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S/N and IACC requirements in electroacoustical sound space re-creation: Garda 2010 case study

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Abstract

Open air Opera summer concert sound reproduction has become more and more popular after the first Three Tenor's 1990 Rome event. The natural acoustics has to be most of the time re-created in unfavourable environmental conditions, as for example a huge number of listeners, inadequate surroundings, imperfect weather and background noise. The up to date acoustics suggests attention to the different important parameters characterizing the original sound field behaviour. They have to be first correctly picked up and then reproduced as close as possible to reality, as experienced by listeners when seated in a real indoor opera theatre or concert hall. A more or less even frequency response, appropriate S/N, well distributed SPL and IACC provide the main spatial impression ratings and are the leading acoustical parameters indices in the Garda classics 2010 demanding listener's requirements.

1 Introduction

From at least 140 years, sound space electroacoustic rendering has become an important issue in music world, always concerned with signal to noise ratio (S/N) and listeners 2 ears inter aural cross correlation (IACC). Today's young listeners habit to good computer game sound effects, older listeners habit to classical music concerts and intergenerational habit to cinema broadband frequency (F) spectrum, high sound pressure level (SPL) and spatialization sound effects all challenge good public adress (PA) sound reproduction in terms of S/N, speech intelligibility, SPL per listener, frequency coverage and sound spatialization.

Many music Summer festivals propose open air electroacoustically "helped" concerts and opera singers are often employed to enhance audience interest. This habit has its modern roots in first Three Tenors concert. Organized in Caracalla (Italy) the day before July 1990 football final FIFA World Cup in Rome. The concert was world television broadcasted and 800 milions viewers followed the event and when concert recording was released on CD it became the biggest selling classical album in music history (2012) [1]. Live event 6.000 listeners experienced electroacoustic sound pickup and reproduction through PA system, as natural sound would be too feeble to be heard in a non ideal S/N environment.

In every PA solution it is important to take into account main sound field acoustic parameters and it is author's opinion that six main acoustic parameters are more or less enough to describe sound field main peculiarities in terms of energy, F and spacial information. All 6 main acoustic parameters are strongly intercorrelated and influence each other; to note here that many other useful acoustic parameters have been developed during second part of last century, as compu-tational capability growht direct consequence, and they all contribute to accurate sound field description.

6 main acoustic parameters are 1) S/N (energetic), which stands for "*Too low difference between disturbing noise and music, disable listeners' good understanding*", as in F. Policardi (2003) [2], rarely analized for left and right listeners ears, 2) good F distribution (F), which stands for appropriate sound source emission and appropriate sound field transmission up to listeners' ears, 3) SPL (energetic), which stands for the ammount of energy arriving to listeners' ears, 4) RT_{60} (F /energetic), which stands for adequate reverberation field construction, in our case mostly through electroacoustic devices, 5) speech transmission index (STI or RASTI) (F), which stands for enough intelligibility in speech information at listeners' ears and 6) IACC (spacial), which stands for sound source positioning listener's capability in relation to performers seen on stage, usually analized for left and right listeners ears but in just 2 rough central octave audio bands.

As far as possible, all appropriate S/N, even frequency response, well distributed SPL and good IACC have been leading acoustic parameters indexes in Garda classics 2010 (Gc2010), as STI did not result critical.

2 Purchaser requests and event location

Associazione musicale Scaligera's director dott. Domenico Marcello Urbinati once again asked for quality open-air sound reinforcement in Lazise, near Garda town, world reknown high quality holiday location on northern Italy Gadra lake. Opera arias sung by different soloists and ensambles accompained by a grand piano would have to be perfectly electroacoustically enhanced as Lazise holiday location is very well established in worldwide high society and callers are cultured people used to refined international music events, as in F. Policardi-Antoncich (2009) [3].

No technical specifications were made other than music program (opera arias from G. Verdi, V. Bellini, G. Rossini and G. Donizzetti) performed on a 160m^2 1,3m hight open stage for presumably 900 skilled listeners in a car park. Photographs and measurements of the over 6.200 m^2 car park showed stage and audience north and west sides surrounded by 2 streets, while east and south stage and audience sides surrounded by a planted park. Rapid information process gave bad news about car

traffic noise, as upper street (north) is one of main Garda lake roads and right street (west) leeds to Lazise town center. Unfortunately, different locations were not available, as previous year Garda classics 2009 success demanded for broader audience sitting places. In planted park a little luna-park was operating, but fortunately closing at 8,45 p m, just 15 minutes before concert start.

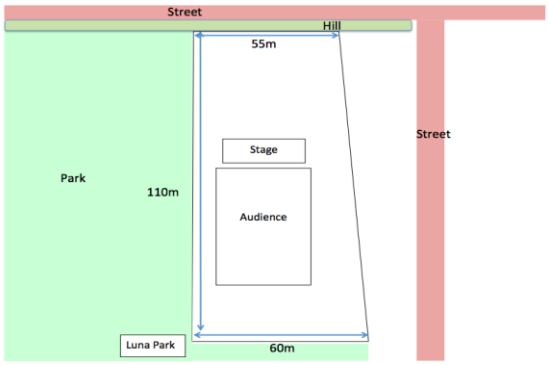

Fig. 1: Lazise main car park: open-air concert location

3 Technical equipment

Evaluation and elaboration process turned out the following musical and technical needs:
1) from 1 to 5 singers at the same time (bass, bariton, tenor, alto and 2 sopranos) + grand piano and speaker; 2) need for a natural and soft soundfield pick-up and stereo live recording; 3) need for a stereophonic multi channel well distributed sound reinforcement system.
Soundfield pick-up equipment was the following:
1) 2 x Neumann U87, 1 x Neumann SM69 and 1 x Schoeps MTSC5 microphones; 2) cables; 3) 2 x MX 12/6 analog Yamaha mixing desks; 4) 1 x Lexicon 960 L digital multichannel reverberator; 5) 2 x DAT recorders.
PA sound reinforcement equipment was the following:
1) 4 x 2 way 250W self bi-amplifyed bass reflex Eclipse E Voice System loudspeakers; 2) 6 x 2 way 250W self bi-amplifyed JBL loudspeakers; 3) 1 x Rion NL-18 precision sound level meter.

Because of opera music broadband F range and reduced signal amplitude (rarely over 90 dB SPL), large diafragm omnidirectional microphones are theoretically the best choice, as S/N ratio is most of the time favourable and wind interference produces less rumbling low F. Gc2010 open air opera concert is then another perfect theoretical case: direct sound widely overcoming reverberant field (just first sound floor reflection), F range from 50Hz grand piano low C fundamental to over 15kHz sunged consonant harmonics, maximum opera SPL of 95 dB in speech F band and need for balanced room acoustics, as well explained in S. Cingolani and R. Spagnolo (2005) [4]. Most of equipment has already been used in for Gc 2009 and exhaustively described in [3]. In this case Schoeps MTSC5 microphones (ORTF system stereo somehow “head-related” microphone arrangement, theoretical recording angle of about 95°, F range 40Hz-19kHz) have been used to pick-up grand piano and Neumann SM69 in central position with 2 U87 each side for singers and speaker. Musicians performed without official stage monitoring, although special care was put on high F backstage reflections and on low F "helped" grand piano stage floor natural amplification. Accurate stage front monitoring positioning and panning well contributed to artists' satisfaction and good feeling on stage. Compared to Gc 2009, listeners' sound field reconstruction has been chosen more distributed, in order to satisfy melomaniacs expectations.

4 Classical music and S/N: SPL

4.1 Theory

All sort of noises are nasty beast in acoustics and enormously influence S/N in terms of energy and F content, time variance and spacial recognizability. Noise is *the* main concern in classic music and traffic noise can be very annoying during open air live listening because of average and peak specific differences. Measured values in dB gives following values showed in Table 1.

Table 1. Lazise traffic noise SPL vs performances

SPL in dB	Min	Max	Average	Traffic noise masking
Speech	25dB	70dB	55dB	complete
Classic music	25dB	100dB	65dB	almost complete
Rock concert	90dB	110dB	100dB	none
Traffic noise	25dB	100dB	75dB	

Energetic differences are almost always in favour of traffic, as maximum SPL time % duration is in classical music very low. Average SPL can be rised up to a maximum of 85dB and not more, in order to maintain a naturallly like sound experience. Measured SPL vs time in % values are shown in Table 2.

Table 2. Lazise traffic noise SPL duration vs performances

SPL in time%	Min	Max	Average	Traffic noise masking
Speech	45%	55%	predictable	almost always
Classic music	65%	35%	predictable	almost always
Rock concert	5%	95%	predictable	almost never
Traffic noise	0%	100%	unpredictable	

Very low energetic differences during time evolution are shown in Table 2 for speech too; classical music persistence in low SPL values is almost for 2/3 of performance duration. Traffic noise is officially recognized as mainly composed by low F and its masking effect on sound signal affecting just this part of F auditory perception. Classical music and opera listeners are used to attend indoor live performances where, for different reasons, real deep low F are rarely really perceived and human auditory perception knowledge can help sound engineer to solve the problem.

Brain correct sound elaboration and interpretation can be bypassed through human acoustic perception illusion phenomena called "missing fundamental", through which the brain attributes the height of a sound relying more on the relationships between sound harmonics than on its fundamental and this was somehow already described by G. Tartini in (1754)

[5].Traffic noise F band coverages are at this point important to understand how to deal with the problem. Table 3 shows traffic noise frequency band coverages respectively: vs speech, with complete masking even if some consonants may overcome undesired effect, vs music, even if its apparent broader F band may induce to underestimate the effect, vs rock concerts, which are more or less not influenced by traffic noise masking phenomena because of their intrinsic very high SPL.

Table 3. Lazise traffic noise SPL frequency band vs performances

SPL in Hz	Min	Max	Typical	Traffic noise masking
Speech	200Hz	10kHz	350Hz - 3,5kHz	always
Classic music	25Hz	18kHz	50Hz - 15kHz	almost always
Rock concert	25Hz	18kHz	30Hz - 18kHz	almost never
Traffic noise	0Hz	16kHz	10Hz - 5kHz	

Comparisons in Tables 1, 2 and 3 clearly illustrate main differences in electroacoustic sound reinforcement and consequent sound engineers' completely different habits.

4.2 Practice

SPL average and peak energetic differences in dB shown in Table 1 evidence how Gc 2010 open air opera concert would be subject to traffic noise masking effects, as it was arranged by just sunged speech acompained by a single grand piano. In normal PA sound reproduction conditions (high SPL concerts or at least 30m away from sound sources and listeners), traffic noise possible overcoming can be achieved through robust bass boost equalization. Gc 2010 outdoor opera example was exactly the opposite case, because traffic noise was emitted at short distances from listeners, still having important energetic content in mid and high F bands; this dramatically influenced S/N, RT60, STI, IACC and subsequent SPL requirements.

As shown in Tables 1, 2 and 3, traffic noise energetic, F and time % masking is of maximal importance in classical music S/N and only possible countermeasure can be a slight electroacoustic SPL rise up to maintain a natural like sound experience for listeners. From author's experience, a reasonable limit can be an average of 85dB SPL and not more, with a constant attention to real time adaptive equalization.

5 Classical music and IACC

Traffic noise is broadband charachterized from low to high F, car type and motorbike specific and street irregularities and traffic intensity dependent. One more distracting characteristic is that vehicles pass by and always change their position in space, determining automatic defensive attention response by listener's brain. All these traffic specific characteristic make it very difficult to manage in classic music contests. Listeners attention and concentration are submitted to distortion in listening and evaluation processes. Brain activity dramatically raises because of acoustic masking process lowering attempt and speech intelligibility drop as in Teija Kujala and Elvira Brattico 2009 [6].

A little 4m high and more than 100m long hill helped to manage Garda classics 2010 traffic noise problem from N side but when cars and motorbikes decelerated, accelerated or used sqweaking brakes on N road and when W street interested listeners passed by driving cars and motorbikes, no solution was possible rather than a slight SPL increase from loudspeakers, thus improving S/N.

6 Audience equipment

To give spaciousness impression and maintain localization control, two 2 way 250W self bi-amplifyed bass reflex Eclipse E Voice Sytem loudspeakers were positioned between stage and audience about 3,5m inside stage sides and an equal delayed system was positioned 5m wider and 6m away from stage. First system was 1,9m high (h), pointing 15° outside and equalized with +5dB gain under 250Hz to give some stage reinforcement; second system was 2,3m h pointing 40° inside with +4dB gain under 250Hz to compensate for distance from center audience and possible traffic noise masking effect and with -2 dB over 13kHz, because of self generated high F noise (sghFn).

Three more 2 way 250W self bi-amplifyed JBL pairs of loudspeakers were positioned at 12, 19 and 27m respectively from stage, all at 2,5m h, to completely surround audience: 3rd system 3m outside audience pointing 45° inside with +4dB gain under 250Hz to compensate for distance from center audience and possible traffic noise masking effect and with -4 dB over 12kHz because of sghFn, 4th system pointing 65° inside with +4dB gain under 250Hz to compensate for distance from center audience and possible traffic noise masking effect and with -4 dB over 12kHz because of sghFn, 5th system was 4m inside pointing 110° inside audience with +4dB gain under 250Hz to compensate for distance from center audience and possible traffic noise masking effect and with -4 dB over 12kHz because of sghFn.

First MX 12/6 analog Yamaha mixing desk fed 48V phantom power to microphones, served as main mix, as stereo recording output and as Eclipse E Voice Sytem loudspeakers fed. Second MX 12/6 analog Yamaha mixing desk served just for delay lines and for JBL pairs of loudspeakers fed through mains out and auxes.
Lexicon 960 L digital multichannel reverberator was calibrated during 60' installation and 10' sound-check with musicians at 8,45 p.m.. Gain level check was performed section by section and with a musical "tutti" confirming a good sound on the stage due to stage Eclipse E Voice Sytem loudspeaker's mid and low F side and rear lobe radiation, avoiding stage monitoring. Audience coverage was within +/-2,5 dB from first to last row, left to right measured with a Rion precision sound level meter NL-18 with UC-51 NO microphone.

7 Concert sound reinforcement

Under author's suggestion, audience was distributed slightly oval in curved parallel seat 1,10 m distant rows, counting from 25 to 32 offset relative to each other seats. A small central space just for the mixing desk has been left free, positioned at about 2/3 of listening area. This solution allowed correct sound reinforcement constant

and real time judgement, easy cable adjustment, free mixer position reaching and last but not least, italian safety law requirements' meeting. First part (stage to mixing position) was 20 rows and second part (from mixing position to rear rank) was 11 rows, for a total of more than 900 possible listening positions (about 6x4 seating positions were occupied by mixing position). Resulting audience had at least 5 meters promenade on both sides as shown in Figure 2.

Fig. 2. Garda 2010 open air opera concert: audience loudspeaker coverage

During afternoon equipment installation temperature was 35° Celsius, rh 45%, wind direction north-west and wind intensity 3,5 to 4 m/s. IACC audience coverage has been checked with specific well known classical music CD recordings, first through author's Codex 121 Einsiedeln (1991) [7], gregorian plainchant recorded with just a Neumann KU81 dummy head and no post production and then through a pure stereo anechoic recording to adjust in a very accurate way complete electroacoustic reproduction chain, in particular delay lines, loudspeaker equalizations and Lexicon 960 L. The choosen solution enabled good sound control under listener's ear situation and position. Musicians and organizer staff were very satisfied and confirmed the expected audio results before the concert. Thermal gra-dient rapidly changed after sunset, lowering temperature to 27° Celsius, rh to 60% and wind direction and intensity to south and 4,5 to 5 m/s, forcing to an "on air" complete equipment re-calibration. Delay lines did not suffer from weather conditions changes but equalisation had to be managed live during whole concert, mostly because unpredictable change of traffic noise intensity and direction. IACC was completely re-created from 4^{th} row onwards, as stage direct sound did not reach 6^{th} row, managing spaciousness and localisation through constant real time multi-channel loudspeaker reproduction SPL and equalization compensations: sound localization was good and in first rows stereo image was naturally compensated by direct sound coming from stage. Audience left side was not too much helped by planted park because traffic noise easily passes through trees, so that as for audience right side, it needed continuous SPL, F equalization and reverberation adjustments.

Traffic noises at first increased because of number of cars and motorbikes and average SPL had to be kept at 90dB. After about 30 minutes traffic noises progres-sively decreased allowing a progressive lowering of average SPL to a more natural 83dB during rest of live performance. Musicians on stage were confortably singing and playing as they were able to hear each other and noise coming from them was practically absent.

Constant F analysis was performed on various microphone and output channels to improve S/N and IACC impression and compensations were capable to increase first reflection's impression modifying Lexicon 960 L parameters.

8 Conclusion

Sad to say, but most classical music electroacoustically "helped" concerts express poor sound quality and per-ceived results are most of the time very unsatisfactory, but good solutions exist as Garda classics 2009 and 2010 demonstrate. During Gc 2010 open-air opera concert the desired effect was again to re-create an indoor acoustical sensation outdoors. In spite of non ideal location and almost 100% electroacoustically generated sound, the expected 900 listeners confirmed the quality of the concert and another almost perfect PA sound reinforcement case study. This is a practical demonstration that S/N can be kept under control beginning from the microphones, so that sound rein-forcement system becomes not the chain's critical ring.
It also demonstrates that with careful listeners seating disposition (even if in unfavorable surroundings), correct sound receivers positioning on stage, accurate mixing procedures and attentive loudspeaker system management, traffic noise can be managed through very careful S/N study and consequent SPL and F real time constant adjustment and compensation during perfor-mance.
Even IACC and first reflections can be managed through real time constant adjustment and compensation during performance. Gc 2010 open-air opera concert purchaser's requests have been again completely sati-sfied and overcame as from audience comments com-pletely supporting musician's and sound reinforcement performance, asking again for more open-air classical music concerts.

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