AFMG

AHNERT FEISTEL MEDIA GROUP

Design for Speech Intelligibility Using Software Modeling

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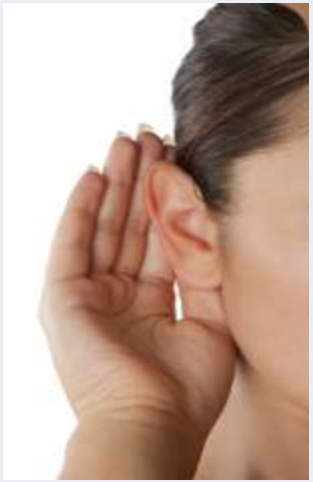
Orlando, FL

Overview

- System Design Concepts
- Definition of STI
  - Background
  - Application
- Simulation of STI in Rooms
  - Methods
  - Statistical Reverberation Time
  - Mean Absorption Coefficient
- EASE Evac Software

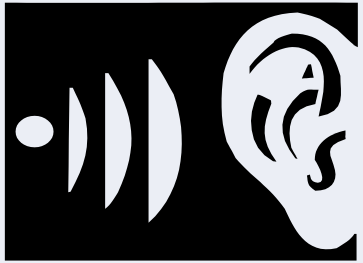
Intelligibility?

- What is Intelligibility - The capability of being understood or comprehended (distinguishable and understandable)
- In simple terms – intelligibility is an evaluation of changes that occur to speech that impact comprehension
- If you can't understand a voice message you cannot be made aware of the emergency event or special instructions



Technical Concepts

- **Audibility**: Measured in decibels (dB A-weighted)
  - Can you hear it?
- **Intelligibility**: Predicted according to "Speech Transmission Index (STI) or "Common Intelligibility Score" (CIS)
  - Can you understand it?



Factors that Impact the Design

- Acoustics of the space
- Ambient noise level
- Distance between devices
- Device sound level
- Device characteristics

Software Features

- ADS defined as a room
- Materials database
- Results output
- Comprehensive Report

Software Modeling Value

System Designers

- Address design issues early
- Meet NFPA codes
- Virtual modeling and pretesting
- Limit costly design changes
- Guide installation
- Provide competitive advantage

AHJs

- Provide documentation
- Reveal potential problems

Building Owners

- Reduce the change of a non-Code compliant system & delaying commissioning
- Raise confidence in your system's intelligibility during an emergency
- Reveal potential problems early

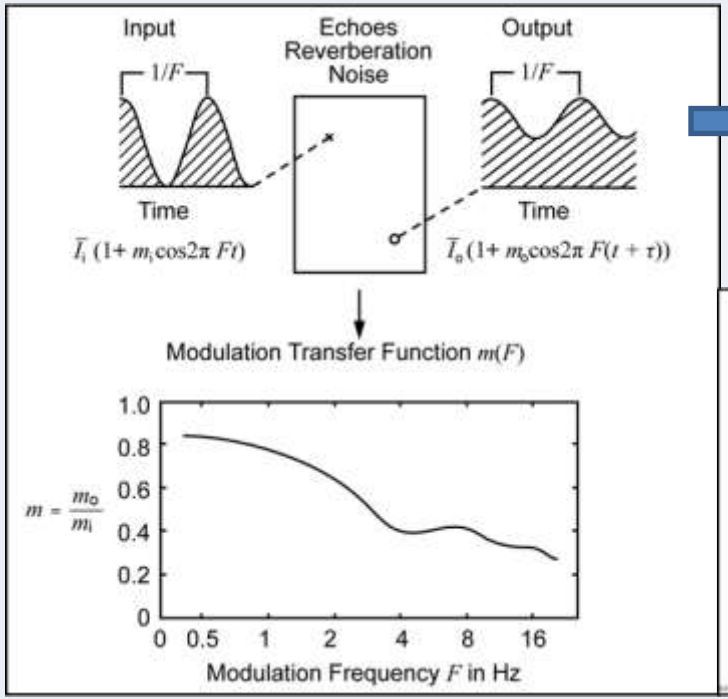
STI – Speech Transmission Index

Requirements for different applications:

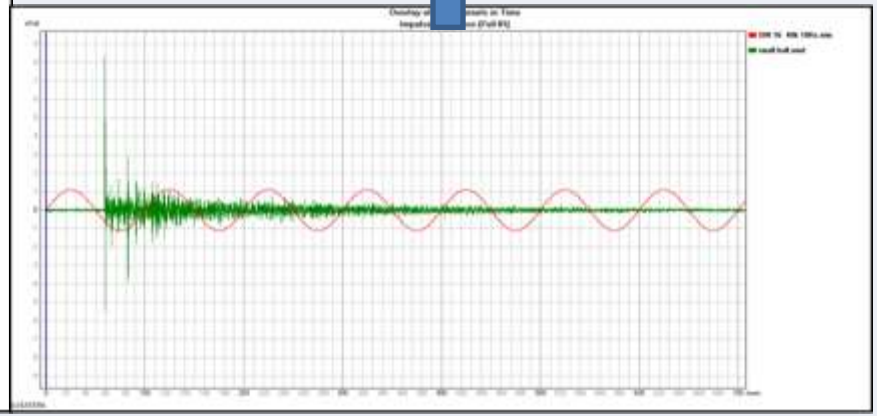
- Conference rooms, lecture halls for speech reproduction
- Churches, multi-purpose halls, “houses of worship”, theatres and concert halls for speech and music
- Stadiums, convention halls for public address
- Railway stations and airports for public address and voice alarm
- Hotels, public buildings, factories, power plants for voice alarm and evacuation
- Also public transport: trains, airplanes, cruise ships
- Worldwide advancements enforced in regulations since Sep. 11.
- STI, STIPa, before: RaSTI, ALCons

STI – Speech Transmission Index

Background:



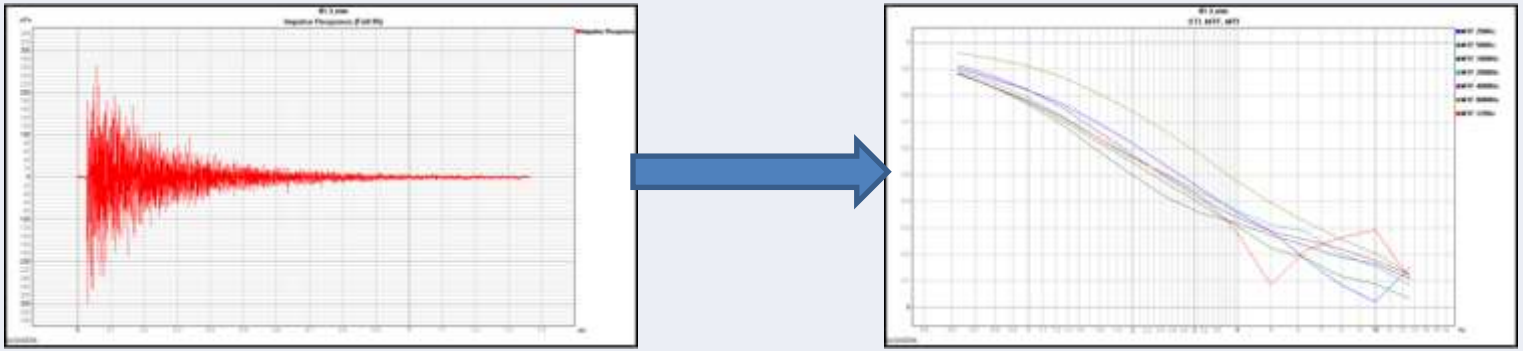
Measurement via modulation or impulse response:
14x7 MTF values => STI



STI – Speech Transmission Index

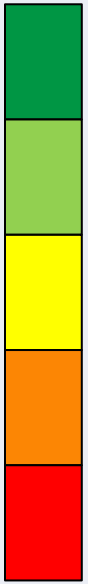
Indirect determination of MTF via impulse response (IR) according to Schroeder:

- Any excitation signal
- Linear, Time-Invariant (LTI) system
- Random noise, fluctuating noise, averaging
- IR data also useful for evaluating other acoustic quantities



STI – Speech Transmission Index

Typical MTF curves, single value STI:



> 0.75 Excellent

0.6 – 0.75 Good

0.45 – 0.6 Fair

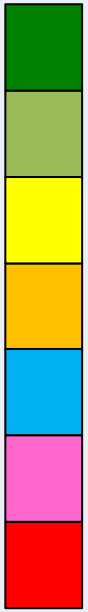
0.3 – 0.45 Poor

< 0.3 Bad

*** Per IEC 60268-16 ed3.0**

STI – Speech Transmission Index

Typical MTF curves, single value STI:



> 0.76 A+

0.64 – 0.76 A, B, C

0.56 – 0.64 D, E

0.48 – 0.56 F, G

0.44 – 0.48 H

0.36 – 0.44 I, J

< 0.36 U

*** Per IEC 60268-16 ed4.0**

STI Categories*

* Per IEC 60268-16 ed4.0

CATEGORY	TYPICAL USE	COMMENT
A+ > 0.76		
A 0.74	Communication systems	
B 0.70	Theatres, speech auditoria assistive listening systems	High speech intelligibility
C 0.66	Theatres, speech auditoria, teleconference rooms, court rooms	High speech intelligibility
D 0.62	Lecture theatres, classrooms, concert halls, modern churches, court rooms	Good speech intelligibility
E 0.58	Concert halls, modern churches	High quality PA systems

STI Categories*

* Per IEC 60268-16 ed4.0

CATEGORY		TYPICAL USE	COMMENT
F	0.54	Shopping malls, public buildings, offices, voice alarm systems	Good quality PA systems
G	0.50	Shopping malls, public buildings, offices, voice alarm systems	Target requirement for VA/PA systems
H	0.46	Voice alarm and public address systems in difficult acoustic environments	Lower target for VA/PA systems
I	0.42	Voice alarm and public address systems in very difficult acoustic environments	Lower limit for useful VA/PA systems
J	0.38	Not suitable for PA systems	
U	< 0.36	Not suitable for PA systems	

STI – Speech Transmission Index

EASERA 1.0, Results of Data: FINALMP2.etm : Measures
STI, MTF, MTI

	MTF 125Hz	MTF 250Hz	MTF 500Hz	MTF 1000Hz	MTF 2000Hz	MTF 4000Hz	MTF 8000Hz
0,63 Hz	0,666	0,732	0,746	0,85	0,877	0,909	0,934
0,8 Hz	0,619	0,659	0,69	0,816	0,842	0,877	0,911
1 Hz	0,558	0,59	0,635	0,783	0,802	0,842	0,883
1,25 Hz	0,492	0,527	0,583	0,745	0,751	0,799	0,844
1,6 Hz	0,431	0,475	0,539	0,694	0,678	0,737	0,781
2 Hz	0,394	0,456	0,505	0,634	0,594	0,673	0,708
2,5 Hz	0,335	0,429	0,476	0,562	0,496	0,605	0,627
3,15 Hz	0,241	0,394	0,397	0,476	0,391	0,545	0,567
4 Hz	0,146	0,416	0,368	0,4	0,348	0,524	0,599
5 Hz	0,029	0,436	0,388	0,352	0,435	0,586	0,721
6,3 Hz	0,235	0,52	0,411	0,351	0,513	0,639	0,808
8 Hz	0,268	0,399	0,266	0,33	0,417	0,545	0,707
10 Hz	0,255	0,266	0,134	0,262	0,287	0,456	0,618
12,5 Hz	0,184	0,373	0,074	0,076	0,219	0,469	0,692

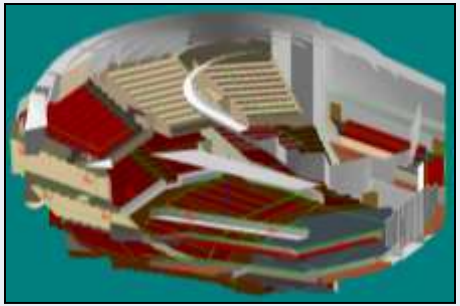
MTI	0,385
STI	0,529
AlCons [%]	9,687
STI (Male)	0,539
STI (Female)	0,554
RaSTI	0,505
Equiv. STIPa (Male)	0,564
Equiv. STIPa (Female)	0,566
STI (Modified)	0,533
STI (Unweighted)	0,522
STI (Custom)	0,529
RaSTI (Weighted)	0,509
STIPa (Modified)	0,56
STIPa (Unweighted)	0,546

RaSTI
STIPA
STI

STI versions:

- STI employs full set of 98 MTF
- STIPA uses 14 MTF
- RaSTI uses 9 MTF in 500 Hz and 2 kHz bands

STI Simulation

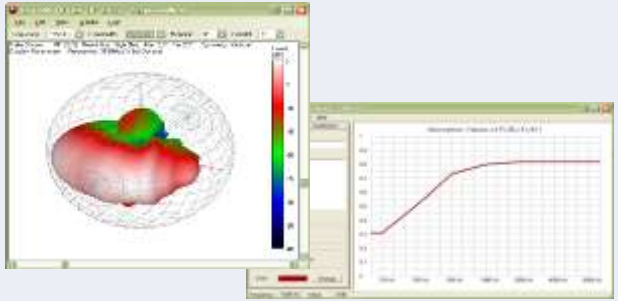


Simulation Parameters

Objective Quantities, Mapping Presentation

EASE or EASE Evac Model
+ Loudspeaker Data
+ Wall Materials

Simulation Algorithm



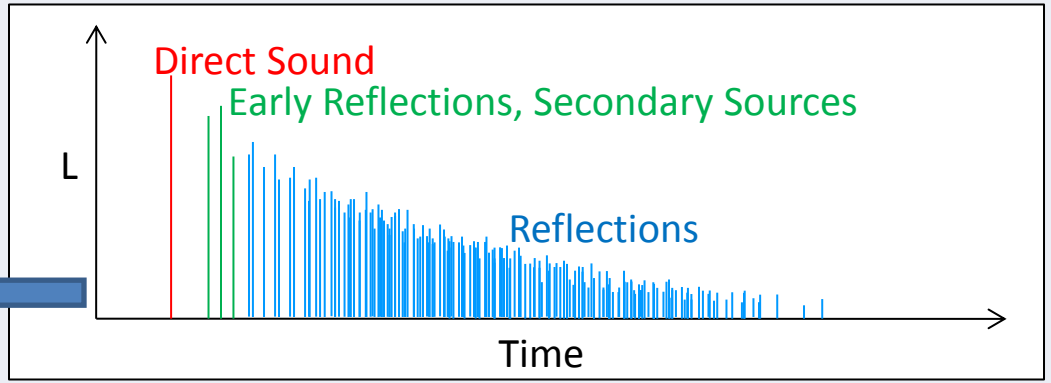
Impulse Responses, Real-Time Convolution

STI Simulation

Implementation in EASE:

- Hybrid ray tracing in EASE AURA

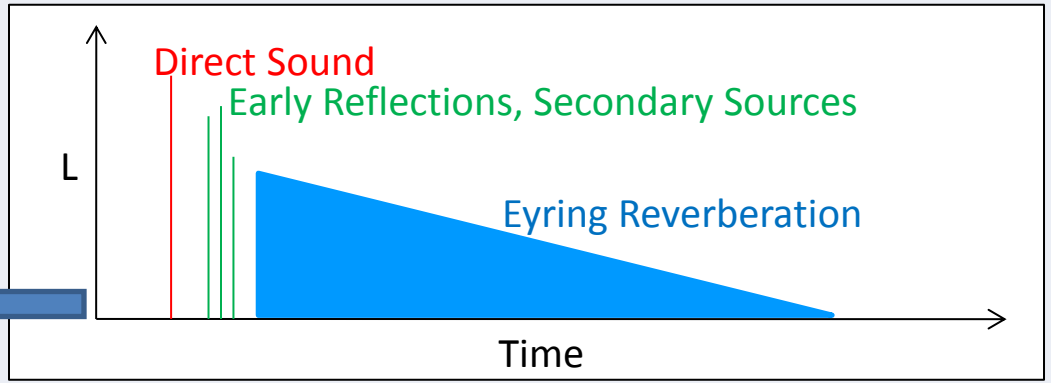
MTF



Implementation in EASE and EASE Evac:

- Statistical model according to Eyring/Sabine

MTF



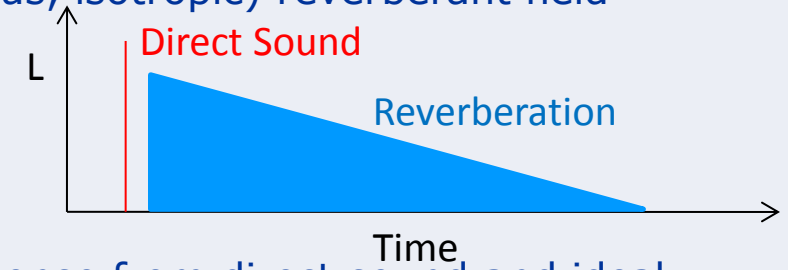
STI Simulation - Eyring

Statistical model according to Eyring/Sabine:

- Volume V, mean absorption coefficient α, acoustically effective surface S, air attenuation m
- Assumption of a diffuse (homogeneous, isotropic) reverberant field

$$T = k\frac{V}{4mV - S\ln(1-\alpha)}$$

- Result: reverberation time RT



- Derivation of a "virtual" impulse response from direct sound and ideal reverberant tail
- But: Discrete reflections or echoes are not accounted for

STI Simulation - Eyring

Validity of statistical assumptions regarding RT in flat rooms:

- Is Eyring's approach still valid?
- Inhomogeneous diffuse field
- Mean free path length l=4V/S is no longer valid
- RT also depends on the location of the source(s)
- Typically two sub rooms: horizontal + vertical

Numerous corrections have been developed:

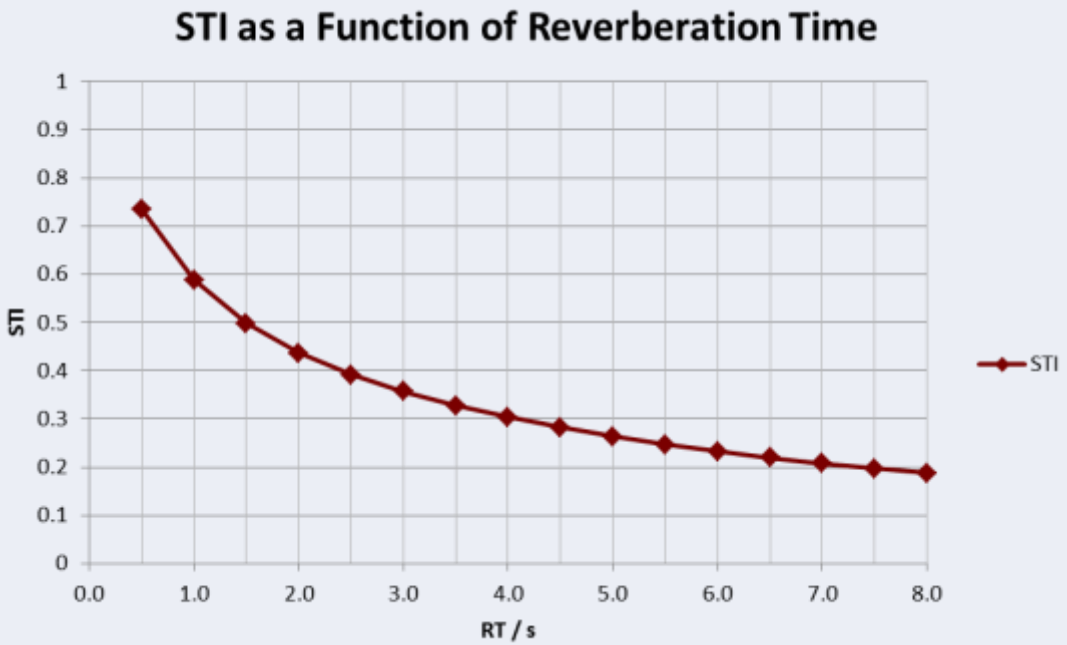
- Kuttruff, Fitzroy, Arau, Tohyama, Millington-Sette,…

STI Simulation - Eyring

- Other factors and sources of errors for STI:
  - Complicated geometry
  - Signal and noise levels have to be accounted for
  - Reflections are neglected
  - Loudspeaker data
  - Uncertainties regarding wall materials in use
  - Diffuse-field absorption coefficients

- Uncertainty for STI = f(RT) ?
- Uncertainty for STI = f(α) ?

STI Simulation - Eyring

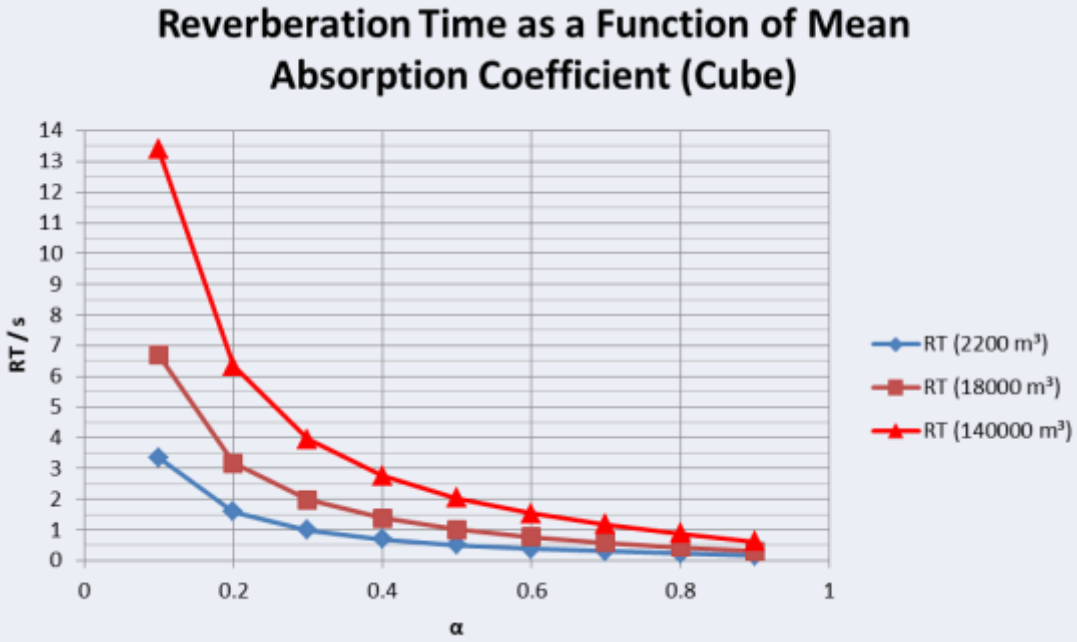


Relationship:

- Here: without direct sound or noise
- Small variation for high reverberation time
- Increased sensitivity for dry rooms

=> A small variation of the RT is insignificant for STI in practice

STI Simulation - Eyring

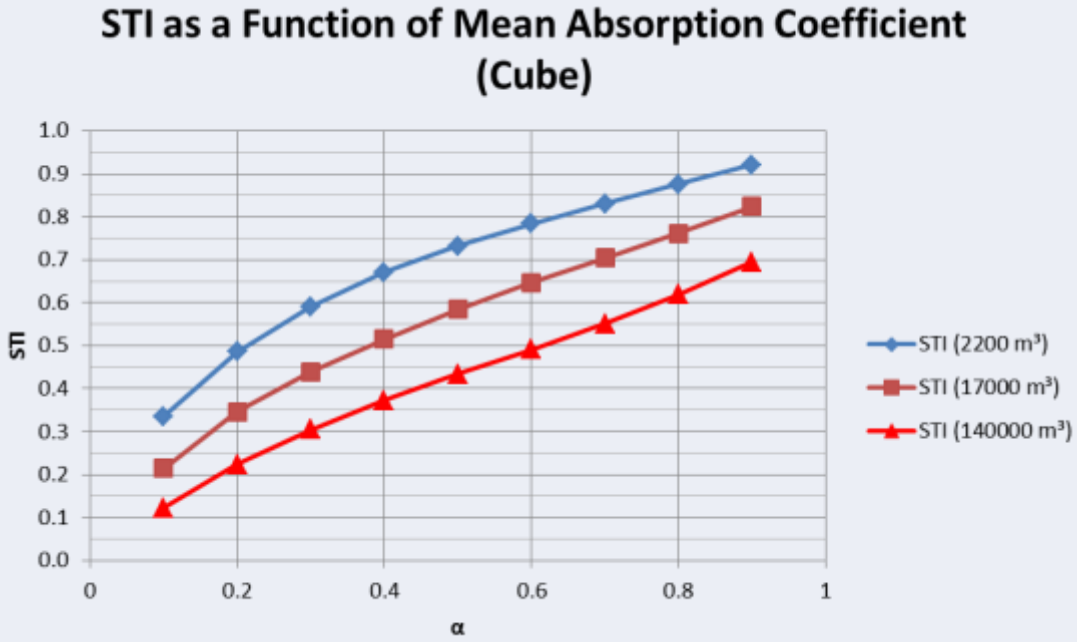


Relationship:

- Small variation for large absorption
- Increased sensitivity for acoustically hard rooms

=> A small variation of the RT is insignificant for STI in practice

STI Simulation - Eyring



Relationship:

- Functions compensate each other roughly
- Course approximately linear
- An error of a = 0.1 equals roughly an error of STI = 0.1

STI Simulation - Eyring

STI calculation based on statistics:

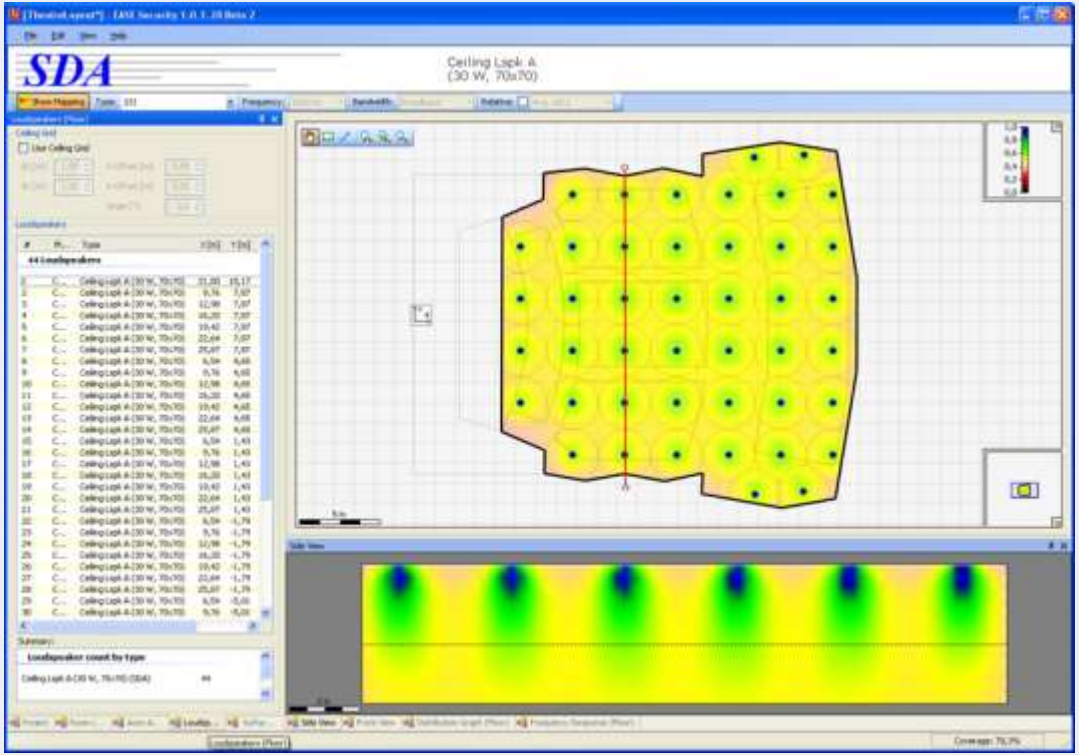
- Other uncertainties are equal or greater than the calculation of reverberation time
- Sensitivity of STI to errors in α is limited
- Uncertainty in determining α should be accounted for in the design!

STI – Speech Transmission Index

Summary:

- STI according to IEC 60268-16 (2003): EASE Evac
- By means of direct modulation method or indirect IR
- Correction factors:
  - Male/Female
  - S/N-Ratio
  - Signal masking, hearing threshold
- Criticism:
  - Masking is defined as a step function, usable level range
  - Smoothness of time function, influence of echoes
  - Linearity, quality, coverage of frequency response
  - Not binaural
- STI according to IEC 60268-16 (2011): EASE
  - masking, bands A-J+U, recommendations, foreign and hearing-impaired listeners

EASE Evac Software



Features:

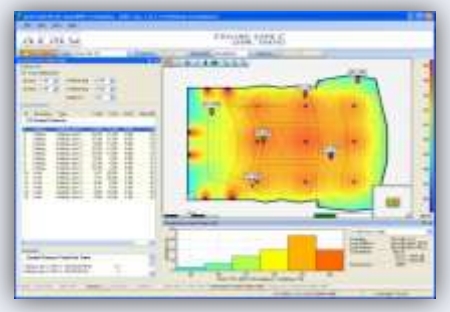
- Entry of room layout
- Abstract objects
- Acoustic materials or Reverberation Time
- Noise levels
- Statistical calculation of STI

=> EN 60849, NFPA 72

=> EASE AURA

EASE Evac Info

- Design pre-planning
  - Avoid surprises at the end of the job
  - Documentation for the AHJ / job file
  - Avoid system pretesting (where required)
  - Report can be used for installers guide



- EASE Evac is exclusively available from AMFG
  - For more information, to register for a trial version or to order the product: http://evac.afmg.eu/

- For technical support on EASE Evac:
  - Support email: support-us@afmg.eu
  - Support Hotline: 855-411-2364

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