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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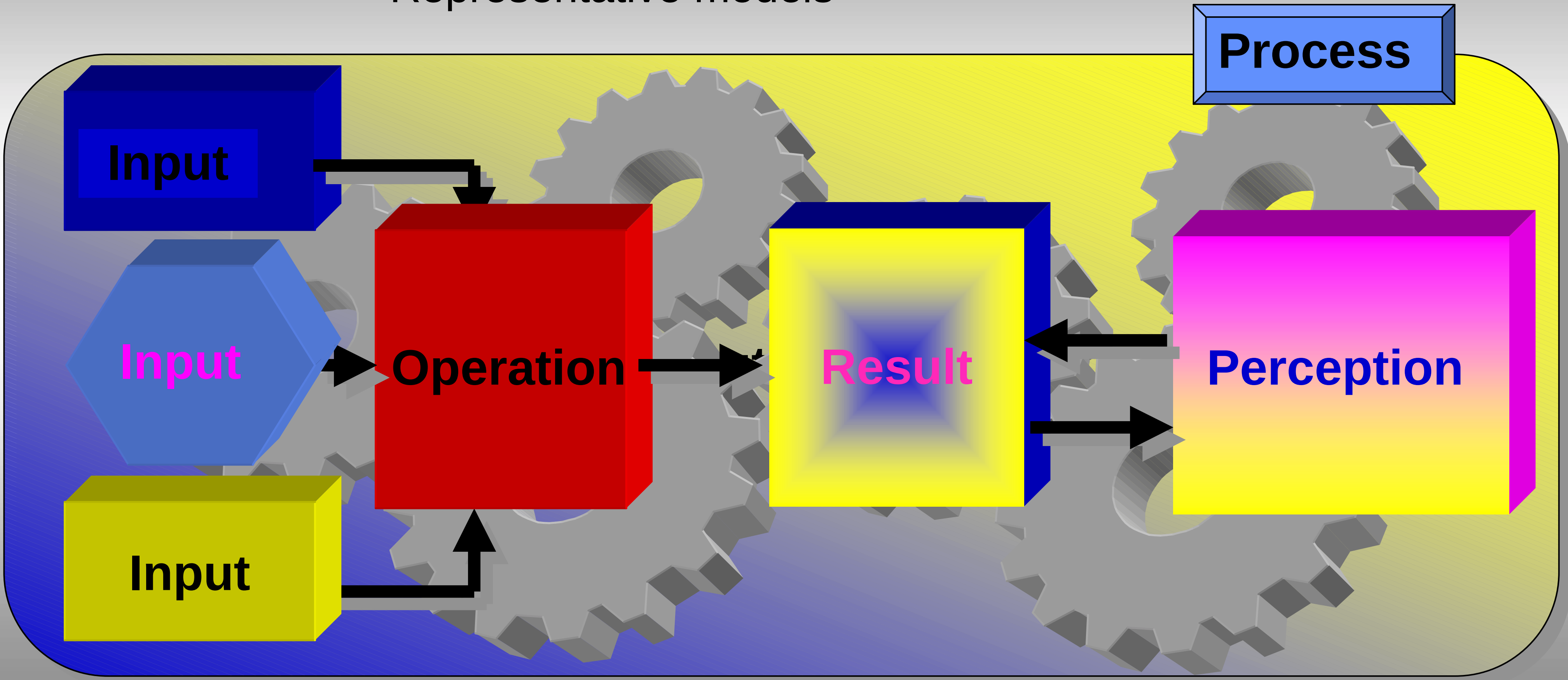
Basic principles of sound propagation

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

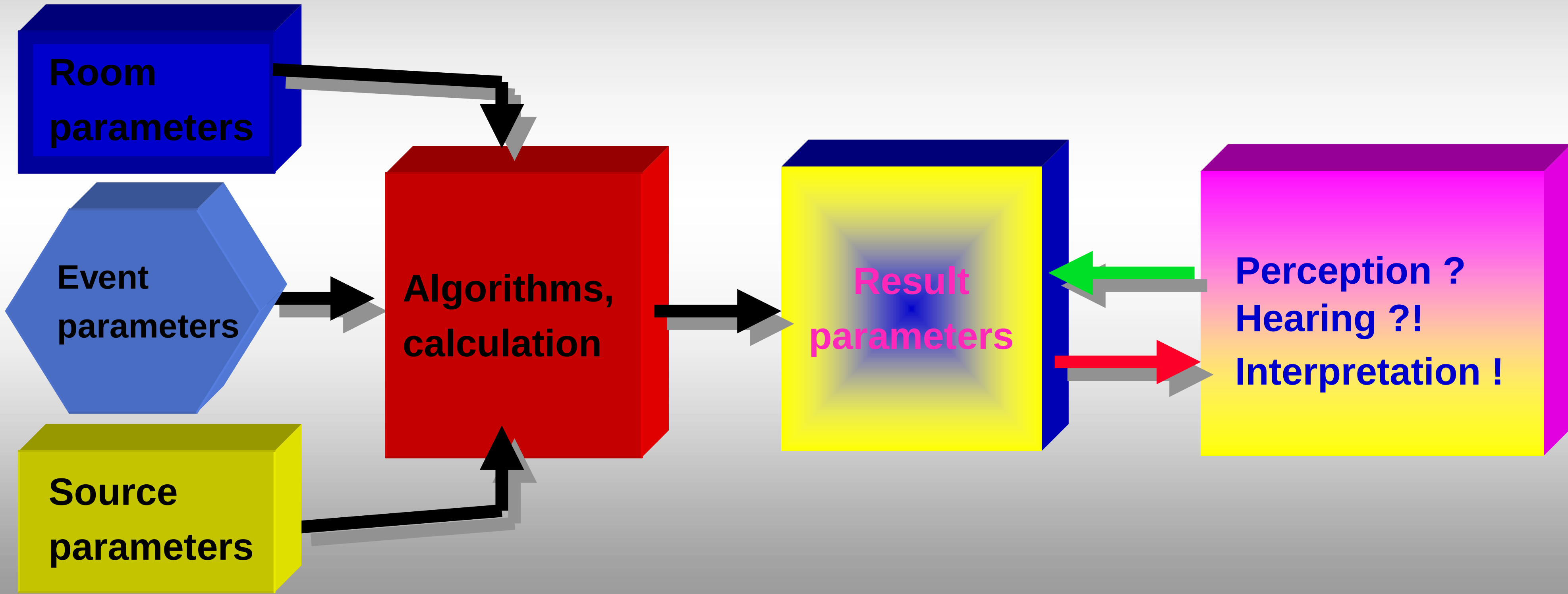
Preliminary remarks

- Processes of nature
- Subjective feeling
- Representative models

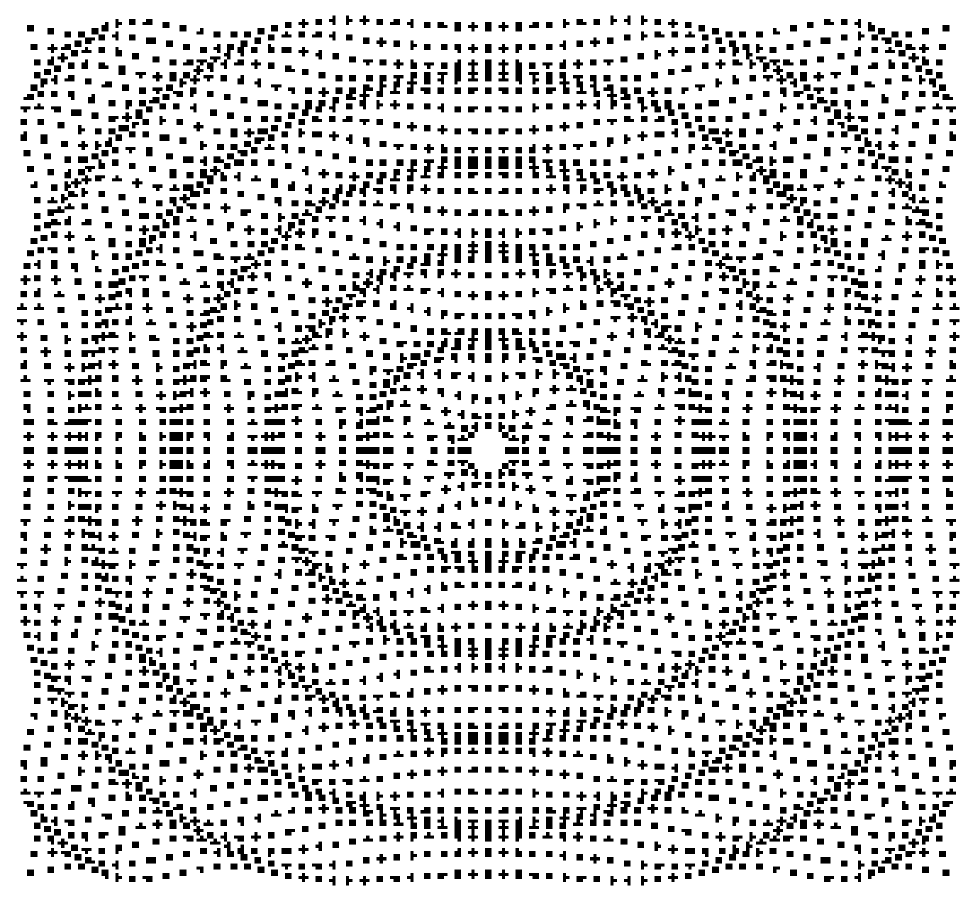


Models, algorithms

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



What is sound ?

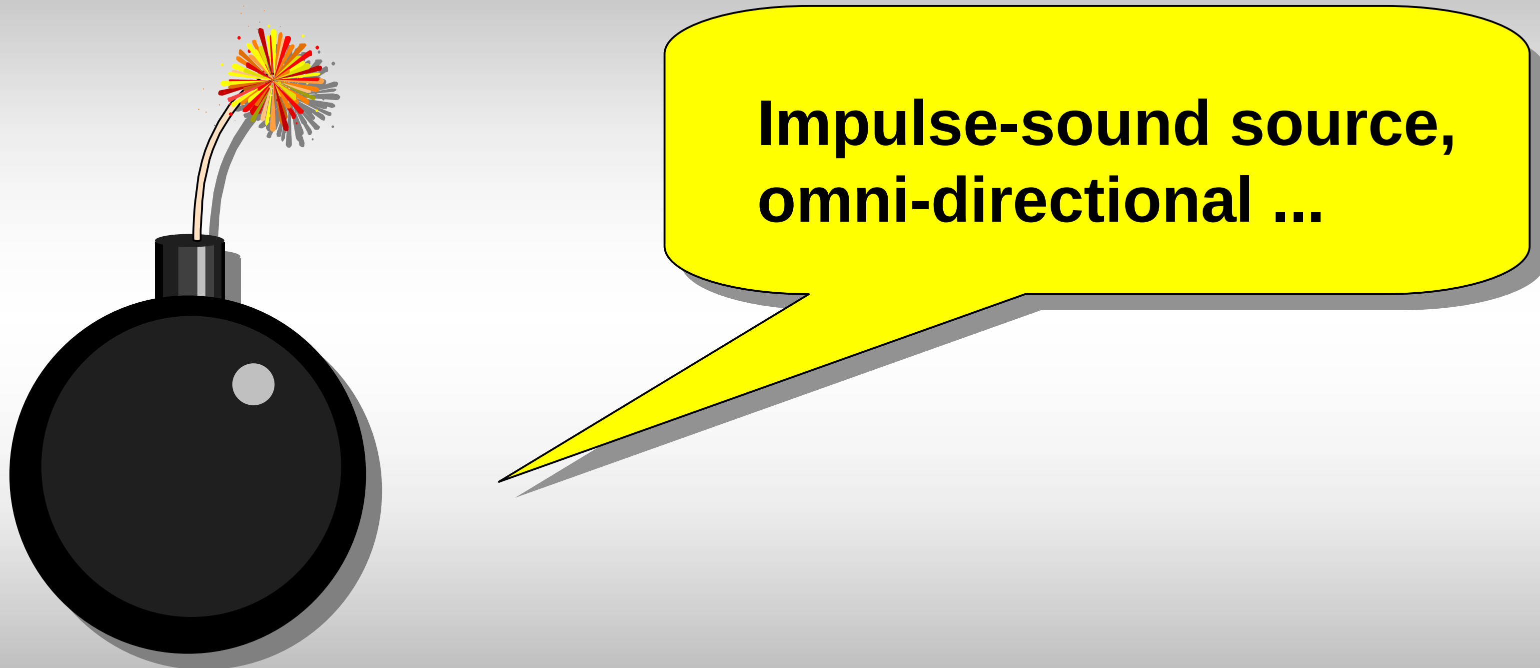


Sound pressure, p

Sound velocity, v

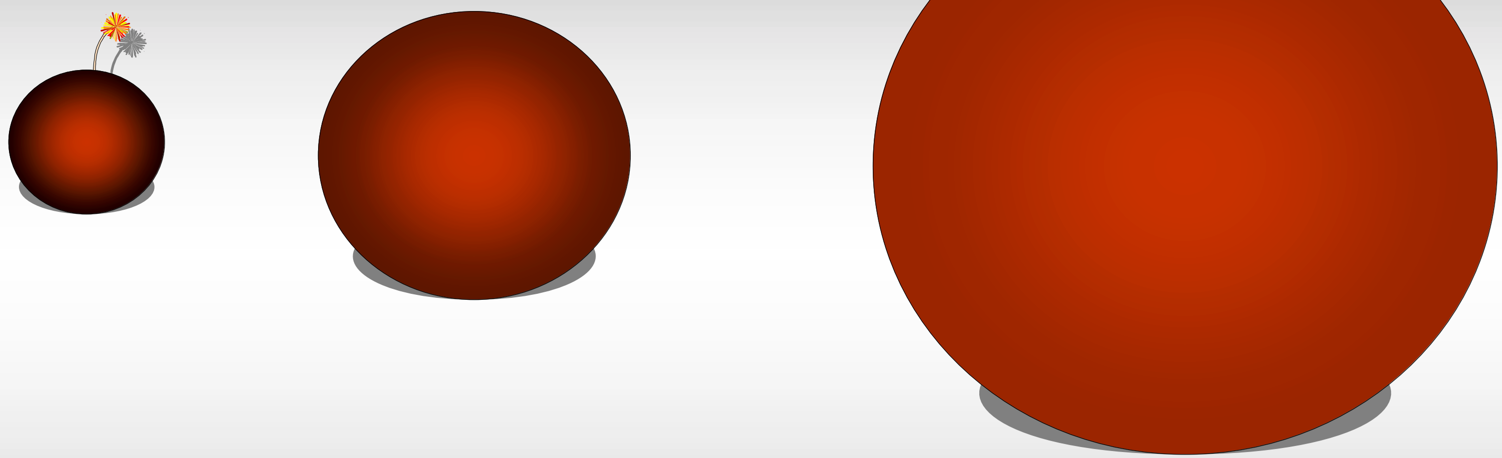
Sound propagagtion velocity, c

Distance law



t = 0 ms

Distance law

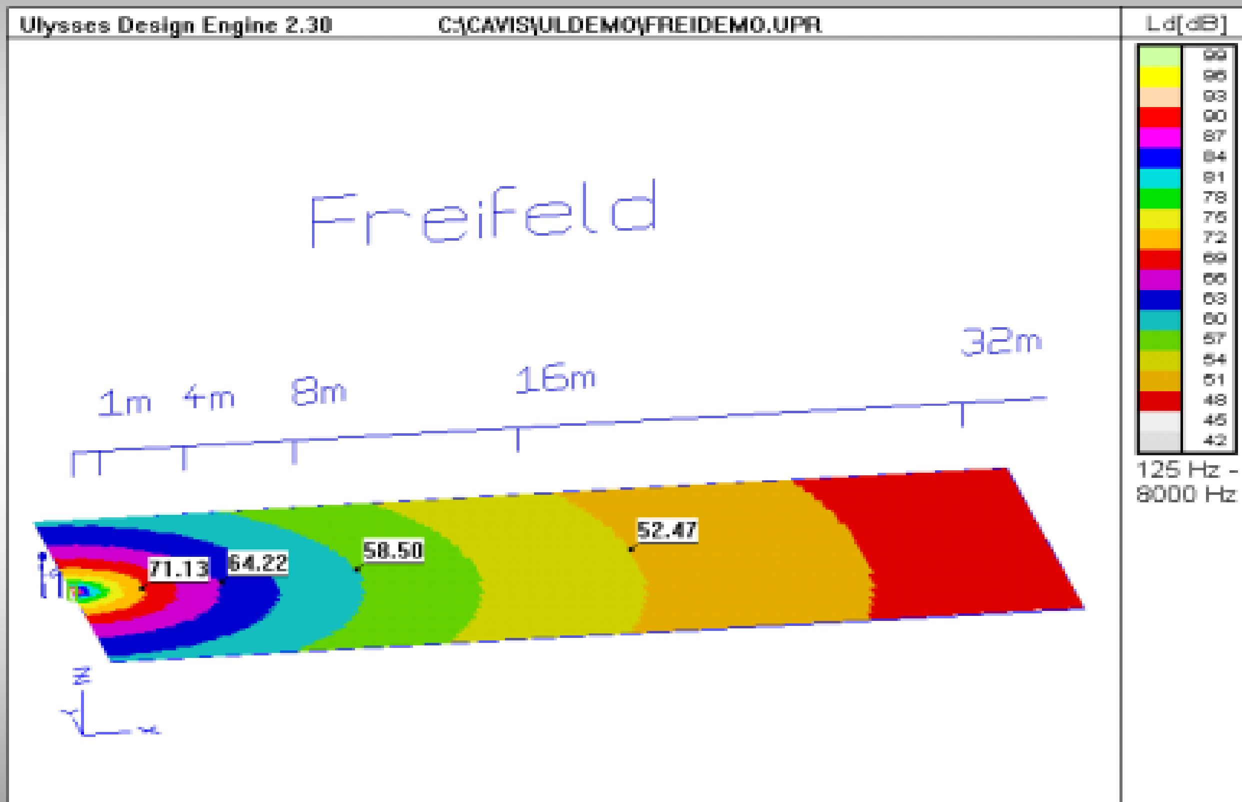


Ld = 0 dB
R = 1m

Ld = -6dB
R = 2m

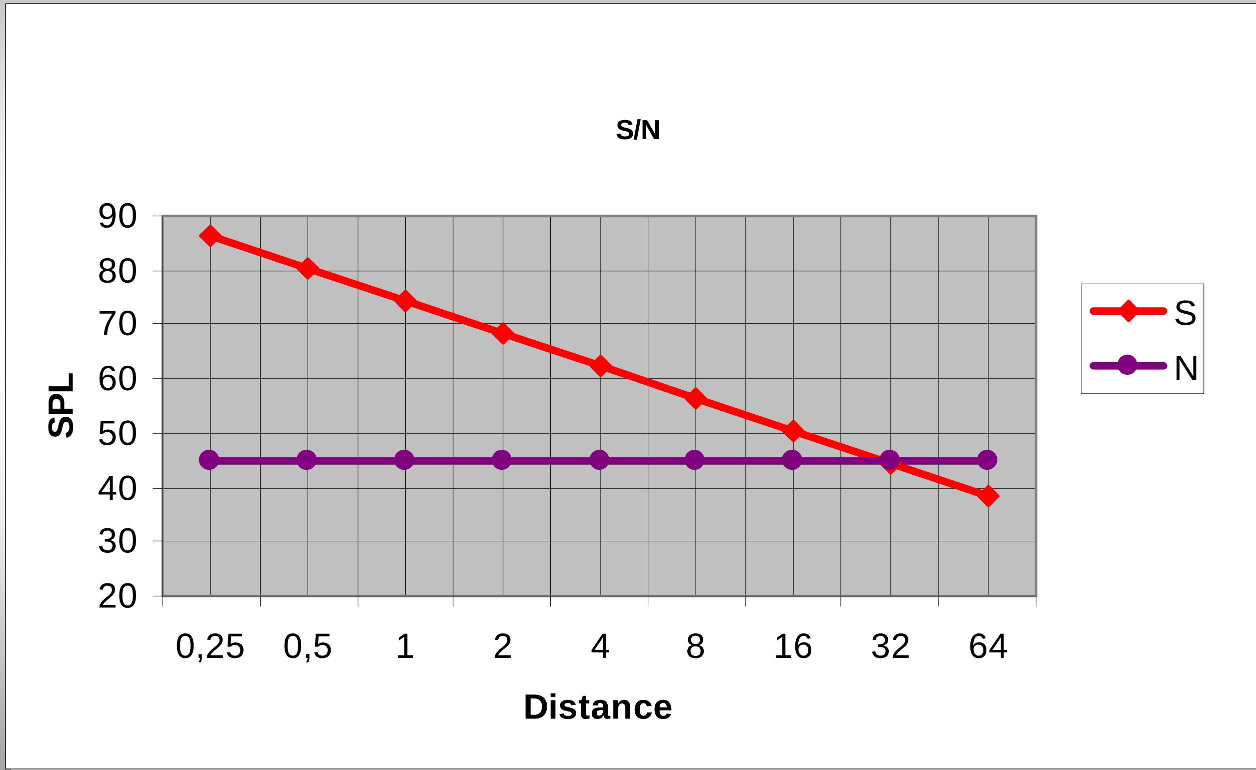
Ld=-12dB
R = 4 m

Freefield

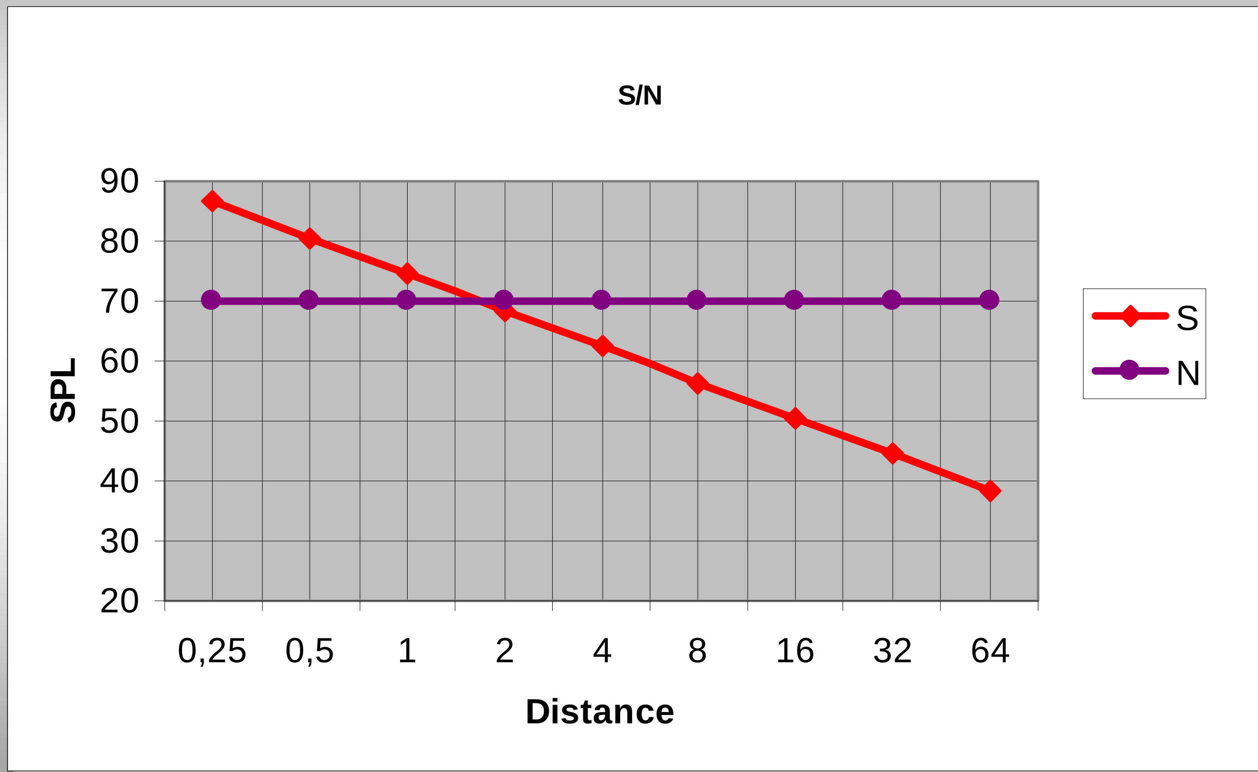


Ulysses Design Engine 2.30
C:\CAVIS\ULDEMO\FREIDEMO.UPR
Ld[dB]
99
96
93
90
87
84
81
78
75
72
69
66
63
60
57
54
51
48
45
42
125 Hz - 8000 Hz
Freifeld
1m
4m
8m
16m
32m
71.13
64.22
58.50
52.47

Signal / Noise

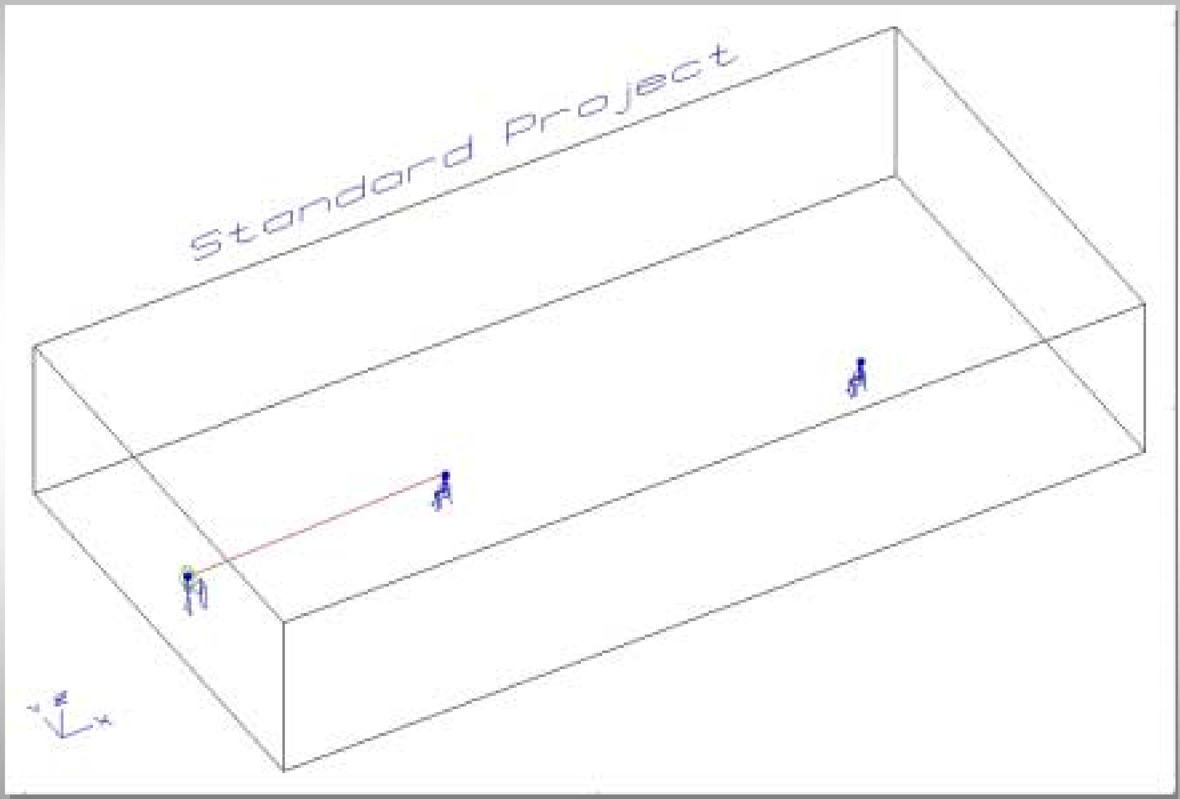


Signal / Noise

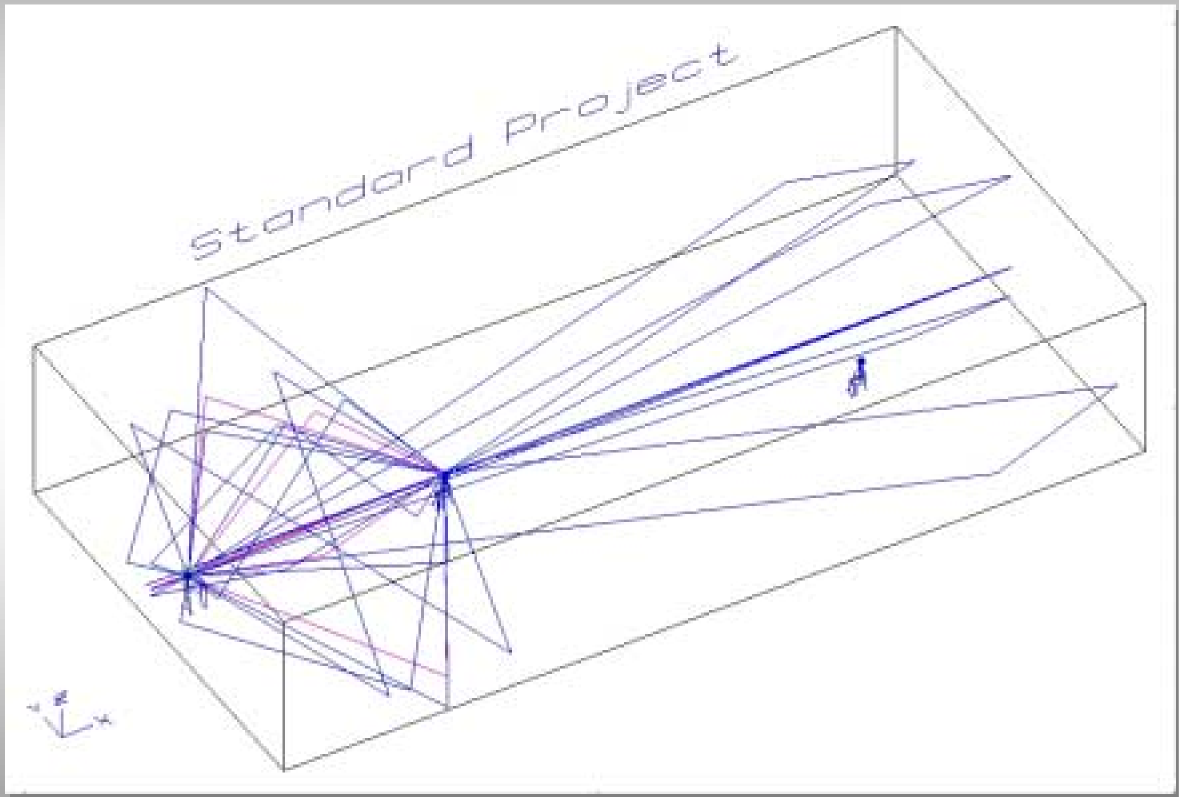


The room

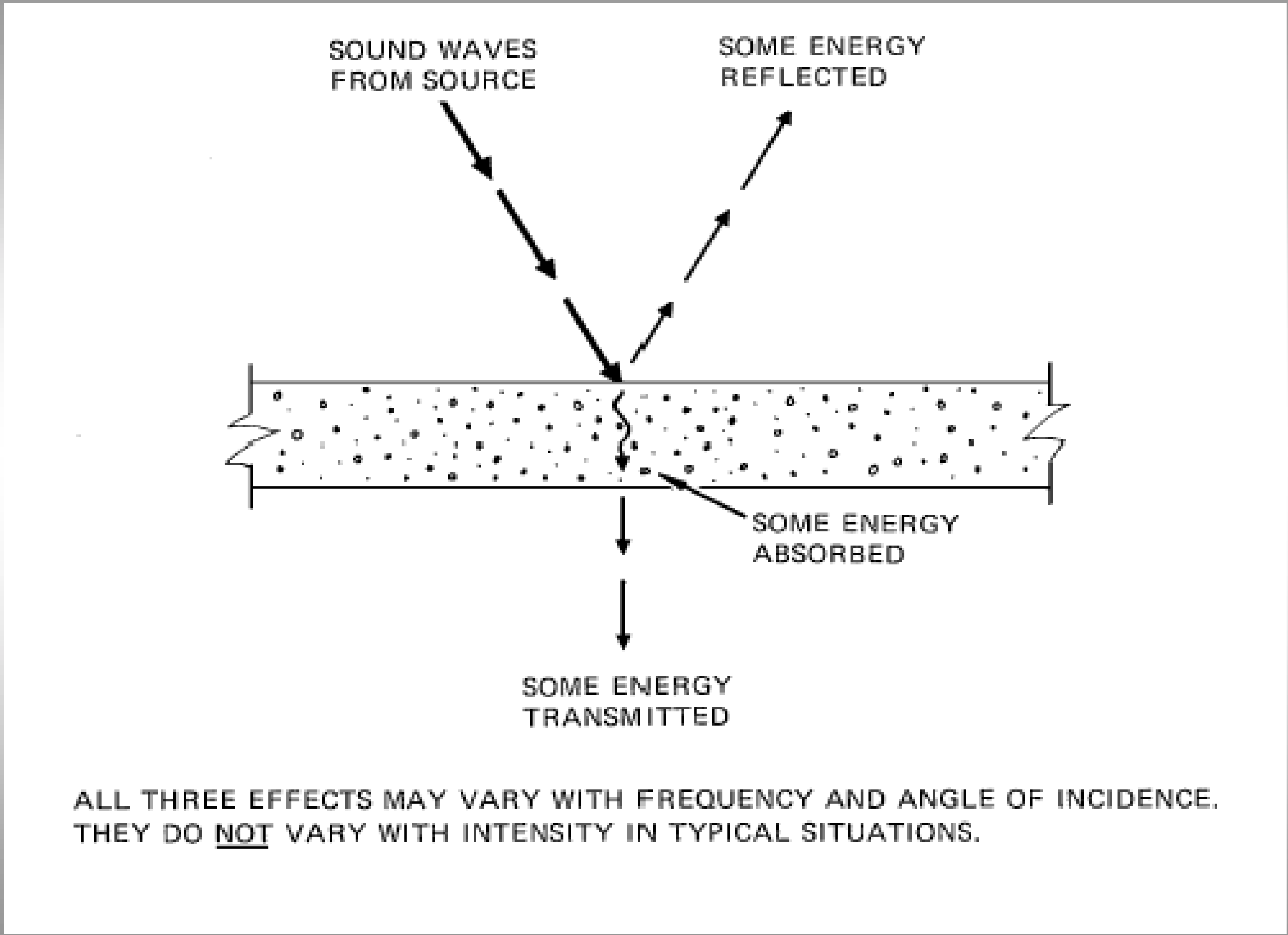
Direct sound Ld



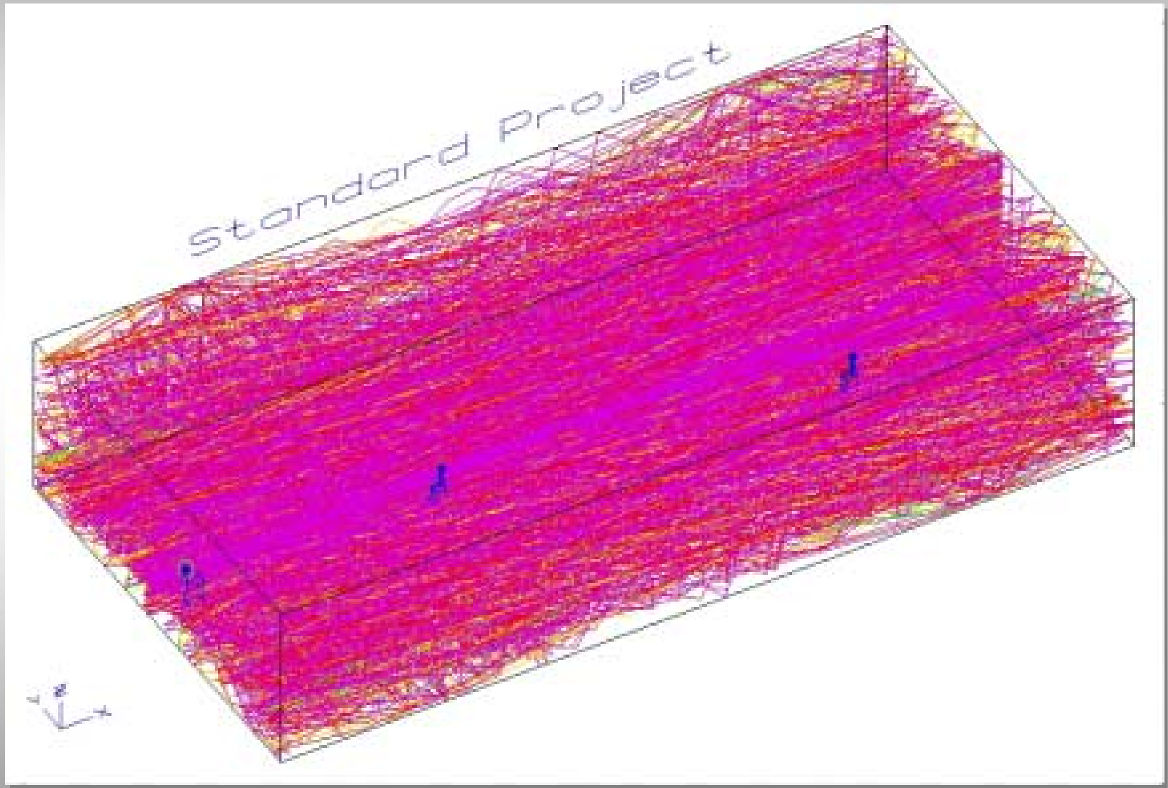
Reflections



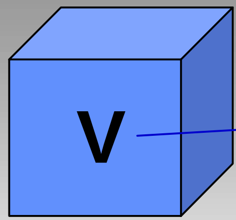
Absorption, Reflection,Transmission



Diffuse field or reverberation field, Lr



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

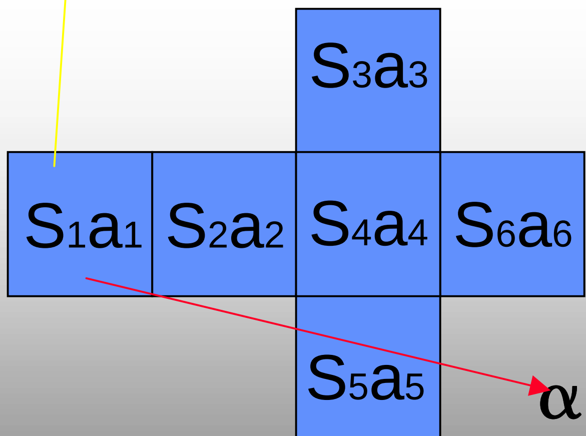


Volume

$$RT_{60} = 0.163 \frac{V}{\sum S_i a_i}$$

S = surface

(equivalent absorption surface)



$S_1a_1 + \ldots S_ia_i = \sum S_ia_i)$

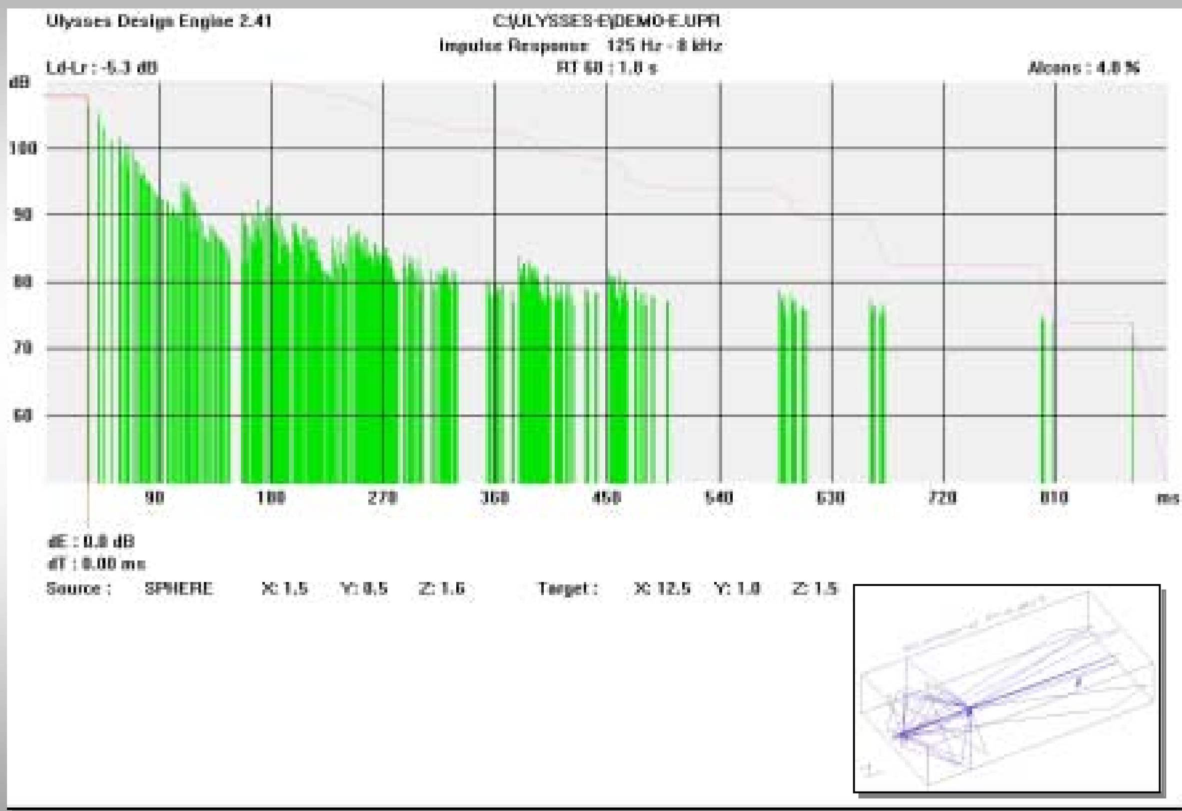
α = absorption coefficient

Sabine, Eyring and Fitzroy approach

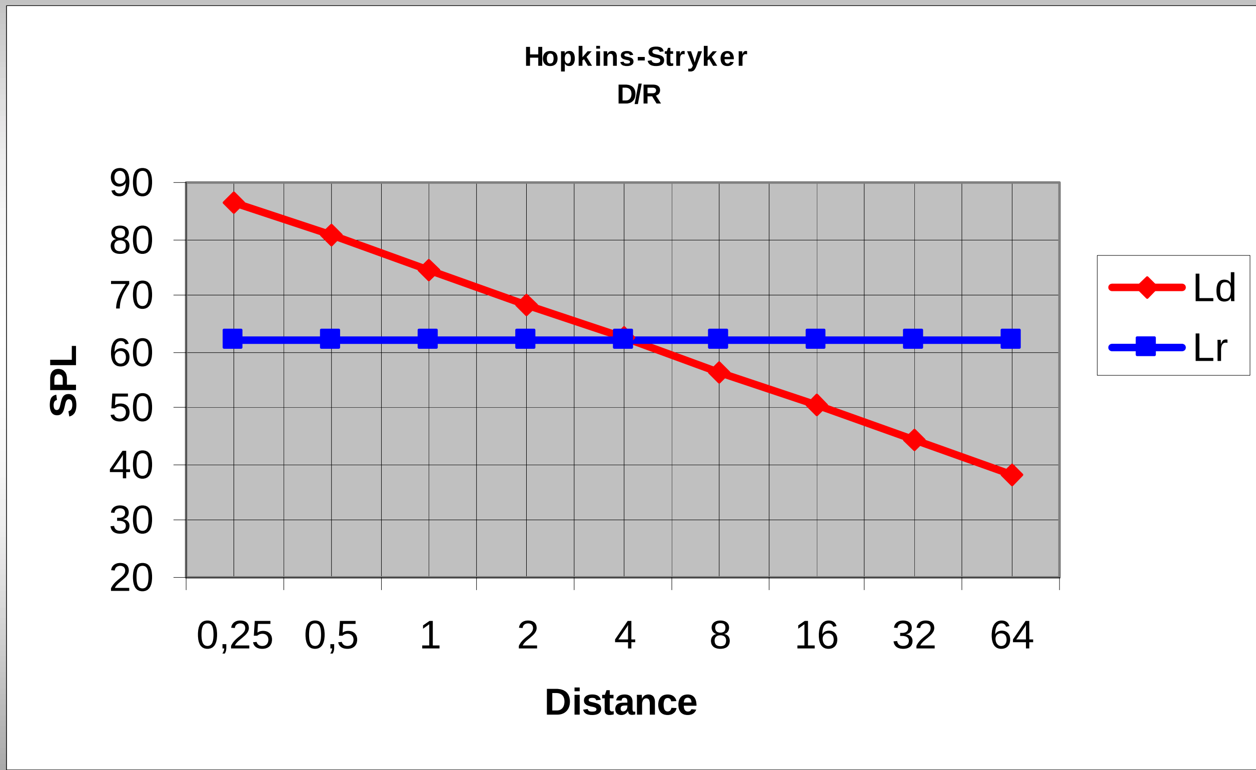
REVERBERATION TIME EQUATIONS: T = 60 dB DECAY TIME IN SECONDS		
EQUATION:	ENGLISH UNITS: S = SURFACE AREA IN FT^2; V = VOLUME IN FT^3	SI UNITS: S = SURFACE AREA IN m^2; V = VOLUME IN m^3
SABINE – GIVES BEST CORRESPONDENCE WITH PUBLISHED ABSORPTION COEFFICIENTS WHERE $\bar{\alpha}$ IS LESS THAN 0.2	$T = \frac{.049V}{S\bar{\alpha}}$	$T = \frac{.16V}{S\bar{\alpha}}$
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.	$T = \frac{.049V}{S^2}\left(\frac{X^2}{X\alpha_x} + \frac{Y^2}{Y\alpha_y} + \frac{Z^2}{Z\alpha_z}\right)$	$T = \frac{.16V}{S^2}\left(\frac{X^2}{X\alpha_x} + \frac{Y^2}{Y\alpha_y} + \frac{Z^2}{Z\alpha_z}\right)$
αx, αy, AND αz ARE AVERAGE ABSORPTION COEFFICIENTS OF OPPOSING PAIRS OF SURFACES WITH TOTAL AREAS x, y, AND z.		

Figure 5-9. Reverberation time equations

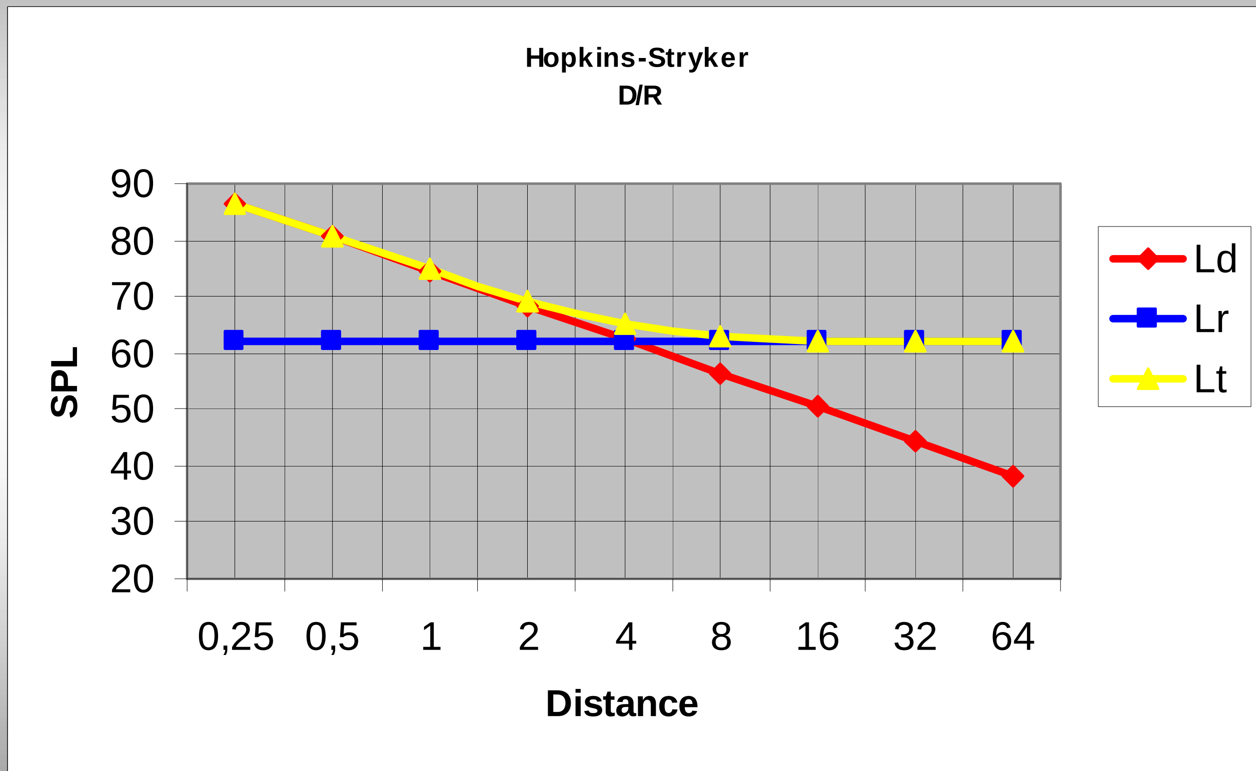
Energy vs. time, reflectogram, reverberation



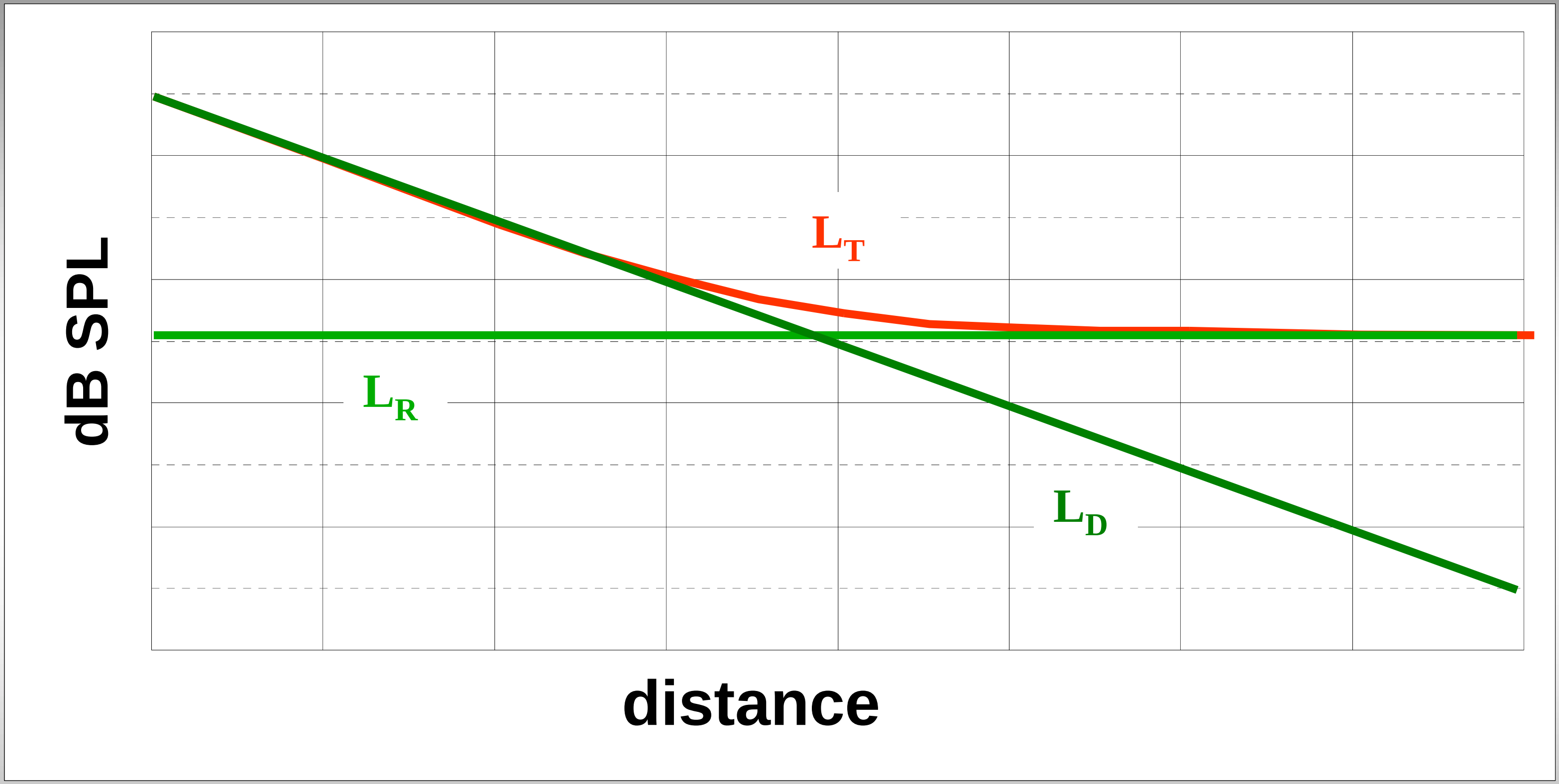
Direct sound and reverberation, Ld & Lr



Total sound field Lt = Ld + Lr



Hopkins Stryker Equation

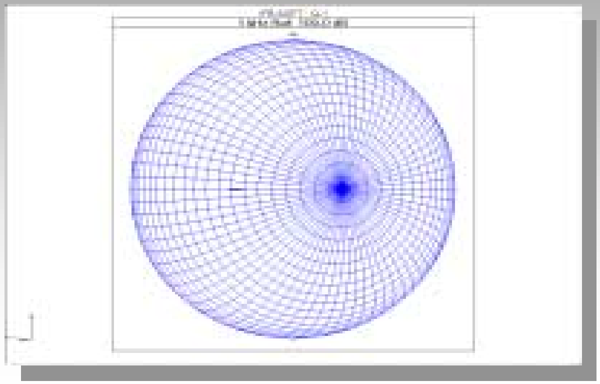


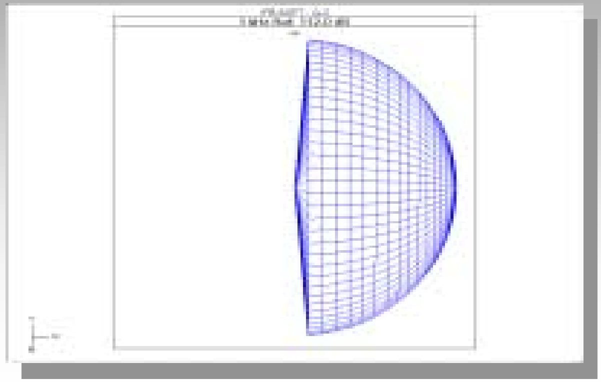
$$\Delta L_D = 10 \log \frac{Q}{4 \pi r^2}$$

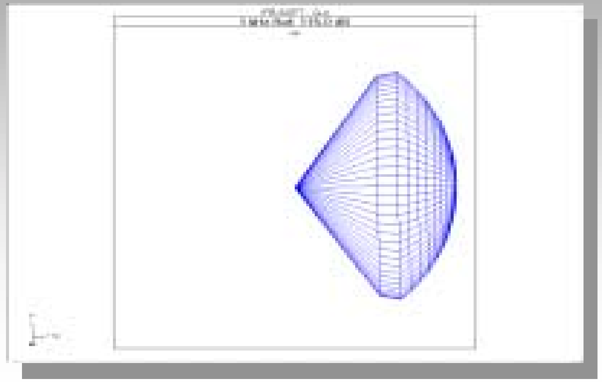
$$\Delta L_R = 10 \log \frac{4}{S \alpha}$$

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

Directivity Q & D_I







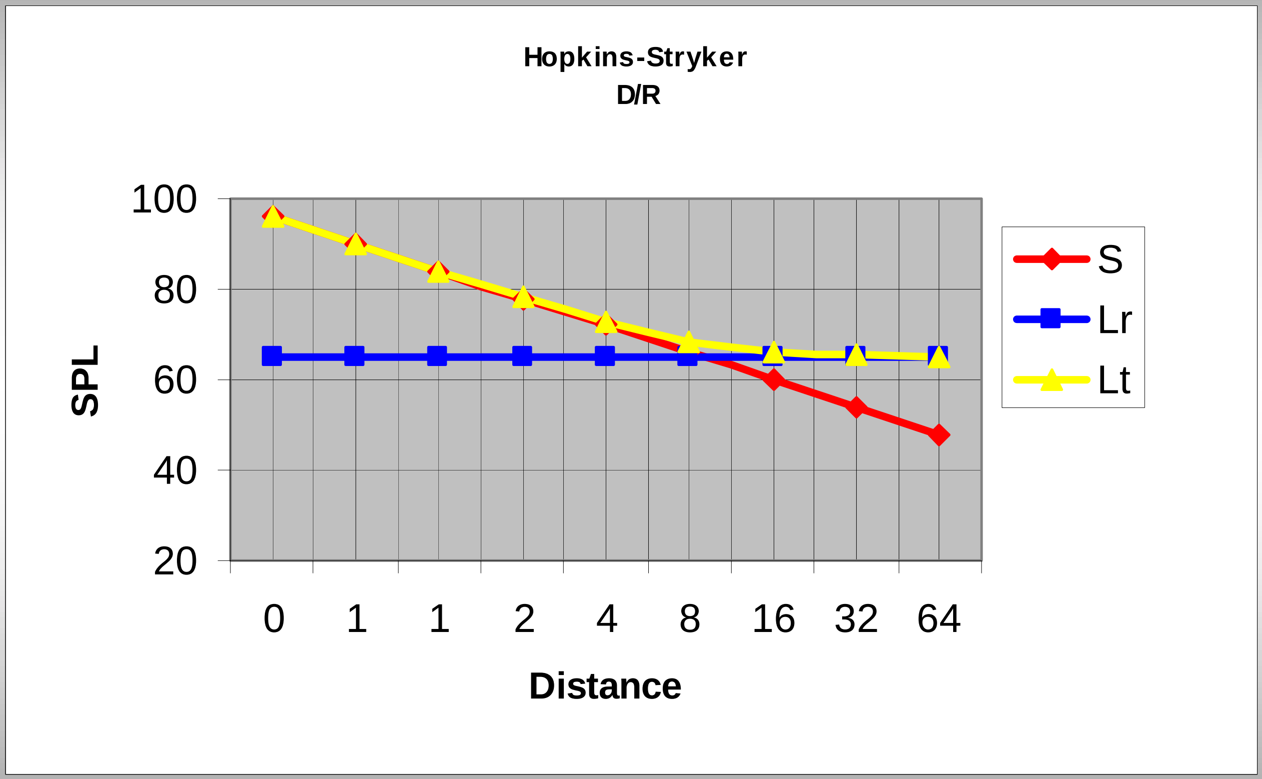
Q= 1
DI= 0 dB

Q= 2
DI= 3 dB

Q= 4
DI= 6dB

$$D_I = 10 \log Q$$

Total sound field Lt = Ld + Lr , Q= 8, DI= 9 dB



Discussion

- Any question is welcome ...

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Thank you for your attention!