STI IN PRACTICE: THE IMPLICATIONS OF FLUCTUATING ACOUSTICS.

Peter Edwards, AMS Acoustics Ltd.

1. INTRODUCTION

When auditing the STI of a sound system, the two main acoustic parameters involved are the reverberation time of the space, and the background noise likely to be present. Usually these are defined as single octave band values but in some situations however, these parameters could be fluctuating significantly which would therefore produce corresponding fluctuations in the system intelligibility. An example of this could be an airport terminal or train station.
It is therefore the purpose of this investigation to study how the STI of a system in an underground Tube Station Platform area (and therefore expected intelligibility) is likely to change as the acoustic environment changes, and to compare the results with the traditional method of predicting the STI which assumes the acoustic environment remains constant.
Further to this, the time varying acoustic predictions will be applied to the concept of installing acoustic treatment to the space and an investigation into the effects of different quantities of absorption undertaken.

2. FLUCTUATING INPUT DATA

Background noise levels of trains entering and leaving the platform were measured and 1 second octave band Leq's were logged. The frequency of trains was approximately every 3 minutes and therefore a 3 minute section was taken from the data which incorporated 1 complete train cycle (ie, the train entering the platform, standing idle, leaving the platform and the period of relative quiet prior to the arrival of the next train).
In an underground platform tunnel, as a train enters the space not only does the ambient noise level change but also the reverberation time. A decrease in volume, along with changes in the absorptive properties of the surfaces (ie; the train covering the track) leads to fluctuations in the reverberation time. In order to simulate these changes, the octave band RT of the space was measured both with and without the train.

With knowledge of the platform length and the time the train takes from standing to entirely leave the platform area it is therefore possible to estimate the distance the train had travelled along the platform at any time assuming a constant acceleration. If we know the reverberation time when the train is in the station and we know the reverberation time when the space is empty, it is possible to give a rough approximation of the reverberation time when the train is partially in the station by associating the distance travelled with the change in acoustic absorption area and a change in volume.

It must be noted that this is only an approximation of the RT at any time, and for more accurate results the RT could be modelled at various intervals assuming absorption coefficients for the both train and the track. For the purpose of this investigation however, the above estimation seems adequate.
Therefore for the 3 minute train cycle, we have 180 sets of octave band RTs and octave band noise levels at 1 second intervals.

The detrimental effect which noise will ultimately have on the STI results will greatly depend on the level which the system is set. It seems the optimum level would be 25 to 30 dB above the background noise so that the S/N ratio does not degrade the results. However, in some circumstances, this would result in a system level which could be intolerably high.
When carrying out Speech Audiometry tests using word scores, there is thought to be an Uncomfortable Loudness Level (UCL) which determines the upper hearing limit for speech[1]. This is the maximum level at which word scores can be accurately administered, and therefore it also seems that above this level, STI results may also be inaccurate. It has been suggested that the normal ear should be able to accept upper hearing levels of 90 to 100dB. Therefore, for the purpose of this investigation a system level of 90dBA will be assumed to allow for most normal hearing.
This was calculated using a speech shaped input signal, the spectrum of a typical industrial loudspeaker and assuming that the reverberant field was dominating. Changes in system level and spectral shape due to changes in RT were also taken into account so that at each 1 second interval, a new S/N ratio could be calculated.

3. RESULTING STI VS TIME

If all the data is input into the STI calculations a graph of the expected STI at each snapshot in time can be produced. This is shown in figure 1 below;

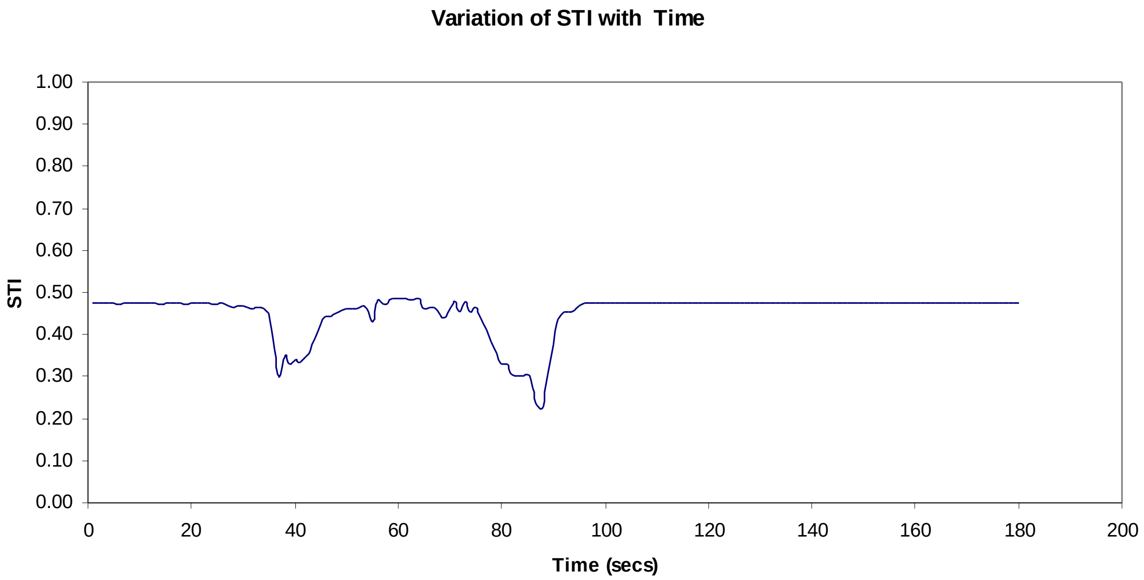

Figure 1

An STI of around 0.48 can be seen when the train is not in the platform. Due to a sharp rise in ambient noise levels when the train enters or leaves the area, the STI drops dramatically. The period when the train stands idle at the platform shows an increased STI of around 0.50 even though the background noise is higher than the non-train period. This is due to the reduction in reverberation time resulting due to the presence of the train.

Using single noise levels and non-varying RT (without the train present), the following STI would be predicted;

	STI	
Noise Parameter	**Noiseless**	**@S/N**
L10	0.48	0.34
Leq	0.48	0.41

Table 2

The results above show a substantial difference depending on which of the two noise parameters is used to calculate STI. In terms of percentage of time for which the actual STI is lower than predicted in Table 2 above

Noise Type Used	% of time lower than Predicted
L10	6.7
Leq	12.4

Table 3

Without a varying RT, you would expect the STI calculated using L_{10} to be lower than predicted for 10% of the period. The value here is slightly less due to the benefits of a reduction in RT.

4. ACOUSTIC TREATMENT OF THE SPACE

If a target STI of say 0.50 was to be achieved, then in our case the RT of the space would need to be reduced in order for the system to meet this target. This could be achieved by installing acoustic treatment to the space. If the total system level could not be increased above the current 90dBA, then the quantity of treatment required would not only depend on the RT of the space but also on the background noise. This can be demonstrated by calculating the area of acoustic treatment needed to reach 0.50 STI using both 3 minute L_{eq} and L_{10} background noise levels and non-varying RT;

Noise used	Treatment required (m^2)	New STI
L10	933	0.50
Leq	225	0.50

Table 4

It can be seen that in this case, the difference in required absorption changes dramatically depending on the background noise. Over 4 times the surface area of treatment is required to reach 0.50 STI if the L10 is used as the background noise than Leq. The effect on the time varying STI for these two scenarios can be seen below;

STI after different quantities of acoustic treatment

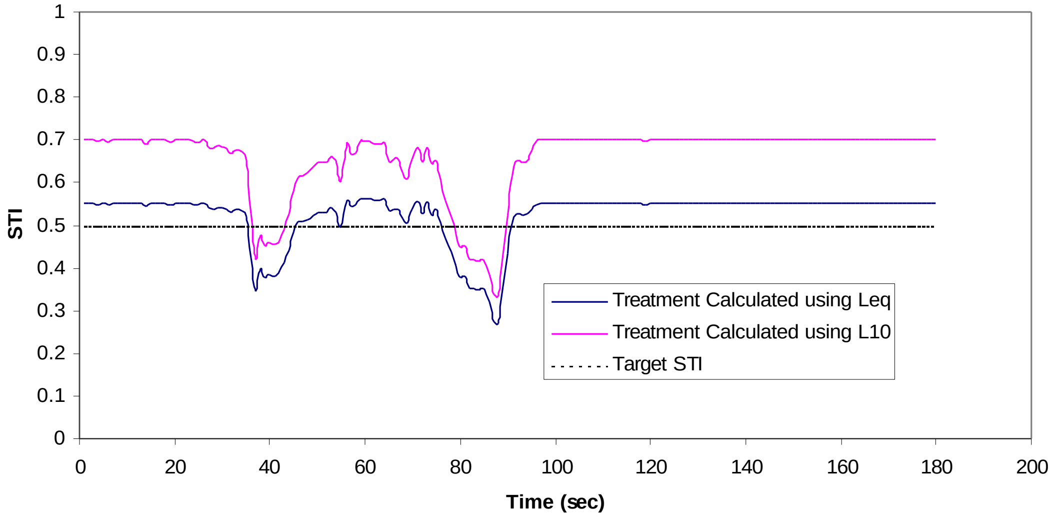

Figure 2

The importance in deciding which noise parameter to use can clearly be seen. Rather than using a single noise value, it could therefore be useful to look at the time varying STI and compare the percentage of time at which the system meets 0.50 STI for differing scenarios of acoustic absorption. This was calculated for differing quantities of acoustic treatment ranging from 0 to 1064 m^2 (1064m^2 being the surface area of the curved wall/ceiling which could be treated and would not be covered by the train). The results can be seen in figure 3 below;

Percentage Fail Vs Area of Treatment

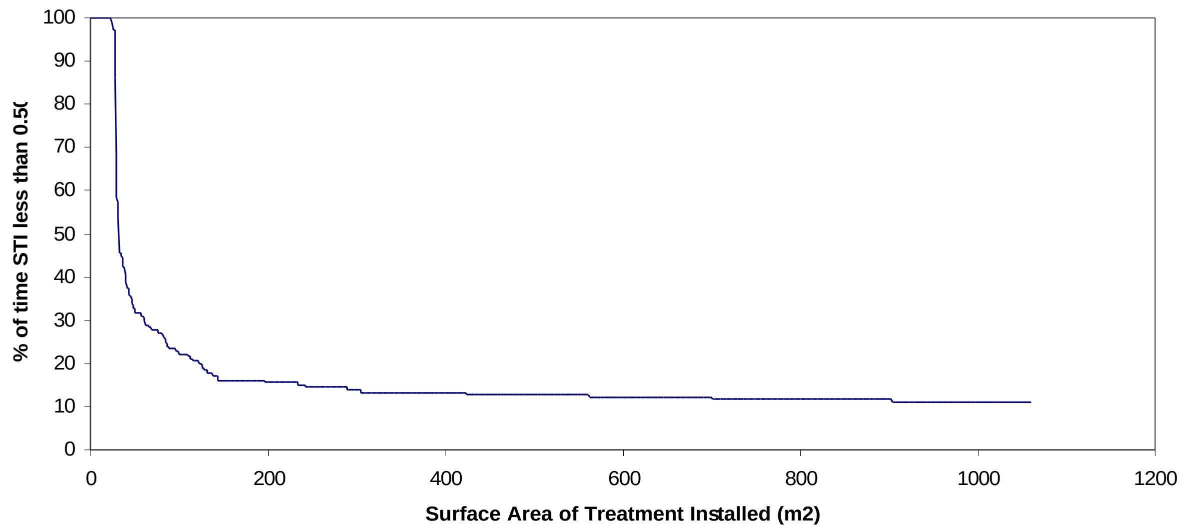

Figure 3

Figure 3 above shows that when the maximum quantity of acoustic treatment is installed (1064m^2 in this case), the system will only be above 0.50 STI for 89% of the time. Without increasing the system level an STI of 0.50 cannot be achieved for 100% of the time.

This graph could actually prove a useful tool for deciding how much absorption to install as the effectiveness of increasing the absorption can be seen. If 1064m^2 would result in compliance for 89% of the time, reading off the graph we can also see that the following results;

% Pass	Area of treatment (m^2)
89	1064
87	424
85	236
80	124
75	85

Table 5

The quantity of absorption increases exponentially as we try to achieve the target STI for more of the time. It doesn't appear very cost effective to try and achieve a target for 89 % of the time when 87% requires less than half the surface area of acoustic treatment.

A total system level of 90 dBA for a speech shaped input signal has been assumed for these calculations. Increasing this level and hence improving the signal to noise ratio would result in an improved STI, the effects of which can be seen below;

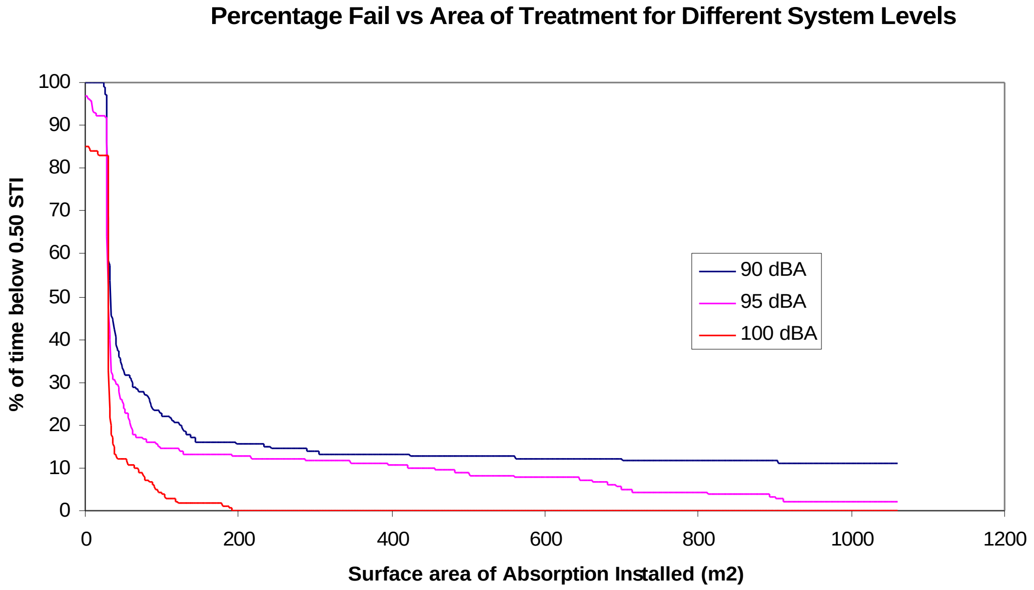

Figure 4

It can clearly be seen that increasing the system level decreases the amount of acoustic treatment required. It may therefore seem possible to increase the level until the system is effectively noiseless to minimize the surface area of absorption needed. A problem may arise here in that the possibility of any detrimental effects on intelligibility that such a high level may incur are not considered in the STI calculations. If it is not really possible to carry out word scores at these high levels then consequently, auditing STI would not seem appropriate.
Another point to add may be that increasing the system level by say 3dBA could well prove more costly in terms of amplifier power than to increase the surface area of acoustic treatment. Not only a doubling of the amplifiers would be required but other costs such as more real estate, more ventilation and a greater power supply and battery backup could be incurred.

5. CONCLUDING REMARKS

It has been shown that not only the reverberation time determines the quantity of acoustic treatment which is necessary to achieve a target STI but also the ambient noise present (assuming that there is a limit on the total system level). Consequently, the surface area of absorption required would differ depending on what parameter is used when measuring the background noise. In the case of this study the difference proved fairly substantial.
It is therefore suggested that rather than deciding on whether say a single set of octave band L_{10} or L_{eq} which represent the train cycle period should be used as the background noise when performing STI calculations, a percentage of time the target STI is met could be decided instead by using the logged 1 second Leq values and varying RTs.

An increase in the total system level will reduce the required absorption, but there must be some limit above which either intelligibility starts to decrease or the system becomes painfully loud. Further to this, an increase in level would result in a need for more power and therefore increased cost. Whether this cost is greater then the cost of a larger surface area of treatment could be investigated.

6. REFERENCES

[1] Walter J. Smoski
"Speech Audiometry"
www.emedecine.com
July 2001