Proceedings of The Institute of Acoustics

ASSISTED RESONANCE IN PRACTICE

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Introduction

It is now fifteen years since the first experimental system was installed in the Royal Festival Hall. Since that time, Assisted Resonance has found further applications and this short paper outlines its development and uses in that time.

Origins of Assisted Resonance

Assisted Resonance was developed for the Royal Festival Hall by Peter Parkin and his colleagues at BBS specifically to counter the lack of warmth experienced over the first few seasons. Drastic alternatives of increasing the auditorium volume or reducing the audience capacity were rejected by the acousticians and the concept of lengthening the hall's reverberation time by a large number of frequency selective channels comprising an electro-acoustic feedback system was born. The full system of 168 channels has now been in operation for over ten years, over which time the Royal Festival Hall has been ranked amongst the world's leading concert halls.

Development

Following this initial success, it was decided to install a second system at the Central Hall at York University and through the work involved there to develop the approach with the aim of offering the optimum commercially viable system. Attention was focused on the relationship between the frequency selectivity of and spacing between individual channels with regard to the resulting lifts in reverberation time across frequency range. From this study and other data from subsequent installations it is possible to offer the following guide to the available lift in octave band reverberation times for two typical system sizes.

No. of Channels	Percentage Lift in Octave Band			
	125 Hz	250 Hz	500 Hz	1000 Hz
72	100	80	50	25
90	100	90	67	50

Naturally the specific circumstances and the design aims of the acoustics consultant will determine the choice of parameters for a particular application.

Design Tool in New Multi-Purpose Halls

The first commercial system was installed in the Concord Pavilion in California. A truly multi-purpose facility, this 3500 seat covered amphitheatre, with additional seating on the surrounding lawn for 4500, presented the consultant with the problem of attaining acoustic criteria for symphonic music in the absence of auditorium walls. He turned to Assisted Resonance to provide the acoustics to suit the use. The pavilion has operated now for five

years offering a wide programme including rock music, jazz, opera, ballet and orchestral works culminating in perhaps the most successful concert there to date, when Leonard Bernstein conducted the New York Philharmonic in Mahler's First Symphony on 16th June to the rapturous applause of over 8000 people.

The next system also went to America. The Scottsdale Centre for the Performing Arts in Arizona was conceived as a conventional 1500 seat theatre. Assisted Resonance was incorporated into the design so as to extend its range of uses. Other than for drama, when the system is not used, the considerable local community interest in chamber music has encouraged the use of the hall for this purpose, a function for which the assisted reverberation time is well suited.

British interest in Assisted Resonance was revived with two new local authority halls, the Alfred Beck Centre in Hillingdon and the Hexagon in Reading. The 500 seat Alfred Beck Centre in its natural state is suited to drama and modern music which form its major uses, whilst with the system in operation successful chamber music concerts have been staged. The Hexagon, in its wide usage, caters for varied tastes including an almost monthly concert by one or other of the London orchestras. In January 1978, at the end of his concert with the London Symphony Orchestra John Georgiadis praised the hall with the public comment "It's the first of all the new halls in the country that sounds like a concert hall".

Of these four systems, where Assisted Resonance was specifically used as one of the measures to achieve a multi-purpose facility, the Concord Pavilion and the Hexagon emerge as the most successful for which due tribute should be paid to the respective acoustics consultants, Christopher Jaffe and Sound Research Laboratories. In both cases, through good design and the use of Assisted Resonance, the consultant has achieved his goal of providing good acoustics for a a variety of events rather than having to be satisfied with a fixed compromise.

Future Projects

Our current involvement is with four halls. Two are new multi-purpose centres in Britain, at Harrogate and at Plymouth. The others comprise a new auditorium in Czechoslovakia which shall have a twin 120 channel system designed to operate in conjunction with a movable ceiling, and the 40 year old municipal auditorium in Kansas City for which Assisted Resonance will be a remedial measure.

Concluding Comments

With the Kansas City installation, Assisted Resonance shall have returned to its original use as a remedial measure for an existing concert hall, in the meantime having been proved a successful tool for multi-purpose auditorium design

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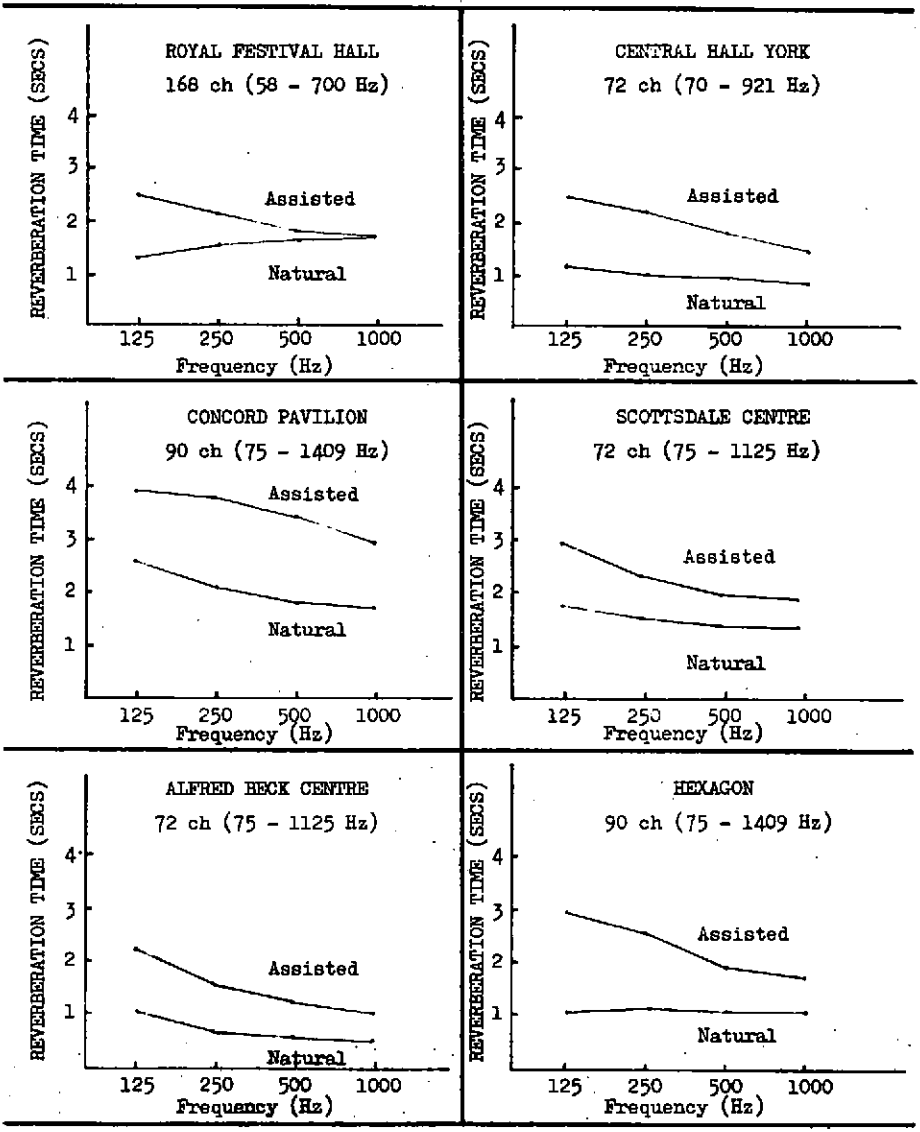

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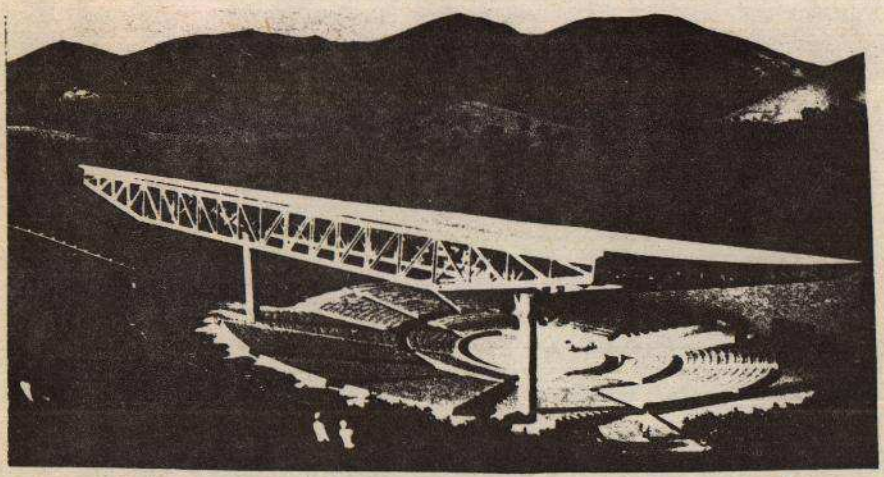
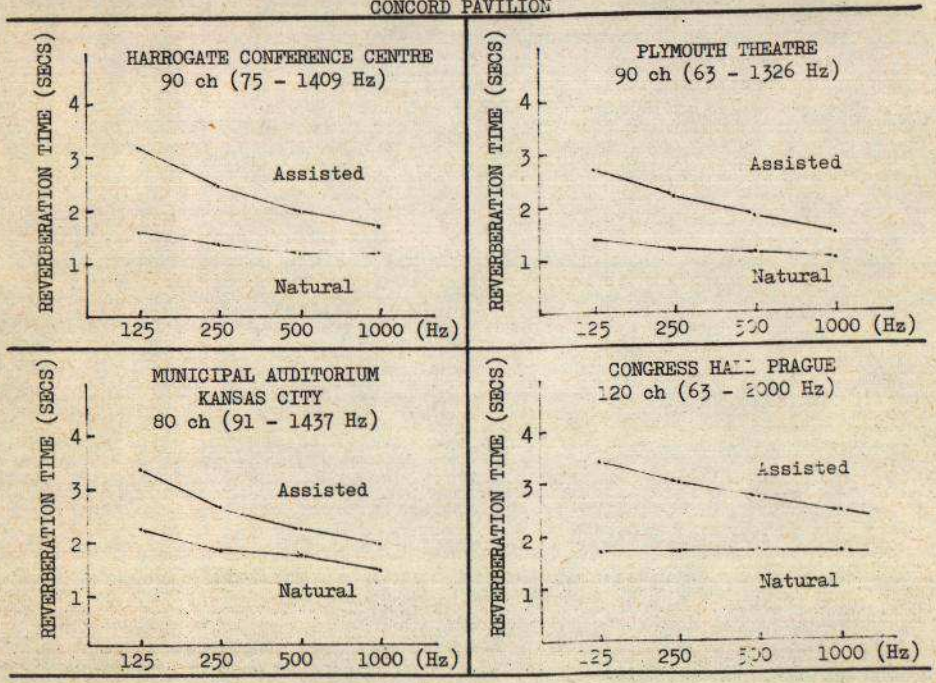


CONCORD PAVILION



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High Amplitude Amplification

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The concert hall platform is the music industry's shop window where new performers will be trying to attract the attention of the talent scouts and promoters while established bands will be promoting the sales of records and concert hall seats. Once the act itself has been perfected, the next consideration is the ability of the sound system to convey the energy and excitement of the music to the audience. The sound system is the band's only channel of communication and success or failure will hinge upon its performance. The widespread availability of home Hi-Fi systems has created an audience which is atuned to sound quality and the concert sound system must surpass by a wide margin, the quality of the average home Hi-Fi. No longer can the band rely on the power of its back line amplification, the acoustic power of the drum kit and get by with a pair of column loudspeakers for vocals.

One of the prime limiting factors is acoustic coupling, or feedback and it will be clear that the standard practices such as limiting frequency response, frequency shifting, the use of line-source loudspeakers etc. are inappropriate to this application. The question is often asked as to why the local P.A. man gets feedback in a given venue with a pair of columns and a 50w. amplifier, while the next day, a rock band turns up and successfully uses a 10,000 watt sound system with no feedback problems! We shall first consider a typical rock band requirement.

With a standard rock band line up of two electric guitars, bass guitar, keyboards, drums and vocals, as many as 30 input channels will be required. Some of these will be microphones for the voices, drums, piano, etc. while others will be direct injected feeds from the back line amplifiers and electronic keyboard instruments. Sometimes, the keyboards and drums are pre-mixed on stage by means of submixers prior to feeding the main mixing console. Most concert hall stages are acoustically fairly live and this, in conjunction with a high ambient noise level provides little separation between between sources thereby making adequate control very difficult. The solution is to 'direct inject' as many sources as posible and often, transducers are physically attached to the instruments to avoid the use of microphones. Those microphones that remain are used in very close proximity to the sound source and are carefully selected for uniform 'cardioid' directional characteristics and freedom from overload at very high SPL's.

The mixing console is usually located out in the auditorium and must be capable of accepting the very high signal levels coming off the stage without overload. Normally, up to four bands of parametric equalisation will be provided along with full signal monitoring facilities. By careful choice of microphones and careful design of the console electronics, most of the contributing factors of poor sound quality and excessive feedback have been overcome.

High Amplitude Amplification - 2

Before the remainder of the signal processing equipment is considered, we must take a look at certain aspects of the loudspeaker system. The design objective must be full range frequency response - say 40Hz. - 16KHz. with controlled radiation and good sensitivity. This cannot be achieved with a single wide-range reproducer or by stacking multiple Hi-Fi type enclosures. The loudspeaker array must be assembled from a number of different types of transducer, each being optimised to a particular part of the frequency spectrum and each fed from a band pass filter. However, at the orders of amplifier power normally employed, passive filters of the type normally fitted to domestic loudspeaker system are not a practicable proposition due to insertion losses and to the physical size of the capacitors and inductors that would be necessary. For these reasons, and also to provide control over the balancing of the loudspeaker system, it is usual to crossover at low level, either 3, 4, or 5 ways and to separately amplify each band of frequencies for feeding to the appropriate section of the loudspeaker system.

In addition to active crossover as this technique is termed, it is usual to employ ⅓rd octave graphic equalisers and compressor/limitors in the signal chain prior to amplification, the graphics being used in conjunction with a real time analyser for room equalisation and the compressor/limitors to prevent amplifier clipping and loudspeaker overload. Surprisingly perhaps, the power amplifiers themselves presen the least of the problems, as these are available from many sources with frequency responses that are flat from almost DC to 50KHz within ½dB or so, with distortion figures below 0.1%, rise times better than 3μsecs and power outputs of up to 700w. per channel stereo. So much has been writen on this particular topic and most commercially available products excede the performance requirements by a huge margin, that there is little of any relevance to add. It is usual to employ the largest amplifiers to feed the low-frequency section of the loudspeaker system, as despite the relatively high efficiency available from a properly designed low frequency reproducer, this remains by far the least sensitive part of the system.

The arrangement of the loudspeaker array is largely pre-determined by the physical factors governing the performance of certain types of transducer. For example, a 12" drive unit does not usually provide sufficient low frequency energy to reproduce the open 'E' string of a bass guitar (42Hz) so a 15" or 18" unit is usually employed in a very larged horn loaded enclosure to handle frequencies up to about 400Hz. In order to avoid the effects of doppler distortion and to retain dispersion control, 12" cone loudspeakers, sometimes horn loaded, sometimes working as direct radiators will handle the lower mid band, between about 400Hz and 1.6KHz. Above this frequency, the response of a 12" unit becomes ragged and radiation angle starts to narrow, so we crossover again to a large radial horn with high power compression drive unit. Such a horn is likely to provide unifrom projection of the upper mid band up to about 5KHz, at which frequency, a specially designed high frequency radiator takes the response to the audiatory limits. On more compact systems, the functions of the bass and lower mid sections, or upper mid and high frequency sections may be combined into single units to provide a 2 way or 3 way array with restricted performance at each end of the spectrum and some sacrifice in radiation.

It is usual to aim for a radiation angle of 90°horizontal and 40°vertical and this is easily achieved using standar components. However, if audience are seated in close proximity to the loudspeaker array it is often necessary to provide near-field coverage of the mid and upper frequencies and this is usually achieved by means of an acoustic lense assebly. This is basically a compression drive unit and horn with a series of specially shaped plates across the mouth of the horn arranged to provide wide spread of energy in the horizontal plane at reduced wavefront energy levels. Conversely, in a particularly long hall or outdoor stadium, it is usual to suppliment the usual loudspeaker system with long throw projector horns. These are highly directional with dispersion angles of about 20°and are intended to project the middle and upper frequencies over very large distances. The on-axis SPL is very high indeed and care must be taken to ensure that no audience are within direct near field range.

What then has been achieved?

1. A common form of distortion due to acoustic overloading of microphones and electrical overloading of the front end electronics has been eliminated thereby removing the harmonically related response peaks thus generated.
2. All subsequent electronics have sufficient headroom to handle a large dynamic range without clipping, with ultimate control by compressor/ limitors.
3. Electronic equalisation is employed so that output energy from the system is reduced at frequencies where room modes would otherwise create a response peak with its attendant certainty of acoustic coupling.
4. The loudspeaker system is carefully designed to ensure a smooth, peak free response with controlled forward propogation at all frequencies thereby ensuring that very little direct energy from the loudspeaker system is present in the vicinity of the microphones. Further, by careful orientation of such a loudspeaker array, first reflections can be effectively surpressed.

Using these techniques, high quality sound reproduction, free from feedback, ringing and distortion can be provided at SPL's of up to 120dB(A) without stress on the reproducing system.

However, we find one main problem, in that by designing to throw all the output power into the auditorium, we have a situation where the musicians have difficulty in hearing their own vocals above the high ambient sound level on stage. Also, they have little 'feel' of the overall sound being fed to the audience. This problem is overcome by the use of a second, entirely independant sound system on stage, where techniques similar to those now under discussion are employed to provide monitor loudspeakers for each individual musician. This system can either be controlled from the main mixing console, or in the case of a larger type of system, a seperate monitor mixing console will be employed actually on the stage. In this situation, hundreds of watts are being fed to loudspeakers placed immediately behind and below the microphones without feedback!