



# Church acoustics: A state-of-the-art review after several decades of research



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## ABSTRACT

This work describes and analyses the principal contributions to the acoustics of occidental Christian churches from the second half of the last century to the present day, mainly in ancient historical churches. After more than six decades of research, it seems appropriate to summarise the major pieces of work in this field, and, to this end, this paper aims to provide an up-to-date document of all the most relevant studies which describe the exhaustive investigations of acoustic characterisation in time-consuming experimental campaigns carried out by several groups of researchers in various European countries. The article presents, for the research into church acoustics developed in each country, the experimental procedures, the results, discussions, the theoretical interpretations of the sound propagation in these spaces, the subjective aspects in the listening experience, and the method of implementation of computer simulation techniques and their applications in these complex enclosures. Other contributions from Asian and American continents are also included. Findings and advances in each of these areas as well as perspectives on their future challenges are summarized and discussed in this work.

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## 1. Introduction and motivation of the paper

Room acoustics is a relatively young scientific discipline. Since its beginnings (Sabine 1868–1919) slightly more than a century ago, systematic research developed by Schroeder [1], Beranek [2], Barron [3], Ando [4], and Bradley [5], among others, has enabled very precise indicators to be ascertained for the acoustic-architectural design of concert halls and auditoriums in relation to the preferred conditions of the audience. The relatively little research on church acoustics, compared with the large number of investigations that have been carried out into the acoustics of theatres and concert halls, provided a major incentive for the launching of the study of the acoustics of churches from transdisciplinary aspects in several countries in the middle of the last century and as indications for the design of new churches.

Since the earliest known societies, mankind has built sumptuous enclosures dedicated to worship and communication with their deities. In our civilisations, remarkable buildings dating back to pre-Christian polytheistic and pagan religious cultures remain conserved, which have exerted great influence in the Christian church.

In the extensive interval of time between the construction of the Greek Odeon and the Auditorium of the 20th century, the church has occupied the most prominent place, among the different models of buildings, as a location that has

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witnessed the birth of music. The subsequent fostering of music, as a consequence of the lack of specialised architecture, marks a fundamental trace, which has to be taken into account to understand the history of church construction and of music.

The clandestine and illegal character of the Christian church of the 1st and 2nd centuries obliged the first Christians to hold their worship meetings in the homes of their members (*Domus Ecclesiae*) and to occupy the underground galleries of ancient mines in Rome (*Catacombs*). The sound of rites and songs must have reverberated for a long time in the galleries, as it corresponds to the acoustics of the cave, and these would have a decisive influence on the later development of the church liturgy. From the Hebrew tradition, the early Christian church inherited the taste for the intonation of fragments of sacred texts to give an emphatic value to the rite and the attainment of transcendent states. This effect had to be greatly reinforced by the surrounding atmosphere created in very reverberant spaces, such as the pre-Romanesque churches. It is also important to note that the role played by Pope Gregory the Great (590–604) [6] would lead to the institutionalization of the choir as a figure in the liturgy and, therefore, the establishment of choir stalls in the church.

As elements that connect acoustics with architecture and furniture of the church, we emphasise the *choir* and the *organ*. The position of the choir in the church has evolved according to the importance granted to singers throughout history, originally clergymen and canons, and to the various architectural styles. In the catacombs, the choir was named as the place reserved in front of the altar for sacred songs. Subsequently, when they occupied the basilicas, the choir was placed in the transept or was arranged behind the altar.

In Byzantine churches, in which the central cruciform floor plan prevails, the choir is located in the transept, below the dome, with the resulting acoustic inconveniences derived from this location. In many Medieval monastic churches, the choir was located in the main nave, closed off with a fence or a balustrade that was supported in the lateral columns. Many cathedrals also adopted this provision, and gave the choir this situation for its sculptural value. In the latter monumental spaces, the choir ends up being the pretext for the furnishing of the interior, acquiring a sculptural character and obviating the functional and acoustic requirements. Gothic architecture encloses the choir with highly decorated walls and with chairs that used to be double in height: high choir, for the canons; and low choir, for the clerics. However, depending on the use of the church, this situation (choir in the nave) can be found coexisting with the choir in the apse. Renaissance architecture, and later Baroque, had a clear vocation to eliminate the choir from the central nave, since it was considered as an obstacle in the perception of the unique space and for the perspective, factors which were valued as greatly superior to the acoustic factors in the hierarchy maintained by the architects of the time. In addition, the singers were no longer clergymen, but largely professionalized groups, for which the protagonism of the choirs was no longer necessary.

Of all the instruments that broke into the instrumental music performed in churches, it was the organ, thanks to its special characteristics, that was destined to be erected as the liturgical instrument par excellence. Its power and wide timbral registry form the basis of this success. The organ, with the imposing presence of the pipe and its versatility for ornamentation, was able to adopt a preeminent place in the church, since it was considered as an element of prestige of the church and constituted part of the ornamentation and architecture of the temple. In the great cathedrals, with the choir at the top of the nave, the organ and its pipe architecture would also be used as an enclosure of the choir. In smaller churches, it would be arranged along a lateral wall, to later occupy, along with the choir, the upper part of the main nave.

It is difficult to find references to the acoustic diagnosis of these spaces in architectural and musical historiography, despite the large number of documentary sources that deal with the relationship between ecclesial architecture and music [6]. In addition, in order to understand the acoustic needs of the Christian church in the 21st century, it is convenient to analyse the origins of the church, for which authors refer readers to the first chapters of Jones's book [7] and to the research by Navarro et al. [8], which will be discussed later.

This work focuses on exposing the major contributions (mainly published in journals) written in English, of ancient and historical Christian churches in European countries, leaving aside the acoustics of other prehistorical Christian churches, such as catacombs, and the acoustics of the Christian churches of the 20th century. With the aim of delimiting this review, numerous contributions published in national congresses and/or in other languages have been excluded, although a number are mentioned due to their relevance, as in the case of an important monograph on historical churches published in German by Meyer [9]. Other contributions of reputed authors in the literature from other continents are also included.

According to UNESCO, the majority of these buildings, especially the cathedrals, are considered part of the cultural heritage. From an architectural point of view, cathedrals are complex monuments resulting from a prolonged effort and exert a cultural projection that works both towards its interior space and towards the outside, thereby providing a spatial reference of the cities, and conditioning its urbanism. In this way, cathedrals hold a social and symbolic value added to their essential religious function. Their current configurations are the result of successive demolition, extensions and reforms, a fact that is common to all European cathedral architecture.

In October 2003, the General Conference of UNESCO approved the Convention for the Safeguarding of the Intangible Cultural Heritage, which entered into force on 20 April 2006 [10]. This Convention recognizes the importance of intangible cultural heritage, which is particularly vulnerable, and often goes unnoticed although it does constitute the melting pot of cultural diversity. The acoustic heritage of historical religious buildings is framed within this intangible cultural heritage and therefore worthy of being investigated and preserved. The acoustic behaviour of religious heritage buildings is highly relevant both for readers of journals with exclusive acoustic content and for readers of other journals of an interdisciplinary nature.

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