INNOVATUS imaging

All the Knowledge You Need About Ultrasound Maintenance and Imaging Artifacts

Tips for Talking the Talk and Walking the Walk with Clinicians and Technicians so You Can Exceed Expectations Without Missing a Beat

SEE BEYOND

It’s of vital importance for service engineers to both understand and be able to communicate using the language used in the clinical environment. It can be a differentiator between a successful service call and great results that exceed your team’s expectations.”

Knowledge of ultrasound system modes, functions and terminology are a huge part of performing not only proper, but also accurate system service. This paper is designed to help you increase your knowledge base in order to ultimately instill a high level of confidence with your customers. Applying the principles in this guide will help you save time and add credibility to the vital role you play. This paper will review the various imaging modes and functions of an ultrasound system and best practices for performing an ultrasound scan in a clinical environment. You will also learn common sources of image artifacts and tips for troubleshooting noise artifacts.

IN THIS REPORT YOU’LL FIND:

- Review of technology:
  - What’s in a “mode”? How and why is each one utilized in the clinical environment
  - 3D vs 4D and so much more
  - What are the benefits and limitations of the various Doppler modes: CW, PW, Color, PDI, TDI and TDE
- Terminology
  - A brief guide to all the terms and acronyms you need to have informed, productive conversations with all imaging stake holders..
- Assessing image quality
  - Rules and tests to assure:
    - Uniformity
    - Resolution
    - Penetration
- Troubleshooting image artifacts and noise artifacts
  - Artifacts based upon root cause
  - Noise Artifacts
  - Troubleshooting Guides

About Innovatus Imaging

Innovatus Imaging was formed in 2017 as a result of the merger of three leading imaging device companies, Bayer Multi Vendor Service, Wetsco, and MD MedTech. Headquartered in Pittsburgh, Pennsylvania, the brand operates three Centers of Excellence focusing on engineering new developments for increasing efficiencies, reliability and durability of imaging device repairs for ultrasound probe and MRI coils, and engineering, manufacturing and quality compliance. Additionally, Innovatus Imaging offers software and hardware products for radiography to support dry film printer, CR system, and DR needs.

The Centers of Excellence are located in Pittsburgh, Pennsylvania (MRI Coil Repair and Radiography), Tulsa, Oklahoma (Ultrasound Probe Repair), and Denver, Colorado (Engineering, Testing, Regulatory Compliance and Manufacturing). Innovatus' Center in Denver is FDA registered and all quality systems across all operations are ISO 13485:2016 certified.

Contents

Review of Technology

IMAGING MODES

B-mode (or Brightness mode):is the default mode of imaging and is a basic 2-dimensional image of a cross section of anatomy. Sound waves are transmitted from the transducer into the body along an “axis of propagation”. Echoes are received and converted to voltages. In-turn, the voltages are amplified and assigned various shades of gray based upon the amplitude of the received echoes.

- Stronger echoes = brighter pixels assigned
    - Bone, dense tissue, vessel walls
- Weaker echoes = darker pixels
    - Soft tissue, interior of vessels, heart chambers, fluid filled structures

3D (or 3D/4D-mode): In order to create a 3D ultrasound image, multiple scan planes are reconstructed, live or semi-live, to create the image. 3D imaging, with the added dimension of time, is 4D imaging or ***Volume Imaging***. Transducers may be mechanical or solid state and are often 2 or 3 times the cost of a 2D transducer. When not imaging in 3D-mode, transducers and the system function similarly to the way they would in 2D-mode.

M-mode (or motion mode): is used to detect temporal motion (motion over time) in cardiac structures. Moving boundaries of anatomy, such as valves and heart walls, create reflections which are used to determine and display their specific velocities. M-mode imaging is, generally, only available on scanners designed for echo-cardiology.

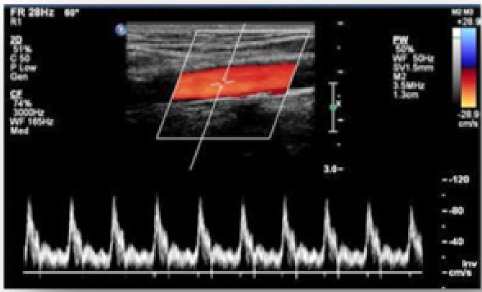
Doppler modes: Doppler imaging, sometimes referred to as ***Spectral Doppler***, uses a signal, reflected off moving anatomy (usually blood), to measure flow or movement. Only 2 measurements are possible using Doppler: speed and direction (together termed velocity).

- ***Pulsed Wave Doppler (PW-mode)***: PW Doppler offers pin-point accuracy of location and velocity due to sound energy being sampled from a movable and sizable region called the ***sample volume***. 2D imaging IS possible when using PW Doppler. Due to limitations within this Doppler mode, it cannot be used to determine high flow rates, such as those within the heart.
    - ***Note***: Combining 2D imaging and PW Doppler results in ***Duplex Imaging***. It’s also possible to combine 2D imaging, PW Doppler, and Color Doppler to result in ***Triplex Imaging***.

- ***Continuous Wave Doppler (CW-mode)***: CW Doppler samples sound energy along the entire path of the sound beam and velocities of ALL blood, and tissue motion, are analyzed and displayed. Because there is no sample volume, CW mode is unable to determine the specific location of velocities within the beam. Also, due to the high sample rate in CW mode, 2D imaging is NOT possible.

  - ***Note***: The benefit of CW mode is that it is able to determine extremely high velocities, such as those within the heart. CW mode is primarily used in echo-cardiology and may not be available on systems in General Radiology.

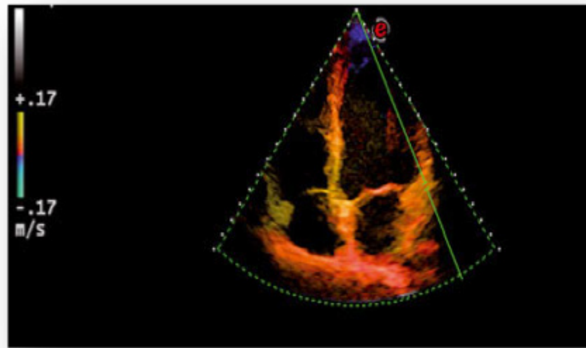
- ***Color Doppler (Color-mode)***: Color Doppler is similar to PW Doppler in that it uses a sample volume. Color-mode uses a large sample volume, called a color box, which is overlaid on top of the 2D image. Velocity information is obtained over a wide field of view and converted to range of colors. A common color map has velocities ranging from light red to dark red in one direction, and light blue to dark blue for the opposite direction. Common acronyms for color Doppler are CDI (color Doppler imaging), CF (color flow) and CFI (color flow imaging). Another acronym that refers to a common color map used by sonographers is BART: Blue away (from transducer), Red towards (transducer)



  - ***Note***: The benefit of using Color-mode is that it allows for more efficient location of blood flow than PW-mode. A potential limitation is that larger color boxes limit the frame rate (or updating) of the display.

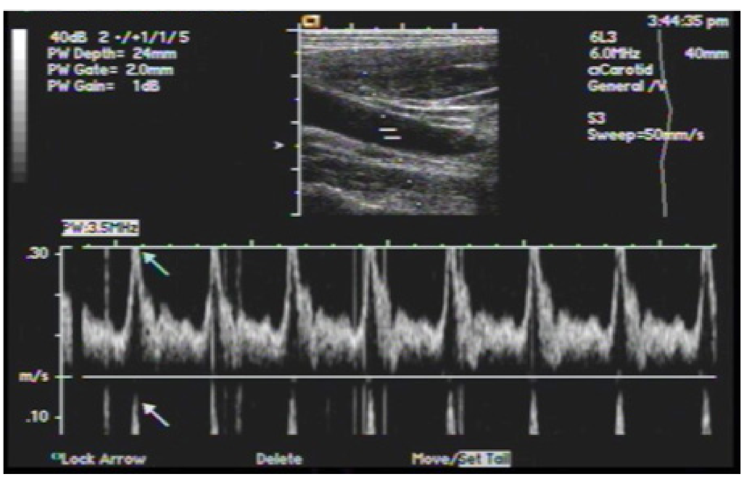
- ***Power/Energy Doppler***: Power Doppler imaging (or ***PDI***) is similar to color Doppler in that a color box is used to define the sample volume. What differentiates the two modes is that Power ONLY displays that flow or motion is present. It does NOT provide information on velocity. Due to Power Doppler's extreme sensitivity, it may be used to assess blood flow in superficial structures, like the thyroid, or anatomy with very low flow rates.

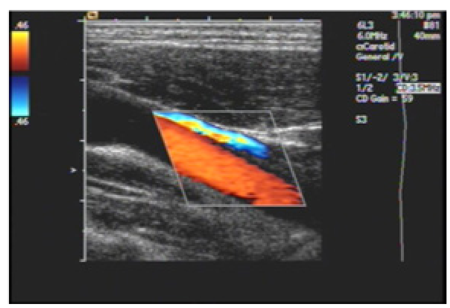
- ***Doppler Tissue Imaging/Velocity***: Doppler Tissue Imaging also functions similar to color Doppler mode using a color box. Unlike color and power Doppler modes, which present blood flow information, tissue imaging displays velocities of moving tissue. This mode is primarily used in Echo-cardiology to assess the velocity of heart tissue with the myocardium. Common acronyms used by various manufacturers are TDI (tissue Doppler imaging), TVI (tissue velocity imaging) and TDE (tissue Doppler echo-cardiology).



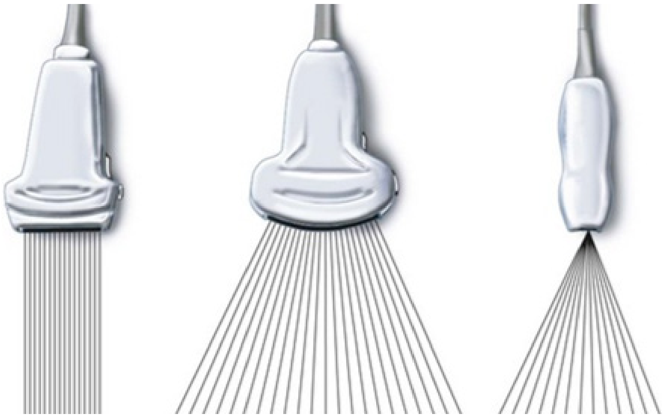
- A common user-induced artifact is called ***doppler aliasing***. Aliasing, sometimes referred to as signal wrap around, is an artifact which occurs when blood flow is occurring faster than system sample rate. The result is that the system displays forward flow as reverse flow. Aliasing can occur in any Doppler imaging mode and to correct, sonographers need to adjust the Scale / PRF or Baseline controls.

    - ***Note***: Signal (and color) wrap-around.





Transducers: Transducers may be referred to as transducers, probes or scanheads synonymously. The primary function of the transducer is to send and receive sound energy. Depending upon the type of anatomy to be imaged, transducers are designed in several formats. In general, imaging should occur as close to the anatomy as possible. Innovatus Imaging has authored a separate paper detailing the intricacies of transducer design and it is available upon request.

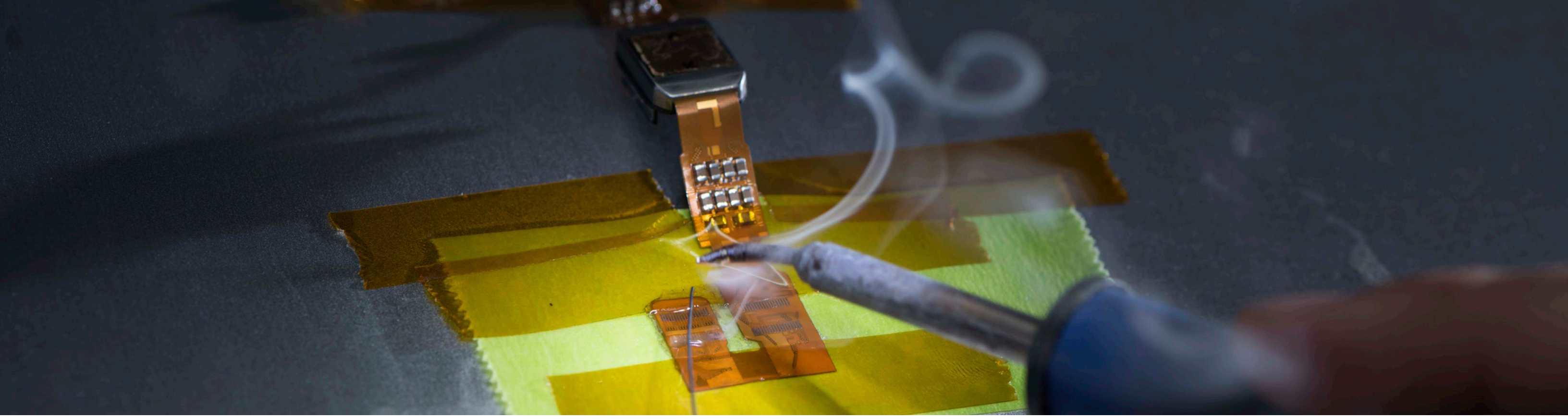


Transducer Types

- Linear
  - Rectangular or trapezoidal image format
  - Applications: Vascular, intra-operative, small parts
- Curved/Curvi-linear
  - Wide near field, wide far field
  - Applications: Abdominal, obstetrical
- Convex/Endo-cavity/Inter-cavity
  - Narrow near field, very wide far field
  - Applications: Obstetrical, urology, endo-cavity
- Sector/Vector
  - Narrow near field, wide far field
  - Applications: cardiac (including transesophageal/TEE), abdominal
- Pencil/Pedof
  - Non-imaging probe that uses CW-Doppler mode to assess blood flow
  - Applications: Cardiac, vascular

Transducer designations: Unfortunately, transducer designations (model numbers) are not standardized in the industry. Technicians can generally glean information about transducers from their model numbers. Designations generally indicate scanhead type and center frequency or the spectrum of frequencies.

- **GE E8C**: ***E***ndo-cavity / ***C***onvex, ***8*** MHz center frequency
- **Philips C5-2**: ***C***urved, ***5*** MHz – ***2*** MHz
- **Siemens 4C1**: ***C***urved, ***4*** MHz – ***1*** MHz
- **GE 9L-D**: ***L***inear, ***9*** MHz center frequency
- **GE ML6-15-D**: ***M***atrix array, ***L***inear, ***6*** MHz – ***15*** MHz, ***D***-type connector
- **GE RIC5-9-D**: ***R***eal-time 4D, ***I***nter-cavity, ***5*** MHz – ***9*** MHz, ***D***-type connector
- **Philips X8-2t**: ***X***-matrix array, ***2*** MHz – ***8*** MHz, ***T***EE probe



Terminology

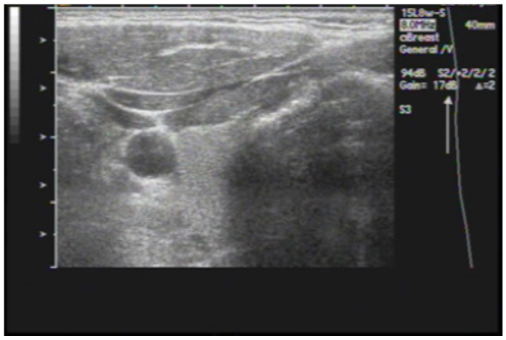
- ***Applications/presets:*** A preset (or application) is a set of 20 – 30 unique system parameter settings which can be adjusted using minimal input (or through a single click or touch). Each one is designed for a specific body part, body type and transducer. Systems come per-configured with factory defined presets, although they are seldom used. Applications Specialists spend hours creating custom presets, which allow for individualized preferences, sometimes for each sonographer in a department. Presets are generally named for the study type, such as: Small Parts, Adult Echo, Pediatric Echo, Abdomen, Abdomen ++ etc.

  - ***Service tip***: Backup the presets on every scanner during every PM inspection as they can become corrupt or lost altogether. Backup often, backup your backup!

- ***Output Power:*** Output power, sometimes referred to as transmit power or acoustic output, is the amount of acoustic / mechanical energy transmitted into the body. It can be equated to the volume control on a stereo. It is a parameter which the system continuously monitors and displays as MI (***Mechanical Index***). The maximum output power available is based on transducer model and is controlled through the system software. During their training, sonographers are taught, and encouraged, to use the minimum amount of acoustic power to obtain a quality image. The common term is ***ALARA*** (As Low As Reasonably Achievable). Output is measured in Decibels (dB) or a percentage of maximum output. Every 3dB change results in a 50% power change. i.e.: 0 dB = 100%, -3 dB = 50%, -6 dB = 25%, etc.

- ***Gain:*** Gain is the level of amplification of received echoes. Gain, like output, is also typically measured in Decibels (dB). Visibly, the gain control adjusts the **overall** brightness or darkness of the image area.

  - ***Note***: Left image has a gain of 17 dB gain and the right -4 dB gain.

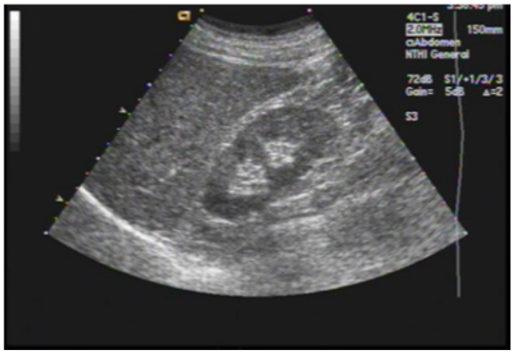


- ***TGC/DGC/LGC:*** These controls, sometimes referred to as ***sliders***, help to optimize image quality by adjusting the gain in specific areas of the image.

  - ***Time/Gain Compensation/Depth/Gain Compensation (TGC's/DGC's)***: Each slider adjusts the brightness of the image, in horizonal bands, vertically throughout the image. TGC's can help to minimize the very bright intensities at the top of the image.
  - ***Lateral Gain Compensation (LGC's)***: Each slider adjusts the brightness of the image, in vertical bands, horizontally throughout the image. LGC's can help to compensate for bright or shadowed areas, which can be common in cardiac studies.

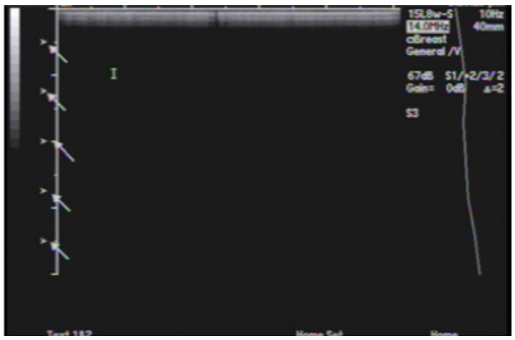
- ***Frequency:*** Modern transducers have the ability to transmit across a variable band of frequencies. Lower frequencies offer deeper penetration but sacrifice resolution, while higher frequencies offer better resolution but sacrifice penetration. The frequency (or bandwidth) is selectable by adjusting the "Frequency" or "Res/Norm/Pen" (Philips / GE) controls on system user interface or touch panel.

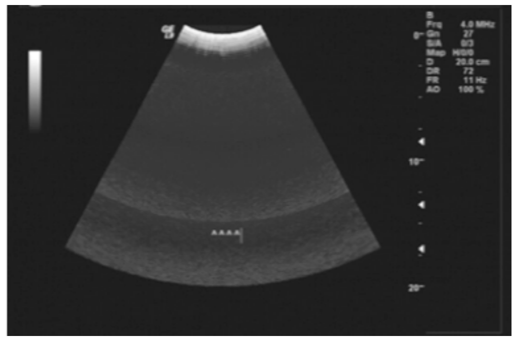
  - ***Best Practice***: Use highest frequency possible for region of interest.
  - ***Note***: Left image is scanned using 2Mhz and the right 4Mhz.



- ***Focal Zone:*** The focal (or transmit) zone is the depth at which the scanner is electronically focusing energy. The probe lens and the array design determine mechanical focus. The focal zone is user selectable and it's possible to have from 1 to 8 or more zones. Adding more zones can increase the level of detail (or ***Spatial Resolution***). Each time that a focal zone is added, the scanner has to acquire an additional number of echoes to create the image. For example and greatly oversimplified: When using 3 focal zones, the scanner acquires 3 times as many echoes to create the same image as it would for a single focal zone. As the number of focal zones increases, the scanner's frame rate (or ***Temporal Resolution***) will decrease.

  - ***Note***: Adding additional focal zones can also result in a "stitching" or horizontal banding artifact.





- ***Dynamic Range:*** Dynamic range is a measure of the number of the shades of gray when processing echoes from strongest to weakest. The lower the dynamic range, the lesser amount of shades of grays. Conversely, the higher the dynamic range, the greater amount of shades of gray. Images processed using higher dynamic range appear smoother than those using lower dynamic range. Typically, lower dynamic range is used in echocardiology and higher dynamic range is used in general radiology.

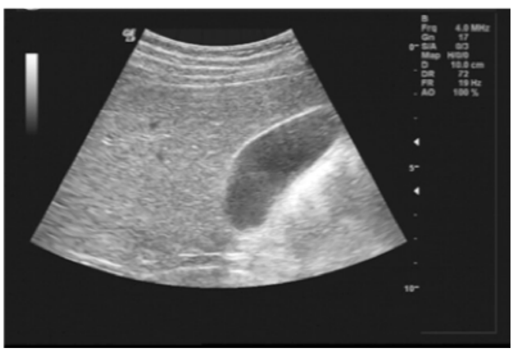
  - ***Note***: Left image has a DR of 67dB and right image 94 dB. Note difference in smoothness.

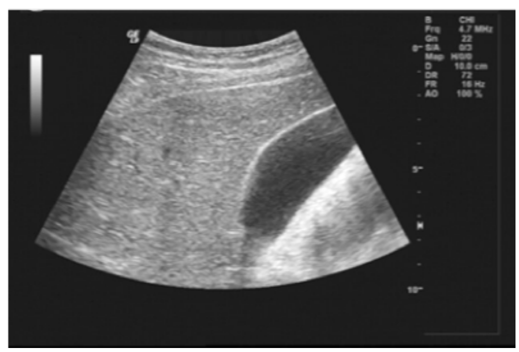
- ***Frame Rate:*** Frame rate is the speed at which the scan image is updated. It is reported in Hertz, the number of times per second that the image is updated. Based upon the image width, image depth, scan line density, number of focal zones and several other parameters, frame rates can greatly vary. Low frame rates typically demonstrate better spatial resolution (ability to distinguish between 2 points in space). High frame rates demonstrate better temporal resolution (ability to detect an object's motion over time).

  - ***Note***: A high frame rate is extremely important in echo-cardiology, where events occur at rapid rates. Frame rate is of lesser importance in general radiology.

- ***Harmonics:*** Harmonics (or ***Harmonic Imaging***) is a mode which allows the system/ transducer to transmit energy at one, fundamental, frequency but process the echoes using a higher, harmonic, frequency. Echoes are received at the fundamental frequency (f) as well as at twice the fundamental frequency (2f). The fundamental frequency is filtered out to allow only the harmonic frequency (2f) to be processed by the system. Harmonic imaging offers noise reduction and can help to improve image quality on difficult-to-image patients. A common acronym is THI (tissue harmonic imaging).

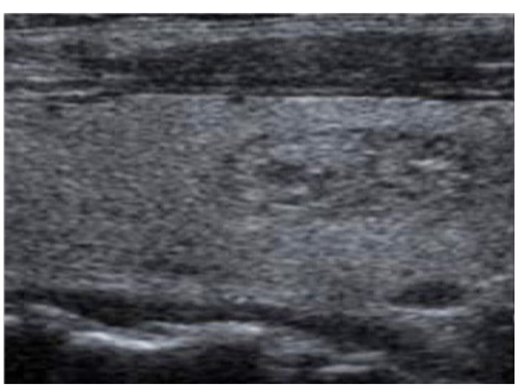
  - ***Note***: THI disabled in left image. Enabled in right image. Note less noise (grainy fill-in) with in gallbladder.





- ***Compound Imaging:*** Compound imaging is a technique that allows the transducer to transmit, receive and analyze echoes from a variety of angles. Compound imaging helps sonographers view anatomy that may be hidden behind (or within the acoustic shadow) of dense anatomy. Common brand-names of this technology are CrossBeam and SonoCT.

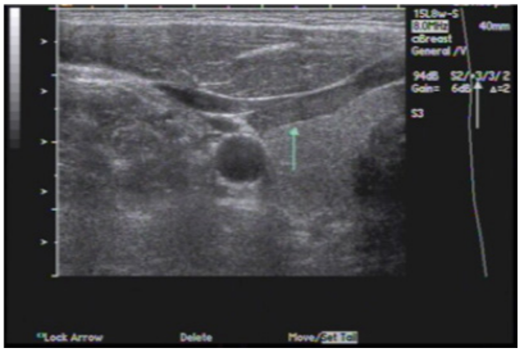
  - ***Note***: Compound imaging disabled in left image, enabled in right. . Note overall improvement in smoothness.



• ***Space time/Resolution:*** Based upon the physics of ultrasound, there needs to be a balance between Spatial Resolution and Temporal Resolution. There is no way that both can be of high priority. Scanners allow sonographers to define the amount of system resources allocated to enhance either Spatial or Temporal resolution. Increasing the spatial priority, increases the axial and lateral resolution. Increasing the temporal priority, increases the frame rate. Adding to one, will detract from the other.

• ***Edge/Pre-processing:*** Edge (or ***Pre-processing)*** has the ability to increase the sharpness of edges or borders of structures. It's similar to the sharpness control on a TV or monitor.

- ***Note***: Left image has Edge set to maximum and right set to minimum. Note the more-defined "edge" of the thyroid in the left image.

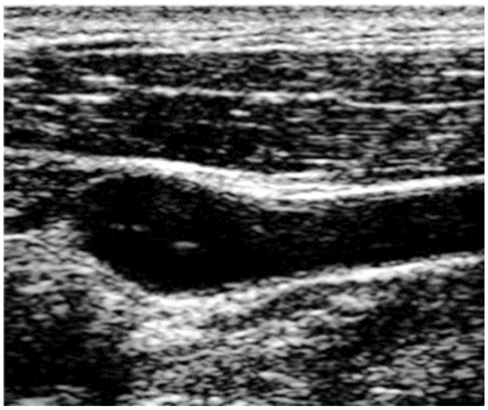



• ***Persistence/Frame Averaging:*** Frame averaging is a technique used to smooth or soften the scan image. To accomplish this, the scanner combines, or averages, several images together, prior to displaying the image. Increasing persistence adds softness to the image, but lowers the frame rate. Decreasing persistence allows the image to update more frequently and, likewise, increases the frame rate.

• ***Post-processing/Gray Map:*** Changing the gray map (or ***Post-processing***) allows sonographers to adjust the number of shades (from white to black) in the image. This permits the brightness of the pixels to be displayed in various shades of gray to represent different echo amplitudes. This control is similar to adjusting the dynamic range, yet it is subtly different. It's also possible to use colors (rather than shades of gray) in post-processing, as the human eye is more sensitive to subtle color changes than grayscale.

- ***Speckle Reduction:*** Due to the extremely small intensity of the echoes received in ultrasound, noise speckling can occur within hollow, or fluid-filled, structures. Manufactures have created complex algorithms to help to decrease noise levels, and thus noise speckling, in scan images. Common acronyms and brand-names for this technology are SRI, XRES and uScan.

  - ***Note***: SRI disabled in left image and enabled in right. Note overall improvement in smoothness.



Assessing Image Quality

Innovatus Imaging previously published a white-paper outlining best-practices for assessing image quality. Readers should request the white-paper from info@innovatusimaging.com to obtain a deeper understanding of the processes and techniques for assessing image quality, but we'll review some of the common rules and terminology.

Rules:

- Ensure a quality equipment ground
- Clean the scanner's probe ports
- Disconnect all probes except the one being tested
- Disconnect the network cable from the rear of the scanner
- Adjust room lighting to typical scanning room intensity
- Display brightness and contrast:
    - Use the system grayscale bar to adjust brightness so the darkest shade of gray is barely visible
    - Assure that the grayscale bars are graduated or stepped
    - Contrast is adjusted for "white whites" but not blooming
- Confirm any recommendations or adjustments with the sonographer

Common Tests:

- ***Uniformity***: Image uniformity is defined as the equipment's ability to present ultrasound echoes, with the same amplitude, as the same shade of gray. Issues with image uniformity can be attributed to failures within the transducer or the front-end of the scanner.

- ***Resolution***: There are several types of resolution that can be assessed as part of a comprehensive QC program, the most common being spatial resolution. Spatial resolution is defined as the system's ability to individually resolve (or display) separate targets. It is usually measured in millimeters and is the minimum distance at which two targets can be individually visualized. Spatial resolution is measured axially (vertically, or parallel to the sound beam) and laterally (horizontally, or perpendicular to the sound beam).

- ***Penetration***: Penetration, or maximum depth of penetration, is defined as the maximum depth at which echoes can be received, processed and displayed. Penetration is indirectly related to the transmitted frequency, in that; the higher the transmitted frequency, the lesser the penetration. Mathematically, the sound beam loses about 1dB/cm/Mhz.

Troubleshooting Artifacts

Artifacts based upon root cause

- ***Probe array***: A single, or well-defined, vertical line of dropout present within the image.
    - **Tip**: Assess image quality using a transducer of the same make and model using the SAME identical settings on the scanner.

- ***Probe cable***: Multiple, well-defined, vertical lines of dropout that appear/disappear when the cable (and most-likely the strain relief) is moved or wiggled.
    - **Tip**: Using color Doppler mode, wiggle the cable and strain relief looking for flashing of color in the image.

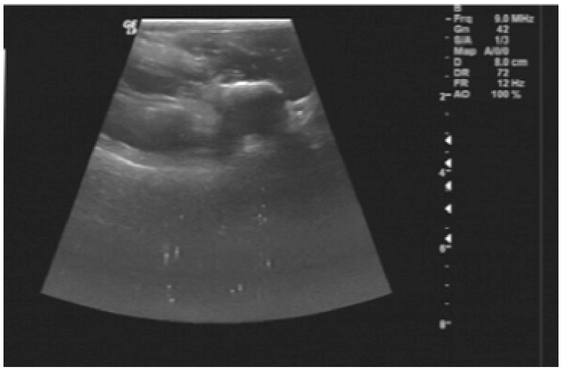
- ***Probe connector/pins***: A single, or well-defined, vertical line of dropout present within the image.
    - **Tip**: Physically inspect the connector for bent, missing, corroded pins/plate.

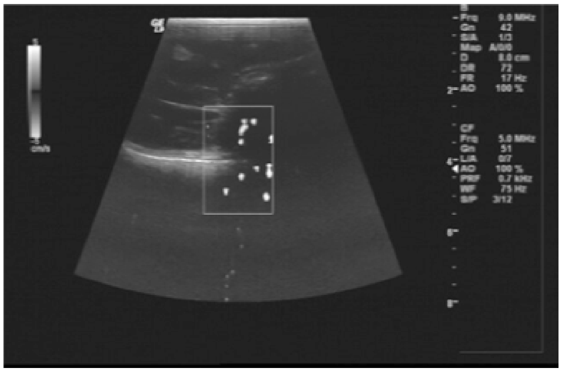
- ***Scanner connector ports***: May cause a variety of intermittent issues such as dropout, probe ID, probe initialization errors, over-temperature errors.
    - **Tips**: Physically inspect the connector ports for bent, damaged pins. Periodically clean the scanner's connector ports. Test the same transducer on a different scanner and compare the results to the those obtained using the first scanner.

- ***Scanner front-end PCB***: May cause a variety of hard failures such as image dropout (no matter which port a probe is used in), a double image, no image present and error codes when a probe is initialized.

Noise Artifacts

- Noise artifacts can be some of the most challenging problems to troubleshoot. Many noise artifacts are intermittent and based upon factors other than the scanner and probe. Manufacturers design their ultrasound scanners and transducers to limit their susceptibility to internal and external RF (Radio Frequency) interference. The majority of today's transducers are specifically designed for increased RF noise suppression. Still, there is no scanner or transducer that is totally impervious to strong sources of RF energy. The suppression of RF interference is mainly accomplished by surrounding the scanner and the transducers with a shielding that is directly attached to the system or earth ground. Any interruption in this direct connection to the grounding system can cause the scanner and/or the transducer to become ***more susceptible*** to internal and/or external RF energy.





- Common symptoms that can contribute to over-sensitivity to RF energy:

  - Poor connection to the hospital's grounding system
  - Broken or loose wires within the receptacle
  - A broken, loose or intermittent ground wire in the scanner's power cord
  - Excessive dust or debris within the scanner
  - Poor physical connections between the scanner and the transducer
  - Broken ground straps or RFI fingers/springs (that surround the scanner's connector ports)
  - Dust, debris and/or corrosion to any components between the scanner and the transducer
  - Broken, loose or intermittent shield wiring within the transducer (or the scanner)

- Common sources of external RF interference (atmospheric noise): Overhead lighting and surgical light sources, microwave ovens, cell phones, land-line phones, copiers, TV and radio broadcasts, other medical equipment, walkie talkies, or from within the scanner itself. Only through thorough research, documentation and process of elimination can the source actually be identified….and then, only some of the time.

Guidelines for troubleshooting noise issues

- Provide a cell phone number to the end-users so that they can contact you WHEN the problem is actually occurring. This is extremely important. You should personally view the noise.
- Identify if the problem is isolated to only one specific transducer.
- Identify if the problem is isolated to only one scanner or if it is present every time on every scanner.
- Identify if the problem is isolated regionally…only occurring in 1 room, within the OR, or only on certain floors. Document the exact location and the exact electrical outlet in-use.
- Identify if the problem is isolated temporally…only occurring in the morning or afternoon. Document the exact time.

- If the problem is isolated to a ***single scanner***:
  - Perform an electrical safety inspection on the scanner AND the transducer.
  - Gel warmers are notorious for causing noise interference. Temporarily unplug or remove them from the immediate environment.
  - Thoroughly clean the scanners internal PCB's AND power supply. Assure that the air filters have been cleaned on the scanner.
  - Identify if the problem is only occurring when using a specific connector port.
  - On the Siemens S-series and GE-E-series scanners, the micro-pins within the connector ports can wear over time causing poor and intermittent connectivity.
  - Closely examine the connector ports on the scanner AND the probe and routinely clean the connector ports on all scanners.
  - Assure that the grounding straps/RF fingers/RF springs, surrounding the connector ports, are present and fully intact.

- If the problem is isolated ***regionally***:
  - Isolate to a single outlet or electrical circuit.
  - Isolate to the proximity to other sources of RF energy. (CT, MRI, X-ray, motors, telemetry systems).
  - Time and location-based events are difficult to resolve. Other suggestions include:
    - Microwave ovens: In-use only during break times. May be located on, above or below the specific location.
    - Gel warmers: May be located in the actual room or in other rooms.
    - Cell phones: Cell phones may be on located on the patient, a visitor, staff members and/or physicians. They may also be located on, above or below the specific location. According to one OEM, a cell phone operating within 10 feet of a probe CAN cause noise to be introduced into the scanner that may distort the image.

All the Knowledge You Need About Ultrasound Maintenance and Imaging Artifacts

Tips for Talking the Talk and Walking the Walk with Clinicians and Technicians so You Can Exceed Expectations Without Missing a Beat

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