C'MON FEEL THE NOISE
(OR HOW GREEN IS MY SOUND)

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1 INTRODUCTION

This paper takes a fresh and pragmatic look at the traditional way of designing a sound system and its use in practice. In particular the concept of using steady state noise as a source for either SPL or STI measurements versus real world signals, and the impact on headroom and thus the financial and environmental costs.

2 BACKGROUND

In the mid 90's at Rangers an HF driver blew up when trying to reach the specified max SPL with pink noise, yet on the previous day, the system had been running at full power with music with no problems.

In 2006 at Bristol City Football Club, the old "inadequate" system was measured at about 96dBA max, on axis, with pink noise. Just prior to the match, the pitch-side announcer was giving it his all, and a consistent 102dBA was measured off axis on the outside edge of the stand with (subjectively) total intelligibility.

In 2007 a potential upgrade to the system was proposed at Twickenham Stadium and one possibility was to use the existing equipment rack locations and add further equipment. There was a question as to whether the mains supply had any spare capacity for the extra equipment and also how big the UPS needed to be. A current meter was inserted in the mains circuit and the current draw recorded pre-match and during the match (the remainder of the time the system was not used). Surprisingly, the peak figure of current draw was about 1/10th of the theoretical load of the amplifiers.

So if a sound system "***measures***" x dBA SPL with pink noise, is it really capable of more in reality when reproducing speech or music?

If that is the case:

a) do we need all that power in the first place?
b) if we don't, can we design for a lower level, with less amplifiers, less copper cable?
c) if we can, can we also reduce the size of the secondary power (batteries)?
d) will we save the Client money?
e) can we reduce the carbon footprint of a system by using less hardware and energy?

3 THE DESIGN PROCESS

Perhaps to understand where the "over-sized" design comes from, it is necessary to look at the traditional design process. Only then will it become apparent what factors need to be taken into account to address the potential to reduce the design. In many respects it all revolves around measurement of steady state sources in the acoustic domain.

A designer looks at a space and looks at what it is to be used for and what the likely ambient noise would be like when occupied. Indeed the new BS5839-8 actually gives the recommendation that if the space exists, then the ambient noise should be measured, but if it does not exist, then an equivalent space should be measured.

The measurement needs to be representative. For example, a stadium should be measured as an LA10,t during a representative event, whereas a station concourse should be measured as an LAeq,t over a short period of say 1 minute during rush hour.

From the noise measurement, the designer then defines and agrees the design SPL to be at least 6dB above the noise measurement. (Guidance in BS7827 for stadia, and now also in BS5839-8 2008). The figure of 6dB above ambient has been shown to be the minimum required in order to achieve an STI of 0.5 in most cases..

3.1 The Electro-Acoustic Design Parameters

The design SPL needs to be established. It is important to realise that the ambient noise is not usually consistent over time. E.g. a restaurant will be noisy when filling up with people, but quiet after they have left. The quality of the sound reproduction will also vary as to whether the reproduction is solely for messages or whether it is to reproduce background music or even foreground music.

The table below is taken from a hotel project where there is a mixture of uses of the sound system ranging from Voice Alarm to background music to speech reinforcement and programme sound (as published in BS5839-8 2008) shows the typical design criteria established at the initial design stage and subsequently agreed with the Client.

This has the advantage of getting Client sign-in to the design and thus the associated costs. It is a step towards reaching the elusive goal of getting the right budget for the job. It also provides strength for any future discussions within the design team when the aesthetics or the speaker locations are in danger of being compromised.

Area / Room	Likely ambient noise dBA	Usage noise increase dBA	Design SPL dBA	Design Coverage	Design Frequency Response
Cultural Centre	70	3	83	80%	300Hz to 6kHz ±3dB
Lounge	70	4	84	80%	125Hz to 12kHz ± 3dB
Toilets	60	9	79	80%	300Hz to 6kHz ±3dB
Entrance Lobby & Lounge	73	6	89	90%	300Hz to 6kHz ±3dB
Bar Lounge	65	9	84	80%	300Hz to 6kHz ±3dB
Speciality Restaurant Internal	65	9	84	80%	300Hz to 6kHz ±3dB
Conference Room	70	6	86	95%	125Hz to 12kHz ± 3dB
Meeting Room	70	6	86	95%	125Hz to 12kHz ± 3dB
Pavilion Internal	68	6	84	80%	300Hz to 6kHz ±3dB
Health Club - Internal	68	6	80	80%	300Hz to 6kHz ±3dB
Health Club - Aerobics	75	12	97	80%	125Hz to 12kHz ± 3dB
Cultural Centre	70	3	83	80%	300Hz to 6kHz +3dB
Lounge	70	4	84	80%	125Hz to 12kHz + 3dB
Toilets	60	9	79	80%	300Hz to 6kHz +3dB
Entrance Lobby & Lounge	73	6	89	90%	300Hz to 6kHz +3dB
Bar Lounge	65	9	84	80%	300Hz to 6kHz +3dB

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The available locations for loudspeakers is usually a good starting point. This then determines the type of loudspeaker which can be used. Calculations can help to prove that the desired level is achievable due to the sensitivity and power rating of the devices. In addition to level (SPL), consideration should be given to the quality of reproduction. Is the requirement for music reproduction or just speech? The impact of music reproduction is very much that of the physical size of the loudspeaker.

CAD programmes whereby the space is modelled and the speakers inserted are used a lot for the bigger projects, but usually only for the bigger (and simpler spaces). The majority of designs still use the rough and ready 6dB loss for a doubling of distance, and a 3dB gain for a doubling of amplifier power. In either case, the power per loudspeaker comes from that calculation, and thus the amplification requirements can be defined. Add to this the desire to zone the system and the scope of the amplification is now much more granular.

It should be noted that “zoning” may take the form of being able to address specific parts of a building separately, OR it can take the form of a large space where there is an identified focal point and the supplementary speakers need to be delayed with respect to this focal source.

An example of such a requirement is at Earls Court Exhibition Centre where there is a huge 100ft high hall which extends into a 24ft high undercroft. The undercroft loudspeakers are therefore delayed with respect to the focal point loudspeaker and this means that each group have to have their own amplifiers driven from the delay line.

3.2 Secondary Power

Whether using amplifiers capable of battery as well as mains power operation, or whether using mains only amplifiers and a UPS, the load will determine the amount of batteries and the size of the inverter. Secondary supplies attract some serious costs – both in monetary and environmental terms - since the batteries need to be replaced about every 5 years.

3.3 The Design of the “Front End” and the “Core”

The front end of the design will be dictated by the operational requirements. The system may be purely a Voice Alarm system which has message stores and maybe an emergency microphone.

Voice Alarm systems will rarely be used in anger, but BS5839-8 2008 has been refined in respect of a greater emphasis on demonstrably acceptable intelligibility.

A system may be a combination of Voice Alarm and Public Address used for entertainment, such as in modern football stadia, racetracks, cricket grounds etc. The fact that it is of dual operational use does not detract from the requirement of intelligibility.

Additional sources, routing of signals to the various zones, and signal processing for operational, intelligibility, and circuit protection are all part of the systems design. Nowadays such signal processing is often done by a Digital Signal Processor unit and custom programmed at the time of installation.

On large sites, the amplification and signal processing is done in multiple locations, so distribution of the signals and control are usually carried out in the digital domain using computer network technology.

In the case of Voice Alarm systems there is also the requirement to monitor the critical signal path to ensure that any fault is flagged up immediately, and action can be taken to work around this, and/or repairs effected.

Not all projects are mega sized, nor are they complex, but the sources and control are an integral part of any sound system.

3.4 The Financial & Environmental Costs

The ideal electro-acoustic system often has its critics on grounds of cost (in addition to aesthetics or loudspeaker mounting possibilities). Having explored the equipment required and put a cost to it, there is inevitably someone wanting the costs to be reduced. This leads to re-thinks about how one arrived at the electro-acoustic design. That translates into the number of speakers, and the amplifiers, and then the batteries for the secondary power source. At some stage the costs have to be agreed before the project can proceed. This may seem obvious, but all will become clear soon.

Nowadays the impact on the environment needs to be taken into consideration. It may not be obvious at first, but the more product that is used, the more its manufacture will “eat” natural resources. By reducing the electro-acoustic system, fewer amplifiers would be needed and fewer batteries would be needed both immediately and through the life-cycle of the system. Indeed, if fewer loudspeakers were required in the process, then less copper cable would also be required.

4 COMMISSIONING OF THE SYSTEM

There may be a consultant involved who has specified the minimum SPL and STI to be achieved. Alternatively there may be an agreed performance by another route, such as an agreed design criteria in a design-build contractor arrangement. At the end of the day, there are Standards to be met and proved to have been met.

Much of each space will require the same level throughout. For example it would not be acceptable for some seats in the bowl of a stadium to be much quieter than others. Indeed a lack of level will reveal a lack of signal to noise ratio which in turn will render those areas to be less (and possibly unacceptably) intelligible.

So how does one measure the evenness? Usually just using music and listening as one walks around the space is not specific enough, though probably quite pleasant. Nevertheless, the system cannot be turned down from maximum all the time because it will not prove that the evenness is achieved when the system is at full power. I,e, some speakers might not produce enough sound, or the amplifier for certain speakers is under-powered.

The usual method is to use pink noise as the source, turn it up to maximum and check that not only is the SPL parameter met, but that it is so with evenness across the space.

4.1 Intelligibility Measurement

There are many different ways of measuring intelligibility objectively and these involve different sources. One of the most popular recently is that of STIPA using a modulated noise to provide a source and measuring the modulation transfer function together with the sound pressure level.

In order to be relevant, the measurements need to be taken when the space is normally occupied and this would mean subjecting people to a horrible noise whilst asking them to act normally. An almost impossible feat.

As a result, most projects require that the measurement is carried out when there is nothing going on in the space, or at least nothing approaching "normal" use. However, this is what is called a "noiseless" measurement. There are other methods which will not provide anything like sensible results if the signal to noise ratio is too great e.g. minimum length sequence assessments (MLSSA).

For those methods which can use noiseless measurements the answer is to measure the noise and its level during normal occupation and then to "contaminate" the intelligibility readings with the noise as part of a desk top exercise. This is known as post-processing. It is far from ideal because there is room for error and manipulation.

Another method is to measure the noise and its level during normal occupation, and then to take a flat response source such as pink noise and shape it to the response measured using an equaliser. This can then be amplified and fed to a speaker local to the STIPA measurement instrument. Therefore now the normal occupation noise has been simulated and it is directly contaminating the STP reading directly. This is the method favoured by the author, especially in large spaces such as stadia, rail termini, racecourses and the like.

5 THE ISSUE OF HEADROOM

If the system reproducing the test signal has no headroom, it will clip the signal and be a form of distortion. Intelligibility measurements will then be low and even invalid. If, as one Standard has in the past, a headroom of 6dB is required, this means that the electro-acoustic system has to be able to reproduce 4 times the sound pressure level and is 4 times more equipment than the system which is on the brink of clipping. In addition, 4 times the equipment will require 4 times the electricity to drive it on peaks and therefore 4 times the batteries. (Admittedly this is only one interpretation). Taking a more pragmatic view, 3dB headroom would seem more sensible, but this is still double the amount of equipment.

5.1 Headroom Depends upon the Source

What is the source operationally? Speech and music. What is our measurement source signal? Pink noise and STIPA tone. What is the difference? The energy under the curve. It is the energy which we need to look at, not the broad spectrum power handling. The energy under the curve is greater for test signals than it is for real world signals.

The amplifier only draws the current according to the energy it needs to reproduce. Our commissioning measurements were therefore drawing 10 times more energy than the real world signals and that represents a huge amount of headroom.

5.2 Test Signals and Test Levels

Test signals for sound systems are usually based upon pink noise which is a sound that contains every frequency within the range of human hearing and has been filtered to have equal energy at every octave. Whilst this may be very useful for testing equipment performance in the electrical state, it is not representative of the acoustic content of real world sounds.

The various tests and alignment which are required to be carried out are:

- signal routing
- level

- relative levels
- evenness of coverage
- equalisation

All of these can be carried out using pink noise.

However, the maximum sound pressure level measured using pink noise will be far more onerous than real world sound signals, as will the STIPA intelligibility measurements at maximum output level. This is due to the fact that pink noise contains all the frequencies at once (constant) whereas real world sound only contain some of the frequencies for some of the time (dynamic).

IEC60268-1 recommends that pink noise shaped to "IEC Simulated Programme Signal" curve should be used for the measurement of temperature rise in sound equipment, and this shaped noise represents continuous, somewhat compressed, music, and it should be used at 1/8th of the non-clipped output power. Thus it would be reasonable to carry out maximum power measurements at approximately -12.5dB of the system capability.

7. **Simulated programme signal**

A signal, whose mean power spectral density closely resembles the average of the mean power spectral densities of a wide range of programme material, including both speech and music of several kinds, is stationary weighted Gaussian noise without amplitude limiting, the weighted power spectrum being in accordance with Table II and Figure 1, page 22, when measured with third-octave filters in accordance with I E C Publication 225.

Such a signal may be obtained from a pink-noise source by means of the filter circuit shown in Figure 2, page 22.

Measurements made with narrow-band signals shall, if appropriate, be made with the relative level in each frequency band corresponding to that indicated in Table II and Figure 1. (Measurements and characteristics related to the use of this signal, especially for amplifiers and loudspeakers, are under consideration.)

Note. — It should be noted that the power level of the signal measured over the full frequency range is approximately 12.5 dB higher than the indicated zero relative level, which is measured over ⅓ octave.

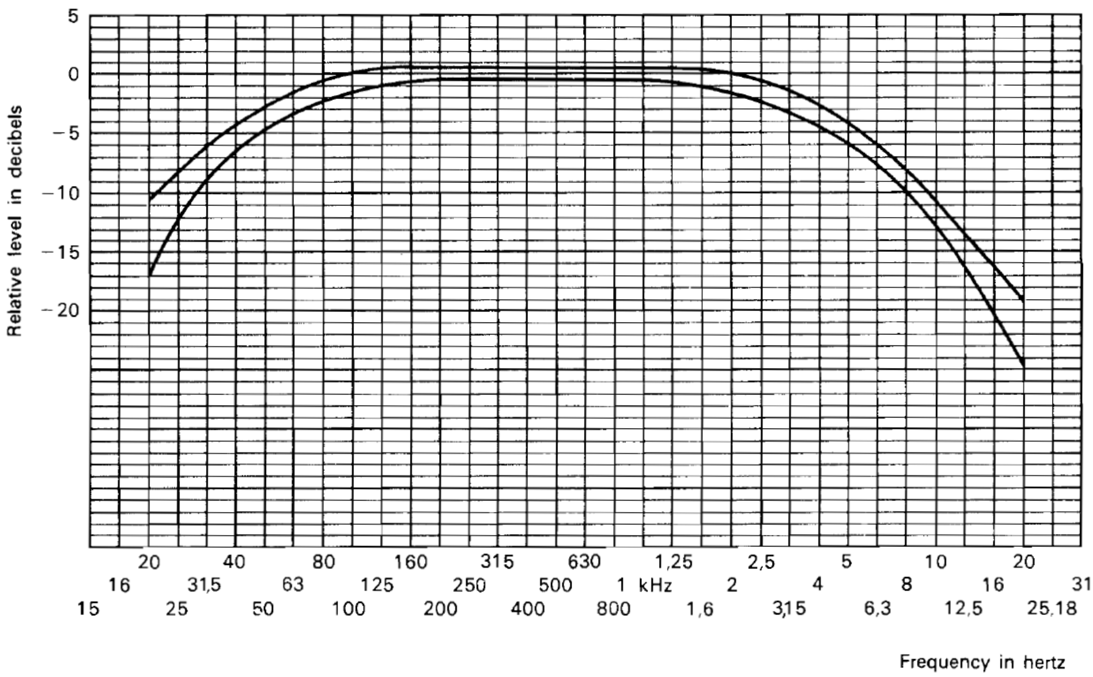
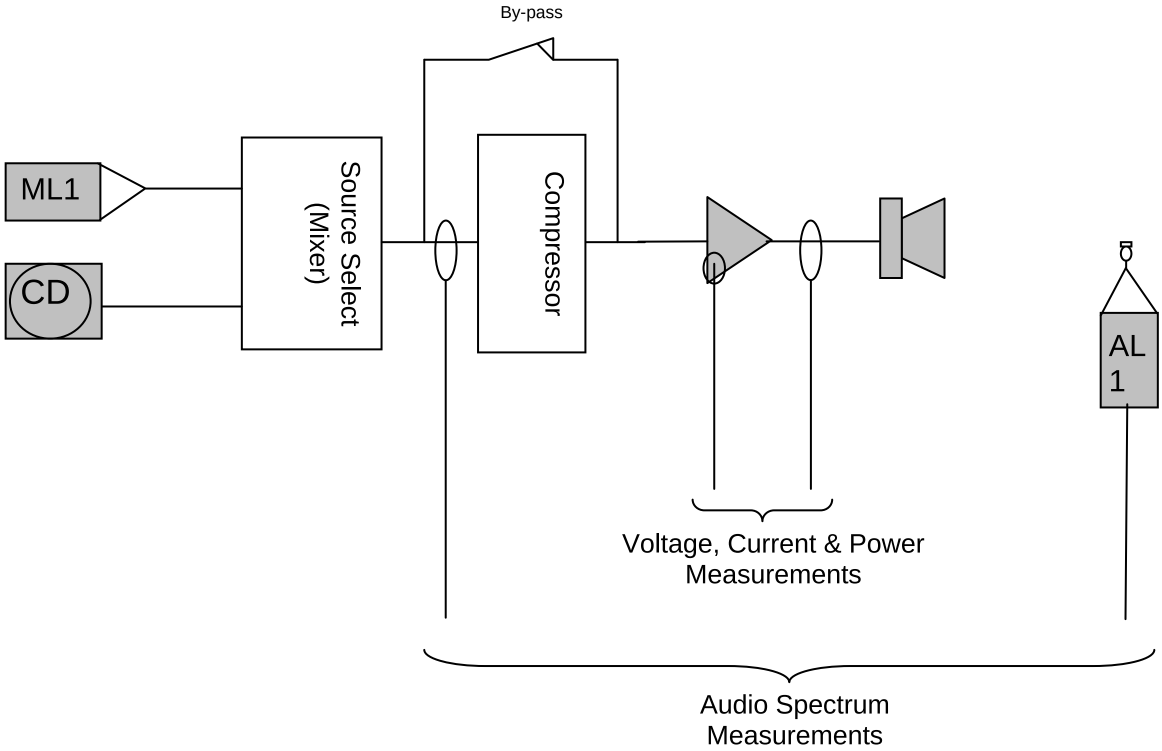


Fig. 1. — Power spectrum of simulated programme signal.

The curve was been established from a series of tests by emininent engineers over a period of time a long time ago and is still unchallenged even though it may not have been used much.
This reduction in level may have originated in the part of the Standard dealing with the temperature rise in equipment, but temperatire rise is a function of energy and therefore it is possible that the precaution was put in place in order to allow for the difference between steady state test signals and real world dynamic signals.

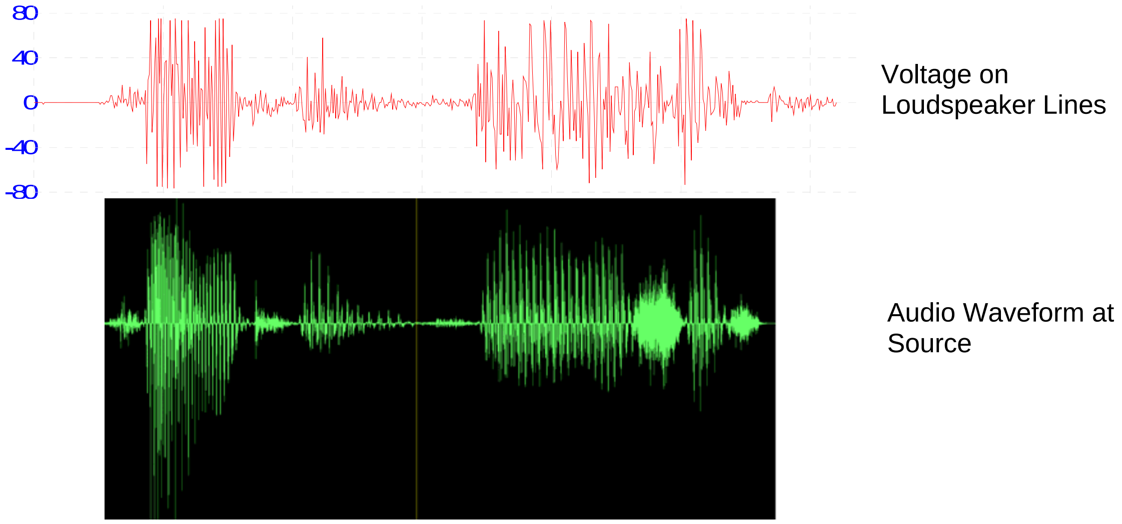
5.3 Steady State Noise v Real World Signals

This rig was set up in order to see how much difference there was between steady state noise and speech in terms of energy consumption and system headroom.



The research is still ongoing and the full results will be published separately at a later date. However it was observed that the speech signal required 18dB more gain in order to send the amplifier into clipping than pink noise did.

5.4 The Energy of Speech Signals



This is amplitude over time. It is therefore analogous to energy over time, it can be seen that it is only a percentage of the energy that a steady state signal would have. The question is "what percentage?"

5.5 The Case for De-Rating

Provided that the loudspeakers and amplifiers are capable of handling transient peaks to a degree, *it is reasonable to design for a maximum output level equal to that degree*, even though the theoretical system capability is lower.

The actual measurement of system output level under such circumstances would need to be taken using a real world signal such as a pre-recorded message and measured as an Leq,t using a very short sampling period such as 5 seconds. This level and its intelligibility should be assessed subjectively at the same time in order to corroborate the measurement.

It would appear that there is a reasoned argument to de-rate the SPL measurements when using shaped noise. There is also an argument for measuring STI using modulated noise, but de-rating the amount of noise contamination.

These arguments lead on to considering both amplifier and battery sizing being based upon real world signals. i.e. much smaller. The differences must be justified at the time of design and taken into account at the time of commissioning and included in the documentation. The critical (and dangerous) factor is that it all depends upon the amplifier and loudspeaker capability to handle transients.

Work is ongoing to try to establish a guide or even a formula whereby systems can be safely de-rated when used for a particular purpose (fixed installations which are not altered) and use particular equipment (transient tolerant amplifiers and loudspeakers).

6 CONCLUSION

It is a tempting thought that a system which would normally be designed for 1000W of amplification could actually be powered by 120W. All this with the knock-on savings of secondary power batteries and maybe some loudspeakers. Nevertheless, even if one could achieve a reduction of 50% in equipment, this represents a significant saving in both financial and environmental terms.