محاضرة
3

Sawa University

Sawa University

College of health and medical techniques

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Third Stage

Radiological Equipment techniques

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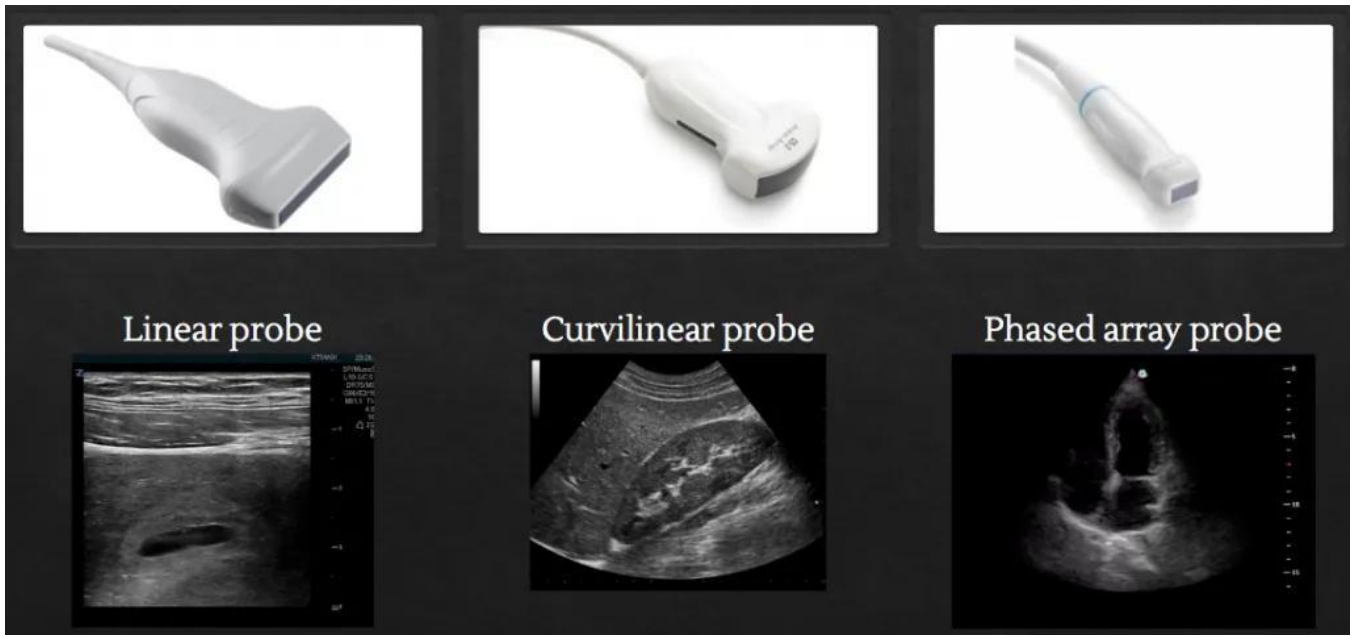
Linear- and Curvilinear-Array Transducers (Beam-Stepping Arrays)

Transducers are critical components in diagnostic ultrasound systems. They convert electrical energy into mechanical sound waves and back into electrical signals. Linear and curvilinear arrays, known as beam-stepping arrays, are commonly used transducers with advanced imaging capabilities.



What Is a Phased Array Transducer?

A phased array transducer is an ultrasonic testing transducer that contains a series of elements that can be pulsed in unison to direct sound waves in a specific direction. This makes it possible to test multiple inspection zones in a single instance.

What is an Array?

An array is an organized arrangement of large quantities of an object. The simplest form of an ultrasonic array for NDT is a series of several single element transducers arranged to increase inspection coverage and/or the speed of an inspection.

In its simplest form, a phased array probe is a series of individual elements in one package. While the elements are much smaller than conventional transducers, these elements can be pulsed as a group to generate directionally controllable wavefronts. This electronic beam forming enables multiple inspection zones to be programmed and analyzed at high rates of speed from a single position transducer.

نم رثكأ رصانعلا أ نأ نيح في .ةدحاو ةمزح في ةيرئاد رصانعلا نم لسلس وه يلاحرملا فيصلا رابسم ،هلاكشأ طسبأ يف عاعشلا لكشتي .ايهاجتا ةفلتخم نكمي تموجم تاهجاو في ةعومجم رصانعلا هذه ضعب نكمي ثيحب ةطاقلا تالوحم .ةدحاو عضوم لوحم نم ةيلاع ةعرس تالدعم اهيجوتو ةددعتم قطانم تجرب اذه ينورتكلإلا

Phased Array Transducer Characteristics

Phased array transducers are functionally categorized according to the following basic parameters

Type: Most phased array transducers are the angle beam type, designed to be used with a plastic wedge, straight plastic shoe (zero-degree wedge), or delay line. Direct contact and immersion transducers are also available.

Frequency: Most ultrasonic flaw detection is done at frequencies between 2 MHz and 10 MHz, so most phased array transducers fall within that range. Lower and higher frequency probes are also available. As with conventional transducers, penetration increases with lower frequency, while resolution and focal sharpness increase with higher frequency.

Number of elements: Phased array transducers commonly have 16 to 128 elements, and some have as many as 256. A larger number of elements increases focusing and steering capability, and it can increase area coverage as well. However, more elements increase both probe and instrumentation costs. Each of these elements is individually pulsed to create the wavefront of interest. As a result, the dimension across these elements is often referred to as the active or steering direction

Size of elements: As element width gets smaller, beam steering capability increases. However, large area coverage will require more elements at a higher cost.

256 ىلإ 128 نم ةدايز عم 16 ىلإ ددعلا اذه ،كلذ عمو .اضيأ ةفلكتلا ةدايز :رصانعلا ددع
نم ديزي نأ نكميو ،ةيجولونكتلا ةيحانلا نم رصانعلا نم ريبك ددع ديزي .ارصنع ةهجاو قلخ يرف لكشب رصانعلا هذه نم رصنع لك .ةزهجألا و
ةيفلكلا نم لك نم ديزت رصانعلا نم ديزملا ةيجولونكتلا وأ طشنلا هاجتالا هذه ىلع رصانعلا ىلإ راشي ام ةلاغ ،كلذ ىلع .ماهتمالا ةجوملا

رصانعلا نم ديزملا ةريبكلا ةفلكتلا ىلإ ةفاضإلاب ،كلذ عمو .ةمزحلا ةجوملا ةقدز ةدازت ،رصنعلا ضرع رغصأ عم :رصانعلا مجح .ىلعأ

The dimensional parameters of a phased array are customarily defined as follows:

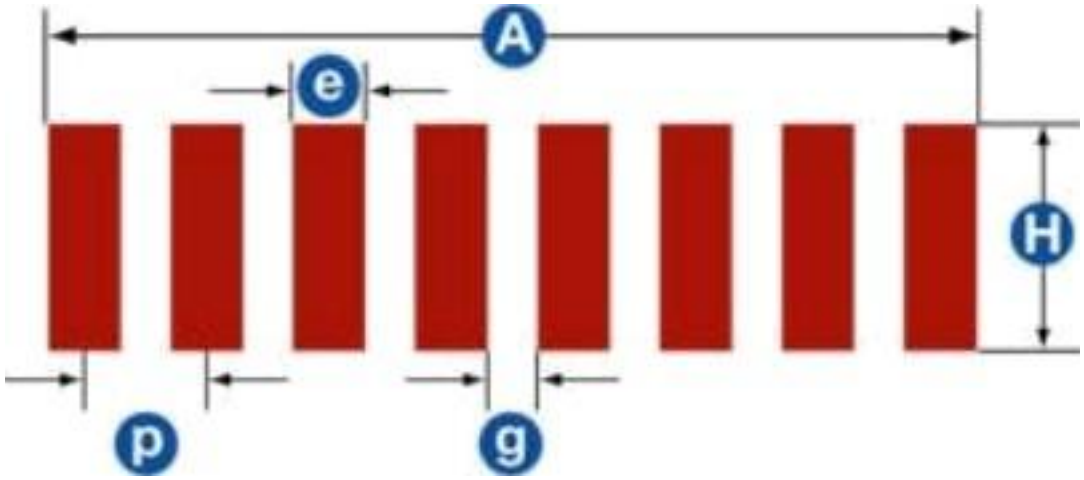
The dimensional parameters of a phased array probe are usually defined as:

- N = the total number of elements in the array
- A = total aperture in steering or active direction
- H = element height or elevation; since this dimension is fixed, it is often referred to as the passive plane
- p = pitch, or center-to-center distance between two successive elements
- e = width of an individual element
- g = spacing between active elements

يلاتلا وحنلا ىلع ةيلحرملا هذهل ةصاخلا داعبألا تاملعم فرعت ةمئاق
يلاتلا وحنلا ىلع يلحرملا هيجوتلا رسلا ةصاخلا داعبألا تاملعم فرعت ةمئاق

N = هذه رصانعلا يلامجإلا ددعلا
A = طشنلا هاجتالا وأ هيجوتلا يف ةيلامجإلا ةحتفلا
H = روشعلا مساب اهيلإ راشي امم لقأ دحلا اذه نأل ارظن ؛عافترالا وأ رصنعلا عافترا ىيلسلا
p = يلاتلا رصنعلا زكرمو زكرملا نم لك سايق متي يذلا دعبلا وأ ةفاسملا
e = يدرف رصنع ضرع
g = تطشنلا رصانعلا يف دعبتلا

Dimensional Parameters of Phased Arzay Probe



N = total n‹xuber of elwr›euts In Ore army

A = total aperture in steering or active direction

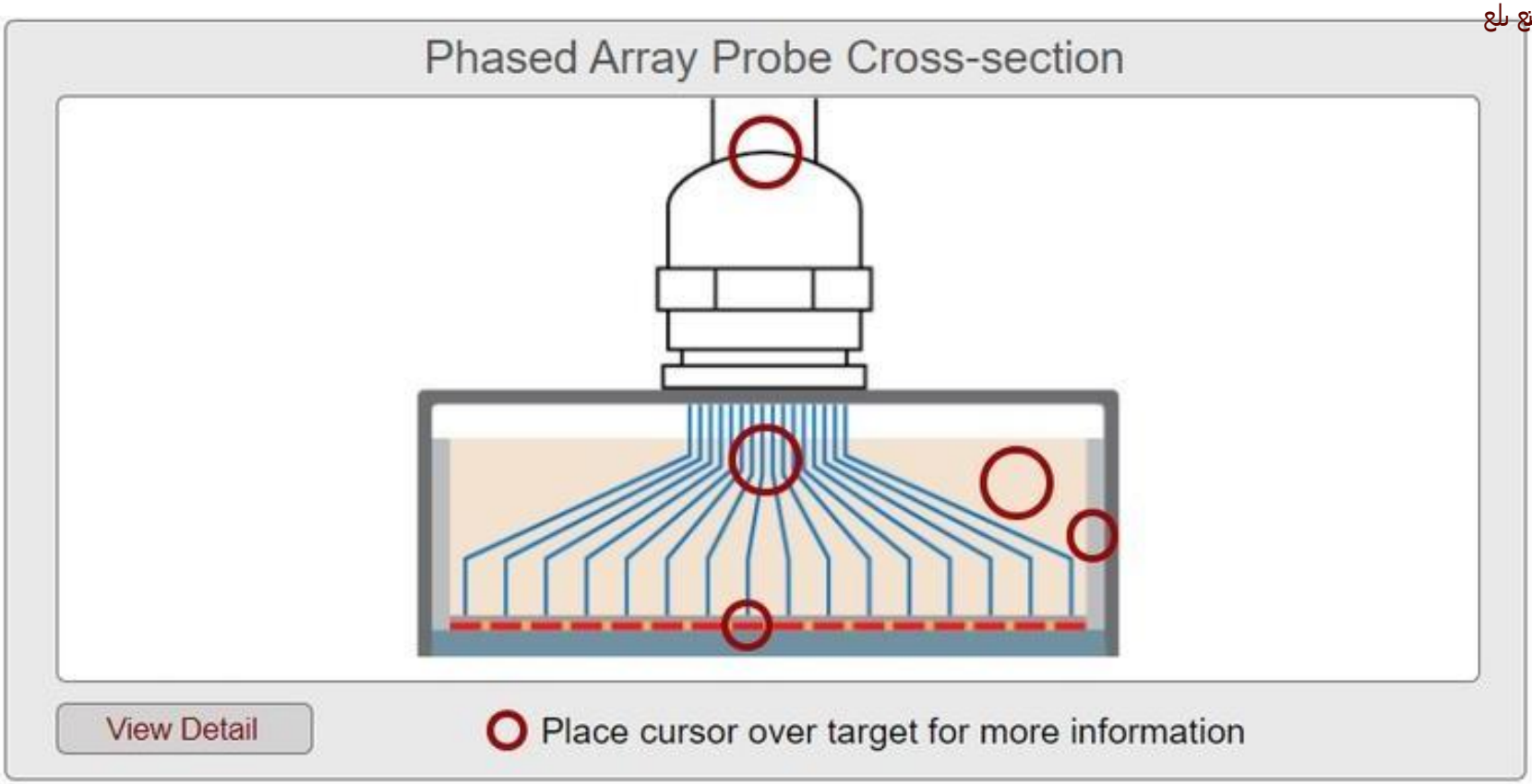
H • element height oreievatlon. 6lroa ihls dmension b 9xed, it is ohan rafwreo to asth paast•e plans.

p - pitch, o r d - t o o d B t ‹cs between to su‹›cessive demons

e = wlbth of an k›aIvMul elwnent

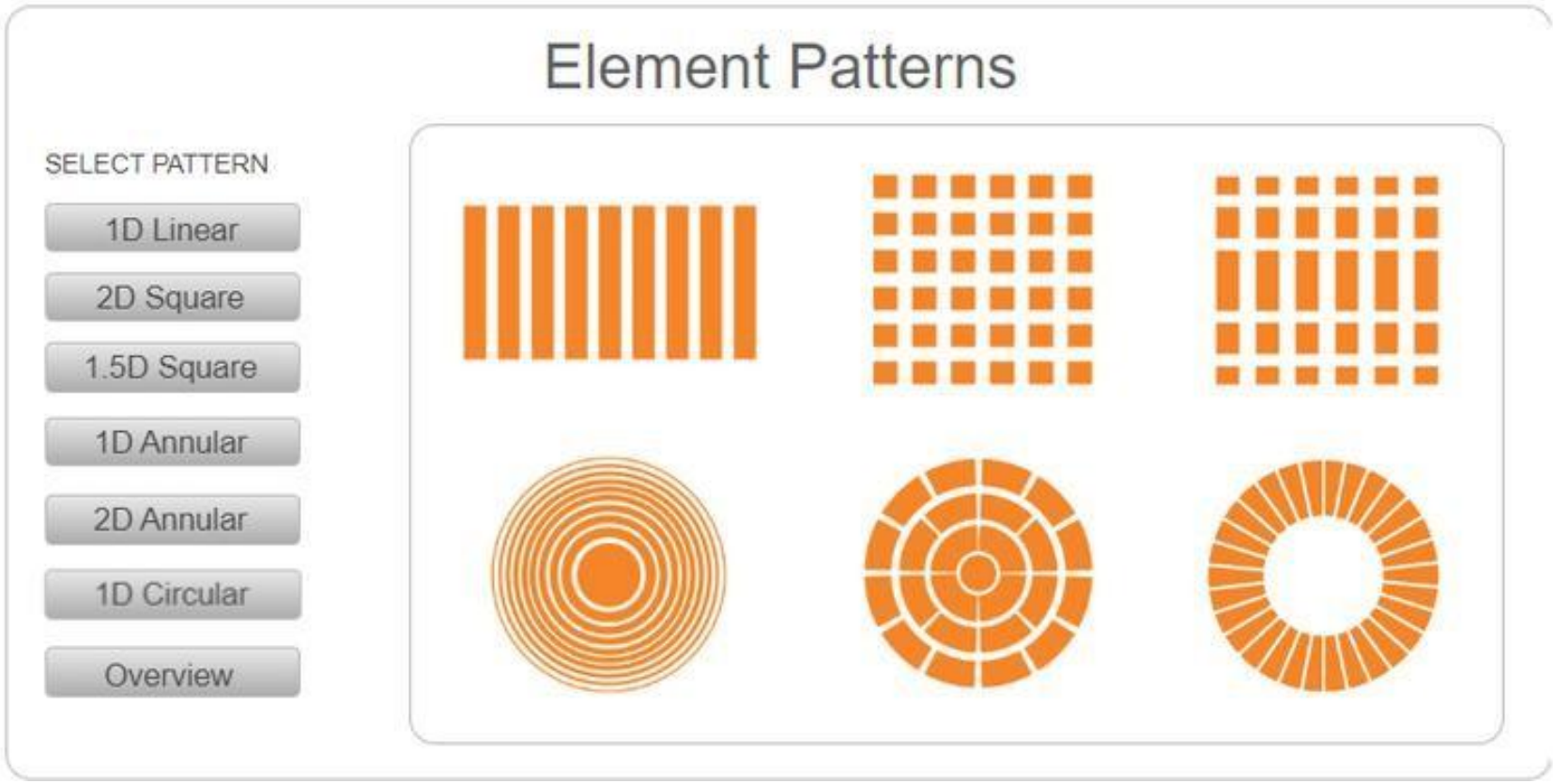
Inside a Phased Array Transducer

Phased array transducers come in a wide range of sizes, shapes, frequencies, and number of elements, but they all contain a piezoelectric element that has been divided into a number of segments.



Types of Phased Array Transducer Configurations

The animation above depicts a linear array with a rectangular footprint. This is a common configuration for a phased array. Arrays can be arranged as a matrix for more beam control over a surface cross section or as circular arrays for a more spherical focusing pattern.



Phased array transducers can be arranged into several different configurations, each with distinct advantages and disadvantages. Common phased array transducer configurations include:

يوجد أيضًا العديد من تكوينات المصفوفة المرحلية المختلفة، كل منها بمزايا وعيوب مميزة. تشمل تكوينات المصفوفة المرحلية الشائعة ما يلي:

Linear Phased Array Transducer

Linear phased array transducers have elements arranged in a straight line and are the most common configuration in phased array ultrasonic testing. Linear phased array transducers are easy to make, but they need to be large for deep focusing.

يطخ يلحرم فيض لوحم

Annular Phased Array Transducer

نوكلا يهو ميقسم طخ في قيم رصانع يلع قيلحرملا قيطخلا ةفوفصملا تالوحم يوتحت عيض لهسلا نم .قيلحرملا ةفوفصملا قيوصلا ةوق تاجوملاب رابتخلالا في اعويش رثكألا .قيمعلا زكيل توك نوكت نأ نلا جاحت اهكلو .قيلحرملا قيطخلا ةفوفصملا تالوحم

Annular phased array transducers and segmented annular phased array transducers feature elements arranged in circular rings with a common center. These transducers can provide elliptical and spherical beams with steering capabilities at different depths. However their complex design makes manufacturing them challenging.

يقلح يلحرم فيض لوحم

زكرم عم قيرئاد تاقلح في قيم رصانع ةأزجملا قيطخلا قيلحرملا ةفوفصملا تالوحمو قيطخلا قيلحرملا ةفوفصملا تالوحم زيمت نإف ،كلذ عمو .ةفلتخم قاطعأ يلع هيجوت نارادق عم قيرئاد تاقلح امزح هذه ةقاطلا تالوحم رفوت نأ نكمي .كرتشم لمعب اهيمصت لجأ نم ةصاخ ةيمعلا اهميمصت

Convex Phased Array Transducer

Convex phased array transducers, also called curved or curvilinear phased array transducers, have elements arranged in an arched line. These transducers are good for in-depth testing, but image resolution can decrease as the depth increases.

Square Phased Array Transducer

Square phased array transducers have their elements arranged in a square pattern. While this pattern provides excellent steering capabilities, the complex design makes manufacturing square phased array transducers difficult.

Circular Phased Array Transducer

Circular phased array transducers feature elements arranged in a circular ring but without a common center. They provide excellent steering capability at varying depths, especially in curved targets. However, their complex design makes manufacturing circular phased array transducers difficult.

Practical part

Array Transducers consist of multiple piezoelectric elements arranged in a specific geometry. Each element can be activated individually or in groups to generate, focus, and receive ultrasound waves.

- **Types of Array Transducers:**

Linear-Array Transducers:

- Elements are arranged in a straight line.

- Produces a rectangular field of view.

-Commonly used for imaging superficial structures such as vascular and musculoskeletal tissues.

Curvilinear-Array Transducers:

- Elements are arranged along a curved arc.
- Produces a wide fan-shaped field of view.
- Typically used for abdominal and obstetric imaging.

Beam-Stepping Mechanism

Beam-stepping arrays use groups of active elements to scan the imaging field. Let’s explore the concept:

Active Group of Elements:

-Instead of activating all elements at once, a subset or group of adjacent elements is energized simultaneously.

-The size of the group determines the beam width and focus.

رصانعلا نم تاطشن ةعومجم:
- دحاو نوف رصانعلا عيمج طيشنت نم لدب ، دحاو نوف ةعومجم طيشنت هني و أ نوف ةعومجملا رصانعلا نم ةعومجم .اهزيكرتو ةمزحلا ضرع ددحي مجح ةعومجملا

Sequential Activation:

- Active groups move or 'step' across the array in a sequence.

- Each step shifts the active group slightly along the array, enabling scanning of the entire imaging field.

- For curvilinear arrays, the steps follow the curved geometry, creating a fan-shaped scan.

.لسلستلا طيشنلا

- تاطشنلا تاعومجملا كرحت "وطخت" و أ نوفصلا ريغ لسلست في نوفصلا .

- ةعومجملا ةوطخ لك لوح نوفصلا لوط ريغ اهنم ةيحانلا حسم جم ا لاجم ربوصلا نكمأ .

- ةروم . ةيحانلا تاوطخلا عبتت نوفصلا هذه ةسدنهلا تاوطخلا دنع اهنم ةيحانلا حسم جم ا يضرع لكش

Overlapping Groups:

- Adjacent groups overlap slightly to avoid gaps in the image.

- This ensures smooth coverage and prevents missing data between beams.

:تاخداصلا تاعومجملا
.قروصلا يف تاوجفلا يلع ظافحلل قرواجملا تاعومجملا لخادتت - .مزحلاب قوفوملا
ةليلا عضو قسلس قيقد نمضي اذه -

Advantages of Active Groups in Beam-Stepping

Beam-stepping allows dynamic focusing and precise control over image formation. Key advantages include:

.1 ***Beam Focusing***: Allows dynamic focusing at varying depths, enhancing resolution.

Beam-Steppingيف قطشنلا تاعومجملا ايازم

.قروصلا نوكت يف قيقدلا مكحتلاو يكيماينيدلا زكرلاب عاعشلا وطخ حمسي يذلا ام قيسيئرلا ايازملا لمشت

.ققدلا زيزعت امم ،قئافخ قامعأ عم يكيماينيدلا زكرلاب حمسي :عاعشلا زكرت .1

.2 ***Image Formation***: Sequential activation provides comprehensive scanning of the region of interest, resulting in real-time, high-resolution images.

2. تروصلا نوكت :يرهاظلا عاطقلا احسم للاستلا طيطختلا يف ةقدلا ةيلاع روص ىلإ يدؤي امم ،مامتهالا تاذ ةقطنملا الماش

3. Flexibility: The number and configuration of active elements can be adjusted to optimize image quality for various applications.

3. ةروصلا :ةيئاهنلا ةدوجلا ىلع رثؤت يتلا ةطشنلا رصانعلا نيوكو ددع ليدعت نكمي

Applications

Linear-Array Transducers:

- Used for imaging shallow structures (e.g., blood vessels, tendons, and nerves.(

- Example: Vascular ultrasound for identifying stenosis or evaluating blood flow.

:ةيطخلا ةروصلا تاودحم ةيقبت

- ةيعوألا تيومدلا ،لاثملا ليبس ىلع) ةحضاولا لكايهلا روصل مدختسي (.باصعألاو رانوألاو

- لاثم: ةروصلا ةدوج نيسحت ىلإ يدؤت ةيقبتملا ةيطخلا تاوطخلا .مدلا قفدت ريدقتو أ

Curvilinear-Array Transducers:

- Ideal for imaging deep structures)e.g., abdominal organs, fetus in obstetrics.(

- Example: Abdominal ultrasound for liver, kidney, or gallbladder examination.

تيحصلا فوصلا تالوحم
.(ملونلا في نيجلاو نطلا ءاضعأ ،لاثملا ليس بلع) ةقيمعلا لكايهلا روصلى يلاثم - .قرارملا وأ بكلا وأ بكلا صحلى نطلى
- لاثم: فوصلا قوف تاجوملا

Key Differences Between Linear and Curvilinear Arrays

Feature	Linear-Array Transducers	Curvilinear-Array Transducers
Element Arrangement	Straight line	Curved arc
Field of View	Rectangular	Fan-shaped
Applications	Superficial imaging	Abdominal and deep tissue imaging

Challenges in Beam-Stepping Arrays

1. Element Crosstalk: Electrical or mechanical interference between adjacent elements can degrade image quality.

2. Trade-off Between Depth and Resolution: High-frequency linear arrays provide better resolution but have limited penetration. Curvilinear arrays provide deeper penetration at the cost of lower resolution for deeper tissues.

عاعشلا وطخت نايدحتلا
ةدوج ىلع ةرواجملا رصانعلا ب يكيلكيلا وأ يئابرهكلا لخادتلا صوقي نأ نكمي :عطاقملا رصنعلا .1 .ةروصلا
.دودحم قارتخا اهل نكلو اضيأ ةقد درنلا تيلاع تيطخلا نوفصملا رفوي :ةقدلاو قمعلا ب ناضقلا .2 رفوي
.ةقيمعلا تجسنألل لقأ ةقد باسح ىلع قمعأ اقارتخا تيحصلا نوفصملا

Conclusion

Linear and curvilinear-array transducers utilize beam-stepping technology to scan and image regions of interest efficiently. Active groups of elements enable precise control over beam generation and

ةمتاخ

نكمت .ةفلتخم اهريوصتو مامتهالا تاذ قطانملا حسمل عاعشلا ةوطخ ةيحصلا تيطخلا ةقاطلا تالوحم مدختست و ةمزحلا هيجوت يف ةيقيلا مكحتلا
نم رصانعلا نم ةطشنلا تاعومجملا

focus, contributing to high-quality diagnostic imaging. Understanding their operation, strengths, and limitations is essential for selecting the appropriate transducer for specific clinical applications.

ايرورض ارمأ اهديقو اهوق طاقنو اهيفشت مهف دعي .ةدوجلا يلاع يصيخشتلا رويصتلا يف ةمهاسملاو ،زيكرتلا
.ةددحم تيريس ايفلخ بسانملا تقاطلا لوحم رايتخا

Interactive Discussion Questions

1. How does the arrangement of piezoelectric elements affect the field of view in linear and curvilinear arrays?

2. What are the advantages of using overlapping active groups in beam-stepping arrays?

3. Can you think of any scenarios where linear arrays might be preferred over curvilinear arrays and vice versa?

ةيلاتلا ةشقانملا ةلئسأ

1. فيك رثؤت ةيفرطلا رصانعلا تيتر يوذلا يف ةيطخلا ةفوفصملا يف ةيرطخلا لا جم يلع ةيطغضرهكلا ةيحانملاو؟

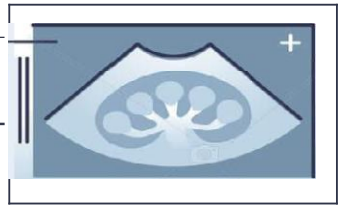
2. ام يه ايازم مادختسا ةعومجملا ةطشنلا ةلخادتملا يف ةوطخ ةفوفصم ةوطخ؟

3. له حيحص سكعلاو ةيحانملا ةفوفصملا يلع ةيطخلا ةفوفصملا ليضفت يف يأ فرظ ةكلا ةكيمي؟

ULTRASOUND

SCREEN

SPEAKER



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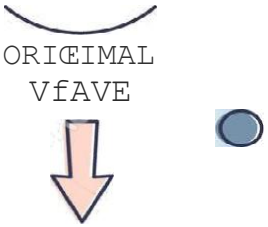
COMPUTER

PREMIER

ORIŒIMAL
VfAVE

REFLECTED
SUAVE



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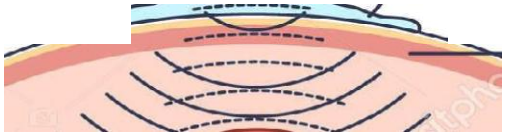

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