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MODELLING OF SOUND PROPAGATION IN UNDERGROUND STATIONS

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1 INTRODUCTION

Predicting the propagation of sound within underground stations is difficult for several reasons including the high absorption of running tunnels and passenger entrances to platforms, diffractional effects from finite sized surfaces and edges, possible focusing effects caused by curved surfaces, and the scattering of sound by passengers and trains. Previous work on underground stations concentrated on full scale and physical scale model measurements[1,2]. However, computer modelling can provide a cheaper, faster and convenient method for predicting the sound field in underground stations.

This paper describes the development of a computer model which has been used to predict sound pressure levels and acoustics parameters. Predictions have been compared with measurements made in a physical scale model of an underground station.

The computer model uses the ray-tracing method and can model complex geometry and the disproportional distribution of sound absorption. Curved surfaces are modelled using an exact representation rather than by approximating by a series of planes. The diffraction effects have been modelled using the "REDIR" method of Dance *et al* [3].

2 THE SCALE MODEL MEASUREMENTS

The measurements were carried out in a 1:16 physical scale model of an underground station with one source. Receivers were positioned along the passenger platform as shown in Figure 1. The tunnel length was 8m in total (128m long full scale), the source position was 1.04m (16.64m full scale) from one end.

The measurements were taken using the MLSSA system [5]. Most of the acoustical parameters were obtained for the third octave bands from 125HzFS to 1000HzFS. The measurements were taken in normal air.

The measurements showed that diffraction effects occurred at the entrances to the running tunnels.

3 MODELLING OF THE STATION

The computer model has been used to predict the sound field in the scale model underground station as shown in Figures 1 and 2. The computer model takes into account the platform and two passenger exits, the semi-circular roof, and the train running tunnels.

The sound source was represented by omni-directional, equal-intensity sound rays whose number can be calculated as follows [4]:

$$N = 10\frac{V_s}{V_r}$$

where V_s is the volume of the space and V_r is the volume of the receiver, a sphere of 1m diameter in this case.

A curved surface is represented exactly in the model, instead of being approximated by a series of flat planes as in most of the current models.

Diffraction effects were modelled at the end of the running tunnels and passenger exits using the REDIR method [3], as shown in Figure 3.

4 RESULTS

Some of the measurements and corresponding computer predictions are shown in Figures 4 to 7. (M Indicates measured and P predicted levels) Figures 4 and 5 show predicted and measured Early Decay Time (EDT) at 2k, 4k, 8k, and 16kHz (125Hz to 1000Hz full scale). Figures 6 and 7 show measured and predicted Sound Pressure level (SPL) at the same frequencies.

Figures 4 to 7 show that the changes in both EDT and SPL along the length of the scale model are correctly predicted at all frequencies.

At the middle frequencies (250HzFS, 500HzFS), there was good agreement between predicted and measured values of EDT along the length of the scale model. The computer model correctly predicts the trend of the change in the sound level with distance along the tunnel, but at individual receiver positions the error can be up to 6dB.

The largest errors in both EDT and SPL predictions occur at the lowest frequency modelled (125HzFS). These are due to the large wavelength compared with the dimensions of the scale model.

At the highest frequency modelled (1000HzFS), predictions are more accurate in the far field than in the near field. This is possibly because the size of the source is large compared with the wavelength, so the source can not be treated as a point source in the near field.

5 CONCLUSIONS

Preliminary results show that it is possible to model the sound field in an underground station by taking into account the curved surfaces and diffractional effects. The model will be further developed to investigate the prediction of speech intelligibility in underground stations.

6 ACKNOWLEDGEMENT

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7 REFERENCES

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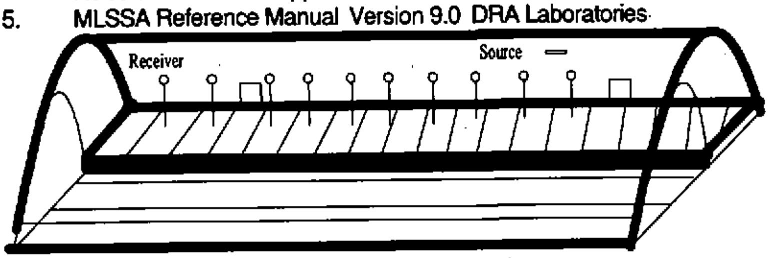

Figure 1 Underground Station model

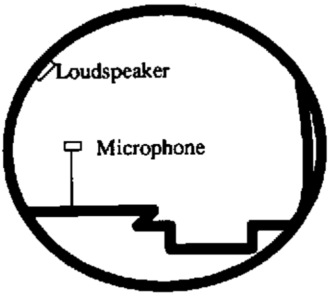

Figure 2 Cross section of model

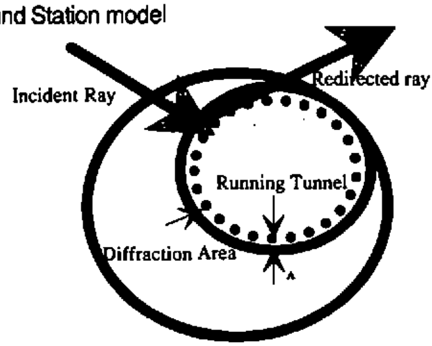

Figure 3 Diffraction Effects

Figure 4. EDT at 125HzFS and 250HzFS

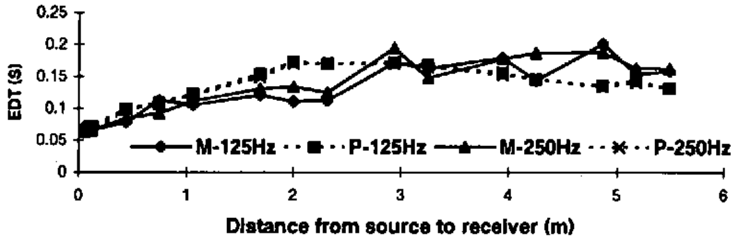

Figure 5. EDT at 500HzFS and 1000HzFS

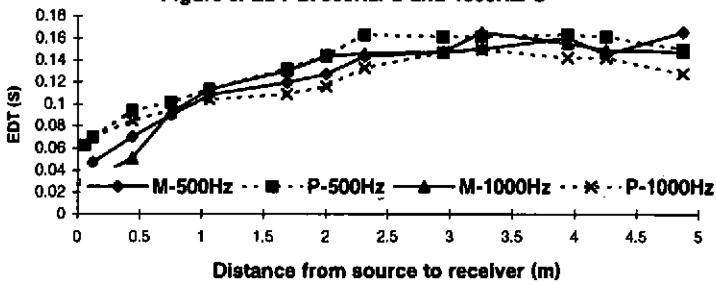

Figure 6. SPL at 250 HzFS and 500HzFS

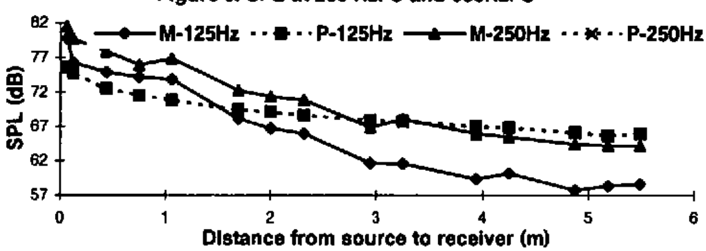

Figure 7. SPL at 500HzFS and 1000HzFS