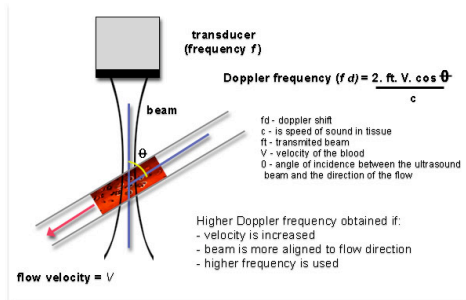


Bioengineering 280A
Principles of Biomedical Imaging

Fall Quarter 2005
Ultrasound Lecture 3

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Doppler Effect



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Doppler Effect

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

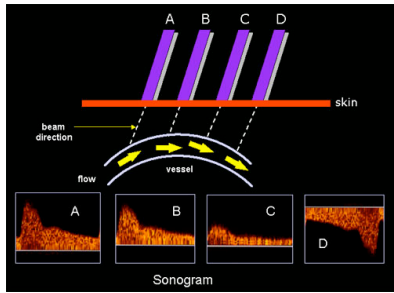
Example

$v = 50 \text{ cm/s}$
 $c = 1500 \text{ m/s}$
 $f_0 = 5 \text{ MHz}$

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

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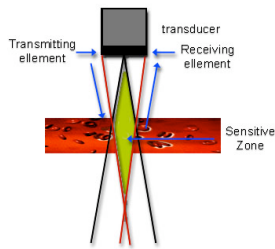
Doppler



http://www.centrus.com.br/DiplomaFMF/SeriesFMF/doppler/capitulo.html#chapter_01.htm

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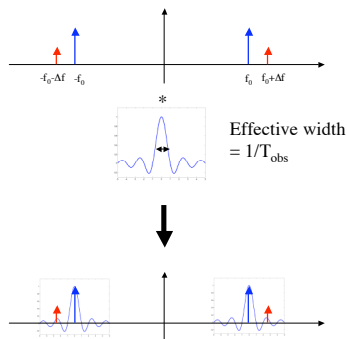
CW Doppler



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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

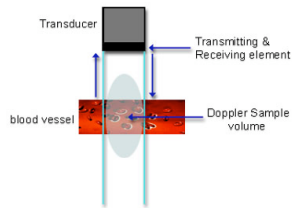
Design goal: $\Delta v = 5 \text{ cm/s}$; $f_0 = 5 \text{ MHz}$

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

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

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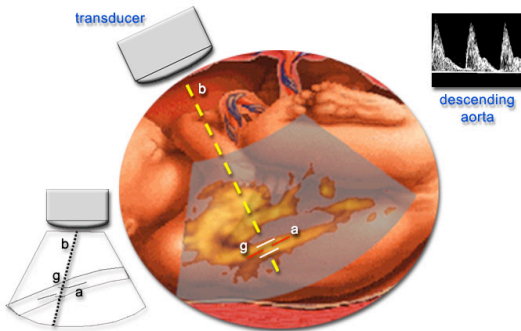
PW Doppler



http://www.centrus.com.br/DiplomaFMF/SerieFMF/doppler/capitulo.html#chapter_01.htm

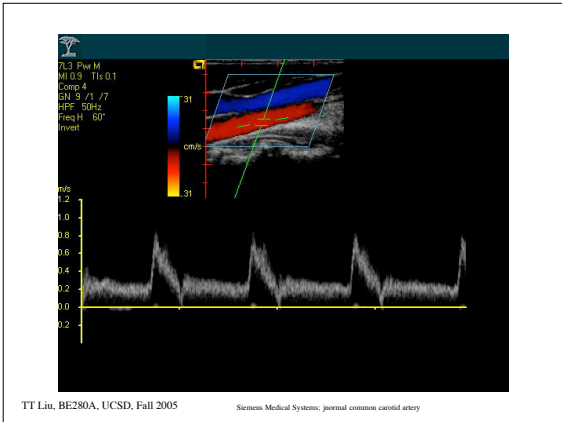
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PW Doppler



http://www.centrus.com.br/DiplomaFMF/SerieFMF/doppler/capitulo.html#chapter_01.htm

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Aliasing

Measure Doppler shifts at a specified range
For unambiguous range, one pulse at a time.

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

To avoid aliasing require

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

Aliased

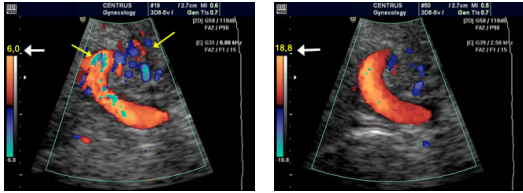
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Aliasing

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

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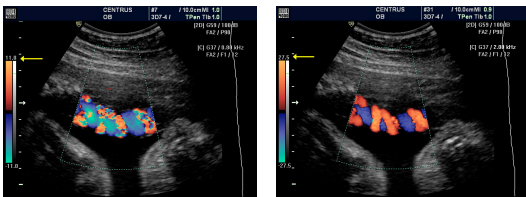
Aliasing



http://www.centrus.com.br/DiplomaFMF/SeriesFMF/doppler/capitulo.html#chapter_01.htm

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Aliasing



http://www.centrus.com.br/DiplomaFMF/SeriesFMF/doppler/capitulo.html#chapter_01.htm

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PW Doppler

Velocity Resolution (same as with CW)

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

Range Resolution

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

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

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

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PW Doppler

Design Example

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

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

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

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

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

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

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