IMASONIC 2018

ULTRASONIC TRANSDUCERS FOR NDT

IMMERSION

TOFD

PHASED ARRAY

CONFORMABLE

Designer & manufacturer since 1989

SUMMARY

Context

Non Destructive Testing (NDT) based on ultrasound is the use of ultrasonic waves to detect, locate and characterize defects in materials, components and assemblies. This technique has evolved enormously over fifty years and changes have been particularly rapid over the last twenty years.

Other NDT techniques (X Rays, Eddy Currents, Visual Inspection, Thermography, etc) complement ultrasonic techniques. Whichever technique is used, the purpose is to ensure that the materials, components or structures are of a satisfactory quality.

The evolution of the performance requirements of NDT has been determined by developments in quality requirements.
The history [1] of the development of these techniques has thus been marked by the evolution in the objectives of inspections: the "zero defect" objective of the 1960s was replaced
in the 1970s by the objective of detection of "critical defects", followed in the 1970s-1980s by the objective of improving the detectability of defects.
It should be noted that the term Non Destructive Evaluation (NDE) has developed for this evolution towards the characterization of defects.
The 1980s-1990s were then marked by the objective of continuous and improved NDT of the systems and structures that are subject to ageing.
In the 1990s-2000s appeared the needs to inspect very large areas, to monitor continuously the health of certain structures through Structural Health Monitoring (SHM), and, at the same time, to reduce the cost of inspections and other evaluations.

The quality requirements behind NDT techniques is currently centred on establishing the key parameters of dimension, shape, orientation and detectability of defects.
In the light of these objectives, the development of the performance of NDT systems plays an essential role in connection with the development of science and techniques in the related fields of material physics, design of components and structures, analysis of the constraints in the life of components and structures, fracture mechanics, reliability evaluation, economic demands, etc.

The techniques of NDT based on ultrasound is gaining interest for several reasons:
- they can be implemented without risk to operators or to the environment
- they can be used on an extremely large range of different materials and at a wide range of depths of use
- they have improved their performance, flexibility and speed through the Phased Array transducer concept and through progress in modelization, microelectronics and microcomputing.

For more than twenty years, IMASONIC has been contributing, with their customers and their partners, to the constant evolution in the techniques of ultrasonic NDT.
With piezocomposite technology, we have been able to increase, in particular:
- the performance in sensitivity
- the focusing capacity (without lens, including aspherical)
- the feasibility of custom-designed and custom-manufactured Phased Array transducers, in order to adapt the performance to the needs of each application

This progress continues with the development of conformable solutions to improve the conditions of inspection for many components.

[1] cf: D.O. Thomson "Evolution of QNDE's Core Interdisciplinary Science and Engineering Base" in Review of quantitative non destructive evaluation - vol 29.

IMASONIC Overview

IMASONIC is an independent, privately-owned company that develops and produces ultrasonic transducers for high socio-economic added-value applications.

IMASONIC's vocation can be summed up as follows:

- to act for the benefit of man and his environment, in particular in the interests of health, safety and quality
- to advance the profession of designer and manufacturer of ultrasound transducers and to do this creatively, innovatively and productively
- to increase recognition of the company and its leading position through the quality of its relationships with customers and partners.

IMASONIC's vocation can also be seen in the willingness to collaborate over the long term with its customers and partners.

IMASONIC is ISO9001: 2015 certified.
80% of the total turnover is exported to all five continents.

Around 67% of the total turnover is dedicated to safety and quality applications, mainly for Non Destructive Testing and industrial measurement.
Customers for NDT transducers and probes are end users, service companies, equipment manufacturers and laboratories.
The main applications for NDT are: power generation, aeronautics, car industry, railways, petrochemicals and metallurgy.

Located in the east of France, close to Switzerland, in a region famous for its microtechnologies and watch industry, IMASONIC is founded on the skills of its team of 105 employees (2018).

Transducers for ultrasonic NDT

The IMASONIC offer

The wide variety of NDT applications and methods leads to a great range of needs.
Over 30 years, IMASONIC has acquired considerable experience in the demands of NDT, and can offer the capacity to design and manufacture transducers adapted to this variety.

A transducer adapted to each application

IMASONIC offers customers its team's expertise and its design capacity to define with them the appropriate transducers for their applications. This service includes, in particular, feasibility studies associating simulation and/or prototyping. In addition, IMASONIC can also provide customers with access to their partner network of specialists for associated needs related to transducers.

"Customized" transducers

Some NDT needs require the development of transducers dedicated to a target application. IMASONIC proposes the production and characterization of "made-to-measure" transducers, defined according to detailed specifications.
IMASONIC's piezocomposite technology has a very large capacity for adaptation to the most varied needs. Over thirty years, IMASONIC has developed a high level of expertise in providing for these types of needs.

"Standard" or "near-standard" transducers

Other NDT needs may be met with transducers whose design may be described as "standard" or "near-standard". For these needs, IMASONIC has developed a technological platform where, in a large number of cases, certain parameters on a predefined design base can be adapted. This approach offers **very competitive prices and rapid delivery, while still offering a high level of quality, reliability and reproducibility.**

Quantities

IMASONIC's industrial and commercial organisation is able to respond appropriately to requirements from just a few units up to production runs of several thousands of units.

IMASONIC's commitments

In a context where the technical and economic performance stakes are high, IMASONIC makes the following commitments:

Quality

In order to provide the most appropriate response for the performance requirements, IMASONIC undertakes to seek from the customer the specific needs for each application. In seeking the highest quality, we also propose and implement solutions adapted to the different development stages, from feasibility studies to finished products destined for industrial applications with reproducibility requirements.

Standards

IMASONIC undertakes to identify with its customers the requirements that apply to the transducers. IMASONIC's commitment is also demonstrated through their contribution to work on establishing industry standards.

Transducer specifications

IMASONIC undertakes to collaborate closely with its customers to identify the essential requirements, conformity criteria and verification conditions (tests and measurements). On delivery, these specifications are completed by recommendations on conditions of integration and use, to reduce any risks linked to an inappropriate use of the product.

Characterization

IMASONIC undertakes to verify conformity to essential requirements and acceptance criteria through tests and measurements. A formal report presents the results. IMASONIC also undertakes to offer characterization solutions that are reproducible and connected to the appropriate standards where they exist.

Reliability and durability

IMASONIC undertakes to collaborate with its customers to identify any risks of failure from the viewpoint of conditions of integration and use, and to check the reliability of the products in their using conditions.

Confidentiality

IMASONIC takes all necessary steps to protect the confidential information of its customers from unauthorized disclosure or use and thus to protect their interests.
In particular, this commitment can be formalized by signing non-disclosure agreements.

Alerts

IMASONIC undertakes to alert its customers if any uncertainty arises regarding the relevance of a study or a manufacturing process in connection with the reliability of a transducer or the safety of its use.

General Technical information

Transducers key components

Piezocomposite material

Specially designed piezocomposite structure is inserted in each type of probe. The composite components and geometry are defined according to the temporal and frequency response specifications, while retaining high sensitivity and signal-to-noise ratio level.
For phased array probes, the piezocomposite structure is also designed to lower the cross-coupling between elements, which is necessary to properly steer the beam with electronic delay laws. Typical cross-coupling is lower than –30dB.

Matching layers

Taking into account the conditions of use of the probe (manual, automated, direct contact, contact with a wedge), the matching layer is designed to optimize the transfer of energy, to shorten the pulse width and to protect the piezocomposite.

Backing material

The backing material is designed to shorten the pulse width and to attenuate the back echo. Specially-designed backing materials allow an interesting trade-off with high damping and high attenuation in reduced dimensions.

Housing

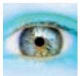
The housing is designed to combine the required geometry with the strength and watertightness of the probe. It can be adapted to mechanical or manual use.

Cable

Performance of the cable is also a key parameter for the overall performance of the probe. Its attenuation must be as low as possible, in particular for high frequency probes. Its electrical impedance is matched with the probe and electronic characteristics. The bending capability is optimized to access small areas, while keeping high mechanical resistance and constant electrical properties.

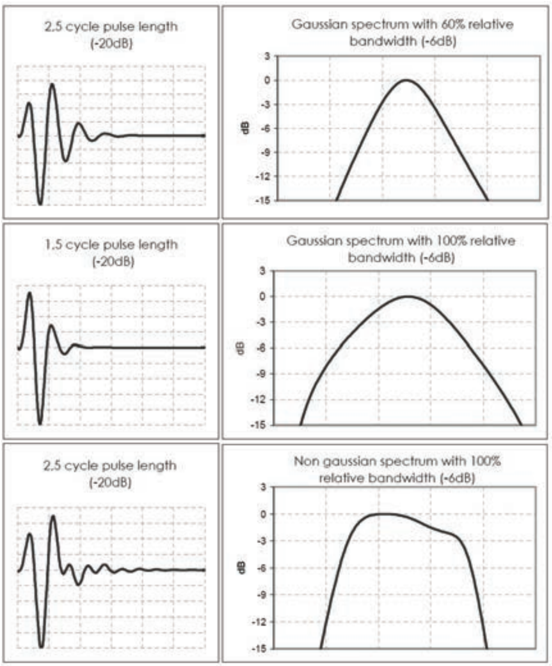
Connector

The connector is most often defined by the electronic system the transducer will be connected to. However, it must be adapted to handling and environmental constraints (frequency of handling, immersion, vibrations, etc), while guaranteeing consistent quality for the electrical contacts.



Technical Information
Bandwidth or pulse width?

The bandwidth of the probe is generally one of the main specifications.
However, it is often specified instead of the pulse width.



When the bandwidth has a Gaussian shape, it is closely linked to the pulse width and specifying the bandwidth is enough to get the pulse width. However, when the shape of the bandwidth is not Gaussian, a rather long pulse can be obtained, as well as a bandwidth of more than 100%.

Some applications really require bandwidth, for example, when the received signal is significantly shifted to the low frequencies due to the attenuation of the material, or for harmonic imaging.
Most applications actually require axial resolution using a short pulse width and in this case it is more appropriate to specify the pulse width than the bandwidth.

In addition, the pulse width and bandwidth largely depend on the driving signal, the electrical impedance and the environment of the pulsers.

IMASONIC probes are optimized for and measured with a negative square pulse with a length of T/2.

See also new acoustic solutions for phased array probes page 22.

Coupling method

Immersion

The transducer and the inspected piece are immersed in a vessel, and the coupling of the ultrasonic beam is done by the liquid, usually water.
This method provides the highest level of acoustic performance due to the constancy of the coupling and to the low ultrasonic attenuation in water, with proper management of unwanted bubbles.
It allows working with complex geometry parts, and many types of transducers, including curved ones, with no other dimensional constraints than those related to the vessel itself.
This method is cumbersome to implement and maintain in case of large components. It also implies the compatibility of inspected parts and the possible mechanical scanners with the immersion. It is not compatible with manual use.
The immersion is sometimes confined in a local water box positioned at the control location, thus reducing the size of the equipment. The immersion can also be implemented with water jets (squirters) in which the ultrasonic beams are guided. They require delicate tuning and are reserved for probes of relatively small dimensions. In both cases, a waste water management is necessary.

Contact with wedge

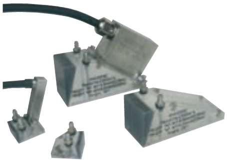
A mechanical part, generally in rigid plastics material, enables the ultrasonic coupling between the probe and the inspected object. A fluid couplant is required at the probe-wedge and wedge-component interfaces.
This method does not require equipment such as a water tank, it is quick and inexpensive to implement, and is compatible with manual and automated inspections.
However wedges reduce acoustic performances compared to immersion

- Attenuation is higher than in water, and the signal loss becomes sensitive beyond 5MHz and very critical beyond 15 MHz
- The wedge-probe and wedge-component interfaces create disturbances that degrade the signal if the thicknesses of couplant are not perfectly homogeneous or if the surface of the component is not regular.

The wedges are easy to implement for planar probes and flat or cylindrical components interfaces. They are difficult to implement with curved probes or with inspected components having complex or variable geometry.

Integrated wedges

An integrated wedge allows a transducer to be more compact and often better adapted to industrial conditions. The coupling between the active part and the wedge is guaranteed by being glued during manufacturing. Thus it is constant and homogeneous, requires no maintenance and guarantees a high level of performance.



Removable wedges

Removable wedges have great flexibility and enable the same transducer to be used in several different configurations. They can also be replaced easily if they show wear or are damaged.

Contact with conformable wedges - *NEW* - *patent pending*

A flexible and robust membrane filled with water is fitted between the probe and the piece to be inspected, to ensure the transmission of ultrasound by combining the advantages of the immersion and contact with a wedge.

Exemple of transducer with conformable wedge

- The coupling is possible on parts with variable or complex geometry
- The acoustic performance is similar to immersion, thanks to transmission through water and acoustically invisible membrane.
- Manual and automated use are possible, in similar conditions to those of conventional wedges.
- A wide range of probes can be used, including linear and matrix arrays. Their active part can be formed.

See transducers with conformable wedges page 39.

Direct contact on inspected part

In some cases, contact transducers can be used without a wedge, for example, if there is not enough space available, or to avoid interference echoes from the wedge.

In this configuration, the unseen area below the surface is larger because of the ringing of the excitation signal. Furthermore, deflection without grating lobes at high angles will require smaller spacing, and consequently a larger number of elements.

Finally, in this case, shear waves with mode conversion between the wedge and the part to be inspected cannot be generated.

Hard face

Wear and tear on the front face may have unexpected effects on probes, such as water penetration or modification of electroacoustical properties.

Conversely, placing a protective layer may alter the pulse width and sensitivity due to the additional interface.For this reason, IMASONIC has implemented a new hard face material that combines appropriate acoustical impedance for high energy transfer and ten times higher resistance to wear than a conventional front face. See Wedges page 44.

Immersion single elements

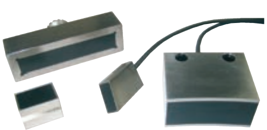
Applications

Automated inspection of various parts and materials:
- Tubes, bars, plates inline inspection
- Pipeline
- Machined and forged parts
- Metals, composite materials, ceramics, plastics, etc.

General Characteristics*

- Piezocomposite
- Acoustically matched to water
- Centre frequency (-6dB): from 200 kHz to 20 MHz
- Active area from 1mm to 300mm
- Relative bandwidth (-6dB): 60 to 90 %
- Circular or rectangular active area
- Flat or focused active area
- Watertight stainless-steel housing
- Connector or integral cable

Options*



- Spherical, cylindrical, or aspherical (see page 15) focusing
- Temperature up to 150°C in continuous or 180°C over short periods
- Pressure up to 600 bars
- Compatibility with chemical agents, oil, sea water
- Halogen-free
- Nuclear radiation withstanding

* Some combinations of active size, frequencies, focusing and options may not be feasible.

Design notes for immersion transducers

Online design

On this page of our website, you can do an on-line simulation of the main characteristics of the ultrasonic beam for circular immersion probes, according to the frequency, the active diameter and the focus.

www.imasonic.com
Search for Online Design

Useful formulas

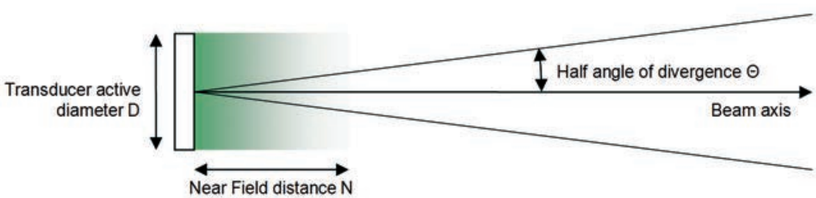
Valid for flat circular transducers

Near field distance $$N = \frac{D^2}{4\lambda}$$

Half angle of divergence $$\sin\theta = K\frac{\lambda}{D}$$

D = active diameter
λ = wavelength
K = 0.51 for -6dB drop
K = 0.87 for -20dB drop

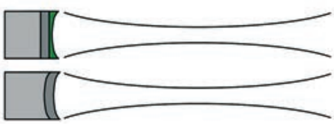
Beam diameter at near field distance for flat transducer $$W(-6dB) = 0,26 \, . \, D$$



Technical Information
Piezocomposite advantages for immersion transducers

Very high sensitivity

The acoustic impedance of IMASONIC piezocomposite materials can be adjusted from approximately 10 to 15 MRay. This impedance, much lower than that of ceramics, is closer to that of water. This results in a better energy transfer which, combined with high electro-acoustic efficiency, gives a sensitivity that is 10 to 32dB higher than that obtained with monolithic piezoelectric ceramics.



Focusing by shaping

Thanks to IMASONIC technology, the shaping of the active area enables the beam to be focused without resorting to using a lens that absorbs some of the energy and only gives an approximate focus because of the phenomena of aberration.

IM transducers

- IMASONIC Piezocomposite technology
- Spherical focus on request
- Straight connector or integral cable
- Connectors: UHF, BNC, Lemo, Microdot

Active diameter (mm)	Centre frequencies available (MHz)								Housing diameter (mm)	Housing length (mm)	Knurled ring diameter (mm)
	0.5	1	2.25	3.5	5	7.5	10	15			
3					■	■	■	■	16	25 - 38.9	19.3
6			■	■	■	■	■	■	16	25 - 38.9	19.3
10			■	■	■	■	■		16	25 - 38.9	19.3
13		■	■	■	■	■			16	25 - 38.9	19.3
19	■	■	■	■	■				25.4	32 - 38.9	27
25	■	■	■	■	■				35	38.9	36.5
29	■	■	■	■					35	38.9	36.5
38	■	■	■						44.5	38.9	46

■ *Standard configurations*

Enhanced focusing - FERMAT concept

Applications

Inspection of critical components and detection of tiny defects.

- Multizone billets inspection
- Thick plates inspection
- Heavy forged parts inspection
- Nuclear vessel inspection

Principle

The aspherically-focused active area is calculated to obtain the best focusing effect at a given location in the material with a given refracted angle, through a flat, cylindrical or toric interface.
Moreover, a large transducer aperture combined with Fermat concept allows very high lateral resolution and signal-to-noise ratio.

It is typical used in immersion with pulse echo technique, but can also be used in contact with a delay line.

Advantages

- Very high resolution and signal-to-noise ratio
- Beam profile very close to simulation thanks to IMASONIC piezocomposite technology
- Fermat concept may be implemented on phased array probes, allowing flexible high-resolution beam focusing and beam scanning

Main Characteristics

- IMASONIC piezocomposite FERMAT technology
- Centre frequency (-6dB): from 1 MHz to 15 MHz
- Relative bandwidth (-6dB): 60 to 90 %
- Acoustic impedance matched to water or delay line
- Watertight stainless steel housing

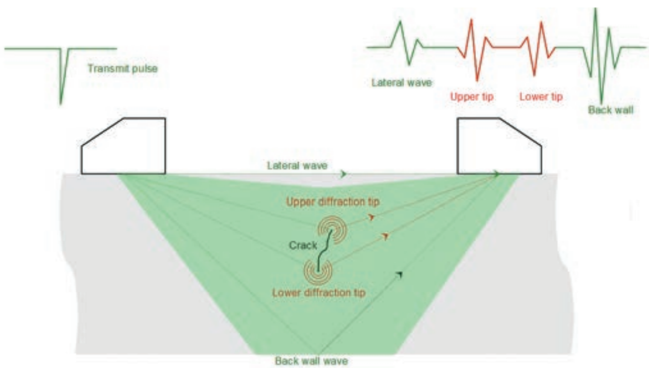
Options

- Custom wiring (cable length, type or positioning, Connector type)
- Housing adaptation to mechanical set-up (probe holder, wedge, etc)
- Adaptation to environnemental contraints (Temperature, pressure, radiation, vibration, etc)

TOFD Transducers

Typical Applications
- Weld inspection, steel components
- Detection and sizing of cracks

Principle
Using the TOFD (Time Of Flight Diffraction) technique, cracks are detected, sized and monitored, irrespective of their type and/or orientation, by using the diffracted sound initiating from the flaw tips.
Two transducers are used to transmit and receive.
The beam divergence is enough to cover the whole thickness of the inspected part, which is displayed between the lateral wave (surface) and the back-wall echo.



Advantages
- Possibility of detecting and sizing the defects
- Reduced dead zone
- Fast technique

General Characteristics
- IMASONIC piezocomposite technology
- Nominal frequency from 1 to 20 MHz
- High resolution/sizing capability because of a short pulse width
- Very high sensitivity/detection capability
- High reliability over time thanks to a design that is watertight and resistant to corrosion, compatible with permanent immersion under a metre of water

Standard TOFD series

- IMASONIC piezocomposite technology
- High sensitivity
- Short pulse width
- Designed for field conditions
- Standard housing

Transducer types			Recommended configurations according to NF EN ISO 16828 standard			
			Thickness <70 mm		Thickness 70-300 mm	
IMASONIC Ref.	Nominal frequency (MHz)	Active diameter (mm)	Depth (mm)	Angle (°)	Depth (mm)	Angle (°)
T0206	2	6	30<70	45-60	-	-
T0212	2	12	30<70	45-60	100<300	45-60
T0306	3.5	6	30<70	45-60	30<100	45-60
T0503	5	3	10<30	50-60	<10	50-70
T0606	5	6	10<30 30<70	50-60 45-60	<10 10<30	50-70 45-60
T0512	5	12	30<70	45-60	30<100	45-60
T0706	7.5	6	10<30	50-60	<10	50-70
T1003	10	3	<10 10<30	50-70 50-60	<10	50-70
T1006	10	6				
T1503	15	3	<10	50-70	-	-

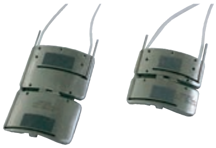
Active Ø	Housing type	Housing diameter and length (mm)	Thread type (mm)	Connector
3-6 mm	Standard	Ø 9.5 x L 30	M12 X 1.75	Lemo 00
3-6 mm	Short	Ø 9.5 x L 20	M12 X 1.75	MCX
12 mm	Standard	Ø 17 x L 29	M20 X 1.5	Lemo 00

Options

- Standard TOFD wedges (45°, 60°, 70°)
- Integrated cable
- High-pressure resistance for offshore application
- Compatibility with oil and chemical agents
- Compatibility with high temperature

Extra-flat TOFD for CRD* inspection

** control rod drive*

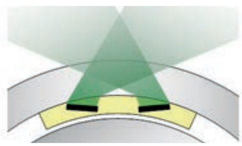


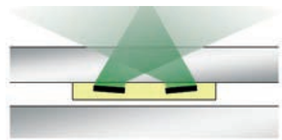
Application

Reactor vessel cover penetration tubes inspection..

Principle

The very low thickness of the probes, combined with their curvature, allows them to be inserted between the control bars and the guide tubes. The transducers can thus inspect the guide tube and peripheral welds (Jweld) in TOFD mode.





The orientation of the transducers enables longitudinal or circumferential defects to be detected.

Advantages

Inspection feasibility, sensitivity, bandwidth.

General Characteristics

These transducers are adapted individually to the inspection constraints, and in particular to the handling, plating and coupling mode.

- Thickness < 2.5 mm (down to 1.5 mm)
- Nominal frequency: 4 to 5 MHz
- Adjustable PCS (Probe Center Spacing)
- Refracted angle range: 45 to 70° LW
- Radius of curvature: 70 mm (typical)
- Longitudinal or circumferential orientation
- Integrated cable

Options

- Water distribution device for the coupling
- Halogen-free
- Mechanical plating solution
- Mechanical guidance solution
- Transducer at 0° for thickness measurement

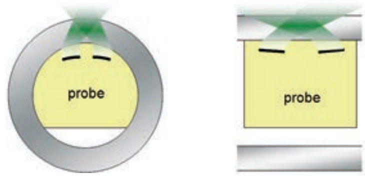
TOFD transducers for tube inspection

Application

Internal inspection of tubes.

Principle

The cylindrical geometry of probes and their small possible diameter enable them to be inserted into tubes for inspection from the inside in TOFD mode. The orientation of the transducers enables longitudinal or circumferential defects to be detected.



Advantages

Inspection feasibility, sensitivity, bandwidth.

General Characteristics

These transducers are adapted individually to the inspection constraints, and in particular to the handling, plating and coupling mode.

- Diameter: down to 12 mm
- Nominal frequency: 4 to 10 MHz
- Refracted angle range: 45 to 70° LW
- Longitudinal or circumferential orientation
- Integrated cable

Options

- see Options for Extra flat TOFD probes (page 18)

Custom TOFD transducers

TOFD probes can be customized on request to meet the requirements of your application. Some examples are:

- Integrated miniature probes for small spaces / short PCS (probe center spacing)
- Custom housing

Note: The TOFD technique is also compatible with phased array probes.
See phased array probes, page 20.

Phased Array summary

Since 1989, IMASONIC has offered the widest range of phased array probes for industrial applications.

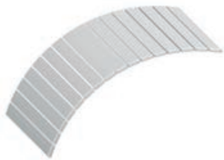
- The standard phased array probes benefit from standardized design that combines reliability, accuracy, performance and competitiveness.
- Customized phased array probes offer numerous possibilities for adaptation to the most demanding applications.

Phased Array transducers

Array types

Phased array transducers consist of several elements that can be activated independently (See Phased Array Principle, page 48). We have grouped them below according to the main types.

*1D Linear array**



*Curved linear array**
(Concave or convex)

*Focused linear array**

*1,5D array**

*2D matrix array**

*Annular sectorial array**

*Annular array**

*Daisy array**

*Circular array (convex)**
Encircling array (concave)

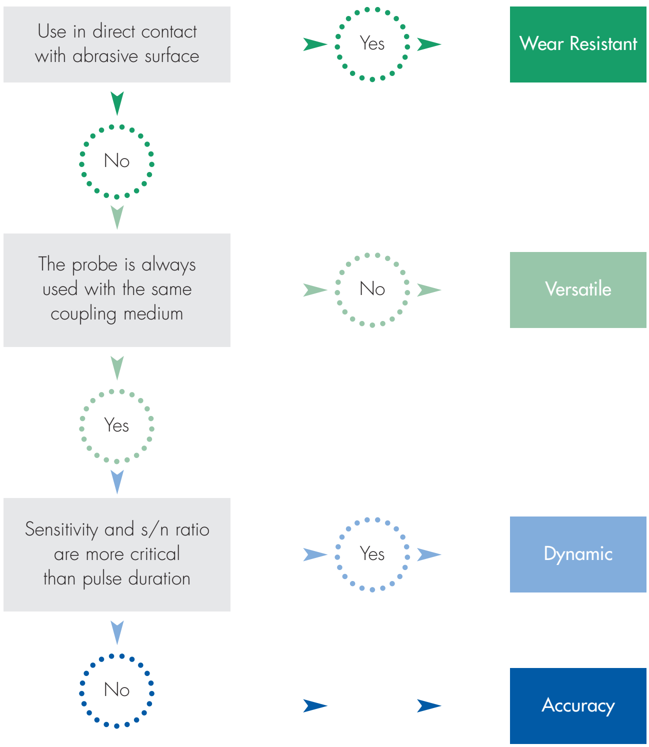
This list is not exhaustive and other types of geometry of the elements that could be associated with shaping the active area (cylindrical or spherical, or aspherical prefocusing) offer a very wide feasibility field.

* According to EN-16018

Acoustic solutions for IMASONIC phased array probes

IMASONIC now offers four types of standard acoustic designs for its linear array probes.

How to choose?



Versatile:

The acoustic design is matched to the coupling medium (water, plexiglas, rexolite, etc.). The performances are slightly affected if the probe is used with another coupling medium. The design is optimized for both high sensitivity and damping in the range of 2.5 cycles (20dB) on average. This technology has been proposed by IMASONIC for several years.

Dynamic:

The acoustic design is particularly optimized to gain about 6dB sensitivity on average compared to versatile design, while keeping the same pulse length. This optimization is valid for the nominal coupling medium. When using the probe with other coupling media, performances degrade faster than the versatile technology.

Accuracy:

The acoustic design is particularly optimized to gain 0.5 to 1 cycle in pulse length on average compared to versatile design, while keeping the same sensitivity. This optimization is valid for the nominal coupling medium. When using the probe with other coupling media, performances degrade faster than the versatile technology.

Wear resistant:

The acoustic design is optimized to keep equivalent performance level than versatile design while implementing a front face 10 times more resistant to abrasion.

	Versatile	Accuracy	Dynamic	Wear resistant
Acoustic matching to the coupling medium (water, plexiglas, rexolite, etc.	Yes	Yes	Yes	No
Pulse length (cycles at -20dB)	2.5	1.5	2.5	No
Sensitivity	Ref.	Ref.	+6dB	Ref.
Performance alteration when using with other coupling medium	-.	+	+	-

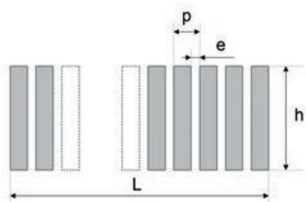
The above mentioned values are indicative and may change depending on probes characteristics, particularly frequency, element size, acoustic matching, cable length, excitation signal.

Linear Array Transducers for steering

Applications

All applications require variable angles and inspection depths:
- General NDT, welds
- Pressurized components, rotors, shafts

Standard Configurations



Freq. (MHz)	Nb elts	Pitch P (mm)	Active length L (mm)	Active width h (mm)	Housing size *(indicative value)
10	32	0.3	9.6	8	17x14x35
10	64	0.25	16	10	24x16x35
10	128	0.25	32	10	40x18x40
5	16	0.6	9.6	8	17x14x35
5	32	0.5	16	12	24x18x40
5	64	0.5	32	15	40x20x40
5	128	0.5	64	15	75x22x45
2.25	32	1	32	20	40x26x35
2.25	64	1	64	20	75x26x35
2.25	128	1	128	20	140x28x40

** dimensions valid for probes with removable wedges, without flanges*

Standard probes come with 3m cable, top or side output.
Standard connectors are Hypertronix/FRB, ITT Canon, Tyco, Conec, Ipex

Typical interface for attaching wedges is lateral flanges with holes or M3 captive screws (the position of the lugs is adjustable and the distance can be optimized to fit with all your existing wedges).

Principle

Generally, linear arrays for steering combine electronic beam steering and focusing.
To avoid grating lobes (see technical information page 48), they require a relatively small inter-element pitch. The number of elements is typically less than 128, and even 64, as electronic scanning is not often used.

Advantages

These transducers can work with angles and electronically-adaptable focusing depths, i.e. without changing or moving the transducer. This allows, in particular:

- a smaller number of probes to be used,
- faster inspection.

They also allow a refracted, non-zero incidence beam to be generated without using a wedge, which opens new possibilities for when there is no room to use a wedge.

General Characteristics

- Frequency from 500 kHz to 15 MHz
- Unlimited number of elements, typically 8 to 128
- Optimized signal/noise ratio and pulse width thanks to acoustic solutions, see page 22
- Reproducibility of the inspection through the homogeneity of performance between the elements of the same probe, and between different probes of the same type
- High reliability over time thanks to a robust, watertight design, compatible with difficult industrial environments

Options

- Hard face for use in direct contact
- Integrated wedge
- Housing customized for the mechanical environment (inspected parts, scanner, wedges, etc)
- Customized connection – page 46
- Adaptation to a particular environment (temperature, pressure, radiation, chemical compatibility)
- Halogen-free for nuclear environments
- Water inlets
- Compliance with NF EN ISO 18563-3 standard

Accessories

- Wedges – page 42
- Cable extensions and adaptors – page 44
- ***NEW*** - Compatibility with conformable wedges, see page 38

Linear Array Transducers for scanning or for long range inspection

Applications

Automated high-performance inspection of submerged parts: metal plates, bars, pipes, composite materials, forged parts, etc.

Principle & Advantages

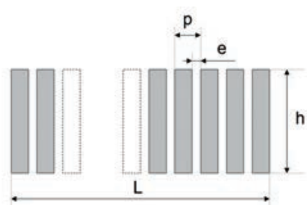
The scanned length (L) is maximised by combining a large number of elements (typically between 64 to 256) to the widest possible inter-element pitch (p).
Electronic focusing can be combined with scanning, for example, to inspect at different depths. In general, electronic deflection is little used for this type of application.

- Inspection time is reduced because of the high speed of the electronic scanning combined with a large scanning width
- The scanning mechanism is simplified

Standard Configurations

Freq. (MHz)	Nb elts	Pitch p (mm)	Active size L x h (mm)	Housing size L x W x H (mm)*
10	64	0.5	32 x 10	40 x 16 x 35
10	128	0.5	64 x 10	75 x 20 x 40
5	64	1	64 x 15	75 x 20 x 40
5	128	1	128 x 15	140 x 25 x 45
2.25	128	1.5	192 x 20	205 x 30 x 45
2.25	64	2	128 x 20	140 x 30 x 35

** indicative values*



Accessories – See page 42 to 45

- ***NEW*** - Compatibility with conformable wedges, see page 38

General Characteristics

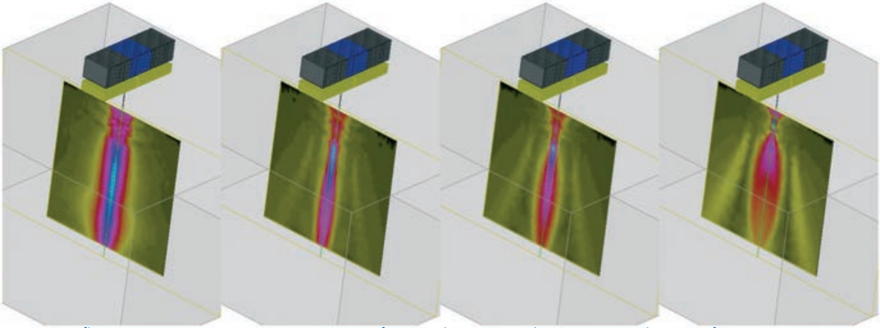
- Frequency from 300 kHz to 20 MHz
- Unlimited number of elements, typically from 64 to 512
- Optimized signal/noise ratio and pulse width thanks to new acoustic solutions, see page 22
- Reproducibility of the inspection because of the homogeneity of the elements of the same probe and the different probes of the same type
- High reliability over time thanks to a design that is watertight and stainless, compatible with permanent immersion under a metre of water

Options

- Pre-focused active area (see below)
- Housing adapted to the probe holder
- Low profile and side cable for wheel probe
- Halogen-free for nuclear environments
- Customized cabling
- Adaptation to a particular environment (temperature, pressure, radiation, chemical compatibility)
- Compliance with NF EN ISO 18563-3 standard

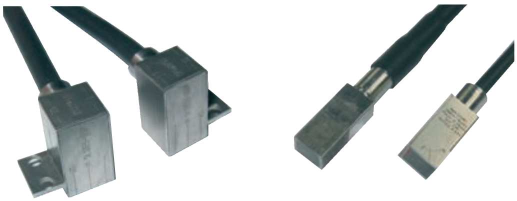
Technical Information
Mechanical Pre-focusing

On linear arrays, electronic focusing is possible only in the plane of incidence. However, in the perpendicular plane (passive aperture), it is possible to adjust focal depth and lateral resolution by using mechanical pre-focusing, by choosing the appropriate radius of curvature, active width (h) and water path.



flat array — pre-focused array with various radiuses of curvature

Small Footprint Linear Arrays



small footprint arrays for removable wedges and with integrated wedges

Applications

These transducers are designed for applications with reduced transducer access, or with surfaces with complex geometry where good coupling is not possible:
- Inspection of turbines, blade roots and fine welds.

General Characteristics

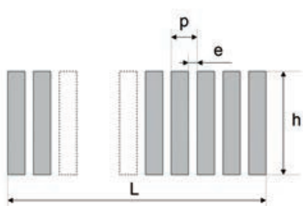
- Footprint ≤ 8 x 8 mm^2
- Center frequency 5 to 15 MHz
- Number of elements: 8 to 20
- Other characteristics similar to standard linear probes

Options

- Hard face for use in direct contact
- Integrated wedge
- Other options similar to standard linear probes

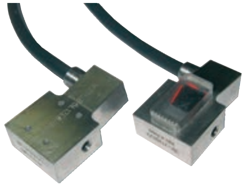
Standard Configurations

Freq. (MHz)	Nb elts	Pitch P (mm)	Active length L (mm)	Active width h (mm)	Footprint* (mm)
10	10	0.31	3	3	5x6
10	16	0.25	4	4	6.5x6
10	16	0.31	5	5	7x7
10	20	0.31	6	6	8x8
5	8	0.5	4	4	6.5x6
5	8	0.6	5	5	7x7
5	12	0.5	6	6	8x8

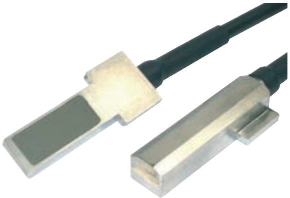


** without flanges or wedge attachment interface*

Low Profile Linear Arrays



5MHz 12ch array
with integral wedge



5MHz 64ch array
10mm height

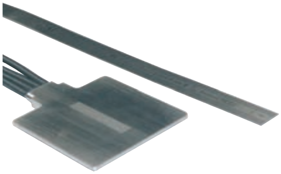
10MHz 26ch
3.5mm flat array

5MHz 32ch curved array
2.5mm thick

Applications

These transducers are designed for inspecting components with a very limited vertical clearance:

- Boiler tubes
- Feeder tubes
- Blade roots of turbines (see picture below)



5MHz 64ch array
5mm height

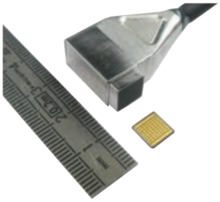
General Characteristics

- Housing height ≤ 10 mm
- Center frequency: 5 to 15 MHz
- Number of elements: up to 64
- Other characteristics similar to standard linear probes

Options

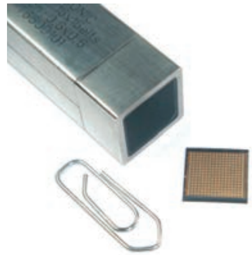
- Hard face for use in direct contact
- Integrated wedge
- Other options similar to standard linear probes

Matrix Arrays

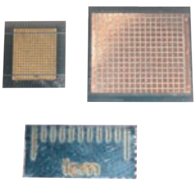


*Miniature 5MHz 8x8elts
0.6x0.8mm pitch matrix array*

*2MHz 11x11elts
1.4x1.4mm pitch matrix array*



*Miniature 5MHz 16x16elts
0.6x0.6mm pitch matrix array*



*10MHz 16x16elts 0.3x0.3mm pitch
and 5MHz 16x16elts
0.6x0.6mm pitch active areas*

Applications

- Weld inspection
- Inspection of parts with complex geometry
- General NDT

Principle & Advantages

Matrix array transducers allow 3D beam focusing and scanning, thus opening up new possibilities:

- Control of the focal zone diameter in 3D, cylindrical beam
- Inspection of volumes from limited points of access
- Detection of defects that may have multiple, un-predetermined orientations

Typical configurations for steering

The matrix array transducer configurations in table below are designed for use when steering capabilities are required.
The pitch is minimized to offer good elementary directivity and steering capability. Consequently, for a given number of elements, the active area is reduced and the beam diameter is larger.

Freq. (MHz)	Elementary active size (mm)	Total active size (mm)	Number of elements
2	1,2 x 1,2	10 x 10	8 x 8 = 64
5	0,6 x 0,6	5 x 5	or 11 x 11 = 121
10	0,3 x 0,3	2,5 x 2,5	or 16 x 16 = 256

Typical configurations for depth / resolution

The matrix array transducer configurations in table below are designed for use when depth and resolution capabilities are required.
The pitch is larger compared to steering configurations. The steering capability is reduced, but for a given number of elements, the active area is larger and the beam diameter (lateral resolution) is thinner.

2D arrays

Freq. (MHz)	Elementary active size (mm)	Total active size (mm)	Number of elements
2	2 x 2	22 x 22	8 x 8 = 64
5	1 x 1	11 x 11	or 11 x 11 = 121
10	0,6 x 0,6	10 x 10	or 16 x 16 = 256

Annular sectorial arrays

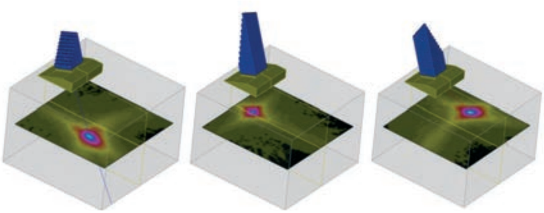
Freq. (MHz)	Active diameter (mm)	Average pitch (mm)	Number of elements
5	10	1.2	64
5	16	1.4	128
2.25	23	2	128

General Characteristics

- Frequency from 500 kHz to 15 MHz
- Unlimited number of elements, typically 16 to 1024
- High S/N ratio and optimized pulse width thanks to acoustic matching to wedge material (Rexolite, Plexiglas, PEI, etc)
- Reproducibility of the inspection through the homogeneity of performance between the elements of the same probe and between different probes of the same type
- High reliability over time thanks to a robust, watertight design, compatible with difficult industrial environments

Options

- Hard face for use in direct contact
- Integrated wedge
- Housing customized for the mechanical environment (inspected parts, scanner, wedges, etc)
- Customized cabling
- Adaptation to a particular environment (temperature, pressure, radiation, chemical compatibility)
- Halogen-free for nuclear environments
- Water inlets



Accessories

- Wedges – page 42
- Cable extensions and adaptors – page 44
- ***NEW*** - compatibility with conformable wedges - see page 38

Simulation of 3D beam steering capability with matrix array

Typical configurations for high resolution annular sectorial arrays

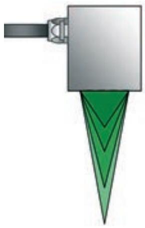
Inspection of thick parts, forged parts, complex interface parts and difficult materials (coarse grain, non homogeneous).

The shaping of the active surface in a 2D array allows 3D beam steering and 3D correction of the focus, which can compensate, for example, for the defocusing effect of a complex interface or an anisotropic material. Furthermore, matrix immersion transducers, like annular arrays, allow electronic focusing at different depths.
As an option, Fermat surface pre-focusing (See Fermat concept page 15).

Freq. (MHz)	Nb elts	Active diameter (mm)	Housing size diameter x height (mm)*
10	128	40	50 x 60
7.5	128	50	60 x 60
5	128	60	70 x 60
2.25	128	80	90 x 60

** indicative value*

Annular Array Transducers



Applications
- Thick parts
- Forged parts

Principle & Advantages
Using electronic focusing, the focusing distance and the depth of field can be changed, thus enabling thick parts to be inspected with excellent lateral resolution over a large depth range, without changing the transducer.

General Characteristics
- Frequency from 300 kHz to 20 MHz
- High sensitivity and signal-to-noise ratio, thanks to the acoustic matching to water allowing a very good transfer of acoustic energy
- Good axial resolution, and reduction of the unseen area below the surface thanks to a short pulse width (See note page 9)
- High reliability over time thanks to a design that is watertight and stainless, compatible with permanent immersion under a metre of water

Standard Configurations

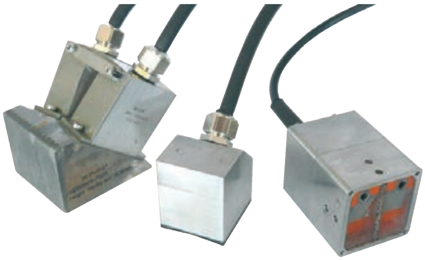
Freq. (MHz)	Nb elts	Active diameter (mm)	Housing size diameter x height (mm)*
10	8	18	25 x 40
10	16	25	35 x 40
10	32	35	45 x 45
5	8	35	45 x 40
5	16	50	60 x 40
5	32	70	80 x 50
2.25	16	80	90 x 50
2.25	32	110	120 x 50

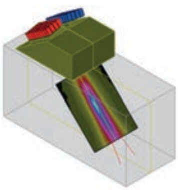
** indicative value*

Options
- Spherical or bifocal mechanical pre-focusing
- Housing adapted to the probe holder
- Halogen-free for nuclear environments
- Customized cabling
- Adaptation to a particular environment (temperature, pressure, radiation, chemical compatibility)

Accessories – See page 42 to 45

TRL Arrays (Separate Transmit Receive)

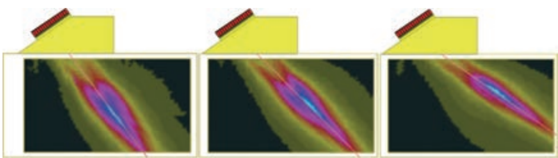




Typical Applications

- Wrought / cast stainless steel components, austenitic structures
- Dissimilar metal welds
- Clad components
- Safe end / sub clad of nuclear vessel
- Pressurised welds

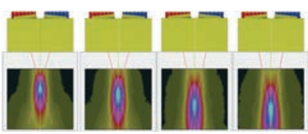
Principle



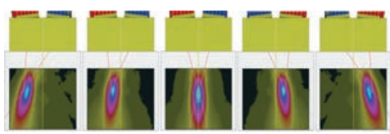
Transducers with separate emission and reception, one linear or matrix array on each side.

Linear transducers allow a variable refraction angle.

Matrix transducers also allow the beam crossing depth to be varied or the beam to be deflected laterally.



Variable focusing depth



Variable skew angle

Standard configuration

Please contact us for the standard configurations corresponding to your application.

Advantages

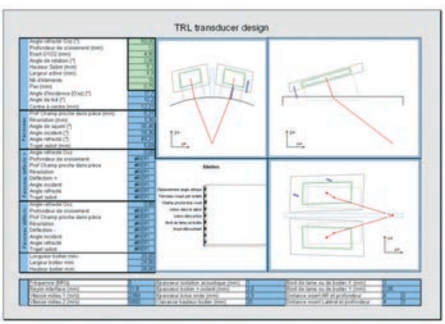
- Possibility of steering and skewing (matrix only) the beam
- Absence of dead zone
- Focusing effect in the beam crossing region
- Improvement of defect response
- Reduction of the backscatter signal
- Improvement of signal to noise ratio

General Characteristics

- Frequency from 500 kHz to 5 MHz
- Unlimited number of elements, typically 2x16 to 2x64
- High S/N ratio and optimized pulse width thanks to acoustic matching to wedge material (Rexolite, Plexiglas, PEI, etc)
- High acoustic insulation between transmit and receive sides
- High reliability over time thanks to a robust, watertight design, compatible with difficult industrial environments

Options

- Integrated wedge
- Housing customized for the mechanical environment (inspected parts, scanner, wedges, etc)
- Customized connection
- Adaptation to a particular environment (temperature, pressure, radiation, chemical compatibility)
- Halogen-free for nuclear environments
- Water inlets



Accessories

- TRL Wedges – page 42
- Cable extensions and adaptors – page 44

TRL Probe Design

IMASONIC can help you to design your TRL probe, and particularly the incidence angle, roof angle and distance between transmit and receive transducers to reach the targeted focal zone with the desired refracted angle.
We can also simulate in detail the beam crossing area to evaluate the detection and sizing capabilities of the probes.

With the customer's agreement, IMASONIC can collaborate with partner companies with experience in inspection methods based on TRL probes, to offer already-qualified solutions for various inspections.

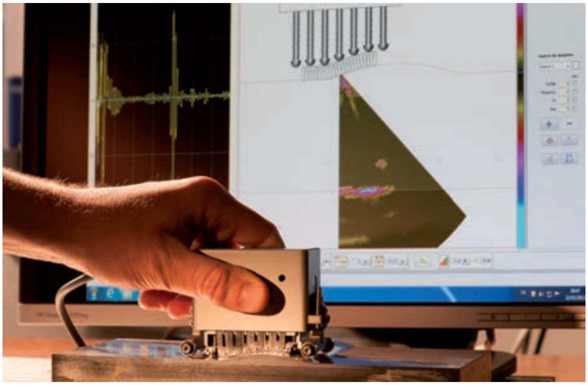
Conformable Array Transducers

Applications

Contact inspection of parts with irregular geometry
- Welds, bends, pipe repairs in nuclear power stations
- Turbine blades, composite materials
- nozzles

Principle

1D or 2D phased array transducers are flexible, and can thus ensure good coupling on the geometry of the inspected part.
The sensor integrates real-time measurement of each element's position, and thus of the surface, so when it is used with compatible electronics, the delay laws can be adapted in real time to steer the beam by compensating for the variations of the interface.



Example of real time adaptation of delay laws of a 1D conformable transducer when passing over a welding seam (courtesy CEA-List France)

Advantages

- Feasibility of certain inspections
- Improvement in focusing quality by being freed from the interface geometry
- Increase in lateral resolution through the use of larger active dimensions

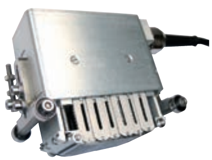
Patented Concept

The concept implemented in these transducers, of updating the delay laws in real time according to the real position of individual elements, is covered by a patent registered with the CEA (Atomic Energy Commission, France).
IMASONIC holds the exclusive licence for the use of this patent in designing and manufacturing these transducers.

Smart Conformable Linear Arrays (1D)

The individual elements are mecanically articulated, allowing convex and concave active profile in the scanning direction.

Existing configurations



Freq. (MHz)	Number of elements	Pitch (mm)	Total aperture (mm)
1.5	24	1.7 x 22	41 x 22
1.5	48	1.5 x 20	72 x 20
2	24	1.4 x 17	34 x 17
2	32	1.4 x 17	45 x 17
4	24	0.9 x 9	22 x 9

Options

Inclinometer allowing to calculate the delay laws in real time taking into account the probe inclination.

Smart Conformable Matrix Arrays (2D)

The active elements are embedded in a flexible membrane which allows concave or convex deformation in two dimensions, to adapt complex and variable profiles.

Existing configurations

Freq. (MHz)	Number of elements			Elementary Pitch (mm)		Elementary size (mm)		Total active aperture (mm)	Radius of curvature (mm)	Steering range (°)		Thickness (mm)
	Tot.	1st Axis	2nd Axis	1st Axis	2nd Axis	1st Axis	2nd Axis			LW	SW	
2	84	12	7	2.8	4	1.8	2.5	34 x 28	Spherical R 50	0-30		20-100
2	64	8	8	3.5	4	2.5	2.5	32 x 28	Spherical R 50	0-30		20-100
2.7	60	12	5	1.5	3	1.0	2.0	18 x 15	Spherical R 45	0-50	35-55	8-30
3.3	48	12	4	1.2	3.1	0.6	2.0	12.5 x 25	Spherical R 25	0	20-60	8-15

NEW: Transducers with conformable wedge

Principle

The conformability is obtained with a flexible membrane filled with water between the transducer and the inspected component. The coupling between the membrane and the component requires a small quantity of water or couplant.

Advantages

The conformable wedge combines (see coupling methods page 10)
- The acoustic performance of immersion technique with good coupling and low attenuation
- The flexibility and ease of use of contact technique
- The compliance with non-regular and/or variable surface geometry

Main features

- Compatible with most types of arrays (linear, matrix, focused, curved, etc.)
- Acoustic performance close to water thanks to acoustically invisible membrane
- Wear resistant membrane *
- Halogen free
- Bubble trap system
- Easy implementation and easy membrane replacement
- Good chemical stability

* No damage observed after a run of 0.5Km at 10cm/s over a corroded steel part with Ra of 20µm, with lubrication and load of 1Kg

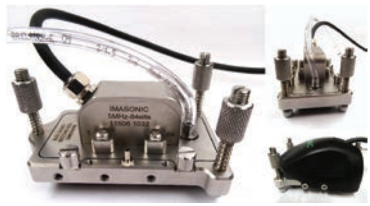
Options

- Probes with integral frame (miniaturization, easier implementation)
- Angled and L0° membranes
- Extra flexible (grey) or extra resistant (blue) membranes
- Water inlets for coupling between wedge and inspected part
- Lateral guides for manual use
- Mechanical interface for automated use with scanner
- Possible use in TRL/SE mode

Standard evaluation kit with 5MHz 64elts pitch 0.8mm phased array probe

- Standard probe mounted on a removable frame
- Water path 20mm
- Can be used manually with the handle or mounted on a scanner without the handle thanks to the 4 lateral taped holes on each side
- Trim setting with 3 adjustable feet

Standard kit (same acoustic design) with reduced size



Exemple of probes for use in TRL mode

Exemple of probes with integral conformable wedge

- Clip system for fast membrane change
- Advanced bubble trap system
- Reduced size
- 3 types of membranes (standard, extra-flexible, extra resistant)

Curved Linear Array Transducers

Applications

These transducers are an adaptation of flat linear arrays for the inspection of parts with circular symmetry. The linear scanning becomes circular to adapt to inspection of tubes, bars or sections.

Principle

360° or sector electronic beam scanning is combined with electronic focusing and beam steering.

- Scanning speed can be adapted to the water path.
- Focusing depth and inspection angle can be electronically selected depending on the tube/bar configuration.

General Characteristics

- Frequency from 1 MHz to 20 MHz
- Number of elements unlimited, typically 64 to 512
- High sensitivity and signal-to-noise ratio, thanks to the acoustic matching to water that allows a very good transfer of acoustic energy.
- Good axial resolution and reduction of the unseen area below the surface thanks to a short pulse width (See note page 9)
- Reproducibility of the inspection through the homogeneity of performance between the elements of the same probe, and between different probes of the same type
- High reliability over time thanks to a watertight and corrosion-resistant design, compatible with permanent immersion in a metre of water in difficult industrial environments

Standard Configuration

Actually there is no standard configuration. The frequency, the number of elements, the spacing and the radius of curvature are defined according to the tubes, bars or sections to be inspected, the defects to be detected and the desired inspection speed in particular.

Options

- Pre-focused active area (See page 27)
- Housing adapted to the probe holder
- Customized cabling
- Adaptation to a particular environment (temperature, pressure, radiation, chemical compatibility)

Daisy Array Transducers

Application

Internal tube and bore inspection (fig. 1)
External tube inspection (fig. 2)

Figure 1

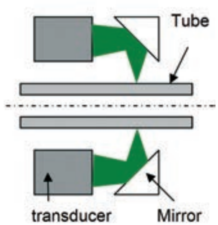


Figure 2

Principle

The ultrasonic beam is emitted by a flat circular transducer and is reflected on the part to be inspected using a mirror.
Electronic scanning allows the beam to be turned through 360°, without rotating the probe or the mirror.
The choice of the angle of the mirror enables the beam to be given a straight or oblique incidence.

Daisy element pattern

General Characteristics

- Frequency from 5 to 15 MHz
- Number of elements: 32 to 256 (according to the tube diameter)
- Minimum internal tube diameter (for internal probes): 15 mm
- High sensitivity and signal-to-noise ratio, thanks to the acoustic matching to water that allows a very good transfer of acoustic energy
- Good axial resolution, and reduction of the unseen area below the surface thanks to a short pulse width (See note page 9)
- Reproducibility of the inspection through the homogeneity of performance between the elements of the same probe, and between different probes of the same type

Options

- Centring device
- Water input device
- Mechanical interfacing with the pusher-puller
- Customized connection
- Adaptation to a particular environment (temperature, pressure, radiation, chemical compatibility)

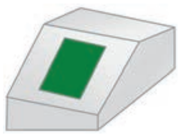
Phased Array Coupling Solutions

Wedges for Contact Transducers

IMASONIC offers a wide variety of wedges for contact probes, fully adaptable to transducers and their conditions of use.

Main Characteristics

Single classic wedge

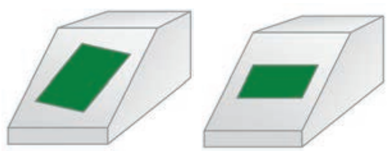


Single wedge with roof angle

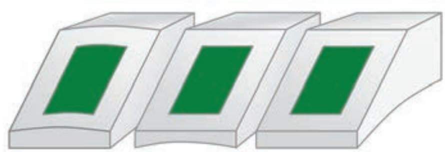
TRL wedge

Parameter	Typical indicative values, can be changed on request
Incidence angle	35-70°SW in steel / 0-70° LW in steel / 0° (Delay line)
Material	Rexolite or Plexiglas
Transducer attachment	2 to 4 threaded metal inserts
Anti-reverberation system	Yes

Options



Skew angle on request



Customized contact face geometry to fit inspected parts or wedge focusing

Option	Typical indicative values, can be changed on request
Interface with probe holder	One hole on each lateral side on the wedge
Irrigation system	Two water inlets connected to a groove on the contact face
Wear pads	4 carbide inserts on the contact face to prevent excessive wear on wedge
High temperature	High temperature material and integrated water cooling system

Wedge interface

IMASONIC offers as standard design M3 captive screws.
Thin flanges with or without holes remain available on request to fit all wedge designs.

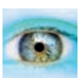
M3 captive screws

Flange with holes

Conformable wedges

Conformable wedges combine acoustic performance of immersion and ease of use of contact technique. Moreover, they comply with non-regular and variable surface geometry. See page 38.

example of conformable wedge



Technical Information
Plexiglas or Rexolite ?

These two materials are the most commonly used for ultrasonic probe wedges.
Rexolite is a very interesting material with low attenuation and low sound velocity of 2350 m/s. It is thus well adapted for reduced-size wedges, thanks to its smaller angle, and for high frequency probes (7.5 MHz and more), thanks to low attenuation combined with shorter acoustic path.
Plexiglas is more resistant to abrasion in some cases, its higher attenuation helps to attenuate internal reverberations in the wedge..

Phased Array Connection Solutions

Cable Characteristics

The standard IMASONIC cables offered on phased array transducers have been carefully selected for their mechanical and electrical properties.

- Little loss through attenuation or signal filtering
- Good flexibility
- Good mechanical resistance to handling
- Compatibility with most industrial environments

Cable type	Multi-coaxial 50 Ohms cable with overall shielding			
Number of channel	Up to 16	Up to 64	Up to 128	Up to 256
Cable diameter	4.1 mm	5.6 mm	7.8 mm	8.7 mm
Minimum static radius of curvature	25 mm	32 mm	50 mm	60 mm
Minimum dynamic radius of curvature	50 mm	64 mm	100 mm	120 mm
External jacket	Black PVC	Black PVC or halogen free PU	Black PVC	Black PVC

Specific cable for high radiation or with low attenuation on request

Cable Protection Options

IMASONIC can offer several different cable protection options adapted to particular environments on request.

Connector Protection Options

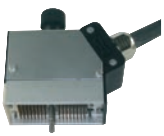
An optional protective jacket can be placed on the connector.

Connector Types

IMASONIC phased array transducers are compatible with most systems on the market. The different standard connectors are available. Among them are the following: Hypertronix/FRB, Tyco, ITT Canon, Ipex, Conec, ODU (non-exhaustive list).
See on the left.

Ipex

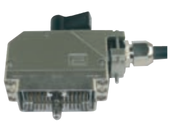
Hypertronix/FRB



ZPAC

Tyco TCZ

ITT Canon DLM96



Conec 78

Cable extensions & Adaptors

In addition to phased array transducers, IMASONIC offers extension cables and adaptors, for connecting several probes to a system, or a probe and a system with different connectors.

The cable lengths and the number of channels are specified individually.
The cable protection options are also available for extensions and adaptors (within the limit of technically possible lengths).

IMASONIC extensions and adaptors have all been tested electrically, to check that the cabling is in perfect order and that there are no short circuits.

Examples of cable extensions and adaptors

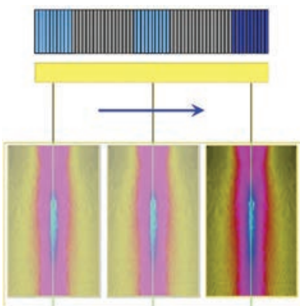
Phased Array Principle

The principle of phased array technology is to activate for each shot all or some of the transducer elements which, with the adapted delay laws, contribute collectively to the generation of the beam.

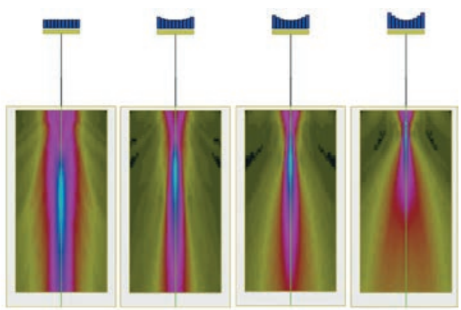
Electronic Commutation (Multiplexor)

The beam is electronically translated by alternatively firing a given number of elements of a linear or circular phased array transducer.

This technique is an alternative to the mechanical translation of a single element probe.
The advantages are:
- Faster inspection
- No mechanical movement required, or reduction of scanline number
- Possibility of combining with electronic focusing and beam steering (See below and next page)



Electronic scanning



Electronic focusing

Delay Laws

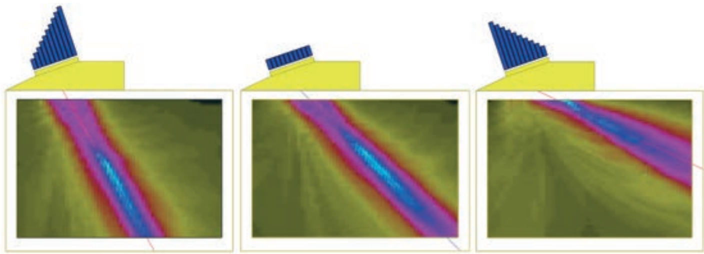
Electronic Focusing

The beam is electronically focused by applying symmetrical delay laws to the different elements of a linear or annular phased array transducer.

This technique is an alternative to using several transducers to focus at different depths.
The advantages are:
- Only one probe for focusing at each depth
- Dynamic focusing speeds up the inspection of thick pieces
- Electronic focusing can compensate for focusing aberrations due to refraction at interfaces

Electronic Steering

The beam is electronically deflected by applying delay laws to different elements of a linear, circular or matrix array. Linear and circular arrays allow for 2D beam steering, while matrix arrays allow for 3D beam steering.

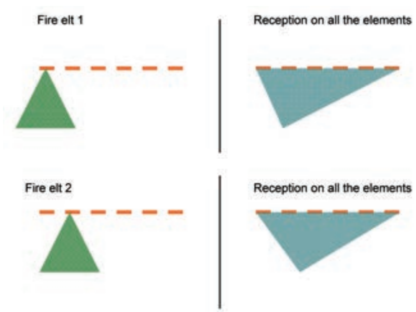


Electronic beam steering

This technique is an alternative to using several transducers at different angles.
The advantages are:
- Only one transducer is required for inspection at variable angles
- Faster inspection of parts with complex geometry
- This technique can be combined with electronic focusing

Full Matrix Capture and Total Focusing Method

FMC (Full Matrix capture) is a specific data acquisition process; each element of an array is successively used as the transmitter, while all other elements are used as receivers.
The efficiency of this acquisition is linked to the directivity diagram of each element: the smaller the element, and the wider the directivity.
When the entire element has been fired, the data acquisition is complete and TFM can be used for data processing.



TFM (Total Focusing method) is a method where the array is focused in emission and reception at every point of the image. This gives very good resolution and high image quality, but does not provide any information on the nature of the defect.

Design Notes for Linear Phased Array

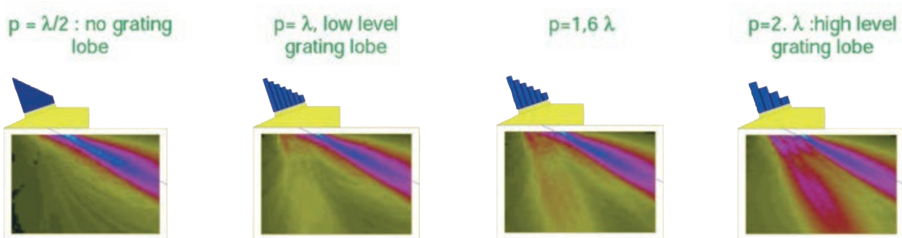
Grating Lobes

When using a phased array transducer, delay laws are applied to each channel to generate a beam with a given refraction angle and focal distance.
The ultrasonic beam is generated by the constructive interference of each transducer element's contribution in the desired direction.
In some cases, this interference can also be constructive in other directions.
These lobes of energy emitted outside the electronically driven direction are called grating lobes.
These energy lobes can interact with the part to be inspected in the same way as the main beam, and thus generate echoes causing interference to the inspection. Therefore they have to be avoided as much as possible.
The angle of the position of grating lobes in relation to the main beam is given by the following formula:

$$\sin \Theta_k = k \cdot \lambda / p \cdot \sin \Theta$$

Θ = refracted angle of the main beam
Θk = refracted angle of the rank k grating lobe (k: integer)
p = pitch of the linear transducer
λ= wavelength in the medium under consideration

Note: this formula is only valid in the case of electronic deflection (linear delay law). In the case of electronic focusing, the angular deviation between the main beam and the grating lobes is reduced.



Example for 70° SW in steel

From the above formula, the following general rule can be obtained:

- If $p < \lambda/2$, then no grating lobe is generated whatever the angle of the main beam
- If $p > \lambda$, then there is always at least one grating lobe generated whatever the angle of the main beam
- Between these two values, the grating lobes appear progressively according to the angle of the main beam. The maximum pitch to avoid grating lobe is given by the formula:

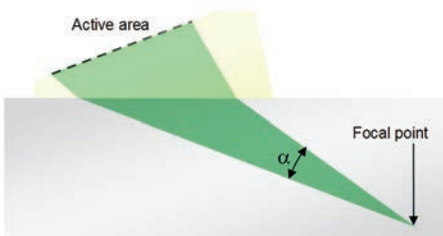
$$p < \lambda / (1 + \sin \Theta)$$

In practice, for typical use in the 30-70° SW or LW range with a wedge for a 45° angle, a pitch of 1.0 λ gives good results.

Lateral Resolution along the Plane of Incidence

The following formula allows a good approximation to be made of the lateral resolution, and a quick check of the link between the active aperture and the lateral resolution.

$$W = 0{,}44 \, . \, \lambda / \sin(\alpha / 2)$$



W = focal spot or beam width (at –6dB in emission reception)
λ = wave length in the medium under consideration
α = angle beneath which the active area is seen from the focal point

Note: This formula is a rough estimate valid when the hypothesis of electronic focusing at the focal point under consideration is made. It does not take into account the energy refraction/reflection law depending on the angle.

Number of Elements

Knowing the inter-element spacing required to avoid grating lobes and the width of the active aperture, the number of elements necessary can be rapidly deduced.

If the appropriate number of electronic channels is not available for technical or economic reasons, the best possible compromise must be found, by readjusting the inter-element spacing, the frequency, and/or the active aperture (and thus the lateral resolution).

Note: Some linear array transducers are also used for electronic scanning. In this case, the beam is generated by only some of the elements. To calculate the lateral resolution, only the size of the active area is taken into account.

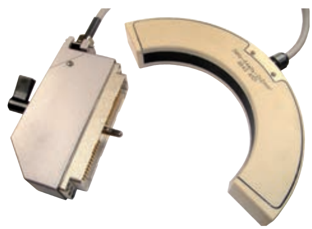
AND MORE ...

These two pages illustrate other IMASONIC capabilities through examples of transducers dedicated to medical applications. These features can be adapted to NDT transducers for new or challenging applications.

Transducers for medical diagnosis

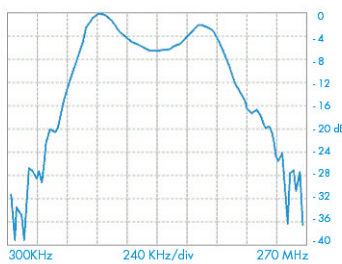
High frequency transducers for high resolution imaging
(eye and skin imaging, frequency up to 20 MHz)
very high sensitivity - direct focusing

Photoacoustic imaging
The technology developed by IMASONIC has important advantages for applications such as photoacoustic imaging, where the level of sensitivity in reception combined with a wide bandwidth is very important



Dual frequency transducers
These transducers are designed with two frequency peaks, as illustrated on the spectrum on the right, with 1MHz and 2MHz peaks.

This kind of feature can be used for application based on harmonic imaging or non linear acoustics. It can also comply with requirements of high attenuation materials that generate important filtering effects toward the low frequencies.



High power focused transducer for prostate cancer treatement

High power transducers for therapeutic applications

IMASONIC is the world leader for high power transducers dedicated to medical therapy through **HIFU technology** (High Intensity Focused Ultrasound).

HIFU is a state of the art acoustic ablation technique, using the power of ultrasound to accurately destroy deep-seated tissues without surgery, and without harming surrounding tissues.

IMASONIC high power technology combines high power capability, direct shaping of the active element, and compatibility with array patterns (see table below).

64 channel circular array for oesophagial cancer treatement – MRI compatible – Including cooling system.

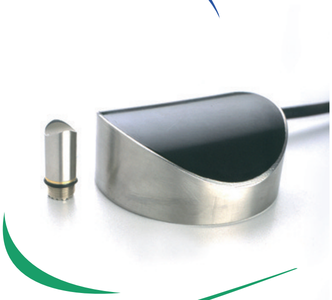
Acoustic power surface	Up to 30W/cm2
Efficiency	50 to 70%
Frequency range	200 kHz to 10 MHz
Shaping capability	F number down to 0.5 (half sphere)
Size range	Up to 300mm
diameter Array capability	Yes
Bandwidth	30 to 70%
MRI compatibility	yes, on request

300 mm diameter half sphere transducer. Matrix array with more than 1000 elts.

High power ultrasound can also be used for **Vibroacoustography**, a novel imaging for nondestructive inspection of materials. This is an ultrasound-based imaging technique that uses the dynamic (oscillatory) radiation force of low-frequency excitation (within kilohertz range) to remotely vibrate objects and detect the ensuing acoustic emission.

The generation of high power ultrasonic beams can also be used for application based on **non linear-acoustics**, like detection of closed cracks or lack of adhesion in composite stuctures.

Miniature endoscopic probe combining imaging and high power capability on a single transducer



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