Proceedings of the Institute of Acoustics

BS 7443: SOUND SYSTEMS FOR EMERGENCY PURPOSES AND SPEECH INTELLIGIBILITY - AN OVERVIEW

P.W. Barnett

AMS Acoustics, 52 Chase Side, Southgate, London, N14 5PA

INTRODUCTION

Despite its light weight BS 7443 landed with a significant thump in June 1991. It became immediately controversial since for the first time, the implication is that sound systems of this type may be subject to an audit.

BS 7443 is a specification and as such it defines amongst other things system performance. In this regard it is succinct since apart from references to the microphone performance, it states that the speech intelligibility of the system shall be at least 0.5 STI when measured according to the RASTI method as given in IEC 268-16 (BS 6840: Part 16).

It is the subject and science of speech intelligibility in terms of its prediction and measurement that concerns this section of our programme.

SPEECH TRANSMISSION INDEX

Speech Transmission Index was proposed by Houtgast and Steeneken *et al* who determined that there was a correlation between the modulation transfer function between two points in space and speech intelligibility.

The STI scale is between zero and unity that being subjectively between unintelligible and perfect intelligibility.

The STI value is derived from the results of the modulation transfer function measured at 14 modulation frequencies in seven octave bands (125Hz to 8kHz). The reduction in modulation is converted to a signal-to-noise ratio as follows:

$$S/N_{app} = \lg \left(\frac{m}{1-m}\right)$$

where: m is the modulation reduction factor which is given by:

$$m(F) = \frac{1}{\sqrt{1+[2\pi F \frac{T}{13.8}]^2}} \cdot \frac{1}{1+10^{(-S/N)/10}}$$

where: m(F) = the reduction in modulation at the modulation frequency F
F = the modulation frequency
T = the early part of the reverberation decay
S/N = the signal-to-noise ratio in dB.

A weighting is applied to the octave band averages and the signal-to-noise ratio is truncated within the range -15dB to +15dB. The STI is then calculated as follows:

$$STI = [\ (S/N_{trunc}) + 15] / 30$$

where: S/N_{trunc} = truncated values between -15dB and +15dB of S/N_{app}.

The introduction of the Standard brought with it three difficulties, Prediction, Measurement and Specification.

PREDICTION

As stated earlier, BS 7443 is a specification thereby inviting an audit. Purveyors and designers of sound systems now face accountability in real objective terms and subjective adjectives such as 'good', 'adequate' and 'highly intelligible' should be avoided.

Accountability brings with it an element of risk and it is this risk which we would seek to reduce by accurate prediction.

Unfortunately, STI is a method of measurement which relies upon the modulation transfer function between the source and receive positions and hence does not allow direct prediction.

There are presently three prediction methods available:

1. Articulated Loss of Consonants ($\%AL_{cons}$) attributed to Peutz and Klein.

2. MSAE method attributed to Barnett and Scarbrough.

3. CAD Methods.

The $\%AL_{cons}$ method revolves around the following formula:

$$\%AL_{cons} = 100\,\{10^{-2[(A+BC)-ABC]} + 0.015\}$$

where:

$$A = -0.32\,Log_{10}\left[\frac{L_{DR} + L_{DN}}{L_{DR}+10L_{DR}L_{DN} + L_{DN}}\right]$$

$$B = -0.32\,Log_{10}\left[\frac{L_{DR}}{10L_{DN}+L_{DR}}\right]$$

$$C = -0.5\,Log_{10}\left[\frac{RT}{12}\right]$$

where:

L_{DR} = Absolute direct-to-reverberant ratio
L_{DN} = Absolute signal-to-noise ratio, and
RT = Reverberation time secs.

which includes both signal-to-noise and direct-to-reverberant ratios.

The MSAE method is based on a series of many STI measurements carried out on simulated environments. In its original form it only considered direct-to-reverberant ratio but a research programme involving many hundreds of measurements and tests is now complete and signal-to-noise ratio has also been considered.

CAD methods are quite new and attempt to include other effects in addition to noise and reverberation such as reflections.

Whatever method is used there is a degree of science and understanding involved in both the mechanics of prediction and the interpretation of the results.

MEASUREMENT

The uncertainty in prediction is only matched by the controversy in measurement.

My understanding at the time of writing this Paper is that there are three commercial systems available:

1. B & K (RASTI)

2. MLSSA (Maximum Length Sequence System Analyser)

3. TEF (Time Energy Frequency).

Each measurement system has its advantages and disadvantages. The problem is not so much the measuring equipment, rather the measurement procedure and the interpretation of the results.

One such problem is the fact that rarely can the measurements be carried out under normal operating and occupancy conditions and hence there is a requirement to extrapolate the result to represent real occupied conditions.

It should be borne in mind that this may not just be an academic exercise as it may represent the difference between a contractor being paid or not, as the case may be, if the system fails an audit.

Hence the extrapolation method must have both credibility and validity.

SPECIFICATION

If BS 7443 is rigourously applied and taken at face value then the specified speech intelligibility shall be greater or equal to 0.5 STI and since 'where' or 'when' is not specified then we are to assume that it is everywhere and always.

At first glance this does not seem to be a major problem since if we are dealing with a space occupied by the public then it would be reasonable to assume that the specified intelligibility should be met in all areas to which the public have access and at all times that the public are present.

Consider the implications in a football stadium. To achieve the 0.5 STI criteria the signal-to-noise ratio has to be at least unity assuming no reverberation or other acoustical effects. In practice the signal-to-noise ratio needs to be in the region 3dB - 6dB.

If we now apply the 'everywhere and always' maxim then the potential acoustic output of the system becomes formidable.

Football crowds can produce considerable noise levels producing maximums in the region of 100dBA to 106dBA, short term L_{Aeq} in the region 95dBA to 100dBA. Hence if we say 'always' then the system output needs to be significantly above 100dBA.

Clearly this is a nonsense and in practice a statistical noise level is taken. The Football Stadia Advisory Design Council recommends that the noise level is taken as the $L_{A10,45min.}$ and the system level is adjusted accordingly to produce the required intelligibility. In practice this means that system levels in football stadia are in the region 90-100dBA depending upon the Club, its support and the stadia capacity.

FINAL COMMENT

BS 7443 is, following a Sound and Communications Industry Federation Conference, under review by an industry working party. The working party comprises representatives from both the fire and public address industry.

With regard to speech intelligibility, it is too early to report their deliberations but it seems likely that they will suggest and recommend some changes both in terms of how intelligibility is specified and how it is measured.

References:

STI Measurements on Simulated Acoustic Environments - P.W.Barnett & P.H.Scarbrough - Proceedings Institute of Acoustics Vol.11: Pt. 7: (1989)
Practical Assessment of Speech Intelligibility - P.W. Barnett - Proceedings of the Institute of Acoustics, Vol. 12: Part 8: (1990)
B & K Technical Review - RASTI
A Review of the MTF Concept in Room Acoustics and its use for Estimating Speech Intelligibility in Auditoria - T. Houtgast & H.J.M. Steeneken
BS 6840: Part 16: 1989 - Guide to RASTI Method for the Objective Rating of Speech Intelligibility in Auditoria
BS 7443: 1991 - Sound Systems for Emergency Purposes