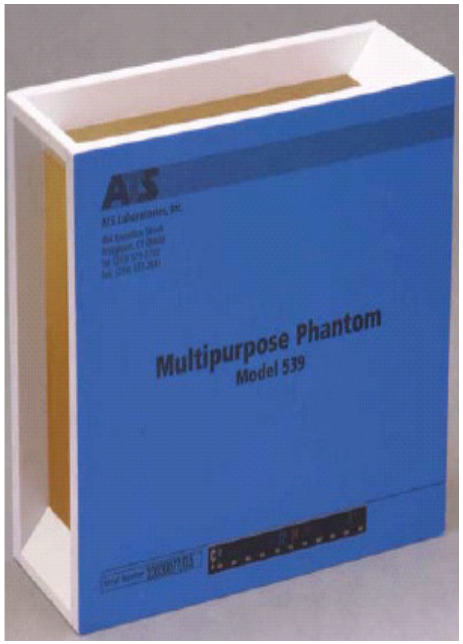

# 2012 :15th SESSION of ESMP

**Lecture presented in Archamps (Salève Building) by :**

**Jean-Martial MARI (INSERM Lyon)**

# Quality Assurance in Medical Ultrasound

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# Overview

- Introduction.
- Test objects
- Quality assurance
  - Imaging
  - Doppler velocity
  - HIFU
- Conclusions

# Introduction: backgrounds of QA

- The AIUM "100 mm" test object and recommended procedures for its use
  (Am Inst Ultrasound Med, 1974)

- Pulse echo ultrasound imaging systems : performance tests and criteria
  (P. Carson, Am Inst Physics, 1977)

- Method of testing performance of pulse-echo diagnostic equipment
  (C. Hill, Int Electrotech Comm, IEC, 1977)

- Test procedures to determine the performance specifications of ultrasonic real-time equipment (IEC, 1990)

# Performance testing: GOALS

- Predicting performance in clinical applications
- Acceptance testing: imaging quality and manufacturers' specifications
- Monitoring of equipment during life cycle

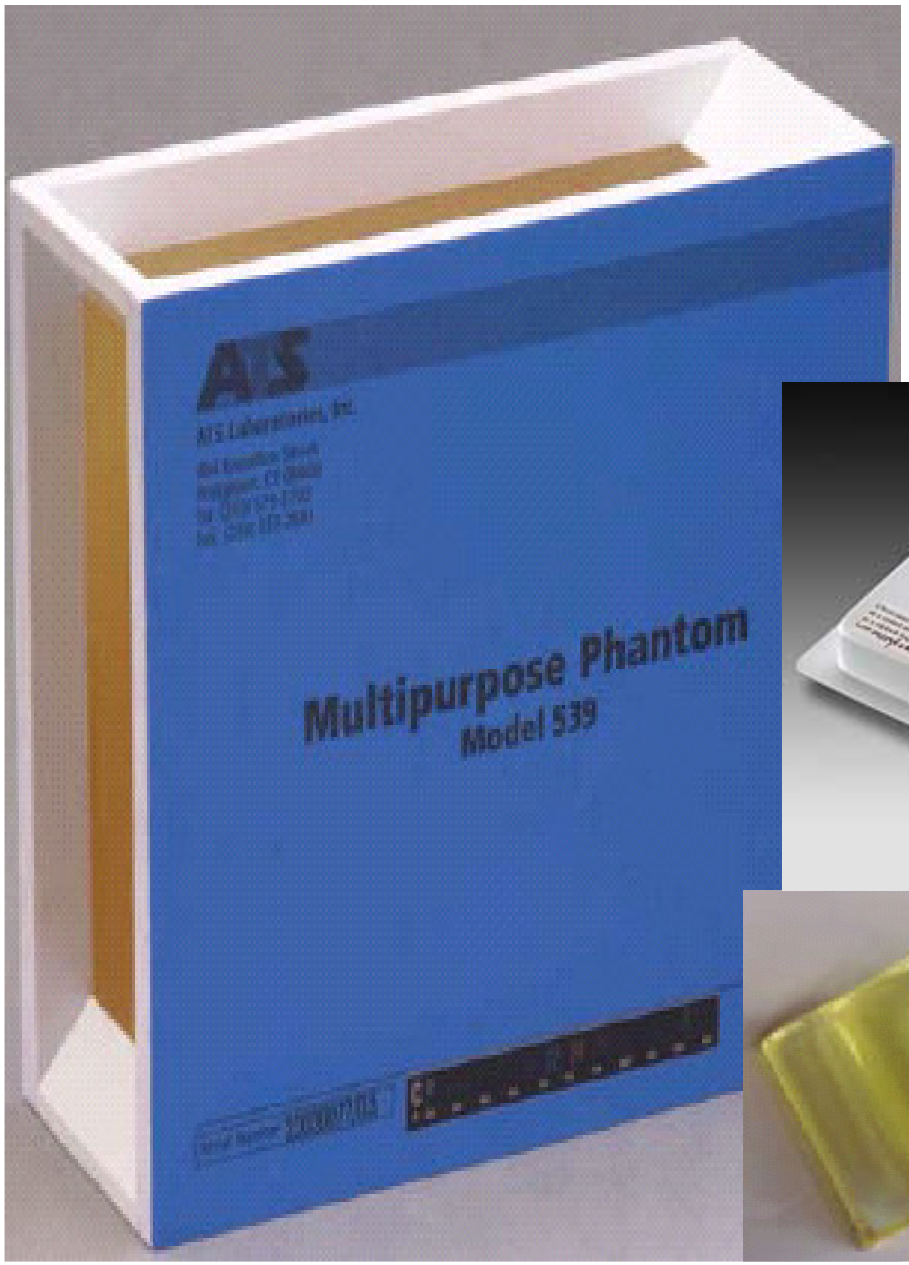
# Quality assurance procedure

- *Subjective - (observer + machine) of displayed images.*
- Objective - (measurement software) of stored images.

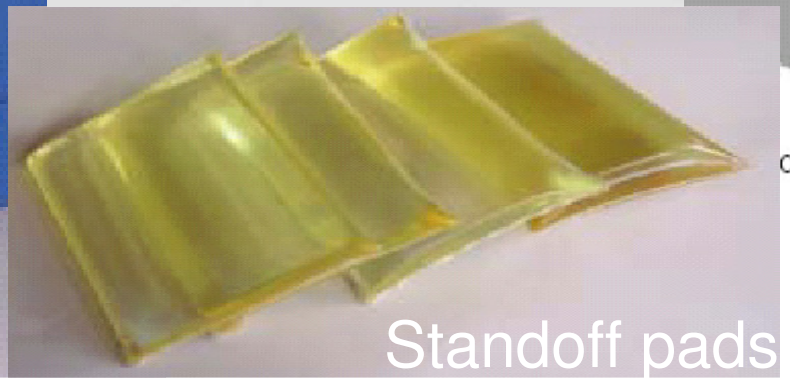
# Overview

- Introduction.
- Test objects ("tissue-mimicking phantoms")

# Tissue Mimicking Phantoms







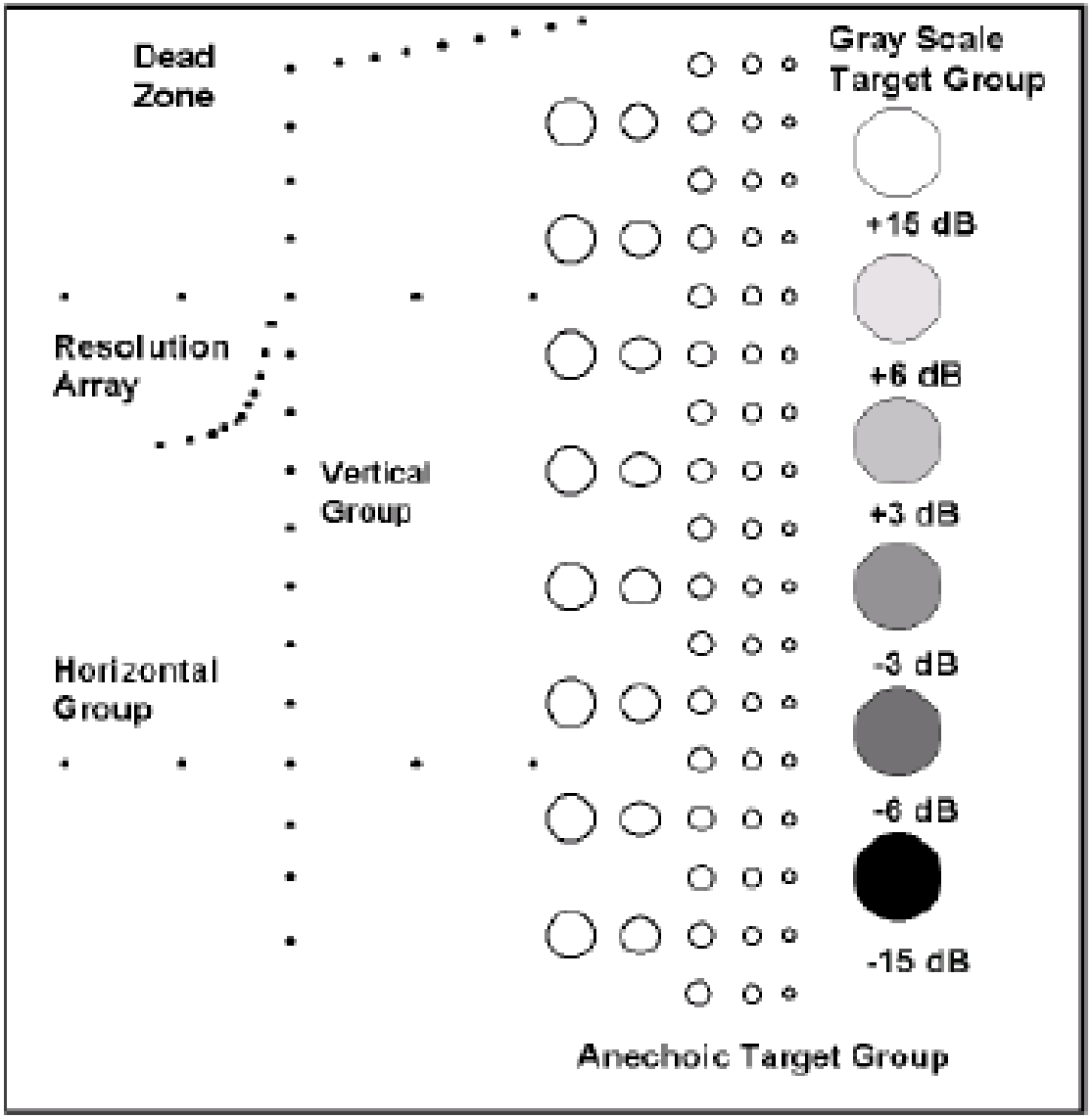
# Tissue-equivalent acoustical parameters

| Parameter | Symbol | Magnitude | Unit |
|---|---|---|---|
| Speed of sound | c | ≈ 1540 | [m/s] |
| Attenuation coëfficient | $\alpha$ | 0.3 to 0.5 | [dB/cm/MHz] |
| Backscattering | s | (1 to 4) $10^{-4}$ | [$m^{-1}.sr^{-1}$] |

# Manufacturers of TM Phantoms

| Manufacturer | Address | Web site |
|---|---|---|
| ATS Laboratories | Bridgeport, CT 06608, USA | www.atslaboratories.com |
| CIRS | Norfolk, VA 23513, USA | www.cirsinc.com |
| Diagnostic Sonar | Livingston, EH54 7BX, UK. | www.diagnosticsonar.com |
| Gammex RMI | Middleton, WI 535620327, USA | www.gammex.com |
| Nuclear Associates | Carle Place, NY 11514-1593, USA | www.flukebiomedical.com |
| Ohmic Inc. | Easton, MD 21601, USA | www.cweb5.com/ohmic |

# ATS phantom

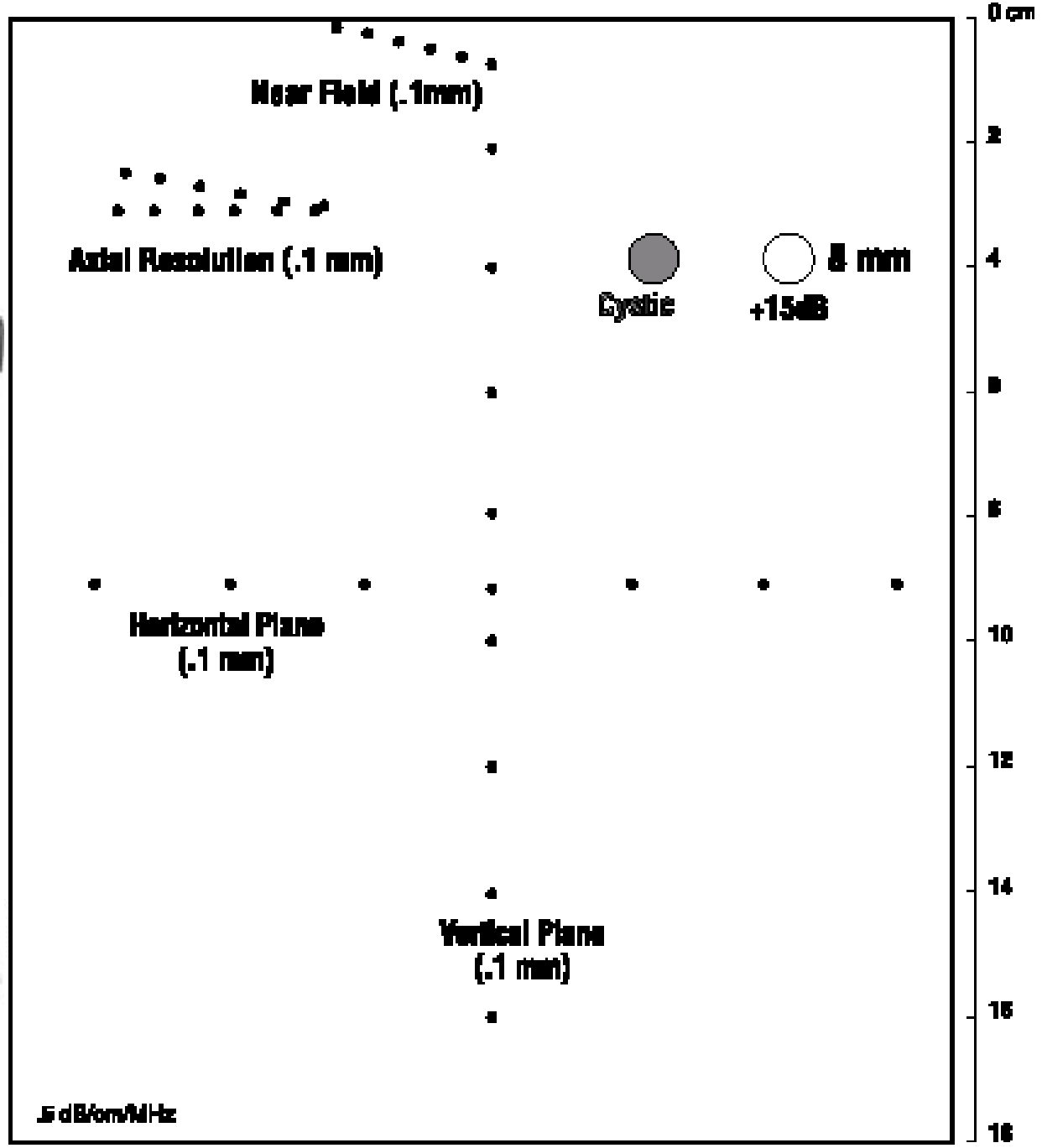

- Urethane rubber base material including
  - thin wires arranged in special patterns
  - Cylindrical objects of known scattering contrast

# CIRS ultrasound phantom


CIRS, model 054

Zerdine (polymer)

Nylon wire 0.1 mm



# Phantom typical prices

- General Purpose phantom : ~ 2000€
- Multi-tissues : ~ 3000 €
- Resolution phantom : ~ 5000 €

# Overview

- Introduction.
- Test objects.
- Quality assurance
    - Imaging

# Test Settings

The settings must be reproducible, i.e the read out numbers should be noted

Fixed:

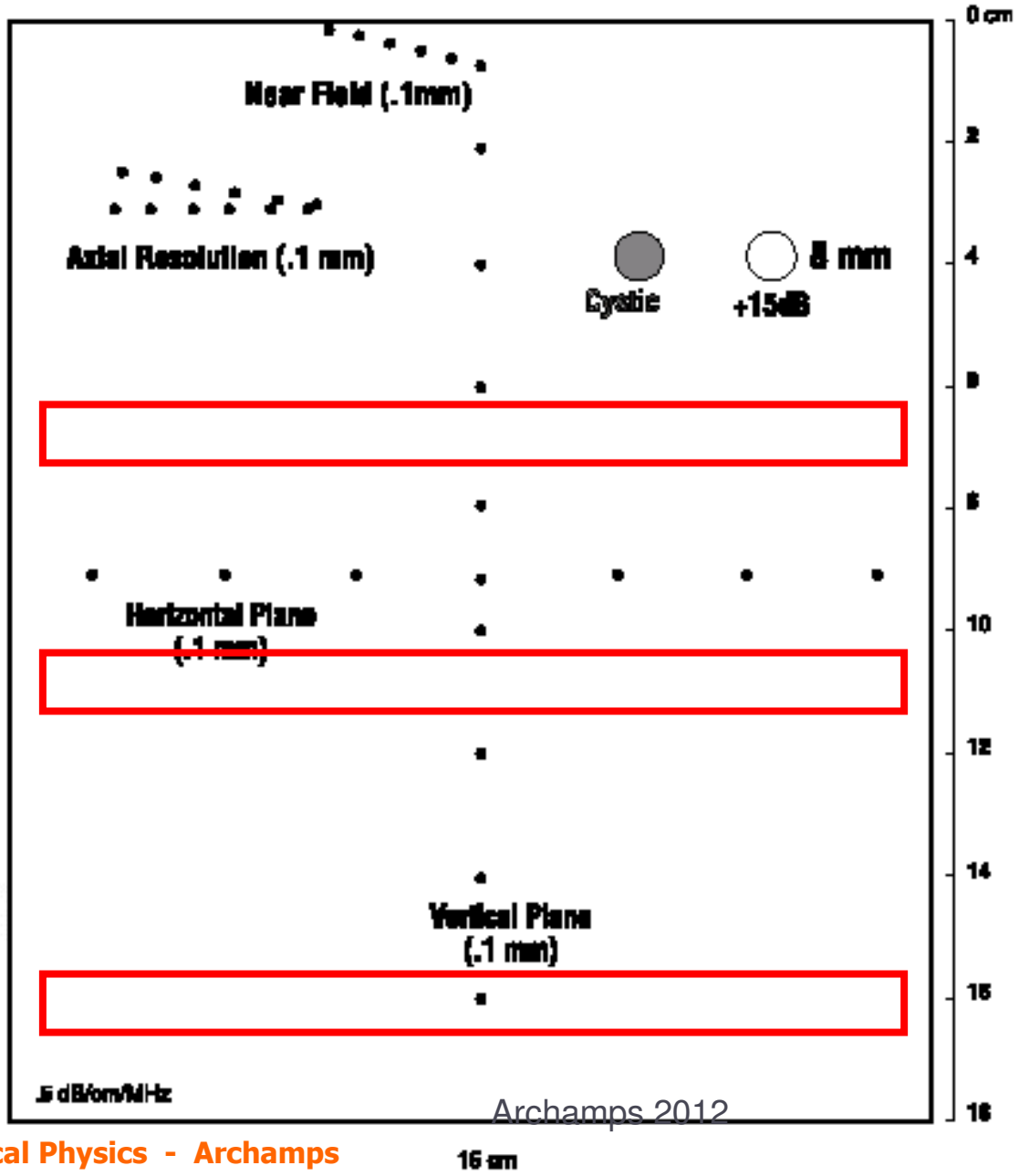
- (display: intensity, contrast, sharpness-optimal)
- post-processing curve: linear (i.e., log[echo] available!!)
- transmit focus at depth of elevation focus
- TGC settings: maximum depth of equal grey level.

# Uniformity

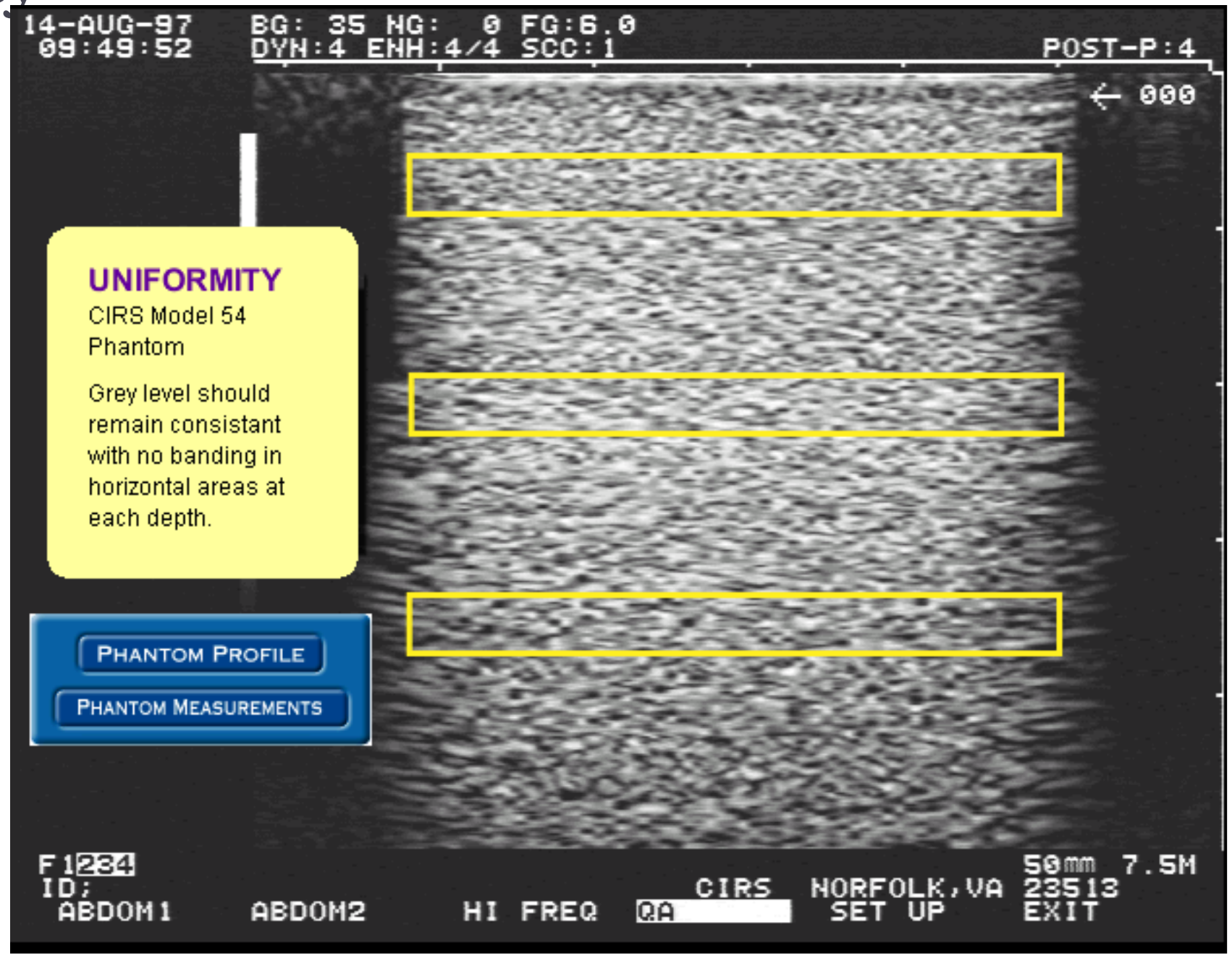
Grey level should remain consistant with no banding in horizontal areas at each depth

This test is used to detect dead piezoelectrique element.

(Note the existence of hand held detector devices)

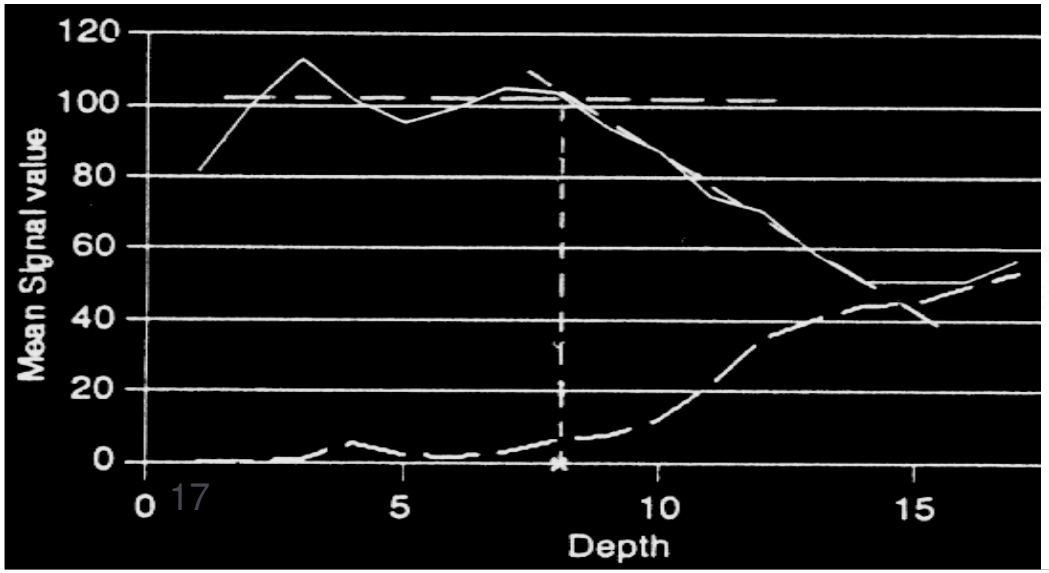


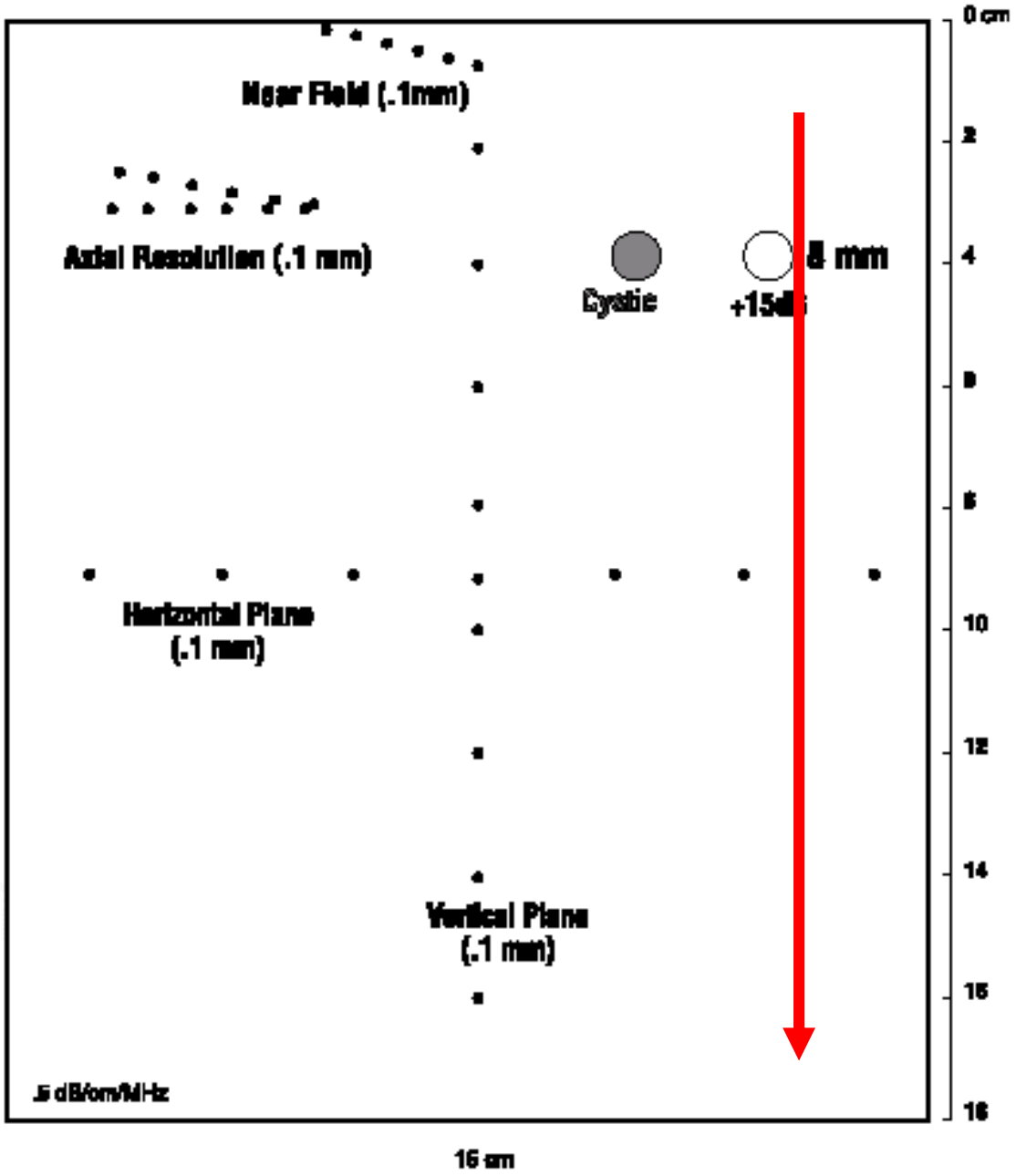
# Uniformity


14-AUG-97
09:49:52
BG: 35 NG: 0 FG:6.0
DYN:4 ENH:4/4 SCC:1
POST-P:4
000
UNIFORMITY
CIRS Model 54
Phantom
Grey level should remain consistant with no banding in horizontal areas at each depth.
PHANTOM PROFILE
PHANTOM MEASUREMENTS
F1234
ID;
ABDOM1
ABDOM2
HI FREQ
CIRS
QA
NORFOLK,VA
23513
SET UP
EXIT
50mm 7.5M

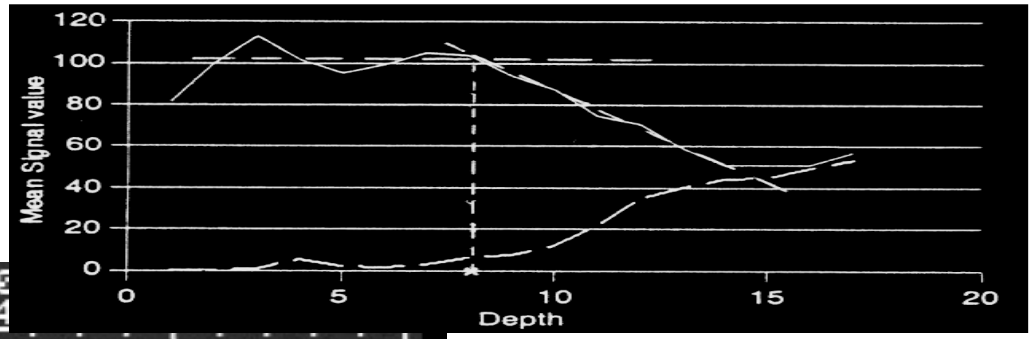
# Depth of penetration

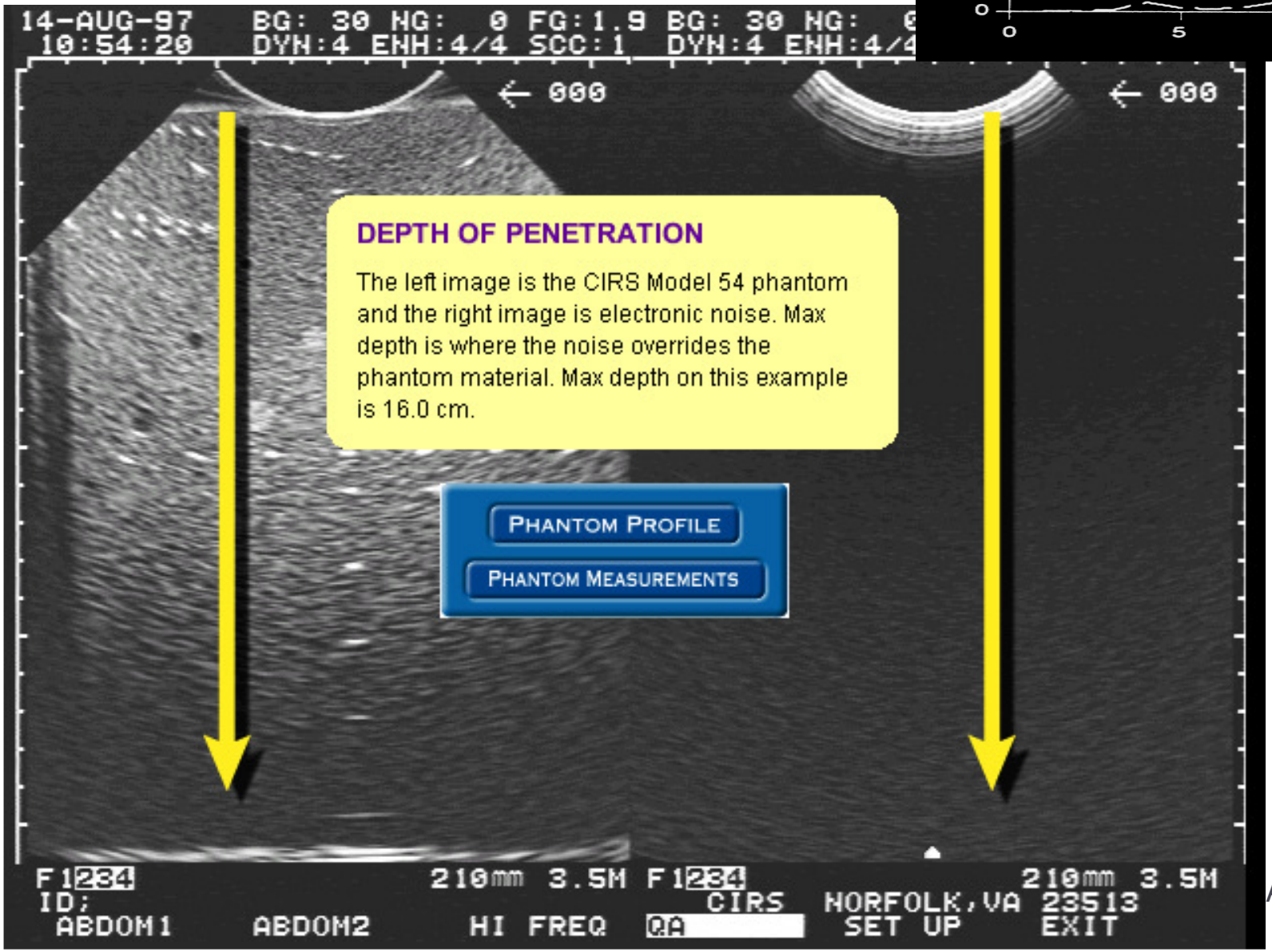
- Max depth is where the noise overrides the phantom material



# Depth of penetration

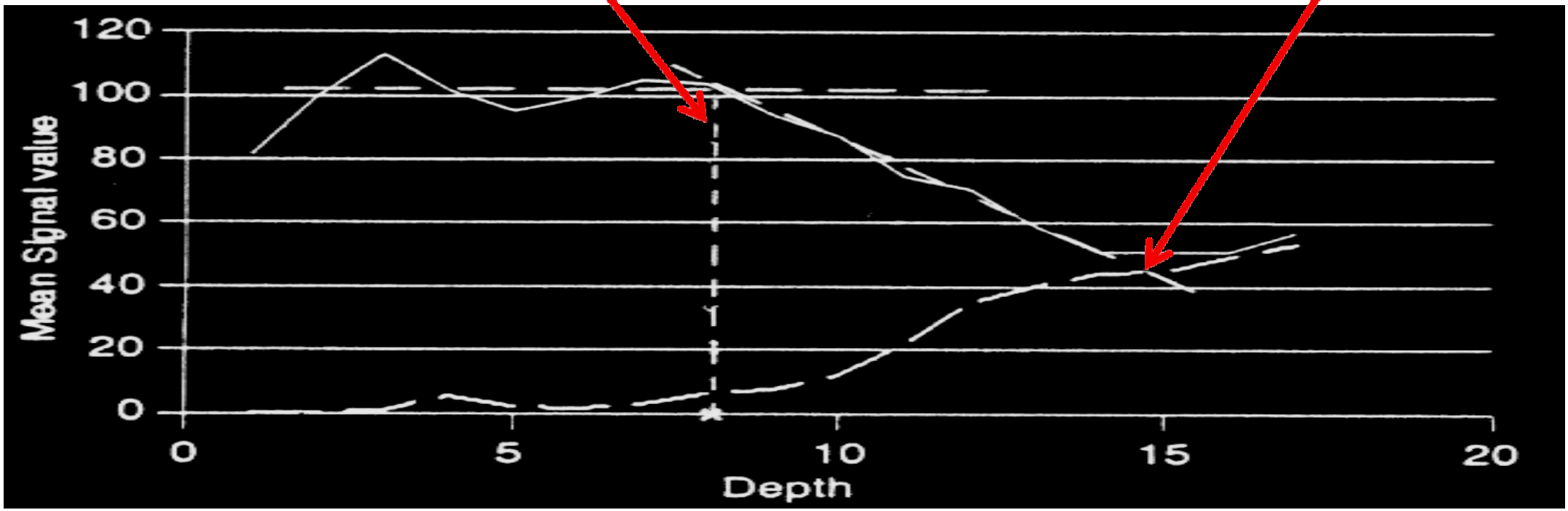


# Depth of Penetration

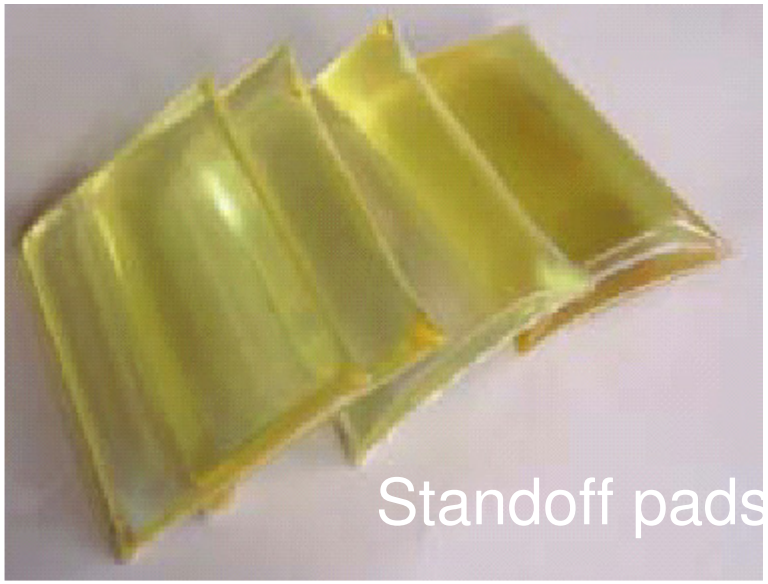
Equivalent to "Sensitivity" of equipment / transducer combination.

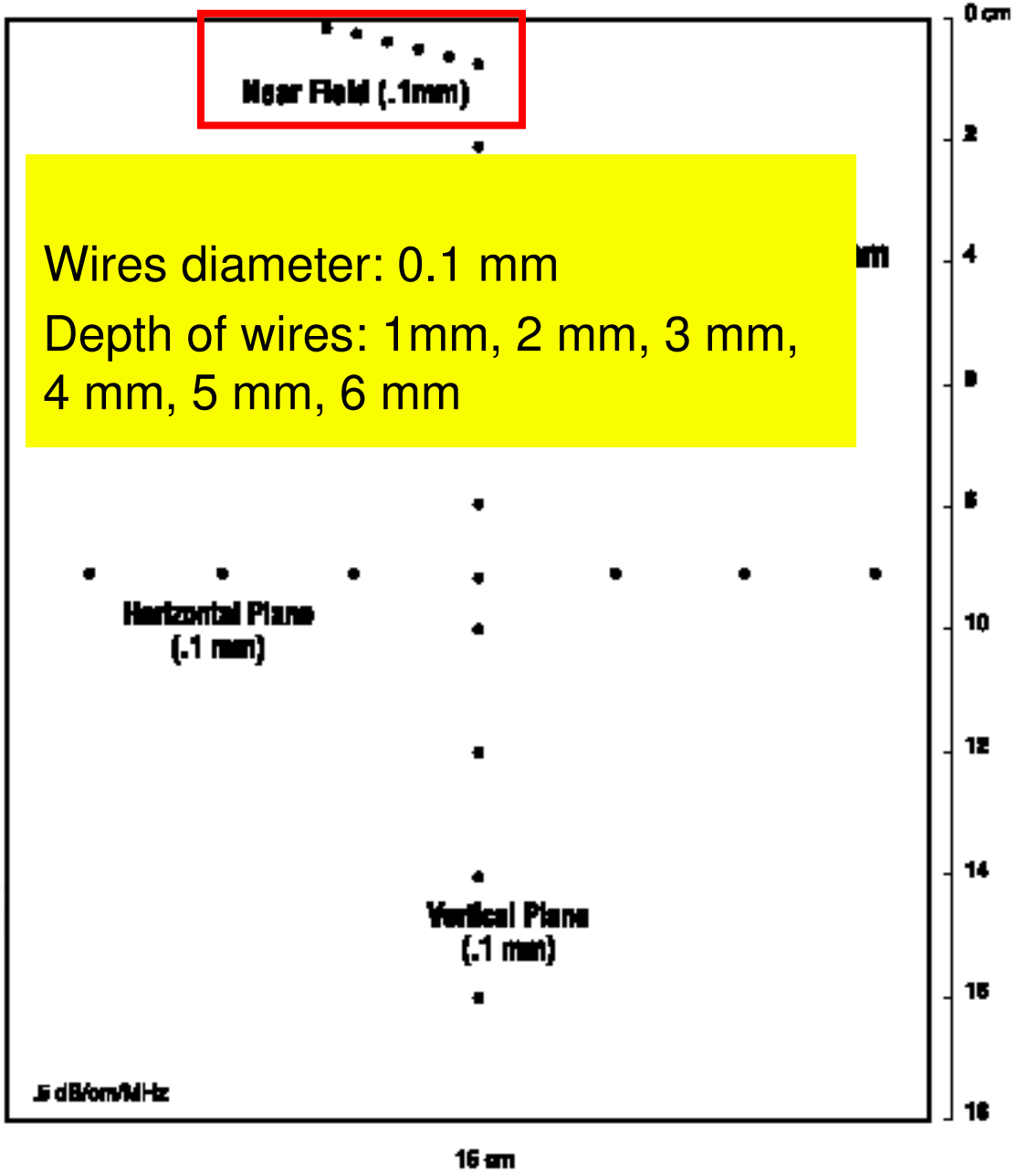
- Depth at which grey level asymptotically starts decreasing (linear curve fitting)
- Depth at which speckle grey level merges with (electronic) noise



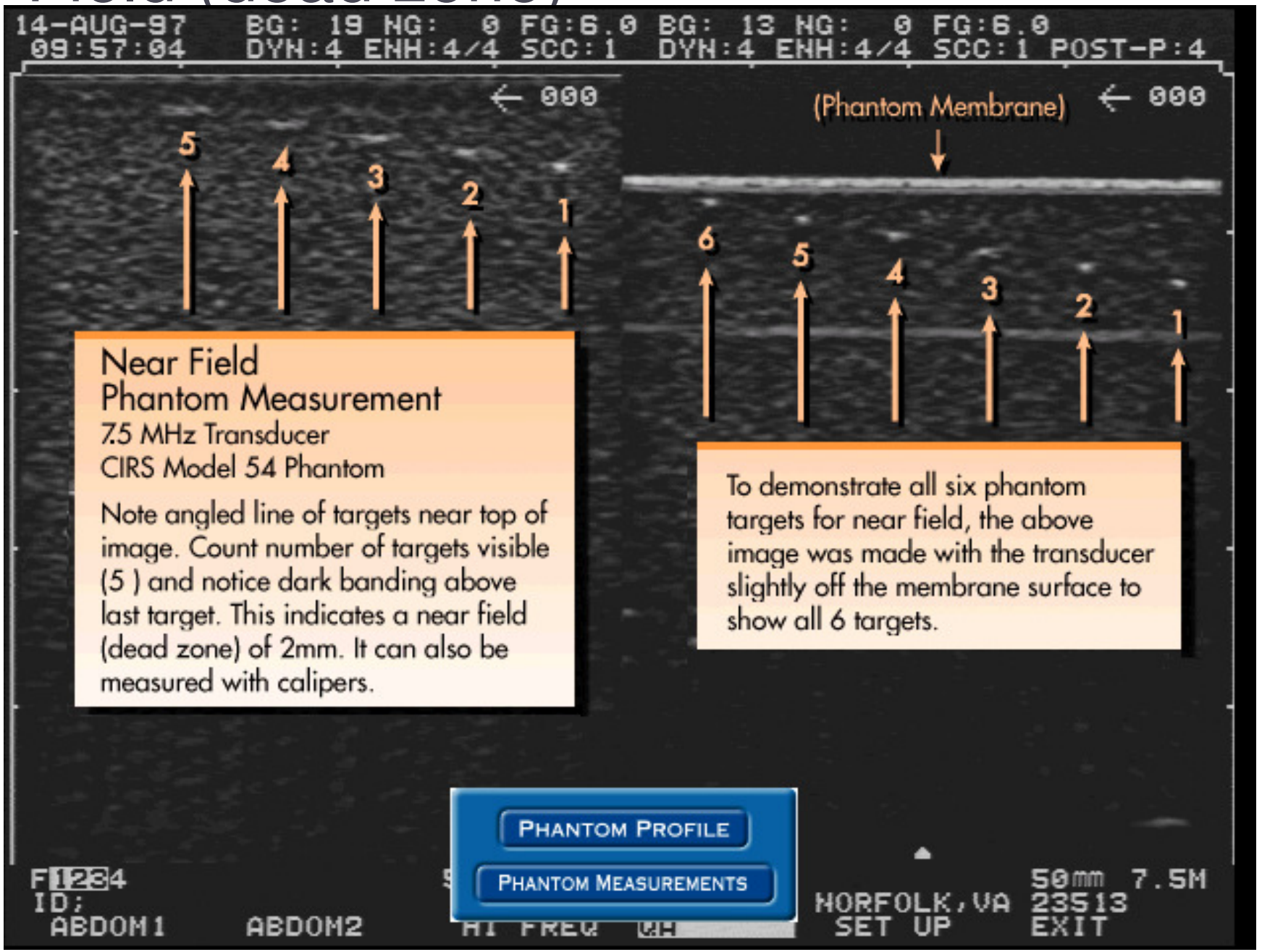
# Near Field (dead zone)

Acoustic Standoffs (AC) provide a means of scanning superficial structures within the near field and regions where acoustic coupling with conventional acoustics gels alone may be difficult to maintain.



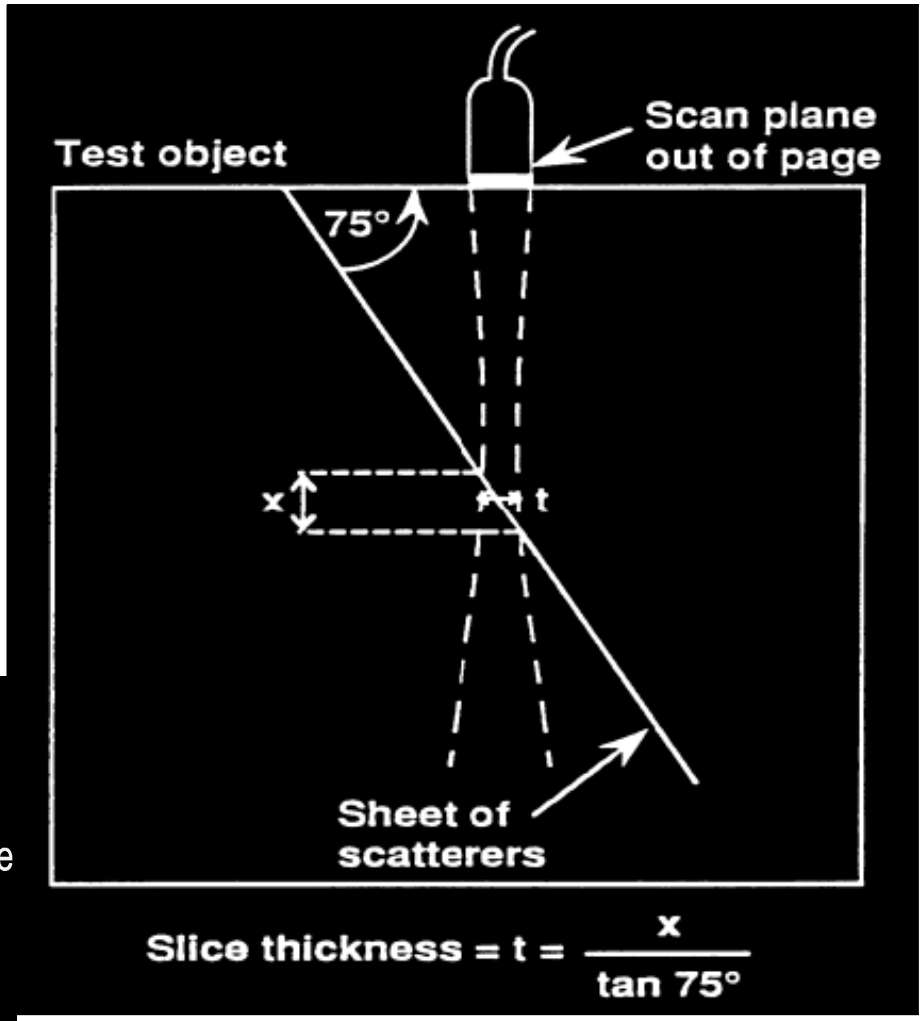
# Near Field (dead zone)

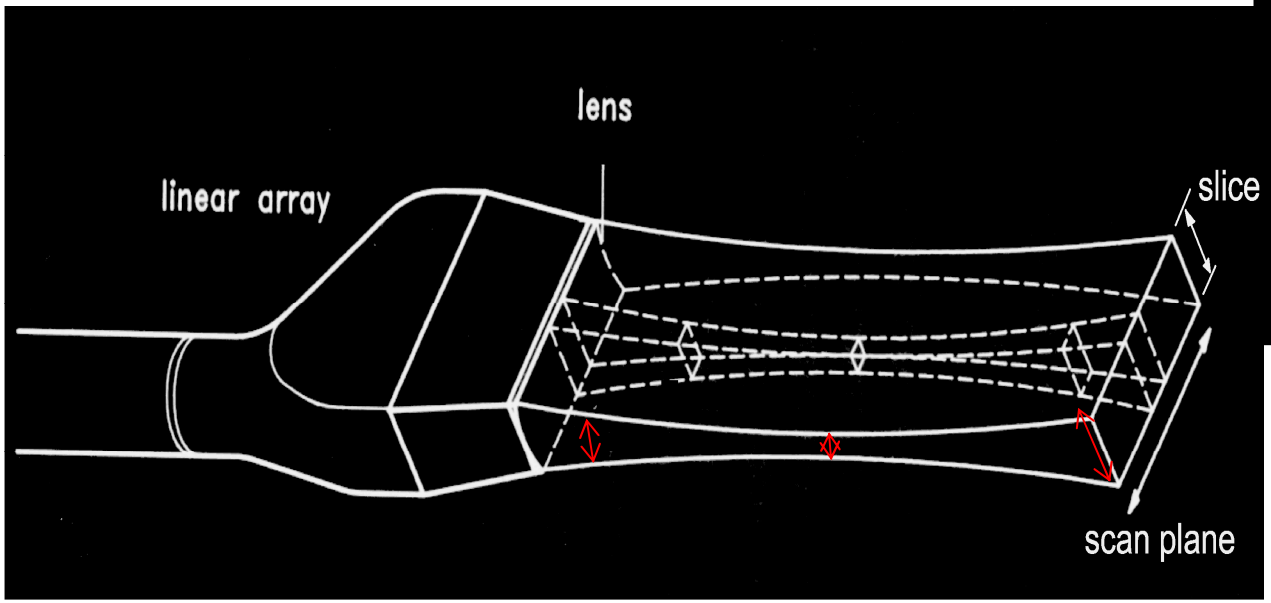


# Slice thickness measurement

Slice thickness ⇔ Elevation focus

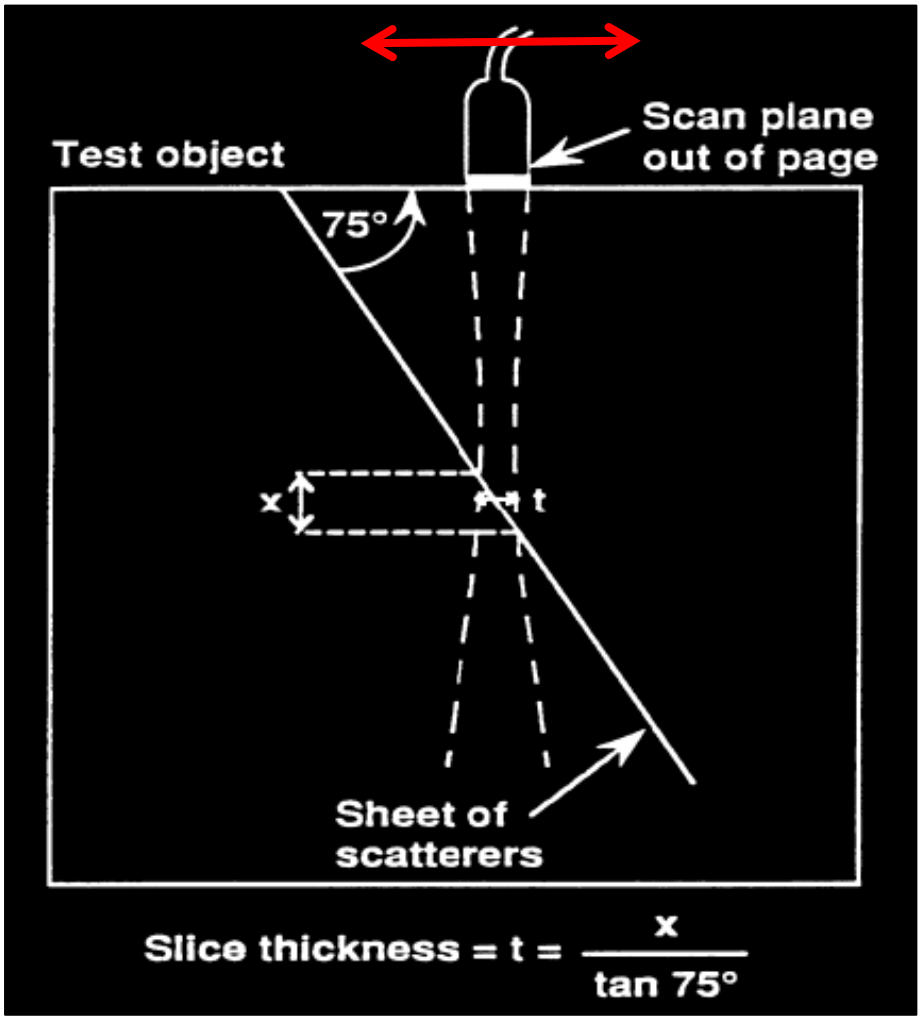
A special phantom is used to measure the depth where the elevation focus is located.

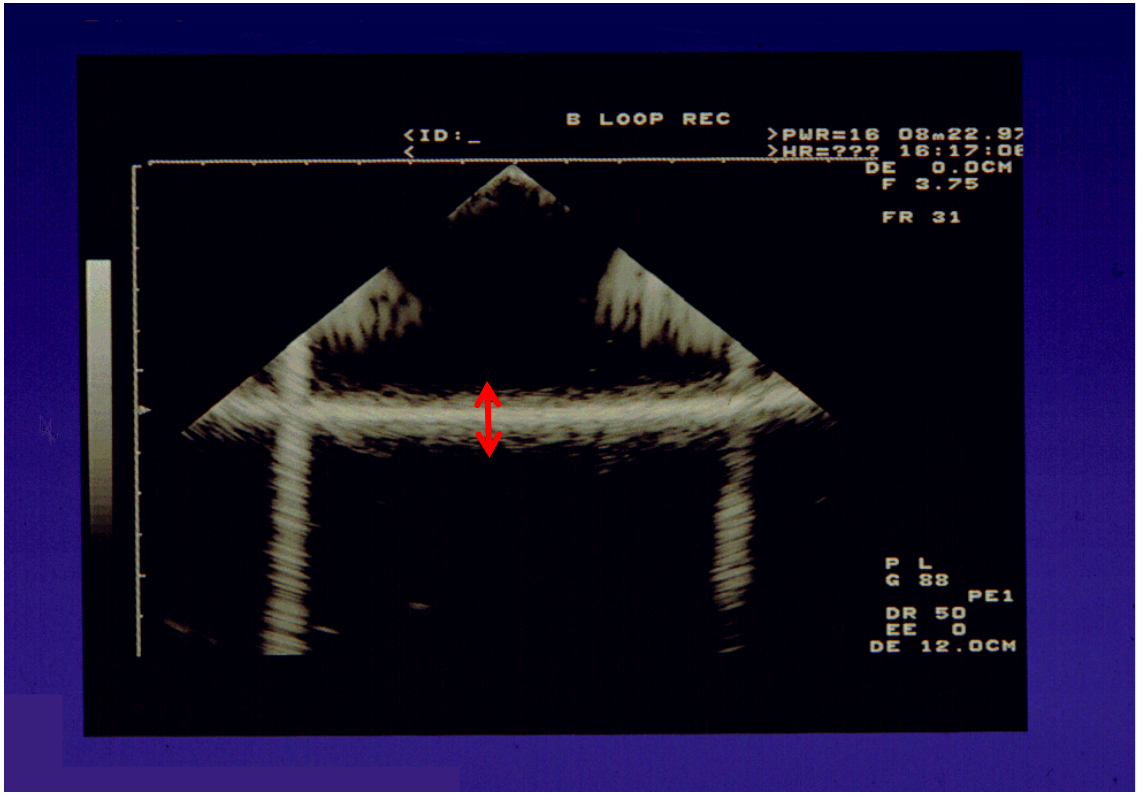



J.M. Thijssen: Quality Assurance Med US

# Slice thickness measurement



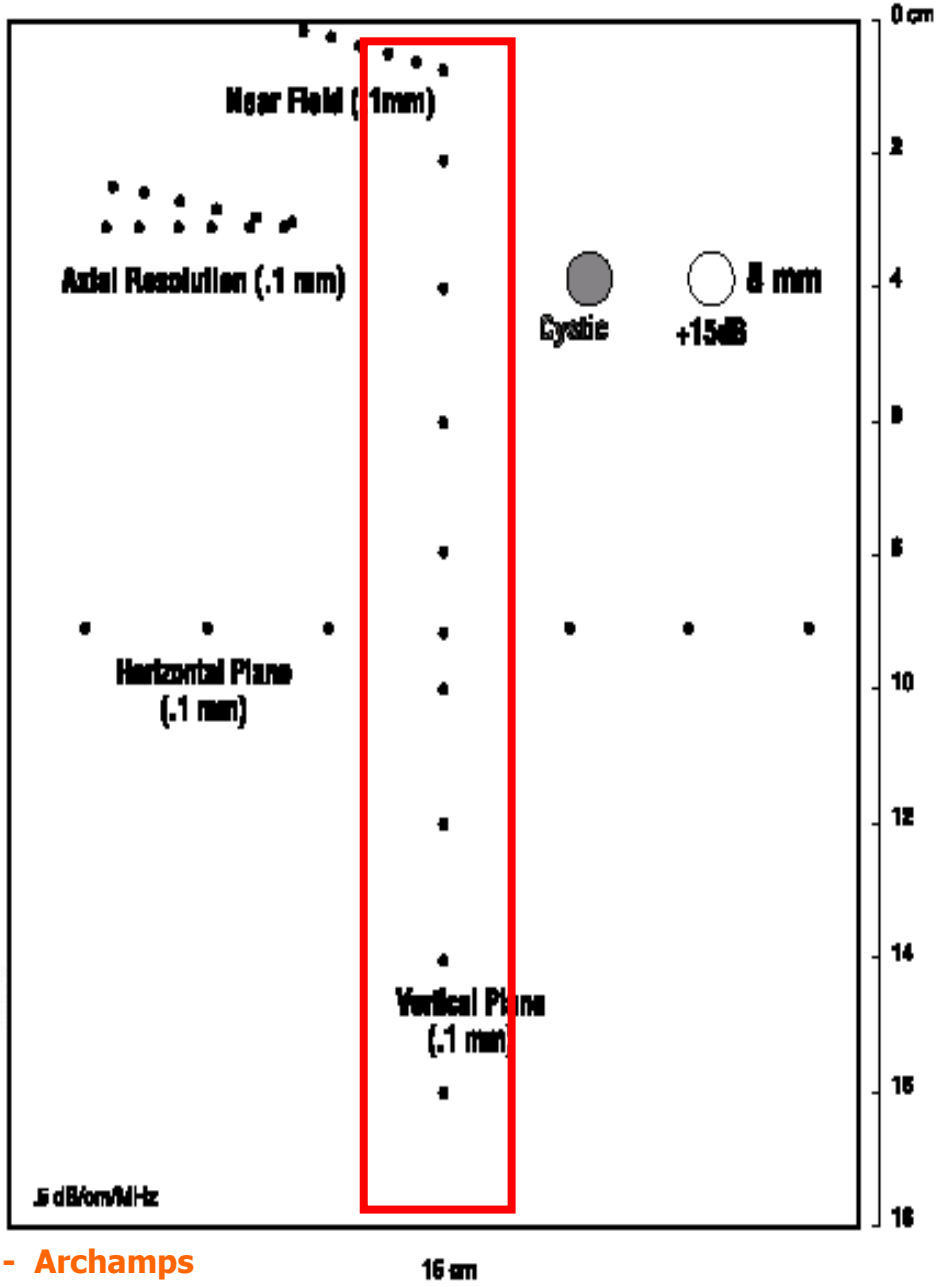




The examiner moves the transducer over the top of the phantom to estimate where the bar width is minimum

# Beam profile

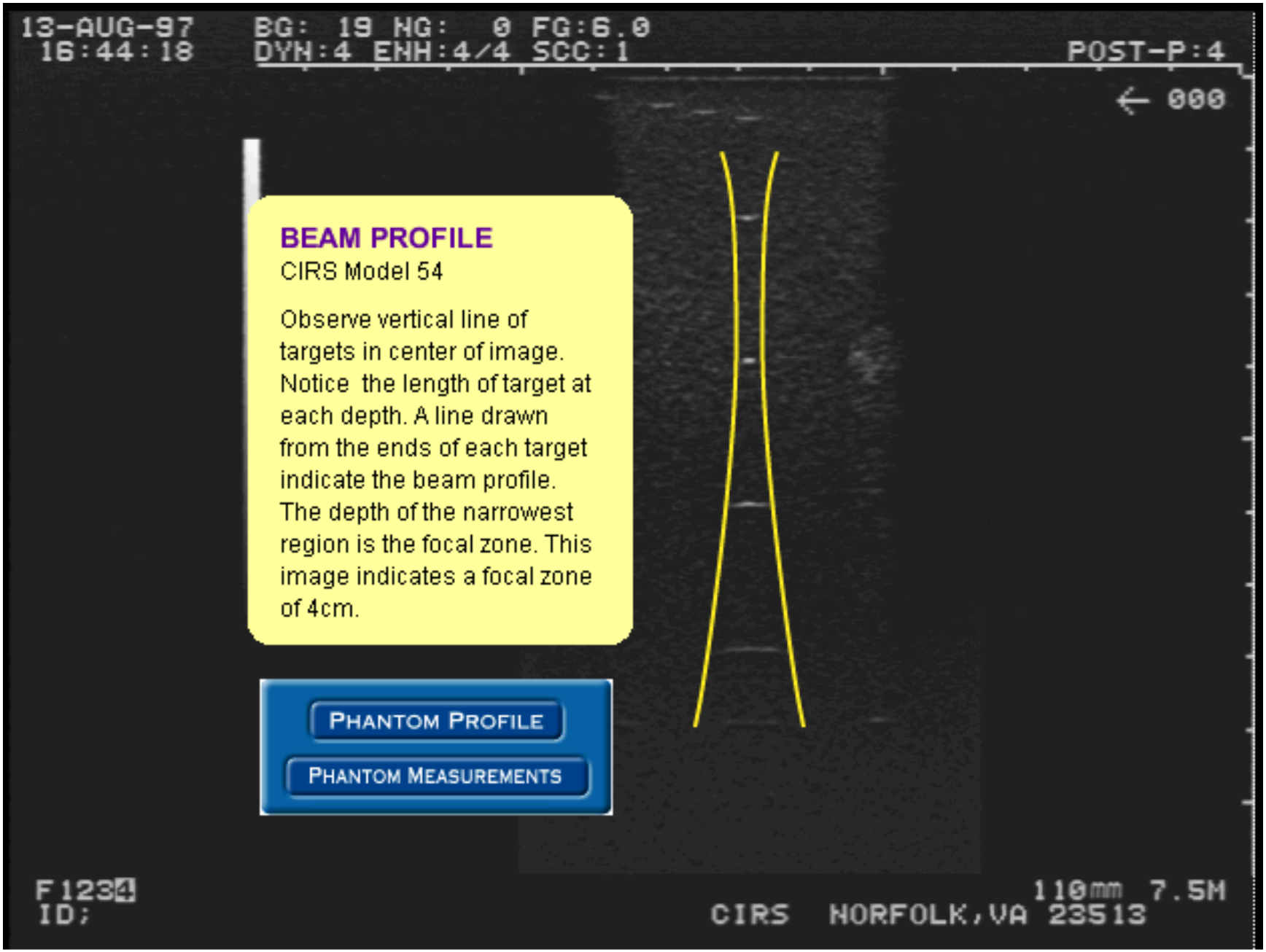
Beam profile ⇔ Lateral focus

The beam thickness changes with the depth. Minimum value is at the focal



# Beam profile

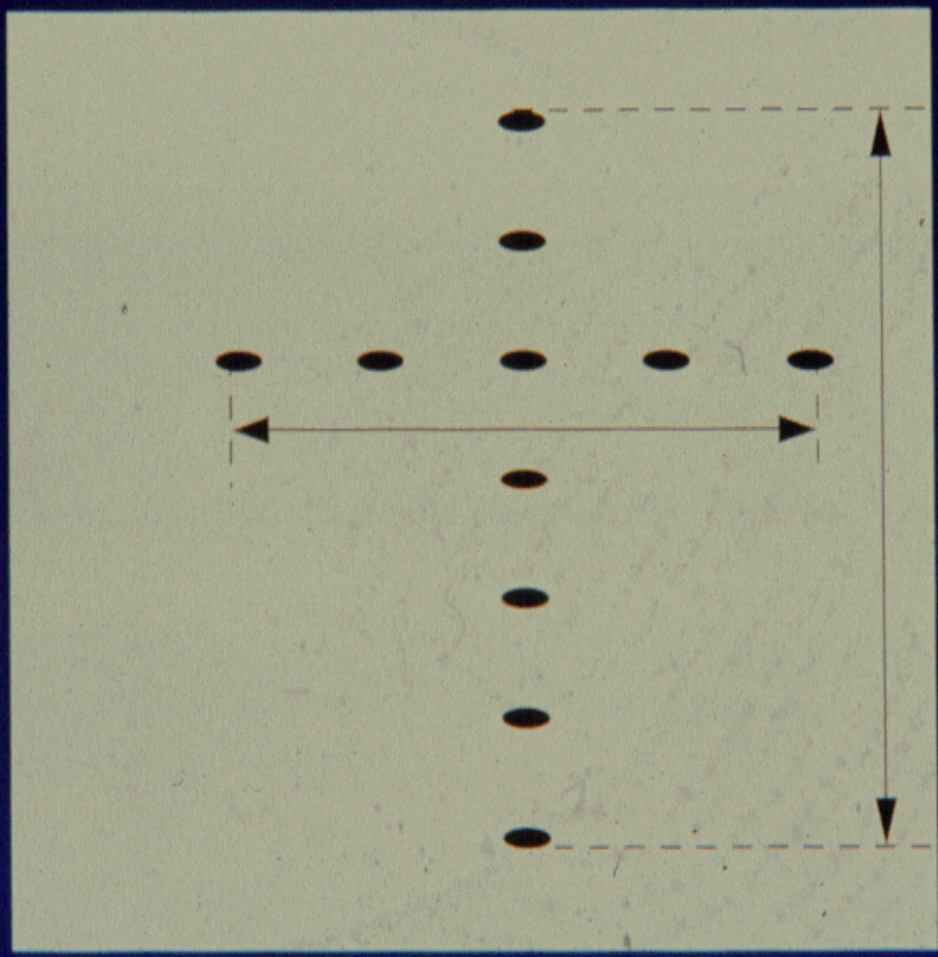




# Image Distortion

- Horizontal
- Vertical

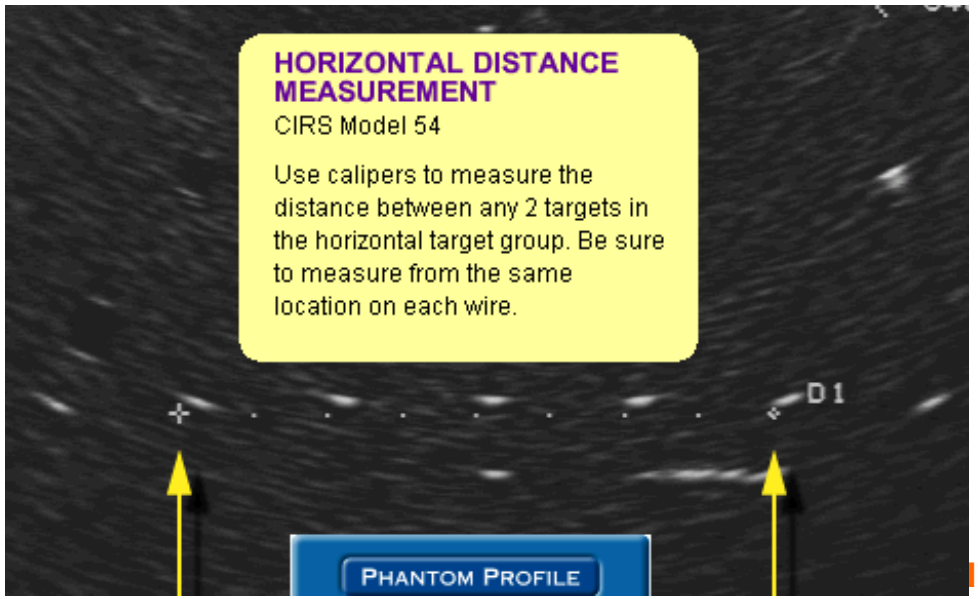
Measurement of distance between outer targets

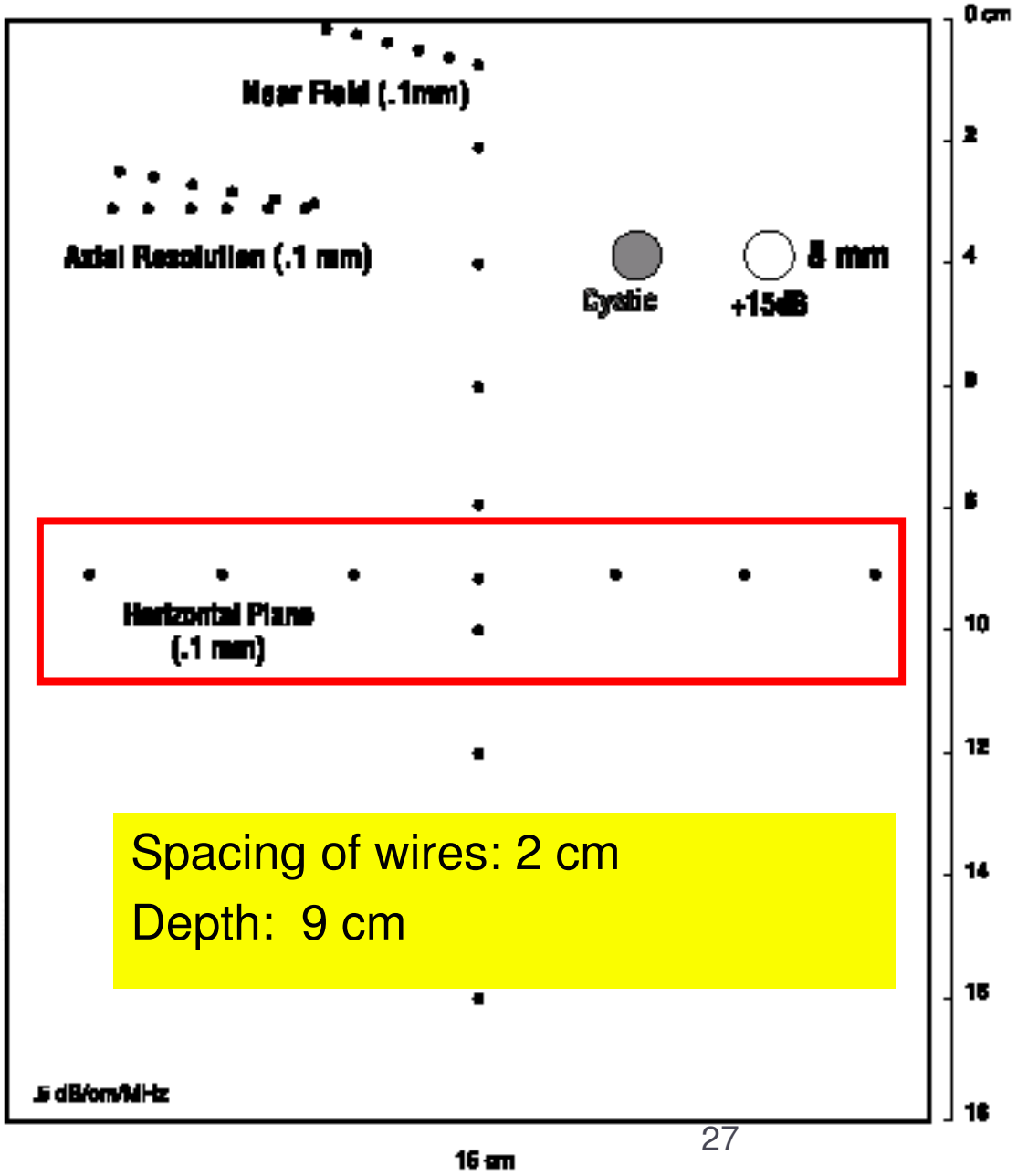


# Horizontal distance measurement

Calibration of lateral length measurement

Measurement of distance between outer targets



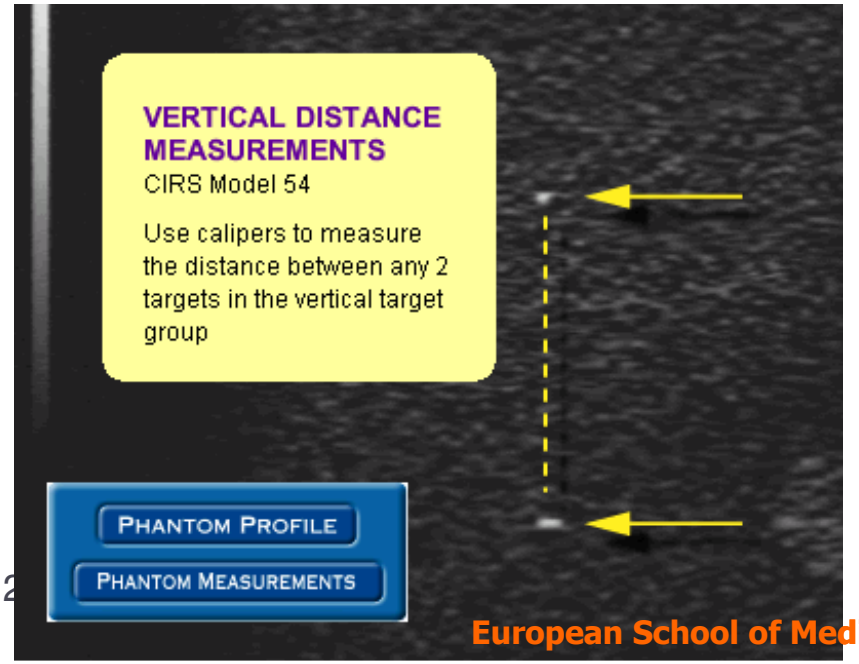

Spacing of wires: 2 cm

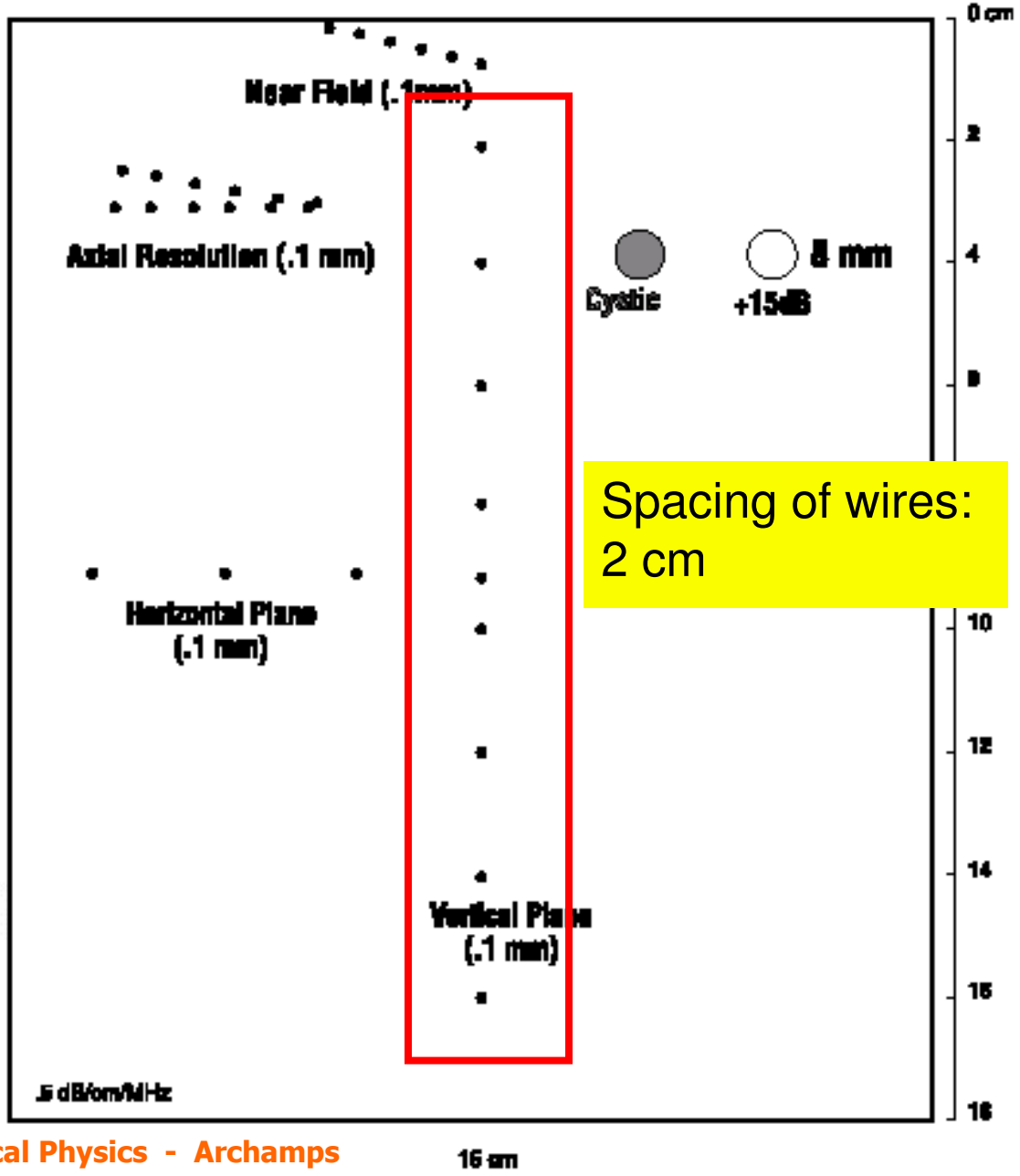
Depth: 9 cm

# Vertical distance measurement

Calibration of lateral length measurement

The velocity introduced in the scanner is 1540 m/s



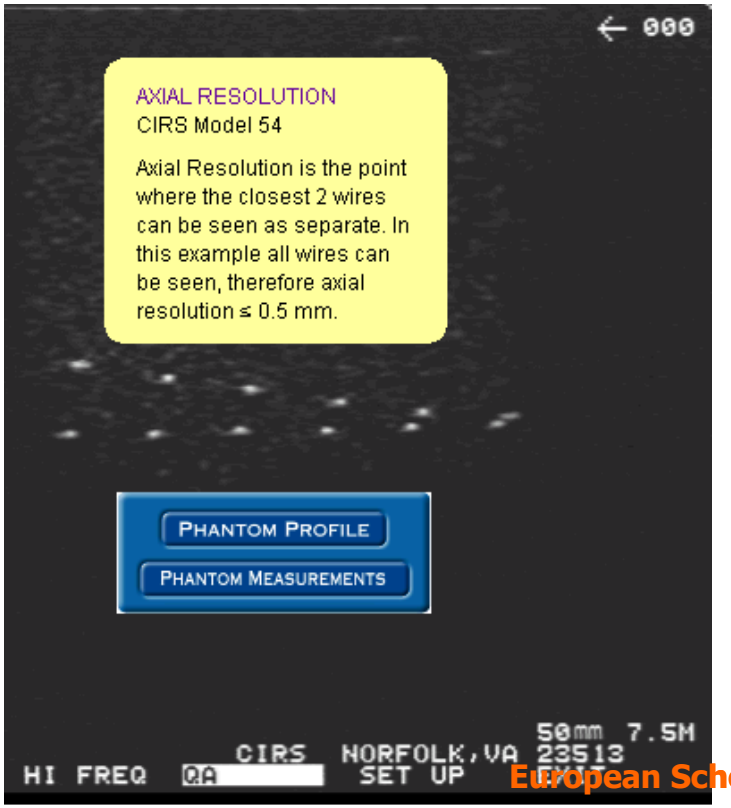



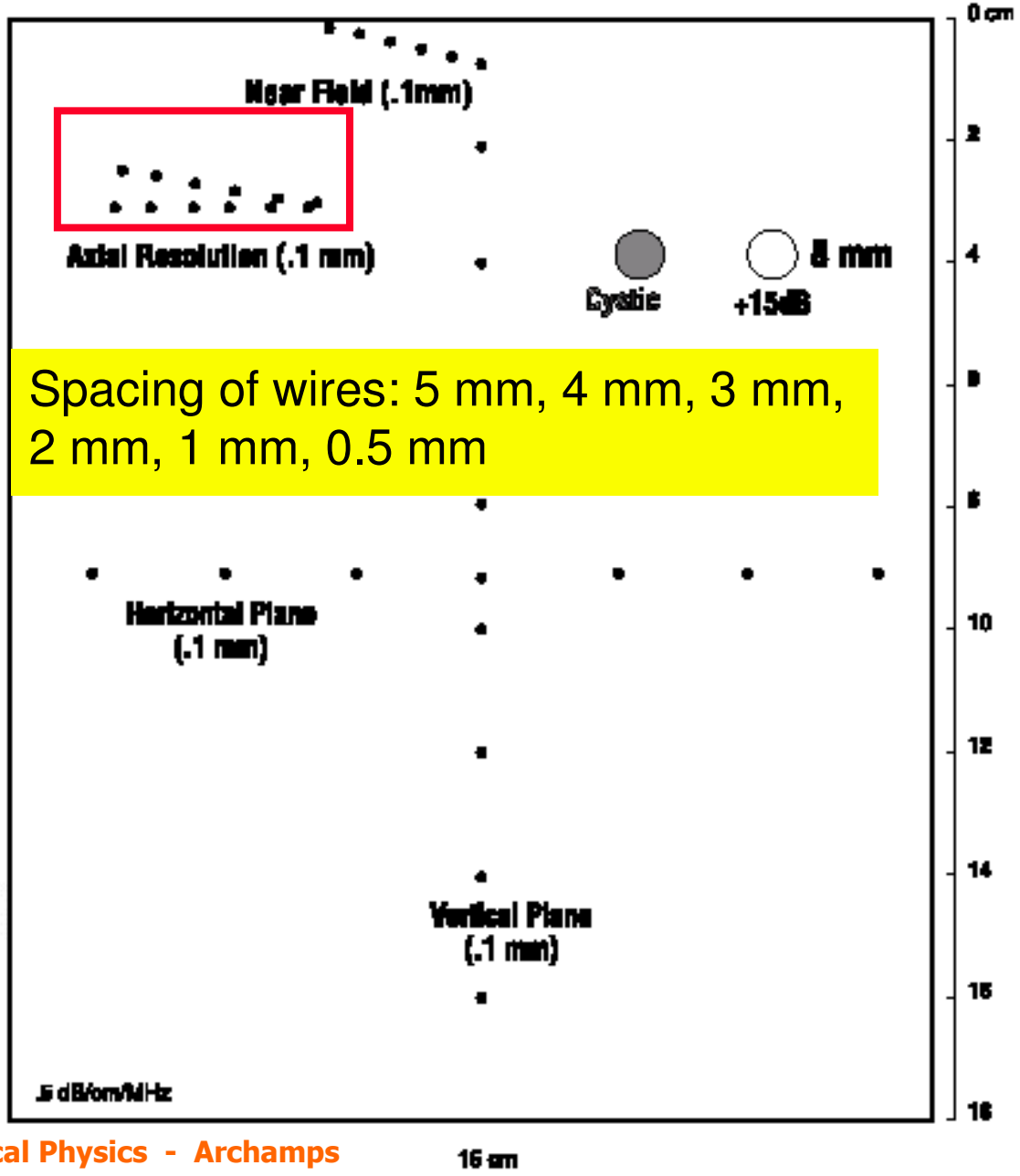

Spacing of wires: 2 cm

# Axial resolution

The closest 2 wires separated

The axial resolution depends of the frequency



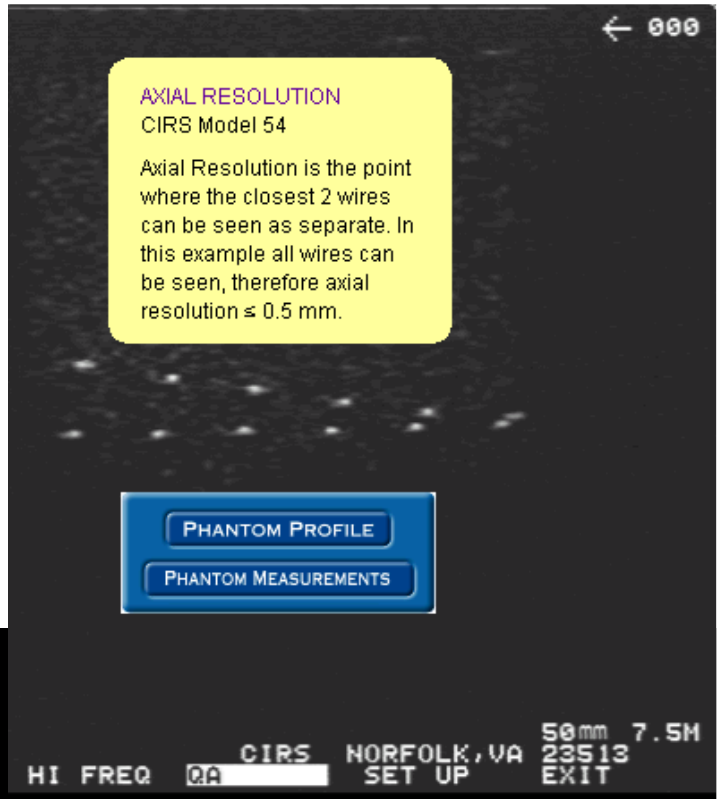



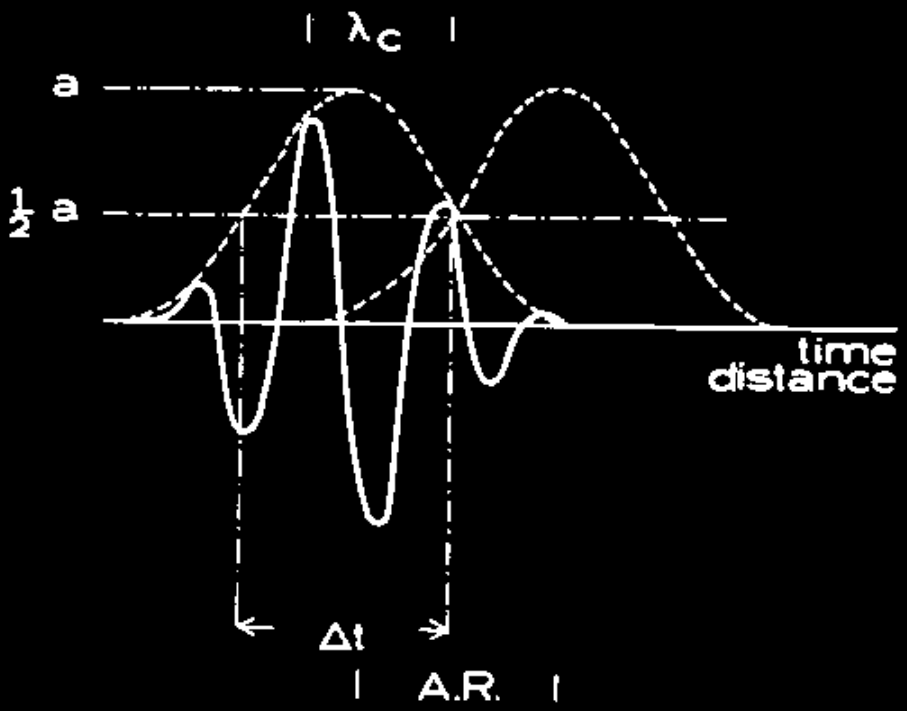
# Axial Resolution

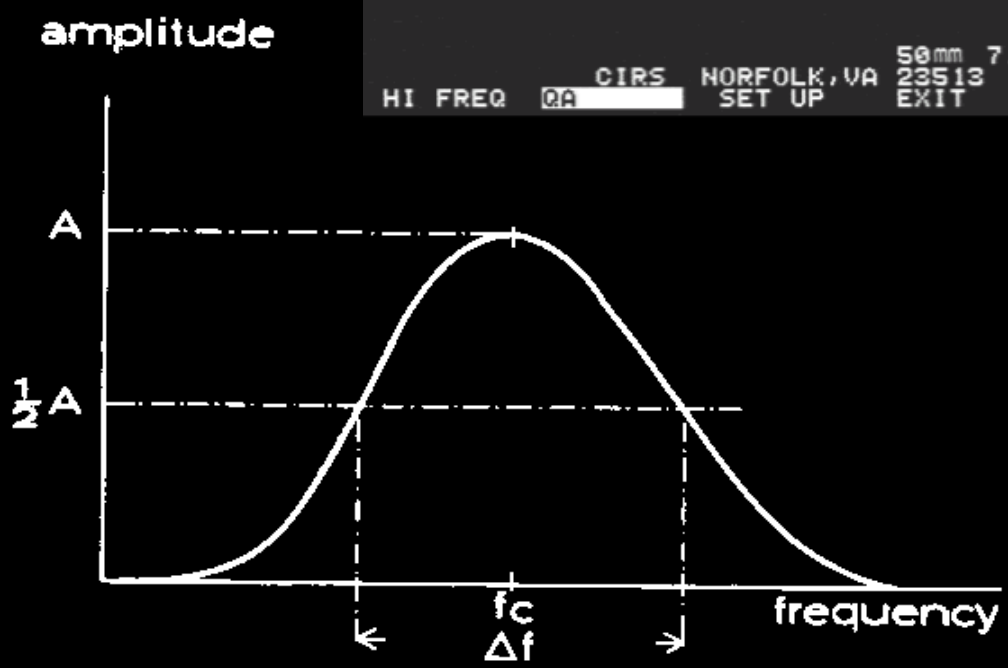
*Full Width at Half Maximum - FWHM*

PSF:

$$\Delta z = 0.66 / \Delta f$$

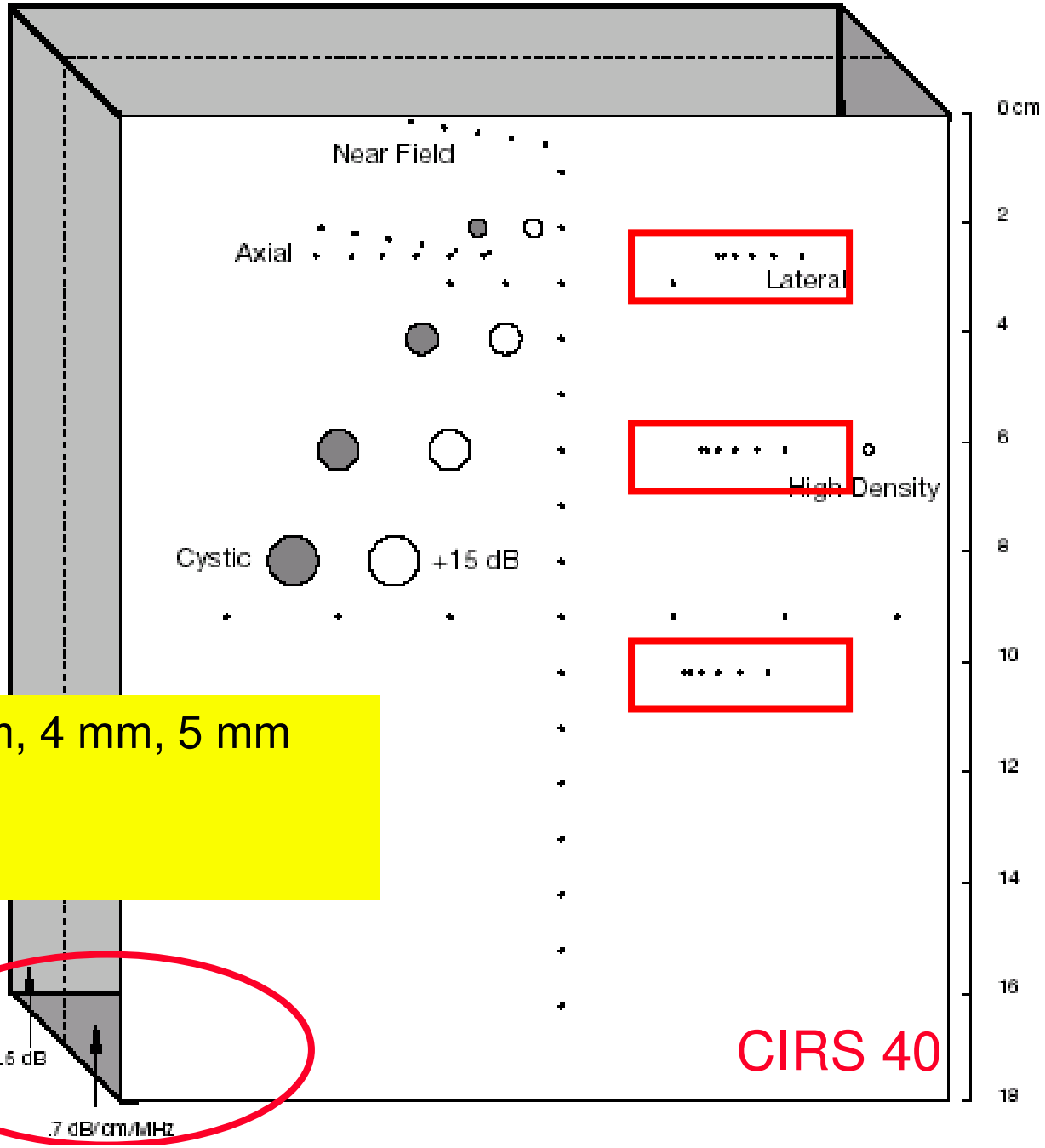


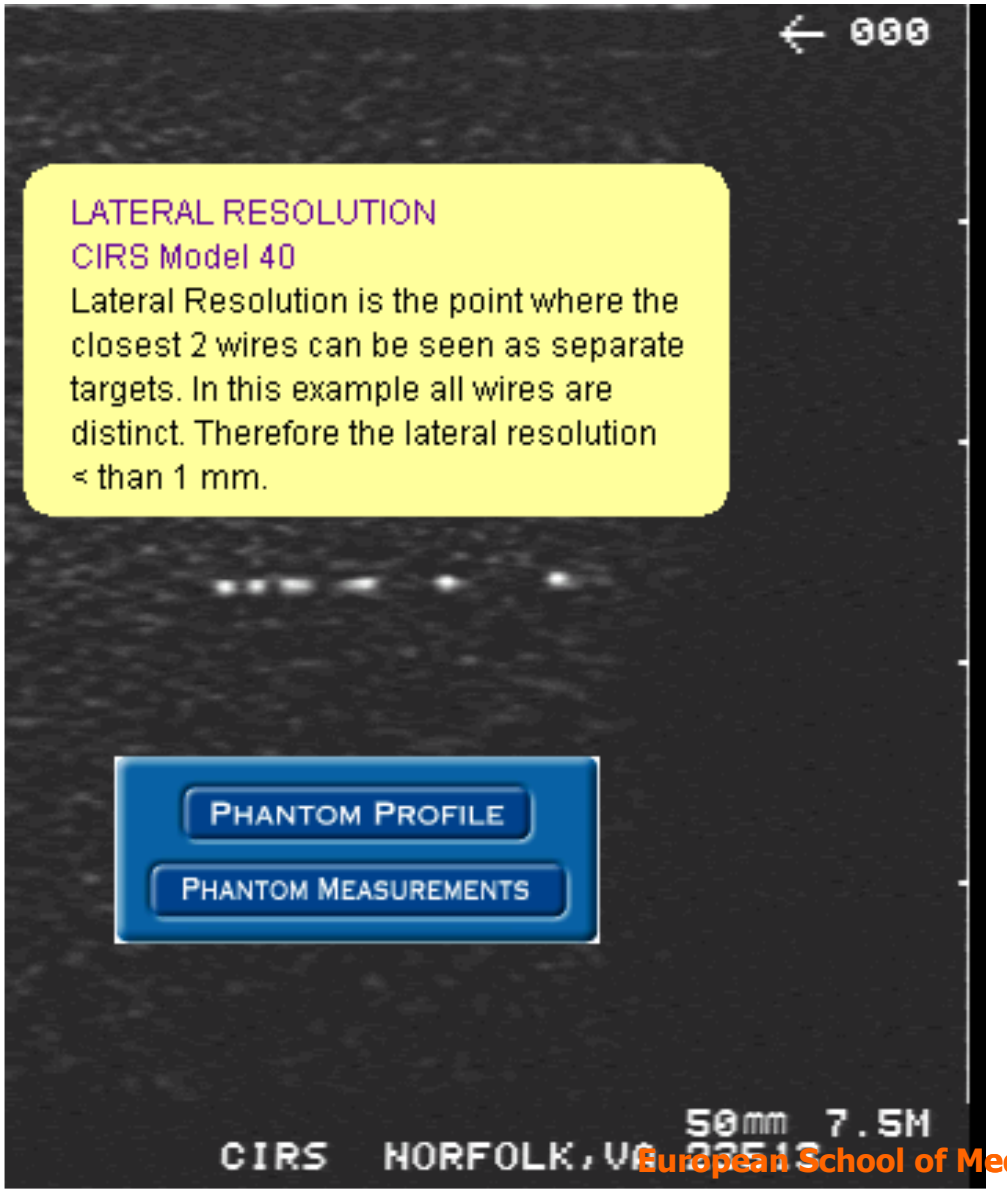
# Lateral Resolution

- Distance where the closest 2 wires can be seen as separate targets




Spacing of wires: 1mm, 2 mm, 3 mm, 4 mm, 5 mm
depth: 2.5 cm, 6 cm, 10 cm

# Lateral resolution




PSF: $\Delta x = 1.02\ c\ F / f_{ce}\ D$

c: velocity

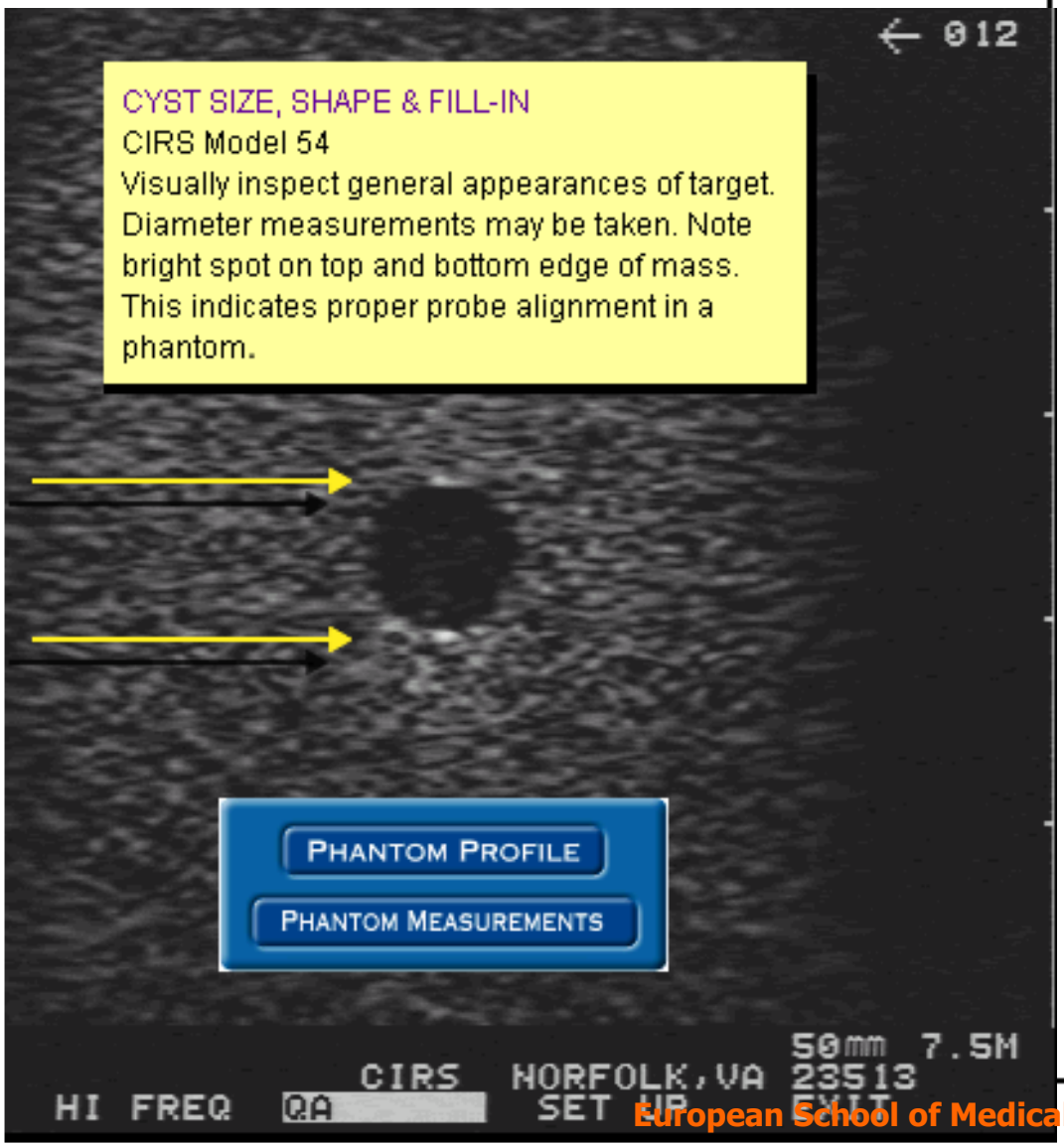
F: focal distance

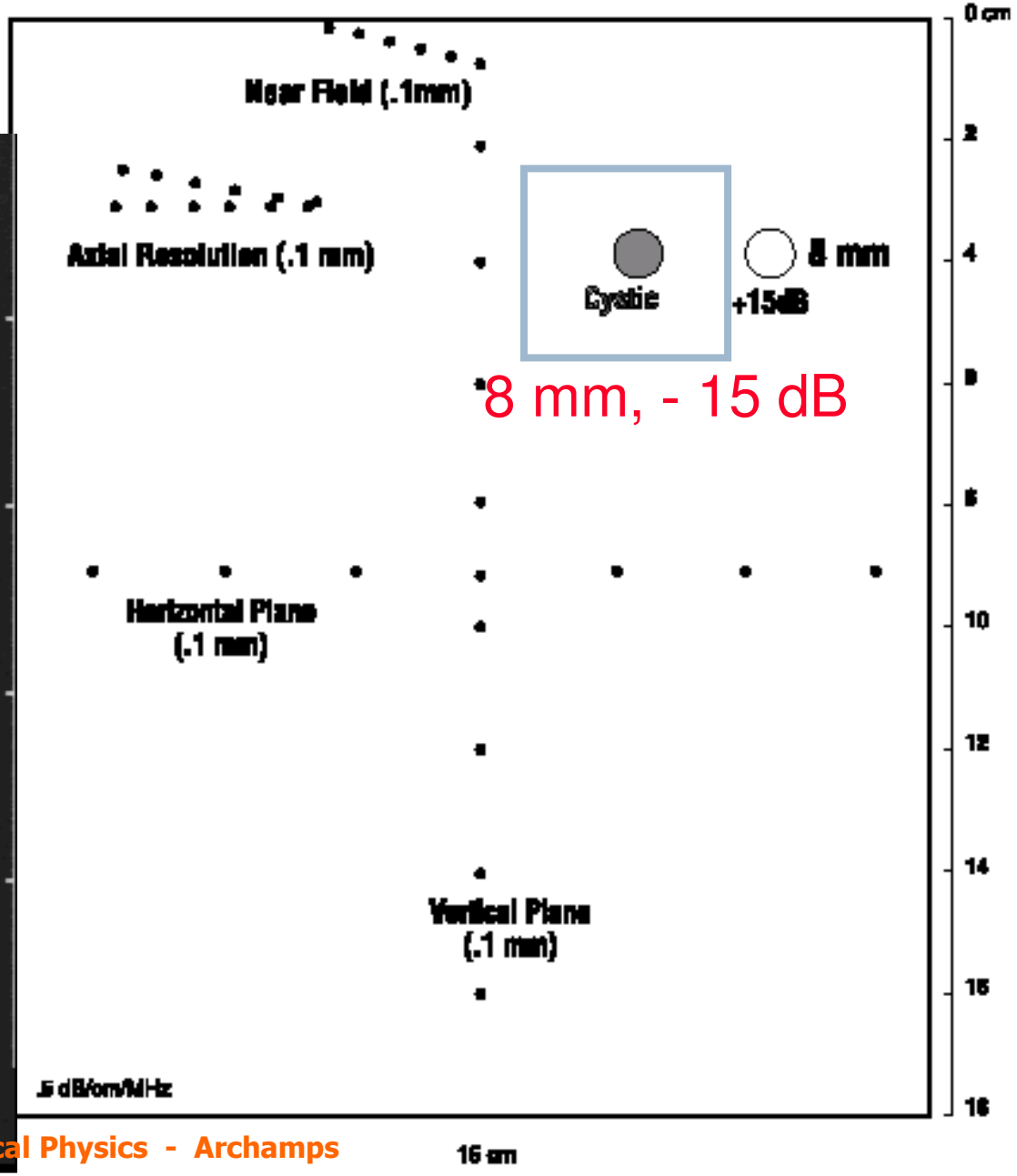
$f_{ce}$: transmitted frequency

D : size of transducer

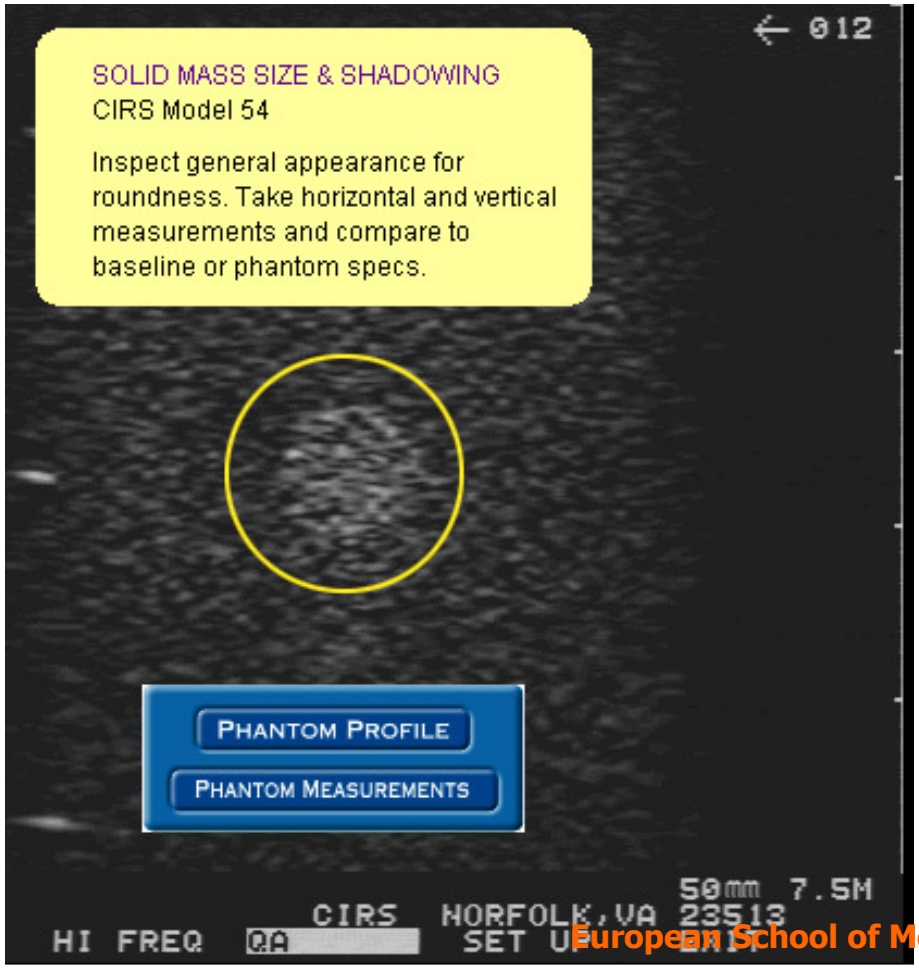
# Image of cyst

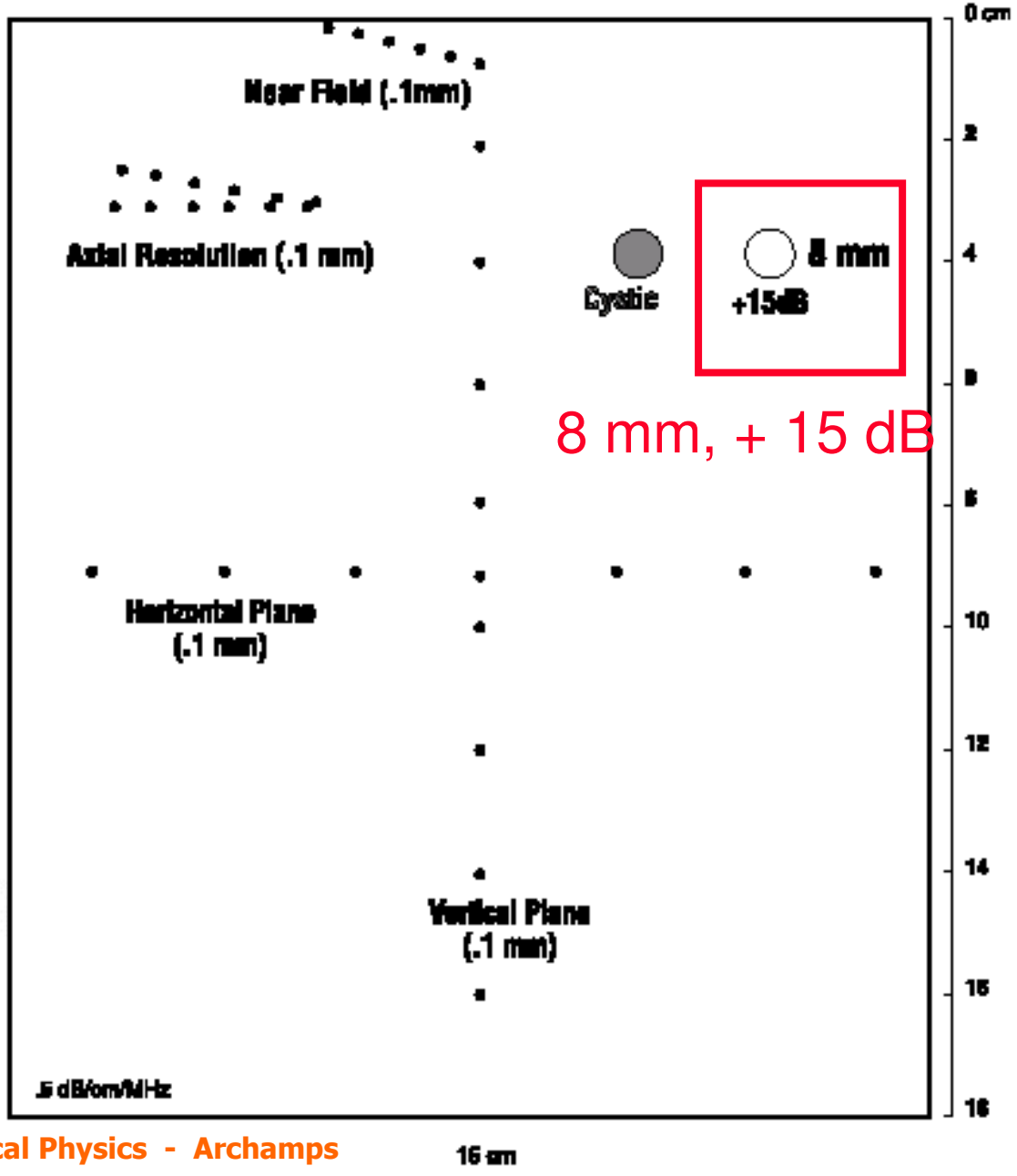
## Anechoic area



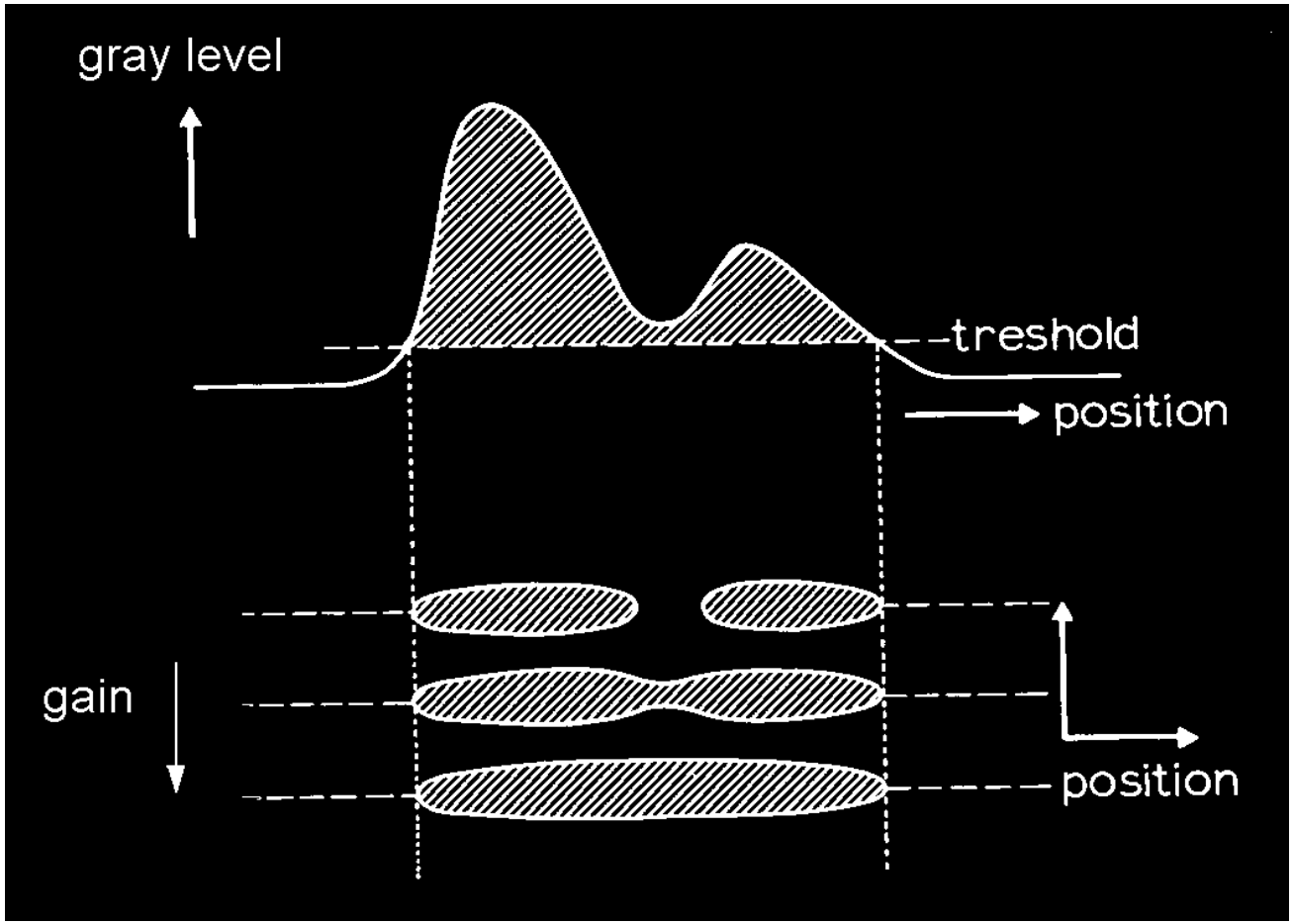



# Solid mass and shadow



# Subjective resolution vs. gain: influenced by gain settings



# Contrast Resolution

- DEFINITIONS
  - **Smallest visible gray level difference for lesion of certain size [dB]**
  - Slope of gray level vs. nominal contrast curve
    [#gray levels/dB → "gamma"]

# Displayed dynamic range

- Definition:
  - Range of echo levels [dB], corresponding to grey levels of display from just visible to saturation

- Technique:
  - Linear post processing curve
  - Measured either by multi contrast phantom, or by systematically changing the overall gain [dB]

# Lesion SNR – Mahalanobis Distance

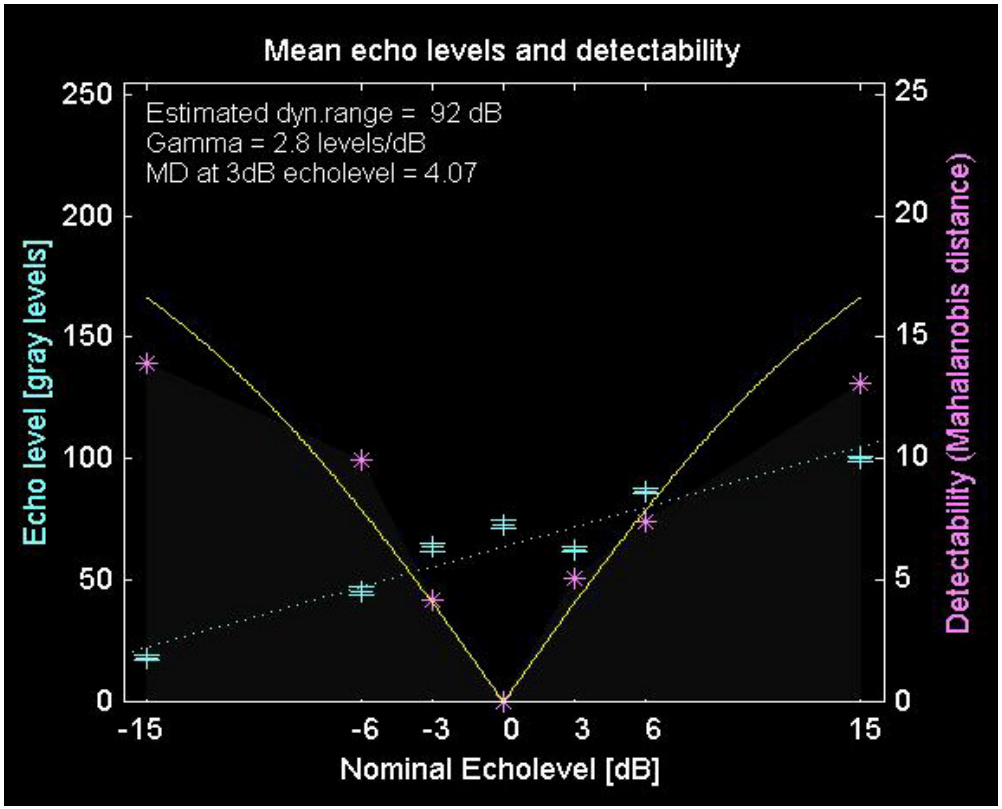
$$SNR_L = \frac{(\langle e_L \rangle - \langle e_B \rangle)}{(\sigma^2_B + \sigma^2_L)^{1/2}}$$

where:

$\langle e \rangle$ = mean echolevel of lesions

$\sigma$ = standard deviation

# Measurement of Contrast sensitivity/dynamic range

# Overview

- Introduction.
- Test objects.
- Quality assurance
    - Imaging
    - Doppler velocity
    - HIFU

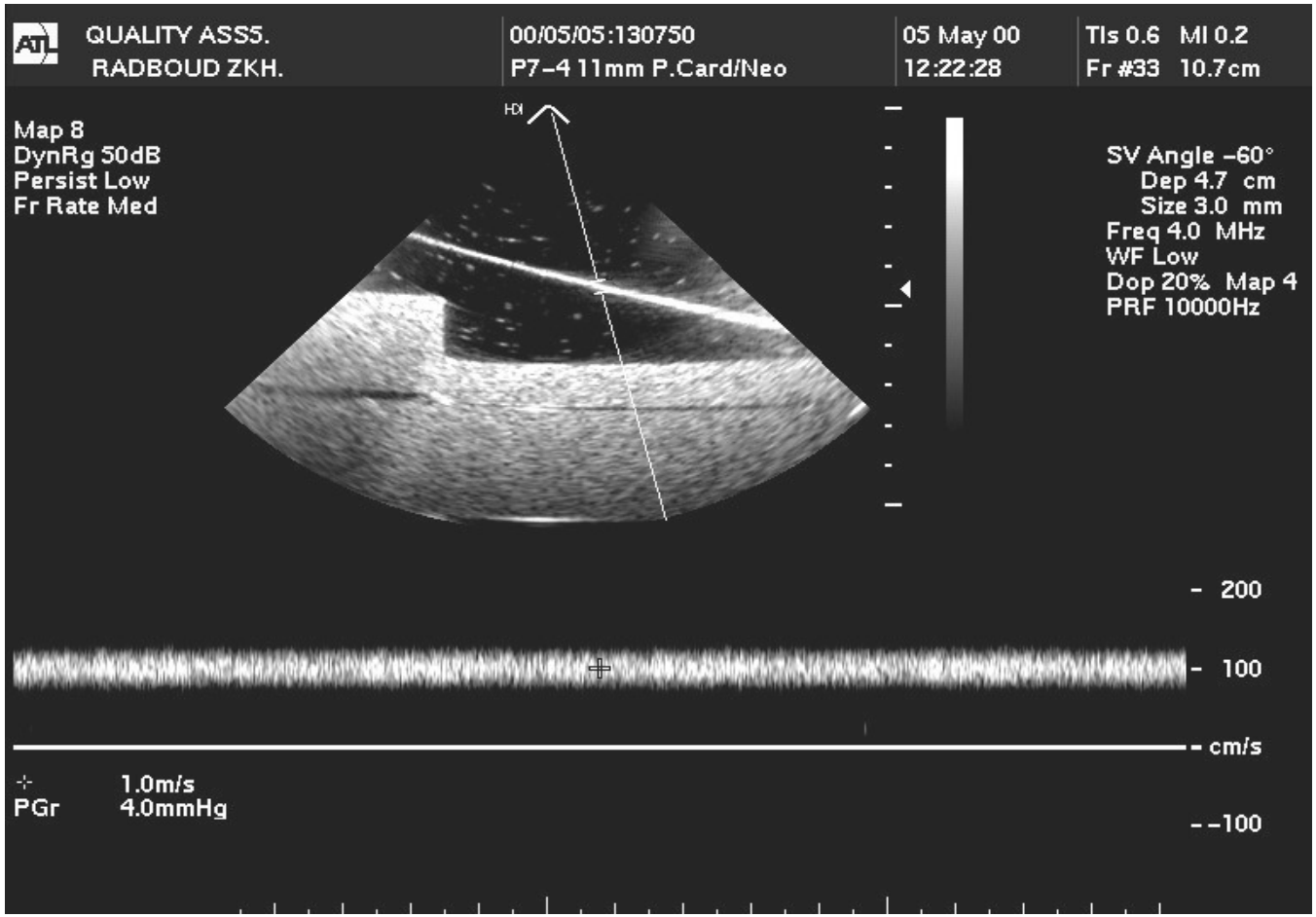
# String test object


- Not tissue/blood equivalent
- Physiological signals
- Very stable velocity

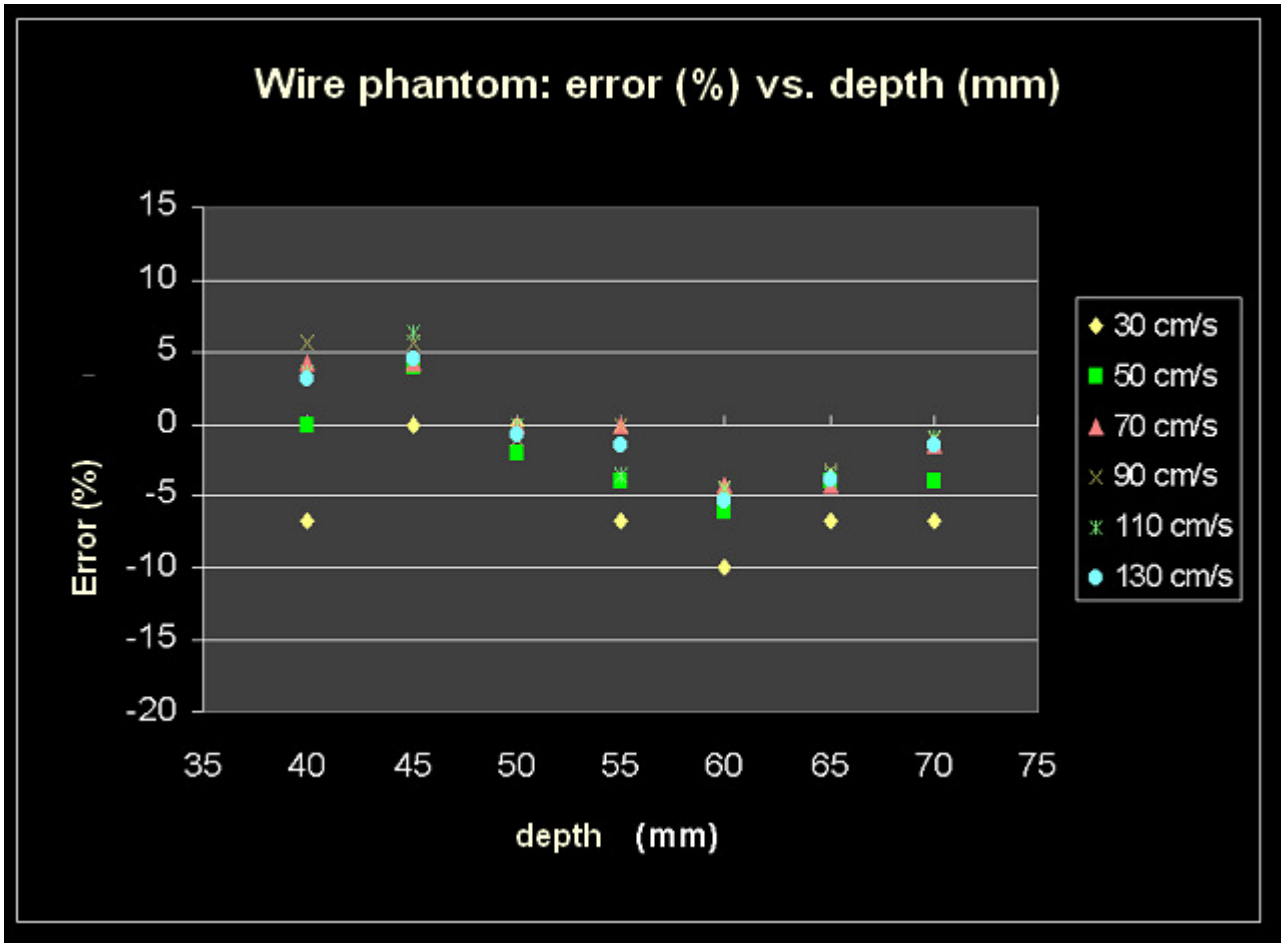
# Overview Doppler Quality

- Sensitivity, D-gain reference
- Sample volume dimensions
- **Velocity measurement**
- Range gate accuracy
- Angle registration
- Direction indication
- Channel separation

# Velocity measurement:
## angle correction by equipment



# Velocity measurement: accuracy optimal in (transmit) focus




- Less spectral broadening
- Focus 50 mm

# Doppler direction indication

- **Equipment**

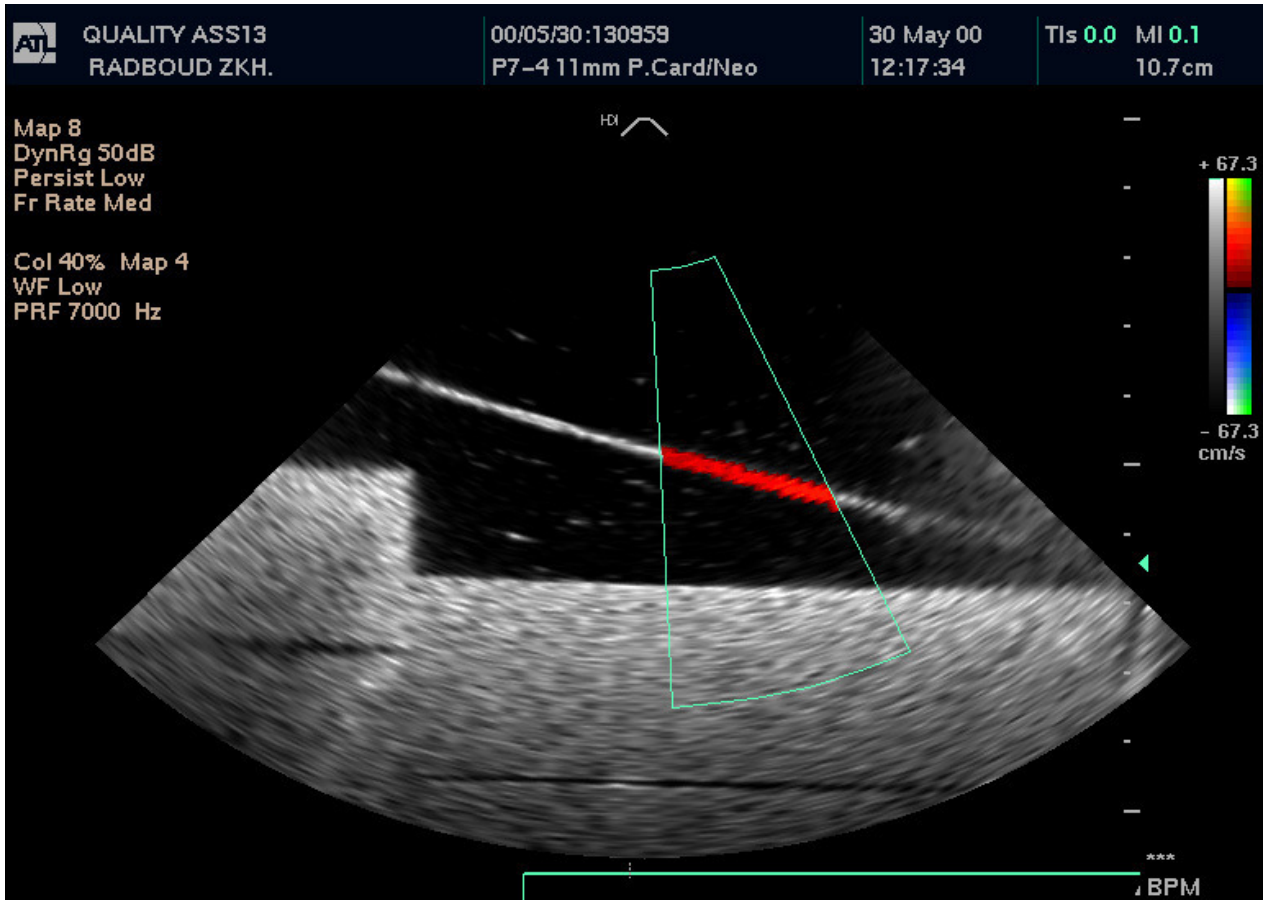
  String test object

- **Measurement**

  Constant speed of string

  $\Rightarrow$ Sign of sonogram correct ?

# Direction indication in 2D color Doppler



# Overview

- Introduction.
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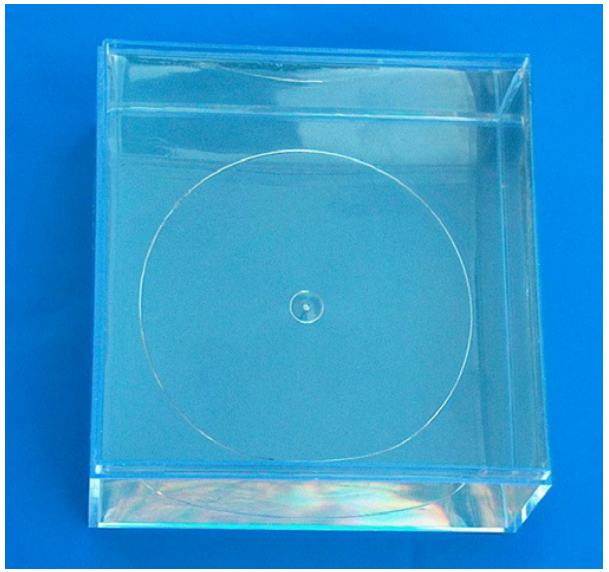
    - Imaging
    - Doppler velocity
    - **HIFU**

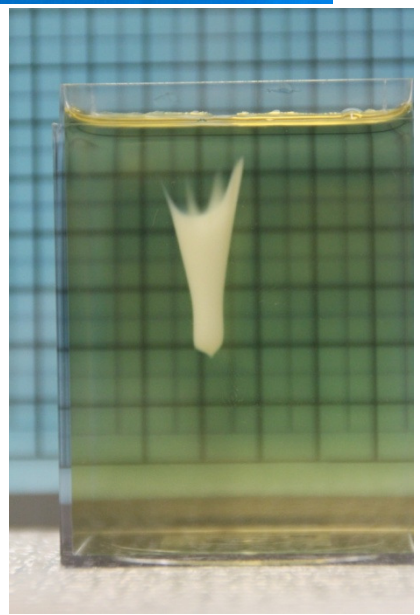
# HIFU – Test Objects

- HIFU also has test objects
- Calibrated attenuation
- Custom made or commercial



## Ex: Onda HIFU Phantom Gel

• Density: 1060 kg / m3
• Phase velocity: 1600 m/s
• Attenuation Coefficient: 0.6 dB/(cm-MHz)
• Specific Heat: 3850 J/(kg-°K)
• Thermal Conductivity: 0.55 W/(cm-°K)
• Optical: Turns permanently opaque when temperature reaches a threshold of 70 °C (this phenomenon results in the formation of tissue-mimicking lesions when the phantom is exposed to high intensity ultrasound)



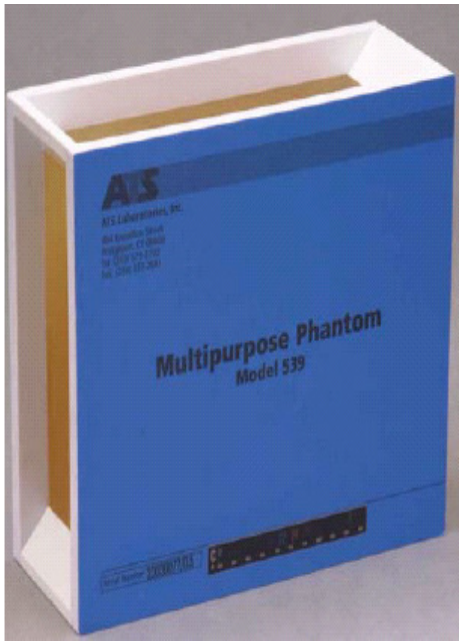
D. Melo de Lima, Inserm, Lyon

# Conclusions Quality Assurance

- Objective assessment to be preferred
- Equipment settings to be reproduced
- Feasible in clinical practice with some investments
- Strict protocol not (yet) internationally accepted

- References:
  - Thijssen et al. Eur J Ultrasound 2002;15:151-61
  - van Wijk & Thijssen. Ultrasonics 2002;40:585-91

# Quality Assurance in Medical Ultrasound





Thank you !

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