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IMPULSE TECHNIQUES IN PREDICTING SPEECH INTELLIGIBILITY IN ROOMS

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Introduction

This paper is concerned firstly with the use of impulse responses obtained in rooms to calculate Reflections Ratio and predict the degree of speech intelligibility; secondly, with the use of impulse responses and integrated impulse responses for comparison of real and synthetic sound fields.

Use of impulse response in prediction of speech intelligibility

Lochner and Burger (1) proposed signal-to-noise ratio as a predictor of speech intelligibility in auditoria. This discriminated between reflections which helped or hindered intelligibility. Latham (2) extended the technique to include the effects of ambient noise, and found this to correlate well with speech intelligibility. A stage in evaluating Latham's modified signal-to-noise ratio is the measurement of the Reflections Ratio of the weighted early energy to late energy.

$$S/N' = 10 \log_{10} \frac{\int_{0}^{95\,mSec} a.p^2 \, dt}{\int_{95}^{\infty} p^2 \, dt + p(N)^2} \qquad (1)$$

where a is Lochner and Burger's temporal weighting for useful energy fraction, and N is the frequency weighted ambient noise.

Evaluation of the Reflections Ratio entailed the recording of an impulse response for given positions of source and receiver in a particular auditorium. The evaluation (in the 1 kHz octave band) was done using a fast transient analyser linked to a microcomputer. The impulse source was an electrical discharge with omni-directional characteristics.

The technique has been applied in a number of auditoria with stages or platforms at one end, but has subsequently been applied to theatre-in-the-round at the Grange Arts Centre, Oldham (3). In this case an attempt was made to simulate the directionality of the voice.

The simulation of sound fields using impulse responses

Our current work is concerned with speech quality in auditoria using multi-dimensional scaling of preference judgements made in synthetic sound fields. Impulse responses are used to set up the simulations in the anechoic chamber. The synthetic sound field has been described (4) and demonstrated at the IOA conference on Room Acoustics with emphasis on Electro-acoustics, August 1979. The sound field utilises anechoic speech as the source material, which is modified by attenuators, delay lines and reverberation processor to produce signals which are fed to an array of loudspeakers in the chamber.

Part of the setting-up process entails matching the impulse response for the simulation to the impulse response from a real auditorium. The major early reflections from specific surfaces are identified, and to simulate direction, signals representing these reflections are fed to appropriately positioned speakers in the chamber. The delay lines and attenuators are adjusted until a comparable impulse response is obtained in the simulated sound field. As an aid to this, impulse responses are fed through an integrating circuit. This circuit (figure 1) performs exponential integration intended to simulate subjective masking of a reflection by a subsequent reflection, using Niese's 25 mSec time constant for hearing (4). Figure 2 shows the matched integrated echograms for three real auditoria and three soundfield simulations. The circuit also acts as a threshold limitation device due to the cut-off of the diode below 0.7V; thus signals with a level of -15 dB or greater re. a typical peak signal of 4V will be transmitted.

Aids to setting-up a simulated soundfield

The uses of impulse responses for predicting speech intelligibility and setting-up soundfields have been described briefly. The conventional impulse response does not of itself convey information regarding the direction of specific reflections or their spectral composition. Two channel recording of impulse responses with a directional and an omni-directional microphone, or with a refined dummy head system, should be

a further aid to adjusting the various components of the simulated soundfield. The simulation could be further developed by spectral analysis of early segments of the impulse response and incorporating the spectral information in the soundfield.

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References

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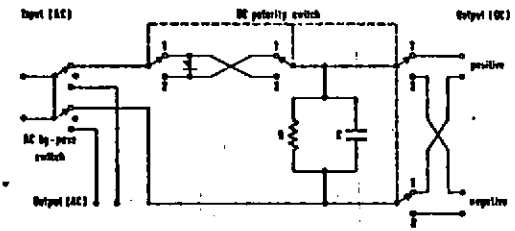

Figure 1 Integration circuit diagram

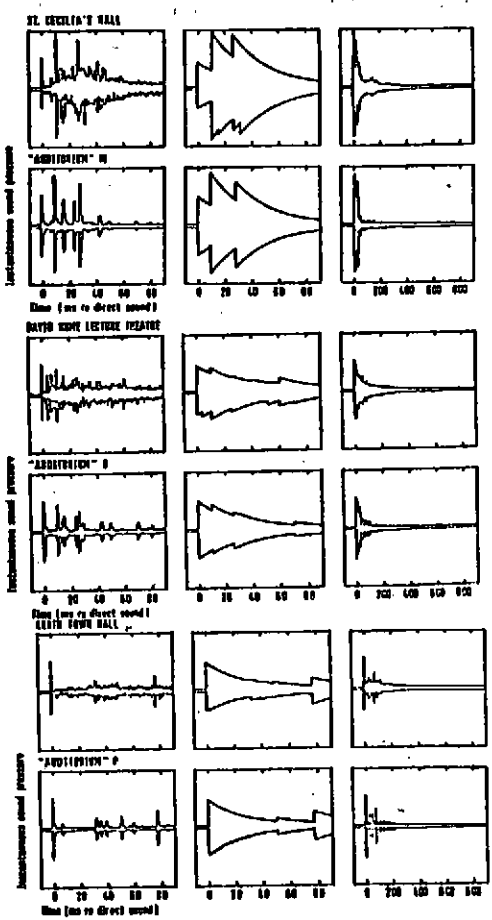

Figure 2 Echograms of real and simulated sound fields