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Ultrasound Applications Essentials and Image Artifacts

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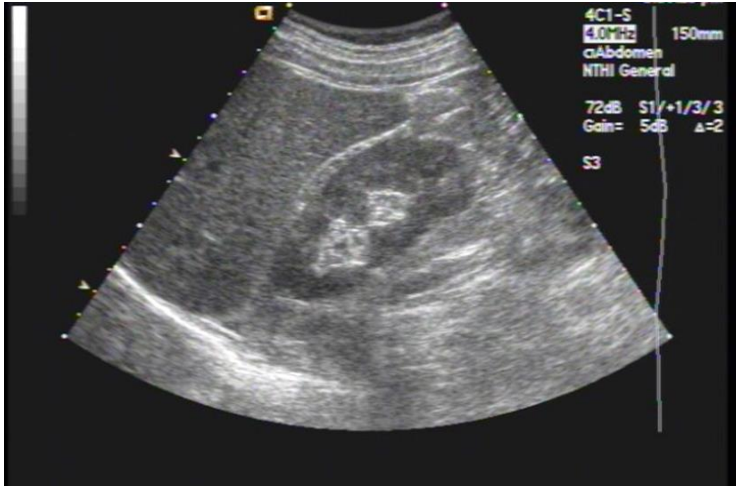
Importance of Knowledge

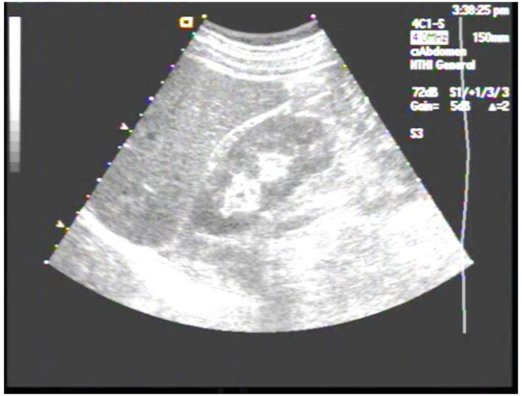
- Instill customer confidence
- Ability to differentiate between applications issue and malfunction
  - Time and credibility saver
- Ability to test system clinically
- Understand the language of the sonographer/technologist
- Differentiator between a good service engineer and great service engineer

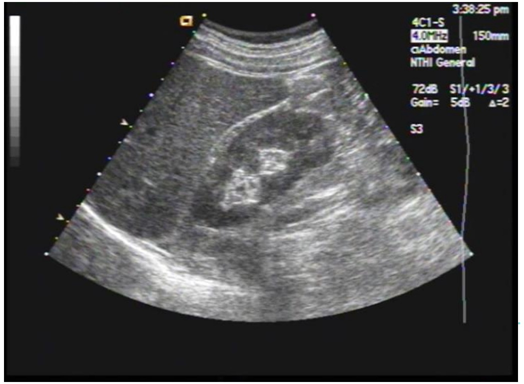


System Display Settings

System display settings must be correct before making any image evaluations or adjustments

- Adjust room lighting to typical scanning room intensity
- Use system grayscale bar to adjust brightness – bottom should be barely visible
  - Bars are graduated or step
- Contrast is adjusted for “white whites” but not blooming
- Requirement for ACR accreditation

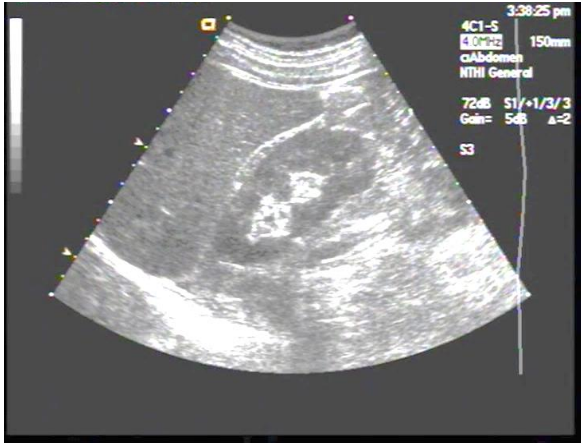


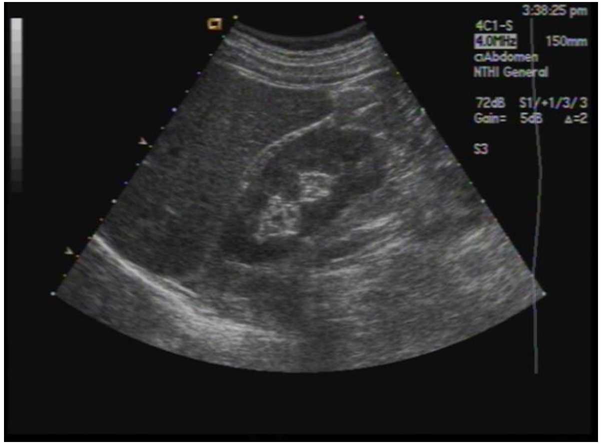


Ensure customer approves of and understands any changes made!

Pop Quiz

- Will adjusting the system's main display settings have any effect on the image presentation on a Picture Archiving and Communication System (PACS) display?





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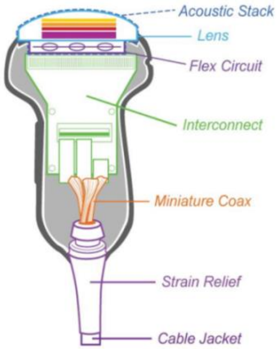
Transducer / Probe / Scanhead Types

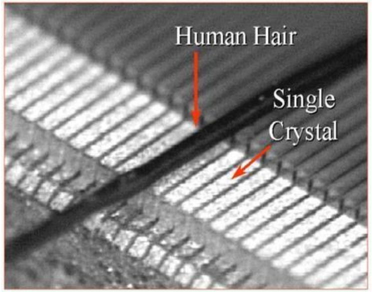
Transducers have different formats for different clinical applications

- Linear / Trapezoidal
  - Rectangular or trapezoidal format
  - Vascular, intraoperative, small parts
- Curved linear / Convex
  - Wide near field, wide far field
  - Abdominal, obstetrical, endocavity
- Sector / Vector
  - Narrow near field, wide far field
  - Cardiac abdominal

Transducer Construction

- Lens
  - Mechanical focus of ultrasound beams
  - Single or multilayer materials
  - Must be ISO 10993 compliant
- Matching layer(s)
  - Maximizes transmission of energy from crystal array to tissue by reducing reflection (acoustic impedance matching)
  - Increases spectrum of frequencies (bandwidth) emitted by transducer
  - Generally ¼ wavelength of center frequency of array in thickness
- Array
  - Piezoelectric material
  - Converts electrical energy to mechanical energy (pressure wave) and vice versa
  - From 1 to thousands of individual elements / crystals
- Shielding
  - Typically around array and backing material
  - Reduces electromagnetic interference
- Backing Material
  - Dampens crystal vibrations to reduce pulse duration which increases axial resolution





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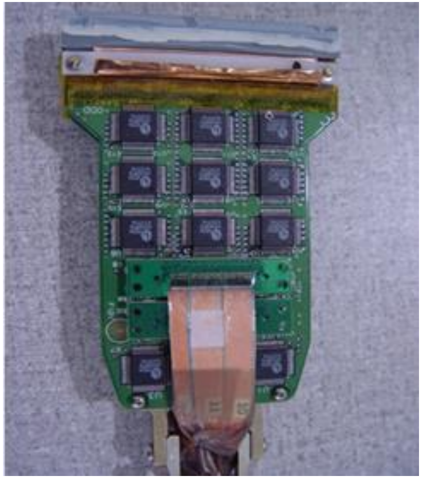
Transducer Construction (cont.)

- Flex circuit
  - Flexible circuit board which connects the interconnect board to the individual elements
- Interconnect
  - Bridge between individual coaxial cables and flex circuit
  - May have multiplexing circuitry
  - May have beam forming circuitry
- Miniature coax
  - Used to transmit pulses and receive echoes
  - Specific impedance and capacitance
- Strain relief
  - Reduces stress on main and coaxial cables
- Cable jacket
  - Protects main transducer cable
- Main Cable
  - Contains 64-128 coaxial cables
    - Specific impendence and capacitance
  - Shielding



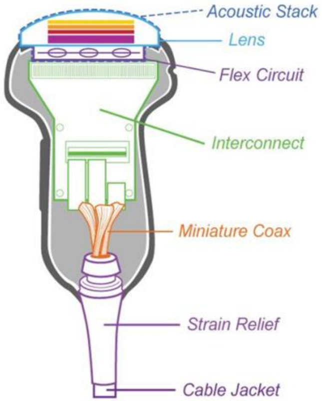


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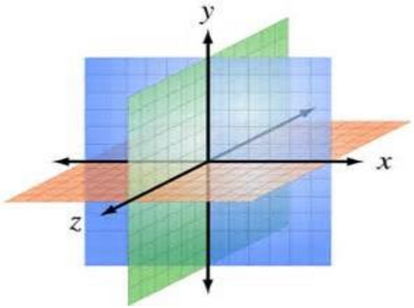
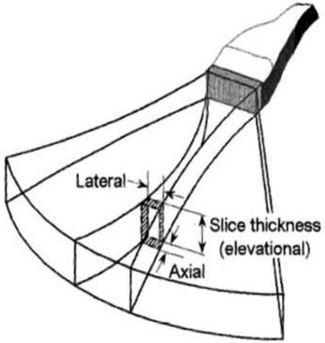
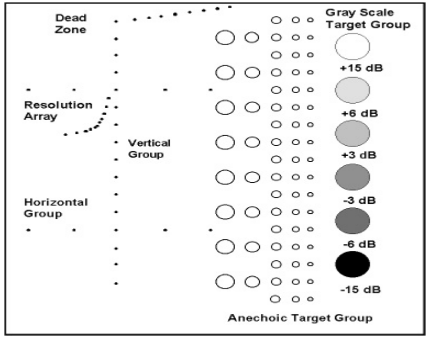
Image Resolution

- Spatial Resolution
  - Lateral (X)
    - Ability to distinguish between two objects perpendicular to ultrasound beam
    - Varies with depth
  - Axial (Y)
    - Ability to distinguish between two objects parallel to ultrasound beam
    - Does not vary with depth
  - Elevational (Z)
    - Ability to distinguish between two objects perpendicular to scan plane (slice thickness)
    - Varies with depth
- Contrast Resolution
  - Ability to distinguish between two regions of similar echogenicity/amplitude
- Temporal
  - Ability to distinguish change over time







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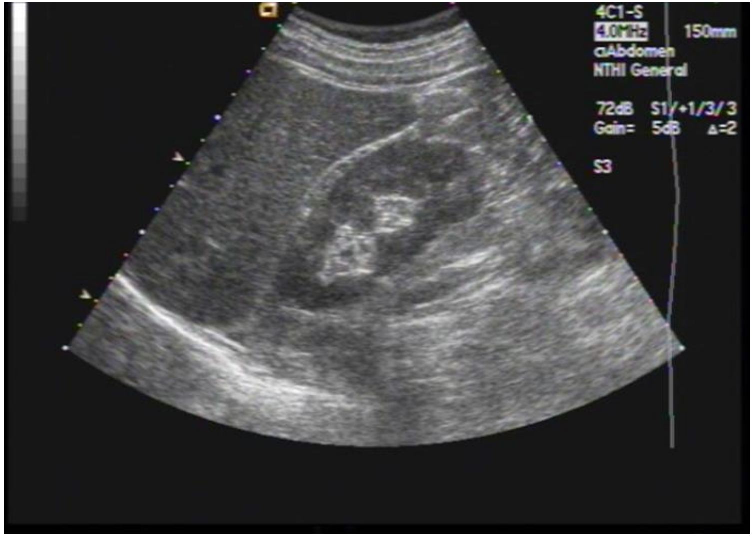
Transducer Designations

Designations *generally* indicate format type and center frequency or spectrum of frequencies

- GE E8C
  - Endocavity / Convex 3.5MHz – 11.5 MHz
- Philips C5-2
  - Convex, 5 MHz – 2 MHz
- Siemens 4C1
  - Convex, 4.5 MHz – 1 MHz
- GE ML 6-15-D
  - Matrix array, linear, 4 MHz – 15 MHz, D type connector



B-Mode Imaging

- B – mode **(Brightness Mode)** is a basic 2 dimensional image of a cross section of tissue
- Sound waves are emitted along axis of propagation
- Echoes received and converted to voltages
- Voltages are amplified and assigned various shades of grey
  - Stronger intensities = brighter pixels assigned
    - Bone, dense tissue, vessel walls
  - Weaker intensities = darker pixels
    - Soft tissue, interior of vessels, heart chambers, fluid filled structures

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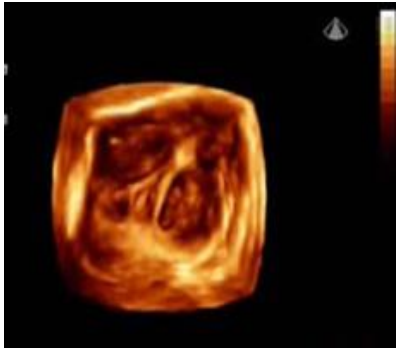
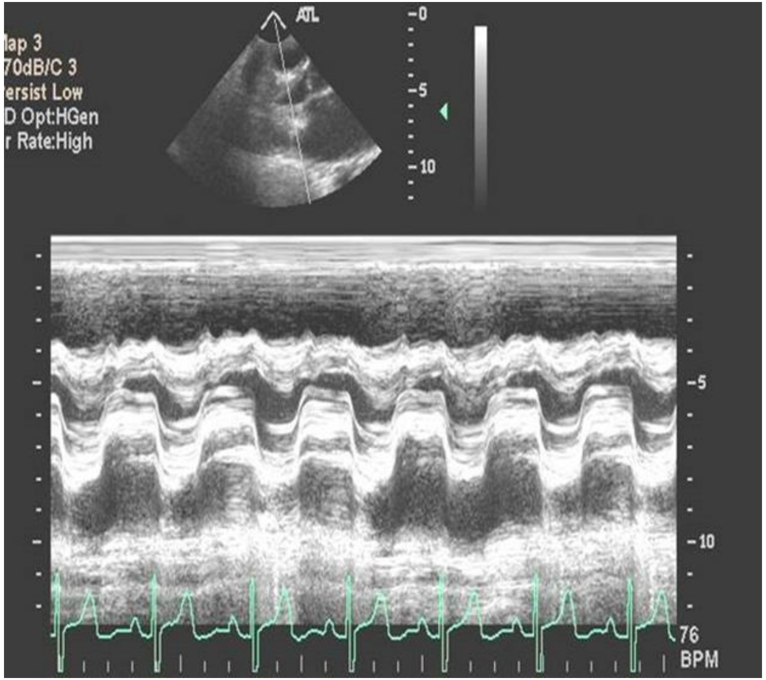
3D / 4D / Volume Imaging

- Three dimensional imaging with the added dimension of time (live) is 4D imaging or volume imaging
- Multiple scan planes are reconstructed live to create image
- Probes may be mechanical or solid state



M-Mode Imaging

- M-mode **(Motion Mode)** is used to detect temporal motion of cardiac structure
- Moving boundaries of anatomy create reflections which are used to determine and display their specific velocities
  - Valves, wall motion



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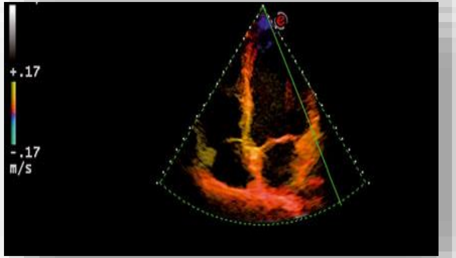
Doppler Mode

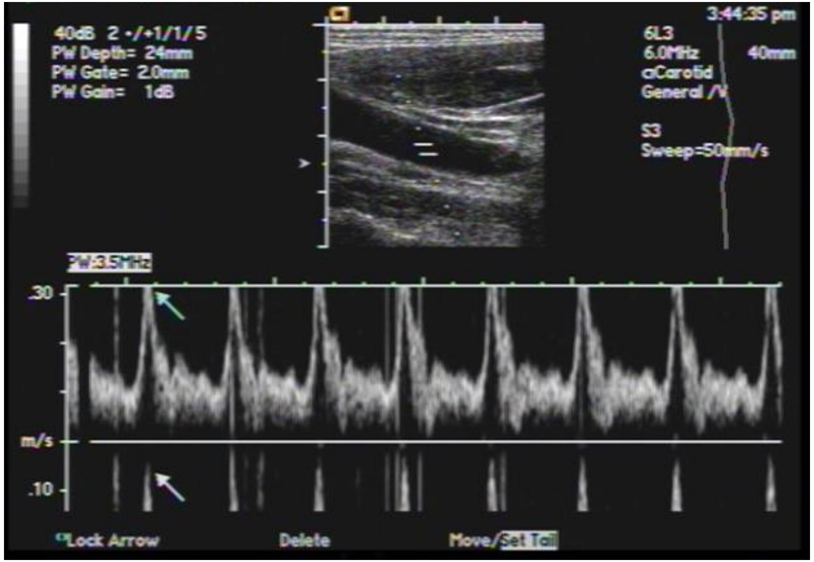
Doppler uses a signal bounced off red blood cells of anatomy to measure flow or movement

- Pulsed Wave Doppler
  - Directional, location and velocity information displayed over time
- Continuous Wave Doppler
  - Directional and velocity information displayed over time
  - Good for high velocities
- Color Doppler
  - Directional and velocity information converted to colors
  - BART: Blue away (from transducer), Red towards (transducer) *generally*
- Power / Energy Doppler
  - Independent of velocity, direction and angle
  - Extremely sensitive
- Doppler Tissue Imaging / Velocity
  - Displays velocities of tissue movement



Doppler Aliasing

- Flow is occurring faster than system sample rate
- System displays as reverse flow
- Scale / PRF or baseline adjustment
- Note signal wraparound



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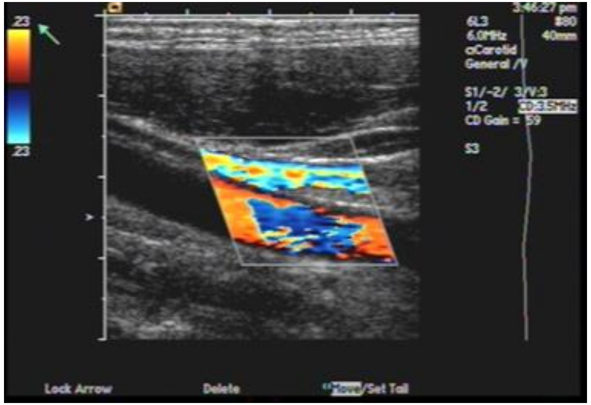
Color Doppler Aliasing

- Top image of Common Carotid Artery has proper scale / Pulse Repetition Frequency (PRF) setting
- Bottom image of Common Carotid Artery scale too low for velocities sampled
- System trying to image faster than sample rate
- Note color wraparound
  - May appear as reverse flow



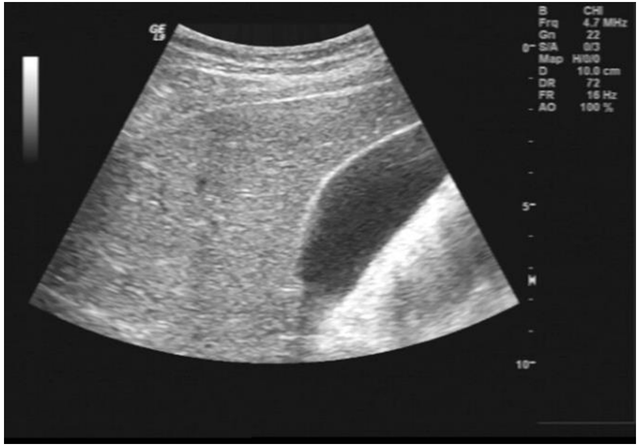
Applications / Presets

- Ultrasound systems have many presets
- Each one is designed for a specific body part, body type and transducer
  - Small Parts, Adult Echo, Pediatric Echo, Abdomen, Abdomen ++ etc.
- Presets are created for individual preferences
- Factory settings are rarely, if ever, used
- Each individual presets has 20-30 unique system parameter settings
- Applications Specialists spend hours creating presets for sonographers
- ***Backup often, backup your backup!***

Power / Acoustic Output

Displayed as Transmit Power or Acoustic Output

- Amount of acoustic / mechanical energy ***transmitted*** into the body
  - System monitors and displays as MI (Mechanical Index)
  - System is calibrated to OEM specifications transducer for accuracy
- ALARA. ***A***s ***L***ow ***A***s ***R***easonably ***Achievable***
- Measured in dB or percentage of maximum output
  - Every 3dB change = 50% power change
    - 0 dB = 100%, -3 dB = 50%, -6 dB = 25%, etc.
- Receiver amplifiers will compensate for changes in transmitted power to a certain degree



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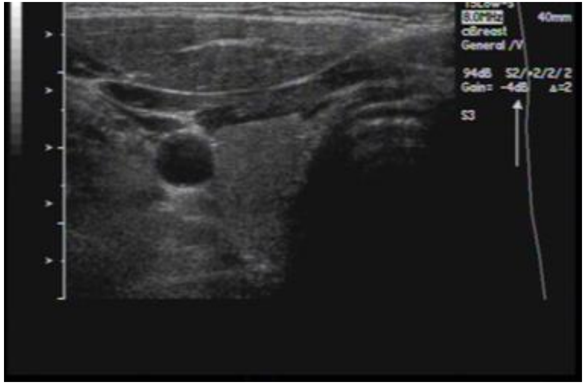
Gain

- This is the level of amplification of the ***received*** echoes from the body
- These images of a thyroid are identical in every way except:
  - Top image has 17 dB gain
  - Bottom image has -4 dB gain



DGC / TGC / LGC

- Depth Gain Control / Time Gain Control
  - Vertical
- Lateral Gain Control
  - Horizontal
- Adjusts image brightness to compensate for hyper-reflective (bright) and hypo-reflective (shadowed) areas
- Can minimize near field "main bang"
- Optimizes image uniformity

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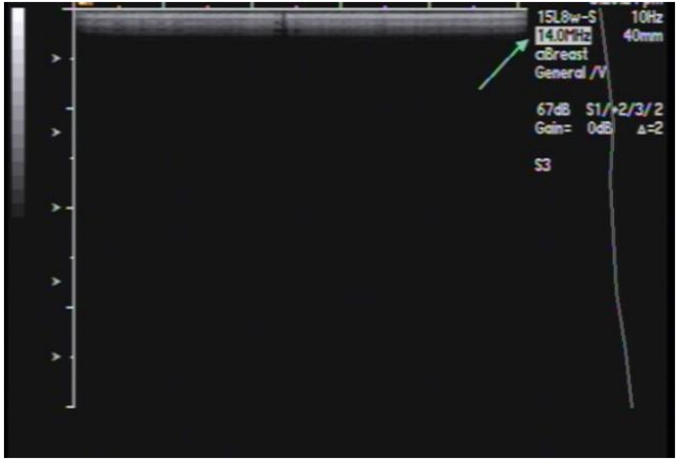
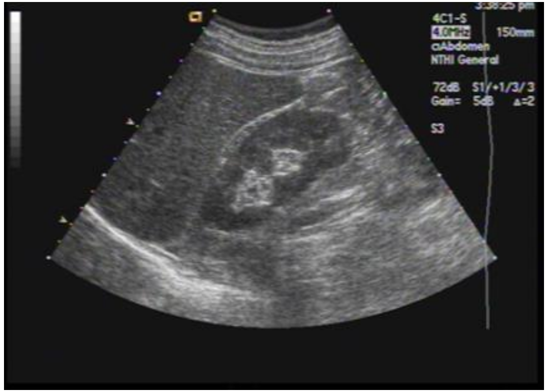
Transducer Frequency

- Transmitted frequencies vary depending on probe and application
- Low frequencies = higher penetration / lower resolution
- High frequencies = lower penetration / higher resolution
  - Thyroid: 12 MHz – 18 MHz
  - Deep abdomen: 1 MHz – 2 MHz
- Modern probes have a wide spectrum of frequencies
- Selectable by frequency or Res / Norm / Pen **(Philips / GE)** controls on system user interface or touch panel



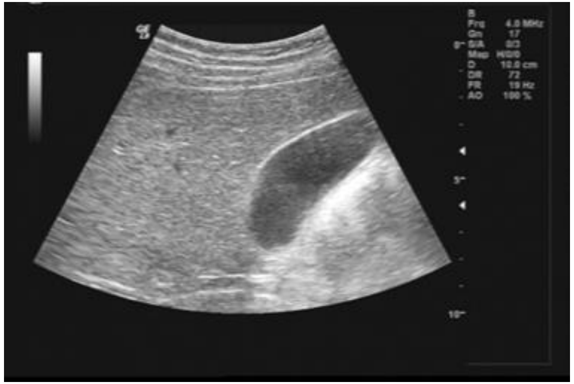
Transducer Frequency

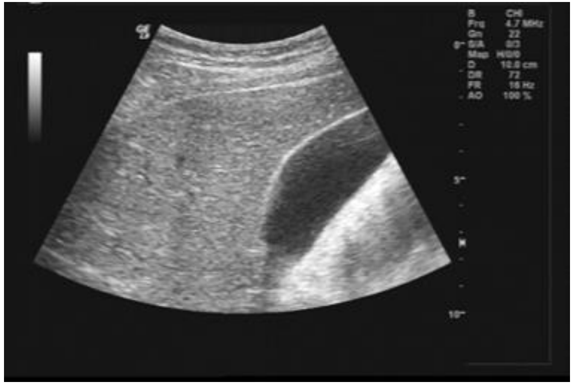
- Identical patient, identical probe, identical present ***except*** transmitted frequency
- Top image of liver / kidney scanned with 2 MHz
- Bottom image of liver / kidney scanned with 4 MHz
  - Note increased spatial resolution in bottom image
- Rule of thumb: Use highest frequency possible for region of interest



Harmonics

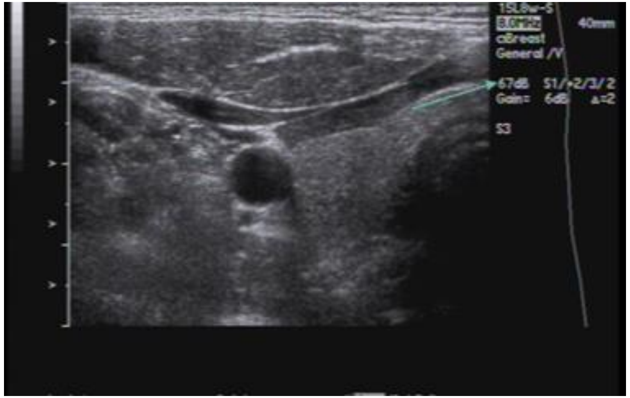
- Harmonics allow a system to transmit pulses at lower frequencies and receive pulses at higher frequencies
  - Fundamental frequency (f) transmitted but filtered out on receive cycle
  - Harmonic frequency (2f) received and processed
- Reduces noise, improves images on difficult-to-image patients
- Identical patient, identical probe, identical present except harmonics is used in lower image
  - Note noise reduction in gall bladder





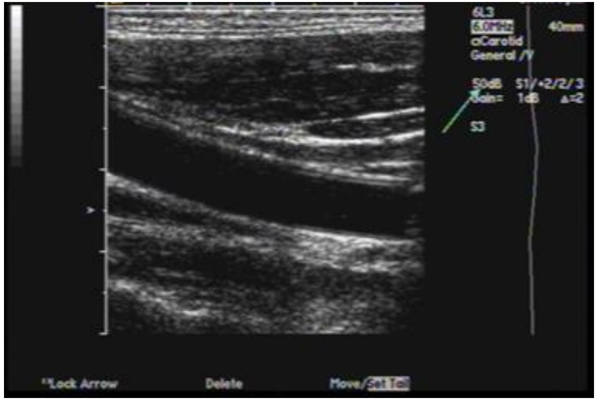
Dynamic Range

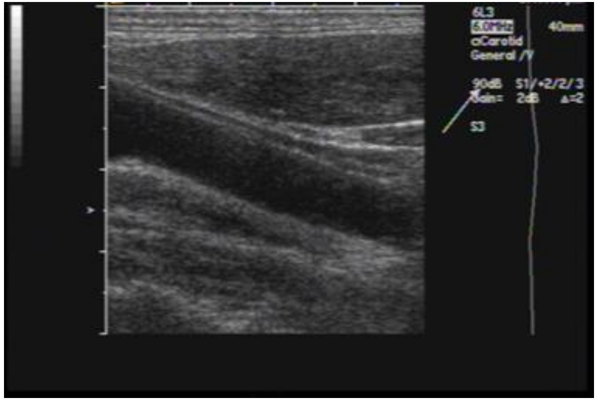
- Range of echoes processed from strongest to weakest
- Lower setting = less range of grays
- Higher setting = more range of grays
  - Thyroid image top = 67dB
  - Thyroid image bottom = 94 dB



Dynamic Range

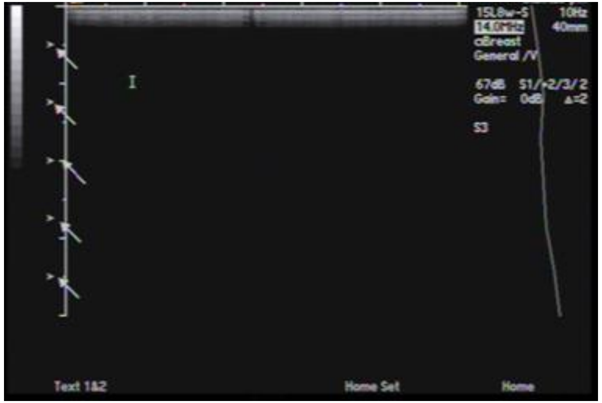
- Common carotid artery images
  - Top image = 50 dB
  - Bottom image = 90 dB
- Which dynamic range is best suited for this type of exam?

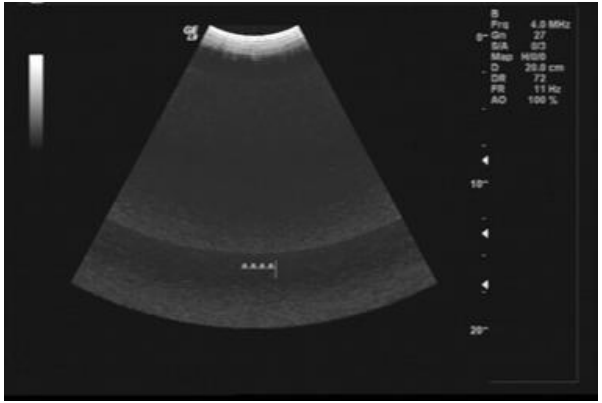




Focal / Transmit Zones

- The region(s) the system is ***electronically*** focusing is determined by focal zone(s) position
  - (Probe lens and array design determines ***mechanical*** focus)
- User selectable
- System can have from 1 to 8 or more
- Frame rate or Temporal Resolution will decrease as number of focal zones increase
- Image or Spatial Resolution will increase as number of focal zones increase
- Systems performs individual pulse – echo sequences
- Note “stitching” artifact in lower image





Frame Rate

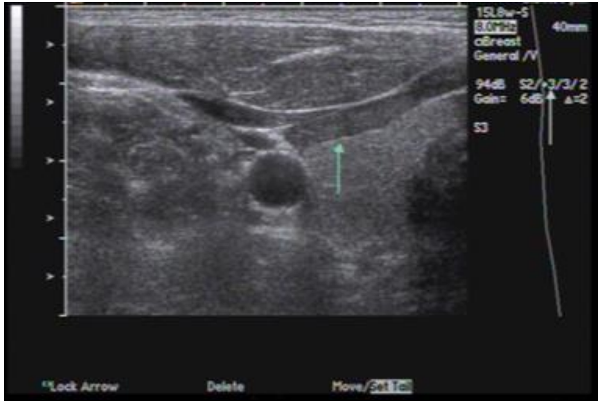
- Ultrasound systems scan at different frame rates depending on:
  - Image width
  - Frequency
  - Depth
  - Scan line density
- Low frame rates typically demonstrate better spatial resolution (ability to distinguish between 2 points in space)
  - Soft tissue, musculoskeletal, small parts
- High frame rates demonstrate better temporal resolution (ability to detect an object's motion over time)
  - Vascular, cardiac
- Note low frame rate of 10 Hz (frames per second) in image due to multiple transmit zones

Space Time / Resolution

- User can define system resource allocation preferences to enhance Spatial or Temporal resolution
- Spatial = axial and lateral resolution centric
- Temporal = frame rate centric
- Top image of thyroid is T(emporal) 1
- Bottom image of thyroid is S(patial) 2

Edge / Pre-Processing

- Sharpens edges or borders of structures
- Increases image contrast around sharp edges
  - Similar to “Sharpness” setting on televisions and monitors
- Top image of thyroid is maximum edge (+3).
  - Note crisp borders but also image noise
- Bottom image of thyroid is minimum edge (-3).
  - Note smooth tissue texture but blurry borders



Persistence / Frame Averaging

- Ultrasound images are typically several frames averaged together
- Top image of thyroid has minimum averaging.
  - Note image noise and contrast
- Bottom image of thyroid has maximum averaging.
  - Note image smoothness

Post Processing / Gray Map

- This is a gray scale map assignment to different echo intensities
- These images are identical in every way except the Post Processing / Gray Map setting
- Colors are also used in post processing for images and Doppler waveforms
  - Human eye is more sensitive to subtle color changes than grayscale

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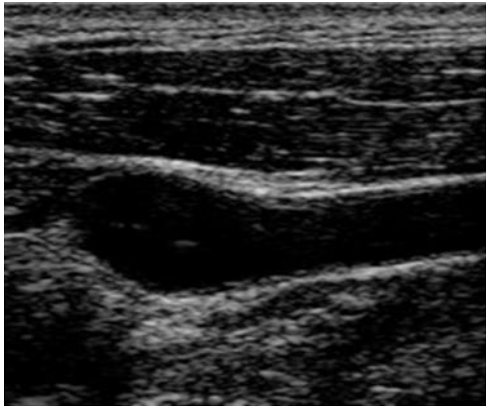
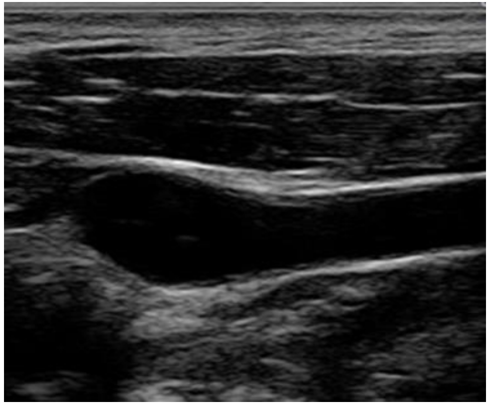
Speckle Reduction Imaging

- Speckle in ultrasound images reduces image quality and contrast
- Called SRI, XRES, uScan etc.
- Top image: SRI off
- Bottom image: SRI on





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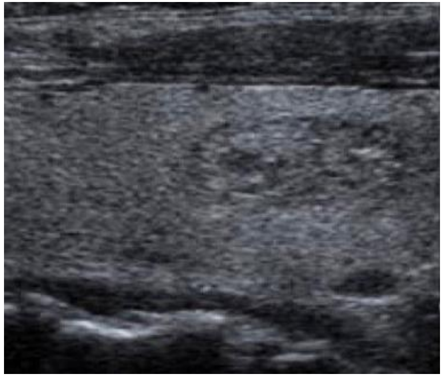
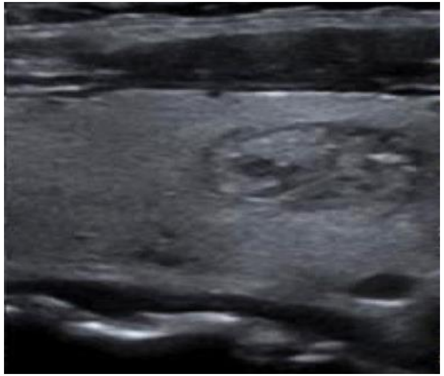
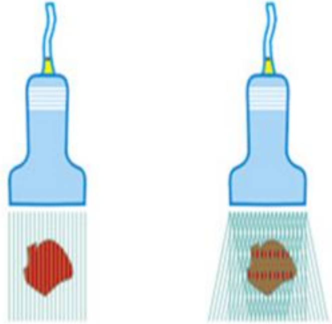
Compound Imaging

- Transmits and receives / analyzes ultrasound lines from a variety of angles at target anatomy
- Called CrossBeam, SonoCT
- Top image: compound imaging off
- Bottom image: compound imaging on



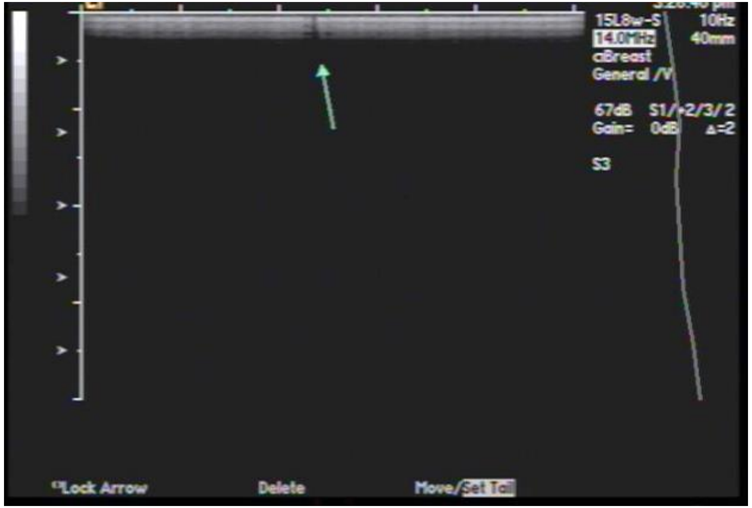




Troubleshooting Artifacts

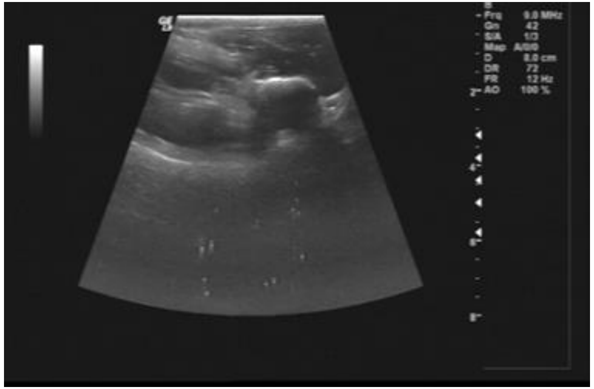
- Potential root causes for the artifact:
  - Probe array
    - A single missing or weak element ***may*** show small artifact
  - Probe cable
    - Typically 128 coaxial cables in main cable assembly
  - Probe pins/connector
    - Inspect regularly
    - Clean pin-less connector interfaces
  - Connector board
    - Inspect regularly
  - System Front End Board

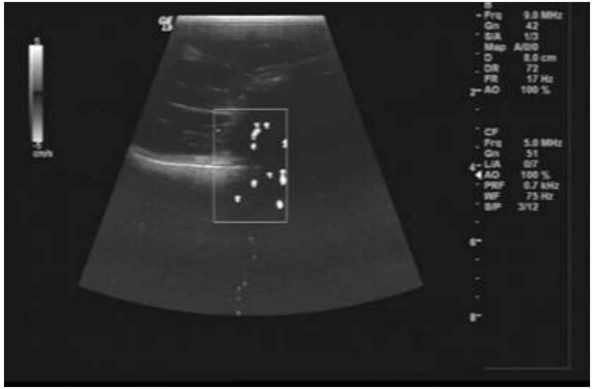
- Note image artifact in near field of image
  - Artifacts are typically hypoechoic vs hyperechoic



Troubleshooting Image Noise

- Image noise sources vary
- Check probe cable – especially at scan head strain relief
  - Enable PW Doppler or Continuous Wave Doppler
- Can you isolate system by unplugging all connected potential noise sources
- Can you try different power source
- Can you move system to a different environment within the facility
- Are system grounds intact ***internally*** and ***externally***
  - GE L9 card cage
  - Power cord
- Is facility ground compromised





Thank You!

Questions?

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