The Quality of Acoustics

The approach to STI measurements

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12Dodicifacce is an Italian Acoustic Engineering company that develop professional solutions and innovative products

Our **passion for music** is what drives us
Our fascination with **sound is our motivation**

Our **R&D team**, acoustic engineers and production workers **have a common goal**

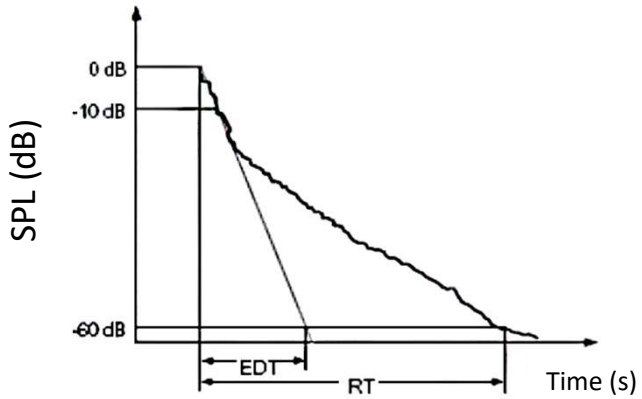
They work to **make** sure the **world sounds** a little bit **better** every day

Outline

- Speech Quality Parameters
- Speech Transmission
  - Speech transmission assessment
- STI
  - STI Modulation Transfer function
  - STI measurement
  - STI WWW (Which, What, Where)
  - Practical example

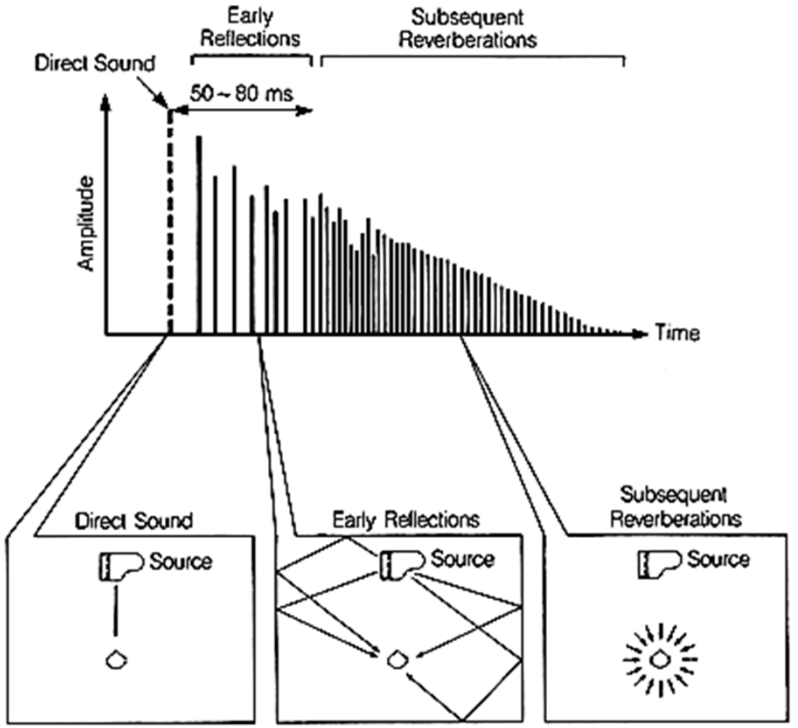
Speech Quality Parameters

- Reverberation time (RT)
  - **RT60** Reverberation time: the time it takes for the SPL to fall by **60 dB** from its 0dB level (interrupted source)
  - Early Decay Time **EDT**: between 0 dB and **10 dB** below the initial level of reverberation decay curve
    short EDT = higher speech intelligibility (**50 ms** early reflections integrates with the direct sound)



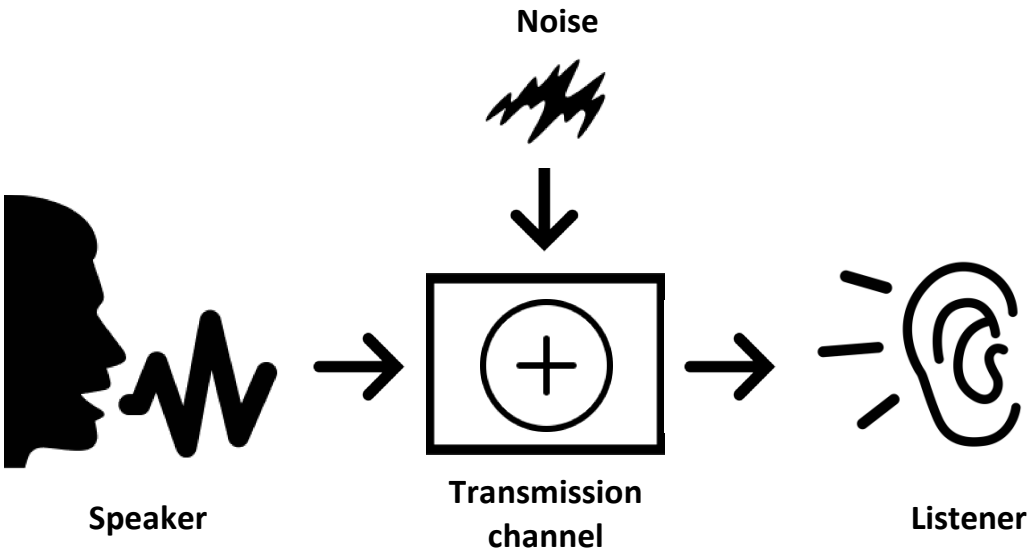
Speech quality parameters

- Energy criteria
  - **Clarity C**: is the ratio between the useful sound reverberation and noise (temporal and frequency transparency).
  - Definition **D50**: D is the ratio between the sound energy between first **50 ms** and the total energy of the impulse response

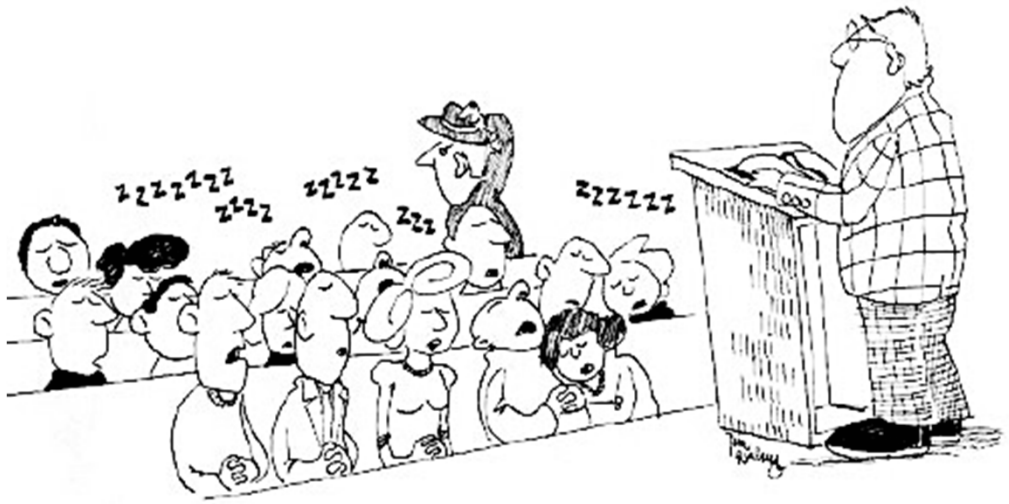


Speech transmission

- Speaker – listener
- Communication channel may ruin the message



Speech transmission



"Thanks for understanding, in lieu of our malfunctioned sound system."

Speech transmission

Original

Short Reverb

STI = 0.92

Long Reverb

STI = 0.35

Noise

Speech transmission assessment

- 3 methods:
  - **Subjective** measures making use of speakers and listeners
  - Predictive measures based on **physical parameters**
    - French and Steinberg (1947) and later evaluated by Beranek (1947). Articulation Index (AI) by Kryter (1962).
  - **Objective** measures obtained by measurements with specific test signals
    - STI (Speech Transmission Index) Houtgast and Steeneken (1971, 1980,1992, 2002)
    - RASTI (Room Acoustical Speech Transmission Index) Steeneken and Houtgast (1979, 1984).

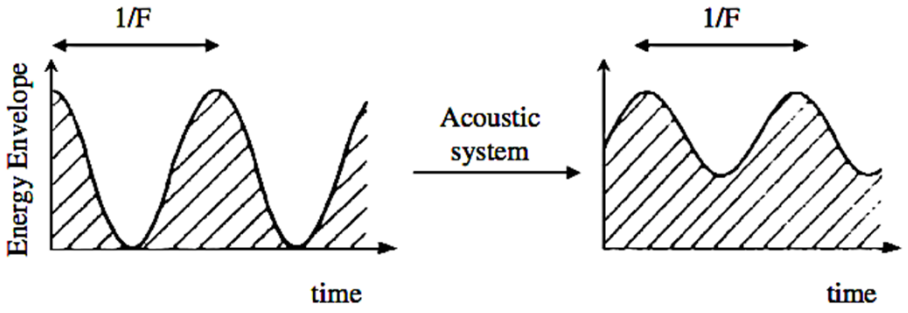
STI (Speech Transmission Index)

- STI is a **well-established** objective measurement predictor of how the characteristics of the transmission channel affect **speech intelligibility**
- Speech Transmission **INDEX** varies from 0 to 1

- STI index is obtained from the Modulation Transfer Function (MTF)

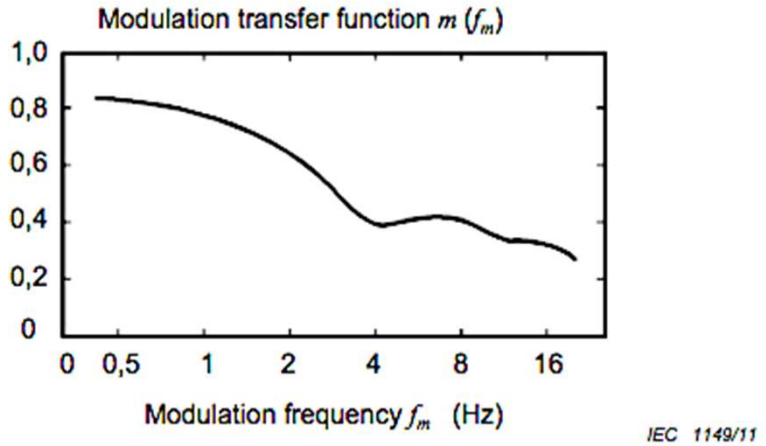
STI MTF (Modulation Transfer Function)

- The modulation index m_i of a test signal is received at a listener position as the modulation index m_o

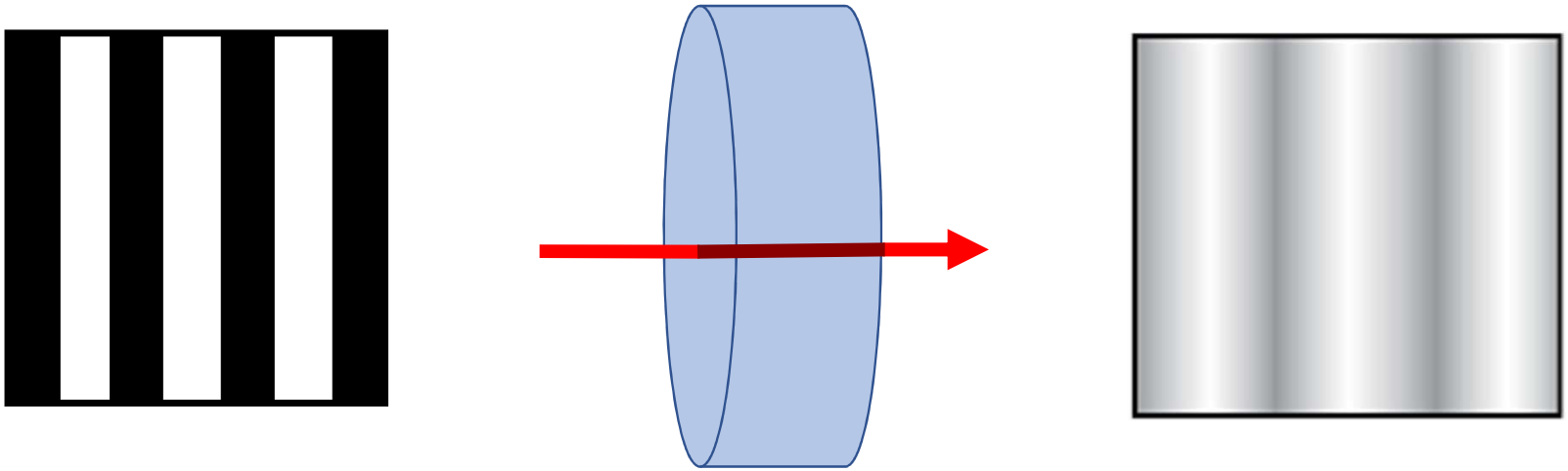


m_i m_o

$$m = \frac{m_o}{m_i}$$

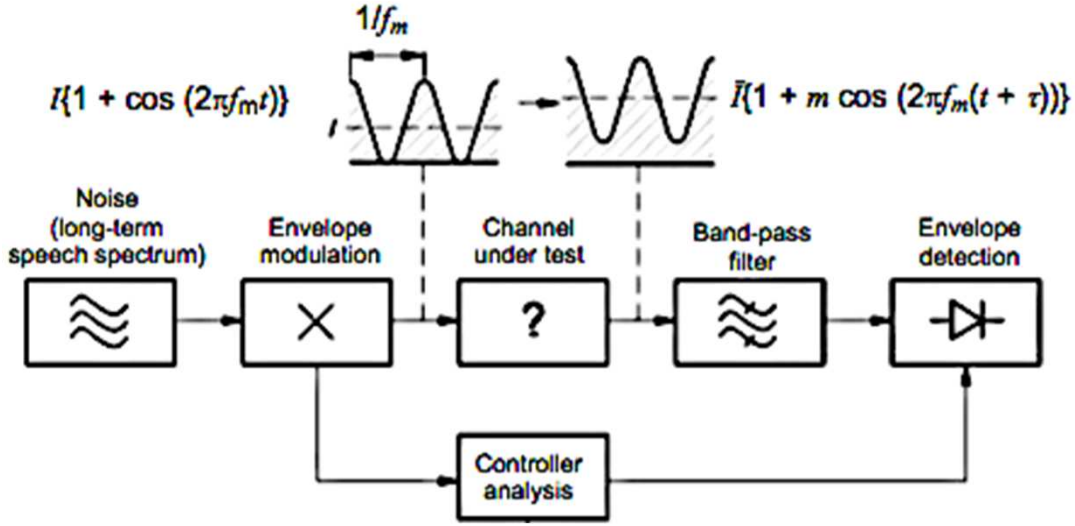


STI MTF (Modulation Transfer Function)



STI measurement

- Pink noise -> filtered -> frequency spectrum of the speech signal
- *Intensity envelope* of each octave-band is modulated
- m = $\frac{I_{test}+I_{noise+room}}{I_{test}}$
- Modulation Transfer Function



STI measurement

- Complete matrix of **98 m-values** and a measuring time for each m-value of 10s = **15 minutes** total measures.
- Some **simplifications** were made to **decrease the measuring time** but these simplifications restrict the range of applicability.

Octave-band Hz	125	250	500	1k	2k	4k	8 k
f_1 = 0,63 Hz	m						
f_2 = 0,8 Hz							
f_3 = 1,0 Hz							
f_4 = 1,25 Hz							
f_5 = 1,6 Hz							
f_6 = 2,0 Hz							
f_7 = 2,5 Hz							
f_8 = 3,15 Hz							
f_9 = 4,0 Hz							
f_{10} = 5,0 Hz							
f_{11} = 6,3 Hz							
f_{12} = 8,0 Hz							
f_{13} = 10 Hz							
f_{14} = 12,5 Hz							
I_k							

STI measurement *Which*WW?

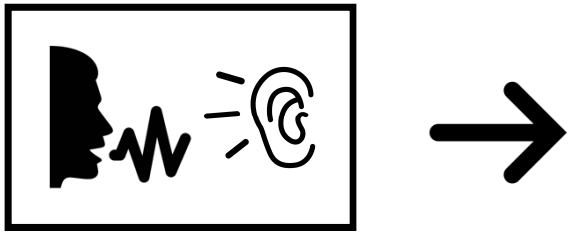
- Signal based
  - **FULL STI**: 14 modulation frequencies for 7 octave band = 98 stimuli
  - **STIPA** : 2 modulation frequencies (phase shifted) for 7 octave band = 1 stimulus
  - STITEL: 1 modulation frequencies for 7 octave band = 1 stimulus
  - RASTI: obsolete
- Acoustic based
  - **Indirect STI**: 1 impulsive response of the room
  - Diagnostics: reverberation time of the room

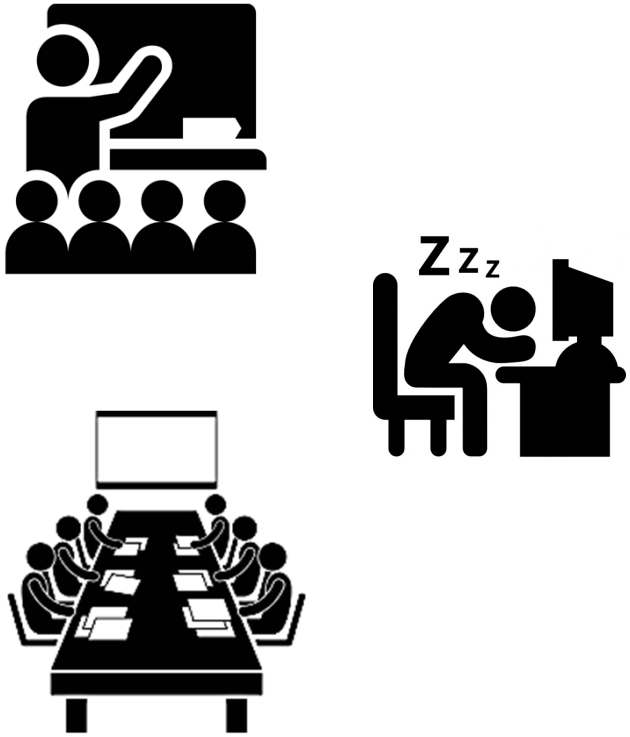
STI measurement W*What*W?

Method	Noise	Reverberation, echoes	Non-linear distortion	Spectral distortion
Direct FULL STI	yes	yes	Pessimistic estimation	yes
Indirect STI	yes	yes	no	yes
STIPA	yes	yes	No severely clipped signal in various frequency bands	yes
STITEL	yes	Reverberation time no frequency dependent	No severely clipped signal in various frequency bands	yes
Diagnostics from reverberation time	no	Purely exponential reverberant decay	no	no

STI measurement WW*Where*?

- Human – Human
  - Classroom
  - Office
  - Meeting room
  - Etc.

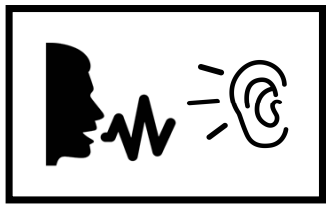




1. Indirect STI
2. Diagnostics from reverberation time
3. FULL STI, STIPA using mouth simulator

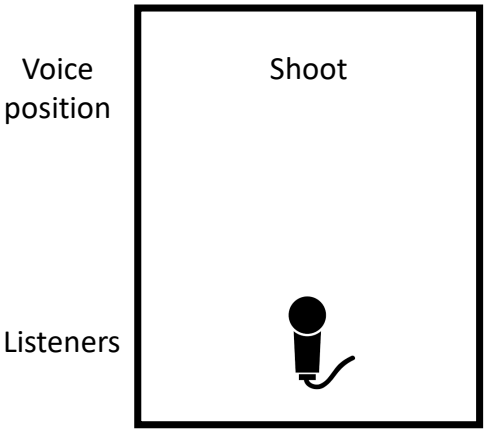
STI measurement WW*Where*?

- Human – Human

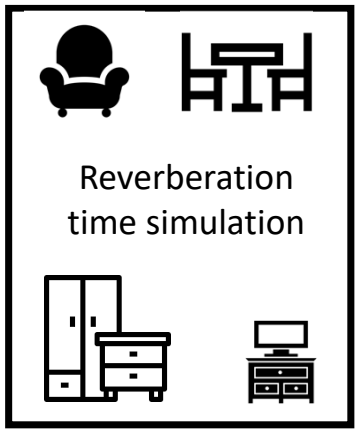


1. Indirect STI

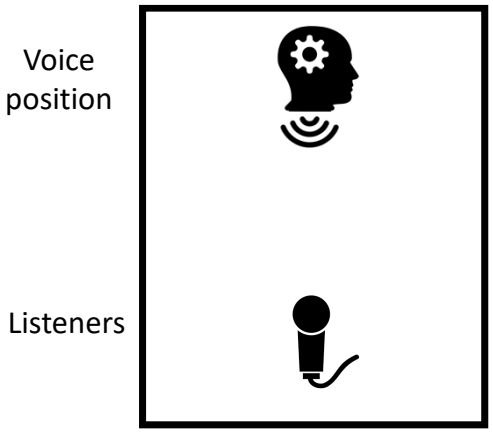
Impulse response measurement



2. Diagnostics from reverberation time

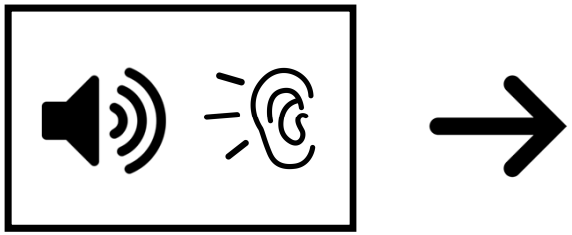


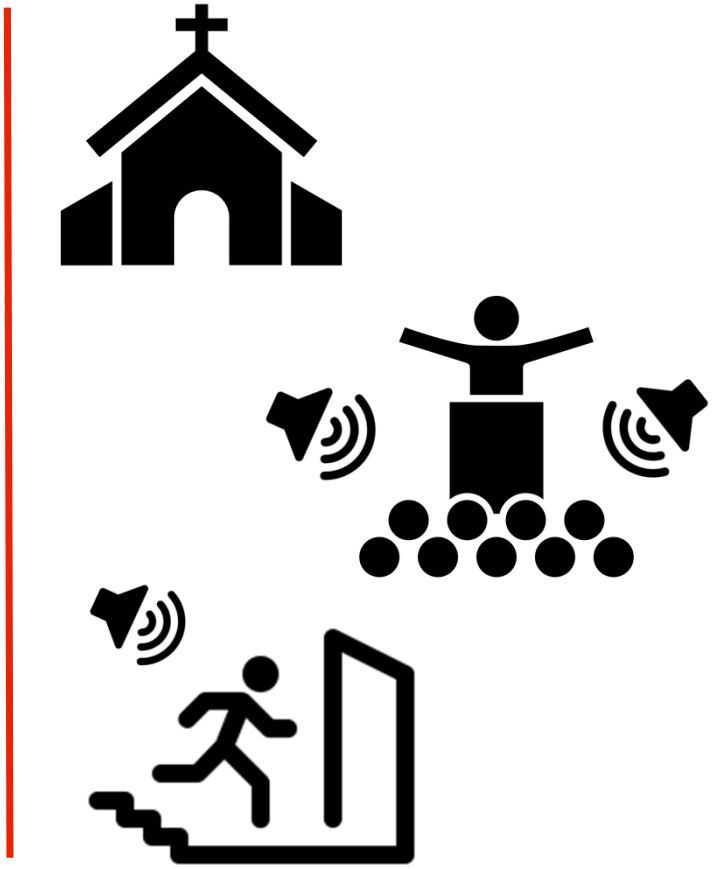
3. FULL STI, STIPA using mouth simulator



STI measurement WW*Where*?

- Loudspeaker – Human
  - Auditorium
  - EVAC systems
  - Public spaces
  - Etc.

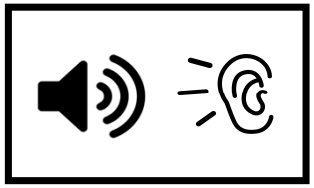




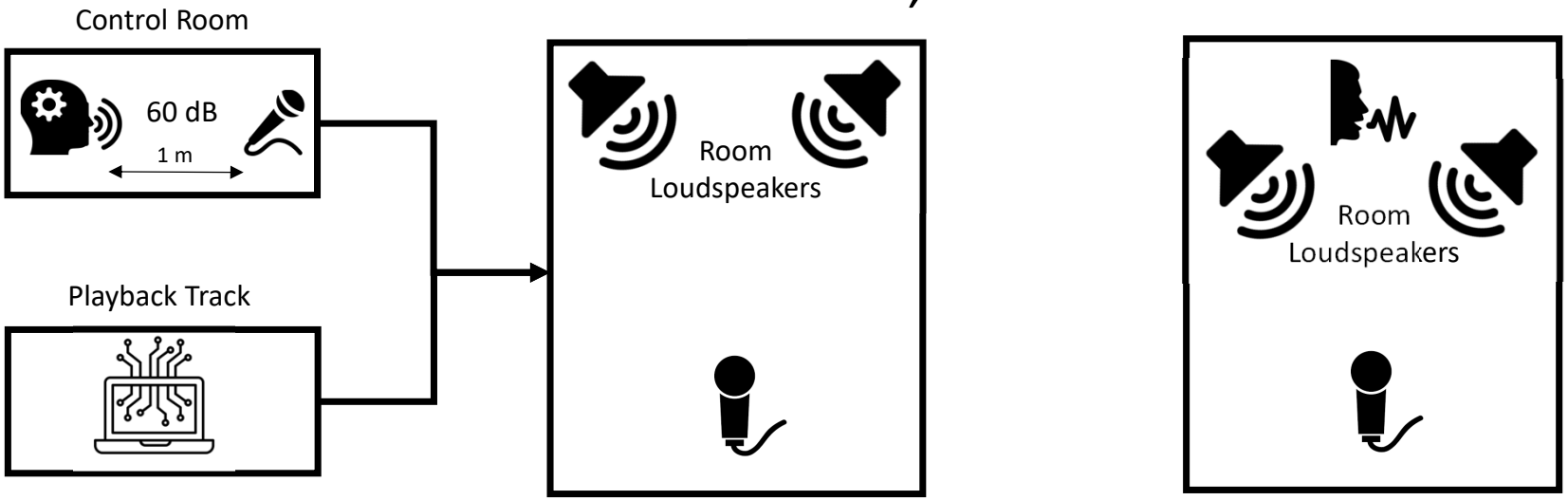
1. FULL STI, STIPA
2. (STITEL)

STI measurement WW*Where*?

- Loudspeaker – Human



1. FULL STI, STIPA



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