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THE COMMON INTELLIGIBILITY SCALE

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INTRODUCTION

BS 7443 (IEC 849): Sound Systems for Emergency Purposes is definite and succinct in its specification of intelligibility; it shall be 0.5 STI (RASTI) as measured in accordance with BS 6840: Part 16. Both Standards are now under review.

An IOA Woking Party was formed to review the various methods of assessing speech intelligibility and in view of the fact that there are several valid alternative methods for measuring intelligibility and that RASTI should not be used to measure a non-linear sound system, the Working Party decided that alternative intelligibility measures should therefore be considered.

INTELLIGIBILITY MEASUREMENT TECHNIQUES

By virtue of the nature of the parameter under audit the measurement methods themselves can only attempt to provide a result which offers a degree of correlation between it and speech intelligibility.

There are fundamentally two approaches to intelligibility measurement:

1. Objective measures.
2. Subjective measures.

It should also be clearly understood that in both of the above cases the qualifier 'measure' has been deliberately used. *Ad hoc* subjective estimations are excluded from this presentation and should not be confused with the subjective measures.

Any measurement method must *ipso facto* be capable of calibration and correlation to other measures. *Ad hoc* methods also by definition cannot satisfy this requirement and hence are excluded.

Although not generally understood the subjective measures are capable of and shall be properly calibrated.

With regard to measurements we should also understand that a 95% score on a word test does not mean that speech intelligibility was also 95%. The methods under consideration by the Working Party were:

Speech Transmission Index (STI)

The STI is calculated from measurements of the modulation transfer function. The analysis is performed in 7 octave bands from 125Hz to 8kHz and 14 modulation frequencies.

The MTF is calculated as follows:

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

Rapid Speech Transmission Index (RASTI)

The RASTI is similar in approach to STI but analysis is limited to 2 octave bands with 4 modulation frequencies in the 500Hz octave band and 5 modulation frequencies in the 2kHz octave band.

Phonetically Balanced (PB) Word Scores

The PB word score method consists of the delivery of phonetically balanced words each contained in a carrier phrase to a panel of listeners who write down what they think each word is. The score, expressed as a percentage, is calculated as follows:

$$\%INT = \frac{100}{T}\left(R - \frac{W}{(N-1)}\right)$$

where: T = set population
R = correct answers
W = wrong answers
N = number of prescribed alternatives.

Articulation Index (AI)

An AI prediction is based on estimates of the spectrum level of speech and noise in each of 20 frequency bands. The calculation is then a determination of noise masking in each

band. Corrections are applied for non-steady state noise, rate of interruption, amplitude distortion and reverberation time.

Articulation Loss of Consonants (%ALcons)

%ALcons can be determined from the results of transmission tests using selected simple words or calculated from the following measurement algorithm:

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

where:

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

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

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

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

RELATIONSHIPS BETWEEN INTELLIGIBILITY MEASURES

A search of literature provided several graphs with connections between intelligibility measurement methods.

The most widely published data presents PB word score, syllable and short sentence tests against Articulation Index[1]. A valuable connection between PB word scores and STI is given by Steeneken and Houtgast[2]. %ALcons is related to STI using the relationship attributed to Farrel Becker as shown below:

$$STI = -0.1845Ln(\%AL_{cons}) + 0.9482$$

An illustration of the references which have been used is shown in fig. 1.

[1]Methods for the Calculation of the Articulation Index, ANSI S3.5-1969.
[2]JASA 67, 318-326, 1980 - Steeneken and Houtgast

THE COMMON INTELLIGIBILITY SCALE

It was felt that to merely refer the Standard to one intelligibility measurement with conversions to others would be to favour one measure above the others. Therefore, the Common Intelligibility Scale has been created to present each measurement method with equal validity and weight. The scale was designed to make the chart both readable and usable and renders the word score data as straight lines indicating a linear relationship between CIS and perceived intelligibility.

The relationship which is used is:

$$CIS = 1 + Lg(STI)$$

Fig. 2 illustrates the Common Intelligibility Scale.

DISCUSSION

Auditing of sound systems may not in the future be restricted to a single measurement method and the most appropriate measure can be chosen to suit the particular circumstances of the system.

Additionally, the suitability of each measurement method is obvious and clearly demonstrable. In general, where the gradients of lines are shallow, the resulting CIS is unreliable. The table below, although not definitive, illustrates this principle.

Expected Result	CIS Value	Preferred Method(s)	Sensitivity	
			Insensitive	Over-sensitive
Excellent	>0.9	STI	Word Scores AL_{cons} Logatoms	AI
Good	0.7-0.9	STI, PB (1000) Words Logatoms	AL_{cons} PB (256) Words Sentences	AI
Fair	0.6-0.7	AI, PB (1000) Words Logatoms STI AL_{cons}	Sentences PB (256) Words	-
Poor	0.5-0.6	PB Words Logatoms Sentences AL_{cons}	STI, AI	
Bad	<0.5	PB (1000) Words AL_{cons}	STI, AI	Sentences, PB (256) Words

Finally, should a new intelligibility measurement technique be developed it may be added to the Common Intelligibility Scale without the need to amend the Standard.

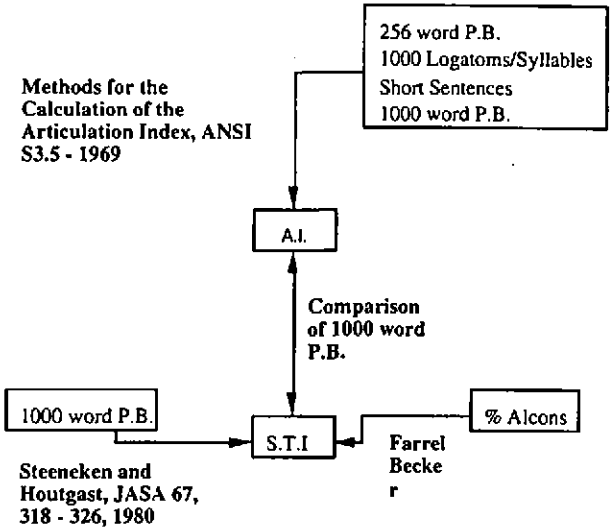

Figure 1 - References for Relationships between Intelligibility Scales

Relationship Between Intelligibility Scales

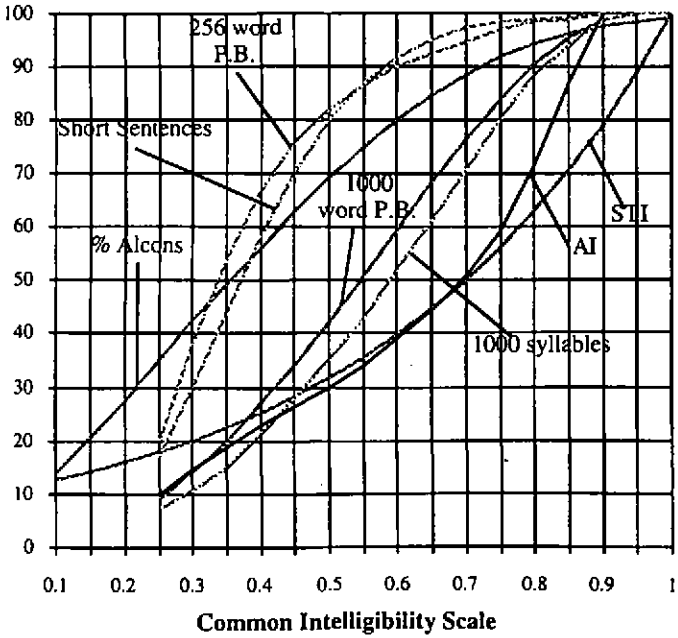

Figure 2