



# Performance Testing Of Medical Ultrasound Equipment

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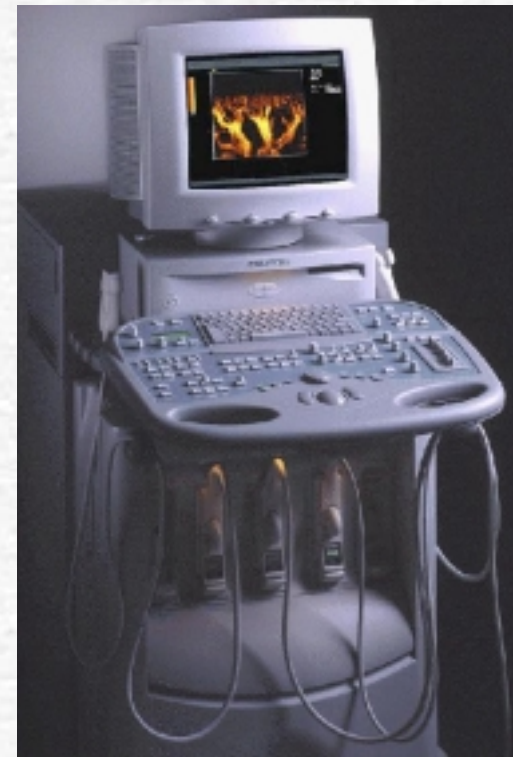
Depts. of Medical Physics, Radiology,  
and Human Oncology

University of Wisconsin, Madison, WI

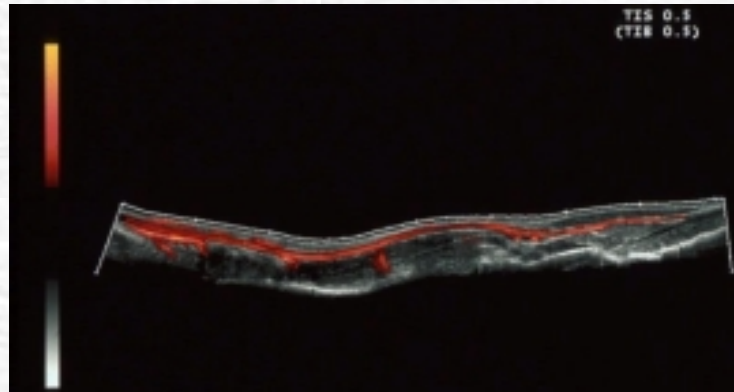


# Should we do routine performance testing in ultrasound?

- Some say "It is not beneficial."
- Others believe there is not sufficient manpower, especially in physics and bme.
- Phantoms are perceived to be expensive and inadequate.



## Routine performance testing ...

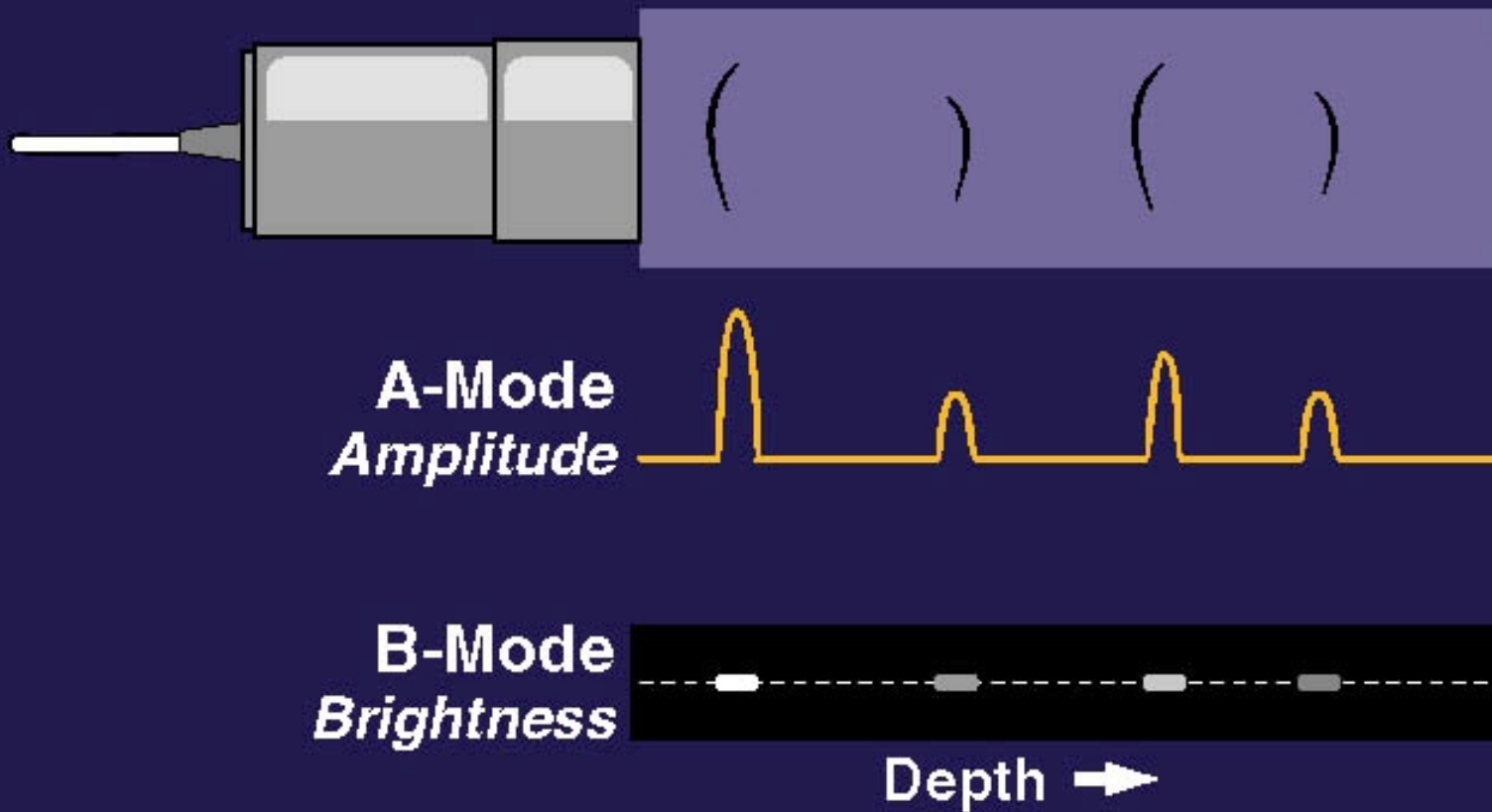


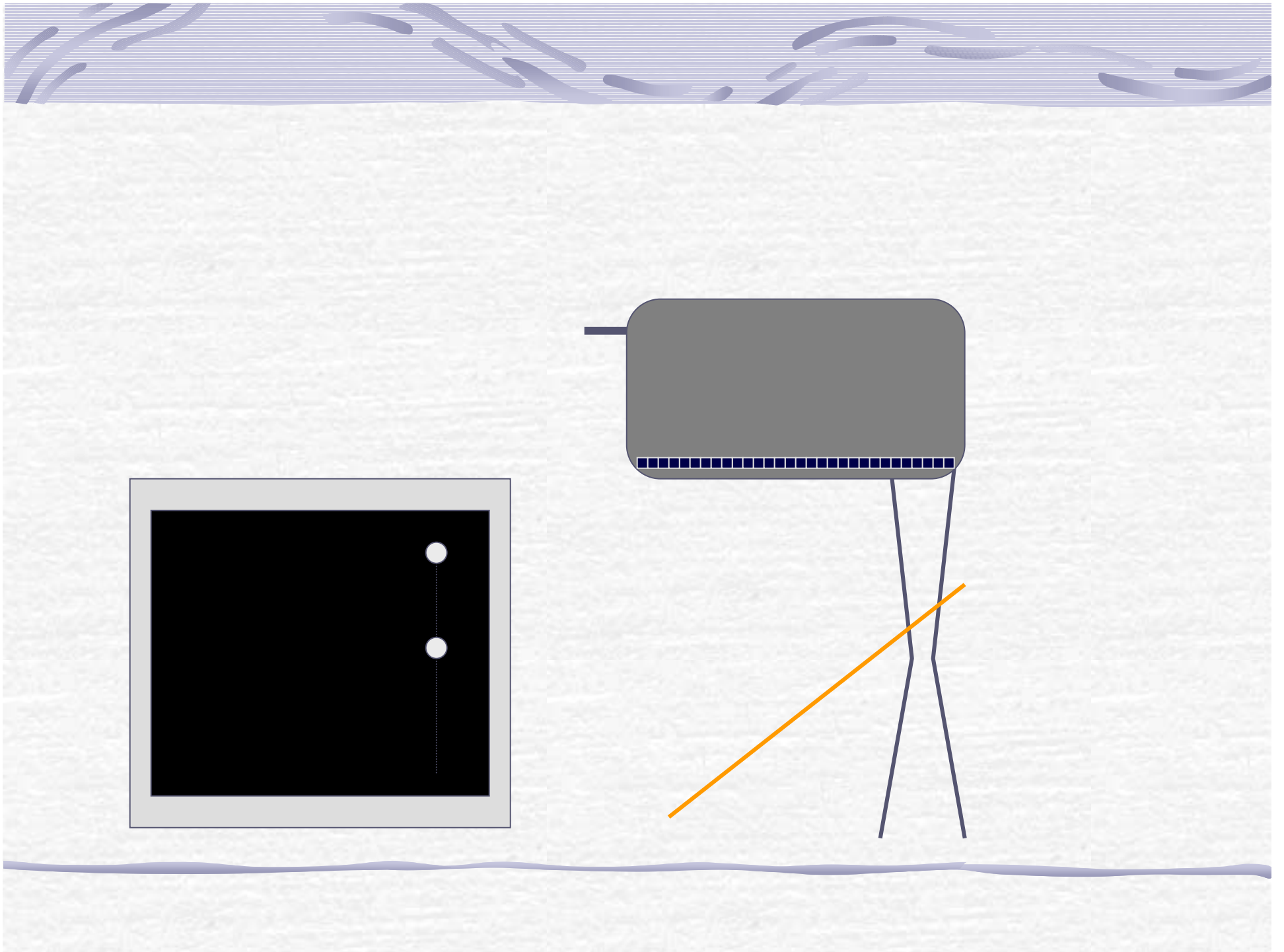
- No established performance standards.
  - Geometry, no problem; image quality is!
- Lack of correlation between performance parameters and clinical performance.
- Imaging is simple; specifying performance is complex.

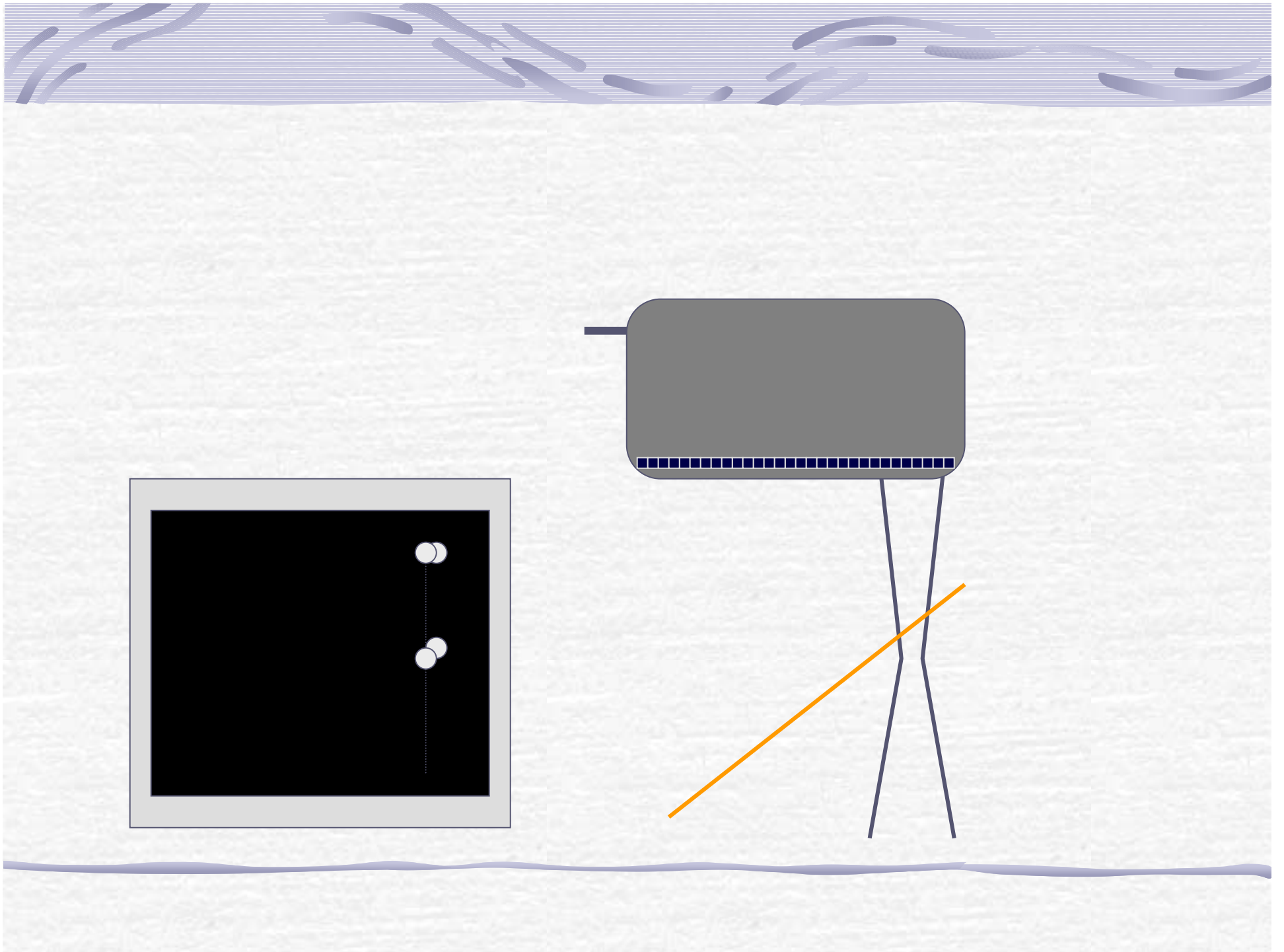
# Contents

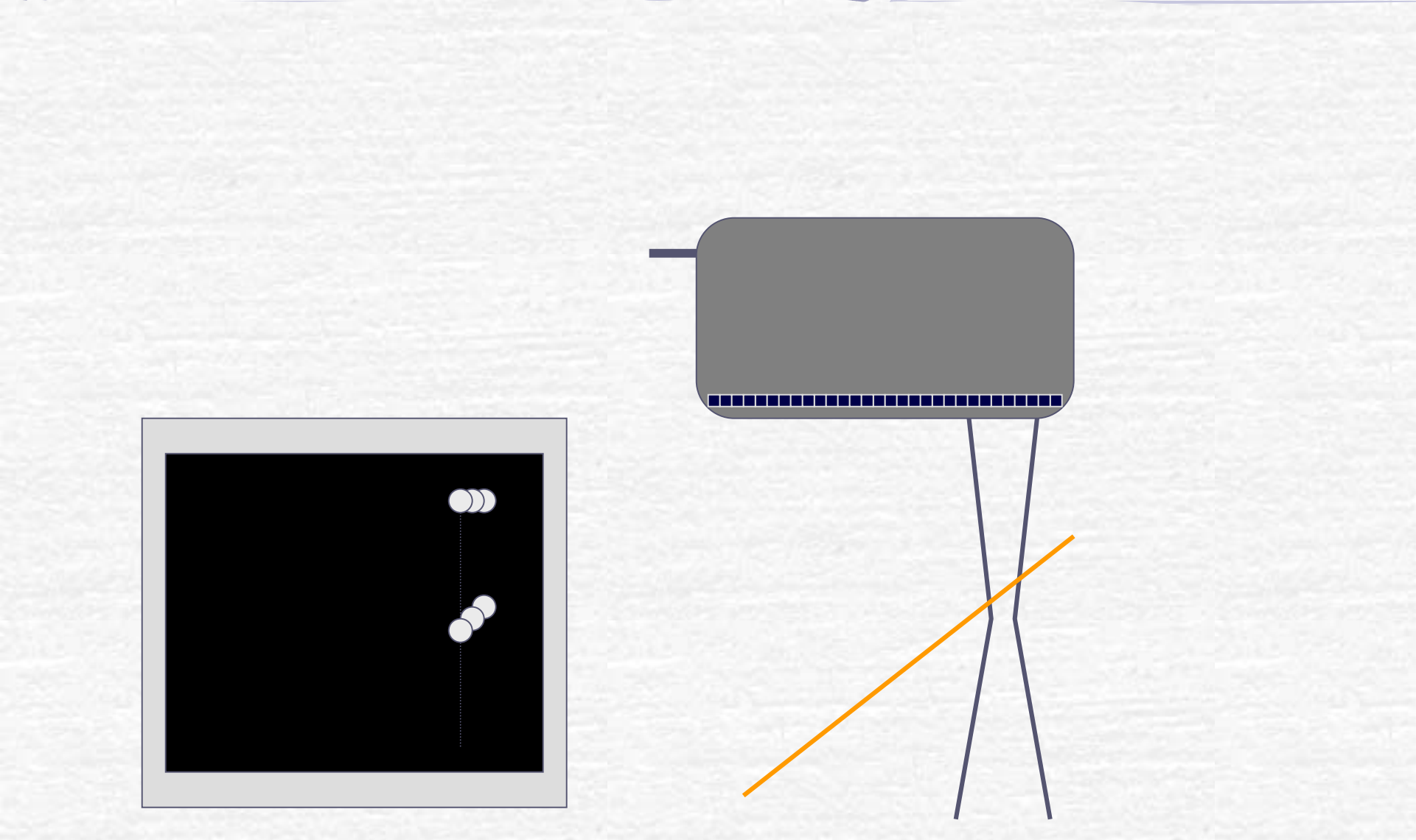
- ☛ Review characteristics of equipment
- ☛ Discuss factors related to physicists measurements of imaging performance
- ☛ Recommend basic QA
- ☛ Discuss role of medical physicists

# A-MODE AND B-MODE

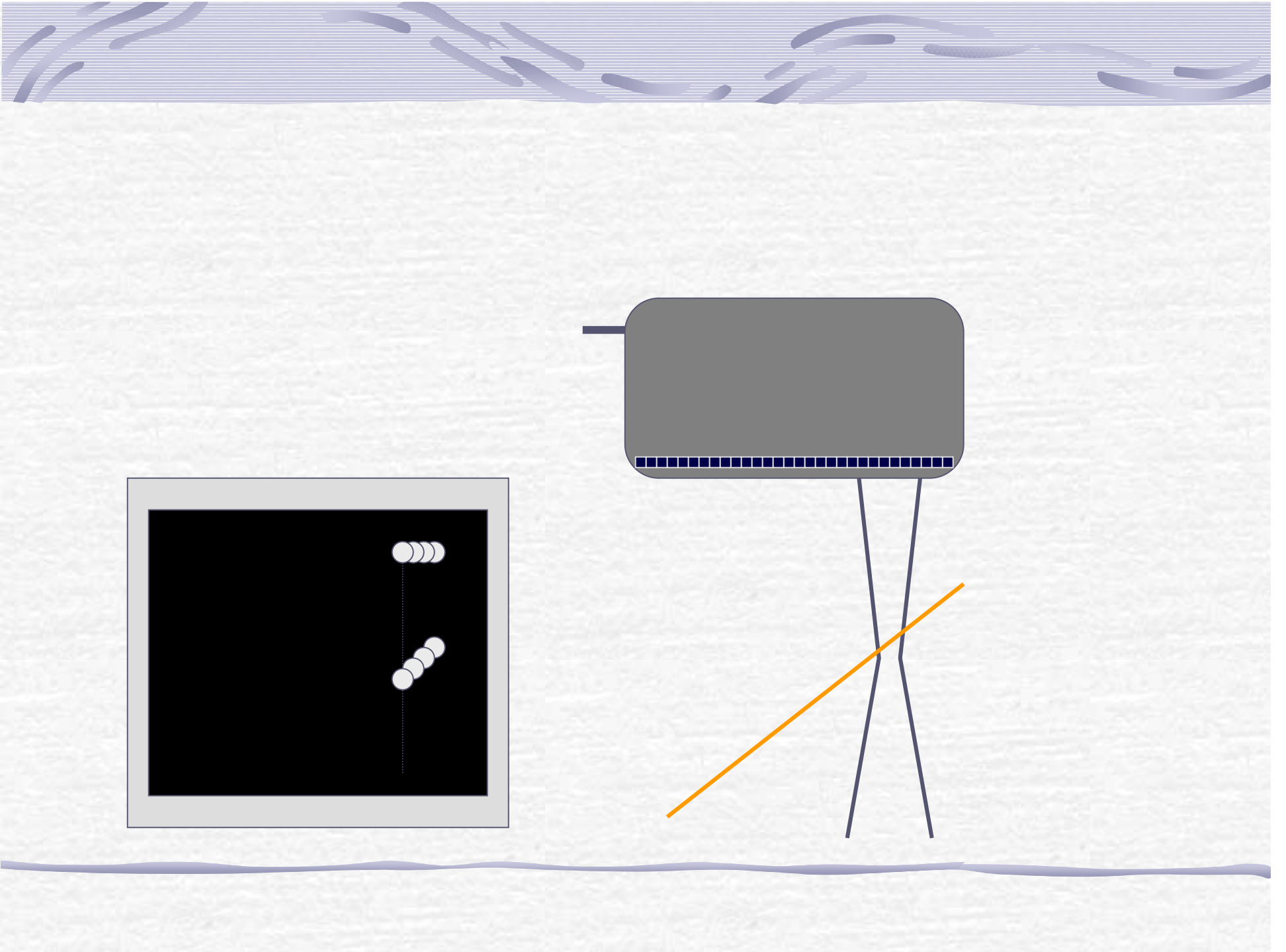


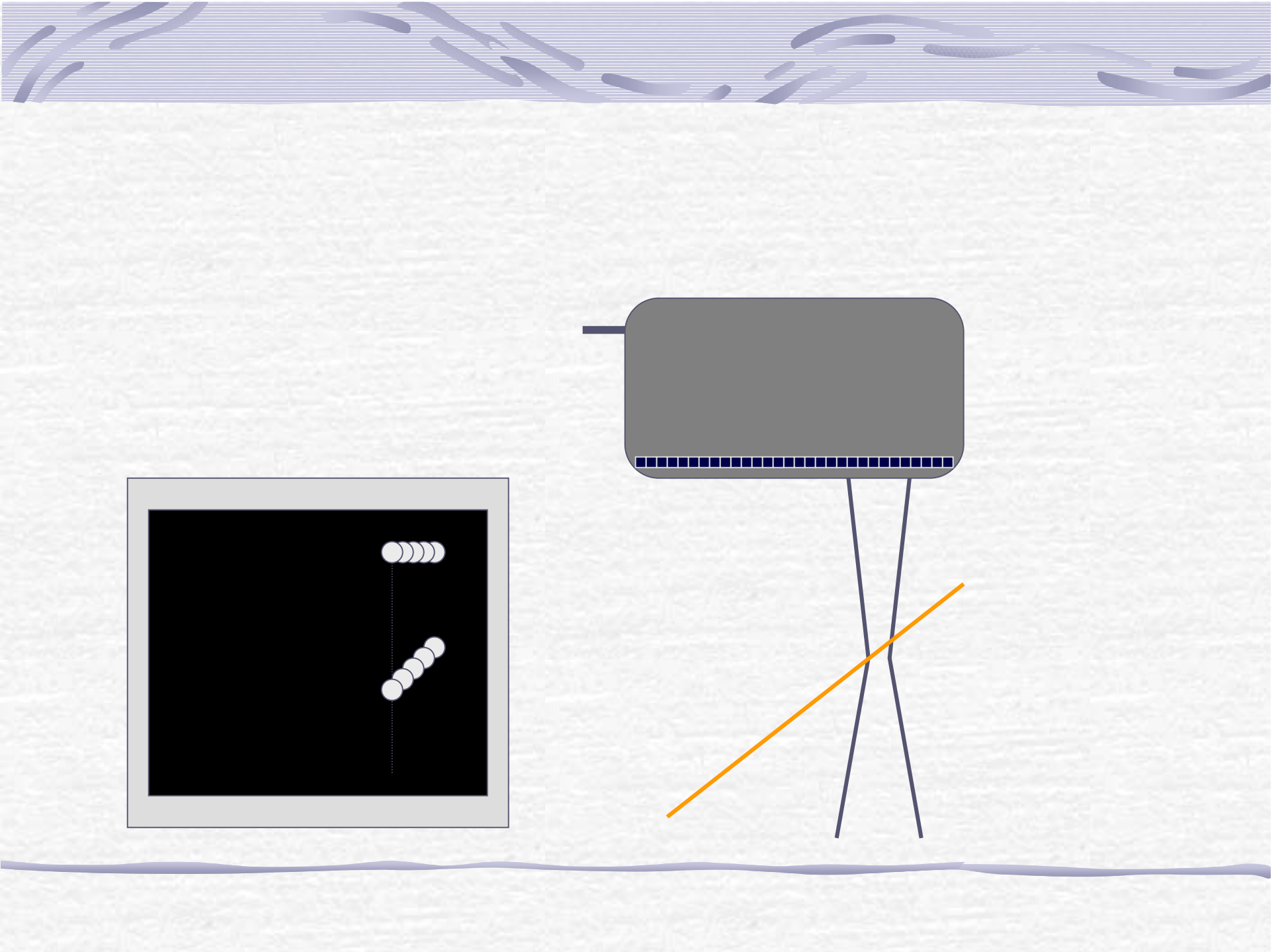


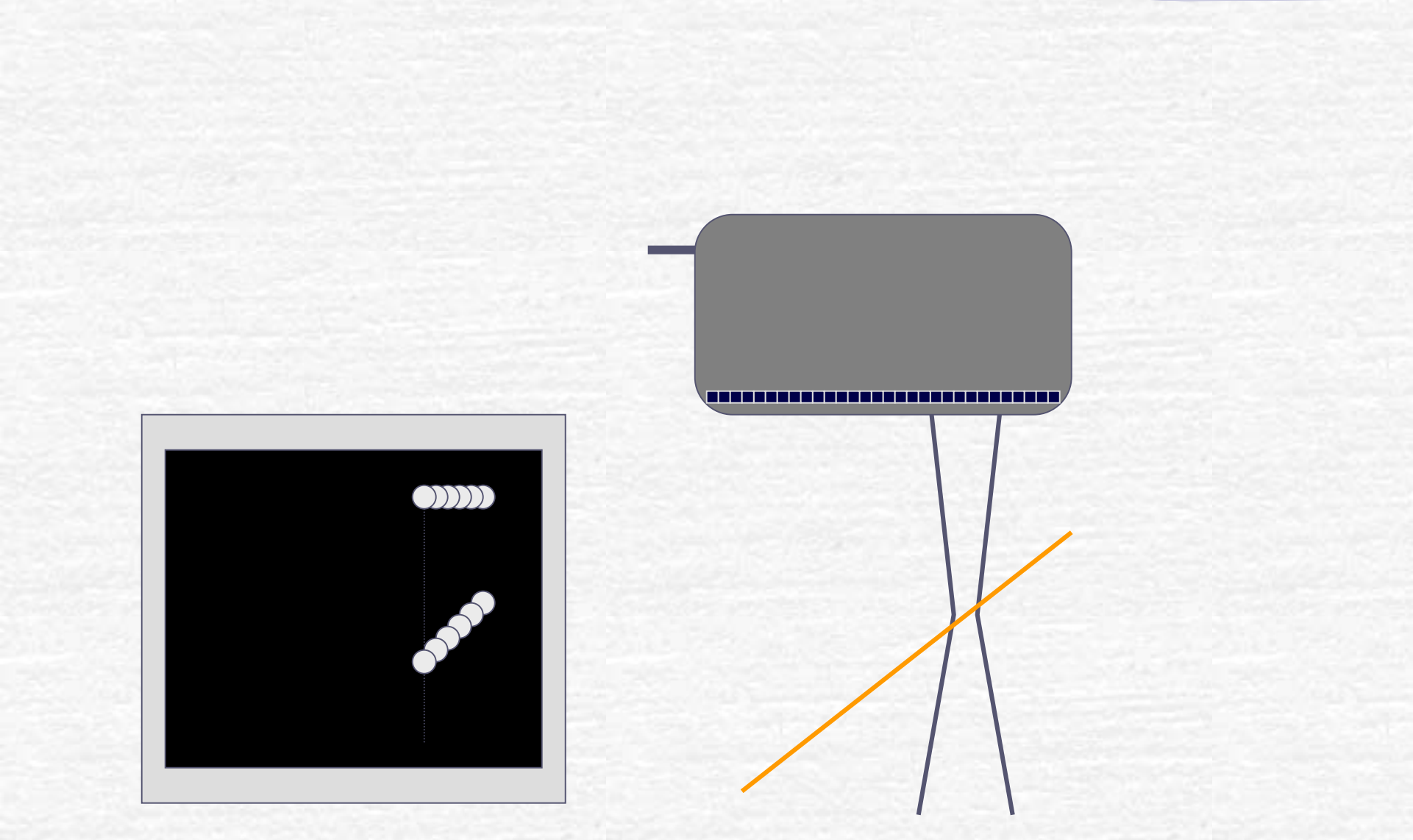


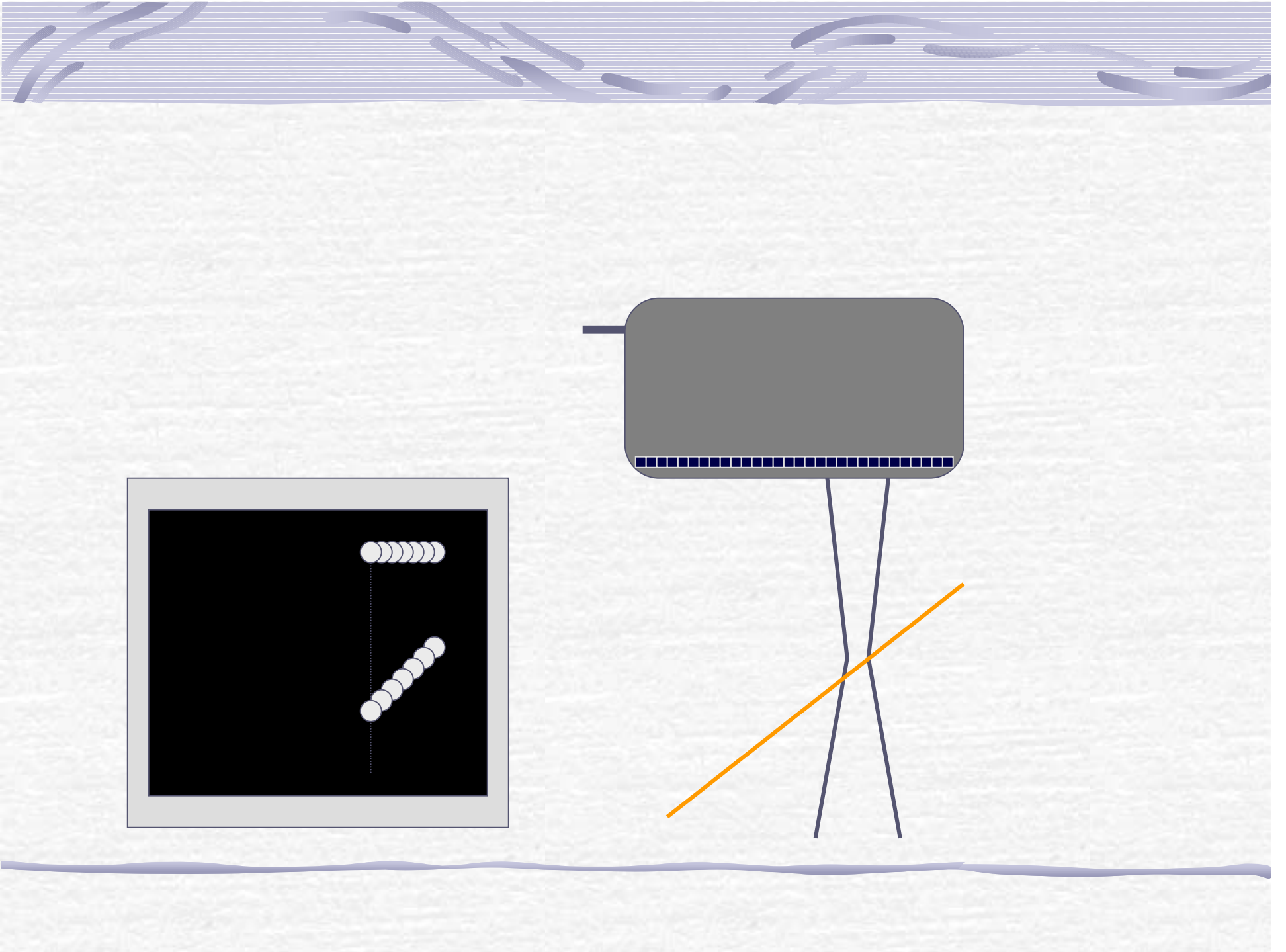


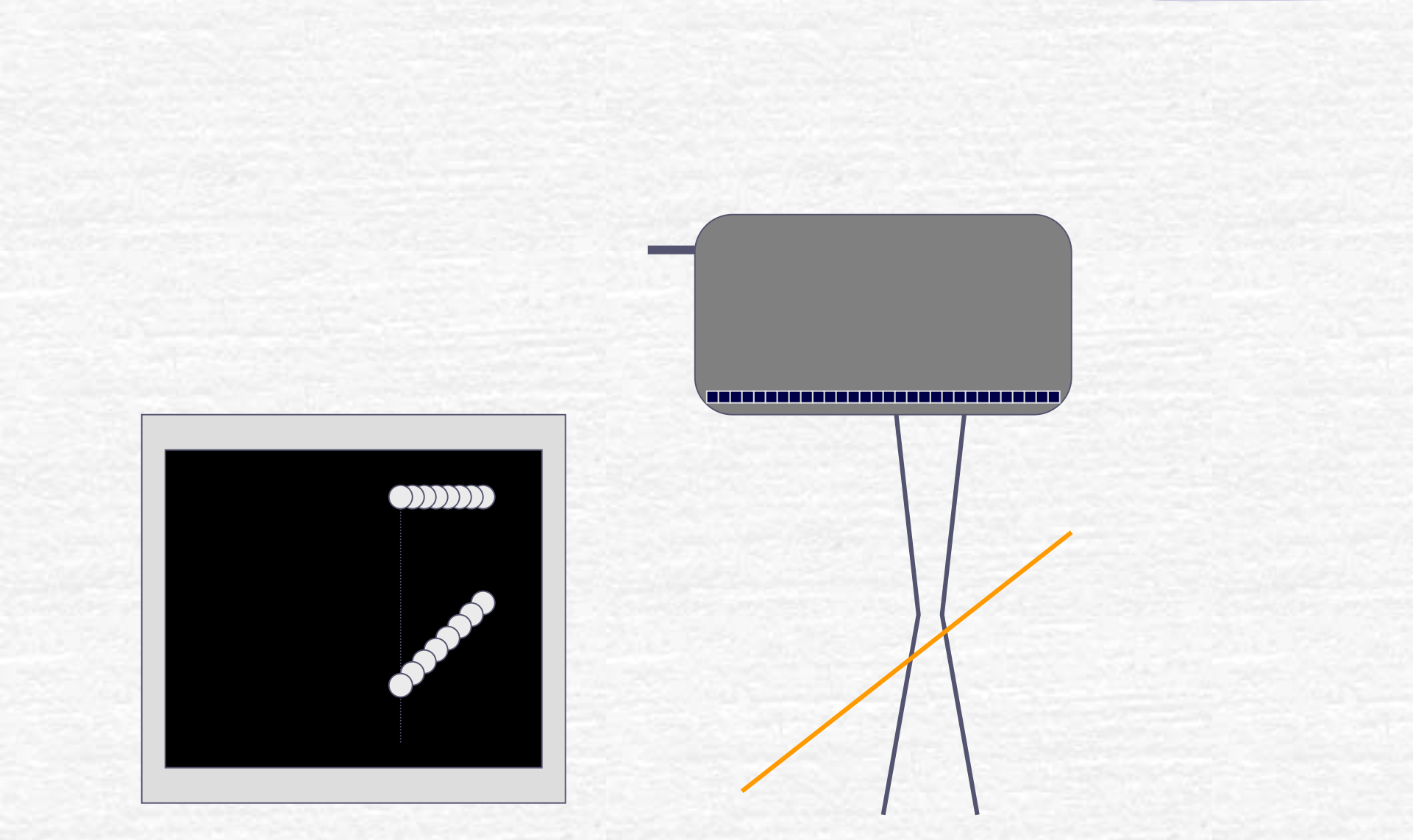


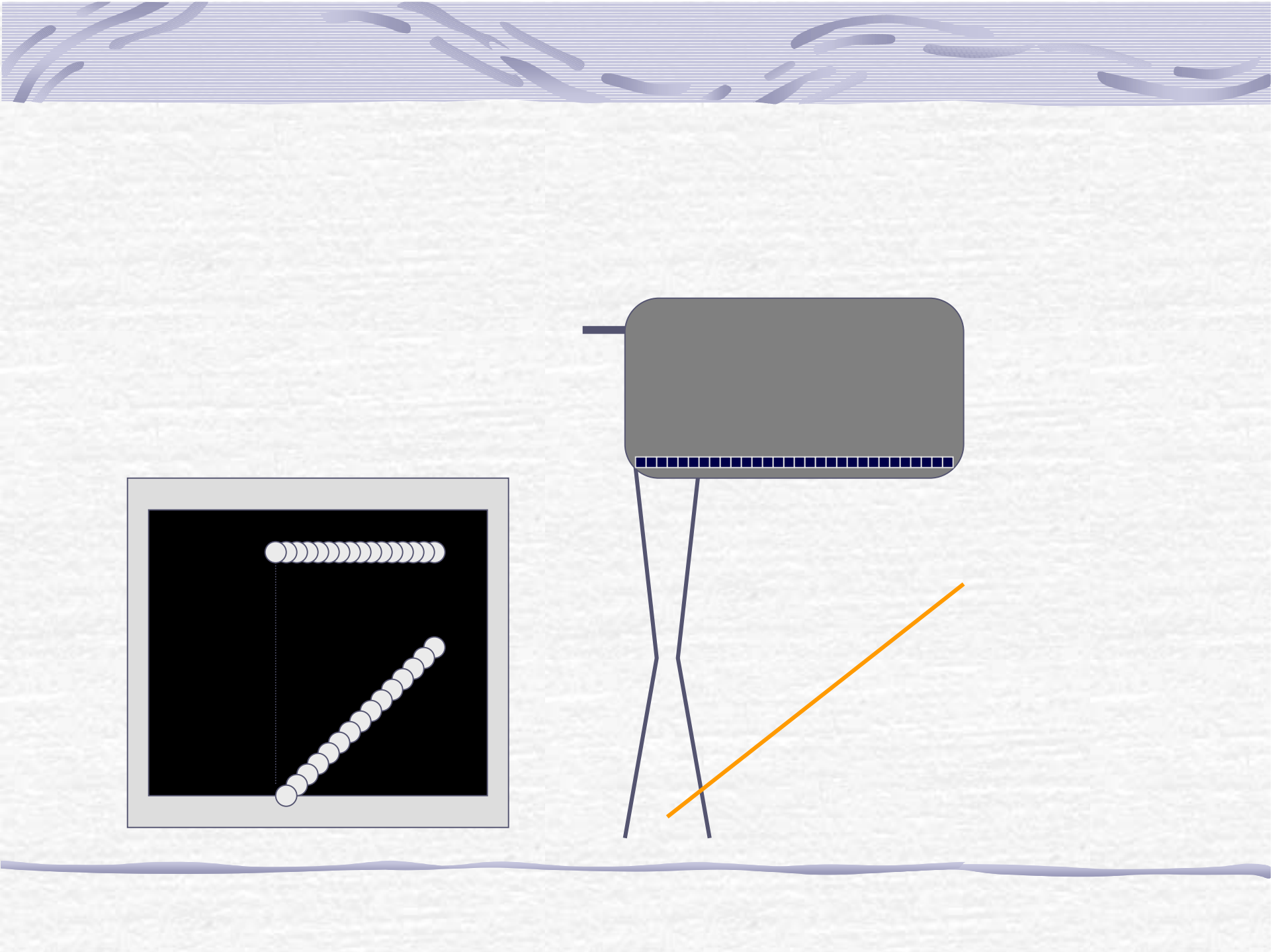




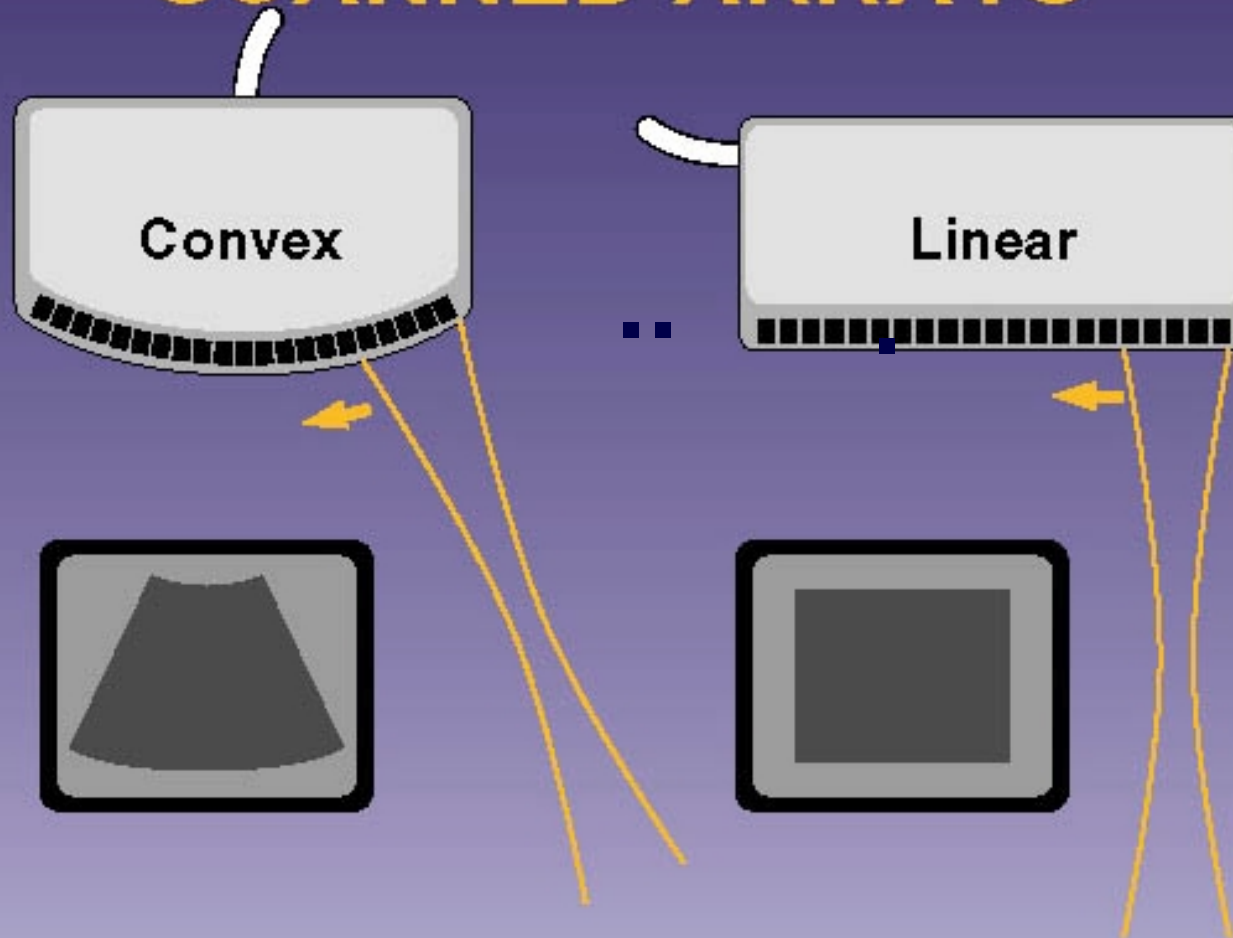




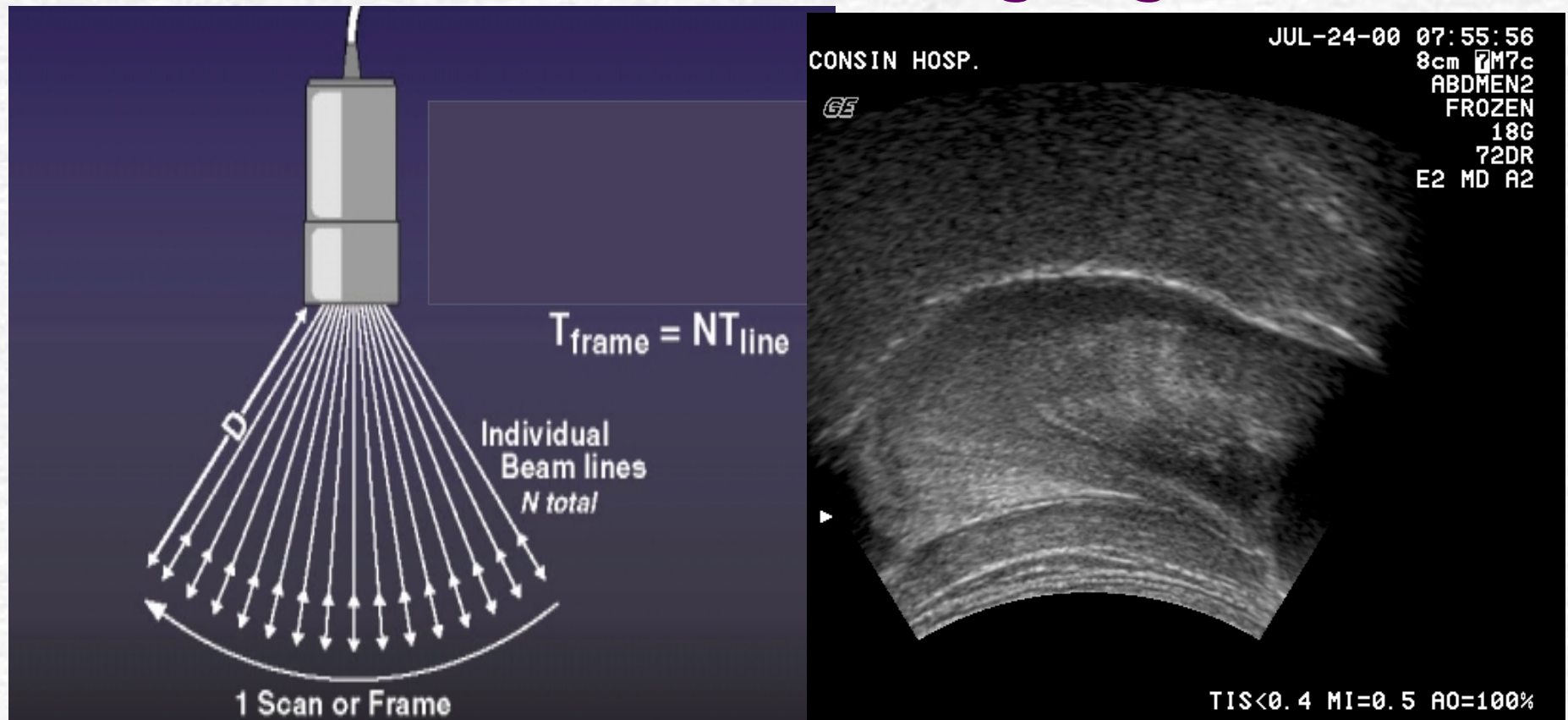




# ELECTRONICALLY SCANNED ARRAYS



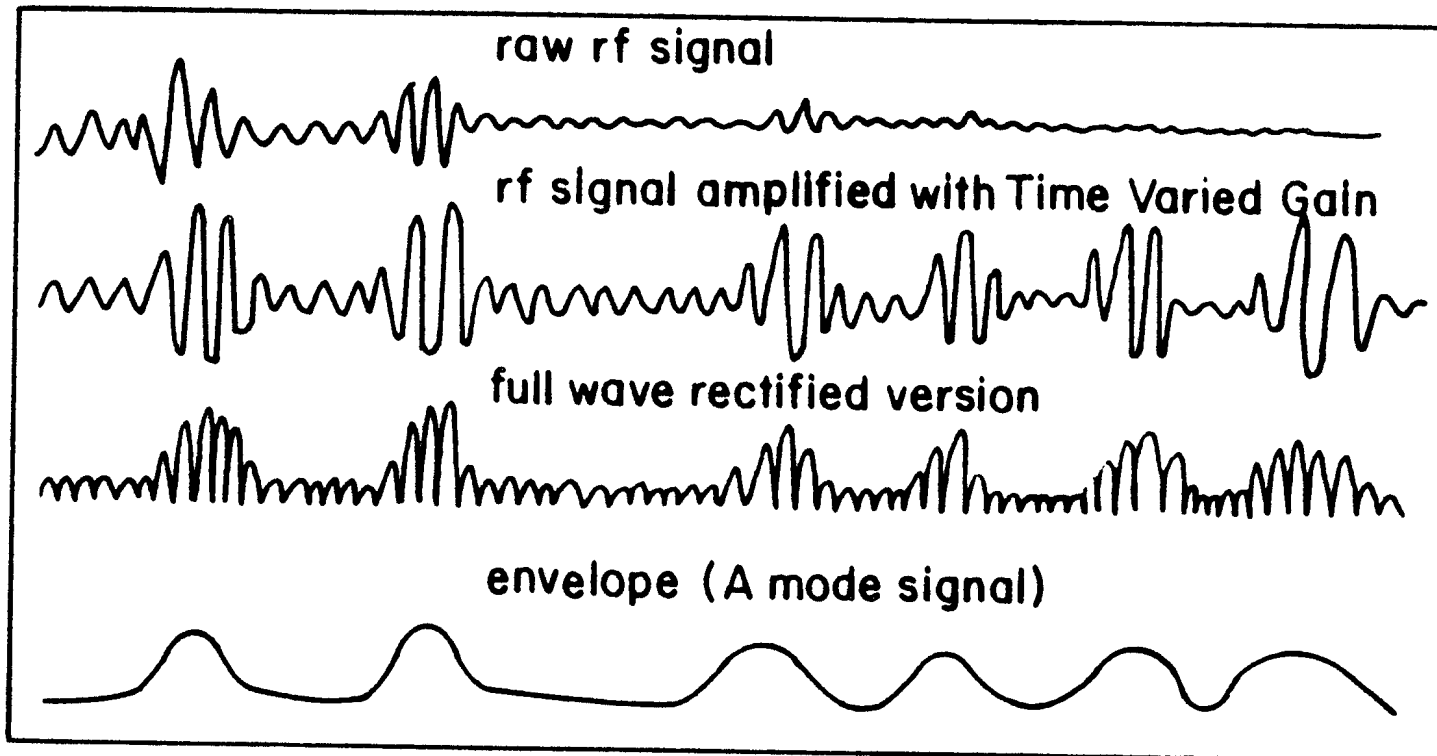
# Real-time imaging



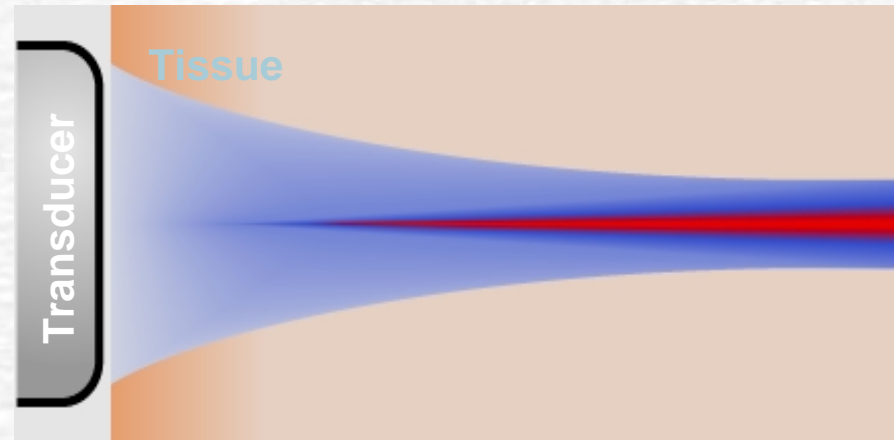
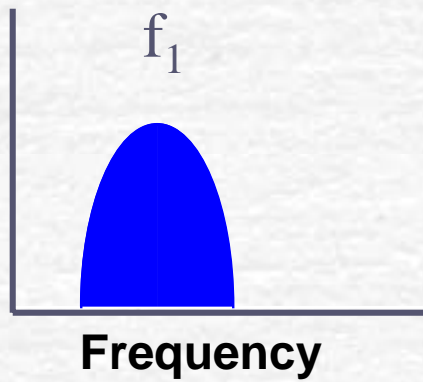
JAZ tongue  
30 frames/s



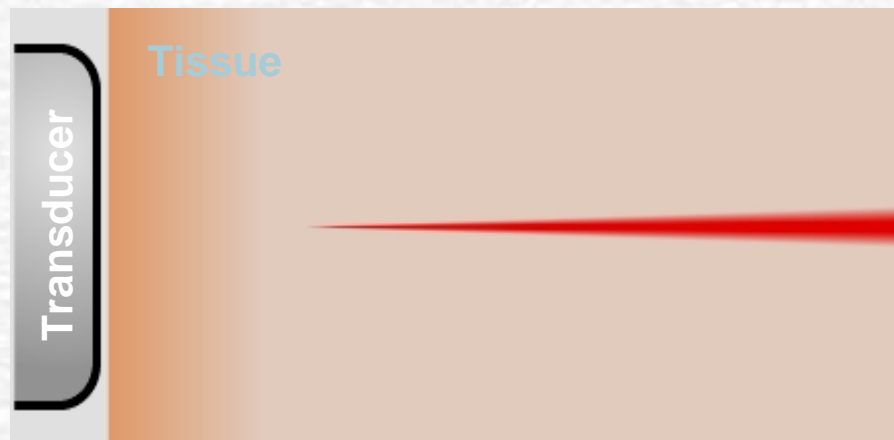
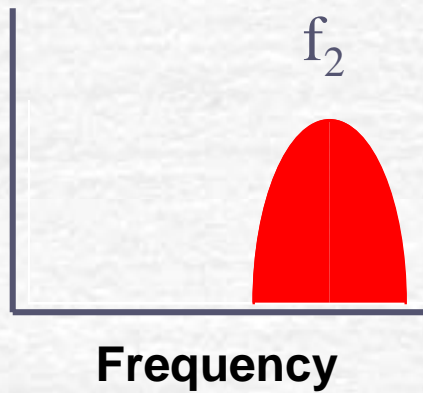
## SIGNAL PROCESSING



# Harmonic Processing

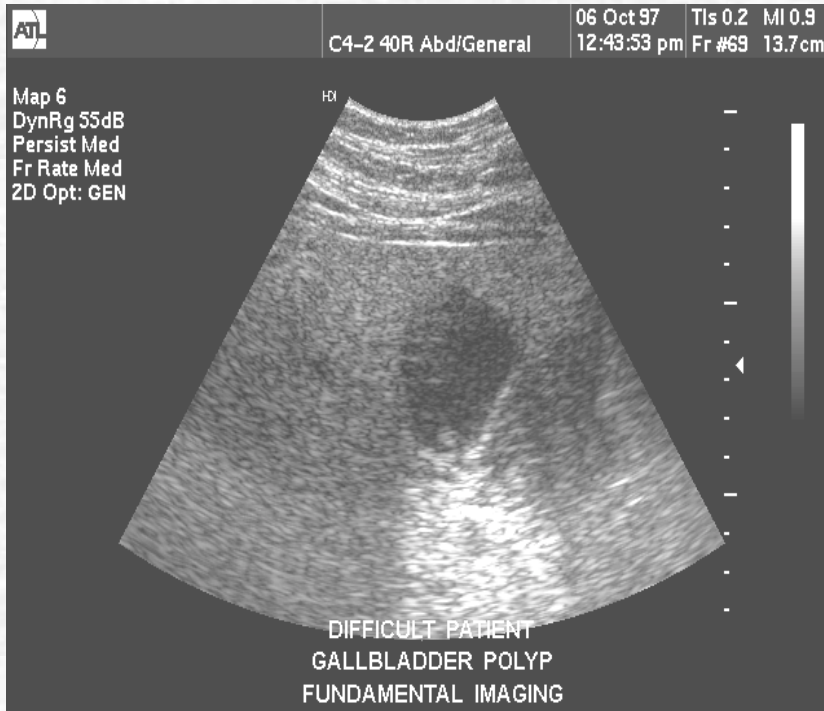


Acoustic field

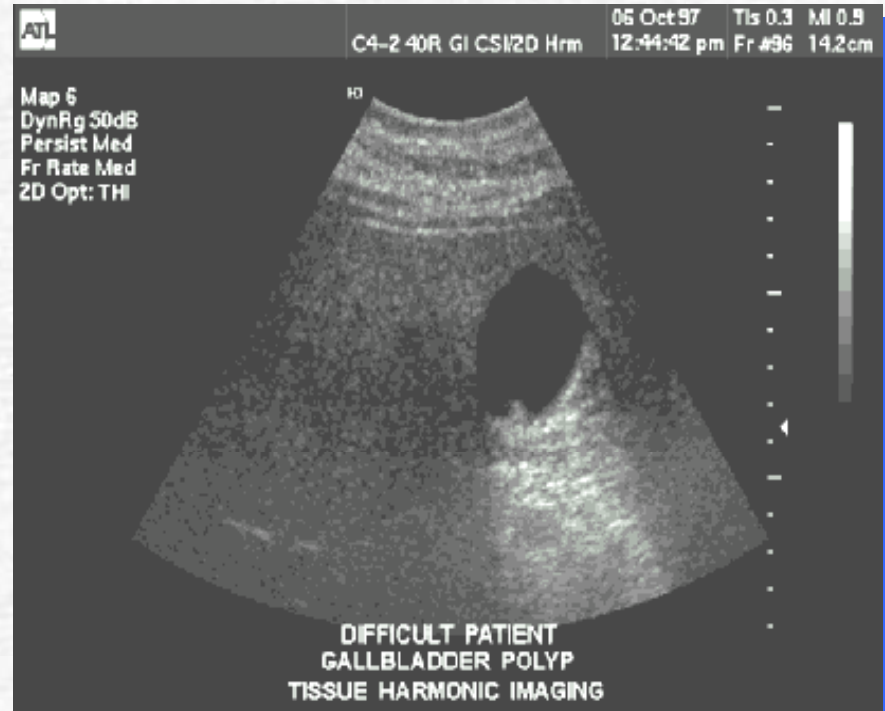


After processing

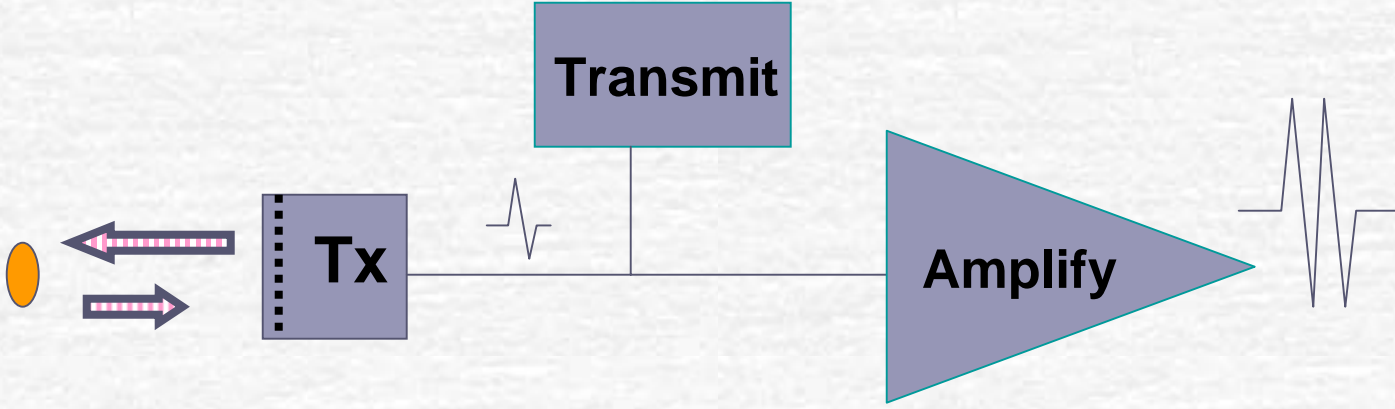
# Gallbladder Polyp



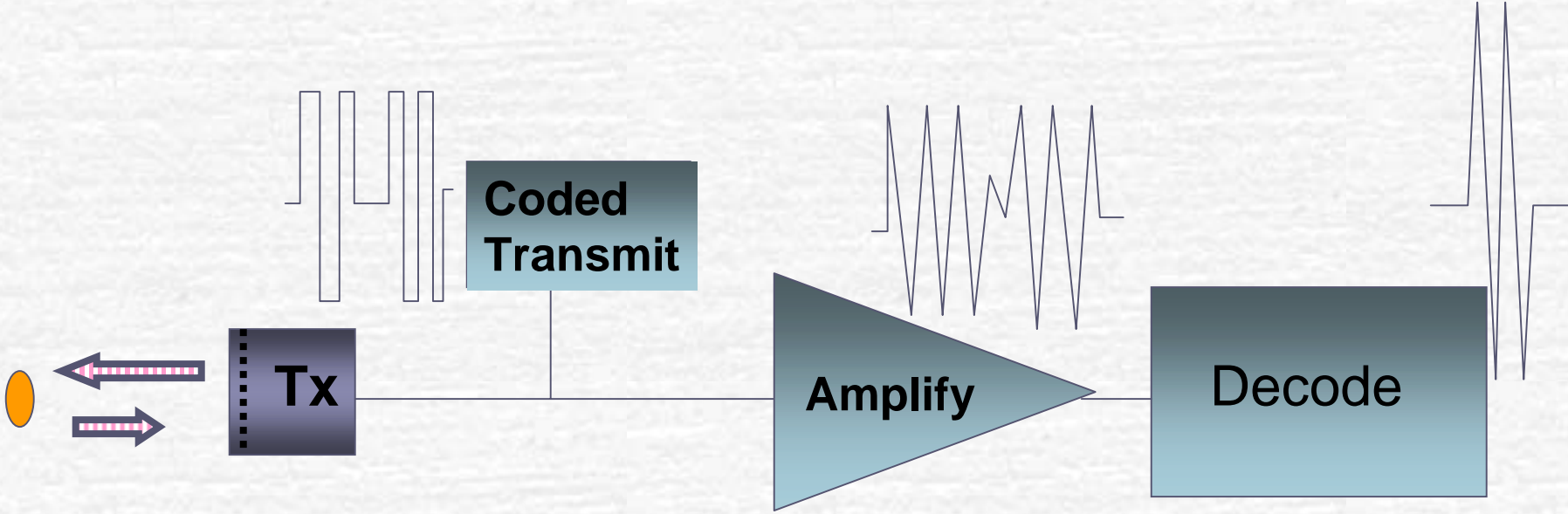
**Fundamental**

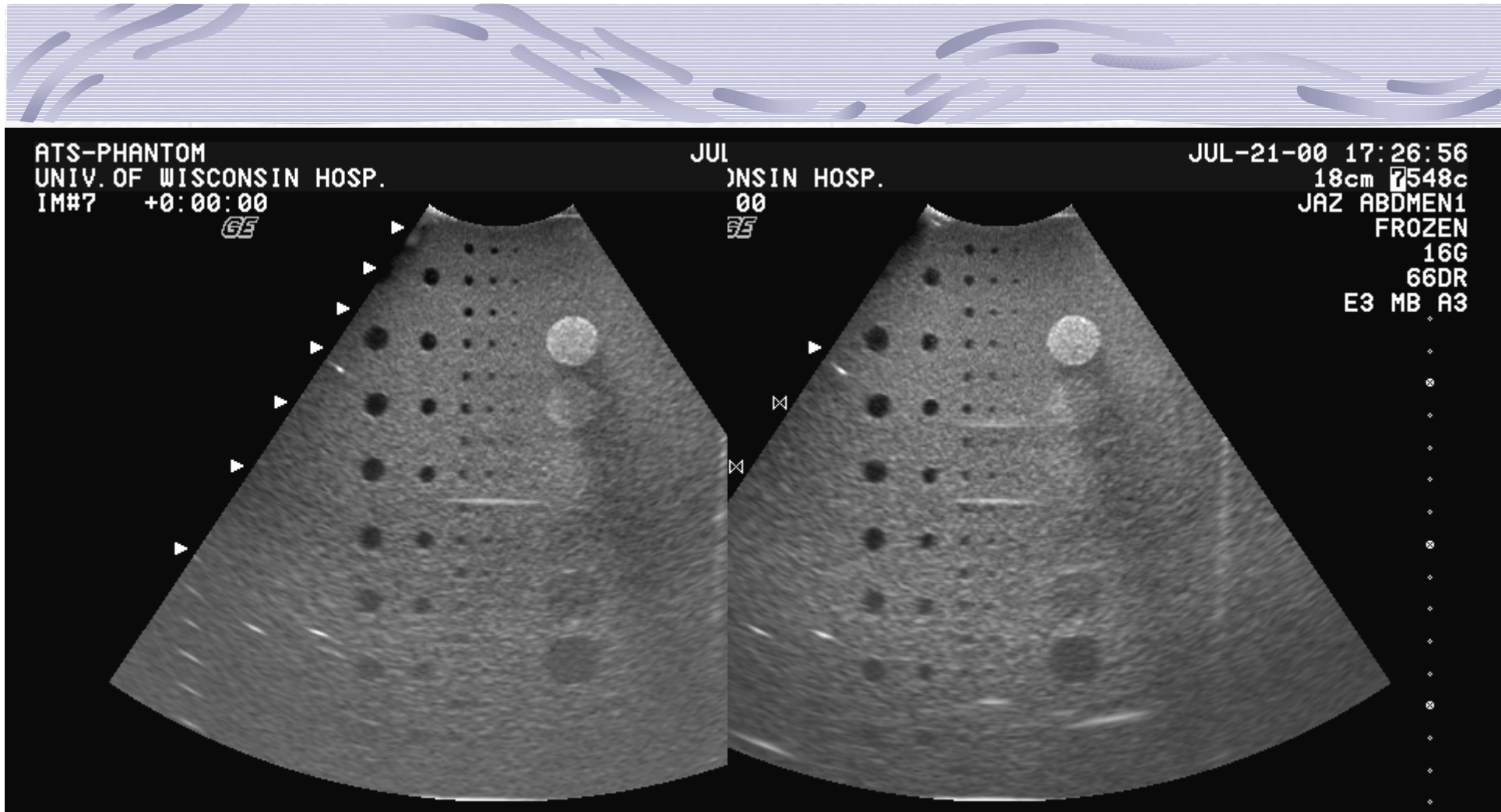


# Standard



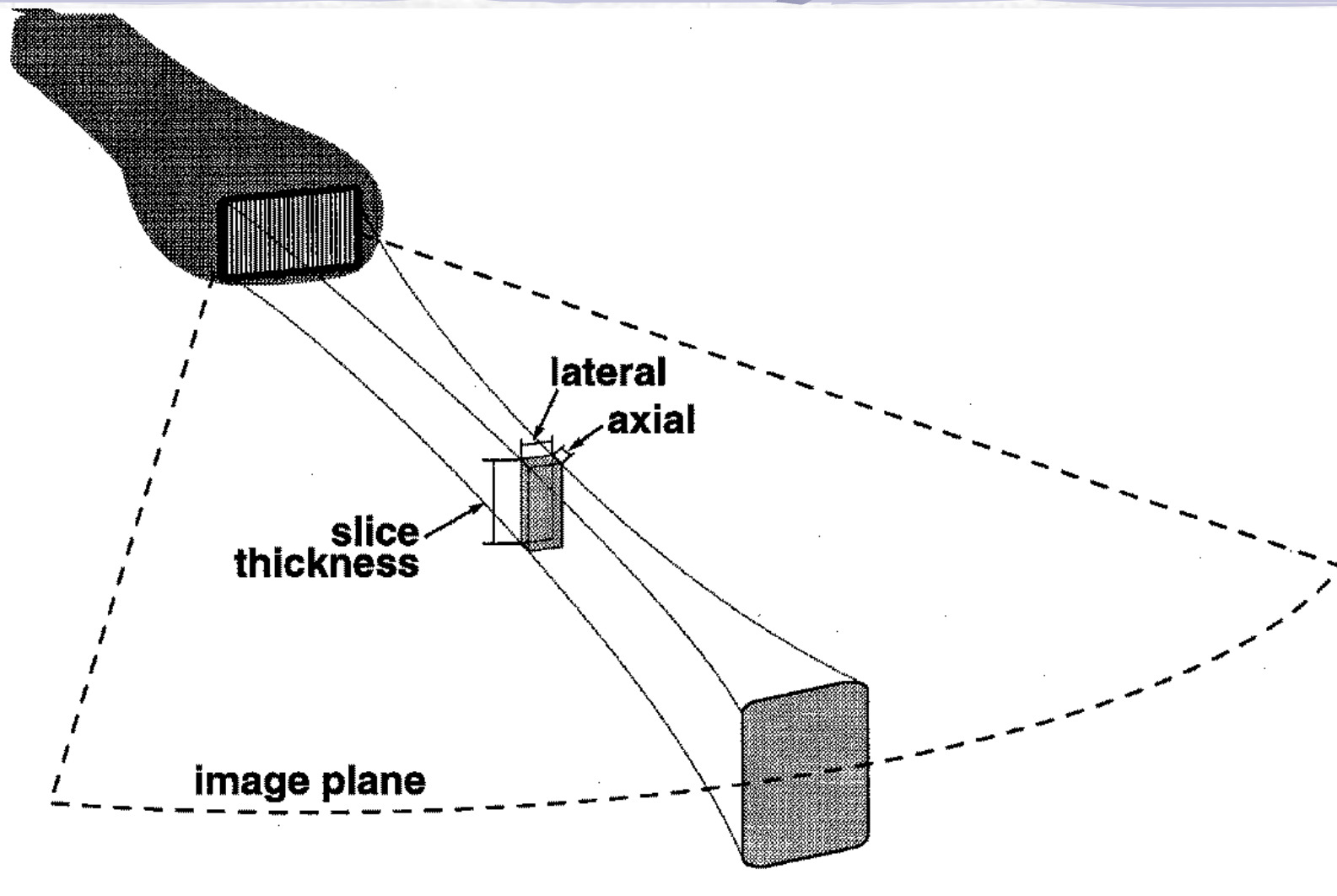
# Coded Excitation





GE 548c  
Standard Transmit

GE 548c  
Coded Excitation

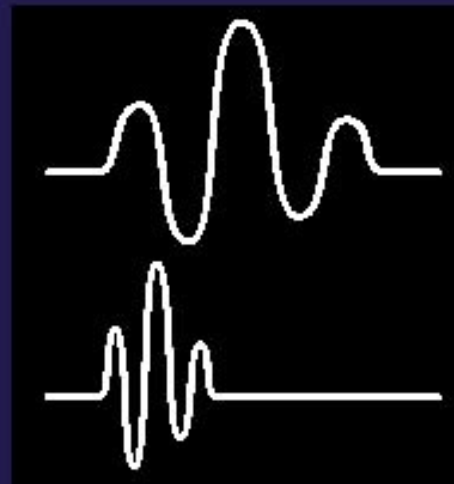


**slice  
thickness**

**lateral  
axial**

**image plane**

# PULSE DURATION AND FREQUENCY



Low frequency pulse

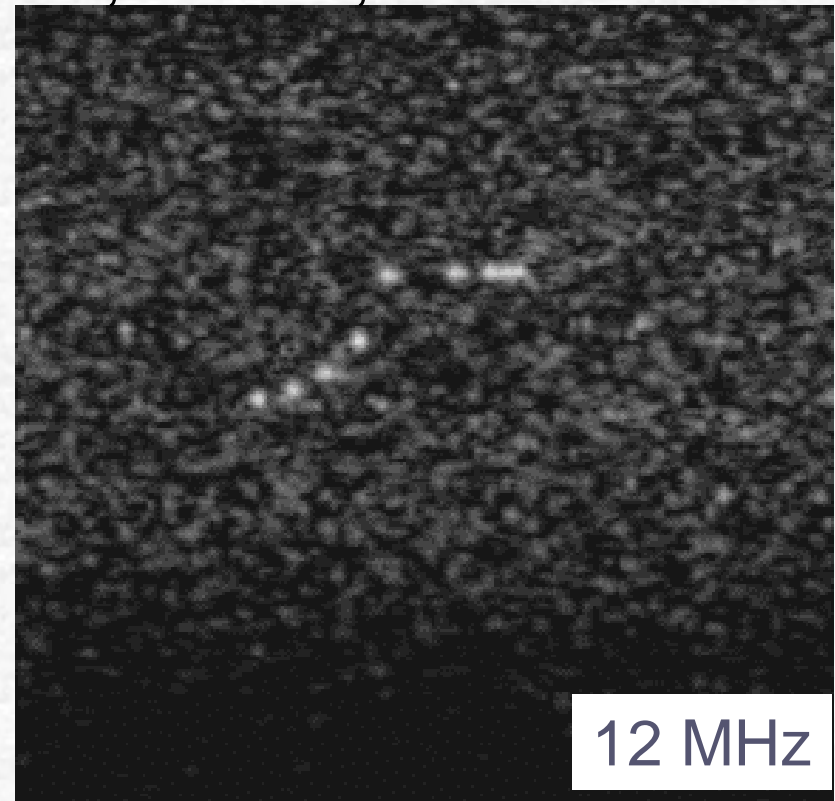
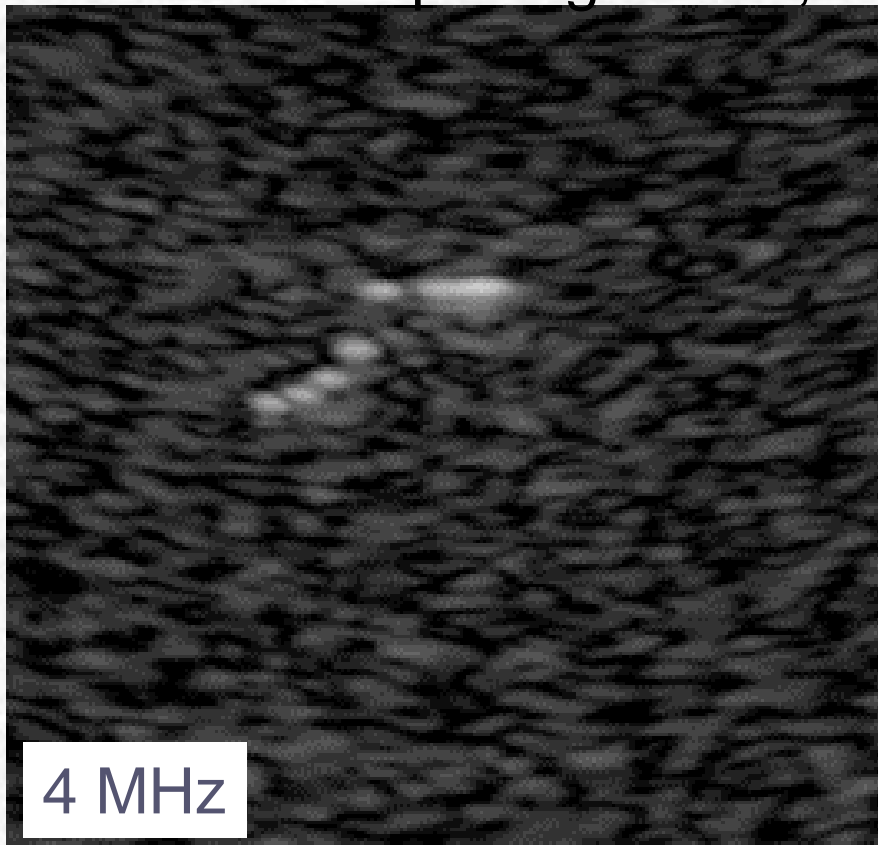
High frequency pulse

- Higher frequencies give shorter duration pulses and better axial resolution

# GE Logiq 700

Horizontal spacing: 2 mm, 1 mm, 0.5 mm, 0.25 mm

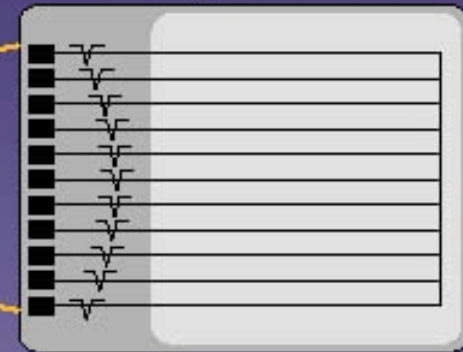
Vertical Spacing: 2 mm, 1 mm, 0.5 mm, 0.25 mm





# SELECTABLE TRANSMIT FOCAL DISTANCE

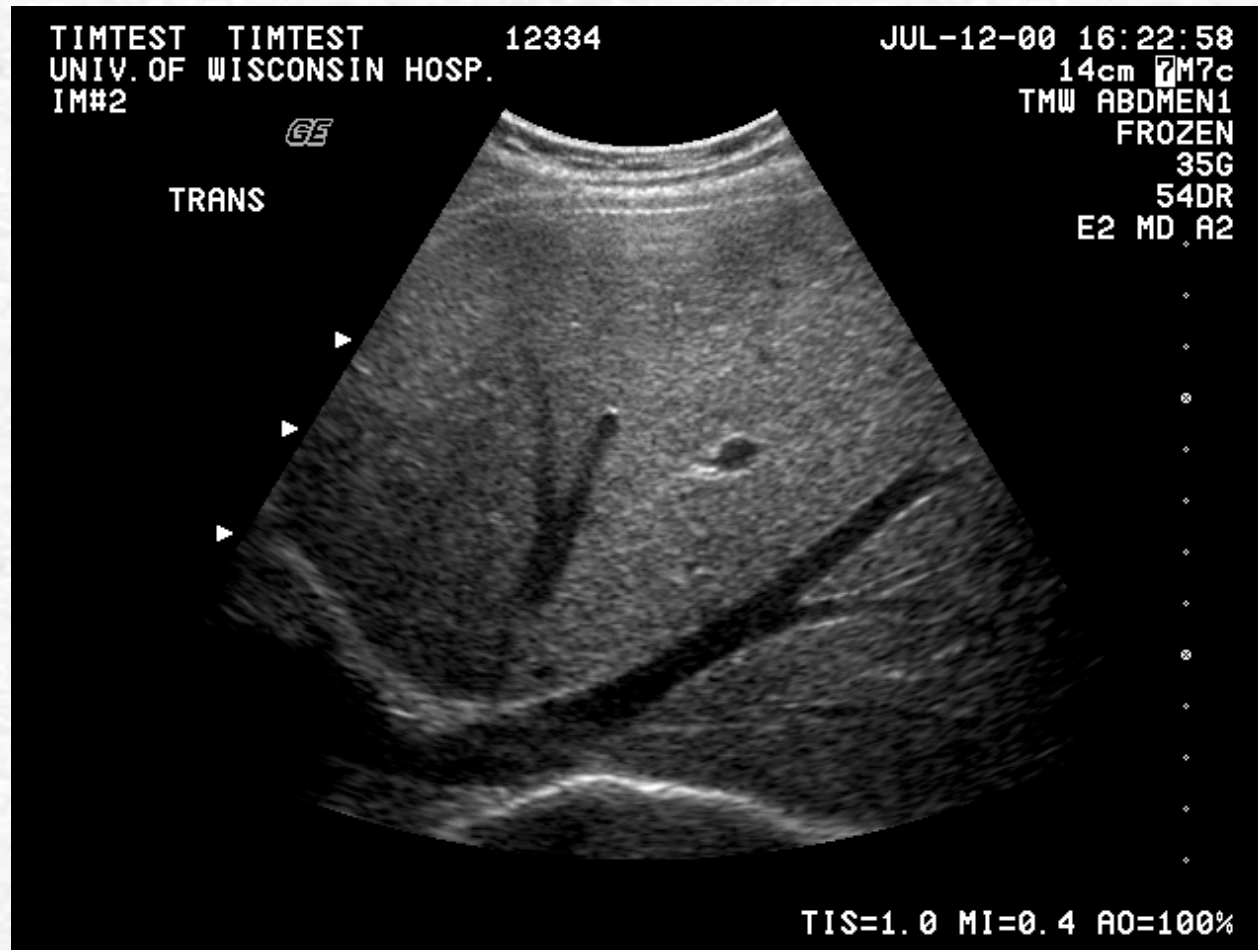
→  
delay time



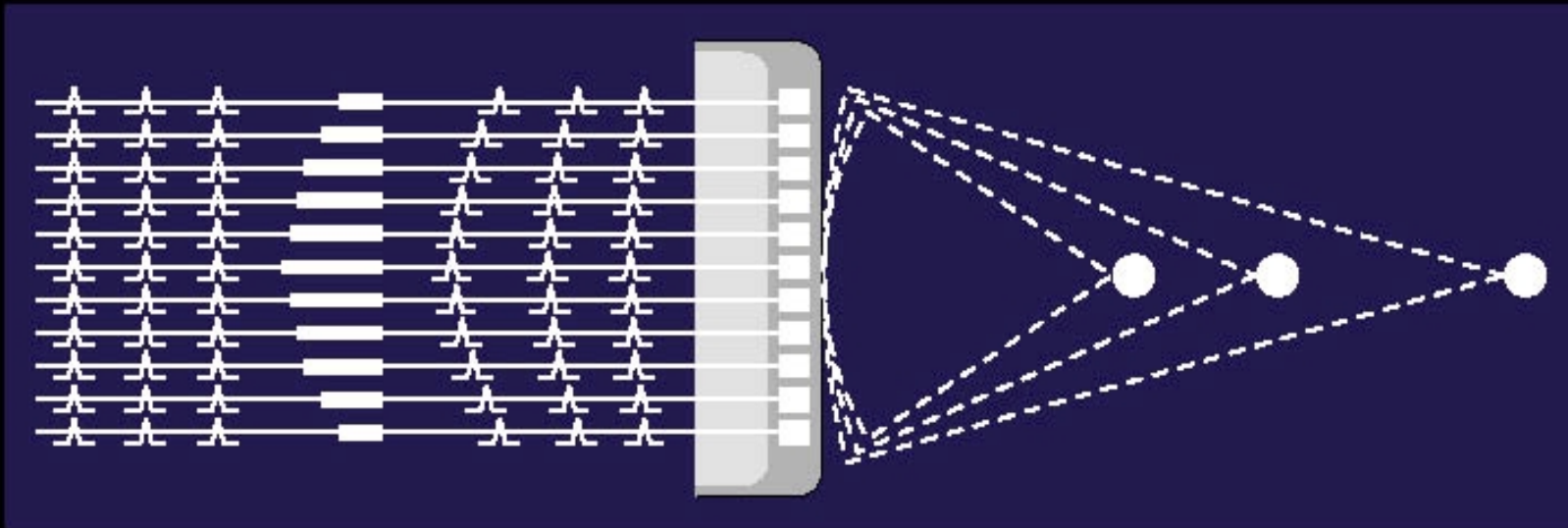
→  
delay time



# Multiple Transmit Focal Zones

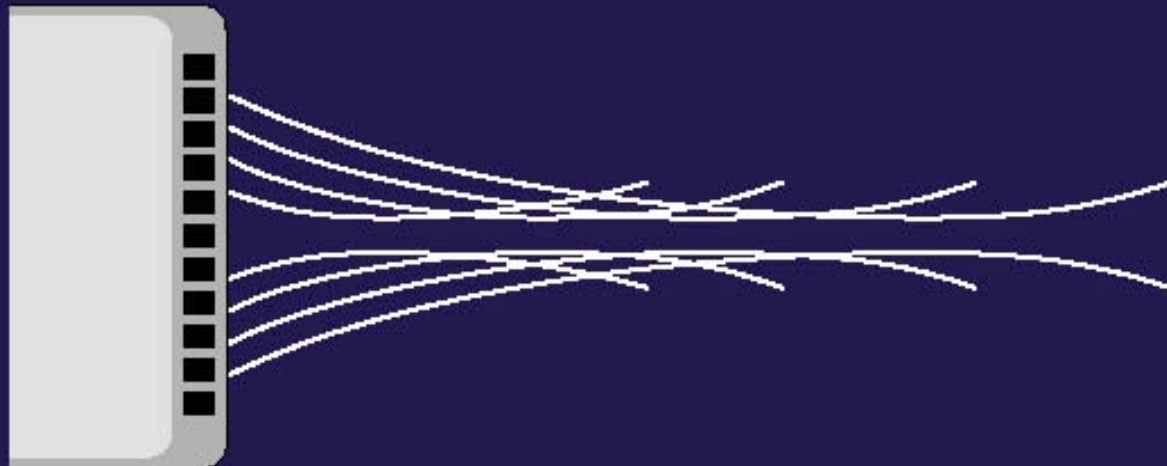


# DYNAMIC RECEIVE MODE FOCUSING



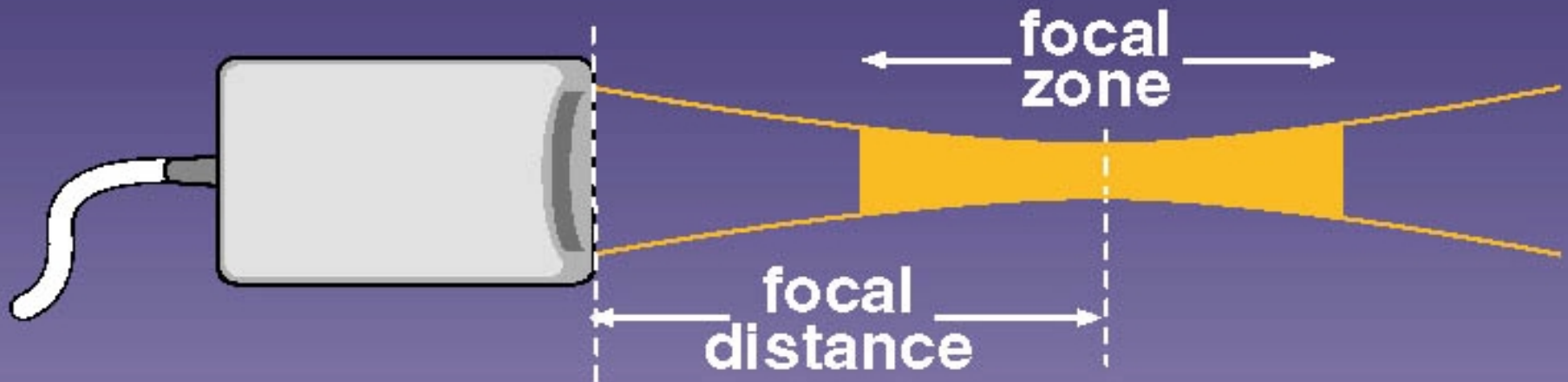
variable  
delays

# DYNAMIC APERTURE



- Number of elements used increases as echos arrive from progressively deeper structures.

# FOCAL ZONE CHARACTERISTICS



$$L \cdot R = \frac{\lambda \cdot F}{D}$$

F = focal distance

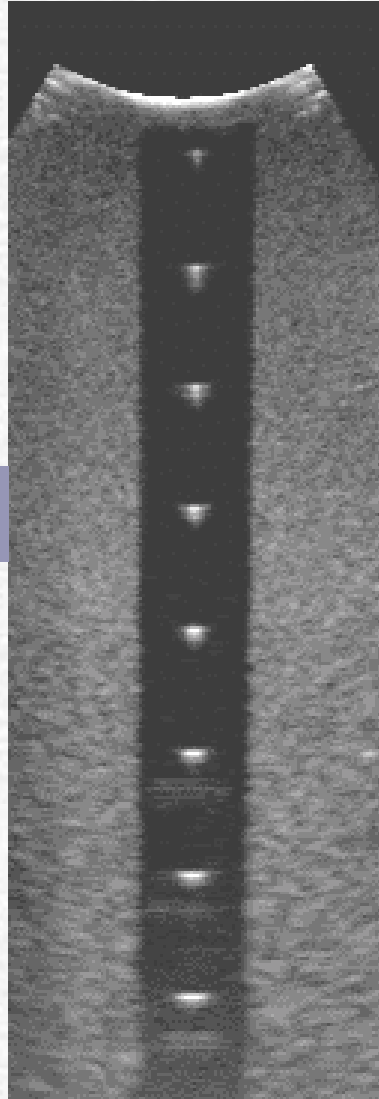
D = aperture (transducer) size

$\lambda$  = wavelength

(smaller for higher frequencies)

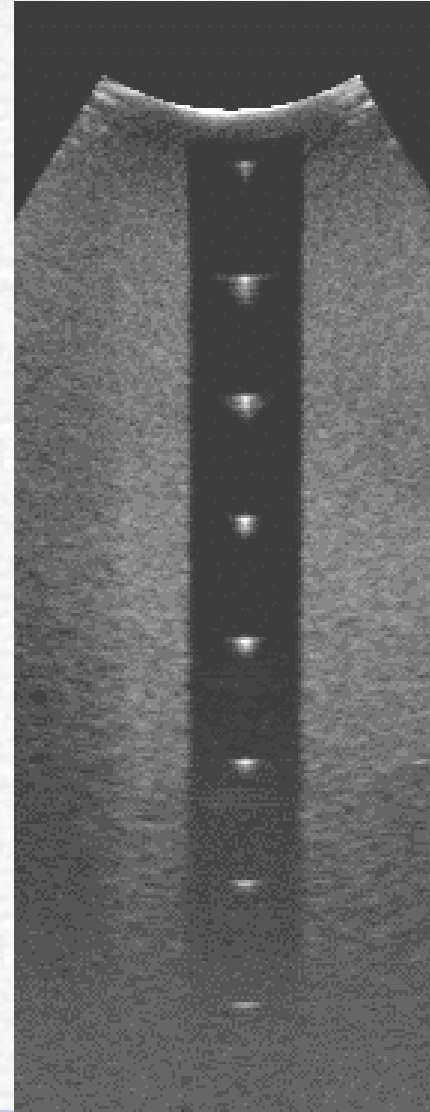
Point targets  
in tm material

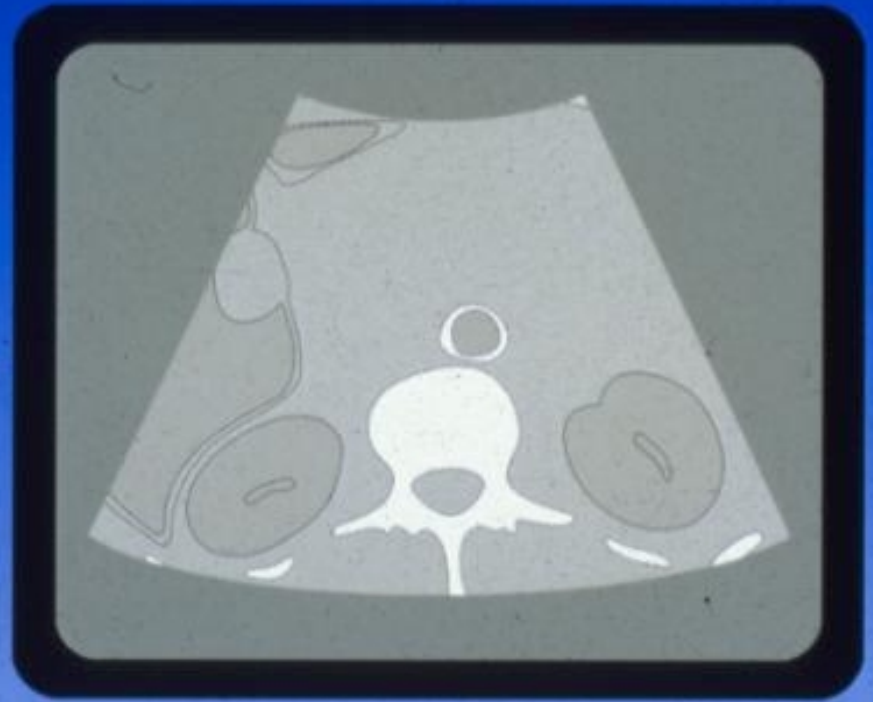
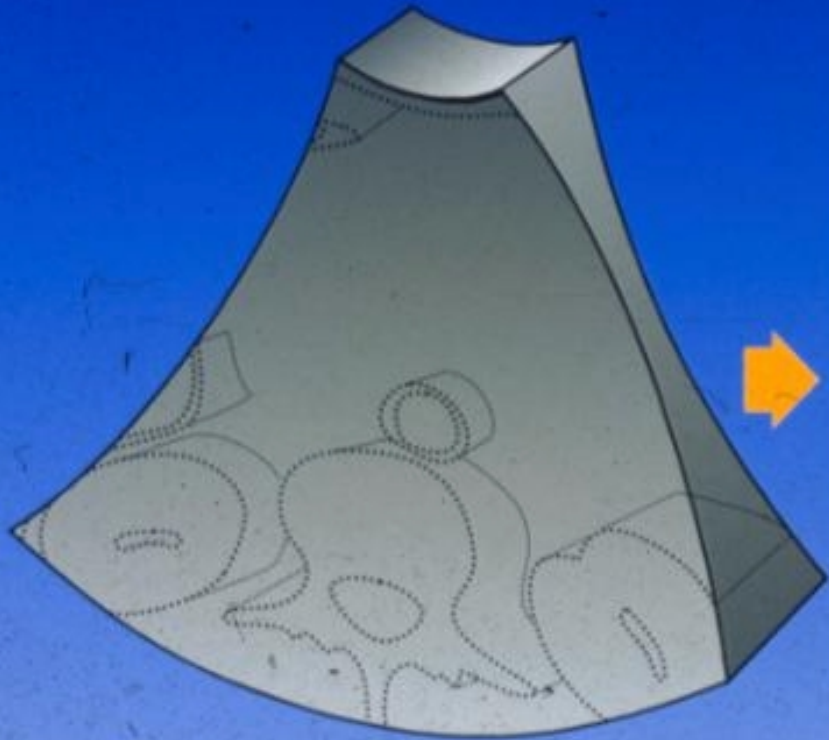
4 MHz



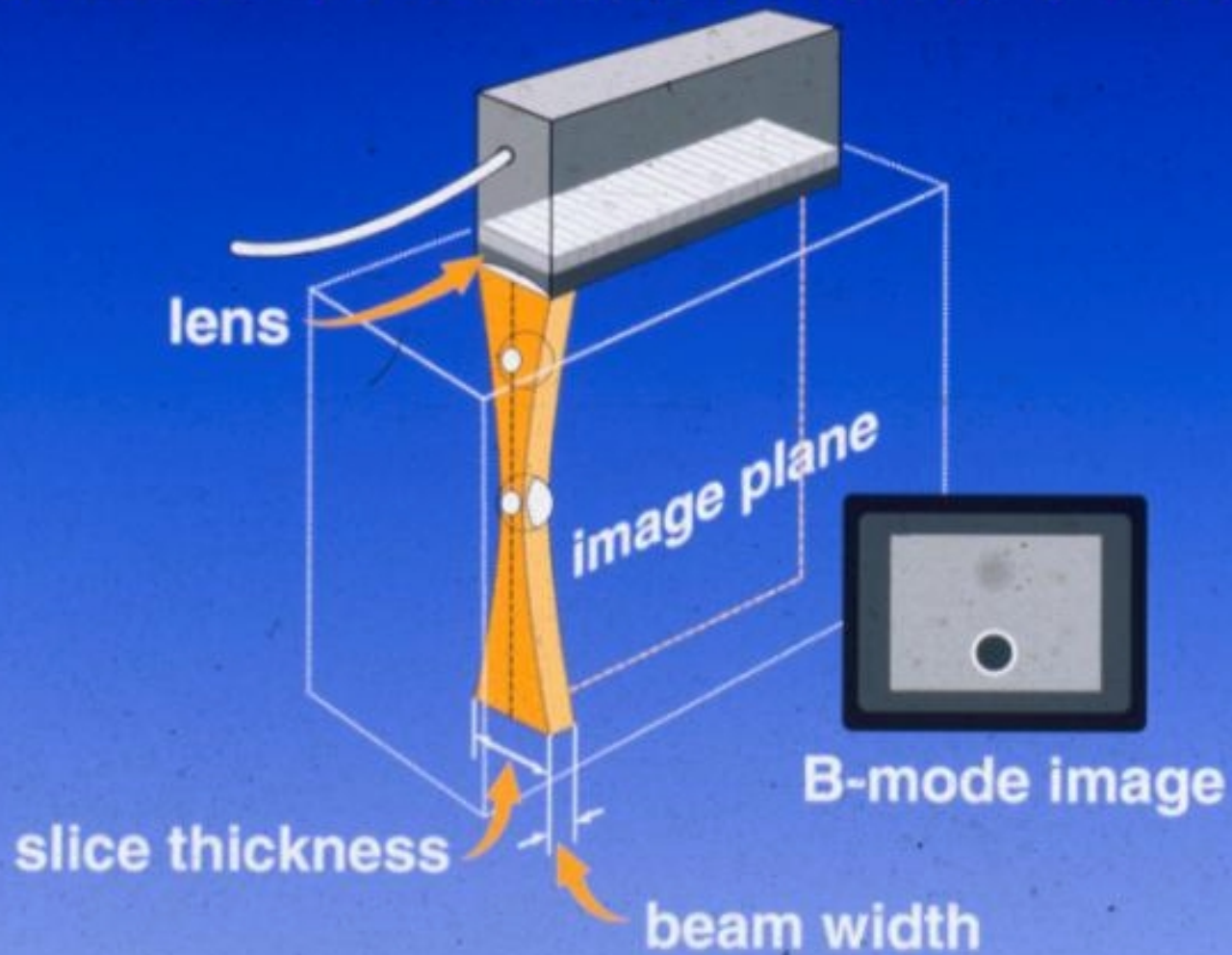
GE C548  
transducer

7 MHz





# SLICE THICKNESS EFFECTS





GE MEDICAL SYSTEMS  
IM#12



APR-30-97 08:43:19

16cm 348c

ABDMEN1

FROZEN

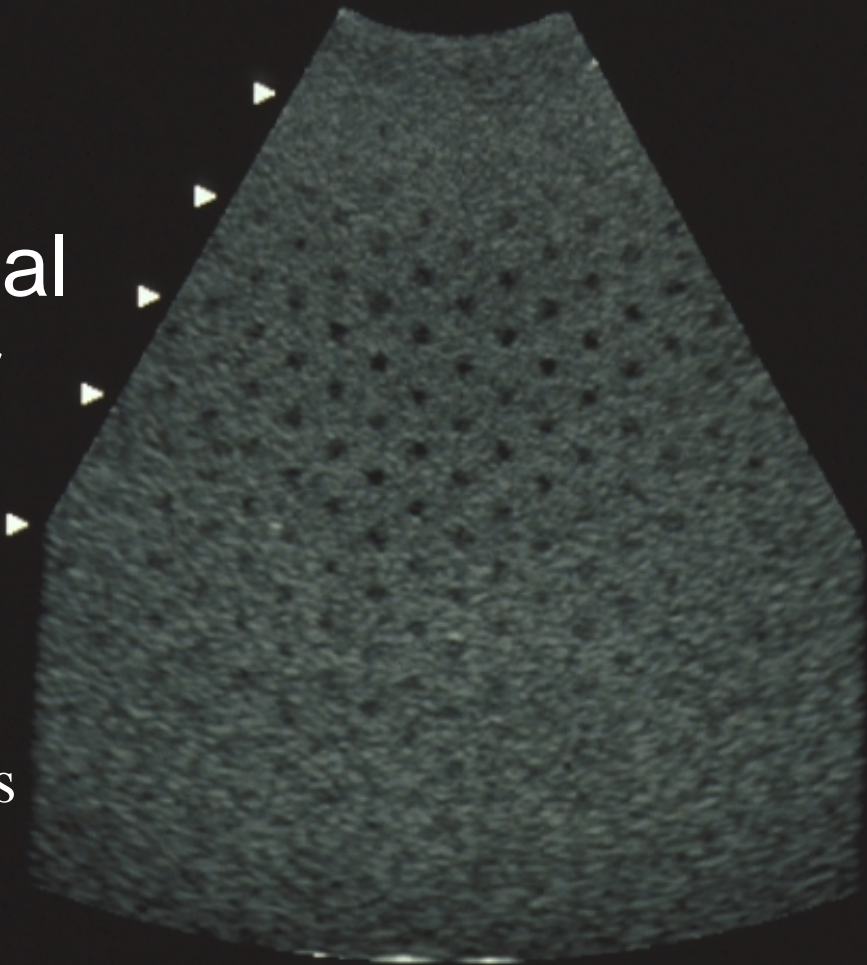
41G

69DR

E4 ME A2

Conventional  
Transducer

4 mm targets



MI=0.4 AO=100%

# Important Performance Features

- ✓ Geometric accuracy
  - (Not at levels considered previously when static scanners were used)
- ✓ Resolution
- ✓ Uniformity
- ✓ Penetration and sensitivity
- ✓ Low contrast detection

# Common US phantoms



# Gel Phantom Material Properties

Property	Value	Degree of Control
Density	$10^3 \text{ kg/m}^3$	Good
SOS	1,540 m/s	Very Good
Attenuation	0.5 to 0.7 dB/cm-MHz	Good
Scatter	Liver like	Good
B/A	Water-like	Fair

# Water-based Gel Phantoms

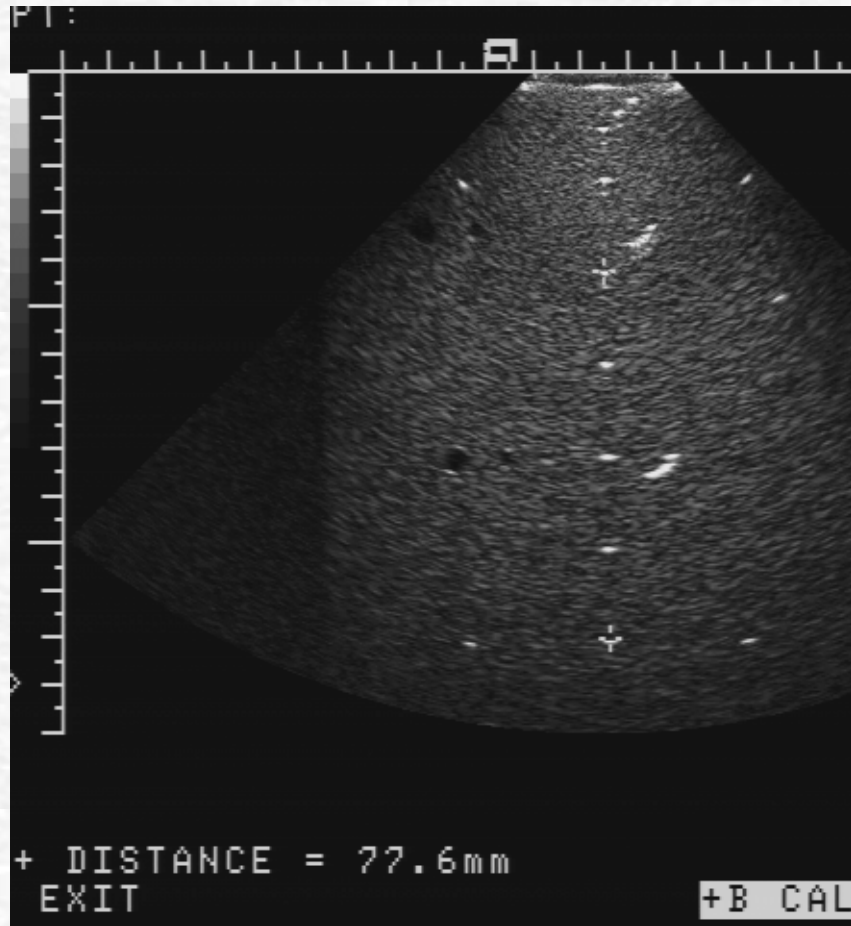
- Gel materials cannot be machined.
- Even **little** bubbles cause **big** problems.
- Care is needed to avoid desiccation.



# Alternative Materials

- Polyurethane rubber
  - stable
- SOS = 1455 m/s
  - (Too low)
- Attenuation changes too rapidly with freq.
- QA tests only?
  - (Goodsitt et al, 1998, Med Physics)





Vertical Distance Accuracy

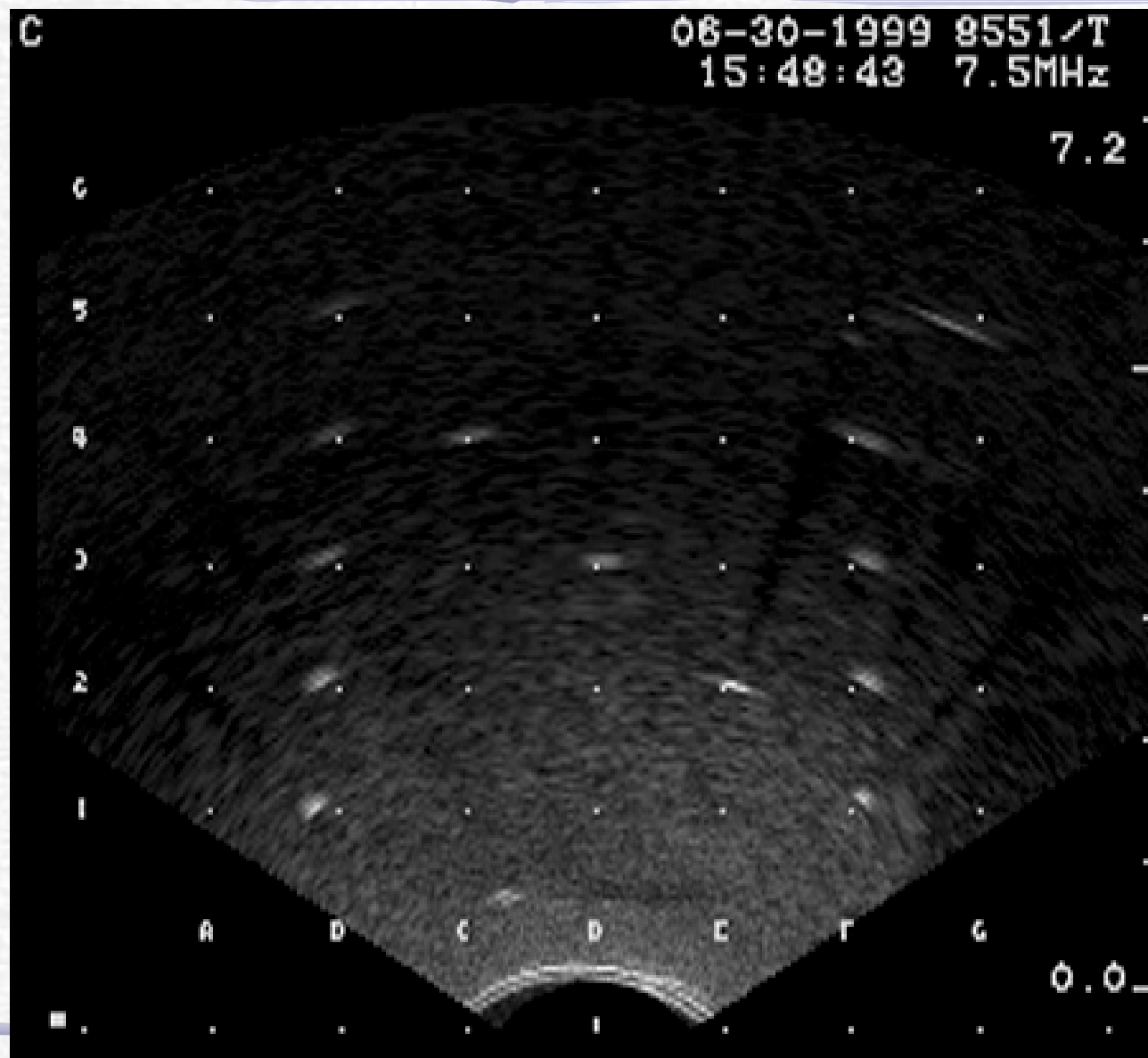


Horizontal Distance Accuracy

## Prostate Implant phantom

Dots indicate templates for insertion points.

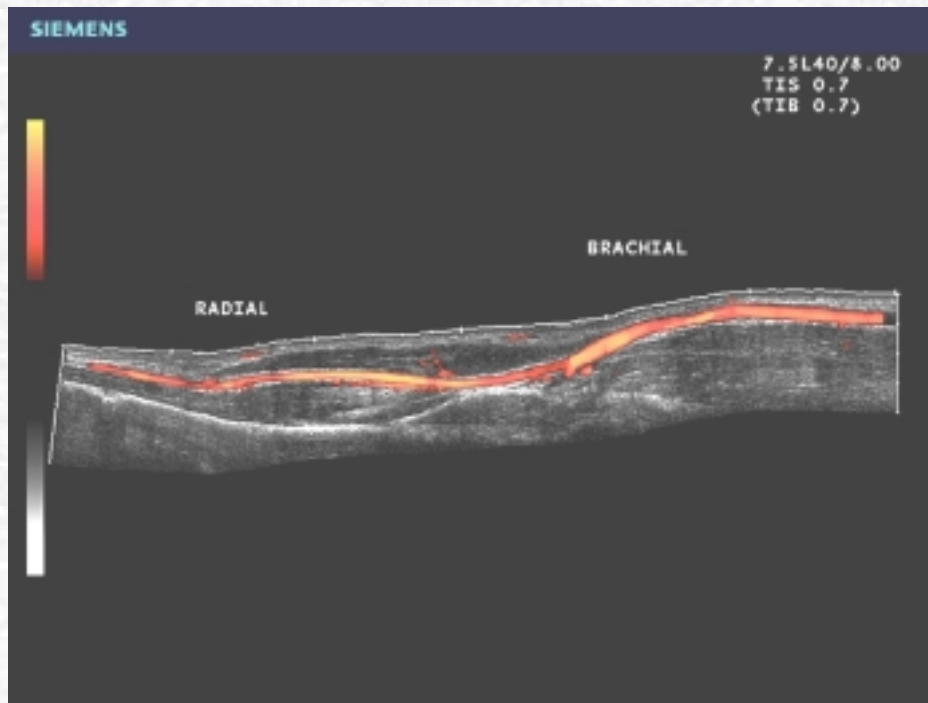
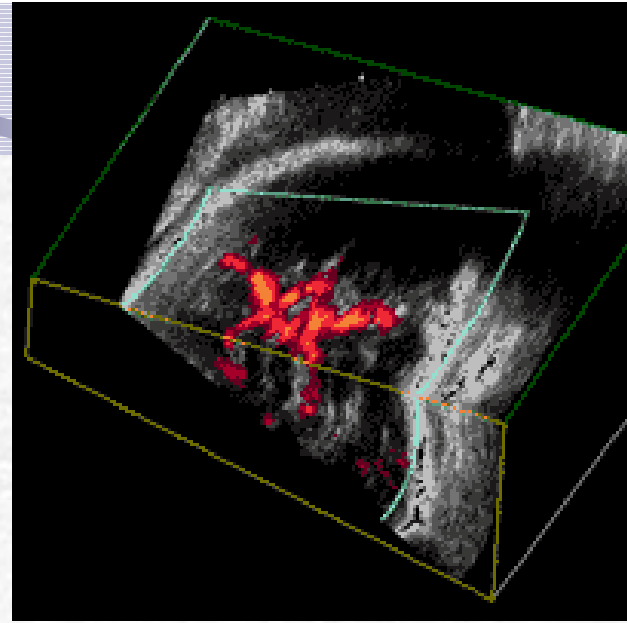
Targets should align with template.



(Courtesy of CIRS)



# Extended Fields

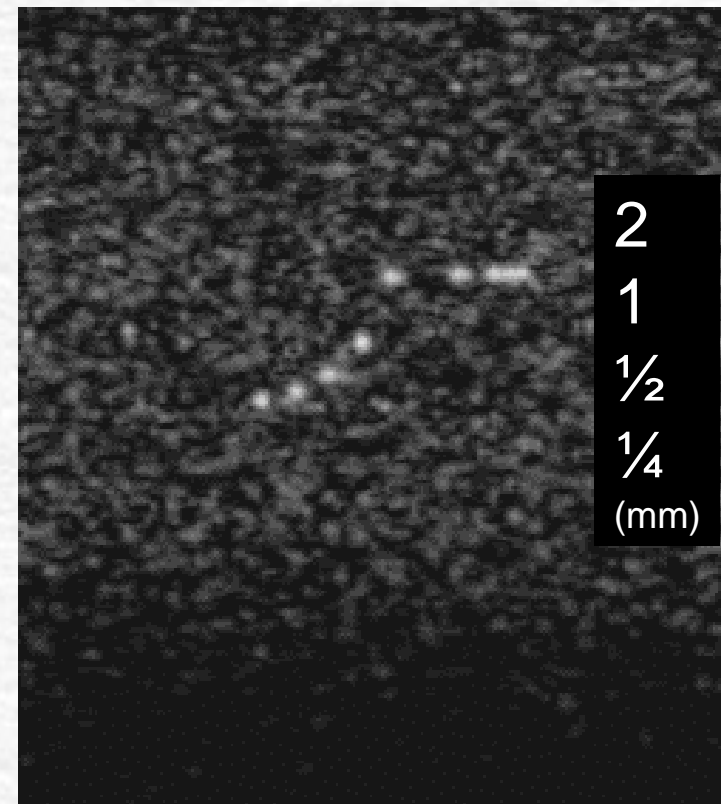
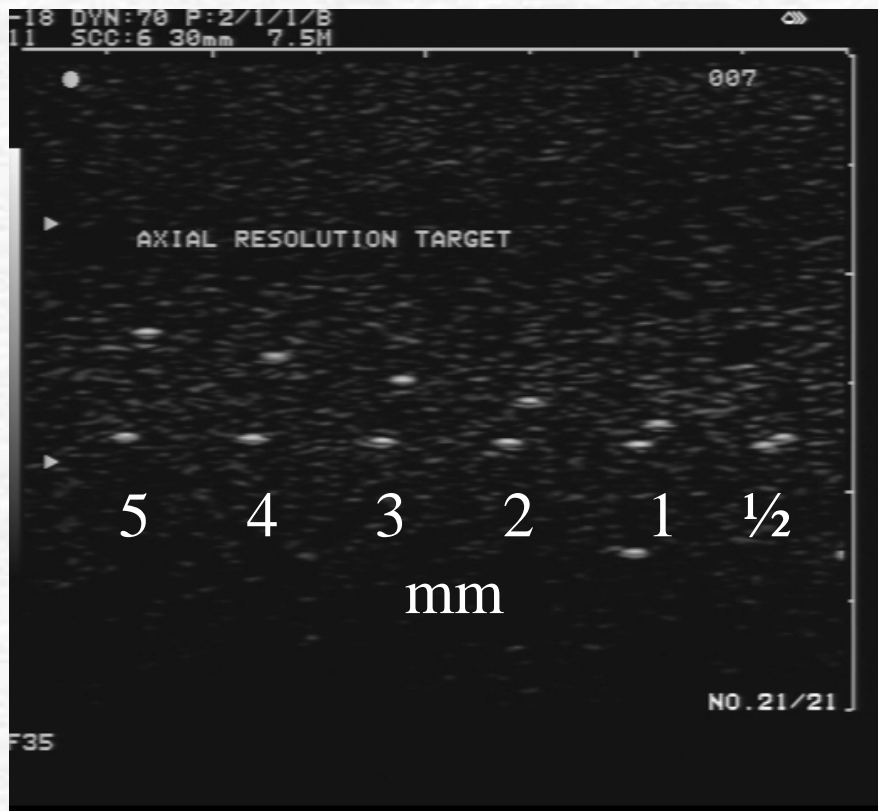


3-D

# 3-D “Egg-Phantom”



# Axial Resolution Targets



# Cautions Regarding Axial Resolution

- ☞ Discrete target separation
  - Scanner performance may fall between target spacing
- ☞ Window material causes reverberations
  - Occasionally see double images of a target
- ☞ Only limited use of quantitation
  - Axial response length (computer or manually)

# Reverberations from Scanning Surface



# Lateral Resolution



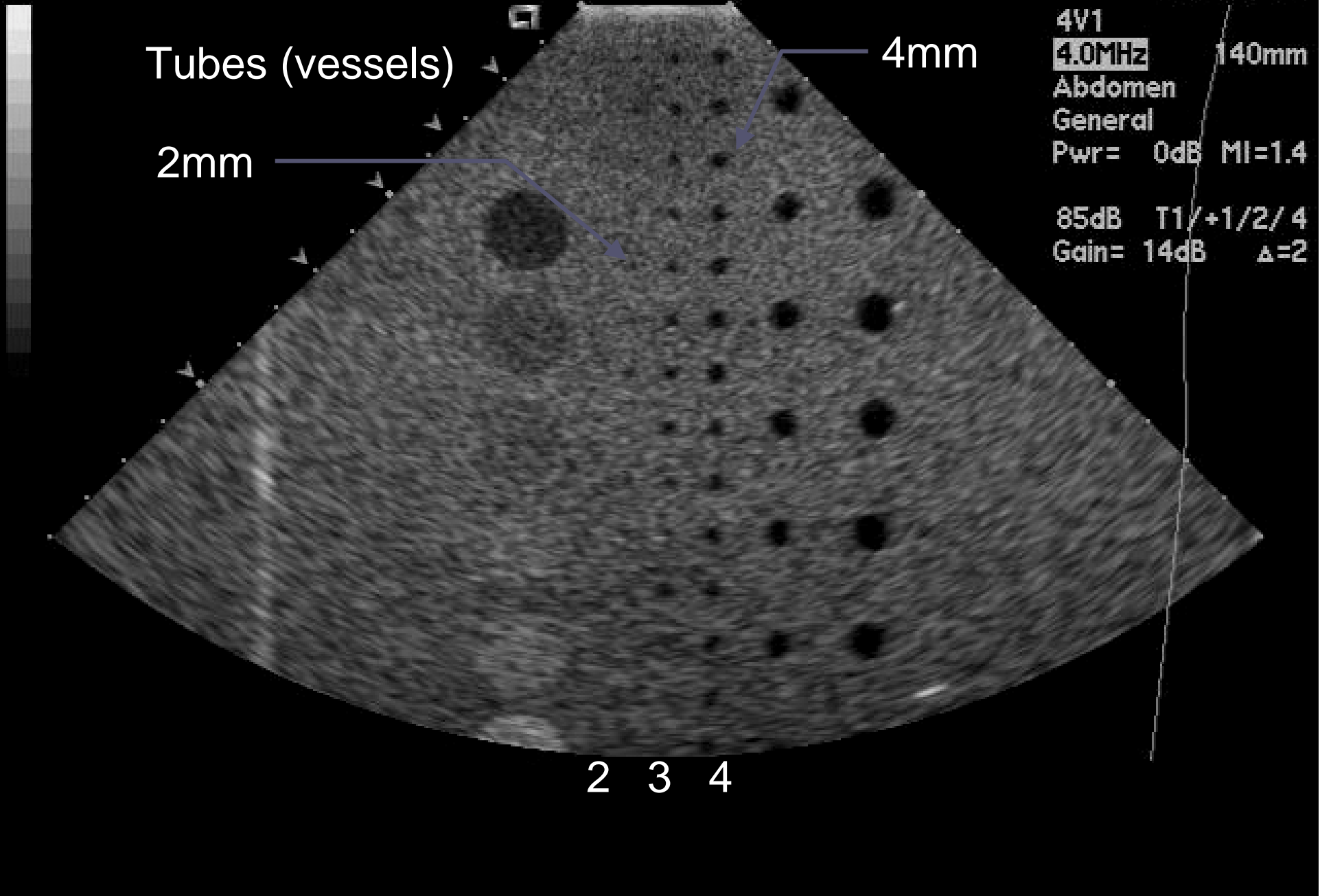
4V1  
4.0MHz 140mm  
Abdomen  
General  
Pwr= 0dB MI=1.4  
85dB T1/+1/2/4  
Gain= 14dB Δ=2

Tubes (vessels)

2mm

4mm

2 3 4



FDI  
5000

QA2  
U.W. Hospital and Clinic

00/10/18:075554  
C5-2 Abd/Gen

18 Oct 00  
7:57:51 am

TIs 0.6 MI 1.4  
Fr #80 14.7cm

Map 3  
150dB/C 3  
Persist Med  
2D Opt:Res  
Fr Rate:High

2mm

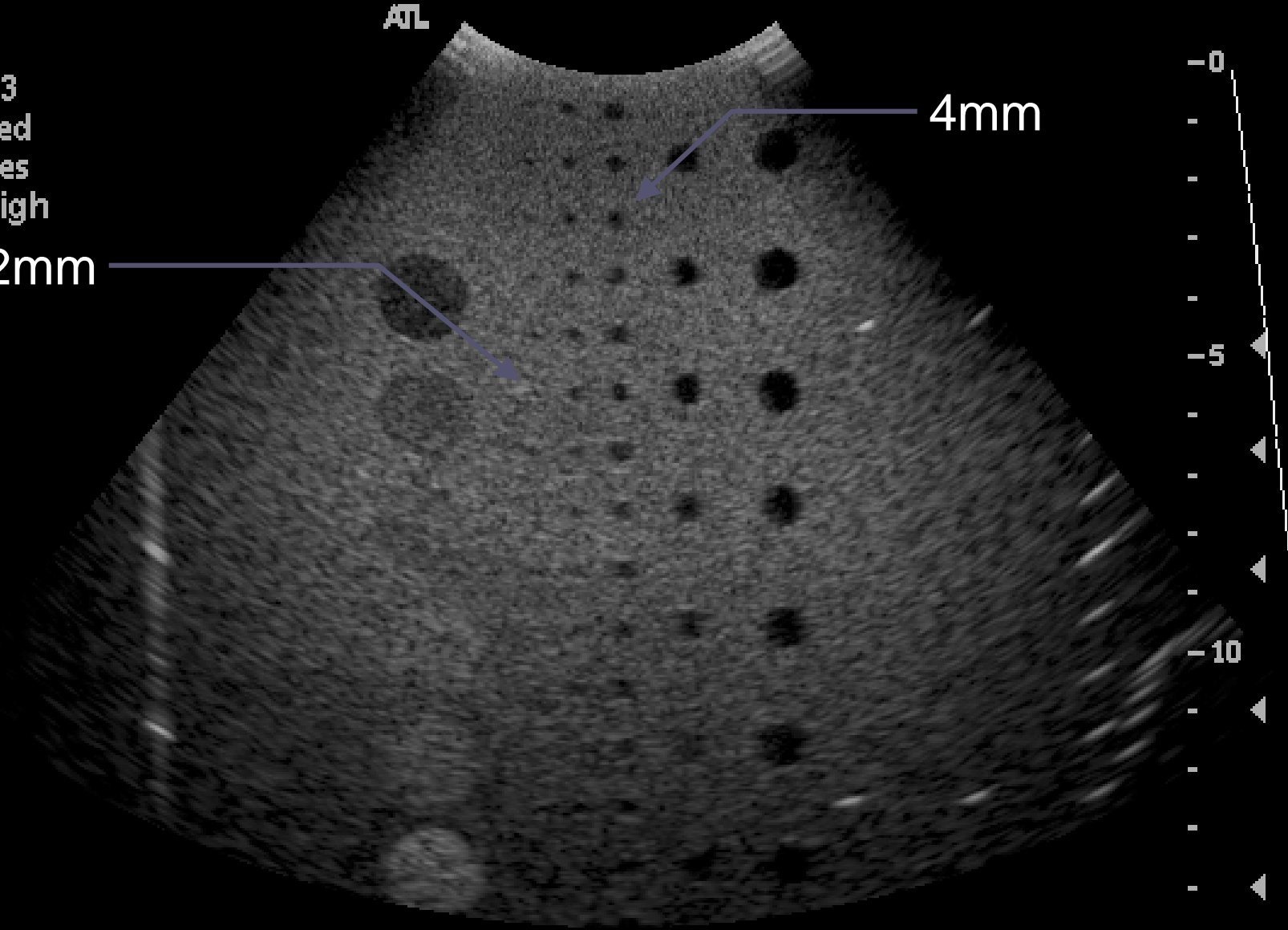
4mm

ATL

-0

-5

-10

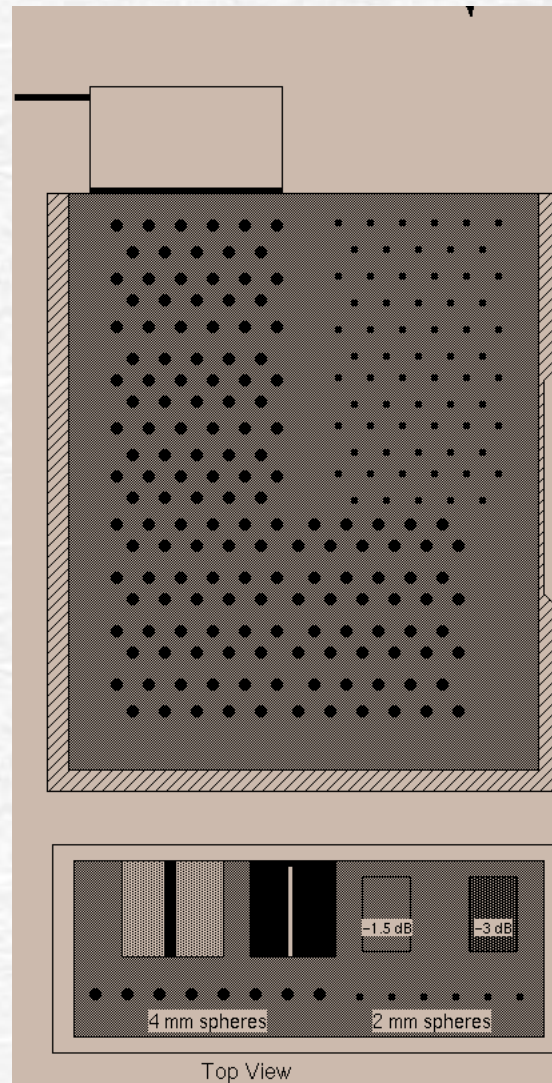




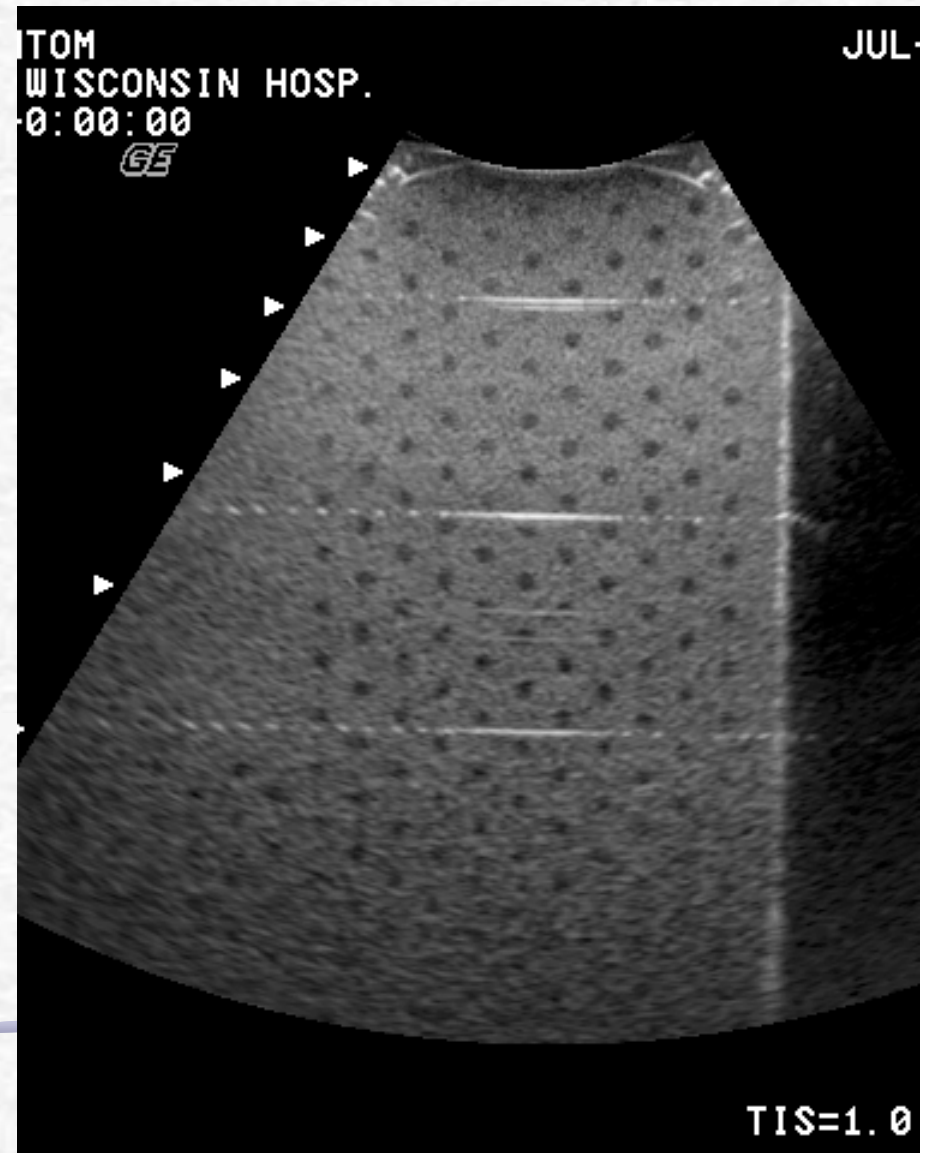
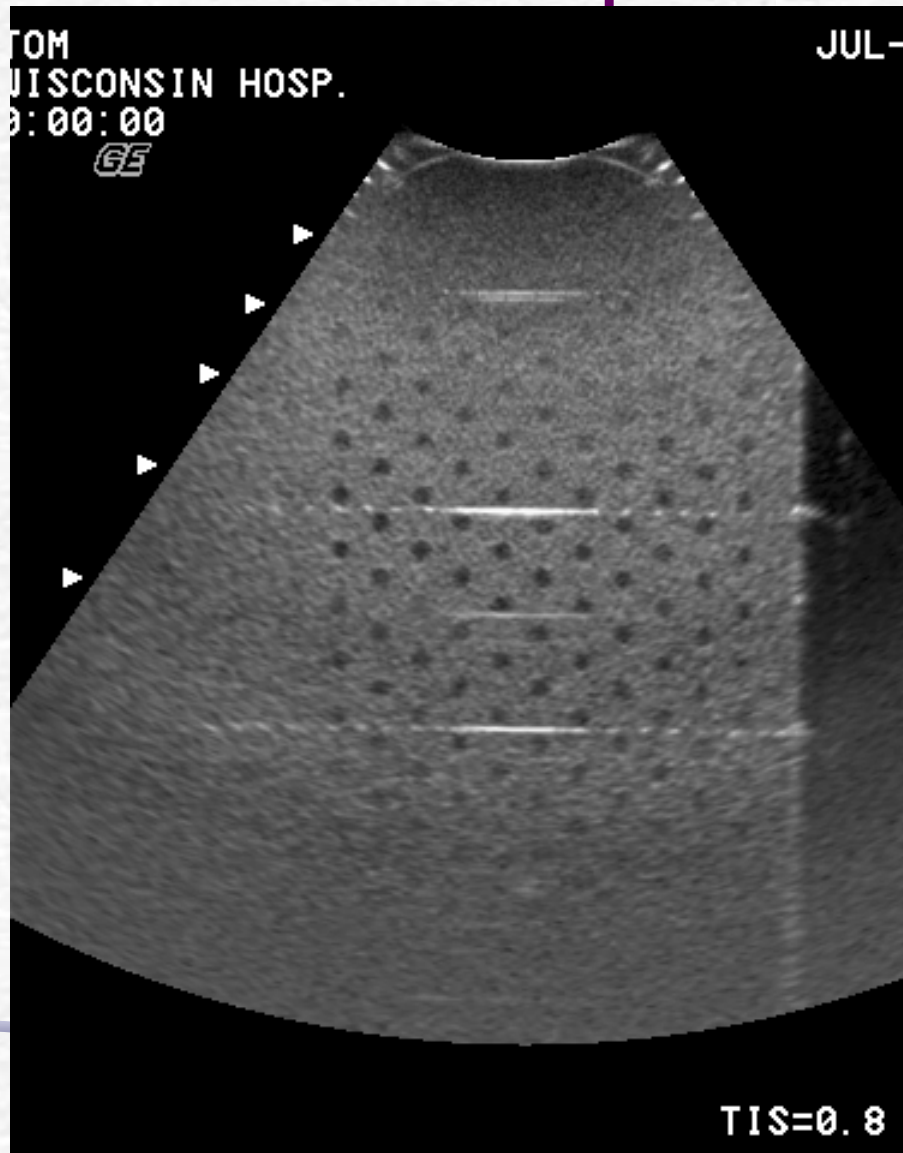
# “Standard Phantom” Attempt (ACR)

P Carson  
E Boote  
T Johnson  
A Siebert  
J Zagzebski  
E Madsen

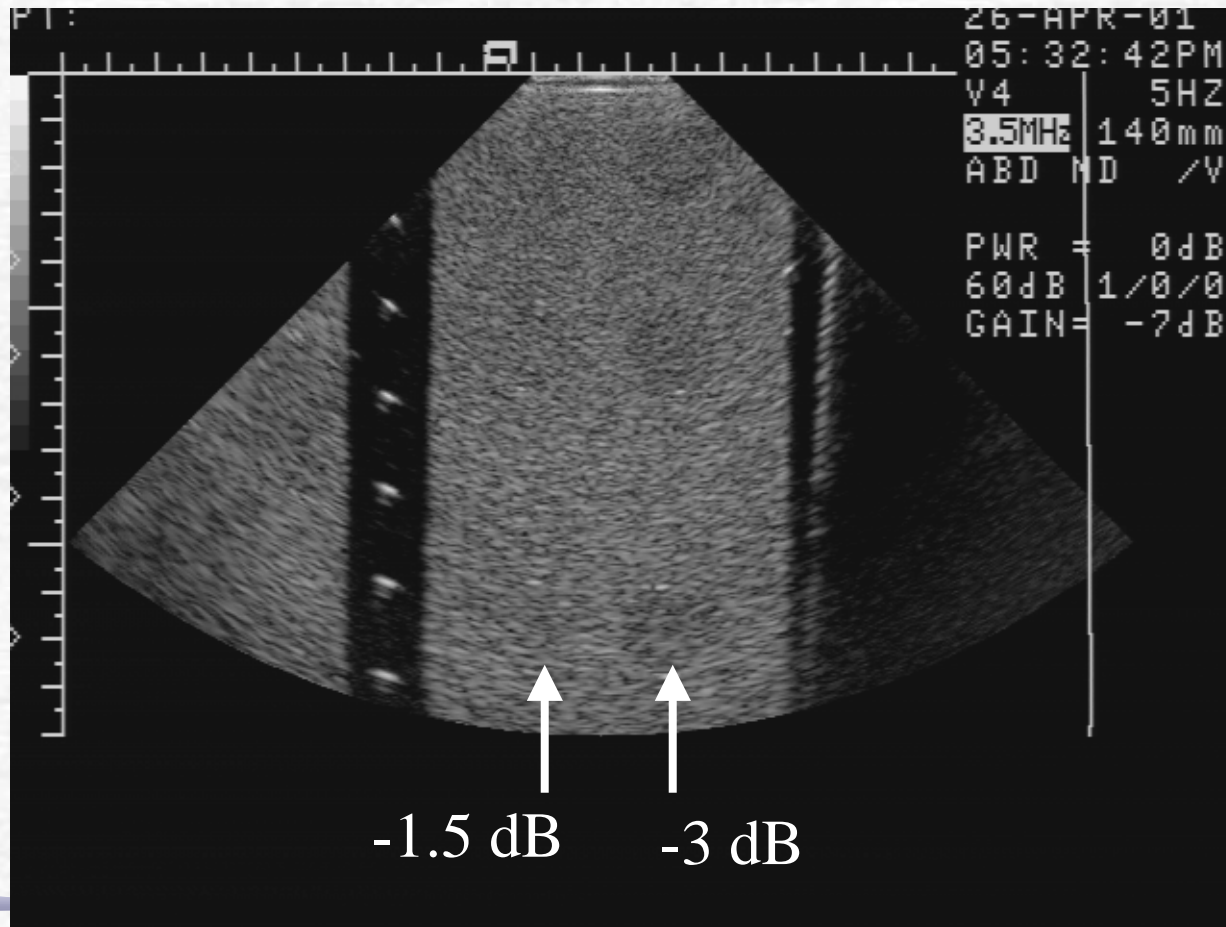
RMI 408A



# Spherical Mass



# Low Contrast Detection



# Routine QA Program

- Equipment inspection
- Penetration into a phantom
- Gray scale photography (workstation monitor)
- Image uniformity
- Distance measurements (where needed)



RMI 403

# Inspection

- ☞ Transducers free of cracks, delaminations
- ☞ Cables in good shape
- ☞ Transducers cleaned after each use
- ☞ Viewing monitors clean
- ☞ Air filters
- ☞ Wheels, locks

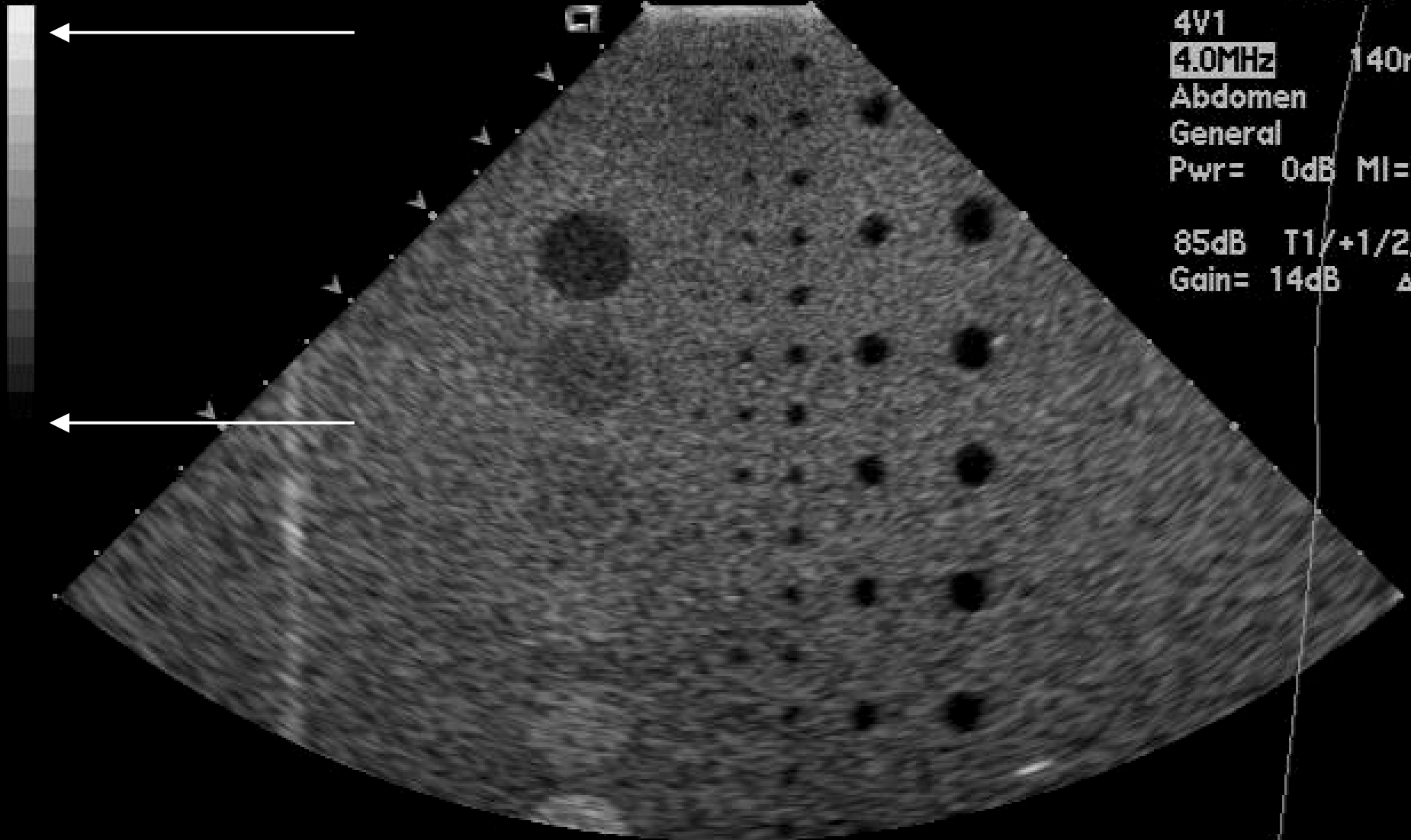
# Maximum Depth of Visualization



# Photography (gray bar)



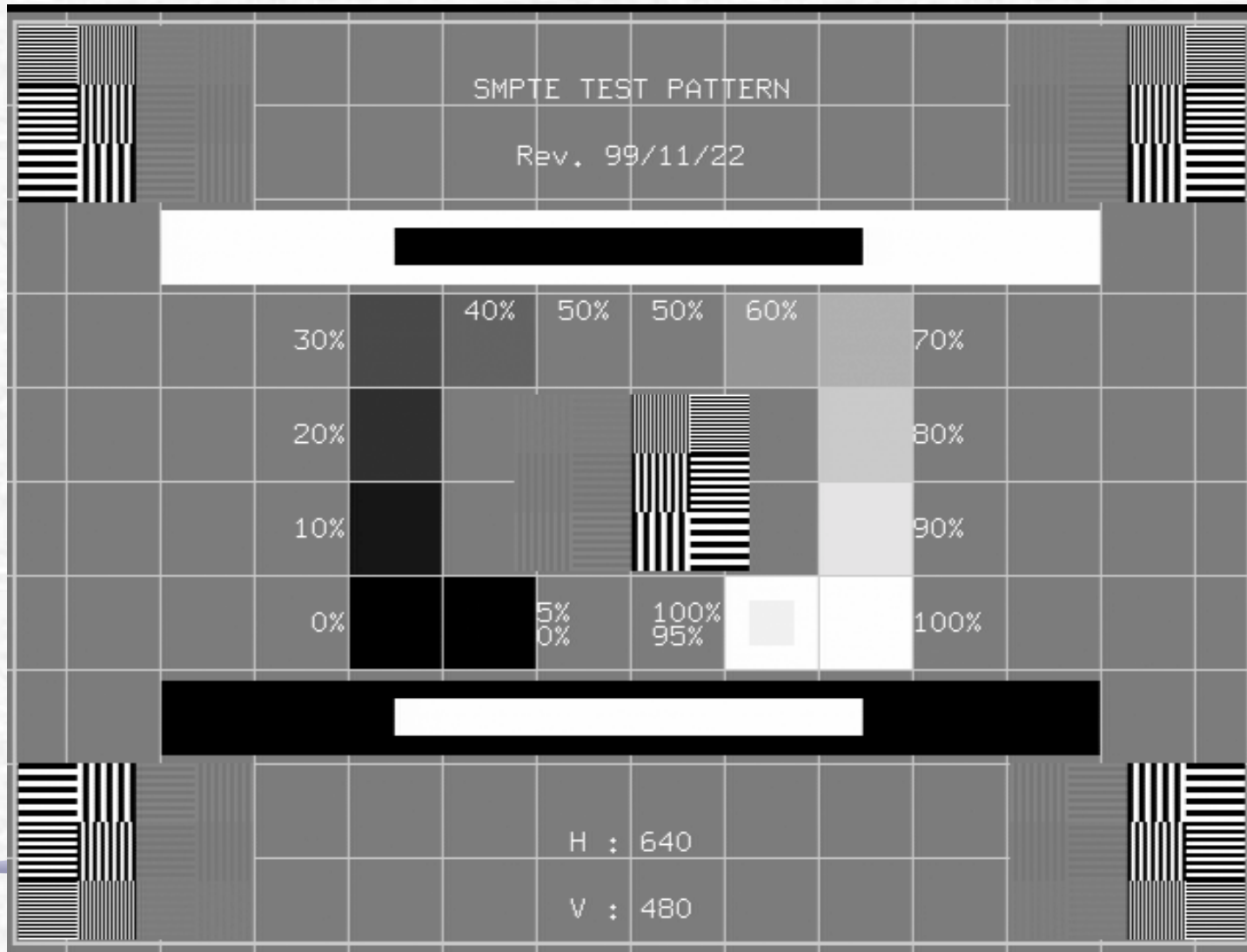
4V1  
4.0MHz 140mm  
Abdomen  
General  
Pwr= 0dB MI=1.4  
85dB T1/+1/2/4  
Gain= 14dB Δ=2



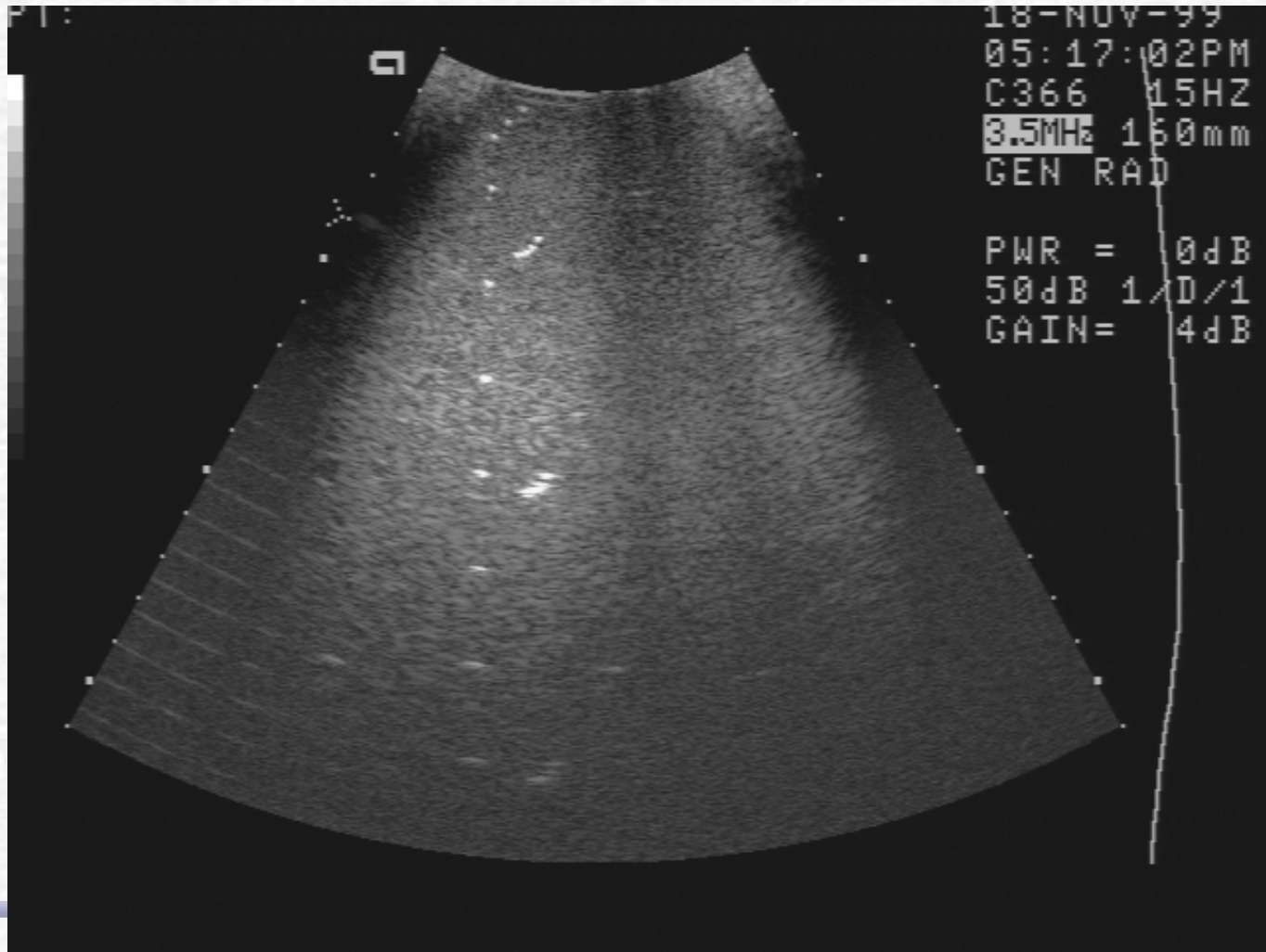
2 3 4



# Photography (SMPTE)



# Image Uniformity (dead elements)



# Role of The Medical Physicist



# Role of The Medical Physicist

- Be knowledgeable in functionality of ultrasound equipment.
- Be aware of issues related to acoustic output levels.
- Help establish QA programs.
- Work beyond routine QA measurements.



# Mechanical and Thermal Indices (MI and TI)

- 1992 (US) Acoustic Output Display Std
- Removed application specific intensity limits
- Contrast agents (MI)
- Research mode (NIH)

