STIPA - The Golden Mean Between Full STI and RASTI

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Introduction

The speech transmission index, STI, has shown to be a valuable tool for objective assessment the speech intelligibility. From the first presentation in Acustica in 1971 [1], the method has been refined and diversified for various applications. Recently the International Electrotechnical Commission, IEC, has launched the third revision of the International Standard specifying the method for calculating the index: IEC 60268-16 [2].

Speech Transmission Index

The basis for the STI-index is that speech intelligibility to a large extent is based on the slowly modulation of the strength of the sound pressure signal acting as a carrier.

For the STI-method the carrier is a stationary gaussian noise signal divided in seven bands in octave steps ranging from 125 Hz to 8 kHz. The bandwidth of each band is one-half octave. Each of the bands is modulated with one of 14 modulation frequencies. The modulation frequencies are selected in one-third octave steps from 0,63 Hz to 12,5 Hz.

In this context, the square of the sound pressure is called intensity. The intensity is the quantity being modulated. A small loudspeaker acting as a talker is normally used for sending out the modulated excitation signal.

The sound in the listener position is received with a microphone. The level and the degree of modulation for each combination of octave band and modulation frequency are used for obtaining the speech transmission index. Noise and reverberation in the room will reduce the observed degree of modulation. The method also considers the effect of the most common types of distortions like harmonic distortion and intermodulation. Some other forms of non-linearity, like frequency shifts and frequency multiplications, are not treated effectively.

The STI-value is a weighted average of the response to the different modulation frequencies. The last revision of the method also considers masking effects and the absolute threshold of hearing.

The measurement of the full STI has to be performed as a sequence of measurements. If each of the 98 combinations is measured in 10 seconds, the total measurement time will be about a quarter of an hour. Such a long measurement time in order to obtain the STI-value in one position of a room limits the applicability of the full STI-method.

RASTI and STIPA

In order to simplify the direct measurement, the RASTI-method (Room Acoustic Speech Transmission Index) was developed at TNO in 1979. Different instruments were developed for the measurement according to this standard. A typical measurement time was 10 to 15 seconds. The RASTI method only considers the two octave bands 500 Hz and 2 kHz. Each band is modulated with four and five frequencies, respectively, in total 9 combinations.

Due to the simplicity in use, the RASTI-instruments were used also for applications beyond the main design goal – room acoustics. The RASTI-value is often used for assessing the quality of public address systems, but comparisons with subjective measurements have shown that the deterioration of speech intelligibility is not handled correct if the PA-system is strongly non-linear or suffers from limited bandwidth.

In order to improve the accuracy in the intelligibility assessment – especially for public address systems – the STIPA-method was developed. It handles effects due to reverberation in the room and distortions commonly found in public address systems. It also performs well for room acoustics and can therefore in nearly all cases replace the RASTI-method and deliver results more closely to the values obtained by the full STI-method.

The STIPA uses all 7 octave bands from the full STI approach and in total 12 modulation indices are measured. The measurement time for a STIPA-measurement is similar to the RASTI-method: 10 – 15 sec.

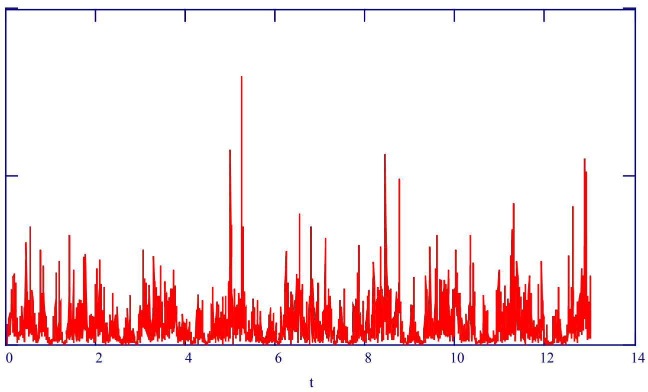

Figure 1: *The sound "intensity" in the 500 Hz band computed from the sound pressure level. The excitation is modulated with 0,63 Hz and 3,15 Hz.*

Measurement with Sound Level Meter *Nor118*

The STIPA-method may be implemented in a standard sound level meter. In the sound level meter Norsonic *Nor118* the method is implemented as a program option in the normal instrument software.

Excitation Signal

A CD delivered with the instrument option contains the excitation signal. The signal is the sum of the bands of noise, each modulated with two frequencies as specified for the STIPA-method. The shape of the spectrum is specified in the standard. The sound level meter in the normal mode of operation may be used for verifying the level and the spectral weighting. The excitation signal runs continuously and no synchronization between the excitation and the instrument is needed.

Measurement

After the mode of operation is selected, pressing the START button initiates a measurement. The measurement runs for about 13 seconds. At the end the STI-value calculated according to the STIPA-method is presented on the screen together with the assessment: “Excellent”, “Good”, “Fair”, “Poor” or “Bad”. Selecting the table display allows the mean level in each band to be displayed as well as each of the twelve measured modulation indices. The corresponding CIS-value (**C**ommon **I**ntelligibility **S**cale) according to IEC 60849 is also indicated [3].

During the measurement the short time equivalent-level in each octave band is measured with a time-resolution of 5 milliseconds. The level is converted to squared sound pressure, Pa^2, or “intensity” in this context. See figure 1. The degree of modulation for each frequency is found by Fourier transformation. By comparing the measured degree of modulation with the degree of modulation in the excitation (55%), the value for the modulation transfer function is obtained. In total, twelve combinations of carrier/modulation frequencies are measured.

The measured modulation transfer function is corrected in order to compensate for the threshold of hearing and for the masking effect in the human auditory organ.

Although not a part of the International Standard, the implementation in the instrument allows the addition of a specified background noise level – one level for each octave. The correction is done according to equation (1):

$$mc_{k,f} = m_{k,f} \frac{I_k}{I_k + Irs_k + Ino_k + Iam_k} \tag{1}$$

where

$mc_{k,f}$ is the corrected modulation transfer function for octave band number *k* and modulation frequency *f*.

$m_{k,f}$ is the measured modulation transfer function.

I_k is the measured “intensity” in octave band number *k*

Irs_k is the “intensity” in octave band number *k* related to the threshold of hearing

Ino_k is an optional “intensity in octave band number *k* corresponding to a specified background noise level. If not used, this value is zero.

Iam_k is the “intensity” in octave band number k used to mimic the masking effect in the auditory organ. The value is a function of the level in the adjacent lower octave band.

Note that the noise correction is an extension from the method specified in IEC 60268-16. This allows a measurement in a situation without the background noise and recalculation of what the STI-value would have been with a specified noise level.

The results may be stored in the instrument and later downloaded to a computer for report generation.

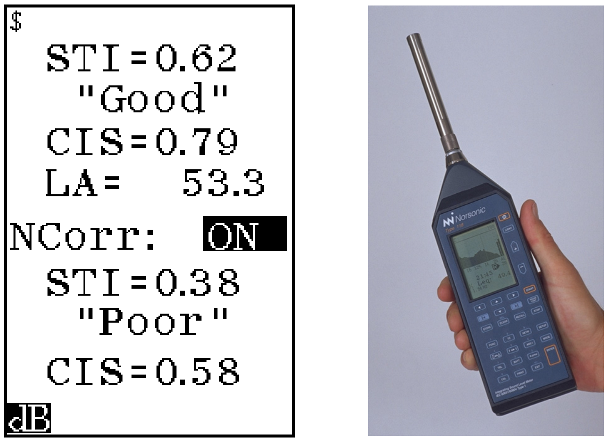

Figure 2: *The STIPA method is implemented as a program option in the sound level meter Norsonic Nor118. Both STI- and CIS-value are presented, without and with a virtual background noise level.*

Concluding Remarks

Implementation of the STIPA-measurement mode in an ordinary sound level meter allows an easy and fast measurement of speech intelligibility. Normally, the STI-value is measured with the normal background noise and the value indicates the speech intelligibility with this level of background noise. For situation where the measurement is performed in an untypical quiet situation, a synthetic background noise may be added and the STI-value related to this situation is indicated. This feature is especially useful when assessing speech intelligibility in auditoriums when measured without an audience.

References

[1] T. Houtgast and H.J.M. Steeneken, (1971). “Evaluation of Speech Transmission Channels by using Artificial Signals”. Acustica vol. 25, pp355–367.

[2] IEC 60268-16 (2003-05) Sound system equipment - Part 16: Objective rating of speech intelligibility by speech transmission index.

[3] IEC 60849 (Ed. 2.0 1998-02) Sound systems for emergency purposes.