GE Healthcare

TiP-TV™ Training in Partnership Program Supplement and Test for Imaging Professionals

US: Physics Revisited

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1.0 ASRT-approved Category A CE Credit

imagination at work

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Program Summary

This page provides an overview of the program content and learning objectives. Please refer to the Table of Contents for a detailed list of the topics covered. We encourage you to file a copy of this Program Summary and the Table of Contents with your continuing education certificate. We also recommend you provide your manager with a copy of this information as a record of your educational achievement.

Program Description

Studying ultrasound physics is one practical way to improve scanning technique and patient care. Both equipment operation and image interpretation are highly operator-dependent. An understanding of the basic physical principles of sound and its interaction with the tissue is a critical component in ultrasound imaging. In addition to reviewing these principles, this program introduces new technologies that are presenting new challenges and explores the future applications of ultrasound.

Program Objectives

By the end of this program, the viewer should be able to:

1. Recognize how an ultrasound image is generated.
2. Review the concept of spatial resolution and recognize the influencing factors.
3. Describe contrast resolution and recognize the influencing factors.
4. Report the importance of great elevational resolution and how to achieve it.

Target Audience

Course objectives for this program specifically target diagnostic medical sonographers, echocardiographers, and vascular technologists. All other professionals practicing in this field may also benefit.

NOTE: Regardless of your imaging specialty, you may apply for continuing education credit. Refer to the Continuing Education Credit page for additional information.

Continuing Education Credit

1.0 ASRT-approved Category A CE Credit

NOTE: Effective February 1, 2005, the ARDMS accepts credits for ASRT-approved CE activities. ARDMS registrants may claim ASRT-approved Category A credit to meet their CE requirements. For more information, visit: www.ardms.org

Continuing Education Credit and Video File Download

Online Process for CE Credit (hls.gehealthcare.com)

In order to receive continuing education credit, you must log into the GE Healthcare Learning System (HLS) and complete all of the required steps. Please refer to the online TiP-TV Quick Start User Guide (click the User Guides link on the HLS Welcome page) for additional information on how to use the GE HLS as needed.

1. **View the entire program video** online or download the video file for later viewing (refer to the process below). This supplement is *not* intended to replace watching the video.
2. Go to the GE HLS web site at **hls.gehealthcare.com** and complete the **feedback form**.
   - NOTE: The Feedback Form link is not activated until the View Video Now module has been completed.
   - This provides valuable information regarding your thoughts on the program's quality and effectiveness.
3. Complete the **program post-test** without aids or assistance of any kind; this is an *individual effort*.
   - You have up to three attempts to successfully complete the test with a minimum passing score of 75% (ASRT and CBRN approved programs) or 80% (SNM-approved programs).
   - The post-test measures knowledge gained and/or provides a self-assessment on a specific topic.
4. Upon successful completion of the online CE information, you can instantly print a **certificate**.

Video Download Process

For programs with an original start date of September 1, 2008 or later, the GE HLS includes an option to download the TiP-TV program video file. You can then watch the program on your personal computer or transfer the video file to your portable video player for viewing.

NOTE: Please refer to the **TiP-TV Video Download Quick Start Guide** for complete details (click the User Guides link on the GE HLS Welcome page).

1. With the desired program in your GE HLS Learning Plan, launch the program content to view the Online Content Structure. In the Video Download (Optional) area, click the Download Video to View Later link.
2. Save the video file on your personal computer, using your existing video download software.
3. View the program on your personal computer or transfer it to your portable video player for later viewing.
4. After viewing the entire program, log into the HLS and complete the CE activities as noted above.

Continuing Education Credit Eligibility — Important Notice!

A GE Healthcare TiP-TV course may be available in several different formats, such as an online web course or CD/DVD. You may be able to receive CE credit only once for a particular course, regardless of the format in which it was viewed. If you have already received credit for a course, you are encouraged to contact your CE certification organization (ARRT, NMTCB, ARDMS, CBRN, etc.) to determine if you can repeat this course for CE credit.

> Thank you for choosing GE Healthcare as your continuing education partner. We hope you will join us for other TiP-TV programs in the future. For more details and program schedule information, please visit our education web site (**www.gehealthcare.com/education**).
>
> Please forward any questions or comments to: **geeducation@ge.com**

Introduction

Years before the first diagnostic ultrasound, the technique of sending out pulses of sound and gleaning valuable information from the returning echoes existed in the natural world. Since early on, bats, dolphins, and whales have utilized a fascinating and innate skill called echolocation to navigate, track their next meals, and communicate with others of their species.

Scientists initially tapped into this technique with the development of SONAR – or sound navigation and ranging – which was used to locate submarines during wartime. Additional advancements in SONAR after World War II led to the beginnings of the many medical applications for ultrasound.

Sound is defined as a mechanical, longitudinal, and compressional energy transmitted by pressure waves through a medium. Ultrasound is sound at a frequency above the level of human hearing, or anything above 20,000 hertz (Hz).

Medical imaging departments use frequencies between 2 and 17 megahertz (MHz) or higher. While it is possible to send these frequencies into the body and generate images without complete understanding of the basic physical principles of sound, it isn't best practice. A well-rounded professional demonstrates competence in every part of the process.

Ultrasound physics is a vital part of that process. If quality patient care is our goal, then education is how we get there, and a great place to start is with physics.

The highlights of this program are:

- How an ultrasound image is made
- Spatial resolution and what affects it
- Contrast resolution and what affects it
- Elevational resolution

Image Generation

Diagnostic ultrasound is a pulse-echo technique. Pulses of sound are sent into the body by a transducer. This same transducer listens for the returning echoes produced by the soft tissues of the body and the system processes the echoes for display.

Obtaining an image involves:

- The propagation of speed of sound in soft tissue
- Transducer arrays
- Beamforming geometry
- Electronics

Anne Hall, Ph.D.

Notes:

Figure 1 How to Make an Image

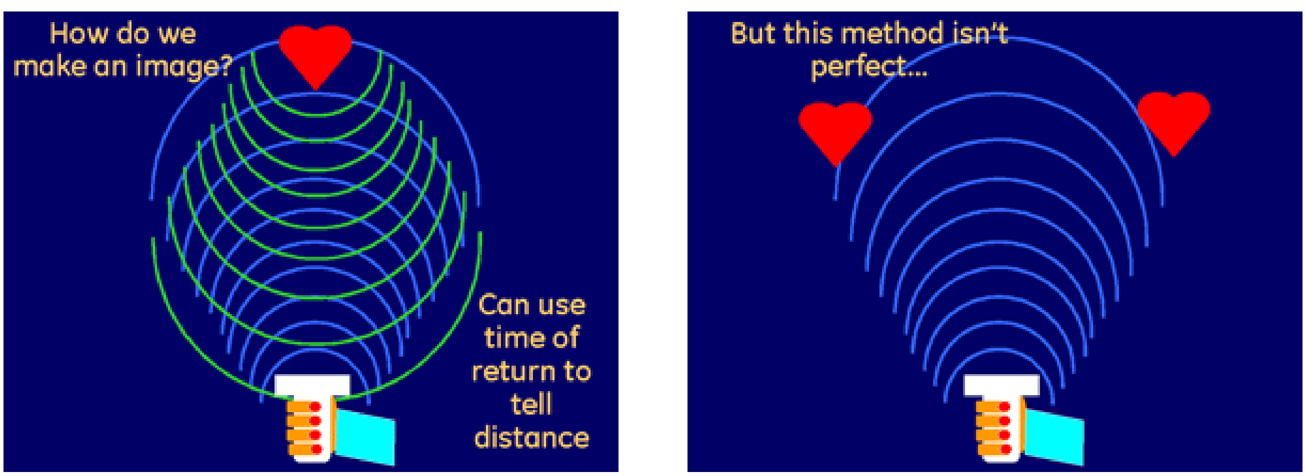
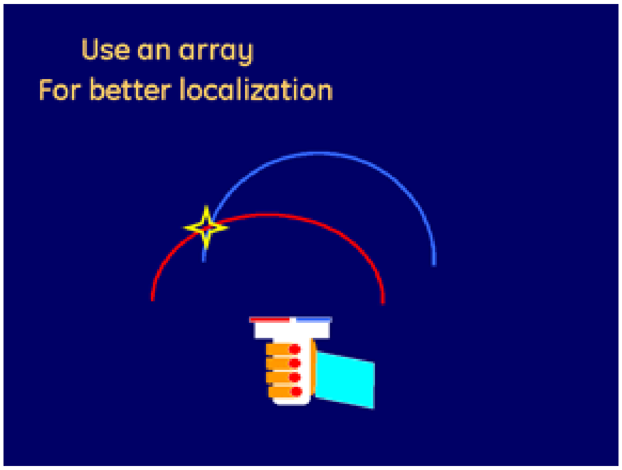
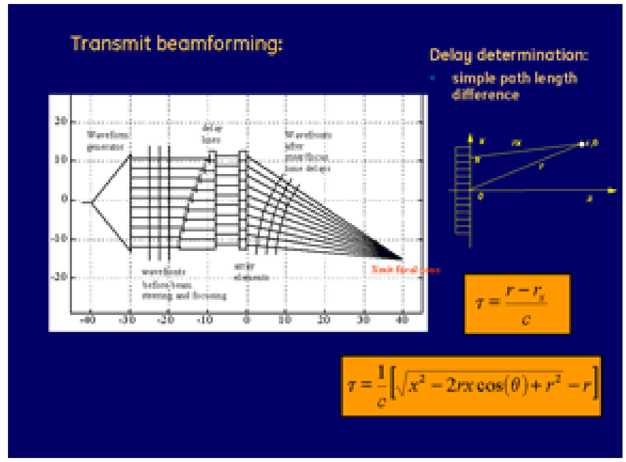


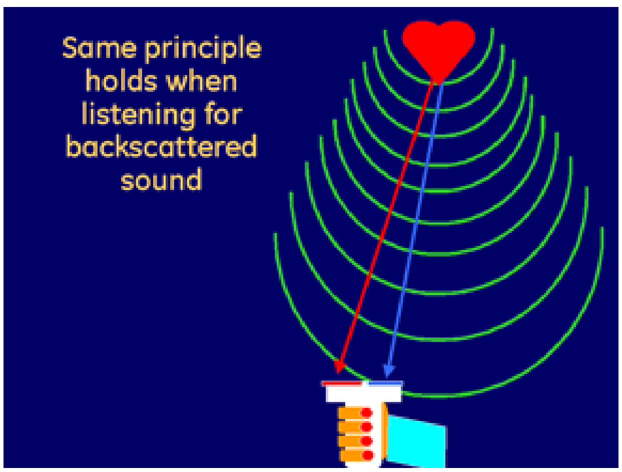
Figure 2 Image Formation



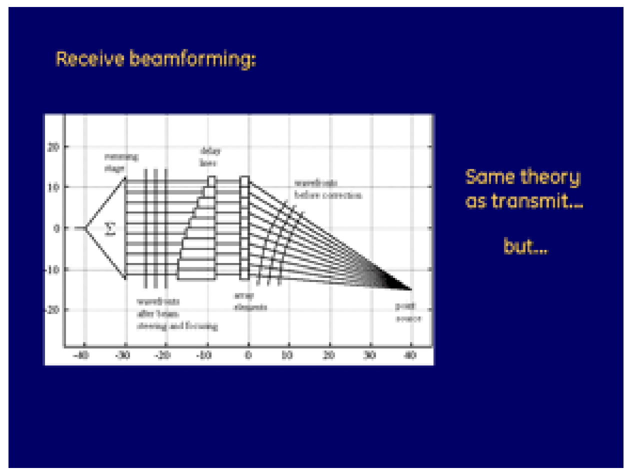
Use an array



Transmit beamforming



Backscattered sound



Receive beamforming

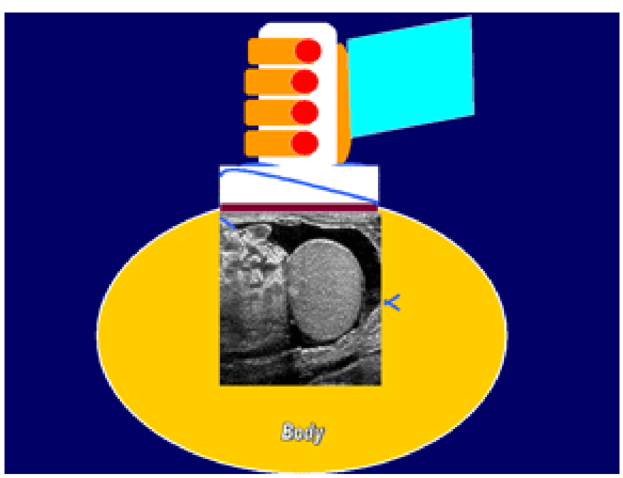
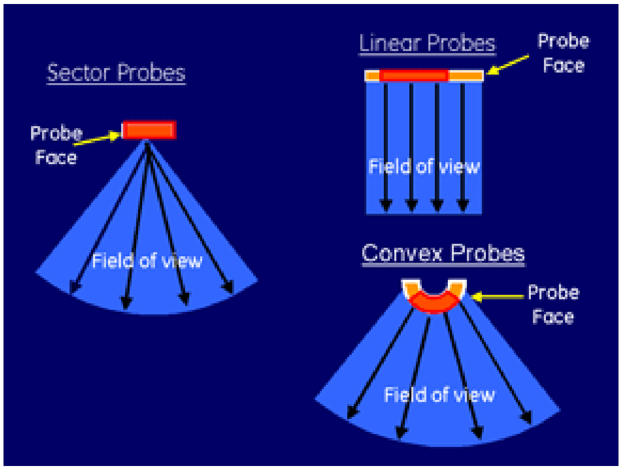


Image formation

Ultrasound Probes

Figure 3 Types of Probes



Sector Probes

Sector probes or transducers are also called phased arrays.

- These transducers have the smallest footprint. Footprint refers to the surface area of the probe in contact with the patient.
- The sector probes usually contain the fewest number of elements and all the elements are utilized as a group, with small time differences, during transmit.
- Transducers are used to image areas of the body where we have a small acoustic window. An example of this is echocardiography. It is important to scan through the ribs in order to visualize the heart.
- The sector probes need to be small enough to fit between the ribs and the beam of sound is steered and focused so the imaging field-of-view (FOV) includes the heart.
- The image is pie-shaped (sector).

Linear Probes

In a linear probe, the ultrasound pulses are sent out perpendicular to the probe and there is little steering done.

- The linear array has many more elements than the sector probes; however, they are not all utilized during transmitting.
- The field of view is built up by walking the active aperture across the face of the probe. Aperture is the physical length of the number of elements being used.
- The footprint may include all 256 elements, but the aperture may only include 128.

Convex Probes

Convex probes are operated exactly like linear probes. The beam is not steered, but you get a pie-shaped view by changing the geometry of the transducer itself.

Anne Hall, Ph.D.

Notes:

Spatial Resolution

Spatial resolution is also called detail resolution. It includes axial and lateral resolution.

Axial Resolution

Axial resolution is the dimension of the image parallel to the direction of sound travel or represented when we describe two structures, one in front of the other, on the display. Axial resolution is associated with the length of the beam or the X axis. It runs from the face of the transducer deep into the body. Axial resolution depends on the wavelength of sound and the number of cycles in the pulse being sent into the body. If we use high frequency, then the wavelength is short and that improves the axial resolution. The only other factor involved is the number of cycles in a pulse. The typical ultrasound pulse is 1 to 3 cycles long. Short pulses are produced and received in a wide bandwidth (or range of frequencies) increasing axial resolution.

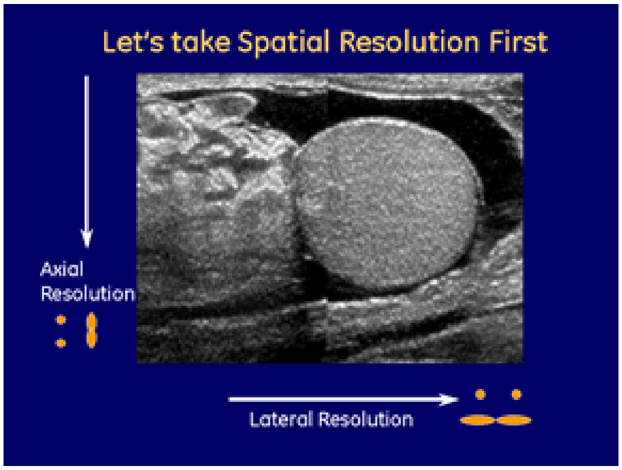
Lateral Resolution

Lateral resolution is the dimension of the image perpendicular to the direction of sound travel or represented when we describe two structures, side by side, on the display. Lateral resolution is associated with the width of the beam or the Y axis and the long axis of the transducer. Focusing, frequency, aperture, the number of elements, and the number of channels affect lateral resolution in a system. Focusing improves lateral resolution because it makes the beam narrow or tight. The smaller the beam diameter, the better the lateral resolution. High frequency and wide aperture transducers produce a long narrow beam and improved lateral resolution. Increasing the elements in a transducer and channels in a system leads to excellent lateral resolution as well.

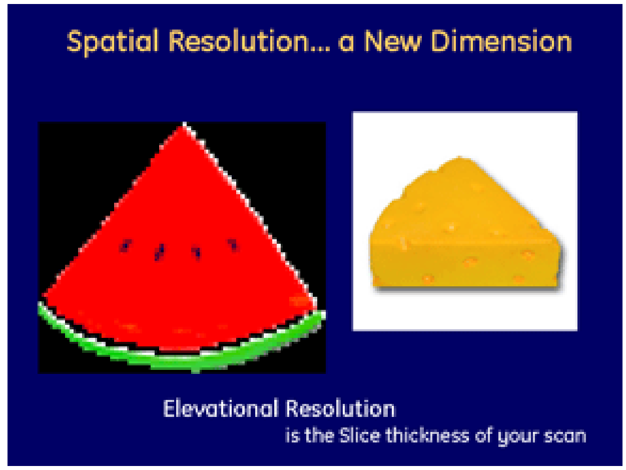
Anne Hall, Ph.D.

Notes:

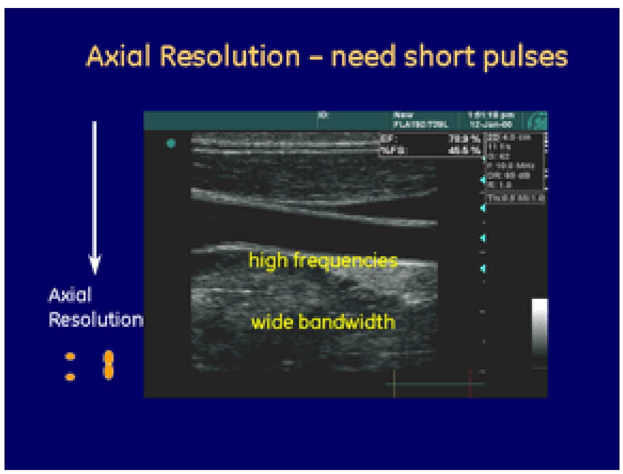
Figure 4 Spatial Resolution



Axial and lateral resolution

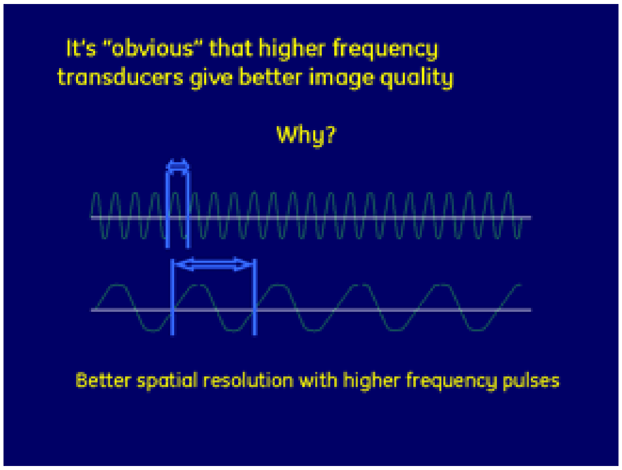


Elevational resolution

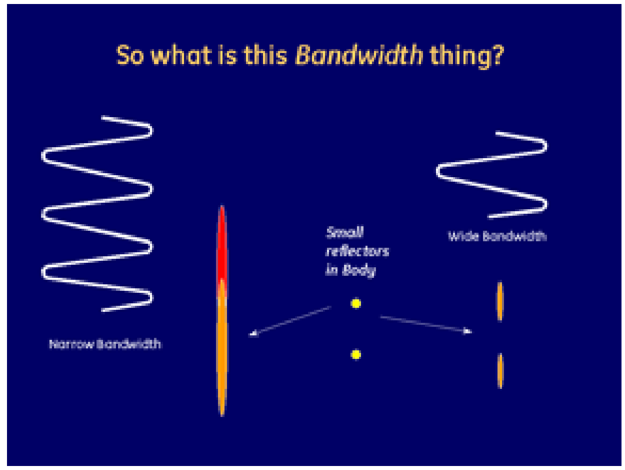


Axial resolution image

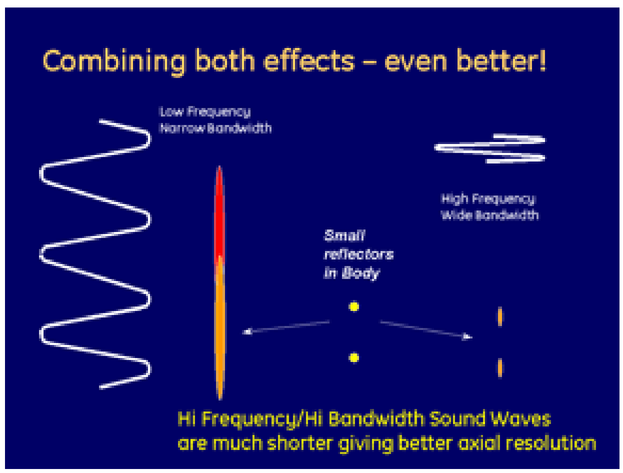
Figure 5 Frequency and Bandwidth



Frequency Differences



Bandwidth



High Frequency and High Bandwidth

CWD = Continuous Wave Doppler

Figure 6 Lateral Resolution Image

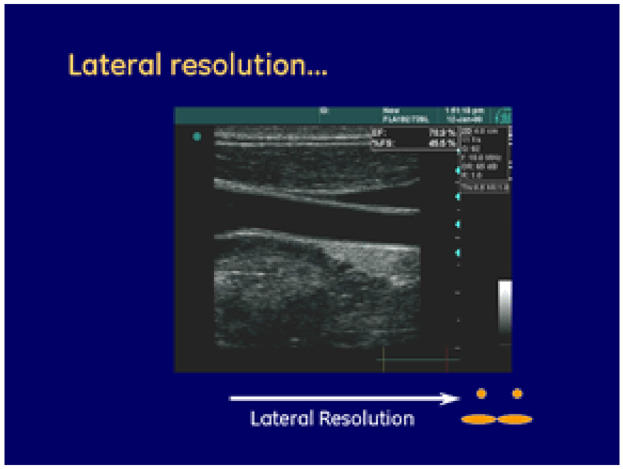


Figure 7 Depth of Focus

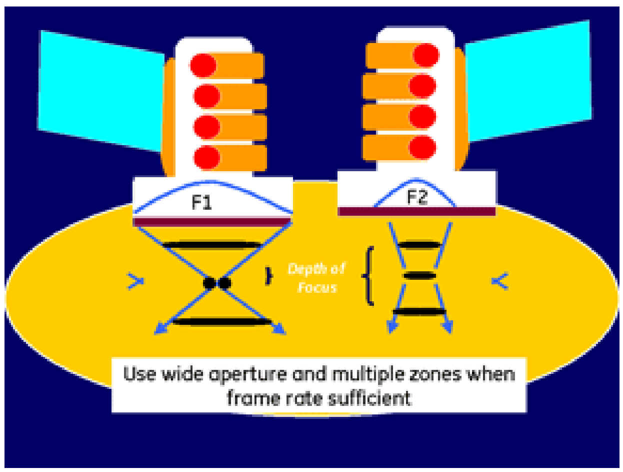
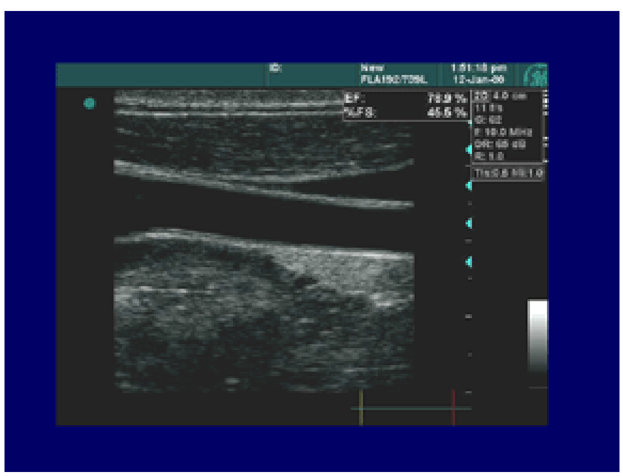


Figure 8 Carotid Ultrasound Image



Contrast Resolution

Contrast resolution is the ability to discern many colors or shades of gray.

Contrast resolution describes the shades of gray that are represented on the image. Dynamic range affects the contrast resolution. Increasing the dynamic range provides more shades of gray and allows us to display subtle differences on the screen. We see the shades of black and white in addition to all the shades of gray in between. High dynamic range is associated with a low contrast image. Decreasing the dynamic range limits the shades of gray displayed and may limit our ability to detect small differences on our image. We are able to display the shades of black and white but fewer shades of gray between. Low dynamic range is associated with a high contrast image. State-of-the-art systems are currently capable of displaying high dynamic range.

Anne Hall, Ph.D.

Notes:

Table 1 Dynamic Range

How Do We Get Good Contrast Resolution? Need Wide Dynamic Range
Dynamic Range – Ability to simultaneously preserve huge and small echoes. Analogies: • Individual voices in a stadium during a concert. • Weighing an elephant when a bug lands on it. GE ultrasound – One can tell the difference between a wall echo in the near field and a blood cell in the very far field when the ratio of their return signals is greater than 31,622,776 to 1 (150 decibels, or dB).

Table 2 What Does Dynamic Range Mean?

What Does Dynamic Range Mean?	
If your machine has 150 dB dynamic range (preserves **8 digits** of precision), it will notice these small changes while preserving the large signals: 31622770 +1 31622771 +1 31622772	What if your machine only preserves **4 digits?** 31620000 +1 31620000 +1 31620000 Then the small changes in information are lost!

Elevational Resolution

Elevational resolution is the slice thickness of your ultrasound scan. Historically, the elevation plane has been set by the manufacturer with an acoustic lens. With the new matrix array technology, the operator is able to control the focus within the elevation plane.

Elevational resolution is known by many other names. It can be called the short axis of the transducer, elevation plane focus, slice thickness, or the Z axis. Traditionally, this dimension of the beam is adjusted by an acoustic lens and focused by the manufacturer for specific applications. If we are scanning the thyroid, we need high frequency with a short focus. In contrast, while scanning in the abdomen, we need low frequency with a long focus. Matrix array technology levels the playing field by allowing a thin elevation plane at every depth. The thickness of the elevation plane is adjusted automatically when we adjust the focal zone.

NOTE: Using a high frequency transducer is one way to improve spatial, contrast, and elevational resolution. The only loss is that of penetration due to increased attenuation.

Anne Hall, Ph.D.

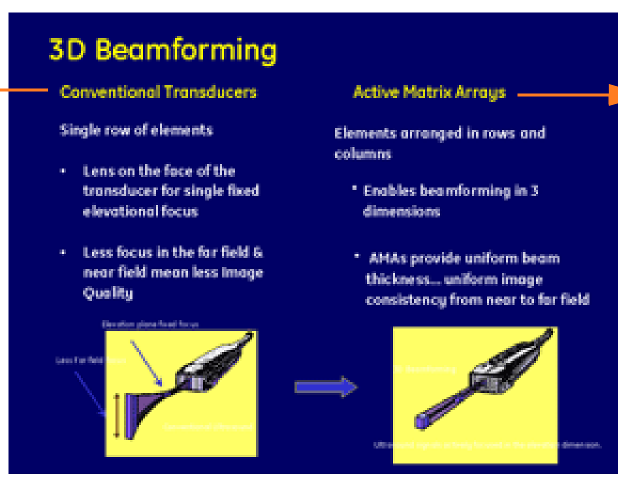
Notes:

Figure 9 3-Dimensional (3D) Beamforming

Conventional Transducers

Single row of elements

- Lens on the face of the transducer for single fixed elevational focus
- Less focus in the far field & near field mean less image quality



Active Matrix Arrays (AMA)

Elements arranged in rows and columns

- Enables beamforming in 3 dimensions
- AMAs provide uniform beam thickness … uniform image consistency from near to far field

Figure 10 Slice Thickness

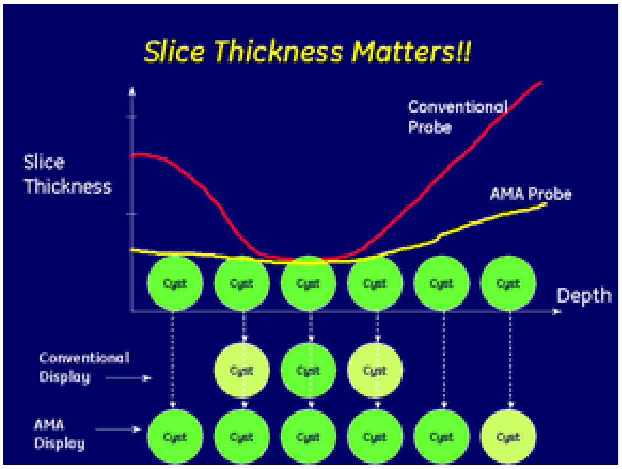
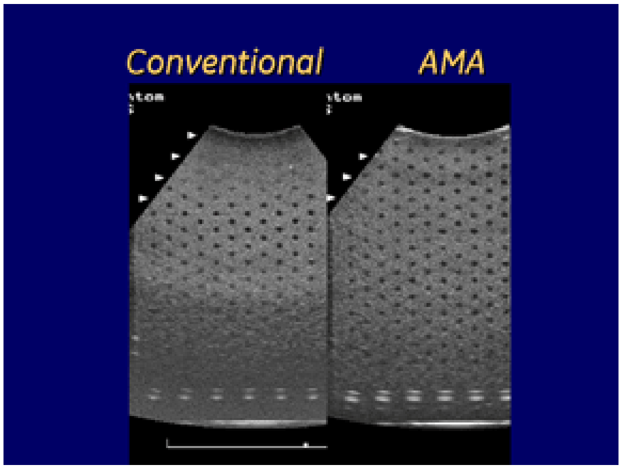


Figure 11 Ultrasound Phantoms (AMA – Active Matrix Array)



Appendix A: Presenters

Denise Lukasik-Sedmak, Ed.D., R.T. (R)(M)(MR)(CT)
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Appendix B: Post-Test

LMS Course Number: 2722

To be eligible for CE credit, you MUST view the video presentation first. Then complete the post-test on the GE Healthcare Learning System **(hls.gehealthcare.com)** by the due date listed online.

1. SONAR is the acronym for ______.
   a. sound navigation rate
   b. sound navigation and ranging
   c. sound navigate and range
   d. sound navigate and rate
2. ______ is defined as a mechanical, longitudinal, and compressional energy transmitted by pressure waves through a medium.
   a. Axial resolution
   b. Frequency
   c. Resolution
   d. Sound
3. Ultrasound is sound at a frequency above the level of human hearing, which is anything above ______ hertz.
   a. 10,000
   b. 15,000
   c. 20,000
   d. 25,000
4. ______ refers to the surface area of the probe in contact with the patient.
   a. Footprint
   b. Display print
   c. Handprint
   d. View print
5. The ______ probe needs to be small enough to fit between the ribs, and the beam of sound is steered and focused so the imaging field of view includes the heart.
   a. axial
   b. convex
   c. linear
   d. sector
6. The ______ probe has a footprint that may include 256 elements, but the aperture may only include 128 elements.
   a. axial
   b. convex
   c. linear
   d. sector

7. Axial resolution is associated with the length of the beam or the ______ axis.
    a. H
    b. X
    c. Y
    d. Z
8. ______ resolution is associated with the width of the beam or the Y axis and the long axis of the transducer.
    a. Axial
    b. Contrast
    c. Elevational
    d. Lateral
9. The smaller the beam diameter, the better the ______ resolution.
    a. axial
    b. elevational
    c. lateral
    d. spatial
10. ______ frequency transducers provide better image quality.
    a. Higher
    b. Equal
    c. Lower
    d. Pulse repetition
11. Spatial resolution is also called ______ resolution.
    a. contrast
    b. detail
    c. lateral
    d. axial
12. In diagnostic ultrasound, the term bandwidth refers to the ______.
    a. rate of data transfer in the analog computer
    b. range of frequencies used in imaging
    c. with of the acoustic window
    d. speed of the interface with the picture archiving and communication systems
13. The dynamic range of an ultrasound image affects the ______ resolution.
    a. axial
    b. contrast
    c. lateral
    d. spatial
14. If your ultrasound machine has 150 decibels dynamic range, it preserves ______ digits of precision.
    a. 4
    b. 6
    c. 8
    d. 10
15. Decreasing the dynamic range limits the ______ displayed.
    a. anatomy
    b. window size
    c. shades of gray
    d. image depth

16. Use of high frequency transducers is one way to improve spatial, contrast, and elevational resolution; however, the loss of _____ is due to increased attenuation.
    a. contrast
    b. depth
    c. focus
    d. penetration
17. The acronym AMA in ultrasound stands for _____.
    a. Active Matrix Array
    b. American Medical Association
    c. Active Member Association
    d. American Matrix Arrays
18. The slice thickness of an ultrasound scan is called _____ resolution.
    a. elevational
    b. axial
    c. lateral
    d. spatial
19. When using a matrix array transducer, the thickness of the elevation plane is adjusted automatically when we adjust the _____.
    a. depth of field
    b. Doppler angle
    c. over all gain
    d. focal zone
20. Elements are arranged in rows and columns in a/an _____ transducer.
    a. active matrix array
    b. lineral array
    c. convex array
    d. sector