Prediction of STI according to IEC 60268-16:2003

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Introduction

The IEC 60268 „Objective rating of speech intelligibility by speech transmission index“ is targeted mainly towards measurement of STI but less written for prediction of STI with room-acoustic software. At the same time, STI has in the past years evolved to probably the most important parameter in prediction of public adress systems which need to comply also with the IEC 60849.

This paper will provide a short overview STI prediction including relevant methods and input data as well as the specific issues regarding the newly implemented features in the 2003 version of the IEC 60268-16.

Known problems with STI

Two major problems are known with measurement and prediction of STI:

a) Linear distortion not adequately taken into account

Even extremely unlinear frequency responses do not show adequate reduction of STI if calculated according to the 1998 version of the IEC. The implementation of the hearing threshold and prediction with background noise may cause the STI to drop if the system frequency response shows drops to higher frequencies but this is also level-dependant and not comparable to subjective intelligibility loss with such systems.

b) Variations of the STI with late echos

Due to the fixed modulation frequencies when calculating the STI, late echoes may cause significant variations of the resulting index depending on the delay time in respect to the direct sound.

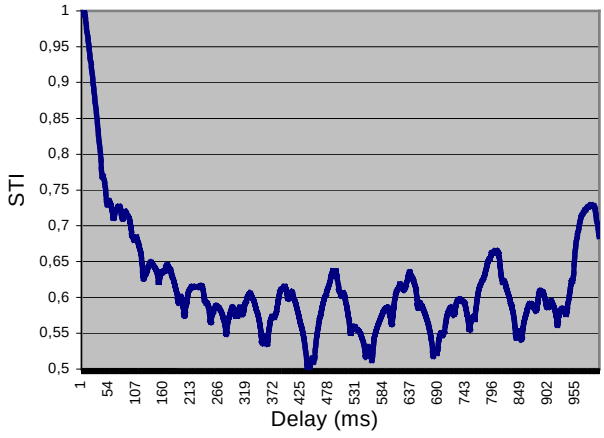

Illustration 1: Variation of the STI (calculated without masking and hearing threshold), predicted for two identical dry impulses with variable delay time between the two impulses.

These variations do not relate to subjective listening whatsoever and may actually cause the STI to increase at certain delay times. An examination of the Modulation Transfer Functions can identify such unwanted effects; however this is not possible when audience area mapping is used. To clearly identify if a local increas or decreas of the STI is caused by an echo, an examination with dedicated receiver positions is necessary—still the necessary positions for receiver placement must be identified first. An STI mapping is not suitable for identifying positions with e.g. focusing echoes; local aberrations shown on a center of gravity-time mapping (Ts) can indicate such positions.

Input Data

In prediction, all results must be regarded in respect with the precision of the input data as opposed to measurements where the most imporant room properties are taken into account by the measurement itself. In hardly any real-life cases the actual absorption-, scattering- and transmission coefficients of the scheduled materials in unfinished buildings is known; thus this data often must be carefully estimated by the consultant. This is also valid for the background noise which has a critical influence in STI prediction.

This major difference to measurements requires that the consultant takes extra care and is aware of his responsibility both with estimating input data and the documentation and interpretation of the prediction results.

Prediction methods, prediction time

Besides the different prediction algorithms and different handling of distance-dependant directivities of the different prediction software available, the necessary number of rays needed to obtain valid results depends on the directivity used.

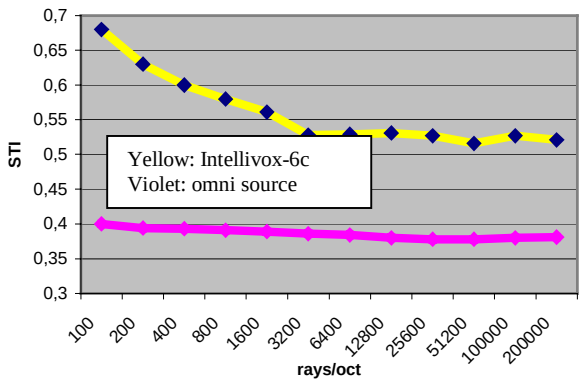

Illustration 2: Variation of STI for one listener position in dependance of the used ray number for two different directivities; sample room with 6sec. RT, predicted with CATT-acoustic

In some situations it may be necessary to find the lowest sufficient number of rays to save calculation time; great care must be taken to ensure that sufficient rays are used especially if using high-Q devices.

Improvements in the IEC 60268:2003

The major changes in the 2003 version of the IEC norm are:

- Introduction of STIPA
- Differentiation between STImale/STIfemale
- Implementation of hearing threshold
- Level-dependant masking

The level-dependant masking is important for public adress systems which are used for emergency announcements with high levels. The used algorithm takes into account the subjectively diminishing intelligibility at very high levels. Together with the absolute hearing threshold, the predicted or measured STI is largely depending on the frequency response of the used system and the absolute levels.

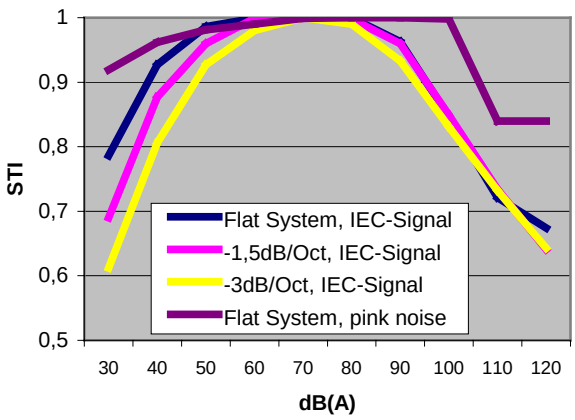

Illustration 3: STI in dependance of system frequency response and absolute level

It is absolutely critical both for measurement and prediction to clearly distinguish between the mandatory signal spectrum as described in the norm and the frequency response of the loudspeaker system. If pink or whicte noise is used instead of the male/female signal, signal-to-noise ratio, hearing threshold and level-dependent masking are not taken into account correctly; the final STI number will be too high.

Significance for prediction of STI in practice

The new algorithm finally enables correct measurement and prediction of STI at high levels. This is especially important and should be mandatory for all systems which must comply with IEC 60849 (e.g. sports arenas). For STI prediction in daily use conditions with average levels around 75dB(A) (e.g. train stations, airports etc.), hearing threshold and masking will have no significant impact on the predicted STI number. For predictions unlike as for measurements, the actual background noise and system level for announcements are not known beforehand; prediction of STI with background noise for such conditions will thus never be very precise but rather roughly indicate the expected drop in STI with noise.

Before the introduction of the additions in the 2003 version of the IEC 60386, prediction of STI without background noise (and then without masking and hearing threshold) could well be used for comparison of different loudspeakers and entire systems in the same room and also to optimize a system in the room. Absolute source levels, equalization and signal spectrum did not influence the result.

The implementation of hearing threshold and level-dependent masking will now influence the result depending of the used levels, EQ and signal spectrum in prediction—even if no background noise is used. For pure examination of loudspeaker-room interaction, this is not meaningful and may lead to wrong conclusions when e.g. a point-source loudspeaker is exchanged for an array with distance-dependant directivity, resulting in higher SPL at a certain listener position with the same levels defined at 1m distance.

Interpretation and documentation

The increased number of relevant input parameters for the results in STI prediction require also that these parameters are documented with the prediction results. For STI measurements, the background noise levels and system levels are documented for each dedicated measurement position. In prediction, the widely used audience area mappings do not allow that the relevant input parameters are are shown for each mapping point and make the evaluation and interpretation of results difficult. Receiver-based predictions enable more clear documentation and later comparison with measurements.

In total, prediction of STI in accordance with the latest version of the IEC 60268 requires greater care not only for prediction but also for documentation.

Conclusion

The implementation of the latest STI prediction algorithms within the commonly used prediction software is a necessity for STI prediction especially for emergency announcement systems in accordance with IEC 60849. Additional care must be taken by the consultant whenever these algorithms are used. However, utilization of the hearing threshold and level-dependent masking is not useful and necessary for all situations. For technical comparisons and system optimization, the calculation of STI without accounting for background noise, hearing threshold and masking is absolutely important for the consultant.

The author suggests that for the next revision of the IEC norm, STI calculation without noise, masking and hearing threshold is described as a legitimate and standardized method for technical comparisons.

For measurements, the new additions have been widely accepted and implemented in soft- and hardware. It is desirable that prediction according to the latest norm becomes a standardized method which takes into account the the specific needs of computer-based prediction.