CAMBRIDGE

Cambridge University Press
978-0-521-75710-2 - Diagnostic Ultrasound: Physics and Equipment, Second Edition
Edited by Peter Hoskins, Kevin Martin and Abigail Thrush
Index
More information

Index

1D, 171
1D ultrasound measurements, 76
1.25D arrays, 33–34
1.5D arrays, 33–34

2D, 171
2D array transducer and systems, 39, 171, 174
2D colour flow imaging, 86, 121–22
2D display of 3D dataset, 174–75
2D ultrasound measurements, 76

3D, 171
3D dataset visualisation, 174–77
  2D display, 174–75
  shaded surface display, 175–76
  stereoscopic viewing, 176–77
3D ultrasound, 171–80
  endoprobe, 174
3D ultrasound applications, 177–78
  cardiac applications in adults, 178
  fetal applications, 177–78
  intra-vascular ultrasound, 178
  trans-rectal examination, 178
3D ultrasound measurements, 178–80
  2D shapes, 179
  3D volumes, 77, 179
  4D measurements, 179–80
  distances, 178–79
3D/4D transducers, 38–39
3D/4D ultrasound systems
  2D array systems, 171, 174
  endoprobe 3D ultrasound, 174
  freehand systems, 171–73
  mechanically-steered array systems, 173–74

4D, 171
4D transducers, 38–39
4D ultrasound, 171
See also 3D/4D ultrasound systems.
4D ultrasound measurements, 179–80

absolute performance measures (B-mode). 144–51
  axial resolution, 146–47
  contrast resolution measurement, 147
  Edinburgh Pipe phantom test, 150
  geometric accuracy, 147–48
  lateral resolution, 146–47
  machine set up for QA, 145–46
  measurement accuracy, 148–49
  parameters, 144–45
  penetration, 147
  recent developments, 149–51
  reliability and value of, 143
  slice thickness resolution, 147
  spatial resolution measurement, 146–47
  test object materials and targets, 145
  test objects, 144–45
  TCC system, 151
  tissue mimicking material (TMM), 145
absolute performance measures (Doppler). *See* Doppler ultrasound testing
absorption coefficient, 156
absorption of ultrasound energy, 12–13
acoustic impedance (z), 8
acoustic lens, 17
acoustic output measurements, 156
acoustic pressure within ultrasound beams, 19–21
active group of elements, 28
adaptive image processing, 61
air tests
  relative performance measures, 143–44
AIUM (American Institute of Ultrasound in Medicine), 142, 151, 163
Albunex, 181
aliasing
  colour flow systems, 136
  PW Doppler systems, 93, 106, 109, 110
  spectral Doppler, 114
alveolar capillary haemorrhage, 162
A-mode, 1
  measurements, 75
A-mode scan, 43
amplification, 47–48
  linear amplification, 47–48
  non-linear amplification, 51–52
amplitude demodulation
  B-mode systems, 56
amplitude modulation (AM)/power modulation (PM) imaging technique, 188
amplitude reflection coefficient (R_A), 9
analogue-to-digital conversion of echo signals, 52–53
angle
  beam-steering angle, 110–11
  Doppler angle cursor, 111
angle dependence of Doppler shift frequency, 114
angle dependence of displayed colour, 136
angle of incidence (θ_i), 10
angle of insonation
  spectral Doppler, 115–18
angle of reflection (θ_r), 10
aperture control in reception
  linear-array transducers, 30–31
apodization, 16
  linear-array transducers, 31
  phased-array transducers, 35
area
  B-mode measurement, 76
  B-mode measurement errors, 80–81
array transducers, 23–24
artefacts
  B-mode imaging, 68–74
  colour flow systems, 134–37
  contrast imaging, 193–94
  sources of (B-mode), 68
  spectral Doppler ultrasound, 114
attenuation artefacts, 71–72
attenuation coefficient, 49
attenuation of ultrasound waves, 12
  absorption of ultrasound energy, 12–13
  compensation for, 49–50
  dependence on frequency, 13
autocorrelation detection, 122
autocorrelation technique, 121, 123–24
automatic measurement
  B-mode systems, 77
axial resolution, 26
  absolute performance measurement, 146–47
  B-mode imaging, 66

backing (damping) layer (transducer component), 24, 25

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-0-521-75710-2 - Diagnostic Ultrasound: Physics and Equipment, Second Edition
Edited by Peter Hoskins, Kevin Martin and Abigail Thrush
Index
More information

baseline control
  colour flow systems, 129
  spectral Doppler, 109–10
beam steering angle
  spectral Doppler, 110–11
beam width, 35–36
beam-former, 23
  colour flow systems, 123
beam-forming, 23–45
beams. *See* ultrasound beams
beam-steering arrays. *See* phased-array transducers
beam-stepping arrays. *See* linear-array transducers
beam-vessel angle. *See* angle
Bel,
benefit. *See* risk
B-flow imaging, 138
binary system,
birth weight and ultrasound exposure, 162
blood flow, 96–104
  collateral flow, 102–03
  disturbed flow, 96–97
  effects of arterial disease, 99, 113–14
  effects of physiological changes on arterial flow, 102
  interpretation of Doppler spectra, 96
  laminar flow, 96
  resistance to flow, 101–02
  reversal of flow, 96, 97, 98, 99
  structure of blood vessel walls, 96
  turbulent flow, 96
  velocity changes within stenoses, 99–100
  velocity profiles, 97
  velocity profiles at arterial branches and curves, 98–99
  velocity profiles at stenoses, 99
  velocity profiles in normal vessels, 97–98
  venous flow, 103–04
  See also Doppler ultrasound systems.
blood flow measurement
  Doppler ultrasound systems, 85–86
blood vessel walls
  structure, 96
blood–tissue discriminator
  colour flow systems, 125–26
B-mode image post processing, 60–61
  adaptive image processing, 61
  edge enhancement, 61
  frame averaging, 60
  grey-level transfer curves (B-mode), 60–61
B-mode image update modes, 59–60
  cine loop, 60
  freeze mode, 59
  real-time display, 59
B-mode imaging, 1–3
  image formation, 2–3
  principles of image formation, 1–2
  pulse–echo principle, 2
  pulse–echo sequence, 2–3
  scan formats, 3
  sources of imperfections, 64
B-mode imaging artefacts, 68–74
  assumptions about ultrasound propagation, 68
  attenuation artefacts, 71–72
  boundary distortion, 69
  edge-shadowing artefacts, 70–71
  mirror image artefacts, 73
  phase aberration, 69–70
  range errors, 68–69
  reflection artefacts, 72–74
  refraction artefacts, 70–71
  reverberations, 73–74
  size errors, 69
  sources of artefacts, 68
  specular reflection, 72–73
  speed of sound artefacts, 68–71
  TGC artefacts, 71–72
B-mode imaging system performance, 64–74
  axial resolution, 66
  factors affecting performance, 64
  image contrast, 66–67
  lateral resolution, 64–65
  movement, 67–68
  perception of changes in brightness, 67
  slice thickness artefacts, 65–66
  spatial properties, 64–66
  speckle, 67
B-mode instrumentation, 47–62
  advantages of digitization, 53
  amplification of echo signals, 47–48
  amplitude demodulation, 56
  analogue-to-digital conversion of echo signals, 52–53
  attenuation, 49–50
  coded excitation of the transmit pulse, 55–56
  compensation for attenuation, 49–50
  compression of dynamic range of echoes, 51–52
  control of amplitude of transmitted pulses, 48–49
  display of images, 61, 62
  dynamic range of echoes, 50–52
  frame averaging, 60
  freeze mode, 59
  harmonic imaging, 53–55
  image memory, 56–57
  image storage, 61, 62
  image storage formats, 62
  image update modes, 59–60
  information storage, 57–58
  interpolation, 58
  networking of image information, 61, 62
  output of imaging systems, 61
  PACS system, 62
  post processing, 60–61
  pulse inversion imaging, 54–55
  read zoom, 59
  reading from the image memory, 58–59
  signal amplitude processing, 47
  swept gain, 49–50
  time–gain compensation (TGC), 49–50
  time–gain control, 49–50
  transmit power control, 48–49
  write zoom, 58
  writing to the image memory, 57–58
B-mode measurement, 75–83
  abdominal examinations, 75
  area, 76
  automatic measurement, 77
  calculations using stored measurements, 77
  choice of equipment, 82
  circumference, 76
  development of measurement systems, 75
  echocardiography, 75
  ellipse fitting, 80
  ellipse fitting systems, 76
  measurement packages, 82
  measurement technique, 82–83
  modern calliper systems, 76
  non-linear distance, 76
  obstetric applications, 75
  point-to-point method, 76, 80
  programmed formulae for calculations, 77
  steps to minimise errors, 83
  storage of measurements, 77
  vascular ultrasound, 75
  volume, 77
B-mode measurement errors, 77–82
  area errors, 80–81
  calliper increment limitation, 79
  circumference errors, 80–81
  coefficient of variation (CoV), 78
  compound errors, 78, 81
  difference between observed and true values, 77
  error of observation, 77
  human error, 78–79, 81
  image pixel size limitation, 79
  image resolution limitations, 79
  random errors, 78
  refraction of the ultrasound beam, 80
  sources of errors in ultrasound systems, 78–81
  steps to minimise errors, 83

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-0-521-75710-2 - Diagnostic Ultrasound: Physics and Equipment, Second Edition
Edited by Peter Hoskins, Kevin Martin and Abigail Thrush
Index
More information

B-mode measurement errors (*cont.*)
systematic errors, 78
ultrasound propagation, 79–80
velocity/distance calibration, 79
volume errors, 81
B-mode measurement interpretation, 81, 83
use of normal reference data, 81–82
BMUS (British Medical Ultrasound Society) guidelines, 164–65
boundary distortion artefacts, 69
box size control
colour flow systems, 128
brightness
perception of changes in, 67
brightness mode. *See* B-mode
bulk modulus *B* and pressure waves, 206–07

calculations using stored measurements, 77
calliper increment limitation, 79
calliper systems of measurement, 76
Cambridge University (UK)
software for 3D acquisition and processing, 173
capacitive micro-machined silicon transducers, 27
cardiac studies
3D ultrasound applications in adults, 178
heart scan format, 3
use of contrast agents, 192–93
catheter-mounted arrays, 45
cavitation effects, 155, 160–61
childhood malignancies and ultrasound exposure, 162
cine loop display, 60, 75
circumference
B-mode measurement, 76
B-mode measurement errors. 80–81
clutter breakthrough, 136
clutter echoes, 53–54
clutter filter, 90, 123, 137
clutter signals
CW Doppler, 90
coded excitation of the transmit pulse, 55–56
coefficient of variation (CoV), 78
collateral flow, 102–03
colour blooming artefacts
contrast imaging, 194
colour box, 122
colour box size control
colour flow systems, 128
colour coding of motion
Doppler tissue imaging (DTI), 139–40
colour Doppler, 126
definition, 121
introduction of, 121
See also colour flow systems.
colour flow
definition, 121
colour flow and tissue imaging, 121–40
colour flow imaging, 92–93
colour flow system artefacts, 134–37
aliasing, 136
angle dependence, 136
audio sound, 136
blood–tissue discrimination effects, 137
clutter breakthrough, 136
clutter filter effects, 137
colour display at vessel–tissue boundaries, 136–37
drop-out, 136
electronic noise, 136
flash artefacts, 136
ghost mirror images, 135
image smoothing effects, 137
noise, 136
partial volume effect, 136
shadowing, 135
speckle, 124–25, 136
tissue vibration, 136
colour flow system components, 121–26
autocorrelation, 123–24
beam-former, 123
blood–tissue discriminator, 125–26
clutter filter, 123
demodulator, 123
Doppler transmitter, 122
mean-frequency estimator, 123–24
post-processor, 124–25
transducer, 122–23
colour flow system controls, 128–30
acquisition of colour flow images, 128–29
baseline, 129
box size, 128
colour box size, 128
colour gain, 129
colour-write priority, 129
depth of field, 129
display of colour flow signals, 129–30
ensemble length, 129
extraction and estimation of Doppler frequencies, 129
filter cut-off, 129
flash filter, 129–30
focal depth, 128
frame averaging, 129
gate length, 128
line density, 128
persistence, 129
power or acoustic output, 128
power threshold, 129
pulse repetition frequency (PRF), 128
steering angle, 128
use in clinical practice, 130
colour flow system features
display of complex flow patterns, 132–34
display of flow in small vessels, 132
display of low velocities, 130–32
display of rapidly changing flow patterns, 134
penetration, 130
colour flow system measurements, 137
quantitative analysis of flow patterns, 137
single site velocity measurement, 137
volume flow, 137
colour flow systems, 96
2D image production, 121–22
autocorrelation detection, 122
autocorrelation technique, 121
colour box, 122
colour Doppler, 126
directional power Doppler, 127–28
early developments, 121
modes, 126–28
phase shift approach, 122
power Doppler, 126–27
time-domain systems, 122, 137–38
colour gain control
colour flow systems, 129
colour-write priority control
colour flow systems, 129
compound scanning, 37–38
compression(sound waves), 4, 6, 18
compression(bulk modulus *B* and pressure waves), 206–07
compression (of dynamic range of echoes), 51–52
computer modelling of transducer performance, 26–27
constructive interference, 13
contrast agents, 181–94
cardiac applications, 192–93
clinical applications, 190–93
commercially available ultrasound contrast agents, 183–84
history of development, 181
kidney studies, 191
liver studies, 191
machine settings for contrast studies, 190
pancreatic studies, 191
performing a contrast scan, 189–90
safety of, 161–62, 193
spleen studies, 191
transcranial studies, 191–92

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-0-521-75710-2 - Diagnostic Ultrasound: Physics and Equipment, Second Edition
Edited by Peter Hoskins, Kevin Martin and Abigail Thrush
Index
More information

contrast imaging artefacts, 193–94
  colour blooming, 194
  multiple scattering, 193–94
  propagation artefacts, 193
contrast microbubbles, 181–83
  commercially available ultrasound contrast agents, 183–84
  history of development, 181
  interaction with ultrasound, 184
  interactions with acoustic pressure, 185–86
  oscillations, 184
  quantification of microbubble enhancement, 190
  resonant frequency, 184–85
contrast resolution measurement
  absolute performance measurement, 147
contrast-specific imaging techniques, 186–89
  amplitude modulation (AM)/power modulation (PM), 188
  flash imaging, 188–89
  fundamental imaging, 186
  high MI techniques, 188–89
  intermittent imaging, 188–89
  low MI techniques, 187–88
  pulse inversion (harmonic imaging)/ phase inversion, 188
  pulse inversion amplitude modulation (PIAM), 188
  second harmonic imaging, 186
  stimulated acoustic emission, 188–89
crystal drop-out
  relative performance measure, 143
C-scan, 39
curved source, 17
curvilinear-array transducers, 27–28
  strongly convex type, 34
curvilinear field of view, 3
cut-off filter
  CW Doppler, 90
CW (continuous wave) Doppler, 86–87, 105
  Doppler signal processor, 88–91
cylindrical arrays, 45

Decibel
Definity/Luminity contrast agent, 193
demodulation
  CW Doppler, 89–90
demodulator
  colour flow systems, 123
density ρ (rho) of a medium
  effect on speed of sound, 6–7
depth of field control
  colour flow systems, 129
destructive interference, 14
diagnosis
  frequencies used, 7–8
  wavelengths used, 7–8
diffraction, 14
diffuse reflection, 11
digitization of signals
  advantages of, 53
directional power Doppler, 127–28
  definition, 121
  See also colour flow systems.
displacement amplitude, 6
display
  B-mode systems, 62
disturbed flow, 96–97
Doppler angle cursor
  spectral Doppler, 111
Doppler display modes
  2D colour flow imaging, 86
  colour flow imaging, 92–93
  spectral Doppler, 86, 92
Doppler effect, 84–86
  in PW Doppler systems, 93
Doppler equation, 85–86
Doppler shift, 84–86
Doppler signal (PW systems), 91
Doppler signal processor (CW), 88–91
  clutter signals, 90
  cut-off filter, 90
  demodulation, 89–90
  frequency estimation, 90–91
  high-pass filtering, 90
  wall thump filter, 90
Doppler signal processor (PW), 91–93
  aliasing phenomenon, 93
  nature of the effect which is measured, 93
  phase-domain method, 91–93
Doppler tissue imaging (DTI), 139–40
Doppler transmitter
  colour flow systems, 122
Doppler ultrasound systems, 84–95, 105–07
  blood flow measurement, 85–86
  continuous wave (CW) systems, 86–87, 105
  Doppler effect, 84–86
  Doppler equation, 85–86
  Doppler shift, 84–86
  nature of the received ultrasound signal, 87–88
  pulsed wave (PW) systems, 86–87, 105–06
  time-domain systems, 93–95
  See also colour Doppler; colour flow systems; spectral Doppler.
Doppler ultrasound testing, 151–54
  flow phantom, 152–53
  quantities of interest, 153–54
  resolution, 153–54
  sensitivity, 153
  standards and guidance, 151
  string phantom, 152
  test objects, 151–53
  velocity, 153
drop out in colour flow systems, 136
duplex Doppler, 43–44, 106–07
duplex linear-array system, 37
dynamic focusing, 29–31
dynamic range of echoes (B-mode), 50–51
  compression, 51–52

echo ranging
  pulse–echo principle, 2
echo signal amplification (B-mode), 47–48
echocardiography
  measurements from, 75
echoes (B-mode)
  compression of dynamic range, 51–52
  dynamic range, 50–51
edge enhancement (post processing), 61
edge-shadowing artefacts, 70–71
Edinburgh Pipe phantom test, 150
elastic moduli
  and wave generation, 205
  bulk modulus B, 206–07
  estimation of elastic modulus, 205
  shear modulus *G*, 207
  values in body tissues, 207
  Young's modulus *E*, 196–98, 207
  See also strain elastography; shear wave elastography.
elasticity, 196–97
elastography, 43, 196–213
  complexity of real tissue elastic behaviour, 213
  definition, 196
  elasticity, 196–97
  ultrasound elastography techniques, 196
  Young's modulus *E*, 196–97, 207
  See also shear wave elastography; strain elastography.
ellipse fitting method of measurement, 76, 80
endo-cavity transducers, 44
endoprobes
  360° mechanical scan, 44–45
  3D ultrasound, 174
ensemble length control
  colour flow systems, 129
epidemiological studies
  effects of ultrasound exposure *in utero*, 162–63

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-0-521-75710-2 - Diagnostic Ultrasound: Physics and Equipment, Second Edition
Edited by Peter Hoskins, Kevin Martin and Abigail Thrush
Index
More information

error
  blood velocity measurement, 115–16
  B-mode measurement errors, 77–82
  range error artefacts, 68–69
  size error artefacts, 69
  spectral Doppler angle of insonation, 115–16
  spectral Doppler volume flow, 118–19
European Committee for Medical Ultrasound Safety (ECMUS), 156
European Federation of Societies for Ultrasound in Medicine and Biology (EFSUMB), 156, 191
European Medical Devices Directive (MDD), 163–64
excess pressure (*p*), 6
exploso-scanning, 40
exposure
  embryological exposure, 167–68
  estimated *in situ* values for exposure, 156
  estimation of exposure levels, 156
  fetal exposure, 168
  in utero exposure to ultrasound, 167–68
  levels of exposure of patient populations, 165–67
  power or acoustic output (Colour Doppler), 128
  transmit power (B-mode), 48
  transmit power (Pulsed Doppler), 107–08

fast Fourier transform (FFT) method, 91
fetal applications. *See in utero* exposure to ultrasound
filter cut-off control
  colour flow systems, 129
filters
  clutter filter, 90, 123, 137
  cut-off filter, 90
  flash filter, 129–30
  high-pass filtering, 90
  spectral Doppler, 110
  wall-thump filter, 90
flash artefacts, 136
flash filter, 129–30
flash imaging with contrast agents, 188–89
flow phantom
  Doppler testing, 152–53
focal depth control
  B-mode systems,
  colour flow systems, 128
  spectral Doppler, 111
focusing of ultrasound beams, 16–17
Food and Drug Adminstration (FDA) regulations, 163
frame averaging control
  colour flow systems, 129
frame averaging of images, 60
freehand systems
  3D/4D ultrasound, 171–73
freeze mode (image update mode), 59
frequencies used in diagnosis, 7–8
frequency and attenuation, 13
frequency estimation
  CW Doppler, 90–91
frequency of waves (*f*), 5
fundamental imaging with contrast agents, 186

gain control
  B-mode,
  spectral Doppler, 107
gas body activation, 155, 160–61
gate length control
  colour flow systems, 128
gate range and length
  PW Doppler, 105–06
gate size and position
  spectral Doppler, 110
geometric accuracy
  absolute performance measurement, 147–48
ghost mirror images, 135
grating lobes
  linear-array transducers, 32–33
  phased-array transducers, 36
grey-level transfer curves (B-mode), 60–61
grey-scale curve
  spectral Doppler, 111

half-wave resonance, 24
harmonic imaging, 18–19, 53–55, 186
harmonics, 18
hazard. *See* risk
heart. *See* cardiac studies
high frame rate imaging, 41–43
  plane wave techniques, 43
  synthetic aperture imaging, 41–43
high MI techniques, 188–89
high-pass filter
  CW Doppler, 90
  spectral Doppler, 110
hybrid beam-stepping/beam-steering transducers, 36–37

image contrast
  B-mode imaging, 66–67
image formation (B-mode), 2–3
  basic principles, 1–2
image formation and storage
  image memory, 56–57
  interpolation, 58
  local storage, 62
  networking of image information, 62
  read zoom, 59
  reading from the image memory, 58–59
  storage formats, 62
  write zoom, 58
  writing to the image memory, 57–58
image formation and storage, 61, 62
imaging workstations, 75
impedance
  acoustic (z), 8
impedance matching layer, *See* matching layer(s)
in utero exposure to ultrasound
  epidemiological studies, 162–63
  fetal 3D ultrasound, 177–78
  fetal Doppler ultrasound, 151
  safety issues, 167–68
information storage, 57–58
intensity of ultrasound waves (*I*), 6
intensity parameters, 19–21
  spatial average temporal average intensity (I_{SATA}), 20
  spatial peak pulse average intensity (I_{SPPA}), 20
  spatial peak temporal average intensity (I_{SPTA}), 20
  spatial peak temporal peak intensity (I_{SPTP}), 20
  temporal average intensity (I_{TA}), 20
intensity reflection coefficient (R_i), 9–10
intensity transmission coefficient (T_i), 10
interference, 13–14
intermittent imaging with contrast agents, 188–89
International Electrotechnical Commission (IEC), 142, 163
interpolation, 58, 137
intestinal haemorrhage, 162
intra-cardiac catheter-mounted arrays, 45
intra-luminal catheter-mounted arrays, 45
intra-vascular 3D ultrasound, 178
intrinsic spectral broadening, 112–13, 114
invert control
  spectral Doppler, 110
inverted mirror image of the Doppler spectrum, 107, 114
IPEM guidance, 142, 143, 151

laminar flow. 96
lateral resolution, 23–24
  absolute performance measurement, 146–47
  B-mode imaging, 64–65

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-0-521-75710-2 - Diagnostic Ultrasound: Physics and Equipment, Second Edition
Edited by Peter Hoskins, Kevin Martin and Abigail Thrush
Index
More information

law of reflection, 10
lead titanate (PT), 27
lead zirconate titanate (PZT), 24–25
lens (transducer component), 24, 26
Levovist, 181
line density control
  colour flow systems, 128
line multiplexing, 39–40
linear propagation, 18
linear-array transducers, 3, 27–28
  active group of elements, 28
  aperture control in reception, 30–31
  compound scanning, 37–38
  dynamic focusing in reception, 29–31
  grating lobes, 32–33
  hybrid beam-stepping/beam-steering transducers, 36–37
  lens, 26
  multi-row arrays, 33–34
  scan plane apodisation, 31
  scan plane focusing in transmission, 28–29
  scan plane multiple-zone focusing, 31–32
  slice thickness, 33–34
  steered linear-array transducers, 37–38
  trapezoidal (virtual curvilinear) scanning, 37
longitudinal waves, 4–5
low MI techniques, 186–88
lung capillary haemorrhage, 162

main lobe of a beam, 15–16
matching layer(s) (transducer components), 24, 25–26
mean frequency estimator
  colour flow systems, 123–24
measurement *See* 1D ultrasound measurement; 2D ultrasound measurement; 3D ultrasound measurement; 4D ultrasound measurement; acoustic output; A-mode measurements; blood flow measurement; B-mode measurement; colour flow system measurements; Doppler ultrasound systems; M-mode measurements; spectral Doppler measurements.
measurement packages, 82
measurement systems
  development of, 75
mechanical index (MI), 108, 159–60, 185
  high MI techniques, 188–89
  low MI techniques, 186–88
mechanically scanned transducers, 44
mechanically-steered array systems
  3D/4D ultrasound, 173–74
Medical Devices Directive (EC), 163–64
memory
  advantage of digitization, 53
  image memory, 56–57
  interpolation, 58
  local storage of images, 62
  networking of image information, 62
  read zoom, 59
  reading from the image memory, 58–59
  write zoom, 58
  writing to the image memory, 57–58
MI techniques, *See* contrast-specific imaging technique
  high MI techniques, 207
  low MI techniques, 186–88
mirror image artefacts, 73, 135
mixed mode scanning, 43–44
M-mode measurements, 75
M-mode scan, 43–44
motion
  Doppler tissue imaging, 139–40
movement
  B-mode imaging, 67–68
multi-frequency transducer, 26
multiple reflection artefacts, 114
multiple scattering artefacts
  contrast imaging, 193–94
multiple-zone focusing
  linear-array transducers, 31–32
  phased-array transducers, 35
multi-row arrays
  linear-array transducers, 33–34

National Electrical Manufacturers Association (NEMA), 163
neonatal scanning
  safety issues, 168–69
networking of image information, 61, 62
neurological development and ultrasound exposure *in utero*, 162
noise
  acoustic noise, 16, 19, 32
  relative performance measure, 144
non-linear distance measurement (B-mode), 76
non-linear propagation of waves, 18
non-thermal mechanisms and effects, 160–62
normal reference data
  evaluation, 81–82
  use in interpretation, 81–82
Nyquist limit, 93

obstetric scanning, 3
  patients with fever, 168
  safety issues, 167–68
  ultrasound measurements, 75
  See also in utero exposure to ultrasound.
ophthalmic scanning
  safety issues, 169
Optison contrast agent, 193

PACS (picture archiving and communication system), 62
parallel beam-forming, 40
partial volume effect, 136
pascal (Pa), 6
peak excess pressure, 6
penetration
  absolute performance measurement, 147
  colour flow systems, 130
performance measures
  absolute performance measures, 143, 144–51
  Doppler ultrasound testing, 151–54
  relative performance measures, 143–44
persistence control
  colour flow systems, 129
phase aberration artefacts, 69–70
phase difference between waves, 6
phase of waves, 5–6
phased-array transducers, 34–35
  apodization, 35
  beam width and sensitivity on angle, 35–36
  electronic beam-steering and focusing in the scan plane, 35
  grating lobes, 36
  hybrid beam-stepping/beam-steering transducers, 36–37
  image quality across the field of view, 35–36
  lens, 26
  multiple-zone focusing in transmission, 35
  scan plane focusing and steering in reception, 35
  scan plane focusing and steering in transmission, 35
phase-domain systems, 91–93
physics, 4–21
  absorbption of ultrasound energy, 12–13
  acoustic impedance (z), 8
  acoustic pressure within ultrasound beams, 19–21
  attenuation, 12–13
  diffraction, 14
  diffuse reflection, 11

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-0-521-75710-2 - Diagnostic Ultrasound: Physics and Equipment, Second Edition
Edited by Peter Hoskins, Kevin Martin and Abigail Thrush
Index
More information

physics (*cont.*)
focusing of ultrasound beams, 16–17
frequencies used in diagnosis, 7–8
frequency, 5
harmonic imaging, 18–19
intensity of ultrasound waves (*I*), 6
interference, 13–14
law of reflection, 10
longitudinal waves, 4–5
non-linear propagation, 18
phase, 5–6
power of ultrasound waves, 6
practical sources for ultrasound beams, 15–16
pressure of ultrasound waves, 6
pulse spectrum, 17–18
reflection, 8–10, 11
reflection of ultrasound waves, 8
refraction, 11–12
scattering, 10–11
Snell's law, 11–12
sound waves, 4–5
speed of sound, 6–7
speed of waves, 5
transverse waves, 4
ultrasound beams, 13
ultrasound pulse, 17
wavelength (λ), 5
wavelengths used in diagnosis, 7–8
waves, 4–5
piezoelectric materials, 27
piezoelectric plate, 24–25
plane circular piston source, *See* plane disc transducer
plane disc transducer, 15–16
plane wave generation, 14
plane wave techniques, 43
PMN–PT, 27
point-to-point method of measurement, 76, 80
post-processing
B-mode, 60–61
post-processor
colour flow systems, 124–25
Pourcelot's resistance index (RI), 119
power Doppler, 121, 126–27
See also colour flow systems.
power of ultrasound waves, 6
power or acoustic output control
B-mode,
colour flow systems, 128
Pulsed Doppler systems,
power threshold control
colour flow systems, 129
pressure of ultrasound waves, 6
propagation artefacts
contrast imaging, 194
PT (lead titanate), 27
pulsatility index (PI), 119
pulse average intensity, 20
pulse duration (PD), 20
pulse inversion (harmonic imaging)/ phase inversion imaging technique, 188
pulse inversion amplitude modulation (PIAM) imaging technique, 188
pulse inversion imaging, 54–55
amplitude modulation (PIAM) imaging, 186
B-mode imaging,
contrast imaging,
pulse repetition frequency, 20
pulse repetition frequency (PRF) control
colour flow systems, 128
spectral Doppler, 109
pulse spectrum, 17–18
harmonics, 18
pulse–echo principle, 2
pulse–echo sequence, 2–3
PW (pulsed wave) Doppler, 86–87, 105–06
Doppler signal processor, 91–93
PZN–PT, 27
PZT (lead zirconate titanate), 24–25

quad processing, 40
quality assurance (QA), 142–54
absolute performance measures (B-mode), 143, 144–51
clinical and technical assessment, 142–43
definition, 142
Doppler ultrasound testing, 151–54
relative performance measures (B-mode), 143–44
standards and guidance, 142
test object materials and targets, 145

radial format, 3
range ambiguity, 114
range error artefacts, 68–69
range gate size and position
spectral Doppler, 110
rayl, 8
See also acoustic impedance.
Rayleigh scattering, 10
read zoom, 59
real-time display
B-mode, 59
receive beam, 23–24
receive focus, 29–31
rectangular field of view, 3
reflection artefacts, 72–74
reflection of ultrasound waves, 8–10
acoustic impedance (*z*), 8
amplitude reflection coefficient (R_A), 9
angle of incidence (θ_i), 10
angle of reflection (θ_r), 10
diffuse reflection, 11
intensity reflection coefficient (R_i), 9–10
intensity transmission coefficient (T_i), 10
law of reflection, 10
scattering, 10–11
refraction
B-mode measurement errors, 80
of ultrasound waves, 11–12
refraction artefacts, 70–71, 114
relative performance measures (B-mode), 143–44
air tests, 143–44
crystal drop-out, 143
definition, 143
noise, 144
sensitivity, 143–44
uniformity, 143
resistance index (RI), 119
resistance to blood flow, 101–02
resolution, 8, 13, 18
axial resolution, 26, 66
Doppler testing, 153–54
lateral resolution, 23–24, 64–65
slice thickness,
resonant frequency of microbubbles, 184–85
reverberation artefacts, 73–74
reversal of blood flow, 96, 97, 98, 99
risk. *See* safety of diagnostic ultrasound
and hazard, 155–56
risk assessment, 155–56
risk/benefit judgements, 155–56
safety of diagnostic ultrasound, 155–69

safety of contrast agents, 161–62, 193
safety of diagnostic ultrasound, 155–69
acoustic output measurements, 156
BMUS guidelines for safety, 164–65
cavitation effects, 155, 160–61
contrast materials, 161–62, 193
embryological exposure, 167–68
epidemiological evidence for hazard, 162–63
estimated *in situ* values for exposure, 156
estimation of exposure levels, 156

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-0-521-75710-2 - Diagnostic Ultrasound: Physics and Equipment, Second Edition
Edited by Peter Hoskins, Kevin Martin and Abigail Thrush
Index
More information

European Medical Devices Directive (MDD), 163–64
examinations requiring particular caution, 165
exposure to ultrasound, 156
fetal exposure, 168
first trimester, 167–68
free-field acoustic output measurements, 156
gas body activation, 155, 160–61
good safety practice, 165
in utero exposure to ultrasound, 167–68
increase in use of diagnostic ultrasound, 167
increasing output from diagnostic scanners, 166
intestinal haemorrhage, 162
levels of exposure of patient populations, 165–67
lung capillary haemorrhage, 162
management of safety, 163
manufacturers' responsibility, 163–64
mechanical index (MI), 157
neonatal scanning, 168–69
new diagnostic modes of operation, 166–67
new technologies, 166–67
non-thermal mechanisms and effects, 160–62
obstetric scanning, 167–68
obstetric scanning on patients with fever, 168
ophthalmic scanning, 169
patients of particular concern, 165
proper maintenance of equipment, 165
risk and hazard, 155–56
risk assessment, 155–56
risk/benefit judgements, 155–56
risks associated with thermal effects, 160
safety for specific uses, 167–69
safety record of ultrasound, 169
second and third trimesters, 168
temperature measurement, 158
temperature predictions, 157–58
thermal effects, 155, 156–60
thermal indices, 158–60
training of users, 164–65
US FDA regulations, 163
use of appropriate equipment, 165
users' responsibility, 164–65
sample volume, 43
and speckle, 67
colour flow systems, 121–22
PW Doppler, 105–06
size and position, 111–12
sample volume selection
spectral Doppler, 110
scale (PRF) control
spectral Doppler, 109
scattering of ultrasound waves, 10–11
second harmonic imaging with contrast agents, 186
sector field of view, 3
sector scanning
phased-array transducers, 34–35
strongly convex curvilinear-array transducers, 34
sensitivity
Doppler testing, 153
relative performance measure, 143–44
shaded surface display of 3D dataset, 175–76
shadowing artefacts, 114, 135
shear force, 207
shear modulus *G* and shear waves, 207
shear wave elastography, 196, 207–13
complexity of real tissue elastic behaviour, 213
elastic modulus estimation (external actuator method), 208–10
elastic modulus estimation (radiation force methods), 210–11
estimating tissue stiffness from shear wave velocity, 207–08
shear wave imaging, 41, 43
side lobes of a beam, 15–16
sine wave, 5
size error artefacts, 69
slice thickness, 23–24
slice thickness artefacts
B-mode imaging, 65–66
slice thickness control
linear-array transducers, 33–34
slice thickness resolution
absolute performance measurement, 146–47
Snell's law, 11–12
SonoVue, 191
sound
speed of, 6–7
sound waves, 4–5
spatial resolution
absolute performance measurement, 146–47
speckle, 37, 67, 124–25, 136
spectral analysis, 107
spectral broadening, 112–13, 114, 119
spectral display, 105
spectral Doppler, 105–20
continuous wave (CW) Doppler, 105
development of ultrasound imaging, 106–07
Doppler ultrasound systems, 105–07
duplex Doppler systems, 106–07
features, 96
pulsed wave (PW) Doppler, 105–06
spectral analysis, 107
spectral display, 105
spectral Doppler artefacts, 114
aliasing, 114
angle dependence, 114
intrinsic spectral broadening, 114
inverted mirror image of the Doppler spectrum, 107, 114
multiple reflections, 114
range ambiguity, 114
refraction, 114
shadowing, 114
spectral Doppler controls and optimisation
baseline, 109–10
beam steering angle, 110–11
Doppler angle cursor, 111
filter, 110
focal depth, 111
gain, 107
gate size and position, 110
grey-scale curve, 111
high-pass filter, 110
invert, 110
pulse repetition frequency (PRF), 109
range gate size and position, 110
sample volume selection, 110
scale (pulse repetition frequency), 109
transmit frequency, 109
transmit power, 107–08
spectral Doppler display, 86, 92
blood flow profile effects, 111
effects caused by equipment set-up, 113
effects of intrinsic spectral broadening, 112–13
effects of pathology, 113–14
effects of sample volume size and position, 111–12
factors affecting, 114
non-uniform insonation effects, 111
spectral Doppler indicators of disease, 113–14
changes in detected Doppler frequency shift, 113
changes in spectral broadening, 114
changes in velocity ratios, 113
changes in waveform shape, 114
spectral Doppler measurement
blood velocity, 114–15
blood velocity measurement errors, 115–16
errors related to angle of insonation, 115–16

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-0-521-75710-2 - Diagnostic Ultrasound: Physics and Equipment, Second Edition
Edited by Peter Hoskins, Kevin Martin and Abigail Thrush
Index
More information

spectral Doppler measurement (*cont.*)
manual versus automated measurement, 119–20
optimising the angle of insonation, 116–18
velocity measurement, 114–18
volume flow, 118–19
spectral Doppler waveform indices, 119
Pourcelot's resistance index (RI), 119
pulsatility index (PI), 119
spectral broadening, 119
specular reflection artefacts, 72–73
speech development and ultrasound exposure *in utero*, 162
speed of sound
and density ρ (rho) of the medium, 6–7
and stiffness (*k*) of the medium, 6–7
speed of sound artefacts, 68–71
speed of waves (*c*), 5
standards and guidance
Doppler testing, 151
static B-mode, 1
steered linear-array transducers, 37–38
steering angle control
colour flow systems, 128
stereoscopic viewing of 3D dataset, 176–77
STIC (spatio-temporal image correlation), 177
stiffness (*k*) of a medium
effect on speed of sound, 6–7
stimulated acoustic emission imaging, 188–89
storage of images
advantages of digitization, 53
image formats, 62
image memory, 56–57
interpolation, 58
local storage, 62
networking of image information, 62
read zoom, 59
reading from the image memory, 58–59
writing to the image memory, 57–58
strain, 198–99
strain elastography, 196
change in strain with depth, 200
clinical and research systems, 199–205
complexity of real tissue elastic behaviour, 213
elasticity, 196–97
estimation of elastic modulus, 205
general principles, 197–98
quantification of elasticity from strain images, 200
strain and strain-ratio, 198–99
strain estimation from A-lines, 198–200
strain estimation from Doppler tissue imaging (DTI), 200
using acoustic radiation force, 204–05
using an externally applied force, 199–200
Young's modulus *E*, 196–98
strain imaging, 41
strain ratio, 199
string phantom
Doppler testing, 152
strongly convex curvilinear-array transducers, 34
swept gain, 49–50
synthetic aperture imaging, 41–43

TCC test object
temperature measurement, 158
temperature predictions, 157–58
test objects
absolute performance measurement, 144–45
for Doppler ultrasound, 151–53
materials and targets, 145
testing of ultrasound machines. *See* quality assurance (QA)
TGC. *See* time–gain compensation
thermal effects, 155
temperarure predictions, 157–58
temperature measurement, 158
thermal indices (TI), 108, 158–60
bone-at-focus thermal index (TIB), 158–60
cranial (or bone-at-surface) thermal index (TIC), 158–60
soft-tissue thermal index (TIS), 158–60
time-domain systems
colour flow systems, 122, 137–38
Doppler systems, 93–95
time–gain compensation (TGC), 49–50
artefacts, 71–72
time-saving techniques for array transducers, 39–40
line multiplexing, 39–40
parallel beam-forming in reception, 40
write zoom, 39
tissue mimicking material (TMM), 145
training of diagnostic ultrasound users, 164–65
transcranial studies, 191–92
transducer array elements, 24
active group, 28
curvilinear array, 27–28
linear array, 27–28
transducer bandwidth, 26
transducer components, 24–26
backing (damping) layer, 24, 25
lens, 24, 26
matching layer(s), 24, 25–26
piezoelectric plate, 24–25
transducer technology
improvements in performance, 26–27
transducers, 23–45
transient elastography, 209
transmission beam, 23–24
transmission focus
linear-array transducers, 28–29
transmit frequency control
spectral Doppler, 109
transmit power control
B-mode imaging, 48–49
spectral Doppler, 107–08
trans-rectal examination using 3D ultrasound, 178
transverse waves, 4
trapezoidal (virtual curvilinear) arrays, 27
trapezoidal (virtual curvilinear) scanning, 37
trapezoidal field of view, 3
turbulent flow, 96

ultrasound beams, 13
acoustic lens, 17
acoustic pressure within, 19–21
apodisation technique, 16
beam divergence, 15
curved source, 17
far field, 15
focusing, 16–17
intensity parameters, 19–21
interference, 13–14
main lobe, 15–16
near field, 15
plane disc source, 15–16
practical sources, 14, 15–16
receive beam, 23–24
side lobes, 15–16
transmission beam, 23–24
ultrasound equipment performance. *See* quality assurance (QA)
ultrasound pulse, 17
pulse spectrum, 17–18
uniformity
relative performance measure, 143
US Food and Drug Adminstration (FDA) regulations, 163

vascular ultrasound measurements, 75
velocity changes within stenoses, 99–100
velocity measurement
spectral Doppler, 114–18
velocity profiles (blood flow), 97
arterial branches and curves, 98–99

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-0-521-75710-2 - Diagnostic Ultrasound: Physics and Equipment, Second Edition
Edited by Peter Hoskins, Kevin Martin and Abigail Thrush
Index
More information

at stenoses, 99
normal vessels, 97–98
velocity ratios
spectral Doppler, 113
venous flow, 103–04
virtual curvilinear (trapezoidal) arrays, 27
virtual curvilinear (trapezoidal) scanning, 37
volume
B-mode measurement, 77
B-mode measurement errors, 81
volume flow measurement, 137
spectral Doppler, 118–19

wall-thump filter
CW Doppler, 90
wave propagation
linear, 18
non-linear, 18
wavelength (λ), 5
wavelengths used in diagnosis, 7–8
waves
frequency (*f*), 5
intensity (*I*), 6
longitudinal waves, 4–5
phase, 5–6
power, 6
pressure, 6
sound waves, 4–5
speed (*c*), 5
transverse waves, 4
wavelength (λ), 5
write zoom, 39, 58

Young's modulus *E*, 196–98, 207

zero-crossing detector, 91

© in this web service Cambridge University Press www.cambridge.org