Studio Six Digital, LLC

STIPA v4 Specification Compliance Study

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Abstract

This paper describes the method for processing a STIPA v4 signal through the STIPA module of AudioTools, which maintains compliance with the 4th edition of the STI standard (IEC 60268-16:2011).

The purpose of this paper is to show that once a STIPA signal is captured in AudioTools and processed in the STIPA application, the determination of the STI follows precisely with the guidelines set forth in IEC 60268-16.

Since it is important for the method by which STI is determined to be accurate, careful examination of the signal path and processing of the test signal is provided in order to determine how the STIPA application of AudioTools complies with the standard.

This paper is the form of logical signal flow, where each step of the determination of STI is documented. The processing in AudioTools is directly compared to the specific signal-processing step in the v4 STI standard.

1. Introduction to the Speech Transmission Index (STI)

The determination of the Speech Transmission Index (STI) was developed in order to quantify the reduction of the modulation envelope of speech by means of calculating the modulation transfer function (MTF) (Steeneken and Houtgast, 1980). The STI measure has been defined in IEC 60268-16:2011, and provides an efficient method of evaluating speech intelligibility in both unamplified direct conversations as well as when the speaker is amplified through a public address (PA) system. This is due to the fact that the STI takes into account distortions due to noise, reverberation and echoes, if present.

The calculation of the STI through the direct measurement, the technique that AudioTools takes for calculating STI, involves replacing actual speech with an analytical signal, which contains the spectral and temporal characteristics of speech. By injecting the test signal at some source location S_i into a device-under-test (DUT, in most cases, an acoustical enclosure or room), and recording the resultant signal at an arbitrary receiver location R_j, the resultant modulation reduction factor, m_r can be determined. The MTF is therefore given by:

$$MTF = m(F) = \frac{m_r}{m_t}$$

where the MTF is determined at a given modulation frequency F by the ratio of the modulation of the response signal m_r and the modulation depth of the probe signal m_t. The calculation of the MTFs are determined for speech frequencies; octave-bands from 125-8000 Hz, f_i, and for one-third octave band modulation frequencies, F_j, between 0.63-16 Hz. More details about the test signal are given in the next sections.

2. Test measurement setup

The following equipment is used for this validation study:

- Apple® iPad™ 2 running iOS 5.0.1
- Studio Six Digital iAudioInterface2.
- Sencore Type 1 Omnidirectional Microphone.
- Genelec 8030a powered loudspeaker.

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3. STIPA test signal spectrum and modulation depth

Studio Six Digital provides a STIPA v4-complient signal at the following URL: http://studiosixdigital.com/downloads-2/stipa-looplong1pt1_44k.wav. The signal is also available to be played back from within the STIPA module of AudioTools.

Looking at the way that the signal is generated shows its compliance with the STIPA v4 standard. The generator that creates the test signal is designed to the specifications of the standard by being comprised of the following:

- Seven bands of noise, one-half octave wide centered on the following frequencies: 125, 250, 500, 1000, 2000, 4000, and 8000 Hz. The noise is pink in shape within a band.
- Noises are generated by adding together closely spaced sine waves with a step size of 1/length of the sample. In the case of the sample that is designed to be looped continuously, that length is 40 seconds. Therefore, the frequency step size is 1/40 Hz per sine wave.
- The rolloff of the noise bands outside the passband are extremely steep by virtue of the signal construction.
- The seven bands are then individually intensity modulated with the frequencies shown in Table 1. These frequencies correspond to those presented in Table B.1 in IEC 60268-16:2011.
- The depth of the intensity modulations are 0.55 for each of the frequencies and a 180 degree phase shift is applied between component one and two as described in Annex B of IEC 60268-16:2011.
- The STIPA signal of AudioTools has a male speech spectrum, which fulfills the requirement of the Standard presented in Table A.4 of IEC 60268-16:2011.

The signal used for the STIPA module in AudioTools fully complies with the signal guidelines set forth in IEC 60268-16:2011 with respect to frequency spectrum and intensity modulation frequency and depth.

TABLE 1: Modulation frequencies used in the STIPA test signal

Octave Band (Hz)	125	250	500	1000	2000	4000	8000
First modulation frequency (Hz)	1.60	1.00	0.63	2.00	1.25	0.80	2.50
Second modulation frequency (Hz)	8.00	5.00	3.15	10.00	6.25	4.00	12.50

4. STIPA signal acquisition time

The recommend signal acquisition time for determining STI from the STIPA signal is between 15-20 seconds. The duration of the signal acquisition time in the STIPA module of AudioTools is 20 seconds, which complies with this measurement window.

5. Integrity of the test signal

A measurement of the sample rate integrity while using the measurement system was carried out. This is to determine if the sampling rate error falls in the window for error. The maximum allowable error rate is 0.05%. An 8000 Hz sine wave generated in the FFT module of AudioTools was looped back through the analog input of the iAudioInterface2. The signal was measured with the FFT module using a 32k point FFT. The peak of the sine wave signal was measured at 8000 Hz, which is within the 0.05% frequency discrepancy window.

6. Determination of the STI using AudioTools STIPA

The following section describes the decomposition and analysis of the STIPA signal in the STIPA module of AudioTools for the determination of the STI. This section deals with the signal after a portion of the signal has been recorded into the input buffer of the software module. The input starts as a full-range STIPA signal, which has been passed trough the system under test, and has been degraded by noise, distortion (if present) and reverberation/reflections. A block diagram of the signal flow in AudioTools STIPA is shown in Figure 1. The probe signal is the reference unprocessed STIPA signal and the response is the STIPA signal measured in the environment in which STI is to be determined.

The STIPA signal is first bandpass filtered into seven bands from 125 Hz to 8 kHz. The signal is then rectified by squaring to look at the intensity envelope within a band. In order to extract just the low-frequency intensity modulations, the signal is then decimated by 150x. The native sampling rate of the STIPA module of AudioTools is 22050 Hz. The signal is first decimated by 15x, and then 10x. The sample rate after decimation is 147 Hz. The transmission index (*TI*) is then determined by comparing the intensity envelope of the probe to the response. This entire process is repeated for each of the seven octave bands of noise and then the STI is determined by taking a weighted sum of each of the band's *TIs*.

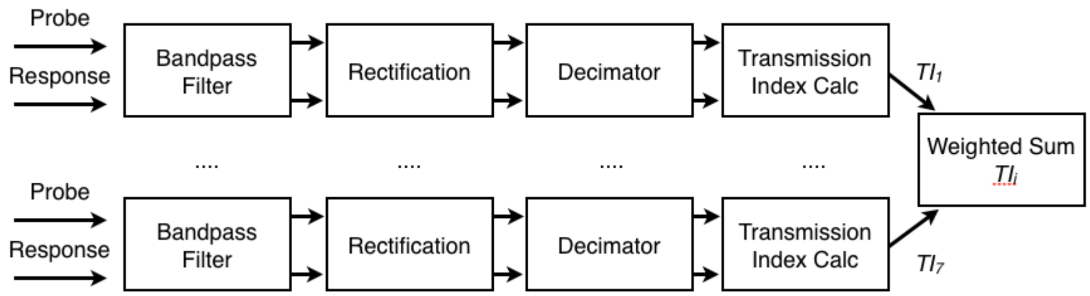

FIGURE 1: Block diagram for STI calculation.

a. Filter STIPA into Octave Bands

The first stage of signal processing involves filtering the STIPA signal into seven octave bands. This is accomplished with 8^{th} order IIR ANSI Type 0 filters centered at 125, 250, 500, 1000, 2000, 4000 and 8000 Hz.

b. Signal Rectification

In order to extract the intensity envelope of the test signal, it must be rectified. This is accomplished by squaring the input signal. The rectification comes directly after band pass filtering.

c. Low-pass filter through decimation

The signal must be low-pass filtered next to extract only the low frequency modulations that are analyzed in the calculation of the STI. This is accomplished through a two-stage decimation filter. The audio coming into the STIPA module of AudioTools is sampled at 22050 Hz. The decimation filters are 15x and 10x 8^{th} order IIR ANSI Type 0 filters. They are applied to each of the bands of filtered and rectified STIPA signal. They are applied in series. After both decimation filters, the new sampling rate becomes 147 Hz for the remainder of the STI calculation.

d. Determination of the Modulation Reduction Factor (MRF)

After the band-passed STIPA signal has been decimated, the next step is to determine the ratio between the response and probe signals of the intensity modulation at each of the two frequencies in Table 1 for each octave band. The ratio of each is the modulation transfer function (MTF). The MTF is then converted to a signal to noise ratio (SNR) by dividing the MTF by 1-MTF. That quantity is multiplied by $10\log_{10}$. Per the STIPA standard, the SNR is restricted to a range of +15 dB SNR and -15 dB SNR. If the SNR is above 15 dB SNR, the value is transformed to 15 dB, and if the value is below -15 dB SNR, the value is transformed to -15 dB SNR. Then the SNR is shifted by 15 dB and divided by 30 in order to generate the *TI*, which is a value between 0 and 1. This is calculated for each of the modulation frequencies in each of the seven octave bands.

The *TI* for each octave band is then averaged across the two modulation frequencies in the band.

e. Correction of MRF based on Level Dependent Auditory Masking

An option in the STIPA module of AudioTools that is turned on by default, in order to comply the with STI v4 standard, is the correction of the *TI* for each octave band based on the sound pressure level (L_{eq}) of the octave band directly below the band being analyzed. The STI standard uses this to account for level dependent auditory masking. AudioTools STIPA calculates the L_{eq} for each octave band after filtering during the recording process. The correction takes places for the 250 Hz – 8000 Hz octave bands. AudioTools STIPA calculates the auditory masking factor for each of the octave bands using the formulas in section A.3.2 of IEC 60268-16:2011 and multiples the calculated *TI* by this corrected factor.

f. Calculating the mean modulation transfer function

The final determination of the STI is completed by taking a weighted average of each octave band's adjusted *TI*. In order to comply with the v4 STIPA standard, the frequency-weighting factors: $\alpha_{k,}$ and redundancy-correction factors: β_k are employed from Table A.3 in IEC 60268-16. These values are reproduced in Table 2 in this document. The male weighting factors are used, since the STIPA signal has a male spectrum. The weighted sum is determined and the resulting display of the STI is displayed on the STIPA output screen in AudioTools. In addition to the STI number, a nominal qualification band is given, which has been derived from the Annex F of IEC 60268-16 standard. These nominal grades are from U to A+.

TABLE 2: Frequency-weighting factors: α_k and redundancy-correction factors: $\beta_{k.}$ Factors assume male speech and the sum of α_k – sum of β_k = 1.

Octave Band (Hz), k-factor	**125,1**	**250,2**	**500,3**	**1000,4**	**2000,5**	**4000,6**	**8000,7**
α_k	0.080	0.114	0.188	0.208	0.303	0.227	0.193
β_k	0.116	0.059	0.025	0.000	0.019	0.095	

CONCULUSION

The STIPA module of AudioTools has been designed following the careful guidance of IEC 60268-16, v4. The standard provides step-by-step instruction for both the generation of a v4-complient STIPA signal as well as the decomposition of that signal in order to extract the necessary information to determine the STI. The STIPA module of AudioTools performs each of the necessary steps to the recorded STIPA signal that have been described in the current STI standard. In addition, the quality of the filters in AudioTools are designed to exceed ANSI Type 0 standards.

In conclusion, the determination of STI from a STIPA signal processed through the STIPA module of AudioTools results in an STI estimation that is fully compliant with the current version of the IEC 60268 v4 standard.

REFERENCES

IEC 60268-16, "Sound system equipment–Part 16: Objective rating of speech intelligibility by speech transmission index," IEC, Switzerland (2011).

Steeneken, H. J. M. and Houtgast, T., "A physical method for measuring speech transmission quality", J Acoust Soc Am **67**, 1980, 318-326.