Principles of sonar

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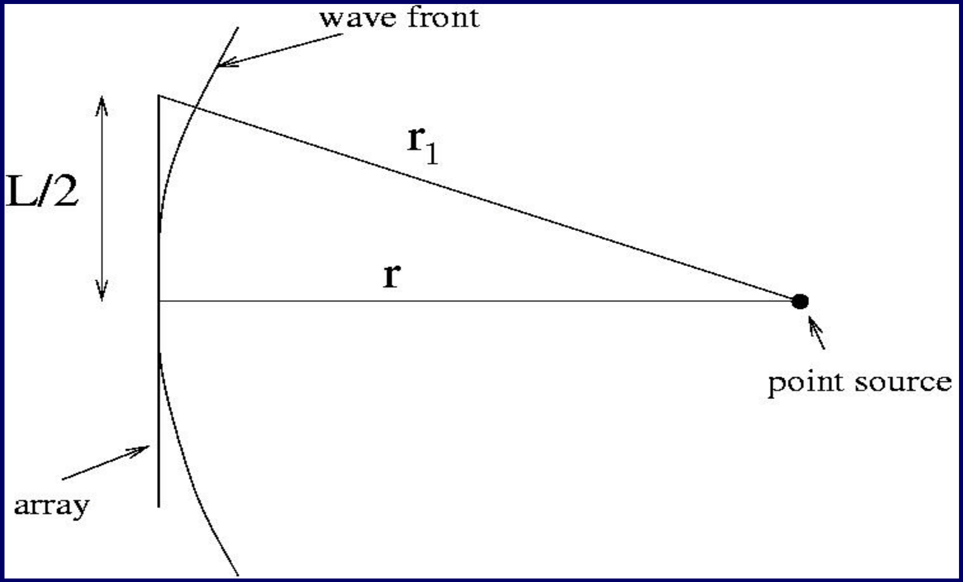
Delft Institute of Earth Observation and Space Systems

Delft University of Technology

The near and far field



$$(L/2)^2 + r^2 = r_1^2$$

$$r_1 - r = \frac{r_1^2 - r^2}{r_1 + r} = \frac{(L/2)^2}{r_1 + r} \approx \frac{L^2}{8r}$$

Fresnel or Rayleigh range

$r_1 - r = \lambda/8$

$$\frac{\lambda}{8} = \frac{L^2}{8r_F} \longrightarrow r_F = \frac{L^2}{\lambda}$$

Far field: Fraunhofer zone

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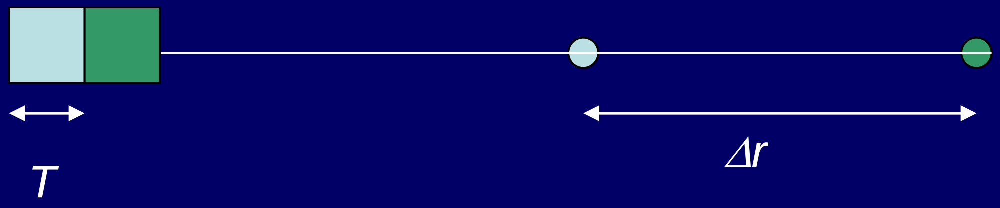
Range resolution

CW pulse $$\Delta r = \frac{cT}{2}$$



Disadvantage of CW pulses: if more power is required:
longer pulses: decrease of resolution

Range resolution

To overcome the problems of CW signals, use is made of FM signals

Matched filtering results in an effective duration of the pulse of $T = \frac{1}{B}$

$$\Delta r = \frac{c}{2B}$$

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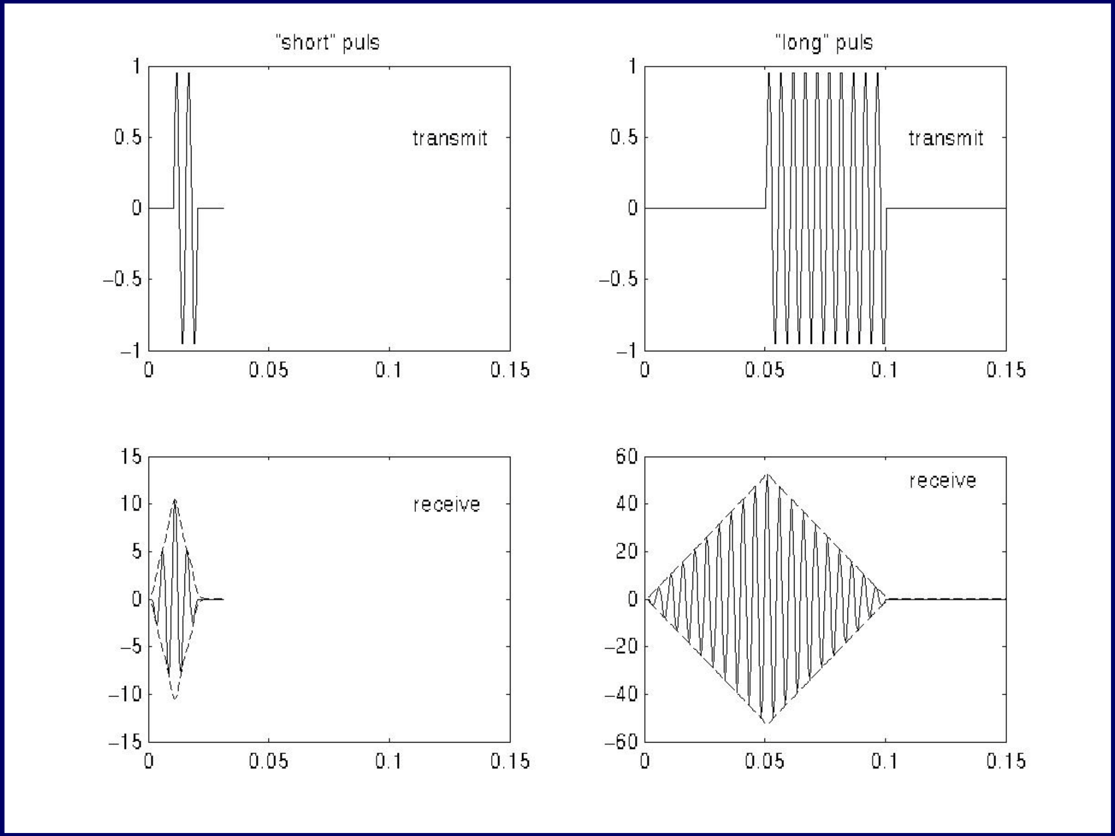
Range resolution
Example



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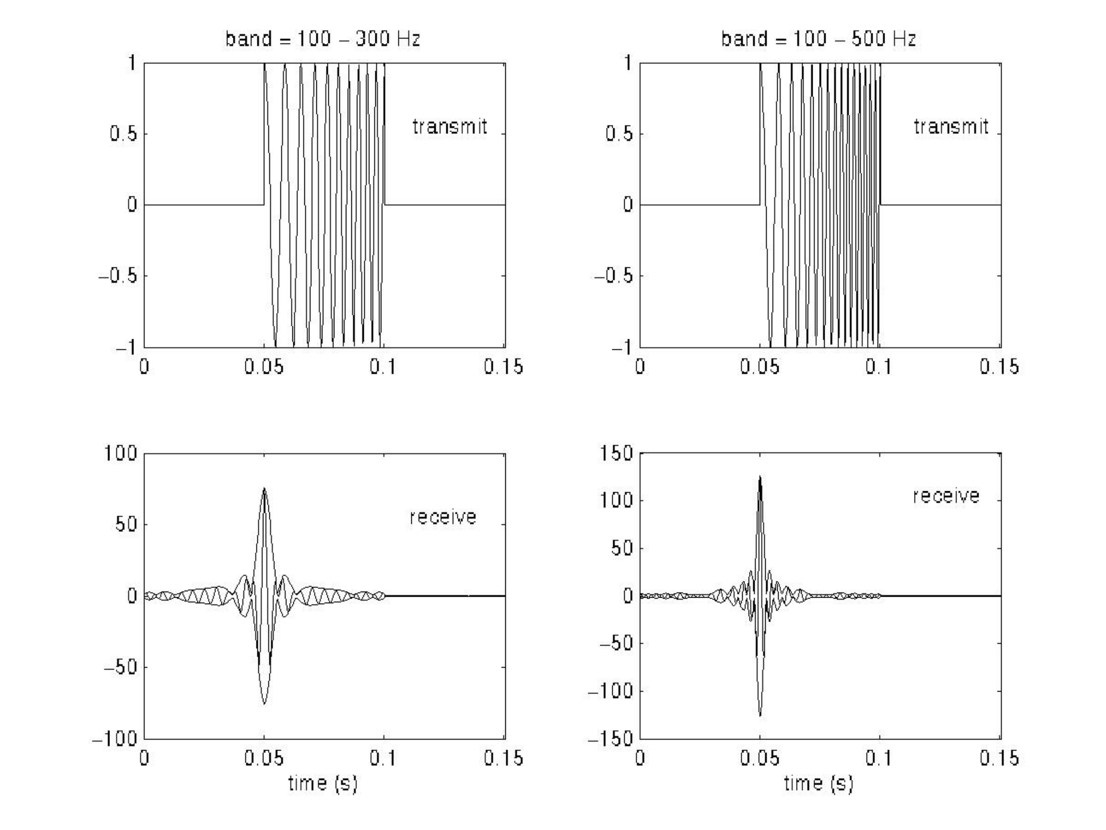
Range resolution
Example

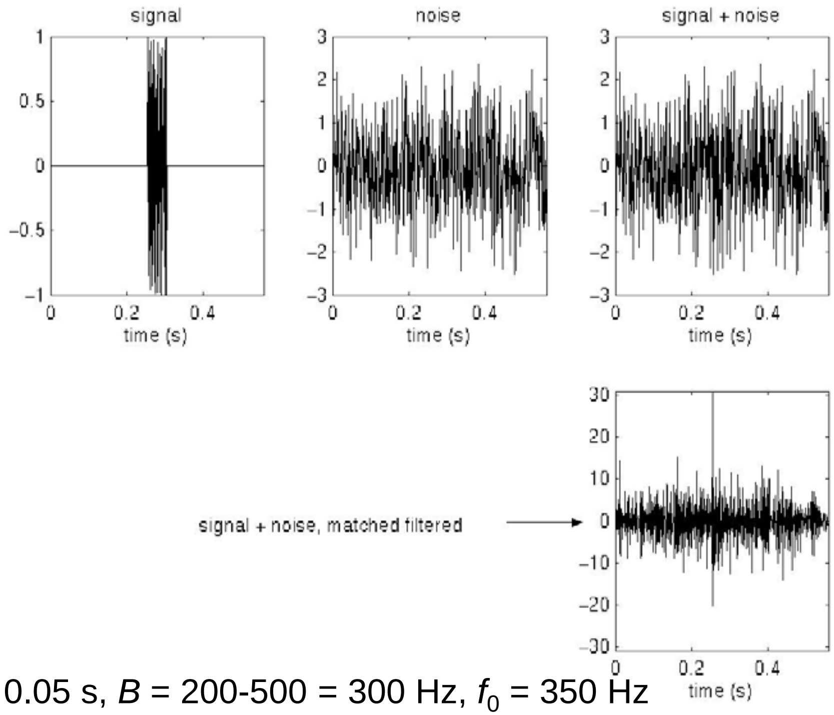


FM sweep (T = 0.05 s,; f_0 = 250 Hz, B = 200 Hz (left plots) and f_0 = 300 Hz, B = 400 Hz (right plots)).

$$\Delta r = \frac{c}{2B} = \frac{1500}{2x200} \approx 4\text{m}$$

$$\Delta r = \frac{c}{2B} = \frac{1500}{2x400} \approx 2\text{m}$$

Range resolution
Example

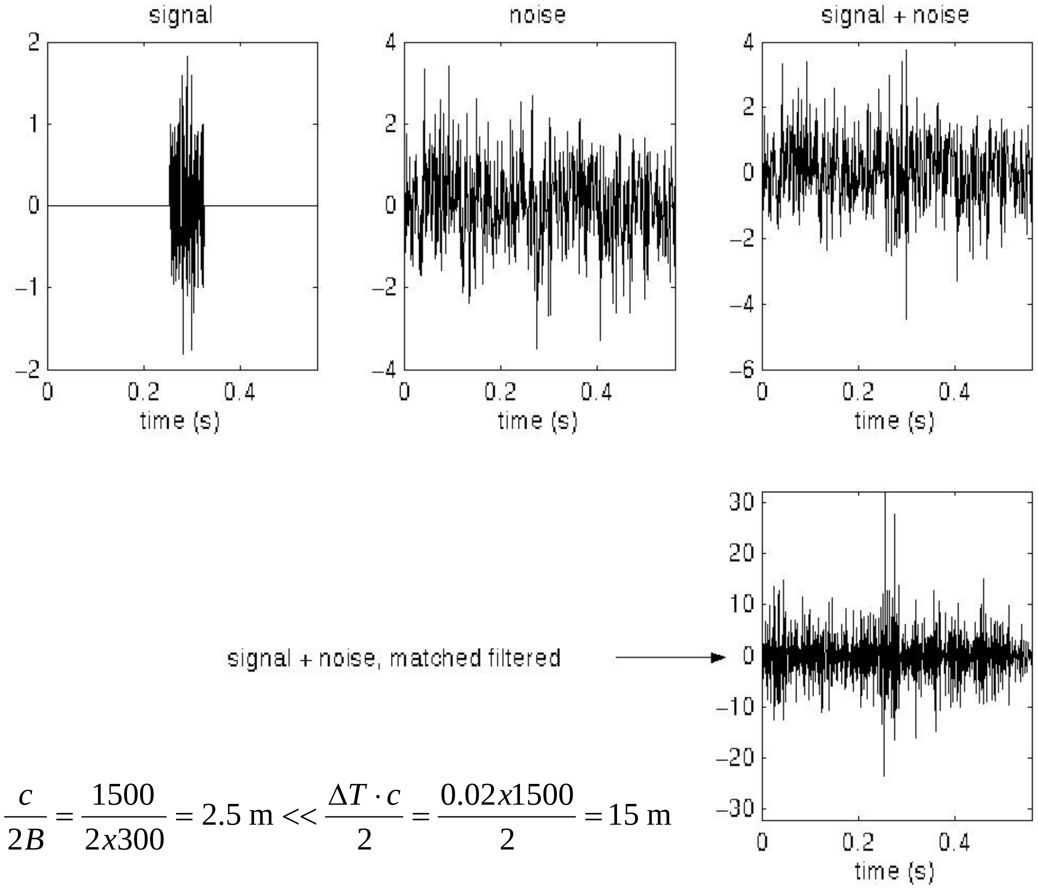


T = 0.05 s, B = 200-500 = 300 Hz, f_0 = 350 Hz

Matched filter: gain in SNR: $2BT$ = 2x300x0.05=30.

Range resolution
Example

Two FM signals, separated in time by 0.02 sec, pulse length of 0.05 sec



$$\Delta r = \frac{c}{2B} = \frac{1500}{2x300} = 2.5\text{ m} << \frac{\Delta T \cdot c}{2} = \frac{0.02x1500}{2} = 15\text{ m}$$

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Source level

The intensity of the radiated sound at 1 m distance from the source, relative to the intensity of a plane wave with a 1 μPa rms pressure

$$SL = 10^{10}\log\frac{p_{rms}{}^2}{10^{-12}} = 120 + 10^{10}\log p_{rms}(1)^2$$

$$I(r) = \frac{p_{rms}(r)^2}{\rho c}$$

P is the radiated acoustic power (Watt)

$$4\pi/(\rho c) = 4\pi/(1000*1500) = 8.38x10^{-6}$$

For an omni-directional sound source:

$$P = 4\pi r^2 I(r) = 8.38\cdot 10^{-6}\, p_{rms}{}^2(1)$$

$$10^{10}\log P = -50.8 + 10^{10}\log p_{rms}{}^2(1)$$

$$SL = 10^{10}\log P + 50.8 + 120 = 10^{10}\log P + 170.8$$

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Source Level

Typically 20-80 %.
Broadband sonars have lower *E*

Efficiency of the projector: $\boxed{E = \frac{P}{P_e}}$

with P_e the electrical power provided to the projector

Now:

$$SL = 170.8 + 10\,{}^{10}\log P_e + 10\,{}^{10}\log E$$

Or for a directional sound source:

$$SL = 170.8 + 10\,{}^{10}\log P_e + 10\,{}^{10}\log E + DI$$

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