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REVERBERATION ENHANCEMENT AND REFLECTED ENERGY SYSTEM - TRINITY CHURCH, SOUTHPORT, CONNECTICUT, U.S.A.

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INTRODUCTION

This Paper deals with a new method for introducing reverberation into auditoria and other related spaces. It is conceptually and operationally different to any other method either past or present. The basic endeavour is to provide a reverberation increase within the space. Such provisions are unfortunately not a simple matter and cannot be effected by the simple inclusion of microphone reverberation means and loudspeakers. The acoustic coupling between the input and output transducers brings with it instability, unwanted disturbances and colouration to the resultant sound field.

It is worth briefly examining the architectural alternative. To effect an increase in reverberation by a factor of two would necessary imply an increase in the volume of the space by a factor of two or a reduction in the total absorption within the space also by a factor of two. Obviously with cost and size limitations, increases in volume are not favoured. Decreases in absorption are perhaps more readily obtained but are always beset by a limit equal to the necessary intrinsic absorption within the space - namely the audience and seating. Realistically, architectural changes of 10-20% represent feasible limits.

HISTORICAL

In 1982 AMS and Jaffe agreed to co-operate initially on a feasibility study for the design and development of a reverberation system which was free from the usual problems. The feasibility study examined the problems associated with this endeavour which included colouration, response bandwidth, installation and commissioning, effect and, of course, cost. Such a new design should ideally, within the constraints of useful working enhancement, be free from colouration, operate over a broad frequency band say 50 Hz - 5 KHz, be readily installed in a short time and commissioned in no longer than one week and in addition, it was determined that the new system cost should be realistic.

The feasibility study concluded that such a system should not operate in the normal expected positive feedback mode since this inherent instability normally results in a protracted installation period. We also determined that a gross improvement in stability was required and that the best means of achieving this was the use of a simple tolerant software algorithm.

It was also determined that recirculation caused by positive feedback was the major cause of colouration.

As a commercial expediency, it was also determined that such reverberation machinery should be compatible and associated with a reflected energy system thereby completing the provision of an acoustical conditioning system.

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By the end of 1985, the essential features of the hardware were defined and prototypes built. The concept now known as RODS (Reverberation on Demand) involves splitting the reverberation component into two parts; that part which is present during running music (when some colouration may be tolerated) and that part which comprises system output only. Fig. 1 shows a much simplified schematic of the system.

The essence of the system is as follows: Switches S1 and S2 are controlled by a mircroprocessor. The state of the switches is dependent upon the sound field; when the field is either steady or rising S1 is closed and S2 is open, when the sound field starts to fall, S1 opens and S2 closes releasing the stored reverberation into the space. Since S1 and S2 cannot be closed at the same time, the problem of recirculation is much reduced.

Clearly, this is a much simplified account, since S1 and S2 are not in fact switches, rather they are digitally-controlled attenuators. Further of course, the attenuators are not used in a simple bi-state. In fact both input and output attenuators are manipulated to provide the optimum input/output conditions.

Fig. 2 shows a comprehensive system not unlike the unit employed in Southport Church. This unit allows for additional channels with the added complexity of two reverberation units.

From initial laboratory studies we were able to identify those system parameters that required control and in addition verification was gained regarding the likely success of our endeavours. Some limited trials were carried out in the United Kingdom and provided excellent support for the reverberation concept but emphasised the need for associated reflections. Reverberation introduced into a theatre space without the necessary attendant reflections, sounded unnatural and out-of-step with the space. It did, however, confirm that gross increases in reverberation time were possible and that the setting and tuning period could be accomplished in a very short space of time. The system in question was temporarily installed, commissioned and set in two-and-a-half days. This included all loudspeaker fixings, cabling, etc.

SOUTHPORT CHURCH

Encouraged by the experiments in the U.K. we decided to carry out more extensive trials and to include the reflected energy concept. At the beginning of 1987 we located a space in Southport, Connecticut where we were able to carry out our development programme and conduct a number of trials.

Trinity Church in Southport is an 1850's frame structure seating approximately 400. Its lightly constructed plaster walls act as fairly efficient diaphragmatic absorbers, exacerbating what would normally be a low reverberation time given the volume of the space. The church has two pipe organs. In the rear gallery is an excellent 1972 Wilhelm tracker organ designed in the baroque manner while in the chancel are the remaining (fully enclosed) ranks from a 1930's era Moeller organ designed in the Romantic tradition. Both instruments suffer in that the natural acoustic environment of the space is not sympathetic to their needs.

In particular, the Wilhelm instrument is overly bright, its sound not well integrated into the space. In addition to the organs, Trinity Church has an active music programme with both adult and children choirs. These factors combined to make the church a good candidate for our experiments.

The system was configured as shown in fig. 3. It is comprised of two distinct parts: reflected energy which is divided into presence and warmth channels and two-channel reverberation which is divided into high and low frequency components.

No specific target was required except that such enhancement should readily be noticed by its absence and that the improvement should be worthwhile for both the organist and congregation (including choir)..

Although the experiments lasted for almost one year, the installation was effected in approximately one week and not more than one month's time was spent on the tuning and experimentation.

SYSTEM DESCRIPTION

The system is actually quite simple and straightforward. Two omnidirectional microphones were employed. One was suspended from the chancel ceiling over the choir stalls near the swell gates for the Moeller organ. The other microphone was attached to a support column midway back in the nave. Microphone signals were preamplified with the resultant line level signals then being sent through notch filters. At this point the signals were routed to the two different sub-systems. The presence channel of the reflected energy sub-system routed the signals through signal delays (nominal delay time 10-20 milliseconds) and amplifiers to 4 x BES SM-90 loudspeakers suspended from the balconies in the nave. The warmth channel was similarly derived, its signal low passed (cut-off 250 Hz), then delayed through an Audio Digital TC-5 Delay (nominal delay time 16-500 milliseconds) and amplified with a Bryston 4B amplifier (250 Watts/channel). Warmth speakers were 1 x Bozak CM-109 and 1 x Bozak CM-199-2 placed at diagonal corners of the galleries.

Signals for the reverberation sub-system were routed to two RODS processors. These processors controlled the audio signal feeding into and returning from the three Industrial Research reverberators. One processor was configured to control two reverberators. Upon entering the RODS processor, the signal was crossed over at 250 Hz. The low pass signal was fed to an Industrial Research XD-1187-72 reverberator (nominal reverberation extension 3.2 seconds). The high pass signal was fed to an XD-1187-48 (nominal extension 1.5 seconds). The other RODS processor was configured similarly but used only a single reverberator, an XD-1187-48 LS (nominal extension 2.2 seconds). High and low bands were summed before being fed to the single reverberator.

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After the RODS processors, the two signals were each routed into four modulated signal delays, a means of introducing artificially produced variable phase shifts. This process de-correlates the signals being fed to the speakers, improving the sense of diffusion in the sound field. After the delays, the eight signals were then fed to twelve Bozak LS-200 through Industrial Research DH-4020 amplifiers (100 Watts/channel). Low frequency reverberation was enhanced by deriving a low pass signal through a Crown VFX2 crossover and then feeding this signal to an amplifier driving Bozak speakers as in the warmth channel but with the speakers placed in opposite corners from the warmth speakers.

The disposition of the system elements is shown in fig. 4.

RESULTS

The final preferred result gave uncoloured enhancement to both organ and choir recitals. In terms of reverberation enhancement, this is shown in fig. 5. It can be seen that the increase in the lower frequencies was greater than factor 2, at the higher frequencies greater than factor 1.5.

The table below gives the results obtained:

	System Off	System On	% Increase
125 Hz	1.7	4.7	176
250 Hz	1.7	3.3	94
500 Hz	1.9	3.2	68
1 KHz	1.7	3.2	88
2 KHz	1.7	2.6	52

The system sound was natural and without noticeable colouration especially during the decay process (when only the system can be heard).

The measured reverberation curves were of good shape and did not exhibit either double slopes or concavity when the system was correctly aligned.

CONCLUSIONS

The achievable enhancement factors are directly comparable to those attained by other systems. In our experience however, there is little comparison in terms of colouration and stability with existing systems. In terms of cost and installation time, we are well within our targets. Based on the success of this and other experiments, systems are being installed in a further four venues. Unfortunately, at the time of writing, no single system is up and running. We believe the results of our endeavours clearly demonstrate that once again electronic reverberation enhancement is a viable and cost-effective alternative to otherwise complicated and expensive architectural methods.

Notwithstanding the above, it is important to understand that a simple reverberation time increase may, in itself, not be sufficient if the space lacks useful reflections or has other acoustical differences.

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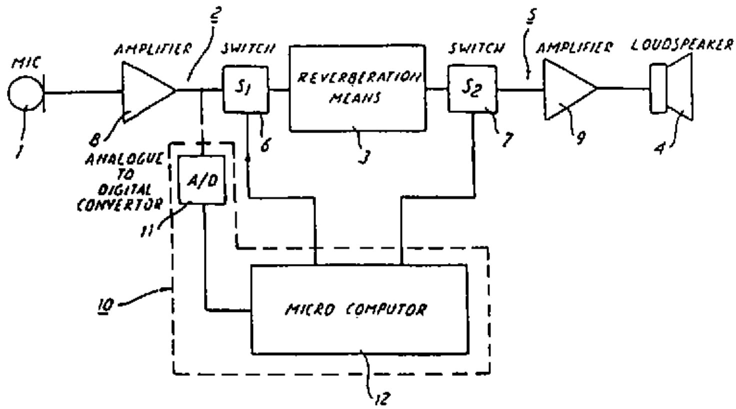
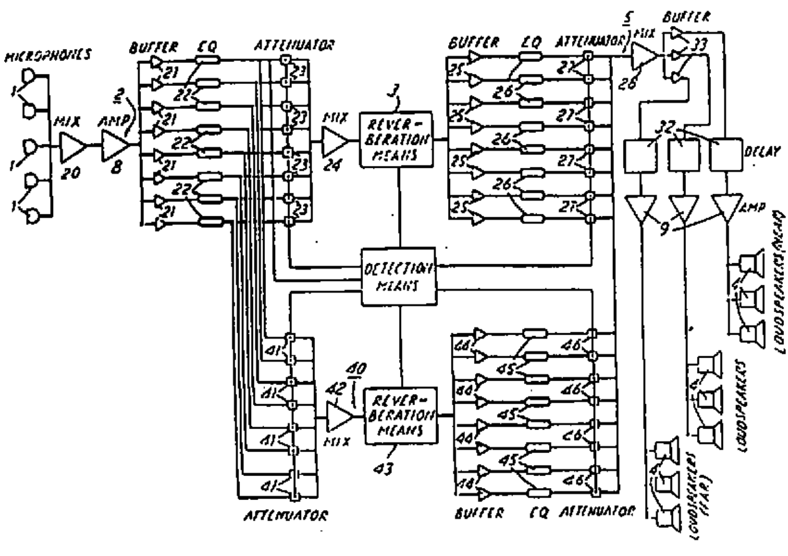


Simple RODS Schematic Fig. 1



Full RODS Schematic Fig. 2

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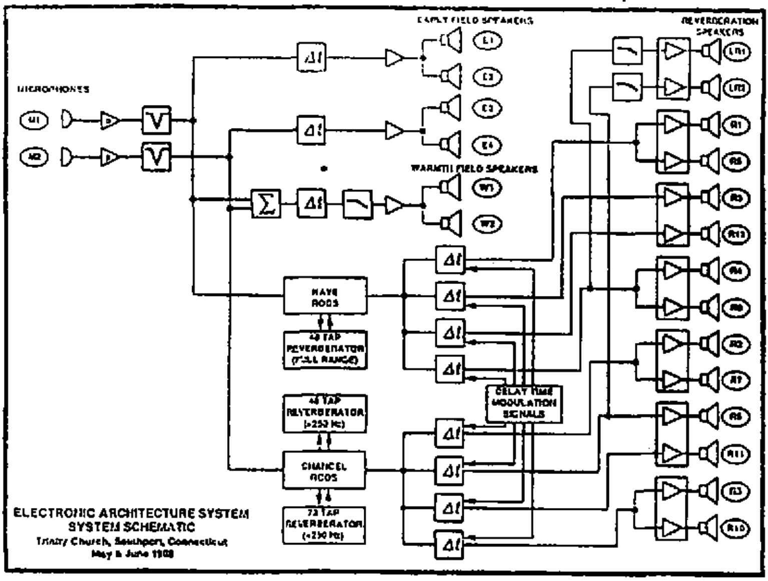

Fig. 3

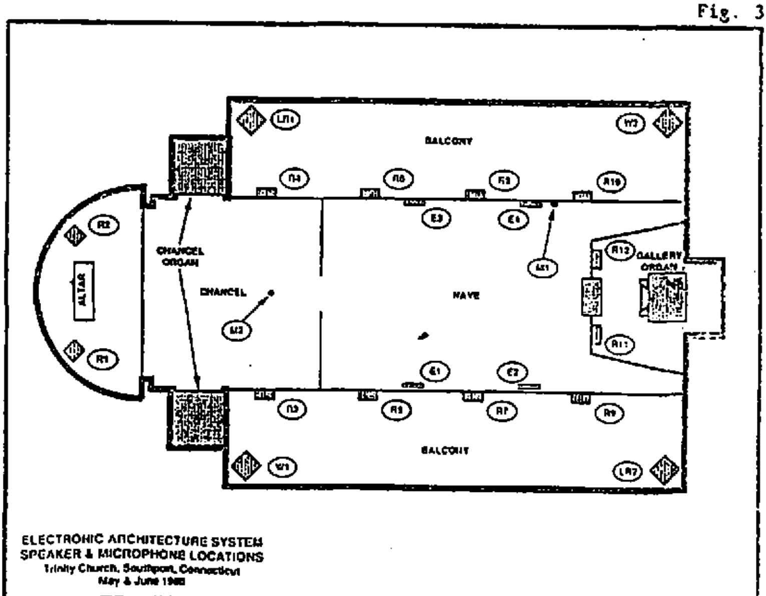

Fig. 4

REVERBERATION ENHANCEMENT AND REFLECTED ENERGY SYSTEM - TRINITY CHURCH, SOUTHPORT, CONNECTICUT, U.S.A.

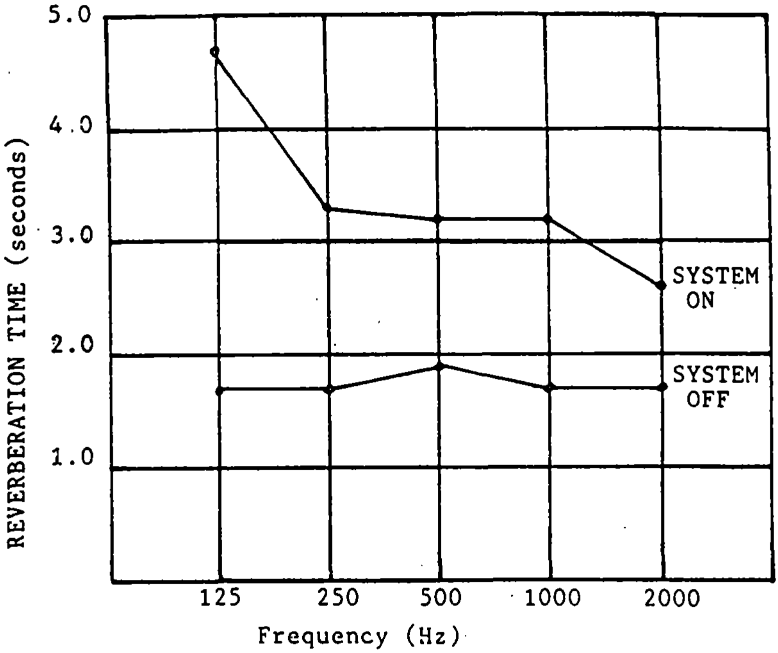

Fig. 5

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