# ACTIVE OR PASSIVE ACOUSTICS FOR AUDITORIA? - a preliminary survey.

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ABSTRACT As the number of "variable acoustics' systems for auditoria continues to grow, hall designers are being tempted by their apparent advantages. For multi- purpose halls they offer selectable acoustics with small hall volumes. This survey looks at the different approaches to variable acoustics that have been tried. It covers the implications of the choice of either of two main categories of electro-acoustical installation, and summarises available data on the comparative performance and experience with both Passive and Active techniques.

## 1 PASSIVE ACOUSTICS - FIXED OR VARIABLE?.

### 1.1 Definition

It is the reflections off boundary surfaces which create the acoustics of a hall. No energy input is needed to make the surfaces reflect (or absorb), thus the process is a PASSIVE one and the resulting hall acoustics we describe as PASSIVE. As long as the materials of a hall retain their original physical properties and the hall remains substantially unchanged, then the acoustics will be fixed.
If 1) a hall is intended for a particular purpose e.g theatre, chamber music or symphonic works, and 2) the design proceeds successfully then fixed acoustics is desirable.
If, on the other hand, our need is for a building which provides for a range of performance activities from the theatrical to the symphonic, then this "fixedness" is a frustration. This is the problem facing designers of multi-purpose halls.

### 1.2 Variable Acoustics

The conclusion appears to be that the ideal multi-purpose auditorium should have the ability to change its acoustics. What, then, should we be looking to make variable? As far as we in New Zealand are concerned the specification and design for a hall would consider, as a minimum, the following criteria:-
1) Loudness
2) Reverberence
3) Clarity
4) Spatial Impression
Given that the suspicion is growing that different listeners have different preferences there is perhaps another criterion by which to judge halls and variable acoustics systems, and that is by their ability to provide a range of acoustical conditions within the same hall at the same time.

### 1.3 Variable systems in existing halls.

The data published by the Journal of the Acoustical Society of America, J.A.S.A. /1/, on halls built in the twenty years between 1962 and 1982, shows that the predominant acoustical criterion considered (or at least reported on) was the Reverberation Time.
A quick look at Sabine's R.T. formula - $RT = 0.061V/A$ - shows us that in order to vary a hall's R.T. we need to change it's volume, or the total sound absorption inside ( or both). The sort of change in R.T. we would be looking for in a multi-purpose hall intended to cover the acoustical spectrum from speech to music would be from roughly 1 to 2s, i.e. a ratio of approximately 2:1.
For the larger halls( e.g. those in excess of 1200 seats) where we could not bring all the audience close enough for theatre use, the range would be somewhat smaller since we would then need only to accomodate the musical repetoire (typically a range from 1.4 to 2.2's-i.e.a ratio of 1.6:1 instead of 2:1).
An analysis the J.A.S.A. compilation,(comprising 51 halls in the USA and 36 from other countries), shows that 1) 49% of halls are intended as multi-purpose, and
2) 39% actually include a system for varying the acoustics (seen primarily as a way of varying the R.T.).
In order of effect the measures have on the reverberation time, they are:
1) a removable orchestra/stage 'shell' - 0.1 to 0.2s
2) curtains, banners and rotatable wall sections for altering the room absorption - 35% average change in RT
3) variable absorption techniques plus volume and seating changes (e.g. hinged ceiling sections, lowerable ceilings (fig ), division of the room volume by curtaining, hard-wall division - e.g. separating off sections into separate rooms) -

46% average change in RT

Thus, on average these techniques cannot provide the adjustment required, - even if we consider only musical performances, where the required variation in R.T. would be approximately 60%. Only where drastic changes to room volume and seating are tolerated can such alterations be achieved. Also passive systems have only a very limited ability to change the value of the RT with frequency, as would be needed when changing from speech to music use.

Furthermore, we must note that any philosophy for passive control requires halls to be built with a large enough volume to give the longest required R.T.

It would be foolish to rule out the possibility of new techniques evolving for PASSIVE variable acoustics systems, but it is clear that present interest is centred on research and development for ACTIVE acoustical control.

## 2 ACTIVE ACOUSTICS

### 2.1 Definition and Aesthetic Acceptability

A simple definition of an ACTIVE system is one which supplies sound energy to the auditorium over and above that supplied naturally by the source. This means that active systems will use microphones and loudspeakers, and this fact alone is a difficulty for some musical purists.

The idea of having "working" or "active" loudspeakers evokes the sense of sounds being replayed. Hence, conciously or unconciously, connections are made with those features that are seen as undesirable in the process of creating and reproducing recorded works - for example,

1) loss of control to an engineer,
2) limitationsfrom the restricted dynamic range of certain conventional recording media
3) distortions from loudspeakers, etc.

In addition, there may be the feeling that sound supplied to listeners coming from energy emitted by loudspeakers constitutes a perversion, purely because it is not part of the original mechanical energy produced by the source. Further parallels drawn with the spread of P/A systems can also cause real fears about changes in musical sensitivity and listening patterns that we might unknowingly induce.

### 2.2 IN- LINE and NON-IN-LINE Active Systems

Given the choice between a recording and a live performance, which would people choose? In the case of both recorded and live performances the artists are communicating with their audience. But the live performances contain an all-important element of two-way communication. This may be subtle during the actual performance (though performers frequently comment on how strongly they feel it) and only become overt during applause etc., but any components we include in a hall which inhibit or imbalance this two-way communication are clearly detrimental. Thus the designer of a concert hall must attempt to preserve all the subtleties of audible two-way communication.

IN-LINE active systems, which place between performers and listeners an electro-acoustical link which requires the performer to play into a microphone and the listeners to listen to a loudspeaker at the other end, clearly contribute a one-way element to the communication, and thus by imbalancing the potential two-way communication process become destructive, at least to some small degree, of the live performance experience.

The more desirable alternative of what we might term NON-IN-LINE systems, while still using microphones and loudspeakers, keep them remote from both performers and listeners, even hidden from sight if this is desirable. But most importantly these systems may be seen not so much as processors of sound signals but more as mechanisms for adjusting the acoustical properties of the boundary surfaces of the auditorium.

One fundamental and very important feature of all the ACTIVE systems (at least those published to date!) is that they add reverberation to a given space. Thus their planned use in buildings offers freedom to architects to design room volumes considerably smaller than those dictated by the requirements for passive reverberation.

Add to this 1) the convenience of being able to change the acoustics at the flick of a switch,
2) the potential for easy adjustment of the frequency
dependence of the reverberation, and
3) in principle, the provision of control over the other features of the acoustics as outlined in the list above,
then ACTIVE systems look almost irresistable.

### 2.3 ASSISTED RESONANCE and MULTI-CHANNEL REVERBERATION.

Parkin/2/, observing that "ringing" in P/A systems constitutes a long reverberation at the ringing frequences, harnessed the effect and developed a system of multiple channels of controlled feedback into the ASSISTED RESONANCE (AR) system - one of the two commercial NON-IN-LINE systems that have been around for some years.

Each channel of an AR system is individually tuned to a frequency in the room response. Hence one drawback of AR is its sensitivity to movement of the response as room occupancy and conditions change. Another drawback is the large number of channels (each containing a minimum of one microphone, amplifier, and loudspeaker) that is required to cover a significant frequency range, e.g. of the order of 100 channels are used to cover the bottom 1 kHz range of the audio frequency spectrum.

An alternative approach taken by Philips in their MULTI-CHANNEL REVERBERATION /3/, instead of

supplying the required energy in the very narrow bandwidths at high gain (as in AR),is to use a comparable number of wide-bandwidth channels working at very low gains. Individually the channels would be inaudible. A difficulty arises because the basic principle of the technique means the spatial requirements are very high (around 40m for each loudspeaker and each microphone). Also it has been shown /4/, that colouration imposes a strict limit on added reverberation, - the increase in RT must be limited to about 50% to be acceptable. In consequence the scope for changing the RT and shaping its variation with frequency is rather restricted - as can be seen from the results from a recent installation of MCR in Norway /4/.
Assisted Resonance does not have this same limitation. However, its gain in RT is predominantly at low and mid frequencies, for two reasons:
1) this is the range where the major difference in RT is required in multi-purpose halls, and
2) the need to restrict the channels to an economic number.

## 3 NEW DEVELOPMENTS.

Two systems were announced at the Concert Hall satellite symposium of the 12th I.C.A. in Canada (1986), and the firms of Roland and Yamaha are also marketing new devices. Regrettably all of these are essentially of the IN-LINE variety, and for them feedback is a large problem.

### 3.1 Acoustical Control System (ACS)

One of these recent systems which merits special mention, is the Dutch ACS system/5/. This system also uses multiple channels of mics and loudspeakers but by means of changing the interconnections between the mics and loudspeakers as time proceeds, controls feedback instability to the point where large changes in RT can be produced. These are sufficient to satisfy our requirement for a factor of two variation referred to at the beginning, and its developers point out the potential of the system for varying clarity and the lateral energy fraction.

Recent results/6/,/7/, confirm the system's ability to produce large changes in RT but show little change for other parameters, and are inconclusive on the subjective acceptability of perceived changes, as indeed for all the variable systems tested. It is, however, essentially an IN-LINE system, and its performance cannot be fully assessed against others until we have adequate means of assessing colouration.

### 3.2 The Future

Guicking et al's experiments at Gottingen with new types of electret loudspeakers/8/, may lead to the most aesthetically satisfying of NON-IN-LINE systems. Their performance, albeit relating to impractical, experimental conditions, varies effective absorption coefficients between 1 and -0.5 (i.e produce reflections with a controllable amplification from zero to a maximum of 1.5). Perhaps these are the embryonic "active wall linings" with which we could produce our multi-purpose halls of the future.

## 4 CONCLUSION.

A) Passive Acoustical Design offers
1) Maintenance - free acoustics for single-purpose auditoria
2) "Natural" - uncoloured sound
3) Inherently stable acoustics from adjustable systems.
but has these disadvantages:
1) Room volume is fixed by the required maximum RT
2) For variable acoustics, major changes to room volume and seating capacity are needed if the RT is to be varied more than about 40%
3) Designs with variable acoustics are likely to be a) time consuming for altering the room conditions b) inflexible if adjustment of frequency dependence is required.
B) Active Acoustical Design offers:
1) Smaller room volumes
2) Freedom from constraints on the positioning of reflectors and room boundary surfaces when designing for "lateral" sound
3) Economical correction of acoustical errors
4) For variable acoustics-a) rapid changes, and b) flexibility of control over both the degree and frequency dependence of changes.
but has these disadvantages:
1) It may incur aesthetic offence
2) Without protection devices it is inherently unstable and may cause coloration of sound
3) It requires maintenance for the electro-acoustic equipment
4) The present generation of active systems have one or more of the following limitations a) a restricted range of RT variation b) large spatial requirements for loudspeakers and microphones c) sensitivity to changes of room configuration d) an insufficient number of installations to establish the dependability and subjective acceptability of the technique.

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