoustics of worship spaces, concert halls, and other performance venues.

[12] Corinna da Fonseca-Wollheim, *How a Historian Stuffed Hagia Sophia's Sound Into a Studio* – New York Times / Stanford University (2020)art.stanford.eduart.stanford.eduart.stanford.edu (regarding the project of recreating the acoustics of hagia sophia: reflections on tempo, melisma, and the manifestation of the Divine presence through sound.). Turgut Erçetin, *Acoustics and Sounds of the Hagia Sophia* – YCBS.eu (2022)ycbs.euycbs.eu (Technical data on the approximately 12-second reverberation in Hagia Sophia and the singular auditory experience shaped by its dome and reflective architecture).

[13] Mila Zaharieva-Schmolke, *Acoustics and Sounds of the Hagia Sophia*, Acoustic research on the Hagia Sophia by the Stanford Team and its project, https://ycbs.eu/en/acoustics-and-sounds-of-the-hagia-sophia/#:~:text=Hagia%20Sophia%20has%20not%20only,Turgut%20Ercetin

[14] Rowland J. Mainstone, *Hagia Sophia: Architecture, Structure, and Liturgy of Justinian's Great Church*, Thames & Hudson, 1997; Ken Dark & Jan Kostenec, H*agia Sophia in Context: An Archaeological Re-examination of the Cathedral of Byzantine Constantinople*, Oxbow Books, 2019/2023.

supernatural dimension.[15] A Cherubic Hymn sung in Hagia Sophia would sound as though performed by a choir of angels, the echo multiplying the voices and making them seem to descend from the vault. Contemporary musicologists have noted that some ancient Byzantine compositions fully reveal their meaning only when heard within the acoustic environment for which they were written. Alexander Lingas, conductor of the Cappella Romana ensemble, discovered this when he reconstructed medieval chants in the virtual acoustics of Hagia Sophia: the tempo had to be slowed down, and those singing in unison made small adjustments to their pitch to synchronize with the maximum resonance frequencies of the space.[16] With these adaptations, the music "came to life" in a breathtaking manner, the sound accumulating in undulating echoes until it simply took off, filling the vault. Such accounts confirm the intention of Byzantine composers: the music was deliberately designed to interact with the cathedral's echo, allowing verbal information to yield to mystical experience.[17] Hagia Sofia Cathedral remains a unique example in the history of Christianity of the fusion between architecture and music, where the built space is not only a setting for worship, but becomes a liturgical instrument in itself.

Theologians and art historians have described the Orthodox church as a "three-dimensional icon," in which each element bears symbolic meaning. If the painted icon is theology in color, the architecture of the church is theology in space.[18] In this context, acoustics represents the sound dimension of the icon, complementing the visual image with an auditory experience. The way in which space "responds" to the singing is an integral part of liturgical symbolism. The prolonged echo of the domes suggests eternity and infinity, and the harmony between sound and architecture becomes an auditory image of cosmic communion. In this sense, singing is not isolated from space, but dialogues with it. The believer does not only hear the hymn, but perceives it as a spatial and mystical experience, in which the word is transformed into a vibration that fills the entire building.

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[15] Dimitri Conomos, "Communion Chants in Magna Graecia and Byzantium", in: *Journal of the American Musicological Society*, Vol. 33, No. 2 (1980), pp. 241 -263.

[16] Alexander Lingas, "From Earth to Heaven: The Changing Soundscape of Byzantine Liturgy." În *Experiencing Byzantium: Papers from the 44th Spring Symposium of the Society for the Promotion of Byzantine Studies, Newcastle and Durham, April 2011*, editat de Claire Nesbitt și Mark Jackson, pp. 311-358. Farnham: Ashgate / Society for the Promotion of Byzantine Studies, 2013.

[17] Lingas, Alexander; Pentcheva, Bissera V.; Abel, Jonathan S.; Eruçman, Duygu; Antonopoulos, Spyridon; Canfield-Dafilou, Elliot K.; a.o. *Lost Voices of Hagia Sophia: Medieval Byzantine Chant Sung in the Virtual Acoustics of Hagia Sophia.* Cappella Romana, 2019.

[18] Vladimir Lossky, *The Mystical Theology of the Eastern Church*. London: James Clarke & Co., 1957, p. 134–136; Leonid Ouspensky, Vladimir Lossky. *The Meaning of Icons*. Crestwood, NY: St Vladimir's Seminary Press, 1982, pp. 45–47.

Thus, the architecture of the church is not acoustically neutral: it determines how chant is received and internalized. Acoustics thus becomes a sonic expression of theology, contributing to the transmission of liturgical mystery and the intensification of spiritual experience.

3. The specificity of psaltic and choral singing and its relationship with the liturgical space

Orthodox church music in Romania has developed in a dual tradition: the psaltic tradition of Byzantine origin, and choral, of Western influence. This coexistence has led to a diversity of sonic practices and, implicitly, a different relationship to the acoustic space of the church.

Psaltic chant, monodic in nature, inherited from Byzantium, is based on Byzantine voices, modes, having a meditative, internalized character with an emphasis on the expressiveness of the text. It is best sustained in spaces with long reverberation, where the sound is prolonged and creates a sense of fluidity and continuity. In such conditions, the melody takes on an ecstatic dimension, close to the ethos of contemplative prayer.[19]

Byzantine music is characterized by the maintenance of a fixed note – the ison – over which the upper melody unfolds in small, linear steps. In a space without reverberation, this form of sound may seem simplistic, yet in the ample acoustics of a Byzantine church it takes on an overwhelming force, giving the impression that the edifice itself is singing along with the choir. It is not difficult to understand that this musical tradition was shaped by the acoustics of the great palaces and marble-adorned churches of Roman antiquity, and Byzantine architects continued over the centuries to build places of worship with similar acoustic properties, precisely to support this conservative musical form[20]. Byzantine music, with its elongated notes and absence of contrapuntal polyphony, seems to have been shaped by the spaces in which it resounded. Byzantine hymnographers and composers, often members of the clergy or the imperial court themselves, composed songs that resonated well with domed churches and apses. As mentioned above, a specific singing tradition developed in the most grandiose church of the time, Hagia Sophia: the priestly *ekphonesis* and the cherubic hymn were intoned in a way that took advantage of the cathedral's long echo, creating an almost supernatural atmosphere.[21] Modern musicologists confirm that many early Byzantine

[19] Daniel Mocanu, "Religious Chants – The Diversity of Church Hymns Types", in: Studia UBB Musica, LXV, 2, 2020, pp. 193-224.

[20] Andrew Gould, "Acoustical Considerations in Orthodox Church Design" in: *Orthodox Arts Journal,* nr 6, (2020).

[21] Robert Taft, "The Liturgy of the Great Church: An Initial Synthesis of Structure and Interpretation on the Eve of Iconoclasm", in: *Dumbarton Oaks Papers*, Vol. 34/35 (1980/1981), pp. 45-75; Robert Taft SJ, "How Liturgies Grow: The Evolution of the Byzantine "Divine Liturgy", in:

compositions have tempos and structures that would not have the same effect in spaces without reverberation and in today's theological and cultural perception.[22]

Psaltic music, due to its monodic nature, highlights each sound, which makes acoustics a decisive factor in the perception of singing. The two essential elements – melody and ison – intertwine in a "sonic carpet" which, in reverberant spaces, acquires an amplified and symbolic dimension. The structure of Byzantine voices, with their specific intervals, generates resonances consonant with the architecture of churches, reinforcing the sensation of sonic fullness.

The dynamics and tempo of the singing are uniform, without sudden contrasts, which allows the echo to prolong the phrases in a smooth flow. However, fast passages are often adapted to space to avoid losing the clarity of the text. Being closely linked to liturgical hymnography, psaltic music aims to convey the sacred word in an intelligible way. Therefore, psalmists make use of the acoustics by prolonging vowels and dosing consonants, so that the text remains intelligible even in the prolonged echo.

Thus, psalmody not only suits the acoustics of the church, but is also composed and performed with full awareness of its interaction with space, transforming the architecture into a living instrument of worship. In these ideal conditions, the faithful perceive psalmody not as mere music, but as prayer in sound, as a call to inner participation. The sacred acoustic space

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Orientalia Christiana Periodica XLIII, Roma 1977, p. 8-30. Oliver Strunk: "The Byzantine Office at Hagia Sophia", in: *Dumbarton Oaks Papers*, Vol. 9 (1956), pp. 175-202. Articolul lui Oliver Strunk, *The Byzantine Office at Hagia Sophia* (Dumbarton Oaks Papers, 1956), The author examines the liturgical tradition of the Great Church of Constantinople, emphasizing the distinctions between the "sung" rite (*akolouthia asmatike*) of Hagia Sophia and the monastic liturgical practice. Drawing upon the testimony of a Russian pilgrim from around 1200 and the treatise of Archbishop Symeon of Thessaloniki, the study elucidates how the services of the Great Church incorporated solemn processions, antiphonal psalmody, refrained chants, and complex ceremonial structures that required a large body of clerics and singers. Strunk demonstrates that this tradition represented a unique synthesis of musical and liturgical expression, preserved only in fragmentary form in later Byzantine manuscripts from Athos, Athens, and Thessaloniki. In contrast to the sobriety and interiority of the monastic rite, the "sung" liturgy of Hagia Sophia embodied the grandeur and ceremonial splendor of the urban ecclesiastical life of Constantinople—an expression that gradually declined following the Latin conquest of 1204.

[22] Tsilfidis, Alexandros, Charalambos Papadakos, Elias Kokkinis, Georgios Chryssochoidis, Dimitrios Delviniotis, Georgios Kouroupetroglou, and John Mourjopoulos. "Reverberation and Dereverberation Effect on Byzantine Chants." *Proceedings of the 134th AES Convention* (2013). Mourjopoulos, John, Charalambos Papadakos, Alexandros Tsilfidis, and Elias Kokkinis. "Optimal Acoustic Reverberation Evaluation of Byzantine Chants in Churches." In *Proceedings of the Joint ICMC–SMC Conference*, Athens, 2014. Delviniotis, Dimitrios, Georgios Kouroupetroglou, and Sergios Theodoridis. "Acoustic Analysis of Musical Intervals in Modern Byzantine Chant Scales." *Journal of the Acoustical Society of America* 124, no. 5 (2008): 3259–3269.

acts as a bridge between the liturgical artist (the psalmist, the choir) and the soul of the listener. Without this bridge, the chant would remain beautiful, but it would not have the same spiritual power. Thus, psaltic music and church acoustics are in a synergistic relationship: the former provides the content, the latter *packages* it and delivers it to the hearts in the most appropriate way.

On the other hand, choral singing entered the Romanian space in the 19th century, through the influence of Western schools and contact with Catholic and Protestant traditions.[23] It is characterized by polyphonic harmony, multi-voice distribution, and a musical notation that requires clarity and balance. While monody can flourish in a space with prolonged echo, choral singing requires moderate acoustics, in which the voices remain distinct, and the harmonic overlaps do not turn into a confusing mass of sound. Typically, an Orthodox choir seeks to benefit from as much reverberation as possible, as this embellishes the singing. However, a problem arises when it comes to the pronunciation of the texts: if the reverberation exceeds approximately 1.5 seconds, it becomes difficult to understand the words. For this reason, in the Orthodox tradition, readings are not done in a normal speaking tone but are sung in a monotone. This keeps the resonance of the building on a single note, avoiding the sound overlap that could obscure the text.[24]

The differences between Byzantine chant and Western church music (Catholic or Protestant) highlight the influence of acoustics. Western Gothic cathedrals, although large, often had architectural features that *shortened low-frequency reverberation*: large stained glass windows and wooden vaults that absorbed or dissipated low-pitched sound.[25] Thus, Western composers were able to develop complex polyphonies and fast bass lines, knowing that the echo of the bass would fade quickly and would not influence the harmony.[26]

In contrast, in the East, stone and marble churches maintained a strong echo at all frequencies, even longer in the low register. As such, Orthodox music remained predominantly monodic; and where later influences (19th-20th centuries), introduced harmonized choral styles, German or Russian,

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[23] Stelian Ionașcu, *Cultura corală bisericească la români. Documente din arhiva Mitropoliei Ungrovlahiei (1876–1897)*. (Church Choral Culture among Romanians. Documents from the Archive of the Metropolis of Ungro-Wallachia (1876–1897) București: Editura Basilica, 2019, pp. 16-83. The volume provides an extensive documentary perspective on the organization, functioning, and cultural life of Romanian church choral music in the decades following 1876.

[24] Hilarion Alfeyev, *Orthodox Christianity,* "Russian Church Singing Church Singing in Kievan and Muscovite Rus'. Znamenny Chant", pp. 306-360.

[25] Andrew Gould, 'Acoustical Considerations in Orthodox Church Design'.

[26] Bagenal, Hope. "Bach's Music and Church Acoustics." *Music & Letters* 11, no. 2 (1930): pp. 146–155; Alberdi, Enedina, Miguel Galindo, Ángel Luis León-Rodríguez, and José León. "Acoustics in Baroque Catholic Church Spaces." *Acoustics* 6, no. 4 (2024): pp. 911–932; Johann Sebastian Bach - The Only Funeral Cantata in His Works: 'Gottes Zeit ist die allerbeste Zeit', BWV 106" de Petruța Maria Coroiu. *Studia UBB Musica*, anul LXIV (2019), nr. 1, pp. 325-330.

they were adapted: chords change very slowly, dwelling on each harmony for a long time (sometimes several seconds per chord) and recitative passages (rhythmic syllabification on the same note) are often used for long texts.

Rapid counterpoint in the bass is avoided, so that Russian choral music, for example, fills cathedrals with sound without the reverberation in the low register creating problems. On the contrary, the Russian tradition has embraced this acoustics: it has pushed the use of extraordinarily low voices (octavists) and powerful chords in the low register, making the deep "boom" of the bass echo a true cultural hallmark.[27] Thus, both Byzantine Orthodox music and later harmonized choral music were composed specifically to sound good in churches with long echoes, using ison, slow tempos and gradually developing melodies, avoiding elements that would be distorted in such sound environments.

This coexistence of the two traditions influenced the way churches were built and used in Romania. In small churches, the psaltic tradition remained dominant, while in large cathedrals and urban churches, where mixed or male choirs were active, the choral tradition gained particular importance.

4. The relationship between timbre, intonation and reverberation

An essential aspect of liturgical music is the interaction between vocal timbre and acoustic space. In Orthodox churches, where instruments are not

[27] Wade, Everett. "Developing Bass Sections through Extended Techniques and Auxiliary Registers." *Choral Journal* 60, no. 2 (Sept. 2019): pp. 56–64; (It explicitly discusses the Slavic choral tradition and the role of the oktavists (low bass singers), illustrating their contribution to the distinctive sonority of Orthodox liturgical music through examples drawn from Rachmaninoff's works, such as the All-Night Vigil (Vsenoshchnoye bdeniye, Op. 37) and the Liturgy of St. John Chrysostom (Liturgiya Svyatogo Ioanna Zlatousta, Op. 31). Galbraith, Robert. "The Case of Rachmaninov's *All-Night Vigil*." *Journal of the International Society for Orthodox Church Music* (JISOCM), 2020: pp. 143–162. (The Russian choral performance tradition is distinguished by its exceptional depth of timbre and resonance, achieved largely through the inclusion of oktavists—bass singers capable of producing pitches an octave below the written bass line. Emerging from the liturgical and monastic chant practices of the Russian Orthodox Church, the oktavist voice became a hallmark of Slavic sacred polyphony, providing a profound sonic foundation and a sense of spiritual gravity to the choral texture. Historical ensembles such as the Synodal Choir of Moscow and the Imperial Court Chapel Choir were renowned for cultivating powerful oktavists, whose extended lower register enriched the harmonic spectrum of works by Bortniansky, Tchesnokov, and Rachmaninoff. In modern times, this tradition continues through ensembles like the Don Cossack Choir, the Moscow Patriarchal Choir, and the State Academic Russian Choir, where prominent oktavists such as Vladimir Miller, Glenn Miller, and Mikhail Zlatopolsky have preserved and refined this distinctive vocal art. The presence of oktavists remains a defining feature of the Russian Orthodox choral sound—an audible symbol of spiritual depth and the resonant "earthliness" of the Slavic liturgical ethos).

used, the human voice is the only sound vehicle, and acoustics can amplify or diminish the quality of intonation.

Reverberation has an ambivalent effect. On the one hand, it can enrich the timbre of voices, giving them fullness and brilliance. This characteristic makes psalmody seem more expansive than it actually is, transforming the singing of a single protopsalt into a collective experience. On the other hand, the same reverberation can cover the liturgical text, making the words difficult for the faithful to understand.

The sermon tends to be the sensitive point. A homily cannot be delivered monotonously, and a preacher with a weak and dull voice will be very difficult to understand in a normal church. Fortunately, a strong, clear orator (usually someone who is also a good singer) can adapt their voice to the reverberation of the space and overcome this difficulty. Live acoustics encourage the preacher to speak more slowly, to use dramatic changes in intonation sparingly, and to pause at the end of a sentence until the sound dies away. All of these are good rhetorical techniques, and the acoustics of a church can support a successful sermon. But this requires the preacher to have the humility and auditory sensitivity to work with the acoustics of the space, not fight against them. Like any other aspect of church ministry, preaching in a space with acoustics that favor singing rather than speaking requires ascetic discipline.[28]

Since the word is fundamental in the Orthodox tradition – the hymnographic text embodies both dogma and prayer – the acoustics must ensure a balance between the beauty of sound and the intelligibility of the text. If the timbre is enhanced by echo, but the words become confused, the liturgical function of singing is compromised. The musical line intended for the Romanian liturgical text should avoid excessive melismas, preserving the clarity and phonetic expressiveness of our language. This simplicity is rooted in the gentle spirituality of the Romanian people, reflected throughout history in church architecture and iconography, but also in the intense religious life marked by renowned saints, martyrs and theologians. Romanian Byzantine chant expresses this gentleness through sober, single-tone liturgical recitative, which emphasizes the transmission of the text's meaning rather than musical ornamentation. Thus, the priority of singing remains fidelity to the hymnographic message, while the greatest dangers are excessive melismatics and a lack of tonal coherence between the singer and the priest in the liturgical dialogue.

For this reason, psalmists and conductors constantly adapt the intonation, speed and dynamics of singing to the acoustic characteristics of the space in which they serve.

[28] Vasile Gordon, *Omiletică, (Homiletics),* Editura Basilica, București, 2015, pp. 496-505.

5. Architectural aspects of religious buildings and their relationship with acoustics

The acoustics of an Orthodox church building are not the result of chance, but the direct consequence of architectural, construction and material choices. Every structural detail influences the way sound propagates, is reflected or absorbed, ultimately determining the quality of the sound experience of the service.

The first defining element is the central dome, specific to Byzantine and post-Byzantine architecture. The dome creates an effect of concentration and redirection of sound waves, amplifying resonance and generating a specific timbre, often perceived by believers as an "elevation" of sound towards the sky. The literature refers to diffusion, whereby sound spreads evenly around the center of the liturgical space. This phenomenon contributes not only to the beauty of the singing, but also to the liturgical symbolism, suggesting a union between the community's prayer and the transcendent space. A dome has a special acoustic force and must be correctly proportioned to function well.[29]

Historically, Orthodox domes were generally narrow in diameter (much smaller than the total width of the building) and very high, always placed above a cylindrical drum.[30] The acoustic effect of such a dome is mainly that of a reverberation chamber – a space in which sound can resonate for a long time without the risk of encountering absorbent surfaces, until it reaches the top of the drum, at which point the dome reflects it back down. As a result, the sound can persist in the dome even after it has faded in the spaces below. Thus, after the choir ends a chord, it is first heard reverberating everywhere, and in the final moment, it is perceived only from the dome. This creates the mystical impression for the listener of a sound descending from the sky, an effect of particular beauty.[31]

The vaults and arches also play an essential role in sound diffusion. Unlike spaces with flat ceilings, which can produce harsh reflections and unwanted echoes, the vaulting creates a natural dispersion of sound, reducing the risk of acoustic concentration in a single point. The side arches, frequently found in Romanian masonry churches, function as multiple reflection surfaces, enriching the sound texture and supporting choral singing. At the same time,

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[29] Richard Krautheimer, *Early Christian and Byzantine Architecture.* Penguin, ed. 1981; Cyril Mango, *Byzantine Architecture.* Electa/Rizzoli, 1985; Bissera V. Pentcheva, (ed.). *Aural Architecture in Byzantium: Music, Acoustics, and Ritual.* Routledge, 2017.

[30] Ene Branișteː *Liturgica generală cu noțiuni de artă bisericească* (*General Liturgics with Notions of Church Art*), p. 580.

[31] Andrew Gould, "Acoustical Considerations in Orthodox Church Design" in: *Orthodox Arts Journal,* nr 6, (2020).

an excessively high vault or the lack of diffusing elements may excessively prolong reverberation, diminishing the clarity of the liturgical text.[32]

Another element with a major acoustic impact is the iconostasis, together with interior furnishings. The iconostasis, although it has a central theological and aesthetic function, also acts as a partial acoustic barrier, separating the altar space from the nave. Its rich carving can contribute to sound diffusion, but the material (usually wood) absorbs some of the frequencies. Furniture such as choir stalls, chairs, and lecterns have a similar effect: they can disperse or absorb sound, influencing the uniformity of the acoustic field. Iconostasis has a significant effect on the acoustics of a church. It blocks the direct sound of the clergy in the altar, whose voices are mainly heard coming from above the iconostasis, where the semi-dome of the apse reflects them towards the nave.[33] At the same time, the iconostasis functions as a large soundboard, reflecting the voices of the choir and readers directly towards the congregation. For this reason, it is important that iconostasis be solidly constructed, with massive icons on sturdy supports.[34]

Last but not least, the construction materials are decisive for the duration of the reverberation. Stone and massive masonry favor a long reverberation, suitable for solemn and ample singing, but with the risk of diminishing clarity. Wood, due to its elastic nature, produces warmer and more intimate acoustics, reducing the duration of the reverberation. Plain plaster or mural painting can function as fine diffusion surfaces, while stone or marble floors amplify reflections. In a church, the balance between these materials determines whether the acoustics are perceived as “angelic” or, on the contrary, as “heavy” and tiring.

Thus, we can conclude that every architectural component, from the dome to the furniture, participates in the configuration of a “sonic icon” of the liturgical space, where aesthetic beauty and theological functionality meet.

6. Acoustics and the emotional-spiritual reception of singing

The acoustics of the liturgical space have a direct impact on how believers perceive and internalize sacred chant. The prolonged sound, with its ample reverberation, creates a sensation of temporal dilation and a

[32] Ene Branișteː *Liturgica generală cu noțiuni de artă bisericească (General Liturgics with Notions of Church Art),* p. 581.

[33] Pavel Florensky, *Iconostasis.* Crestwood, NY: St. Vladimir’s Seminary Press, 1996; Leonid Uspensky, *Teologia icoanei în biserica ortodoxă*, (The Theology of the Icon in the Orthodox Church), studiu introductiv şi traducere Teodor Baconsky, Editura Anastasia, București, 1994.

[34] Andrew Gould, “Acoustical Considerations in Orthodox Church Design” in: *Orthodox Arts Journal,* nr 6, (2020).

transcendence of everyday reality. This auditory experience, often described as "heavenly," promotes a state of deep prayer and inner transfiguration. It is no coincidence that many believers associate the lingering echo of psaltic and choral singing with the image of an angelic liturgy.

Orthodox believers experience the service not only visually (through icons and liturgical gestures) or olfactorily (through the scent of incense), but also acoustically, in a very special way. The reverberations of sound in a high church, the choral echo that floats under the vault after the completion of an ektenia, create an effect of "echo of eternity" as if the sound of prayer does not fade immediately, but continues to vibrate towards the sky. Many believers testify that the voices of the choir in a cathedral with rich acoustics can arouse intense emotion, a state of humility and spiritual elevation that is difficult to describe in words. The space itself seems to come alive, singing along with the people: the walls reflect and prolong the singing, giving it a magnitude that exceeds individual human powers. This perception of "supernatural" sound can be interpreted theologically as the presence of grace – the "voice" of the stone church unites with the voice of the Church as a gathering of believers, praising God.

On the other hand, a lack of acoustics or, conversely, inadequate acoustics can cause auditory fatigue. Weak sound, lacking resonance, transforms singing into a simple recitation devoid of emotional depth. Under these conditions, the intensity of religious experience is reduced, and singing loses its power to lead the soul to contemplation.

Thus, acoustics become a pastoral tool: it can elevate or, on the contrary, hinder spiritual experience. Therefore, priests, psalmists and architects must be aware that the sound environment of the church directly influences the effectiveness of collective prayer.

The musical experience of the liturgy is not limited to the intellectual dimension of receiving the text. Believers also perceive singing on a physical level, through the sound vibrations that propagate throughout the church. These vibrations create a sense of unity and communion, in which the entire community is integrated into a common sound flow.

From a psychological perspective, religious music acts as a factor of social cohesion.[35] The ample reverberation "melts" individual voices into a single

[35] Bradshaw, Matt, Christopher G. Ellison, Qijuan Fang, și Collin Mueller. "Listening to Religious Music and Mental Health in Later Life." *The Gerontologist* 55, nr. 6 (2015): 961–971; Gao, Junling, Stavros Skouras, Hang Kin Leung, et al. "Repetitive Religious Chanting Invokes Positive Emotional Schema to Counterbalance Fear: A Multi-Modal Functional and Structural MRI Study." *Frontiers in Behavioral Neuroscience* 14 (2020); Kreutz, Gunter, Stephan Bongard, Sonja Rohrmann, Volker Hodapp, și Dorothee Grebe. "Effects of Choir Singing or Listening on Secretory Immunoglobulin A, Cortisol, and Emotional State." *Journal of Behavioral Medicine* 27, nr. 6 (2004): 623–635. Oprea Severina-Maria. *Muzica liturgică în practica meloterapeutică,* (*Liturgical Music in Melotherapeutic Practice*) Editura Vatra Veche, 2020.

communal one, symbolizing the unity of the Church. In this way, participation is not limited to listening but becomes a corporeal and relational experience.

On the other hand, if the sound environment is unbalanced – either too reverberant or lacking in resonance – the community risks feeling either overwhelmed or disconnected from the singing. Acoustics, therefore, is not neutral, but has an important pastoral dimension: it determines the extent to which the community feels involved and participates in communal prayer.

A delicate but essential aspect is the balance between aesthetic pleasure and theological understanding of the singing. For many believers, the musical beauty of the service is a gateway to the religious experience. Balanced acoustics transform singing into a sound event that touches the soul, evoking emotion and compassion. From a pastoral perspective, this balance between music and theology is vital. Clergy and singers must realize that church music is more than art: it is sung prayer, and its spiritual effectiveness depends directly on how it is perceived in the liturgical space.

7. The role of technology in determining the right acoustics for sacred spaces

In a context where the Romanian Orthodox Church continues to build numerous churches and restore heritage monuments, these implications take on major importance both from a liturgical perspective and from that of heritage protection.

In the modern era, with the introduction of electronic amplification systems, it has been found that traditional acoustics (designed for natural voice and rich echo) can become a technical impediment, as loudspeakers require a space with less echo, otherwise the amplified sound becomes chaotic. Therefore, a balance is required: preserving the acoustics that uplift the soul but also managing them so that the word can be heard and understood by all.

Current solutions sometimes include the discreet use of sound-absorbing materials (wooden panels, curtains, thick carpets) in certain areas to reduce excessive reverberation, or the use of sound engineers to fine-tune the level of the speakers. Regardless of the means, the goal remains to maximize the spiritual experience: the believer should feel immersed in a sacred sound environment that speaks to their soul, without the message becoming incomprehensible.

One of the greatest contemporary challenges is to design new churches that simultaneously meet architectural, liturgical and acoustic requirements. In this regard, it is essential that architects, acousticians and musicologists collaborate from the design stage of the project.

Traditionally, many churches have been designed solely from an architectural and artistic point of view, without paying particular attention to acoustics. The result was that some buildings, although impressive in appearance, proved unsuitable for liturgical singing, having either excessive reverberation or a lack of resonance. To avoid these problems, digital simulation studies are becoming indispensable.

Both in the design of new churches and in the restoration of old ones, acoustics should not be viewed as a secondary technical detail, but as an essential element of the liturgical experience. Through interdisciplinary collaboration and the use of modern technology, it is possible to preserve and enhance what tradition has instinctively intuited: that sacred sound is an integral part of sacred space.

Technological progress in recent decades has opened up new perspectives on the study and optimization of the acoustics of Orthodox churches. Whereas in the past sound quality was assessed only through subjective impressions, today researchers, architects and musicologists can use high-precision instruments to understand how sound propagates in sacred space and to propose concrete solutions for improvement.

The first step in acoustic analysis is to take objective measurements in the church. Using specialized instruments (sound level meters, omnidirectional measurement microphones, calibrated sound sources), essential parameters can be determined: Reverberation time (RT60) – the time required for the sound to decrease by 60 dB after the source has stopped. In the wooden churches of Maramureș, the values are relatively low (below 1.5 seconds), while in monumental cathedrals they can exceed 5 seconds. Clarity (C50, C80) – indicators that show the extent to which the sung text can be understood by the faithful. Signal-to-noise ratio and sound distribution uniformity – which influence how each worshipper, regardless of where they are, perceives the chant.[36]

[36] Lubman D., Wetherill E. *Acoustics of worship spaces*, American Institute of Physics, New York, 1985. This work constitutes the first modern synthesis to assemble case studies on the acoustics of sacred spaces—churches, synagogues, mosques, and temples. It includes architectural plans and photographic documentation alongside tabulated metrics (RT/EDT, clarity, intelligibility), articulates the inherent trade-offs between musical richness and speech intelligibility within liturgical practice, and advances design principles—spanning geometry, materiality, acoustic treatments, and electroacoustic reinforcement—to realize either a music-forward acoustic, a speech-optimized environment, or a calibrated balance of the two. The volume is widely recognized as a foundational cornerstone for subsequent scholarship on worship-space acoustics. Małecki P., Wiciak J. (2011), *Acoustic parameters of chosen orthodox churches overview and preliminary psychoacoustic tests using choral music*, Proceedings of 130th AES Convention, London, UK; Rossing T., *Handbook of Acoustics,* Springer, Stanford, 2007.

Current technology offers the possibility of performing computer simulations of a church's acoustics. Using programmes such as *Odeon*, *CATT-Acoustic* or *EASE*, architects and acousticians can build three-dimensional models of space and introduce variables related to materials, volume and architectural forms.

In many cases, technology also allows for acoustic optimisation interventions without altering the sacred and aesthetic character of the church. Solutions must be discreet and aesthetically integrated so as not to contrast with the liturgical and symbolic function of the building. These include: acoustic absorption panels concealed in decorative elements, for example, integrated into wooden pews or ceilings; sound-absorbing textiles, carpets, liturgical drapes, and coverings that can reduce excessive reflections; furniture with a diffuser role (benches, pews, carved iconostases) that 'break' sound waves and reduce disturbing echoes; adaptive digital sound systems, which, without replacing the natural voice, can correct certain sound imbalances in very large spaces.

Such solutions must be applied with discernment, so as not to transform the church into a mere concert hall, but to preserve the unity between architecture, acoustics and liturgy.

Conclusions

In the Orthodox tradition, the sound space is integral to liturgical logic itself: the way in which the church "responds" to the chant determines both the intelligibility of the sacred word and its affective-mystagogical power. The dome, vault and reflective materials (stone, marble, dense plaster) generate an acoustic field that has nourished, over the centuries, the monodic aesthetics of psaltic music (ison, slow tempo, legato phrasing). In large, highly reverberant spaces, singing acquires the "extension" and fluidity that support its ethos. Psaltic singing flourishes in ample reverberations (where the prolonged sound of the ison and melismas can breathe), while harmonized choral singing requires balance: sufficient resonance for timbre, but clarity for text and polyphony. This results in interpretative adaptations (tempo, articulation, consonant placement) required by each space. Hagia Sophia remains the paradigm of space-sound synergy. Its example shows that architecture can become a "liturgical instrument": the long reverberation and diffusion of the dome transform singing into a theological experience of space. This paradigm explains why certain Byzantine musical pieces reveal their full meaning only in spacious acoustics. The iconostasis, the furniture, the presence of faithful and the distribution of volumes decisively influence the clarity and homogeneity of the sound field. A visually "beautiful" but acoustically unsuitable space can

weaken the catechetical and prayerful function of music. From wooden churches (short reverberations, intimacy) to urban cathedrals (long reverberations, monumentality), the sound identity varies and shapes local practices. This diversity requires nuanced solutions, not uniform "recipes." Technology is a means, not an end. Parameter measurement, auralisation, and 3D simulation can guide design/restoration, but interventions must be discreet and compatible with symbolism and liturgical function. The goal remains mystagogical: clarity of speech accompanied by timbral fullness.

In essence, the acoustics of the Orthodox church is a "sound icon" in which the theology of space, musical practice and community experience come together. When conceived together, architecture and singing produce not only a beautiful sound, but an experience that catechises, unites and leads to prayer.

Translated from Romanian by Angelica Marcu

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