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Historical and chronological evolution of the concert hall acoustics parameters

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The present paper examines the historical evolution of the concert halls acoustic parameters, in the international field. From the beginnings of twentieth century, the acoustic parameters have had a continuous evolution, covering more and more aspects of the concert hall acoustics qualification.
Since the bibliography about these is fragmented, we performed in this article, a global and updated presentation on the chronology and the evolution of the studied parameters.
Considering the great variety of the same, we presents the appearance of each parameter, located in decades, who has proposed them and, where is possible, indicates articles or publications where they have been presented for the first time. Thus, the historical presentation of the majority of the acoustic parameters of concert halls, it optimizes and can be useful for future research as a central platform in a bibliographical study. The presentation of the same is also grouped according to quality criteria.

1 Introduction

The acoustics of halls, in our case the concert hall, has had a great development, since Clemens Wallace Sabine [1] If, initially the discovery of "the reverberation time" as persistence of the sound in an enclosure constituted the most important parameter in the evaluation of the hall (already from its definition is clearly a perceptive, subjective and multidisciplinary parameter), in the following decades, new descriptors are added to analyze and to design the existent halls as well as those in phase of construction. It is necessary to emphasize that the objective of the study, is not to present the parameters definitions that can be found in specialized bibliography, is the most possible complete review of the developed acoustic parameters throughout the time. At present the acoustic investigators have stated the existence of independent parameters and other interdependent ones, which had lead to a different approaches and a great diversity of scientific opinions on the matter. In this direction, Gimenez [2] studied the evolution of investigators groups of belonging to schools of: Dresden (Reichardt, Schmidt, Shultz, Cremer, Kürer), Goettingen (Gottlob, Siebrasse, Eysholdt and Schroeder), Berlin (Lehman and Wilkers), Japanese School (Hidaka, Maekawa, Morimoto, Okano) and acoustic as Ando, Barron, Beranek, Fricke, Gade, Haan, Marshall, Kahle, Farina. In the Spanish land, investigators from Universities of four Independent Communities (Catalonia, Navarre, Seville and Valencia), study the correlation between objectives parameters and the subjective answers of the listeners. [3].

2 Qualifying Parameters

The study it is initiated with Leo Leroy Beranek, due to the extensive study realized in the concerts hall acoustics research. . The parameters proposed by Beranek [4] are the following ones:

1)-Reverberation and Fullness of tone, 2)-Direct sound, Early Sound, Reverberant Sound, 3)-Early Decay Time-EDT,. 4)-Speed of Successive Tones, 5) - Definition or Clarity, 6) - Resonancy, 7)-Intimacy or Presence and Initial Time –Delay Gap, 8)-Liveness or Mid Frequencies, 9) - Spaciousness, 10)-Warmth, 11-Listener Envelopment, 12) - Strength of sound and Loudness,. 13)-Timbre and Tone Colour, 14)-Acoustical glare, 15)-Brilliance, 16) - Balance. 17)-Blend,. 18)-Ensamble. 19)-Immediacy of response (Attack), 20)-Texture, 21) –Echoes,. 22)-Dynamic Range, and Background Level, 23)-Detriments to Tonal Quallity., 24)- Uniformity of sound in Audience areas.

2.1 Chronological Order

In the following table, a list of acoustic parameters, in chronogical order, we present:

Year	Parameter	Author	Reference
1922	Reverberation Time	Sabine	[1]
1930	Reverberation Time Eyring	Eyring, Norris	[5]
1933	Reverberation Time Milingtone	Milingtone Sette	[6] [7]
1953	D50-Definition	Thiele	[8]
1953	D80-Definition	Thiele	[8]
1959	Reverberation Time Fitzroy	Fitzroy	[9]
1961	Signal-to-noise ratio	Lochner y Burger	[10]
1962	Br, Brilliance	Beranek	[11]
1962	Timbre, BR	Beranek,	[11]
1962	Texture	Beranek	[11]
1965	R-reverberance	Beranek	[12]
1965	Hallmas	Beranek, Shultz	[12]
1965	Steepness	Schroeder	[13]
1966	Hallabstand	Reichardt, Schmidt	[14]
1967	ASW, apparent source width	Marshall	[15]
1968	BQI,Binaural Quality Index	Keet	[4]]
1970	EDT, Early Decay Time	Jordan	[16]
1971	T_S, Center Time	Kürer,R.	[17]

Year	Parameter	Author	Reference
			[18]
1971	LF,Lateral Fraction	Barron	[19]
1971	Alcons	Peutz	[41]
1973	K, Korrelationsgrad	Gottlob	[20]
1974	C50, Clarity 50, speech	Reichard y Abdel Alim	[21]
1974	C80-Clarity 80, music	Reichard y Abdel Alim	[21]
1974	IACC, Interaural Cross Correlation	Schroeder/ Ando	[22]
1975	Inversion Index	Jordan	[23]
1976	Reverberation Time, Kuttruff	Kuttruff	[24]
1976	G-Strenght	Lehmann	[25]
1976	S-Spectral Density	Eyshold	[26]
1979	ITDG	Davis	[27]
1980	STI, Speech Transmission Index	Steenek, Houtgast	[28]
1980	C7-direct sound level	Ahnert	[29]
1980	LE, lateral efficieny	Jordan	[30]
1981	SI-Spatial impression	Barron	[18]
1982	Rise Time	Jordan	[31]
1983	ITDG2	Ando	[32]
1985	RASTI, Rapid Speech Transmission Index	Steenek, Houtgast	[33]
1986	EK speech	Dietsch	[34]
1986	EK music	Dietsch	[34]
1988	RECC, Reflective Energy Cumulative Curve	Toyota	[35]
1989	LFC, lateral fraction coefficent	Kleiner	[36]
1989	EEL,Early Ensemble Level	Gade	[37] [38]
1995	LEV,Listener Envelopment	Bradley, Soloudre	[39]
1999	Reverberation Time Neubauer	Neubauer	[40]
2004	[1-IACCE3], BQI	Beranek	[4]

2.2 Acoustic Quality Criteria Order

At present, the parameters descriptors of the concert acoustics halls can be grouped in the following three generic criteria:

a) – Energy Criteria, studying the transparency of the hall (separated perception of tones in the time and the instruments playing simultaneously), among which the most important are: Definition introduced by Thiele in 1953 [8], Clarity defined by Abdel Alim and Reichardt in 1974 [21], G-Strenght defined in 1976 by Lehmann [25].

b) - Time Criteria that quantify the Reverberation. (degree of the hall liveliness). The most known is the Reverberation Time [1] developed later by Eyring -1930, Millington - 1933, Fitzroy-1959, Kuttruf-1976, in Spain by Higini Arau. - 1988 [42], Neubauer-1999.

Furthermore, it was established the equations for calculation of T10, T20, T30. For the time being EDT (Early Decay Time) defined by Jordan in 1970, is considered the most representative parameter by the majority of the investigators.

c) - Spatial Criteria, to define the space Impression (feeling like surrounded by the sound, get the impression of small room and near the sound source).

Parameters like: Lateral Fraction (LF), defined by Marshall and developed by Barron or the similar parameter Lateral Efficiency (LE), defined by Jordan. In 1968 Keet [4] proposes the BQI, that later will define the form [1-IACC3]. A very important binaural parameter that was introduced by Schroeder and Ando, in 1974, is Interaural Cross Correlation (IACC) with its two components the IACCE and the IACCL.

Due to the importance of the space impression, the acousticians continue developing this line with other quantification parameters like: apparent source width (ASW) defined by Marshall and developed by Barron that becomes a subjective parameter of the space in the concert halls and is related to the level of the early lateral reflections. Marshal and Barron developed the equations for the ASW calculation.

Another component of the spatiality is LEV (listener envelopment), and describes generally the impression of a listener being surrounded by the sound. Beranek [4] considers that the IACCL can be considered a parameter of measurement for LEV. According to Bradley and Soloudre [39] the level of the delayed lateral energy can measure the LEV. The IACCE measures the apparent source width ASW and IACCL measures the envelopment of listener LEV.

Year	Time Criteria	Autor
1922	Reverberation Time	Sabine
1930	Reverberation Time Eyring	Eyring, Norris
1933	Reverberation Time Millington	Milingtone Sette
1959	Reverberation Time Fitzroy	Fitzroy
1962	Timbre, Bass Ratio	Beranek
1962	Br, brilliance	Beranek

Year	Time Criteria	Author
1962	Texture	Beranek
1965	Steepness	Schroeder
1970	Early Decay Time	Jordan
1975	Inversion Index	Jordan
1976	Reverberation Time Kuttruff	Kuttruff
1979	Initial Time Delay GAP	Davis
1982	Rise Time	Jordan
1983	ITDG2	Ando
1988	Reflective Energy Cumulative Curve	Toyota
1999	Reverberation Time Neubauer	Neubauer

Year	Energy Criteria	Author
1953	Definition	Thiele
1965	Hallmass	Beraneck, Shultz
1966	Hallabstand	Reichard, Schmidt
1974	Clarity	Reichardt, Lehmann, Abdel Alim
1976	Strength	Lehmann
1971	Centre Time	Cremer-Kurer
1976	S, Spectral Density	Eysholdt
1982	EEB, Early Energy Balance	Jordan

Year	Spatial criteria	Author
1960	SDI, Surface Diffusivity Index	Haan, Fricke
1960	SI, spatial Impression	Barron, Marshall
1960	RR, index of roomresponse	Dresden school
1971	LF, Lateral Fraction	Barron, Marshall
1973	K, Correlation degree	Gottlob
1974	IACC, Interaural Cross Corelation	Ando
1974	IACCE, Interaural Cross Corelation, early	
1974	IACCL, Interaural Cross Correlation, late	
1980	LE, Lateral Efficiency	Jordan
1989	LFC, Lateral Fraction Coefficient	Kleiner

Year	Stage criteria	Author
1989	EEL-Early Essembly Level	Gade
1989	Room suport, ST1(2)	Gade

Year	Speech Criteria	Author
1953	D50, Definition	Thiele
1971	ALcons	Peuz
1980	C-50, Clarity	Ahnert
1985	RASTI-STI	Steeneken, Houtgast
1986	Echo criterio	Dietsch

2.3 Alfabetical Order Index

[1-IACC3], Beranek, 2004
ASW, Apparent Source Width, Marshall, 1967
BQI, Binaural Quality Index, Keet, 1968
Br, Brilliance, Beranek, 1962
BR, Bass ratio, Beranek, 1962
C7, Direct sound measure, Ahnert, 1980
C80, Clarity, Abdel Alim y Reichardt, 1974
D80, Definition, Thiele-1953
EDT, Early Decay Time, Jordan, 1980
EEB, Early Energy balance-Jordan, 1982
EEL, Early Ensemble Level, Gade, 1989
EK music (Echo criterion), Dietsch, 1986
G, Strenght, Lehmann, 1976
Hallabstand, Reichard y Schmidt, 1966
Hallmass, Beranek y Schultz, 1965
IACC, Interaural Cross Corelation, Ando, Schroeder, 1974
IACCE, Interaural Cross Corelation Early, Schroeder, 1974
IACCL, Interaural Cross Correlation Late, Schroeder, 1974
II, Inversion Index, Jordan, 1975
ITDG, Initial Time Delay Gap, Davis, 1979
ITDG2, Ando, 1983
K, Korrelationsgrad, Gottlob, 1973
LE, Lateral Eficiency, Jordan, 1980
LEV, Listener envelopement, Bradley, 1995
LFC, Lateral Fraction Coefficient, Kleiner, 1989
LF, Lateral Fraction, Lateral, Marshall, Barron, 1983.
RASTI, Rapid Speech Transmission Index, Steenek, Houtgast, 1985
RECC, Reflective Energy Cumulative Curve, Toyota, 1988
Ratio Signal-to-noise, Lochner y Bruger-1961
R-Reverberance Measure-Beranek, 1965
Reverberation Time, Arau, 1988
Reverberation Time, Eyring, 1930
Reverberation Time, Fitzroy, 1959
Reverberation Time, Kuttruff, 1976
Reverberation Time, Milingtone, 1933
Reverberation Time, Neubauer, 1999
Reverberation Time, Sabine, 1922

TR, Rise time, Jordan, 1982

Ts, Center Time, Cremer-Kürer, 1971

S-Spectral Density -Eysholdt 1976

SI, Spatial Impression, Barron, Marshall, 1981

S, Steepness, Schroeder, 1965

ST1/2-Soporte-Support-Gade, 1989

STI-Speech Transmission Index, Steenek, Houtgast, 1980

3 Conclusions

The paper presents a review concerning the historical evolution of the acoustic concert halls parameters, at the international level. Since the bibliography about these is fragmented, we performed in this article a global and updated presentation on the chronology and the evolution of the studied parameters and, where is possible, indicates articles or publications where they have been presented for the first time, to serve to the researcher interested in the room acoustics study.

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