Performance hall stereophonic reverberation time accurate measurement and new graphic implementation

Franz Policardi[1]

[1] *DIENCA, Engineering Faculty Bologna University, 40123 Bologna, E-Mail: franz.policardi@mail.ing.unibo.it*

Abstract

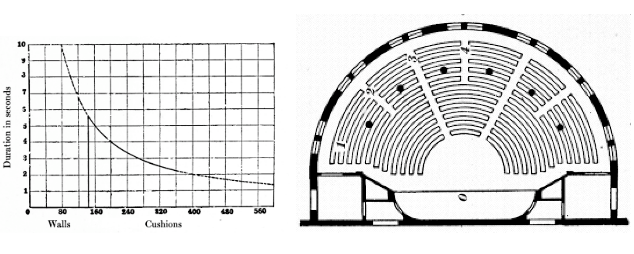
Modern reverberation time (RT) measurement in performance spaces is usually performed in accordance with ISO 3382 part 1. Mentioned measurement system is derived from sound propagation physical characteristics and takes less into account real listener's positions in the room. This study describes accurate stereophonic reverberation time measurement and distribution over a complete theatre parterre and its octave band new graphic implementation (GI) in stereophonic form. The aim is to allow real different listener's sensation better understanding over the full listening area and data elaboration show very interesting and unespected results.

Introduction

Many scientists and technicians still referr to RT as *the* acoustical parameter as in [1] pp VII and in Annex A introduction. Although during past century many other room acoustic sound qualities have been investigated and coded, most performance space acoustic investigation starts from RT. From a mathematical point of view its comprehension is deep enough and measurements define a room with a charachteristic RT number. Accurate room measurenents and modern simulations evidence different RT values in different room positions and author's working high end classical music recording experience tells about very subtle RT differences discrimination capabilities by colleagues and musicians. Acousticians seem still adher to ISO 3382 classic understanding, representation and GI [1].

Historical RT GI representation

W. C. Sabine RT historical representation tells about a matematician elaborating a mathematicah RT theory from experimental results. Sabine's representation was a cartesian graphical representation which was for those time already very innovative. While Sabine's measurements where binaural (made using Sabine's own ears), in this representation no acoustic space information is present rather than O observer's position and from 1 to 4 absorbers positions. Measurements have been performed through 4 single different organ pipes as sources, averaging results up to 1/100s. [2]



Figures 1a and b: 1a Sabine's original 1898 RT graphical representation, 1b experimantal positions (pag 22 and 19).

Subsequent Sabine's experiments took into account listener's position investigating RT fluctuations in the room and again organ pipes have been used as sound sources. Experiment results showed practically that "*variations there shown are within the limit of accuracy of the apparatus employed*" ([2] pag. 17) determining the assumption that "*The duration of audibility is nearly indipendent of the position of the source*" [2] pag. 18. One channel information is presented. Interesting to notice that Sabine has probably indirectly inspired ISO 3382 various versions in relation to results averaging as in [1] 5.2.2 and Figure 2. But is this correct?

Station	Duration	Station	Duration
1	2.12	5	2.23
2	2.17	6	2.27
3	2.23	7	2.20
4	2.20	8	2.26

Figure 2: Sabine's original RT duration measurements in relation to listener's position in the room ([1] pag 17)

Interesting to notice that Sabine has probably indirectly inspired ISO 3382 various versions in relation to receiver positions as in Figure 3 and in ISO 3382 page 19 „*Because most halls are symmetrical about the centre line, receiver positions can be arranged on only one side of the hall with source positions located symmetrically about the centre line* " [1]. Acoustic measurements are therefor performed in just half of the performance halls. But is this correct?

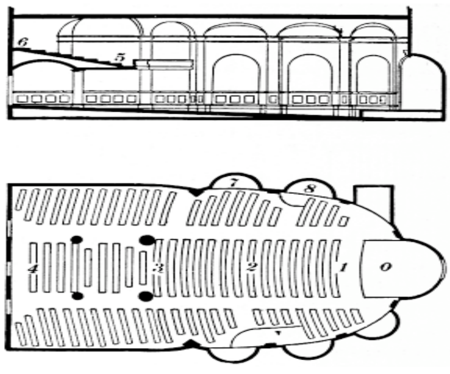


Figure 3: Sabine's original RT source and listener's positions in the room ([1] pag 17)

In Max Adam's 1958 book [3] is explained Basel Grosser Koncertsaal acoustic measurement evolution through 2 decades telling about 12 to 18 averaged positions showing RT frequency dependence. Noticeable the RT measurement frequency extension: 100Hz – 4.544Hz in 1936 and 1944 extended to 50Hz – 6.400Hz in 1957 and its ½ octave looking investigation. RT duration differences are due to various room renovations and no source – receiver information is present. We can assume a half room measurement. Werther many experiments were at that time well known on multichannel listening and recording [4], one channel information is here presented too.

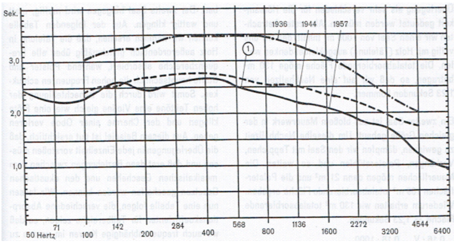


Figure 4: Basel Grosser Koncertsaal RT measurement evolution in [3] pp 61

If we look at Beranek [5] we find a single number characterizing RT for a complete hall, Barron [6] shows a single characteristic curve GI and even in today's most updated 36th DAGA official book [7] we see a single characteristic curve GI without measurement position or two ears information.

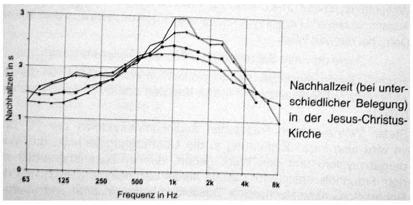
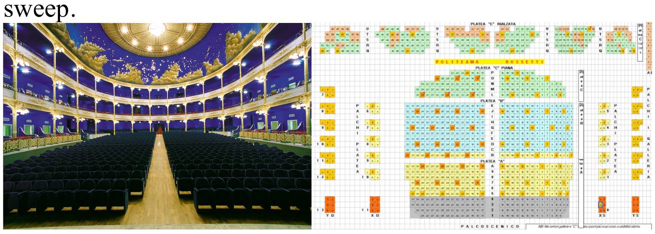


Figure 5: 36th DAGA official book 1/3 octave RT measurement p 25

We can then assume that this is *the* RT usual GI. But, taking into account that humans have two ears, that in different seating positions perceived sound is different, that perceived sound is different for two ears, that computational power greatly increased in last decade, that simple computer graphics can deliver enormous visual informations at the same time, is then this any more correct and enough?

Measurements

Having investigated listener's habits first, acoustic perceived problems subsequently and chosen an appropriate performance space, 10 hot July 2009 days have been spent in Trieste Politeama Rossetti to map its parterre. 950 seats have been mapped as in Figure 6b through 2 x Neumann KU 100 dummy heads stimulated by a 30'' 20Hz – 20kHz sine sweep.

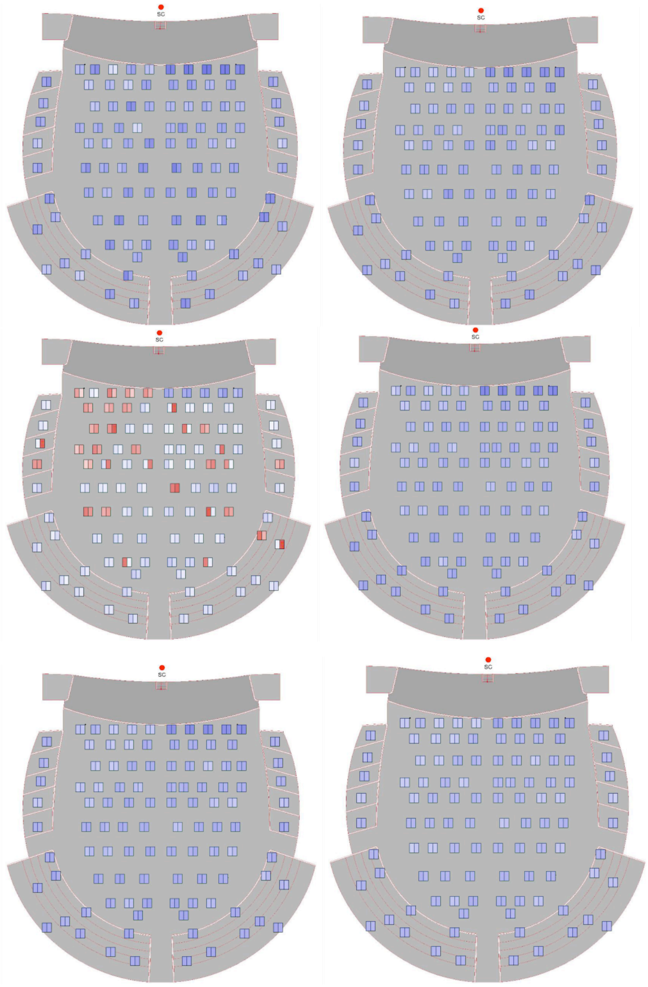


Figures 6a and b: 6a Trieste Politeama Rossetti room view from stage, 6b parterre 104 receivers positions

Recording was PC based and post processing performed on Aurora 4.2. All ISO 3382 part 1 measurement requirements have been matched as concerns souce requirements, equipment S/N, room temperature, humidity and so on. It has been decided to not match receivers placement limitations because listeners seats are situated in theses positions also. N.8 Spacial averaging has not been performed and N.9 Statement of results GI has been updated through a now binaural an innovative GI. Annex A requirements have been overcame also, choosing 104 receivers positions instead of 8, as advised in [1] p20. Measurements took a lot of time because of microphone positioning and particular care on room S/N and because of sometimes complicated miocrophone-stand positioning as close as possible to performance space walls because of real seats positions.

New graphic implementation Results

Octave band analysis show interesting phenomena as for example non equal acoustic room behaviour even if architectonically symmetrycal, unespected seating position acoustic micro behaviour even if very close, differences in single listener's RT binaural perceivings over 5% JND [5].



Figures 7a, b, c, d, e and f: 7a RT 125Hz, 7b RT 250Hz, 7c RT 500Hz with speech (red 1-1,4s) and music (blue 1,4-2s) best positions differentiation, 7d RT 1kHz, 7e RT 2kHz and 7f RT 4 kHz

Comparison with other graphical implementations

Other GI are actually already present in room acoustics and a validation comparison seemed appropriate. Trieste Politeama Rossetti was acoustically accurately investigated by Ferrara University colleagues [7] in 2006 under ISO 3382 part 1 requirements and this allows good comparison capabilities. Official measurments have been graphically implemented as stated in ISO 3382. RT30 shows 4 source positions average data graphs and explains its results without listener's point of „hearing". Too much low frequency reverberation, well averaged for mid and high frequency bands are explained as seen in Figure 8 and that's all.

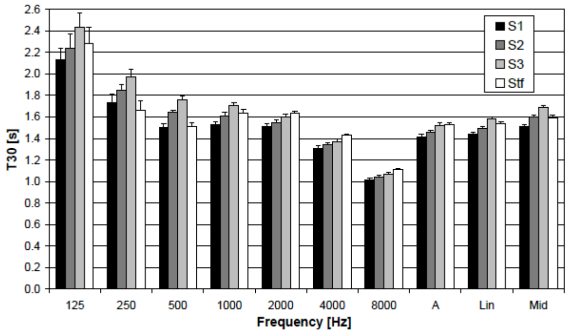
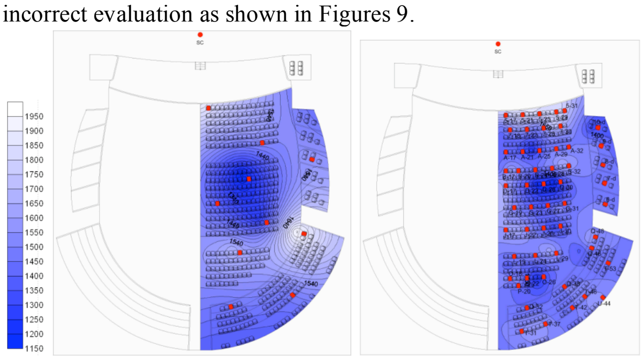


Figure 8: Ferrara 2006 study: T30 for S01, S02, S03 and Stf (closed fire curtain) listening positions, from 125Hz to 8kHz

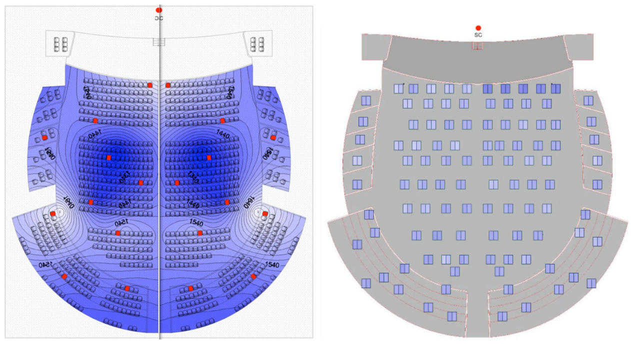
No RT seating dependent information is present as regards performance space user, because this is not requred and is clearly not allowed in [1] requiring data averaging: „ *The results measured for the range of source and microphone positions can be combined either for separate identified areas or for the room as a whole to give spatial average values*." (point 8, page 10).

Using same data collected in July 2009, a monophonic comparative simulation has been performed under [1] requirements with just 10 listener's positions (half parterre, low resolution) and with author's 104 monophonic averaged measurements (complete parterre, high resolution). Surfer 2D isolevel technique comparative plots show impossible real RT behaviour comprehension in many hall areas using [1] requirements and half parterre low resolution technique. For example right front first row longer duration is neither detected with [1] averaging process nor with low resolution technique. Depending on which hall half is measured, RT evaluation is either too high if right side is investifgated or too low if left side is investigated and higher not real RT is plotted in close to central exit position using low resolution technique leading in both cases to incorrect evaluation as shown in Figures 9.



Figures 9a and b: Low and high resolution T30 behaviour comparison

A comparison between half parterre and complete perterre mapping shows how, depending on which hall half is measured, RT evaluation is either too high if right side is investifgated or too low if left side is investigated leading in both cases to incorrect evaluation as shown in Figures 10.



Figures 10a and b: Low resolution half parterre vs high resolution complete parterre T30 behaviour comparison (1kHz)

Discussion and conclusion

Data evidence allows to state that this sort of seat FEM „stereophonic" or better „binaural" graphical implementation performed with many more positions than required in [1] allows a lot better RT comprehension, even if more time and effort demanding. This aproach opens many developments and can for example give the possibility to match listener's hearing capability to single seat acoustic microenvironment, listener's seating position can also be chosen in respect to artistic program, tickets can be sold in respect to acoustical listener's habits and not only in respect of visual cues and many others.

Because western music is standardized in semitones it would be interesting to investigate RT up to this definition. Arabic or indian music may require even more subtle investigations. All main acoustic parameters are now under investigation through this new graphical implementation and will be presented in author's doctoral thesis.

Aknowledgments

Ing. StephanPeus from Neumann GmbH for KU 100 borrowing, ing. Gianni Amadasi from 01dB for loudspeaker borrowing and dott. Stefano Curti for Trieste Politeama Rossetti „borrowing".

Literatur

[1] ISO 3382 Part 1, *Acoustics – Measurement of the reverberation time*, Geneve 2003;

[2] Sabine, W. C., *Collected Papers On Acoustics*, Harvard University Press, Cambridge 1923;

[3] Max Adam, *Akustik*, Verlag Paul Haupt, Bern 1958, pp 60-61;

[4] F. Policardi, *Good old digital in bad digital era (for music) or ... ?,* (keynote lecture, invited paper) 17. EKR 2008, Portorož - Slovenia;

[5] Beranek L. L., *Concert halls and opera houses*, Springer, New York 2004;

[6] Barron M., *Architectural acoustics and architectural design*, Taylor&Francis, London 2009, p 59;

[7] N. Prodi, *Relazione Tecnica: misure di qualificazione acustica del Politeama Rossetti di Trieste*, Ferrara 2006.