Chapter 10: Exposimetry

Introduction

- Safety regulations.
- Physical parameters vs. Bio-effects.
- Measurement techniques.
- Dose: Energy absorption in tissue.
  - Temperature rise, cell damage.
  - Dosimetry: measurements of such effects.
- Exposure: Characteristics of ultrasound field.
  - Pressure, intensity, power.
  - Exposimetry: measurements of temporal/spatial characterisitics.

Field Parameters

- Acoustic power:
  - Emitted acoustic energy per second.
  - Instantaneous vs. average.
  - Pulse average vs. temporal average.
  - Spatial peak.
  - Measured by hydrophone, force balance and thermal techniques.

Field Parameters

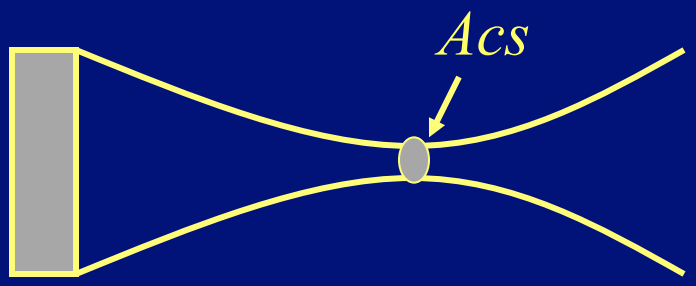
- Pulse repetition frequency (PRF).
- Scan Repetition frequency (SRF).
- Duty factor: Pulse duration/PRI.

PRF=1/PRI

SRF=PRF/N_{lines}=Frame Rate

Field Parameters

- Beam cross-sectional area (A_{cs}, -6 dB).
- Intensity *I(x, y, t)*: instantaneous power per unit area.



Field Parameters

- Temporal average intensity:

$$I_{TA}(x,y) = \frac{1}{T_{rep}} \int_{T_{rep}} I(t,x,y)\,dt$$

- Spatial peak-temporal average intensity:

$$I_{SPTA} = \max_{x,y} \left| I_{TA}(x,y) \right|$$

Field Parameters

- Spatial average-temporal average intensity:

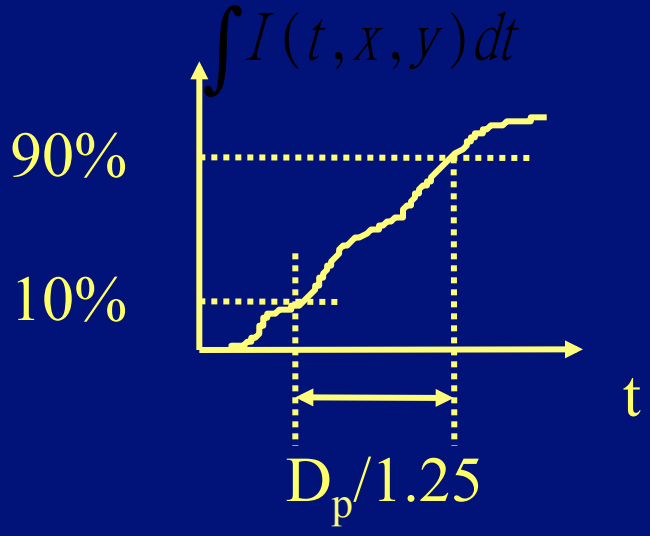
$$I_{SATA} = \frac{1}{A_{cs}} \int_{A_{cs}} I_{TA}(x, y)\, dA$$

- Spatial peak-temporal peak intensity:

$$I_{SPTP} = \max_{t, x, y} \left| I(t, x, y) \right|$$

Field Parameters

- Spatial peak-pulse average intensity:



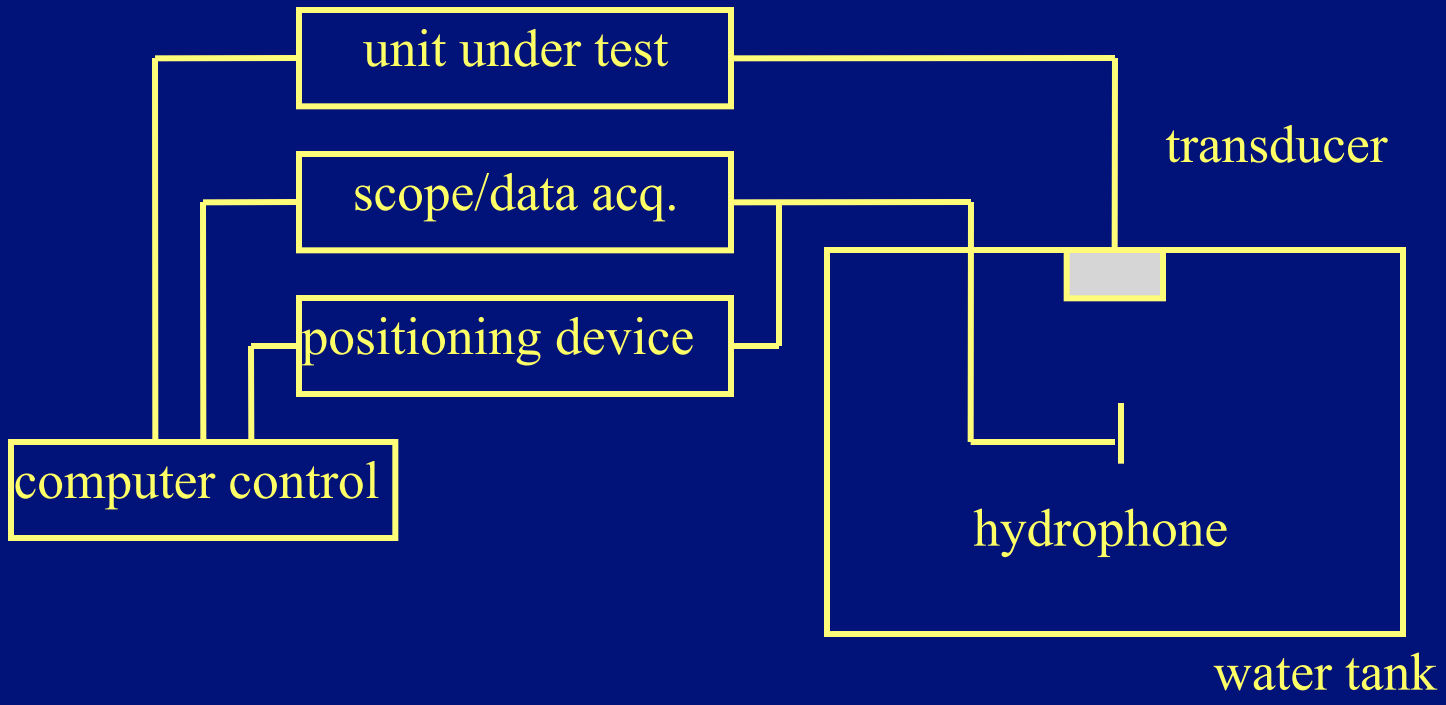
$$I_{SPPA} = \max_{x,y}\left(\frac{1.25}{D_p}\int_{t_{10\%}}^{t_{90\%}} I(t,x,y)\,dt\right)$$

$$I_{SPTA} \approx \frac{D_p}{T_{rep}} I_{SPPA}$$

Intensity Measurements

- Hydrophone, force balance, thermal methods.
- PVDF.
- Needle and membrane.
- Calibration:
  - Known pressure field.
  - Broadband response. $v(f)/p(x,y,f)$
  - Linearity.
  - Propagation non-linearity: temporal average.

Hydrophone Measurements



Bio-Effects

- Temperature rise and cell damage (cavitation).
- FDA Track I: Pre-amendments.
  - I_{SPTA} (720 mW/cm^2) and I_{SPPA} (190 W/cm^2).
  - Derated by 0.3 dB/cm/MHz.
- FDA Track III:
  - TI (Thermal Index) and MI (Mechanical Index).
- ALARA (as low as reasonably achievable).

Bio-Effects

- Thermal index (TI):
  - TIS, TIB, TIC.
  - Analytical.

$$TI \equiv \frac{W_o}{W_{\deg}}$$

- Mechanical Index (MI):
  - Experimental.
  - Destruction of bubble with different sizes at various frequencies.

$$MI \equiv \frac{P_{0.3}}{\sqrt{f_c}}$$

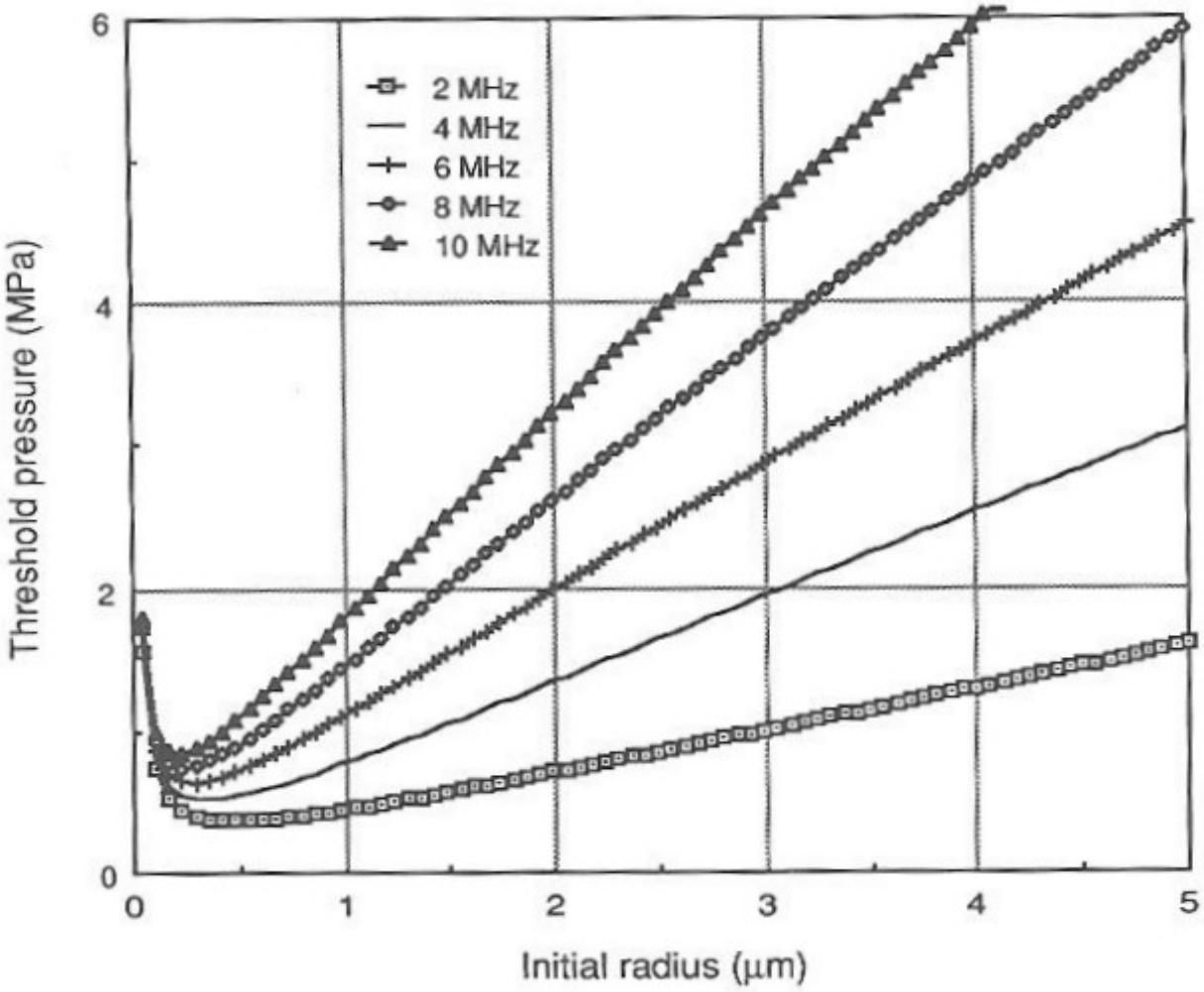


FIGURE 13. Variation of the cavitation pressure threshold with radii of cavitation nuclei and with the frequency of applied ultrasound. The range of nuclei sizes that may cavitate increases with decreasing frequency. Similarly, the minimum pressure threshold decreases with decreasing frequency. At extremely low frequencies, the curve decreases to that associated with the Blake pressure. (After Apfel, R. E., *J. Acoust. Soc. Am.*, 69(6), 1624, 1981.)

Bio-Effects

- Tissue dependent.
- Complicated, requires more studies.
- ALARA is always important.