

Ultrasound Physics Vocabulary Reference

Chapters 9–18 | Edelman, *Understanding Ultrasound Physics*, 4th Ed.

An In-Depth Review by Dr. Alice Matthews

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Chapter 9: Transducers

Term	Definition	Analogy / Example
Acoustic Insulator	A thin barrier of cork or rubber inside the transducer case that isolates the internal components from the case. It prevents vibrations in the case from inducing unwanted electrical voltages in the PZT.	Like rubber feet on a washing machine that keep vibrations from shaking the floor.
Active Element (PZT Crystal)	The piezoelectric crystal within the transducer that converts electrical energy to sound and vice versa. Shaped like a coin in simple probes, its thickness determines the frequency of pulsed-wave sound. The PZT is one-half wavelength thick.	Think of it as the vocal cord of the transducer: its size and shape determine the pitch (frequency) of the sound produced.
Curie Temperature	The critical temperature above which a piezoelectric material permanently loses its piezoelectric properties. Transducers must not be autoclaved or exposed to extreme heat.	Like a chocolate chip that melts and never returns to its original shape: once the PZT exceeds its Curie temperature, the crystal is permanently ruined.
Electrical Shield	A thin metallic barrier lining the inside of the transducer case that prevents spurious electrical signals in the environment from contaminating the clinically important signals used to create images.	Like the foil lining inside a chip bag that keeps the contents fresh by blocking outside elements.

Chapter 10: Sound Beams & Focusing

Term	Definition	Analogy / Example
Beam Divergence	The gradual spreading of the ultrasound beam in the far field beyond the focal point. Determined by transducer diameter and frequency: larger diameters and higher frequencies produce less divergence.	A flashlight beam fans out past its tightest point. A wider lens (larger transducer) and tighter focus (higher frequency) keep the beam narrower for longer.
Dynamic Aperture	A technique that changes the number of active elements used during reception to maintain a narrow beam over a greater range of depths, optimizing lateral resolution throughout the image.	Like adjusting the iris of a camera for each shot: the system dynamically opens up to use more elements for deeper echoes.
Electronic Focusing	A method of focusing the beam using electronic time delays (phasing) applied to multiple array elements. Unlike lens or curved crystal focusing, electronic focusing is adjustable by the sonographer.	Like a group of people doing "the wave" in a stadium: precise timing of each person determines where the wave peaks.
External Focusing (Acoustic Lens)	A method of narrowing the beam by placing a lens made of acoustic material on the face of the transducer. The lens refracts sound to converge it toward a focal point.	Works exactly like a magnifying glass focuses sunlight into a small, bright spot.

Term	Definition	Analogy / Example
Focal Length (Focal Depth / Near Zone Length)	The distance from the transducer face to the focus (the narrowest point of the beam). Determined by the diameter of the crystal and the frequency of sound: larger diameter and higher frequency yield a longer focal length.	A wider garden hose nozzle and a finer mist setting (higher frequency) both push the tightest part of the spray farther from your hand.
Grating Lobes	Similar to side lobes but produced by array transducers. These off-axis beams result from the regular spacing between array elements and degrade lateral resolution.	Like light passing through a picket fence: the regularly spaced gaps create extra, unwanted beams of light at predictable angles.
Huygens' Principle	The theory that a large active element behaves as millions of tiny, distinct point sources, each creating V-shaped wavelets. These wavelets interfere with one another to produce the overall hourglass-shaped sound beam.	Like many small pebbles dropped into a pond at once: each creates its own ripple, and the ripples combine into one large, organized wave front.
Internal Focusing (Curved Crystal)	A method of narrowing the beam by shaping the piezoelectric crystal into a concave curve, so that sound naturally converges toward a point in front of the transducer.	Like a satellite dish that concentrates signals toward its center receiver.
Side Lobes	Additional areas of sound energy created by single-element transducers that radiate at angles off the main beam axis. They degrade image quality by creating false echoes from structures outside the main beam.	Like the dim, unwanted rings of light around a flashlight's main beam.
Slice Thickness (Elevational Resolution)	The third dimension of image resolution, dealing with the beam's thickness in the direction perpendicular to the imaging plane (above-to-below). Poor slice thickness creates volume averaging artifacts. Typically the worst of the three resolution types.	Imagine slicing a tomato: slice thickness determines how thick each slice is. A thick slice blurs structures above and below the imaging plane together.

Chapter 11: Display Modes

Term	Definition	Analogy / Example
A-Mode (Amplitude Mode)	A display format where returning echoes are shown as upward spikes on a graph. The x-axis represents depth and the y-axis represents the amplitude (strength) of each echo. The oldest and simplest display mode.	The display looks like a city skyline: each spike represents a reflecting structure, and taller spikes mean stronger echoes.
Bistable Display	An image composed of only two shades: black and white (no gray). Bistable images have the narrowest possible dynamic range and the highest contrast.	Like a silhouette or a shadow puppet: everything is either fully black or fully white with no shades in between.
M-Mode (Motion Mode)	A display that shows the changing position of reflectors over time. A single scan line is repeatedly interrogated, with the x-axis representing time and the y-axis representing depth. Commonly used for cardiac imaging.	Like a time-lapse photograph of a swinging pendulum: you can see the back-and-forth motion of a heart valve recorded across the screen over time.

Chapter 12: Two-Dimensional Imaging & Array Transducers

Term	Definition	Analogy / Example
Annular Phased Array	A transducer whose elements are arranged as concentric rings (like a bullseye). It provides excellent focusing in all planes but requires mechanical steering to sweep the beam, making it slower.	Like a dartboard: the rings allow focusing in every direction, but the whole assembly must physically rotate to steer the beam.
Channel	The combination of one active element, its connecting wire, and its associated system electronics. The number of channels determines how many elements can fire or receive simultaneously.	Each channel is like one musician in an orchestra: the number of channels determines how many instruments can play at once.
Convex (Curvilinear) Array	A linear sequential array built on a curved surface, producing a wider, fan-shaped field of view than a flat linear array. Commonly used for abdominal imaging.	Like bending a flat ruler into a curve: the same sequential firing now fans out to cover a wider area.
Dynamic Receive Focusing	The application of time delays during reception (listening) so that returning echoes from different depths are properly aligned, improving lateral resolution across the entire image. Unlike transmit focusing, receive focusing can occur at many depths simultaneously.	Like adjusting your hearing aid in real time as sounds arrive from different distances, so everything comes in clearly.
Electronic Steering	The use of a sloped pattern of phase delays across array elements to direct the sound beam at different angles without physically moving the transducer.	Like tilting a row of flashlights at an angle by slightly delaying when each one turns on: the combined light sweeps in a new direction.
Linear Phased Array	A transducer with many small elements that use electronic time delays to both steer and focus the sound beam, producing a sector-shaped (pie-shaped) image from a small footprint. No moving parts.	Like a marching band that pivots direction by having members slightly delay their steps: the beam is electronically steered without physically moving the transducer.
Linear Sequential Array	A transducer with many rectangular elements arranged in a line. Small groups of adjacent elements fire together in sequence to produce a rectangular-shaped image. Commonly used for vascular and small-parts imaging.	Like a row of spotlights on a stage turning on in groups, one after another, from left to right: each group illuminates one scan line.
Mechanical Steering	Physically moving or rotating the transducer element(s) to sweep the sound beam and build up a two-dimensional image. Used in annular arrays and older sector scanners.	Like a lighthouse rotating its lamp to sweep light across the ocean: the element physically turns.
Phasing (Phase Delays)	The electronic technique of applying tiny time differences (often billionths of a second) to the firing of individual array elements. The pattern of delays determines whether the beam is steered, focused, or both.	Like a row of dominoes set up so each one falls a split second after the previous one: the precise timing determines the direction of the "wave."
Vector Array	A hybrid transducer combining linear sequential and linear phased array technologies. It produces an image that is rectangular near the top and widens into a trapezoid (sector) shape at depth.	Like a flashlight beam that starts as a narrow rectangle near the lens and fans out into a wider cone farther away.

Chapter 13: Real-Time Imaging

Term	Definition	Analogy / Example
Field of View (Sector Size)	The angular width or overall size of the image. Increasing the field of view requires more pulses per image, which decreases frame rate and degrades temporal resolution.	Like choosing between a narrow and wide camera lens: a wider lens captures more of the scene but requires more processing time.
Frame Rate	The number of complete images (frames) produced per second by the ultrasound system; measured in Hertz (Hz) or “frames per second.” Determined by imaging depth, number of pulses per image (line density), and sector size.	Like the frames-per-second rate on a video camera: higher frame rate = smoother motion, but each frame may have less detail.
Line Density	The spacing between scan lines in an image. Higher line density means more pulses per image, which improves spatial detail (lateral resolution) but reduces frame rate and temporal resolution.	Like the thread count in a fabric: more threads per inch (higher density) creates a finer, more detailed picture, but takes longer to weave.
Temporal Resolution	The accuracy of imaging in time; the ability to correctly locate moving structures at any particular instant. Determined entirely by frame rate. Temporal resolution is the reciprocal of frame rate.	A camera with a fast shutter speed (high frame rate) captures a hummingbird’s wings sharply; a slow shutter speed blurs them.

Chapter 14: Pulsed Echo Instrumentation

Term	Definition	Analogy / Example
Amplification (Receiver Gain)	The first receiver function, where every returning signal is made larger by an identical amount. Adjustable by the sonographer. Changes overall image brightness but does not improve the signal-to-noise ratio. Measured in decibels (dB).	Turning up the volume knob on a radio: everything gets louder, including the static.
Beam Former	Sophisticated electronics that coordinate the complex timing of phase delays for array transducers, controlling both the steering direction and focal depth of the sound beam.	The conductor of an orchestra, telling each musician (element) exactly when to play.
Compensation (TGC / DGC)	The second receiver function, also called Time Gain Compensation or Depth Gain Compensation. It selectively amplifies signals from deeper structures more than those from shallow structures, correcting for attenuation so that similar reflectors appear at the same brightness regardless of depth.	Like adjusting the equalizer on a stereo so the bass (deep echoes) and treble (shallow echoes) are balanced.
Compression (Log Compression)	The third receiver function, which reduces the total range of signal strengths to a range the human eye and display monitor can manage. Maps a very large dynamic range (e.g., 110 dB) into a smaller range (e.g., 50 dB). Reported in decibels.	Like compressing a novel into a one-page summary: you keep the key information but fit it into a manageable size.
Demodulation	The fourth receiver function, a two-part process (rectification and smoothing) that converts the high-frequency electrical signals into a form suitable for display. This is automatic and cannot be adjusted by the sonographer.	Like converting a raw audio recording into a smooth waveform that a speaker can play: the signal is cleaned up and made display-ready.

Term	Definition	Analogy / Example
Output Power (Transmit Power)	The strength of the electrical voltage applied to the PZT crystal by the pulser. Higher output power increases the amplitude of the transmitted pulse and the brightness of the resulting image. Unlike receiver gain, changing output power alters patient exposure.	Like turning up the brightness of a flashlight: more power = stronger beam, but also more energy hitting whatever you shine it on.
Preamplification	The process of improving signal quality as close to the active elements as practical (often within the transducer housing itself) before the signal reaches the main receiver. Designed to prevent electronic noise from contaminating the tiny signals from the PZT.	Like a microphone's built-in preamp that boosts a singer's voice before it reaches the mixing board, keeping the signal clean.
Pulser (Transmitter)	The system component that creates the brief electrical voltage spikes that excite the PZT crystal to produce sound pulses. Controls the amplitude and timing of the transmitted pulse.	The "spark plug" of the ultrasound system: it sends the initial jolt that starts each pulse.
Receiver	The system component that processes the tiny electrical signals returning from the transducer. Performs five sequential functions: amplification, compensation, compression, demodulation, and reject.	Like a photo editing pipeline: the raw image (signal) goes through brightness adjustment, exposure correction, contrast compression, conversion, and noise removal.
Reject (Threshold / Suppression)	The fifth receiver function, which eliminates low-level signals (noise and weak echoes) below a chosen threshold from the image. Adjustable by the sonographer.	Like a noise gate on a microphone that cuts out background hum below a certain volume, so only meaningful sounds (signals) come through.

Chapter 15: Displays & Image Storage

Term	Definition	Analogy / Example
Bit (Binary Digit)	The smallest unit of computer memory, having a value of either 0 or 1. The number of bits per pixel determines how many shades of gray can be displayed: $n \text{ bits} = 2^n \text{ shades}$. For example, 8 bits = 256 shades of gray.	Like a light switch: each switch (bit) can be on or off. With 8 switches, you can create 256 different combinations.
Persistence (Temporal Compounding / Frame Averaging)	Displaying information from multiple previous frames averaged with the current frame to reduce noise and create a smoother image. Higher persistence reduces noise but can blur moving structures.	Like stacking multiple long-exposure photos in photography: the consistent structures are reinforced while random noise averages out.
Pixel (Picture Element)	The smallest building block of a digital image. Each pixel stores a brightness value. The more pixels in an image, the greater the spatial detail.	Zooming into a digital photo until you see tiny squares of color: each square is one pixel.
Postprocessing	Manipulation of image data after storage in the scan converter. Can be applied to frozen images without rescanning. Examples include changing brightness, contrast, or gray-scale mapping.	Like adjusting the brightness and contrast of a photo after it's already been taken and saved.
Preprocessing	Any manipulation of image data that occurs before storage in the scan converter. Must be selected before scanning; changes apply to the incoming data. Examples include write magnification and edge enhancement.	Like choosing your camera settings (ISO, aperture, shutter speed) before you take the picture.

Term	Definition	Analogy / Example
Read Magnification (Read Zoom)	Magnifying an image after it has been stored by simply enlarging the existing pixels. Does not add new information; the image may appear blocky or coarse. This is a postprocessing function.	Like pinching to zoom on a phone photo: the image gets bigger, but no new detail appears and it eventually looks pixelated.
Scan Converter	The component that stores image information in digital memory and allows it to be displayed on a monitor. Incoming echo data is “written” to the scan converter, then “read” from it for display.	Like a camera’s memory card that captures the raw data and then sends it to the screen for viewing.
Spatial Compounding	Combining image data acquired from multiple different beam angles into a single image. Reduces speckle and improves visualization of tissue boundaries and curved surfaces.	Like photographing a sculpture from several angles and combining the photos: shadows and artifacts from one angle are filled in by another.
Write Magnification (Write Zoom)	Magnifying an image during data acquisition by rescanning only the region of interest. Improves detail because the same number of pixels covers a smaller area, increasing pixel density. This is a preprocessing function.	Like cropping a photo before printing and then reprinting at full size: the enlarged area has real, captured detail.

Chapter 16: Dynamic Range

Term	Definition	Analogy / Example
Dynamic Range	The ratio of the largest to the smallest signal that a system component can handle; reported in decibels (dB). A wide dynamic range means many shades of gray (low contrast). A narrow dynamic range means few shades (high contrast, approaching bistable). Each component has its own dynamic range.	A bathroom scale with a range of 0 to 300 lbs has a wide dynamic range. A coin scale measuring 0 to 5 grams has a narrow one. The receiver has a much wider dynamic range than the display monitor.
Signal-to-Noise Ratio (SNR)	The comparison of meaningful diagnostic information (signal) to unwanted random electronic disturbance (noise). Higher SNR means a cleaner, more diagnostic image. Increasing output power is the only way to improve SNR.	Trying to hear a friend at a loud concert: the friend’s voice is the signal, the crowd noise is the noise. Moving closer (increasing output power) improves SNR.

Chapter 17: Harmonics & Contrast Agents

Term	Definition	Analogy / Example
Contrast Agents (Microbubbles)	Gas-filled bubbles (typically 1 to 10 micrometers in diameter) injected intravenously that produce strong echoes due to their nonlinear oscillation. They resonate, expand, and compress in the sound field, producing powerful harmonic signals. Bubble disruption creates the strongest harmonics.	Like tiny bouncy balls in the bloodstream that vibrate vigorously when hit by sound waves, sending back strong echoes that light up the blood pool on the image.
Fundamental Frequency	The frequency of the sound pulse as originally created by the transducer and transmitted into the body. In harmonic imaging, the system filters out the fundamental and uses only the harmonic signal.	Like the original note a tuning fork plays: this is the “starting pitch” that the transducer sends out.

Term	Definition	Analogy / Example
Nonlinear Behavior (Propagation)	The phenomenon where sound in compressions (high-pressure regions) travels slightly faster than sound in rarefactions (low-pressure regions). This speed difference distorts the wave shape and generates harmonic frequencies.	Like a crowd pushing through a narrow doorway: the front (compression) speeds up while the back (rarefaction) lags. This distortion creates new frequencies.
Tissue Harmonics (Second Harmonic)	A frequency exactly twice the transmitted (fundamental) frequency, generated as sound travels through tissue due to nonlinear behavior. Tissue harmonic imaging creates cleaner images because harmonics form along the main beam axis (not in side lobes) and do not form at the skin surface, avoiding near-field clutter.	If you transmit at 2 MHz, the tissue harmonic is 4 MHz. The system listens for these higher-frequency echoes to build a sharper picture.

Chapter 18: Hemodynamics

Term	Definition	Analogy / Example
Bernoulli's Principle	The principle stating that as the velocity of a fluid increases, its pressure decreases (and vice versa), assuming total energy is conserved. Clinically used to estimate pressure gradients across stenotic heart valves.	A garden hose nozzle: when you squeeze it (narrowing), water speeds up but the pressure against your thumb drops. This is why blood pressure drops significantly within a stenosis.
Continuity Equation	The principle that flow rate (volume per unit time) must remain the same at all points in a closed system: $A_1 V_1 = A_2 V_2$ (area times velocity is constant). Clinically used to calculate the area of stenotic heart valves.	Like water flowing through a garden hose: when the hose narrows, the water must speed up to maintain the same total flow. If you know the speed and diameter at one point, you can calculate the area at another.
Hemodynamics	The study of blood moving through the circulatory system, including the forces, pressures, and flow patterns involved.	Like studying traffic flow on a highway: how fast cars move, where they slow down, where traffic jams form, and what forces affect the flow.
Hydrostatic Pressure	Pressure caused by the weight of a column of blood acting on a vessel, measured relative to heart level. Positive below the heart, negative above the heart, and zero at heart level. In a standing patient, measured arterial pressure = circulatory pressure + hydrostatic pressure.	Like the pressure you feel on your eardrums at the bottom of a swimming pool. A standing patient has much higher measured pressure at the ankle (+100 mmHg) than at the neck (-30 mmHg) due to the weight of the blood column.
Laminar Flow	Smooth, orderly flow with parallel streamlines. Has two forms: (1) Plug flow, where all layers move at the same velocity, and (2) Parabolic flow, where velocity is highest in the center and decreases toward the vessel walls in a bullet-shaped profile.	Plug flow is like cars on a highway all traveling at the same speed. Parabolic flow is like a river: the center moves fastest while the edges drag along the banks.
Pulsatile vs. Phasic Flow	Pulsatile flow is rhythmic flow driven by the heartbeat, typically found in arteries. Phasic flow varies with the respiratory cycle, typically found in veins. Both patterns result in energy losses beyond those in steady flow.	Pulsatile is like water from a hand pump that surges with each pump stroke (heartbeat). Phasic is like breathing affecting a candle flame: the airflow pattern changes with each inhale and exhale.

Term	Definition	Analogy / Example
Reynolds Number	A unitless number used to predict whether blood flow will be laminar or turbulent. Accounts for flow velocity, vessel diameter, blood density, and viscosity. Values above approximately 2,000 predict turbulent flow.	Like a speed limit sign for blood flow: exceed the Reynolds threshold and orderly traffic breaks down into chaos.
Stenosis	An abnormal narrowing of a blood vessel or heart valve. According to the continuity equation, blood velocity increases through the narrowing. According to Bernoulli's principle, pressure drops within the narrowing. Turbulence often develops distal to the stenosis.	Like pinching a garden hose: the water jets through the narrow section at high speed and then sprays turbulently on the other side.
Turbulent Flow	Chaotic, disorderly flow characterized by eddies, swirls, and random motion. Converts flow energy into sound (bruit) and vibration (thrill). Typically predicted when the Reynolds number exceeds 2,000.	Like whitewater rapids in a river where rocks and narrow passages create swirling chaos. The audible sound of turbulence is a bruit; the palpable vibration is a thrill.
Viscosity (Viscous Loss)	A measure of a fluid's internal "thickness" or resistance to flow. Higher viscosity means more energy is lost as blood flows. Measured in Poise. Blood viscosity is influenced by hematocrit (the percentage of red blood cells, normally ~45%).	Honey has high viscosity (thick, slow), while water has low viscosity (thin, fast). Anemia reduces hematocrit, lowering blood viscosity and reducing viscous energy loss.

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