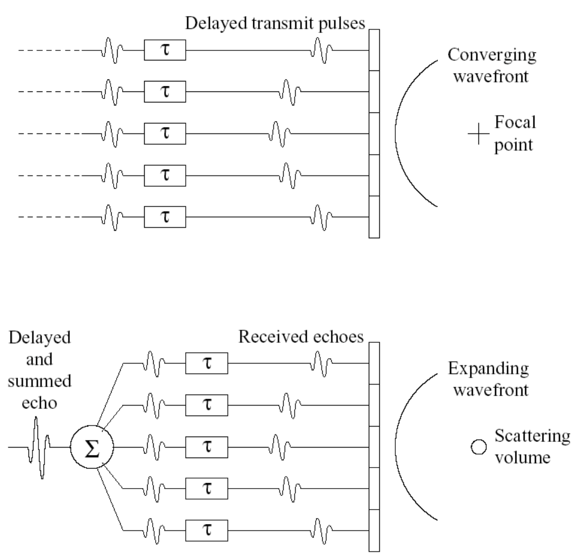
Bioengineering 280A
Principles of Biomedical Imaging

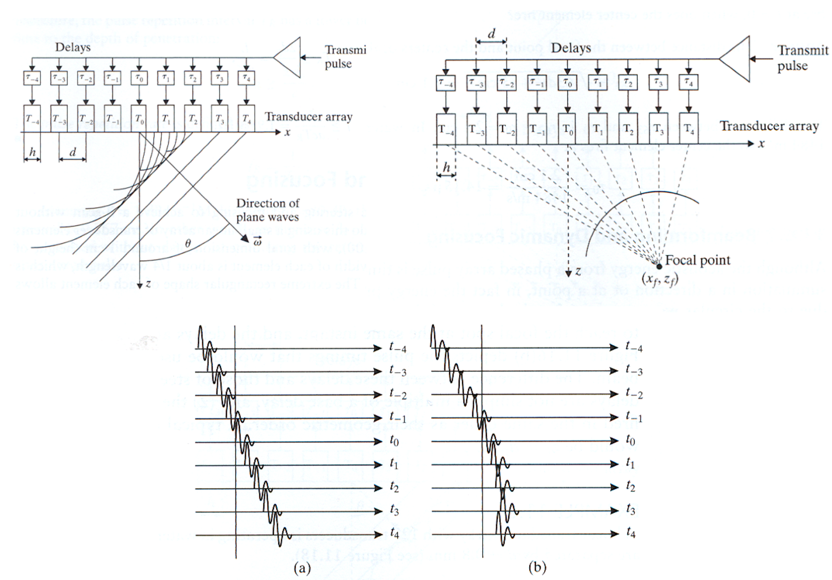
Fall Quarter 2006
Ultrasound Lecture 3

Focusing with Phased Array



Anderson and Trahey 2000

Focusing and Steering



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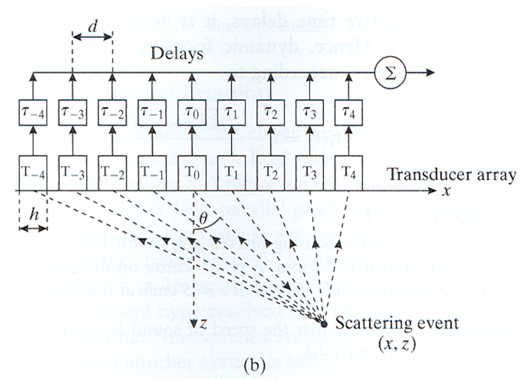
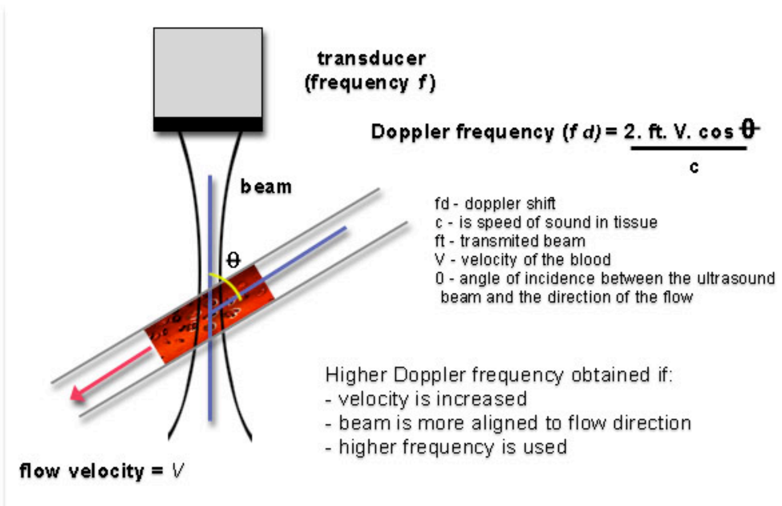
Prince and Links 2005

Dynamic Focusing



Prince and Links 2005

Doppler Effect



http://www.centrus.com.br/DiplomaFMF/SeriesFMF/doppler/capitulos-html/chapter_01.htm

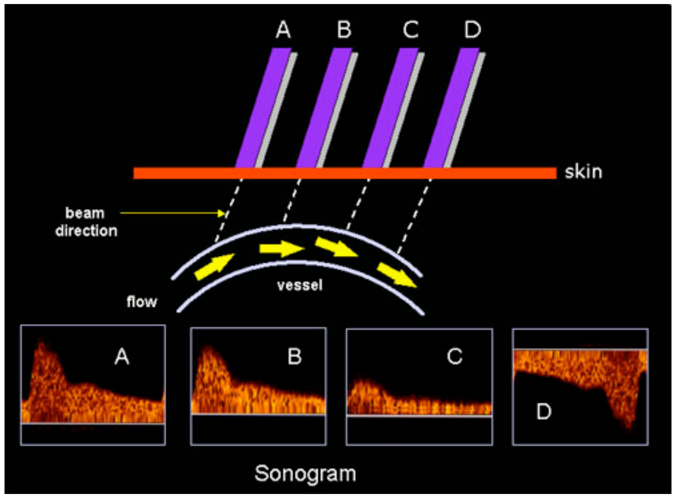
Doppler Effect

$$\Delta f = \frac{2vf_0}{c-v} \approx \frac{2vf_0}{c}$$

Example
$v = 50$ cm/s
c = 1500 m/s
f0 = 5 MHz

$$\frac{2vf_0}{c} = 3333\ Hz$$

Doppler



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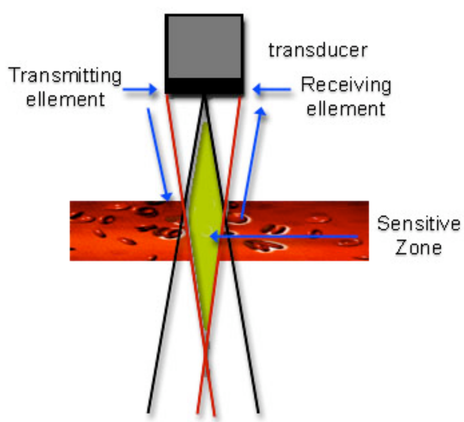
CW Doppler



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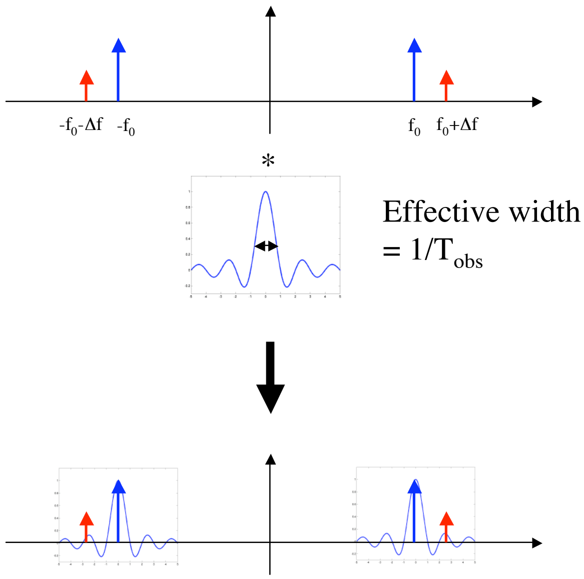
CW Doppler



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CW Doppler

Resolution $\Delta f = 1/T_{obs}$

$$\Delta v = \frac{c\Delta f}{2f_0} = \frac{c}{2T_{obs}f_0}$$

Example
Design goal: $\Delta v = 5\ cm/s;\ f_0 = 5\ MHz$

$$T_{obs} = \frac{c}{2\Delta v f_0} = \frac{1500 m/s}{2(0.05 m/s)(5\times 10^6)} = 3ms$$

Note that for a depth of 15 cm, it takes only 200 usec for echos to return.

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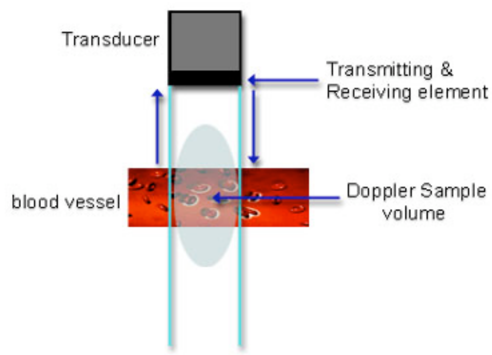
PW Doppler



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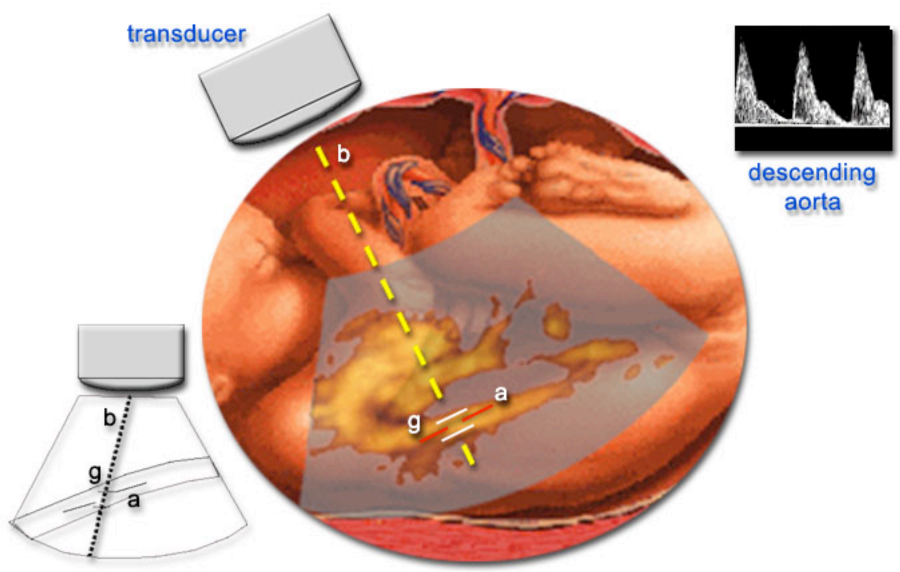
PW Doppler



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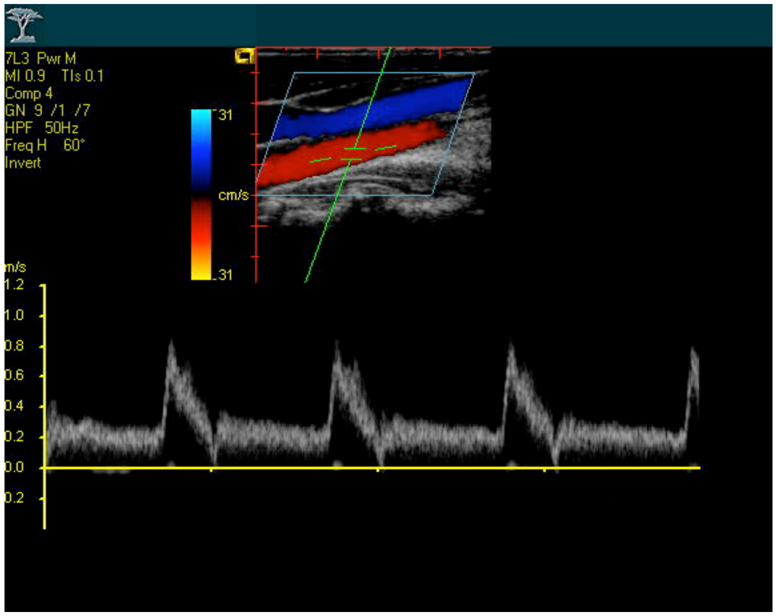


Siemens Medical Systems; jnormal common carotid artery

Aliasing

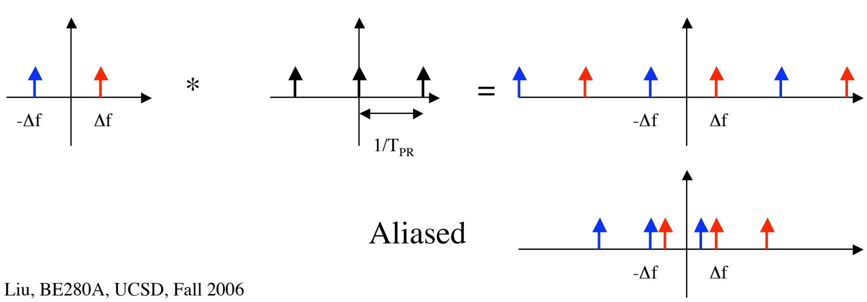
Measure Doppler shifts at a specified range

For unambiguous range, one pulse at a time.

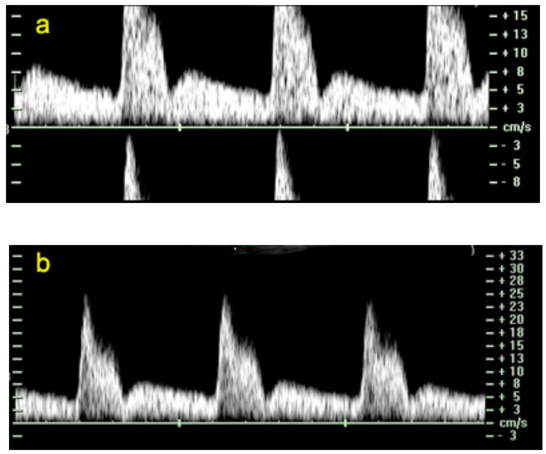
$T_{PR} = \frac{2r_{max}}{c}$ (e.g. 200 usec for 15 cm depth)

To avoid aliasing require

$$\frac{1}{T_{PR}} > 2\Delta f_{max}$$



Aliasing



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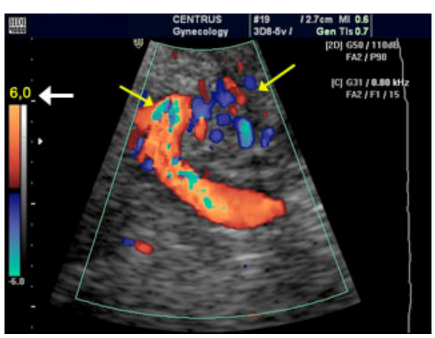
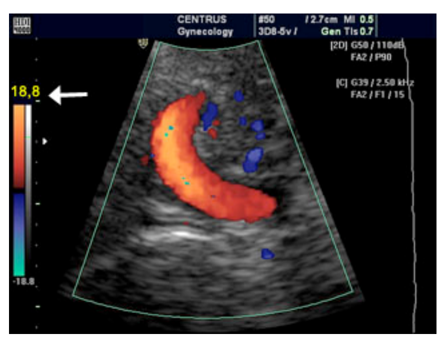
Aliasing





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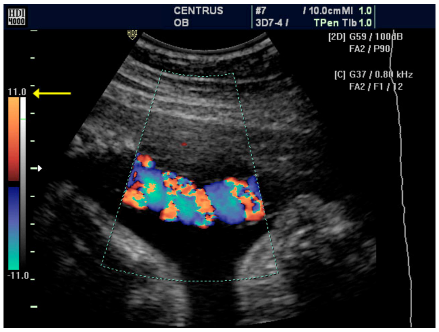
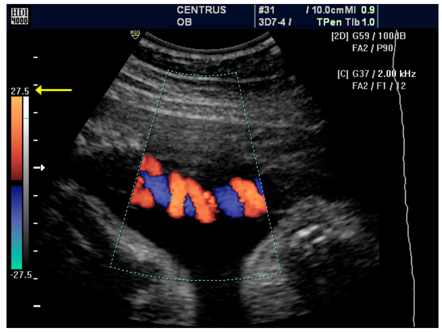
Aliasing





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PW Doppler

Velocity Resolution (same as with CW)

$$T_{obs} > \frac{1}{\Delta f} = \frac{c}{2\Delta v f_0}$$

Range Resolution

Want to interrogate velocities from a small region $\Delta z = \frac{cT_{pulse}}{2}$

We also need to make sure that particles remain within this region over the observation time T_{obs}

$$v_{\max} T_{obs} < \Delta z \Rightarrow T_{obs} < \frac{\Delta z}{v_{\max}} = \frac{cT_{pulse}}{2v_{\max}}$$

PW Doppler

Design Example

$R_{max} = 6\text{ cm} \Rightarrow \quad T_{PR} = \frac{2(0.06m)}{1500m/s} = 80\ \mu\text{sec}$

$\frac{1}{T_{PR}} > 2\Delta f_{max} = \frac{4v_{max}f_0}{c}$

$\frac{c}{4T_{PR}f_0} > v_{max} \Rightarrow$ for $f_0 = 5MHz$ we find that $v_{max} < 93.75cm/s$

If we choose $\Delta v = 1cm/s$ then $T_{obs} = \frac{c}{2\Delta v_{max} f_0} = 15ms$

Range resolution: $\Delta z > v_{max}T_{obs} = 1.4cm$

$T_{pulse} = \frac{2\Delta z}{c} = 18.8u\text{sec}$