

Recommended Ultrasound Terminology

Fourth Edition



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Preface to the Fourth Edition

In 1980, the American Institute of Ultrasound in Medicine (AIUM) published its first document concerning ultrasound terminology. It had been prepared by the AIUM Standards Committee and was entitled, *AIUM Recommended Nomenclature: Physics and Engineering*. This was found to be very helpful but was inadequate especially with respect to the number of terms included. In the mid-1980s, within the AIUM Standards Committee, a Subcommittee on Ultrasound Terminology was created to develop a more encompassing and useful compendium of recommended ultrasound terminology and definitions. This effort led to publication in 1990 of a new document that was sufficiently larger and worthy of being given a new name: *Recommended Ultrasound Terminology*. The success of this document spurred a desire to update and enlarge it in future editions. The second edition, published in 1997 included many new terms and their definitions. Also included were a number of figures.

A third edition, published in 2008, involved a major revision of the Second Edition of *Recommended Ultrasound Terminology*. Some terms were modified, some deleted, and many new terms were been added. The goal remained the same, that is, to make available in one source those terms and definitions making up the vocabulary for the field of medical ultrasound. Because many of these terms are technical in nature, considerable effort has been directed toward expressing the definitions in ways that would be understandable to those individuals without a strong background in physical science. Occasionally, a more user-friendly definition is given that provides an intuitive notion of the term, even though it lacks the precision and rigor of the definition that would appear in a dictionary for physicists and engineers. There are many proprietary terms used by manufacturers for identifying their specific instruments and processing techniques. It was decided that it would be prudent to avoid including them in this document. We also acknowledged the use of documents developed by other organizations, both national and international. These organizations include the Society of Diagnostic Medical Sonography, the American Society of Echocardiography, the Dutch Society of Echocardiography, the International Electrotechnical Commission, the Italian Association of Medical Radiology, and the British Standards Institution.

The explosion of ultrasound inventiveness in the past decade has created many new instrumentation advances and new terms. As a result, the Fourth Edition of *Recommended Ultrasound Terminology* is also a major revision. Many new terms have been added, each previous definition was reviewed, and archaic and inconsistent terms were dropped. The number of figures was expanded by 50%. In addition, small explanatory figures were embedded in the text for convenience. Extensive cross referencing is now available with most words; these facilitate on-line searches for related aspects of terminology.

This document has been prepared by the Recommended Ultrasound Terminology Subcommittee of the AIUM Technical Standards Committee. Earlier versions of this document were reviewed by members of the AIUM Technical Standards Committee, and we are grateful for their suggestions. We recognize that the development of a good dictionary is never really complete. The vocabulary of ultrasound is constantly changing because diagnostic ultrasound is a rapidly growing medical imaging modality. Therefore, this committee welcomes comments and suggestions from all individuals interested in ultrasound. We hope that the online version of the terminology can be updated more frequently to keep up.

We would like to acknowledge a great debt to the officers and staff of the AIUM for their support of the development of this document. Special thanks go to Kathi Minton, AIUM committee specialist, who so skillfully and enthusiastically assisted our committee in every way, and to Glynis Harvey, Executive Director of AIUM.

Finally, I would like to thank our amazing team for their broad in-depth knowledge of arcane information and cutting-edge technology, their creativity and willingness to take the time and care to fashion clear, consistent and current definitions, and their patience, perseverance and hard work. It was a pleasure to work together, learn from each other and have a few laughs in the process. The present subcommittee included Marvin C. Ziskin, MD, Shigao Chen, PhD, and Kenneth Hoyt, PhD. With a subcommittee half the size of the previous one, we managed to generate hundreds of new definitions and many new figures over a three-year period. Special thanks go to Marvin Ziskin for his love of words.

Respectfully submitted,

Thomas L. Szabo, PhD, *Chair*
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Number

1-dimensional array (1D array)

A transducer array in which the transducer elements are arranged in a single row.

Related terms: 1.5-dimensional array, 1.75-dimensional array, 2-dimensional array, matrix array

1.5-dimensional array (1.5D array)

A transducer array in which the addressable elements are arranged in more than 2 symmetric rows, with corresponding elements in the rows connected together in pairs. This is most often done to enable electronic focusing and dynamic aperture control to minimize slice thickness over the imaged field. In 1.5-dimensional arrays, the electrical excitation pattern is symmetric above and below the center row of elements, so no beam steering can occur, as would be needed for 3-dimensional scanning.

Related terms: 1D array, 1.75-dimensional array, 2-dimensional array, matrix array

1.5 harmonic contrast-enhanced sonography

A contrast-enhanced modality in which images are obtained in a frequency band intermediate between the fundamental mode and second harmonic mode and whose center frequency is higher than the fundamental by a factor of 3/2.

1.75-dimensional array (1.75D array)

A transducer array in which the elements are arranged in 4 or more individually addressable rows to enable electronic focusing and dynamic aperture in the elevational direction as well as to allow limited beam steering in the elevational direction. Beam steering is possible because elements may be excited individually, allowing for an asymmetric excitation pattern between rows. There usually is not a sufficient number of rows, however, to allow beam steering over a wide angular range in the elevational direction, as would be needed for 3-dimensional scanning.

Related terms: 1-dimensional linear array, 1.5-dimensional array, 2-dimensional array, matrix array

2-dimensional array (2D array)

A multiple-element transducer array that can be configured to control the characteristics and direction of an acoustic beam usually in 2 orthogonal scan planes.

Related terms: 1-dimensional linear array, 1.5-dimensional array, 1.75-dimensional array

2-dimensional echocardiography (2D echocardiography)

Two-dimensional B-mode imaging of the heart.

3-dimensional echocardiography (3D echocardiography)

Three-dimensional ultrasound imaging of the heart.

3-dimensional acquisition (3D acquisition)

Scanning methods used to acquire 3-dimensional data. Includes freehand, position-sensed freehand, mechanically swept, and electronically swept (2-dimensional array).

Related terms: electronically swept scanning (2-dimensional array), freehand scanning, mechanically swept scanning, position-sensed freehand scanning

3-dimensional imaging (3D imaging)

An ultrasound technique in which the desired structure can be viewed in 3 dimensions.

Related terms: 3-dimensional acquisition, electronically swept imaging scanning (3-dimensional), freehand scanning, mechanically swept scanning, position-sensed freehand scanning

4-dimensional imaging (4D imaging)

An ultrasound technique in which the desired structure can be viewed in 4 dimensions (ie, 3-dimensional imaging in time). This technique allows the viewing of fetal, heart, and other anatomic movements in 3 dimensions.

Related term: 3-dimensional imaging

A

aberration

The failure of transmitted or received waves to align in phase and amplitude at an intended point, curve, or plane, which may be due to different sound speeds in tissues or materials in the acoustic paths.

aberration correction

A method of realignment or compensation to bring aberrated waves into synchronous convergence at an intended point, curve, or plane.

absolute maximum

The largest possible value of a specified quantity, either for an individual instrument or for all instruments of a given generic type. This value shall include effects of inaccuracies and imprecision of the measurement process(es) used to determine it.

absolute minimum

The smallest possible value of a specified quantity, either for an individual instrument or for all instruments of a given generic type. This value shall include effects of inaccuracies and imprecision of the measurement process(es) used to determine it.

absorbed dose

The thermal energy imparted to matter by absorption of acoustic radiation of irradiated material at the site of interest. The unit is joule (J).

absorption

The process by which energy is deposited in the medium through which it propagates. The absorbed energy is ultimately converted to thermal energy ("heat").

absorption coefficient

Fractional decrease of the amplitude of sound waves solely due to absorption per unit distance. Also called the amplitude absorption coefficient. The unit is neper per centimeter (Np/cm) or decibel per centimeter (dB/cm). The unit neper per centimeter is sometimes given as cm^{-1} . Note: Because absorption varies with frequency, the frequency at which the absorption coefficient is measured should be specified. Sometimes, absorption is expressed as a power law of frequency, $\alpha = \alpha_0 \cdot f^y$, where f is frequency in megahertz, α_0 is the absorption coefficient at 1.0 MHz, and y is the power exponent. For typical tissues, $y \sim 1$; for water, $y = 2$. Then the absorption coefficient, α , is described by the unit Np/(cm-MHz ^{y}) or dB/(cm-MHz ^{y}).

Related terms: specific absorption rate (SAR), absorption, absorption loss

absorption dose rate

The time rate of deposition of absorbed dose. The unit is watt (W).

absorption loss

That part of the transmission loss due to the conversion of sound energy to thermal energy, within the medium. The unit is neper or decibel (Np or dB). That part of the transmission loss of amplitude solely due to absorption within the medium. The unit is neper or decibel (Np or dB).

Related terms: absorption, acoustic signal loss, attenuation, attenuation coefficient, attenuation loss

absorption per wavelength

Absorption of the ultrasound beam intensity over a distance equal to the wavelength.

acceleration

The rate of change of velocity. Acceleration is a vector quantity whose magnitude is measured in meters per second squared (m/s^2) in a specified direction.

acoustic absorption

See *absorption*.

acoustic, acoustical

The qualifying adjectives "acoustic" and "acoustical" mean containing, producing, arising from, actuated by, related to, or associated with sound. Acoustic is used when the term being qualified designates something that has the properties, dimensions, or physical characteristics associated with sound waves; acoustical is used when the term being qualified does not designate explicitly something that has such properties, dimensions, or physical characteristics. Note 1: The following examples qualify as having the properties or physical characteristics associated with waves and hence would take "acoustic": impedance, output (sound power), energy, wave, medium, signal, and transducer. Note 2: The following examples do not have the requisite physical characteristics and therefore take "acoustical": method, engineer, symbol, problem, and measurement. Note 3: As illustrated in the preceding notes, usually the generic term is modified by "acoustical," whereas the specific technical implication calls for "acoustic."

acoustical system

System capable of receiving, transmitting, or generating acoustic signals.

acoustical window

See *scanning window*.

acoustic angiography

An ultrasound imaging technique used to visualize the inside (or lumen) of blood vessels of the body. This is typically performed by injecting and imaging a microbubble intravascular contrast agent.

acoustic attenuation

The reduction of the amplitude or intensity of an acoustic signal as it propagates through a material. It includes the effects of absorption, scattering, and beam divergence.

Related term: attenuation

acoustic axis

See *beam axis*.

acoustic cavitation

Cavitation caused by acoustic waves.

Related term: cavitation

acoustic crest factor

The ratio of the spatial-peak temporal-peak acoustic pressure to the root mean square (RMS) acoustic pressure at the position in an acoustic field corresponding to the spatial-peak temporal-peak acoustic pressure. The RMS acoustic pressure is taken over the pulse-peak cycle at the point in the acoustic field corresponding to the spatial-peak temporal-peak acoustic pressure (see Figure 31).

acoustic energy

Mechanical energy transported by an acoustic wave. The unit is joule (J).

acoustic enhancement

A manifestation of an increased acoustic signal amplitude returning from regions lying beyond an object that causes little or no attenuation of the sound beam. Contrasts with acoustic shadow. Acoustic enhancement is one type of sonographic artifact (see Figure 15).

acoustic field

The distribution of acoustic energy in space or space and time.

acoustic holography

See *holography*.

acoustic impedance

The ratio of the instantaneous acoustic pressure at a point to the instantaneous particle velocity (specific acoustic impedance). A property of a medium computed as the product of the density and sound propagation speed (characteristic acoustic impedance). In general, the acoustic impedance is a complex number: the resistance is the real part, and the reactance is the imaginary part.

Related terms: acoustic impedance mismatch, acoustic reactance, acoustic resistance, complex number, complex parameter, imaginary, real

acoustic impedance match

The condition in which two contiguous media have equal or nearly equal characteristic acoustic impedances, thereby minimizing reflection of acoustic energy at the interface.

Related terms: impedance ratio, reflection coefficient

acoustic impedance mismatch

The condition in which two contiguous media have different characteristic acoustic impedances, thereby providing a mechanism for the production of acoustic reflections. Waves incident on discontinuities in acoustic impedance are reflected. These reflections are the main mechanism for producing pulse echoes on which ultrasound imaging and color flow Doppler detection are based. Reflection causes a reduction in transmission of ultrasound.

Related terms: impedance ratio, reflection coefficient, transmission coefficient

acoustic initialization fraction

See *acoustic power-up fraction*.

acoustic insulation material

Material used to prevent the transmission of sound.

acoustic intensity

See *intensity*.

acoustic lens

See *lens*.

acoustic micrograph

The recorded image from an acoustic microscope. The image results from the interaction of an acoustic wave with the object, in contrast to a photomicrograph (made by a light microscope), in which the image results from the interaction of light with the object.

acoustic microscope

A device for the generation of an acoustic micrograph. Acoustic microscopes usually operate at frequencies greater than 100 MHz, and their resolution is comparable with that of optical microscopes.

acoustic oscillation

Movement of particles in an elastic medium about an equilibrium position.

Related term: sound

acoustic output

The total energy emitted by a source such as an ultrasound transducer. Acoustic output may be quantified by one or more experimentally measurable physical quantities such as particle velocity, pressure, or power or a parameter mathematically derived from these variables such as I_{SPTA} (spatial-peak temporal-average intensity).

acoustic output freeze

A condition of a system for which the acoustic output is disabled when there is no active updating of ultrasonic echo information.

Related term: freeze frame

acoustic phase coefficient

See wave number.

acoustic power

Acoustic energy transported per unit time (usually a temporal average is quoted). The unit is watt (W).

Related term: average acoustic power

acoustic power-up fraction

Ratio of the peak negative pressure when the system is in power-up of a specified mode to the maximum value for any system settings for that mode. This ratio is determined from measurements made at the position that yields the maximum pulse-pressure-squared integral (or maximum mean square acoustic pressure for continuous wave systems). The ratio is usually expressed as a percentage (see Figures 12, 31, and 32).

acoustic pressure

The value of the total (absolute) pressure minus the ambient pressure. The unit is pascal (Pa).

acoustic pulse waveform

The temporal waveform of the acoustic pressure at a specified position in an acoustic field, displayed over a period sufficiently long to include all significant acoustic information from a single pulse or tone burst or from 1 or more cycles in a continuous wave (see Figures 12, 31, and 32).

acoustic radiation force imaging (ARFI)

An imaging technique whereby the radiation force due to an applied intense sound field generates a shear wave in a medium, whose speed of propagation can be measured and related to the shear elastic properties of the medium.

acoustic radiation pressure

Pressure exerted on a surface by an acoustic wave.

acoustic radiometer

Instrument for measuring acoustic radiation pressure.

acoustic reactance

Imaginary part of acoustic impedance. Acoustic impedance is a complex quantity consisting of a real part (resistance) and an imaginary part (reactance).

Related terms: imaginary part, complex number

acoustic resistance

Real part of acoustic impedance.

Related term: complex number

acoustics

The science of sound, including its production, propagation, and effects.

acoustic scan line

A direction along which echo information is both transmitted and acquired.

Related terms: scan line, synthetic scan line

acoustic shadow

Sonographic appearance of reduced echo amplitude from regions lying beyond an attenuating object. It is important to distinguish between acoustic shadows and regions of low reflectivity. An acoustic shadow is one type of sonographic artifact. The opposite of acoustic shadow is acoustic enhancement (see Figures 16 and 22).

acoustic signal loss

The decrease in amplitude or intensity as sound travels through a material caused by attenuation, reflection, and beam variations.

acoustic stiffness

The reciprocal of acoustic compressibility. The ratio of the change in pressure to the fractional change in volume. The unit is pascal (Pa).

acoustic streaming

An acoustically generated transport of fluid within the body of the insonified fluid or tissue.

acoustic vibration

See sound.

acoustic wave

A mechanical vibration that propagates in a medium. An acoustic wave cannot travel in a vacuum. Liquids and gases support longitudinal (compressional) waves. Solids support other vibrational modes in addition to longitudinal waves. Soft tissues support primarily longitudinal waves. Compact bone supports both longitudinal and other vibrational modes.

Related terms: longitudinal wave, shear wave

acoustic wave field

See acoustic field.

acoustic waveform

See waveform.

acoustic wavefront

A contiguous surface of equal phase in a propagating wave.

acoustic wavelength

The distance traveled by a wave during the period of one cycle. The distance between any two adjacent points at which the phase, at the same instant, differs by 2π radians; $\lambda = c/f$, where λ is the wavelength, c is the speed of sound, and f is the frequency. For water or tissue at 1 MHz, the wavelength is approximately 1.5 mm.

acoustic working frequency

The mean of the frequencies f_1 and f_2 at which the amplitude of the spectrum of the acoustic signal; ie, the output of a hydrophone placed in an acoustic field at a specified position, first becomes 3 dB lower than the peak amplitude. The mean may be either arithmetic $(f_1 + f_2)/2$ or geometric $\sqrt{f_1 \cdot f_2}$. The unit is megahertz (MHz).

acousto-optical converter

Any device that permits the visualization of a sound wave by converting the sound energy into a corresponding light pattern.

active element

The region of a single transducer that is capable of being energized.

active transducer aperture

The active transducer aperture is the part of the surface of the transducer or transducer assembly that emits ultrasonic radiation.

Related terms: transducer, transducer aperture

adaptive gain adjustment

The automatic adjustment of an ultrasound system's gain settings based on echo information obtained during the examination of a patient. Both the time-gain compensation (TGC) and overall gain of a system may be adjusted in this form of image optimization. Also known as automatic gain adjustment or automatic time-gain compensation adjustment.

adaptive image optimization

An image optimization technique in which an ultrasound system's gain and control settings are automatically determined by the echo information obtained from the patient being examined. Control adjustments may include overall gain, time-gain compensation, gray scale, color, frequency filtering, focusing adjustments, and Doppler settings.

adiabatic bulk modulus

The elastic modulus associated with the volume elasticity of a fluid medium when heat is not exchanged with the external environment. The adiabatic bulk modulus (K) is given by $K = 1/b$, where b is the adiabatic compressibility. The unit is pascal (Pa).

adiabatic compressibility

The fractional change in volume V per unit change in pressure for fluid media when heat is not exchanged with the external environment. Adiabatic compressibility (b) is the reciprocal of the adiabatic bulk modulus (K). The unit is inverse pascal (Pa^{-1}).

admittance

Reciprocal of impedance.

after-ringing

Undesired damped oscillation of a transducer occurring after the main pulse (see Figure 20).

aliasing

The introduction of artifactual low-frequency components into a recovered signal as a result of sampling an original signal at a rate that is lower than twice its highest frequency component. Aliasing of a Doppler signal will result in an erroneous representation of the Doppler shift frequency.

A-line

See *A-mode*.

ALARA

Acronym for “as low as reasonably achievable.” It means making every reasonable effort to use the lowest possible acoustic output and transducer dwell time to obtain ultrasound images and measurements with quality sufficient for clinical diagnosis.

AM

Amplitude modulation or amplitude-modulated.

ambient

Refers to the local environment surrounding an object.

ambient pressure

The absolute pressure at a point in the absence of acoustic waves.

A-mode (amplitude mode)

A method of displaying echoes received from a specific direction in which time is represented along a vertical axis and echo amplitudes are displayed along a horizontal axis. Since time is proportional to reflector distance, this trace also represents echo signal amplitude versus reflector distance (see Figure 28).

Related term: *A-line*

amorphous tissue

In the acoustical sense, tissue lacking echo-producing structures. These tissues include fluid-filled structures such as cysts and other acoustically homogeneous regions.

amplifier

A device that magnifies the amplitude or power of its input signal.

amplitude modulation (AM)

A process by which the amplitude of a higher-frequency (“carrier”) wave is multiplied by a lower-frequency (“signal”) wave as a means of transmitting information.

amplitude-modulated display (A-mode)

See *A-mode*.

amplitude modulation factor

The value of the expression $100 H(A - B)/A$, expressed as a percentage, where A and B are the respective absolute maximum and minimum amplitudes of the envelope of an amplitude-modulated acoustical or electrical carrier (first-order quantity).

analog signal

A signal that can have all values between its minimum and maximum values and that may change continuously as a function of time.

analytic signal

A complex signal, the real part of which is the original signal, and the imaginary part, also called the quadrature signal, is calculated by taking the Hilbert transform of the real signal (see Figure 26).

Related terms: complex parameter, Hilbert transform, imaginary, real

analytic signal envelope

An envelope formed by taking the square root of the sum of the real original signal squared plus the quadrature signal squared (see Figure 26).

Related term: Contrast with *rectification*

anechoic

The property of appearing echo free or without echoes in an ultrasound image. A clear cyst appears anechoic in the absence of any artifact (see Figure 17).

angle of attack

See *beam-to-vessel angle*.

angle of incidence

The angle between the axis of an acoustic beam encountering an interface and the vector normal (perpendicular) to the interface (see Figure 6).

Related terms: angle of reflection, angle of refraction, Snell's law

angle of reflection

The angle between the axis of the reflected beam and the axis of the normal of a reflecting surface. The magnitude of the angle of reflection equals that of the angle of incidence (see Figure 6).

Related terms: angle of incidence, angle of refraction, Snell's law

angle of refraction

The angle between the axis of the reflected beam and the axis of the normal of a reflecting surface. The magnitude of the angle of reflection equals that of the angle of incidence (see Figure 6).

Related terms: angle of incidence, angle of refraction, Snell's law

angular deviation loss

Sensitivity level on the principal axis minus the sensitivity level of the transducer for a specified direction. The unit is decibel (dB).

angular frequency

Frequency expressed as radian/second, symbol: $\omega = 2\pi f$, (f = frequency in hertz [Hz]).

anisotropic

Exhibiting properties that vary with direction. For example, the speed of sound in muscle differs when propagating parallel to the fibers than when propagating at right angles to the fibers. Antonym: isotropic.

annular array

A multiple-element transducer array in which the individual transducer elements are arranged in concentric rings around a central circular element (see Figure 18).

annular enhancement (arterial)

See *rim enhancement*.

antinode

Point, line, or surface in a standing wave where some specified characteristic of the wave field has a local maximum amplitude. Note: The appropriate modifier should be used before the word "antinode" to signify the type that is intended: eg, displacement antinode, particle velocity antinode, or sound pressure antinode.

antiradial scanning (breast)

A method of orienting the plane of view in breast sonography such that the scan plane is perpendicular to that in radial scanning.

Related term: radial scanning (breast)

antiresonance

Phenomenon of a system in forced oscillation such that any change in the frequency of excitation, however small, results in an increase in a response of the system. Antiresonance is a condition for which the impedance of an electrical or acoustical system is very high. Note: The quantity that is observed for the measurement of response must be indicated: eg, velocity antiresonance.

aperture path difference

The difference in acoustic path lengths to a specified geometric focus from 2 points in the transducer aperture: one at the intersection with the beam axis and the other at the intersection with the geometric beam boundary.

aperture width

The full width of the transducer aperture measured orthogonal to the beam axis (see Figures 2 and 7).

apodization

The electronic, mechanical, or computational amplitude weighting or shading of the elements in a transducer array aperture. The purpose of apodization is to shape the beam and suppress side lobes.

Related term: side lobe

apparent backscatter

The measured backscattered ultrasonic signal uncompensated for the effects of attenuation and beam diffraction.

arc scan

A scanning technique in which the transducer is swept through an arc with its beam directed toward a fixed point.

array

A spatial arrangement of 2 or more individually addressable transducers or transducer elements. The array may be a linear array (ie, elements arranged in a line) or a rectangular array (ie, transducers arranged in a rectangular pattern) or may be formed in other patterns such as hexagonal, annular, circular, etc. (See Figures 19, 27, 29, 30, and 33–35.)

See *transducer element*.

array elements

Group of transducer elements (see Figures, 19, 27, and 35).

See *subelement*.

artefact (archaic term)

See *artifact*.

arterial phase of enhancement

The phase of contrast medium circulation when contrast-enhanced blood reaches an organ through its arterial supply. It starts a few seconds after the enhancement of large arteries. In this phase, parenchymal and lesion enhancement results exclusively from arterial flow (although in the liver, there is a rapid overlap with the portal venous induced enhancement). In the liver, this vascular phase starts 10 to 20 seconds after contrast medium injection in a peripheral vein and ends as soon as 30 to 40 seconds after contrast medium injection, depending on the agent used. The synonymous term “early phase” should be avoided because it may be erroneously intended as the whole vascular phase (in opposition to the late or postvascular phase).

artifact

An echo feature, present or absent in a sonogram, that does not correspond to the presence or absence of a real target. Reverberations and shadowing are examples of such artifacts (see Figures 15, 16, and 21–24).

A-scan

A scanning procedure in which echo information is displayed using the A-mode (see Figure 28).

Related term: A-mode.

attack, angle of

See *beam-to-vessel angle*.

attenuation

The decrease in amplitude or intensity as sound travels through a material. Attenuation is due to absorption and scattering, which are properties of the medium.

Related terms: absorption, acoustic signal loss, attenuation coefficient, attenuation loss

attenuation coefficient

The quantitative measure of attenuation due to the medium and not to beam divergence. The relative change in the acoustic wave amplitude per unit path length in a medium. Commonly used units are decibels per centimeter (dB/cm) and nepers per centimeter (Np/cm). The attenuation coefficient is specified for a given frequency. Note: To be distinguished from absorption coefficient.

Related terms: absorption, acoustic signal loss, attenuation, attenuation loss

attenuation-compensated flowmeter

A device based on a technique that does not require knowledge of the vessel cross-sectional area or Doppler angle to estimate blood flow rate. The specialized ultrasound beam geometries required at present limit this technique to large vessels.

attenuation compensation

See *time-gain compensation (TGC)*.

attenuation loss

The transmission loss due to attenuation. The unit is neper (Np) or decibel (dB).

Related terms: absorption, acoustic signal loss, attenuation, attenuation coefficient

attenuator

A device or material that reduces the amplitude of a signal.

atypical hemangioma

A hemangioma without the typical contrast-enhanced ultrasound image enhancement pattern (ie, peripheral globular enhancement with progressive fill-in). An atypical hemangioma may show very fast and homogeneous enhancement or very slow enhancement with incomplete fill-in.

autocorrelation

A mathematical procedure in which a waveform is multiplied by successively time-shifted versions of itself, and the results are summed. The autocorrelation method can be used to quantify periodicity or the time variation in an ultrasound echo signal.

Related term: correlation

auto-scanning systems

Historical term describing ultrasonic devices in which the beam was steered mechanically or electronically but not manually.

automated breast ultrasound (ABUS)

A diagnostic imaging modality used to automatically acquire a 3-dimensional volume set of ultrasound images of the entire breast, either by pulse-echo or through-transmission methods.

autospectral density

See *power spectrum*.

autospectrum

See *power spectrum*.

avascular lesion

Lesion appearing anechoic, with lack of contrast enhancement (markedly negative lesion-to-parenchyma contrast gradient). There is no subjective or measured difference in lesion echogenicity before and after contrast medium injection.

average acoustic power

The power output from an acoustic transducer averaged over time.

average intensity

See *intensity*.

axial direction

See *beam axis* (see Figure 27).

axial maximum

The point on the beam axis where an acoustic variable has its largest magnitude. For measurement purposes, this is usually where the pulse-pressure-squared integral has its largest value. Other variables can be pressure and intensity. In the case of several maxima, the one farthest from the transducer or acoustic source is usually selected.

Related terms: beam axis, pulse-pressure-squared integral, spatial peak

axial resolution

The minimum detectable separation between two targets along the axis of sound travel. In general, the axial resolution will depend on the control setting, range, and nature of the targets.

Related terms: azimuthal resolution, depth resolution, longitudinal resolution, range resolution

axial resolving power

Maximum axial resolution achieved by an ultrasound instrument.

axial sensitivity

Of a hydrophone, for a specified frequency, free-field sensitivity to sound waves whose direction of propagation is toward the hydrophone and along the principal axis.

axial strain

A component of the strain tensor in the direction of the main axis of compression. The axis of compression is usually coincident with the axis of the ultrasonic beam and is thus in the imaging plane.

axial strain elastogram

An elastogram that depicts the distribution of the axial strain.

azimuthal axis

An axis in the azimuthal plane perpendicular to the beam axis.

azimuthal plane

The scan plane or principal longitudinal plane (see Figures 9 and 27).

Related term: elevation plane

azimuthal resolution

The minimum angular separation between 2 equally reflecting point targets at the same range such that each can be separately distinguished on the display. The resolution is limited by the beamwidth of the transducer at that range of the targets.

Related terms: axial resolution, depth resolution, lateral resolution, longitudinal resolution, range resolution

B

B/A

A measure of the nonlinearity of a material. It is defined as the ratio of the values of A and B , the coefficients of the first and second terms of the Taylor series expansion of the equation relating the acoustic pressure exerted on a material to its density. The equation defining A and B is:

pressure = A (relative change in density) + $(B/2)$ (relative change in density)²

Related terms: coefficient of nonlinearity, acoustic impedance, speed of sound

back end

Term used to describe the part of a conventional ultrasound imaging system involved with the signal processing and display of beamformed ultrasound signals. In systems with software beamforming, the beamforming and display functions may be interrelated.

background noise

The unwanted residual signal that is present whether the sound source of interest is in operation.

backing layer

Absorbing material at the back of the active transducer material that enhances the response of the transducer. This material attenuates ultrasound going in the opposite of the intended direction for propagation and reflects ultrasound into the preferred direction. It broadens the bandwidth and shortens the time response of the transducer (see Figure 20).

Related terms: damping (transducer), matching layer

backscatter

The scattered sound that travels back toward the source transducer. When used as a verb, backscatter means to scatter a traveling sound wave in a direction generally opposite to that of the incident wave.

backscatter coefficient

The acoustic power scattered in a direction opposite to that of the incident beam per unit volume of material, per steradian, per unit incident beam intensity.

backscatter contrast

Related term: contrast (object)

backscattered energy

The portion of the incident acoustic energy scattered back toward the source.

band sound pressure level

The level of the sound pressure produced within a specified frequency band. Note: The band may be specified by its lower and upper cutoff frequencies or by its geometric center frequency and bandwidth. The width of the band may be indicated by a modifier such as one octave band (sound pressure) level, one-half octave band level, or one-third octave band level.

bandpass filter

A device that has a limited bandwidth. Bandpass filters are sometimes used in the receiver of an ultrasound scanner to filter away signals outside the frequency band of desired signals from the transducer. Piezoelectric transducers may also be considered bandpass filters in that when shock is excited by a wideband pulse, they produce pulses containing a relatively narrow band of frequencies.

bandwidth

A measure of the range of frequencies that a device is capable of transmitting or receiving (colloquial). Difference in the frequencies f_1 and f_2 at which the amplitude of the spectrum of the acoustic pressure first becomes 3 dB lower than the peak amplitude. Bandwidth is usually specified in megahertz (MHz).

Related term: center frequency

barium titanate (BaTiO₃)

A material belonging to a class of ferroelectric ceramics from which piezoelectric transducers are often fabricated.

Barker code

A family of unique binary sequences of N values of -1 and $+1$, satisfying the condition that all sums of the products of the terms taken 2 at a time never exceed 1. Barker codes are useful in producing coded pulse trains.

Related term: coded excitation

baseline shift (zero shift)

A control that allows the axis representing the Doppler shift frequency on the spectral display to be allocated entirely to forward flow, reverse flow, or a mixture of the two. The effect is to “shift” the zero frequency axis up or down. This procedure is useful when aliasing is present in a signal representing unidirectional flow. It does not affect the Nyquist limit.

basket pattern

Color Doppler and contrast-enhanced ultrasound pattern of macrovascularization consisting of a vascular ring that circumscribes the lesion starting from a pole and then gives discrete, irregular branches intralesionally. A common feature of hepatocellular carcinoma.

beam

The directed acoustic emission produced by a transducer (see Figures 4 and 10).

Related term: beam pattern

beam alignment axis

See *beam axis*.

beam area

The cross-sectional area of an ultrasound beam (colloquial). For measurement purposes, beam area is the area bounded by the -6 -dB pulse-pressure-squared integral contour in a specified plane perpendicular to the beam axis. It can be estimated by $\pi ab/4$, where a and b are the -6 -dB beamwidths along the azimuth and elevation axes.

Related terms: azimuth plane, beam, beam pattern, beamwidth, elevation plane

beam-average pulse acoustic pressure

The pulse acoustic pressure from one ultrasonic transducer or ultrasonic transducer element group averaged over the -6 -dB beam area in a specified plane or in a plane containing the spatial-peak temporal-peak acoustic pressure for that particular ultrasonic transducer or ultrasonic transducer element group. The unit is pascal (Pa). Note: A -6 -dB beam area is commonly used; however, other beam areas may be used.

Related terms: beam area, temporal-peak acoustic pressure, ultrasonic transducer, ultrasonic transducer element group

beam-average pulse-average intensity

The pulse-average intensity from one ultrasonic transducer or ultrasonic transducer element group averaged over the -6 -dB beam-area in a specified plane or in a plane containing the spatial-peak temporal-peak acoustic pressure for that particular ultrasonic transducer or ultrasonic transducer element group. The unit is watt per square meter (W/m^2). Note: A -6 -dB beam area is commonly used; however, other beam areas may be used.

Related terms: beam area, intensity, ultrasonic transducer, ultrasonic transducer element group

beam-average root mean square acoustic pressure

The root mean square acoustic pressure from one ultrasonic transducer or ultrasonic transducer element group averaged over the –6-dB beam area in a specified plane or in a plane containing the spatial-peak temporal-peak acoustic pressure for that particular ultrasonic transducer or ultrasonic transducer element group. The unit is pascal (Pa). Note: A –6-dB beam area is commonly used; however, other beam areas may be used.

beam-average temporal-average intensity

The temporal-average intensity from one ultrasonic transducer or ultrasonic transducer element group averaged over the –6-dB beam area in a specified plane or in a plane containing the spatial-peak temporal-peak acoustic pressure for that particular ultrasonic transducer or ultrasonic transducer element group. The unit is watt per square meter (W/m^2). Note: A –6-dB beam area is commonly used; however, other beam areas may be used.

Related term: intensity

beam axis

A convenient indicator of the direction of a sound beam. The beam axis is located at the center of an ultrasound beam and lies along the direction of sound propagation (see Figures 2, 3, 5, 7, 9, and 27).

beam center

A point in a scan plane, usually perpendicular to the beam alignment axis, at which the spatial-peak temporal-peak acoustic intensity occurs.

Related term: beam axis

beam cross-sectional area

Transmitted beam cross-sectional area is the area on the surface of a plane perpendicular to the beam axis consisting of all points where the acoustic pressure is greater than 50% of the maximum acoustic pressure in that plane. Also used less often to describe an area in reflection as the area of that portion of a surface, in a plane perpendicular to the beam axis, that is bounded by that contour of the pulse-echo amplitude from a specified point or line reflector that exceeds a specified percentage of the maximum, eg, 25% (–12 dB), transducer signal in that plane.

beam cross-sectional profile

See beam profile.

beam divergence

The widening of the beam as it travels away from the transducer.

beamformer

Component of an ultrasound imaging system that determines transmit and/or receive beam patterns of arrays with respect to directivity and sensitivity.

Related terms: array, beam pattern

beamforming

The process whereby the beam former and/or mechanical lenses, concave transducer elements, or mirrors determine the complete transmit or receive beam pattern.

beam-minimum

The location along the beam axis in a specified longitudinal plane where the field of a nonfocusing ultrasonic transducer has minimum –6-dB beamwidth (see Figures 3 and 7). Under ideal conditions, this location corresponds to the transition distance for circularly symmetric fields and close to the transition distance for other geometries. For an example of minimum beamwidth when the specified longitudinal plane is the elevation plane, see Figure 33.

Related terms: beam-minimum depth, transition distance

beam-minimum depth

The distance from the beam-minimum to the transducer aperture plane, or in the case of measurement, the source aperture plane (see Figures 3 and 7).

Related terms: beam-minimum, source aperture plane, transducer aperture plane

beam pattern

A description, often presented graphically, of the response of the transducer as a function of the angle with respect to the direction of the transmitted or incident sound waves in a specified plane and at a specified frequency. A complete description of the beam pattern of a transducer would require a 3-dimensional presentation. The beam pattern is often shown as the response relative to the maximum response. Note that the beam pattern for a transducer may be different for transmit and receive modes (see Figures 4, 14, and 10).

beam plot

A graphic representation of a beam profile (see Figure 14).

Related term: beam pattern

beam profile

The sound pressure amplitude distribution along a line perpendicular to the beam axis (see Figures 14 and 25).

Related terms: pulse-echo response profile, beam pattern

beam-to-vessel angle

The angle between the axis of the ultrasound beam and the axis of a vessel lumen. This will only be equal to the Doppler angle when flow is parallel to the vessel axis.

Related terms: beam, Doppler angle

beam uniformity ratio

The ratio of the spatial-peak temporal-average intensity (I_{SPTA}) to the spatial-average temporal-average intensity (I_{SATA}) where both quantities are measured in a plane perpendicular to the beam axis.

Related terms: beam axis, intensity

beamformer

A beamformer is a method of adjusting, combining, or processing waveforms going into or received from an array of transducer elements to produce an ultrasound beam.

See *delay and sum beamformer*, *receive beamformer*, and *transmit beamformer*.

beamwidth (transmission)

The maximum transverse distance between points on the beam profile at a given depth where the acoustic pressure is a specified fraction of the maximum acoustic pressure in the profile. This may also be expressed as the angle formed between lines from the location of these two points to the point of intersection of the beam axis and the surface of the transducer assembly (see Figure 14).

beamwidth cylindrical focus

For nonaxisymmetric fields, the point on the beam axis for which the –6-dB beamwidth perpendicular to the axis in a given longitudinal plane is a minimum. When cylindrical focusing has been used, this position will, in general, be different for different longitudinal planes.

Related terms: beam axis, beamwidth, cylindrical wave, focusing, longitudinal plane

beamwidth focal line

The line perpendicular to the beam axis in a given longitudinal plane that passes through the cylindrical beamwidth focus for that longitudinal plane.

Related terms: beam axis, beamwidth, cylindrical wave, focusing, longitudinal plane

beamwidth focal plane

The plane perpendicular to the beam axis that contains the spherical beam focus.

Related terms: beam axis, focus, spherical wave

beamwidth spherical focus

The point along the beam axis for which the –6-dB beam area perpendicular to the axis is a minimum.

Related terms: beam axis, focus, spherical wave

beat

The periodic variation in the amplitude of a wave that is the superposition of two simple harmonic waves of different frequencies.

bel

The logarithm to the base 10 of the ratio of two powers or intensities.

Related term: decibel

Bernoulli, Daniel (1700–1782)

Swiss mathematician, sometimes referred to as the founder of mathematical physics, who unified the study of hydrodynamics under what became known later as the principle of the conservation of energy. Daniel Bernoulli was one of an extraordinary dynasty of 8 mathematicians spanning 3 generations of the same family. Their collective contributions to mathematics and science are too numerous to list.

Bernoulli effect

The reduction in pressure that accompanies an increase in the velocity of fluid flow.

Bernoulli equation

The equation that states that the total fluid energy per unit volume along a streamline of fluid flow is constant. This is a form of the more general law of conservation of energy.

bioeffect

A change in the structure or function of a biological structure, ie, a biological effect.

bioeffect (ultrasound induced)

A change in a biological structure caused by ultrasound.

Related term: intensity

bit

A contraction of “binary digit.” A bit can assume one of two possible values usually represented by 0 and 1.

blood pool contrast media

Those contrast agents that remain intravascular and do not spread to the interstitium. Blood pool agents act as flow tracers.

B-mode (brightness modulated)

A method of image display in which the amplitude envelope of the echo signal is represented by modulation of the brightness of the corresponding image point. The position of the echo, displayed in the scan plane, is determined from the position and angulation of the beam and the transit time of the acoustic pulse (see Figures 29 and 30).

Related terms: pulse echo, scan plane

bone conduction

The transmission of sound to the internal ear mediated by mechanical vibration of the cranial bones and soft tissues.

bone thermal index (TIB)

The thermal index developed for ultrasound exposures that include bone positioned deep within the body, such as the fetal skull but not the postnatal or adult skull.

Related terms: cranial thermal index (TIC), soft issue thermal index (TIS), thermal index

boundary conditions

The geometric conditions that must be satisfied at boundaries when a solution to a problem is applied in a specific application or instance.

boundary layer

The thin layer of quasistationary fluid in contact with the walls of the containing vessel.

Bragg diffraction

In acoustics, the process of scattering from an array of scatterers such that, through constructive and destructive interference, there results more sound energy in some directions and less in others.

brightness-modulated display

See *B-mode*.

brightness modulation

An echo display technique in which the brightness of a displayed echo varies with the echo amplitude.

Related term: *B-mode*

broadband signal

A signal containing a wide range of frequencies (colloquial). A broadband signal is one for which the product of the pulse duration and the effective frequency is less than 2.

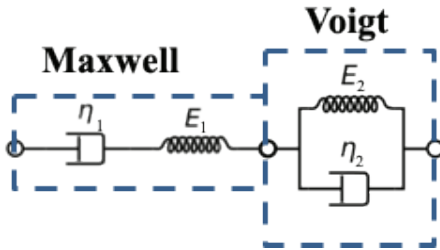
Related terms: Contrast with *narrow bandwidth*, *wideband*

bruit

The name given to sounds sometimes associated with disturbed and turbulent flow. They arise from the periodic variation in shear stress on the vessel wall, which causes it to vibrate.

Burgers model

A complex model of a viscoelastic material represented by a series connection of a Maxwell model and a Voigt model as shown in the diagram below. This model contains two dashpots and two purely elastic springs.



Related terms: dashpot, elastic spring, Maxwell model, Kelvin model, Kelvin-Voigt model, standard linear viscoelastic model, Voigt model

B-scan

A scanning procedure in which echo information is displayed in the B-mode.

Related term: B-mode

B-scan image

A sonogram produced by a B-scan procedure. Alternatively, a B-mode image.

bubble

A cavity that is nearly or completely surrounded by a different material, usually liquid.

bubble, encapsulated

A bubble in which the gas and liquid phases are separated by a thin shell of insoluble or liquid material.

bubble noise artifact (spectral)

Spectral Doppler artifact due to the presence of contrast medium microbubbles within the sampled volume. Sharp, needle-shaped signals of high amplitude appear on the Doppler spectrum, and a crackling noise is heard in the audio. Spectral Doppler analysis should be performed before contrast medium injection. Otherwise, it may be necessary to decrease Doppler gain and to increase Doppler signal filtering. Further research is needed to determine the effects of sonographic contrast media on spectral waveforms.

Related terms: Doppler spectrum, microbubble, waveform

bulk elastic modulus

See *bulk modulus*.

bulk modulus

A measure of stiffness. The ratio of the change in pressure to the resulting fractional reduction in volume. This equals the reciprocal of compressibility: $B = -dp/(dV/V_0)$, where B is bulk modulus, dp is the increase in pressure, and dV/V_0 is the fractional increase in volume.

Related terms: compressibility, stiffness

C

calibration

Determination of the accuracy of an instrument, usually by measurement of its variation from a standard, to ascertain necessary correction factors.

calipers (electronic)

Two or more electronic cursors generated on a display, which can be manipulated to coincide with echoes of interest on the screen. On an image, the distance between the cursors is calibrated to provide the correct dimensions of the structure of interest. On an M-mode or Doppler display, calipers may be used to measure such quantities as time, frequency, and velocity.

Related terms: Doppler, M-mode

carbon dioxide (enhanced) sonography

Transabdominal imaging of the liver during transcatheter injection of carbon dioxide in the hepatic arterial system. Vascularized lesions become hyperechoic for up to 10 to 15 minutes.

cathode ray tube (CRT)

An electron beam tube formerly used for 2-dimensional display of signals as a function of their coordinates in space, time, or both. It consists of an electron source (gun), a means for deflecting the electron beam in the horizontal and vertical directions, and a phosphor-coated screen on which the position of the electron beam is visible. The brightness of the display can be modulated by varying the current to the electron source or the voltage on the grid of the CRT.

Related terms: light-emitting diode display, liquid crystal display

cavitation

The creation of a mechanical response of one or more cavities in a liquid or other medium of interest subjected to stress produced by acoustic, hydrodynamic, or other means. Cavitation may be inertial or noninertial.

cavitation, inertial

See inertial cavitation.

cavitation, noninertial

See noninertial cavitation.

cavitation nucleus

A cavity that can serve as a site for cavitation.

cavitation, stable

See stable cavitation.

cavitation, transient

Deprecated term.

See inertial cavitation.

cavity

A volume filled with gas, vapor, or both.

cavity, Rayleigh

See Rayleigh cavity.

center frequency

The average frequency over the bandwidth of a signal. The sound leaving a transducer in a pulse-echo system contains not one but a spectrum of frequencies. The center frequency is usually determined by $[(f_1 + f_2)/2]$, where f_1 and f_2 are the frequencies used in defining the bandwidth. In some pulse-echo systems, the median frequency is used for the center frequency.

Related term: bandwidth

center of gravity

A unique point in a structure where the total weight of the structure may be thought to be concentrated. Any structure, if supported at its center of gravity, can be balanced.

central axis

See *beam axis*.

central scan line

For automatic scanning systems, the scan line closest to the symmetry axis of the scan plane.

centrifugal arterial blood supply

Color Doppler and contrast-enhanced ultrasound image pattern of intralesional macrovascularization consisting of a vessel that branches from the center toward the periphery of a lesion. Discrete arteries showing progressive enhancement from the center to periphery, with an overall stellate distribution. It is a common pattern of focal nodular hyperplasia. The overall appearance is sometimes referred to as spoked wheel-like, stellate, starlike, or spiderlike.

Related term: Contrast with *centrifugal enhancement*

centrifugal enhancement

Progressive enhancement of a lesion from the center to periphery, eg, during a contrast-enhanced ultrasound study. This is an uncommon feature of liver hemangioma and peliosis hepatis.

centripetal enhancement

Progressive enhancement of a lesion from the periphery to the center, eg, during a contrast-enhanced ultrasound study. A common pattern of liver hemangioma, where globular enhancement is followed by progressive filling in and predominantly during the arterial or portal phase.

centroid

A weighted average of a function or a quantity. For example, the centroid of a frequency spectrum is the sum of all of the frequencies in the spectrum that are weighted by their individual relative amplitudes divided by the range of frequencies. It can also be used to determine a weighted average across a beam (see Figures 7 and 9).

Related term: center of gravity

cgs

The system of units based on the centimeter, gram, and second. Although the cgs system is still commonly used, the SI system, based on the meter, kilogram, and second, is preferred.

Related term: SI

characteristic acoustic impedance

The product of the speed of sound and density of a medium in which sound is traveling. Changes in acoustic impedance are responsible for the echoes on which ultrasound imaging and color flow Doppler are based.

Related terms: reflection, reflection coefficient

chirp pulse (ultrasound)

Transmit pulse in which the ultrasound frequency varies over the duration of the pulse. Chirp pulses are used in some systems to increase the energy of the acoustic pulse while not increasing the amplitude, eg, to improve the echo signal-to-noise ratio. Short-duration echo signals can be recovered in such systems with the use of pulse compression techniques, such as matched filtering.

cine loop

The continuously repeated display of a record of images or frames from memory.

Related term: cine memory

cine memory

The set of images temporarily retained for display as individual images or cine loops until replaced as new images are required.

Related term: cine loop

clipping

A technique by which the amplitude of a signal is prevented from exceeding a predetermined value. In clipping, the amplitude is set to a predetermined maximum value whenever the signal would otherwise exceed that value. Clipping results in distortion of the signal. Also known as "hard limiting."

Related term: Contrast with *soft limiting*

clutter

Unwanted components in images or Doppler signals generally caused by undesired backscattered signals from interfering structures that obscure the desired signal. In Doppler measurements, clutter is often caused by high-amplitude, stationary, or slowly moving structures, such as vessel walls.

Related term: Doppler

C-mode (constant depth mode)

A method of display of cross-sectional echo data in which the plane imaged is at a constant distance from the transducer and is perpendicular to the interrogating beam.

Related term: pulse echo

CMUT

Capacitive micromachined ultrasound transducers (CMUTs) that contain miniature capacitors, backed by gas, whose membranes generate outgoing ultrasound waves with applied voltages and also generate voltages in response to incoming ultrasound waves. They are often made in 2-dimensional arrays with silicon technology reproducibly in large numbers and can be integrated with microelectronics on the same substrates.

coarse gain

An operational control provided on some ultrasonic systems for gross adjustments of amplifier gain. Generally, it is supplemented by a fine-gain control for more precise adjustment.

coded excitation (ultrasound)

A method of altering the shape of the transmit waveform such that returning echoes can be uniquely detected, resulting in increased penetration depth and signal-to-noise ratio. Coded excitation is used in some systems to increase the energy of the acoustic pulse, thereby improving the signal-to-noise ratio; to enhance signals from contrast agents; or to detect blood flow. In this approach, low-amplitude, short-duration backscattered signals can be recovered with the use of special signal-processing techniques, such as matched filtering, that use features encoded in the transmitted pulse sequences. Examples of codes used are chirp, Golay, and Barker.

Related terms: Barker code, chirp pulse, Golay code

coefficient of nonlinearity (β)

A measure of the nonlinearity of a material (gas, solid, or fluid) and defined as $\beta = 1 + B/2A$. For water it equals 3.5; blood, 4.0; fat, 6.2; and liver, 4.3.

Related term: B/A

coherence

The degree of phase agreement among the signals making up a composite wave; if all of the signals are in phase, the wave is said to be coherent. There are various degrees of coherence that describe waves with less than full coherence. If no phase agreement exists, the wave is called incoherent.

Related term: incoherence

collimator

An acoustic lens used to focus an acoustic beam at infinity, ie, to produce plane parallel waves. In practice, collimators may provide weak focusing.

color amplitude imaging

Related term: power Doppler imaging

color blooming

Related term: color blooming artifact

color blooming artifact

A color Doppler imaging artifact in which grayscale pixels are seen changing to a color display in regions where flow is not present. It results when the color signal exceeds the display capability of a pixel and "spills over" into surrounding pixels. In contrast-enhanced sonography, a color blooming artifact sometimes occurs at the moment when contrast-enhanced blood arrives in the scanned area. To avoid this phenomenon, it is necessary to decrease color gain, decrease output power, or inject the contrast medium more slowly.

Related term: color Doppler imaging

color coding

See parametric imaging.

color Doppler imaging

A form of pulsed Doppler imaging in which a large number of estimates of the mean Doppler frequency shift and direction are color coded and overlaid in the location of their detection on the grayscale image. The overlaid color is often depicted as a velocity with units of centimeters per second (cm/s) assuming a 0° Doppler angle throughout the imaging plane. Color Doppler imaging systems operate within the range of "real-time" frame rates (see Figure 19).

Related terms: color flow imaging, power Doppler imaging

color flow Doppler

The 2-dimensional presentation of Doppler shift information superimposed on a real-time grayscale anatomic cross-sectional image. Flow directions toward and away from the transducer, ie, positive and negative Doppler shifts, are presented as different colors on the display.

color flow imaging

See color flow Doppler.

Related terms: color Doppler imaging, power Doppler imaging

combined operating mode

Mode of operation of a system that combines more than one discrete operating mode. Note: Examples of combined operating modes are real-time B-mode combined with M-mode (B + M), real-time B-mode combined with pulsed Doppler (B + D), color M-mode (cM), and real-time B-mode combined with real-time flow-mapping Doppler (B + rD), ie, flow-mapping in which different types of acoustic pulses are used to generate the Doppler information and the imaging information.

Related terms: B-mode, color Doppler imaging, M-mode, power Doppler imaging, pulsed Doppler

comet tail artifact

A sonographic artifact that appears as a dense tapering trail of echoes just distal to a strongly reflecting structure. The tail is caused by reverberations within an object that appear brighter near the actual object and decrease in amplitude along its length due to decaying reverberations. Typical targets that cause these tails are air bubbles, air pockets or interfaces, and small metal objects. The key thing that distinguishes it from other reverberation-type artifacts is that its geometric shape is similar to a comet tail (see Figure 23).

complex impedance

Related terms: acoustic impedance, acoustic reactance, acoustic resistance

complex number

A combination of two numbers, usually written in the form $a + ib$, where i is the square root of -1 . The first number, a , is called the real part, and ib , the second, is called the imaginary part. In mathematical equations, a complex number is handled as a single entity and is therefore a convenient way to manipulate two quantities at the same time.

Related terms: complex parameter, imaginary, real

complex parameter

Any parameter requiring the specification of two quantities for its complete characterization. For example, acoustic impedance is a complex parameter that is characterized by a complex number consisting of a real part (resistance) and an imaginary part (reactance).

Related terms: acoustic impedance, acoustic reactance, acoustic resistance, complex impedance, imaginary, real

compliance

The rate of change of the volume of a distensible vessel with pressure (volume compliance), the rate of change of the cross-sectional area with pressure (area compliance), or the rate of change of the diameter with pressure (diameter compliance).

compliance (of a vessel)

Relative change of the cross-sectional area of a blood vessel per unit of pressure change: $C = (\Delta V/V)/\Delta p$, where $\Delta V = \Delta A \times L$, and where A is the cross-sectional area, and L is the length of segment. The unit is reciprocal pascal (Pa).

compound image

An ultrasound image combining echo information using different parameters (eg, overlapping scan lines and/or multiple frequencies) to enhance echoes from real structures and reduce speckle to provide an overall improvement in image contrast.

Related terms: contrast (image), pulse echo, scan line, speckle

compressibility

The fractional change in the volume of a medium or an object with change in pressure is sometimes called volume compliance; the fractional change in cross-sectional area with change in pressure is sometimes called area compliance; and the fractional change in diameter with change in pressure is sometimes called diameter compliance. Volume compliance (C) = $(\Delta V/V)/\Delta p$, where $\Delta V/V$ is the fractional change in volume, and Δp is the change in pressure.

compression (elastography)

The reduction in size when an object is subjected to a compressive stress. It is the opposite of tension.

Related term: tension

compression (image processing)

The reduction in bits used to represent an image. Compression is used primarily to reduce the image size needed for transmission and storage while preserving the information as much as possible.

compression (of dynamic range)

Decrease of the total amplitude range of echo signals by means of a nonlinear amplifier (eg, a logarithmic amplifier) or by using a nonlinear lookup table in a case of a digitized signal.

compression (signal processing)

The reduction in bits used to represent a signal. Compression is used to reduce the number of bits required to transmit and store the signal while preserving the information as much as possible.

compressional wave

Wave in an elastic medium that causes an element of the medium to change its volume and density without undergoing rotation. Note: Mathematically, a compressional wave is one whose velocity field has zero curl.

compressional wave

See longitudinal wave.

compressive modulus

The ratio of compressive stress to compressive strain.

compressive strain

The fractional reduction in the length of an object when subjected to a compressive stress (dimensionless).

compressive stress

The force per unit area that when applied to an object causes a dimension of the object to shorten. The unit is pascal (Pa).

Related term: tensile stress

compressor

A device capable of applying a compressive stress to an object or material.

condensations

When a sound beam passes through a material, some regions of the material are compressed, while other regions expand. The compressed regions are called condensations.

Related term: rarefaction

confocal

Lenses or transducers positioned so that their focal points coincide.

conjugate impedances

Impedances whose real components (resistances) are equal and whose imaginary components (reactances) are equal but opposite in sign. Note: Conjugate impedances are expressed by conjugate complex quantities.

Related terms: acoustic impedance, acoustic reactance, acoustic resistance, complex impedance

constitutive equation (elasticity)

An equation that relates the response of a material to an applied force in which the response depends on the properties of the material. For example, the equation that relates all the tensor components of stress to all the tensor components of strain through a matrix of elastic constants is a constitutive equation pertinent to elastography.

Related terms: elastography, strain, stress

constitutive equation (general)

A relationship between two physical quantities (eg, stress and strain) that incorporates a specific property of a material or substance. It is typically used in combination with other equations representing physical laws to express or solve a specific physical problem.

Related term: constitutive equation (elasticity)

contact coupling

Acoustic coupling of a transducer by direct contact with the skin, using liquid or gel to exclude air from the space between the transducer and skin.

continuous mode

Uninterrupted real-time acquisition of sonographic images.

continuous spectrum

A spectrum whose components are continuously distributed over a given frequency range.

continuous wave (CW) Doppler system

An ultrasonic system that detects Doppler-shifted signals by continuous and simultaneous transmission and reception of sound waves. The CW Doppler system provides no range resolution.

continuous wave (CW) ultrasound

A wave of constant or nearly constant amplitude that persists for a large number of cycles. Also known as an eternal sine wave.

Related term: tone burst signal

contour enhancement

Improvement of contour outlining of anatomic structures by electronic means (preprocessing) or by image processing after storage in a scan converter (postprocessing).

contour plot

A topographic representation of a quantity over a 2-dimensional plane in which amplitudes or intensities of the same value are represented by one or more closed curves that are either identified by a value (such as -6 dB) or color coded. The plot is usually plotted in decibel values with reference to the maximum value in the plane. Most often used to represent an ultrasound beam in a selected plane. Analogous to topographic maps (see Figure 4).

contrast (image)

In the image display, the ratio of the mean perceived luminance (brightness) within a region of interest (ROI) to the mean luminance of an equally sized area adjacent to the ROI. It is usually expressed in decibels (dB). This parameter can also be expressed in percent as the difference in luminance divided by the luminance of the adjacent ROI.

contrast (object)

The ratio of the mean backscattered intensity from within a target to the mean backscattered intensity from within an equally sized volume of surrounding background material. It is usually expressed in decibels (dB) as $10\log_{10}(I_{\text{obj}}/I_{\text{sur}})$ where I denotes the intensity of the object (subscript obj) and surroundings (subscript sur), respectively. Object contrast is a property of the target and the surrounding medium. Also called backscatter contrast.

contrast (target)

The ratio of the backscattered intensity from within a target volume to the backscattered intensity from the background.

contrast agent

A material that when introduced into a region of interest results in an increased or a decreased signal strength compared to its surroundings. A contrast agent is used to enhance the contrast between an anatomic structure and that of the surrounding tissue, thereby making the structure easier to detect (ie, increases the contrast resolution level).

contrast agent, vascular

A collection of gas-filled microbubbles (1–10 μm in diameter). Following intravenous injection, the microbubbles circulate in the bloodstream and provide a marked increase in the blood-to-clutter signal-to-noise ratio.

contrast arrival (imaging at)

Assessment of contrast-enhanced ultrasound image intensity during the first passage of a contrast agent flowing through an organ or tissue.

contrast arrival time

Time intervening between the beginning of contrast agent injection and arrival within a given organ vessel as measured using contrast-enhanced ultrasound imaging.

contrast detail analysis

A test method to measure an imaging system's ability to resolve structures based on their size and object contrast. At a specified transducer frequency, set of display settings, and depth range, this test measures the smallest diameter target that can be differentiated from the background at a specified level of confidence (detection threshold). The contrast detail analysis yields a plot of the object contrast versus target diameter, the object contrast being the minimum such that the corresponding diameter can be detected.

contrast detail detectability

The minimum diameter target that is just detectable, at a specified level of confidence, as a function of the contrast of the target with the background.

contrast-enhanced ultrasound

Any ultrasound technique performed after injection of a contrast agent.

contrast-enhanced tissue harmonic imaging

Contrast-specific imaging mode where the scanner is configured to transmit at one frequency and receive at harmonic or subharmonic frequencies. This scheme accentuates the nonlinear behavior of tissue and contrast microbubbles to generate images that contain fewer artifacts.

See contrast agent, contrast harmonic imaging, contrast subharmonic, contrast-enhanced sonography, harmonic imaging, and subharmonic imaging.

contrast enhancement

The increase in echo amplitude from tissue lying distal to a weak reflector such as a cyst or the increase in echo intensity in an organ or lesion due to the presence of a contrast medium.

contrast extravasation

Detection of contrast agent signals from extravasated blood after intravenous injection.

contrast gradient

The ratio of the change in contrast to the change in distance.

contrast harmonic imaging

Contrast-specific imaging mode where the scanner is configured to transmit at one frequency and receive at harmonic or subharmonic frequencies. This scheme accentuates the differences between tissue and the contrast medium as the contrast microbubbles respond more strongly at the (sub)harmonic frequency than the surrounding tissue.

Related terms: contrast agent, harmonic imaging, microbubble, subharmonic imaging

contrast medium

Related term: contrast agent

contrast pulse sequencing (CPS)

An ultrasound imaging method for detecting and processing the nonlinear signal generated by ultrasound contrast agents. In this approach, for example, the ultrasound scanner transmits a given pulse waveform 3 times scaled in amplitude by the coefficients 0.5, -1, and 0.5, respectively, before summing the corresponding echoes that suppress the linear component and enhance the nonlinear terms.

contrast ratio

Related terms: contrast (image), contrast (object)

contrast ratio (image)

Related term: contrast (image)

contrast resolution

The ability of an imaging system to distinguish a target with low contrast in an image from its surrounding background.

contrast subharmonic contrast-enhanced sonography

Experimental technique using that portion of the returned signal having a frequency one-half of that of the transmission frequency.

Related term: harmonic imaging

contrast transfer efficiency (CTE)

The ratio of the contrast ratio of the strain between an inclusion and the surrounding medium to the contrast ratio of their elastic moduli. The CTE is a dimensionless number that is generally less than or equal to 1. For stiff circular inclusions in a softer medium, the CTE is approximately equal to 0.5.

contrast transit time

Time interval between the arrival of a contrast agent in the artery feeding an organ and its arrival within the related venous drainage as measured using contrast-enhanced ultrasound imaging.

Related term: contrast agent

control settings

The settings of the controls on an ultrasound instrument. Such controls would include the power output control, the focal zone control, the imaging range control, etc.

conventional sonography

See *unenhanced sonography*.

convex array

A curvilinear array transducer with cylindrical outward curvature, producing a sectorlike image with the top part of the image defined by the arc of the curvilinear transducer (see Figure 30).

Related term: curvilinear array

coronal image plane

Any plane perpendicular to a sagittal plane and parallel to the long axis of the body. Each coronal image plane extends from left to right through the body (see Figure 1).

coronal plane

See *coronal image plane*.

correlation

For ultrasound, a mathematical procedure that is used to quantify the similarity between two signals.

Related terms: autocorrelation, cross-correlation

coupled modes

Modes of oscillation that are not independent but influenced by the transfer of energy from one mode to the other.

coupling

The formation of a transmission path for a sound wave between the transducer and the object being imaged. This is usually accomplished by replacing the air between the transducer and the object with a fluid or gel.

Related term: contact coupling

coupling agent

A medium used to enhance transmission of sound from the transducer into the body.

Related term: contact coupling

coupling method

The method by which ultrasound is transmitted from a transducer to the subject and vice versa. These methods include contact coupling, immersion coupling, and liquid coupling.

Cramér-Rao lower bound (CRLB)

The CRLB sets a lower bound on the variance of any unbiased estimator, such as a strain estimator. It is often used in calculating the best possible performance of such estimators.

cranial thermal index (TIC)

The thermal index developed for ultrasound exposures for which the acoustic beam passes through bone near the beam entrance into the body. Such exposures include the neonatal and adult skull but not the in-utero fetal skull.

Related terms: bone thermal index (TIB), soft tissue thermal index (TIS), thermal index

crawling wave

A slowly moving shear wave interference pattern induced by a pair of mechanical sources vibrating at slightly offset ("beat") frequencies.

Related term: shear wave interference pattern

crawling wave elastography

An elastographic method in which slowly moving interference patterns produced by two oppositely directed shear waves with a slight difference in frequency are used. The apparent spatial wavelength from the interference pattern is proportional to the underlying shear wave speed, which can be used to estimate the tissue shear modulus.

Related term: crawling wave

critical angle

The angle of incidence of a sound beam on an interface at which the angle of transmission just reaches 90° with respect to the normal to the interface. A critical angle can only be reached if the medium on the proximal side of the interface has a sound speed that is less than that of the medium on the distal side of the interface. At and above the critical angle, no transmission of the sound beam into the distal material occurs beyond the interface.

Related terms: angle of incidence, angle of reflection, angle of refraction, Snell's law

critical damping

Damping that will allow an oscillating electrical or mechanical system to return to rest in the minimum amount of time.

critical Reynolds number

The Reynolds number above which the transition from laminar to turbulent flow takes place.

Related term: turbulence

critical stenosis

Stenosis of sufficient diameter reduction that the flow rate and pressure are dangerously diminished. The term implies that the flow rate is so reduced that a stroke or occlusion may be imminent. In most modern stenosis grading schemes, critical stenosis corresponds to a diameter reduction of 80% or greater.

cross-correlation

A mathematical procedure whereby one waveform is multiplied by successively time-shifted versions of another waveform and the results are summed. Cross-correlation of successive ultrasound scan lines can be used to quantify movement of tissue, including blood.

cross-correlation function

A mathematical function that involves the summation (or integration) of products of successively shifted samples of a first signal with respect to a second signal and plotting the amplitude of the result as a function of the shift (lag) between the signals. The cross-correlation function may be used to study the shift between signals and the degree of similarity. Two-dimensional cross-correlation can be applied in image processing.

CRT

Abbreviation for cathode ray tube.

crystal

A colloquial term for the piezoelectric element of the transducer. Most piezoelectric elements are made of crystalline materials, such as quartz and certain ceramics.

C-scan

A class of data acquisition geometry in which echo information is acquired from points lying in a scanned plane, or other section, intersecting an interrogating principal acoustic axis.

Related term: C-mode

Curie point

The temperature above which a material loses its piezoelectric properties.

curtain artifact

A noisy appearance of the strain in an elastogram that is a result of excessive lateral displacements of tissue elements at the lateral edges of the elastogram. These artifacts may be reduced by compensation for the undesired lateral displacements.

Related term: elastography

curvilinear array

A curvilinear array consists of in-line transducer elements on a curved surface, which can be electrically configured to control the characteristics and/or direction of an acoustic beam. A convex array is a type of curvilinear array.

Related terms: convex array

cutoff frequency

Frequency at which the transmission through an electronic filter is decreased by –3 dB or some other specified amount with respect to the maximum amplitude at any frequency.

cylindrical wave

Wave of which the wavefronts are coaxial cylinders.

D

damping (transducer)

Any mechanism that removes mechanical or electrical energy from the transducer. This can include internal absorption in the transducer as well as electrical or mechanical loading of a transducer to produce a more rapid decrease in the trailing edge of the transmitted acoustic pulse and the received echoes. Damping is used to improve axial resolution, usually at the expense of sensitivity (see Figure 20).

Related term: backing layer

damping ratio

Ratio of the actual damping to the critical damping.

dashpot

A damping element in a viscoelastic model in which the resulting force is proportional to the rate of change of strain with respect to time; the graphical symbol for a dashpot (η) is:



dB

Abbreviation for decibel.

dead time

The time interval between the start of the transmission pulse and the reception of the first identifiable echo. The dead time is determined by such factors as the ring-down time of the transducer and the recovery time of the receiving amplifier.

dead zone

Region close to the transducer in which imaging cannot be performed due to echo arrival during dead time.

Related term: dead time

decay rate

Time rate at which the sound pressure level decreases at a given frequency.

decibel

A unit representing a ratio, used to express how much larger or smaller a quantity is with respect to a reference quantity. The precise definition is $10 \cdot \log_{10}(I/I_0)$, where I is the intensity of interest, and I_0 is the reference intensity. The abbreviation is dB. This unit can be used for other than intensity ratios and is frequently used for defining the magnitude of echoes. Because sound amplitude is proportional to the square root of intensity, the formula for decibel becomes $20 \cdot \log_{10}(A/A_0)$ when comparing echo amplitudes, where A is the amplitude of interest, and A_0 is the reference amplitude. Note the formulas for amplitude and corresponding intensity give the same value in decibels. For example, an amplitude ratio of $1/2$ and an intensity ratio value of $1/4$ are both represented by -6 dB. Although the bel is the primary unit, a decibel is $1/10$ of a bel and is used more often.

Related term: bel

deflection plates

Two pairs of parallel plates in a cathode ray tube between which an applied electrical voltage creates an electrical field that deflect the electron beam in x- and/or y-directions.

delay line

System that enables the time delay of a signal (in analog or digital form) used for delayed transmission and reception of signals of individual elements of array transducers.

delay and sum beamformer

A delay and sum receive beamformer adjusts the excitation delay and propagation path delay from each transducer element to concentrate the energy at a selected focal point and produce an amplitude gain there.

Related terms: beamformer, receive beamformer, transmit beamformer

delivered acoustic energy

The product of acoustic power and exposure time at the prescribed site.

delivered acoustic pulse energy

See energy per pulse.

demodulation

Removal of the carrier signal from a modulated wave to produce a signal representing the desired information (eg, the Doppler shift or the amplitude of the echo). The process of demodulation is a type of detection.

demodulator, Doppler

The electrical device in the Doppler receiver responsible for shifting the center frequency of the received signal from that of the transmitted signal to DC (direct current), so that echoes from stationary tissue may be eliminated by high-pass filtering.

density

Mass per unit volume.

density, photographic

See optical density.

depth

The distance along the sound path from the point of entry into the patient, or other object being examined, to the point of interest. Distance along the time axis of the display is assumed to correspond proportionally to depth in the tissue.

depth-gain compensation

See time-gain compensation.

depth of field

The range around the focal length in which targets remain in focus. For circularly symmetric lenses in optics, it represents a distance between the points at which the axial intensity drops by -3 dB (a ratio of 1:2). This relation does not hold for ultrasound imaging, where rectangular arrays are used as well as different types of focusing in the azimuth and elevation planes. A criterion based on narrowness of the beam in a specified plane is more appropriate: the distance between two points along the beam axis, which are defined by the locations where the -6 -dB beamwidths increase over the minimum beamwidth by a factor of 2 (see Figure 7).

Related terms: array, azimuth plane, beamwidth, elevation plane, depth of field, focus, focal zone, lens

depth of focus

See depth of field.

depth of penetration

The maximum distance from the transducer into the medium along the beam axis from which echoes can be detected. This distance will increase with ultrasound beam intensity and decrease with greater attenuation of the medium. The depth of penetration is usually given in centimeters (cm) and less frequently in wavelengths.

depth resolution

See axial resolution.

destruction-replenishment (or destruction-reperfusion) technique

A method of perfusion quantification based on microbubble disruption within a selected area of interest and subsequent assessment of its refilling by new, incoming microbubbles.

detectability, Doppler

The ability of a Doppler-shifted echo from moving targets (such as blood in a small vessel) to be detected by the system. Related to Doppler sensitivity and dynamic range.

Related terms: Doppler, dynamic range

detector

A device that gives a measurable response on receipt of energy and is used to detect the presence of a signal.

derated quantities

Physical quantities, such as pressure and intensity, that are measured in water and reduced in value by the product of a predetermined acoustic attenuation coefficient times a predetermined path length. Most commonly, the predetermined acoustic attenuation is 0.3 dB/cm/MHz, and the predetermined path length is the distance from the transducer to the measurement point of the ultrasound beam. The purpose of derating is to convert the values of quantities measured in water to what they would be in situ.

Related terms: absorption, absorption coefficient, acoustic output, attenuation, in situ

diagnostic ultrasound

Use of ultrasound waves to produce signals or images that help diagnose (detect and/or identify) a medical condition.

diametrical beam scan

A set of measurements of the hydrophone output voltage made in a straight line passing through the beam center and normal to the beam alignment axis. The diametrical beam scan may extend to different distances on either side of the beam center.

diastole

The relaxation period in the cardiac cycle in which the ventricles fill and the aortic and pulmonary valves are closed.

Related term: Contrast with systole

DICOM

A file formatting and communications standard for medical images. Acronym for the Digital Imaging and Communications in Medicine standard.

dicrotic notch

A brief, abrupt upswing in pressure during the deceleration phase of systole, forming a "notch" in the pressure and velocity waveforms. The dicrotic notch and the small undulations following the notch, known as the dicrotic wave, can be traced to reflections from the distal arterial tree.

differential scattering cross section

Power scattered per unit of solid angle per unit of incident intensity. The unit is square centimeter per steradian ($\text{cm}^2/\text{steradian}$).

differentiation

A mathematical operation for calculating the rate of change of a variable. In ultrasound imaging, differentiation is used to process signals to enhance edges of the structures. This is accomplished by using circuits whose output depends on the rate of change of the input or by software.

diffraction

The general term for various phenomena in which waves from different parts of a source add or subtract. It is the shaping of an ultrasound field caused by the contributions of waves radiated by a source. The source can be primary such as a transducer or secondary such as a scatterer. The diffraction phenomenon occurs for sources or objects whose size or surface irregularities are on the order of the wavelength.

Related terms: beam, scatterer

diffraction constant

Ratio of sound pressure acting on a transducer to the free-field sound pressure at that place in the absence of the transducer.

diffraction loss

That part of the detected loss of acoustic power that is due to diffraction (spreading) of the propagating wave from a transducer. Also called divergence loss or spreading loss.

Related terms: divergence loss, spreading loss

diffractive scattering

Waves that are reradiated from objects whose size or surface irregularities are comparable to the insonifying acoustic wavelength. The direction of the scattered wave deviates from that of the incident wave in proportion to the ratio of the acoustic speeds in the materials on each side of the reflecting surface.

Related terms: acoustic wavelength, intermediate scattering

diffuse enhancement

Echo enhancement distributed throughout a lesion. It can be homogeneous or heterogeneous. In liver contrast studies, diffuse enhancement may occur in the arterial, portal, and sinusoidal phases.

diffuse reflector

Reflecting interface having surface irregularities of dimensions on the order of or greater than the ultrasonic wavelength. In contrast to the case of a specular reflector, echoes from a diffuse reflector travel in different directions. This allows echoes from a diffuse reflector to be detected even when it is not perpendicular to the ultrasound beam.

diffuse sound field

Sound field that in a given region has statistically uniform energy density, for which the directions of propagation at any point are randomly distributed.

diffusive scattering

Waves that are reradiated from objects whose size or curvature is much smaller than the insonifying acoustic wavelength. The reflected waves spread out in a wide angular range.

Related terms: acoustic wavelength, Rayleigh scattering; contrast with specular scattering, diffractive scattering

digital (signal)

A signal whose values consist of discrete numbers. For example, a binary signal is a digital signal that can assume at any moment only one of two possible values: 0 or 1. Contrast with an analog signal, whose values can consist of any value between its minimum and maximum values.

digital beamforming

The formation of a desired transmit or receive beam pattern by digital means. Digital transmit beamforming typically uses synchronized and precisely timed digitally delayed excitations across transducer elements to achieve transmit focusing and/or steering of the ultrasound beam. Receive beamforming is commonly done by the delay-and-sum of digitized echo signals from multiple elements of an array ultrasound transducer. Digital receive beamforming is flexible and can include other methods such as plane wave compounding.

Related term: beamforming

digital signal processing

The mathematical operation or numerical manipulation of a discrete-valued time or space varying process (signal) to modify it or produce new information. An algorithm that manipulates a series of discrete-valued numbers. The *discrete Fourier transform* (DFT) is an example of digital signal processing.

See Fourier transform.

digitization (quantization) noise

The noise introduced when a continuously varying (analog) signal is converted (sampled) into a signal possessing only discrete values (a digital signal). The amplitude of this noise is equal to the difference between the amplitudes of the analog and digital signals.

dimensionless

The property of a physical quantity or parameter whose magnitude does not have any units (such as meters, seconds, kilograms, or volts) in its complete description.

dipole (acoustical)

A pair of acoustical sources, usually separated by one half-wavelength, that generate sound pressure waves of approximately equal amplitudes and 180° out of phase.

dipole (electrical)

Positive and negative electrical charges at a short distance from each other.

directional Doppler system

Doppler equipment that measures not only the velocity of the bloodstream in a vessel but also the direction (unidirectional) or directions (bidirectional) of the stream as well.

directional gain

See directivity factor.

directional hydrophone

Hydrophone the response of which is dependent on the direction of sound incidence.

Related term: Compare with omnidirectional hydrophone

directional pattern

See directivity pattern.

directional response

See *directivity function*.

directivity factor

A ratio of the intensity in a given direction over that for an omnidirectional radiator of the same power.

directivity function

The quantitative description of the dependence of irradiated acoustic intensity or sensitivity of a transducer on direction (see Figure 10).

directivity pattern

The directivity function plotted in polar coordinates.

discrete Fourier transform

Digital version of Fourier transform (DFT).

discrete operating mode

Mode of operation of medical diagnostic ultrasonic equipment in which the purpose of the excitation of the ultrasonic transducer or ultrasonic transducer element group is to use only one diagnostic method. Note: Examples of discrete operating modes are A-mode (A), M-mode (M), static B-mode (sB), real-time B-mode (B), continuous wave Doppler (cwD), pulsed Doppler (D), static flow-mapping Doppler (sD), and real-time flow-mapping Doppler (rD) using only one type of acoustic pulse.

dispersion

The variation in phase velocity with frequency in a medium.

dispersive medium

A medium in which the phase velocity of an acoustic wave is a function of frequency.

displacement

The amount by which an object, such as a tissue element, moves.

display

Visible presentation of ultrasound parameters. For example, B-mode or Doppler. Also an electronic device for the visual presentation of data.

Related terms: display format, cathode ray tube, liquid crystal display, light-emitting diode display

display dynamic range

See *dynamic range*.

display format

The manner in which information is presented to the diagnostician, eg, A-mode, B-mode, C-mode, etc.

dissipation

Any loss of energy, generally by conversion into heat.

dissipation factor

Ratio of sound energy dissipated as heat to the energy of the incident sound wave.

distortion

Undesired change of a waveform. Note: Distortion may result from (1) a nonlinear relation between the input and output, (2) nonuniform transmission at different frequencies, or (3) a phase shift not proportional to the frequency.

disturbed flow

Deviations from laminar flow consisting of oscillatory variations in direction or the formation of vortices. Disturbance of blood flow may be caused by high velocities, by curving, branching, and divergence of vessels, or by projections in the vessel lumen.

divergence (beam)

The continual widening of a sound beam as it propagates.

divergence loss

Related term: diffraction loss

Doppler angle

The angle between the direction of propagation of the ultrasound beam and the direction of flow. As an approximation, the angle between the axis of the ultrasound beam and the axis of the vessel lumen is generally used.

Doppler

Contraction (colloquial) for the Doppler effect or Doppler ultrasound or Christian Andreas Doppler.

Related terms: Doppler effect, Doppler, Christian Andreas Doppler, Doppler ultrasound

Doppler, Christian Andreas (1805–1853)

Son of an Austrian stonemason, Doppler became a professor of mathematics in Prague. He enunciated his principle in 1842 but unfortunately confused its interpretation (he was, it turned out, incorrectly using it to attempt to explain the color of binary stars). The acoustical Doppler effect was demonstrated in 1845 by Buys Ballot using a trumpeter riding on a steam locomotive, which was loaned for the occasion by the Dutch government.

Doppler, continuous wave

Doppler processing using continuous wave ultrasound.

Related terms: continuous wave (CW) ultrasound, continuous wave (CW) Doppler system

Doppler effect

An apparent change in the observed sound frequency caused by relative motion between the sound source or reflector and the observer.

Doppler frequency shift

The difference between the frequencies of transmitted and received waves. The shift in frequency is proportional to the velocity of relative motion between the transducer and the reflector.

Doppler frequency shift, maximum

The highest Doppler shift frequency at a moment in time or in an individual Doppler spectrum. This corresponds to the fastest moving target in the Doppler sample volume. Because of the effect of noise, some form of signal conditioning is usually performed before the maximum frequency is measured.

Doppler frequency shift, mean

The average Doppler shift frequency in a given power spectrum.

Doppler frequency shift, median

The Doppler shift frequency above and below which one-half of the total power in the spectrum resides.

Doppler frequency shift, mode

The Doppler shift frequency with the greatest power in a given spectrum.

Doppler, pulsed

See *pulsed Doppler*.

Doppler shift frequency

See *Doppler frequency shift*.

Doppler spectrum

Spectrum of a Doppler signal.

Doppler ultrasound

Application of the Doppler effect in ultrasound to detect movement of scatterers by the analysis of the change in the frequency of the returning echoes.

Doppler velocity signal

A signal whose instantaneous voltage is proportional to the instantaneous Doppler frequency shift, derived by a frequency-to-voltage conversion of the Doppler signal.

dosimetry

The quantitative determination of the amount of acoustic radiation absorbed.

duplex mode

An imaging mode in which two modes such as real-time B-mode and Doppler are displayed simultaneously.

Related term: *duplex scanner*

duplex scanner

An ultrasound instrument that has duplex mode processing and display capabilities.

Related term: *duplex mode*

duty factor

The product of the pulse duration and the pulse repetition rate. The fraction of time the transducer is active when excited by a sequence of pulses.

dwelt time

The total time that a specified anatomic structure is continuously exposed to the ultrasound beam during an ultrasound examination.

dynamic contrast-enhanced ultrasound (DCE-US)

The application of microbubble contrast media to traditional ultrasound imaging. Acquisition of a contrast-enhanced ultrasound image sequence describes the time history of intravascular contrast agent flow as an indicator of blood flow.

Related terms: *contrast agent, intravascular ultrasound*

dynamic focusing

A method of extending the depth of focus during real-time imaging. For receive dynamic focusing, the receive beam is refocused at nearly each depth within the limits of the receive aperture available. For transmit, the depth of focus can be extended by splicing together an image from short depth ranges, each one with an appropriate transmit focal length within the range.

Related terms: depth of field, receive aperture, receive beamforming

dynamic imaging

Imaging of an object in motion, a technique that is frequently referred to as real-time imaging.

dynamic range

The ratio of the minimum to maximum signal amplitude that can be applied to a device without producing distortion in the output signal (expressed in decibels [dB]). The largest signal is usually limited by saturation and the smallest by the background noise level. This concept applies to amplifiers, displays, and other devices.

dynamic range compression

Related terms: compression, dynamic range

dynamic range expansion (elastography)

A technique by which the dynamic range of an elastogram may be increased. This is done by successively applying increasing amounts of strain to the tissue and selecting only those strain estimates from each resulting elastogram that are of acceptable quality. These estimates are then combined to generate a composite elastogram that depicts a large dynamic range of strain.

Related terms: dynamic range, elastography, strain

E

early phase of enhancement

See *arterial phase of enhancement*.

echo

A sound wave that has been reflected and arrives with such a magnitude and sufficient time interval after the direct transmitted sound wave to be distinguishable.

echo amplifier (or enhancer)

Deprecated term for contrast agent.

echocardiogram

An ultrasound image of the heart.

Related terms: 2-dimensional echocardiography, 3-dimensional echocardiograph

echocardiograph

An instrument used to record an echocardiogram.

echocardiography

Examination of the heart by diagnostic ultrasound.

echo contrast agent

Related term: contrast agent

echo detection capability

The difference (expressed in decibels between the echo level due to an ideal plane echo interface and the peak level of noise or spurious signals arising simultaneously with the echo. If a value of echo detection capability is quoted without qualification, this will relate to the position of the target on the principal acoustic axis that corresponds to the standard working distance.

Related term: depth of penetration

echoencephalography

Examination of the brain by diagnostic ultrasound.

echo enhancement

See *acoustic enhancement*.

echogenic

Describes a structure or medium (eg, tissue) that is capable of producing echoes. Contrast with the terms *hypoechoic*, *hyperechoic*, and *anechoic*, which refer to the paucity, abundance, and absence of echoes displayed on the image.

echogenicity

The tendency of a tissue or material to generate echoes.

echogram

A record obtained using acoustic reflection techniques with one of the various display modes.

echography

Any imaging method using reflected sound.

Related term: sonography

echo listening time

Pulse repetition period minus the pulse duration. It is the time between one pulse and the next during which the transducer is able to detect echoes.

echolucent

A misnomer for anechoic and/or transsonic.

Related terms: anechoic, transsonic

echo-ophthalmography

Examination of the eye and orbit by diagnostic ultrasound.

echo ranging

A technique for measuring distances in materials of known acoustic velocity by measuring the transit time for the sound to propagate from the transducer to the target and return. Echo-ranging techniques, in particular pulse-echo ultrasound, form the basis of most ultrasonic visualization systems.

Related term: pulse echo

echoscope

Instrument that displays a sonogram on a screen.

echo (signal) shaping

Image modification in which the echo waveform is changed using techniques such as limiting and differentiation.

echo strength

The magnitude of an echo.

echoventriculography

A method for echoencephalographic measurements of the cerebral ventricles or measurement of other ventricles as appropriate in the field of application.

edge enhancement

An image-processing technique that makes edges in an image more apparent.

effective acoustic center

For a sound-emitting transducer, in a specified direction and range of distances, position of the virtual point source from which sound pressure varies inversely with distance. Also called virtual acoustic center.

effective area of an ultrasonic transducer

The area of a perfect pistonlike ultrasonic transducer, which has a predicted axial acoustic pressure distribution approximately equivalent to the observed axial acoustic pressure distribution over a limited axial distance. The unit is square meter (m²).

Related term: active aperture

effective frequency

A single frequency used to characterize a signal containing many frequencies. The effective frequency of an ultrasound beam is determined by the centroid of the power spectrum of the acoustic waveform at the pressure focus over the -3-dB bandwidth.

Related term: bandwidth

effective pressure

The root mean square value of acoustic pressure. The unit is pascal (Pa).

effective radius of a hydrophone active element

The radius of a stiff disk receiver hydrophone that has a predicted directional response function with an angular width equal to the observed angular width. The angular width is determined at a specified level below the peak of the directional response function. For the specified levels of 3 and 6 dB, the radii are denoted by a_3 and a_6 , respectively. The unit is meter (m).

Related term: effective area of an ultrasonic transducer

effective wavelength

The effective wavelength of a field is equal to the longitudinal sound velocity in the propagation medium divided by the effective frequency.

elastic compression modulus

See bulk elastic modulus.

elastic modulus

The ratio of a specified stress to the corresponding strain in the material.

elastic spring

A purely elastic element in a viscoelastic model in which the resulting force is proportional to the strain; the graphical symbol for a spring (E) is:



elastogram (tissue)

An image depicting the spatial distribution of an elastic parameter of tissue. Examples are axial strain elastogram, lateral strain elastogram, modulus elastogram, shear strain elastogram, and poro-elastogram.

elastography (tissue)

An imaging technique producing an elastogram.

Related term: elastogram

elastomicrography

An elastographic method where the resolution of the elastograms is below 1 mm.

electroacoustic effect

The occurrence of a deformation of a material after applying an electrical voltage on opposite sides.

electroacoustic force factor

Of a reciprocal electroacoustic transducer, (1) the quotient of the resulting sound pressure in the blocked acoustical system by the corresponding current in the electrical system; or (2) the quotient of the resulting open-circuit voltage in the electrical system, by the volume velocity in the acoustical system; if there is gyroscopic antireciprocal coupling, the sign is reversed.

electroacoustic reciprocity principle

For a linear, passive reversible electroacoustic transducer, the principle according to which the relationship between the voltage (or current) sensitivity of the transducer when used as a sound receiver and its corresponding current (or voltage) sensitivity when used as a sound emitter depends only on the system geometry, the frequency, and the physical properties of the medium.

electroacoustic transducer

Transducer designed to receive input signals from an electrical system and to furnish acoustic output signals or vice versa.

electromechanical force factor

Of a reciprocal electromechanical transducer, (1) the quotient of the resulting force in the blocked mechanical system by the corresponding current in the electrical system; or (2) the quotient of the open-circuit voltage in the electrical system by the corresponding velocity in the mechanical system; if there is gyroscopic antireciprocal coupling, the sign is reversed.

electromechanical transducer

Transducer designed to receive input signals from an electrical system and to furnish output signals to a mechanical system or vice versa.

electronically swept scanning (3-dimensional)

Producing 3-dimensional echo information with a 2-dimensional array using electronic sweeping.

Related term: Contrast with *mechanically swept scanning*

electronic focusing

Method to achieve transmit and/or receive focusing of an array transducer by means of signal time delays between neighboring elements of the array.

See *dynamic focusing*.

electronic sector scan

Sector scanner using a phased array transducer without mechanically moving parts.

electronic tissue model

Electronic apparatus that produces signals that mimic acoustic echoes received from tissue.

electrostatic actuator

Device comprising an auxiliary electrode that permits the application of an electrostatic force to the metallic or metalized diaphragm of a microphone to obtain a calibration.

electrostatic loudspeaker

Loudspeaker that operates by electrostatic forces.

electrostatic microphone/capacitor microphone/condenser microphone

Microphone that operates by variation of electrical capacitance.

elevation axis

An axis in the elevation plane perpendicular to the beam axis.

elevation plane

The plane that contains the beam axis and is perpendicular to the principal longitudinal (azimuth or scan) plane (see Figures 27, 33, and 36).

Related term: azimuthal plane

elevational resolution

The resolution at right angles to the scan plane. This is sometimes referred to as orthogonal resolution, vertical resolution, or slice thickness resolution.

encapsulated bubble

A gas bubble that is covered with a layer of a material to retard the dissolving of the gas into the surrounding liquid. Microbubbles used in ultrasonic applications are encapsulated to permit them to last long enough to be useful.

Related terms: contrast agent, microbubble

endocavitary

Term describing sonographic examinations that use a transducer that is placed within a body cavity, including endoesophageal, endorectal, endovaginal, and endovascular.

Related terms: transesophageal, transrectal, transvaginal imaging

end-of-cable loaded sensitivity of a hydrophone

The ratio of the voltage at the end of any integral cable or connector of a hydrophone, when connected to a specified electrical input impedance, to the instantaneous acoustic pressure in the undisturbed free field of a plane wave in the position of the acoustic center of the hydrophone if the hydrophone were removed. The unit is volt per pascal (V/Pa).

end-of-cable open-circuit sensitivity factor

A modified expression for the free-field pressure sensitivity to account for the impedance of the cable connected to a hydrophone to an oscilloscope.

Related term: free-field pressure sensitivity

end-of-cable open-circuit sensitivity of a hydrophone

The ratio of the open-circuit voltage at the end of any integral cable or connector of a hydrophone to the instantaneous acoustic pressure in the undisturbed free field of a plane wave in the position of the acoustic center of the hydrophone if the hydrophone were removed. The unit is volt per pascal (V/Pa). Note: This definition differs from that given in Subclause 8.8 of IEC Publication 866, as the latter refers to a hydrophone excluding any integral cable.

endovaginal imaging

Imaging of the female pelvis while the transducer is placed in the vagina.

Related term: transvaginal imaging

energizing pulse (transmitter pulse)

An electrical pulse used to excite (or “shock”) an ultrasonic transducer. Frequently, the pulse is an impulse or “spike” whose rise time is short compared to the natural period for the fundamental resonant oscillations of the transducer.

energy per pulse

The ratio of the average acoustic power to the pulse repetition frequency, measured in joules (J).

energy, kinetic

Energy associated with the motion of a mass. It is equal to $\frac{1}{2} mv^2$, where m is mass, and v is velocity.

energy, potential

Energy associated with the ability to do work. Examples are the gravitational (or hydrostatic energy of an object (or volume of fluid) raised to a height in a gravitational field and pressure in a fluid.

energy, total fluid

The sum of the kinetic energy (related to velocity), inertial energy (related to acceleration), potential energy (related to pressure or gravity), and viscous energy (related to fluid friction) in a volume of fluid. The unit of energy is joule (J).

energy, viscous

Energy used to overcome the internal cohesion of a liquid to, for example, maintain laminar flow. Energy expended in this way is converted to heat.

enhanced subharmonic imaging

Related term: subharmonic contrast-enhanced sonography

ensemble (of scatterers)

A collection of inhomogeneities that scatter acoustic energy.

ensemble length (color flow Doppler)

The number of pulses emitted by a color flow Doppler imaging system to create Doppler data in the image. Also known as packet length.

entrance beam dimensions

The dimensions of the beam cross-sectional area where the beam enters the patient. For contact transducers, these dimensions can be taken as the dimensions of the radiating element. Also called the footprint of the transducer on the patient.

entrance dimensions of the scan (for auto-scanning)

The dimensions of the scan cross-sectional area over the surface through which the scan beams enter the patient.

Related term: footprint

entrance effect (fluid)

The change in the velocity profile experienced by flow when there is a sudden change in the diameter of a vessel. Laminar flow will tend to stabilize some distance downstream: the distance over which this occurs is known as the entrance length.

Related term: laminar flow

envelope

A smooth curve connecting the maximum peaks of the absolute values of a signal (see Figure 26).

Related term: analytic signal envelope

error detection

The ability to detect errors that are made because of noise or other impairments during reception or transmission of signals.

estimator (statistical)

A measure that approximates the actual quantity that is to be measured.

evanescent wave

For an incident wave past the critical angle at the boundary of a second medium, the exponentially decaying nonpropagating wave in the second medium.

Related terms: angle of incidence, angle of reflection, critical angle, refraction

exit effects

The change in the velocity profile experienced by flow when there is a sudden increase in the lumen area, for example, downstream from a stenotic orifice. Flow disturbance can result, with accompanying energy loss.

expansion amplifier

Amplifier that yields more amplification the stronger the input signal (reciprocal of compression).

exposimetry

Measurement methods for quantifying and estimating acoustic output reaching a region of interest.

exposure time

The total amount of time the transducer assembly is delivering ultrasonic energy to the subject. For a pulsed waveform, this includes the time between pulses.

ex vivo

The condition of being outside the living body. An ex vivo study refers to one carried out on tissue after it has been extracted from a living body. It is used to denote the removal of an organ, such as the kidney, for study or reparative surgery, after which it is returned to its original site.

F

false echoes

Related term: artifact

far field (Fraunhofer zone)

The region of the ultrasound beam sufficiently far from the transducer so that wavefronts arriving from different regions of the transducer surface reinforce each other. An ultrasound beam is conveniently divided into two regions. The region farthest from the transducer is called the far field and sometimes called the Fraunhofer zone. For an unfocused circular transducer, the transition from the near field to the far field occurs at approximately r^2/λ , where r is the transducer radius, and λ is the wavelength.

Related term: Contrast with *near field*

far Fresnel zone (archaic term)

Preferred term: postfocal zone

far transition distance

The distance past which the postfocal zone begins for a focusing transducer (see Figure 5).

Related terms: near transition zone, focal zone, prefocal zone, postfocal zone

fast Fourier transform (FFT)

An efficient method of computing the Fourier transform of a function. The Fourier transform is a mathematical operation that decomposes a function into an equivalent group of sinusoidal functions of various frequencies and amplitudes. The amplitudes of the frequency components are often displayed as a plot of relative amplitude versus frequency, known as the amplitude spectrum. The FFT is frequently used to compute the frequency components of the Doppler signal.

Related terms: Doppler, Fourier transform

ferroelectricity

A dielectric phenomenon, analogous to ferromagnetism, characterized by spontaneous polarization of crystalline domains. The remanent polarization of a material may be reversed or reoriented by the application of an external electric field.

ferroelectric material

A crystalline or ceramic material that exhibits a remanent polarization, which can be reversed or reoriented by the application of an external electric field. Some ferroelectric materials can be rendered piezoelectric and used as ultrasound transducers.

fiber-optic hydrophone

See optical hydrophone.

field, far

See far field.

field, near

See near field.

filling in

See centripetal enhancement.

filling out

See *centrifugal enhancement*.

filter

A device or material used for suppressing acoustic or electromagnetic waves of certain frequencies while allowing others to pass. In digital computing, a filter is often an algorithm or a program that is used to eliminate or modify specific types of information in a file while leaving the remaining data more or less intact.

filter, bandpass

A device or material that allows only a limited range of frequencies to pass.

filter, high-pass

A device or material that allows high-frequency but not low-frequency signals to pass. An example is the electrical filter used in Doppler devices to eliminate low-frequency Doppler shifts caused by arterial wall motion.

filter, low-pass

A device or material that allows low-frequency but not high-frequency signals to pass. By preferentially attenuating sound at higher frequencies, most tissues act as low-pass filters.

finite amplitude

A term associated with an ultrasonic field whose pressure amplitude is relatively large. Typically used to contrast with an infinitesimal amplitude. Usually meant to describe amplitudes capable of generating nonlinear fields and nonlinear propagation.

first-order quantity

In acoustics, this refers to the fundamental parameters pertaining to wave propagation. Particle velocity, acoustic pressure, and material density are first-order quantities. In contrast, intensity and power are second-order quantities because the first-order quantities appear as squared terms in the expressions defining them.

fixed focus

An unchangeable mechanism capable of focusing in only one location. Usually applied to focusing by use of a physical lens or a curved transducer surface.

Related term: Contrast with *dynamic focusing*

flash (beamforming)

The use of a transmitted plane wave to illuminate a region of interest as opposed to line-by-line acoustic transmission.

flash (energy)

A sudden rise in acoustic power that is triggered by the operator to better assess a given area or to destroy the microbubbles filling the insonated parenchymal region and obtain functional data from the refilling kinetics of microbubbles.

See *destruction-replenishment technique*.

flaw detector

Echographic equipment for examining (solid) materials for structural defects.

flicker

A visibly apparent brightness fluctuation due to a display frame rate that is too low for visual perception of continuous brightness. Typically this will occur when the frame rate is below 15 frames per second. Other factors that affect flicker include phosphor persistence and brightness.

flow rate

The rate of transfer of volume of fluid with time. Measured in liters/second or milliliters/minute.

flow separation

A phenomenon occurring when flowing fluid travels at a high velocity adjacent to fluid traveling at a lower velocity. At the flow separation boundary, both a high-velocity gradient and high shear stress are present. Flow separation often occurs just distal to a vessel stenosis.

fluid (flow) resistance

Proportionality constant (R) between volume flow (F_v) and pressure difference at two positions along a blood vessel: $\Delta p = (p_2 - p_1) = RF_v$.

flux density

See *intensity*.

FM

Frequency modulation or frequency-modulated.

f-number

The focal length of a focused transducer divided by the diameter or length of its radiating surface. This ratio is a measure of the focusing power of the lens.

focal area

The area of the focal surface.

Related term: focal surface

focal diameter

For a sound beam with a circular cross section, the diameter of the beam at -6 dB (or -20 dB) of the peak amplitude level in the focus.

focal dimension

See *focal diameter*, and *focal n-dB beam area*.

focal Fraunhofer zone (archaic)

Preferred term: postfocal zone

focal length

The axial distance from the geometric center of the radiating surface of a focusing transducer assembly to the focal surface. In other words, the distance from the surface of the transducer assembly to the narrowest point (focus) of the beam.

Preferred term: geometric focal length

focal n-dB beam area

The smallest of areas containing all the points of a plane perpendicular to the sound beam axis where the received signal exceeds a value of n-dB below the maximum signal value.

focal pressure

One half of the maximum peak-to-peak acoustic pressure at the pressure focus.

focal ratio

See *f-number*.

focal surface

The surface perpendicular to the beam axis containing the smallest of all beam cross-sectional areas of a focusing transducer assembly at –6 dB relative to the maximum signal value or at another specified level.

focal zone

Region along the beam axis that is bounded by the near transition distance and the far transition distance. Equivalently, the region of an ultrasound field about a geometric focus in a specified longitudinal plane (see Figures 3–5).

Related terms: near transition distance, far transition distance

focus (focal point)

The point on the axis of an ultrasonic beam where the width of the beam has a minimum value. Generally, all the waves passing through the focus are in phase in relation to the surface of the transducer.

Related terms: geometric cylindrical focus, geometric focal point, geometric focal length

focus, depth of

See *depth of focus*.

focal zone

The region of a focused beam where the beam is the narrowest and is bounded axially by the near- and far-field transition distances (usually defined in a longitudinal plane; see Figures 3 and 5). For circular transducers, the elevational focus and azimuthal focus will be the same; for noncircular transducers, the elevation plane focus is different than the azimuth plane focus.

Related terms: azimuth plane, elevation plane

focused field

A deliberate narrowing of the ultrasound beam to create an increased acoustic pressure at a specific point on the beam axis. This narrowing is significantly more than would occur with a flat transducer with the same aperture (see Figures 3–7 and 9).

Related term: focusing transducer

focused reflector

A device that produces by reflection an acoustic pressure at some point along the beam axis that is greater than a specified factor (eg, 2.5) above the root mean square acoustic pressure averaged over the geometric area of the transducer.

focusing transducer

Electro-acoustic device that produces a narrower –6-dB beamwidth in a longitudinal plane that is less than that of a flat transducer with the same source aperture size (and apodization, if any) and same excitation at a distance less than the transition distance from the source aperture plane (see Figures 2–6).

Related terms: apodization, beamwidth, longitudinal plane, source aperture, transition distance

focused ultrasound

The concentration of ultrasound energy in a selected region. It can be used for diagnostic or therapeutic applications.

Related term: lens

focusing

See *focused field*.

focusing, dynamic

See *dynamic focusing*.

focusing gain (geometric)

Ratio of pressure at geometric focal point on beam axis to average pressure on the transducer face.

footprint

The area covered on a surface when an object is applied to that surface. For example, the footprint of a transducer is the skin surface area in contact with the transducer when scanning.

force constant

The constant of proportionality between the applied force and the change in length when an object is stretched. $F = k \cdot x$, where F is the force, k is the force constant, and x is the displacement.

forced oscillation

Oscillation driven by an external force.

forward problem (elastography)

The mathematical problem of estimating the distribution of the strains in a target from knowledge of the applied strain or stress and the known distribution of the elastic moduli therein.

Fourier analysis

A mathematical technique for the representation of a function (such as a time-varying waveform) as a sum of sinusoidal functions of different frequencies. For a periodic function, each of these constituent functions has a frequency that is an exact multiple of the fundamental frequency. Fourier analysis can be used to describe a Doppler signal in terms of the relative amplitude of the various Doppler shift frequencies of which it is composed.

Related terms: discrete Fourier transform, Doppler effect, Fourier transform

Fourier, Joseph (1768–1830)

Son of a French tailor who was persuaded to leave his Benedictine monastery to become a professor of mathematics at the age of 21. Among his many original and outstanding contributions to mathematical physics is the analytic theory of heat, which Lord Kelvin called “a great mathematical poem.” Some say that his death was speeded by his insistence that heat was good for the healthy and his later habit of living in rooms “hotter than the Sahara desert.”

fractional bandwidth

A relative measure of bandwidth equal to the ratio of bandwidth to center frequency.

frame

A single image in a sequence of many similar images.

frame rate

The rate at which pictures are refreshed on the display of a real-time system. This rate would normally correspond to the scan rate of the transducer. In some systems, such as television, a single frame is composed of two interlaced fields. The frame rate of standard television in the United States is 30 frames per second.

Related term: scan repetition rate

Fourier transform

A mathematical algorithm that converts a waveform into its spectrum. The waveform could be in space or time or be multidimensional.

Fraunhofer focal zone

Preferred term: postfocal zone

Fraunhofer zone

Preferred term: far field

free field

Sound field in a medium with negligible interference from extraneous sources of sound or reflections.

free-field current sensitivity

Of a hydrophone, for a specified frequency and a specified direction of sound incidence, the ratio of the short-circuit current at the output terminals of the hydrophone to the sound pressure in the undisturbed free field.

free-field pressure sensitivity

As applied to a hydrophone, the voltage induced per unit of applied acoustic pressure. The preferred unit is volts per pascal (V/Pa).

free-field voltage sensitivity

Of a microphone, for a specified frequency and a specified direction of sound incidence, the quotient of the output open-circuit voltage by sound pressure in the undisturbed free field. Note: The load impedance must be specified if other than open-circuit.

freehand scanning

Acquiring a volume of echo information through manual movement of the transducer without restriction on the possible motion.

freehand scanning (3-dimensional)

Acquiring a volume of echo information through manual movement of the transducer without restriction on the possible motion without sensing the position of the image plane. Quantitative measurements in such data sets may be inaccurate.

free oscillation

Oscillation that continues after removal of any external excitation.

free progressive wave

Wave propagating in a medium, free from boundary effects.

free sound field

See free field.

freeze

The status of sonographic equipment that causes cessation of the acoustic output, and the most recent image is stored in a scan converter memory and displayed continuously on a monitor.

Related term: cine loop

freeze frame

Control setting of sonographic equipment that causes the most recent image to be stored in a scan converter memory and continuously displayed on a monitor.

frequency

Number of cycles of a periodic process per unit of time, expressed in hertz (Hz) or multiples such as megahertz (1 MHz = 10⁶ Hz). 1 Hz = 1 cycle per second.

See *angular frequency*.

frequency ambiguity

See *aliasing*.

frequency compounding

Acquiring and combining echo data from the same location but at different ultrasonic frequencies. The signals may be acquired using transmit pulses at different frequencies or by filtering echo signals following a broad-bandwidth transmit pulse. Envelope data at the various frequencies are combined at each location.

Related terms: compound image, spatial compounding

frequency domain

A mathematical framework in which a signal's magnitude and phase are characterized in terms of frequency. In this domain, variables are described in terms of frequency rather than in terms of time or space.

frequency domain processing

A signal-processing scheme that operates on the spectral representation of signals rather than the temporal representation of the signals.

frequency, Doppler shift

See *Doppler frequency shift*.

frequency interval

The difference between two frequencies.

frequency, received

The frequency of the signal detected by the receiving transducer.

frequency response

A measure of the effectiveness with which a circuit, device, or system transmits the different frequencies applied to it. It is the ratio of the output signal to the input signal, considered as a function of frequency. Often frequency response is considered only between bounding frequencies of interest.

See *bandwidth*.

frequency modulation (FM)

Encoding of information into a carrier wave by variation of its instantaneous frequency in accordance with the amplitude of an input signal.

frequency spectrum, instantaneous

The frequency spectrum of a signal at a given point in time.

frequency spectrum, mean

The average of any set of frequency spectra.

Fresnel zone

See *near field*.

front end

The section of a medical ultrasound system (usually an imaging system) that interfaces directly with each transducer element. It sends the desired waveforms to each transducer element and captures the incoming echoes from each transducer element. Transmit and receive beamforming and amplification such as time-gain compensation are usually included in this section.

full-width half-maximum

The minimum separation between two half-maximum amplitude points, abbreviated as FWHM. Example of beam FWHM in Figure 25. FWHM can also be used for envelopes (see Figure 26).

functional ultrasound (fUS)

The medical imaging of physiologic activities, such as changes in metabolism or blood flow, by ultrasound.

fundamental component

See *fundamental frequency*.

fundamental frequency

The center frequency of the transmitted acoustic wave.

fundamental mode (imaging)

“Conventional” (grayscale) sonographic and Doppler techniques based on the transmission frequency of a sonography system. The echoes chosen to create the image are at the same frequency as that of the transmitted frequency.

Related term: Contrast with *harmonic imaging*

fundamental mode of oscillation

Mode of oscillation of a system having the lowest natural frequency.

G

gain

The increase in signal power or signal amplitude produced by a system. For an amplifier, it is the ratio of the output voltage to the input voltage, usually expressed in decibels (dB).

gamma (display monitor)

Term that quantifies the relationship between the monitor luminance (brightness) and applied voltage. The relationship is of the form $\text{luminance} = C \times \text{voltage}^{\text{gamma}}$, where C is a constant.

gamma (photographic)

The slope of the straight part of the film density versus the exposure characteristic curve. The higher the gamma, the higher the contrast.

gantry

A mechanical support device for mounting an object, such as a transducer probe, and providing a means for motion of the object.

gas body

A stabilized collection of gas within a liquid or solid. A bubble is a gas body that is completely (or nearly completely) surrounded by liquid.

gas body activation

A form of acoustic cavitation nucleated by stable gas bodies of a size large enough to be visible with an optical microscope.

gas bubble

A volume of gas completely surrounded by a liquid. Bubbles tend to be spherical in shape.

gate

A device that can be switched electronically to control the passage of a signal. A gate may select a part of the signal based on the time interval during which the signal was received. For example, a range gate may be designed to accept signals only from a specific range, or an electrocardiographically triggered gate may pass signals from a specified portion of the cardiac cycle.

geometric area of an ultrasonic transducer

The area defined by the ultrasonic transducer dimensions or ultrasonic transducer element group dimensions. The unit is square meter (m^2).

geometric beam boundary

The surface containing straight lines passing through the geometric focus and all points around the periphery of the transducer aperture (see Figure 5).

geometric cylindrical focus

A geometric cylindrical focus is an axis centered on equidistant radial acoustic delay paths from a cylindrical (or its quadratic approximation) transducer or reflector radiating surface.

geometric focal length

The distance along the beam axis from the center of the face of the transducer or lens to the geometric focal point. In the case of an array, there may be a separate focal length for a mechanical lens and another for electronic focusing (see Figures 3 and 5).

geometric focal point

The point of intersection of the greatest number of rays from the active transmitting element(s) of the transducer. Each ray is perpendicular to a small element of a given surface area and may be refracted by lenses and/or reflected by mirrors in the sound path.

geometric line focus

An axis of symmetry for acoustic delay paths from a transducer or reflector radiating surface with cylindrical symmetry (see Figure 8).

geometric radius of a hydrophone active element

The radius derived from the equivalent circular area determined by the dimensions of the active element of a hydrophone. The unit is meter (m).

geometric spherical focus

The focal point that has equidistant total delay paths (acoustic and/or electronic) from a spherical transducer, lens, or reflector radiating surface. Sometimes called point focus (see Figure 8).

GHz

Abbreviation for gigahertz, equal to 1 billion hertz; 1 GHz = 10^9 Hz.

globular enhancement

A discontinuous ring of contrast-enhanced peripheral globules (puddles or nodules) predominantly in the arterial or portal phase. These globules usually enlarge over time, with centripetal enhancement of the lesion. This is a common feature of liver hemangioma.

Golay code

An error-correcting code in which words of up to 12 bits are encoded into 23 or 24 bits according to specific rules.

graphical user interface

An interface that employs graphical elements (such as dialog boxes, icons, menus, and scroll bars) in addition to text characters to let users interact with the device (ultrasound system or computer).

grating lobes

Beams of sound radiating in directions different from the primary beam resulting from the multielement structure of transducer arrays. The grating lobes may be responsible for introducing artifactual echoes into an ultrasound image. A grating lobe is an approximate replica of the main lobe at another angle, and its direction is determined by the interelement spacing and the wavelength (see Figure 10).

Related term: Contrast with *side lobes*

gray scale

A display technique in which echo amplitude or intensity information is recorded as variations in brightness (shades of gray).

grayscale compression

A form of image processing that compresses the dynamic range of selected gray levels in the image.

Related term: Contrast with *grayscale stretching*

grayscale map

A table or relationship between the echo signal amplitude and the displayed brightness (shade of gray) on a sonogram. The grayscale map is used in postprocessing to relate values of the echo signal, Doppler shift, or other ultrasound data residing in memory to signals that control grayscale or color values in the display.

grayscale stretching

A form of image processing that extends the dynamic range of selected gray levels in the image. It is effective when an original image does not use the entire range of gray levels.

Related term: Contrast with *grayscale compression*

group velocity

Velocity of the envelope of a group of waves traveling in the same direction having different frequencies and phase velocities. Group velocity is ordinarily the velocity of propagation of the energy associated with an ultrasonic pulse.

Related term: Contrast with *phase velocity*

H

half-power distance

See *half-value layer*.

half-value layer

The distance an ultrasound pulse must travel in one direction in a medium to reduce its power to one half of its original value. The half-value layer is a means for quantifying tissue attenuation.

hard copy

A permanent visual record stored on materials such as paper, radiographic film, or photographic film, as opposed to an image displayed on a video screen, stored on magnetic tape, or retained in a digital format such as in memory or on a disk.

hard limiting

See *clipping*.

harmonic

A whole number multiple of the fundamental frequency of a periodic quantity. For example, the second harmonic of a 1-MHz piezoelectric element is at 2 MHz. (Subharmonics also are possible, eg, at $\frac{1}{2}$, $\frac{1}{3}$, etc, of the fundamental frequency.)

harmonic imaging

Method of imaging in which ultrasound is transmitted at a fundamental frequency and is detected at harmonic frequencies. Harmonics are generated by the propagation medium or by nonlinear reflectors such as contrast microbubbles. The resulting harmonic is displayed as an image to improve the resolution for a given penetration.

Helmholtz resonator

An enclosure consisting of a relatively large volume and a straight tube having a small orifice. It will have a resonance frequency determined by the volume of the enclosure, length of the tube, area of the orifice, and speed of sound.

hertz

The standard unit of frequency, equal to 1 cycle/s. The abbreviation is Hz.

heterogeneous

Refers to a property of a medium whose value is substantially different in different locations within the medium. Contrast with *homogeneous* and *inhomogeneous*.

High-intensity focused ultrasound (HIFU)

An intense, highly focused ultrasonic beam designed to deliver large amounts of thermal energy to tissue. Typically used for ultrasonic surgery applications.

high-flow lesion

A lesion showing very rapid echo enhancement in the arterial phase.

Hilbert transform

A mathematical process used to calculate the quadrature component of a signal.

Related terms: *analytic signal*, *envelope*

histotripsy

Ultrasound-induced tissue disintegration through cavitation. A process by which repetitive high-pressure ultrasound pulses result in mechanical effects that completely disintegrate and liquefy tissues.

holography

A 2-stage process of imaging. The object to be visualized is uniformly irradiated with ultrasound (or light), and the reflected or transmitted waves are sampled over a large area. The resulting image or hologram is generated by recording the sum of the reflected or transmitted waves and a reference wave or signal. This resulting image is an interference pattern where the contours are lines of constant phase. Although holograms contain 3-dimensional data, they are usually reconstructed in acoustics so that only 2 dimensions are displayed.

homogeneous

Refers to a property of a medium whose value is the same throughout the medium.

Related terms: Contrast with *inhomogeneous*, *heterogeneous*

honeycomb-like enhancement

Inhomogeneous enhancement with gross enhancing septa and with small or large unenhanced areas that are more than one half of the size of the lesion area (on 2-dimensional images). Found in liver abscesses. A particular type of inhomogeneous enhancement.

Hooke's law

A law stating stress is proportional to strain, providing the strain is not too large. Hooke's law may also be stated as the elongation of a body in tension is directly proportional to the stretching force, and the shortening of a body in compression is directly proportional to the compressing force.

Related term: *force constant*

horn (acoustic)

Tube of varying cross section, larger at one end than the other, intended to achieve an acoustic impedance match and, possibly, to produce a directional effect.

Huygens' principle

The principle that states that any wave phenomenon can be synthesized by the addition of the contributory wavelets from the distribution of point sources properly selected in phase and amplitude to represent the physical situation.

hydrophone

A receiving transducer designed for underwater measurement of acoustic fields. The diameter of a hydrophone is usually smaller than the wavelength of ultrasound to be measured, and its bandwidth is large.

hyperechoic

An adjective describing a region for which echoes are noticeably of a higher amplitude (brighter) than their usual ultrasonic appearance or of a higher amplitude than those from surrounding structures.

hyperenhanced lesion

Lesion with relatively stronger echogenicity (enhancement) than the surrounding normal parenchyma.

hyperthermia

A condition in which the body temperature rises above normal. In humans, the normal body temperature is approximately 37°C. Often refers to the artificial heating of all or part of the body for therapeutic purposes (as to treat cancer).

hypoechoic

An adjective describing a region for which echoes are noticeably of a lower amplitude (darker) than their usual ultrasonic appearance or of a lower amplitude than those from surrounding structures.

hypoenhanced lesion

Lesion with relatively weaker echogenicity (enhancement) than the surrounding normal parenchyma.

hysterosonography (HSG)

An ultrasound examination, usually performed endovaginally, to evaluate the female pelvis during and after the instillation of fluid into the endometrial cavity.

Related term: sonohysterography (SHG)

Hz

Abbreviation for hertz, the unit of frequency. One hertz is 1 cycle/s.

image fusion

The process of aligning and/or combining relevant information from two or more images and/or imaging modalities into a single image.

image optimization

Any technique or processing procedure that is used to obtain the best image to achieve a stated aim. The usual aim is to obtain the image that will have the greatest diagnostic value.

image plane

See *scan plane*.

imaginary number

In mathematics, the second of the two numbers comprising a complex number.

Related term: complex number

immersion coupling

A method of coupling an ultrasonic transducer to an object by placing both in a bath of a coupling medium, such as water.

impedance

See *acoustic impedance*.

impedance, acoustic

See *acoustic impedance*.

impedance (fluid)

The ratio of pressure to the flow rate in a vessel. The ratio may be expressed as a function of frequency in time-varying flow. Impedance summarizes the effect on the flow rate of resistance, compliance, and inertia when the pressure varies with time.

impedance ratio

The ratio Z_2/Z_1 , where Z_1 and Z_2 are the characteristic acoustic impedances of two contiguous media, respectively.

impediography

A technique for measuring and displaying acoustic impedances, whereby the impedance is plotted as a continuous function of position.

impulse (electrical)

A short excitation, much shorter than the response of the system excited.

impulse excitation

A type of excitation in which a very short electrical impulse is applied to the device or system for the purpose of either generating a short pulse or for characterizing the system response. Also called shock excitation.

impulse (mechanical)

Time integral of a force over the time during which the force is applied.

impulse response

The response of a device or system following an impulse excitation.

inclusive mode

Combined operating mode having acoustic output levels (peak negative acoustic pressure and spatial-peak temporal-average intensity) less than those corresponding to a specified discrete operating mode.

incoherence

A condition in which the component wavelets in a sound beam are not in phase. This occurs, for example, when several independent unsynchronized transducer outputs are combined to produce a sound beam.

Related term: Contrast with *coherence*

indentation test (tissue)

A mechanical test of the elastic properties of a tissue sample by which a known compressive load is applied to the sample and the resultant deformation is measured.

inertial cavitation

A short-lived cavitation event initiated by a negative pressure wave. A spherical cavity contracts such that the inward motion approximates that of a Rayleigh cavity, and the speed of collapse increases until a rapid rise in pressure within the cavity arrests the inward motion. Sometimes called collapse cavitation, it is associated with large mechanical stresses, high localized pressures and temperatures, shock waves and jet generation, and chemical reactions involving free radicals. Previously called transient cavitation.

infrasound

Acoustic oscillation whose frequency is below the low-frequency limit of audible sound (about 20 Hz).

inhomogeneous

Refers to a property of a medium whose value is slightly different throughout the medium.

Related term: Contrast with *homogeneous*, *heterogeneous*

inhomogeneous enhancement

Coexistence of enhanced and unenhanced areas. Patterns such as mosaic or honeycomb-like enhancement are included among inhomogeneous enhancement patterns.

initialization mode

A defined state of an ultrasound system corresponding to the mode of operation and system settings when a new patient procedure is initiated.

in phase

Having waveforms that are of the same frequency and that pass through corresponding values at the same instant.

insertion loss

The decrease in received power when an object is placed within a signal pathway relative to the power in its absence. In the context of a 1-way ultrasound transmission pathway, if A_1 is the attenuation (in decibels) in the absence of an object of interest and A_2 is the attenuation (in decibels) in its presence, then the insertion loss (IL) is given by $IL = A_2 - A_1$. Usually refers to the ratio of the round trip (pulse echo) into a specified electrical load (A_2) relative to the source connected to the same specified load (A_1), expressed in decibels (dB) as a function of frequency.

in situ

The condition in which the structure of interest is in its natural or normal location.

insonation

See *insonification*.

insonification

Application of sound to an object, medium, or person.

instantaneous acoustic (or sound) pressure

The value of the pressure amplitude minus the ambient pressure at a particular instant in time and at a particular point in an acoustic field. The unit is pascal (Pa).

instantaneous particle acceleration

The time derivative of instantaneous particle velocity.

instantaneous particle displacement

In an elastic medium, a vector whose extremity is the position of the particle at a given instance and whose origin is at the equilibrium position of the particle.

instantaneous potential sound energy density

One half of the quotient of the square of the instantaneous sound pressure divided by the modulus of elasticity of the medium.

instantaneous sound pressure

At a point in a medium, the difference between sound pressure: the pressure existing at the instant considered and the static pressure.

instantaneous (value)

The value of a quantity at a given point in time. This is in contrast to quantities that represent values averaged over a time interval.

integer

A number that can be written without a fractional component. For example, 1, 2, 4, 9, 0, -2, -4, and -8 are integers. The following are not integers: $\frac{1}{2}$, $-\frac{3}{4}$, 3.1459, and $\sqrt{2}$.

Synonym: whole number

integrated backscatter

An estimate of the backscattered ultrasonic energy from a volume of tissue. It is computed from the mean value of the backscattered energy over a finite bandwidth or time period.

integration

A mathematical operation applied to a function over an interval giving the area under the function between the upper and lower limits of the interval. Integration is the inverse of differentiation.

intensity

The rate of energy flow (power) through a unit area perpendicular to the direction of propagation. The unit of intensity is watts per square meter (W/m^2) or, more commonly, watts per square centimeter (W/cm^2). The particular intensity intended should be specified as defined below:

instantaneous intensity

The acoustic energy transmitted per unit time in the direction of acoustic wave propagation per unit area normal to this direction at a particular instant in time and at a particular point in an acoustic field. For measurement purposes, this point is restricted to where it is reasonable to assume that the acoustic pressure and particle velocity are in phase, namely, in the far field or the area of the focus. Under such conditions, the instantaneous intensity can be expressed as: $I = p^2/\rho c$, where p is the instantaneous acoustic pressure, ρ is the density of the medium, and c is the speed of sound in the medium.

pulse-average intensity

The time average of instantaneous intensity at a point in space when averaged over the pulse duration. (May be calculated approximately as the ratio of the temporal-average intensity to the duty factor.)

spatial-average intensity

The same as the spatial-average temporal-average intensity. Generally, this parameter is used when specifying the intensity for continuous wave ultrasound (see Figure 31).

spatial-average pulse-average intensity (I_{SAPA})

The pulse-average intensity averaged over the beam cross-sectional area. (May be calculated as the ratio of acoustic power to the product of duty factor and beam cross-sectional area.)

spatial-average temporal-average intensity (I_{SATA})

The temporal-average intensity averaged over the beam cross-sectional area in a specified plane. (May be calculated as the ratio of acoustic power to the beam cross-sectional area.)

spatial-peak pulse-average intensity (I_{SPPA})

The value of the pulse-average intensity at the point in the acoustic field where the pulse average intensity is a maximum or is a local maximum within a specified region.

spatial-peak temporal-average intensity (I_{SPTA})

The temporal-average intensity at the point in the acoustic field where this intensity is a maximum or is a local maximum within a specified region.

spatial-peak temporal-peak intensity (I_{SPTP})

The value of temporal-peak intensity at the point in the acoustic field where the temporal-peak intensity is a maximum or is a local maximum within a specified region.

temporal-average intensity

The time average of instantaneous intensity at a point in space; this is equal to the mean value of the instantaneous intensity at the point considered. For non-auto-scanning systems, the average is taken over one or more pulse repetition periods. For auto-scanning systems, the instantaneous intensity is averaged over one or more scan repetition periods for a specified operating mode (see Figure 12).

temporal-peak intensity

The peak value of the intensity at the point considered (see Figures 12 and 31).

intensity calibration factor (hydrophone)

The received hydrophone voltage squared per unit of intensity in a plane wave of specified frequency, f , in water at a specified temperature.

intensity modulation

Regulation of the luminance of a display to represent information, such as echo amplitude, as variations of the luminance.

interference

The phenomenon in which two or more waves add together (constructively or destructively, depending on their relative amplitudes and phases).

interference, constructive

The phenomenon of interference in which the resultant wave has an amplitude greater than that of either of the two interfering waves alone.

interference, destructive

The phenomenon of interference in which the resultant wave has an amplitude less than that of either of the two interfering waves alone.

interferometry

Method of measuring a property of a material or wave that uses interference between two or more waves.

intermediate scattering

Scattering from an intermediate-sized scatterer which is approximately the same size as the incident acoustic wavelength
See intermediate-sized scatterer.

intermediate-sized scatterer

Scatterer whose dimensions are on the order of the ultrasonic wavelength, which produces diffractive scattering.
Related terms: diffractive scatterer, diffuse reflector, Rayleigh scatterer, specular reflector

intermittent imaging

Low-frame rate imaging (usually <5 Hz). Often used in contrast imaging to limit interaction between the acoustic field and the microbubbles.

intermittent mode

Very low-frame rate acquisition, generally used during and immediately after the destruction mode. The high-power pulses of the destruction mode may be emitted automatically under software control or manually by the operator. Some protocols include continuous acquisition during the arterial phase and intermittent imaging thereafter.

interpulse interval

See pulse repetition period.

interpulse phase inversion

See pulse inversion mode imaging.

interval delay imaging (archaic)

See intermittent imaging.

interval delay imaging

When microbubbles are disrupted by a high-pressure beam (see intermittent mode), and intense enhancement is detected, it is necessary to wait a minimum interval to have replenishment of the insonated area by new incoming microbubbles. Hence, the intermittent mode is also known as the interval delay scanning technique.

See *intermittent mode*.

intracardiac imaging

Ultrasonic imaging from within the heart.

intraoperative imaging

In vivo imaging performed during a surgical procedure.

intravascular ultrasound (IVUS)

The application of ultrasound for imaging or therapy from inside blood vessels using a miniaturized ultrasound probe(s) attached to a catheter.

inverse problem (elastography)

The mathematical problem of deriving the distribution of elastic moduli in a target from the knowledge of the distribution of the strains therein, the boundary conditions, and knowledge of applied stress, under some restrictions.

inverse Fourier transform

A mathematical algorithm that converts a spectrum into a waveform.

in vitro

Experimental condition in which a specimen of interest is removed from an organism and studied in an artificial environment, usually a test tube or a Petri dish.

in vivo

Tissue in its natural condition within the living subject.

ionizing radiation

Radiation sufficiently energetic to be able to eject one or more electrons from atoms to produce ions. Ultrasound is a nonionizing kind of radiation.

isochronous

An adjective meaning "at the same time"; a synonym for *synchronous* or *simultaneous*.

isochronous volume

Region where acoustic waves or wavefronts arrive at the same time.

isoenhanced lesion

Lesion with the same echogenicity (enhancement) as that of the surrounding normal parenchyma.

isotropic

Having nondirectional properties (ie, physical properties that are independent of direction). For example, the speed of sound is not a function of the direction of propagation through an isotropic material. In contrast, the velocity of sound in muscle differs when propagating parallel to the fibers than when propagating at a right angle to the fibers; thus, muscle is anisotropic.

J

jail bar artifact

A lack of color along some image lines due to power Doppler signal saturation after contrast medium injection.

jet

A region of very high blood flow velocity such as that extending downstream from vessel stenosis.

jitter

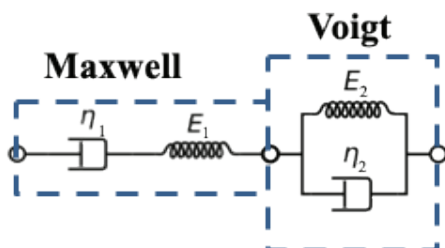
Small rapid irregularities in a waveform or an image display due to electronic noise, a mechanical disturbance, the supply voltage, changes in properties of components, etc.

joule (J)

A unit of energy. One joule is the amount of energy required to move an object with a force of 1 newton (N) over a distance of 1 m. $4.18 \text{ J} = 1 \text{ calorie}$.

Kelvin model

A p model of a material that can be represented by a dashpot η and a purely elastic spring E_2 connected in series in parallel with a second elastic spring E_1 , as shown in the diagram below.



Related terms: Burgers model, dashpot, elastic spring, Maxwell model, Kelvin model, Kelvin-Voigt model, standard linear viscoelastic model, Voigt model

Kelvin-Voigt model

The preferred name of this viscoelastic model is the Voigt model.

See *Burgers model, Maxwell model, Kelvin model, standard linear viscoelastic model, and Voigt model.*

kerf

A width of the groove or slit between adjacent elements in an array transducer.

kHz

Abbreviation for kilohertz (1000 Hz).

kinetic energy

The energy that a body possesses because of its motion; in classical mechanics, it is equal to one half of the body's mass times the square of its speed.

knobology

Deprecated term referring to the knowledge required for the proper setting of the control settings of an ultrasound scanner.

Related term: control settings

laminar flow

Flow in which there is smooth and gradual variation of velocity with position. Flow may be thought of as comprising a series of individual laminae, each moving at one velocity, with viscous cohesion maintaining the flow of adjacent laminae at nearly the same velocity.

late phase of enhancement

See *parenchymal phase of enhancement* and *sinusoidal phase of enhancement*.

Related terms: *parenchymal phase of enhancement, sinusoidal phase of enhancement*

lateral gain control (LGC)

A means of altering receiver gain with the lateral position in the image. This is often used to compensate for a loss in echo amplitude arising from anisotropic attenuation properties.

lateral resolution

The minimum separation between two equally reflecting point reflectors in a direction perpendicular to the beam axis at which the individual reflectors can be distinguished in the image display. Alternatively, the distance, across the principal acoustic axis, between the two points farthest on each side from the point of maximum response at which the response of a pulse echo system is at a specified level, such as -6 dB relative to the maximum.

Related term: Compare with *azimuthal resolution*

lateral strain elastogram

An elastogram that depicts the distribution of the lateral strain.

LCD monitor

See *liquid crystal display monitor*.

lead metaniobate

A ferroelectric ceramic used for piezoelectric elements in transducer assemblies. The abbreviation is PbNiO.

lead zirconate titanate

A ferroelectric ceramic used for piezoelectric elements in transducer assemblies. The abbreviation is PbZrTiO.

lens

An object that produces the focus or divergence of an ultrasound beam by refracting the acoustic rays. Most lenses in diagnostic imaging are used to bring an ultrasound beam to a focus at a desired point in the body. Lenses in therapeutic ultrasound are used to focus the ultrasound beam on the desired target to concentrate energy on the therapeutic target and minimize the energy applied to surrounding normal tissue. An acoustic lens can be simulated by electronically delaying echo signals arriving at or emitted by various transducer elements (see Figure 36).

Related term: *focused ultrasound*

light-emitting diode display

An electronic display that uses light-emitting diodes (LEDs). Light-emitting diodes are semiconductor light sources that emit light when activated.

Related terms: Contrast with *cathode ray tube, liquid crystal display, plasma monitor*

lighthouse artifact

See *comet tail artifact* (see Figure 23).

limiting

A technique that does not permit a voltage level to exceed a specified value. This may be an inherent limitation of a component or a system rather than a technique per se.

linear amplification

Amplification where the output signal is proportional to the input signal.

linear amplifier

An amplifier for which the output amplitude varies linearly with the input amplitude over a considerable range of the input signal.

linear array

A transducer assembly consisting of transducer elements arranged in a row, which can be electrically configured to control the characteristics and scanning of acoustic beams along the array length. With linear arrays, the beam axis is translated sequentially along the array (see Figure 27).

Related term: Compare with *phased array*

linear scan

The motion of an ultrasound beam axis along a straight line, usually at right angles to the beam.

line density

Number of scan lines per unit length or angle used in formation of an image.

line spectrum

Spectrum containing only discrete frequency components.

liquid coupling

A technique using a liquid, such as water, to couple the transducer to the object.

Related term: *coupling method*

liquid crystal display monitor

Monitor containing a liquid crystal display (LCD) to view data or images. In an LCD, a liquid crystal is positioned between sheets of polarizing material. Passage of light through spots on the material is controlled by an electric charge that can be stored in tiny components positioned adjacent to the material. Some LCD displays are used for soft menu control of the device.

Related terms: Contrast with *cathode ray tube*, *light-emitting diode display*, *plasma monitor*

lithotripsy

The use of high-pressure ultrasound waves to break up kidney stones and gallstones.

liver-specific (late) phase of enhancement

See *parenchymal phase of enhancement*.

loaded acoustic impedance

Input acoustic impedance of an electroacoustic transducer, when the electric output is connected to a normal load.

logarithmic amplifier

An amplifier for which the output is proportional to the logarithm of the ratio of an input voltage and a reference voltage. Logarithmic amplifiers selectively enhance the distinguishability of small echoes in grayscale displays.

logarithmic decrement

Natural logarithm of the ratio of any two successive maxima of like sign in the decay of a single-frequency oscillation.

logarithmic frequency interval/interval

Logarithm of the ratio of two frequencies.

longitudinal

Parallel to the beam axis or to the long axis of the body or other object of interest: eg, a longitudinal scan or longitudinal sound wave.

longitudinal image plane

Any image plane that passes through or is parallel to the long axis of the body. Sagittal and coronal planes are both specific types of longitudinal image planes (see Figure 1).

longitudinal plane

A plane containing the beam axis. It is defined by the beam axis and a specified orthogonal axis.

longitudinal resolution

See axial resolution.

longitudinal wave

Wave motion for which the particle displacement in the medium is parallel to the direction of wave propagation.

lossless medium

A medium that is nonattenuating.

lossy

An adjective describing a material that attenuates an ultrasound wave.

low-flow lesion

A lesion showing very slow enhancement over time.

M

macrocirculation (tumor)

Major intranodular vessels seen as discrete hyperechoic (hyperenhanced) vessels on contrast-enhanced scans.

magnetic resonance-guided focused ultrasound

A technology that combines magnetic resonance imaging to guide focused ultrasound energy for the treatment of deep tissue.

main lobe

Region of strong acoustic pressure or response centered on the beam axis (see Figure 10).

Maltese cross artifact (elastography)

A fanning crosslike pattern of strain concentrations and dilutions that surrounds a circular or spherical inclusion in a medium.

manual scanning

See freehand scanning.

marginal enhancement

Similar to rim enhancement but with a rim particularly irregular and thick. A feature of hypovascular metastasis.

mass density

Amount of mass of a material per unit of volume. The unit is kilogram per cubic meter (kg/m^3).

matched filtering

In signal processing, the practice of correlating a signal with a known template to detect the presence of the template in the signal. Matched filters are commonly used after coded excitation or chirp transmit pulses to produce short-duration high-amplitude echo signals with a high signal-to-noise ratio from these pulses. The filter template is derived from the code or chirp pulse.

matching layer

One or more layers of material applied to the radiating surface of a transducer with the intent of optimizing the acoustic impedance match between the transducer material and the subject. Energy transmission is optimized by choosing the impedance of the matching layer(s) to be the geometric mean(s) of the impedances of the adjoining media and the thickness of the matching layer(s) to be one-quarter wavelength in each layer.

matrix

A rectangular arrangement of elements or numbers in columns and rows.

matrix array

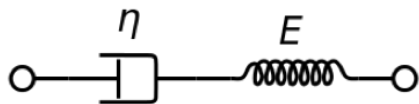
Transducer containing a 2-dimensional array. In general, these arrays can be other shapes than rectangular and not completely filled in as in a sparse array.

matrix element

Array element in a matrix array.

Maxwell model

A viscoelastic model of a material that can be represented by a dashpot η and a purely elastic spring E connected in series, as shown in the diagram below.



Related terms: Burgers model, dashpot, elastic spring, Kelvin model, Kelvin-Voigt model, standard linear viscoelastic model, Voigt model

mean peak cycle acoustic pressure

The arithmetic mean of the maximum positive and modulus of the maximum negative instantaneous acoustic pressure during a pulse peak cycle. The unit is pascal (Pa).

mechanical coupler

Device of predetermined mechanical impedance used for the calibration of a bone conduction vibrator or bone vibrator in conjunction with a calibrated microphone adapted to measure the pressure developed within the cavity.

mechanical impedance

Quotient of a force applied to a linear mechanical system, by the resulting velocity in the direction of the force, at its point of application. Note: In the case of torsional mechanical impedance, the words "force" and "velocity" are replaced by "torque" and "angular velocity."

mechanical index (MI)

A dimensionless number used to represent the likelihood of an ultrasound-induced bioeffect caused by a mechanical process such as cavitation. It is equal to the ratio of the maximum negative derated negative pressure maximum amplitude, $Pr.3$, to the square root of the frequency in megahertz, f_c .

$$MI = \frac{Pr.3}{\sqrt{f_c}}$$

mechanical reactance

Imaginary part of mechanical impedance.

mechanical resistance

Real part of mechanical impedance.

mechanical sector scanner

Scanning device in which the transducer is mechanically rotated, or pivoted, producing a fan-shaped movement of the ultrasound beam.

mechanically swept scanning (3-dimensional)

Acquiring a volume of echo information through motorized movement of the transducer to control the positions of the acquisition planes.

Related term: Contrast with *electronically swept scanning*

medical diagnostic ultrasonic system

The combination of the ultrasound instrument console and associated transducer assembly(ies).

medium

Any material through which a sound wave travels.

microbeamformer

A beamforming method by which fine delays are applied to subgroups of (2D) array elements and summed prior to the application of coarser delays to each subgroup.

microbubble

A small gas bubble, usually with a diameter in the 1- to 20-micrometer (μm) range. May be used as an ultrasound contrast agent.

microbubble cavitation imaging

An ultrasound imaging technique used to visualize cavitation (inertial or noninertial).

microcirculation (tumor)

Tumor microvessels developing as a consequence of neoangiogenesis. These vessels have a diameter of 2 to 5 μm , which is below the resolution threshold of all in vivo imaging modalities, contrast-enhanced sonography included. Contrast-enhanced grayscale sonography can detect a signal from small vessels below the resolution of unenhanced sonography and Doppler techniques. Contrast-enhanced grayscale sonography allows demonstration of tumor enhancement, but it should be always remembered that this only indirectly reflects the tumor microcirculation.

micrometer

A unit of length equal to 1 millionth of a meter, formerly called a micron. The abbreviation is μm . Also, a device for the precise measurement of small distances, typically within $\pm 1 \mu\text{m}$.

microparticle

A solid or liquid particle with a diameter in the micrometer range, typically 1 to 10 μm . May be used as an ultrasound contrast agent or for drug delivery.

microphone

Electroacoustical transducer by which electrical signals are obtained from acoustical oscillations.

microspheres

Small spherical bodies comprising solid, liquid, or gas, or some combination of these, usually with diameters measuring several micrometers. Microspheres may be used to enhance diagnostic imaging, to promote cavitation for therapeutic purposes, to deliver drugs or genetic material to specific locations, or for other medical reasons.

microstreaming

Small-scale eddy currents or flow in the neighborhood of ultrasonically driven oscillating bubbles.

microvascular imaging

A technique for improving depiction of small capillary vessels with a low concentration of a contrast medium.

mirror image artifact (Doppler)

The appearance of Doppler spectral components on the “wrong” side of the zero-flow baseline, so that flow spectra in both directions are mirror images of each other. Caused by a Doppler angle of 90° , by technical deficiencies in the Doppler demodulator, or by overload of the equipment.

mirror image artifact (imaging)

A multiple-path reflection artifact in which the sonographic image of a structure is duplicated in a different location and appears as a mirror image of the original (see Figure 21).

mirroring

See *mirror image artifact (Doppler)*.

mixer

A device that combines two or more signals. In ultrasound instrumentation, mixers multiply two signals to obtain one signal, which contains both the sum and the difference of the two input frequencies.

M-mode (motion mode)

A method of display in which the tissue interface position is displayed along one axis and time is displayed along the second axis. The M-mode is used frequently to display echocardiographic data in which heart wall motion and valve motion are displayed as functions of time.

mode conversion

A change of one type of acoustic wave to another. For example, the change from a longitudinal wave to a transverse wave (or a shear wave), and vice versa, when an acoustic wave traverses a boundary between two objects with different material properties.

mode of oscillation

See *mode of vibration*.

mode of vibration

A state of motion of a freely vibrating system (not driven) in which all moving parts of the system are oscillating in phase with the same frequency. A mechanical system usually can exhibit many such states of motion, each with its own frequency. The fundamental and harmonic frequencies of a violin string correspond to such a mode of vibration.

modulus

Magnitude of a quantity, the absolute value. An additional meaning is the ratio of stress to strain in an elastic or a viscoelastic medium, as in Young's modulus.

modulus of rigidity

See *shear modulus*.

molecular imaging

A class of noninvasive imaging methods to visualize and characterize both normal and pathologic processes with a living organism at the cellular and subcellular levels.

molecular ultrasound imaging

An ultrasound-based imaging method that uses a target-specific microbubble to noninvasively locate and characterize both normal and pathologic processes within a living organism at the cellular and subcellular levels.

See *molecular imaging*.

monochromatic

Having a single frequency (from analogy with light).

monopole

See *point source of sound*.

monostable multivibrator

An electrical device or circuit that produces a second pulse at a known delay following the application of a triggering pulse.

mosaiclike enhancement

Term derived from computed tomographic terminology to indicate patchy enhancement. A type of inhomogeneous enhancement.

ms⁻¹

Abbreviation for meters per second.

multi-D array

A transducer array in which transducer elements are arranged in multiple rows.

multielement transducer

A configuration of two or more transducer elements within dependent electrical addressability (see Figures 19 and 27).

multifocusing

Ability of scanners employing array transducers to position the transmission or reception focus by software control or to use more than one transmitted focus at a reduced frame rate.

multigate pulsed Doppler system

Pulsed Doppler system enabling velocity measurement at several depths simultaneously.

multiplanar

Refers to or consists of several orientations. In 3-dimensional imaging, it refers to the simultaneous display of two or more orthogonal planes.

N

nanoparticle

A solid or liquid particle with a diameter in the nanometer range, typically 1 to 500 nm. May be used as an ultrasound contrast agent or for drug delivery.

narrow-bandwidth

An adjective referring to the ability of a device to pass only a very limited range of frequencies in a signal. The resulting frequency spectrum usually consists of a single narrow peak.

narrow-bandwidth transducer

A transducer with a bandwidth that is less than 15% of its center frequency.

natural focus (archaic)

Related and current term: beam minimum

natural frequency

Frequency of a freely oscillating (undriven) system. For a multiple-degree-of-freedom system, the natural frequencies are the frequencies of the normal modes of oscillation.

Navier-Stokes equations

A set of equations that describe the motion of fluid substances such as liquids and gases. These equations establish that changes in momentum (acceleration) of fluid particles are simply the product of changes in pressure and dissipative viscous forces (similar to friction) acting inside the fluid. These viscous forces originate molecular interactions and dictate how sticky (viscous) a fluid is. Thus, the Navier-Stokes equations are dynamic statements of the balance of forces acting at any given region of the fluid.

near field (Fresnel zone)

For a nonfocusing transducer, the region within the transition distance from the transducer in a specified longitudinal plane. This region of the ultrasound field undergoes rapid fluctuations in the shape of the beam near the transducer. The region of the acoustic field close to the transducer (colloquial). For a given frequency, the near field is the region closest to the transducer, characterized by its inhomogeneity and where the particle velocity and instantaneous acoustic pressure are not in phase. For a circular transducer, the transition from the near field to the far field occurs approximately at a range of r^2/λ , where r is the radius of the transducer, and λ is the wavelength. For planar transducers, this is at a distance less than $A/\pi\lambda$, where A is the effective area of the transducer (see Figure 3).

Related terms: transition distance; contrast with far field

near Fresnel zone (archaic)

See preferred term: prefocal zone (see Figure 3).

near gain

Amplification of echo signals arising from structures close to the transducer. These signals tend to be larger than those received from more distant structures because of attenuation in the propagating medium.

near point

The near point of a transducer or transducer assembly is the point in the source aperture plane for which the integral over the source plane of the product of the acoustic pressure and the vectorial displacement from that point is zero. For a transducer or a transducer assembly with an active transducer aperture with symmetry in the source aperture plane, the near point is in the center of the source aperture.

near sound field

See near field.

near transition distance

The distance past which the focal zone begins for a focusing transducer (see Figure 6).

Related terms: far transition zone, focal zone, prefocal zone, postfocal zone

neper

A logarithmic unit used for expressing the amplitude ratio of two quantities having the same units. If the two amplitudes are A_1 and A_2 , then the corresponding number of nepers is $\ln(A_1/A_2)$. The symbol $\ln$ is the logarithm to the base e (1 neper [Np] = 8.686 decibels [dB]).

neurosonography

Ultrasound imaging of the nervous system.

newton

A unit of force. One newton is the force required to cause an object with a mass of 1 kg to accelerate at a rate of 1 m/s². The abbreviation is N.

newtonian fluid

An incompressible fluid in which the viscosity is constant. Consequently, the shear stress at any point is proportional to the rate of strain.

node

Point, line, or surface in a standing wave where some specified characteristic of the wave field has essentially zero amplitude. In practice, this amplitude is generally not zero but simply a minimum. The node is then said to be partial. The appropriate modifier should be used before the "node" to signify the type that is intended: eg, displacement node, particle velocity node, or sound pressure node.

nodule-in-nodule appearance

Postcontrast recognition of a nodule of different (usually increased) echogenicity within a larger one.

noise

Unwanted and usually random signals.

noise (digitization)

See *digitization noise*.

noise (electrical)

Noise signals that are present in electrical circuits even in the absence of intended signals.

noise (quantization)

The noise introduced when a continuously varying (analog) signal is converted into discrete values (a digital signal). The amplitude of this noise is equal to the difference between the amplitudes of the analog and the digital signals.

noise (thermal)

Electric noise produced by thermal agitation of electrons in conductors and semiconductors. Also known as Johnson noise or resistance noise.

nominal frequency

A convenient value used to represent the actual frequency or frequencies emitted by a transducer. The nominal value is usually specified by a manufacturer and is approximately equal to the actual value.

nonfocusing transducer

A transducer that does not produce a focused field (see Figures 2 and 3).

noninertial cavitation

Any form of cavitation that is not inertial. It includes various types of sonically induced activities involving bubbles or gas bodies such as translational motions, surface distortions, jet formations, rectified diffusion, and acoustic microstreaming. In contrast to inertial cavitation, free radicals are not produced, and temperature and pressure elevations are much lower.

Related term: inertial cavitation

nonlinear

A condition in which the amplitude of the output or response of a system or medium is not proportional to the input signal.

nonlinear amplification

Amplification in which the output signal is not directly proportional to the input signal. An example is logarithmic amplification.

nonlinear mode

Sonographic techniques detecting and forming images using nonlinear components of echoes. Opposite to the fundamental mode, in which a linear portion of the response is used to form the image.

nonlinear propagation

Passage of a sound wave in which the waveform becomes progressively distorted due to the medium. This usually occurs when the amplitude of the sound wave is large.

nonlinear propagation parameter

An index that indicates the degree of distortion of an ultrasound wave due to nonlinear propagation. This parameter will vary with the propagation medium.

nonlinearity

A relationship between two variables in which each one is not proportional to the other.

nonscanning mode

A mode of operation of a system that is restricted to one acoustic path. M-mode and pulsed Doppler are examples of nonscanning modes.

normal

(1) At right angles, eg to a line or surface. Synonym: perpendicular. (2) Usual, typical, expected, or standard.

normalized cross-correlation function

The cross-correlation function whose amplitude is normalized by the square root of the product of the autocorrelation functions of the respective signals.

normal mode of oscillation

Assuming sufficiently small displacements, this is a free (undriven) characteristic oscillation of a mechanical system in which all parts oscillate at the same frequency, called the natural frequency of the normal mode of oscillation. For a given system, there can be more than one normal mode of oscillation, each mode having a natural frequency generally different from that of any other normal mode of vibration of the system. For sufficiently small time-dependent displacements, any motion of a system corresponds to a linear superposition of its normal mode oscillations.

Nyquist criterion

The requirement that a band-limited signal can only be unambiguously represented by instantaneous samples if the sampling frequency is more than twice the maximum frequency present in the spectrum of the signal.

Related term: sampling theorem

Nyquist limit

The highest frequency in a waveform that can be represented unambiguously by a sampled signal, equal to one half of the sampling frequency. In Doppler systems, this is one half of the pulse repetition rate when detecting flow in both directions.



offset distance

The distance between the near point of a device and its active transducer aperture, measured along the beam axis (see Figures 2, 7, and 9).

off time

The duration of time that an acoustically coupled transducer is not emitting sound. For pulsed systems, it is the sum of the time intervals between pulses during the total time that the transducer is acoustically coupled to the subject or object of interest.

Related terms: Contrast with *duty factor*, *echo listening time*, *on time*

Ohm's law

The relationship between voltage, V , and current, I , usually given for a resistance load, R : $V = IR$.

omnidirectional hydrophone

Hydrophone the response of which is substantially independent of the direction of sound incidence.

Related term: Contrast with *directional hydrophone*

on time

The time in which the transducer is actively emitting sound. For pulsed systems, it is the sum of pulse durations during the total time that the transducer is acoustically coupled to the subject or other object of interest.

Related terms: Compare with *duty factor*, *echo listening time*, *off time*

opacification

Increased level of ultrasonic backscatter (image brightness) often associated with the presence of an ultrasonic contrast agent.

opacification

Term derived from x-ray terminology. Increased echogenicity should be termed enhancement and not opacification.

open-circuit mechanical impedance

Input mechanical impedance when the electric output is connected to an infinite load: an open circuit.

operating condition

Any unique combination of control settings for a selected operating mode.

operating mode

Any one or combination of the possible modes of an ultrasound instrument. Examples are A-mode, M-mode, B-scan, pulsed Doppler, and duplex mode.

optical density

Logarithm of the ratio of light intensity falling on photographic film material and transmitted intensity. It is defined as $\log_{10}(I_{inc}/I_{trans})$, where I_{inc} is the light intensity incident, and I_{trans} is light intensity transmitted through the film.

optical hydrophone

A hydrophone whereby the sensitive element for measuring ultrasound pressure is an optical glass fiber. The ultrasound signal is detected by pressure-induced changes in the optical properties of the fiber. It is used for measuring high pressures such as those used in therapeutic ultrasound.

output beam area

Area of the ultrasonic beam derived from the output beam dimensions. The unit is square centimeter (cm²).

output beam dimension

Dimension of the ultrasonic beam (eg, -6-dB pulse beamwidth) in a specific direction normal to the beam alignment axis at the transducer output face. The unit is millimeter (mm).

output display standard (ODS)

Also known as the standard for real-time display of thermal and mechanical indices on diagnostic ultrasound equipment. It provides a method for visual feedback on diagnostic ultrasound imaging systems of the potential for bioeffects through thermal and mechanical indices displayed on the imaging screen for the particular control settings selected to implement the ALARA principle. The ODS provides visual feedback on diagnostic ultrasound imaging systems of the potential for the induction of adverse biological effects. The likelihood of an adverse bioeffect occurring because of a thermal mechanism is indicated by a thermal index (TI), and the likelihood of an adverse bioeffect due to a nonthermal mechanism, such as cavitation, is indicated by a mechanical index (MI) (AIUM/NEMA, 1998).

Related terms: thermal index (TI), mechanical index (MI), ALARA principle

output power

Time-average ultrasonic power radiated by an ultrasonic transducer. The unit is watt (W).

overall gain (general engineering)

The gain of an entire system. The overall gain (in decibels [dB]) equals the sum of the individual gains (in dB) of each of the system's individual components.

overall gain (ultrasound)

Amount of amplification applied to echo signals over the entire field of view. In most systems, overall gain can be varied by the operator using a single control; it differs from time-gain compensation, where gain varies with depth in the image, and lateral gain compensation, where gain varies with lateral position in the image.

overshoot

Those portions of a transient signal whose magnitudes are greater than the steady-state value (see Figure 13).

P

Pa

The abbreviation for pascal.

Related term: pascal

packet length

See *ensemble length*.

PACS

Abbreviation for picture archiving and communication system. PACSs are designed to digitize, store, archive, retrieve, display, and communicate images.

parallel receive beamforming

The parallel processing of incoming signals from different receive elements of an array to form multiple beams from the same data.

Related terms: beamforming, pulse echo

parametric imaging

Depiction of different quantitative levels of a parameter in a color scale according to their value. In contrast-enhanced sonography, parametric imaging is used to depict the different values of flow or perfusion magnitude in the different parenchymal regions. Also called color coding.

parasagittal plane

A plane parallel to the sagittal plane.

Related term: sagittal plane

parenchymal phase of enhancement

Some sonographic contrast media show first an intravascular phase and then a more or less pronounced phase of extravascular retention within liver and spleen parenchyma. To image the liver during this phase, scans are taken from 2 to 5 minutes after contrast medium injection up to 6 to 10 minutes, when the enhancing effect vanishes (depending on the type of contrast medium used). The parenchymal phase is also described as "late," "delayed," "liver-specific," or "postvascular," but "parenchymal phase of contrast enhancement" is the most appropriate description.

particle

Any small subdivision of matter. In ultrasonics, the particle is usually taken to have a homogeneous composition and a diameter that is much less than the wavelengths involved.

particle displacement

Instantaneous displacement of a particle from its mean position.

particle velocity

Derivative with respect to the time of particle displacement.

pascal

The unit for pressure. One pascal equals 1 N/m². The abbreviation is Pa.

Pascal's law

The statement that pressure applied to the surface of a fluid is transmitted unchanged to all parts of the fluid.

peak compressional pressure (pc)

The spatial-peak temporal-peak positive pressure amplitude (see Figure 32).

Related term: peak positive pressure

peak instantaneous intensity

See this entry under *intensity*.

peak intensity

See this entry under *intensity*.

peak negative (or peak rarefactional) acoustic pressure

The maximum of the modulus of the negative instantaneous acoustic pressure in an acoustic field or in a specified plane. Peak negative acoustic pressure is expressed as a positive number. The unit is pascal (Pa). The symbol is p_- (or p_r) (see Figure 32).

Related term: peak rarefactional pressure

peak particle displacement

Greatest instantaneous particle displacement during a given time interval.

peak positive (or peak compressional) acoustic pressure

The maximum positive instantaneous acoustic pressure in an acoustic field or in a specified plane. The unit is pascal (Pa). The symbol is p_+ (or p_c).

Related term: peak compressional pressure

peak rarefactional pressure (pr)

The spatial-peak temporal-peak negative pressure amplitude.

Related term: peak negative pressure

peak sound pressure

Greatest absolute value of instantaneous sound pressure during a given time interval.

penetration

See *depth of penetration*.

perfect reflector

A planar interface for which the reflection coefficient equals 1.

Related term: scan plane

perfusion

Total blood flow, including capillary flow, to an organ. Perfusion of a tumor includes its microcirculation, but it is not a synonymous term.

perfusion defect

An area of poor or absent enhancement within parenchyma due to infarction or ischemia, appearing within normally enhanced surrounding parenchyma.

perfusion imaging

Imaging of flow at the capillary level. Usually used as synonymous with continuous mode, allowing real-time demonstration of parenchymal and lesional perfusion.

peripheral enhancement

An enhancement pattern found in ultrasound images such as near or at an outer tissue or tumor boundary.

persistence

The degree to which images or other data acquired sequentially in time are combined or averaged. Persistence can reduce the appearance of speckle and other variations, such as noise, in the displayed image or data. Also referred to as frame-to-frame averaging.

phantom

A device that simulates some parameters of the human body, allowing measurements of ultrasound system parameters or visualization of simulated anatomic features. Phantoms are useful for assessing the clinical performance of a diagnostic or therapeutic ultrasound system and for teaching.

phantom, Doppler

A phantom designed to provide an acoustic simulation of biological tissue containing moving scatterers, usually blood.

phase

The fraction of the period of a periodic signal that has elapsed relative to a specified origin. The origin is usually taken to be the last previous passing through zero amplitude from the negative to the positive direction.

Related term: Compare with *phase angle*

phase angle

The measure of progression of a periodic signal in time or space from a specified origin. The phase angle is obtained by multiplying the phase by 360° or by 2π radians. The unit is degree or radian.

Related term: Compare with *phase*

phased array

A transducer configuration that consists of multiple independent elements that can be controlled individually. Using proper time delays of the excitations, a wavefront of a desired configuration can be synthesized. Phased arrays are used for electronic beam steering and dynamic focusing (see Figure 35).

Related term: *transducer element*

phase difference

The difference between the phase angle of a sinusoidally varying quantity and the phase angle of a second quantity that varies sinusoidally at the same frequency. The unit is degree or radian.

Related terms: Compare with *phase*, *phase angle*

phase domain processing

Any signal-processing scheme that operates on signals according to their phases.

phase inversion imaging

See *pulse inversion imaging*.

Related term: *pulse inversion imaging*

phase quadrature processing

A signal-processing technique using a reference sinusoidal signal and another reference signal equal to the first but shifted through 90° of phase angle. The input signal is then multiplied by each reference signal.

phases of contrast enhancement

In dynamic computed tomography and magnetic resonance imaging, the concept of phase is limited to the peak of enhancement in a given phase of contrast-enhanced blood distribution. In contrast-enhanced sonography, instead, the term "phase" refers to the entire duration of a given phase. Particularly for the liver, which has a double blood supply system, there is partial overlap between the final part of the arterial phase and the initial part of the portal phase, the latter starting when the enhancement of portal branches starts. For the liver, phases for contrast-enhanced sonography should be termed as "arterial" (vascular, ranging approximately from 15 to 40 seconds after peripheral contrast medium injection), "portal sinusoidal" (vascular, ranging approximately from 40 to 300 seconds after contrast medium injection), and eventually "parenchymal" (postvascular, for those contrast media showing late intraparenchymal uptake, lasting up to 10 minutes after contrast medium injection).

phase-change contrast agents (PCCAs)

A class of ultrasound contrast agents that exist as encapsulated liquid droplets under ambient conditions but are triggered (activated) using ultrasound energy to undergo phase transition into gaseous microbubbles that are suitable for both intravascular and extravascular ultrasound imaging studies.

phase shift

A change in the phase of a signal or in the phase difference between two signals.

phase tracking

A technique for following changes in the phase of a signal.

phase velocity

The velocity of a point that moves with a wavefront in the direction of propagation in such a way that the phase at the point is constant.

photoacoustic effect

The generation of sound waves in a material by the absorption of light.

photoacoustics

A method for imaging opaque (and biological) systems using the photoacoustic effect. Photoacoustic contrast is mainly determined by contrast in the optical absorption coefficient. It is often applied to the visualization of vessels because of the high optical absorption of blood.

Related term: thermoelastic expansion

piezoelectric effect

The property of some materials by which a mechanical deformation produces an electrical voltage across the material and vice versa. The production of voltage by the application of mechanical stress is called the direct piezoelectric effect. The production of a mechanical deformation by an applied voltage is called the reverse piezoelectric effect. The direct piezoelectric effect is used in the detection of ultrasound echoes, and the indirect piezoelectric effect is used in the generation of ultrasound pulses.

pink noise

Noise whose power spectral density is inversely proportional to frequency.

pitch

(1) Distance between adjacent array elements. (2) The perceived apparent frequency of a sound.

pixel

A contraction of “picture element.” It is the smallest spatial unit or cell size of a digitized 2-dimensional array representation of an image. Each pixel has an address, (a set of x- and y-coordinates corresponding to its position in the array) and a specific brightness level.

plane

A flat surface.

plane strain

Strain that is confined within a plane.

plane stress

Stress that is confined within a plane.

plane wave

Wave in which the wavefronts are parallel planes normal to the direction of propagation.

Related terms: plane wave angular compounding, plane wave imaging

plane wave angular compounding

An ultrasound imaging technique that uses a collection of unfocused plane wave transmissions over a range of angles to form a composite ultrasound image frame after summation.

Related terms: plane wave, plane wave imaging

plane wave imaging

A fast ultrasound imaging technique that uses plane wave transmission to form an ultrasound image.

Related terms: plane wave, plane wave angular compounding

plasma monitor

Monitor containing many tiny cells in the screen, each having an inert mixture of a noble gas such as neon or xenon. When an electrical signal representing the brightness or color of a spot on the image is applied, the gas in the cells is turned into a plasma, that is, an ionized gas, which excites phosphors that emit light.

Related terms: Contrast with cathode ray tube, light-emitting diode display, liquid crystal display monitor

plug flow

A region of flow with a flat velocity profile, ie, in which nearly all the flow is at a single velocity, except for the boundary layer.

pocket ultrasound device

A complete ultrasound imaging system, with display, small enough to fit easily in the palm of a hand.

pod

An incorrect, but frequently used, term for a potentiometer.

point source of sound

Source that is small compared to the wavelength that radiates sound equally in all directions in a free field.

Related term: Huygen's principle

point spread function

The output response of a system to a point source is a point spread function. This is a convenient characterization of an imaging system. The combined spatial and temporal response of a system or the beamforming part of an ultrasound system in three dimensions to a point scatterer. Pulse envelopes along the time axis of propagation are measured in two spatial dimensions (usually azimuth and elevation) perpendicular to the pulse.

Related terms: azimuth axis, diffractive scattering, diffusive scattering, elevation axis, specular scattering, specular reflection

point-of-care ultrasound

The use of a mobile ultrasound device where it is needed such as at a patient's bedside or a physician's office for imaging or therapy, or even outside the clinical environment.

point scatterer

A scattering object that is much smaller than the insonifying acoustic wavelength. A point scatterer scatters sound equally in all directions.

Related terms: diffractive scattering, diffusive scattering, specular scattering, specular reflection

poise

The cgs unit of viscosity. One poise is equal to 10 pascal seconds (Pa · s).

Poiseuille flow

The steady flow of an incompressible fluid parallel to the axis of a long circular vessel. It is produced by a pressure gradient along the vessel. The flow velocity is greatest in the center and is zero at the vessel wall, resulting in a parabolic velocity profile.

Related terms: velocity profile, parabolic

Poiseuille, Jean Leonard M. (1797–1869)

French physician and physicist who performed the first experiments demonstrating viscosity in a fluid and its relationship to the pressure gradient in a tube. Poiseuille also refined the techniques of Hales for measuring pressure in the arterial circulation.

Poiseuille's law

The law stating that the volume flow of an incompressible fluid, such as blood, through a circular tube is proportional to the pressure difference between the ends of the tube times the fourth power of the tube's radius divided by the product of the tube's length and the viscosity of the fluid. The equation is $F = [\pi \cdot (P_1 - P_2) \cdot r^4] / [8 \cdot L \cdot \eta]$, where F is the volume flow, P_1 is the pressure at the beginning of the tube, P_2 is the pressure at the end of the tube, r is the tube radius, L is the length of the tube, and η is the viscosity of the fluid.

Poisson elastogram

An elastogram depicting the distribution of Poisson's ratio in a medium.

Poisson's ratio

The fractional reduction in width divided by the fractional increase in length when a material is subjected to a tensile stress. The ratio between the lateral and axial strain in a medium.

polar coordinates

A point in a plane can be represented by coordinates (r, Θ) , where Θ is the angle between the positive x-axis of a cartesian (x, y) system and the line from the origin to the point, and r is the length of that line; r and Θ are the polar coordinates of the point.

poling

A means of conferring piezoelectric properties by alignment of the dipoles in a suitable material through the application of an electric field while the temperature of that material is raised above the Curie point and then lowered below it.

poro-elasticity

The property of a material that is both porous and elastic.

portable imaging systems

Imaging systems that can be easily transported.

portal venous phase of enhancement

The phase of contrast medium circulation when contrast-enhanced blood reaches the liver through the venous portal system (from 40 to 50 seconds after contrast medium injection to 100 to 120 seconds after contrast medium injection). Since the liver has a double feeding system, arterial and portal, the portal phase of enhancement is not exactly the same concept as the venous phase in other organs. This is the phase when liver parenchyma (properly, small intrahepatic portal vessels) reaches its peak of enhancement.

position-sensed freehand scanning (3-dimensional)

Acquiring a volume of echo information through manual movement of the transducer without restriction on the possible motion while sensing the position of the image plane to provide geometrically accurate reconstruction.

postfocal zone

The region beyond the focal zone for an ultrasonic focused transducer in a specified longitudinal plane (see Figures 3–5).

postnatal

See *postpartum*.

postpartum

The period beginning immediately after birth and lasting 6 weeks. Also called the postnatal period.

postprocessing

Processing of image data after it has been assembled and stored in a 2- or 3-dimensional format and before display on the monitor.

postvascular phase of enhancement

Some sonographic contrast media show first an intravascular phase and then a more or less pronounced phase of intraparenchymal accumulation.

See *parenchymal phase of enhancement*.

potential energy

The capacity to do work that a body or system has by virtue of its state, position, or configuration.

Related term: Compare with *kinetic energy*

potentiometer

A device for changing and controlling electrical resistance. It consists of a resistor having a continuously adjustable sliding contact. Also known as a pot (archaic slang as this slang term now is used to refer to marijuana).

Pourcelot's index

See *resistive index*.

power

The rate of doing work per unit time. The unit of power is the watt (W), and $1\text{ W} = 1\text{ joule per second (J/s)}$.

power cross-spectrum

The spectral density of two real or complex input signals usually computed in the frequency domain by various methods such as taking the Fourier transform of the cross-correlation functions of two signals. It is used for estimating attenuation from backscattered ultrasound signals.

power Doppler

A Doppler imaging mode in which the signal displayed is based on an estimate of the integrated Doppler signal power over a period of time at a given position. The signal represents the energy in the Doppler signal and is usually displayed in color. This value is related to the volume of blood present in the resolution volume, rather than its velocity.

power Doppler imaging

A form of pulsed Doppler in which a large number of estimates of Doppler signal power or amplitude are color coded and overlaid in the location of their detection on the grayscale image. Power Doppler imaging systems operate within the range of "real-time" frame rates. Also referred to as color amplitude imaging.

Related terms: color Doppler imaging, color flow imaging

power modulation imaging

Nonlinear techniques in which two separate pulses are transmitted down each scanning line, the second being at one-half of the acoustic pressure of the first. The second returned signal is doubled and subtracted from the first. The symmetric echoes from linear structures such as tissues cancel each other, whereas those from contrast-induced, harmonic components (nonlinear scattering) produce the image line.

power spectral density

Power per unit frequency interval in a power spectrum. The unit is watt per megahertz (W/MHz).

power spectrum

A frequency distribution of the power contained in a signal. It is often displayed as a graph showing the relative power of each frequency component contained in a signal. One way of calculating power is taking the square of the magnitude of the Fourier transform of the signal. Alternatively, the power spectrum can be calculated as the Fourier transform of the autocorrelation function of the signal.

power-up mode

A defined state of a system corresponding to the mode of operation and system settings automatically established when power to the system is first turned on.

preamp

Abbreviation for preamplifier.

preamplifier

A low-noise amplifier that is connected to a low-level signal source and precedes the main amplifier. It provides amplification and electrical impedance matching with minimal noise.

prefocal zone

The region before the focal zone for an ultrasonic focused transducer in a specified longitudinal plane (see Figures 3–5).

preprocessing

Processing of ultrasound signals before they have been stored in a 2- or 3-dimensional format. In preprocessing, the original sequence in which the signals were received need not be lost.

presets

Preprogrammed operating conditions for specific diagnostic applications.

Related term: operating conditions

pressure

Force per unit area. The unit is pascal (Pa) (see Figures 31 and 32).

Related term: Compare with *acoustic pressure*

pressure amplitude

The value of the envelope of the acoustic pressure oscillation (equals one-half of the peak-to-peak value in case of continuous wave ultrasound. In pulsed ultrasound, pressure amplitude usually refers to the peak value of the envelope (see Figures 26, 31, and 32).

pressure focal area

The area in the pressure focal plane bounded by the locus of all points where the pulse pressure-squared integral is at least one-quarter of that at the pressure focus. If there is more than one closed region defined by these points, only the area of the region containing the pressure focus should be taken.

pressure focal gain

The square root of the pulse pressure-squared integral at the pressure focus divided by the source aperture average pressure.

pressure focal plane

The plane perpendicular to the beam axis that contains the pressure focus (see Figures 2 and 9).

pressure focus

The position of the maximum pulse pressure-squared integral throughout the field (see Figures 2 and 9).

pressure gradient hydrophone

A hydrophone whose output voltage is proportional to the pressure gradient.

pressure gradient microphone

Microphone that responds substantially to the gradient of the sound pressure.

pressure sensitivity

Of a hydrophone, for a given frequency, quotient of the output open-circuit voltage by the actual sound pressure existing over the region of the hydrophone designed to receive sound. Note: The load impedance must be specified if other than open circuit.

pressure waves

See *acoustic waves*.

principal acoustic axis

See *beam axis*.

principal axis

Geometric reference axis passing through the reference point that serves as the origin of angular coordinates for description of directional characteristics of an electroacoustic transducer. The direction of the maximum response at a stated frequency is usually chosen as the principal axis, which is often an axis of geometric symmetry.

probe assembly

An assembly consisting of one or more ultrasound transducers together with the driving mechanism and/or with associated electronics in a single housing.

probe hydrophone

Hydrophone adapted to explore a sound field without significantly disturbing it.

puddle enhancement

See *globular enhancement*.

pulsatility index (PI)

A parameter used to convey the pulsatility of a time-varying waveform such as the Doppler shift frequency of the signal from an artery. Indices of pulsatility are usually ratios of Doppler shift frequencies and are hence, independent of Doppler angle. The most common definition of the PI of a waveform is the difference between the maximum and minimum values divided by the mean value of the waveform over the cardiac cycle. Other types of PIs are also used.

pulse acoustic pressure

The square root of the ratio of the pulse pressure-squared integral to the pulse duration at a particular point in an acoustic field. The unit is pascal (Pa).

pulse-average intensity

See *this entry under intensity*.

pulse beamwidth

See *beamwidth (reception)*, *beamwidth (transmission)*.

pulsed Doppler (range-gated Doppler)

Doppler interrogation using a pulsed mode of transmission. Temporal gating of the returning echoes allows determination of the Doppler shift from within a specific region at a known distance from the transducer. This region is known as the sample volume.

Related term: multigate pulsed Doppler system

pulse duration

Time required for the instantaneous value of an excitation to rise from some stated fraction of its maximum value and to decay to the same fractional value.

pulse echo

A received reflected or backscattered sound signal usually caused by a repetitively transmitted pulse of sound.

pulse-echo imaging

Process of forming a sonogram. Short-duration ultrasound pulses are transmitted into tissue, and echoes from scatterers and reflectors are detected and displayed. At each location on the image, display brightness indicates the echo amplitude from the corresponding location in tissue.

Related term: sonogram

pulse-echo response profile

Graph of an echo signal parameter, such as echo amplitude or frequency content, as a function of the position, relative to the transducer, of a well-defined reflector.

pulse-echo technique

See *echo ranging*.

pulse intensity integral

The time integral of intensity, for any specific point and pulse, integrated over the time in which the envelope of acoustic pressure or hydrophone signal for the specific pulse is nonzero. For a transducer assembly operating in a non-auto-scanning mode, this is equivalent to the product of the temporal-average intensity and pulse repetition period.

pulse length

See *pulse duration*.

pulse (or phase) inversion mode imaging

Nonlinear techniques in which two separate pulses are transmitted down each scanning line, the second being an inverted copy of the first (ie, two pulses phase shifted by 180°). On summation of the two returned signals, the symmetric echoes from linear structures such as tissues cancel each other, whereas those from contrast-induced, harmonic components (nonlinear scattering) are summed to produce the image line. Tissue pulse inversion imaging and contrast-enhanced coded pulse inversion harmonic imaging are both possible. Contrast-enhanced pulse inversion may be used either as a continuous mode or an intermittent mode.

pulse pair covariance

Particular type of autocorrelation processing in which signals obtained from successive pulses are correlated.

pulse-peak cycle

A single cycle of an acoustic pulse waveform between two points of zero instantaneous acoustic pressure. This single cycle is composed of the half-cycle containing the temporal peak acoustic pressure and whichever of the two adjacent half cycles contains the larger peak instantaneous acoustic pressure.

pulse pressure

The difference between the peak systolic and minimum diastolic pressures in the cardiac cycle.

pulse pressure (physiologic)

The difference between the maximum and minimum pressures in the cardiac cycle. It equals the systolic pressure minus the diastolic pressure.

pulse pressure-squared integral

Time integral of the square of the instantaneous acoustic pressure at a particular point in an acoustic field integrated over the acoustic pulse waveform. The unit is square pascal second (Pa²s).

pulse repetition frequency (PRF)

In a pulsed system, the number of ultrasonic pulses emitted by the transducer per second. Typically, the PRF of a diagnostic ultrasound system may be in the range of 0.5 to 15 kHz.

pulse repetition period

The time interval between two successive pulses or tone bursts. The unit is second.

pulse repetition rate

See pulse repetition frequency.

pulse rise time

Interval of time required for the leading edge of a pulse to rise from some specified small fraction to some specified larger fraction of the maximum value.

pulse stretching

Increase in pulse duration due, for example, to the imposition of a bandwidth limitation.

pulse waveform

The amplitude of a sound pulse as a function of time.

pure (sound/tone)

Sinusoidal acoustic oscillation.

push beam

A high-intensity pulsed ultrasound beam that is used to move objects in the direction of beam propagation. The forward motion of the object is caused by the radiation force of the ultrasound beam.

Related term: acoustic radiation force imaging (ARFI)

Q

quadrature

State of being separated in phase by 90° . Also known as phase quadrature.

quadrature signal

A signal derived from the original signal by a Hilbert transform or a 90° phase shift. For example, the quadrature signal of cosine is a sine.

quality factor

A measure of the sharpness of resonance of a system, being 2π times the ratio of the maximum stored energy to the energy dissipated during one cycle. Note: Historically, the letter Q was an arbitrarily chosen symbol to designate the ratio of reactance to resistance of a circuit element. The name "quality factor" was introduced later.

quantization noise

See *digitation noise*.

quarter-wavelength matching

The addition of a layer in front of a transducer with the thickness of the layer equaling one-fourth of the acoustic wavelength within it. This layer is intended to result in the maximum transfer of acoustic power to and from the transducer, thus providing the greatest sensitivity. For example, the impedance of a single matching layer is the geometric mean of the transducer and tissue impedances for maximum power transfer. In more sophisticated transducers, two or more such layers are sometimes used for improved performance.

Related term: matching layer

quartz

A naturally occurring crystal with piezoelectric properties formerly used in the construction of ultrasonic transducers but still used for frequency control purposes.

quasi

An adjective meaning somewhat, to some degree, in some manner, resembling, or having a likeness to.

quasistatic

A description of a condition in which change is so slow that for practical purposes it can be considered stationary or constant in value.

quasistatic elastography

A method for producing an elastogram using slowly applied external forces.

Related terms: elastography, (tissue) sonoelasticity imaging, sonoelastography, transient elastography

R

radial mode

A mode of vibration in a piezoelectric disk in which all particle motions are perpendicular to the axis of symmetry of the disk. It does not contribute to the desired acoustic output of the transducer. Therefore, it is regarded as a parasitic oscillation.

radial scan

An ultrasound image obtained by the 360° rotation of the beam of an endocavitary transducer.

Related term: endoscopic sonography

radial scanning (breast)

A method of orienting and describing the plane of view in breast sonography in which the scan plane is centered on the nipple and is parallel to the chest wall. In radial scanning, the location of an anatomic structure is specified by the radial distance and direction from the nipple and the distance beneath the skin.

Related term: Contrast with *antiradial scanning*

radian

Measure of an angle, expressed as the ratio of the arc length to the radius of a circle. A full circle contains 2π radians; 1 radian = $360^\circ/2\pi = 57.3^\circ$.

radiating area

Total area of the transducer(s) that transmits or receives the ultrasonic radiation.

radiating cross-sectional area

The beam cross-sectional area at and parallel to the transducer face consisting of all points where the acoustic pressure is greater than 10% of the maximum acoustic pressure in that plane. The area of the active element of the transducer assembly may be taken as an approximation for the radiating cross-sectional area.

radiation

The emission and propagation of waves transmitting energy through a medium.

radiation factor

Ratio of sound power radiated by a plate of a given area vibrating with a given root mean square velocity over the area to that power that would be emitted as a plane wave by a plate of the same area vibrating in phase with the same vibration velocity.

radiation force

The constant unidirectional force exerted on an interface by an incident acoustic wave. The force results from the transfer to the second medium of momentum carried by the wave to the interface. The unit is newton (N).

Related term: radiation pressure

radiation force balance

A device used to measure the acoustic radiation force and determine the output power generated by an ultrasound source.

Related term: acoustic radiation force

radiation index

In decibels (dB), 10 times the logarithm to the base 10 of the radiation factor.

radiation pressure (acoustic radiation pressure)

Radiation force per unit area.

radiofrequency

A frequency within the range used in radio broadcasting, namely 10 kHz to 100,000 MHz. In ultrasonics, radiofrequency refers to the frequency(ies) of the signals at the electrical terminals of the transducer, ie, the frequency(ies) of signals from the transducer before detection.

radiofrequency presentation

Display of the radiofrequency signals before signal processing.

radius of curvature

A quantitative measure of a curvature. The radius of curvature of a curve is equal to the radius of the circle whose curvature best approximates that of the curve. For ultrasound, the curve is usually the curved surface of a convex or concave array or a transducer lens.

RAM

Abbreviation for random access memory.

ramp

A linearly time-varying waveform. For example, the linear time base for an oscilloscope is generated by a ramp.

Related term: time-gain compensation

random-access memory (RAM)

An information storage device that permits direct storage and retrieval of any bit of the information. This is a type of memory used in digital computers and scan converters.

random noise

Noise due to the aggregate of a large number of elementary disturbances with random amplitudes and occurrences in time.

Related term: noise

range

See *depth*.

range, dynamic

See *dynamic range*.

range gate

A means of selecting an ultrasonic signal according to its depth along the ultrasonic beam by gating the signal with an appropriate time delay.

Related term: range gating

range gating

An electronic process in which all echo signals are ignored except for those occurring within a preselected "window." This is accomplished using an appropriate time delay circuit to select for analysis a portion of an ultrasound signal according to its depth along the ultrasound beam.

Related term: range gate

range resolution

See *axial resolution*.

rarefaction

When a sound beam passes through a medium, localized regions of the medium are alternately compressed and expanded. The expanded regions are called rarefactions.

raster display

A method of constructing a 2-dimensional image from multiple lines.

rayl

Unit of acoustic impedance; $1 \text{ rayl} = 1 \text{ kg} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$. A typical value of soft tissue acoustic impedance is 1.6 Mrayl. The term is named in honor of Lord Rayleigh.

Rayleigh cavity

A model for a bubble in which it is assumed that an empty spherical cavity exists within a liquid for which the pressure at infinity is greater than zero and that the cavity remains empty as it contracts from its initial size.

Rayleigh distance

See *Rayleigh length*.

Rayleigh length

For a given longitudinal plane, the equivalent area of the ultrasonic transducer aperture width divided by the effective wavelength.

Related terms: *Rayleigh distance*; contrast with *transition distance*

Rayleigh, Lord (1842–1919)

Born John William Strutt in Essex, England, third baron Rayleigh was the son of a duke and member of Parliament for Essex. Although educated at Cambridge, where he became Cavendish professor of physics and eventually chancellor, he carried out much of his work in his private laboratory at his home in Terling. He received the Nobel Prize for Physics in 1904 for his experimental work on the atmospheric elements but is perhaps better remembered for his classic and comprehensive treatise on the theory of sound published in 1877. He is credited with many discoveries and accomplishments that later were useful in ultrasound imaging. For example, the unit rayl for acoustic impedance was named in his honor, in addition to the Rayleigh criterion for resolution, the Rayleigh integral for calculating beam characteristics, the Rayleigh length for describing a beam, Rayleigh scattering used for tissue, the Rayleigh distribution used for describing statistical scattering from tissue, and his contributions to nonlinear acoustics (harmonics), radiation pressure, and cavitation.

Rayleigh scattering

The name given to the reradiation of waves by a target or targets much smaller than the wavelength of the incident radiation. Red blood cells are Rayleigh scatterers to ultrasound. The intensity of ultrasound scattered back to the transducer by the Rayleigh process is proportional to the fourth power of frequency.

Related terms: *intermediate scattering*; contrast with *diffusive scattering*, *specular scattering*

Rayleigh wave

Surface wave associated with the free boundary of a solid or liquid such that a surface particle describes an ellipse whose major axis is normal to the surface and whose center is situated on the initially undisturbed surface. Note: At maximum particle displacement away from this initially undisturbed surface, the motion of the particle is opposite to that of the wave. The propagation velocity of a Rayleigh wave is slightly less than that of a shear wave in the solid. The wave amplitude of the Rayleigh wave diminishes exponentially with depth.

reactance

The imaginary part of impedance. The unit is ohm (Ω).

read-only memory (ROM)

An information storage device that permits retrieval but does not permit storage of new information.

read zoom

Process of magnifying the displayed image data stored within the scan converter memory as these data are read out to the monitor. The stored image data from pixels within the region of interest are expanded to fill the whole screen on the viewing monitor.

Related term: write zoom

real number

In mathematics, the first of the two numbers comprising a complex number.

Related terms: complex number, imaginary number

real-time

See *real-time display*.

real-time contrast-enhanced sonography

See *contrast-enhanced sonography*.

real-time display

The scanning and display of ultrasonic images at a sufficiently rapid rate that moving structures can be perceived to move at their natural rate. Frame rates of 10 frames per second or greater are considered real-time.

real-time ultrasound system

An ultrasound system providing an update of ultrasound images at frame rates of 10 frames per second or greater.

receive aperture

The active surface of an array or transducer through which ultrasound signals can be received and recorded.

receive beamformer

A receive beamformer processes the waveforms arriving at each transducer element to enhance the combined output of all active elements.

Related terms: beamformer, delay and sum beamformer, transmit beamformer

receive beam pattern

See *beam pattern*.

receive focus

The focal point of an ultrasound transducer during echo reception. For a single-element transducer, this is the same as the transmit focus. For instruments using transducer arrays, the receive focal point is controlled electronically using time delays and usually changes dynamically during echo reception.

Related term: dynamic focusing

receiver gain

The amplification of a signal by a receiver.

Related term: gain

receiving transducer

A transducer that can receive sound. In most continuous wave systems, both a transmitting transducer and a receiving transducer are used. In most pulse-echo systems, the same transducer acts a transmitter and a receiver of ultrasound.

reciprocity

A physical principle stating that transmission characteristics of any sound path are the same in either direction. One application of this concept is that the directivity pattern of a plane piston acting as a transmitting transducer is identical to its directivity pattern when it is acting as a receiving transducer. Because of reciprocity, it is possible to calibrate the absolute sensitivity of a transducer for both transmission and reception. The same principle applies to transducer arrays as long as the active aperture, focusing, steering parameters, and electrical loading are the same on transmit and receive.

reciprocity coefficient

For a reciprocal electroacoustic transducer, at a specified frequency, the ratio of the voltage sensitivity of the transducer used as a sound receiver to the current sensitivity of the transducer used as a sound emitter.

reciprocity parameter

See reciprocity coefficient.

recirculation

The effect of continuous circulation of blood through the pulmonary and peripheral circulation. In contrast-enhanced sonography, microbubbles circulate through the lungs several times before vanishing, and this allows sonographic scanning for several minutes. However, this phenomenon may impede functional studies because the recirculated microbubbles interfere with building of a pure time-intensity curve.

rectangular array

A multielement transducer array in which the piezoelectric elements are arranged in a rectangular pattern.

rectangular scan format

The rectangular-shaped image pattern resulting from a sequentially fired linear transducer array.

rectification

The process of converting alternating current (AC) to direct current (DC). For example, rectification is done in power supplies, where AC line current is converted to DC power needed for computers, digital circuits, etc. Both full-wave rectifiers and half-wave rectifiers are in use (see Figure 11). Rectification also is a step in some older forms of echo signal envelope detection, where radiofrequency signal waveforms were first rectified and then filtered, yielding an approximation of the envelope. In current systems, envelope detection is more commonly done using digital signal processing (see Figure 11).

Related terms: analytic signal envelope, envelope

red cell stasis

An in vivo phenomenon wherein the erythrocytes within small blood vessels stop flowing and collect in the nodes of a standing wave field. This phenomenon does not occur with pulsed diagnostic ultrasound systems.

reference direction

For systems with scanning modes, the direction normal to the beam alignment axis and parallel to the direction of the maximum -6 -dB pulse beamwidth.

reference sound pressure

Pressure conventionally chosen equal to 20 μPa in air and 1 μPa in water.

reflected acoustic pulse

See *pulse echo*.

reflection

Change in the amplitude, phase, and direction of propagation of a wave that is propagating in one medium when it encounters a large (compared to wavelength) interface with another medium of different acoustic properties. The amplitude of the reflected wave is proportional to the difference between the acoustic impedances of the two media. (The acoustic impedance of a material is its density multiplied by its speed of sound.) The angle of reflection equals the angle of incidence.

Related terms: angle of incidence, angle of reflection, angle of refraction, critical angle, refraction

reflection coefficient (amplitude)

The ratio, r , of the reflected to the incident wave pressure amplitudes for normal incidence on a smooth planar interface between two media; $r = (Z_2 - Z_1)/(Z_2 + Z_1)$, where Z_1 and Z_2 are the characteristic acoustic impedances of the first and second media, respectively. A negative value for r indicates a change in the polarity of the reflected wave with respect to the incident wave.

reflection coefficient (intensity)

The ratio, R , of the reflected to the incident wave intensities for normal incidence on a smooth planar interface between two media; $R = (Z_2 - Z_1)^2/(Z_2 + Z_1)^2$, where Z_1 and Z_2 are the characteristic acoustic impedances of the first and second media, respectively. The value of R is always between 0 and 1.

reflection mode imaging

A technique that makes use of the reflected acoustic energy to produce the image. Also called echo ranging.

Related term: Contrast with *transmission imaging*

reflection, specular

The phenomenon of reflection of a wave by a smooth surface that is large relative to the wavelength where the reflected angle is equal to the incident angle.

reflectivity

The capability of reflecting sound.

reflux

Backward flow.

refraction

The change of direction of propagation of a sound wave when it passes from one medium to another in which the sound speed is different or when there is spatial variation in a medium's sound speed (see Figures 6 and 22).

refraction loss

That part of the transmission loss due to refraction resulting from nonuniformity of the medium. In those cases where the incident angle exceeds the critical angle, energy can be lost to evanescent waves in the second medium.

Related terms: angle of incidence, angle of reflection, critical angle, evanescent wave

refractive index (acoustic)

The ratio of the speed of sound within an object to the speed in some reference material.

regurgitation

Backward flow through an incompetent opening: eg, retrograde flow of contrast-enhanced blood from the right atrium to hepatic veins.

rejection

A nonlinear signal-processing technique intended to improve the apparent signal-to-noise ratio by eliminating low-amplitude signals from a display. This technique retains stronger echoes at the expense of noise and weaker echoes.

relative sensitivity

Sensitivity under a particular condition relative to sensitivity under a stated reference condition.

relaxation

A process in which a physical system approaches a steady state after conditions affecting it have been suddenly changed and slowly decays.

remanent polarization

The polarization remaining in a ferroelectric material after any externally applied electric field is removed.

resistance, fluid

With steady flow, the resistance is the ratio of the pressure drop to the flow rate.

resistive index (RI)

An index of pulsatility defined as the difference between the maximum and minimum Doppler shifts divided by the maximum. Also known as the Pourcelot index.

resolution (spatial)

A measure of the ability of a system to display distinguishable images of two closely spaced point structures as discrete targets. It is expressed as the minimum distance between two objects that can be distinguished as separate entities.

Related terms: azimuthal resolution, lateral resolution, axial (longitudinal) resolution, elevational resolution, resolution (temporal)

resolution (temporal)

The smallest time interval between two successive events that allows the identification of each event as a separate entity. High frame rates improve temporal resolution; eg, 60 frames per second and higher are used to provide sufficient temporal resolution to depict ventricular wall motion in a beating heart accurately.

See *temporal resolution*.

resonance

A phenomenon exhibited by a physical system acted on by an external periodic driving force, in which the resulting amplitude of oscillation of the system becomes large when the frequency of the driving force approaches a natural free oscillation frequency of the system.

resonance frequency

A frequency at which some measure of the response of a physical system to an external periodic driving force is a maximum.

response

Of a device or system, the motion, or other output, that results from a stimulus (excitation) under specified conditions. The kinds of input and output being used must be indicated.

reverberation

The phenomenon of multiple reflections within a closed system. This phenomenon causes echoes to be misplaced, thereby presenting false information (see Figure 23).

reverberation time

Of an enclosure, for a sound of a given frequency or frequency band, the time that would be required for the sound pressure level in the enclosure to decrease by some specified amount, after the source has been stopped.

Reynolds number

A number expressing the balance of inertial and viscous forces acting on a flowing fluid. Reynolds numbers higher than a critical value result in disturbed or turbulent flow.

Reynolds stress

The increased resistance to flow offered by a fluid in turbulence, which has its origin in viscous forces resulting from chaotically oriented velocity gradients.

Reynolds, Sir Osborne (1842–1912)

English mechanical and civil engineer who pioneered the study of vortical and turbulent flow in liquids and laid the theoretical basis for subsequent study of the behavior of viscous fluids. Reynolds also built a steam engine for the determination of the mechanical equivalent of heat and held patents for the design of marine turbines.

RF

Abbreviation for radiofrequency.

Related term: radiofrequency

rheological model

A model used to study the flow of matter, primarily in a liquid state, but also in soft solids, under conditions in which they become deformed when subjected to stress.

rheology

The scientific study of the flow of liquids and deformable solids.

ribbon microphone

Moving conductor microphone in which the conductor is a thin ribbon and is driven directly by the sound waves.

rigidity

The property of resisting a change in shape.

rim enhancement (arterial)

Also described as “ring enhancement” or “annular enhancement.” A continuous (thin or thick) annulus of peripheral contrast enhancement in a lesion. This is a typical pattern seen in liver metastasis.

ring enhancement (arterial)

See *rim enhancement*.

ring-down

See *transducer ring-down*.

ring-down artifact

See *dead zone*.

ring-down time

Interval between the time of the main transmission pulse and the time when after-ringing falls below 10% (–20 dB) of the amplitude of the main pulse.

rise time

The amount of time required for the amplitude of a pulse or echo to increase from 10% to 90% of its peak value (see Figure 13).

RMS

Abbreviation for root mean square.

root mean square acoustic pressure

The root mean square of the instantaneous acoustic pressure at a particular point in an acoustic field. The mean should be taken over an integral number of acoustic repetition periods unless otherwise specified. The unit is pascal (Pa).

ROM

Abbreviation for read-only memory.

root mean square (RMS)

An average of a time-varying signal in which negative portions of the signal do not cancel out the positive portions. It is the square root of the mean squared value of the signal, ie,

$$v(rms) = \sqrt{\frac{1}{T} \int_{t_1}^{t_2} v^2(t) dt}$$

where $v(t)$ is the instantaneous value of the signal, and $T = (t_2 - t_1)$ is the time over which the signal is averaged.

rotational wave/shear wave

Wave propagating in an elastic medium that causes an element of the medium to change its shape without a change of volume. Note: Mathematically, the particle velocity of a shear wave has zero divergence.

round-trip time

The time taken for an ultrasound pulse to travel from a transducer to an internal structure and return to the transducer as an echo.

S

sagittal plane

The anteroposterior plane parallel to the long axis of the body and passing through the midline. Anteroposterior planes not passing through the center of the body are frequently called parasagittal planes (see Figure 1).

sample volume

The region of the ultrasound beam (or beams in a continuous wave system) sensitive to the presence of Doppler-shifted echoes. In a pulsed Doppler system, the axial position and extent of the sample volume are under control of the operator.

sampling angle

The acute angle ($<90^\circ$) between the ultrasound beam axis and the direction of flow within the imaged plane. This angle may be estimated during the Doppler examination. Often called the Doppler angle. Note: The Doppler angle is not necessarily the same as the angle of incidence. For example, in a vessel, the Doppler angle = 90° minus the angle of incidence relative to the direction of flow.

Related term: Doppler frequency shift

sampling rate

The rate at which an analog (continuously varying) signal is sampled. It is the reciprocal of the time interval between digitization samples of an analog-to-digital conversion. The unit is hertz (Hz).

sampling theorem

Any band-limited signal can be specified completely by its sampled values, taken at regular intervals, provided that the sampling rate is more than twice the maximum frequency present in the frequency spectrum of the signal.

saturation

Limiting and distorting process that alters the linear relationship between the output and input of a device or a medium. The output is limited even with increasing input amplitude.

Related terms: saturation (acoustic), saturation (electronic)

saturation (acoustic)

An amplitude-limiting process due to the distortion of an acoustic wave signal caused by the nonlinear properties of the propagation medium. This severe distortion is a consequence of a relatively large-amplitude signal, with most of the energy going to harmonics or subharmonics. Further increases in a source signal amplitude do not result in an appreciable increase in an amplitude of the acoustic signal.

Related terms: saturation, saturation (electronic)

saturation (electronic)

Electronic limiting of the amplification that occurs if the input signal exceeds certain levels.

Related terms: saturation, saturation (acoustic)

sawtooth signal

A signal that increases linearly with time and is periodically reset to zero.

scale factor

A constant of proportionality used to compare sizes of objects, graphs, images, etc. Usually the objects are similar. In ultrasound diagnosis, it commonly refers to the ratio of the displayed size of an object to the real size of the object.

scan

The effective movement of an acoustic beam to produce an image, for which the ultrasound beam and the display movements are synchronized in space and time. For an electronic scan, the movement is usually lateral or 2-dimensional, and the scan lines are the same length. For mechanical scanning, the transducer itself is moved. For freehand scanning, the location and orientation of each scan line are registered by a position- and direction-sensing device for later reconstruction.

Related terms: *acoustic scan area, freehand scanning, freehand scanning (3-dimensional), mechanical sector scanner, mechanically swept scanning (3-dimensional, scan format, scan line), scan line separation, scanning system, scanning window, scan plane, scan repetition period, scan repetition rate, scan surface, scan volume, synthetic scan line*

scan area

For scanning systems, the area on a surface, consisting of all points within the beam area of any beam passing through the surface, during a scan repetition period. The unit is square meter (m²).

scan converter

An instrument or memory device that transforms pictorial information from one format into another. In diagnostic ultrasound instrumentation, the scan converter receives scan lines of echo information and changes this information into the desired rate and spatial arrangement for display.

scan cross-sectional area (for auto-scanning systems)

See *scan area*.

scan format

The 2- or 3-dimensional spatial pattern of a sonographic image display. Two-dimensional scan formats include rectangular, sector, and trapezoidal types.

scanhead (also scan head)

See *transducer array* or *transducer assembly*.

scan line

A representation of the echoes along a specified direction. Ultrasound images are composed of many scan lines. The more scan lines an image has, the more detail that can be portrayed, up to the resolution limit of the system (see Figures 29 and 30).

Related terms: *acoustic scan line, synthetic scan line*

scan line separation

The distance or angle between two specified scan lines of the same type within a specified plane. The unit is meter (m) or degree.

scanner

A device that moves an acoustic scan line relative to a target. This is accomplished mechanically or electronically by using a multielement transducer array.

Related term: *medical diagnostic ultrasound system*

scanning system

Any instrumentation that provides the ability to obtain ultrasound scans.

scanning window

The region on the skin surface through which an internal structure can be most readily imaged.

scan plane

A plane made up of scan lines (see Figure 27).

scan repetition period

The time interval between identical points on two successive frames, sectors, or scans. This applies to automatic scanning systems only. The unit is second.

Related term: scan repetition rate

scan repetition rate

The inverse of the scan repetition period. The repetition rate of a complete frame, sector, or scan. The term applies to auto-scanning systems only. The unit is hertz (Hz).

See frame rate.

Related terms: azimuthal plane, scan repetition period

scan surface

A scan surface (or plane) contains all the scan lines in a repetitive sequence often used to form an image frame. Usually for 2-dimensional imaging, the scan plane is the azimuth plane.

scan volume

A scan volume contains all the scan surfaces (planes) in a repetitive sequence used to form an image.

scatter

The generation of secondary waves in response to insonification by a primary wave by regions in the target that have inhomogeneities and heterogeneities in density and/or compressibility and/or by the boundary of the target.

scatterer

An inhomogeneity or heterogeneity within the medium, which reflects ultrasound.

Related terms: diffractive scattering, diffusive scattering, intermediate scattering, Rayleigh scattering, specular reflection, specular scattering

scattering

The production of scatter.

Related term: scatter

scattering cross section of a surface

Area of a plane progressive wave intercepting an amount of sound power equal to that scattered from the stated surface over a hemisphere.

scattering cross section of an object or volume

Equivalent area intercepting an amount of sound power of a plane progressive wave equal to that scattered in all directions by the object or by the scatterers in the stated volume.

s-d ratio

An index of pulsatility defined as the ratio of the maximum (usually the peak systolic) to the minimum (usually the end-diastolic) Doppler shift frequencies or the estimated velocities. Sometimes called a-b ratio.

second harmonic

The acoustic signal at twice the fundamental frequency of the transmitted acoustic wave.

second-harmonic imaging

See *harmonic imaging*.

sector

An area having the shape of a fan or a piece of a pie.

sector scan

A system of scanning in which the transducer or transmitted beam is rotated through an angle (see Figures 29, 30, and 35).

sector scan format

The pie- or sector-shaped image pattern resulting from a sector scan (see Figure 29).

segmentation

An image-processing technique that divides a volume of information into recognizable and separate components.

self-heating

See *transducer self-heating*.

sensitivity, Doppler

A measure of the minimum detectable signal level at a specified Doppler shift frequency and output power level. This is one component of Doppler detectability.

Related terms: detectability, Doppler; dynamic range, Doppler

sequential access storage

An information storage process that requires the sequential interrogation of information in a device until the sought-after information is obtained. A magnetic tape is such a device.

Related term: Compare with *random-access memory*

shadowing

Reduction in echo amplitudes distal to a strongly attenuating or reflecting structure (see Figures 16 and 22).

Related term: acoustic shadow

shear modulus

The ratio of shear stress to shear strain. Also called the modulus of rigidity or torsion modulus. The unit is pascal (Pa).

shear strain

The fractional lateral (tangential) displacement of a material when the surface of that material is subjected to a shear stress. It has no unit.

shear stress

The force tangent to a material surface divided by the area on which the force acts. The unit is pascal (Pa).

shear wave

Wave motion in which the particle displacement in the medium is perpendicular to the direction of wave propagation. A vertical shear wave has a vertical displacement perpendicular to the propagation direction. A horizontal shear wave has a horizontal displacement perpendicular to the propagation direction.

Related term: Contrast with *longitudinal wave*

shear wave elasticity imaging

Imaging of tissue mechanical properties derived from shear wave propagation parameters measured in tissue. Shear waves induced within tissue by external mechanical vibrations, intrinsic physiologic motions, or the radiation force of a focused ultrasound beam can be detected. Typically, the shear modulus can be determined from the measured shear wave propagation speed, c_s , and ρ , the density of tissue through the formula $\mu = \rho c_s^2$, which assumes a homogeneous, isotropic, perfectly elastic medium.

shear wave interference pattern

The interference pattern produced by multiple propagating shear waves.

Related term: *crawling wave elastography*

shear wave speed

The rate at which shear waves propagate through a material (m/s), which is quantitatively related to the shear modulus and density of the medium. For viscoelastic media, the shear wave speed is also affected by the viscous properties of the medium.

shock parameter

A parameter characterizing the degree of nonlinearity in the propagation of an ultrasound beam. A value of less than 1 would indicate a linear condition, and a value greater than 3 would indicate a marked nonlinear condition.

shock wave

The shape of a large-amplitude acoustic waveform that is maximally distorted by nonlinear propagation effects and looks like the letter N.

short-axis scan (echocardiography)

A cardiac scan in which the scanning plane is at right angles to the long axis of the heart (base to apex).

short-circuit acoustic impedance

Input acoustic impedance of an electroacoustic transducer, when the electric output is connected to zero impedance: a short circuit.

SI

The internationally accepted version of the metric system of units. The abbreviation comes from the French *Système International d'Unités*. This modernized metric system is based on 7 base units, including the meter, kilogram, and second. All other physical units are derived units, formed by multiplying and dividing units within the system.

side band

The components of a signal whose frequencies are either above (upper side band) or below (lower side band) the frequency of the transmitted (carrier) signal.

side lobe

Secondary beam regions generated by a transducer and deviating from the direction of the main beam or grating lobes. Usually the maximum intensity of the side lobe is significantly less than that of the main lobe. The presence of side lobes may be responsible for introducing artifactual echoes into an ultrasound image. A side lobe is narrower and weaker than the main lobe and is a result of the finite size and weighting of the transducer aperture. The lower the level of the side lobes, the better the contrast resolution of the image (see Figure 10).

Related term: Contrast with *grating lobe*

signal (electrical)

The component of a varying electrical voltage or current that contains information, as opposed to containing noise.

signal enhancer

Deprecated term for contrast agent.

signal-to-noise ratio

The ratio of the signal power to the noise power over a given bandwidth. The larger the signal-to-noise ratio, the easier it is to detect and measure a signal. The sensitivity of any device is ultimately limited by the signal-to-noise ratio. This ratio is usually expressed in decibels (dB).

signal type

Classification of the acoustic pressure waveform into continuous wave, tone burst, or broad-band.

simple sound source

See *point source of sound*.

single-level (or single-slice) technique

Contrast-enhanced sonographic acquisition modality done without any movement of the transducer over the patient's body surface. Used for lesion characterization and functional studies.

sinusoidal phase of enhancement

The phase of contrast medium circulation when contrast-enhanced blood leaves the liver through its venous drainage (from 90 to 120 seconds after contrast medium injection to about 300 seconds after contrast medium injection, depending on the contrast medium used). Liver enhancement progressively declines to the baseline appearance. The sinusoidal phase is sometimes referred to as the late vascular or extended portal venous phase.

slice thickness

The width of the point spread function (PSF) in the elevation direction perpendicular to the scan plane, usually given in decibels (dB), most commonly as the -6 -dB width. This dimension gives the "thickness" of an ultrasound beam "slice" through the imaged tissue and varies with imaging or axial depth (see Figure 33).

Related term: *point spread function*

slice thickness artifact

A sonographic artifact caused when the beam slice thickness is larger than the thickness of the anatomic structure, introducing echoes originating outside the scan plane into the scan plane.

small parts

See *superficial*.

small-parts scanner

Scanning device adapted to diagnostic examination of small and superficial organs (eg, eye and thyroid).

Related term: superficial

Snell's law

When sound travels from one medium into another, the incident and refractive rays (1) lie in one and the same plane with the normal to the surface, (2) are on opposite sides of the normal, and (3) make angles with the normal whose sines have a constant ratio to one another. The angle of the beam transmitted at the interface into a medium is related to the angle of incidence at the interface and to the speed of sound of the two media by $(\sin \theta_1)/v_1 = (\sin \theta_2)/v_2$, where θ_1 is the incidence angle in medium 1, θ_2 is the refraction (transmission) angle in medium 2, v_1 is the speed of sound in medium 1, and v_2 is the speed of sound in medium 2 (see Figure 6).

soft copy

A document or record that exists in electronic form, on a video screen, on magnetic tape, or stored in computer memory.

Related term: Contrast with *hard copy*

soft limiting

A technique by which the gain of a system is a function of the output amplitude for the purpose of preventing the output signal from exceeding a predetermined value. The output waveform is therefore distorted but not clipped.

Related term: Contrast with *clipping*

soft tissue thermal index (TIS)

The thermal index developed for ultrasound exposures limited to soft tissue.

Related terms: thermal index, bone thermal index (TIB), transcranial thermal index (TIC)

solid angle

A 3-dimensional angle (colloquial). A surface formed by rays with a common origin, the vertex of the solid angle, and passing through a closed curve. The unit is steradian. The total solid angle about a point is equal to 4π steradians.

Related term: steradian

sonar

The term "sonar" is the generic term for echo ranging and imaging underwater, usually at frequencies below 1 MHz. Acronym for sound navigation ranging.

sonic

An adjective relating to sound.

sonoelasticity imaging

A method for imaging the mechanical response of tissue to the passage of an applied shear wave therein. The method involves the detection of continuous wave vibration amplitudes using Doppler imaging.

Related term: sonoelastography

sonoencephalography

See *echoencephalography*.

sonogram

The pictorial record of an ultrasound examination.

sonographer

A highly skilled professional qualified by technological education to provide patient services using diagnostic ultrasound under the supervision of a doctor of medicine or osteopathy. Sonographers assist physicians in performing ultrasound examinations and gathering sonographic data necessary to reach diagnostic decisions.

sonography

Any imaging method using sound and yielding an image or a graphic representation of the subject. This is a more inclusive term than echography inasmuch as transmission sonography is also included.

sonohysterography (SHG)

An ultrasound examination, usually performed endovaginally, to evaluate the female pelvis during and after the instillation of fluid into the endometrial cavity.

Related term: Hysterosonography (HSG)

sonologist

The physician who interprets a sonogram.

sonolucent

The property of a medium allowing easy passage of sound; ie, it has very low attenuation. Sonolucent is a misnomer for anechoic.

See anechoic.

sonoluminescence

Production of light by a medium when subjected to intense levels of sound. Byproduct of an inertial cavitation event.

Related term: inertial cavitation

sonopaque

The property of a medium that obstructs the passage of sound; ie, it has very high attenuation (very high absorption and/or very high scattering). Sonopaque is a misnomer for a region on a B-scan completely filled in with echoes.

Related term: Compare with sonolucent

sonoporation

The use of ultrasound energy to increase cell membrane permeability to enhance extracellular molecular internalization. Typically, stable cavitation is used to modify permeability. A former definition is the use of ultrasound to propel a chemical agent or drug subcutaneously into tissue.

sound

Vibrational energy that propagates through a medium. Liquids and gases support longitudinal (compressional) waves. Solids support other vibrational modes in addition to longitudinal waves.

sound-absorbing material

A material characterized by a relatively large capability of absorbing sound.

sound absorption

See absorption.

sound absorption coefficient

See absorption coefficient.

Related terms: absorption, statistical sound

sound analyzer

Apparatus for the determination of the spectrum of a sound source.

sound energy

Acoustic or elastic energy of propagating sound waves in units of joules (J).

sound field

Region of an elastic medium containing sound waves.

sound intensity

Rate of energy flow (power) of a propagating acoustic or elastic wave through a unit area perpendicular to the direction of propagation. The unit of intensity is watts per square meter (W/m^2) or, more commonly, watts per square centimeter (W/cm^2).

sound power

See acoustic power.

sound power density

See sound intensity.

sound power of a source

Total sound energy radiated by the source in a specified frequency band over a certain time interval divided by the interval.

sound pressure

See acoustic pressure.

sound pressure amplitude

The deviation from the ambient value of the pressure in a medium due to the presence of an acoustic or elastic wave.

sound pressure reflection coefficient

See reflection coefficient (amplitude).

sound propagation speed

See speed of sound.

sound reflection coefficient

See reflection coefficient.

sound spectrum

Representation of the magnitudes (and sometimes phases) of the components of a complex sound as a function of frequency.

sound wave velocity

See velocity of sound.

source

The origin of the wave in question. For example, a primary source would be the transmitting transducer, and a secondary source would be the surface or object reflecting or scattering the wave.

source aperture

An equivalent aperture for measurement purposes formed by the intersection of the radiated acoustic energy from the active transducer aperture and the source aperture plane (see Figures 2, 7, and 9).

source aperture average pressure

This parameter is one-half of the peak-to-peak acoustic pressure, averaged over the –20-dB beam area in the source aperture plane. The region for this averaging includes all points where the pressure is at least 1/10 of the maximum pressure in the source aperture plane and is bounded by the continuous curve of minimum length that encloses these points.

source aperture plane

The closest possible measurement plane to the active transducer aperture that is perpendicular to the direction of propagation of the emitted ultrasound (see Figures 2, 7, and 9).

source aperture width

In a specified longitudinal plane, the –20-dB beamwidth along the line of intersection between the designated longitudinal plane and the source aperture plane (see Figure 2).

sparse array

An array in which few of the elements are active. For example, in an ultrasound sparse 2D array 2D transducer, most of its elements are inactive, or signals from these elements are not recorded.

spatial-average intensity

See this entry under intensity.

spatial-average pulse acoustic pressure

For non–auto-scanning systems, equal to the beam-average pulse acoustic pressure. Note: Spatial-average pulse acoustic pressure does not apply to automatic scanning systems; beam-average pulse acoustic pressure applies only. The unit is pascal (Pa).

spatial-average pulse-average intensity (I_{SAPA})

See this entry under intensity.

spatial-average root mean square acoustic pressure

For non–automatic-scanning systems, equal to the beam-average root mean square (RMS) acoustic pressure. For automatic scanning systems, equal to the RMS acoustic pressure averaged over the scan area, where the RMS acoustic pressure is taken over the scan repetition period. The unit is pascal (Pa).

spatial-average temporal-average intensity (I_{SATA})

See this entry under intensity.

spatial coherence

The correlation between signals at different points in space.

Related term: correlation

spatial compounding

Acquiring and combining ultrasound echo data from the same location but with different acoustic or synthetic scan line orientations. For linear and curvilinear arrays, this may be done by combining electronic beam steering and beam translation, resulting in overlapping scan lines. Thus, internal anatomic structures are scanned from many directions.

See compound imaging and frequency compounding (see Figure 34).

spatial-peak pulse acoustic pressure

The maximum value of the pulse acoustic pressure in an acoustic field or in a specified plane. The unit is pascal (Pa).

spatial-peak pulse-average intensity (I_{SPPA})

See this entry under intensity.

spatial-peak pulse intensity integral

The maximum value of the pulse intensity integral in an acoustic field or in a specified plane. The unit is joules per square meter (J/m^2).

spatial-peak root mean square acoustic pressure

The maximum value of the root mean square acoustic pressure in an acoustic field or in a specified plane. The unit is pascal (Pa).

spatial-peak temporal-average intensity (I_{SPTA})

See this entry under intensity.

spatial-peak temporal-peak acoustic pressure (or peak sound pressure)

The larger of the peak-positive acoustic pressure or the peak-negative acoustic pressure. The unit is pascal (Pa).

spatial-peak temporal-peak intensity (I_{SPTP})

See this entry under intensity.

spatiotemporal image correlation (STIC)

A 4-dimensional (4D) scanning technique to visualize the beating fetal heart. During the volume acquisition phase, which may take 10 seconds or so, the fetal heart may beat 20 to 25 times. To provide the best imaging of the heart, the B-mode frames are reordered according their spatial and temporal relation to the fetal heartbeat. The 4D visualization can be performed with the heart frozen at a particular phase of the heartbeat or viewed with the heart in normal motion.

specific absorption rate (SAR)

The rate at which energy is absorbed per unit mass of tissue. SAR is expressed in units of watts per kilogram (W/kg).

specific acoustic admittance

Reciprocal of the specific acoustic impedance. Note: The real part is the specific acoustic conductance, and the imaginary part is the specific acoustic susceptance.

specific acoustic impedance

The ratio of instantaneous acoustic pressure to instantaneous particle velocity. For a plane progressive (forward propagating) wave in a lossless medium, the specific acoustic impedance is numerically equal to the characteristic acoustic impedance. For a negative propagating wave, this impedance is negative.

specific acoustic reactance

Imaginary part of specific acoustic impedance.

specific acoustic resistance

Real part of specific acoustic impedance.

speckle

The granular appearance of an ultrasound image due to the coherent addition (ie, constructive and destructive interference) of detected echo signals arising from unresolved distributed scatterers within a sample volume.

speckle reduction

The smoothing of tissue texture in an ultrasound image by various methods such as spatial or frequency compounding.

speckle tracking

Determination of local ultrasound displacement and/or movement by using the spatially invariant or deterministic properties of speckle over short periods of time. Typically, A-lines or images at different sequential times are cross-correlated to obtain local changes in displacement. Major applications include time domain Doppler, elastography, and assessing thermally induced changes in tissue.

spectral analysis

Estimation of amplitude at all frequencies contained in the spectrum corresponding to a time signal (obtained by Fourier analysis or by a Doppler measurement).

spectral broadening

The increase of the range of Doppler shift frequencies either by occurrence of turbulence in the bloodstream (such as after passing a stenosis) or due to the finite size of the sampling volume (transit time spectral broadening).

spectral bubble noise

An artifact associated with ultrasound contrast agent studies, where the Doppler spectrum contains very large excursions caused by bubble destruction within the sample volume. It is always associated with a loud “crackling” noise in the audio signal. Spectral bubble noise is of minor clinical importance.

spectral density/spectrum density

Limit, as the bandwidth approaches zero, of the mean square value of a field quantity divided by bandwidth. The kind of field quantity must be specified, such as sound pressure, particle velocity, or particle acceleration. Also called spectrum density.

spectral Doppler

A name commonly used to refer to the combination of either continuous wave or pulsed Doppler with a spectral display, usually of measured velocities.

spectral width

See *bandwidth*.

spectrum

- (1) The distribution of the amplitude (and sometimes phase) of the components of the wave as a function of frequency.
- (2) The set of frequencies, wavelengths, or related quantities involved in an ultrasonic pulse or electronic signal.

spectrum density

See *spectral density*.

specular highlight (ultrasound)

Bright, high-amplitude echo arising from a localized region on a tissue interface when the region is perpendicular or nearly perpendicular to the incident beam. In pulse-echo imaging, specular highlights are often seen for small regions on curved interfaces and for isolated areas on the surface of tightly curved structures when the region or area is oriented perpendicularly to the beam.

specular reflection

Reflection of sound energy from a smooth surface that is large compared to the wavelength. Specular reflection implies that the angle of reflection equals the angle of incidence.

Related terms: scatterer, diffractive scattering, diffusive scattering, intermediate scattering, Rayleigh scattering, specular scattering

specular scattering

Waves that are reradiated from objects whose size or surface irregularities are much greater than the insonifying acoustic wavelength.

Related terms: acoustic wavelength, specular reflection

speed of sound

The rate at which an acoustic wave propagates through a material. The speed of sound depends on the density and the elastic properties of the medium. The unit is meters per second (m/s).

spherical wave

A wave that emanates from a point source and propagates evenly in all directions, producing a spherical wavefront. The wavefronts are concentric spheres.

spider sign

See centrifugal arterial blood supply.

spleen-specific phase of enhancement

See parenchymal phase of enhancement.

spoked wheel-shaped pattern

See centrifugal arterial blood supply.

spot-poled region

A small region in a ferroelectric material that has been poled.

Related term: poling

spreading loss

See diffraction loss.

stable cavitation

A form of noninertial cavitation characterized by a steady oscillation of a bubble due to the passage of a sound wave. Mechanical movements, such as acoustic streaming, occur in the vicinity of the bubble.

Related terms: cavitation, inertial cavitation, noninertial cavitation, transient cavitation

stand-alone

Being able to operate without support or control from another system.

standard linear viscoelastic model

Preferred name: Kelvin model

Related terms: Burgers model, dashpot, elastic spring, Maxwell model, Kelvin model, Kelvin-Voigt model, Voigt model

standing wave

Periodic wave having a fixed distribution in space that is the result of interference of progressive waves of the same frequency and kind. Note: Such waves are characterized by the existence of nodes or partial nodes and antinodes that are fixed in space.

Related term: standing wave field

standing wave field

Pattern of a standing wave in a medium. When two sound waves of equal magnitude and frequency travel in opposite directions, a pattern of stationary pressure peaks with nodes occurring at half-wavelength intervals results. In this situation, there is no net flow of acoustic energy.

Related term: standing wave

standoff

A device placed between a transducer and the skin so that ultrasound imaging can be performed so that focusing can occur near the region of interest, usually near the skin surface. A secondary benefit of this device is to reduce artifacts that would arise in contact scanning. Standoff devices are particularly helpful in scanning superficial structures, such as the thyroid gland, and in maintaining good acoustic coupling on sharply curved surfaces, such as the neck. The material within the standoff, whether liquid or solid, should be very low in attenuation and should be well matched acoustically to the body.

starlike pattern

See centrifugal arterial blood supply.

statistical sound absorption coefficient

Sound power absorption coefficient measured or calculated with plane waves at randomly distributed angles of incidence.

See absorption, sound absorption coefficient.

steady state

The existence of a situation stable for sufficiently long periods to allow variations with time to be neglected.

steady-state oscillation

Oscillation that continues without change.

steering

The changing of the direction of an ultrasound beam. Steering is produced in a transducer array by exciting the transducer elements not synchronously, but with increasing delays in the firing of successive elements such that the emerging beam leaves the transducer in a chosen direction. Continuously changing this type of excitation delay pattern results in a sector scan. Also known as electronic beam steering (see Figure 35).

Related term: phased array and scan

stellate pattern

See centrifugal arterial blood supply.

stenosis

The local narrowing of a vessel lumen or other structure, usually as the result of a disease process.

steradian

The unit of measure of a solid (3-dimensional) angle. One steradian equals the solid angle, which, having its vertex in the center of a sphere, subtends an area on the surface equal to the radius squared. There are 4π steradians in the solid angle comprising a complete sphere.

stereoscopic

Pertaining to 3-dimensional viewing with depth perception.

stiffness

An elastic coefficient matrix determined by the vector ratio of stress to strain. In general, there are components of stress generated in other directions in addition to those of the applied strain. The unit is pascal (Pa).

stiffness (tissue)

The firmness of a tissue element that is due to its elastic modulus as well as its geometric position, shape, and boundaries.

stimulus excitation

Archaic term for external force, or other input, applied to a system.

stippled pattern of enhancement

In contrast-enhanced sonography, diffuse chaotically disposed discrete vessels within a lesion. This is a typical color Doppler and contrast-enhanced sonographic pattern seen in hepatocellular carcinoma.

strain

The fractional change in the shape or size of a structure due to an imposed stress. For example, in one dimension, strain is the ratio of the change in length divided by the original length. The strain is termed elastic if the material returns to its original shape and size after removal of the stress. The strain is called plastic if the material does not return to its original shape and size.

strain filter

A statistical function depicting the upper bound of the elastographic signal-to-noise ratio that can be theoretically attained in an elastogram of a uniformly elastic medium as a function of the applied strain. The shape of the strain filter resembles a bandpass characteristic in the strain domain and is influenced by several mechanical, acoustical, and signal-processing parameters.

strain imaging (echocardiography)

An imaging method in which the degree of tissue deformation (ie, strain) is displayed.

strain-induced spectral broadening

The increase in the spectral bandwidth of a received echo signal that is a result of incurring a small compressive strain. Conversely, the bandwidth is narrowed when the strain is tensile.

strain-induced spectral shift

The upward shift in the center frequency of a wideband pulse spectrum as a result of incurring a small compressive strain. Conversely, the spectral shift is downward when the strain is tensile.

strain rate imaging (echocardiography)

An imaging method in which the rate of tissue deformation (ie, strain) is displayed.

strain shadowing

A misnomer for strain concentration.

Related term: strain concentration

strain tensor

A tensor in which each of its 9 elements represents a strain. The elements of the strain tensor are usually represented by the symbol ij , where i is the row, and j is the column position. $i = 1, 2$, or 3 , indicating the direction of the strain, and $j = 1, 2$, or 3 , indicating the direction of the surface undergoing the strain.

streamline

A line that is everywhere parallel to the direction of fluid flow at a given instant.

strength of a simple sound source

Maximum instantaneous volume velocity produced by a simple source, small compared with the wavelength, emitting a wave with sinusoidal variation with time.

stress

The force per unit area applied to a structure. The unit is pascal (Pa).

stress concentration

An increase in the stress in a selected area in an elastogram due to changes in internal or external boundary conditions.

stress decay

The diminution of the stress as a function of distance. The exact behavior of the stress decay depends on the geometry and the boundary conditions and on the details of the applied stress.

stress dilution

A decrease in the stress in a selected area in an elastogram due to changes in internal or external boundary conditions.

stress tensor

A tensor in which each of its 9 elements represents a stress. The elements of the stress tensor are usually represented by the symbol S_{ij} , where i is the row, and j is the column position. $i = 1, 2$, or 3 , indicating the direction of the stress, and $j = 1, 2$, or 3 , indicating the direction of the surface acted on by the stress.

subelement

An element forming part of a group or subgroup of elements which together function as an array element.

subharmonic

The signal with a harmonic frequency below the fundamental frequency. The n th subharmonic of a fundamental frequency F is a signal with frequency F/n , where n is a positive integer.

Related term: integer

subharmonic imaging

Method of imaging in which ultrasound is transmitted at a fundamental frequency and is detected at subharmonic frequencies. Subharmonics are generated by nonlinear reflectors such as contrast microbubbles. The resulting subharmonic is displayed as an image to improve the signal-to-noise ratio.

subharmonic response

Periodic response of a system at a frequency that is a submultiple fraction of the fundamental frequency.

superficial (sonographic)

Applies to sonographic examinations of tissues near or just under the skin. Includes breast, muscles, testicular, thyroid, and other tissues. Formerly called "small parts." Superficial sonographic examinations are performed using higher-frequency transducers.

Related term: small-parts scanner

superharmonic

Synonymous with ultraharmonic.

superposition principle

A principle stating that if a linear physical system is acted on by a number of independent influences, the resultant response is the sum of the responses from each of the influences acting individually.

supersonic shear wave imaging

A shear wave elasticity imaging technology that uses shear waves produced by rapidly moving the focus of a push beam at a speed higher than the shear wave propagation speed within the medium being imaged. The technology can generate shear wave fronts with different axial extents and inclination angles to suit different shear wave imaging applications.

supplying artery

An artery entering into an anatomic structure. It may be seen as an enhanced vessel outside the nodule (malignant lesions) or even central to the nodule (focal nodular hyperplasia).

suppression

The reduction of undesired noise in a noisy signal. Rejection eliminates weak signals below a threshold level. Logarithmic amplification suppresses large signals relative to weak ones. Squaring the signals suppresses weak signals relative to strong ones.

surface-rendered

See surface rendering.

surface rendering

An imaging display technique in 3-dimensional (3D) ultrasound in which the echo information obtained by volume acquisition is modified to produce a smooth continuous superficial surface of an object. Surface rendering is especially helpful in producing realistic 3D views of the fetal face.

survey scan

An initial sonographic scan that provides an overview and orientation before the diagnostic images are recorded. Surveying is recommended at the start of every type of ultrasound examination.

swept gain

The process by which the gain of a pulse-echo system is varied with time to compensate for the effects of attenuation.

Related terms: time-gain compensation, attenuation compensation

symmetry axis of the scan plane

An imaginary line in the scan plane on each side of which an equal number of ultrasonic scan lines occur. Synthetic aperture.

See synthetic aperture ultrasound imaging.

synthetic aperture imaging

See synthetic aperture ultrasound imaging.

synthetic aperture ultrasound imaging

A method in which low-resolution images obtained from transmitting a single or a subset of all available transducer elements are compounded together to form a higher-resolution image with fewer artifacts. Reception is on all elements. Images with twice the resolution can be obtained for this method without any added focusing.

synthetic scan line

A reconstruction of echo information along an arbitrarily specified direction within a collection of acoustic scan lines. The direction of the scan line may not correspond to the direction of original acoustic scan line.

Related terms: *acoustic scan line, scan line*

systole

The portion of the cardiac cycle during which myocardial contraction occurs.

Related term: Contrast with *diastole*

systolic

See systole; window, systolic.

systolic window

See window, systolic.

T

target

An object to be interrogated by an ultrasound beam. For example, (1) a device specially designed to be inserted into the ultrasonic field to serve as the object on which the radiation force is to be measured, (2) a scatterer or ensemble of scatterers giving rise to a signal within the effective ultrasonic beam, or (3) a string in a test object.

targeted microbubble

See *target-specific microbubble*.

target-specific microbubble

A microbubble prepared to transport ligands that are specific for a given tumor, thrombus, or other target. Used in therapeutic applications. Sometimes called targeted microbubble or therapeutic microbubble.

temporal

Pertaining to time.

temporal-average intensity

See *this entry under intensity*.

temporal-peak acoustic pressure

The maximum value of the modulus of the instantaneous acoustic pressure at a particular point in an acoustic field. The unit is pascal (Pa).

temporal-peak intensity

See *this entry under intensity*.

temporal resolution

See *resolution (temporal)*.

tensile modulus

The ratio of tensile stress to tensile strain.

tensile strain

The fractional change in the length of an object when subjected to a tensile stress.

tensile stress

The force per unit area that when applied to an object causes the object to lengthen or stretch. The unit is pascal (Pa).

Related term: Compare with *compressive stress*

tensor

A generalization of the concepts of vectors and matrices. In elastography, tensors are represented by matrices containing 9 elements arranged in 3 rows and 3 columns. Each element is a vector representing the magnitude and direction of a stress or strain.

Related terms: *stress tensor, strain tensor*

test object

A device for the evaluation of one or more parameters of an ultrasound system. In distinction with a phantom, it does not necessarily duplicate the acoustical properties of the human body. It usually contains wires and possibly other targets giving rise to echoes in response to an ultrasonic pulse.

Related term: Compare with *phantom*

test object, Doppler

A device designed to create a reproducible acoustic and physical setting in which one or more aspects of a Doppler system's performance may be tested or calibrated.

texture pattern of echoes

The sonographic pattern arising from an area of interest in the body. The pattern depends primarily on the transducer frequency and beam characteristics and secondarily on the structure of the scattering tissues.

Related term: Compare with *speckle*

theoretical angular beam width

The computed angle subtended by two far-field, off-axis points in a plane containing the beam axis, where the computed quantity (specified pressure, velocity, or intensity) is at its first null (or some other specified value) of its axial magnitude; the angular beamwidth is computed on the basis of continuous excitation unless otherwise specified.

theranostics

The development of more specific, individualized therapies for various diseases, by combining diagnostic and therapeutic capabilities into a single agent.

therapeutic microbubble

See *target-specific microbubble*.

therapeutic ultrasound

The use of ultrasound for the treatment of disease and injury rather than for diagnosis. The practice of applying ultrasound to a region of the body to achieve soft tissue healing, functional restoration, and pain reduction.

thermal dose

The quantity of ultrasound energy absorbed by a structure that is exposed to an ultrasound beam. The unit is joule (J).

thermal dose index

A dimensionless quantity representing the likelihood of an ultrasound-induced, thermal bioeffect that takes into account both the magnitude and duration of the rise in temperature of the exposed tissue

thermal energy

Energy due to random molecular motion.

thermal index (TI)

A dimensionless number used to represent the likelihood of an ultrasound-induced bioeffect caused by a rise in temperature. It is numerically defined as the ratio of the attenuated power of an ultrasound beam to the attenuated power that would cause the exposed tissue to rise to a maximum of 1°C in a specific tissue model.

Related terms: bone thermal index (TIC), soft issue thermal index (TIS), transcranial thermal index (TIC), output display standard (ODS), mechanical index (MI)

thermally equivalent time

The duration of exposure to an acoustic beam required to produce the same magnitude of a thermally induced bioeffect, ie, an "isoeffect," at a specified reference temperature, usually 43°C, as is produced by an exposure of a different duration and temperature, where the temperature may vary in time. The thermal dose used most often clinically is the cumulative number of equivalent minutes at 43°C, CEM43°C, or simply CEM43.

Related term: thermally equivalent time index

thermally equivalent time index

See thermal dose index.

thermoelastic expansion

The enlargement of a material due to the absorption of energy. The absorption of energy causes the local temperature to rise, the temperature elevation results in a rapid volumetric expansion of the material initiating the onset of an acoustic wave.

thresholding

Elimination of weak echoes and noise with amplitudes that are below a selected threshold level to increase the signal-to-noise ratio in a sonogram.

through-transmission imaging

The process of imaging by transmitting a sound beam through the specimen and receiving the transmitted energy on a far surface by a receiving transducer or array.

Related terms: holography, transsonogram

time-compensated gain

See time-gain compensation.

time constant

Time required for the amplitude of an exponentially decaying field quantity to decrease to $1/e = 0.368$ times an initial amplitude.

time delay estimation (TDE)

The estimation of the delay between two similar waveforms. This estimation is usually made by techniques such as cross-correlation lag and signal phase measurements.

time-gain compensation (TGC)

A means of altering receiver gain with time introduced to compensate for loss in echo amplitude, usually due to attenuation and diffraction, with depth. Sometimes called depth gain compensation, ramp, attenuation compensation, and swept gain.

Related terms: automatic gain control, lateral gain control

time-intensity curve

See wash-in–wash-out curve.

time interval histogram

A kind of frequency spectral display in which the signal is displayed as a histogram representing the frequency of occurrence of a spectrum of bands of zero crossing frequencies.

time-motion display

See M-mode.

time reversal

A fundamental symmetry found in physics that states that the reversal of the final conditions (waveforms) of a process in time will elicit the initial conditions.

time sidelobes

The humps of the envelope of a pulse that trail behind the main peak of a pulse echo.

time to peak (contrast sonography)

The time intervening between contrast medium injection and the moment of maximum contrast enhancement.

tissue Doppler imaging

Ultrasonic imaging modality that measures and displays the velocity of tissue motion toward and away from the transducer.

tissue harmonic imaging

Harmonic imaging of tissue without the use of contrast microbubbles.

See *harmonic imaging*.

tissue-mimicking material

A material possessing acoustic propagation properties, such as the speed of sound, scatter, and attenuation, similar to that of tissue. This type of material is often used in the construction of phantoms.

tissue-mimicking phantom

A test object composed of materials possessing one or more acoustic properties that are the same as in tissue.

tissue-specific contrast medium.

Sonographic contrast medium capable of being retained within a specified tissue (mainly, liver and spleen).

T-M echography

See *M-mode*.

T-M mode

See *M-mode*.

tomography

A method of imaging in which a "slice" of a 3-dimensional region of a patient is portrayed as a 2-dimensional image. Even though contemporary ultrasound imaging may be considered a form of tomography, it is no longer described as "tomography." Most often, this word refers to computed tomography, a tomographic reconstruction in which a section or imaging plane is calculated from data obtained from oppositely sited transmitter-receiver pairs rotated many times.

tone burst signal

A tone burst signal is one that has a constant amplitude for a certain length of time before decreasing essentially to zero. This pattern of excitation may occur once or be repeated many times. The product of the duration of the tone burst and the carrier frequency (ie, the effective frequency) must be 2 or more.

torsion modulus

See *shear modulus*.

total pressure

The sum of the ambient pressure and the acoustic pressure.

total reflection

A phenomenon in which no transmission across a boundary occurs if the angle of incidence is equal to or larger than the “critical angle.”

See *critical angle*.

transceiver

A transducer used for both transmission and reception of acoustic energy. This is the customary configuration in diagnostic ultrasound.

See *pulse-echo and pulse-echo imaging*.

transceiver voltage response

The ratio of the voltage amplitude of the energizing pulse to the resulting voltage amplitude corresponding to the echo from a perfect planar reflector at a specified distance at normal incidence. Usually measured in decibels (dB).

See *transceiver*.

transcranial

Passing or performed through the skull.

transcranial thermal index (TIC)

See *cranial thermal index (TIC)*.

transcranial ultrasound

A procedure in which an ultrasound beam is transmitted through the skull bone to treat or examine the brain, cerebral blood vessels, and other intracranial structures.

transducer

A device capable of converting energy from one form to another. Specifically in ultrasonics, it is a device capable of converting electrical energy to mechanical energy within the ultrasonic frequency range and conversely of converting mechanical energy to electrical energy. If the device is used only to transmit or to receive, the device should be referred to as the “transmitting” or “receiving” transducer. If, in the application, the device performs both functions, the term may be left unqualified or called a transceiver.

transducer aperture

The totality of the radiating surfaces of the transducer elements or transducer(s) (see Figures 2, 5, 7, and 9).

Related term: *source aperture*

transducer aperture plane

The plane that is orthogonal to the beam axis of the unsteered beam and is adjacent physically to the ultrasonic transducer totality of the radiating surfaces of the transducer elements or transducer(s) (see Figures 5, 7, and 9).

Related terms: *source aperture, source aperture plane, transducer aperture*

transducer array

A group of transducers working together to form a functional unit. Arrays may be of several types, depending on the transducer configuration: linear, annular, rectangular, etc.

transducer assembly

Those parts of medical ultrasonic equipment comprising the ultrasonic transducer and/or ultrasonic transducer element group together with any integral components, such as an acoustic lens, integral standoff, etc. The transducer assembly is usually separable from the ultrasound instrument console.

See *standoff, transducer element, ultrasonic transducer element group.*

transducer dynamic response

See *dynamic response.*

transducer efficiency

The ratio of ultrasonic output power from a transmitting transducer to the electrical input power. Also, the ratio of electrical output power from a receiving transducer to the ultrasonic input power. These ratios need not be equal.

Related term: *transducer loss*

transducer element

An individually electrically addressable transducer with a radiating surface. It is a single part of a contiguous arrangement of other transducers (see Figures 18 and 19).

transducer element group

See *ultrasonic element group.*

transducer loss

The ratio of ultrasonic output power from a transmitting transducer connected to an electrical source of a known impedance to the electrical power of the source connected to a load matching its impedance. Also, the ratio of electrical output power from a receiving transducer connected to a known electrical load to the ultrasonic input power as connected to a known medium such as water or tissue. Usually these ratios are expressed in decibels (dB).

Related term: *transducer efficiency*

transducer output face

External surface of a transducer assembly that is either directly in contact with the patient or is in contact with a water or liquid path to the target. Also called probe face.

Related term: *transducer assembly*

transducer ring-down

The duration of decay of oscillation following the generation of a pulse. When an ultrasonic transducer is used in the pulsed mode, it is shock excited by a voltage spike, which puts energy into the resonant mechanical system of the transducer. This energy is dissipated by the combination of the viscous damping in the transducer, the acoustic load at the front and back of the transducer, and the dynamic damping provided by the trailing edge of the excitation. The resulting damped oscillation has been referred to by some authors as "ring-down." The total damping provides for improved axial resolution by shortening the pulse duration.

transducer standoff distance

Shortest distance between the transducer output face and the patient entry plane. The term "contact" is used to connote direct contact between the transducer output face and the patient, with the transducer standoff distance equal to zero. The unit is millimeter (mm).

Related term: *standoff*

transducer self-heating

The temperature elevation occurring within a transducer probe caused by circuits overcoming electrical resistance and by absorbed ultrasound. When a heated transducer is placed in contact with tissue, temperature elevation can be caused by heat conduction. This mechanism is different from the temperature elevation occurring in tissue caused by the absorption of propagating ultrasonic energy.

transducer voltage response

See *transceiver voltage response*.

transesophageal

A sonographic examination performed with a special transducer that is inserted into the esophagus. Also called a transesophageal echocardiogram (TEE) when examining the heart.

transfer function

A mathematical formula used to characterize a system. It is the ratio of the output frequency spectrum to the input frequency spectrum and therefore permits the prediction of the output of any linear system for any given input.

transient

A pulsed, damped oscillation or other temporary phenomenon occurring in a system before reaching a steady-state condition.

transient elastography

A method similar to sonoelasticity imaging but where the applied shear wave is a transient pulse, and the detection involves estimating the velocity of the shear wave from rapid B-mode imaging sequences. The speed of propagation of the shear wave is related to the density and shear elasticity of the medium.

transition distance

For a given longitudinal plane, the equivalent area of the ultrasonic transducer aperture width divided by π times the effective wavelength. For example, for a circular transducer or spherical transducer of radius a , it is $z_t = a^2/\lambda$. For a square transducer with a side L , $z_t = L^2/\lambda$ (see Figure 3).

Related term: Contrast with *Rayleigh distance*

transition zone

That portion of the acoustic field around the transition distance that includes neighboring parts of the near field (Fresnel zone) and the far field (Fraunhofer zone). The transition zone has no distinct boundaries but frequently is taken to be centered at the position of the transition distance.

transit time broadening

The spectral broadening that occurs as a consequence of the movement of scatterers through a Doppler sample volume of finite size. The smaller the sample volume, the more pronounced the transit time broadening. Also known as geometric or intrinsic spectral broadening.

transluminal echography

A sonographic technique in which an ultrasound transducer is brought into a body cavity or blood vessel and the ultrasound is transmitted through the wall. Endovascular, transesophageal, and endovaginal echography are examples.

transmission

A general term implying passage of energy through a material.

transmission coefficient

Ratio between pressure amplitude of incident and transmitted waves at an interface between two media:
 $t = 2Z_2/(Z_2 + Z_1)$, where t is the transmission coefficient, and Z_1 and Z_2 are acoustic impedances of the media.

transmission imaging

The production of an image by analysis of sound that completely traverses the body and is detected by a second transducer located on the opposite side.

transmission loss

See *attenuation loss*.

transmit beam pattern

See *beam pattern*.

transmit beamformer

A transmit beamformer organizes the excitation pulses going to array elements to control the ultrasound beam propagating from the transducer elements.

See *beamformer*, *delay and sum beamformer*, and *receive beamformer*.

transmit focus

The focal point of an emitted ultrasound beam.

Related term: Contrast with *receive focus*

transmit power

See *output power*.

transmitted acoustic pulse

The acoustic pulse transmitted from the transducer into the medium following the application of an energizing pulse.

transmitter pulse

See *energizing pulse*.

transmitting transducer

A transducer dedicated to transmitting sound.

transpulmonary contrast medium

All modern commercially available contrast media consist of microbubbles able to pass through the pulmonary vascular bed and reach the left cardiac chambers and the peripheral circulation. It is no longer necessary to specify this characteristic.

transrectal imaging

Imaging of the anatomic structures within the pelvic region while the transducer is inserted in the rectum.

transsonic

Describes a region of a relatively unattenuating medium. A distinction should be made between a transsonic region and a shadowing region; generally, this is done by observing the back boundary and underlying structures.

Related term: Compare with *anechoic*

trans-sonogram

See *through-transmission imaging*.

transvaginal imaging

Imaging of the anatomic structures within the female pelvis while the transducer is placed in the vagina.

Related term: endovaginal imaging

transverse image plane

A plane perpendicular to the long axis of the body or structure of interest. With respect to the body, a transverse plane extends from left to right and divides the body into cephalic and caudal regions (see Figure 1).

transverse oscillation method

A way of implementing vector Doppler on conventional imaging systems and transducers. It uses two parallel receive beams with a 90° phase shift to calculate longitudinal and lateral Doppler components to create a 2-dimensional velocity vector field.

transverse plane (ultrasound beam)

A plane that is perpendicular to the beam axis.

transverse wave

Wave in which the direction of particle displacement at each point of the medium is parallel to the wavefront.

triplex imaging

Presentation of 3 modes: usually 2-dimensional, color flow, and pulsed Doppler.

tumor stain

Dense (homogeneous or inhomogeneous) enhancement of a (hypervascular) lesion during the arterial phase. An angiographic term that should be avoided in contrast-enhanced sonographic imaging.

turbulence

Disorganized flow, chaotically oriented in many directions simultaneously. Occurs in disturbed flow when a critical value of the Reynolds number is exceeded.

type testing values

For acoustical output parameters, the maximum probable acoustical output levels for a specified system.

U

ultraharmonic

An oscillation at a frequency that is an odd integer multiple (greater than 1) of half the fundamental frequency of the oscillation ($3/2f_0$, $5/2f_0$...).

ultraharmonic imaging

An imaging technique used to enhance the contrast between echoes from ultrasound contrast agents and tissue echoes. It employs pulse sequences in which excitations of microbubbles produce ultraharmonic echoes which can be differentiated from echoes arising from tissue.

See *ultraharmonic*.

ultrasonic

Pertaining to sound at frequencies higher than that which can be detected by the human ear. Usually refers to sound with a frequency greater than 20 kHz.

ultrasonic pulse

A short burst of ultrasound that is transmitted into the body by a pulse-echo ultrasound instrument.

ultrasonic scan line separation

For automatic scanning systems, the distance or angle between the points of intersection of two specified consecutive ultrasonic scan lines of the same type with a specified plane. The unit is meter (m).

ultrasonic shadow

See *acoustic shadow* (see *Figure 16*).

ultrasonic tissue characterization

Usage of pulse-echo or through-transmission ultrasound data to detect, extract, and display quantitative information about tissue function, structure, and pathology.

ultrasonic transducer

A device that converts ultrasonic energy into an electrical signal and vice versa.

Related term: *transducer*

ultrasonic transducer element group

A group of elements of an ultrasonic transducer that are excited together to produce a single acoustic pulse.

ultrasonogram

See *sonogram*.

ultrasonography

See *sonography*.

ultrasound

Acoustic oscillation whose frequency is above the high-frequency limit of audible sound (about 20 kHz).

ultrasound computed tomography (UCT)

An ultrasound imaging method in which the image is reconstructed by a computer in a manner analogous to conventional x-ray computed tomographic reconstruction.

ultrasound dosimetry

The measurement of the quantity of ultrasound energy that is absorbed when a subject is exposed to an ultrasound beam. The unit is joule (J).

Related term: Contrast with *ultrasound exposimetry*

ultrasound exposimetry

The measurement of the quantity of ultrasound to which a subject is exposed.

Related term: Contrast with *ultrasound dosimetry*

ultrasound instrument console

Electronic unit to which the transducer assembly is attached.

ultrasound research system

An ultrasound system intended for research and technical development purposes, which can be programmed by the user to achieve new functions.

ultrasound therapy

See *therapeutic ultrasound*.

ultrasound-induced bioeffect

A change in the structure or function of a biological structure resulting from exposure to ultrasound.

ultrasound-mediated drug delivery

An ultrasound technique that enhances the delivery of drugs into the target tissue. Often, this technique relies on the interaction of ultrasound energy with systemically circulating microbubble contrast media to reversibly disrupt nearby cell and neovascular membranes and enable uptake of the therapeutic agent.

ultrasound-stimulated gene delivery

An ultrasound technique that enhances the delivery of gene therapy vectors into the target. Often, this technique relies on the interaction of ultrasound energy with a systemically circulating microbubble contrast medium to reversibly disrupt nearby cell and neovascular membranes and enable uptake of the genetic material.

unbiased estimator

An estimator for which its expected value equals the true mean value.

uncoupled mode

A normal mode oscillating independently of other modes.

undamped natural frequency

Frequency of free oscillation resulting from only elastic and inertial forces of the system.

Related term: *resonance frequency*

unenhanced sonography

Sonography in which a contrast agent is not used.

unidirectional hydrophone

Directional hydrophone the response of which has a prominent maximum for one direction of the sound wave.

uniform insonation method

An ultrasonic method used in the estimation of volume flow in which Doppler signals are acquired equally from an entire cross section of the vessel being interrogated.

unipolar pulse or waveform

A waveform that has either positive or negative excursions from the baseline but not both. A unipolar waveform can be produced by rectification of radio frequency signals.

user interface

The part of an ultrasound system by which the user can configure the system to work in a desired mode of operation. The user interface also provides the means of transferring information into and out of the system, as well as controlling and displaying parameters of an ultrasound imaging system.

V

vascular

Adjective relating to a blood vessel.

vascular contrast agent

See *contrast agent, vascular*.

vascular morphology

Related to the geometry and structural features of blood vessels and typically used to describe vascular function or abnormalities.

Related term: vessel tortuosity

vascular phases of enhancement

Used to indicate the phases when contrast agent microbubbles circulate within the vascular system of the body. This is useful because some contrast media also show a postvascular phase.

vector

A quantity possessing both magnitude and direction.

vector Doppler

A type of vector flow using Doppler shift techniques to determine both longitudinal and transverse directions simultaneously.

vector flow

An ultrasound method used to determine flow in both longitudinal and transverse directions simultaneously.

velocity

A vector, the magnitude of which is the speed of a moving object and the direction is that in which the object is moving.

velocity, critical

The flow velocity at which the Reynolds number attains its critical value and the onset of turbulence occurs.

velocity gradient

The rate of change of velocity with position. With steady laminar flow in a blood vessel, this gradient is usually in a radial direction.

velocity hydrophone

A hydrophone whose output voltage is proportional to particle velocity.

velocity of sound

The speed of sound in a specified direction.

See *speed of sound*.

velocity profile

The variation of velocity with radial position for flow in a tube.

velocity profile, blunted

A modification of the parabolic flow profile that is commonly encountered in physiologic circumstances. The central laminae move at almost the same velocity.

Related term: velocity profile, parabolic

velocity profile, parabolic

The form of the velocity profile found with steady flow in a round vessel that exhibits flow resistance only. The parabolic flow profile has the special property that the average velocity across the vessel is exactly one-half of the maximum velocity in the center stream. Also called Poiseuille flow.

Related term: velocity profile, blunted

venous phase of enhancement

The phase of contrast medium circulation when contrast-enhanced blood leaves an organ through its venous drainage. For liver imaging, it is synonymous with the sinusoidal phase rather than the portal phase.

vessel tortuosity

A geometric feature of some vessels characterized by abnormally excessive curvature and shape.

Related term: vessel morphology

video signal

The processed envelopes of echo signals in an ultrasonic imaging system generally are referred to as "video signals" by analogy with television nomenclature. Processing may include compression and postprocessing and/or preprocessing.

video signal (ultrasound)

The envelope of echo signals in an ultrasonic imaging system generally are referred to as "video signals" by analogy with television nomenclature. The final stream of information from which images are displayed.

viscoelastic

Pertaining to a substance having both viscous and elastic properties.

Related term: viscoelasticity

viscoelasticity

A property of a material that is viscous and also exhibits elasticity. The application of a stress to a viscoelastic material gives rise to a strain that approaches its equilibrium value slowly.

viscosity

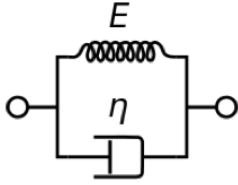
The tendency of a material or fluid to resist deformation. The slow response to either a stress or strain stimulus.

viscous damping

Mechanical damping that occurs to a wave or particle moving in a medium in which there is a resisting force that opposes the motion. The magnitude of the resisting force is often proportional to the particle velocity and in a direction opposing that of the particle. This process results in a viscous loss and most often with a change in phase velocity.

Voigt model

A viscoelastic model of a material that can be represented by a dashpot η in parallel with a purely elastic spring E , as shown in the diagram below. Also known as the Kelvin-Voigt model.



Related terms: Burgers model, dashpot, elastic spring, Maxwell model, Kelvin-Voigt model, standard viscoelastic linear model

volume acquisition

A process of scanning in which many ultrasound scans are obtained to image a structure in 3 dimensions.

Related term: 3-dimensional acquisition

volume flow

The volume of fluid passing through a surface (usually imaginary) per unit time. In a blood vessel, volume flow (F) equals the product of the cross-sectional area (A) and the average blood velocity (v); ie, $F = A \cdot v$. The unit is liters per second (L/s).

volume scattering coefficient

The quotient of the scattering cross section of the volume considered divided by that volume.

volume strain

The change in volume divided by the original volume.

See *strain*.

volume velocity

Integral, over a vibration surface, of the product of the component of particle velocity normal to the surface and the differential surface area.

vortex

See *vortices*.

vortices

Elements of rotational flow often seen with flow separation, disturbance, and turbulence. Rotating flow comprises a wide range of velocities aligned in both directions along a line passing through its center. Doppler shifts from vortical flow are thus characterized by spectral broadening. Simultaneous forward and reverse flow will also be seen if the vortex velocity exceeds the component of the longitudinal flow speed along the beam.

voxel

The smallest volume element or cell size in a digitized 3-dimensional (3D) image. Each voxel has an address and a brightness or color. The address is given by a set of x , y , and z coordinates corresponding to the voxel's position in the 3D array. Compare with pixel, the smallest element of a 2-dimensional image.

W

wall admittance

Quotient of the particle velocity normal to a wall to the sound pressure acting on the wall.

wall filter

See *filter, high-pass*.

wall impedance

Quotient of the sound pressure acting on a wall to the particle velocity normal to the wall.

wall thump

A strong, low-frequency clutter signal tending to obscure the Doppler frequency spectrum of interest, often arising from motion of the walls of a blood vessel.

wall (thump) filter

An electronic signal filter in a Doppler system that rejects echo information from low-velocity reflectors such as stationary or slow-moving tissue. This filtering is needed to keep high-amplitude tissue echoes from saturating the Doppler receiver, masking very low-amplitude echoes from flowing blood.

See *wall thump*.

wash-in

Initial enhancement of a vascularized lesion, a vessel lumen, or a cardiac chamber. A lesion (or vessel or chamber) becomes rapidly or slowly enhanced.

Related terms: wash-out, wash-in–wash-out curve

wash-out

De-enhancement of a vascularized lesion, a vessel lumen, or a cardiac chamber. A formerly enhanced lesion (or vessel or chamber) becomes rapidly or slowly less enhanced than previously. The time of wash-out indicates whether a lesion becomes hypoenhanced, which is a feature of malignancy. Conversely, sustained enhancement is commonly encountered in benign lesions.

Related terms: wash-in, wash-in–wash-out curve

wash-in–wash-out curve

Graphic plotting intensity of a microbubble signal over time from contrast medium injection. Also called a time-intensity curve.

Related terms: wash-in, wash-out curve

water immersion

A situation in which part or all of a technique is performed under water.

watt (W)

The unit of power; $1 \text{ W} = 1 \text{ joule per second (J/s)}$.

watt per square centimeter (W/cm^2)

A unit of intensity; $1 \text{ W}/\text{cm}^2 = 10^4 \text{ W}/\text{m}^2$.

wave

See *acoustic wave*.

waveform

The graphic representation of an acoustical or electrical parameter as a function of time.

wavefront

An imaginary surface passing through all particles that are in the same phase of vibration within a propagating sound wave.

See *acoustic wavelength*.

wavelength

See *acoustic wavelength*.

wavelet

A tiny wave.

wavenumber

2π times the number of oscillations per unit length. Wavenumber (k) = $2\pi/\lambda$, where λ is the wavelength. The unit is radian per meter or reciprocal meter (m^{-1}).

See *acoustic wavelength*.

wave reflection

As the velocity pulse of blood flow travels along the arterial tree, reflections, consisting of pressure waves traveling in a proximal direction (toward the heart), occur at discontinuities of fluid impedance, mainly at branch points.

Related term: reflection

wave reflection (fluid)

As the velocity pulse of blood flow travels along the arterial tree, reflections, consisting of waves traveling in a proximal direction, occur at discontinuities of fluid impedance, mainly at branch points.

wave velocity

With respect to the cardiovascular system, the velocity of propagation of a pressure pulse along the arterial tree. This velocity varies from about 5 m/s in the aorta to about 5 cm/s in small vessels.

Related term: velocity of sound

white noise

Noise whose power spectral density is essentially independent of frequency.

whole number

A member of the set of positive integers and 0, ie, the numbers 0, 1, 2, 3, ..., etc. There is no fractional or decimal part. Whole numbers are also known as the counting numbers.

wideband

An adjective referring to the ability of a device to pass a very wide range of frequencies in a signal. Wideband also refers to a signal that contains frequency components distributed over a wide range.

Related term: Contrast with narrow bandwidth

wide view

A transducer technique used in linear arrays to expand the lateral field of view. Using electronic timing delays as in phased array imaging, the ultrasound beam is steered to view beyond the lateral edges of the transducer.

window

See scanning window.

window, systolic

A relatively signal-free area between the arterial Doppler shift signal and the baseline during the systolic portion of a Doppler spectral display. The window tends to be obliterated by turbulent flow.

wire phantom

Container filled with medium having a known sound speed in which thin wires are fixed at regular distances. Used for calibration of the time base (distance calibration) and estimation of axial and lateral resolution.

working frequency

See acoustic working frequency.

write zoom

Process of enlarging a region of interest by optimizing the scanning parameters and rescanning the region. Instruments that have this feature allow the operator to first select the region to be enlarged by applying cursors to the original image. Only echo data arising from within the zoomed region are written to the memory, and all pixels in the memory are used to represent this region. Thus the image should not lose the detail that it might when using read zoom.

Related term: read zoom

Y

Young's modulus

The ratio of the tensile stress to tensile strain in one dimension. The unit is pascal (Pa).

Z

zero crossing detector

An algorithm or device that detects the rate at which the value of a time-varying signal crosses zero.

zoom

See read zoom and write zoom.

abbreviations

Organizational Acronyms

AAN	American Academy of Neurology
ACCME	Accreditation Council for Continuing Medical Education
ACOG	American College of Obstetricians and Gynecologists
ACR	American College of Radiology
AHCPR	Agency for Health Care Policy and Research Practice Guidelines
AIUM	American Institute of Ultrasound in Medicine
AOCR	American Osteopathic College of Radiology
ARDMS	American Registry for Diagnostic Medical Sonography
ARRS	American Roentgen Ray Society
ARRT	American Registry of Radiologic Technologists
ASE	American Society of Echocardiography
ASN	American Society of Neuroimaging
ASRT	American Society of Radiologic Technologists
ASOU	American Society of Ophthalmologic Ultrasound
CAAHEP	Commission on Accreditation for Allied Health Education Programs
CCI	Cardiovascular Credentialing International
CDRH	Center for Devices and Radiological Health
CHEA	Council for Higher Education Accreditation
ICAVL	Intersocietal Commission for the Accreditation of Vascular Laboratories
IEC	International Electrotechnical Commission
JCAHO	Joint Commission on Accreditation of Health Organizations
JRCDS	Joint Review Committee on Education in Diagnostic Medical Sonography
NCRP	National Council on Radiation Protection and Measurements
NEMA	National Electrical Manufacturers Association
RSNA	Radiological Society of North America
SDMS	Society of Diagnostic Medical Sonography
SMFM	Society for Maternal-Fetal Medicine
SOPE	Society of Pediatric Echocardiography
SPR	Society for Pediatric Radiology
SRU	Society of Radiologists in Ultrasound
SVS	Society for Vascular Surgery
SVU	Society for Vascular Ultrasound
WFUMB	World Federation for Ultrasound in Medicine and Biology

abbreviations *continued*

Suggested Abbreviations

2DS	2-dimensional sonography
2DUS	2-dimensional ultrasound
3DS	3-dimensional sonography
3DUS	3-dimensional ultrasound
4DS	4-dimensional sonography
4DUS	4-dimensional ultrasound
AGC	automatic gain control
ALARA	as low as reasonably achievable
A-mode	amplitude mode
B-mode	brightness mode
CD	color Doppler
CDE	color Doppler energy
CDI	color Doppler imaging
CDS	color Doppler sonography
CDUS	color Doppler ultrasound
CE-PIHI	contrast-enhanced pulse inversion harmonic imaging
CES	contrast-enhanced sonography
CEUS	contrast-enhanced ultrasound
CFDS	color flow Doppler sonography
CFDU	color flow Doppler ultrasound
CRT	cathode ray tube
CW	continuous wave
CWD	continuous wave Doppler
DS	Doppler sonography, duplex sonography
DTI	Doppler tissue imaging
DUS	Doppler ultrasound, duplex ultrasound
EVS	endovaginal sonography
EVUS	endovaginal ultrasound
FAST	focused assessment with sonography for trauma
FFT	fast Fourier transform
FI	flow index
FVR	flow volume rate
FWHM	full width, half-maximum
HIFU	high-intensity focused ultrasound

abbreviations *continued*

Suggested Abbreviations *continued*

HMD	head-mounted display
HRS	high-resolution sonography
HRUS	high-resolution ultrasound
HSG	hysterosalpingography
IOS	intraoperative sonography
IOUS	intraoperative ultrasound
ISAPA	spatial-average pulse-average intensity
ISATA	spatial-average temporal-average intensity
ISPPA	spatial-peak pulse-average intensity
ISPTA	spatial-peak temporal-average intensity
ISPTP	spatial-peak temporal-peak intensity
IVS	intravascular sonography
IVUS	intravascular ultrasound
LCD	liquid crystal display
LIPUS	low-intensity pulsed ultrasound
MI	mechanical index
M-mode	motion mode
OD	optical density
p–	peak negative acoustic pressure
Pa	pascal
PACS	picture archiving and communications system
pc	peak compressional pressure
PD	power Doppler
PDS	power Doppler sonography
PDUS	power Doppler ultrasound
PI	pulsatility index
pr	peak rarefactional acoustic pressure
PRF	pulse repetition frequency
PZT	lead zirconate titanate
RADIUS	Routine Antenatal Diagnostic Imaging With Ultrasound
RF	radio frequency
RFA	radio frequency ablation
RI	resistive index
RMS	root mean square

abbreviations *continued*

Suggested Abbreviations *continued*

ROI	region of interest
SAR	specific absorption rate
S/N	ratio signal-to-noise ratio
SHG	sonohysterography
TCCD	transcranial color Doppler
TCCS	transcranial color sonography
TCD	transcranial Doppler
TCDS	transcranial Doppler sonography
TCG	time-compensated gain
TGC	time-gain compensation
THI	tissue harmonic imaging
TI	thermal index
TRS	transrectal sonography
TRUS	transrectal ultrasound
TVCDs	transvaginal color Doppler sonography
TVS	transvaginal sonography
TVUS	transvaginal ultrasound
UCT	ultrasound computed tomography
VFI	vascularization flow index
VI	vascularization index

illustrations

Acknowledgment

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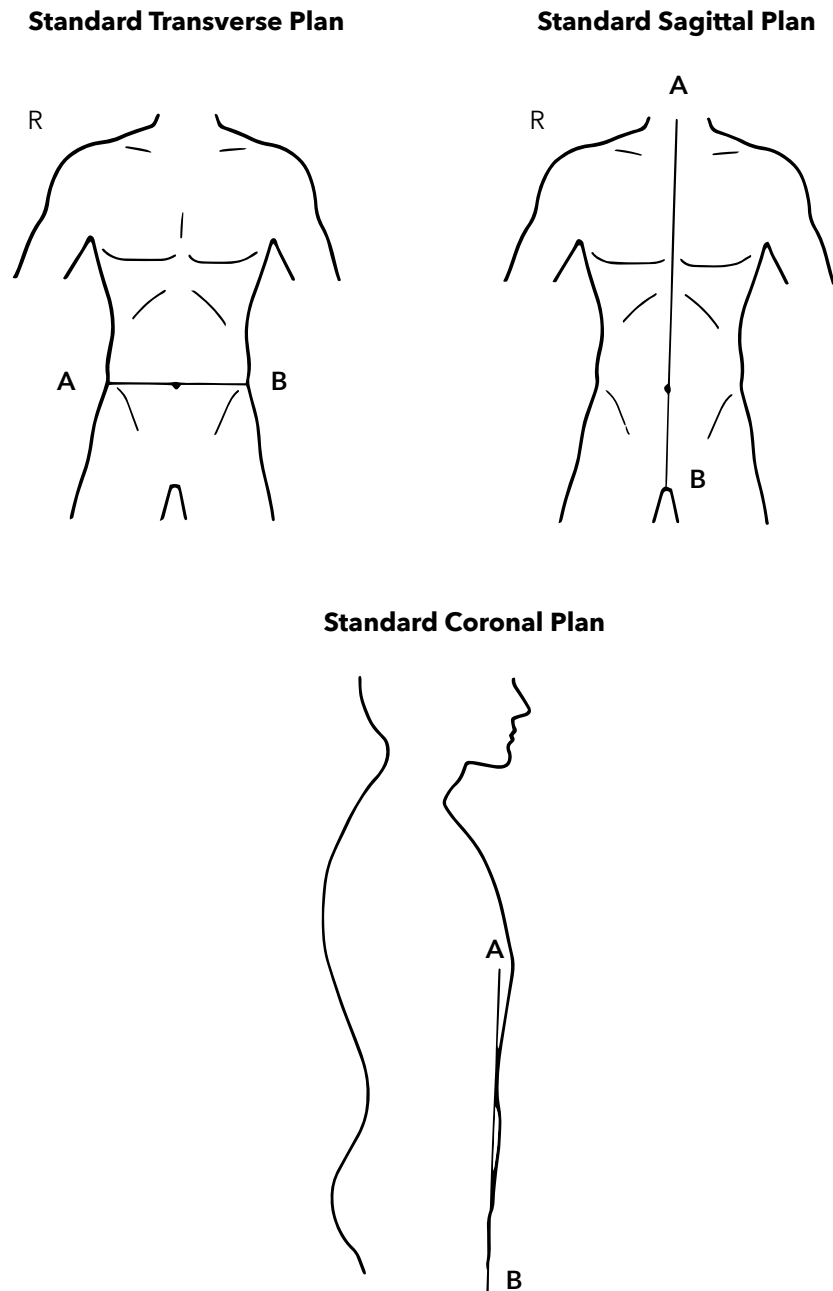


Figure 1

Standard body planes in ultrasound imaging, indicated by the plane perpendicular to the plane of this page and passing through the line A–B.

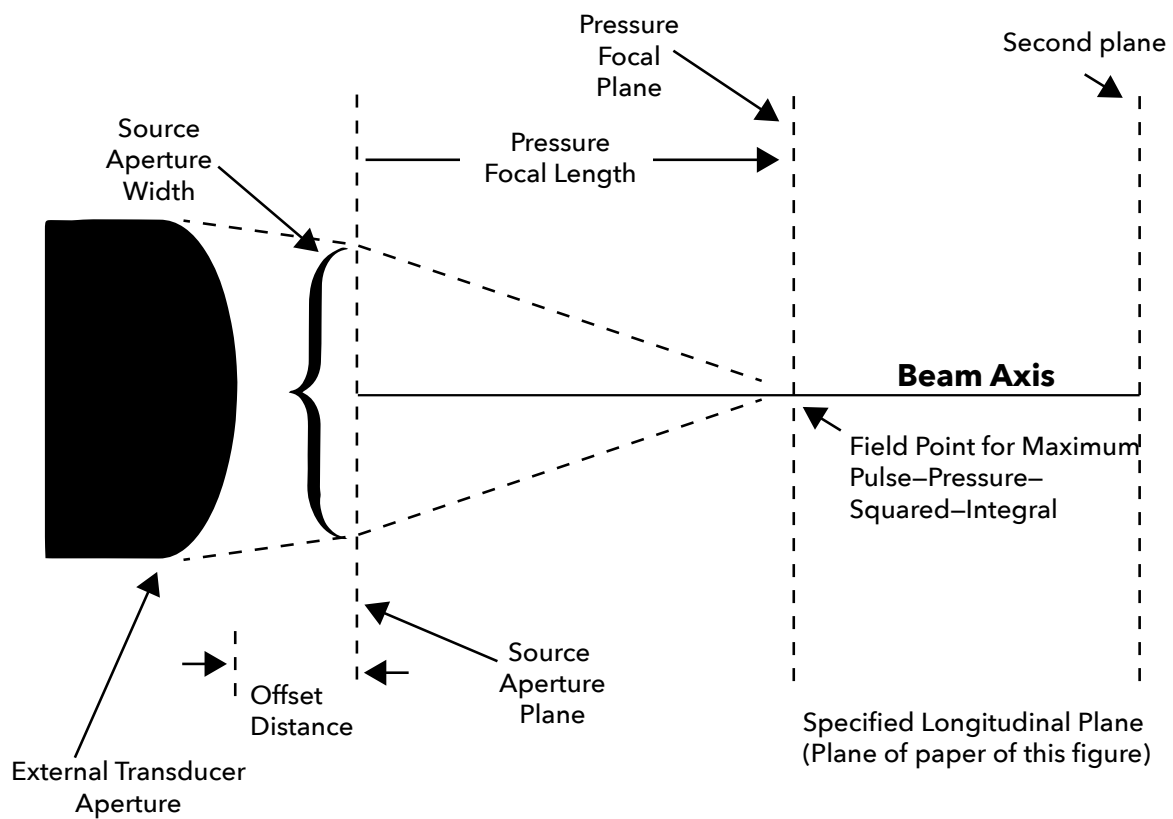
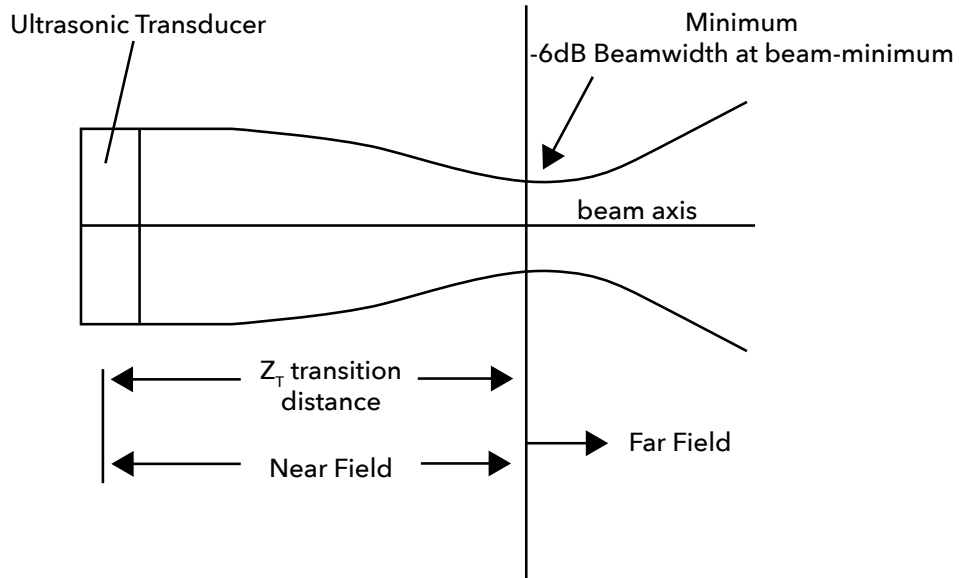


Figure 2

Definitions for focusing measurements when the transducer geometry is unknown Ultrasonic transducer

Nonfocusing Transducer



Focusing Transducer

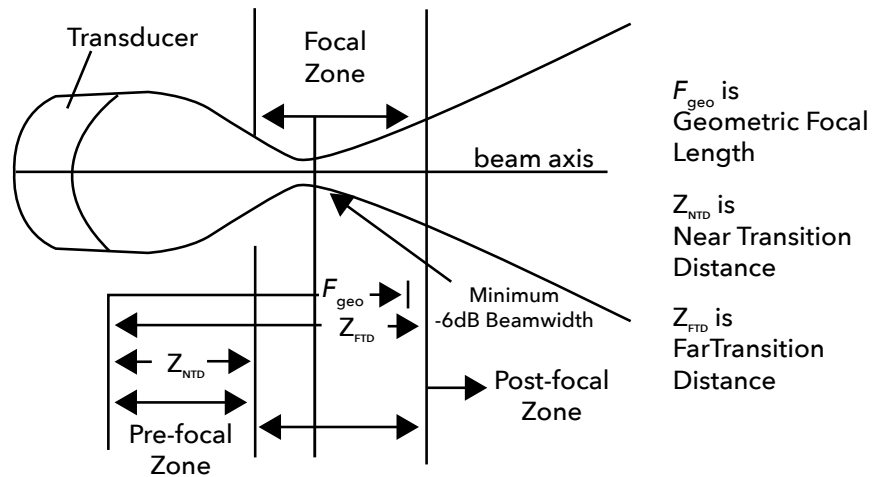


Figure 3

Top, Field parameters for a nonfocusing transducer. Bottom, Field parameters for a focusing transducers.

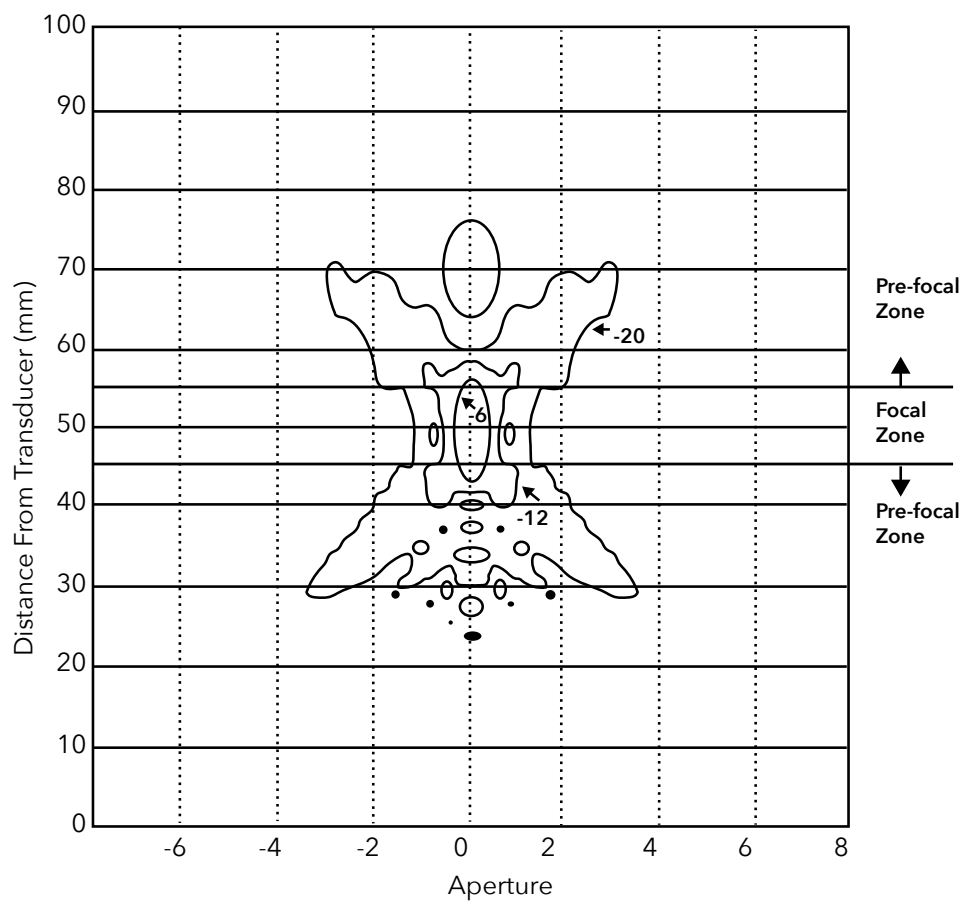


Figure 4

Beam contour (–6, –12, and –20 dB) for a 5-MHz curved transducer centered at location 0,0 (bottom center of graph) with a diameter of 25 mm and a radius of curvature of 50 mm.

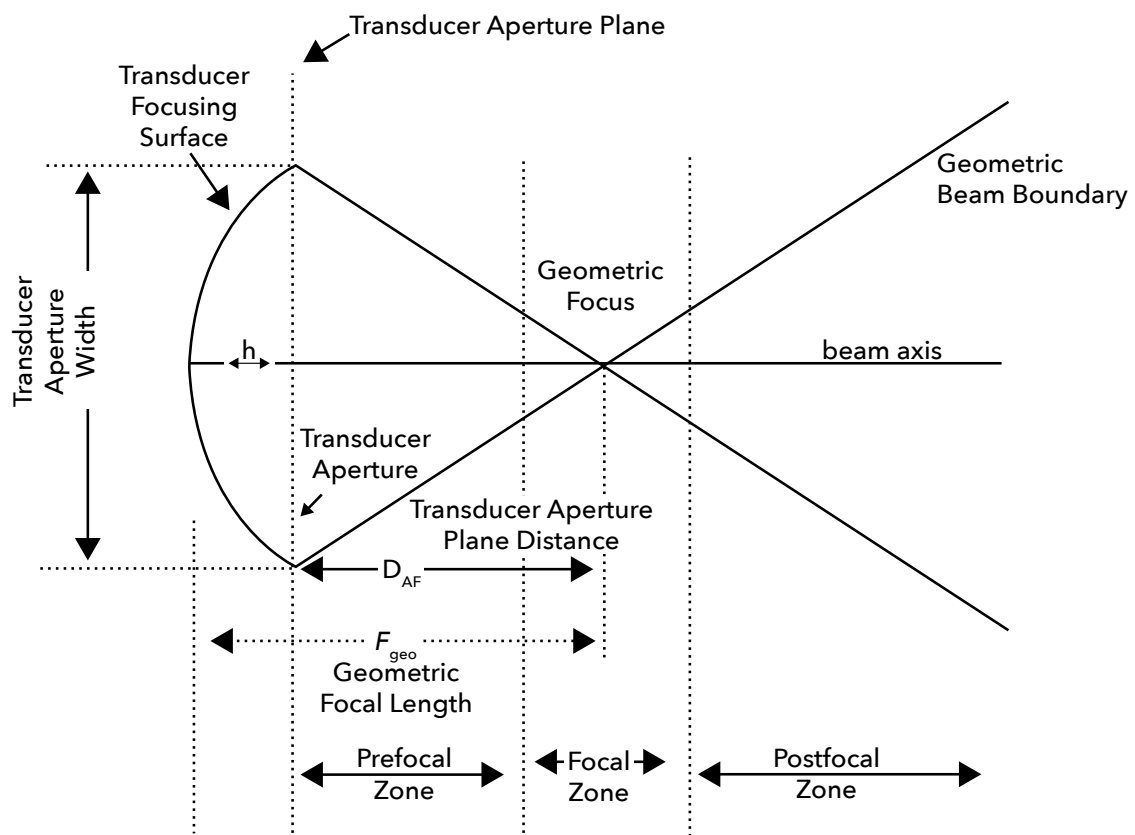


Figure 5

Parameters for describing a focusing transducer of a known geometry.

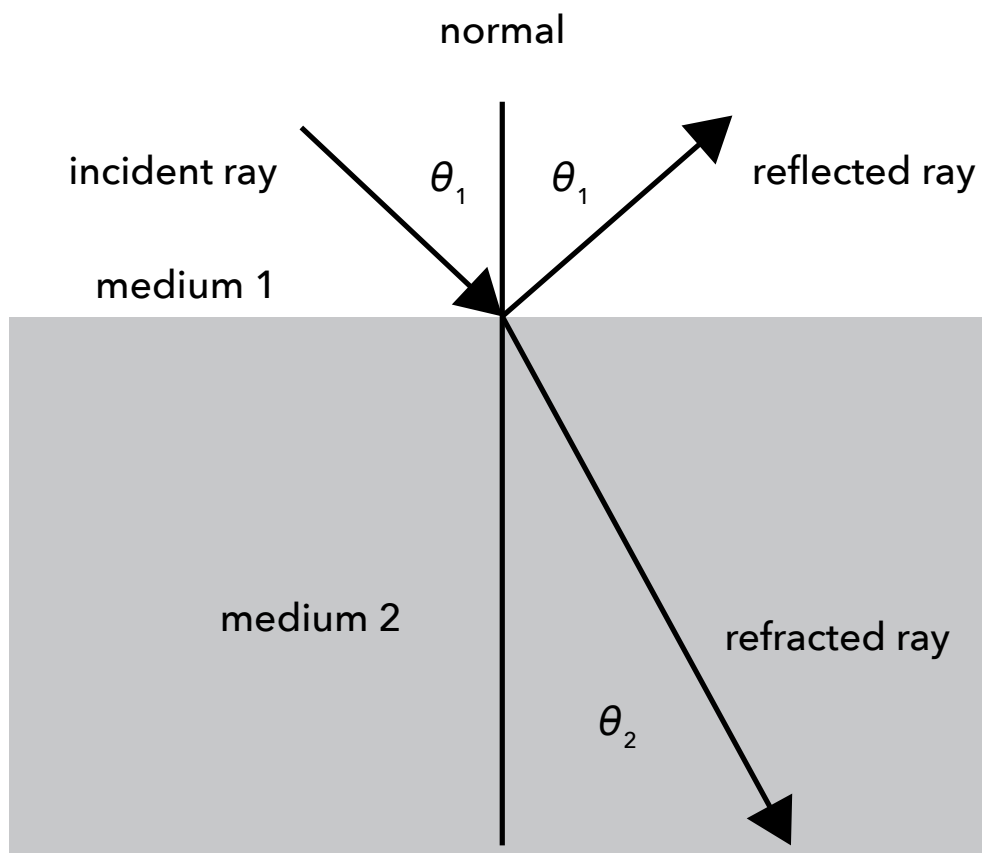


Figure 6

Reflection and refraction at a boundary between two media.

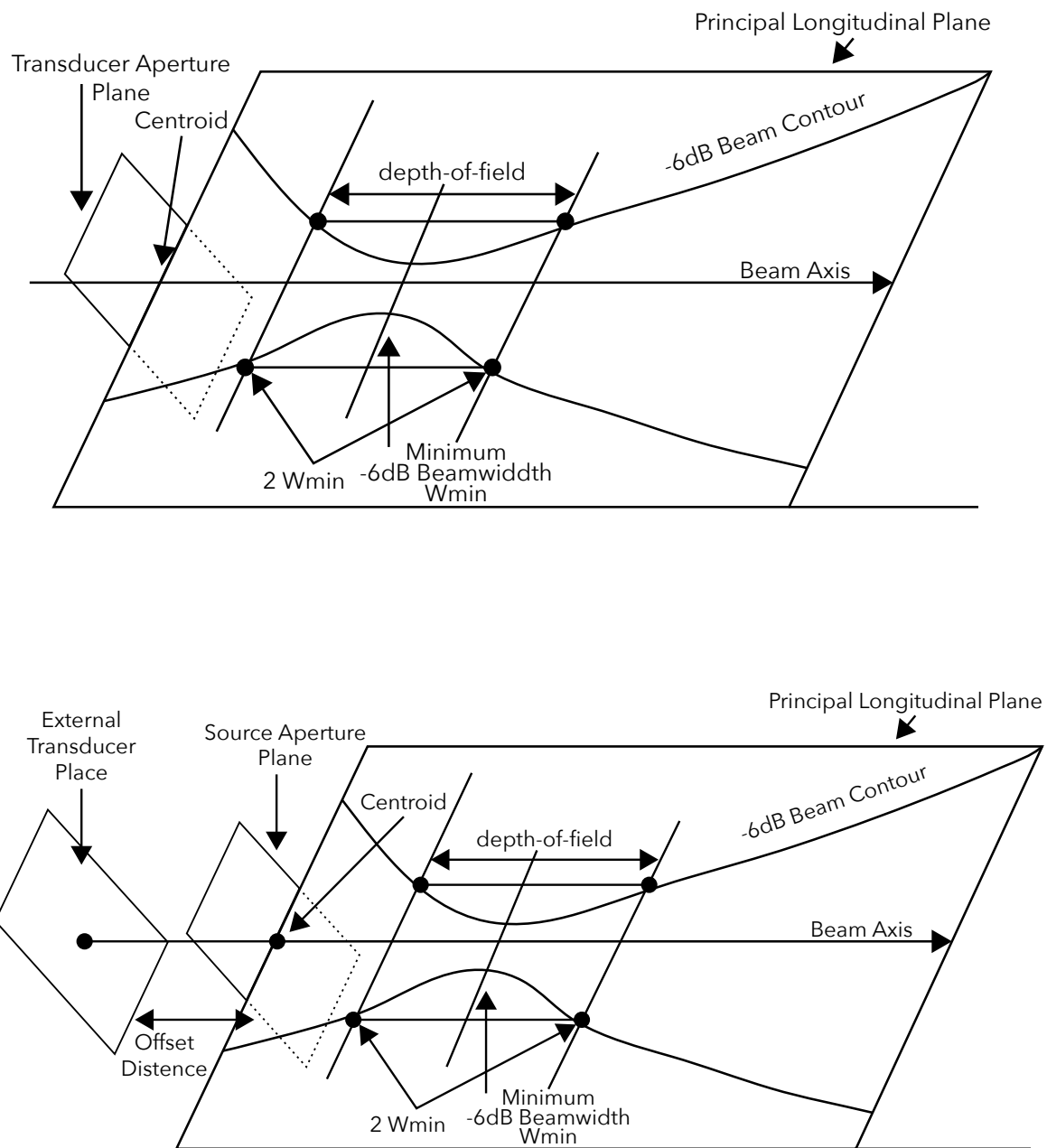


Figure 7

Beamwidth focus in a principal longitudinal plane. Top, For a transducer of known geometry. Bottom, for a transducer of unknown geometry (measurement case).

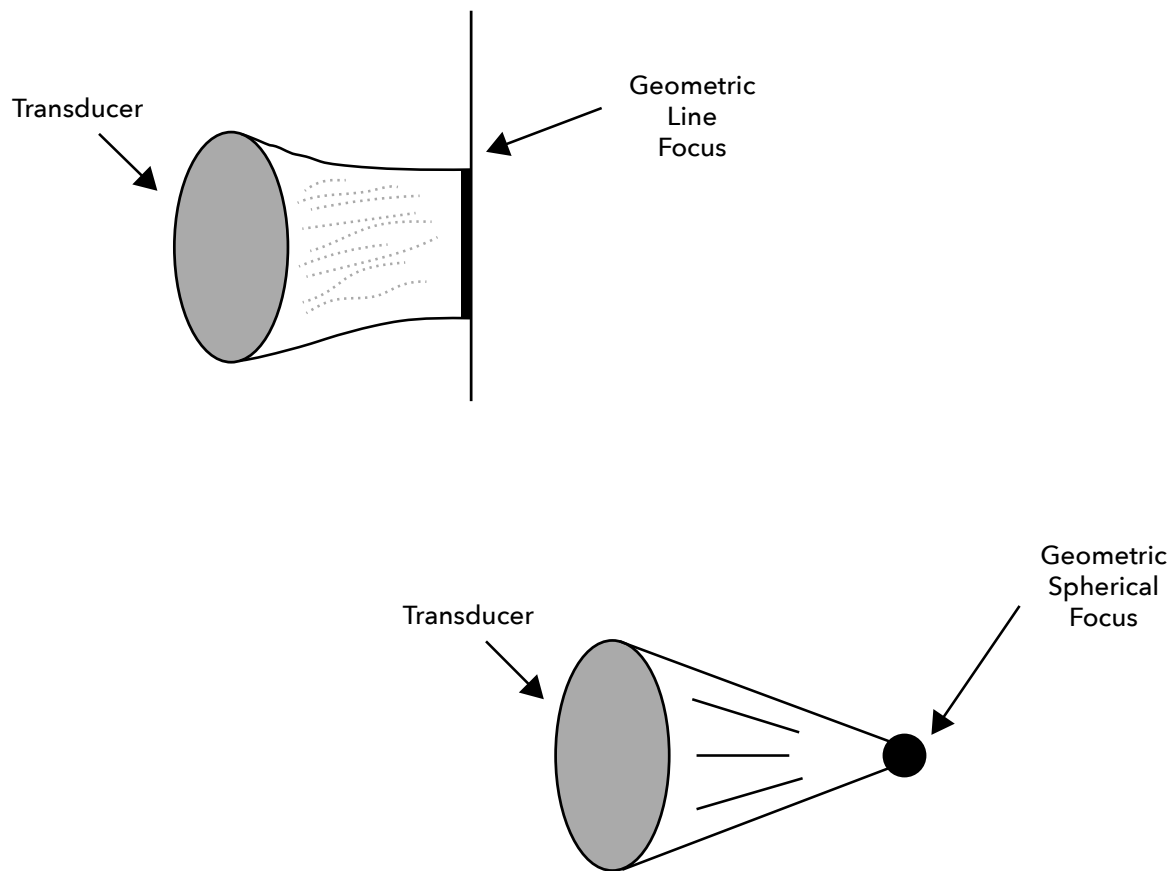


Figure 8

Types of geometric focusing. Top, Geometric line focus. Bottom, Geometric spherical focus.

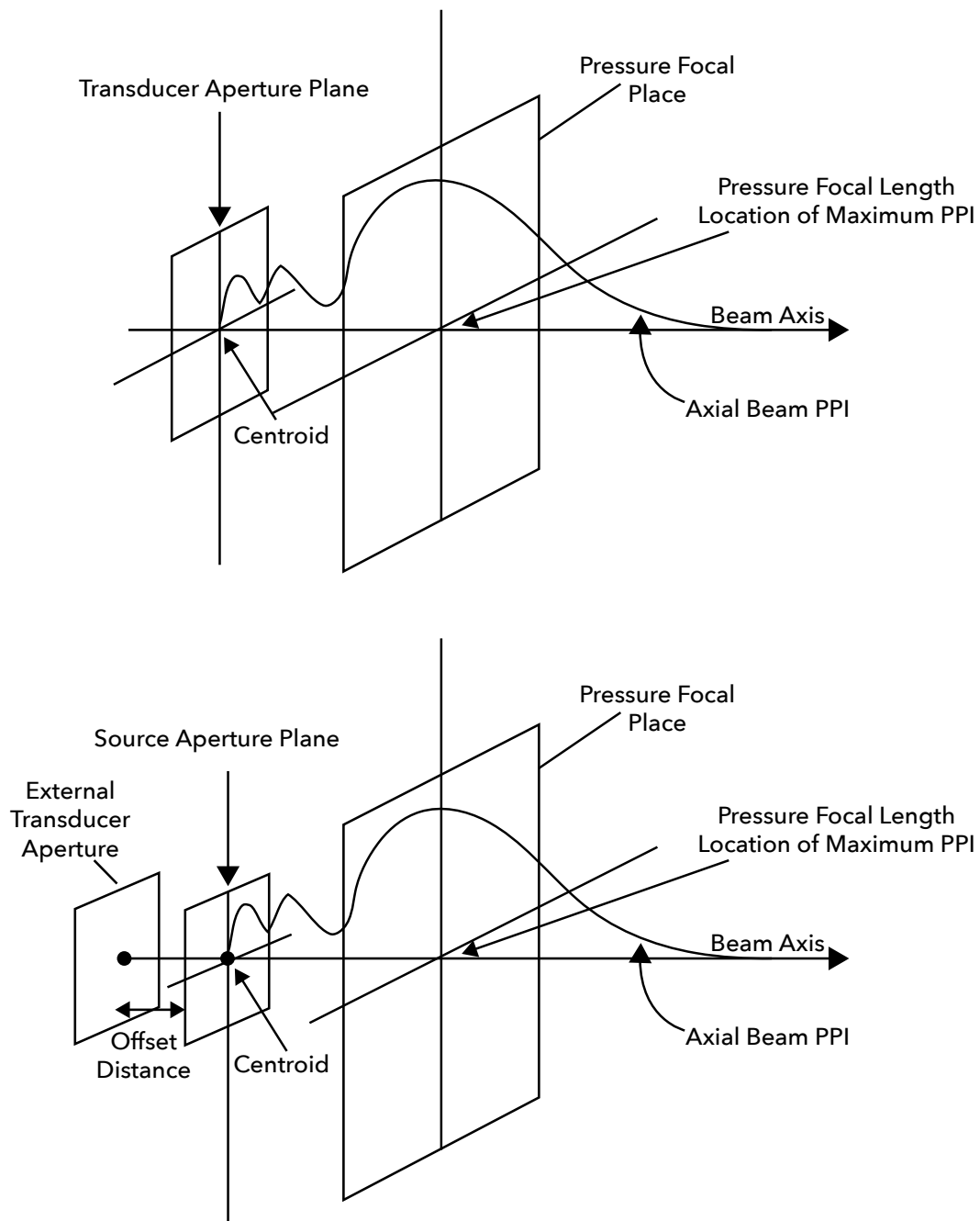
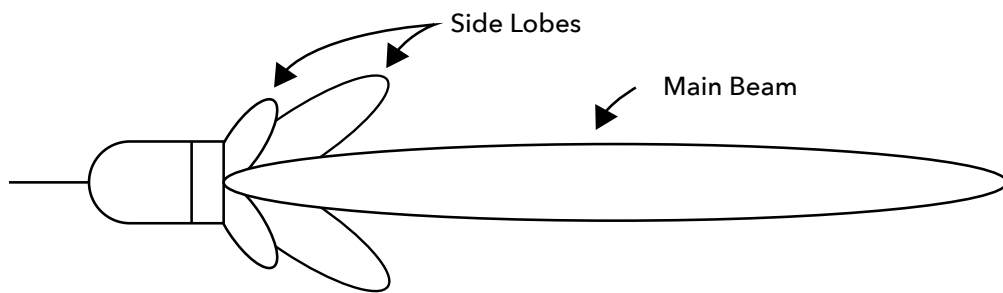
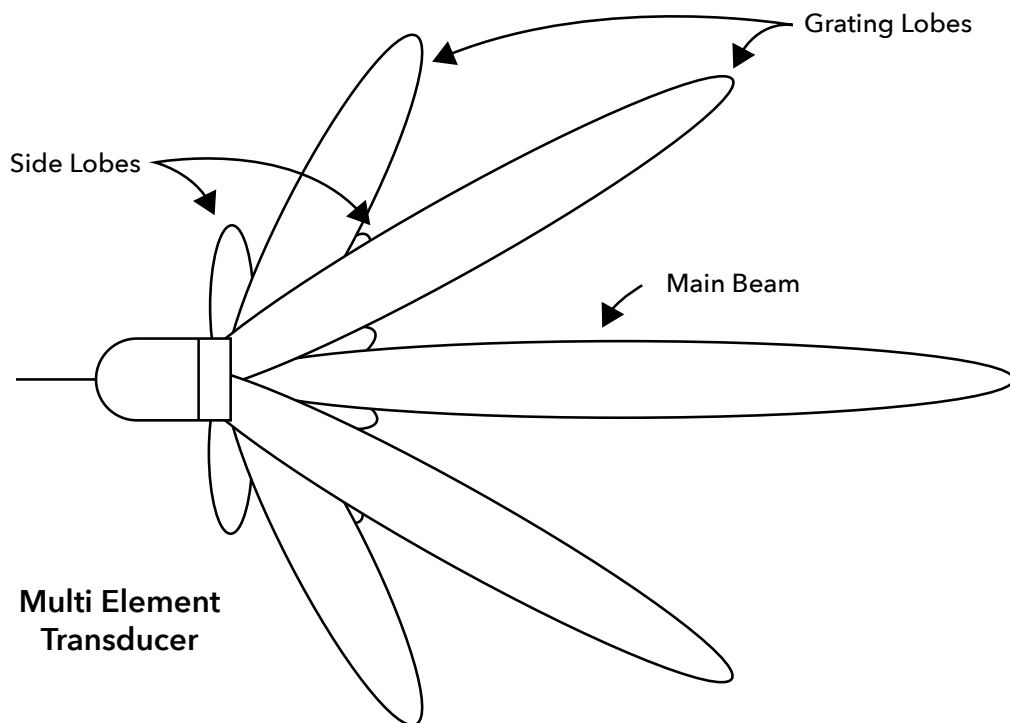


Figure 9

Pressure focus in a principal longitudinal plane. Top, For a transducer of known geometry. Bottom, for a transducer of unknown geometry (measurement case).



Single Element Transducer



**Multi Element
Transducer**

Figure 10

Beam patterns of single-element and multielement transducers showing side lobes and grating lobes.

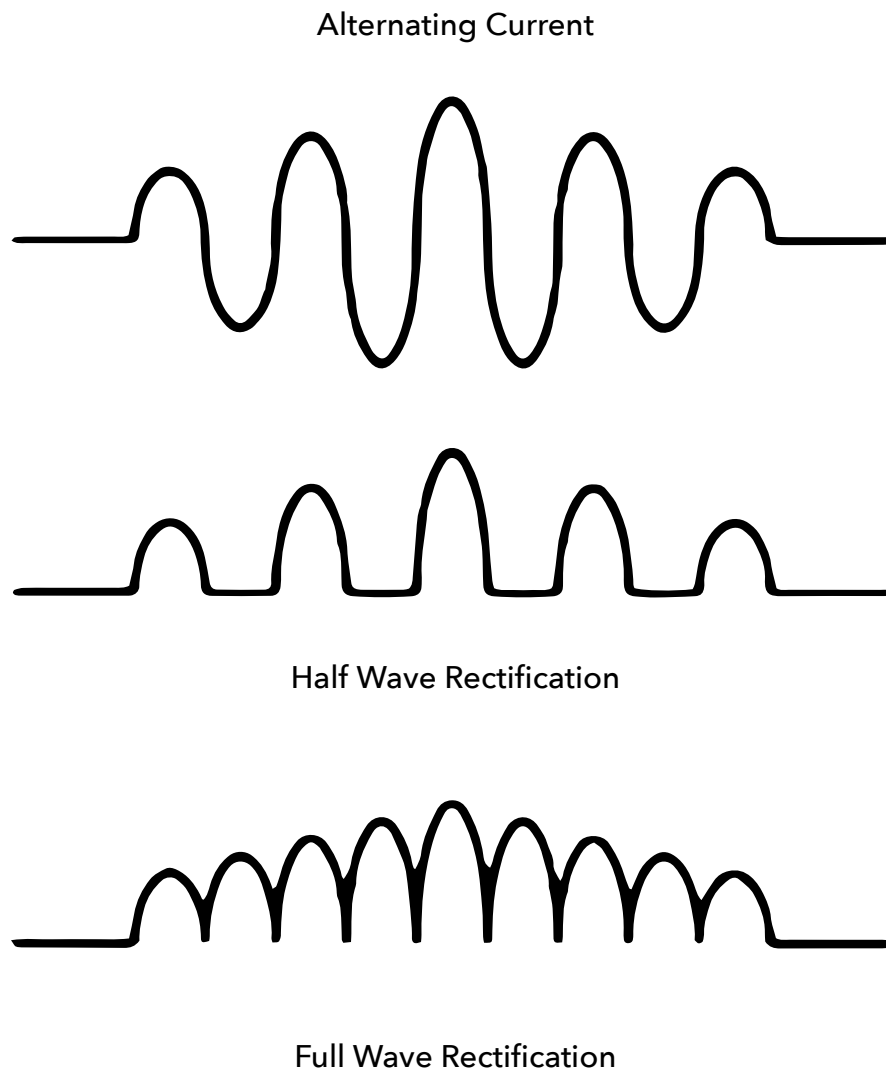


Figure 11

Half wave and full wave rectification.

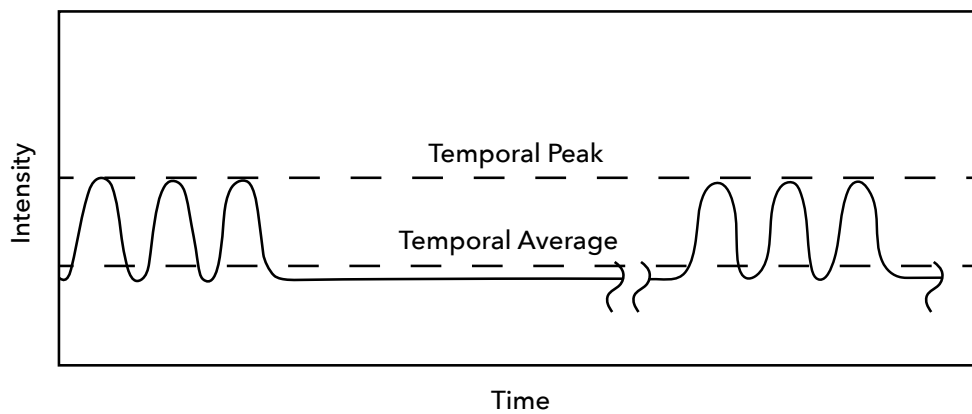


Figure 12

Temporal-peak and temporal-average intensities.

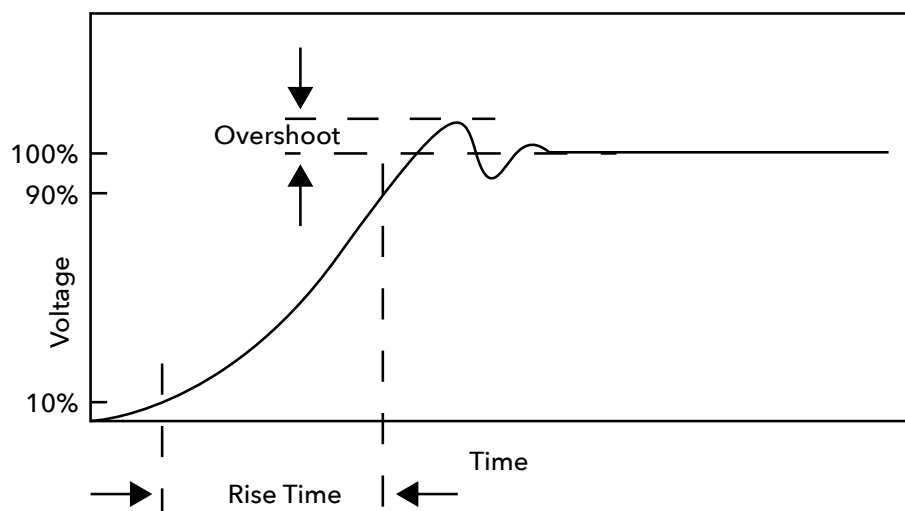


Figure 13

Voltage overshoot.

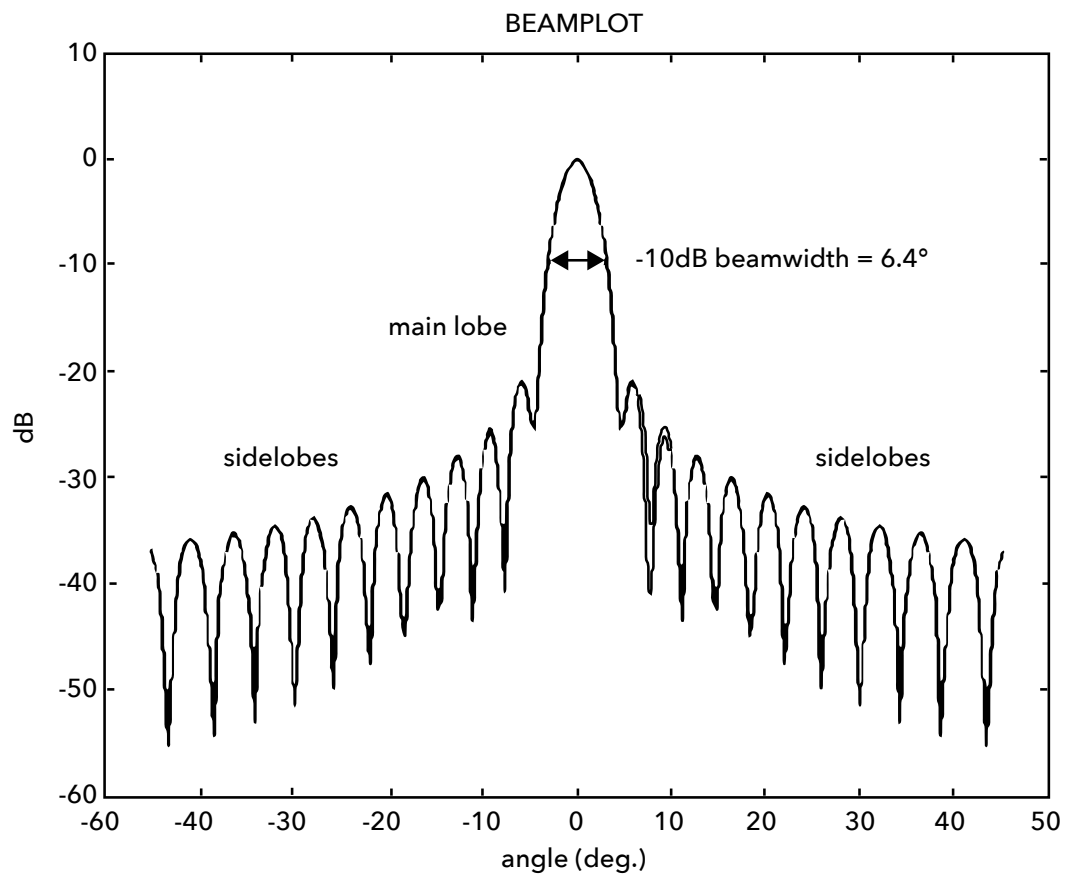


Figure 14

Beam plot showing side lobes, plotted in decibels versus angle. Shown are the main lobe centered at 0°, and at either side of the main lobe are the side lobes.

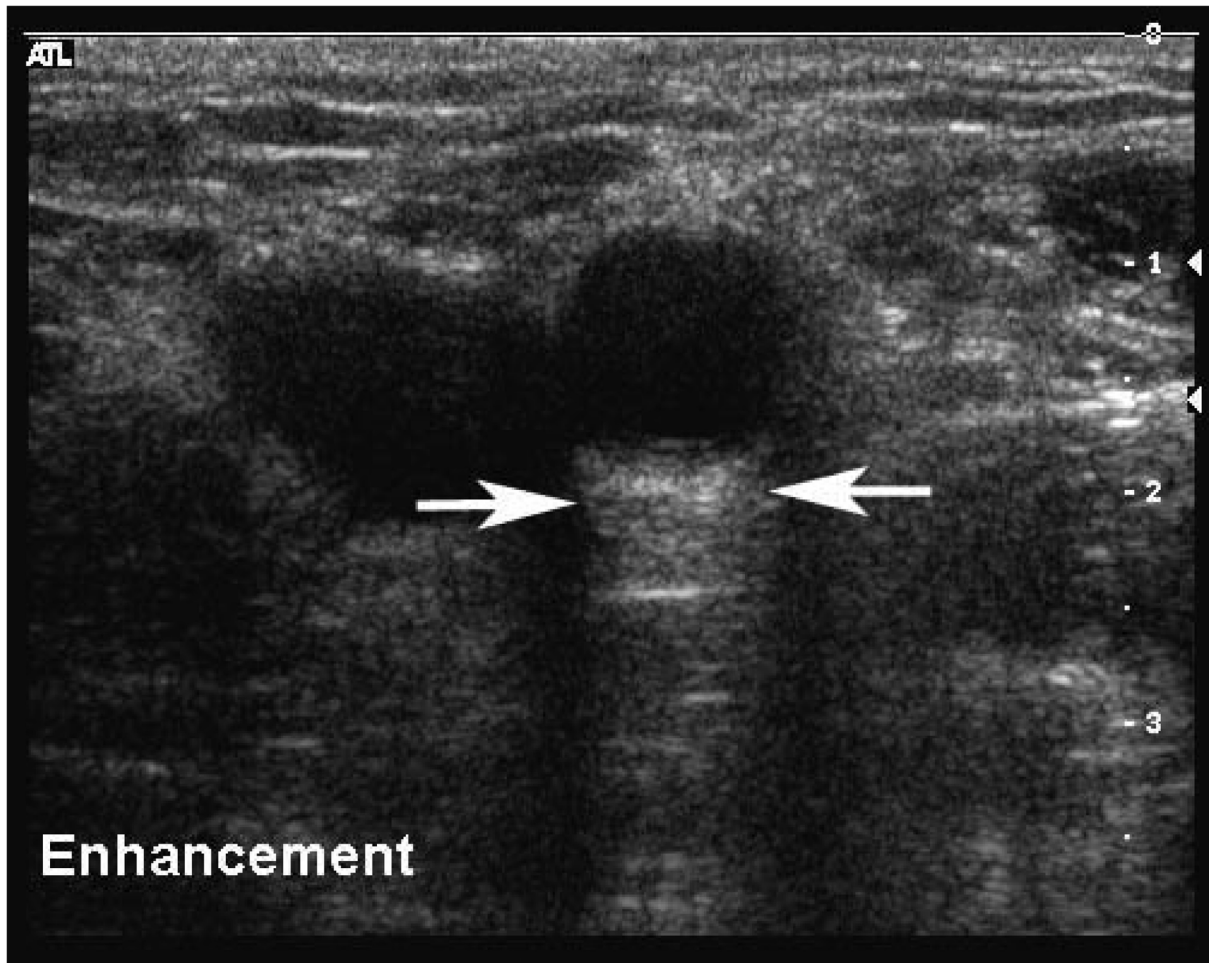


Figure 15

Acoustic enhancement seen distal to a low attenuating structure.



Figure 16

Acoustic shadow seen distal to a high-attenuating structure.

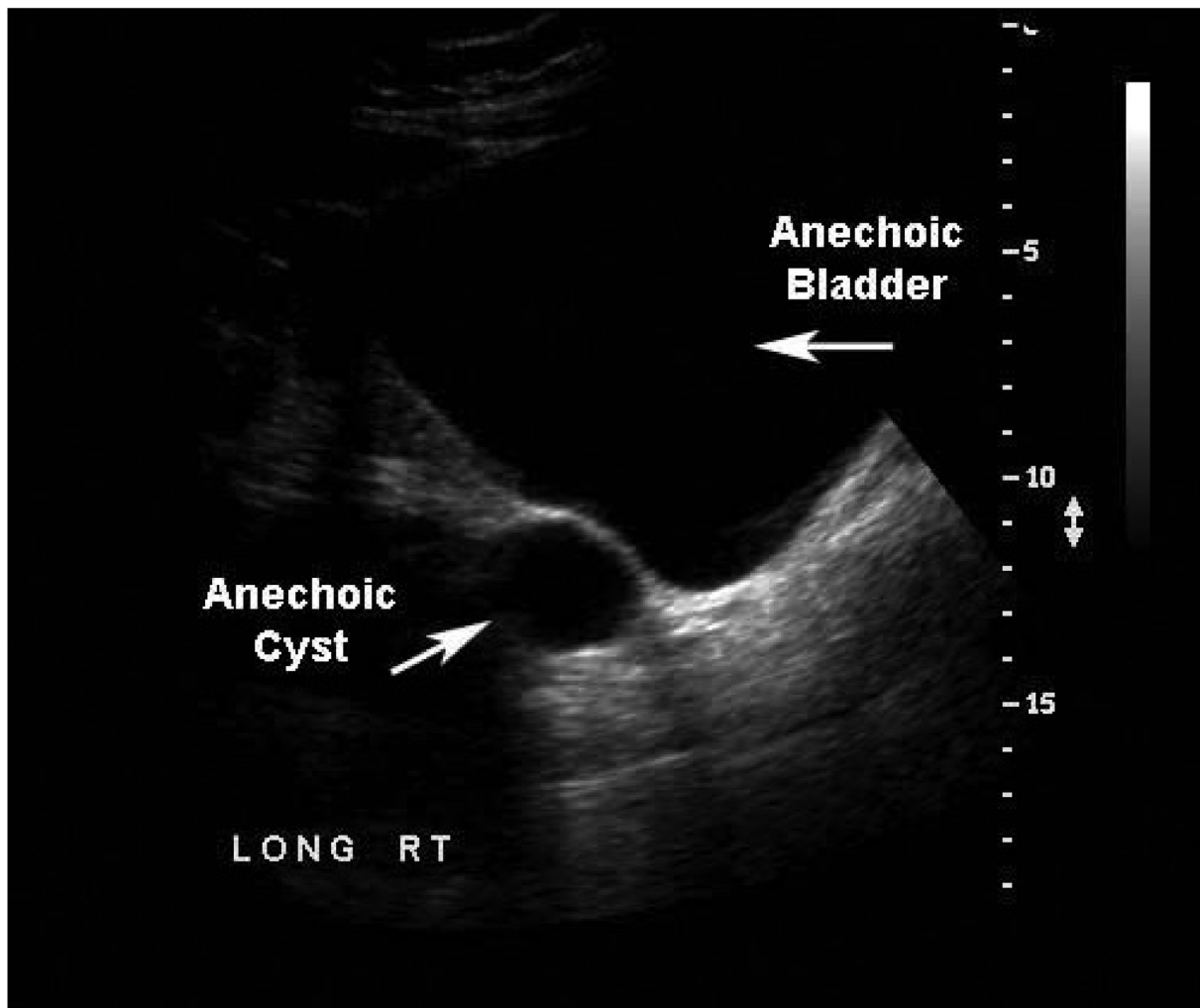
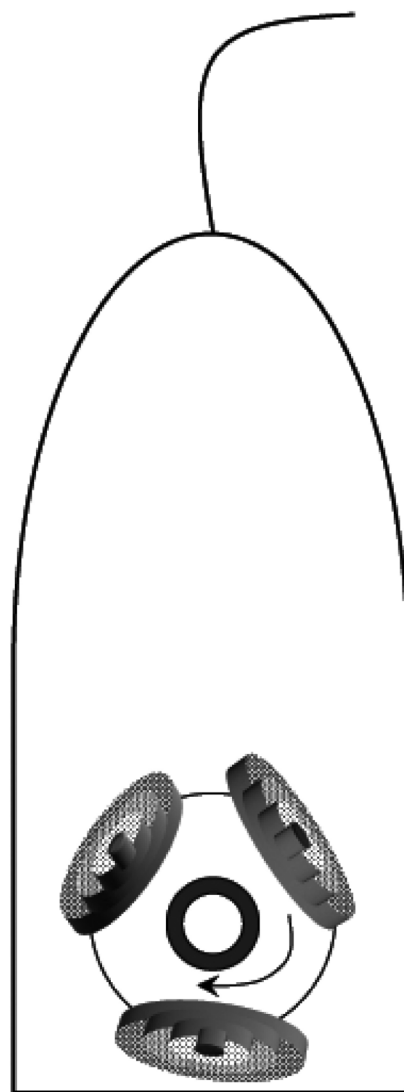
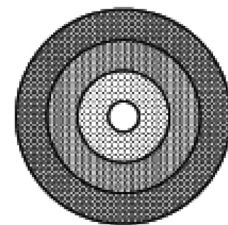


Figure 17

Anechoic regions in fluid-filled structures.



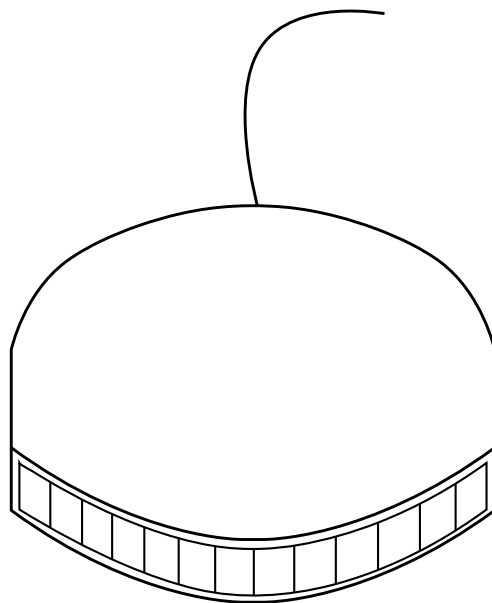
Annular Array Transducer
Multiple Element Arrays Mounted
on a Rotating Wheel to
Mechanically Steer the
Ultrasound Beam



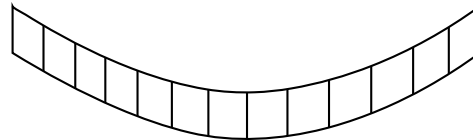
Annular Array Piezoelectric Elements:
Elements Arranged in Target Formation;
Excited From Innermost to Outermost
to Electronically Focus

Figure 18

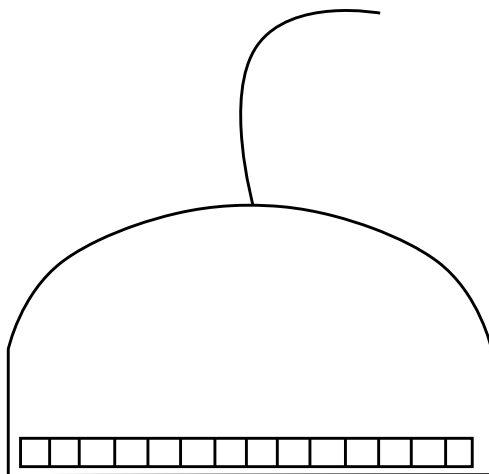
Annular transducer arrays. Note elements are in the form of concentric rings that are shaped like a bull's eye target.



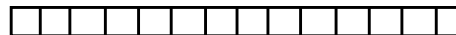
Curved Linear Array Transducer



Array Piezoelectric Elements:
Elements Arranged in a Curved Linear Formation; Produces a trapezoid image



Linear Array Transducer



Array Piezoelectric Elements:
Elements Arranged in a Linear Formation; Produces a box image

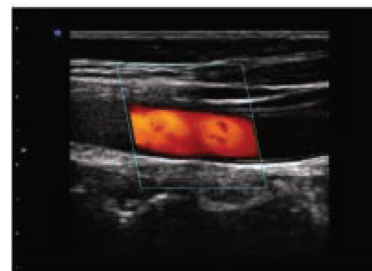


Figure 19

Linear transducer arrays. The top shows a curved linear array and its image format. The bottom shows an ordinary (straight) linear array and its image format, which is rectangular. Within the rectangle is a parallelogram-shaped inset commonly used for color flow or Doppler imaging. Note that phased arrays look physically like linear arrays but scan in an angle from a central point in the array and have a sector-shaped format exemplified by Figures 21 and 29.

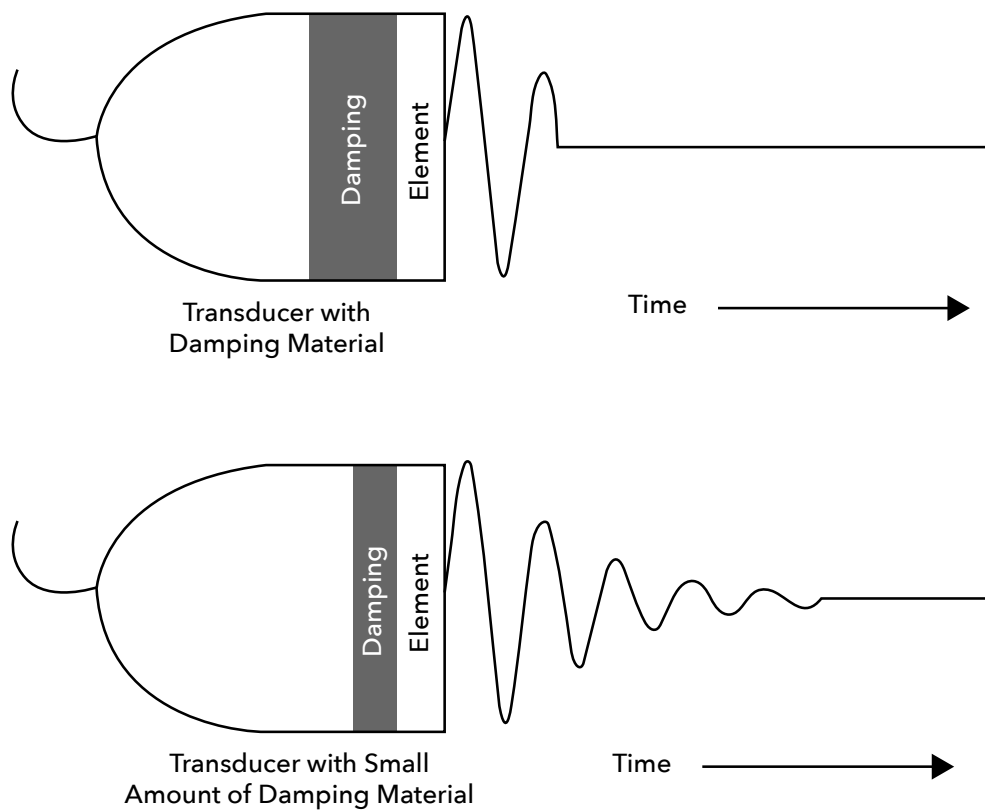


Figure 20

Effect of damping on transmitted pulse length. Shortening the transmitted pulse length produces better axial resolution.



Figure 21

Mirror image artifact.

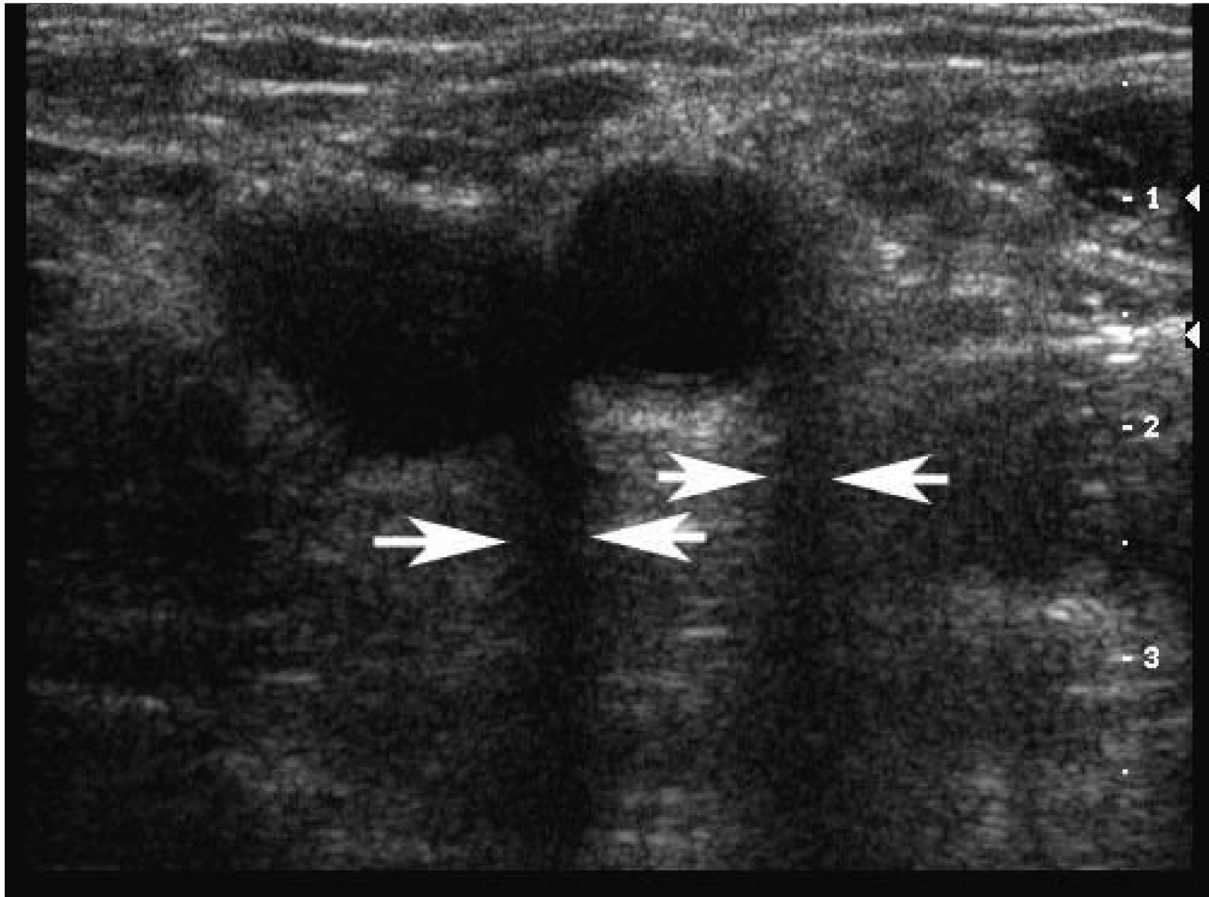


Figure 22

Refraction edge shadows.

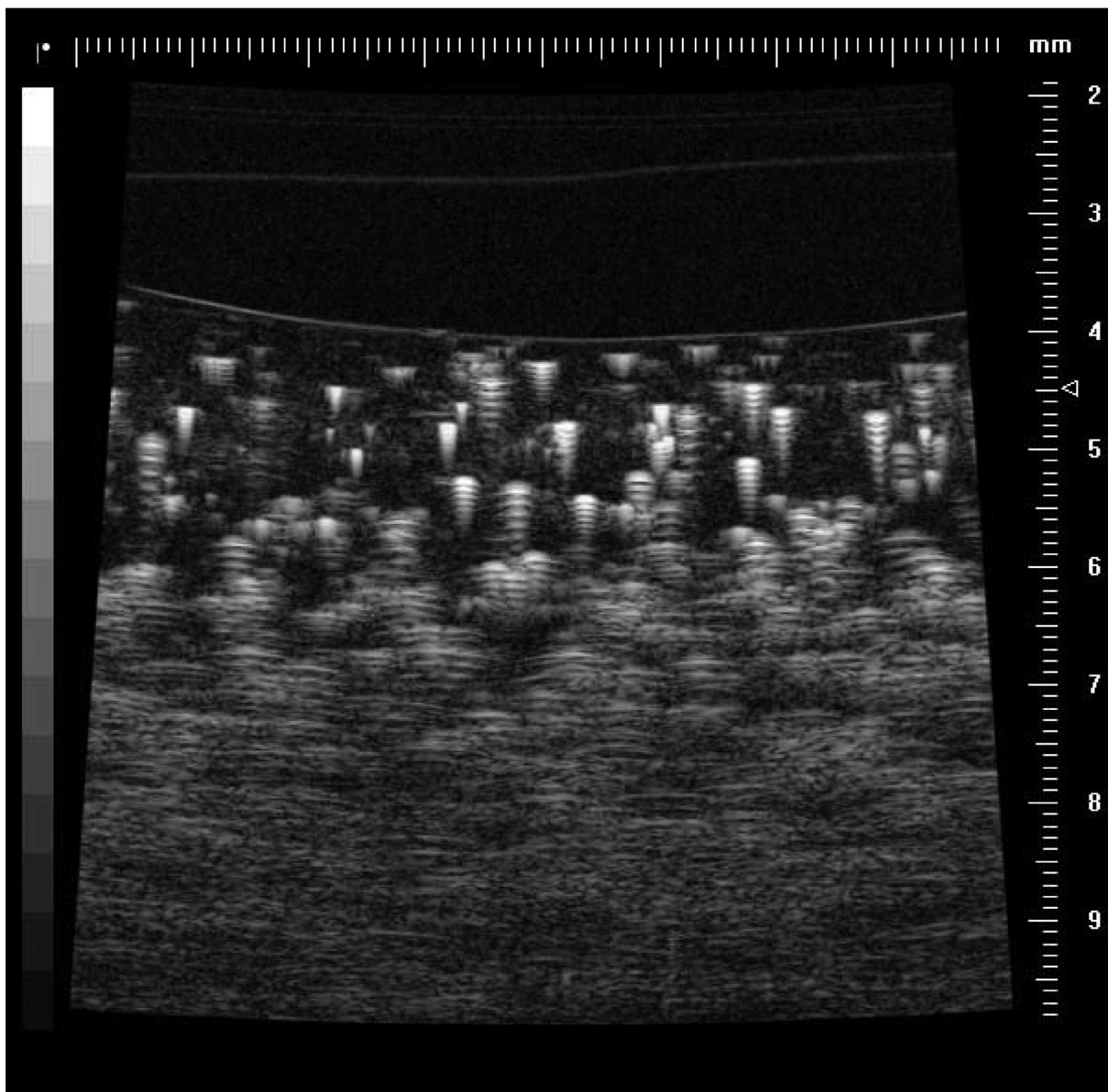


Figure 23

Multiple comet tail artifacts (reverberation).

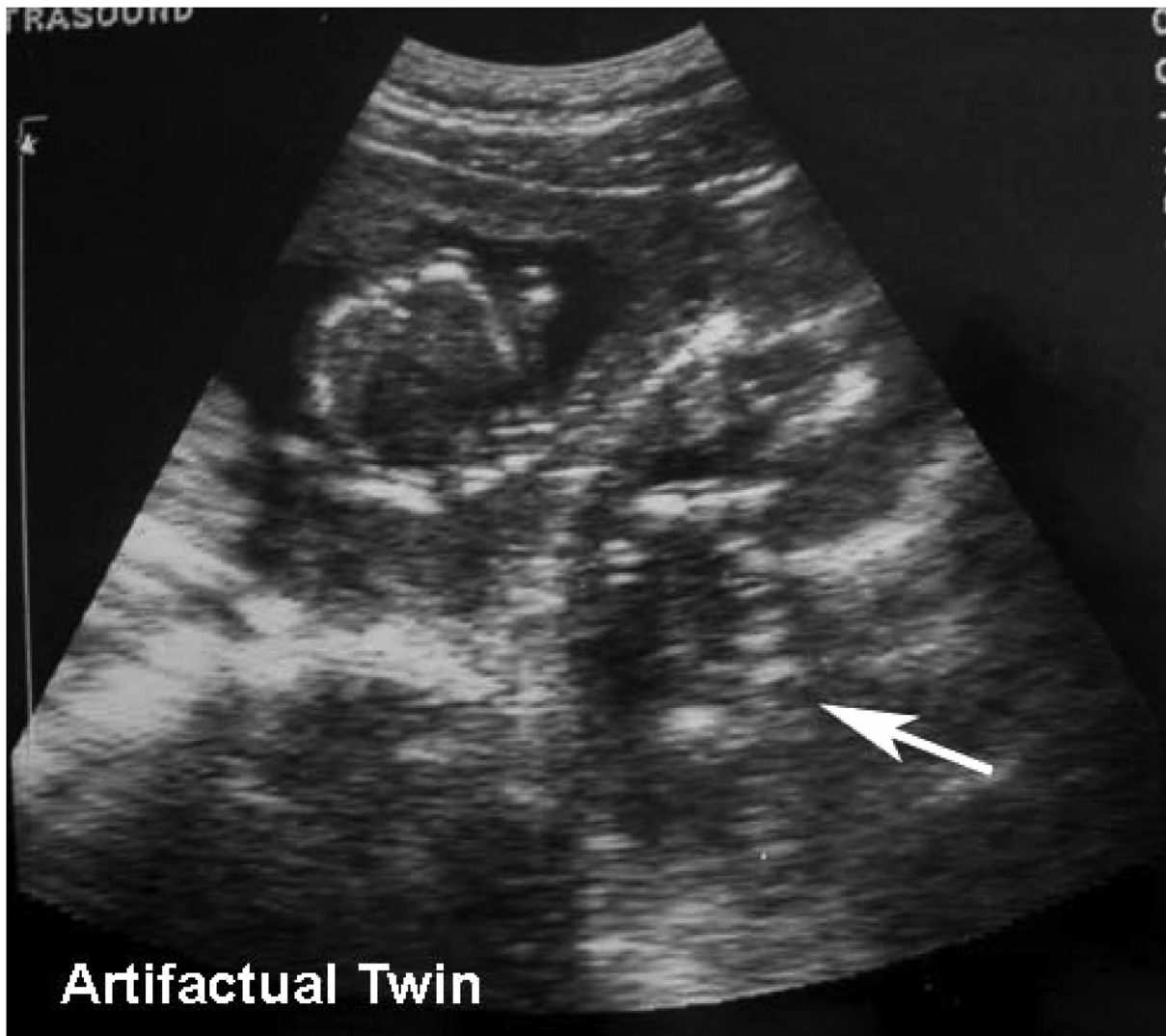


Figure 24

Artifactual twin resulting from refraction through the rectus muscle.

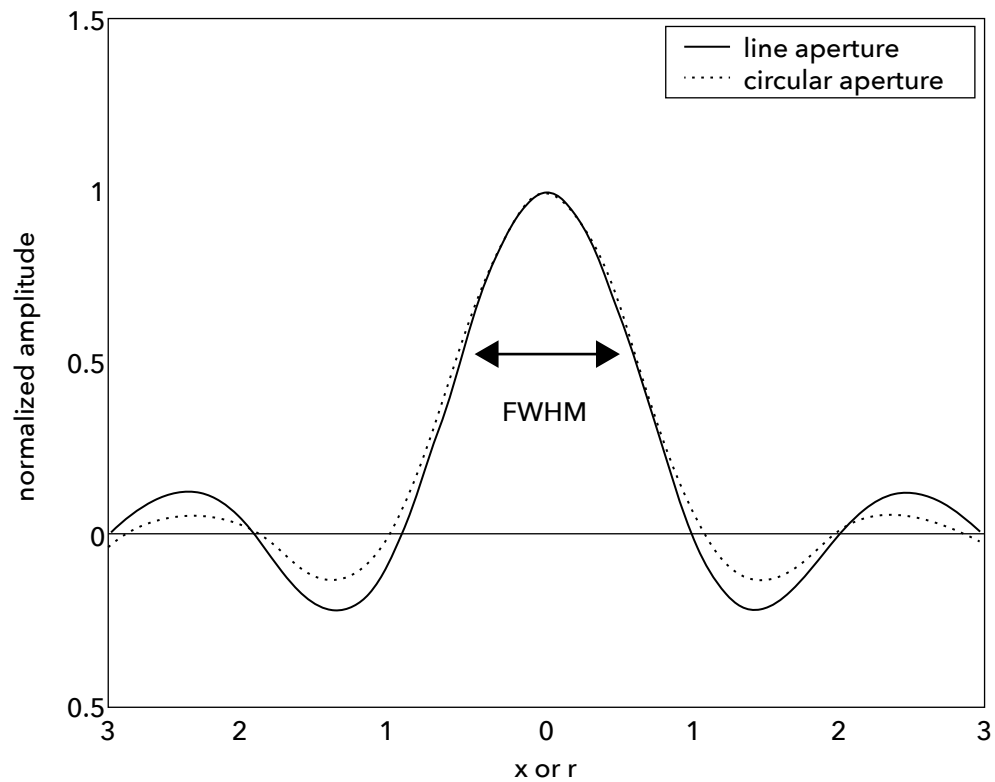


Figure 25

Full width half maximum widths of beams in a focal plane from either a line aperture or a circular aperture. Scaling adjusted so a square aperture (a line aperture on a side) and a circular aperture have the same area.

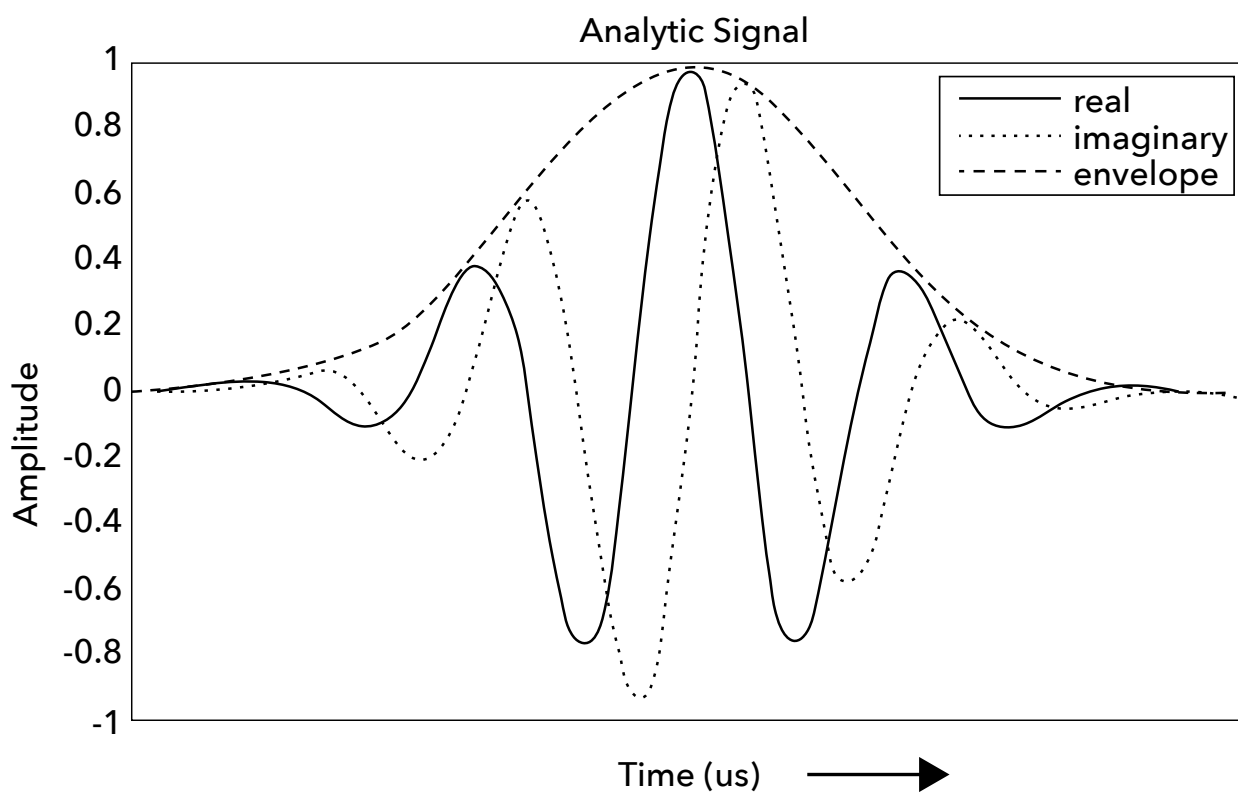


Figure 26

Envelope of a waveform. The envelope and quadrature (complex imaginary) signal are derived from the real signal. The real and quadrature signals are part of a complex analytic signal.

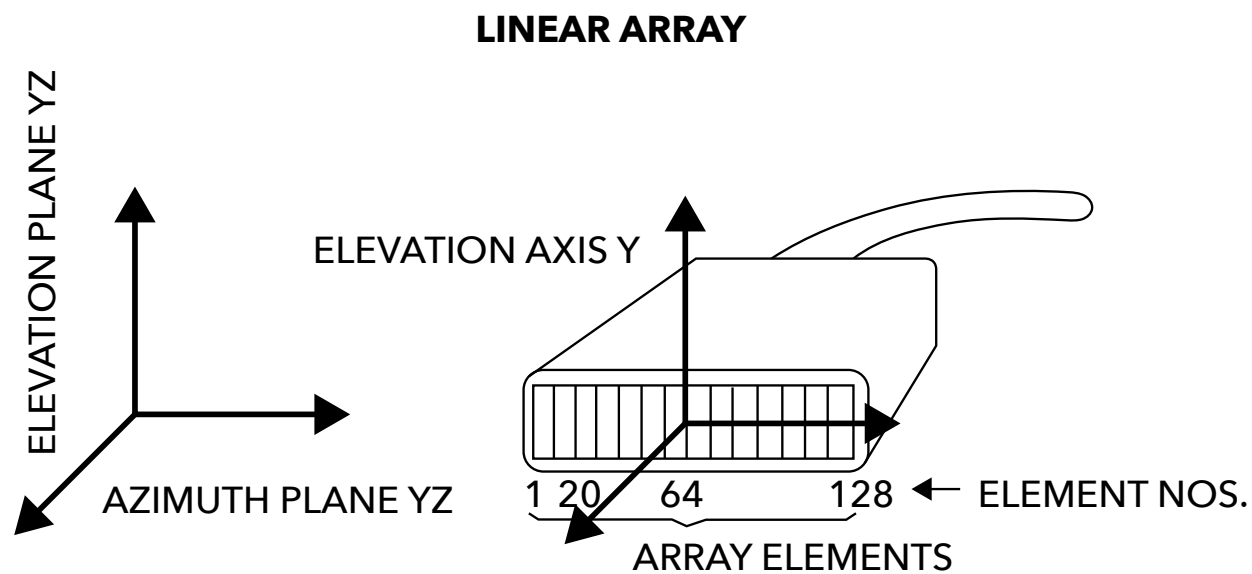


Figure 27

Coordinate system showing the relationship among the elevation and azimuthal (scan) planes and a linear array with array elements.

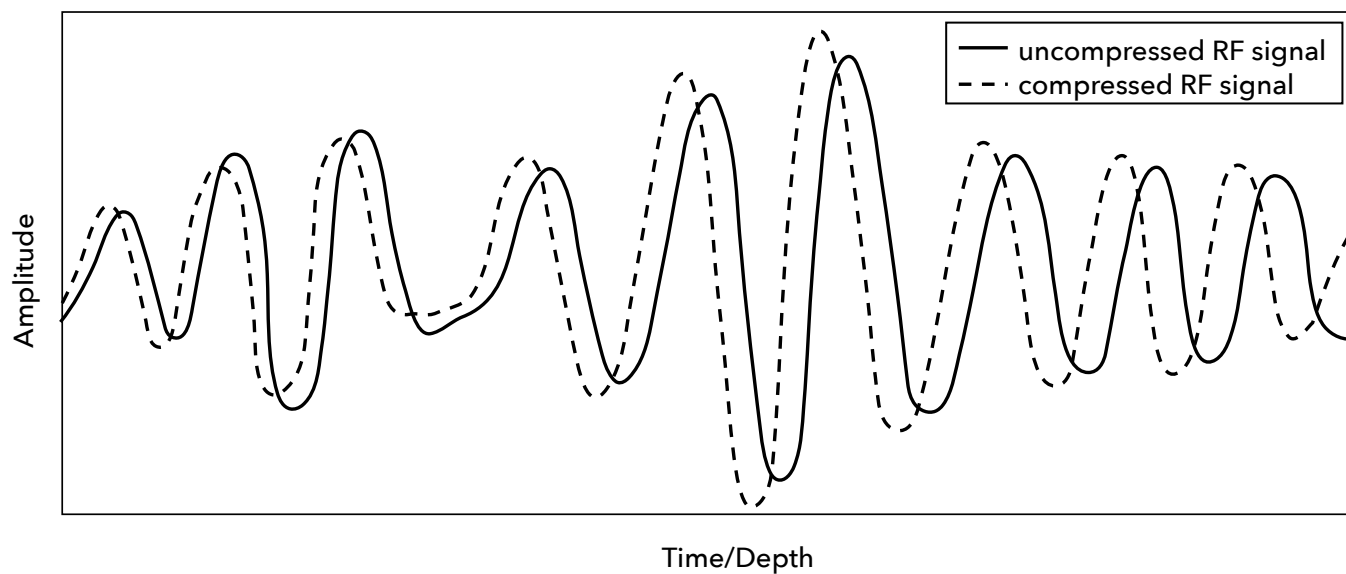


Figure 28

A typical pair of A-lines before (solid line) and after (dashed line) compression.

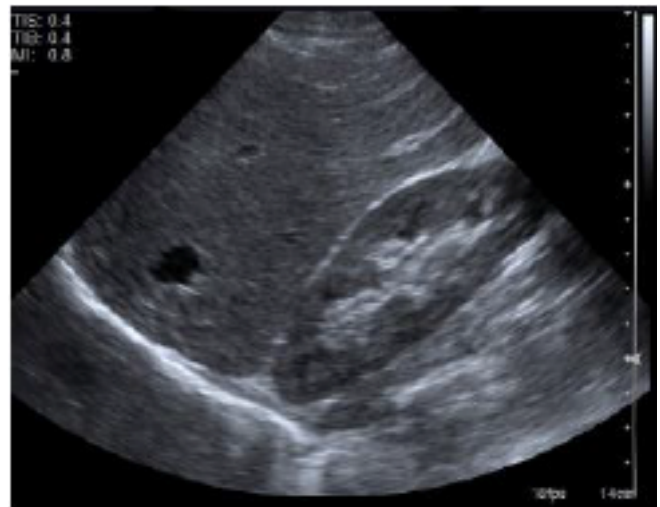
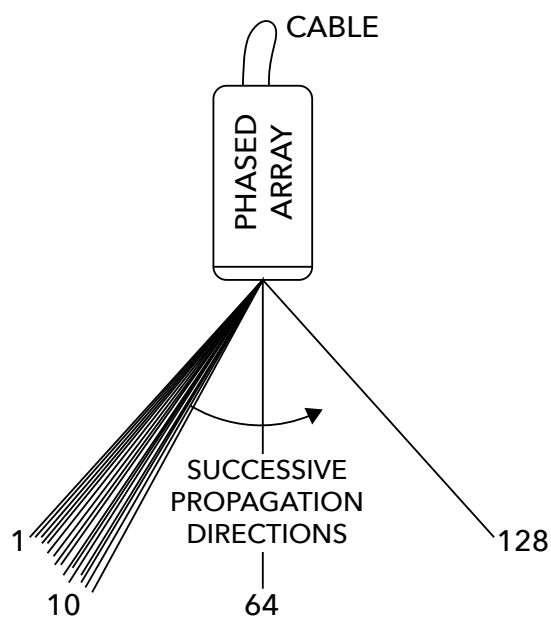


Figure 29

Diagram of a sector transducer (left) shows successive lines of propagation sweeping from left to right and numbered 1 through 128. The sector shape of the image on the display is shown on the right.

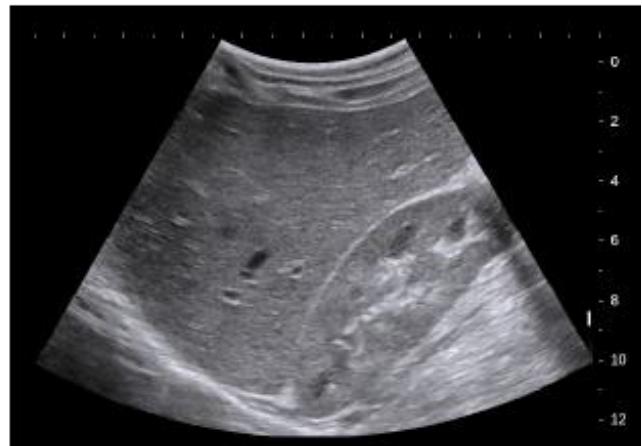
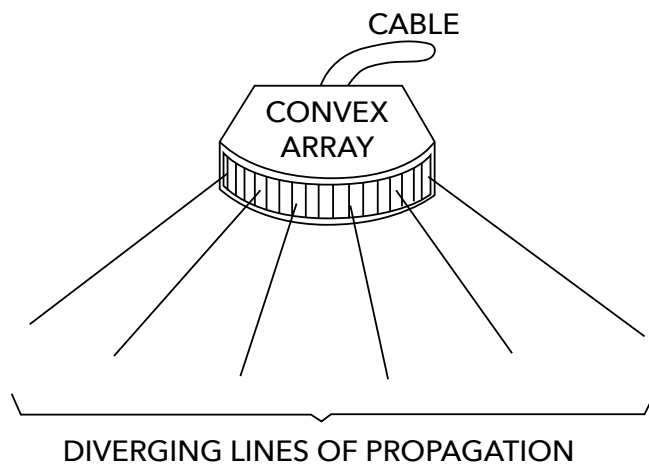
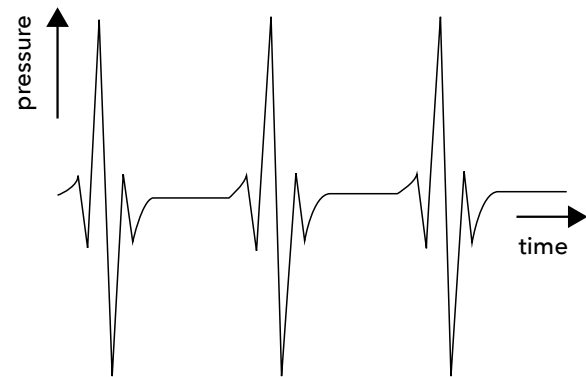
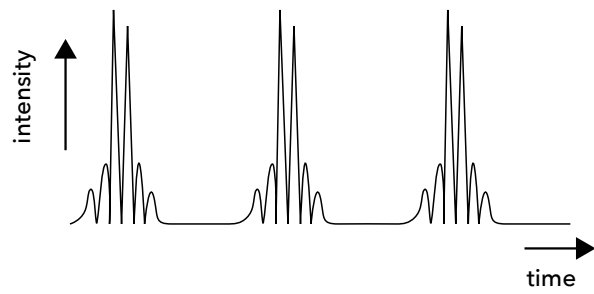


Figure 30

Convex array with scan lines and corresponding B-mode image.



Pulsed pressure waveform



Pulsed intensity waveform

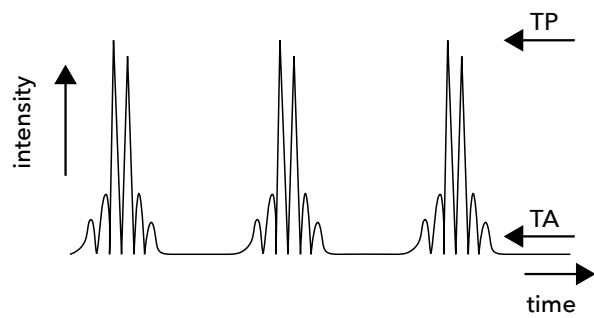


Figure 31

(top) Repeated pressure waveforms vs time. (middle) Pulsed intensity vs time (bottom) temporal peak (TP) and temporal average (TA) intensities vs time.

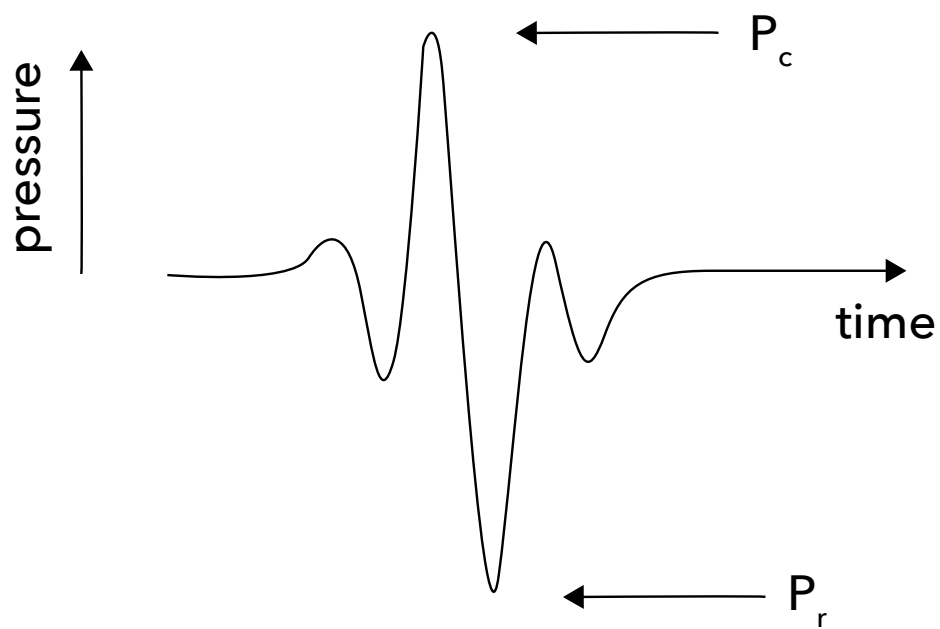


Figure 32

Peak compressional (pc) and peak rarefactional (pr) pressures depicted on a pressure waveform vs time.

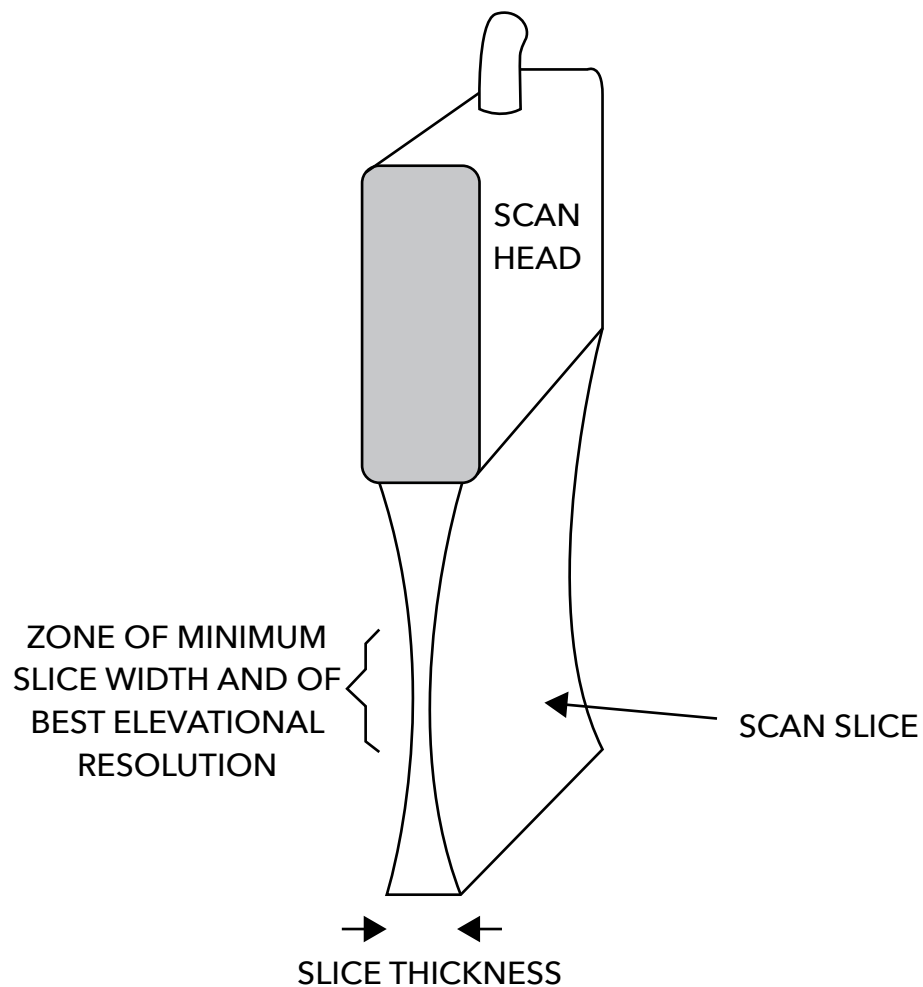


Figure 33

Diagram shows variation in elevational slice width with depth. Pulses propagate downward from the linear array within the slice depicted below the array. Elevational resolution is best where the slice width is minimum.

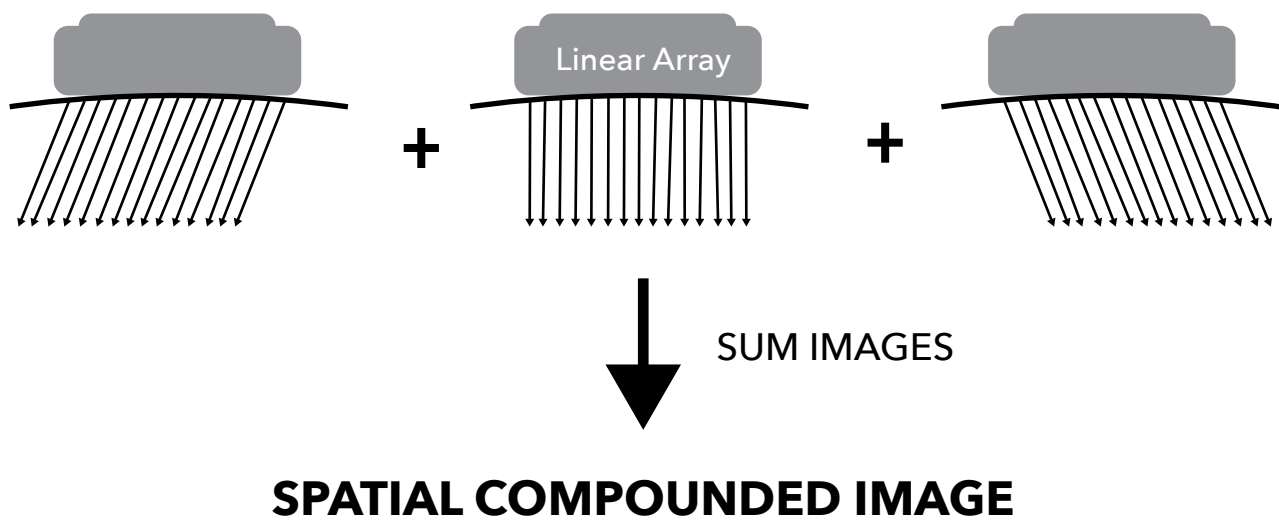


Figure 34

The summing the amplitudes of acoustic scan lines of the linear array steered in different directions (here three are shown) produces a spatially compounded image with less speckle.

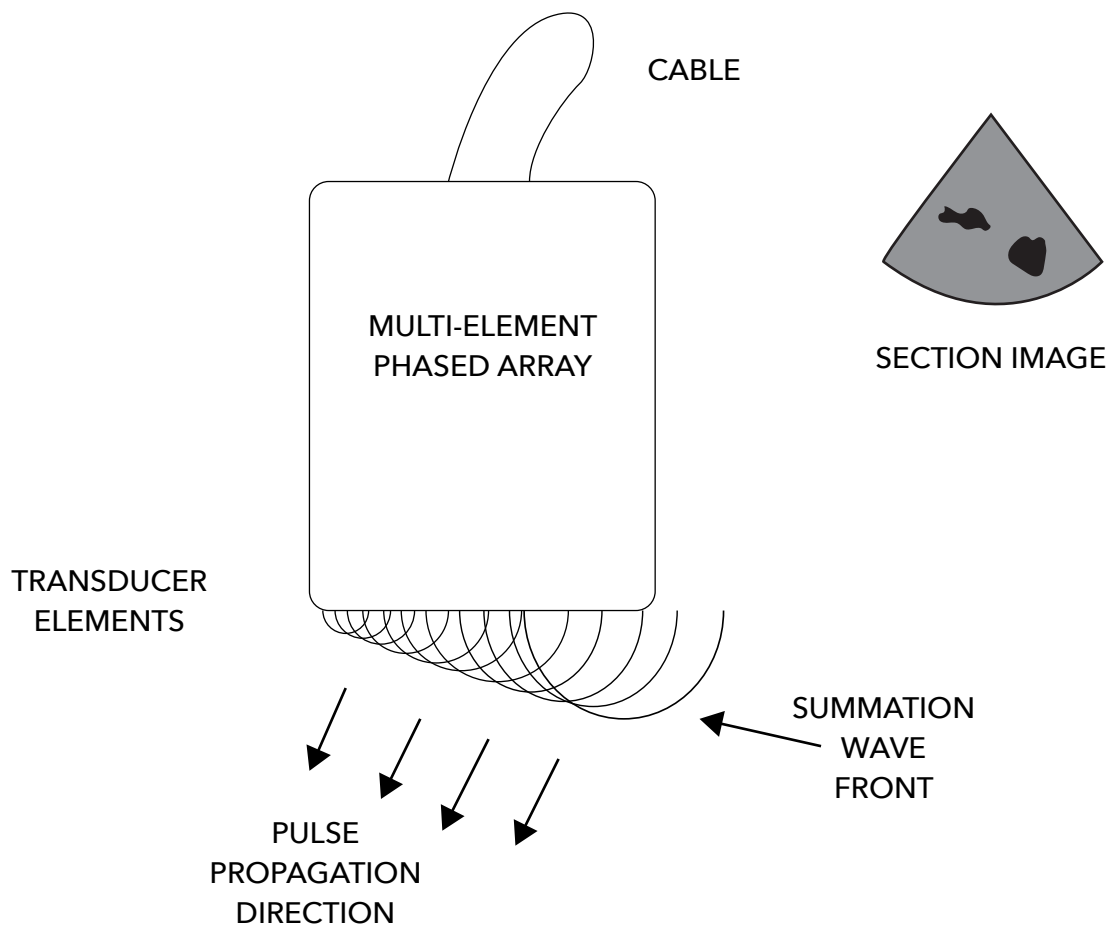


Figure 35

Steered wavefront from a phased array.

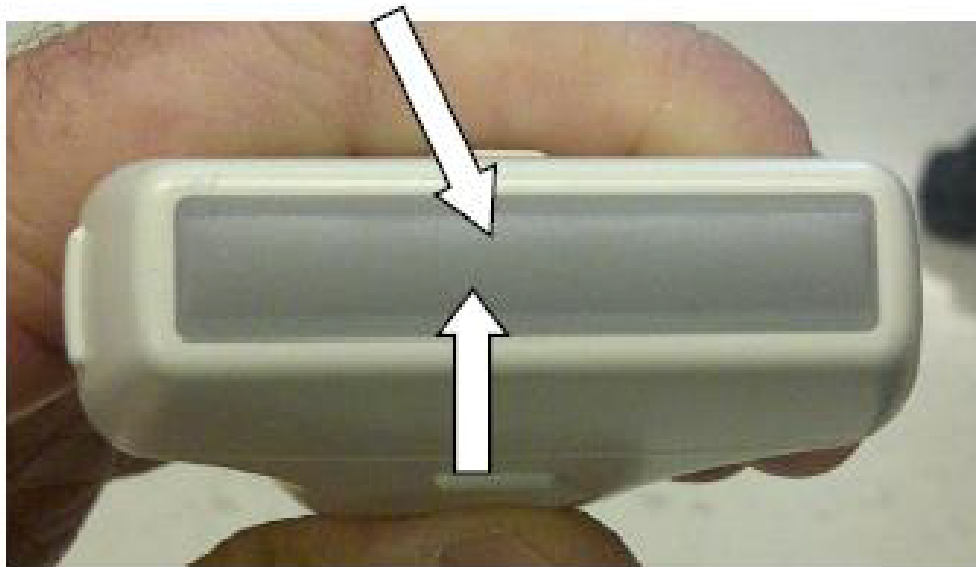
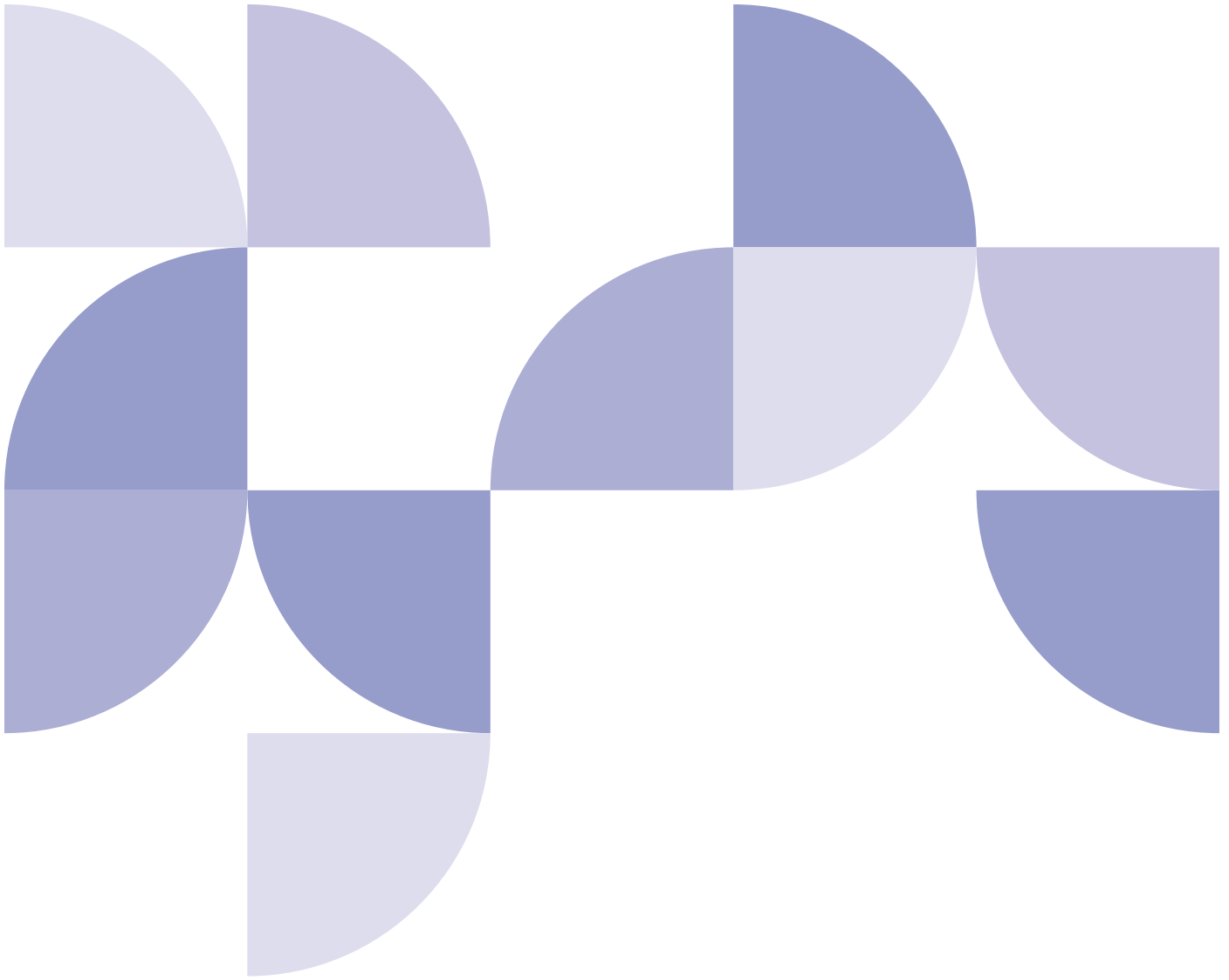


Figure 36

Transducer with an acoustic lens built into the transducer face (the ridge is shown between the arrows). This lens is used to focus the beam in the elevation plane. See Figure 33.



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