Proceedings

ROOM ACOUSTICS
WITH EMPHASIS ON ELECTROACOUSTICS

BUILDING ACOUSTICS GROUP CONFERENCE
EDINBURGH

23-24 August 1979

INSTITUTE OF ACOUSTICS

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THE USE OF DIGITAL TECHNIQUES IN ACOUSTIC SCALE MODELLING

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INTRODUCTION

Acoustic scale models are now recognised as having a useful part to play in the design of auditoria. Models can be used to obtain objective data such as reverberation times, sound distribution, the characteristics of early reflections, etc. The acoustics of a particular design can also be subjectively evaluated prior to construction using the scaled recording technique developed by Spandock and his co-workers (1). The majority of models employed to date have been constructed to a scale of either one eighth or one tenth hence they are expensive and occupy a large space. For these reasons considerable interest has been expressed in one fiftieth scale models. At the present time these have only been used for objective and not subjective evaluation of room acoustics (2). Use of the scaled recording technique with such models is not satisfactory for a number of reasons. In the first place there are no transducers suitable for handling the full range of frequencies necessary for subjective tests and in the second place the absorption of sound in the air within the model is far higher than would be experienced in a full scale building at the corresponding frequencies.

This paper describes a technique which may permit room designs to be subjectively evaluated using small models. A schematic diagram of the technique is shown in Figure 1. The acoustical characteristics of the room are obtained by recording the response of the model to an impulsive source such as a spark discharge. This information is used to program a digital computer which then operates on digitally encoded anechoic recordings. The resultant digital signal is reconverted into analogue form and re-recorded for subsequent listening tests.

THE SYSTEM

The Impulse Response

The impulse response obtained by means of the spark discharge can be employed in two ways. The first method is to convolve this response with the sampled signal. In the course of this procedure corrections for source directionality, microphone response and air absorption could be made. The second method is to use the spark response to obtain "echograms" which will yield information concerning the relative intensities and time delays of early reflections. In this latter technique it is assumed that room acoustics are determined by the early reflected sound plus later reflections which merge together to constitute reverberation. The echogram information is used in the computer program to add reflections with the appropriate time delay and intensity to the direct sound. Reverberation can also be added by the computer (3)(4).

Of these two methods the first is to be preferred since it involves no compromises. Unfortunately the computing power required for this technique is immense and it would take a considerable amount of computer time to process even a small sample of speech or music. The second method involves a considerable degree of compromise as indeed does subjective evaluation of room designs by conventional analogue modelling methods. It is reasonable to expect that this method would be satisfactory for speech sources where the objective in room design is to achieve adequate intelligibility at all points in the room. Intelligibility is determined by the high frequency components of speech which would be expected to be reflected in a specular manner similar to the pulses recorded by means of the echogram. The effects of the directionality of human speakers could be taken into account when processing the signal thus making the technique suitable for the evaluation of thrust stage auditoria.

The situation with regard to music sources is less clear but it is probable that the technique could be used to achieve results comparable with the use of analogue techniques on larger models.

Analogue to Digital and Digital to Analogue Conversion

Analogue to digital and digital to analogue converters come in many forms. Their most important parameters are the number of bits and maximum sampling rate. The dynamic range of these devices is equal to six times the number of bits. However, since a change of one bit at the lowest level corresponds to a change in the analogue signal of 6 dB it is necessary to employ a device with a greater number of bits than considerations of dynamic range alone would suggest. Schroeder has employed a twelve bit device in computer studies of room acoustics (4). This probably represents the minimum acceptable number and fourteen or sixteen bit devices would be preferable.

According to sampling theory the sampling rate should be at least twice the highest frequency in the sampled waveform. This means that if a recording of anechoic music is to be sampled in real time a minimum rate of 30,000 samples per second should be employed. This is well within the capacity of available A.D.C.'s.

The Computer Program

As stated above the performance of a complete convolution on the anechoic signal makes enormous demands on the computer. The use of the echogram technique also requires considerable computing power. If a limited number of reflections are considered then it is feasible to process the anechoic signal in real time. Failing this it is necessary to dump the digitally encoded anechoic signal onto disc storage and to process it in small packets. A similar procedure must also be employed to retrieve the processed signal prior to listening tests.

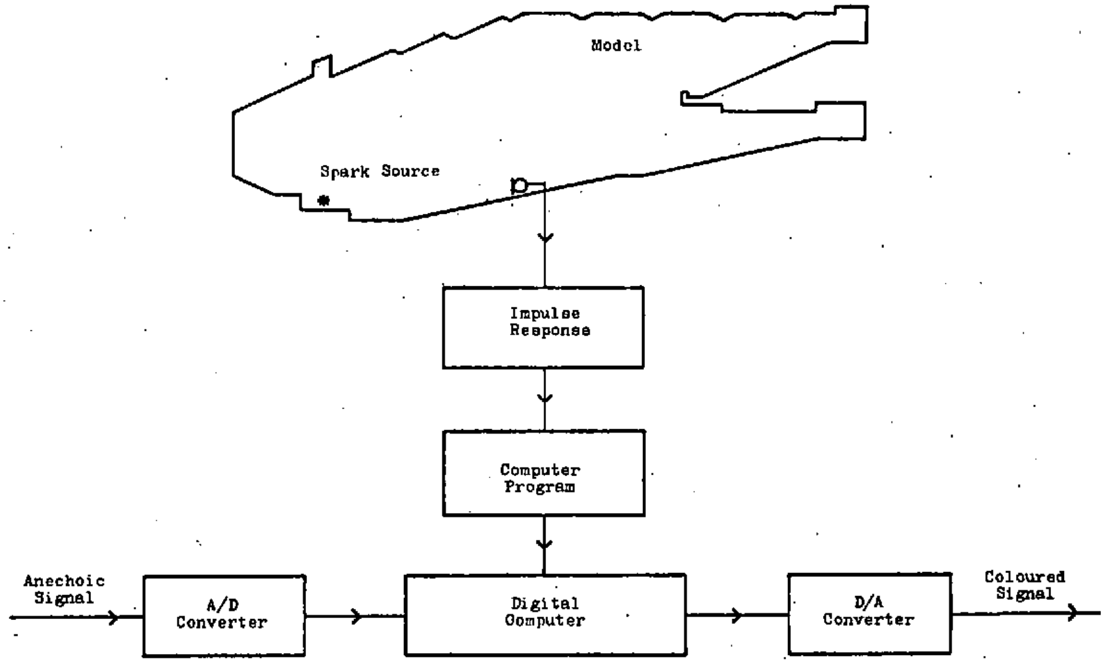

Figure 1 Schematic diagram of the system

DIGITAL TECHNIQUES IN ACOUSTIC MODELLING

CONCLUSION

With the rapidly decreasing cost of components due to large scale circuit integration the use of digital techniques for scale model studies of room acoustics is becoming an attractive alternative to conventional analogue methods. Digital methods offer the possibility of performing subjective tests on smaller models than can be employed with analogue methods with a resultant saving in costs. One result of this lowering of costs may be the use of scale models to test the design of a larger number of auditoria than at the present time when only the most prestigious buildings are evaluated in this way.

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