Urban Physics

7S0X0, 2020-2021 Quartile 3

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Urban Physics

Week 7 Computing urban acoustics, II

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Contents week 6

- Cnossos sound propagation model

- Sound power
- Atmospheric absorption
- Divergence term
- Screening term
- Ground reflection

Contents week 7

- Cnossos sound propagation model
- Favourable conditions
  - Ground term
  - Diffraction term
- Buildings
  - Diffraction around horizontal edges
  - Reflection from buildings

Cnossos homogeneous conditions

$L_{p,n,i} = L_{w,n,i} - A_{div,n} - A_{atm,n,i} - A_{boundary,H,n,i}$

$L_{p,n,i}$ sound pressure level due to sound path *n* for frequency band *i*

$L_{w,n,i}$ sound power

$A_{div,n}$ attenuation due to geometrical divergence

$A_{atm,n,i}$ attenuation due to atmospheric absorption

$A_{boundary,H,n,i}$

either

$A_{ground,H,n,i}$ attenuation due to the ground in homogeneous conditions

or

$A_{dif,H,n,i}$ attenuation due to diffraction

Cnossos favourable conditions

$L_{p,n,i} = L_{w,n,i} - A_{div,n} - A_{atm,n,i} - A_{boundary,F,n,i}$

$L_{p,n,i}$ sound pressure level due to sound path n for frequency band i

$L_{w,n,i}$ sound power

$A_{div,n}$ attenuation due to geometrical divergence

$A_{atm,n,i}$ attenuation due to atmospheric absorption

$A_{boundary,F,n,i}$

either

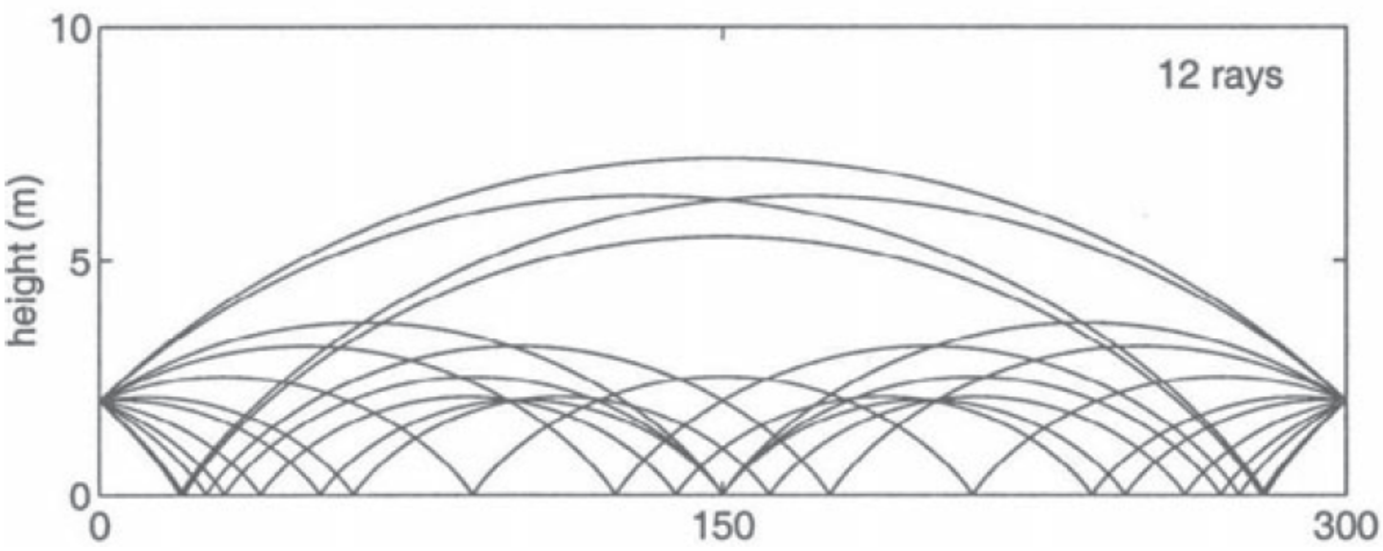
$A_{ground,F,n,i}$ attenuation due to the ground in homogeneous conditions

or

$A_{dif,F,n,i}$ attenuation due to diffraction

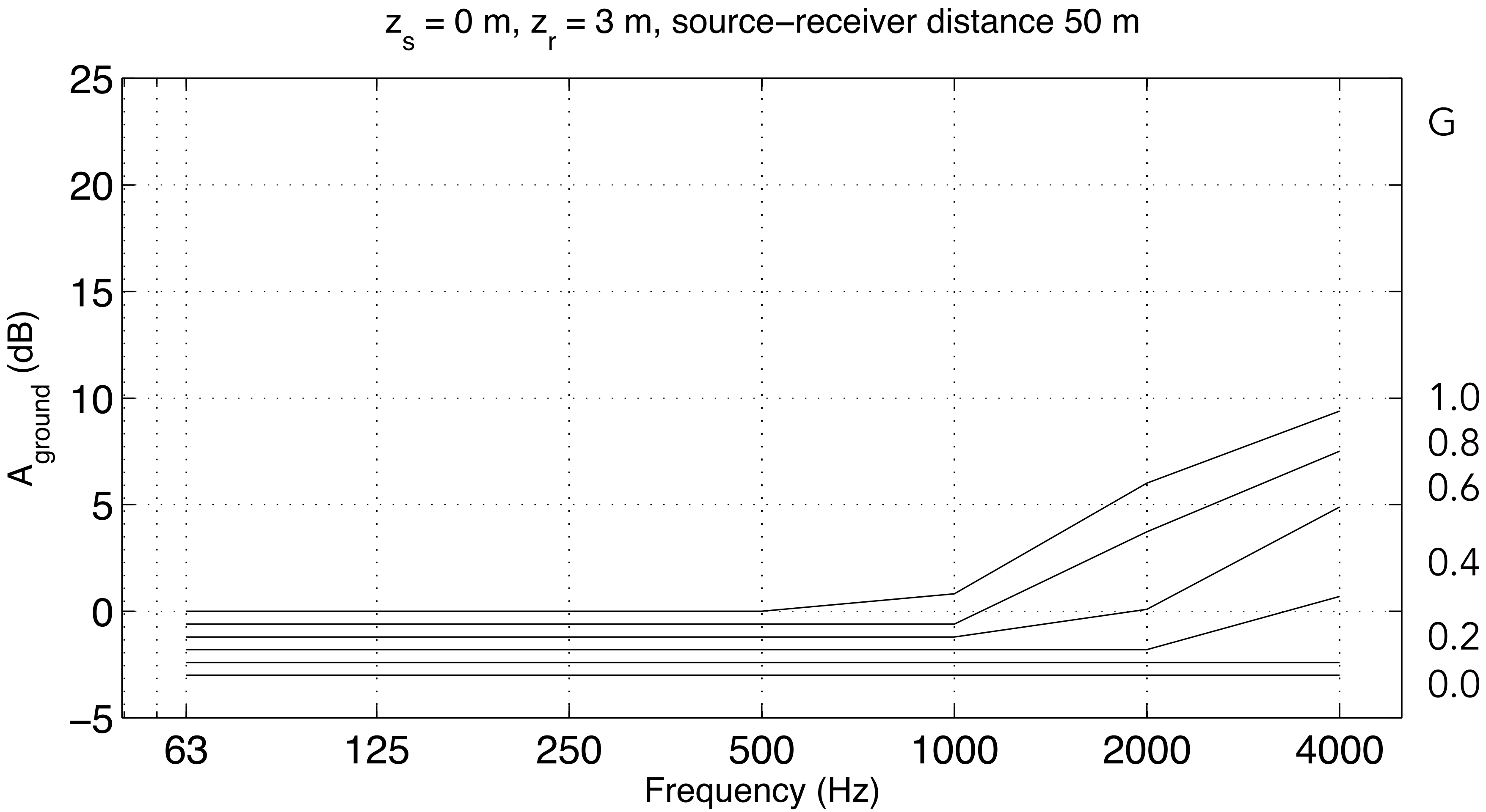
$A_{ground,F}$ attenuation due to the ground in favourable conditions

- Includes effect of downwind and atmospheric turbulence
- Only **one** favourable condition (not depending on wind velocity)
- This term is non-existent if a barrier is present!

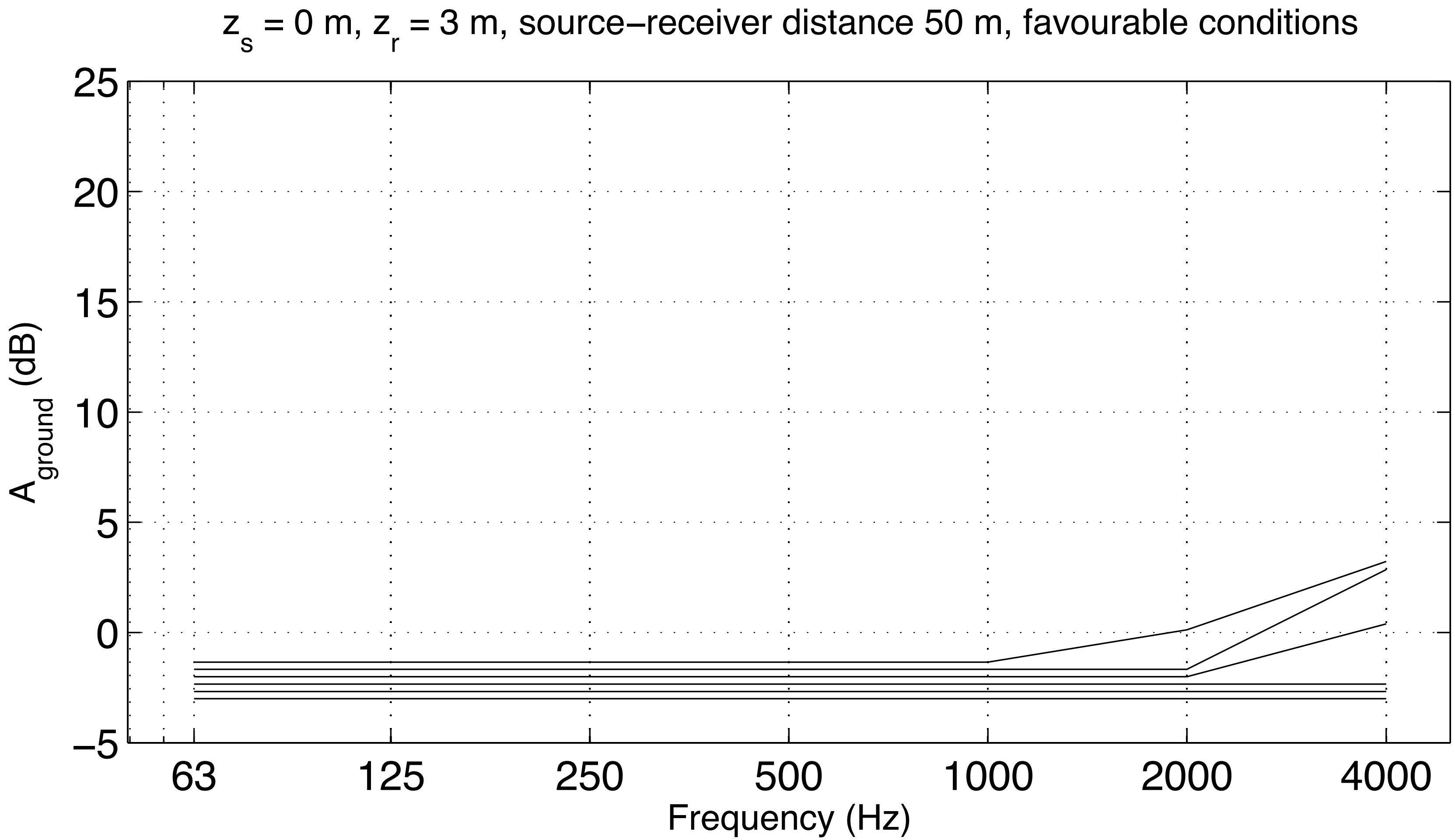


Salomons, E., Computational Atmospheric Acoustics. Springer 2001.

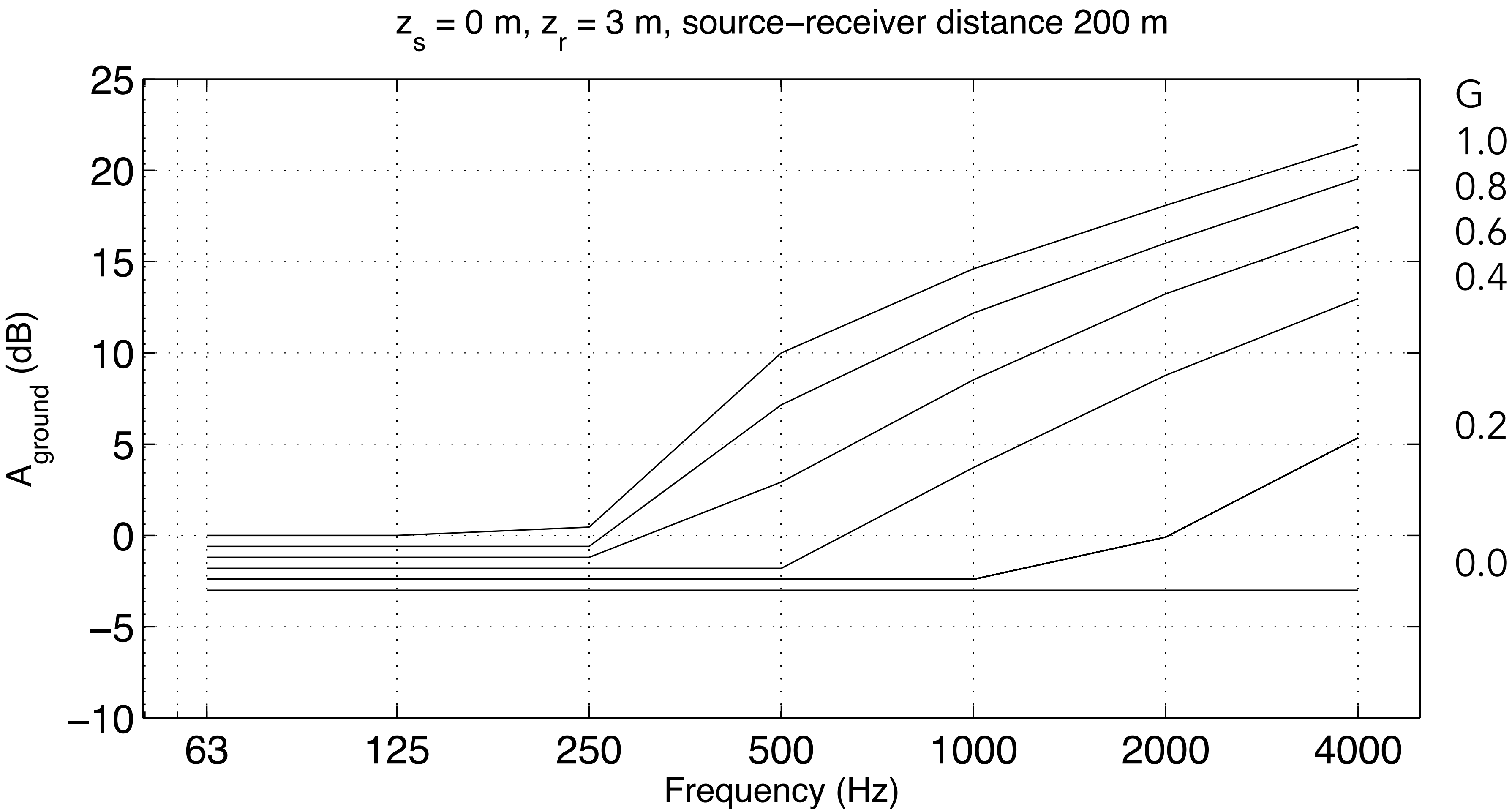
$A_{ground,H}$ homogeneous conditions



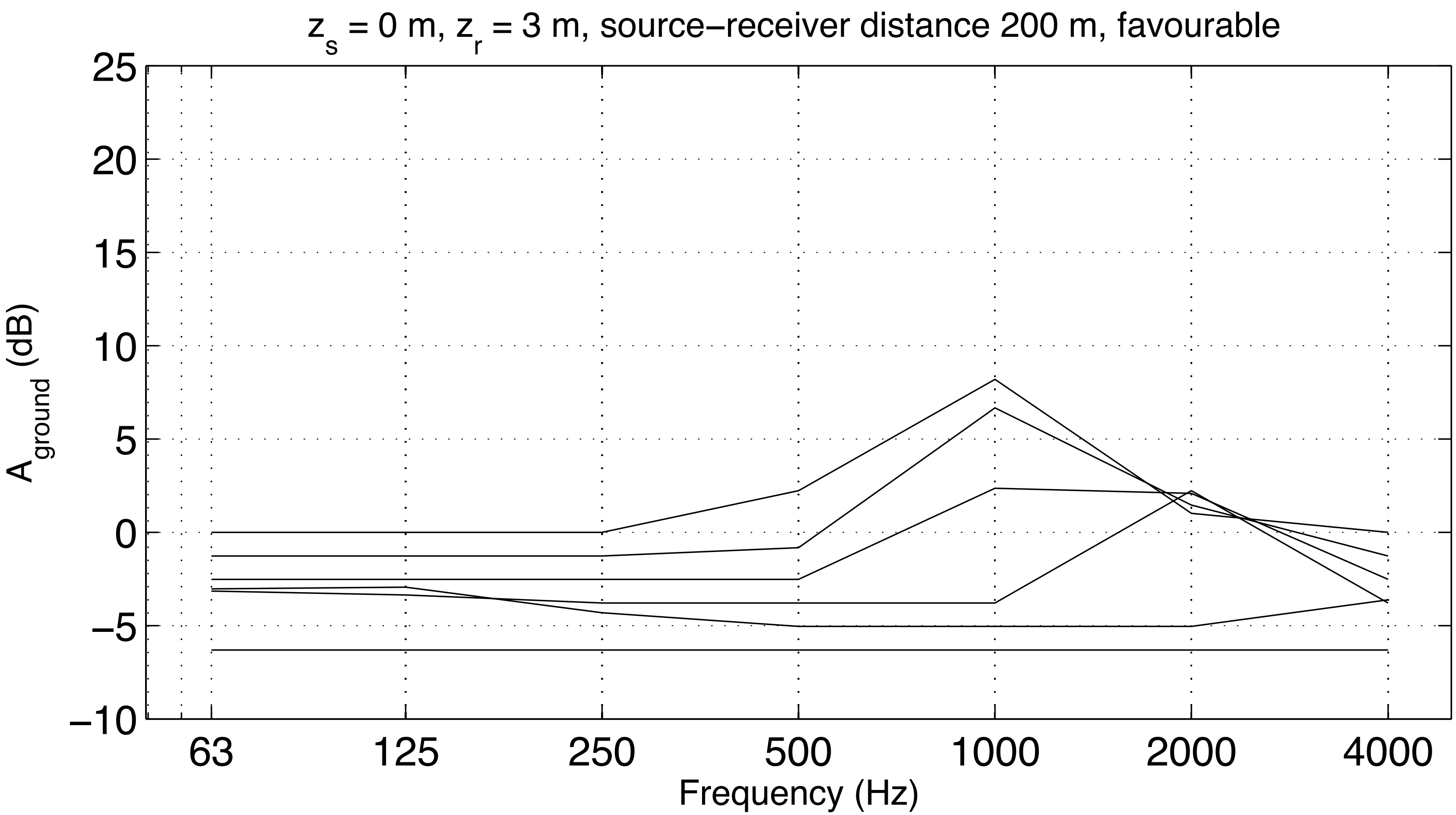
$A_{ground,F}$ *favourable conditions*



$A_{ground,H}$ *homogeneous conditions*



$A_{ground,F}$ *favourable conditions*



$A_{dif,H}$ no ground surface

$$A_{dif,H} = \Delta_{dif,SR} = \begin{cases} C_h 10\log_{10}\left(3+\dfrac{40\delta}{\lambda}\right) & \text{if } \dfrac{40\delta}{\lambda} \geq -2 \\ 0 & \text{otherwise} \end{cases}$$

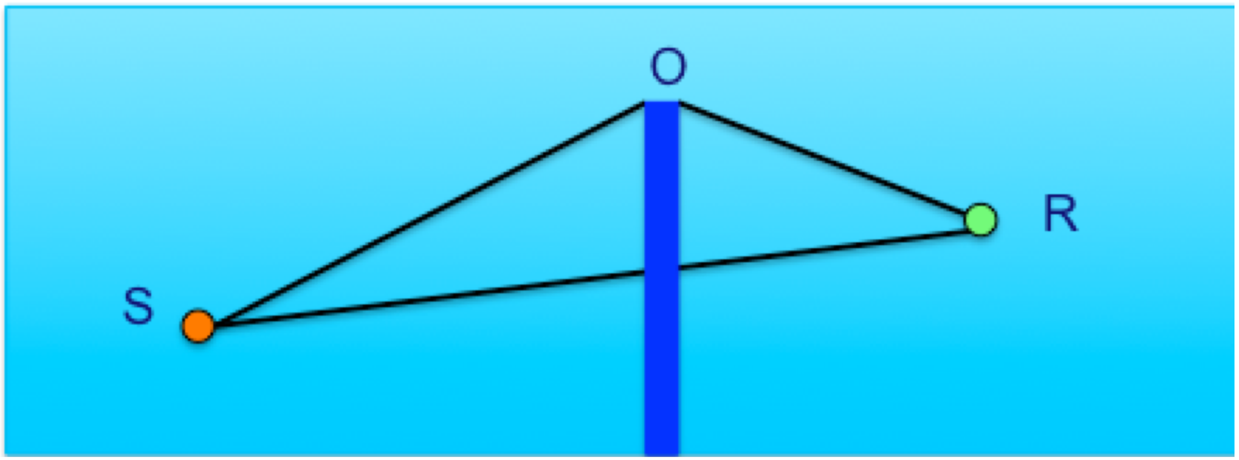
$$C_h = \min\left(\frac{f_m h_0}{250}, 1\right)$$

$$\delta = SO + OR - SR$$

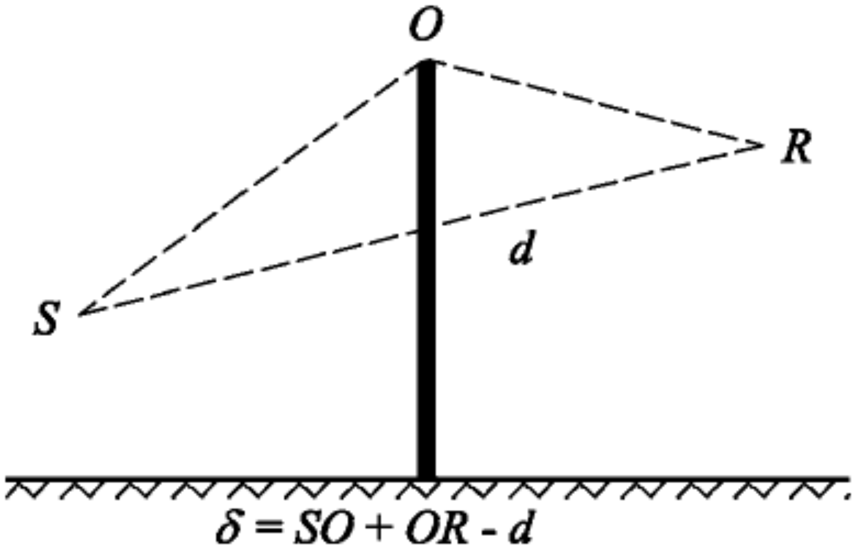
$h_0 =$ screen height (m)

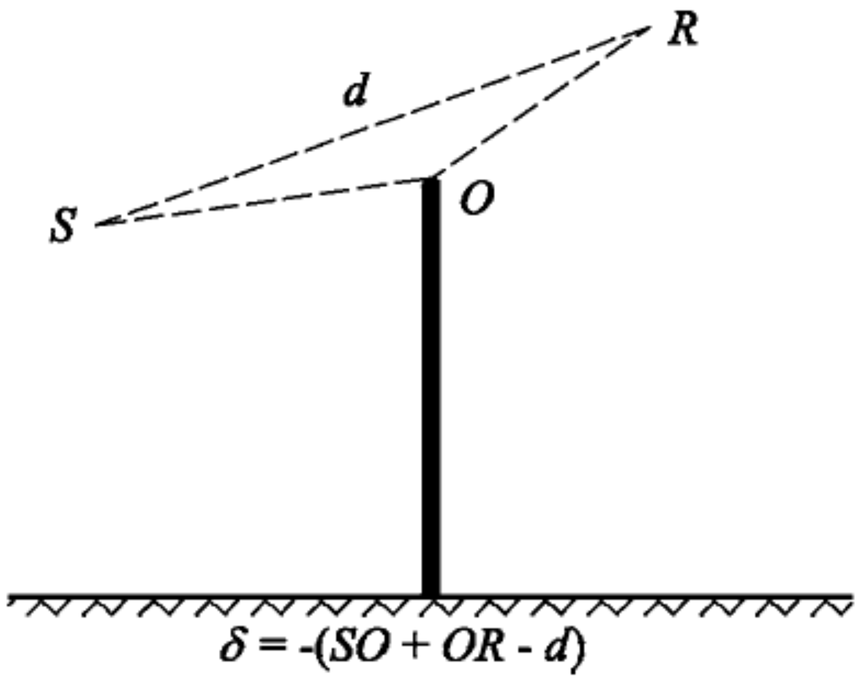
$\lambda =$ c/f = wavelength (m^{-1})

if $\Delta_{dif,SR} > 25$ dB , $\Delta_{dif,SR} = 25$ dB



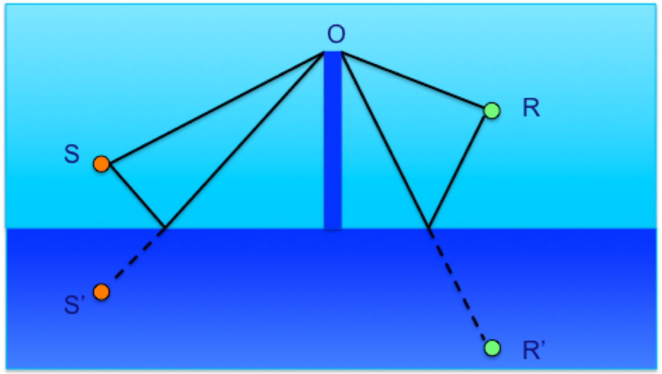
$A_{dif,H}$ no ground surface





Common Noise Assessment Methods in Europe (CNOSSOS-EU)

$A_{dif,H}$ with ground surface



$$A_{dif,H} = \Delta_{dif,SR} + \Delta_{ground,SO} + \Delta_{ground,OR}$$

$$\Delta_{ground,SO} = -20\log_{10}\left(1+\left(10^{\frac{-Aground(SO)}{20}}-1\right)10^{\frac{-\left(\Delta_{dif,S'R}-\Delta_{dif,SR}\right)}{20}}\right)$$

attenuation due to the ground effect on the source side, weighted by the diffraction on the source side

$$\Delta_{ground,OR} = -20\log_{10}\left(1+\left(10^{\frac{-Aground(OR)}{20}}-1\right)10^{\frac{-\left(\Delta_{dif,SR'}-\Delta_{dif,SR}\right)}{20}}\right)$$

attenuation due to the ground effect on the receiver side, weighted by the diffraction on the receiver side

$A_{dif,H}$ no ground surface, wide screen

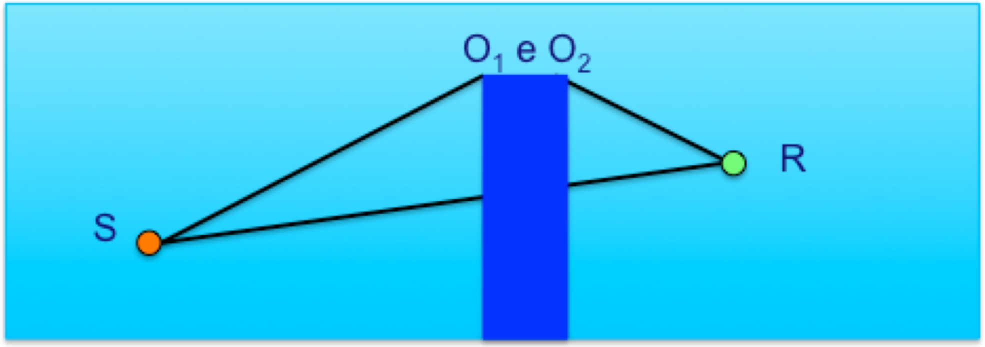
$$A_{dif,H} = \Delta_{dif,SR} = \begin{cases} C_h 10\log_{10}\left(3 + C''\dfrac{40\delta}{\lambda}\right) & \text{if } \dfrac{40\delta}{\lambda} \geq -2 \\ 0 & \text{otherwise} \end{cases}$$

$$C_h = \min\left(\frac{f_m h_0}{250}, 1\right)$$

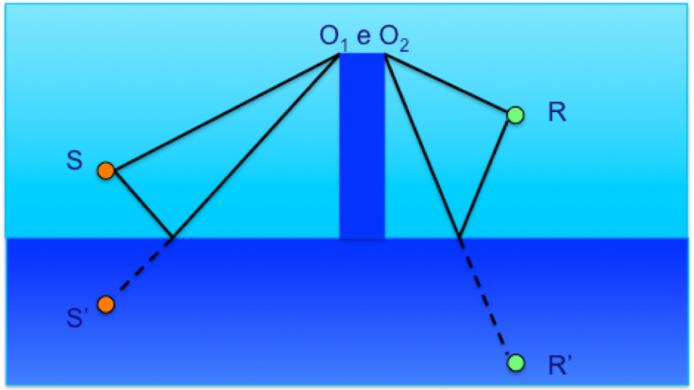
$$\delta = SO_1 + e + O_2R - SR$$

$$\boxed{\text{if } \Delta_{dif,SR} > 25 \text{ dB}\ ,\ \Delta_{dif,SR} = 25 \text{ dB}}$$

$$C'' = \frac{1 + (5\lambda/e)^2}{\frac{1}{3} + (5\lambda/e)^2} \quad \text{(if e >0.3 m, otherwise, C''=1)}$$



$A_{dif,H}$ ground surface, wide screen



$$A_{dif,H} = \Delta_{dif,SR} + \Delta_{ground,SO_1} + \Delta_{ground,O_2R}$$

$$\Delta_{ground,SO_1} = -20\log_{10}\left(1+\left(10^{\frac{-Aground(SO_1)}{20}}-1\right)10^{\frac{-(\Delta_{dif,S'R}-\Delta_{dif,SR})}{20}}\right)$$

attenuation due to the ground effect on the source side, weighted by the diffraction on the source side

$$\Delta_{ground,O_2R} = -20\log_{10}\left(1+\left(10^{\frac{-Aground(O_2R)}{20}}-1\right)10^{\frac{-(\Delta_{dif,SR'}-\Delta_{dif,SR})}{20}}\right)$$

attenuation due to the ground effect on the receiver side, weighted by the diffraction on the receiver side

$A_{dif,F}$ no ground surface

$$A_{dif,F} = \Delta_{dif,\widehat{SR}} = \begin{cases} C_h 10\log_{10}\left(3+\frac{40\delta_F}{\lambda}\right) & \text{if } \frac{40\delta_F}{\lambda} \geq -2 \\ 0 & \text{otherwise} \end{cases}$$

$$C_h = \min\left(\frac{f_m h_0}{250}, 1\right)$$

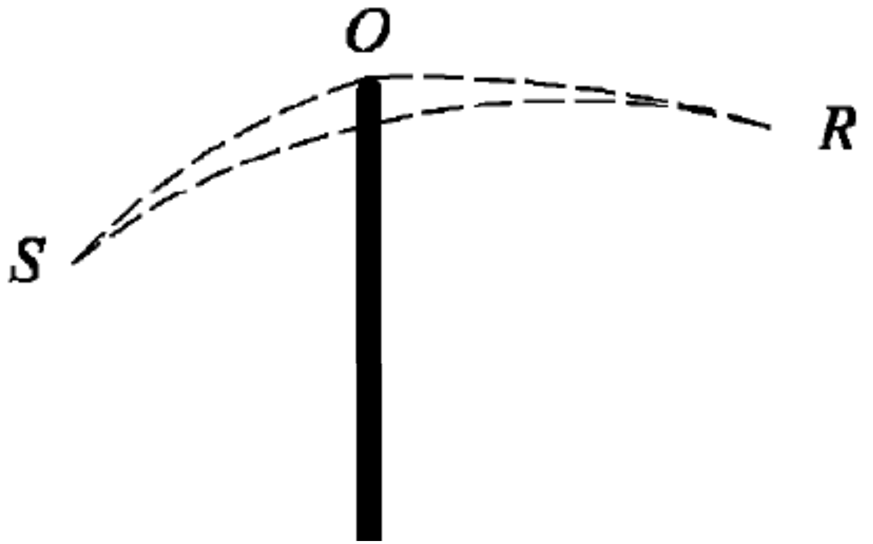
$$\delta_F = \widehat{SO} + \widehat{OR} - \widehat{SR}$$

$$\widehat{SO} = 2\Gamma \arcsin\left(\frac{SO}{2\Gamma}\right)$$

$$\widehat{OR} = 2\Gamma \arcsin\left(\frac{OR}{2\Gamma}\right)$$

$$\widehat{SR} = 2\Gamma \arcsin\left(\frac{SR}{2\Gamma}\right)$$

$$\Gamma = \max\left(1000, SR\right)$$



$A_{dif,F}$ with ground surface

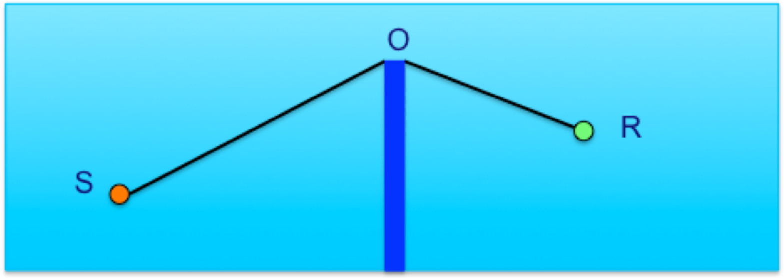
$$A_{dif,F} = \Delta_{dif,\widehat{S}R} + \Delta_{ground,\widehat{S}O} + \Delta_{ground,\widehat{O}R}$$

$$\Delta_{ground,\widehat{S}O} = -20\log_{10}\left(1+\left(10^{\frac{-Aground(\widehat{S}O)}{20}}-1\right)10^{\frac{-\left(\Delta_{dif,\widehat{S}'R}-\Delta_{dif,\widehat{S}R}\right)}{20}}\right)$$

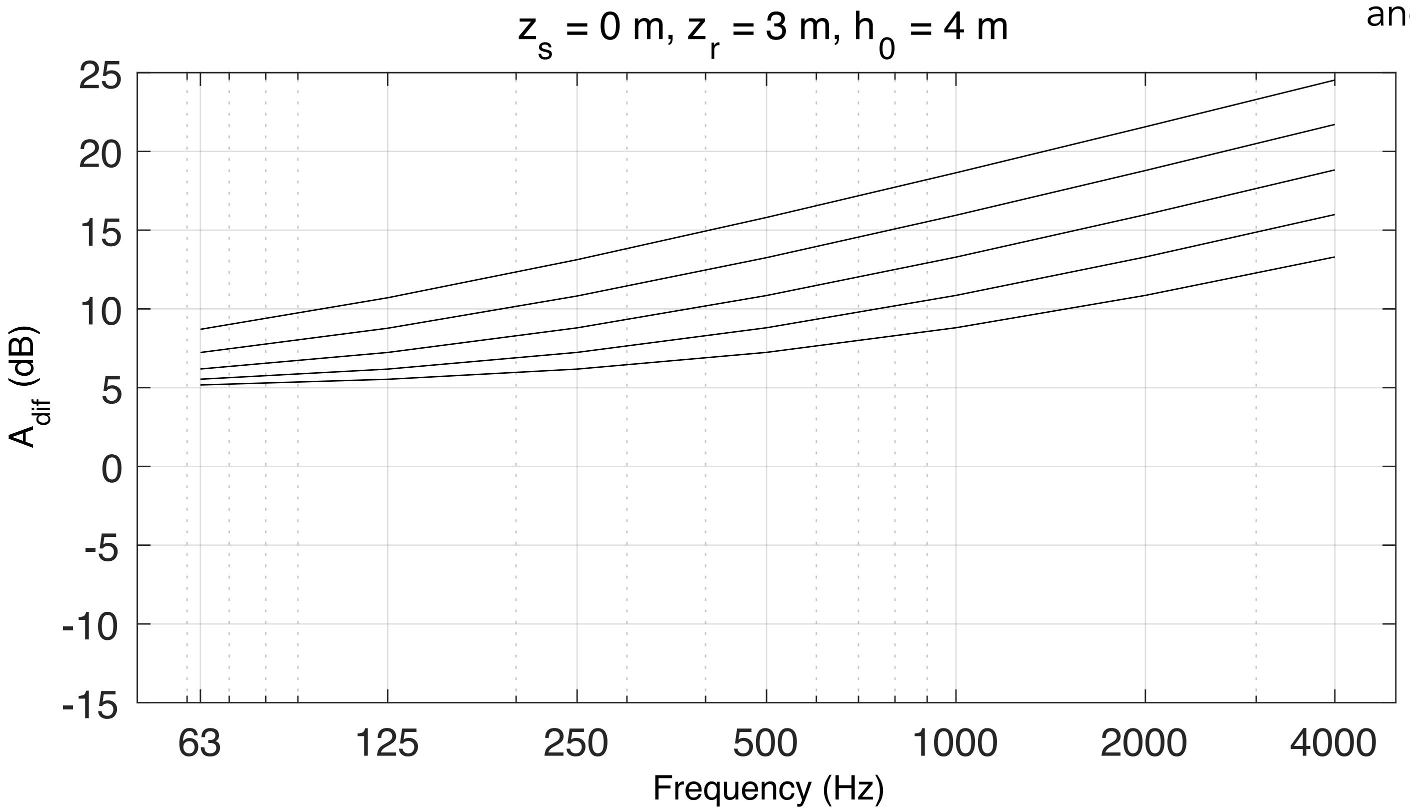
$$\Delta_{ground,\widehat{O}R} = -20\log_{10}\left(1+\left(10^{\frac{-Aground(\widehat{O}R)}{20}}-1\right)10^{\frac{-\left(\Delta_{dif,\widehat{S}R'}-\Delta_{dif,\widehat{S}R}\right)}{20}}\right)$$

A_{dif}

$A_{dif,H}$ *homogeneous conditions*

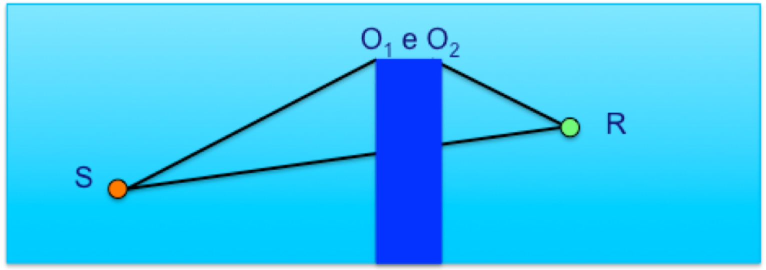


Horizontal distance source-screen and screen receiver
10 m
20 m
40 m
80 m
160 m



A_{dif}

$A_{dif,H}$ homogeneous conditions



Horizontal distance source-screen and screen receiver
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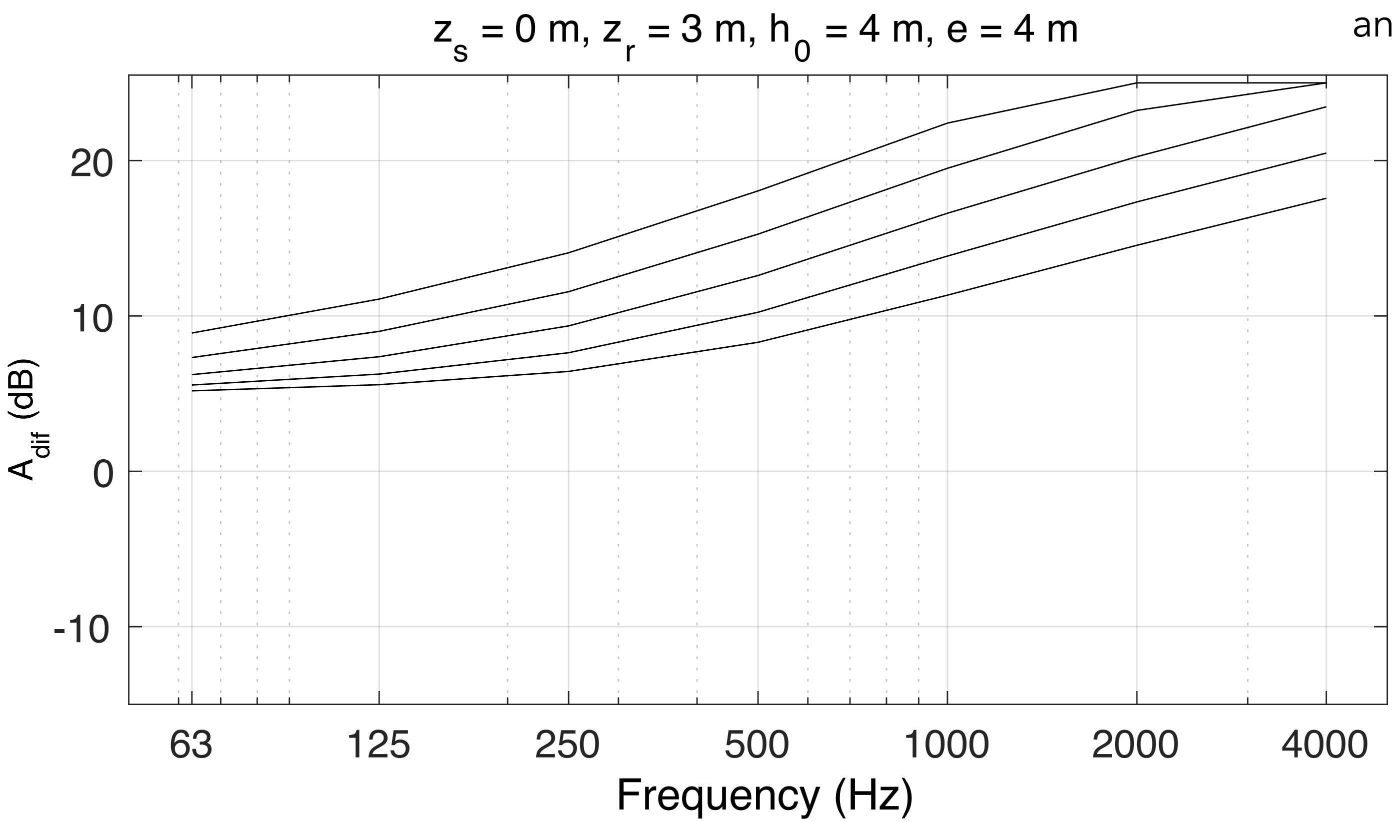
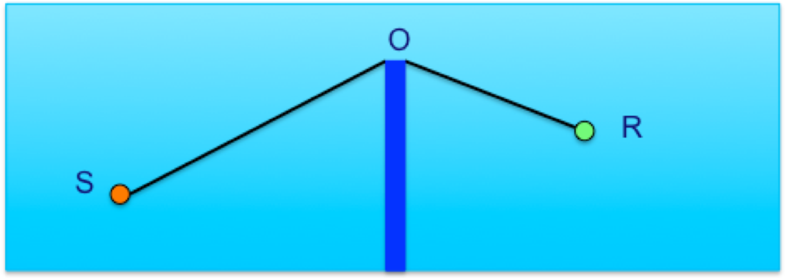
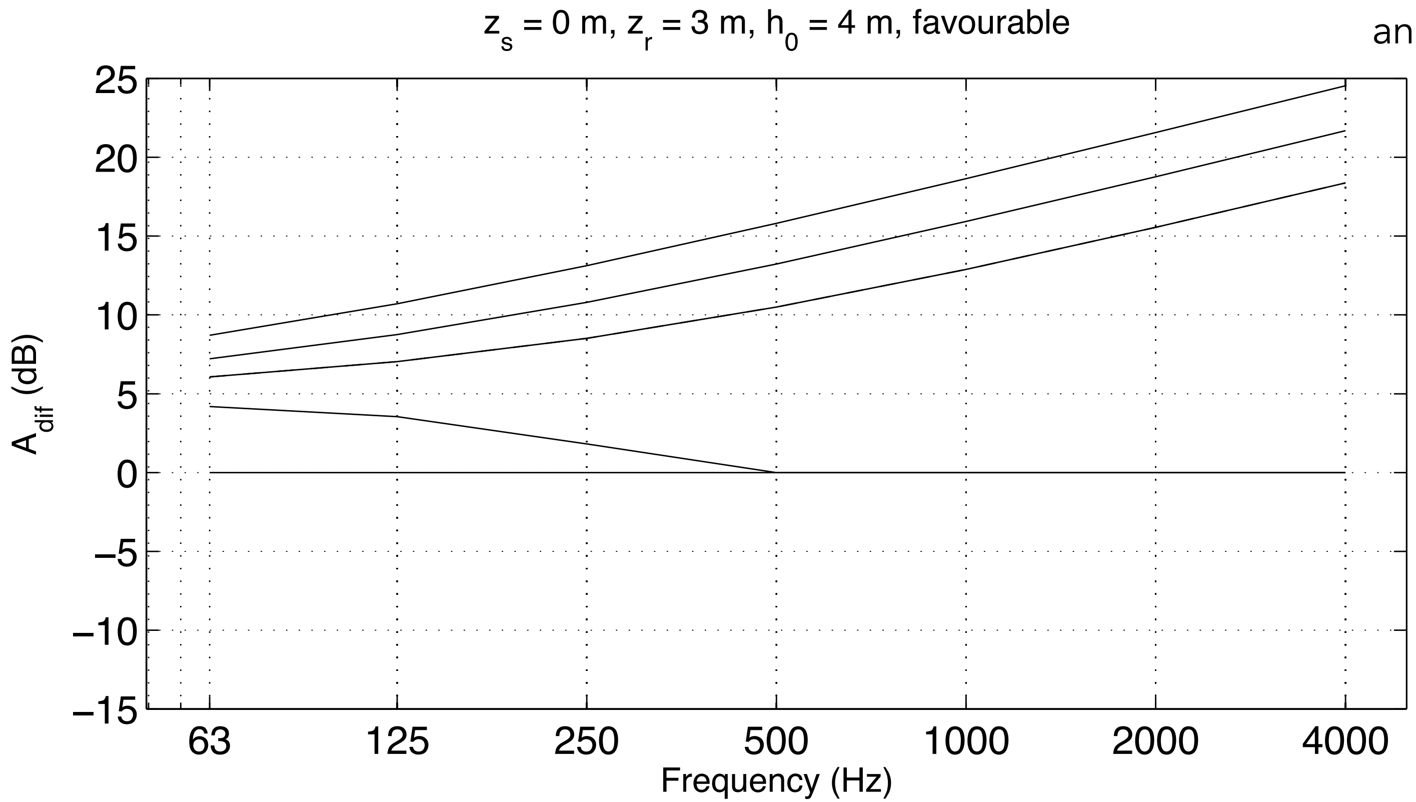


A_{dif}

$A_{dif,F}$ *favourable conditions*

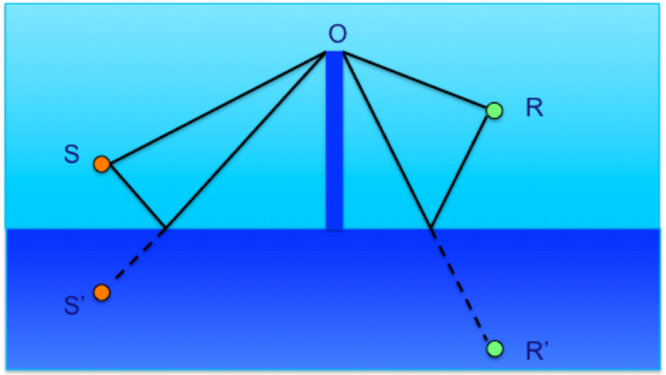


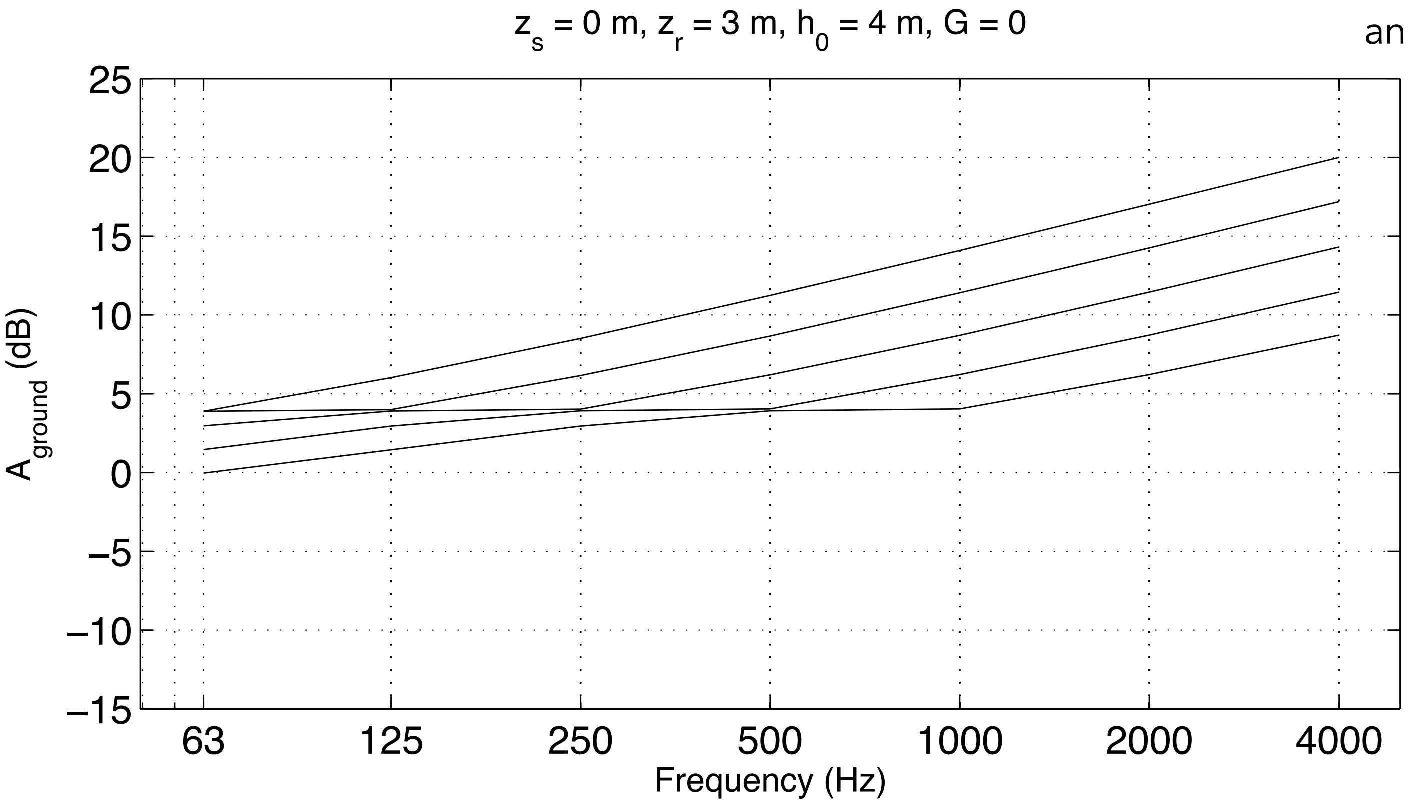


Horizontal distance source-screen and screen receiver
10 m
20 m
40 m
80 m
160 m

A_{dif}

$A_{dif,H}$ *homogeneous conditions*

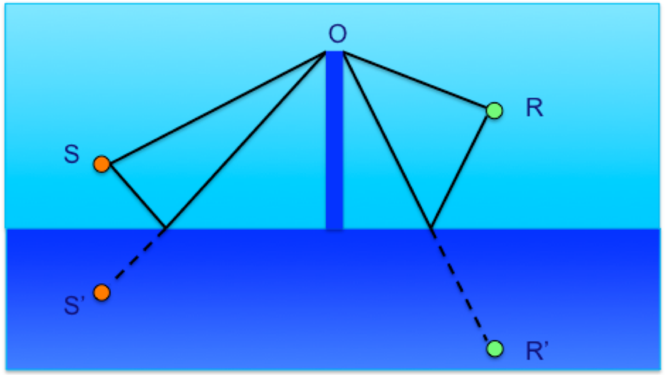


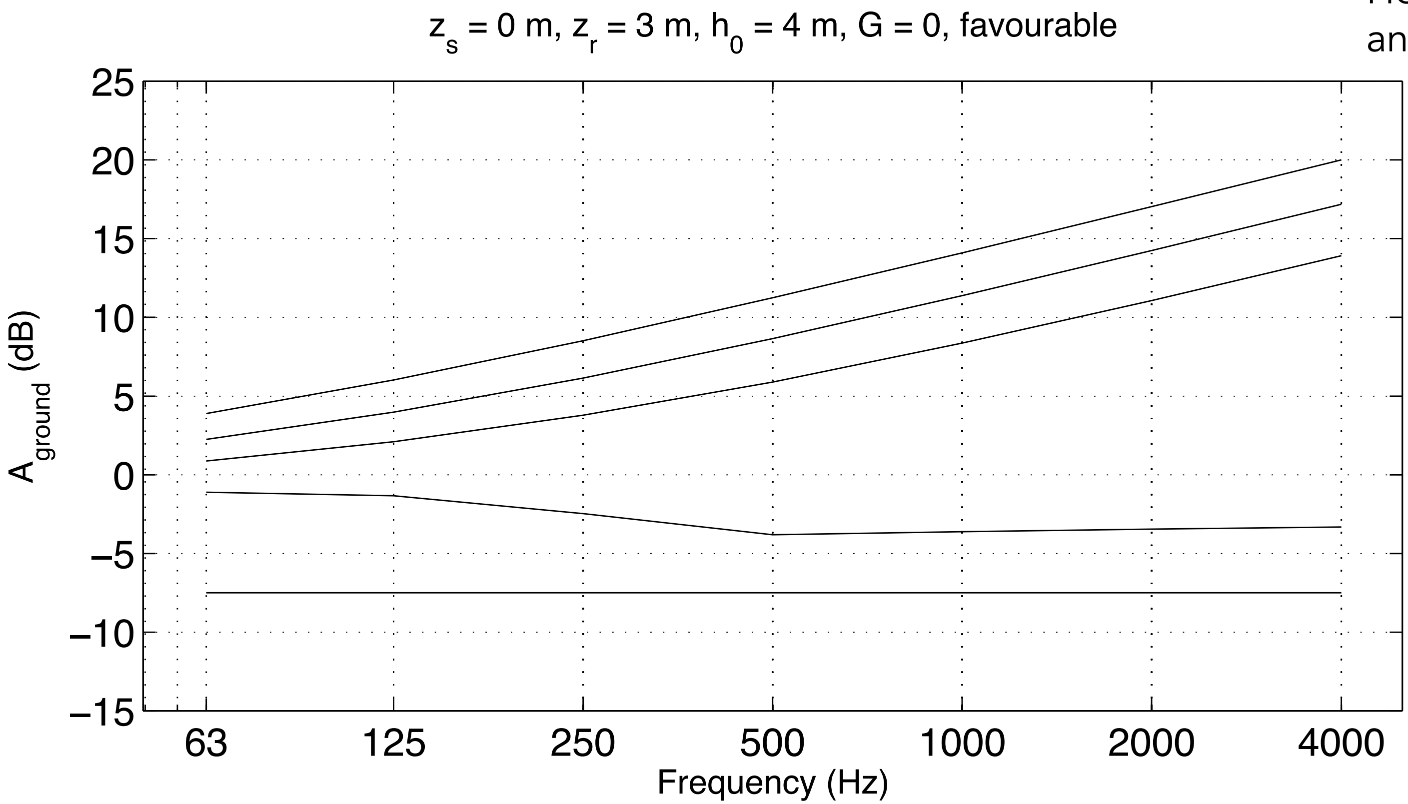


Horizontal distance source-screen and screen receiver

10 m
20 m
40 m
80 m
160 m

$A_{dif,F}$ *favourable conditions*

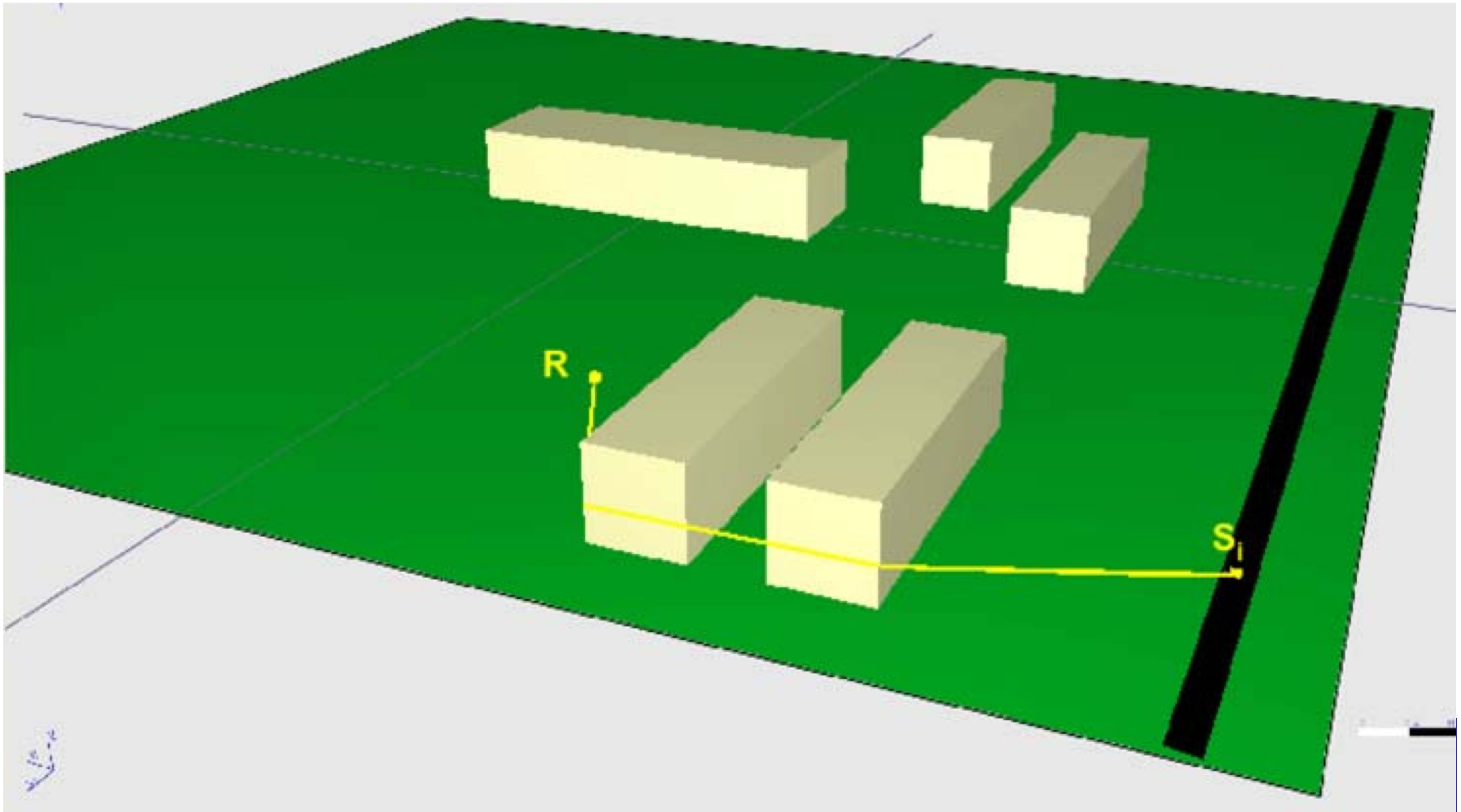




Horizontal distance source-screen and screen receiver
10 m
20 m
40 m
80 m
160 m

Diffraction around vertical edges

Another propagation path => new calculation of $L_{p,n,i}$



Diffraction around vertical edges

$L_{p,n,i} = L_{w,n,i} - A_{div,n} - A_{atm,n,i} - A_{boundary,H,n,i}$

$A_{div,n}$ calculated with direct source-receiver distance

$A_{atm,n,i}$ calculated with total length of sound path

$A_{boundary,H,n,i}$

$A_{ground,H,n,i}$ calculated with total length of sound path

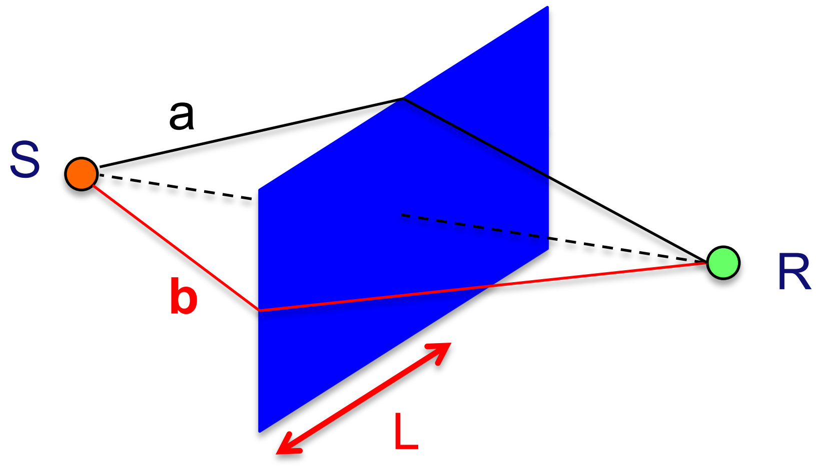
$+$

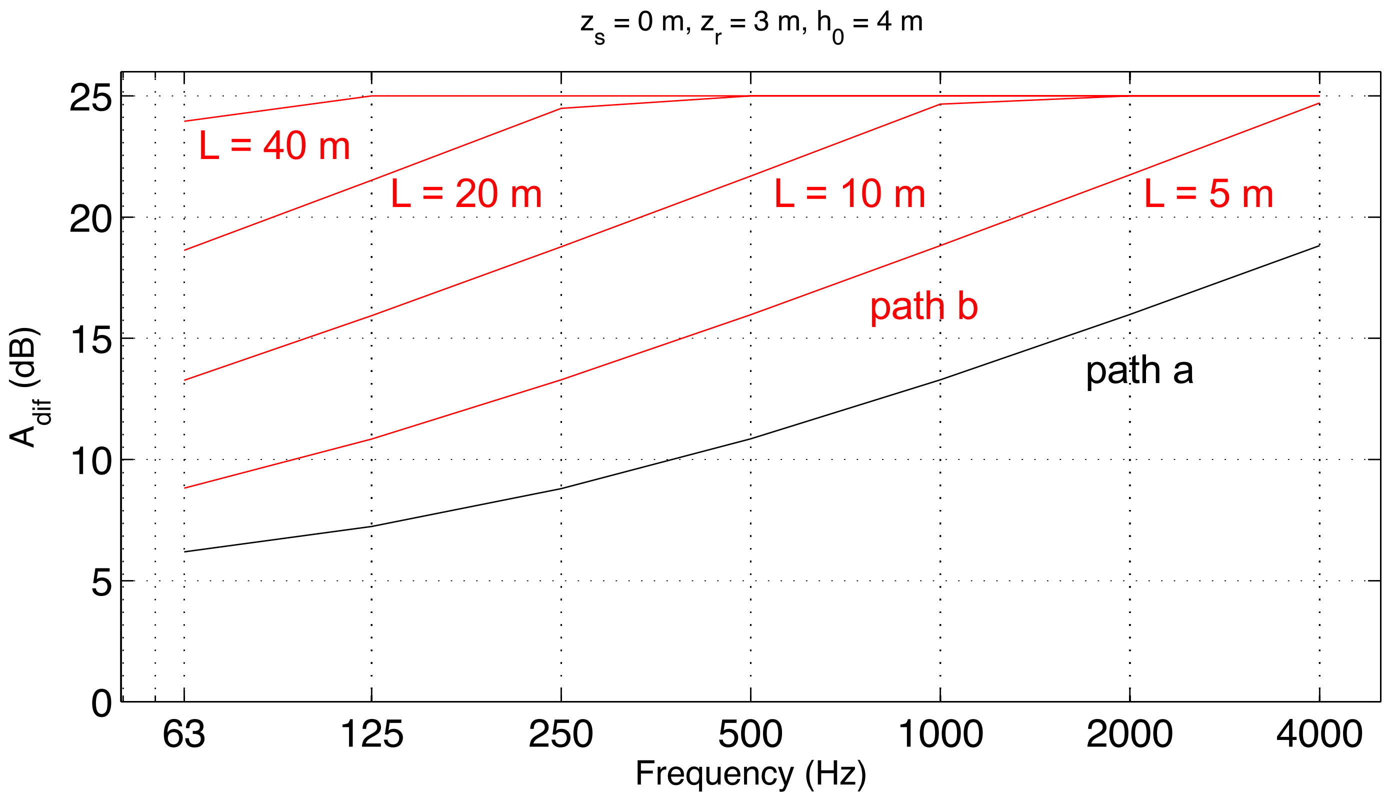
$A_{dif,H,n,i} = D_{dif,SR}$

Diffraction around vertical edges

Source-screen and screen-receiver distance 40 m

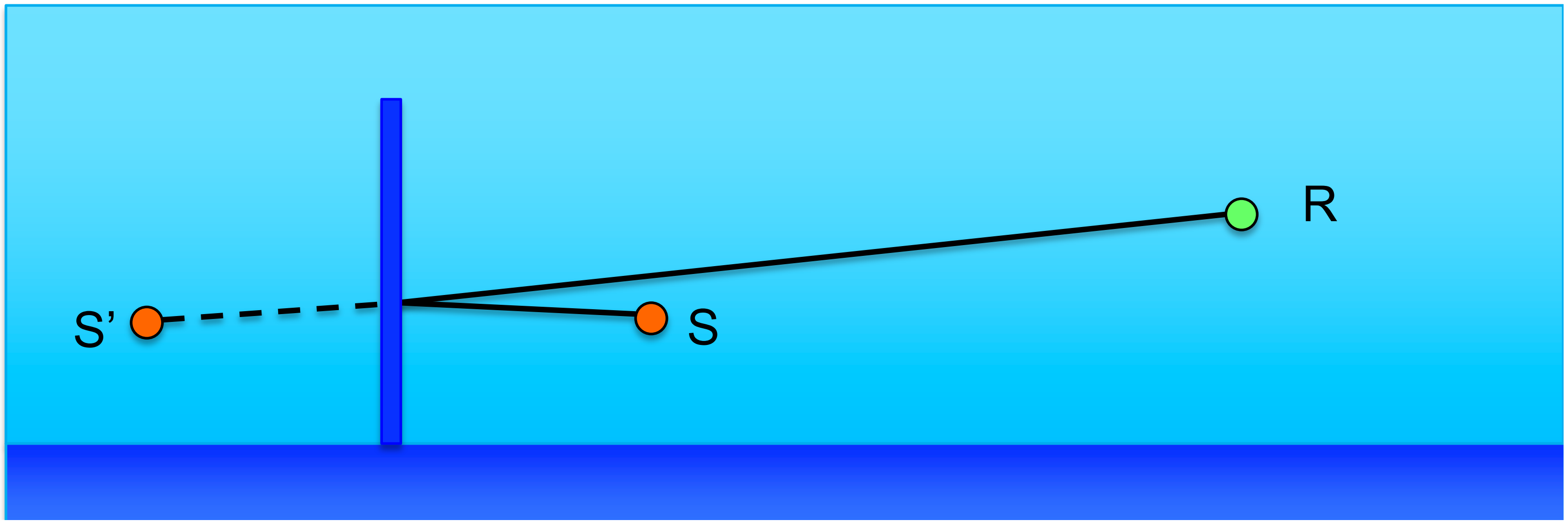
Varying screen length L





Reflection from buildings

- New source position S'
- All calculations for $L_{p,n,i}$ can be carried out as for source position S apart from different source power term L_w



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Reflection from buildings

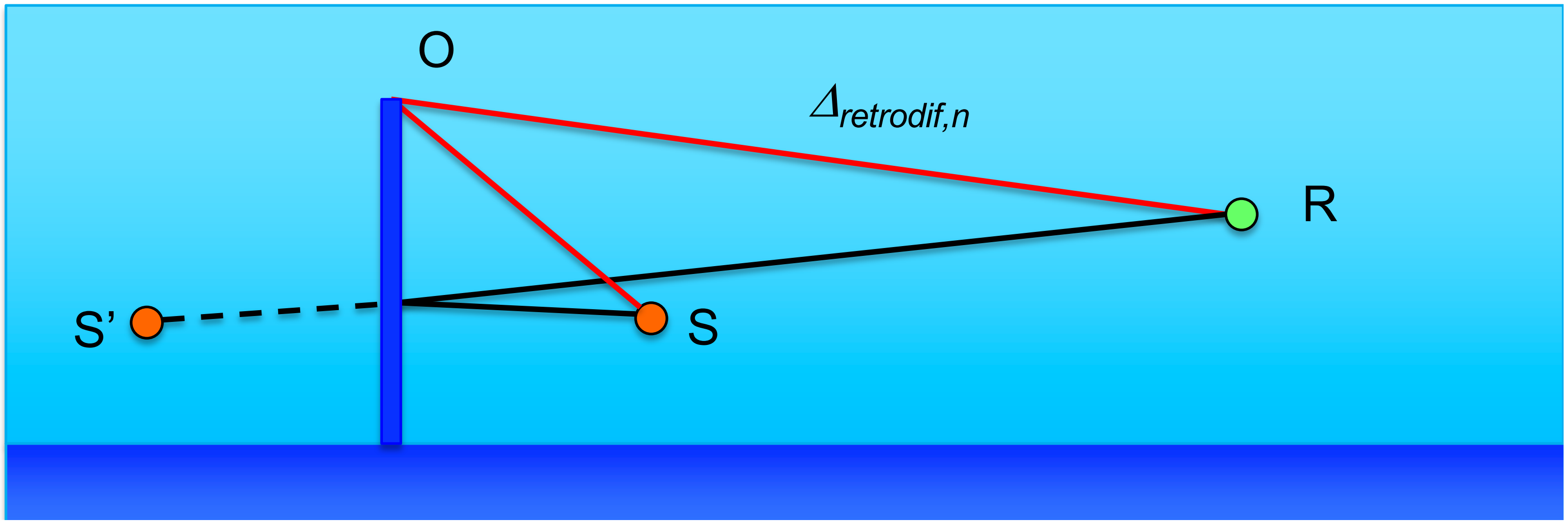
$$L_{w',n,i} = L_{w,n,i} + 10\log_{10}\left(1-\alpha_{r,i}\right) - \Delta_{retrodif,n}$$

$\alpha_{r,i}$ = frequency dependent absorption coefficient of vertical surface

$\Delta_{retrodif,n}$ = retrodiffraction term

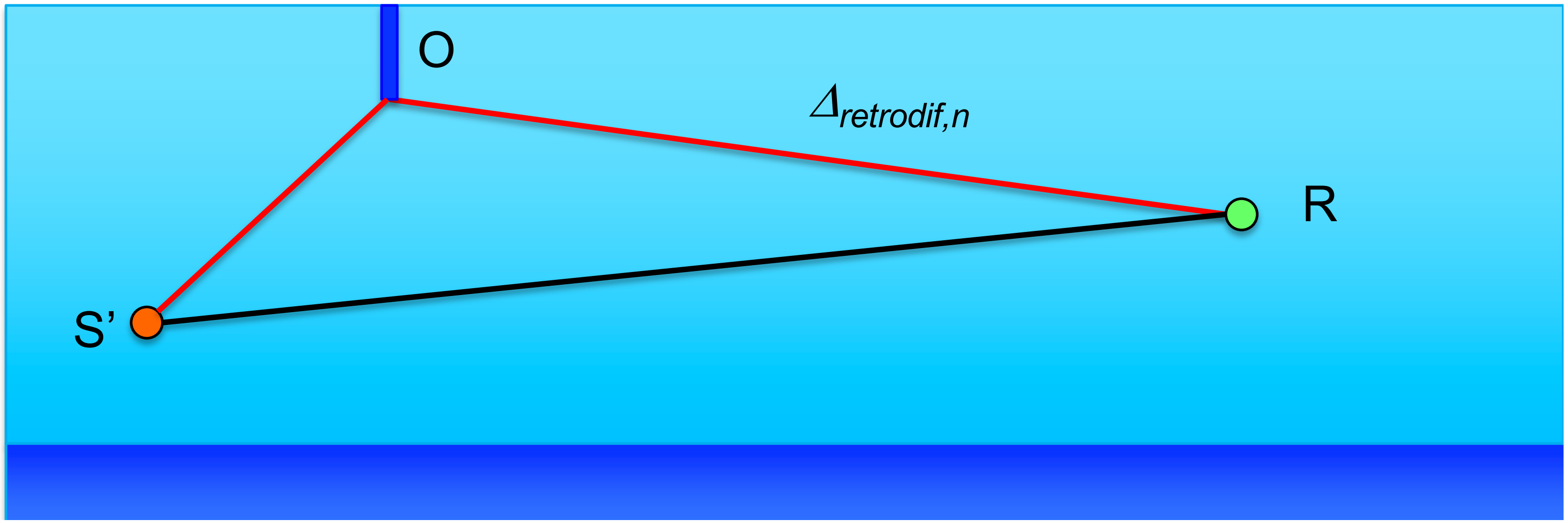
$$= \begin{cases} C_h 10\log_{10}\left(3+\dfrac{40\delta'}{\lambda}\right) & \text{if } \dfrac{40\delta'}{\lambda} \geq -2 \\ 0 & \text{otherwise} \end{cases}$$

$$\delta' = S'R - SO - OR$$



Reflection from buildings

Interpretation of back diffraction



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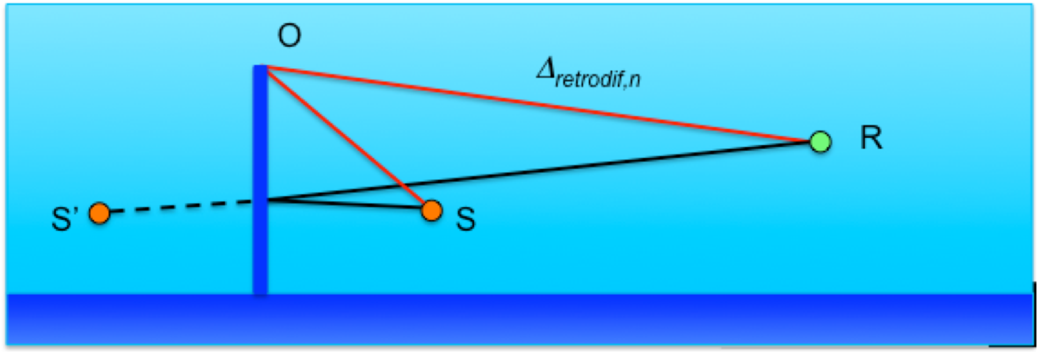
Reflection from buildings

Screen-source distance = 10 m

Screen-receiver distance = 40 m



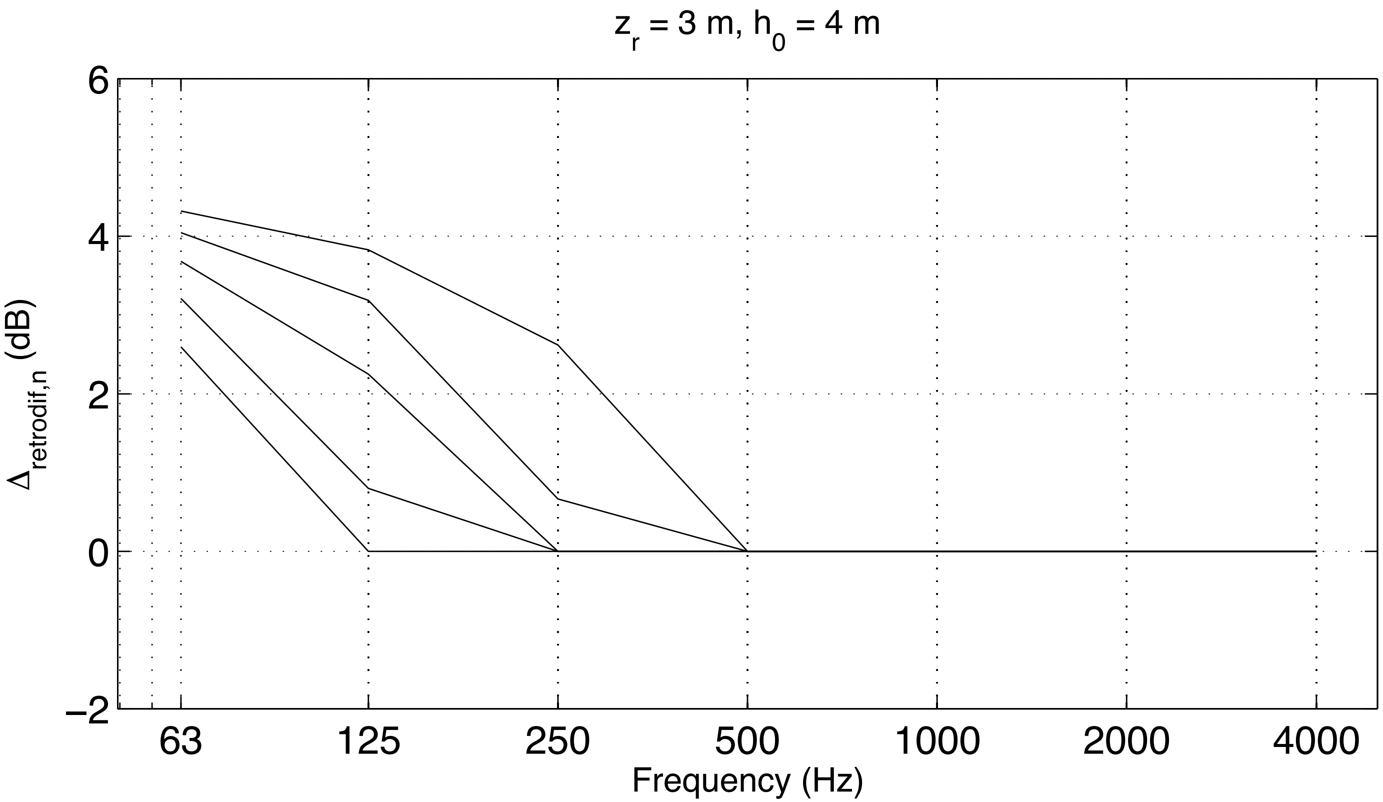
z_s = 4 m

z_s = 3 m

z_s = 2 m

z_s = 1 m

z_s = 0 m



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