DMS-235A: SONOGRAPHIC PRINCIPLES, PERFORMANCE, AND SAFETY

Cuyahoga Community College

Viewing: DMS-235A : Sonographic Principles, Performance, and Safety

Board of Trustees:
March 2020

Academic Term:
Fall 2021

Subject Code
DMS - Diagnostic Medical Sonography

Course Number:
235A

Title:
Sonographic Principles, Performance, and Safety

Catalog Description:
Physics and related mathematics as applied to ultrasound including the study of acoustical principles, sound transmission, signal processing, transducer construction, ultrasound instrumentation, quality assurance, and bioeffects of diagnostic ultrasound on soft tissue.

Credit Hour(s):
2

Lecture Hour(s):
2

Requisites

Prerequisite and Corequisite
DMS-1071 Physical Concepts in Diagnostic Sonography; and ENG-0995 Applied College Literacies, or appropriate score on English Placement Test.
Note: ENG-0990 Language Fundamentals II taken prior to Fall 2021 will also meet prerequisite requirements.

Outcomes

Course Outcome(s):
Apply and understand physical concepts of sound as it relates to ultrasound.

Objective(s):
1. Describe the physical properties of sound.
2. Differentiate between an analog and digital signal describing advantages and disadvantages.
3. Describe the advantages of multi-crystal transducers configurations.
4. Describe the anatomy of an ultrasound beam and the factors that affect it.
5. Categorize the methods used to focus and steer the sound beam.
6. Define the piezoelectric and reverse piezoelectric effect.
7. Relate the various parts of the transducer construction to their purpose.
8. Explain the principles of pulsed ultrasound creation, the parameters that define a pulse and the factors that influence those parameters.
9. Describe the purpose of the various components that modify the returning echo.
10. Differentiate between an analog and digital signal describing advantages and disadvantages.
11. Describe the advantages of multi-crystal transducers configurations.

Course Outcome(s):
Evaluate the various methods and the purpose behind signal processing in the ultrasound system.

Objective(s):

1. Identify the types of artifacts encountered in diagnostic ultrasound and state their probable causes.
2. Describe the various devices used to perform quality assurance on ultrasound equipment.
3. Explain the importance behind current research that describes how ultrasound produces bioeffects.

Methods of Evaluation:

1. Weekly quizzes
2. Weekly written assignments
3. Comprehensive mid term examination
4. QA project
5. Comprehensive final examination

Course Content Outline:

1. Concepts
   a. Critical thinking
   b. Sound properties
   c. Sound beam
   d. Transducers
   e. Digital devices
   f. Instrumentation
   g. Artifacts
   h. Bioeffects
   i. Quality assurance
2. Skills
   a. Manipulate machine adjustments for quality images
   b. Maintain safe machine operation
   c. Develop risk versus benefit machine adjustments
   d. Evaluate the performance of an ultrasound system with a phantom.
3. Issues
   a. Benefits
   b. Limitations
   c. Operator dependent
   d. Quality assurance
   e. Safety
   f. Interpretation results
   g. Atypical studies
   h. Accuracy

Topical Outline

1. Review of basic mathematics
2. Review sound properties
   a. Longitudinal mechanical waves
   b. Pulsed Wave
   c. Pulse production
   d. Ultrasound transmission
3. Sound Beam
   a. Formation - Near Field and Far Field (Fresnel and Fraunhofer Zones)
   b. Interference phenomena
      i. Huygen's principle
      ii. Diffraction (divergence)
      iii. Bandwidth
   c. Length of near field (focal distance)
   d. Shape of near field and far field
      i. Beam width
      ii. Natural focus
   e. Dependence on frequency and crystal or aperture size
   f. Beam steering

i. Transmission time delays
ii. Reception time delays

g. Beam focusing
i. Time delays
ii. Dynamic reception focus
iii. Multiple transmission foci
iv. Apodization
v. Subdicing
vi. Dynamic aperture

h. Clinical usage
i. On screen display
j. Identifying failure

4. Transducer Construction and Characteristics
a. Thickness resonance of crystal
b. Operating (resonance) frequency
i. Crystal thickness
ii. Speed of sound in crystal material

c. Frequency characteristics (spectrum)
i. Bandwidth
1. Quality factor
2. Effect of damping

ii. Multi-Hertz
iii. Harmonics

d. Damping
e. Matching layer-numerical example

5. Scanning Speed Limitations
a. Applications of range equation and relationship to pulsing characteristics
b. Real-time systems-relationships between
i. Pulsing characteristics
ii. Frame rate and time required to generate one frame
iii. Number of lines per frame
iv. Number of focal regions
v. Field of view (e.g., sector angle)
vi. Image depth (penetration)

6. Digital Devices
a. Binary system
i. Terminology (bits, bytes, pixels)
ii. Discrete nature of binary numbers

b. Steps in processing echo information
i. Analog-to-digital converter
ii. Digital memory
1. Spatial resolution
a. Pixels
b. Matrix
c. Field of view

2. Contrast resolution

iii. Digital-to-analog converter
iv. Display devices

7. Instrumentation
a. Signal types
i. Analog
ii. Digital
iii. Scan conversion

b. Transmitter (Output)
i. Effect of transmitter voltage on penetration
ii. Effect of transmitter voltage on intensity and on patient exposure

c. Receiver

i. Amplification
1. Output power
2. Receiver gain
ii. Compensation-time gain control
iii. Compression and dynamic range
d. Demodulation
i. Rectification
ii. Smoothing (enveloping)
e. Rejection
f. Pre and post processing
i. Definition
ii. Preprocessing functions
1. Time (depth) gain compensation
2. Logarithmic compression
3. Write magnification
iii. Postprocessing function
1. Freeze frame
2. Black/white inversion
3. Read magnification
4. Contrast variation
iv. Preprocessing or postprocessing functions (equipment manufacturers' discretion)
1. Persistence
2. Frame averaging
3. Edge enhancement
4. Smoothing
5. Fill-in interpolation

8. Storage devices
a. Video format
i. Display (monitors)
ii. TV monitors
1. High resolution monitors
a. Lines and spatial resolution
b. Brightness
c. Contrast
d. Frame rate
iii. Single or multi-image cameras and laser imagers
1. Photographic film
2. Emulsion film
iv. Recorders
1. Fiber-optic
2. Videotape cassette
v. Printer
1. Thermal
2. Laser
b. Digital format
i. Magneto-optical disc (digital still recorder)
ii. PACS (Picture Archiving and Communication System)
c. Contrast and brightness control adjustments
9. Artifacts
a. Definition
b. Artifact Recognition in Performing and Interpreting Examinations
i. Echoes not representing actual interfaces
ii. Missing echoes
iii. Misrepresented interface location
iv. Misrepresented interface amplitude
c. Artifacts Associated with Resolution and Propagation (Axial Resolution, Lateral Resolution, Section Thickness, Acoustic Speckle)
i. Definitions
ii. Mechanisms of Production
iii. Appearance

d. Artifacts Associated with Propagation (Reverberation, Comet-tail, Ring-down, Mirror Image, Multipath, Side Lobes, Grating Lobes, Refraction, Speed Error; and Range Ambiguity)
    i. Definitions
    ii. Mechanisms of Production
    iii. Appearance
e. Artifacts Associated with Attenuation (Shadowing, Enhancement, and Focal Enhancement or Focal Banding)
    i. Definitions
    ii. Mechanisms of Production
    iii. Appearance
f. Other (Electronic Noise, Equipment Malfunction)
    i. Definitions
    ii. Mechanisms of Production
    iii. Appearance
g. Artifact Effects on Measurements (velocity or speed error and range ambiguity)

10. Quality Assurance of Ultrasound Instruments
    a. Need for and Nature of a Quality Assurance Program
    b. Methods for Evaluating Instrument Performance
        i. Test objects
        ii. Phantoms (tissue, Doppler, flow)
    c. Parameters to Be Evaluated
        i. Test object
            1. Dead zone
            2. Axial resolution and lateral resolution (beam width)
            3. Depth calibration accuracy
            4. Time Gain Compensation (TGC) characteristics
            5. Uniformity
            6. System sensitivity
        ii. Tissue equivalent (mimicking) phantom
            1. Dead zone
            2. Depth calibration accuracy
            3. Lateral (horizontal) distance measurement accuracy
            4. Axial, lateral, and section thickness (elevational) resolution
            5. TGC characteristics
            6. System sensitivity
            7. Dynamic range
            8. Contrast resolution
            9. Lesion detection
        iii. Doppler flow, string, or belt phantoms
            1. Maximum depth
            2. Pulsed Doppler sample volume alignment (gate position accuracy)
            3. Velocity accuracy
            4. Color flow penetration
            5. Image congruency test
    d. Preventive Equipment Maintenance
        i. Cleaning
        ii. Disinfecting
        iii. Sterilization
    e. Record Keeping
    f. Statistical Indices
        i. Sensitivity/specificity
        ii. Negative/positive predictive value
        iii. Accuracy
11. Bioeffects and Safety
    a. Acoustic Output Quantities
        i. Pressure
            1. Units
            2. Peak pressures
            3. Methods of determining pressure (miniature hydrophone)
        ii. Power

1. Units (mw)
2. Methods of determining power (radiation force, hydrophone)

iii. Intensity
1. Units (mW/cm2, W/cm2)
2. Spatial and temporal considerations
3. Average and peak intensities
4. Methods of determining intensity (hydrophones)
5. Common intensities
   a. SATA - spatial average temporal average
   b. SPTA - spatial peak temporal average
   c. SPPA - spatial peak pulse average
   d. SPTP - spatial peak temporal peak
6. Intensity and power values for different operating modes

b. Acoustic Output Labeling Standard
i. Thermal index
1. TIS - soft tissue thermal index
2. TIB - bone thermal index
3. TIC - cranial bone thermal index

ii. Mechanical index

c. Acoustic Exposure
i. Definition and concepts of prudent use (ALARA)
ii. Methods of reducing acoustic exposure

d. Primary Mechanisms of Biologic Effect Production
i. Cavitation mechanisms: relevant acoustic parameters
ii. Thermal mechanisms: relevant acoustic parameters

e. Experimental Biological Effect Studies
i. Animal studies
ii. In vitro studies
iii. Epidemiologic studies

f. Guidelines and Regulations
i. American Institute of Ultrasound in Medicine (AIUM) Statements e.g., mammalian, epidemiology, in vitro)
ii. National Electrical Manufacturers Association (NEMA)
iii. Food and Drug Administration (FDA)

g. Electrical and Mechanical Hazards
i. Patient susceptibility to electrical hazard
ii. Equipment components which could present a hazard

Resources

Hedrick, Wayne R. *Technology for Diagnostic Sonography.* 1st ed. St. Louis, MO: Elsevier Science, 2012.

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Kremkau, Frederick W. *Diagnostic Ultrasound Principles and Instruments*. 10th ed. St. Louis: Saunder, 2020.

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Edelman, Sidney K. *Understanding Ultrasound Physics.* 4th ed. Dallas, TX: ESP, 2012.

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Owen, Cindy A and Zagzebski, James. A. *Ultrasound Physics Review: A Review for the ARDMS SPI Exam.*. Pasadena: Davies, 2017.

Penny, Steven M., Traci B. Fox and Cathy Godwin. *Examination Review for Ultrasound: Sonography Principles & Instrumentation*. 2nd ed. Philadelphia, PA: Lippincott Williams & Wilkins, 2017.

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