STI MEASUREMENT USING THE BRUEL & KJAER type 3361.

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1. INTRODUCTION

The what, the why and the how of RASTI and it's uses.

What is RASTI? It stands for RApid STI.

The next question is what is STI? It is the Speech Transmission Index, a single number index representing the effect on speech intelligibility of a transmission system. This could represent a wholly acoustic transmission path or an electronic one or a combination of an acoustic and electronic system.

Why STI?

There has always been a need to simplify the complex parameters which determine the performance of a sound transmission system. The index STI is based on a matrix comprising 98 data points from which are derived a set of 7 Modulation Transfer Function (MTF) curves.

The How of RASTI.

For the vast majority of acoustic situations it is not necessary to use the full set of Modulation Transfer Functions. A reduced set based on 9 data points is used in this rapid measurement procedure for the fast evaluation of auditorium conditions. Two MTF curves give enough information to derive an STI value within 8 seconds.

2. MTF and STI

When a speaker addresses an audience - be it in a room, in an auditorium or outdoors with a public-address system - the speech signal reaching the listener will be altered to some degree, which may lead to reduced intelligibility. In general the received signal is not a perfect copy of the input.

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Possible causes of changes to the fluctuations in the original signal are echoes and reverberation, spectral deformation, ambient noise, etc. The changes, or the less than perfect relationship of the received to transmitted signal, can be described by the Modulation Transfer Function.

The application of the MTF concept in room acoustics has been described in various papers [1,2,3]. The MTF quantifies to what extent the modulations in the original signal are reduced, as a function of the modulation frequency.

Since most disturbances vary as a function of frequency the analysis uses octave bands of random noise. Each band is modulated sinusoidally in it's intensity envelope as interfering noise or reverberation will only affect the degree of modulation of such a signal without affecting the sine-wave shape. The mean intensity of the test signal is a critical parameter and should be related to the level of speech as normally produced by a speaker at that location.

In Fig.1 there is an example of one octave band with a centre frequency at 500Hz showing the 14 modulation frequencies. Two simple sound transmission systems are illustrated. One having only a reverberation of 2.5 seconds and the other with only interfering noise equal to the signal (S/N=0dB).

Illustrating the combined effect of reverberation and noise a 100% intensity modulated noise carrier was analysed for each modulation frequency successively. In Fig.2 a different combination of RT and S/N was used for each carrier.

For the full STI an algorithm transforms the set of m values, the experimental verification for this is described elsewhere [4,5]. The most essential step in the transformation is to convert each of the 98 m values into an apparent signal-to-noise ratio. This is irrespective of the actual type of the disturbance causing the m value.

The STI index ranges from 0 to 1 as the measure of speech intelligibility. This is shown in Fig.3 with the associated subjective intelligibility scale. These qualification intervals from Bad to Excellent are based on a large-scale study [6]. In the middle range the qualification intervals are at STI intervals of 0.15. Accordingly the measurement of the STI index for repeated measurements must have a standard deviation considerably smaller than 0.15.

At each carrier frequency the curve produced by the combined action of noise and reverberation can be used to evaluate the separate parts. An estimated Signal-to-Noise ratio and Early Decay Time can therefore be derived.

3. THE RASTI METHOD

In the RApid Speech Transmission Index calculation only two bands of octave noise are used. Sinusoidal intensity modulated pink noise is filtered into two bands at 500Hz and 2kHz. The 500Hz band has 4 modulation frequencies and the 2kHz band has 5 modulation frequencies. By selecting these 9 modulations at increments of 1/2 octave from 0.7 Hz and 11.2 Hz between the two noise bands then parallel analysis can be performed on the composite transmitted signal. The specific test signal was developed with both octave bands present simultaneously and each modulation frequency also simultaneously present. Since the intensity envelope cannot drop below zero, the modulation index for each individual modulation frequency can only be 0.4 for the 500Hz band and 0.32 for the 2kHz band. When calculating the modulation reduction factor the index is referred to this initial modulation index.

The modulation frequencies for the 500Hz band are 1, 2, 4 and 8Hz and for the 2kHz band they are 0.7, 1.4, 2.8, 5.6 and 11.2Hz. The noise carriers of the two octave bands have repetition frequencies of 1Hz for the 500Hz band and 0.71Hz for the 2kHz band.

By using this approach the test signal is produced continuously and there is no need for any synchronisation between the source and receiver. The duration of the time interval during which the analysis is performed has a great influence on the accuracy, that is the reproducibility, of the resulting RASTI value.

4. 3361 SPEECH TRANSMISSION METER

The 3361 Speech Transmission Meter comprises two independent instruments. The Transmitter type 4225 containing the noise generator, band filters, intensity modulators and outputs for the integral speaker and external speaker. The Receiver type 4419 contains the microphone input, band filtering, the demodulation of the intensity level, the conversion to equivalent S/N ratio and calculation of the RASTI index.

The method of operation of the 3361 is explained in the IEC Standard 268 Part 16 (BS 6840 Part 16). These are for the objective rating of speech intelligibility in auditoria. The output level of sound is specified to be 60dB at 1 metre in front of a talker position. The level in the 500Hz band to be 59dB and in the 2kHz band to be 50dB.

As previously stated the degree of accuracy depends on the duration of the measurement. This is due primarily to the fact that the carrier signals are random noise and therefore contain measurable low frequency modulations. It follows that if the RASTI test signal is fed electrically into the receiver a RASTI value of exactly 1 will not always be measured. Similarly if an unmodulated random noise signal was used a RASTI value of 0 would not be measured, some small value would be indicated. There are also systematic errors at the extreme RASTI values due to the truncation involved in the calculation procedures when the S/N ratio exceeds +/-15dB.

In general longer measurement periods will produce smaller random and bias errors and also a wider useful measurement range. Measurement periods of 8, 16 and 32 seconds are provided. In Fig.4 the expected standard deviations for the individual band STI values and the overall RASTI value are plotted for the three periods.

An exception to using longer measurement periods is where the background noise is not stationary within the measurement period. In this case it is better to use the 8 second period and take a sequence of measurements.

One of the factors affecting the speech intelligibility is the local background noise. When evaluating a site the background noise may not be present. In this situation an additional noise floor can be entered in each of the octave bands and this is then added to the measured signal.

From the modulation reduction indices at each band comparisons can be made with curves expected for pure exponential reverberation decay. From this comparison a calculated EDT and S/N ratio is derived assuming each was the only mechanism.

The 3361 Speech Transmission Meter is a battery portable instrument system which is easy to use for the evaluation of speech intelligibility in many situations. These can include auditoria, lecture rooms, churches, trains, aircraft, drilling platforms, automobiles, etc.

Specifically RASTI values are called for in BS 7443 "Sound Systems for Emergency Purposes", Statium Public Address Systems from the Football Stadia Advisory Design Council and in the Specification 15 from the CAA for Passenger Aircraft public address systems.

5. REFERENCES

(1) T HOUTGAST & H J M STEENEKEN, "The Modulation Transfer Function in Room Acoustics as a Predictor of Speech Intelligibility", Acustica 28 (1973), 66-73

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(3) T HOUTGAST & H J M STEENEKEN, "A Review of the MTF Concept in Room Acoustics and its Use for Estimating Speech Intelligibility in Auditoria", accepted for publication by the J. Acoust. Soc. Amer.77 (1985), 1060-1077

(4) H J M STEENEKEN & T HOUTGAST, "A Physical Method for Measuring Speech-Transmission Quality", J. Acoust. Soc. Amer.67 (1980), 318-326

(5) T HOUTGAST & H J M STEENEKEN, "A Multi-Language Evaluation of the RASTI-Method for Estimating Speech Intelligibility in Auditoria", Acustica 54 (1984), 185-199

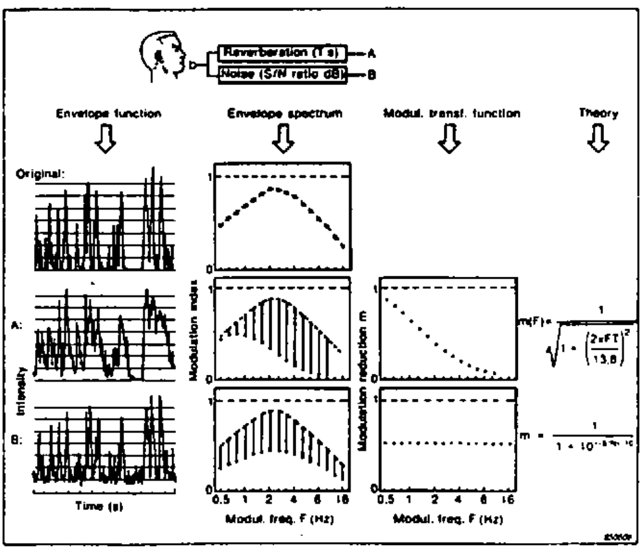

Fig.1. Typical MTF's showing envelope reduction of interfering noise and reverberation

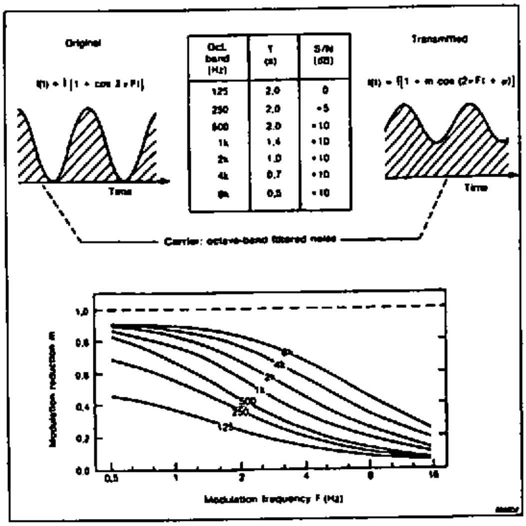

Fig.2. 100% intensity modulated carrier. Curves derived for various T and S/N values

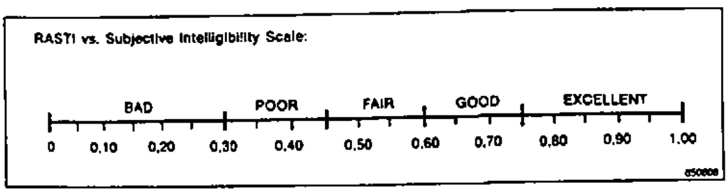

Fig.3. The RASTI scale for speech intelligibility

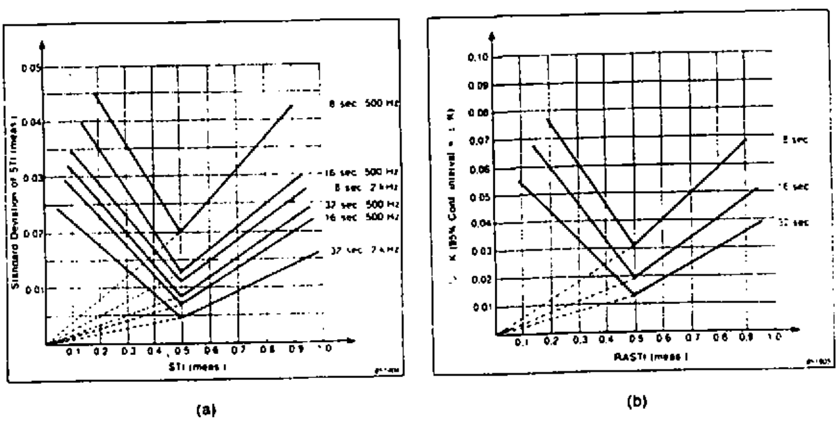

Fig.4. STI octave standard deviations and 95% RASTI confidence curved, dotted RT only