

Fundamentals of Room Acoustics

Is it really possible to calculate acoustics ?

How does the acoustics of a room affect the sound of the loudspeakers ?

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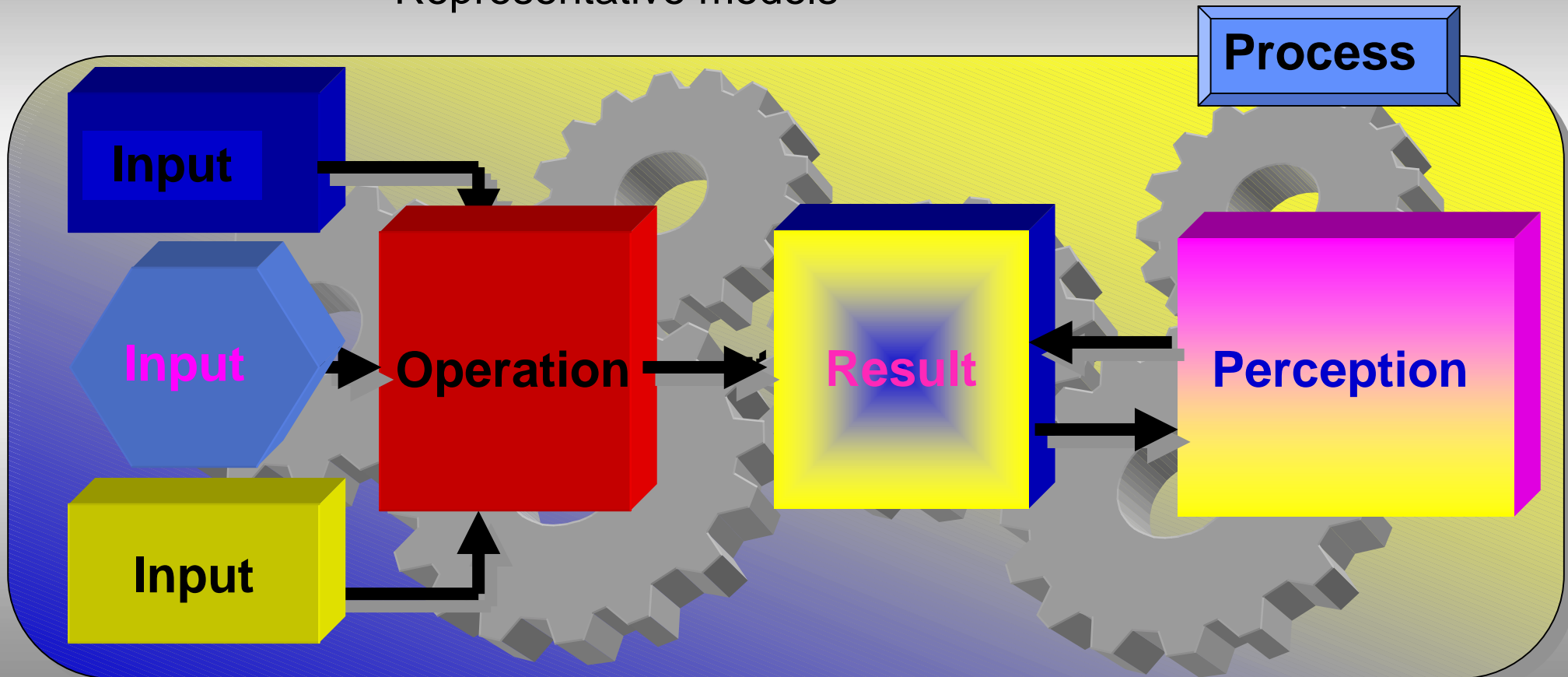


Basic principles of sound propagation

- Direct sound, inverse square law
- Signal/Noise
- Room acoustics
- Direct sound and reverberation
- Total sound field

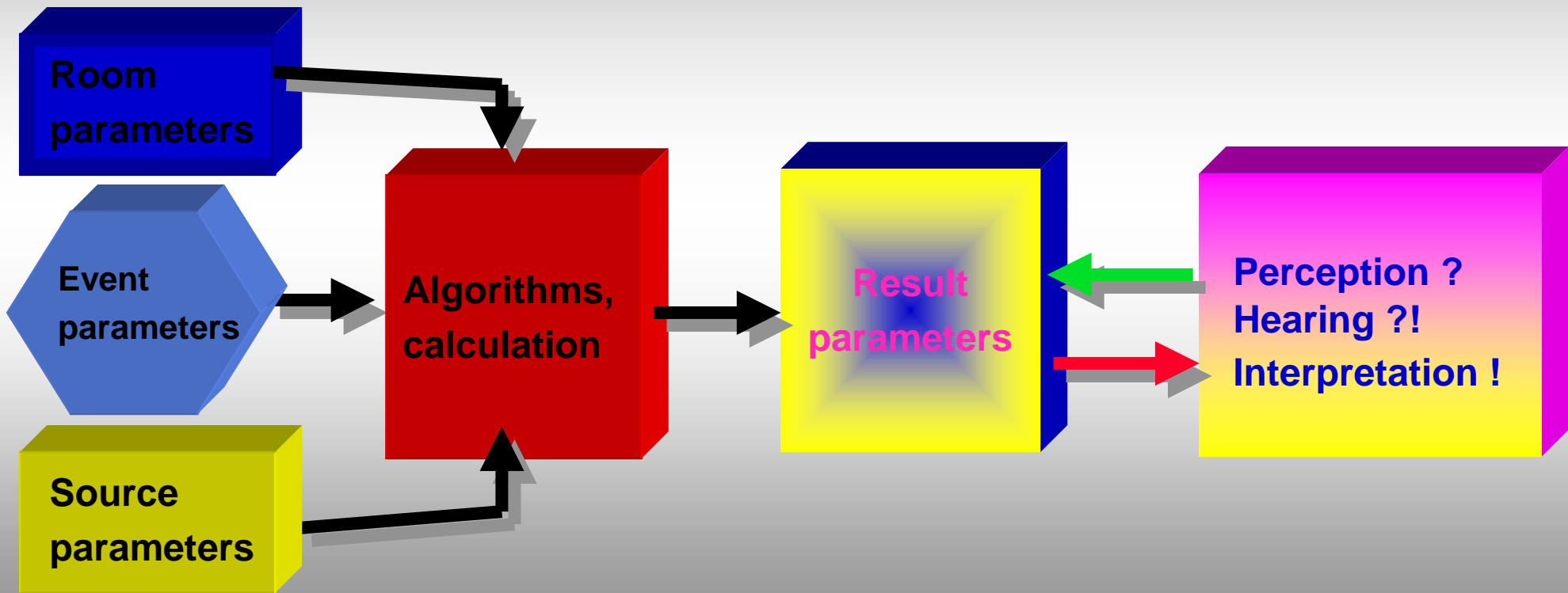
Preliminary remarks

- Processes of nature
- Subjective feeling
- Representative models

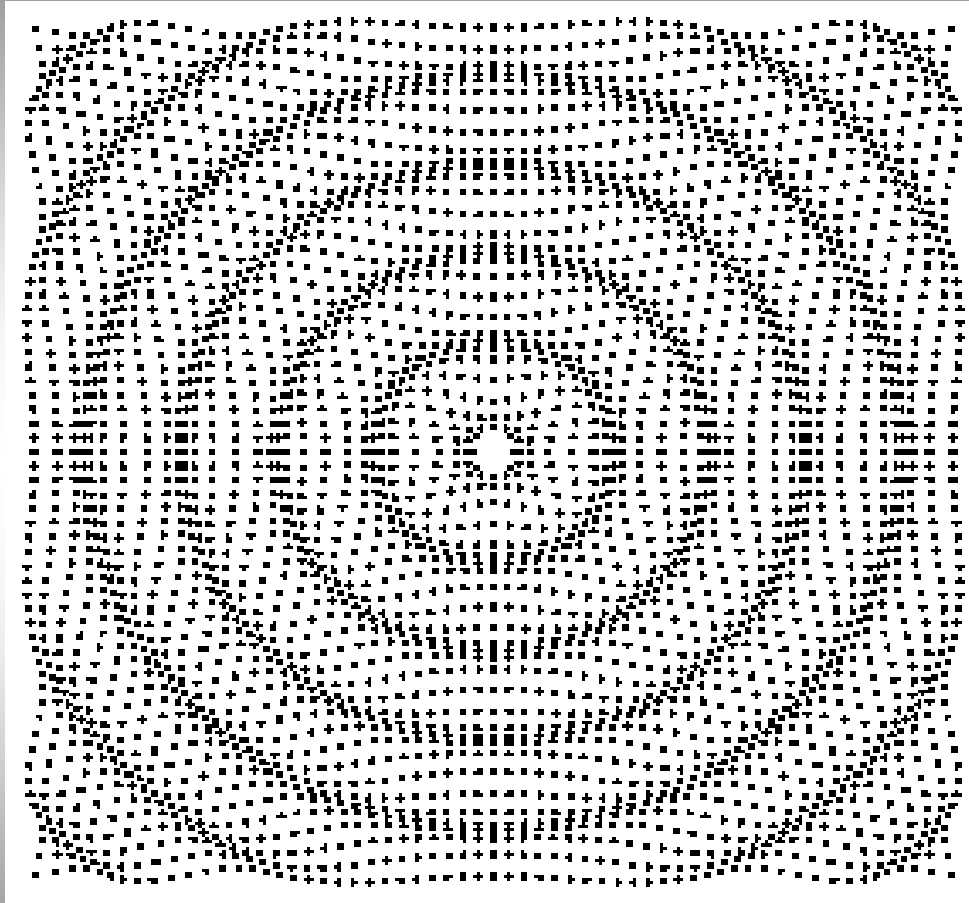


Models, algorithms

- Simplify the processes of the natural world
- Understand and recognise interrelations
- Calculate result parameters



What is sound ?

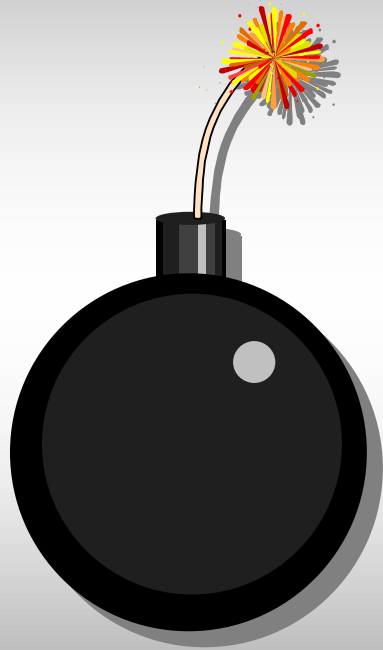


Sound pressure, p

Sound velocity, v

Sound propagation velocity, c

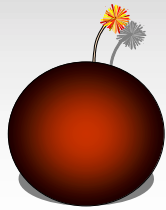
Distance law



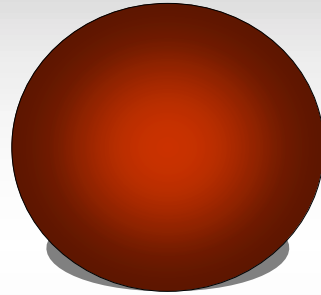
**Impulse-sound source,
omni-directional ...**

$t = 0$ ms

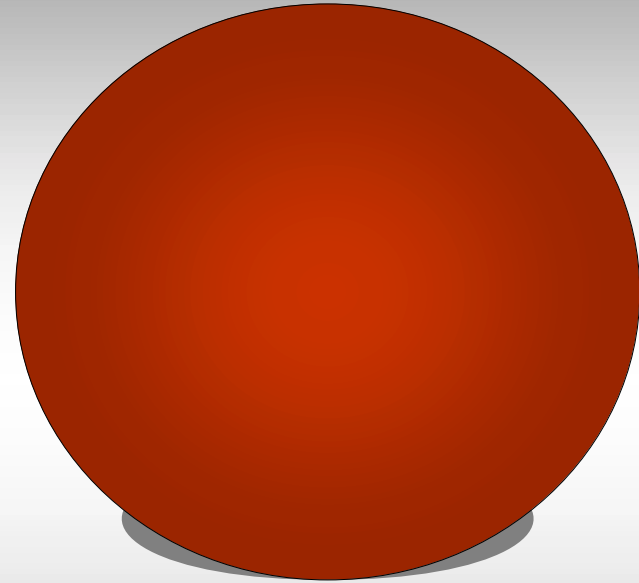
Distance law



$L_d = 0 \text{ dB}$
 $R = 1 \text{ m}$

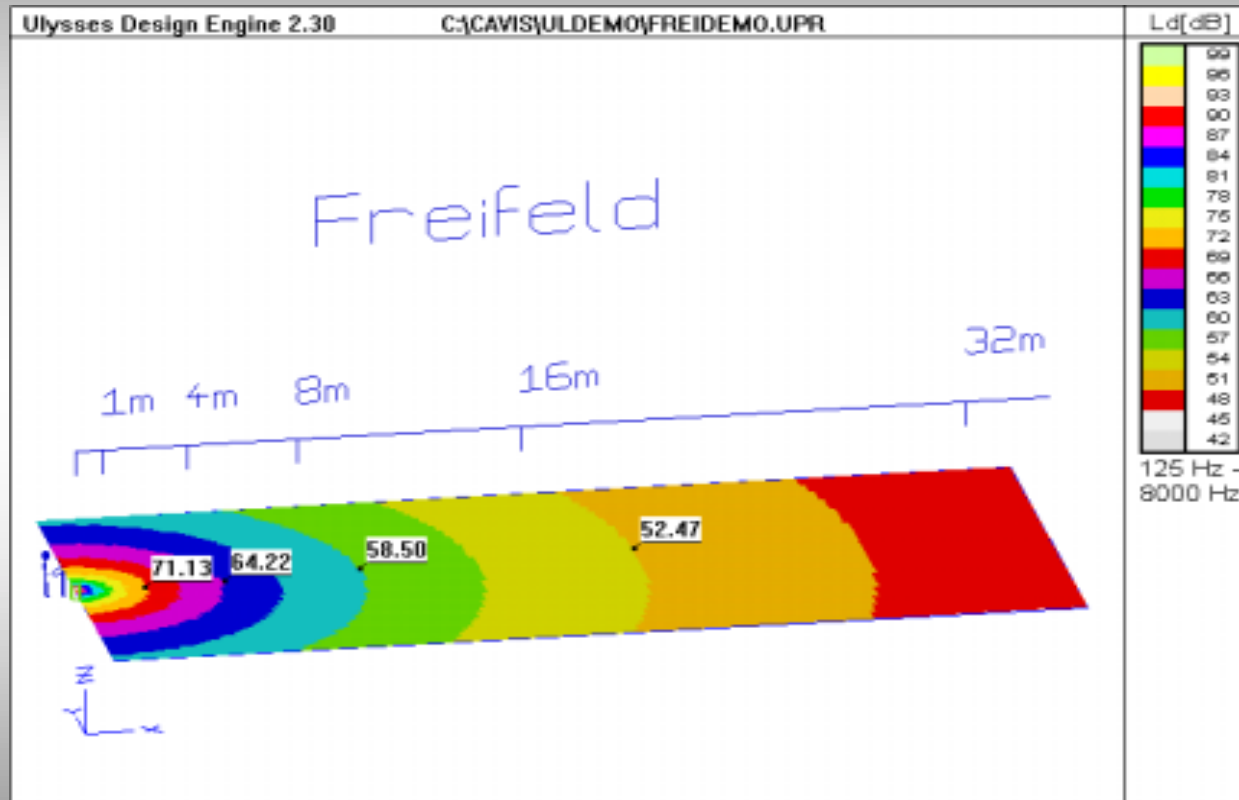


$L_d = -6 \text{ dB}$
 $R = 2 \text{ m}$

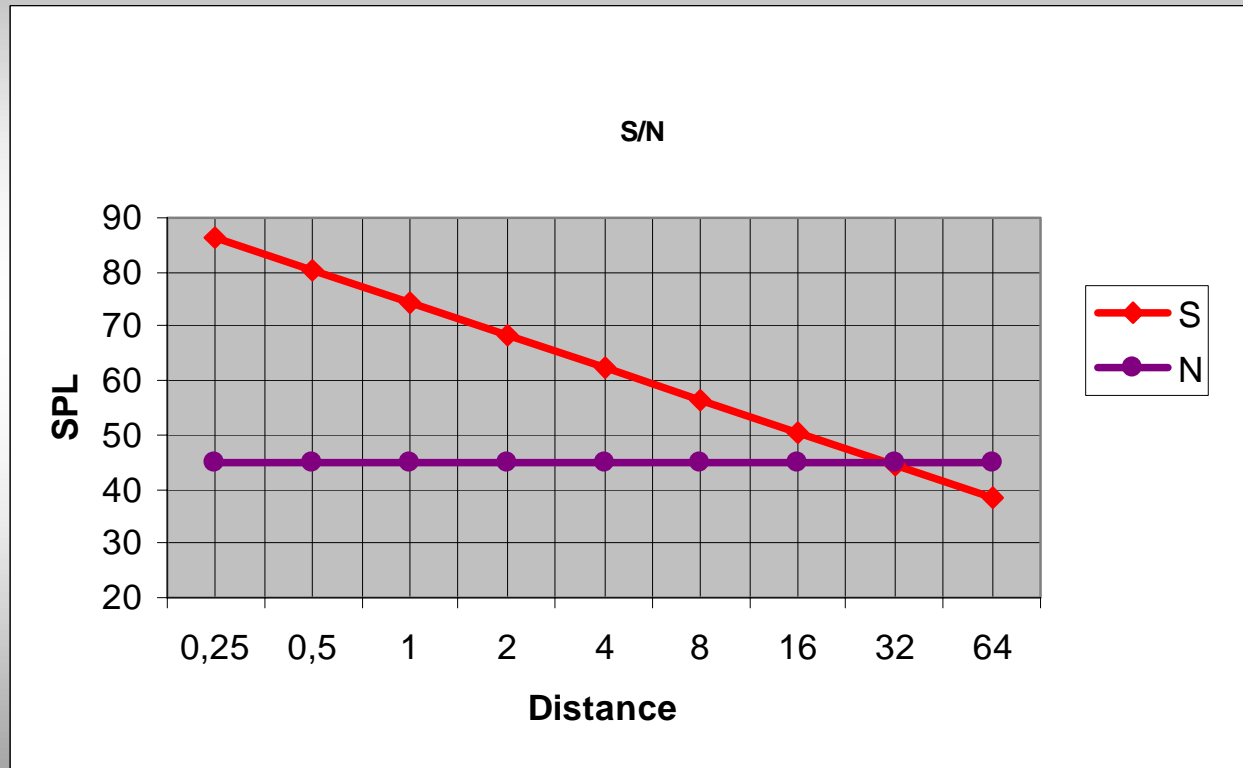


$L_d = -12 \text{ dB}$
 $R = 4 \text{ m}$

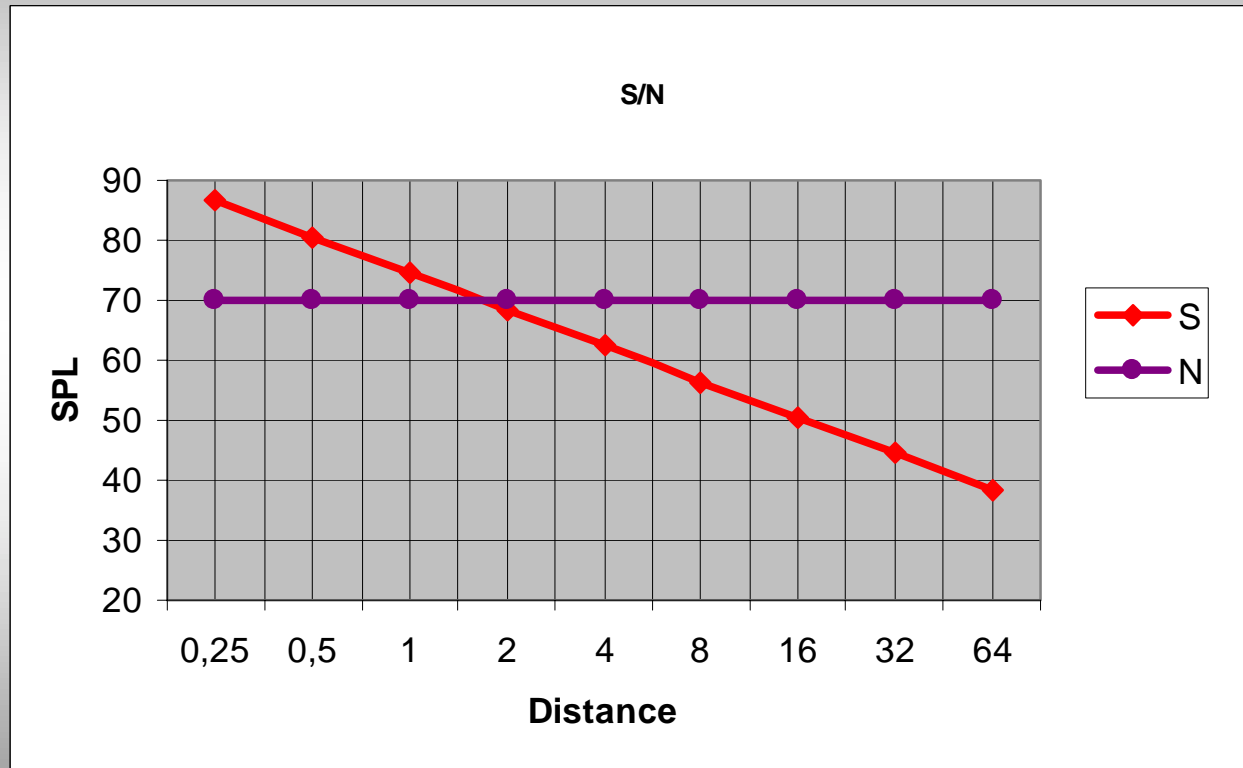
Freefield



Signal / Noise



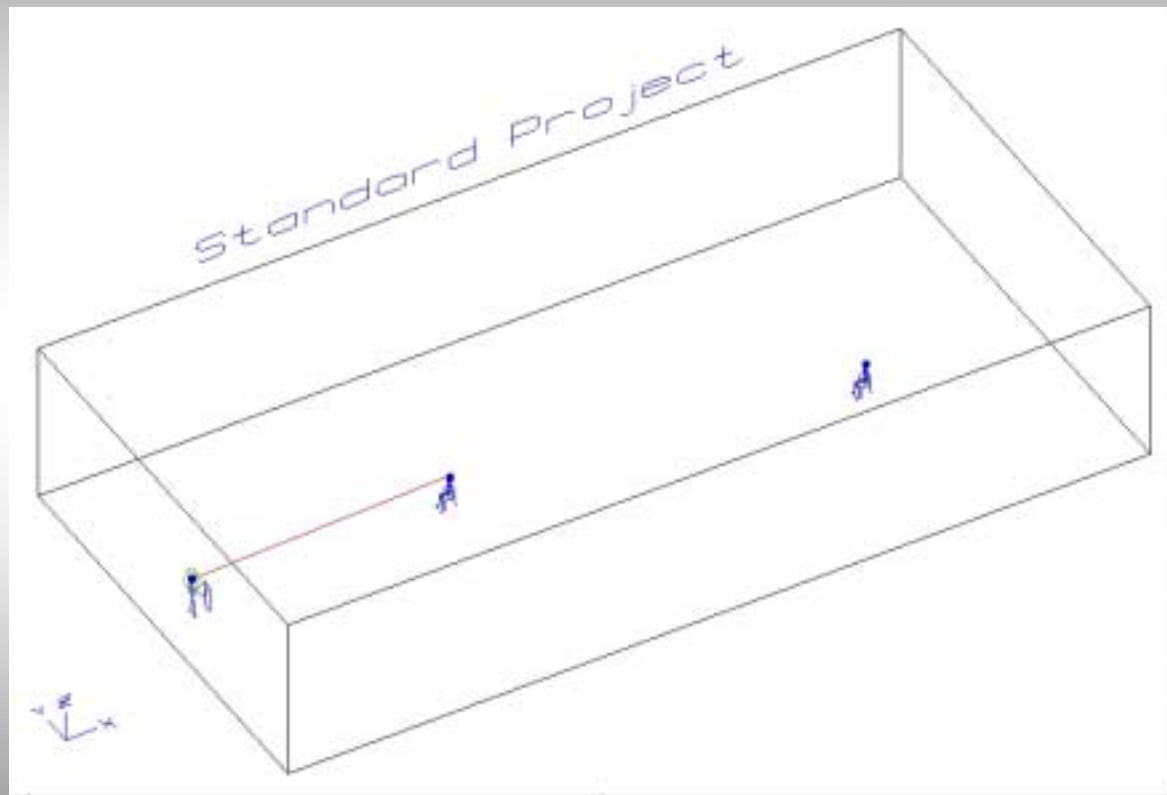
Signal / Noise



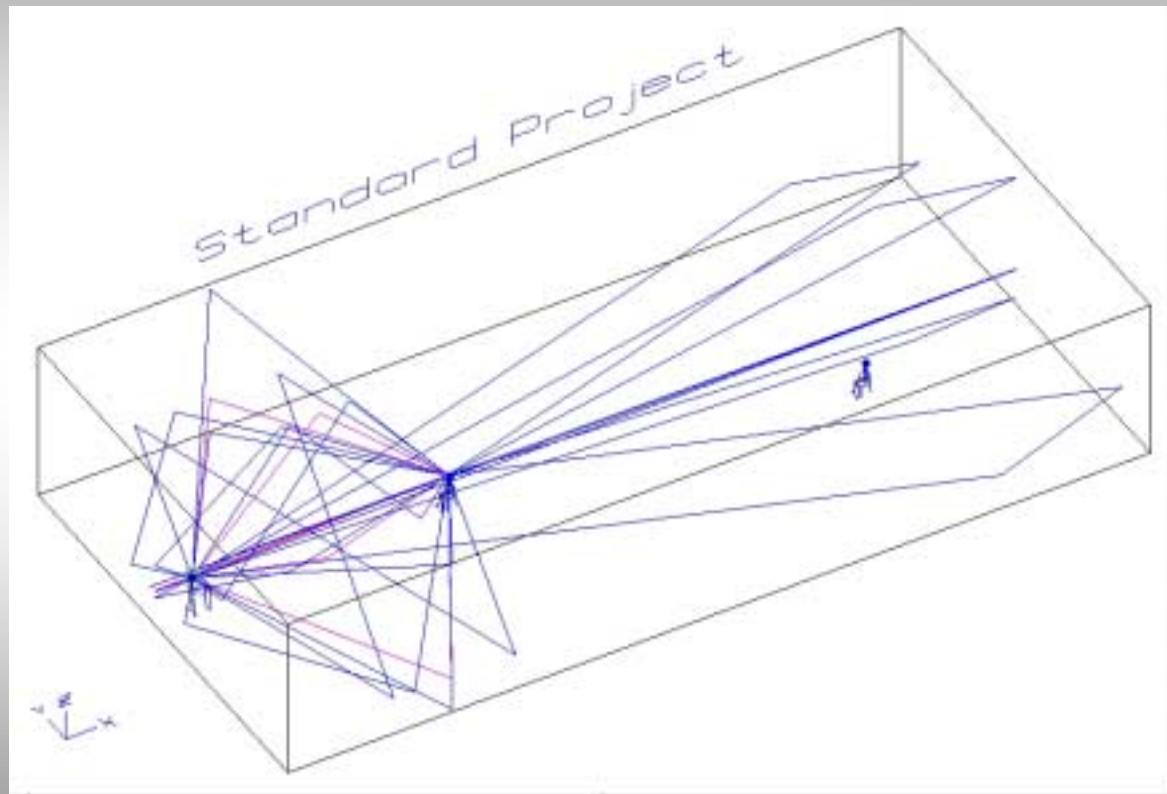
The room



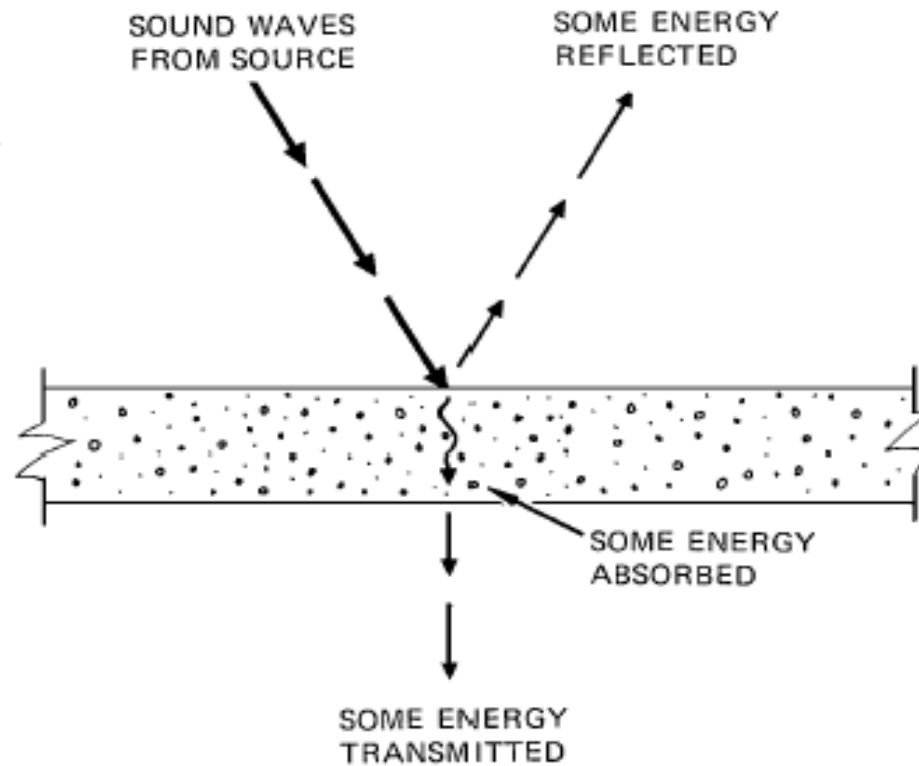
Direct sound L_d



Reflections

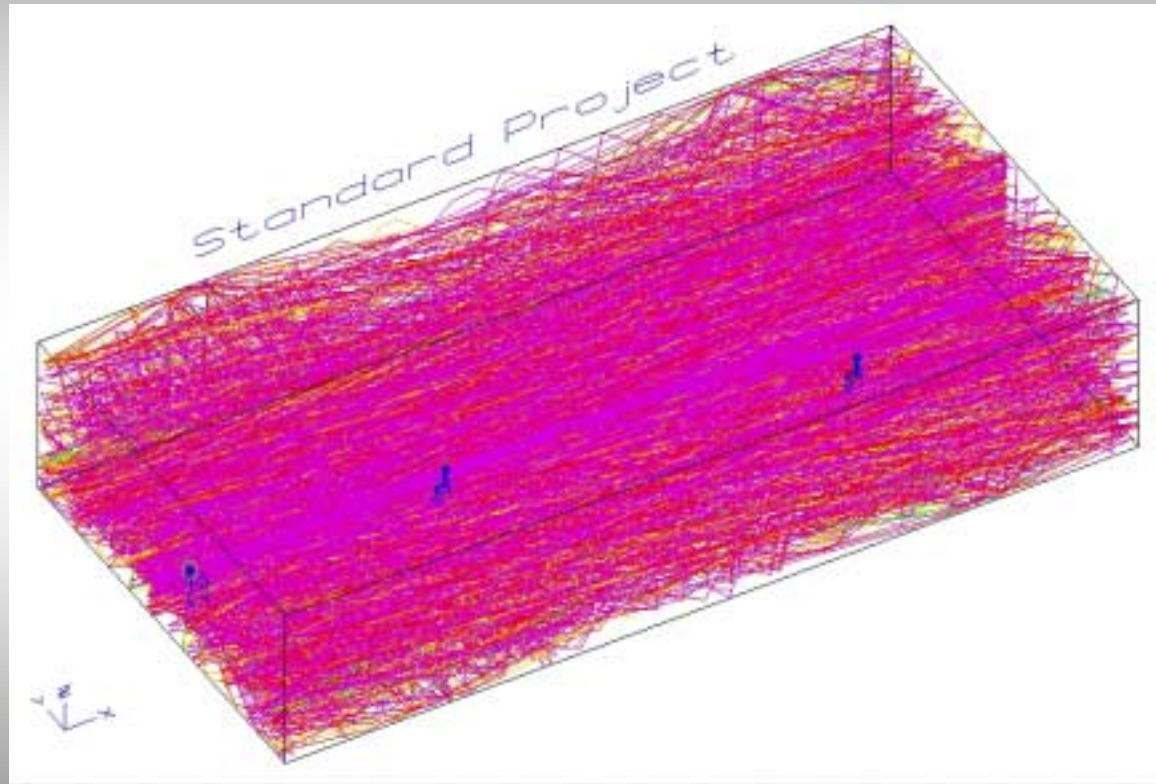


Absorption, Reflection, Transmission

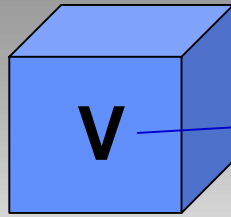


ALL THREE EFFECTS MAY VARY WITH FREQUENCY AND ANGLE OF INCIDENCE.
THEY DO NOT VARY WITH INTENSITY IN TYPICAL SITUATIONS.

Diffuse field or reverberation field, L_r



Reverberation time RT_{60} (W.C. Sabine) (SI metric!)



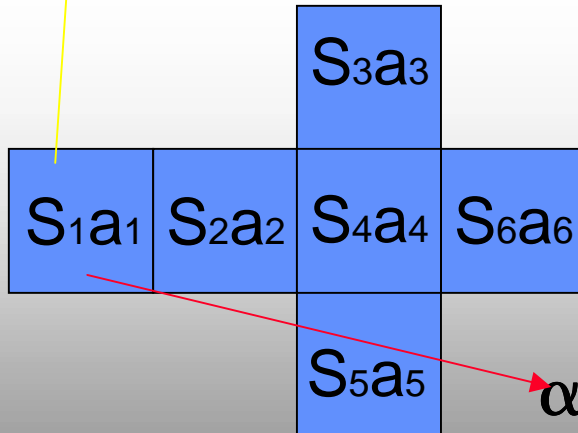
Volume

V

$$\frac{V}{\sum S_i a_i}$$

$$RT_{60} = 0.163$$

$S =$ surface



(equivalent absorption surface)

$$S_1 a_1 + \dots S_i a_i = \sum S_i a_i$$

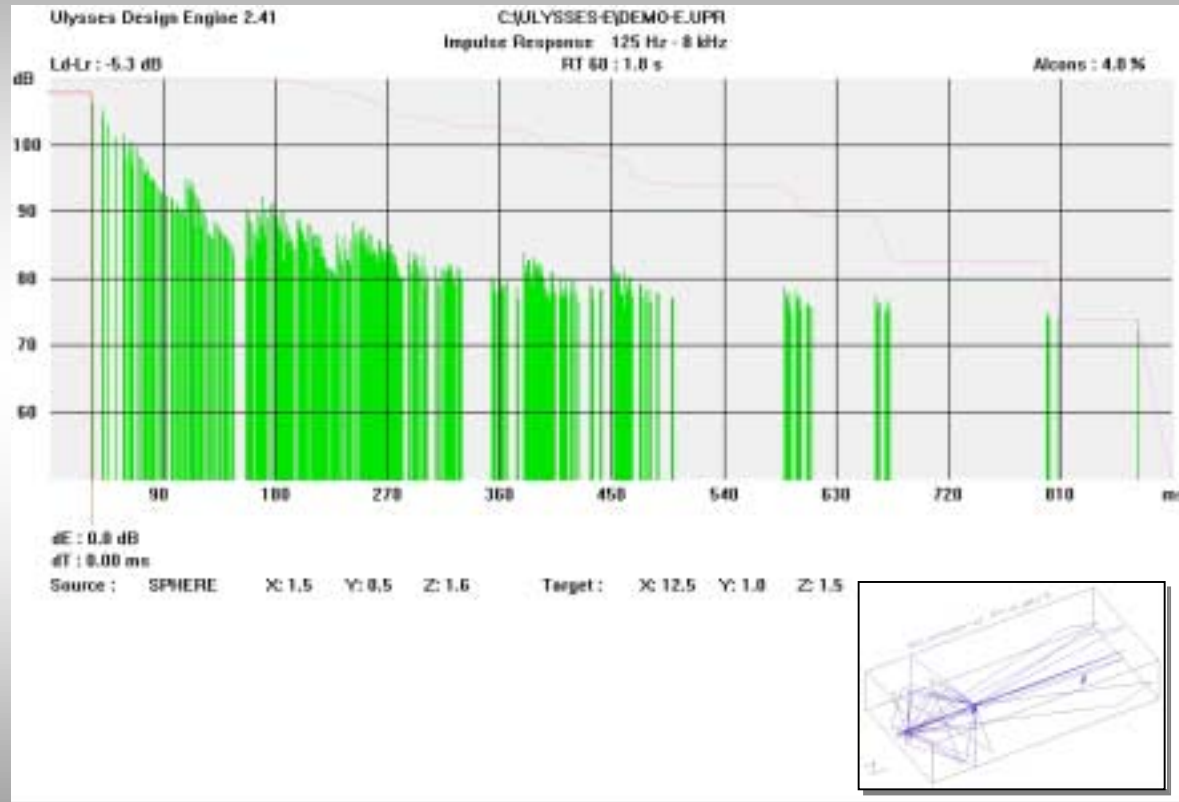
$\alpha =$ absorption coefficient

Sabine, Eyring and Fitzroy approach

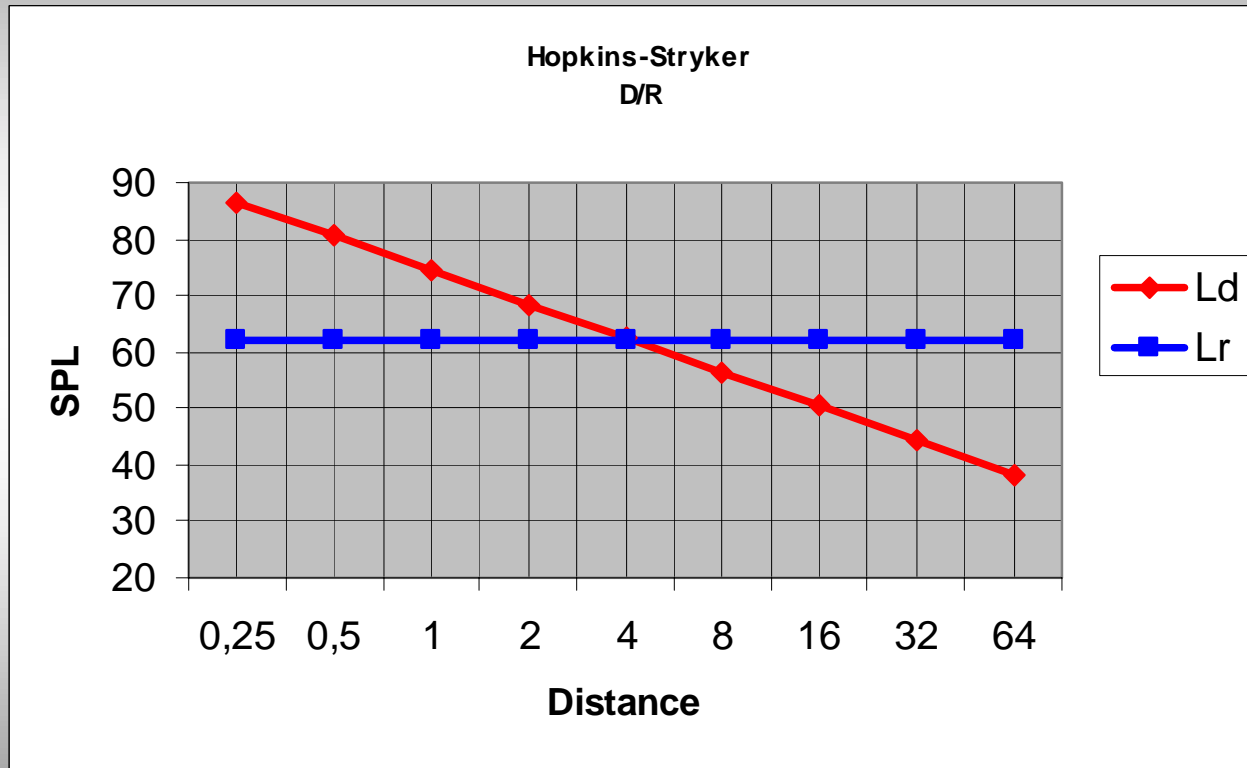
REVERBERATION TIME EQUATIONS: T = 60 dB DECAY TIME IN SECONDS		
EQUATION:	ENGLISH UNITS:	SI UNITS:
	S = SURFACE AREA IN FT ² V = VOLUME IN FT ³	S = SURFACE AREA IN m ² V = VOLUME IN m ³
SABINE – GIVES BEST CORRESPONDENCE WITH PUBLISHED ABSORPTION COEFFICIENTS WHERE $\bar{\alpha}$ IS LESS THAN 0.2	$T = \frac{.049V}{S\bar{\alpha}}$	$T = \frac{.16V}{S\bar{\alpha}}$
EYRING – PREFERRED FORMULA FOR WELL-BEHAVED ROOMS HAVING $\bar{\alpha}$ GREATER THAN 0.2 OR SO	$T = \frac{.049V}{-S \ln (1-\bar{\alpha})}$	$T = \frac{.16V}{-S \ln (1-\bar{\alpha})}$
FITZROY-(SABIN) – FOR RECTANGULAR ROOMS IN WHICH ABSORPTION IS NOT WELL DISTRIBUTED.	$T = \frac{.049V}{S^2} \left(\frac{x^2}{x\alpha_x} + \frac{y^2}{y\alpha_y} + \frac{z^2}{z\alpha_z} \right)$	$T = \frac{.16V}{S^2} \left(\frac{x^2}{x\alpha_x} + \frac{y^2}{y\alpha_y} + \frac{z^2}{z\alpha_z} \right)$
α_x , α_y , AND α_z ARE AVERAGE ABSORPTION COEFFICIENTS OF OPPOSING PAIRS OF SURFACES WITH TOTAL AREAS x, y, AND z.		

Figure 5-9. Reverberation time equations

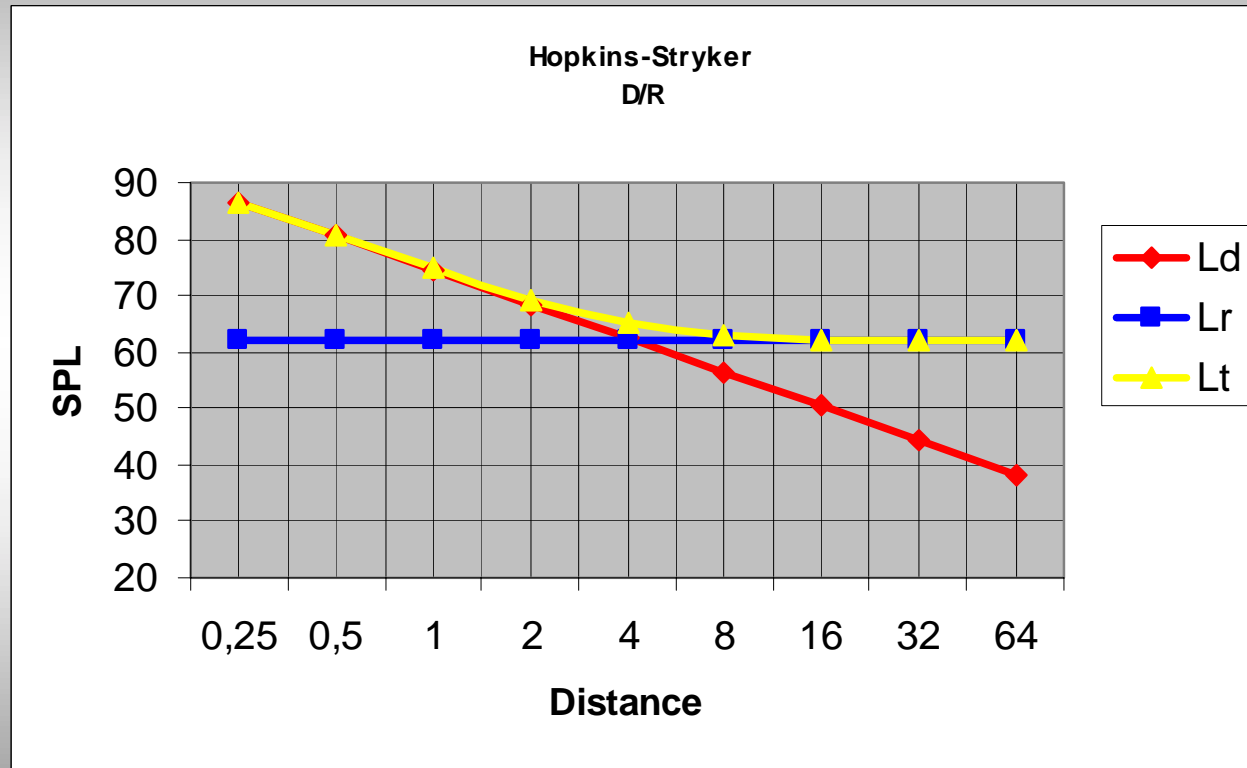
Energy vs. time, reflectogram, reverberation



Direct sound and reverberation, Ld & Lr



Total sound field $L_t = L_d + L_r$



Hopkins Stryker Equation

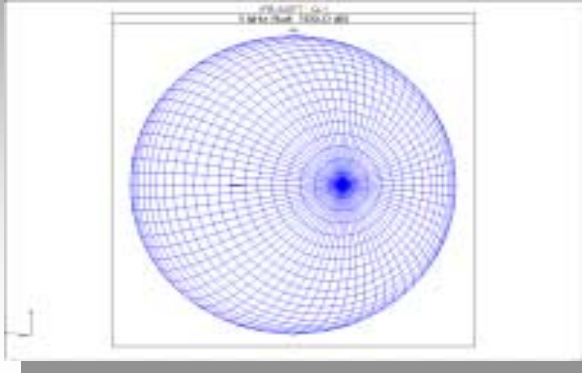


$$\Delta L_D = 10 \log \frac{Q}{4 \pi r^2}$$

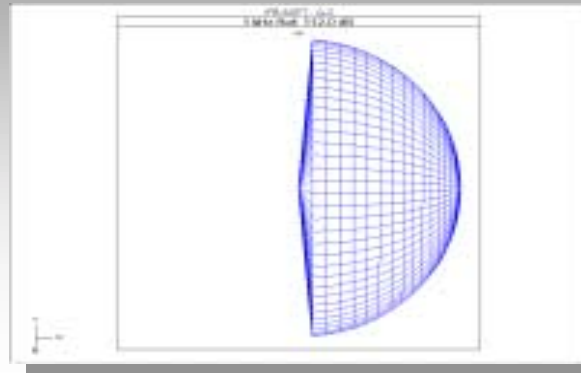
$$\Delta L_R = 10 \log \frac{4}{S \alpha}$$

$$\Delta L_T = 10 \log \left(\frac{Q}{4 \pi r^2} + \frac{4}{S \alpha} \right)$$

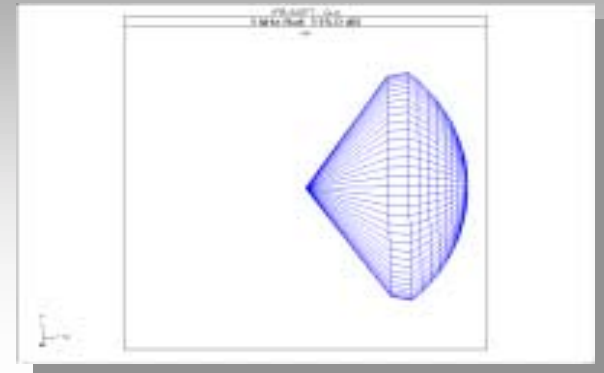
Directivity Q & DI



$Q=1$
 $DI=0\text{ dB}$



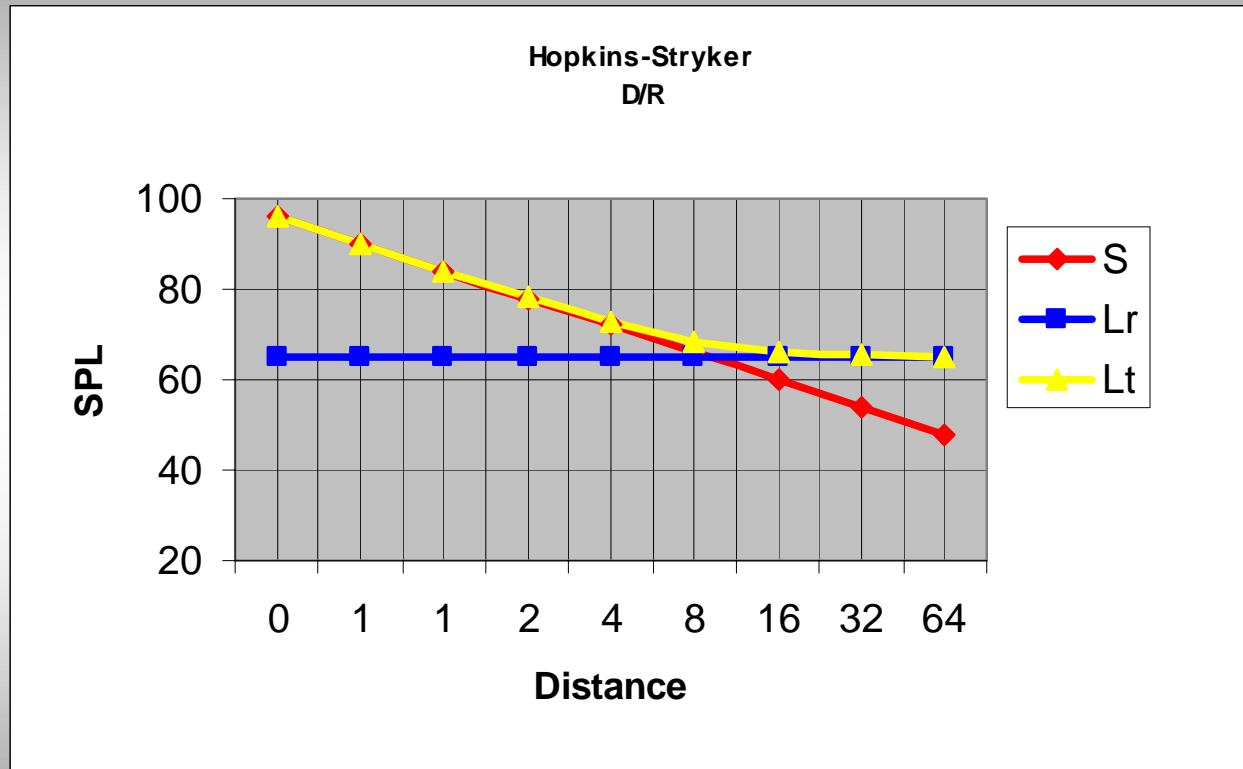
$Q=2$
 $DI=3\text{ dB}$



$Q=4$
 $DI=6\text{ dB}$

$$DI = 10 \log Q$$

Total sound field $L_t = L_d + L_r$, $Q = 8$, $D_l = 9$ dB



Discussion

- Any question is welcome ...



Thank you for your attention!