1. Gericht geluid en kanaal-arrays
2. Massa-veer systemen

Datum 28 november 2018

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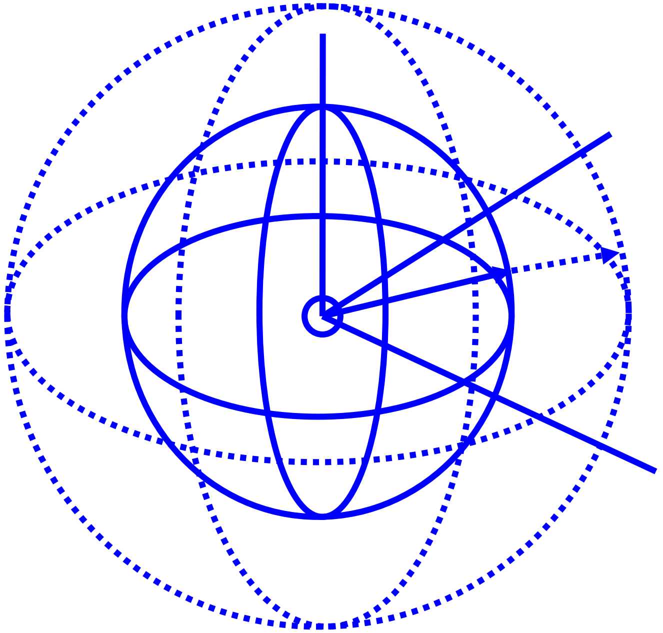
1. RICHTEN VAN GELUID

- Eén bolbron: rondom geluid

- Twee bolbronnen in fase: interferentie

Bolvormige golven



Golfvergelijking:

$$\boxed{\frac{\partial^2 (rp)}{\partial r^2} = \frac{1}{c^2} \cdot \frac{\partial^2 (rp)}{\partial t^2}}$$

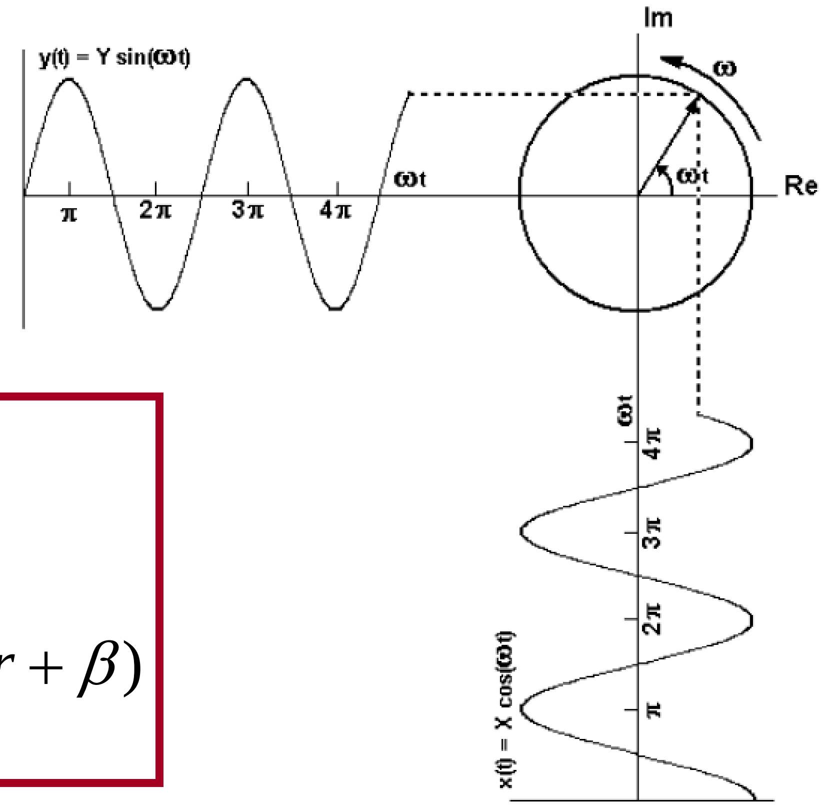
Bolvormige golven

$$k \cdot r = \frac{2 \cdot \pi}{\lambda} \cdot r = \frac{2 \cdot \pi \cdot f \cdot r}{c} = \frac{\omega \cdot r}{c}$$

Harmonische oplossing

$$p = \frac{A}{r} \cdot \sin(\omega \cdot t - k \cdot r + \beta)$$

$$u = \frac{k \cdot A}{\omega \cdot \rho \cdot r} \cdot \sin(\omega \cdot t - k \cdot r + \beta) - \frac{A}{\omega \cdot \rho \cdot r^2} \cdot \cos(\omega \cdot t - k \cdot r + \beta)$$



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Bolvormige golven

impedantie voor harmonische oplossing

$$\boxed{\frac{p}{u} = \rho \cdot c \cdot \frac{j \cdot k \cdot r}{1 + j \cdot k \cdot r}}$$

$$k \cdot r = \frac{2 \cdot \pi \cdot r}{\lambda}$$

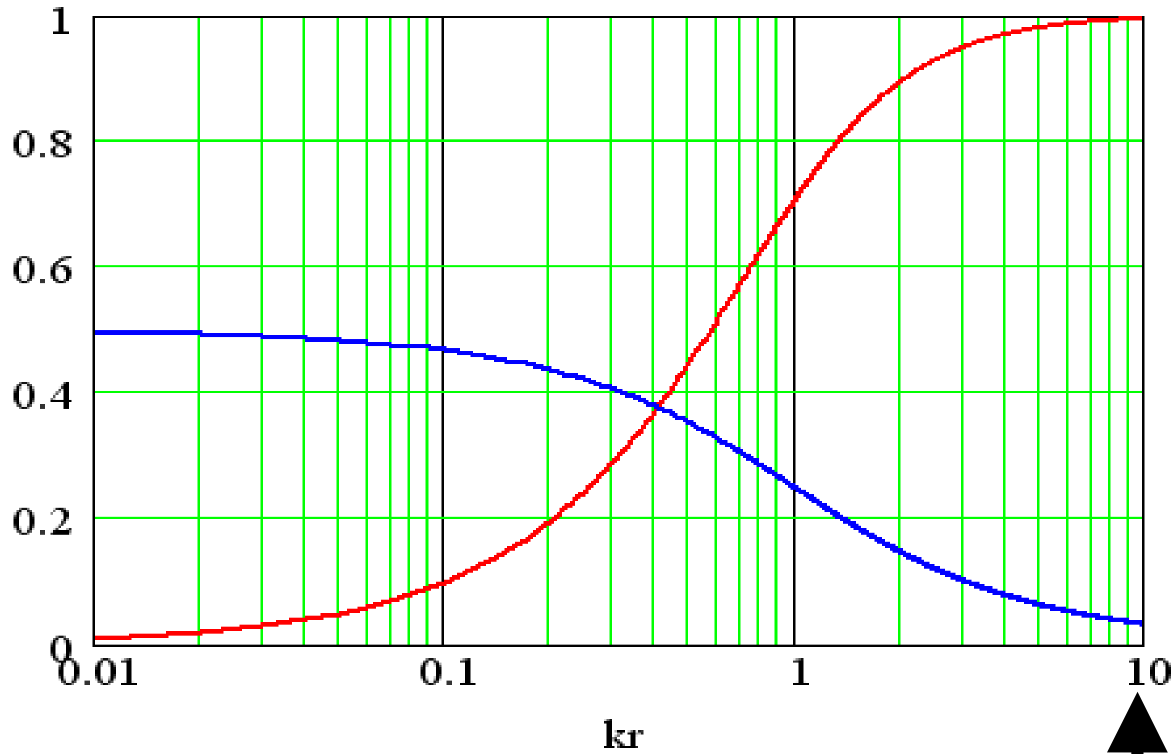
$$r = \lambda \; dan: \quad k \cdot r = 2 \cdot \pi \approx 6{,}28$$

Bolvormige golven: **impedantie**

logaritmische schaal voor kr

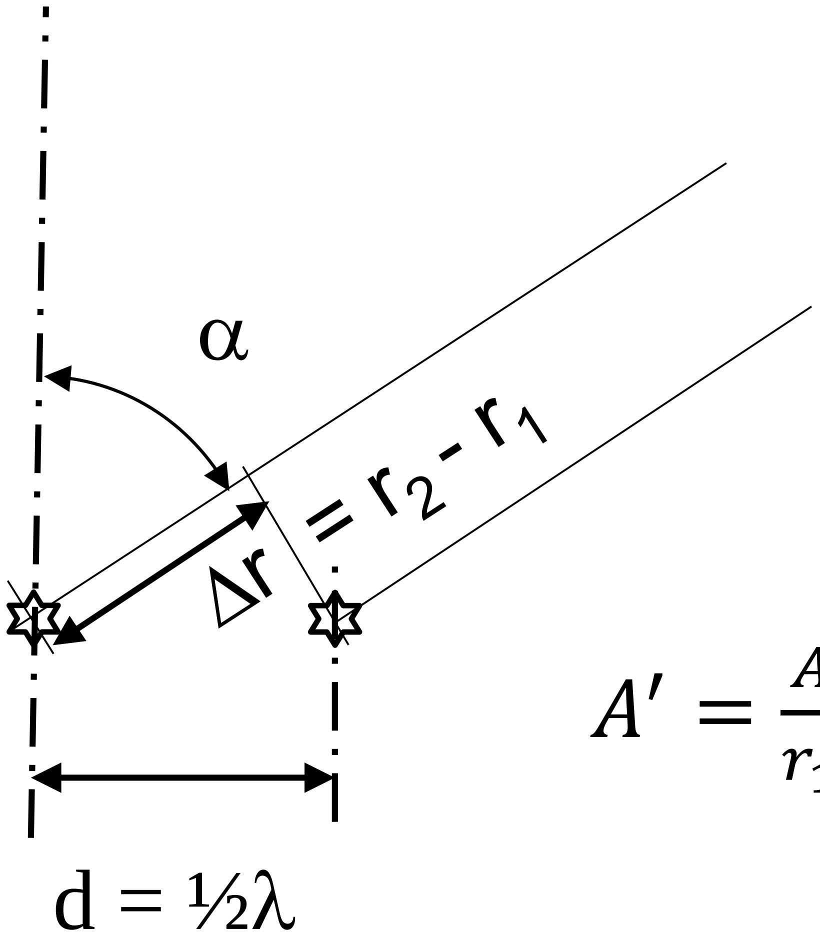
amplitude $\left|\frac{j \cdot kr}{1 + j \cdot kr}\right|$

fase (rad/π) $\frac{1}{\pi}\,\mathrm{atan}\left(\frac{1}{kr}\right)$



"Verre veld" geldt als: $\boxed{r = 1{,}5 \cdot \lambda \quad dan: \quad k \cdot r \approx 10}$

Richtwerking 2 identieke bronnen op halve golflengte



Op grote afstand:

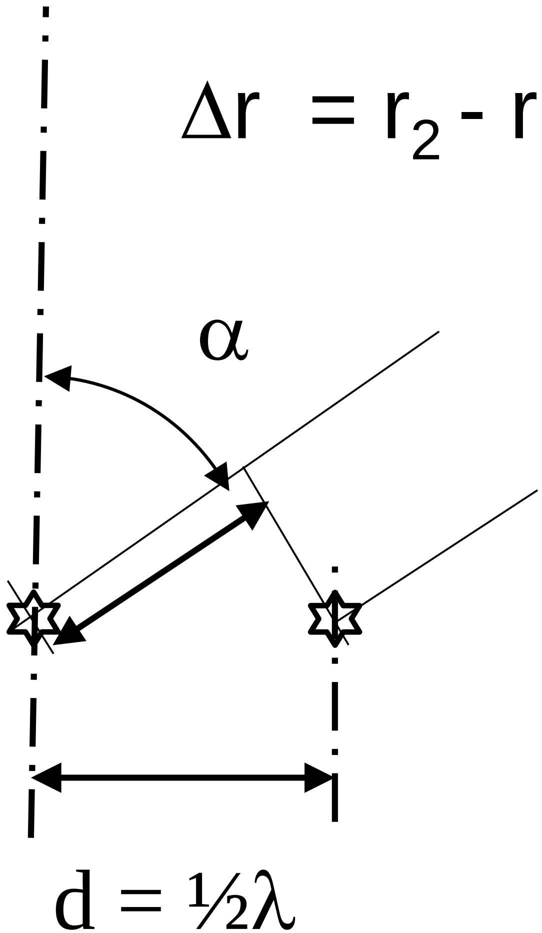
$$p_2 = A'' \cdot e^{j\cdot(\omega t - kr_2)}$$

$$p_1 = A' \cdot e^{j\cdot(\omega t - kr_1)}$$

$$A' = \frac{A}{r_1}\ ; A'' = \frac{A}{r_2}\ \ ; A'' \approx A'$$

Richtwerking 2 identieke bronnen op halve golflengte

$$\Delta r = r_2 - r_1 = d \cdot \sin(\alpha) = \lambda \cdot \sin(\alpha)/2$$



Richtwerking 2 identieke bronnen op halve golflengte

$$p = p_1 + p_2 = A \cdot \left(e^{j\cdot(\omega t - kr_1)} + e^{j\cdot(\omega t - kr_2)}\right) =$$

$$= p_1 \cdot \left(1 + e^{-j\cdot(\Delta r_2)}\right) \quad \ldots\ldots\ldots\ldots$$

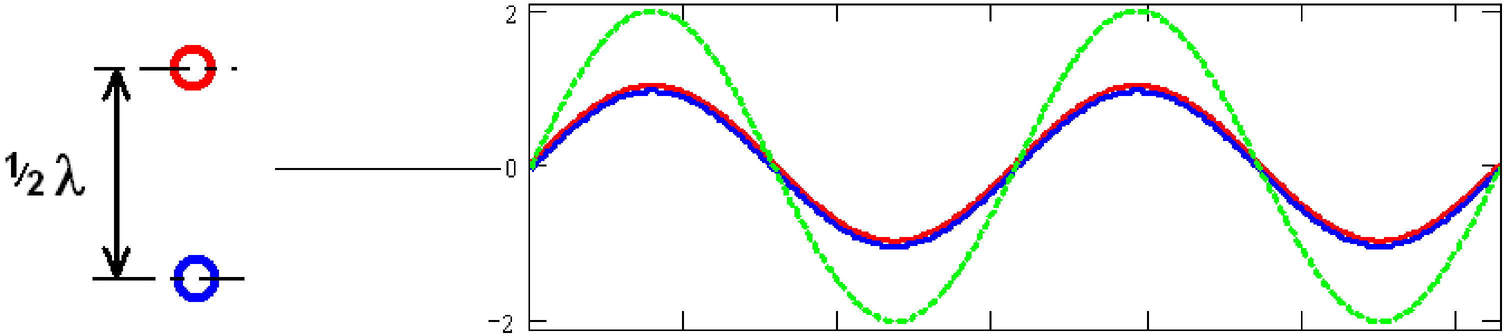
$$|p| = A \cdot \sqrt{2 + 2 \cdot \cos(\pi \cdot \sin(\alpha))}$$

$\alpha = 0$: $|p| = 2A$ in fase optelling

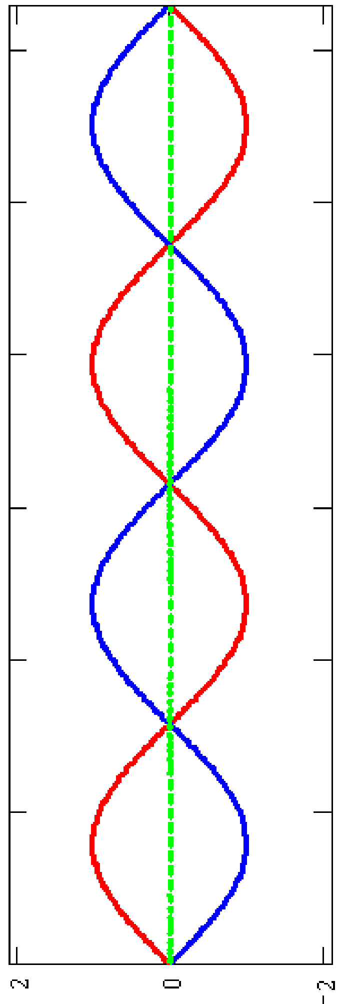
$\alpha = \pi/2$: $|p| = 0$ volledige uitdoving

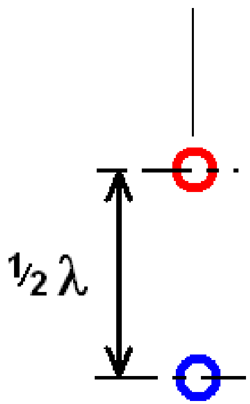
De werking:

Red: from opening 1
Blue: from opening 2
Green: sum

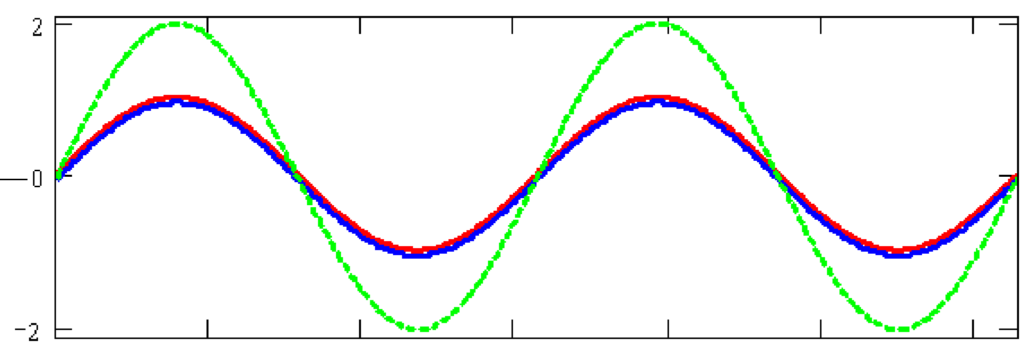


De werking:

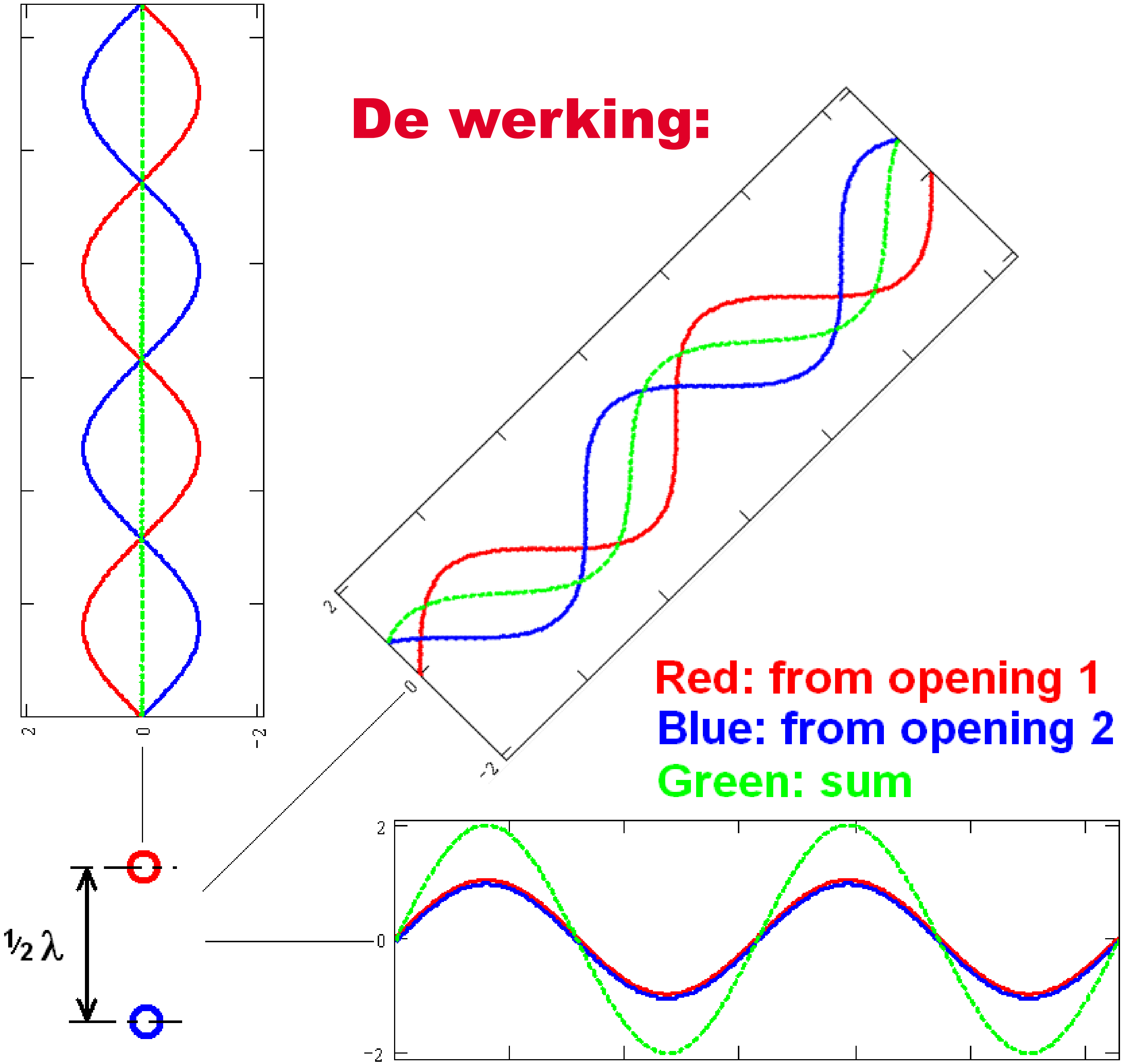




Red: from opening 1
Blue: from opening 2
Green: sum

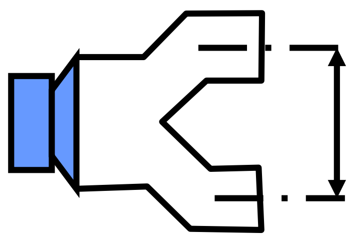


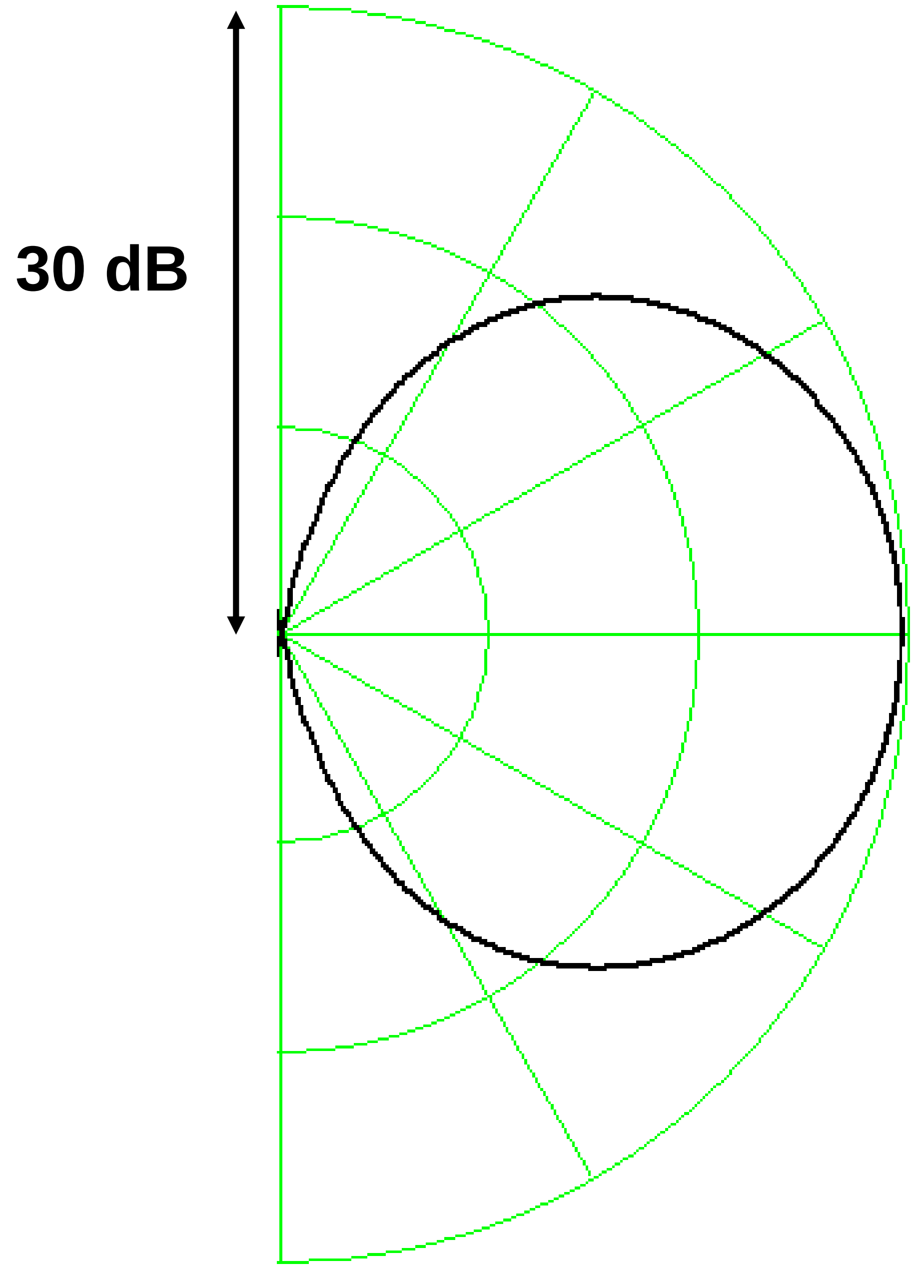
De werking:



Red: from opening 1
Blue: from opening 2
Green: sum

Richtwerking bij 2 openingen

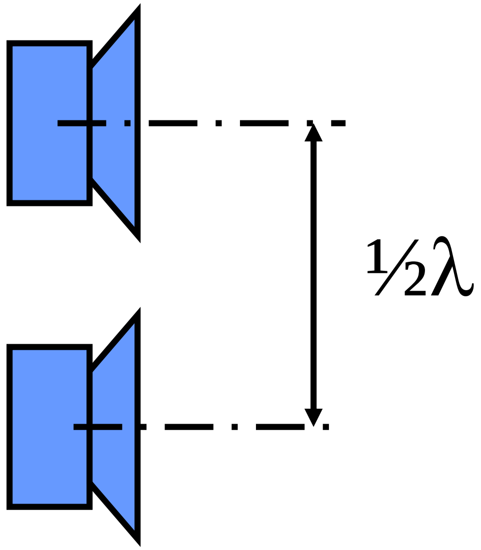




Richtwerking voor verminderen hinder

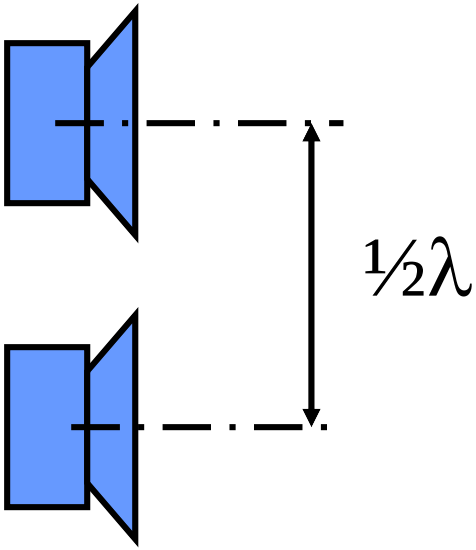
- Hoe richten?
  - luidspreker zelf?
  - afschermende plaat?
  - parabool?

  - **twee fase-gerelateerde bronnen nabij elkaar**:
    - hoe fase zekerstellen?
    - regel-electronica, etc.

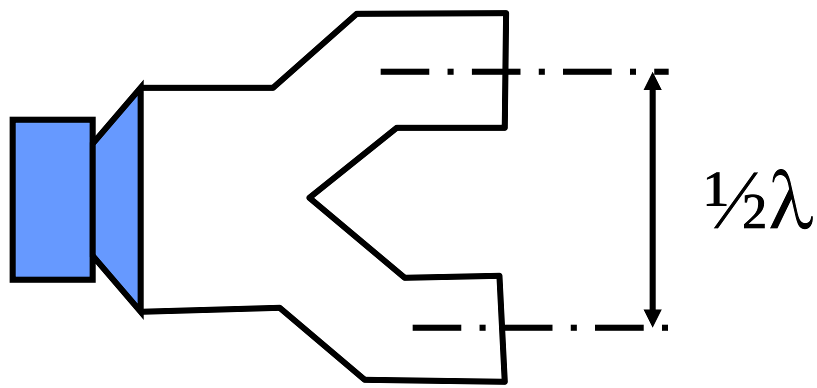


De ½ λ richter

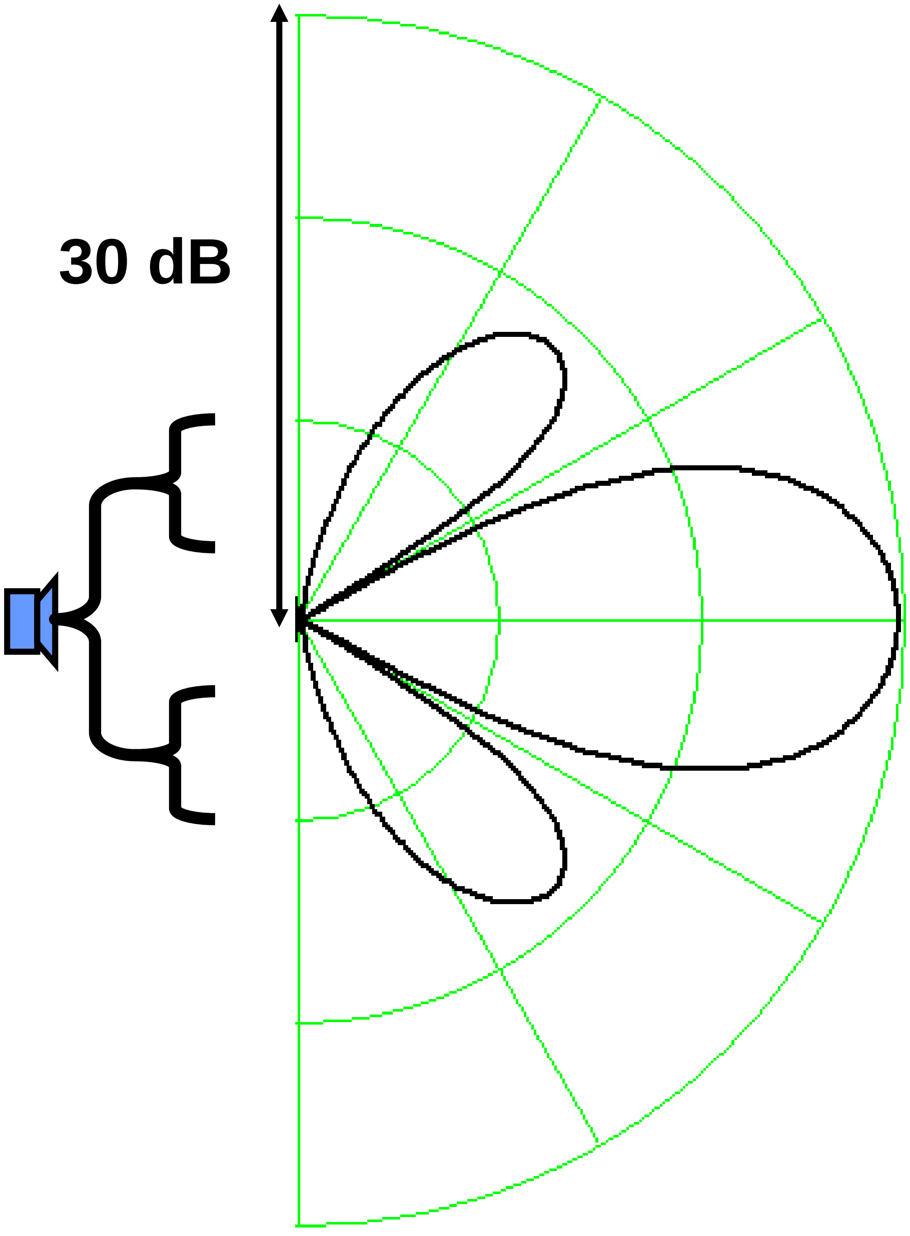
- Bekend:



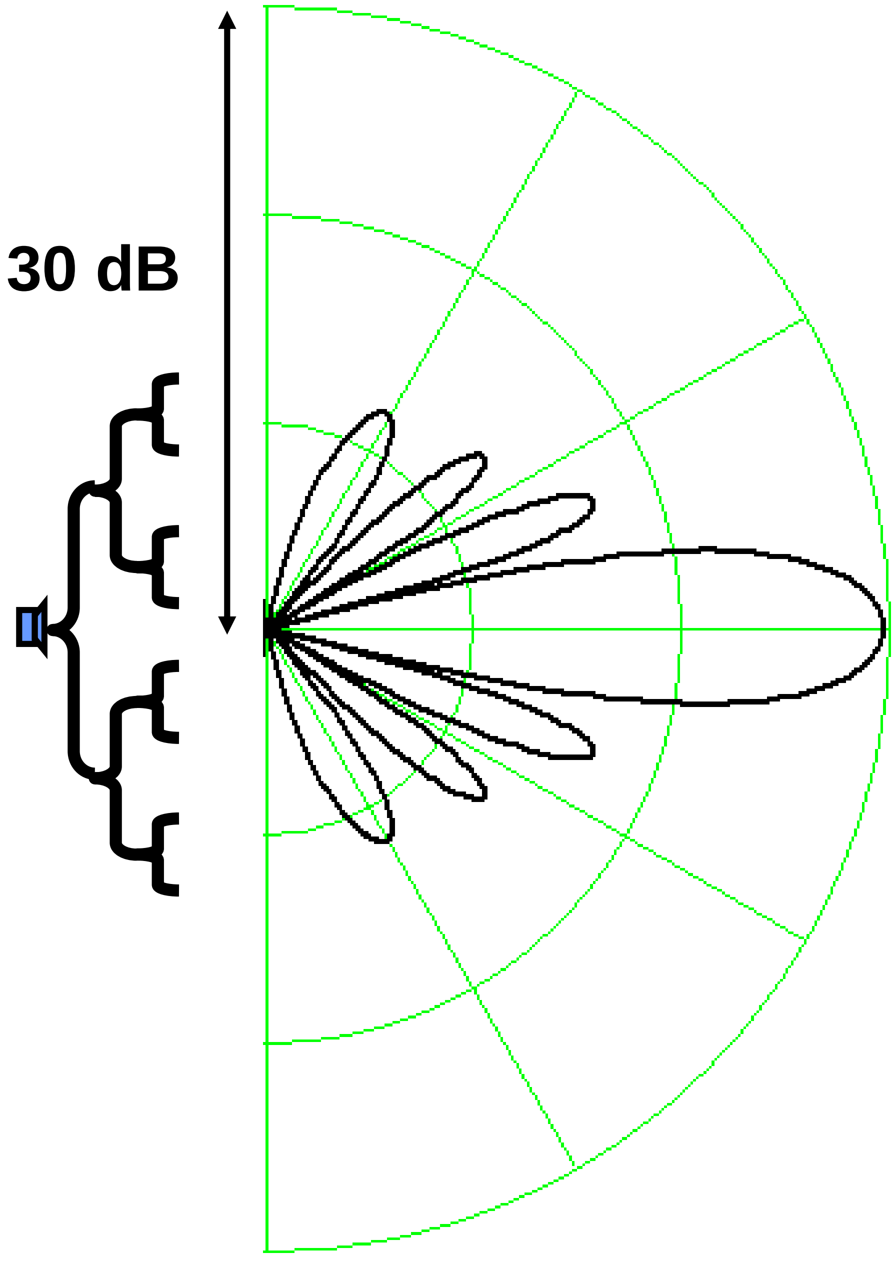
- Kanaal-array:



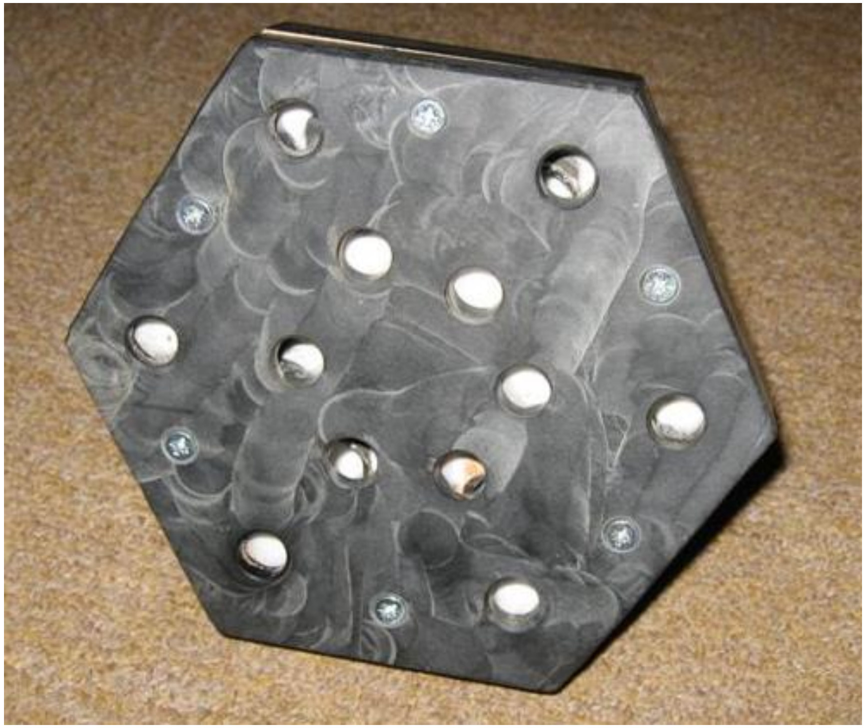
Richtwerking bij 4 openingen



Richtwerking bij 8 openingen



Demonstratie



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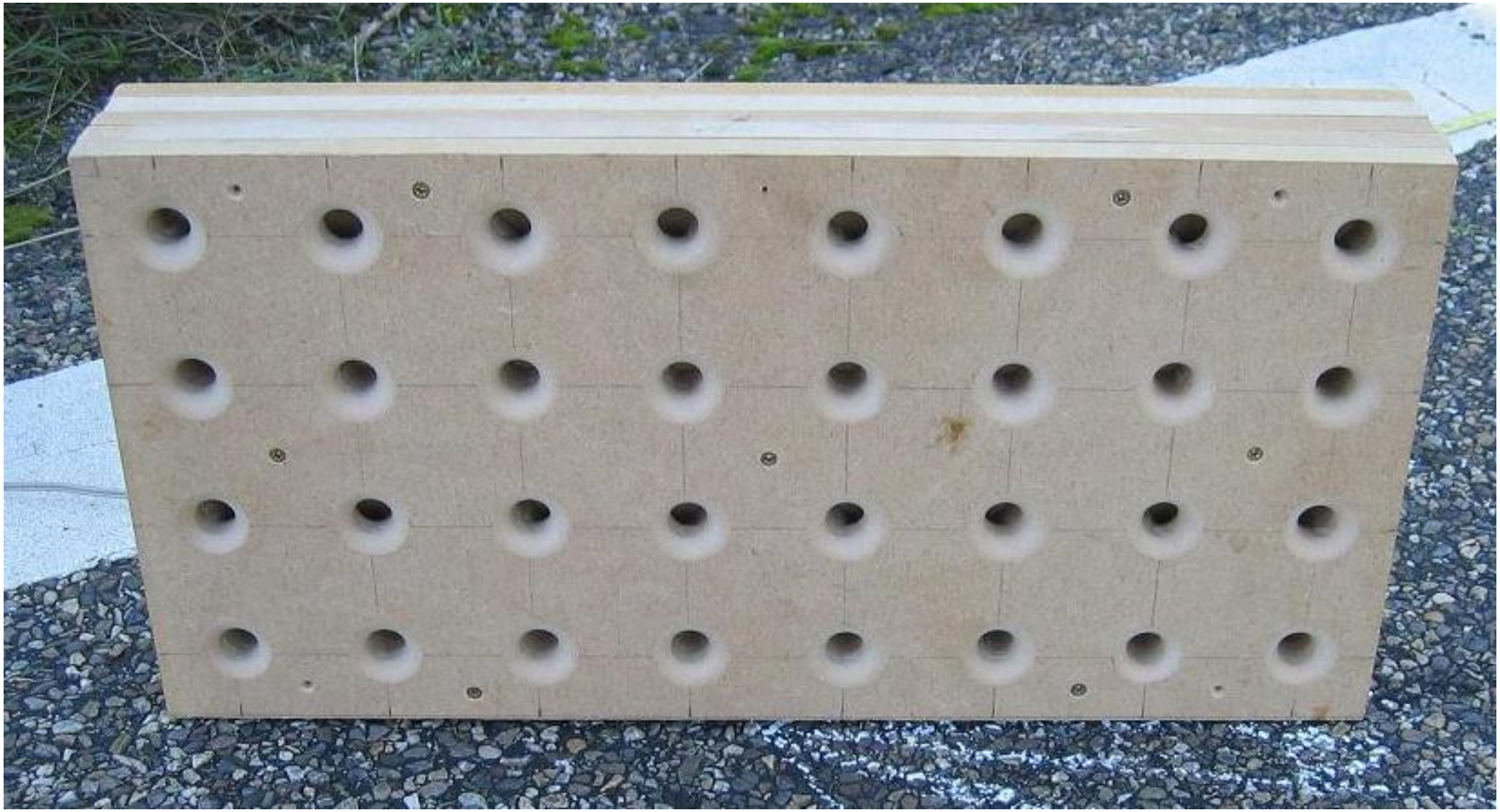
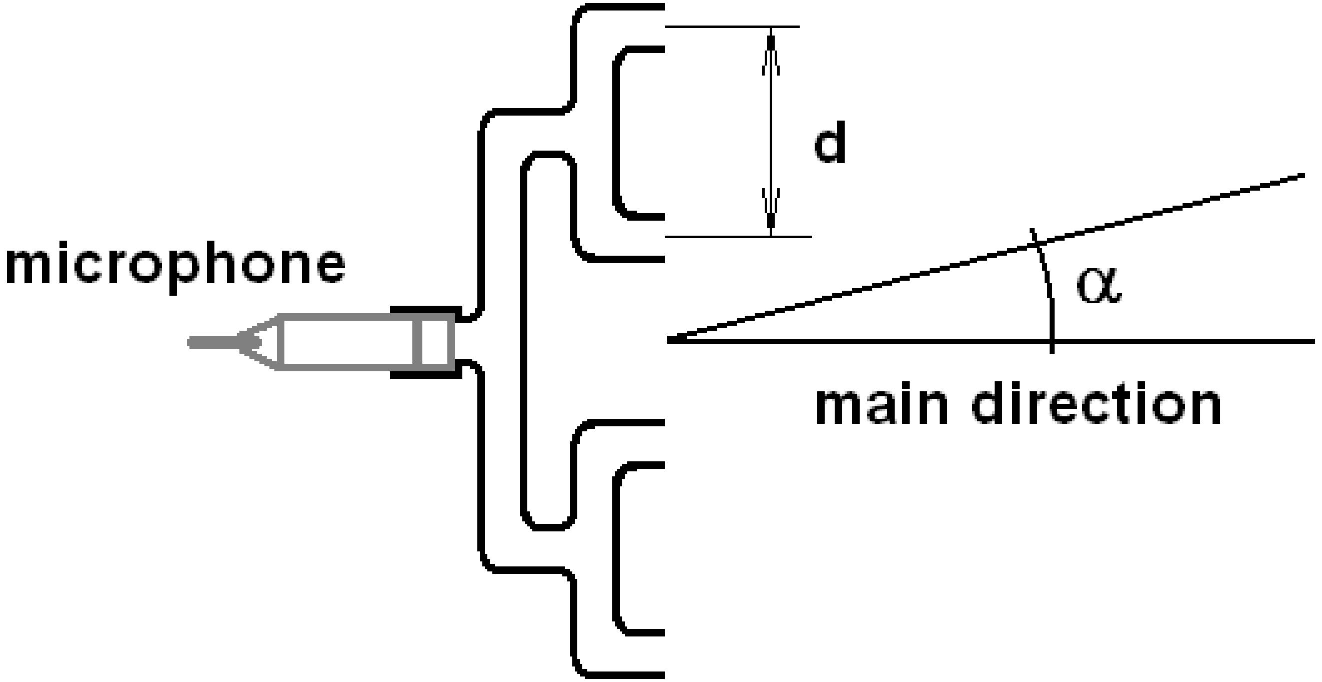
Demonstratie



Richtmicrofoon

gericht zenden = gericht ontvangen



Prototype

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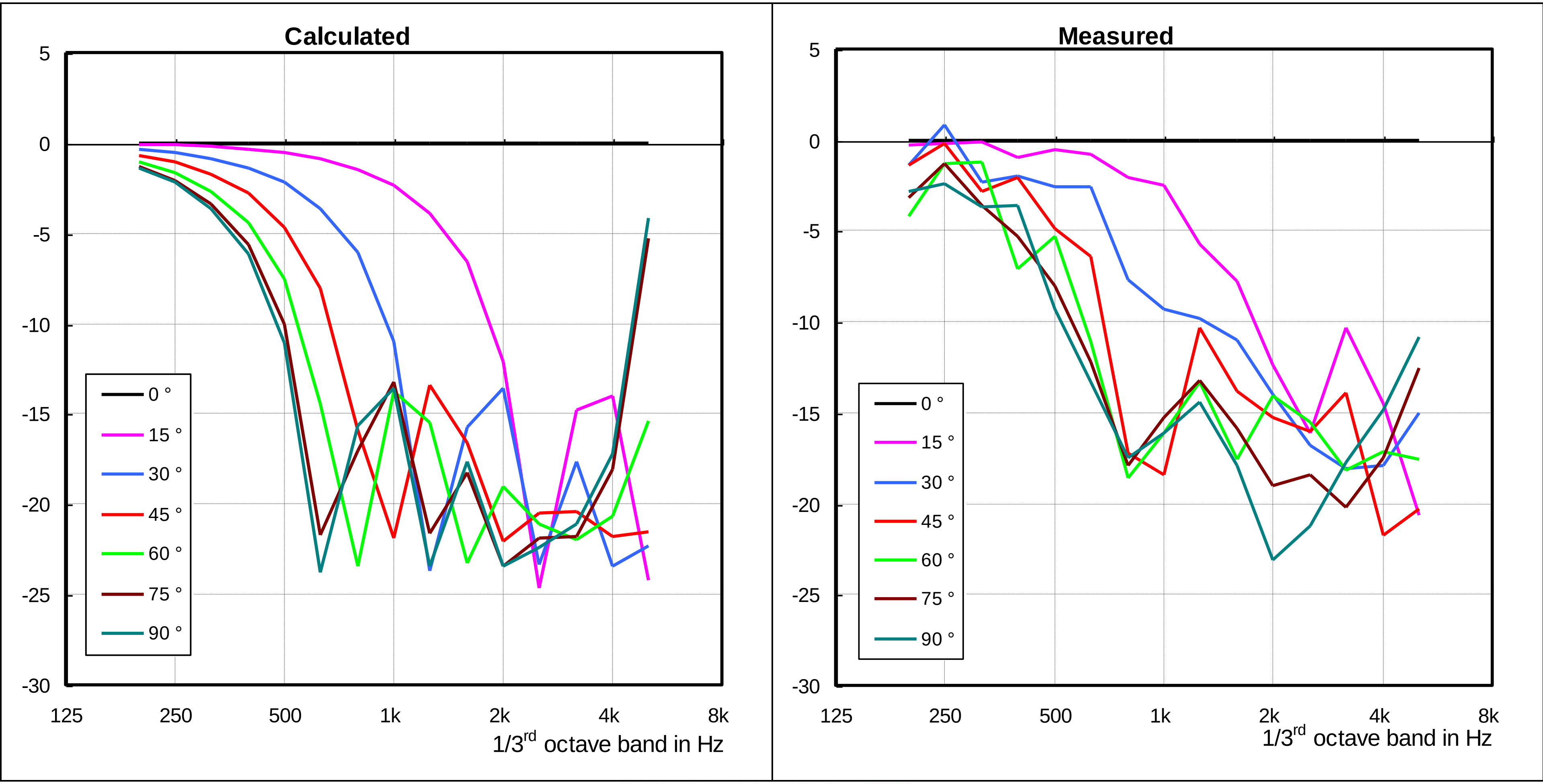
Theorie vs. meting: tertsbanden

Alle hoeken



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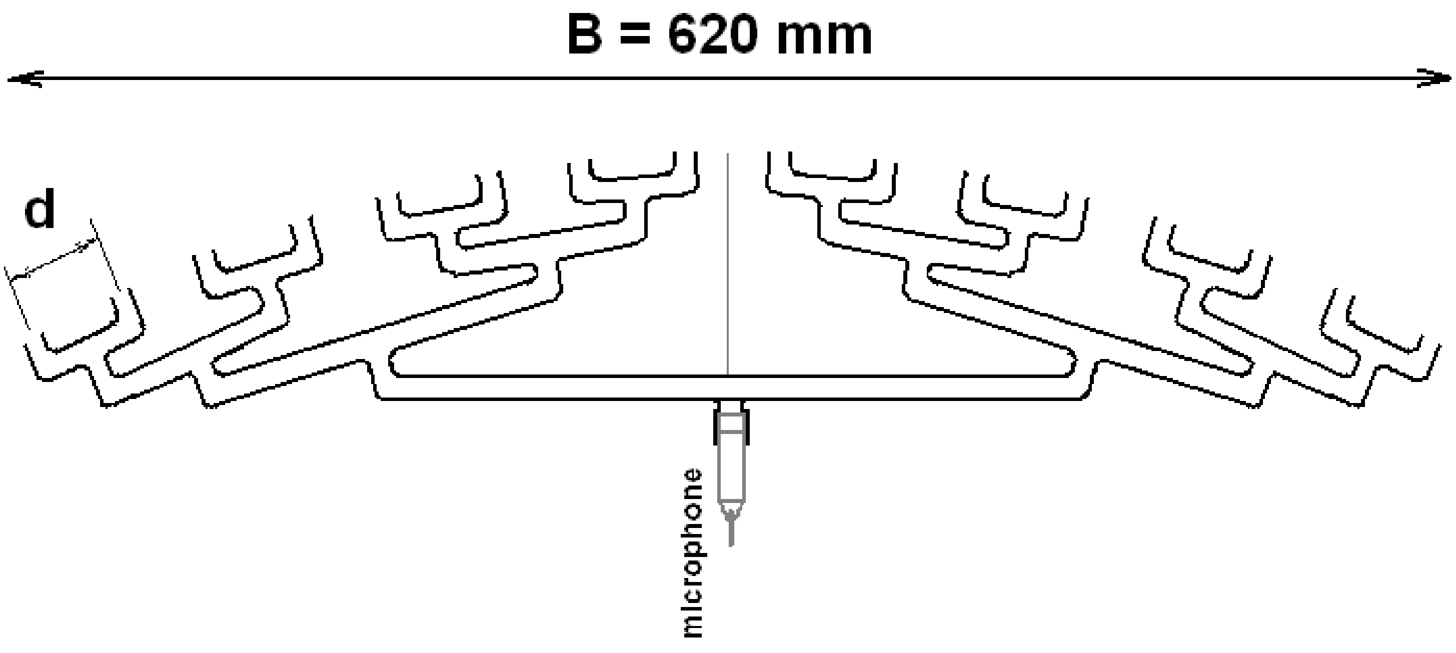
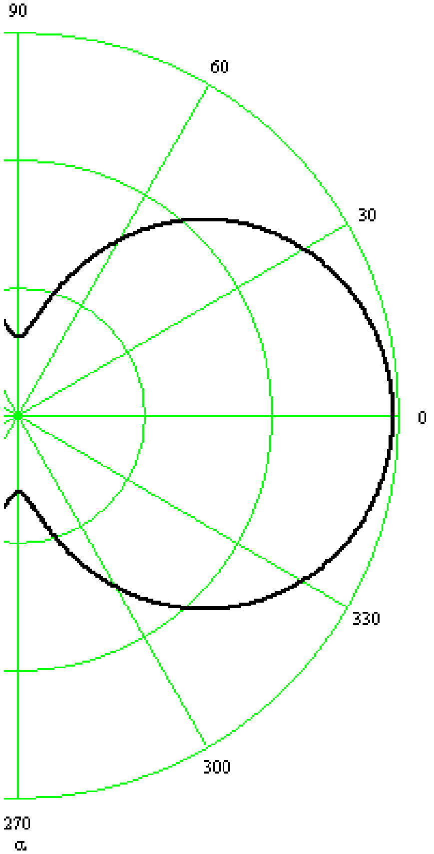
Verdere optimalistatie:

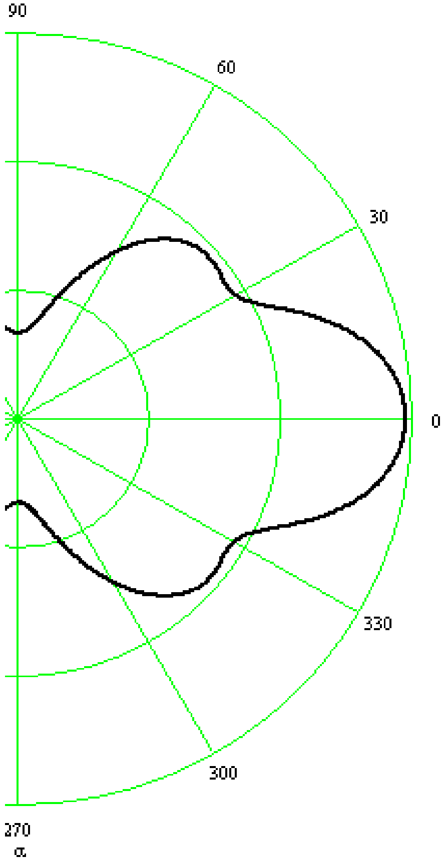
- 16 openingen
- Afstand tussen openingen: d = 43 mm
- op cirkel met straal 0,573 m



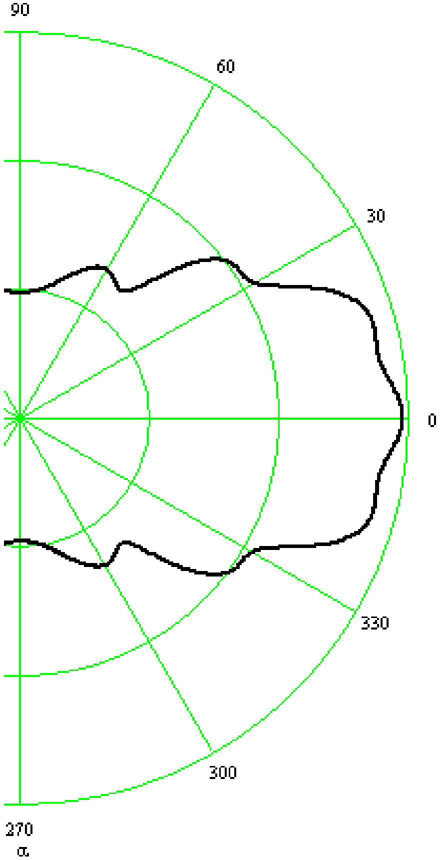
Theoretisch gedrag:



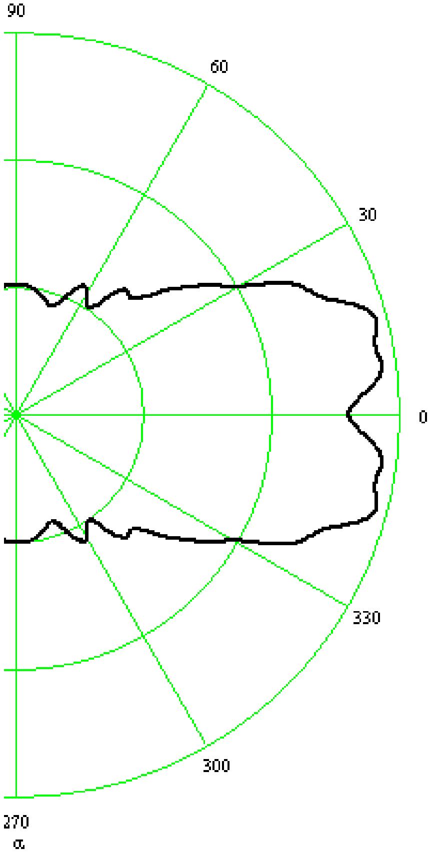
e. openings on curve
500 Hz 1/3rd octave



f. openings on curve
1000 Hz 1/3rd octave



g. openings on curve
2000 Hz 1/3rd octave

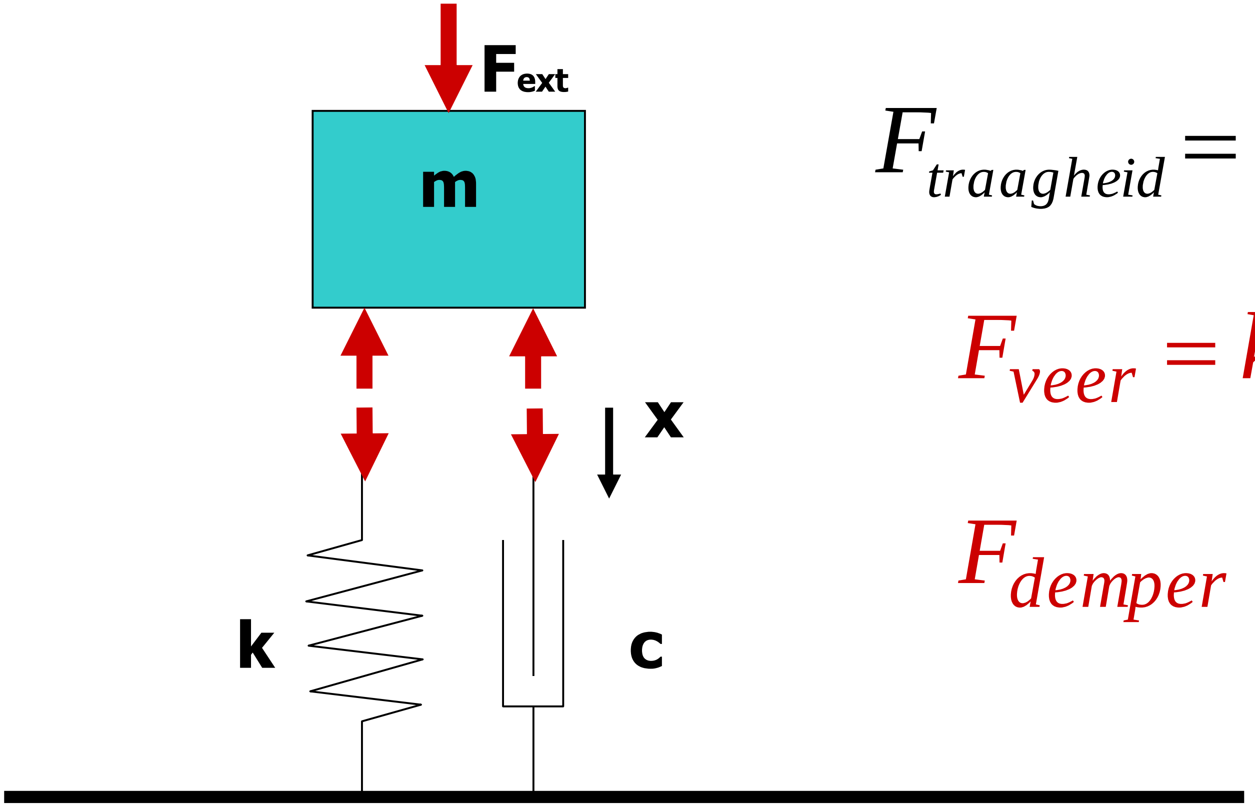


h. openings on curve
4000 Hz 1/3rd octave

2. MASSA VEER SYSTEEM

- Isoleren van trillingen van een machine naar vloer
- Isoleren van trillingen van vloer naar machine

2. Massa-veer systeem



$$F_{traagheid} = m \cdot \frac{d^2x}{dt^2}$$

$$F_{veer} = k \cdot x$$

$$F_{demper} = c \cdot \frac{dx}{dt}$$

formule (krachten op massa M)

$$m \cdot \frac{d^2x}{dt^2} + c \cdot \frac{dx}{dt} + k \cdot x = F_{ext}(t)$$

Uitwerking

stel: $x(t) = X \cdot e^{j\omega \cdot t}$ en $F_{ext}(t) = F \cdot e^{j(\omega \cdot t + \phi)}$

dan: $\dfrac{dx}{dt} = X \cdot j\omega \cdot e^{j\omega \cdot t} = j\omega \cdot x(t)$

en: $\dfrac{d^2x}{dt^2} = X \cdot j^2\omega^2 \cdot e^{j\omega \cdot t} = -\omega^2 \cdot x(t)$

$$F_{ext}(t) = -\omega^2 \cdot m \cdot X \cdot e^{j \cdot \omega \cdot t} + j \cdot \omega \cdot c \cdot X \cdot e^{j \cdot \omega \cdot t} + k \cdot X \cdot e^{j \cdot \omega \cdot t}$$

$$= \left[k - \omega^2 \cdot m + j \cdot (\omega \cdot c)\right] \cdot X \cdot e^{j \cdot \omega \cdot t} = F \cdot e^{j \cdot (\omega \cdot t + \phi)}$$

$$F_{ext}(t) = -\omega^2 \cdot m \cdot X \cdot e^{j\cdot\omega\cdot t} + j\cdot\omega\cdot c\cdot X\cdot e^{j\cdot\omega\cdot t} + k\cdot X\cdot e^{j\cdot\omega\cdot t}$$

$$= \left[k - \omega^2 \cdot m + j\cdot(\omega\cdot c)\right]\cdot X\cdot e^{j\cdot\omega\cdot t} = F\cdot e^{j\cdot(\omega\cdot t+\phi)} = F\cdot e^{j\cdot\phi}\cdot e^{j\cdot\omega\cdot t}$$

$$delen\ \ door\ \ e^{j\cdot\omega\cdot t}\ \ geeft:$$

$$\left[-\omega^2\cdot m + \omega\cdot(j\cdot c) + k\right]\cdot X = F\cdot e^{j\cdot\phi}$$

$$vrije\ \ trilling, geen\ \ kracht,\ \ dus:\ F = 0,$$

$$dus\ \ dan\ \ oplossen: \boxed{-\omega^2\cdot m + \omega\cdot(j\cdot c) + k = 0,}$$

$$ziet\ \ er\ \ uit\ \ als\ \ \tilde{a}\cdot x^2 + \tilde{b}\cdot x + \tilde{c} = 0 \quad (x = \omega).$$

$$toepassen\ \ wortelformule\ \ x_{1,2} = \frac{-\tilde{b} \pm \sqrt{\tilde{b}^2 - 4\cdot\tilde{a}\cdot\tilde{c}}}{2\cdot\tilde{a}};$$

$$invullen\ \ van\ \ \tilde{a} := m;\ \ \tilde{b} := -j\cdot c;\ \ \tilde{c} := -k$$

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Eigenfrequentie

$$\omega_{1,2} = \frac{j \cdot c \pm \sqrt{-c^2 + 4mk}}{2m}$$

Stel: geen demping, c = 0:

$$\omega_{1,2} = \frac{\pm\sqrt{4mk}}{2m} = \pm\sqrt{\frac{k}{m}} \quad \text{ofwel: } \mathrm{f}_{1,2} = \pm 2\pi\sqrt{\frac{k}{m}}$$

$$\boxed{\mathrm{f} = 2\pi\sqrt{\frac{k}{m}}}$$

Kritische demping

$$\omega_{1,2} = \frac{j \cdot c \pm \sqrt{-c^2 + 4mk}}{2m}$$

Omslag als $-c^2 + 4mk = 0$

$$\boxed{c_{crit} = 2\sqrt{m \cdot k}}$$

$c < c_{crit}$: harmonische beweging

$c \geq c_{crit}$: niet harmonisch gedempt

Overdracht: isolatie

$$F \cdot e^{j \cdot \phi} = \left[k - \omega^2 \cdot M + j \cdot (\omega \cdot c) \right] \cdot X$$

daaruit volgt de overdracht:

$$\left| \frac{X}{F} \right| = \left| \frac{1}{k - \omega^2 \cdot M + j \cdot (\omega \cdot c)} \right| = \frac{1}{\sqrt{\left(k - \omega^2 \cdot M\right)^2 + (\omega \cdot c)^2}}$$

$$\phi = \arctan\left(\frac{\omega \cdot c}{k - \omega^2 \cdot M} \right)$$

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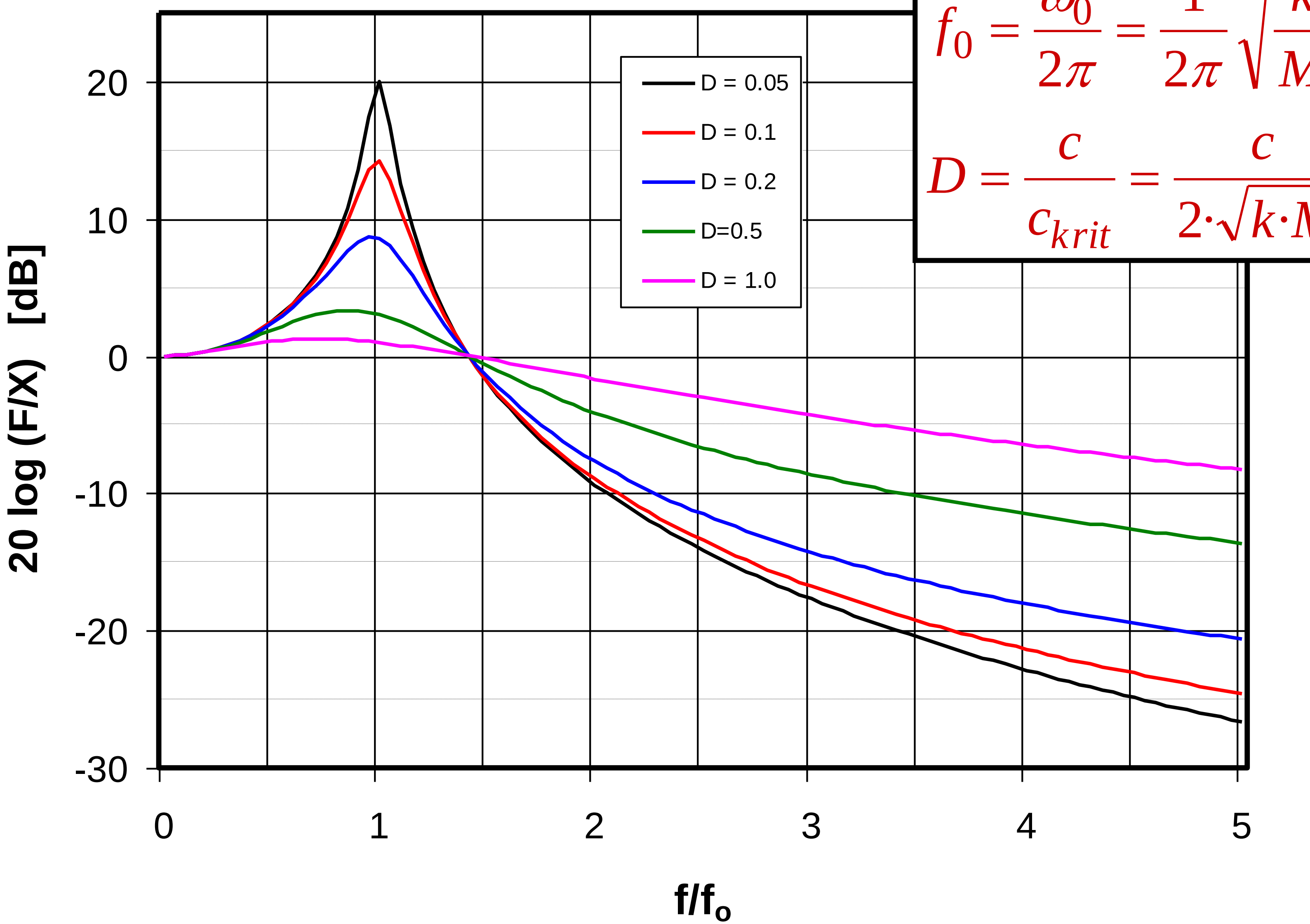
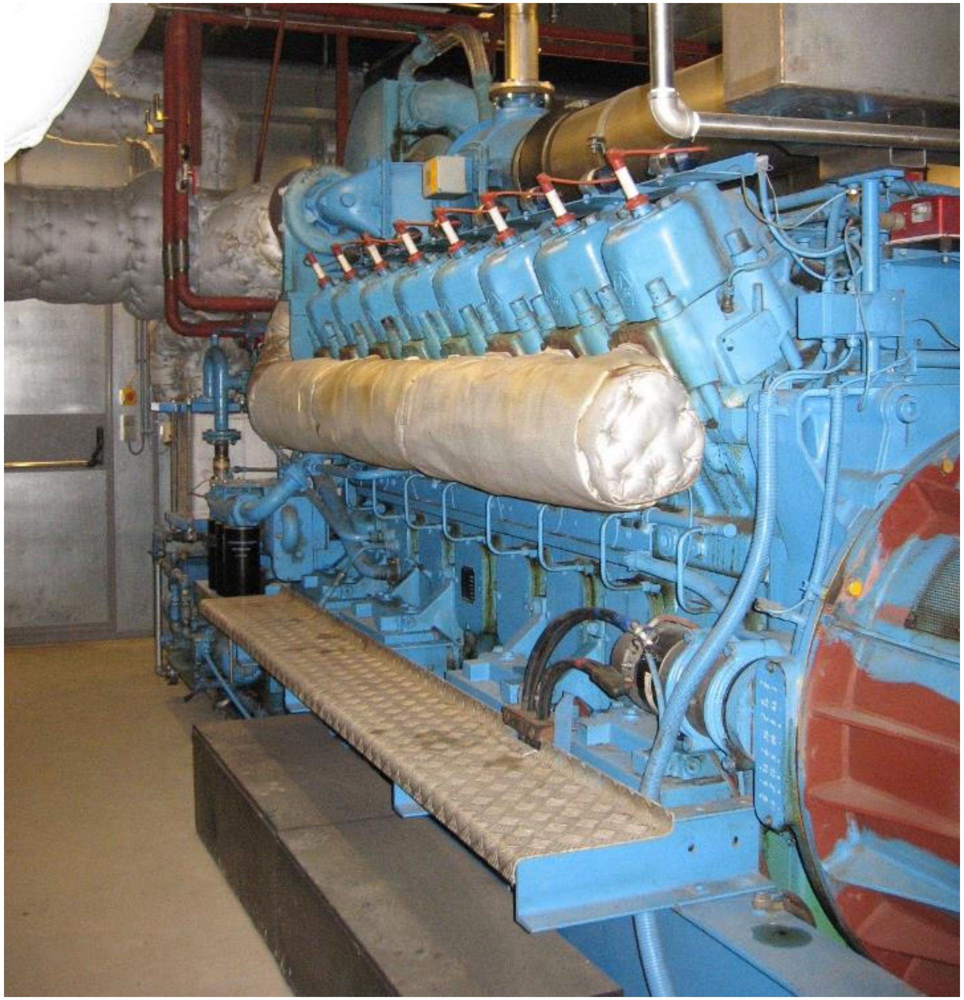
Grafische weergave

$$f_0 = \frac{\omega_0}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{k}{M}}$$

$$D = \frac{c}{c_{krit}} = \frac{c}{2\cdot\sqrt{k\cdot M}}$$



Casus 1: Gasmotor



Casus 1: Maatregel

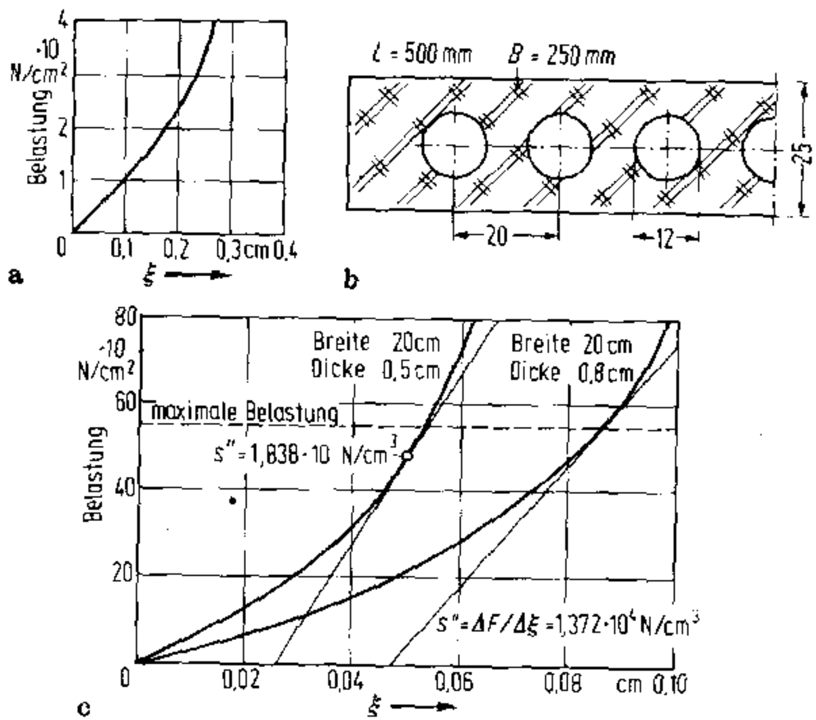


Bild 22.5. Federkennlinien von flächigen Lagerungen.
a, *b* gelochte Gummiplatte; *c* ungelochte Gummiplatte

- Taschenbuch der Technischen Akustik - Heckl & Müller
  - 2. Auflage

Casus 2: Ventilatoren parkeergarage

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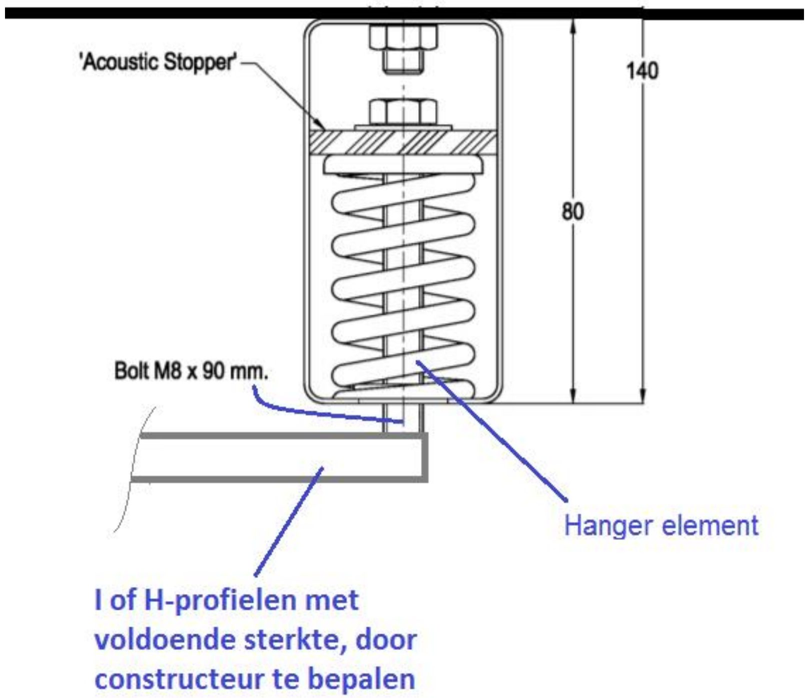
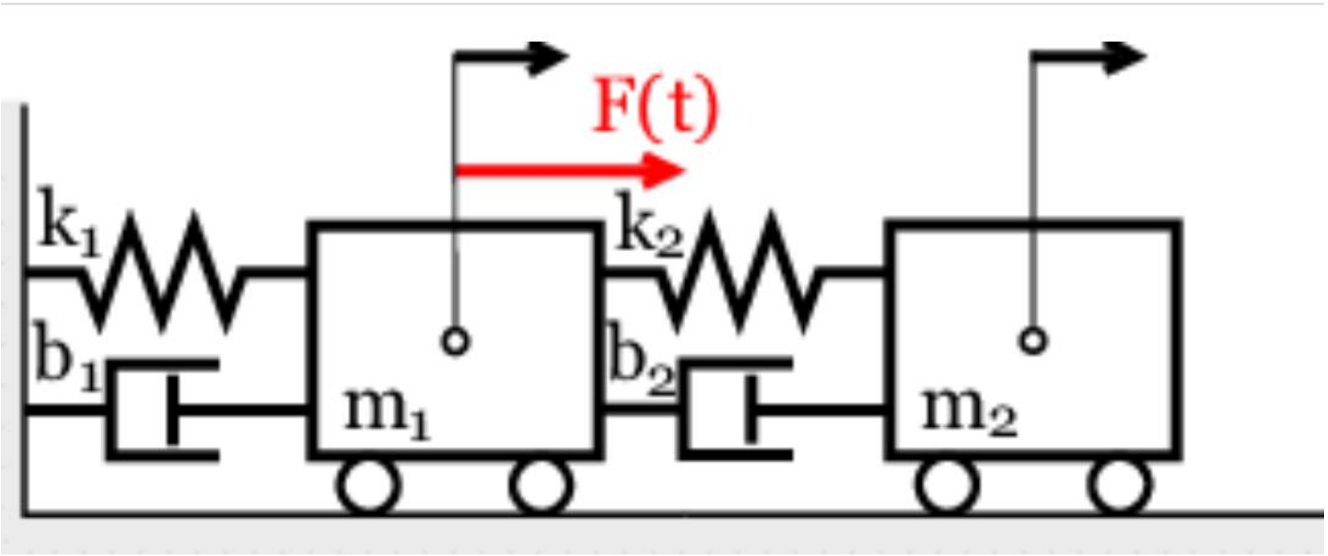
Casus 2: Ventilatoren parkeergarage

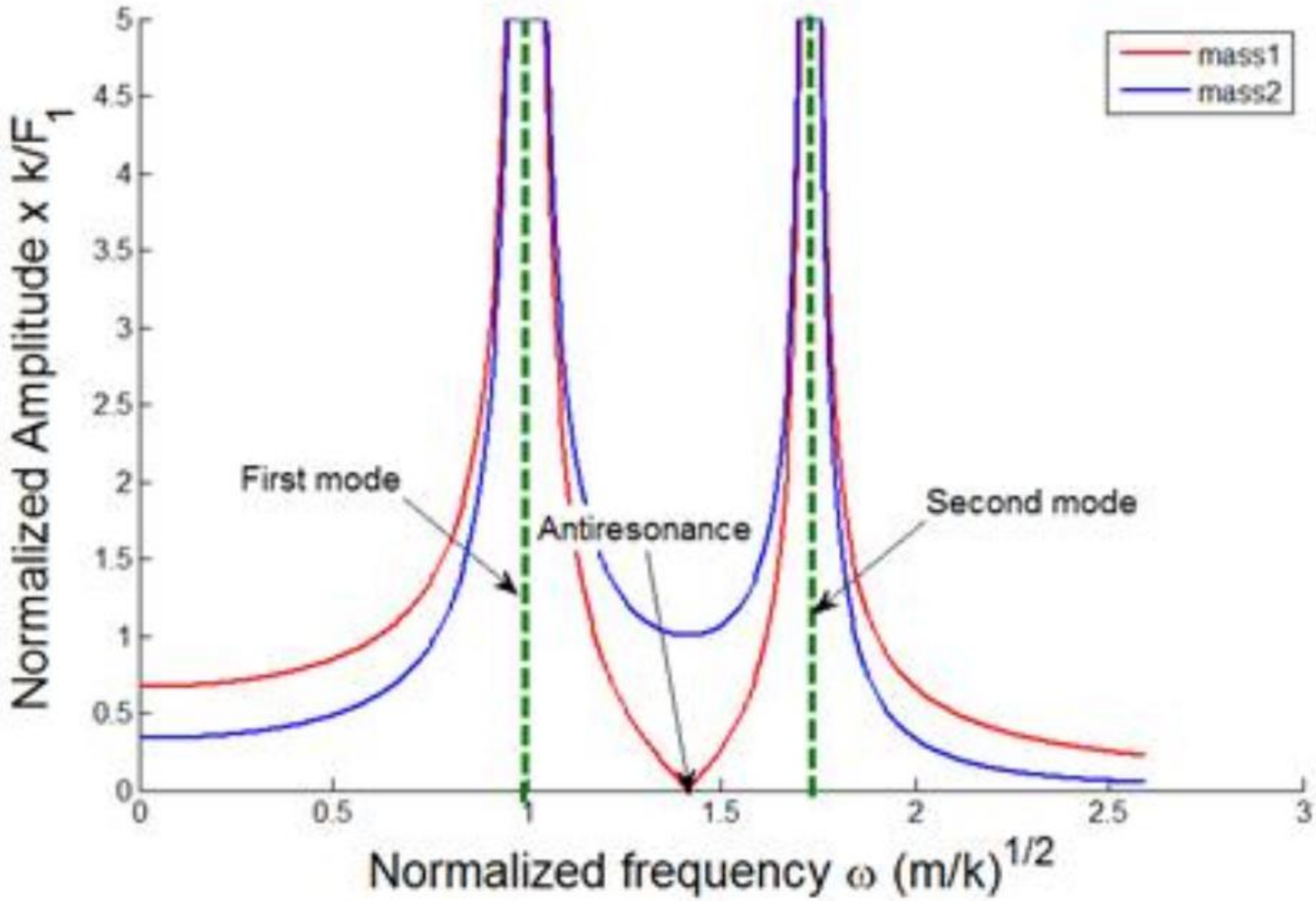


Casus 2: Ventilatoren parkeergarage

2 graden van vrijheid



2 graden van vrijheid



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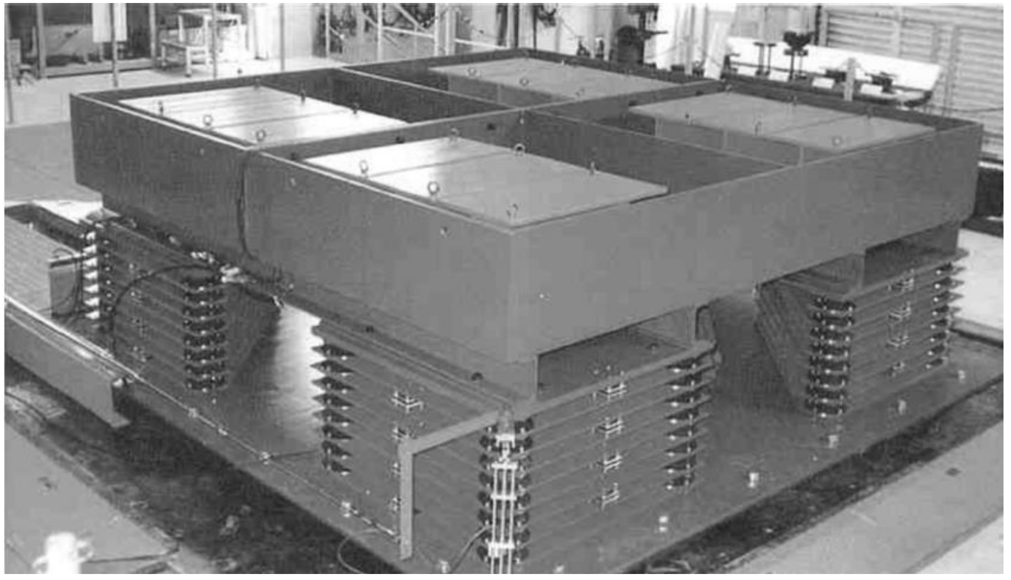
2 graden van vrijheid

Toepassing: Tuned mass damper



Bron: J.Connor, Huis ten Bosch tower, Nagasaki

Dank voor uw aandacht

Vragen, bespreking, discussie

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