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IN-TRAIN PA

P.W. Barnett & R.D. Knight

AMS Acoustics, 43 Chase Side, Southgate, London, N14 5BP.

INTRODUCTION

This paper covers tests and measurements carried out on the train PA system for Type 'A' rolling stock on the Metropolitan Line.

The measurements made during a journey from Neasden to Watford and subsequently in the depot included electronic, acoustic and vibration measurements. These measurements comprised: frequency response, distortion, cable loss, coverage, RASTI, Word Scores, noise levels and other subsidiary performance indicators.

We understand from LUL that PA is a preferred passenger information service and that the purpose of the In-Train PA is to provide the following:

(i) Safety-related announcements

(ii) Service information announcements.

Within this context safety announcements we assume could be made at any time but most likely when the train is stationary. In this regard we assume that compliance with a target of 0.5 RASTI would be desirable.

Service-related announcements we assume may include apologies for delay, rescheduling, unscheduled train termination, perhaps even reference to following services.

Again, we assume that these announcements would be generally made when the train is stationary and although no definite intelligibility performance indicator would be specified. We assume that the expectation would be not less than that required by safety announcements especially in view of the possible increased complexity of a service-related announcement. There may even be a case for increased intelligibility.

TRAIN AND SYSTEM DESCRIPTION

The measurements were carried out on a type 'A' train comprising 2 No. motor carriages and 2 No. compressor carriages. These train units are larger than those normally encountered in central London and have lateral rather than longitudinal seating. Most of the track on the Metropolitan network is open.

Each train is normally fitted with two complete sets of PA equipment, one in each driving motor car at each end of the train. Only one can be activated at any time. The train examined was a four-car unit and had only one set of equipment.

The signal source is a telephone handset which doubles as the communication link between the two driving motor cars.

The signal level is increased by the unit containing the handset and then sent to the amplifier unit located in a robust sealed metal box which is fixed to the structure of the train under a seat in the driving motor car. The box contains two complete amplifiers which provide redundancy and these, in turn, drive the loudspeakers. The loudspeakers are 178mm x 101mm elliptical units of 50 ohm impedance. Three are fitted in each car and they are wired to two circuits with two loudspeakers on circuit A and one on circuit B in one car and one in circuit A and two on circuit B in the next car. This ensures that the loading on the two circuits is approximately equal.

ELECTRONIC AND ELECTRICAL INVESTIGATION

The following measurements where made

- (i) Frequency response
- (ii) System output capability
- (iii) Cable loss
- (iv) Distortion

The frequency response of the complete system from telephone handset to loudspeaker output was also measured as shown below.

Frequency Response of all System Components

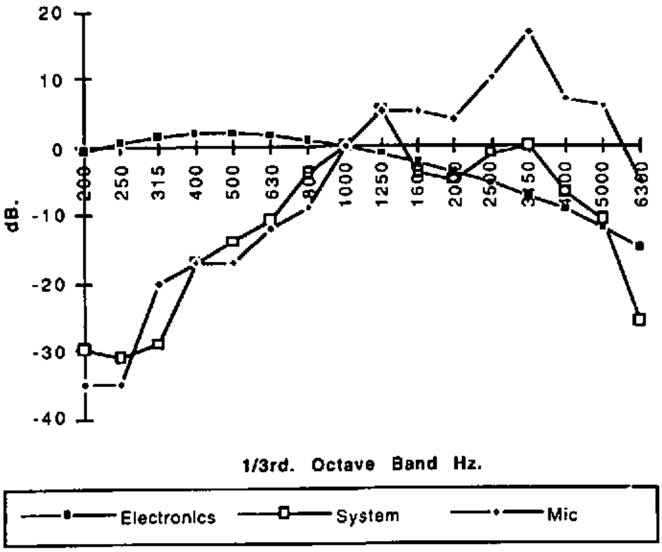

Fig. 1

Clearly the frequency response of the electronics had been tailored to suit the poor response of the microphone

The results of the output power are given in the table below:

Output Level Prior to Clipping

Condition	Parameter	
	Output Voltage	Output Power (50 ohm)
Prior to onset of clipping	21	8..8 Watt

The cable loss along the length of the train was measured and the results were as follows:

Cable Loss

Amplifier Output Level	Level Across Farthest Loudspeaker	Loss	
		Volts	dB
800mV	676mV	24mV	0.7

The system distortion was measured and the results shown below.

Distortion Products - Complete System

Product	Level (dB)	%
Even	-43.9	0.004
Odd	-33.1	0.05
Total	-32.8	0.05

From the foregoing it can be seen that the frequency response of the amplification chain was unexpectedly poor, although to an extent it may have been deliberate to compensate for the increased high frequency response of the handset.

With regard to the distortion products, whilst this could be improved we do not believe it is a major factor in the performance of the system. The cable loss and amplifier output is much as expected.

ACOUSTICAL CONSIDERATIONS

The following measurements were made:

- (i) Direct statistical analysis of noise.
- (ii) Direct recording of noise.
- (iii) Binaural recording of noise.
- (iv) Coverage recordings.
- (v) RASTI
- (vi) Word Scores.

Most of the measurements where recorded and subsequently analysed

A statistical analysis of the train noise during the journey was made, results are shown below:

Average Statistical Noise Levels of Train Journey - Neasden to Watford

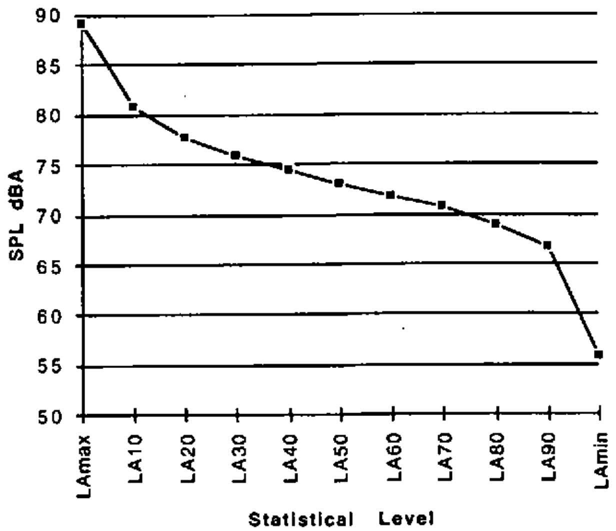

Fig. 2

The activities measured were as follows:

(i) Train on open track - windows open
(ii) Train on open track - windows closed
(iii) Train over points - window open
(iv) Train over points - windows closed.
(v) Train standing in station - doors open
(vi) Train on open track with another train passing.

A summary of the results are given below:

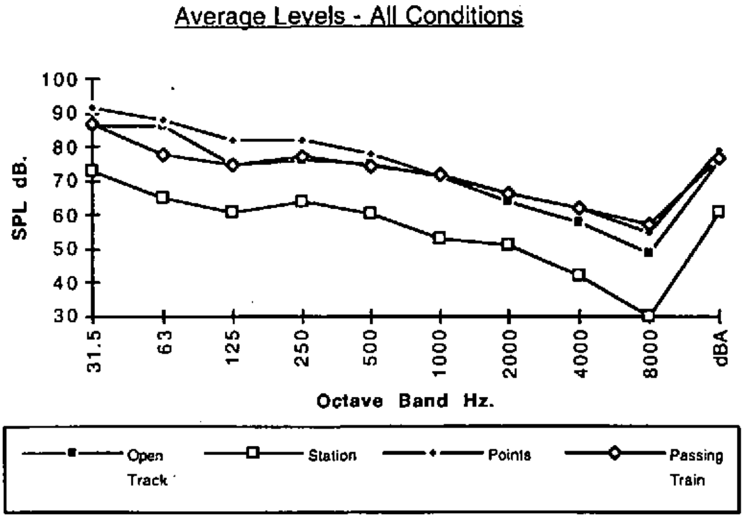

Fig. 3

These results were also used in the RASTI analysis. Binaural recordings were also made throughout the journey and were used for two purposes. Firstly for determining the noise levels to be used in conjunction with the Word Score tests and secondly to make a subjective determination of a PA announcement.

The system coverage was measured by recording a traverse from one end of a carriage to the other with pink noise input to the system, spot measurement data is shown in the table overleaf.

Coverage Spot Measurements

Position	Octave Band (Hz)				dBA
	500	1k	2k	4k	
Position 1 Sitting at end of carriage - back to glass	-23	-10	-14	-17	-7
Position 2 Standing in aisle of main seating area	-22	-9	-14	-6	-7
Position 3 Main seating area facing glass - seat next to aisle	-22	-9	-14	-6	-7
Position 4 As above but next to window	-24	-10	-15	-8	-8
Position 5 As Position 3 but opposite seat	-22	-9	-14	-7	-7
Position 6 Directly under doorway speaker	-14	-2	-7	-8	0

RASTI measurements were made at various measurement positions in the carriage whilst the train was standing in the depot and subsequently analysed with the addition of the train noise. The results are shown in the table below.

RASTI Results - All Conditions
with Operational Noise

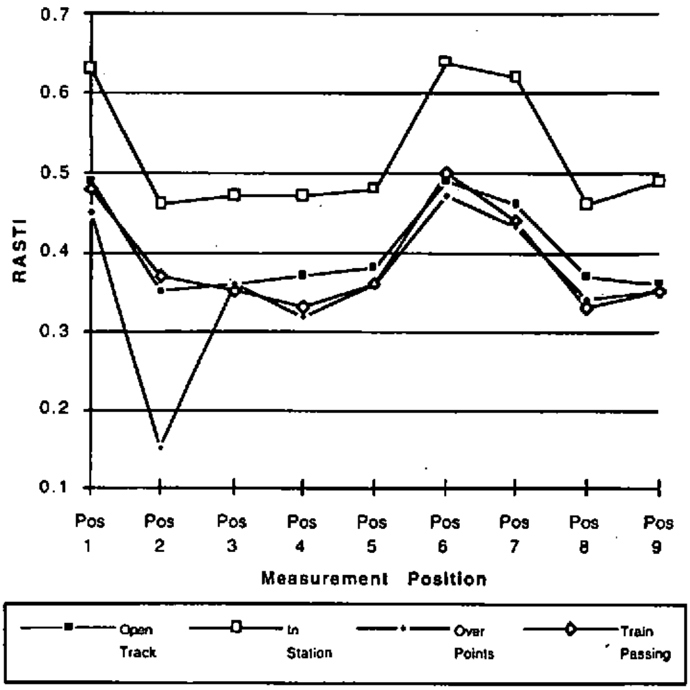

Fig. 4

For completeness sake both the RASTI and STI data is plotted against signal-to-noise ratio irrespective of the type of noise.

RASTI Data Points plotted against
Signal-to-Noise Ratio giving 'Best Fit' Line

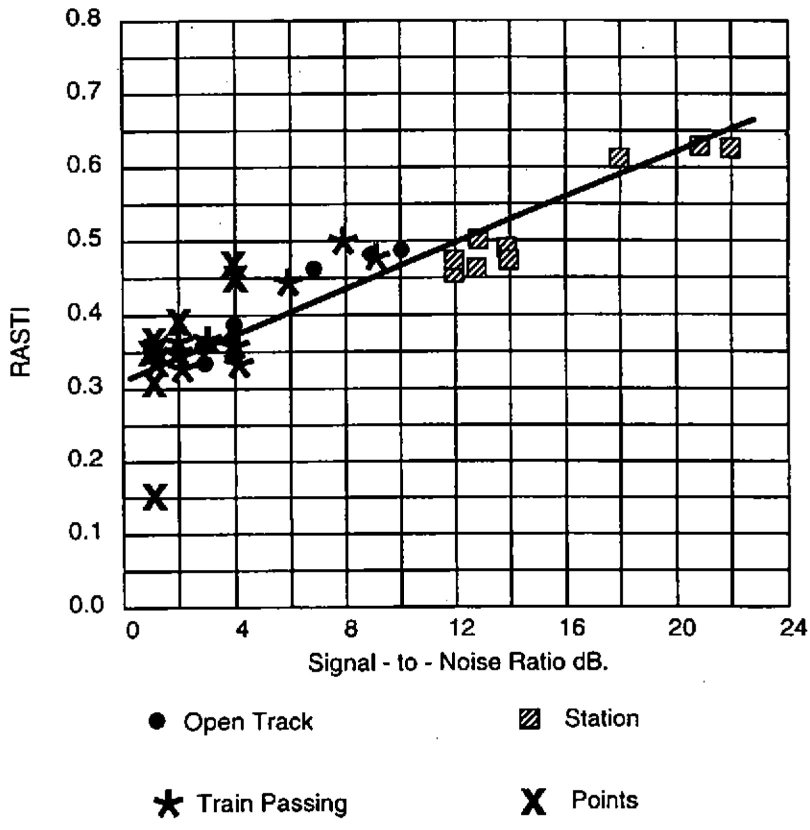

Fig. 5

Word scores were injected into the train PA system and recorded binaurally in two positions, seated and standing under noiseless conditions. The Word Scores were subsequently contaminated with operational noise derived from the earlier recordings.

In all, ten sets of words, each of 50 words content, were recorded at the depot. The full results are presented in fig. 6

Word Score Results plotted against
Signal-to-Noise Ratio

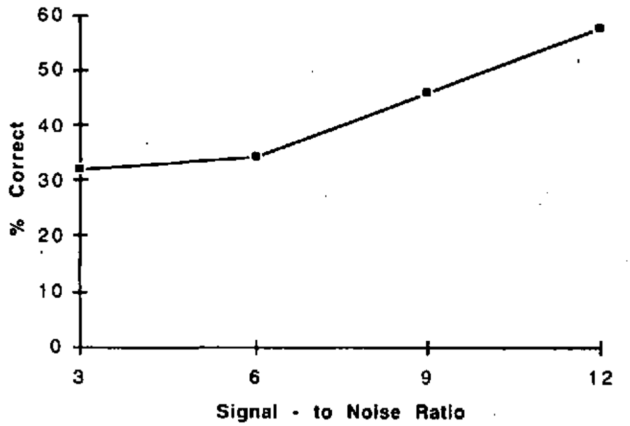

Fig. 6

From the data obtained it can be seen that (from fig. 2) the average noise level exceeded for 50% of the time during a surface journey is in the region of 75dBA. At around 1 metre from the loudspeaker the announcement level was in the region of 85dBA giving a signal-to-noise ratio of circa 10dBA.

The minimum for good intelligibility (given all other factors) is normally taken as around 6dBA. Since the reverberation time is low and since the degradation of the signal due to reverberation time will be small, the actual signal-to-noise ratio for 'minimum good' intelligibility may be as low as 3dB. Hence if we accept that with improvements to the system 3dB would be acceptable, then this would mean that this new criteria signal-to-noise ration = 3dB (equivalent to carriage noise level of 78dB) would be met for between 70% and 80% of the time.

The system coverage is important since it effectively describes the actual signal-to-noise ratio. If we assume that the operational noise level is ubiquitous throughout the carriage then reduced coverage level represents reduced signal-to-noise ratio. The reduction in coverage is caused by screening by solid objects i.e. seats and glass screens, distance and acoustical absorption.

From the RASTI measurements made, with the present loudspeaker arrangement a performance of 0.5 RASTI is only achieved at most positions when the train is stationary. Even then in some positions the situation is marginal.

It can be seen that the 'best fit' line demonstrates that for the present system the signal-to-noise ratio must be in the region of +8dB if a RASTI performance of 0.5 is to be achieved.

The Word Scores at best did not achieve 60%. This would correspond to around 0.3 on the RASTI scale.

We are of the opinion that the poor frequency response of the system is contributory in giving this anomalous result. For good correlation between speech intelligibility and RASTI the frequency response of the system under test should extend from around 200Hz to 6kHz (essentially flat) and It can be seen from the electrical measurements that this criteria is not met.

CONCLUSIONS

A passenger carriage of a train is quite unlike any other space in the LUL system. Mostly, the common problem encountered in LUL situations is high reverberation and modest noise levels. In this instance the problem is different in that the noise levels are slightly higher but with the exception of obstructions, the acoustics are favourable

The main contributory factors to reduced performance are as follows:

- (i) Poor sound coverage.
- (ii) Poor overall frequency response.
- (iii) Low quality loudspeakers.

At present there are two major contributions to the poor response:

- (i) Electronics
- (ii) Microphone.

The loudspeakers should be as small diameter (and circular) as possible to improve the high frequency dispersion.

The difference between the Word Score results and the RASTI results is disturbing.

We believe the difference or apparent anomaly between these results is due to the reduced and very poor frequency response of the system.

Finally there is the matter of when to make announcements.

Obviously in emergencies little can be done. However routine announcements should not be made at times of high noise level or when high noise levels are expected.

Preferably announcements should be made when the train is stationary in the station.