# Advanced Calculator

## User's Manual

Software Version 2.10

DMTA-20039-01EN [U8778541] — Revision B

September 2022

EVIDENT CANADA, INC., 3415, Rue Pierre-Ardouin, Québec (QC) G1P 0B3
Canada



This document was prepared with particular attention to usage to ensure the accuracy of the information contained therein, and corresponds to the version of the product manufactured prior to the date appearing on the title page. There could, however, be some differences between the manual and the product if the product was modified thereafter.

The information contained in this document is subject to change without notice.

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Revision B
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# List of Abbreviations

| | |
|---|---|
| AFiSiMO | acoustic field simulation module |
| DDF | dynamic depth focusing |
| ED | electronic delay |
| EMAT | electro-magnetic acoustic transducer |
| FT | flight time |
| GD | global delay |
| HEX | hexadecimal |
| ID | inside diameter |
| LD | law delay |
| LW | longitudinal waves |
| OD | outside diameter |
| OPD | optical path difference |
| PA | phased array |
| SW | shear waves |
| UT | ultrasonic testing |
| VC | volume corrected |
| WD | wedge delay |

# Important Information — Please Read Before Use

## Intended Use

The Advanced Calculator software is designed to calculate phased array probe element delays to be used with Evident instruments for nondestructive ultrasonic inspections of industrial and commercial materials. The Advanced Calculator software also performs acoustic field and beams simulation.

## Instruction Manual

This instruction manual contains essential information on using this Evident product safely and effectively. Before using this product, thoroughly review this instruction manual, and use the product as instructed.

Keep this instruction manual in a safe, accessible location.

## Safety Symbols

The following safety symbols might appear on the instrument and in the instruction manual:

General warning symbol:

This symbol is used to alert the user to potential hazards. All safety messages that follow this symbol shall be obeyed to avoid possible harm.

High voltage warning symbol:

This symbol is used to alert the user to potential electric shock hazards greater than 1,000 volts. All safety messages that follow this symbol shall be obeyed to avoid possible harm.

## Safety Signal Words

The following safety symbols might appear in the documentation of the instrument:

**DANGER**

The DANGER signal word indicates an imminently hazardous situation. It calls attention to a procedure, practice, or the like, which, if not correctly performed or adhered to, could result in death or serious personal injury. Do not proceed beyond a DANGER signal word until the indicated conditions are fully understood and met.

**WARNING**

The WARNING signal word indicates a potentially hazardous situation. It calls attention to a procedure, practice, or the like, which, if not correctly performed or adhered to, could result in death or serious personal injury. Do not proceed beyond a WARNING signal word until the indicated conditions are fully understood and met.

**CAUTION**

The CAUTION signal word indicates a potentially hazardous situation. It calls attention to an operating procedure, practice, or the like, which, if not correctly performed or adhered to, could result in minor or moderate personal injury, material damage, particularly to the product, destruction of part or all of the product, or loss of data. Do not proceed beyond a CAUTION signal word until the indicated conditions are fully understood and met.

## Notes Signal Words

The following safety symbols could appear in the documentation of the instrument:

**IMPORTANT**

The IMPORTANT signal word calls attention to a note that provides important information, or information essential to the completion of a task.

**NOTE**

The NOTE signal word calls attention to an operating procedure, practice, or the like, which requires special attention. A note also denotes related parenthetical information that is useful, but not imperative.

**TIP**

The TIP signal word calls attention to a type of note that helps you apply the techniques and procedures described in the manual to your specific needs, or provides hints on how to effectively use the capabilities of the product.

## Warranty Information

Evident guarantees your Evident product to be free from defects in materials and workmanship for a specific period, and in accordance with conditions specified in the Terms and Conditions available at https://www.olympus-ims.com/en/terms/.

The Evident warranty only covers equipment that has been used in a proper manner, as described in this instruction manual, and that has not been subjected to excessive abuse, attempted unauthorized repair, or modification.

Inspect materials thoroughly on receipt for evidence of external or internal damage that might have occurred during shipment. Immediately notify the carrier making the delivery of any damage, because the carrier is normally liable for damage during shipment. Retain packing materials, waybills, and other shipping documentation needed in order to file a damage claim. After notifying the carrier, contact Evident for assistance with the damage claim and equipment replacement, if necessary.

This instruction manual explains the proper operation of your Evident product. The information contained herein is intended solely as a teaching aid, and shall not be used in any particular application without independent testing and/or verification by the operator or the supervisor. Such independent verification of procedures becomes increasingly important as the criticality of the application increases. For this reason, Evident makes no warranty, expressed or implied, that the techniques, examples, or procedures described herein are consistent with industry standards, nor that they meet the requirements of any particular application.

Evident reserves the right to modify any product without incurring the responsibility for modifying previously manufactured products.

## Technical Support

Evident is firmly committed to providing the highest level of customer service and product support. If you experience any difficulties when using our product, or if it fails to operate as described in the documentation, first consult the user's manual, and then, if you are still in need of assistance, contact our After-Sales Service. To locate the nearest service center, visit the Service Centers page on the Evident Scientific Web site.

# 1. Introduction

This document describes the user interface and the various features of the Advanced Calculator. You can use this tool to generate and visualize ultrasonic beams with various types of conventional (UT) probes, phased array (PA) probes, and wedges. The Advanced Calculator saves the individual element delays in a text file formats. You can import these files in TomoView for use with the supported acquisition units. You can also directly import the .law files in the OmniScan portable phased array system.

You can use the Advanced Calculator as a standalone software or launch it from TomoView.

This document also provides guidelines on how to use the Advanced Calculator to generate ultrasonic beams for various typical phased array probe configurations.

## 1.1 About the Advanced Calculator User Interface

The Advanced Calculator user interface includes a menu bar and a selection of tabs at the top of the screen (see Figure 1-1 on page 13). The menu bar is simple. It provides file related and help related commands. The first five tabs regroup parameters related to a specific type of probe. The last three tabs present graphically rendered illustration and probe element information.

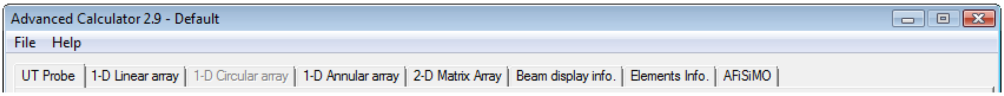


**Figure 1-1 The menu bar and the available tabs**

A button bar is available at the bottom of the Advanced Calculator window (see Figure 1-2 on page 14).

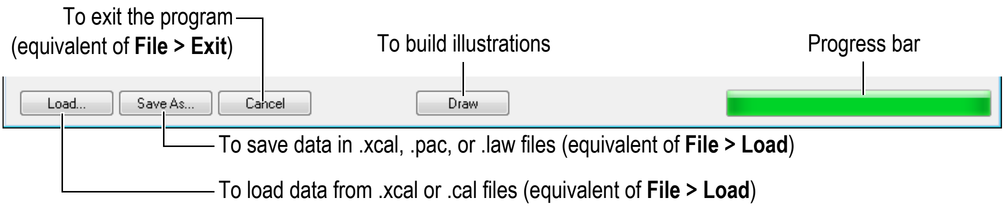


**Figure 1-2 The button bar**

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**NOTE**

The presence of some Advanced Calculator user interface elements depends on whether you launched the Advanced Calculator from TomoView or as a standalone software.

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## 1.2 About the Menu Bar

The Advanced Calculator menu bar contains two menus: **File** and **Help**.

### 1.2.1 File Menu Commands

The **File** menu contains the following commands:

**Load**

Used to open the **Open** dialog box in which you can select a calculator setup file to load (.cal or .xcal format).

**Save As**

Used to open the **Save As** dialog box in which you can select the name, location, and format (.xcal, .pac, or .law) of the file to which you save the calculator data. This creates one .law file for each group. The file contains delays to be applied for all ultrasonic beams.

**Export elementary law**

This command includes a submenu with two items (**Delay** and **No Delay**). Both submenu commands are used to open the **Save As** dialog box in which you can select the name and location of a .law file in which to save ultrasonic beam data, respectively, with or without the delay data. This creates one .law file for each ultrasonic beam in the current group. Each .law file contains one beam per element used in the aperture.

**Run AFiSiMO Batch**

Used to open a **Browse** dialog box in which you can select a folder containing one or more calculator setup files (.xcal format). The Advanced Calculator then performs the AFiSiMO simulations for all configurations stored in the .xcal files in the selected folder. The generated simulation data is saved in the .xcal files.

**Preferences**

Used to open the **Preferences** dialog box in which you can select the measurement units (**Metric** or **US Cust**.) used in the Advanced Calculator user interface.

**Exit**

Used to terminate the execution of the Advanced Calculator program.

### 1.2.2 Help Menu Commands

The **Help** menu contains the following commands:

**Advanced Calculator Help**

Used to open the Advanced Calculator online help.

**About Advanced Calculator**

Used to open the **About** Advanced Calculator dialog box that contains the Advanced Calculator version, option, and copyright information.

## 1.3 About the Supported File Formats

The Advanced Calculator can open and save data using the file formats described in Table 1 on page 16 and open the legacy file formats described in Table 2 on page 16.

**Table 1 File formats supported by the Advanced Calculator**

| File type | Extension | File content |
|---|---|---|
| Calculator setup | .xcal | Extended Advanced Calculator setup file |
| Calculator setup | .law | Calculated ultrasonic beam parameters also readable by the OmniScan.<br>Refer to Appendix C on page 147 for details. |
| Calculator setup | .pac | Calculated ultrasonic beam parameters.<br>Refer to Appendix D on page 157 for details. |

**Table 2 Legacy file format supported by the Advanced Calculator**

| File type | Extension | File content |
|---|---|---|
| Calculator setup | .cal | Advanced Calculator setup file |

# 2. Phased Array Technique

This section describes the main concepts of a phased array inspection and the phased array data views.

Phased array technology allows the generation of an ultrasonic beam with the possibility of modifying the ultrasonic beam parameters such as angle, focal distance, and focal spot size with software. Furthermore, this ultrasonic beam can be multiplexed over a large array, thus creating a movement of the ultrasonic beam along the array. These capabilities open a series of new possibilities. For example, it is possible to quickly vary the angle of the ultrasonic beam to scan a part or weld without moving the probe itself. Phased array capabilities also allow the replacement of multiple probes, and mechanical scanning devices. Inspecting a part or weld with a variable-angle ultrasonic beam also improves detection, regardless of the defect orientation, while optimizing signal-to-noise ratio.

## 2.1 Physical Principles

To generate an ultrasonic beam, the various probe elements are pulsed at slightly different times. By precisely controlling the delays between the probe elements, ultrasonic beams of various angles, focal distances, and focal spot sizes can be produced. As shown in Figure 2-1 on page 18, the echo from the desired focal point hits the various transducer elements with a computable time shift. The echo signals received at each transducer element are time-shifted before being summed together. The resulting sum is an A-scan that emphasizes the response from the desired focal point and attenuates various other echoes from other points in the material.

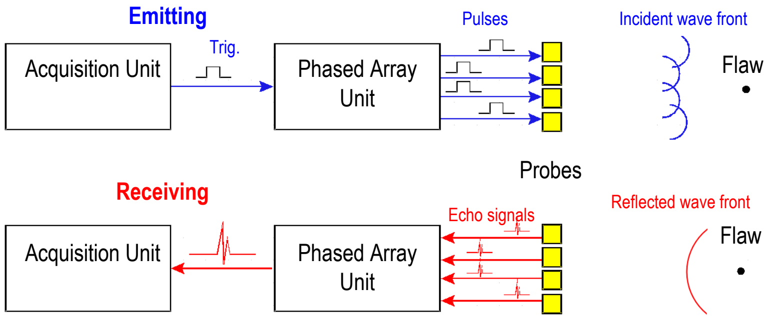


**Figure 2-1 Emitting and receiving in a phased array system**

A phased array probe is typically a one- or two-dimensional array of small transducer elements. To control the ultrasonic beam characteristics, the excitation pulse is applied at different times to the various elements of the probe.

The phased array probe is composed of multiple elements that allow ultrasonic beam angle control (see section 2.1.1 on page 18) and ultrasonic beam focus control (see section 2.1.2 on page 20).

### 2.1.1 Beam Angle Control

Beam angle control involves the production of a wave front. As shown in Figure 2-2 on page 19, simultaneous firing of all elements of a linear multielement probe produces a series arc circle waves, one from each transducer element. As all wave fronts are at the same distance from their respective emitter, the resulting wave front, or envelope, is parallel to the transducer plane. This, in fact, is very similar to pulsing a single element transducer of the same size.

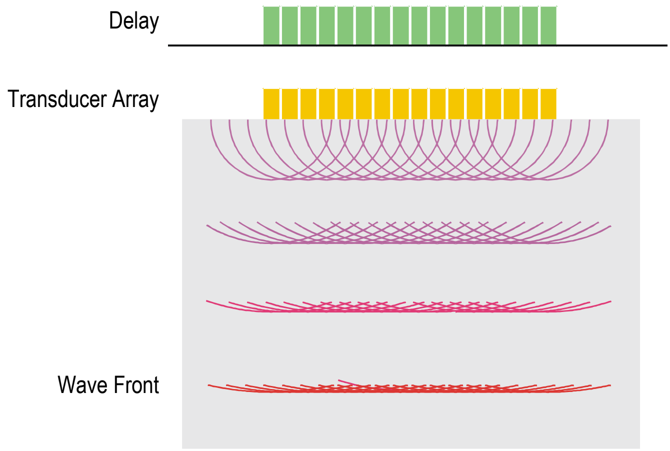


**Figure 2-2 Ultrasonic wave front of a linear array**

The phased array unit allows the pulsing of the various elements in a sequential manner with a small and precisely controlled time delay between each element. Sequential firing of the various transducer elements produces a series of arc circle waves. The resulting envelope is a wave front, which is no longer parallel to the transducer surface but propagates at an angle (see Figure 2-3 on page 19). It is possible to adjust the pulse delays to produce any desired wave-front angle.

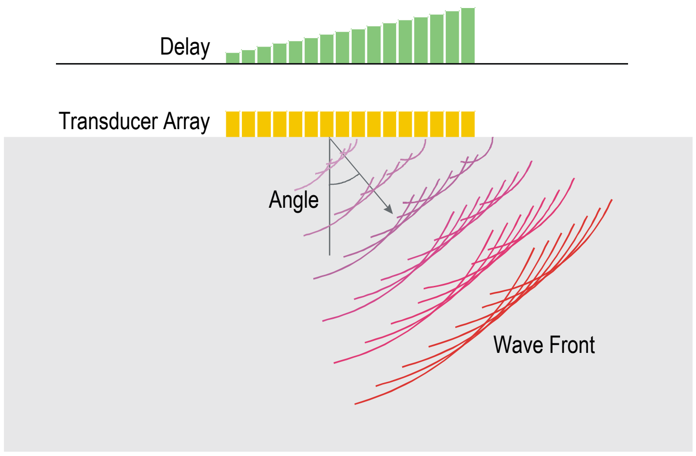


**Figure 2-3 Ultrasonic beam angle control of a linear array**

### 2.1.2 Beam Focus Control

When generating a focused beam, the delays are adjusted so that all individual wave fronts stay in phase along the path leading to the desired focal point, while canceling each other out at all other points. By accurately controlling the pulse delays, it is possible to focus the beam at a desired point (see Figure 2-4 on page 20).

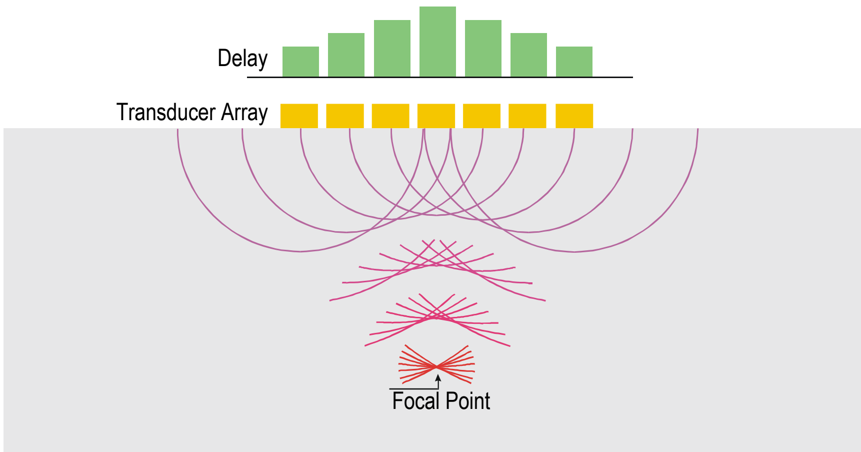


**Figure 2-4 Ultrasonic beam focusing of a linear array**

For beam angle control and beam focus control, signals received by every element are time-synchronized by the phased array system prior to summing the various responses.

## 2.2 Phased Array Applications

The ultrasonic beam generated by a phased array probe is treated as an ordinary ultrasonic beam by the TomoView ultrasonic visualization and analysis software, and as such can be used to generate all the regular data views (A-scan views, B-scan views, volumetric views, etc.).

Phased array also offers the possibility of performing inspections with various angles and focal lengths. It provides hardware and software tools for different application types.

The application types that you can select in the Advanced Calculator dialog box are:

- Sectorial scanning
- Depth scanning
- Linear electronic scanning

### 2.2.1 Sectorial and Depth Scanning

The sectorial scanning of the phased array signal is obtained by applying several beams in sequence at each X-Y coordinate of the inspected area.

For a particular X-Y position of the inspection sequence, an array of elements is used to deflect the ultrasound beam without moving the probe. The scanning can be done along a horizontal axis (see Figure 2-5 on page 21), at different depths in the material (see Figure 2-6 on page 22), or for a combination of these two modes.

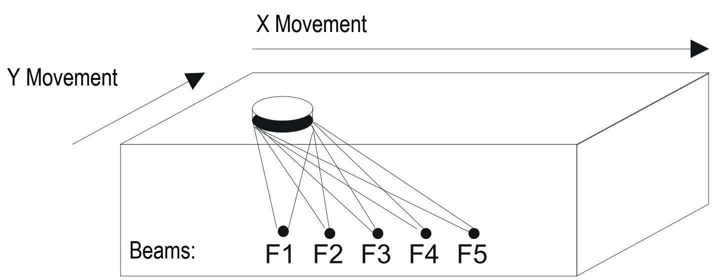


**Figure 2-5 Sectorial scanning of X-axis using phased array deflection**

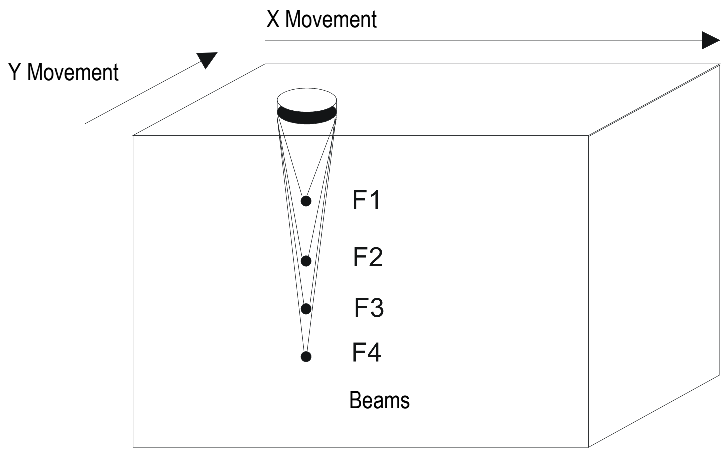


**Figure 2-6 Scanning at different depths**

For certain applications, a conventional UT inspection would require a number of different transducers. A single phased array probe can be made to sequentially produce the various angles and focal points required by the application (see Figure 2-7 on page 22).

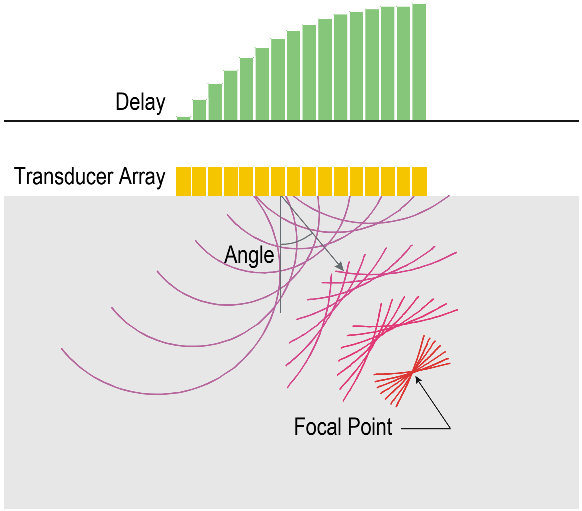


**Figure 2-7 Ultrasonic beam angle control and focusing of a linear array**

### 2.2.2 Linear Electronic Scanning

For large phased array probes containing a high number of elements, the phased array unit can apply the same beam to different sets of elements. By moving the beam along a transducer array, the scanning of an inspection axis is realized electronically without any need for physical displacement of the transducer (see Figure 2-8 on page 23).

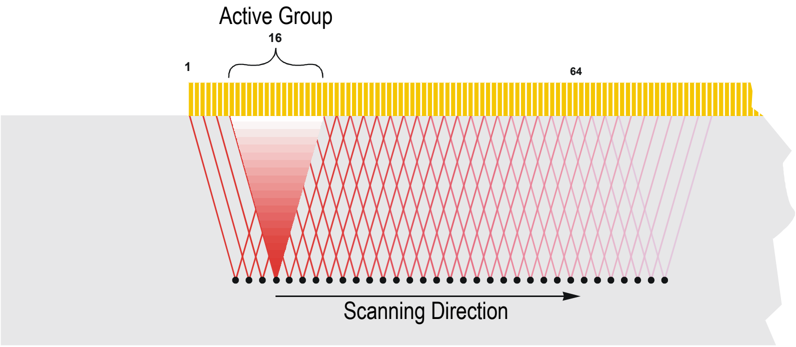


**Figure 2-8 Electronic scanning along an axis**

In Figure 2-8 on page 23, a focused beam is created using a few of the many transducer elements of a long phased array probe. The beam is then shifted (or multiplexed) to the other elements to perform a high-speed scan of the part with no transducer movement along scanning axis. More than one scan can be performed with various inspection angles.

# 3. The UT Probe Tab

The **UT Probe** tab provides parameters to define a single-element conventional probe and the wedge used to perform acoustic field simulation in the **AFiSiMO** tab.

**NOTE**

The **UT Probe** tab is enabled only when you start the Advanced Calculator as a standalone software.

The **UT Probe** tab is divided into nine areas (see Figure 3-1 on page 26). A few areas are not applicable to this tab and are therefore empty or disabled. A description of the applicable areas follows.

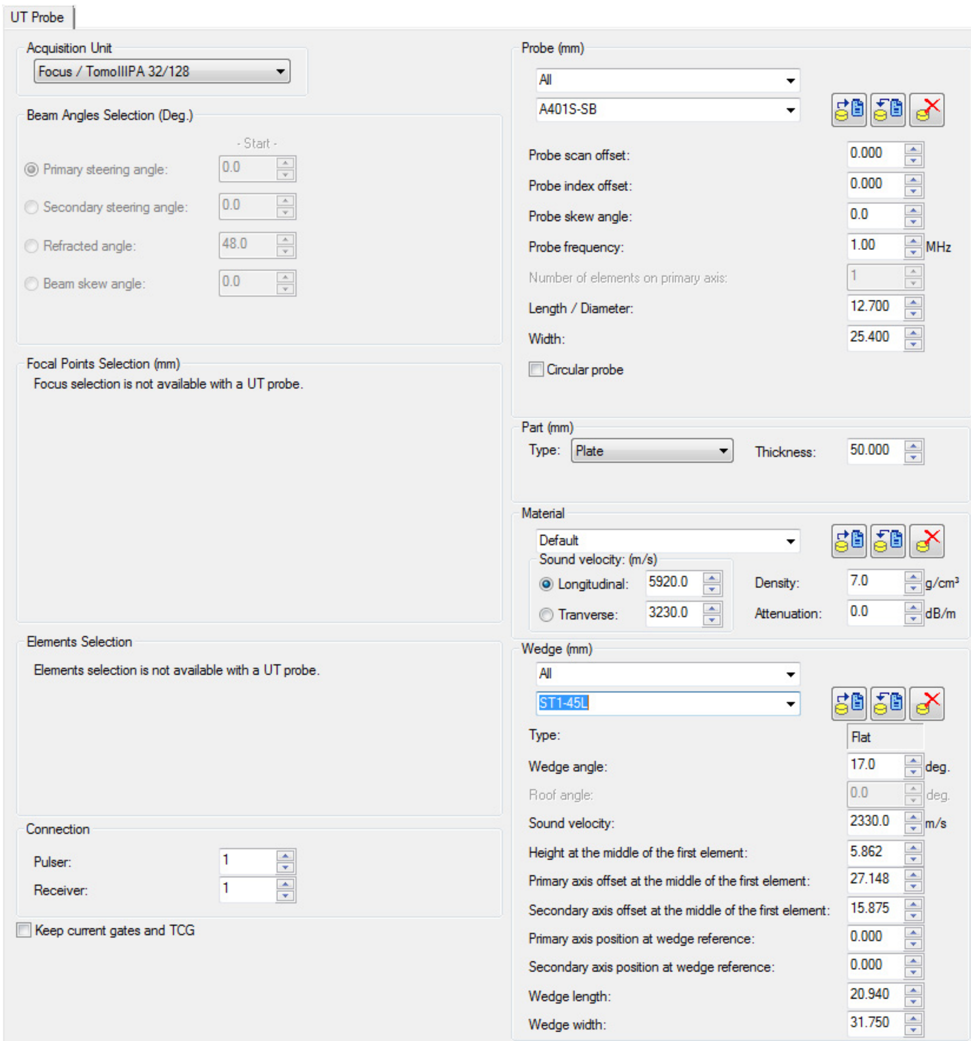


**Figure 3-1 The 1-D Linear array tab**

## 3.1 Acquisition Unit Area

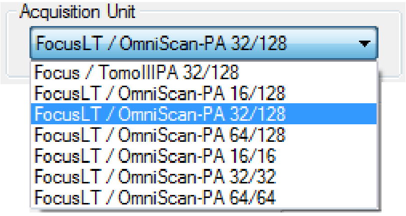


**Figure 3-2 The Acquisition Unit area**

The **Acquisition Unit** area (Figure 3-2 on page 27) contains only one drop-down combo box used to select the type of acquisition unit for which you want to create beams. The drop-down combo box is available only when no acquisition unit is connected to the computer. The acquisition unit is automatically detected when it communicates with the computer.

## 3.2 Connection Area

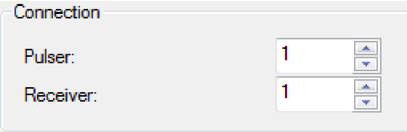


**Figure 3-3 The Connection area**

The **Connection** area (see Figure 3-3 on page 27) contains the following elements:

**Pulser** and **Receiver**

When using only one probe, always set the value of these parameters to 1.

Use these parameters when connecting two UT probes for measurement in a symmetric configuration.

## 3.3 Probe Area

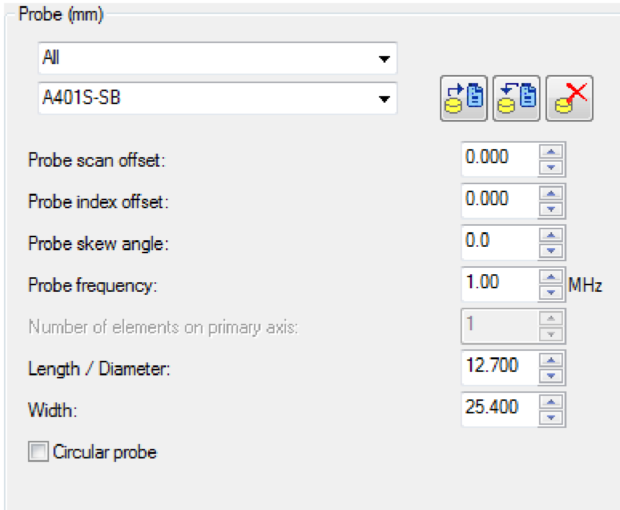


**Figure 3-4 The Probe area**

The **Probe** area contains the following (see Figure 3-4 on page 28):

**Probe** database

The drop-down combo box allows you to select a probe from the probe database.

 **Load from database** button

Allows you to load a probe configuration from the probe database.

 **Save in database** button

Allows you to save the active probe configuration in the probe database.

 **Delete from database** button

Allows you to delete a probe configuration from the probe database.

**Probe scan offset**

Defines the distance between the center of the element and the scan-axis origin.

**Probe index offset**

Defines the distance between the front of the wedge and the index-axis origin.

**Probe skew angle**

For angle beam probes, defines the skew angle of the probe. The **Probe skew angle** is defined as the angle between the projected beam angle and the scan-axis. It can have values between 0° and 360°, and is positive when turning from the positive scan-axis towards the positive index- axis.

**Probe frequency**

Defines the probe frequency.

**Length / Diameter**

Defines the length or diameter of the element.

**Width**

Defines the width of a rectangular element.

**Circular probe**

Select when the probe element is circular.

## 3.4 Part Area


**Figure 3-5 The Part area for flat part**

The **Part** area (see Figure 3-5 on page 29) contains the following:

**Type**

Defines the part type supported by the Advanced Calculator:

**Plate:** flat part.

**Pipe OD:** cylindrical part inspected from the outside diameter.

**Pipe ID:** cylindrical part inspected from the inside diameter.

**Thickness (mm)**

Defines the thickness of the part to be displayed on the **Beam Display Info.** tab.

**Radius (mm)**

Defines the radius of the cylindrical part. For a **Pipe OD** part, this value represents the outer radius (inner radius + thickness). For **Pipe ID** part, the radius represents the inner radius.

## 3.5 Material Area

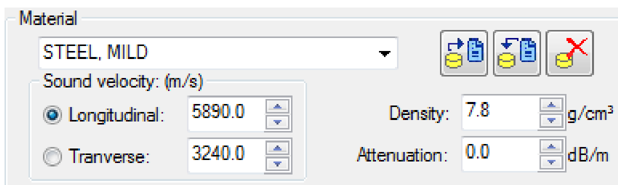


**Figure 3-6 The Material area for flat part**

**Material** database

Allows the use of the **Material** database:

 **Load from database** button

Allows you to load a material configuration from the material database.

 **Save in database** button

Allows you to save the active material configuration in the material database.

 **Delete from database** button

Allows you to delete a material configuration from the material database.

**Sound velocity** area

Defines the sound velocities in the material to be inspected for the available wave types (**Longitudinal** [compression] or **Transverse** [shear]) waves (m/s).

**Density**

Defines the density of the selected material.

**Attenuation**

Used to set the ultrasonic attenuation for the selected material. Note that attenuation is frequency dependent.

## 3.6 Wedge Area

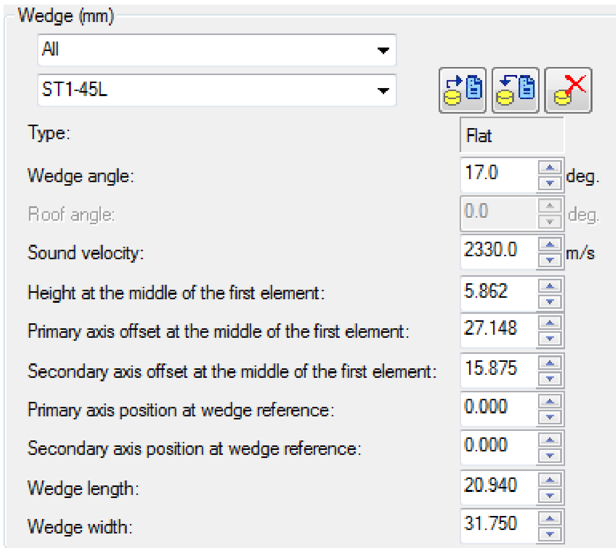


**Figure 3-7 The Wedge area**

The **Wedge** area (see Figure 3-7 on page 31) contains the following:

**Wedge** database

Allows the use of the **Wedge** database:

 **Load from database** button

Allows you to load a wedge configuration from the wedge database.

 **Save in database** button

Allows you to save the active wedge configuration in the wedge database.

 **Delete from database** button

Allows you to delete a wedge configuration from the wedge database.

**Wedge angle**

Defines the wedge angle in degrees. The **Wedge angle** is the angle between the element surface (when it is fixed on the wedge) and the surface of the part (or the tangential plane to the surface of the part in the case of a cylindrical geometry). It is obtained by a rotation around the secondary axis of the probe, and can have values between 0° and 89.9°.

**Sound velocity**

Defines the sound velocity in the wedge.

**Height at the middle of the first element**

Defines the height of the middle of the element, relative to the material surface.

For cylindrical part, the height is measured relative to the flat surface obtained by drawing a line between the contact points of the wedge, and is always positive.

**Primary axis offset of the middle of the first element**

Defines the offset of the middle of the element along the primary axis, relative to the back of the wedge. The offset is always measured along a straight line, and normally has positive values.

**Secondary axis offset of the middle of the first element**

Defines the offset of the middle of the element along the secondary axis, relative to the left side of the wedge. The offset is always measured along a straight line, and normally has positive values.

**Primary axis position of wedge reference**

Defines the primary axis position of the wedge reference relative to the mechanical reference. The offset is always measured along the part surface and is positive along the positive scan-axis direction.

**Secondary axis position of wedge reference**

Defines the secondary axis position of the wedge reference relative to the mechanical reference. The offset is always measured along the part surface and is positive along the positive index-axis direction.

**Wedge length**

The **Wedge length** is defined as the actual length of the wedge.

For a cylindrical part with a curvature along primary axis, the wedge length represents the distance between the contact points of the wedge.

### Wedge width

The **Wedge width** is defined as the actual width of the wedge.

For a cylindrical part with a curvature along secondary axis, the wedge width represents the distance between the contact points of the wedge.

# 4. The 1-D Linear Arrays Tab

This section presents the 1-D linear arrays and describes the **1-D Linear array** tab.

## 4.1 Generic Conventions

You should consider generic conventions regarding probe, wedge, and part geometry to generate beams for 1-D linear arrays in the most efficient and accurate way. Generic conventions exist on aspects such as orientations and positive directions of axes, reference points and signs of offsets, and definition and signs of angles.

### 4.1.1 Probe Conventions

#### Axis definition

The axis convention for a **1-D Linear array** as described in section 4.2 on page 52 (see **Probe** area), is illustrated in Figure 4-1 on page 36.

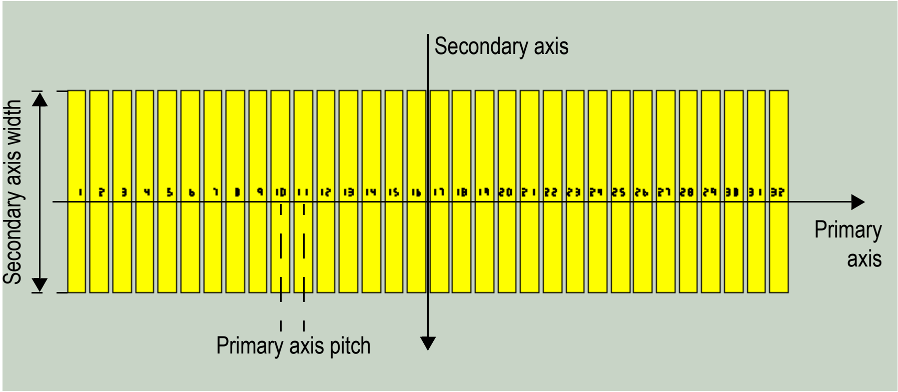


**Figure 4-1 Probe axis definition**

### Refracted angle

The *refracted angle* of the ultrasound beam is defined as the angle between the central ray of the ultrasound beam in the material and the normal on the surface at the entrance point of the central ray (see Figure 4-2 on page 36 and Figure 4-3 on page 37). The refracted angle can have values between –89.9° and 89.9°.

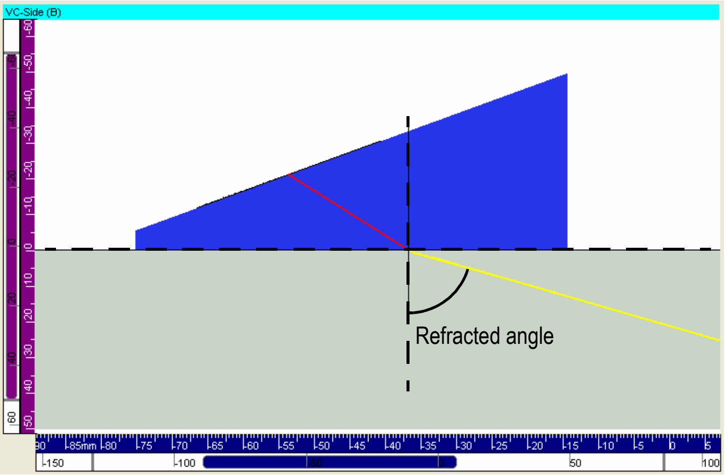


**Figure 4-2 Refracted angle on flat part**

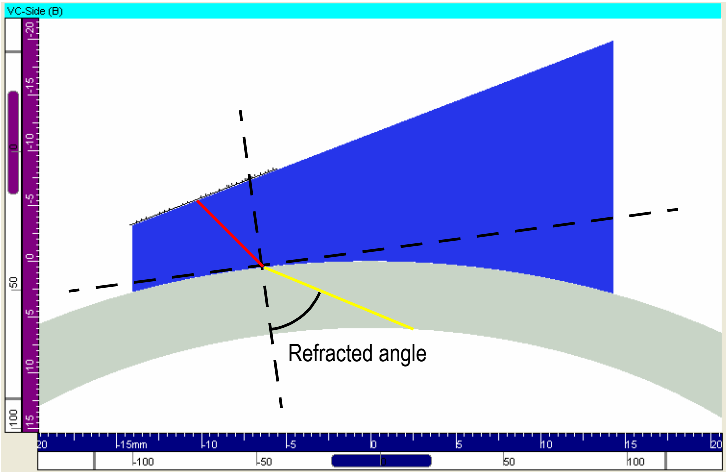


**Figure 4-3 Refracted angle on pipe part**

### Skew angle

The total skew angle is the sum of two components: the *beam skew angle* (for definition, see section 4.2.3 on page 54) and the *probe skew angle* (for definition, see section 4.2.7 on page 63). In both cases, the TomoView conventions are used. The skew angle can have values between 0° and 359.9°.

### Beam skew angle

Since the 1-D linear array as no skewing capability, only a beam skew angle different from 0° can be obtained when using a wedge with a roof angle.

The *beam skew angle* is defined as the angle between the ultrasound beam (central ray) projection on the scanning surface and the primary axis of the array. The beam skew angle can have values between –179.9° and 179.9°, and it has a positive value when turning from the positive primary axis towards the positive secondary axis.

An example of a beam skew angle going from 70° to 110° with a resolution of 10° is illustrated in Figure 4-4 on page 38.

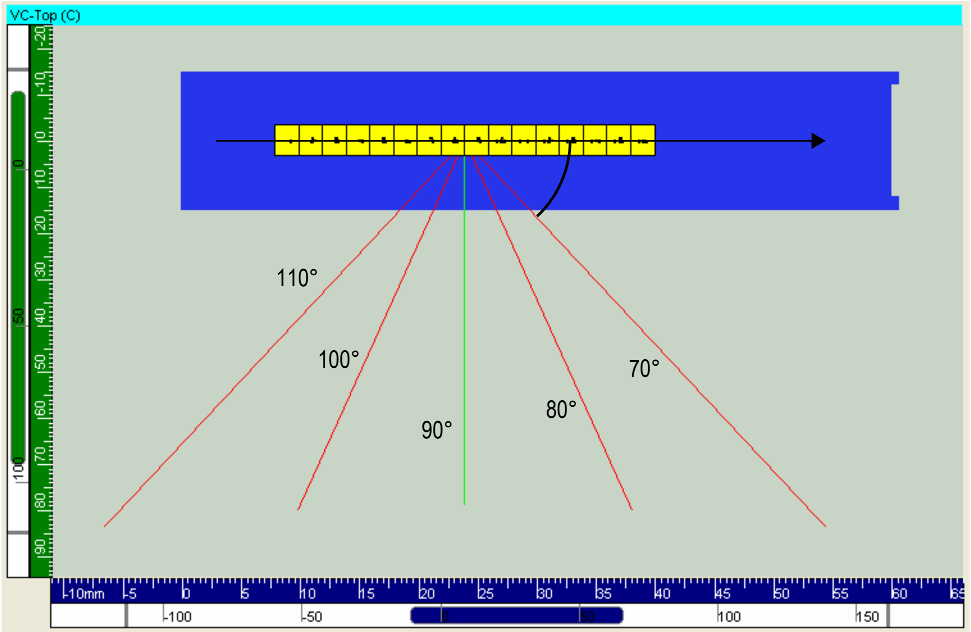


**Figure 4-4 Example of a beam skew angle**

### Probe skew angle

The *probe skew angle* is defined as the angle between the primary axis of the probe and the scan-axis. It can have values between 0° and 360°, and is positive when turning from the positive scan-axis towards the positive index-axis.

Examples of different probe skew angles, between 0° to 135°, are illustrated in Figure 4-5 on page 39 to Figure 4-8 on page 40.

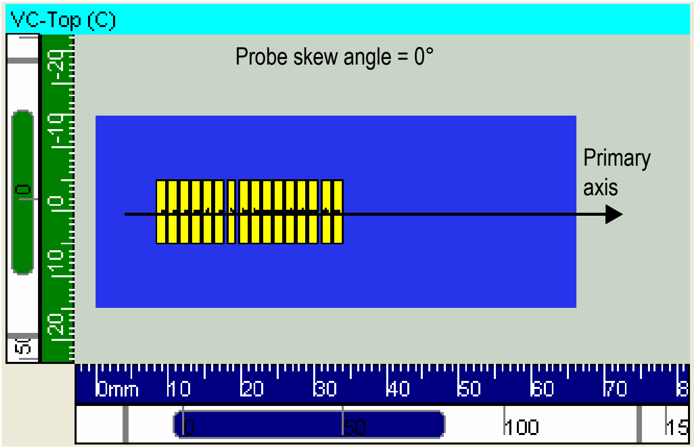


**Figure 4-5 Example of a probe skew angle equal to 0°**

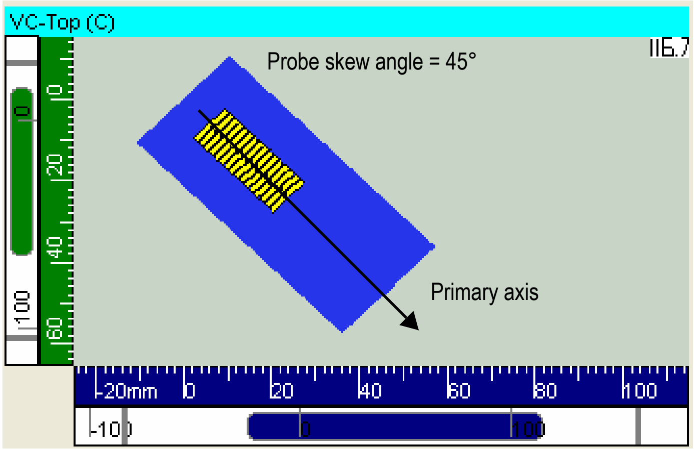


**Figure 4-6 Example of a probe skew angle equal to 45°**

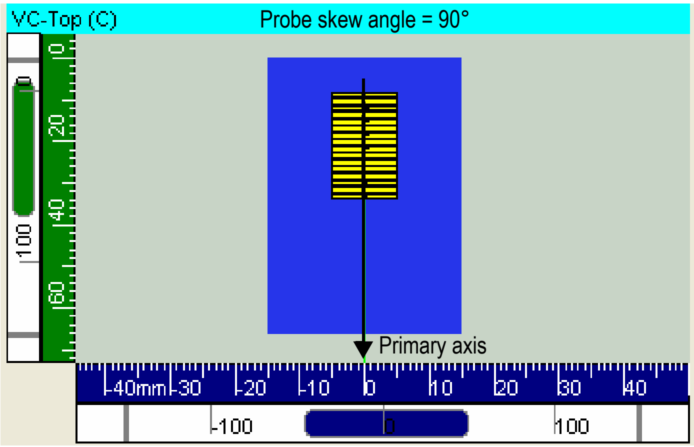


**Figure 4-7 Example of a probe skew angle equal to 90°**

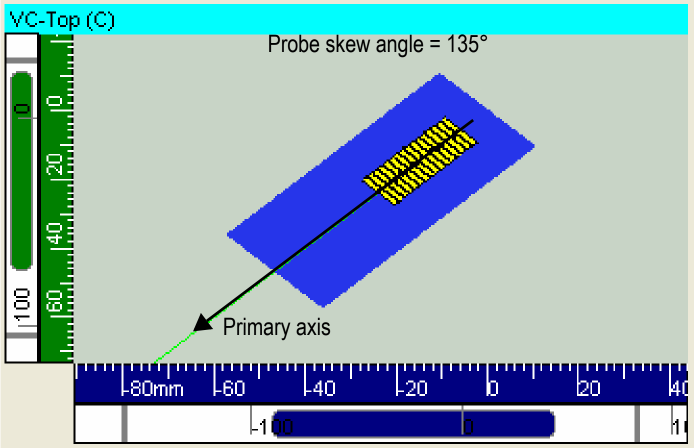


**Figure 4-8 Example of a probe skew angle equal to 135°**

### Total skew angle

The combination of a probe skew angle of 90° and a beam skew angle of 15°, resulting in a *total skew angle* of 152.51°, is illustrated in Figure 4-9 on page 41.

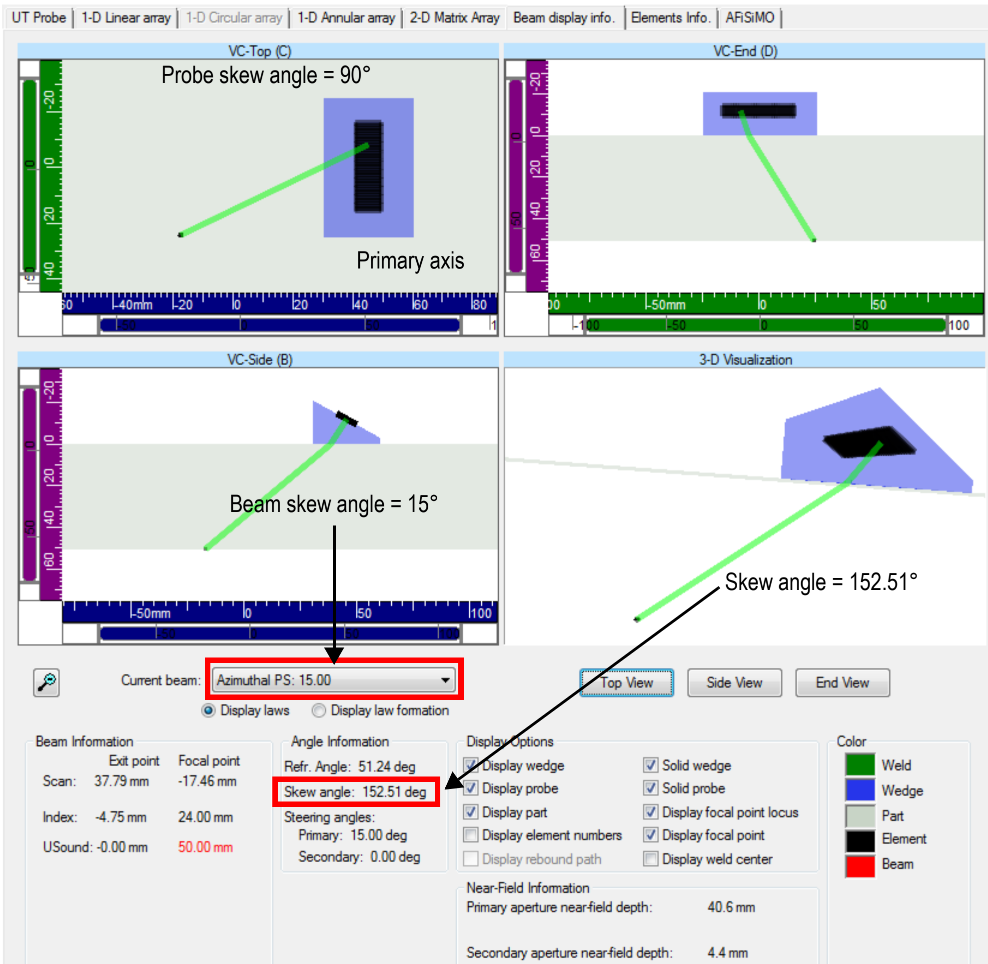


Figure 4-9 Total skew angle

### 4.1.2 Wedge Conventions

In the Advanced Calculator, the different rotations, which define the *wedge*, *roof*, and *squint* angles are performed in such a way that they are independent. This is mathematically possible because the rotations are performed around adequate axes (not necessarily Scan, Index, and Usound). Consequently, the chronology of the rotations is not important. The value specified for each angle will be correctly applied.

#### Wedge angle

The *wedge angle* is the angle between the primary axis of the probe (when it is fixed on the wedge) and the surface of the component (or the tangential plane to the surface of the component in the case of a cylindrical geometry). It is obtained by a rotation around the secondary axis of the probe, and can have values between 0° and 89.9°.

Figure 4-10 on page 42 gives an example of a wedge with a wedge angle and no roof angle.

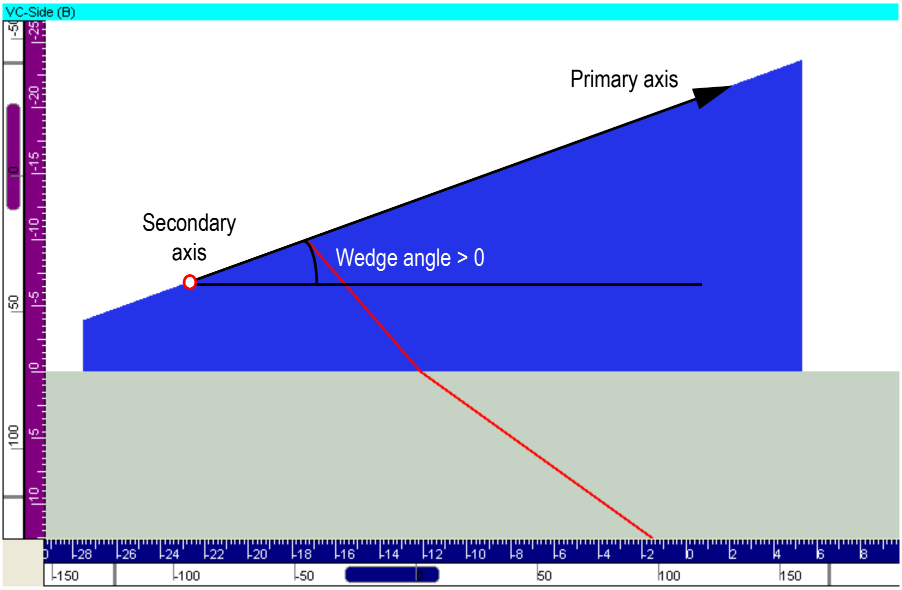


**Figure 4-10 Wedge angle definition**

### Roof angle

The *roof angle* is the rotation angle around the primary axis of the probe, and can have values between –89.9° and 89.9°. For a probe skew of 0°, a positive roof angle will generate beams with total skew angles between 0° and 180°.

Figure 4-11 on page 43 gives an example of a wedge with a positive roof angle and no wedge angle.

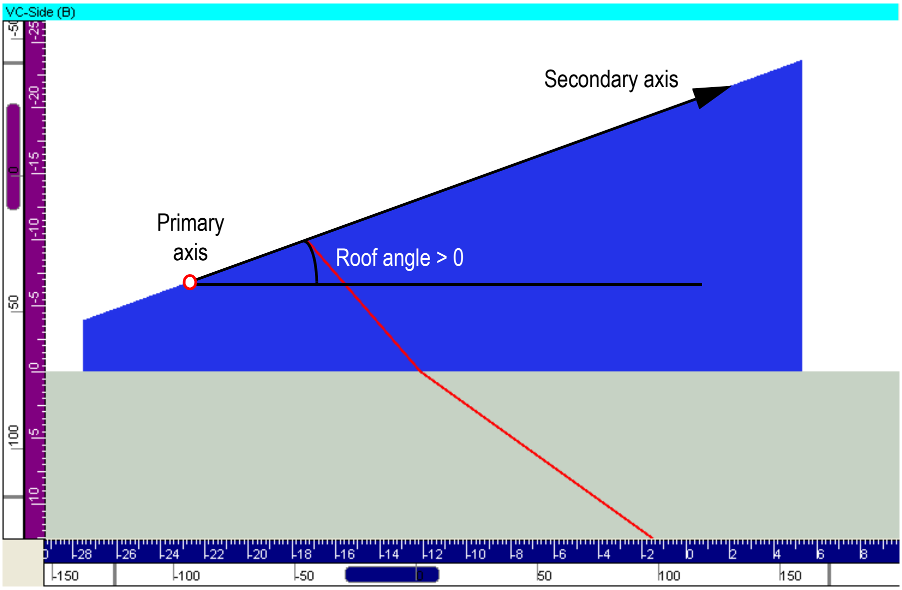


**Figure 4-11 Roof angle definition**

For pitch-and-catch configurations, the *probe separation* and the *squint angle* parameters must be appropriately set.

### Probe separation

The *probe separation* defines the spacing (center-to-center distance) between the first element of the transmitters array and the first element of the receivers array (see Figure 4-12 on page 44).

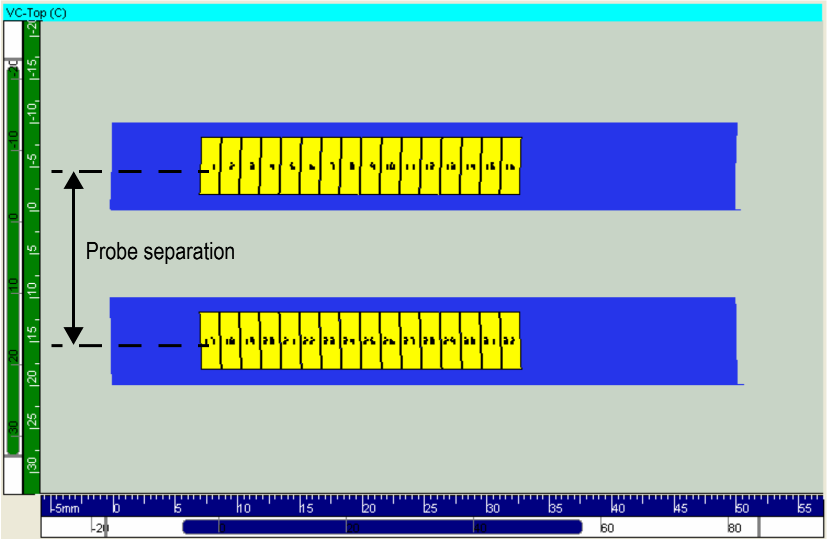


**Figure 4-12 Probe separation**

### Squint angle

The *squint angle* is defined as half the angle between the primary axes of transmitter and receiver arrays. A symmetrical rotation is automatically applied to the receiving array. The squint angle can have values between –89.9° and 89.9°, and a positive squint angle means that the primary axes of the arrays cross in front of the arrays (see Figure 4-13 on page 45).

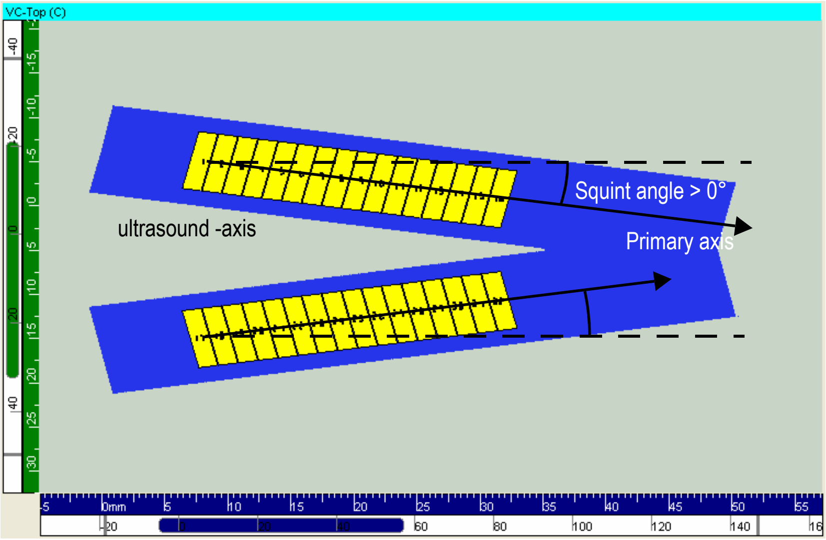


**Figure 4-13 Squint angle definition**

### Position of the probe relative to the wedge

In the **Wedge** area of the Advanced Calculator, the values for the **Primary axis position of wedge reference (mm)** and **Secondary axis position of wedge reference (mm)** parameters are adjusted so that the probe is correctly positioned relative to the wedge. In the example shown in Figure 4-14 on page 46, the front of the wedge is at zero on the index-axis and the center of the wedge is at zero on the scan-axis.

---

**IMPORTANT**

For standard flat wedges, in the **Wedge** area of the Advanced Calculator, do not change the values of the **Primary axis position of wedge reference** and the **Secondary axis position of wedge reference** parameters (see section 4.2.10 on page 68)

---

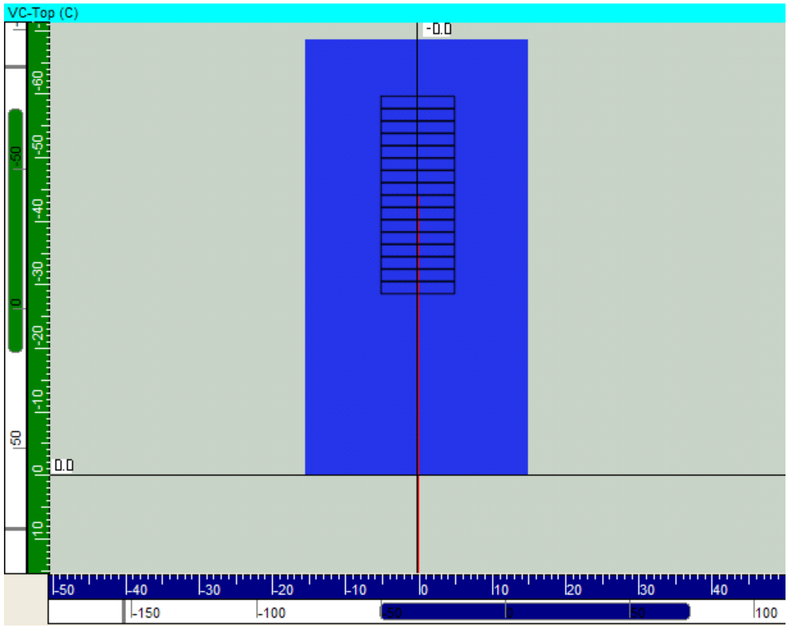


**Figure 4-14 Wedge reference positions**

## 4.1.3 Conventions Related to the Part

In order to increase the flexibility with regards to selection of reference points, the Advanced Calculator considers two different reference points:

- The *wedge reference point* is the intrinsic reference point used by the calculator and is always located at the rear-left corner of the wedge. The probe is then positioned with regards to the *wedge reference* by specifying the **Primary axis offset of the middle of the first element** parameter and the **Secondary axis offset of the middle of the first element** parameter (for definition, see section 4.2.10 on page 68).
- The *mechanical reference point* is an arbitrary reference point that can be used by the operator to define the position of the intrinsic wedge reference relative to an alternative wedge reference (for example, the front of the wedge) or a reference point on a scanning mechanism. The wedge reference is positioned with regards to the *mechanical reference* by specifying the **Primary axis position of wedge reference** parameter or the **Secondary axis position of wedge reference** parameter (for definition, see section 4.2.10 on page 68). In the visualization of the

considered configurations on the **Beam Display Info.** tab, the *mechanical reference* is always positioned at the origin.

- When using **Primary axis position of wedge reference** and/or **Secondary axis position of wedge reference** values different from zero, the Advanced Calculator takes these values into account for the scan and/or index offset values in the **Beam Information** area of the **Beam Display Info.** tab.

Examples for flat and cylindrical parts are illustrated in Figure 4-15 on page 48, Figure 4-16 on page 49, and Figure 4-17 on page 50.

#### Flat part

---

**IMPORTANT**

For standard probes and wedges, to correctly position the wedge and the probe relative to the part, enter proper values in the **Probe scan offset (mm)** and **Probe index offset (mm)** parameters in the **Probe** area of the Advanced Calculator (see section 4.2.7 on page 63).

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For custom wedges, refer to Figure 4-15 on page 48 to understand the physical meaning of the various Advanced Calculator parameters.

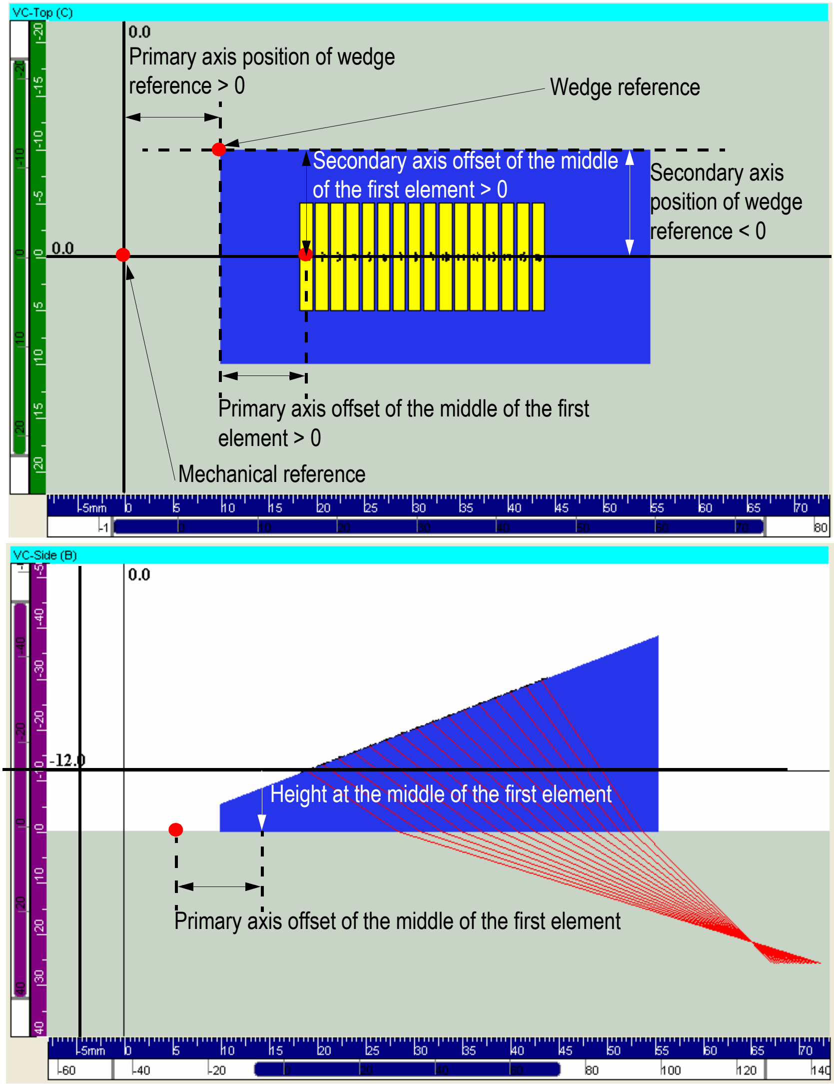


**Figure 4-15 Flat part: offset definition**

### Cylindrical part

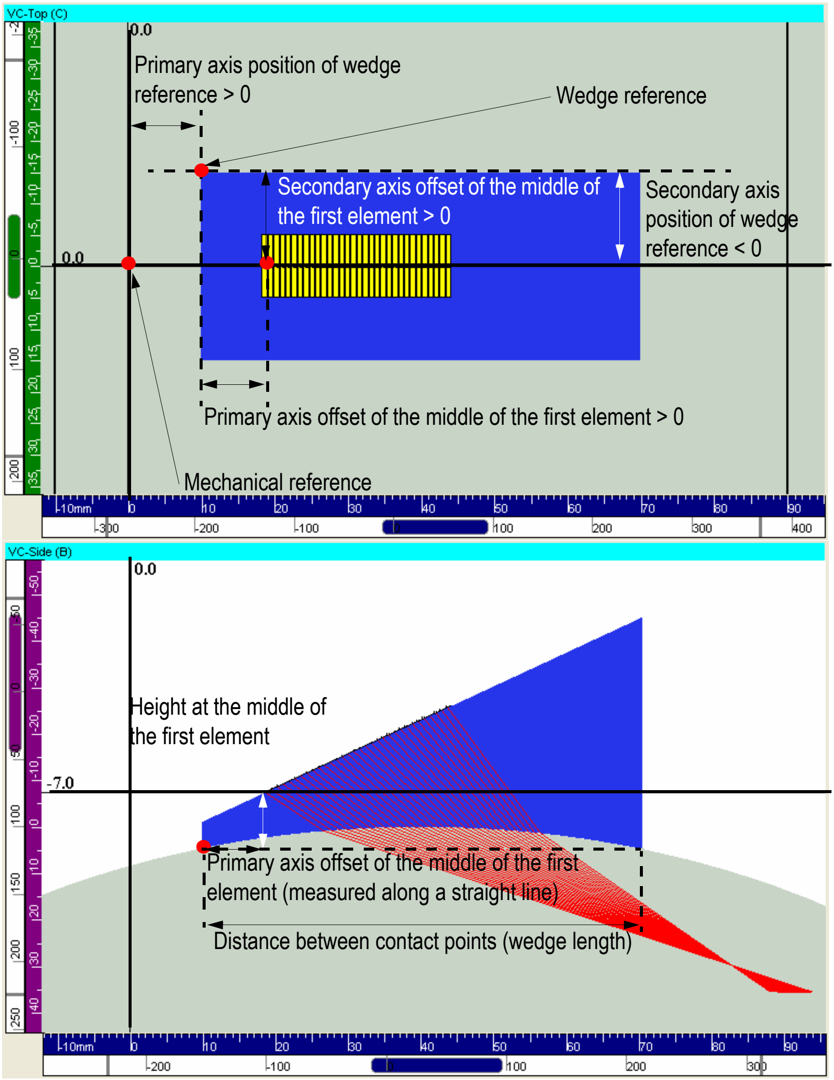


**Figure 4-16 Pipe OD with a curvature along the primary axis: offset definition**

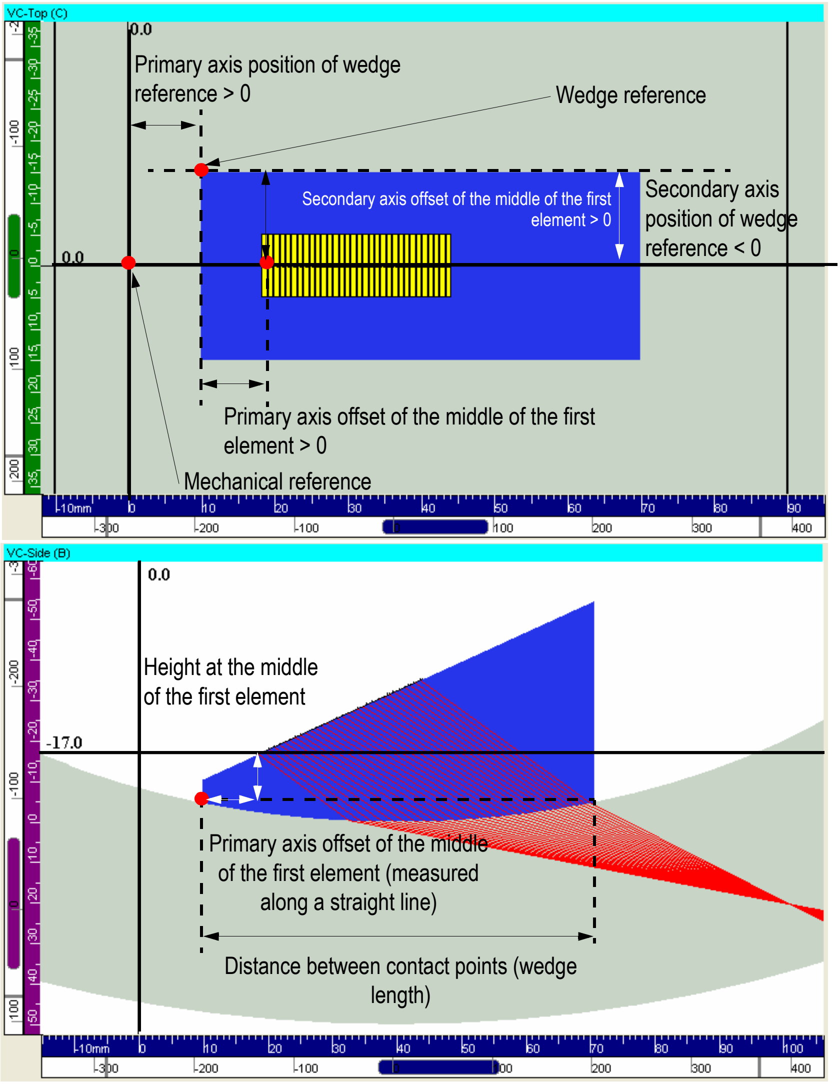


**Figure 4-17 Pipe ID with a curvature along the primary axis: offset definition**

For cylindrical parts (**Pipe OD** or **Pipe ID**), it is important to notice that the wedge is, by definition, considered as centered on the center of the pipe.

Similar conventions apply to a **Pipe OD** and **Pipe ID** with a *curvature along secondary axis*, with a difference that the **Distance between contact points** represents the *wedge width*.

## 4.2 1-D Linear Array Tab Description

The **1-D Linear array** tab is divided into ten areas (see Figure 4-18 on page 52).

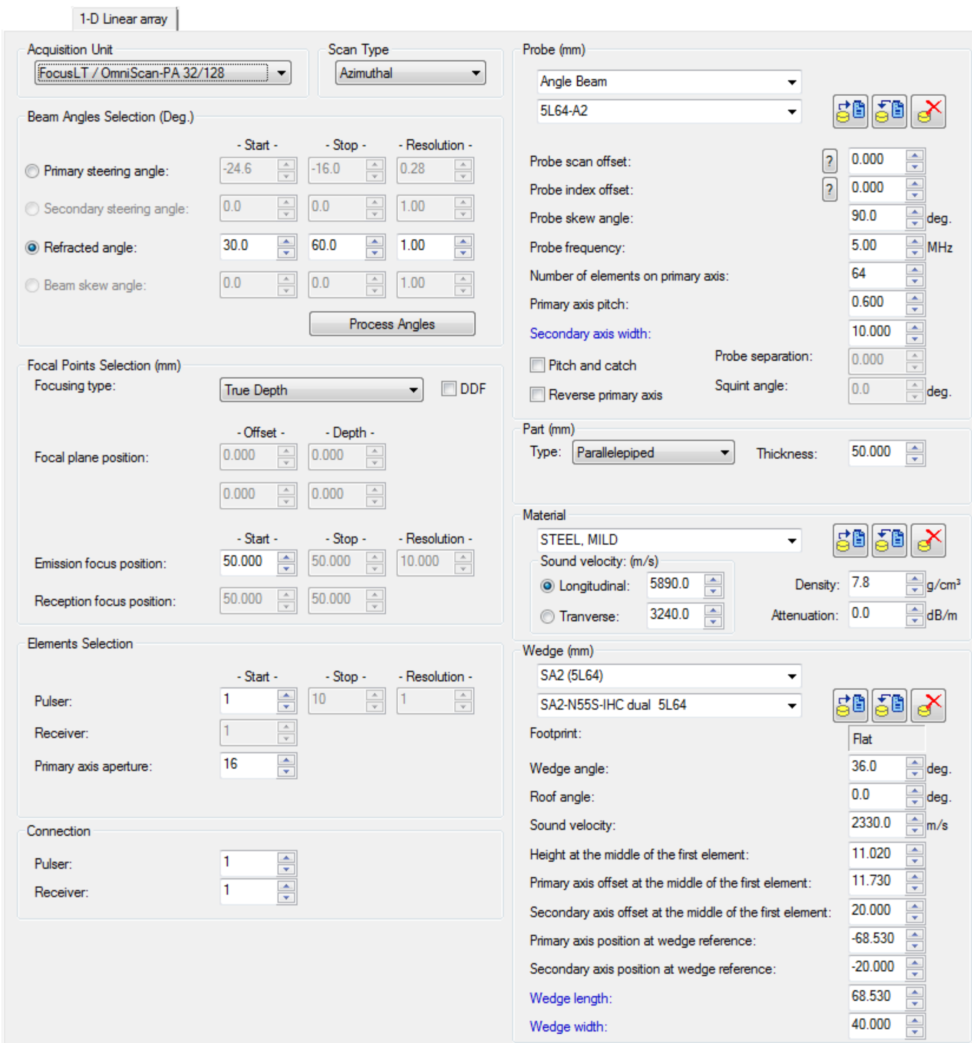


**Figure 4-18 The 1-D Linear array tab**

### 4.2.1 Acquisition Unit Area

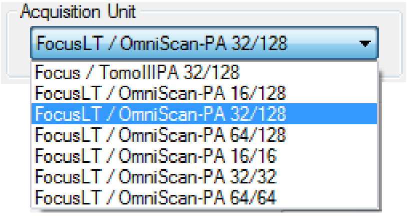


**Figure 4-19 The Acquisition Unit area**

The **Acquisition Unit** area (Figure 4-19 on page 53) contains only one drop-down combo box used to select the type of acquisition unit for which you want to create beams. The beam calculation uses a slightly different compensation gain for each acquisition unit type. The drop-down combo box is available only when no acquisition unit is connected to the computer. The acquisition unit is automatically detected when it communicates with the computer.

### 4.2.2 Scan Type Area

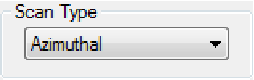


**Figure 4-20 The Scan area**

The **Scan Type** area (Figure 4-20 on page 53) contains the following:

**Type**

Selects the type of beams to be generated:

- **Sectorial:** the refracted or inspection angle varies (see section 2.2.1 on page 21 and section 4.5 on page 78).
- **Linear:** the primary aperture travels along the array (see section 2.2.2 on page 23 and section 4.6 on page 90).
- **Depth:** the focusing depth of the ultrasound beam varies (see section 2.2.1 on page 21 and section 4.4 on page 75).

- **Static:** the refracted angle, the focusing depth, and the primary aperture are fixed values (generates a single beam) [see section 4.3 on page 71].

## 4.2.3 Beam Angles Selection Area

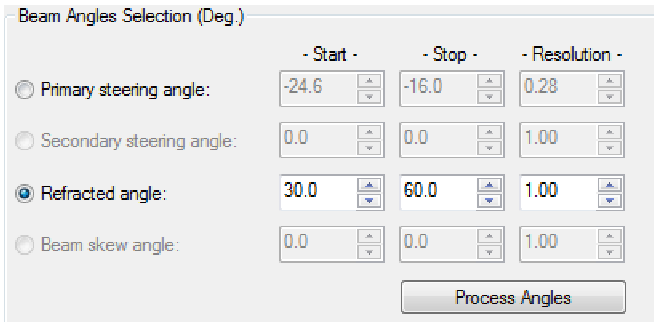


**Figure 4-21 The Beam angles selection area**

The **Beam Angles Selection** area (see Figure 4-21 on page 54) contains the following:

**Primary steering angle (deg)**

Is the angle between the central ray of the beam generated at the probe surface and the normal on the wedge surface in contact with the probe. It is generated by electronic steering of the array probe and determines the resulting incident angle (α) in the wedge, used to calculate the refracted angle of the ultrasound beam to be generated according to Sell's law (see Figure 4-22 on page 55). The **Primary steering angle** can have values between –89.9° and 89.9°, and a "0" value generates the nominal angle defined by the wedge parameters.

For **Sectorial** beams: the three **Primary steering angle** spin boxes are used to set the first and last primary steering angles, and the angular primary steering angle resolution between two consecutive beams.

For **Linear**, **Depth**, and **Static** beams: only the **Start** box can be modified to set the primary steering angle of the ultrasound beam to be used to generate the beams.

Not applicable for pitch-and-catch configurations.

**Secondary steering angle (deg)**

Not applicable for a 1-D linear array.

**Refracted angle (deg)**

Defines the refracted angle of the ultrasound beam to be generated. The refracted angle of the ultrasound beam is defined as the angle between the central ray of the ultrasound beam in the material and the normal on the incidence plane. The refracted angle (β) is calculated using the probe incidence angle (α), sound velocity in the wedge, and sound velocity in the material according to Snell's law (see Figure 4-22 on page 55).

$$\frac{\sin\alpha}{\sin\beta} = \frac{\text{Sound velocity in wedge}}{\text{Sound velocity in material}}$$

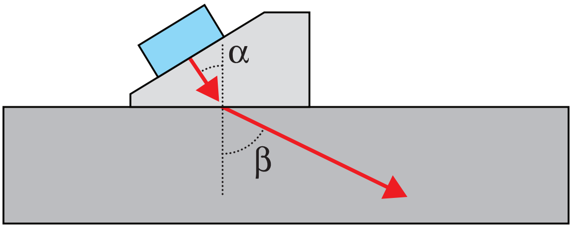


**Figure 4-22 Refracted angle**

The refracted angle can have values between –89.9° and 89.9°.

For **Sectorial** beams: the three **Refracted angle** spin boxes are used to set the first and last refracted angles, and the angular refracted angle resolution between two consecutive beams.

For **Linear**, **Depth**, and **Static** beams: only the **Start** box can be modified to select the refracted angle of the ultrasound beam to be generated by the beams.

**Beam skew angle (deg)**

Defines the skew angle of the ultrasound beam to be generated. This skew angle is defined as the angle between the ultrasound beam (central ray) projection on the scanning surface and the primary axis of the array. The **Beam skew angle** can have values between –179.9° and 179.9°, and, has a positive value when turning from the positive primary axis towards the positive secondary axis. The **Beam skew angle** value does not take into account the probe skew angle described in the **Probe** area (see Figure 4-4 on page 38).

For **Sectorial** beams: the three **Beam skew angle** spin boxes are used to set the first and last skew angles, and the angular beam skew angle resolution between two consecutive beams.

For **Linear**, **Depth**, and **Static** beams: only the **Start** box can be modified to set the beam skew angle of the ultrasound beam to be generated by the beams.

Not applicable for pitch-and-catch configurations.

**Process angles** button

Calculates the values of the primary steering angle, refracted angle, and/or beam skew angle associated with the beam angle selection.

### 4.2.4 Focal Points Selection Area

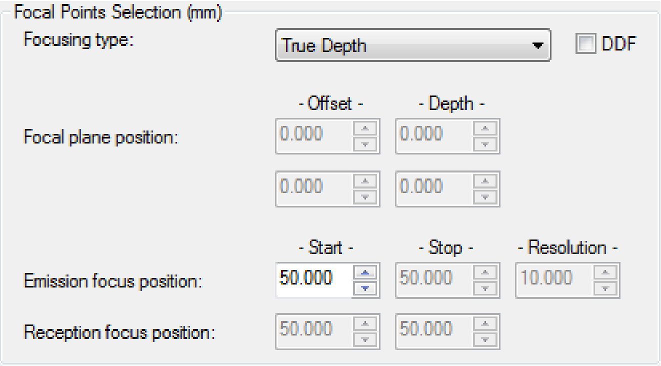


**Figure 4-23  The Focal points selection area**

The **Focal Points Selection** area (see Figure 4-23 on page 56) contains the following:

**Focusing type**

Selects the type of focusing of the beams to be generated:

- **True depth:** all beams are focused at a constant true-depth value (see Figure 4-24 on page 58). For cylindrical part, the true-depth value is defined as the depth in the cylindrical geometry.
- **Half path:** all beams are focused at a constant half-path (distance) value (see Figure 4-25 on page 58).

- **Projection:** all beams are focused on a given vertical plane (see Figure 4-26 on page 59); this option is not applicable for depth laws, for DDF (dynamic depth focusing) laws, and for pitch-and-catch configurations.
- **Focal plane:** all beams are focused on a user-defined focal plane (see Figure 4-27 on page 59); this option is not applicable for depth laws, DDF laws, and for pitch-and-catch configurations.
- **Auto:** the focalization depth is automatically calculated in order to have the transmitter and the receiver focused at the same point in space. The focalization is thus made at the geometrical intersection of the transmitter and the receiver central rays (see Figure 4-28 on page 60). This option is only applicable for pitch-and-catch configurations.

**DDF**

When this check box is selected, the dynamic depth focusing (DDF) algorithm is applied on the beams for the considered **Reception focus position** (depth or half-path).

Not applicable for pitch-and-catch configurations.

**Focal plane position**

Defines the focalization plane:

- **Projection:** the first **Offset** box is used to define the position, in scan or in index (depending on the skew angle of the probe) of the vertical focal plane (see Figure 4-26 on page 59).
- **Focal plane:** the **Offset** and **Depth** boxes are used to set the two points (in scan or index, and in depth) defining the focal plane (see Figure 4-27 on page 59).

**Emission focus position (mm)**

Defines the desired focusing position (depth or half-path) of the ultrasound beam to be generated.

For **Depth** beams: the three boxes are used to set the initial (**Start**) and final (**Stop**) desired focusing position (depth or half-path) of the ultrasound beam to be generated and the resolution.

**Reception focus position (mm)**

Defines the desired focusing position (depth or half-path) (applied delay) for the received signal.

When the **DDF** check box is selected, both boxes are used to set the initial (**Start**) and final (**Stop**) desired focusing position (depth or half-path) at reception.

When the **DDF** check box is not selected, the **Emission focus position** is equal to the **Reception focus position**.

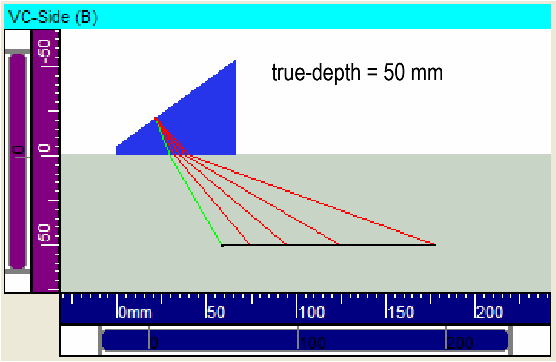


**Figure 4-24 True depth focalization**

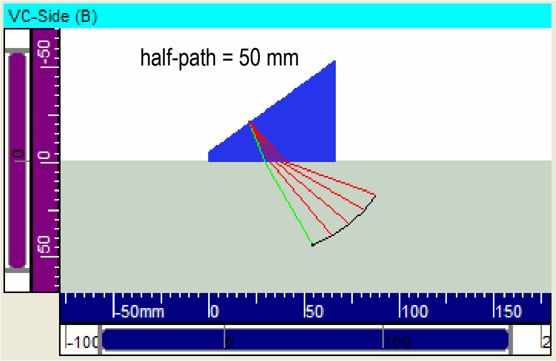


**Figure 4-25 Half-path focalization**

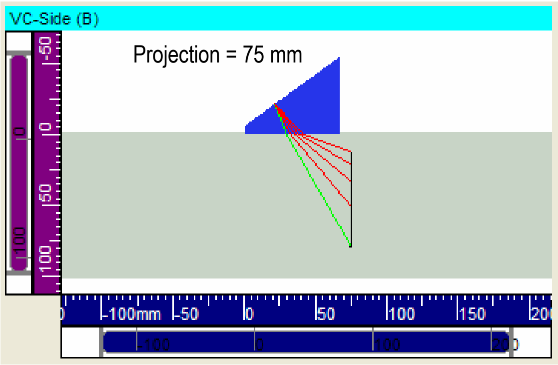


**Figure 4-26  Projection focalization**

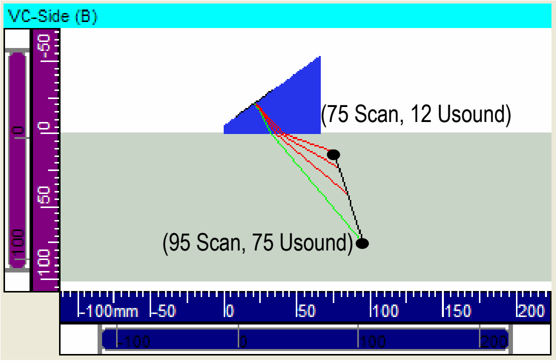


**Figure 4-27  Focal plane focalization**

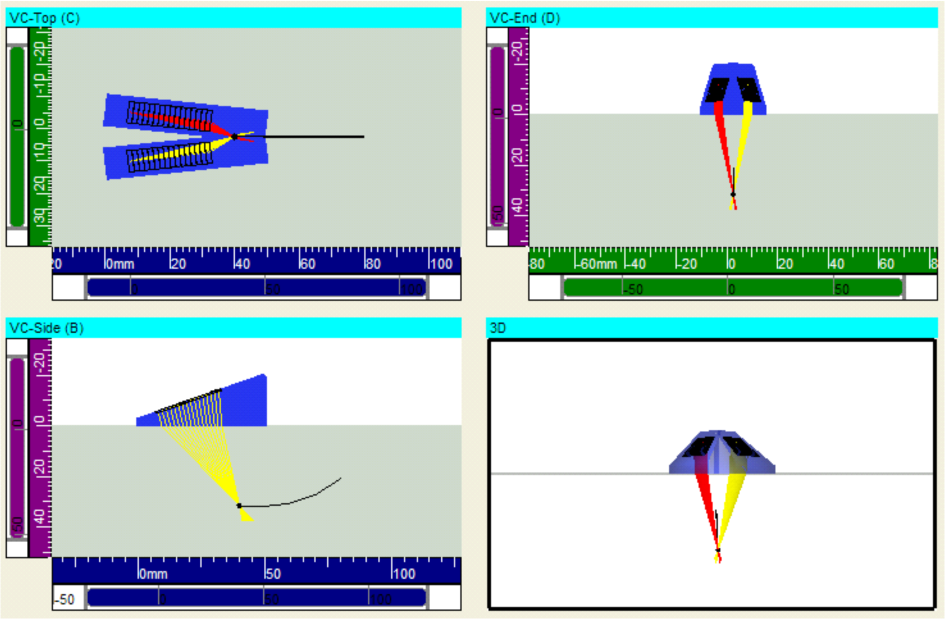


**Figure 4-28 Autofocalization for pitch-and-catch configuration**

### 4.2.5 Elements Selection Area

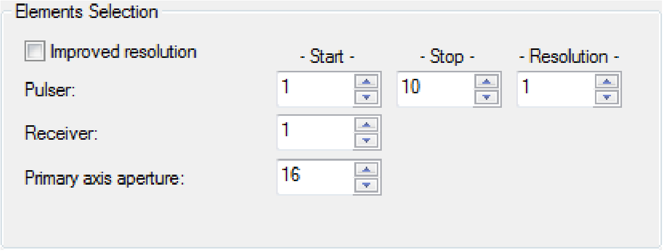


**Figure 4-29 The Elements selection area**

The **Elements Selection** area (see Figure 4-29 on page 60) contains the following:

**Improved resolution**

This check box appears when **Linear** is selected in the **Scan** area and can only be selected when the **Resolution of the Pulser** parameter is set to 1.

When the **Improved resolution** check box is selected, for each beam to be generated with the defined **Active aperture**, another beam will be generated with "**Active aperture** + 1" elements.

Therefore, the element step (**Resolution**) between two beams is reduced to 1/2 element.

**Pulser**

Sets the first element of the active pulser group.

For Linear beams: the three boxes define the elements that are used during the scan.

**Start**

Sets the first element of the first group of active elements (aperture).

**Stop**

Sets the first element of the last group of active elements (aperture).

**Resolution**

Sets the increment (in number of elements) for linear beams.

**Receiver**

Sets the first element of the active receiver group.

**Primary axis aperture**

Sets the number of elements used simultaneously to generate beams.

### 4.2.6 Connection Area


**Figure 4-30 The Connection area**

The **Connection** area (see Figure 4-30 on page 61) contains the following:

**Pulser** and **Receiver**

When using only one probe, always set the value of these parameters to 1.

Use these parameters when connecting two phased array probes to a splitter box (such as the OMNI-A-ADP05 shown in Figure 4-31 on page 62) for measurement in a symmetric configuration. In this case, you need to separately calculate the beams for each probe using the same values for all parameters of the Advanced Calculator except for the **Pulser connection** and **Receiver connection** parameters. For a given probe, the **Pulser connection** and **Receiver connection** parameters must have the same value. If you are working with 128-element probes, the value can be between 1 and 64 for the first probe and between 65 and 128 for the second probe (see Figure 4-31 on page 62).

**NOTE**

In the case of TOFD probes, you need to connect the pulser and receiver on different connectors and note the element numbers used in the respective parameters.

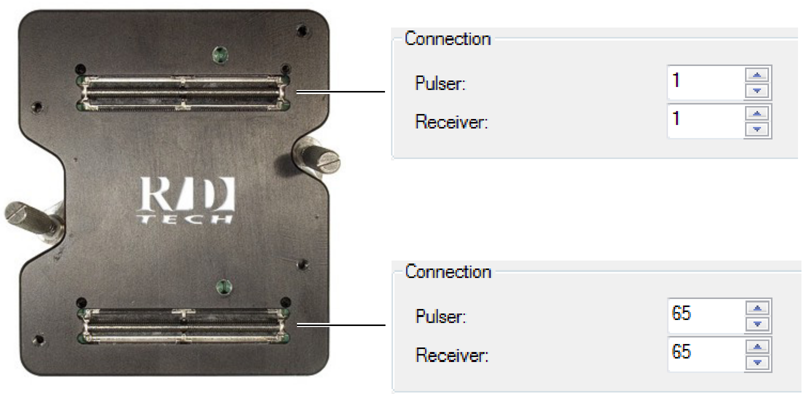


**Figure 4-31 Example of Pulser and Receiver connection parameter configuration for two 128-element probes connected to an OMNI-A-ADP05 splitter box**

## 4.2.7 Probe Area

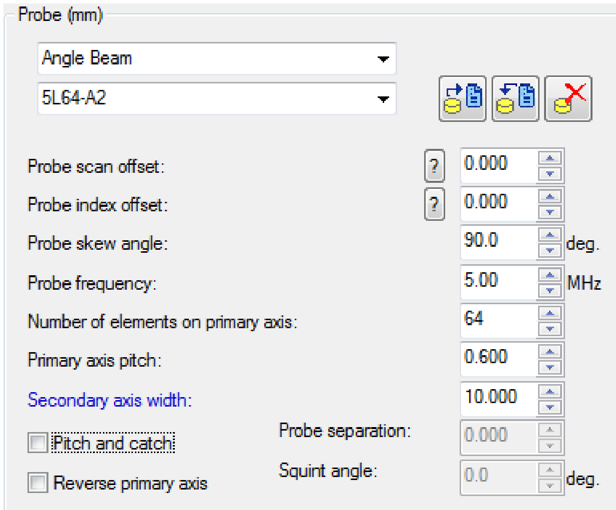


**Figure 4-32 The Probe area**

The **Probe** area contains the following (see Figure 4-32 on page 63):

**Probe** database

The drop-down combo box allows you to select a probe from the probe database.

 **Load from database** button

Allows you to load a probe configuration from the probe database.

 **Save in database** button

Allows you to save the active probe configuration in the probe database.

 **Delete from database** button

Allows you to delete a probe configuration from the probe database.

**Probe scan offset**

Defines the distance between the center of the first element and the scan-axis origin. Clicking the  button on the same line brings the information window shown in Figure 4-33 on page 64.

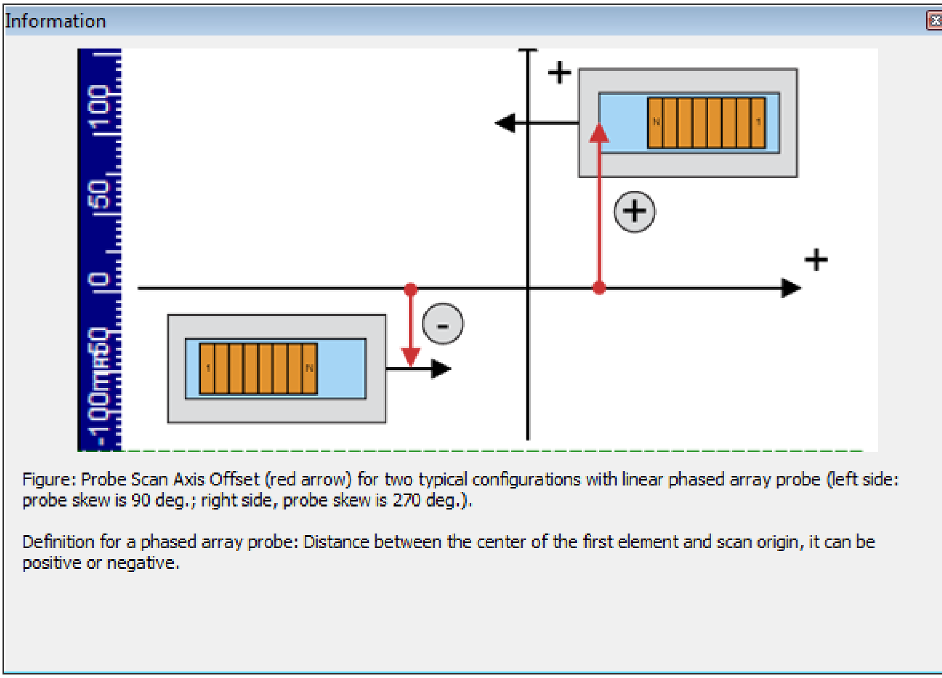


**Figure 4-33 Definition of the probe scan offset**

**Probe index offset**

Defines the distance between the front of the wedge and the index-axis origin.

Clicking ? on the same line brings the information window shown in Figure 4-34 on page 65.

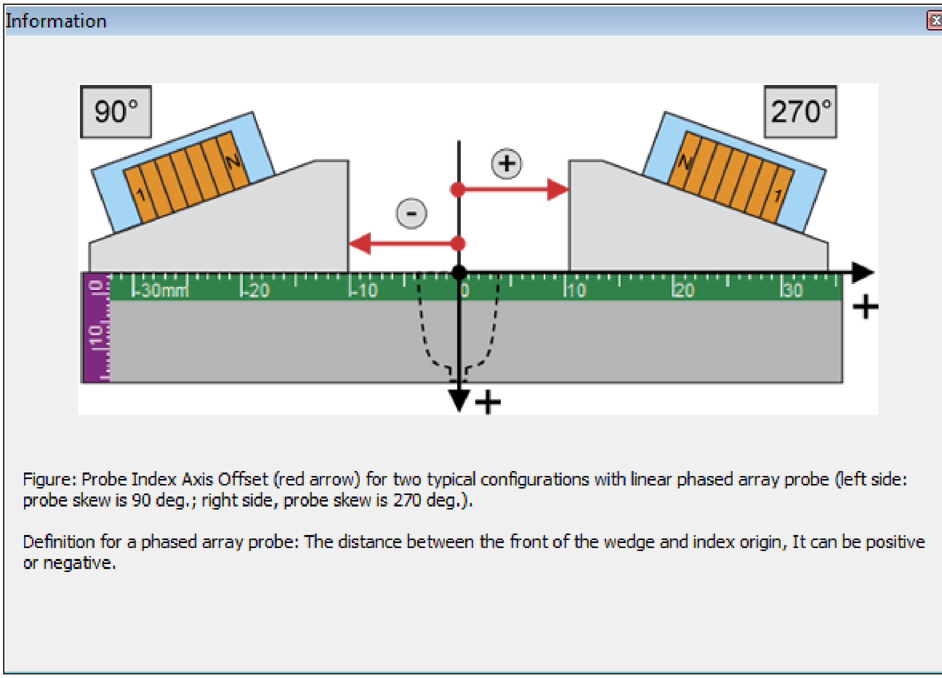


**Figure 4-34 Definition of the probe index offset**

### Probe skew angle

Defines the skew angle of the probe. The **Probe skew angle** is defined as the angle between the primary axis of the probe and the scan-axis. It can have values between 0° and 360°, and is positive when turning from the positive scan-axis towards the positive index-axis (see Figure 4-8 on page 40).

### Probe frequency

Defines the probe frequency.

### Number of elements on primary axis

Defines the number of elements on the primary axis of the current probe (see Figure 4-1 on page 36).

### Primary axis pitch

Defines the spacing (center-to-center distance) between consecutive probe elements on the primary axis of the probe (see Figure 4-1 on page 36).

**Secondary axis width**

Defines the width of the elements (see Figure 4-1 on page 36).

**Pitch and Catch**

Allows the creation of a pitch-and-catch side-by-side probe configuration.

**Reverse primary axis**

Inverts the order of the element numbers in the calculation of the beams.

**Probe separation**

Defines the spacing (center-to-center distance) between the first element of the transmitters array and the first element of the receivers array (see Figure 4-12 on page 44). This option is only applicable for pitch-and-catch configurations.

**Squint angle**

Defines the squint angle of the transmitter and the receiver array. The **Squint angle** is defined as half the angle between the primary axes of transmitter and receiver arrays. A symmetrical rotation is automatically applied to the receiving array. **Squint angle** can have values between –89.9° and 89.9°, and a positive squint angle means that the primary axes of the array cross in front of the arrays (see Figure 4-13 on page 45). Only applicable for pitch-and-catch configurations.

## 4.2.8 Part Area

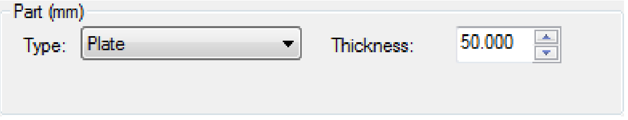


**Figure 4-35 The Part area for flat part**

The **Part** area (see Figure 4-35 on page 66) contains the following:

**Type**

Defines the part type supported by the Advanced Calculator:

**Plate:** flat part.

**Pipe OD:** cylindrical part inspected from the outside diameter.

**Pipe ID:** cylindrical part inspected from the inside diameter.

**Thickness (mm)**

Defines the thickness of the part to be displayed on the **Beam Display Info.** tab.

**Radius (mm)**

Defines the radius of the cylindrical part. For a **Pipe OD** part, this value represents the outer radius (inner radius + thickness). For **Pipe ID** part, the radius represents the inner radius.

## 4.2.9 Material Area

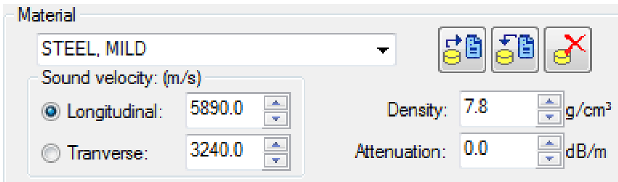


**Figure 4-36 The Material area for flat part**

**Material** database

Allows the use of the **Material** database:

 **Load from database** button

Allows you to load a material configuration from the material database.

 **Save in database** button

Allows you to save the active material configuration in the material database.

 **Delete from database** button

Allows you to delete a material configuration from the material database.

**Sound velocity** area

Defines the sound velocities in the material to be inspected for the available wave types (**Longitudinal** [compression] or **Transverse** [shear]) waves (m/s).

**Density**

Defines the density of the selected material.

**Attenuation**

Used to set the ultrasonic attenuation for the selected material.

## 4.2.10 Wedge Area

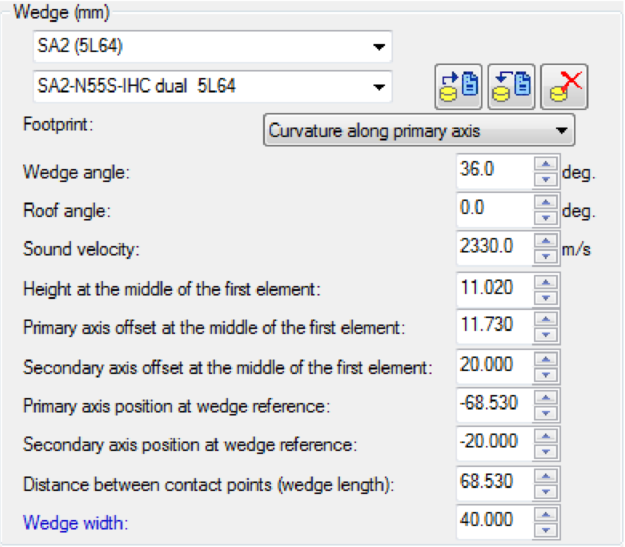


**Figure 4-37 The Wedge area**

The **Wedge** area (see Figure 4-37 on page 68) contains the following:

**Wedge** database

Allows the use of the **Wedge** database:

 **Load from database** button

Allows you to load a wedge configuration from the wedge database.

 **Save in database** button

Allows you to save the active wedge configuration in the wedge database.

 **Delete from database** button

Allows you to delete a wedge configuration from the wedge database.

**Footprint**

Defines the footprint of the wedge. For a **Plate** part, the footprint is set to **Flat**. For a cylindrical part, the footprint has to be selected from: **Curvature along primary axis** or **Curvature along secondary axis**.

**Wedge angle**

Defines the wedge angle in degrees. The **Wedge angle** is the angle between the primary axis of the probe (when it is fixed on the wedge) and the surface of the component (or the tangential plane to the surface of the component in the case of a cylindrical geometry). It is obtained by a rotation around the secondary axis of the probe, and can have values between 0° and 89.9° (see Figure 4-10 on page 42).

**Roof angle**

Defines the roof angle in degrees. The **Roof angle** is defined as the rotation angle around the primary axis of the probe, and can have values between –89.9° and 89.9°. For a probe skew of 0°, a positive roof angle will generate beams with total skew angles between 0° and 180° (see Figure 4-11 on page 43).

**Sound velocity**

Defines the sound velocity in the wedge.

**Height at the middle of the first element**

Defines the height of the middle of the first element, relative to the material surface (see Figure 4-15 on page 48).

For cylindrical part, the height is measured relative to the flat surface obtained by drawing a line between the contact points of the wedge, and is always positive (see Figure 4-16 on page 49, Figure 4-17 on page 50).

**Primary axis offset of the middle of the first element**

Defines the offset of the middle of the first element along the primary axis, relative to the back of the wedge (see Figure 4-15 on page 48). The offset is always measured along a straight line, and normally has positive values.

**Secondary axis offset of the middle of the first element**

Defines the offset of the middle of the first element along the secondary axis, relative to the left side of the wedge (see Figure 4-15 on page 48). The offset is always measured along a straight line, and normally has positive values.

**Primary axis position of wedge reference**

Defines the primary axis position of the wedge reference relative to the mechanical reference (see Figure 4-15 on page 48). The offset is always measured along the part surface and is positive along the positive scan-axis direction.

**Secondary axis position of wedge reference**

Defines the secondary axis position of the wedge reference relative to the mechanical reference (see Figure 4-15 on page 48). The offset is always measured along the part surface and is positive along the positive index-axis direction.

**Wedge length** or **Distance between contact points (wedge length)**

The **Wedge length** is defined as the actual length of the wedge.

For a cylindrical part with a curvature along primary axis, the wedge length represents the distance between the contact points of the wedge (see Figure 4-16 on page 49, Figure 4-17 on page 50).

**Wedge width** or **Distance between contact points (wedge width)**

The **Wedge width** is defined as the actual width of the wedge.

For a cylindrical part with a curvature along secondary axis, the wedge width represents the distance between the contact points of the wedge.

## 4.3 Creating a Static Beam

A **Static** beam is used to generate, with a phased array probe, an ultrasound beam similar to the one obtained by a conventional probe. The refracted angle, the focusing depth, and the primary aperture cannot be modified; they are fixed. A single beam is generated.

To illustrate the use of the calculator for creating a **Static** beam for a 1-D linear array probe, the following typical application is given as an example:

#### Example 1: single array, flat part, probe parallel to scan-axis

The following configuration is considered:

- Single 1-D linear array probe, with the following characteristics: nominal frequency 5 MHz, 32 elements, pitch 1 mm, and width of the elements 10 mm
- A Rexolite wedge with the following characteristics: wedge angle 36°, no roof angle, wedge velocity 2330 m/s, height at the middle of the first element 12 mm, primary axis offset of the first element 9 mm
- A flat carbon steel part with a wall-thickness of 50 mm
- The probe is oriented parallel to the scanning axis (skew 0°), and the rear end of the probe is positioned at 75 mm from the scan-axis reference (0-point).
- The probe generates a shear-wave beam in pulse-echo mode at a 60° refracted angle, focusing at a true-depth of 30 mm; all 32 elements of the probe are used to generate the beam.

In order to generate this **Static** beam, the input parameters must be set as shown in Figure 4-38 on page 73.

Attention should be paid to the setting of the following parameters:

- **Height of the middle of the first element:** 12 mm, as mentioned previously.
- **Primary axis offset of the first element:** 9 mm, as mentioned previously.
- **Secondary axis offset of the first element:** 15 mm, in order to position the probe in the middle of the wedge with a width of 30 mm
- Primary axis position of wedge reference: –75 mm, in order to position the rear end of the wedge at a distance of 75 mm from the scan-axis zero reference (mechanical reference point)

- Secondary axis position of wedge reference: –15 mm, in order to position the middle of the wedge at the rear end of index-axis zero reference (mechanical reference point)

Also, note that the database has been used to save probe, wedge, and material parameters (see section 10 on page 133).

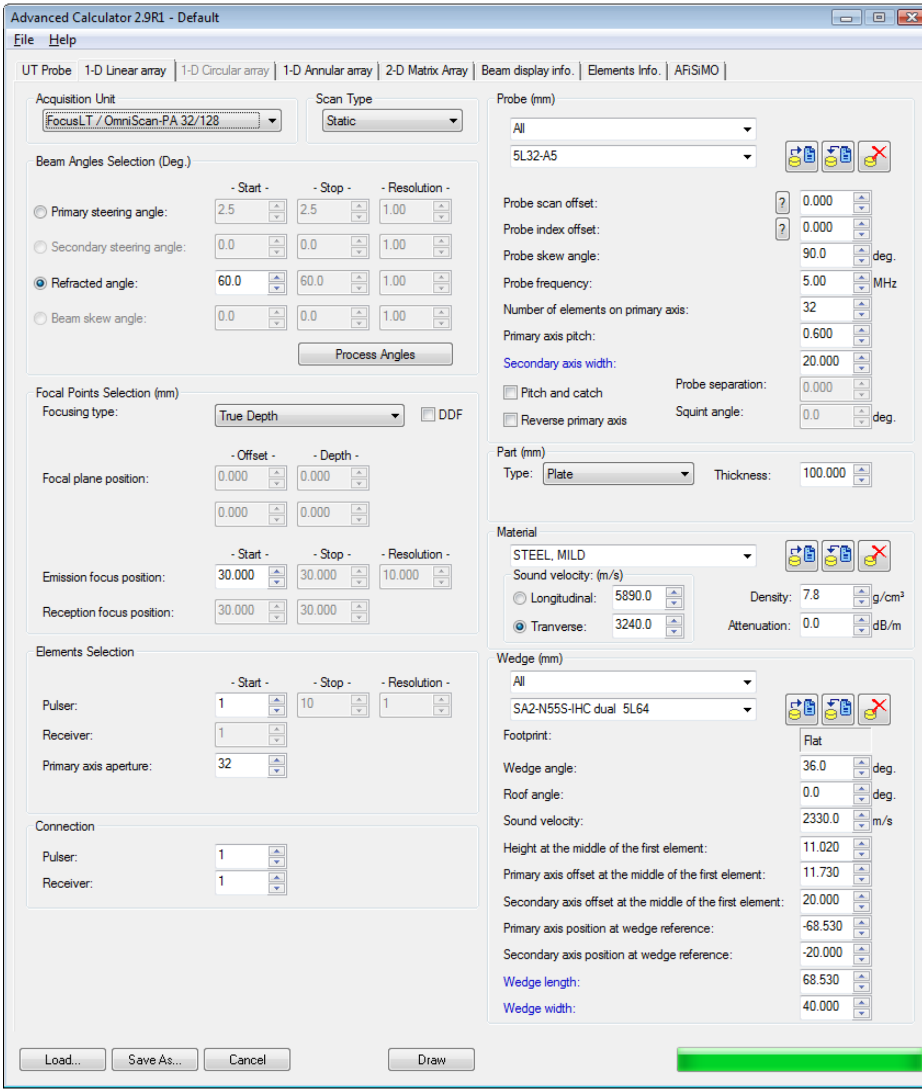


**Figure 4-38 Static Beam: input parameters**

Graphical and numerical information concerning the generated law can be found on the corresponding **Beam Display Info.** tab (see Figure 4-39 on page 74).

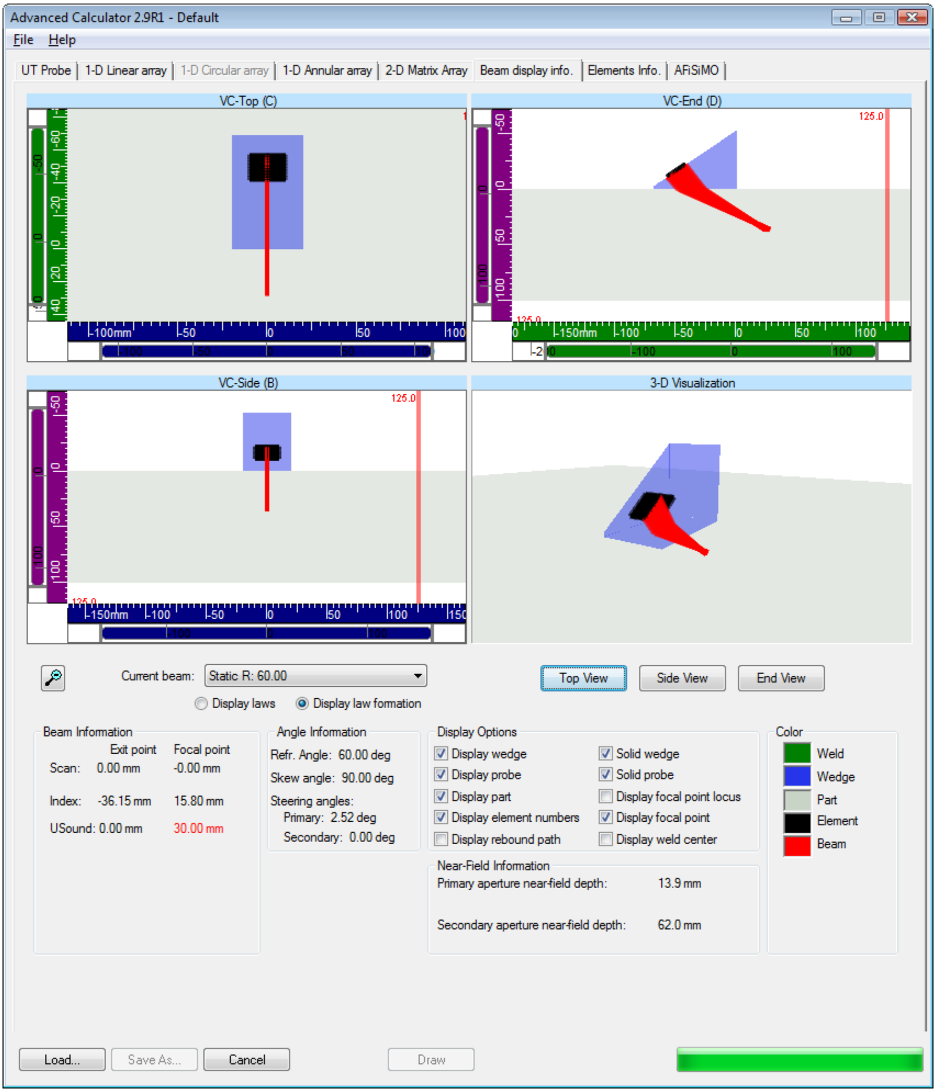


**Figure 4-39 Static beam: visualization**

## 4.4 Creating Depth Beams

**Depth** beams are used to generate, at a fixed refracted angle and with a fixed primary aperture, a set of ultrasound beams that focus at different depths.

To illustrate the use of the calculator for creating **Depth** beams for a 1-D linear array probe, the following typical application is given as an example:

#### Example 1: single array, flat part, probe perpendicular to scan-axis

The following configuration is considered:

- Single 1-D linear array probe, with the following characteristics: nominal frequency 5 MHz, 32 elements, pitch 1 mm, and width of the elements 10 mm
- A Rexolite wedge with the following characteristics: wedge angle 36°, no roof angle, wedge velocity 2330 m/s, height at the middle of the first element 12 mm, primary axis offset of the first element 9 mm
- A flat carbon steel part with a wall thickness of 100 mm
- The probe is oriented perpendicular to the scanning axis (skew 90°), and the rear end of the probe is positioned at 75 mm from the index-axis reference (0-point).
- The probe generates shear-wave beams in pulse-echo mode at a refracted angle of 45°, focusing between a true-depth distance of 20 mm to 80 mm with a depth resolution of 10 mm; all 32 elements of the probe are to be used to generate the beam.

In order to generate this set of **Depth** beams, the input parameters must be set as shown in Figure 4-40 on page 76.

Attention should be paid to the setting of the following parameters:

- **Height of the middle of the first element:** 12 mm, as mentioned previously.
- **Primary axis offset of the first element:** 9 mm, as mentioned previously.
- **Secondary axis offset of the first element:** 15 mm, in order to position the probe in the middle of the wedge with a width of 30 mm
- **Primary axis position of wedge reference:** –75 mm, in order to position the rear end of the wedge at a distance of 75 mm from the index-axis zero reference
- **Secondary axis position of wedge reference:** –15 mm, in order to position the middle of the wedge at the rear end of scan-axis zero reference

Also, note that the database has been used to save probe, wedge, and material parameters (see section 10 on page 133).

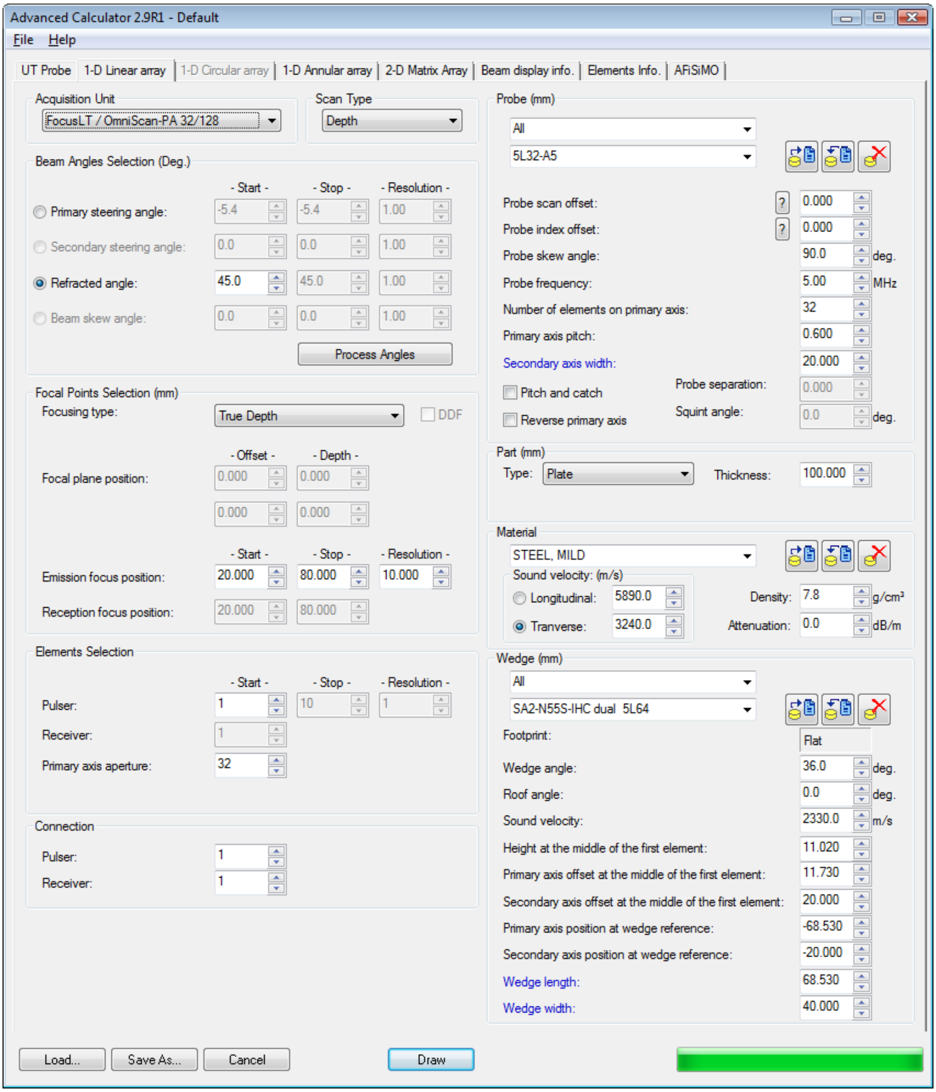


**Figure 4-40 Depth beams: input parameters**

Graphical and numerical information concerning the generated laws can be found on the corresponding **Beam Display Info.** tab (see Figure 4-41 on page 77).

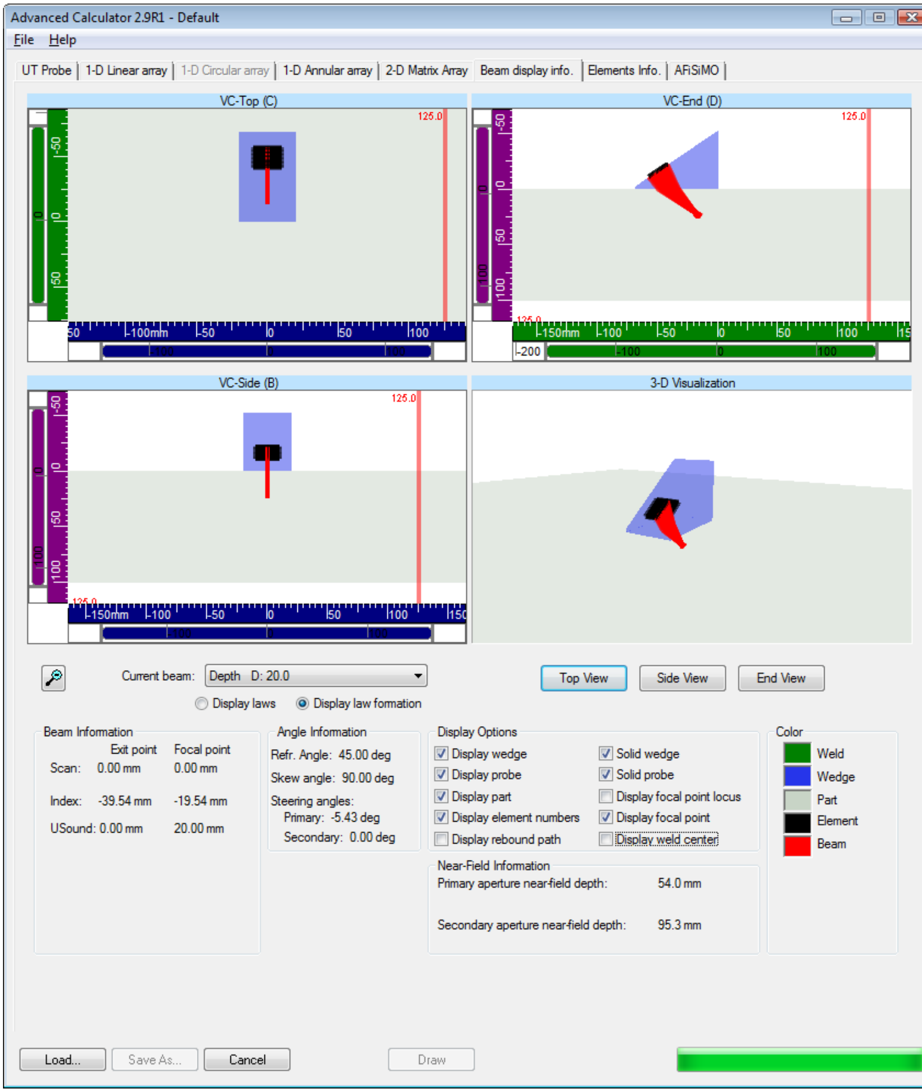


**Figure 4-41 Depth beams: visualization**

## 4.5 Creating Sectorial Beams

**Sectorial** beams are used to generate, at a fixed focusing distance and with a fixed primary aperture, a set of ultrasound beams with different inspection angles (refracted angles and/or skew angles).

To illustrate the use of the calculator for creating a set of **Sectorial** beams for 1-D linear array probes, various typical applications are given as examples.

#### Example 1: single array, flat part, probe perpendicular to scan-axis

The following configuration is considered:

- Single 1-D linear array probe, with the following characteristics: nominal frequency 5 MHz, 32 elements, pitch 1 mm, and width of the elements 10 mm
- A Rexolite wedge with the following characteristics: wedge angle 36°, no roof angle, wedge velocity 2330 m/s, height at the middle of the first element 12 mm, primary axis offset of the first element 9 mm
- A flat carbon steel part with a wall thickness of 50 mm
- The probe is oriented perpendicular to the scanning axis (skew 90°), and the rear end of the probe is positioned at 70 mm from the index-axis reference (0-point).
- The probe generates shear-wave beams in pulse-echo mode at refracted angles from 40° to 70° with a resolution of 5°, focusing at a constant half-path distance of 40 mm; all 32 elements of the probe are to be used to generate the beam.

In order to generate this set of **Sectorial** beams, the input parameters must be set as shown in Figure 4-42 on page 79.

Attention should be paid to the setting of the following parameters:

- **Height of the middle of the first element:** 12 mm, as mentioned previously.
- **Primary axis offset of the first element:** 9 mm, as mentioned previously.
- **Secondary axis offset of the first element:** 15 mm, in order to position the probe in the middle of the wedge with a width of 30 mm
- **Primary axis position of wedge reference:** –70 mm, in order to position the rear end of the wedge at a distance of 70 mm from the index-axis zero reference
- **Secondary axis position of wedge reference:** –15 mm, in order to position the middle of the wedge at the rear end of scan-axis zero reference

Also, note that the database has been used to save probe, wedge, and material parameters (see section 10 on page 133).

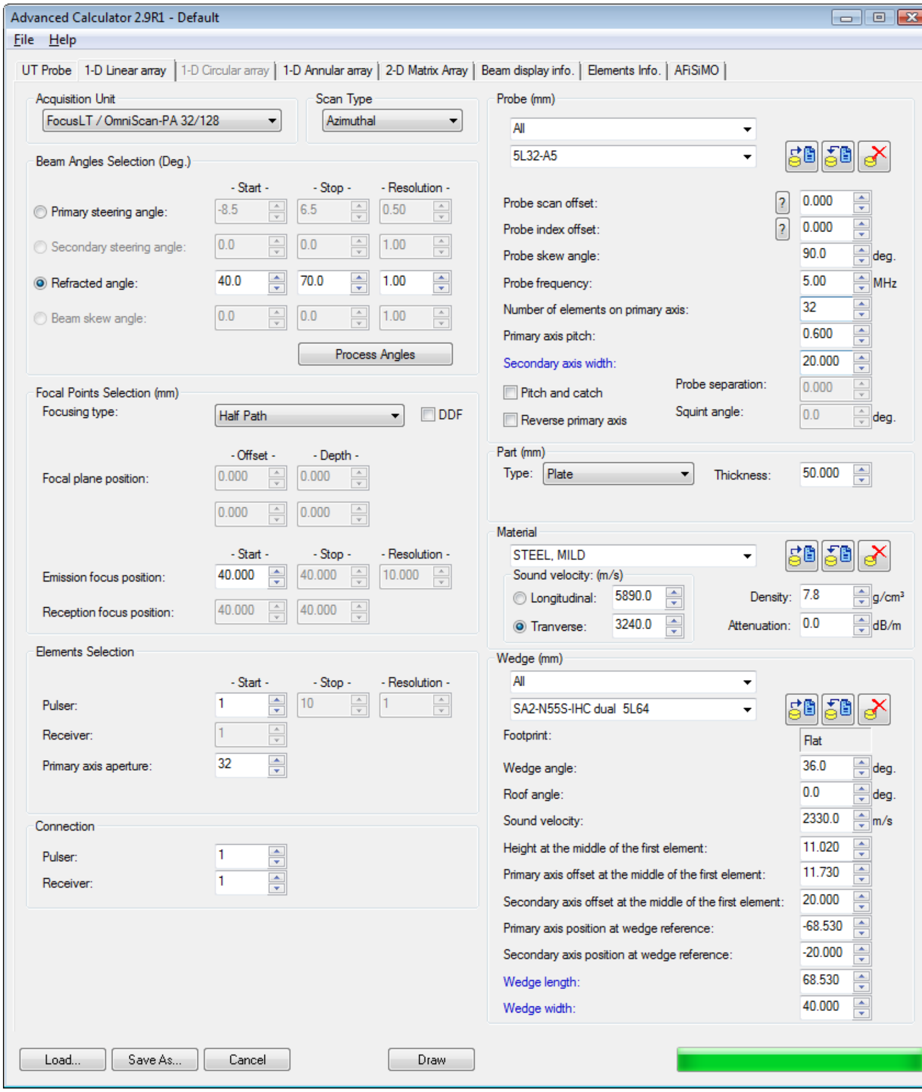


**Figure 4-42 Sectorial beams: input parameters for sectorial sweep on a flat part**

Graphical and numerical information concerning the generated laws can be found on the corresponding **Beam Display Info.** tab (see Figure 4-43 on page 80).

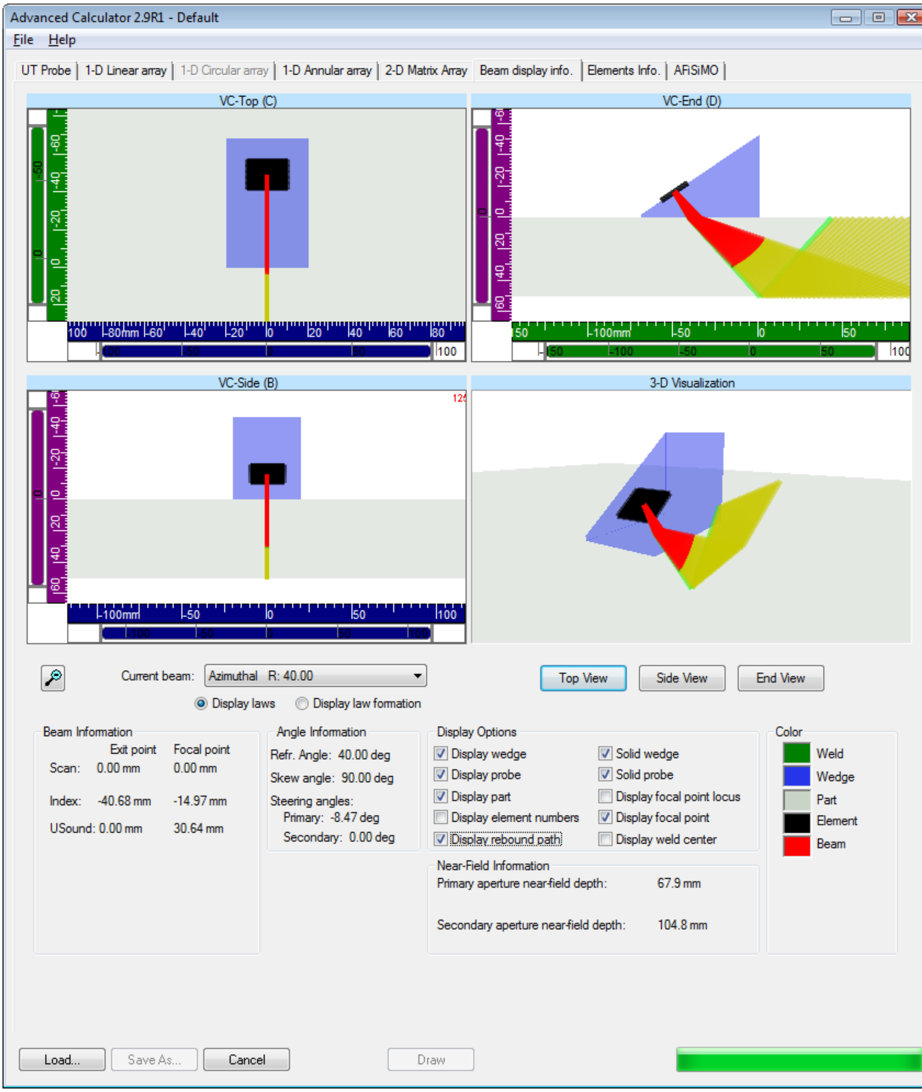


**Figure 4-43 Sectorial beams: visualization of sectorial sweep on a flat part**

#### Example 2: single array, flat part, probe parallel to scan-axis, "Lateral scan"

The following configuration is considered:

- Single 1-D linear array probe, with the following characteristics: nominal frequency 5 MHz, 32 elements, pitch 1 mm, and width of the elements 10 mm
- A Rexolite wedge with the following characteristics: no wedge angle, roof angle 31°, wedge velocity 2330 m/s, height at the middle of the first element 12 mm, primary axis offset of the first element 9 mm
- A flat carbon steel part with a wall-thickness of 50 mm
- The probe is used to generate shear-wave beams at refracted angles of approximately 45°, skewed from at least –30° to +30° relative to the orientation perpendicular to the scan-axis, and focusing at a constant depth of 35 mm; all 32 elements of the probe are to be used to generate the beams.
- The probe itself is oriented parallel to the scanning axis (skew 0°), and the probe is positioned so that the focal points coincide approximately with the index-axis reference (0-point), and that the centre beam is aimed at the scan-axis reference.
- This type of configuration is often called a "lateral scan" mode, and can be used to improve detection of misoriented (skewed) flaws.

In order to generate this set of sectorial beams, the input parameters must be set as shown in Figure 4-44 on page 82.

Attention should be paid to the following parameters:

- The beam angles are selected using the **Primary steering angle** as the input parameter. In the case of a lateral scan with a linear array probe, this is the most efficient way to define the angles, since the refracted angle changes from 53.4° down to 45.6° and back to 53.4°.
- **Height of the middle of the first element:** 12 mm, as mentioned previously.
- **Primary axis offset of the first element:** 9 mm, as mentioned previously.
- **Secondary axis offset of the first element:** 15 mm, in order to position the probe in the middle of the wedge with a width of 30 mm
- **Primary axis position of wedge reference:** –25 mm, in order to position the centre beam focal point end at the scan-axis reference
- **Secondary axis position of wedge reference:** –60 mm, in order to position the focal point locus at the index-axis reference

Also, note that the database has been used to save probe, wedge, and material parameters (see section 10 on page 133).

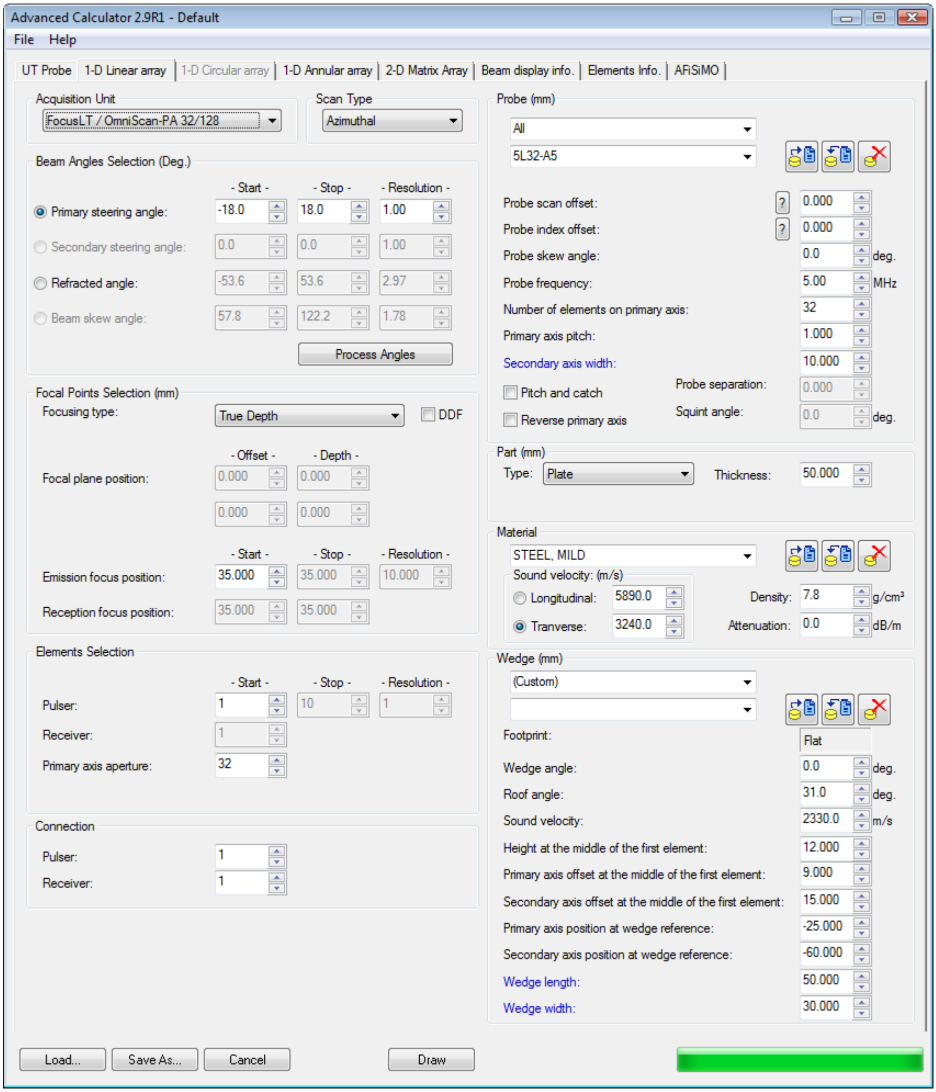


**Figure 4-44 Sectorial beams: input parameters for "Lateral scan" on a flat part**

Graphical and numerical information concerning the generated laws can be found on the corresponding **Beam Display Info.** tab (see Figure 4-45 on page 83).


**Figure 4-45 Sectorial beams: visualization of “lateral scan” on a flat part**

## Example 3: dual array, flat part, probe parallel to scan-axis

The following configuration is considered:

- Dual 1-D linear array probe (pitch-and-catch), with the following characteristics: nominal frequency 2.25 MHz, 2 × 16 elements, pitch 1.7 mm, width of the elements 6.6 mm
- The probe contains two identical Rexolite wedges with the following characteristics: wedge angle 19.2°, roof angle 4.7°, wedge velocity 2330 m/s, height at the middle of the first element 5.4 mm, primary axis offset of the first element 7.9 mm; probe separation 15 mm, squint angle 6°
- A flat carbon steel part with a wall-thickness of 50 mm
- The probe is oriented parallel to the scanning axis (skew 0°), and the rear end of the probe is positioned at 50 mm from the scan-axis reference (0-point).
- The probe generates compression wave beams in pitch-and-catch mode at refracted angles from 45° to 70° with a resolution of 5°; all 16 elements of the transmitter and receiver arrays are used to generate the beams. The focalization depth is automatically calculated to focus the transmitter and the receiver at the same position. The focalization is therefore made at the geometrical intersection of the transmitter and the receiver.

In order to generate this set of sectorial beams, the input parameters must be set as shown in Figure 4-46 on page 85.

Attention should be paid to the setting of the following parameters:

- **Height of the middle of the first element:** 5.4 mm, as mentioned previously.
- **Primary axis offset of the first element:** 7.9 mm, as mentioned previously.
- **Secondary axis offset of the first element:** 5 mm, in order to position the probe in the middle of the wedge with a width of 10 mm
- **Primary axis position of wedge reference:** –50 mm, in order to position the rear end of the wedge at a distance of 50 mm from the scan-axis zero reference
- Secondary axis position of wedge reference: –12.5 mm, in order to position the symmetrical line between the transmitter and the receiver array at the index-axis zero reference

Also, note that the database has been used to save probe, wedge, and material parameters (see section 10 on page 133).

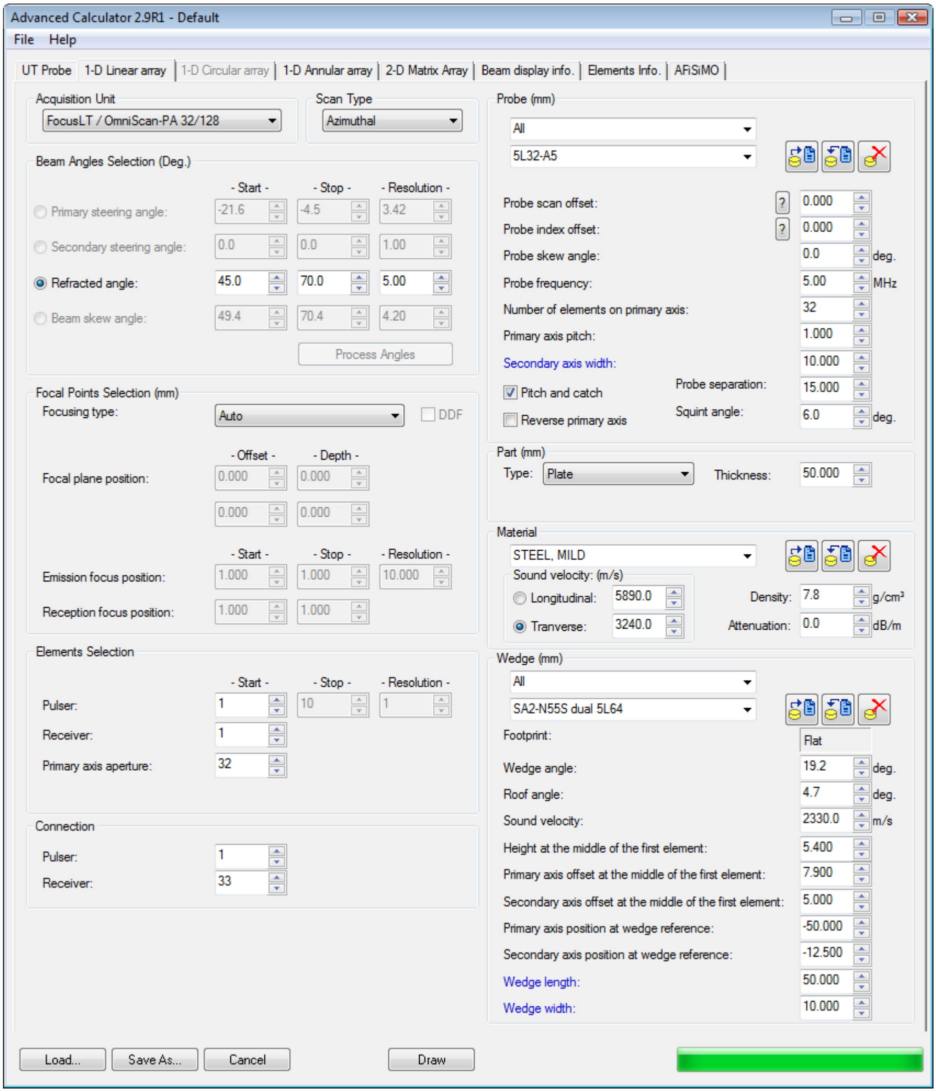


**Figure 4-46 Sectorial beams: input parameters for a pitch-and-catch configuration**

Graphical and numerical information concerning the generated laws can be found on the corresponding **Beam Display Info.** tab (see Figure 4-47 on page 86).

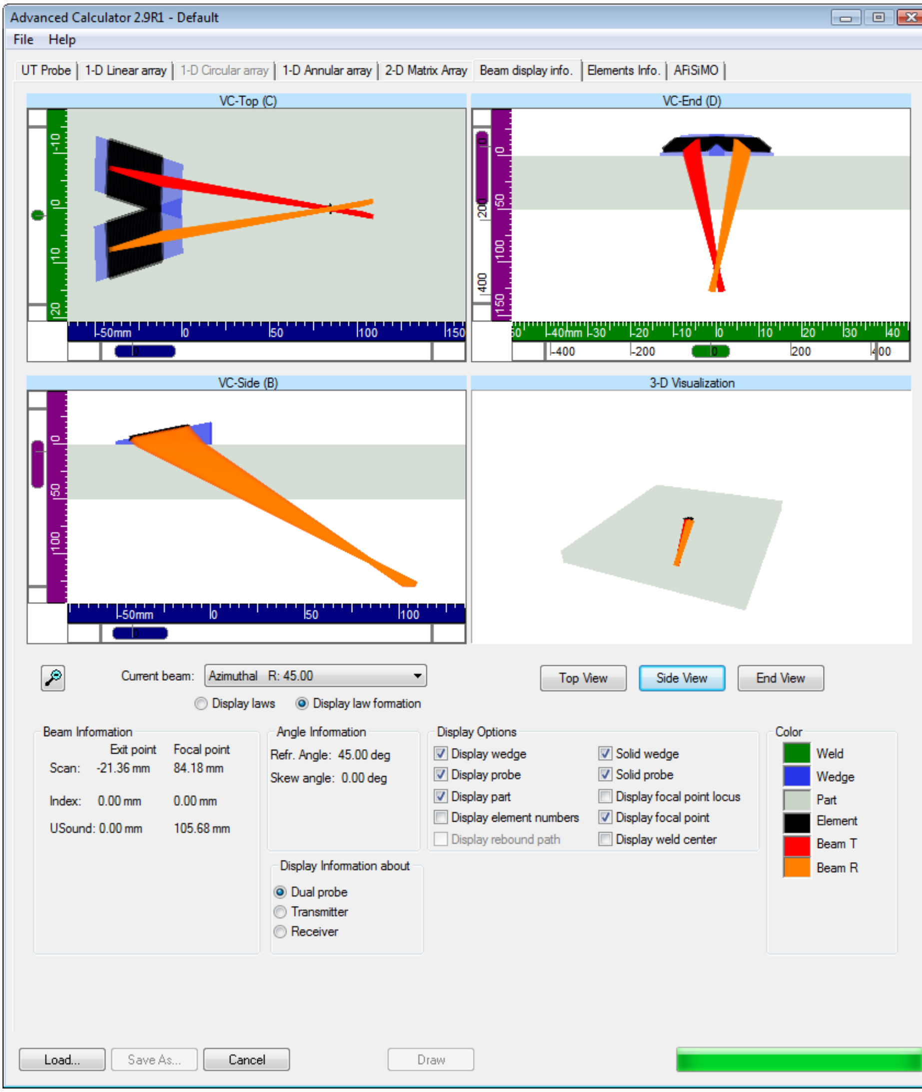


**Figure 4-47 Sectorial beams: visualization of a pitch-and-catch configuration**

#### Example 4: single array, pipe OD, probe perpendicular to pipe axis

## The following configuration is considered:

- Single 1-D linear array probe, with the following characteristics: nominal frequency 5 MHz, 32 elements, pitch 1 mm, and width of the elements 10 mm
- A Rexolite wedge with the following characteristics: wedge angle 36°, no roof angle, wedge velocity 2330 m/s, height at the middle of the first element 9 mm, primary axis offset of the first element 7 mm, curvature along primary axis, distance between contact points 80 mm
- A pipe inspected from the outside diameter (Pipe OD) in carbon steel with an outside radius of 150 mm and a wall-thickness of 25 mm
- The probe is oriented parallel to the scanning axis (skew 0°) and perpendicular to the pipe axis. The rear end of the probe is positioned at 40 mm from the scan-axis reference (0-point).
- The probe generates shear-wave beams in pulse-echo mode at refracted angles from 35° to 55° with a resolution of 5°, focusing at a constant cylindrical depth of 25 mm (focusing on the back wall of the pipe); all 32 elements of the probe are to be used to generate the beam.

In order to generate this set of sectorial beams, the input parameters must be set as shown in Figure 4-48 on page 88.

Attention should be paid to the setting of the following parameters:

- **Height of the middle of the first element:** 9 mm, as mentioned previously.
- **Primary axis offset of the first element:** 7 mm, as mentioned previously.
- **Secondary axis offset of the first element:** 20 mm, in order to position the probe in the middle of the wedge with a width of 40 mm
- **Primary axis position of wedge reference:** –40 mm, in order to position the rear end of the wedge at a distance of 40 mm from the scan-axis zero reference, and to position the centre of the pipe at the scan-axis zero reference
- **Secondary axis position of wedge reference:** –20 mm, in order to position the middle of the wedge at the index-axis zero reference

Also, note that the database has been used to save probe, wedge, and material parameters (see section 10 on page 133).

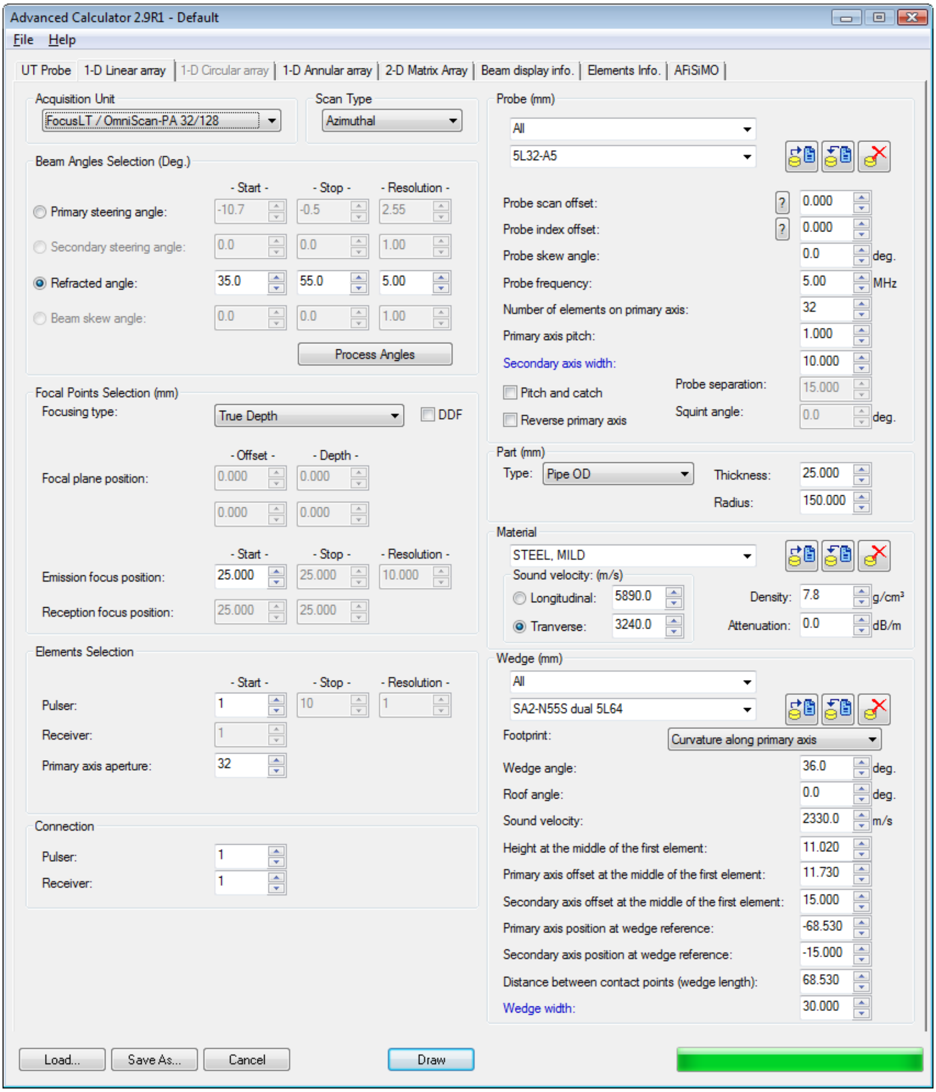


**Figure 4-48 Sectorial beams: input parameters for sectorial sweep on a pipe part**

Graphical and numerical information concerning the generated laws can be found on the corresponding **Beam Display Info.** tab (see Figure 4-49 on page 89).

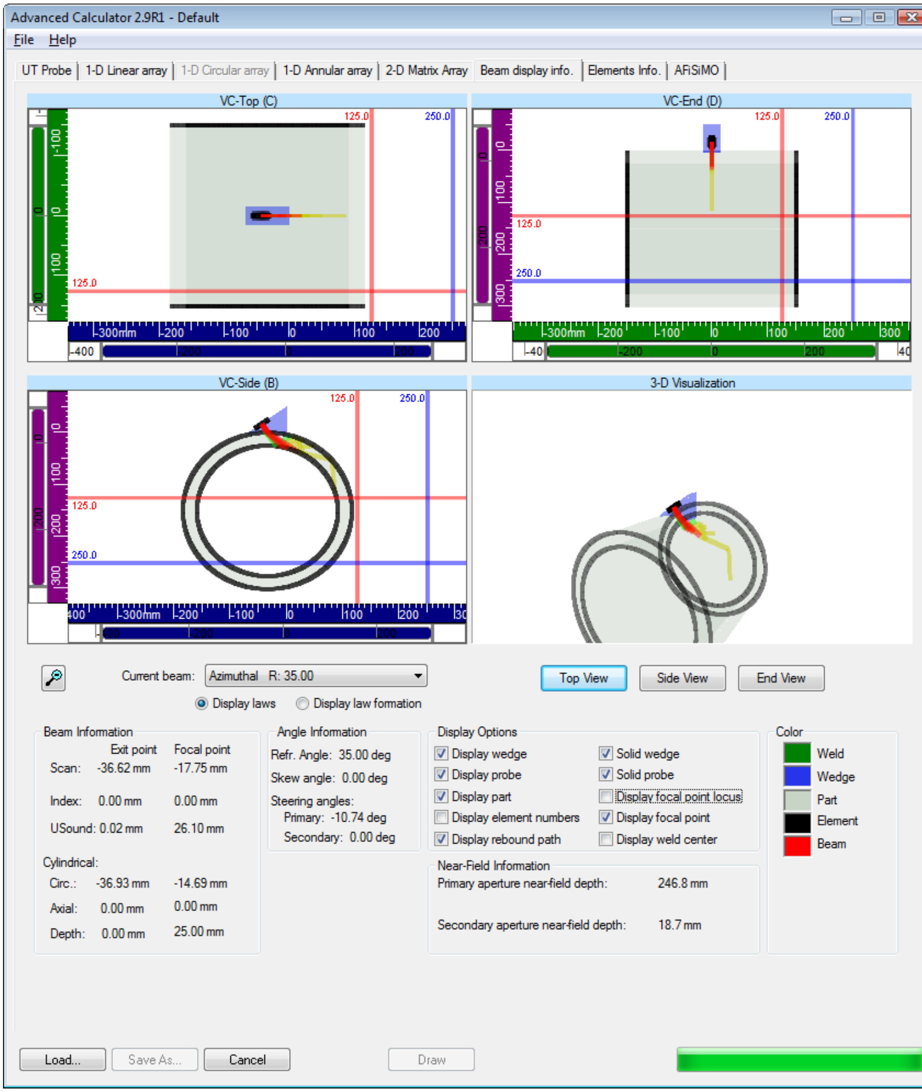


**Figure 4-49 Sectorial beams: visualization of sectorial sweep on a pipe part**

## 4.6 Creating Linear Beams

Linear beams are used to generate ultrasonic beams at a fixed refracted angle and a fixed focusing distance, but with a primary aperture traveling along the array, thus generating the same beams with a different set of active elements. By moving the beam along a transducer array, the scanning along an inspection axis is realized electronically without any need to physically displace the transducer (see Figure 4-50 on page 90).

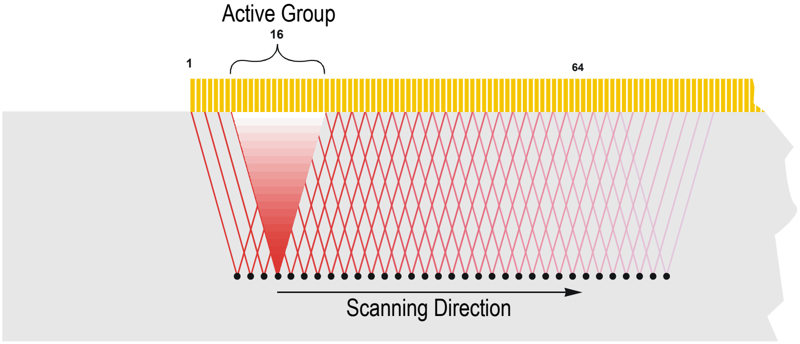


**Figure 4-50 Electronic scanning along an axis**

To illustrate the use of the calculator for creating Linear beams for a 1-D linear array probe, the following typical application is given as an example.

### Example 1: single array, flat part, probe perpendicular to scan-axis

The following configuration is considered:

- Single 1-D linear array probe, with the following characteristics: nominal frequency 5 MHz, 64 elements, pitch 1 mm, and width of the elements 10 mm
- A Rexolite wedge with the following characteristics: wedge angle 36°, no roof angle, wedge velocity 2330 m/s, height at the middle of the first element 12 mm, primary axis offset of the first element 9 mm
- A flat carbon steel part with a wall-thickness of 50 mm
- The probe is oriented perpendicular to the scanning axis (skew 90°), and the rear end of the probe is positioned at 100 mm from the index-axis reference (0-point).

- The probe generates shear-wave beams in pulse-echo mode at a refracted angle of 55°, focusing at a constant half-path distance of 50 mm. 16 elements of the probe are used to generate the beams.

In order to generate this set of **Linear** beams, the input parameters must be set as shown in Figure 4-51 on page 92.

Attention should be paid to the setting of the following parameters:

- **Height of the middle of the first element:** 12 mm, as mentioned previously.
- **Primary axis offset of the first element:** 9 mm, as mentioned previously.
- **Secondary axis offset of the first element:** 15 mm, in order to position the probe in the middle of the wedge with a width of 30 mm
- **Primary axis position of wedge reference:** –100 mm, in order to position the rear end of the wedge at a distance of 100 mm from the index-axis zero reference
- **Secondary axis position of wedge reference:** –15 mm, in order to position the middle of the wedge at the rear end of scan-axis zero reference

Also, note that the database has been used to save probe, wedge, and material parameters (see section 10 on page 133).

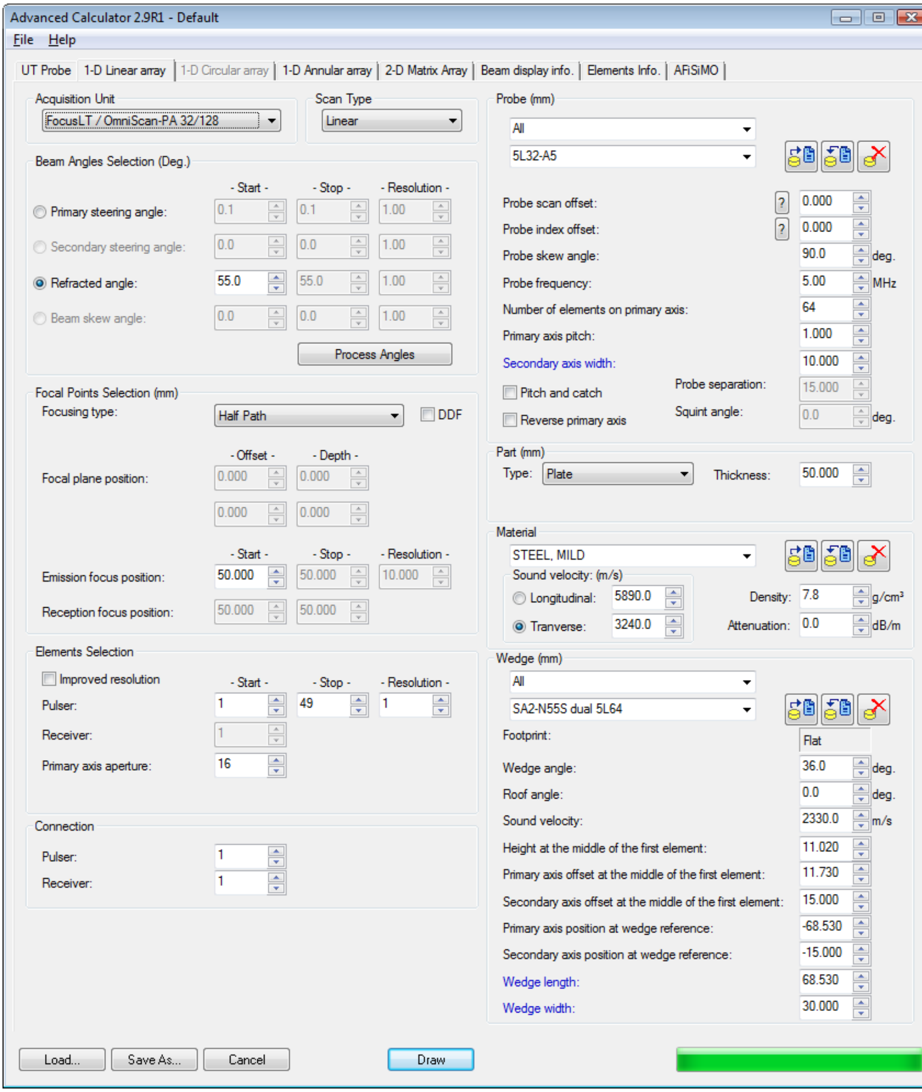


**Figure 4-51 Linear beams: input parameters**

Graphical and numerical information concerning the generated laws can be found on the corresponding **Beam Display Info.** tab (see Figure 4-52 on page 93).

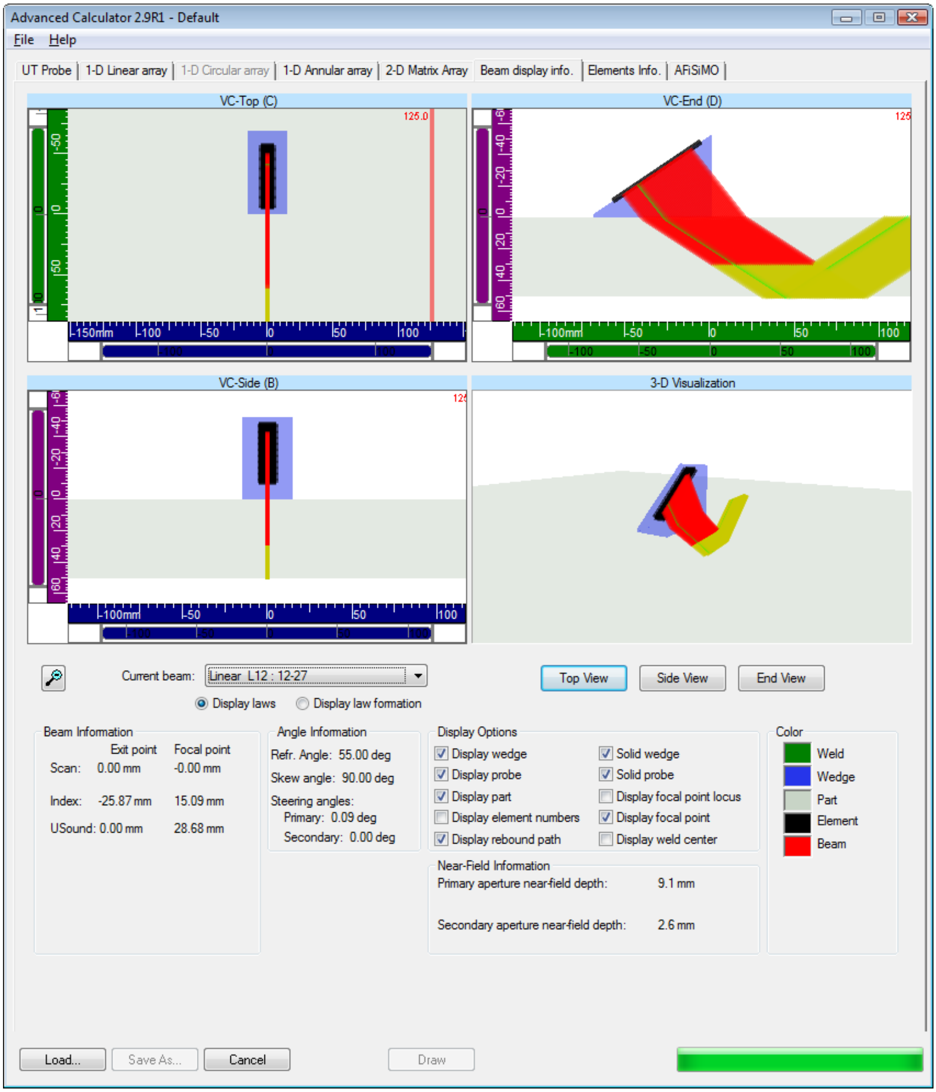


**Figure 4-52 Linear beams: visualization**

# 4.7 Saving a Calculator Setup File (.xcal)

## To save a calculator setup file (.xcal)

1. Enter the parameters of the beams to be generated.
2. On the menu, select **File > Save As** or click **Save As** at the bottom of the Advanced Calculator dialog box.
3. In the **Save As** dialog box:
   *a)* Select the folder where you want to save the .xcal file.
   *b)* Enter an appropriate file name.
   *c)* In the **Save as type** drop-down box, select **Extended Calculator Setup Files (*.xcal)**.
   *d)* Click **Save** (see Figure 4-53 on page 94).

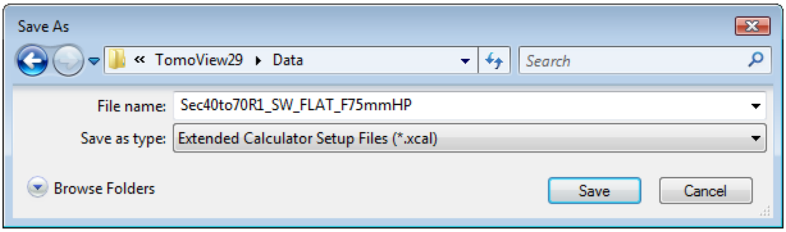


**Figure 4-53  The Save As dialog box**

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**NOTE**

The Calculator Setup File contains only the parameter values and settings entered in the Advanced Calculator; it does not contain the generated beams (the delays to be programmed in the instrument).

---

## 4.8 Saving a Beam File (.law)

You can import the beam configuration created with the Advanced Calculator into an OmniScan. This is done by first saving the Advanced Calculator configuration to a beam file (.law), and then importing the beam file into the OmniScan.

### To save a beam file (.law)

1. Enter the parameters of the beams to be generated
2. On the menu, select **File > Save As** or click **Save As** at the bottom of the Advanced Calculator dialog box.
3. In the **Save As** dialog box:
   *a)* Select the folder where the .law file has to be saved.
   *b)* Enter an appropriate file name.
   *c)* In the **Save as type** drop-down box, select **Law Files (*.law)**.
   *d)* Click **Save** (see Figure 4-54 on page 95).

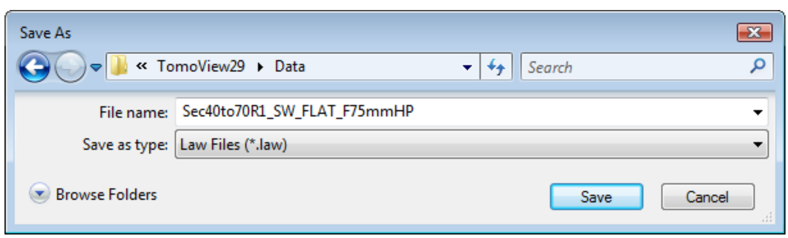


**Figure 4-54 The Save As dialog box**

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**NOTE**

If you try to save a .law file containing DDF beams, a message box appears, mentioning that DDF law files are not supported. You need to save DDF beams in a .pac file format (for details, see section 4.10 on page 100).

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## 4.9 Creating a DDF Law

**DDF** beams are used to generate an ultrasonic beam that has the capability to dynamically change the focusing depth of the received signals (see Appendix B on page 143), allowing a better depth resolution than standard focusing.

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**NOTE**

DDF is supported by all FOCUS LT models as well as by OmniScan instruments equipped of a 32:128 PA module and connected TomoView.

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It is important to notice that DDF can only give the expected result if the requested focal point is before the natural focal point determined by the frequency and by the effective aperture of the probe. Information concerning the **Primary Aperture Near-field Depth** and the **Secondary Aperture Near-field Depth** displayed on the **Element Info** tab can be used to correctly determine the focalization range on which DDF beams can be adequately used.

To illustrate the use of the calculator for creating a DDF beam for a 1-D linear array probe, the following typical application is given as an example.

#### Example 1: single array, flat part, probe perpendicular to scan-axis

- Single 1-D linear array probe, with the following characteristics: nominal frequency 5 MHz, 32 elements, pitch 1 mm, and width of the elements 10 mm
- A Rexolite wedge with the following characteristics: wedge angle 36°, no roof angle, wedge velocity 2330 m/s, height at the middle of the first element 12 mm, primary axis offset of the first element 9 mm
- A flat carbon steel part with a wall-thickness of 100 mm
- The probe is oriented perpendicular to the scanning axis (skew 90°), and the rear end of the probe is positioned at 70 mm from the index-axis reference (0-point).
- The probe generates shear-wave beams in pulse-echo mode at a refracted angle of 40°, focusing in emission at a true-depth distance of 50 mm and in reception between a true-depth distance of 10 mm to 90 mm; all 32 elements of the probe are to be used to generate the beam.

In order to generate this set DDF beam, the input parameters must be set as shown in Figure 4-55 on page 98.

Attention should be paid to the setting of the following parameters:

- **Height of the middle of the first element:** 12 mm, as mentioned previously.
- **Primary axis offset of the first element:** 9 mm, as mentioned previously.
- **Secondary axis offset of the first element:** 15 mm, in order to position the probe in the middle of the wedge with a width of 30 mm
- **Primary axis position of wedge reference:** –70 mm, in order to position the rear end of the wedge at a distance of 70 mm from the index-axis zero reference
- **Secondary axis position of wedge reference:** –15 mm, in order to position the middle of the wedge at the rear end of scan-axis zero reference

Also, note that the database has been used to save probe, wedge, and material parameters (see section 10 on page 133).

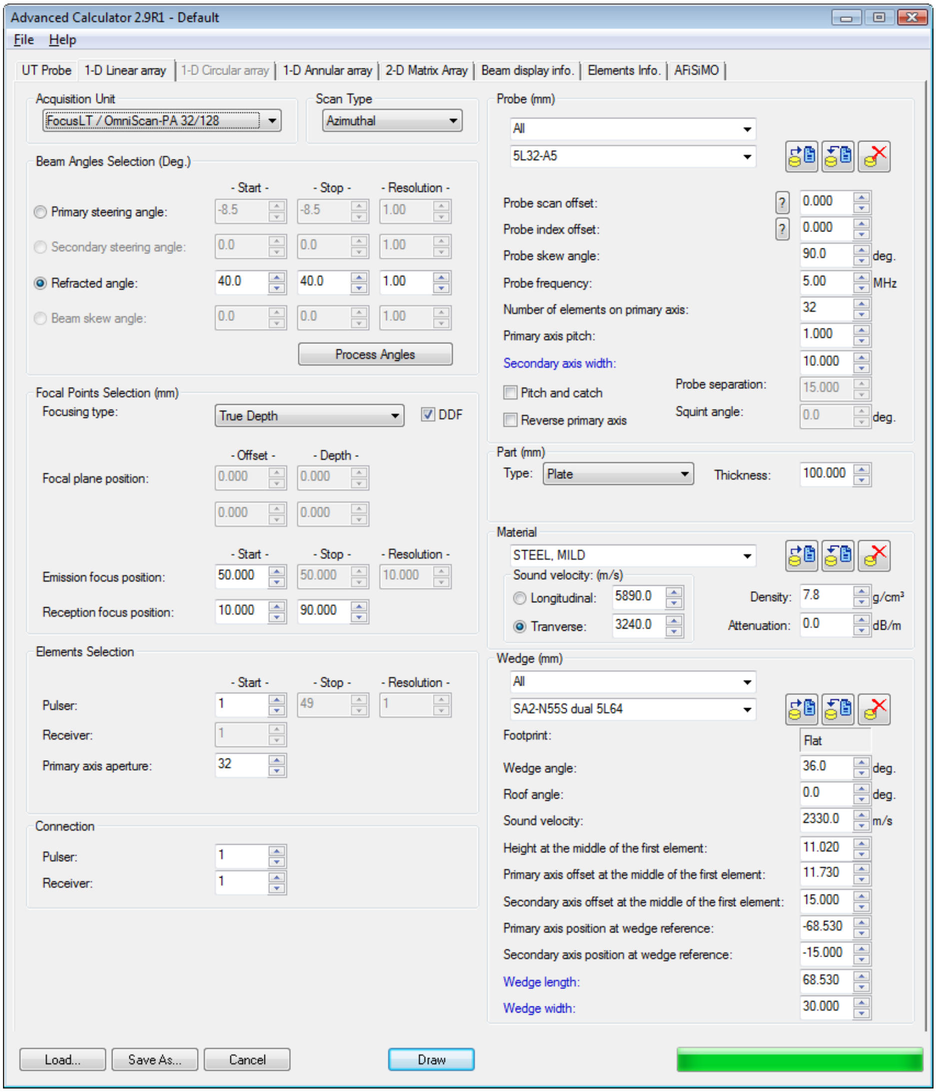


**Figure 4-55 DDF beam: input parameters**

Graphical and numerical information concerning the generated law can be found on the corresponding **Beam Display Info.** tab (see Figure 4-56 on page 99).

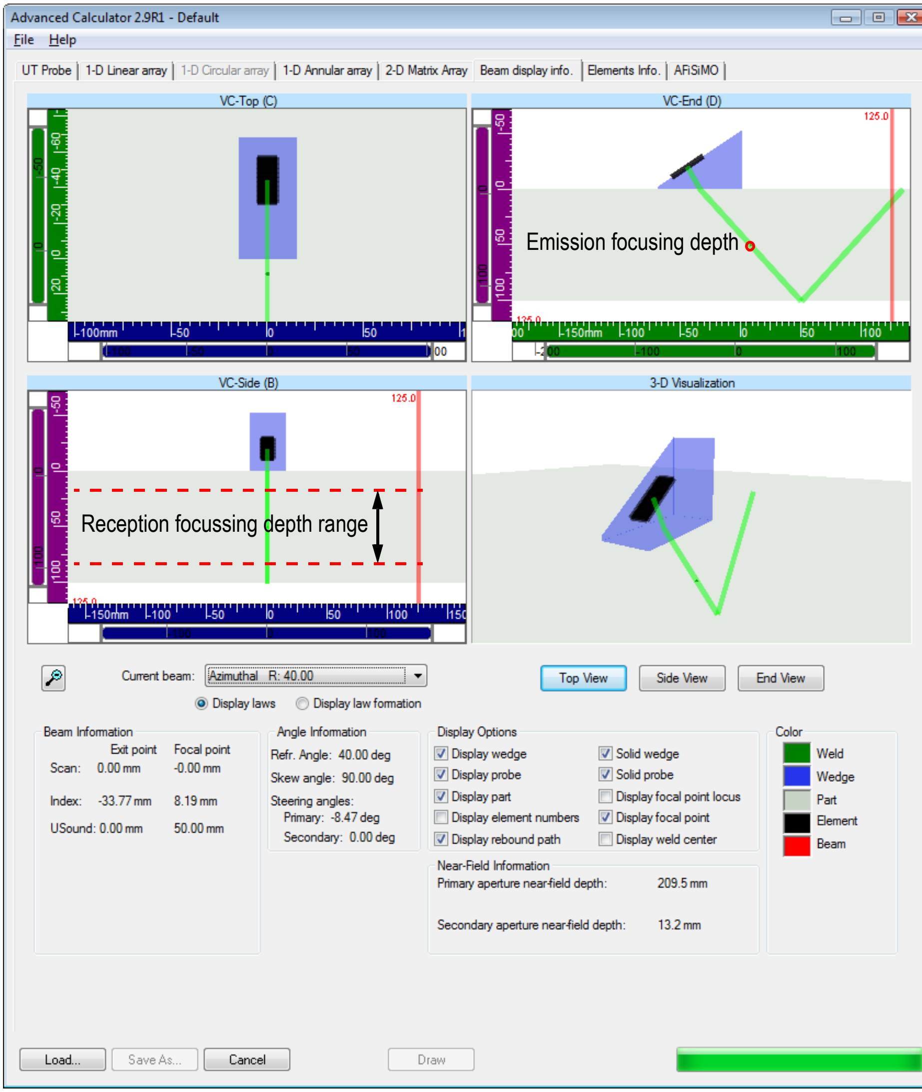


**Figure 4-56 DDF beam: visualization**

## 4.10 Saving a DDF Law File (.pac)

### To save a DDF law file (.pac)

1. Enter the parameters of the beams to be generated
2. On the menu, select **File > Save As** or click **Save As** at the bottom of the Advanced Calculator dialog box.
3. In the **Save As** dialog box:
   *a)* Select the folder where you want to save the .pac file.
   *b)* Enter an appropriate file name.
   *c)* In the **Save as type** drop-down box, select **Phased Array Control files (*.pac)**.
   *d)* Click **Save** (see Figure 4-57 on page 100).

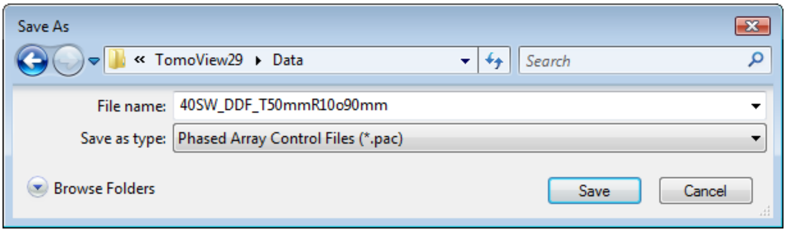


**Figure 4-57 The Save As dialog box**

# 5. The 1-D Annular Arrays Tab

This section presents the 1-D annular arrays and describes the **1-D Annular array** tab.

## 5.1 Generic Conventions

To generate beams for 1-D annular arrays in the most efficient and accurate way, the operator should take into account the generic conventions regarding the probe wedge.

### 5.1.1 Conventions Related to the Probe

#### Fresnel annular array

When a Fresnel type annular array is used, only the **First radius ($R_1$)** and the **Spacing between elements (S)** (see section 5.2.6 on page 109) must be specified. Based on these values, the internal and external radiuses of the successive elements are calculated according to the following formula:

$$R_1^2 = R_1^{ext^2} - R_1^{int^2} = R_N^{ext^2} - R_N^{int^2}$$

A Fresnel type annular array is characterized by the fact that all elements have the same surface (same area) and are separated by a constant distance (see Figure 5-1 on page 102).

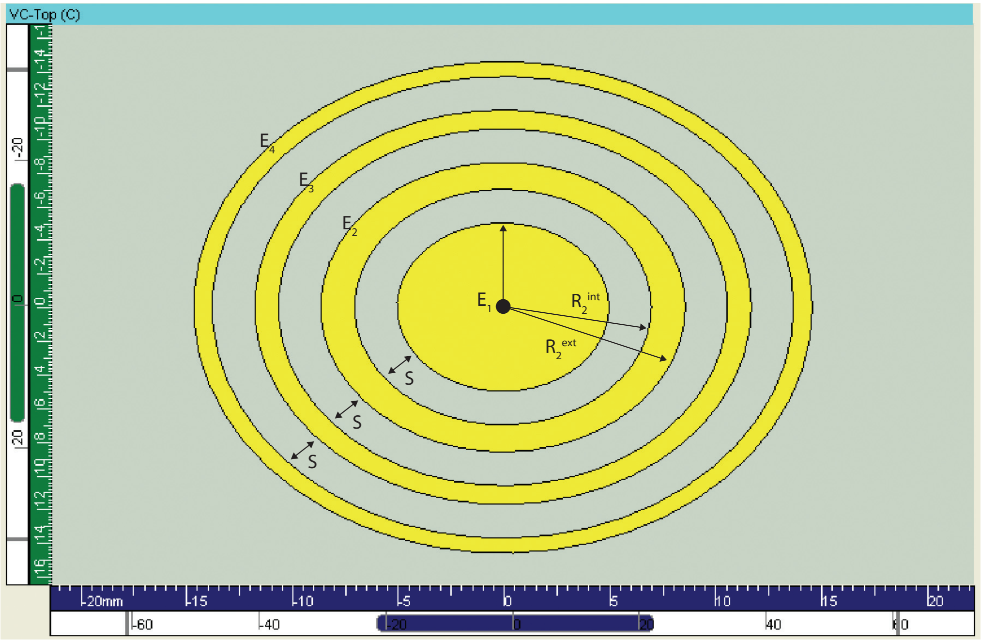


**Figure 5-1 Fresnel annular array**

The central element is always positioned at the zero point of the scan-axis and of the index-axis.

## Custom annular array

When a **Custom** type annular array is used the *internal radius* ($R_n^{int}$) and the *external radius* ($R_n^{ext}$) of each element must be specified (see **Probe** area). Based on these values, the distance between each element is calculated.

A **Custom** type annular array can have different radii and a variable spacing between consecutive elements (see Figure 5-2 on page 103).

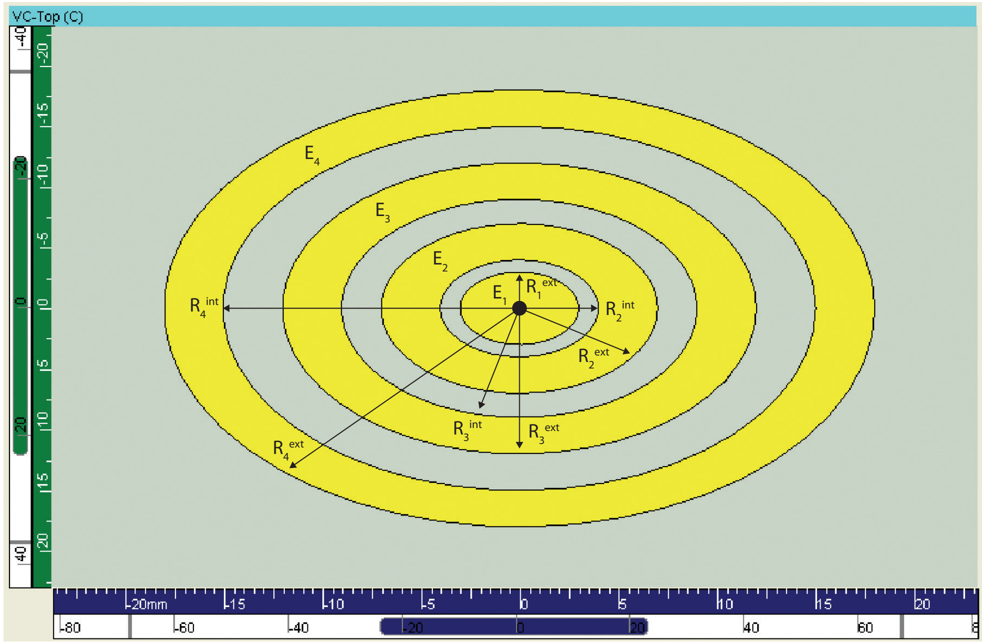


**Figure 5-2 Custom annular array**

The central element is always positioned at the 0-point in scan and in index.

### 5.1.2 Important Remark Concerning the Delay Calculation

For both **Fresnel** type and **Custom** type annular arrays, the delay for each element is calculated at the radius $R_i^{calc}$, for which the following statement is true: half of the surface of the element is within this radius and half of the surface of the element is outside of this radius. Mathematically, this is expressed as follows:

$$R_i^{ext^2} - R_i^{calc^2} = R_i^{calc^2} - R_i^{int^2}$$

## 5.2 Description

The **1-D Annular array** tab is divided into seven areas (see Figure 5-3 on page 104).

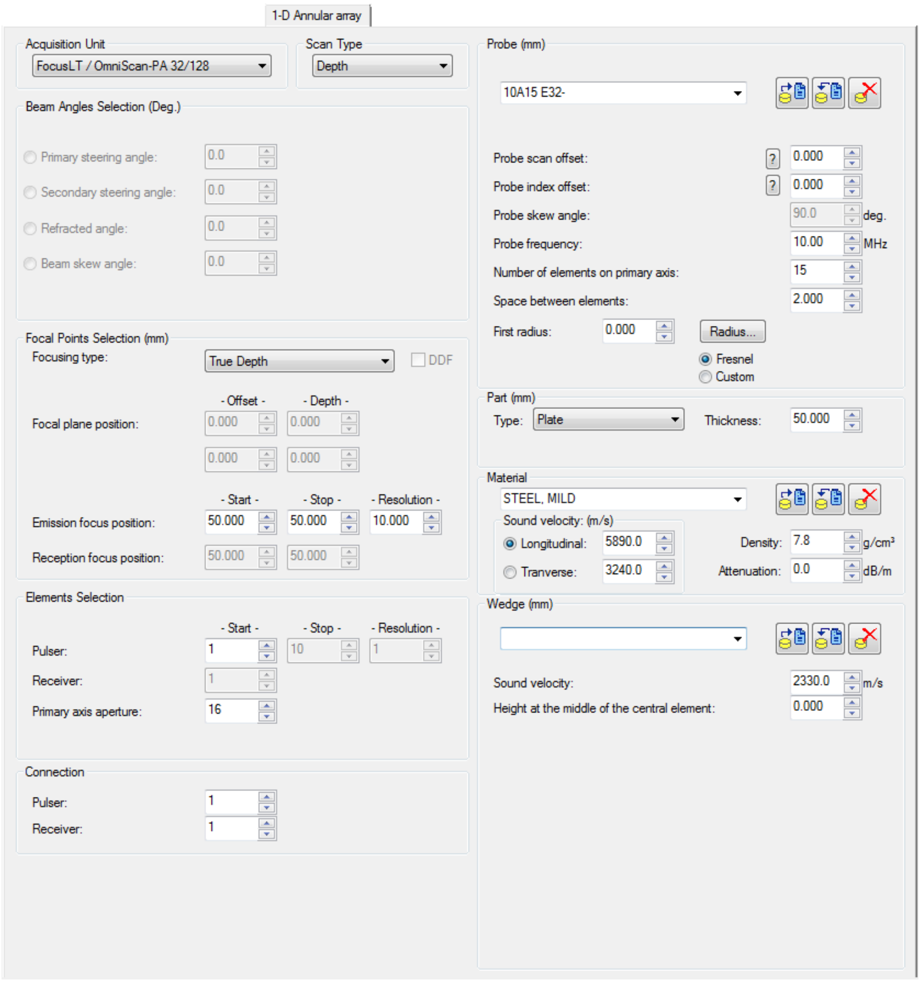


**Figure 5-3 The 1-D Annular array tab**

### 5.2.1 Acquisition Unit Area

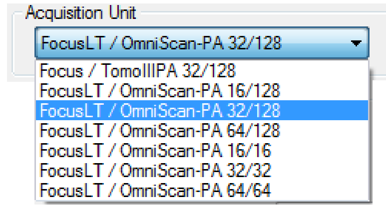


**Figure 5-4 The Acquisition Unit area**

The **Acquisition Unit** area (Figure 5-4 on page 105) contains only one drop-down combo box for the selection of the type of acquisition unit for which you want to create beams. The beam calculation uses slightly different compensation gain for each acquisition unit type. The drop-down combo box is available only when no acquisition unit is connected to the computer. The acquisition unit is automatically detected when it communicates with the computer.

### 5.2.2 Scan Area

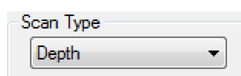


**Figure 5-5 The Scan Type area**

The **Scan** area (see Figure 5-5 on page 105) contains the following:

**Type**

Selects the type of beams to be generated:

- **Depth:** the focusing depth of the ultrasound beam varies.
- **Static:** the focusing depth of the ultrasound beam is fixed (generates a single beam).

### 5.2.3 Beam Angles Selection Area


**Figure 5-6 The Beam angles selection area**

The **Beam angles selection** area (see Figure 5-6 on page 106) is not applicable for the 1-D annular array option, since only beams for ultrasound beams at 0° (longitudinal waves) are considered.

### 5.2.4 Focal Points Selection Area

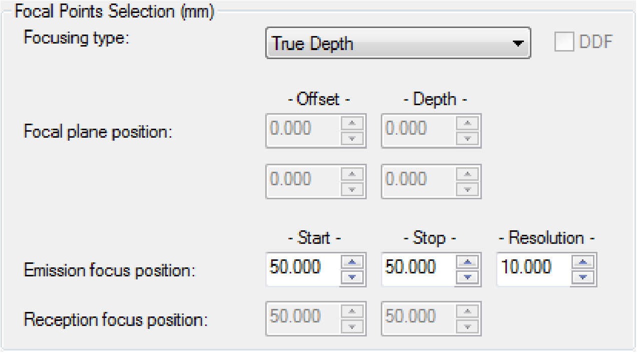


**Figure 5-7 The Focal points selection area**

The **Focal points selection** area (see Figure 5-7 on page 106) contains the following:

**Focusing type**

Selects the type of focusing of the beams to be generated:

- **True depth:** all beams are focused at a constant true-depth value. For a cylindrical part, the true-depth value is defined as the depth in the cylindrical geometry.
- **Half path:** all beams are focused at a constant half-path (distance) value.
- **Projection:** all beams are focused on a given vertical plane; this option is not applicable for depth laws, for DDF laws, and for pitch-and-catch configurations.
- **Focal plane:** all beams are focused on a user-defined focal plane (see Figure 4-27 on page 59); this option is not applicable for depth laws, DDF laws, and for pitch-and-catch configurations.

**DDF**

When this check box is selected, the dynamic depth focusing algorithm is applied on the beams for the considered **Reception focus position** (depth).

**Focal plane position (mm)**

Not applicable for a 1-D annular array.

**Emission focus depth (mm)**

Defines the desired focusing depth of the ultrasound beam to be generated.

For **Depth** beams: the three boxes are used to set the initial (**Start**) and final (**Stop**) desired focusing depth of the ultrasound beam to be generated and to set its resolution.

**Reception focus depth (mm)**

Defines the desired focusing depth (applied delay) for the received signal.

When the **DDF** check box is selected, both boxes are used to set the initial (**Start**) and final (**Stop**) desired focusing depth at reception.

When the **DDF** check box is selected along with **Depth** beams, the initial (**Start**) and final (**Stop**) focusing depth at reception is automatically calculated (but not displayed) as follows:

- **Start:**

  Reception focus depth = Emission focus depth – Resolution

- **Stop:**

  Reception focus depth = Emission focus depth + Resolution

When the **DDF** check box is not selected, the **Emission focus position** is equal to the **Reception focus position**.

### 5.2.5 Elements Selection Area

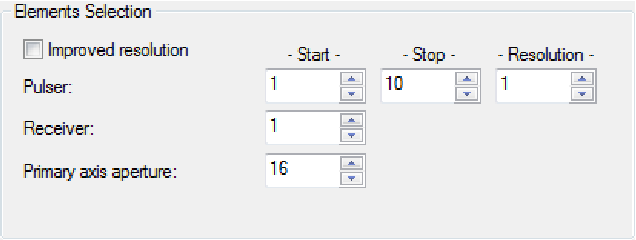


**Figure 5-8 The Elements selection area**

The **Elements selection** area (see Figure 5-8 on page 108) contains the following:

**Pulser**

Sets the first element of the active pulser group.

**Receiver**

Sets the first element of the active receiver group.

**Primary axis aperture**

Sets the number of elements used simultaneously to generate beams.

### 5.2.6 Probe Area

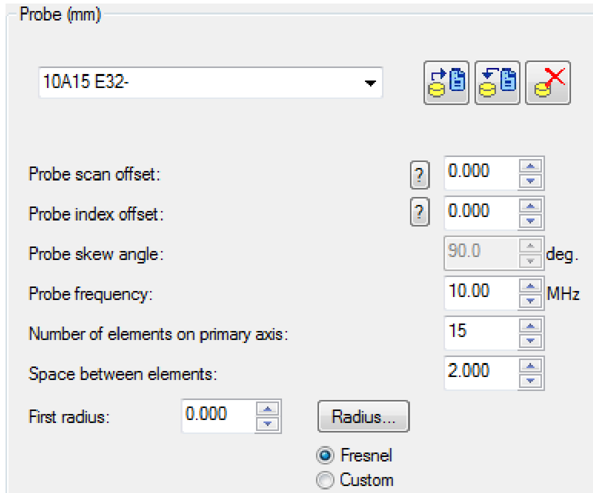


**Figure 5-9 The Probe area for annular arrays**

The **Probe** area (see Figure 5-9 on page 109) contains the following:

**Probe** database

Allows the use of the **Probe** database:

 **Load from database**

Allows one to load a probe configuration from the probe database.

 **Save in database**

Allows one to save the active probe configuration in the probe database.

 **Delete from database**

Allows one to delete a probe configuration from the probe database.

**Probe skew angle (deg)**

Defines the skew angle of the probe. The probe skew angle is always 0° for a 1-D annular array, since it only generates ultrasound beams at 0°.

**Probe frequency (MHz)**

Defines the probe frequency.

**Number of elements on primary axis**

Defines the number of elements on the primary axis (radial) of the current probe.

**First radius (mm)**

Defines the radius of the central element. Only applicable for Fresnel type annular arrays (see Figure 5-1 on page 102).

**Space between elements (mm)**

Defines the space between two consecutive elements [that is, the distance between the external radius of the $n^{th}$ element to the internal radius of the $(n+1)^{th}$ element]. Only applicable for Fresnel type annular arrays (see Figure 5-1 on page 102).

**Radius** button

Opens the **Annular Array Radius** dialog box (see Figure 5-10 on page 111), which allows the creation of a **Custom** annular array.

When a **Fresnel** type annular array is used, the dialog box gives the possibility to verify the radius of each element.

**Fresnel** option button

Defines a **Fresnel** type annular array, characterized by the fact that each element has the same surface (same area) and is separated by a constant distance (see Figure 5-1 on page 102).

**Custom** option button

Defines a **Custom** type annular array, with arbitrary radii and a variable spacing between consecutive elements (see Figure 5-2 on page 103).

### 5.2.7 Annular Array Radius Dialog Box

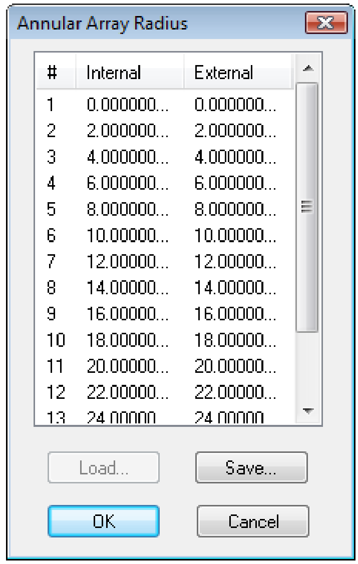


**Figure 5-10 The Annular Array Radius dialog box**

The **Annular Array Radius** dialog box (see Figure 5-10 on page 111) contains the following:

**Load** button

Opens a standard **Open** dialog box, allowing one to load a text file (.txt file) containing the internal and external radius of each element.

**Save** button

Opens a standard **Save As** dialog box, allowing one to save the internal and the external radius of each element in a text file (.txt file).

It is important to note that the internal and external radii of a **Custom** annular array defined in the **Annular Array Radius** dialog box are not saved in the .xcal file.

**OK** button

Applies the defined radius.

**Cancel** button

Closes the **Annular Array Radius** dialog box.

### 5.2.8 Part Area


**Figure 5-11 The Part area for flat part**

The **Part** area (see Figure 5-11 on page 112) contains the following:

**Type**

Defines the part type supported by the Advanced Calculator:

**Plate:** flat part.

**Thickness (mm)**

Defines the thickness of the part to be displayed on the **Beam Display Info.** tab.

### 5.2.9 Material Area

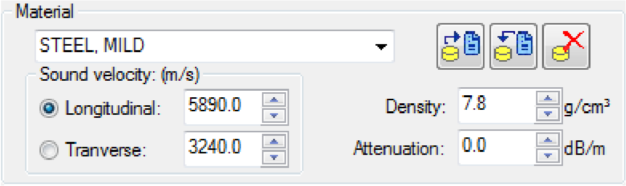


**Figure 5-12 The Material area for flat part**

**Material** database

Allows the use of the **Material** database:

 **Load from database** button

Allows you to load a material configuration from the material database.

 **Save in database** button

Allows you to save the active material configuration in the material database.

 **Delete from database** button

Allows you to delete a material configuration from the material database.

**Sound velocity** area

Defines the sound velocities in the material to be inspected for the available wave types (**Longitudinal** [compression] or **Transverse** [shear]) waves (m/s).

**Density**

Defines the density of the selected material.

**Attenuation**

Used to set the ultrasonic attenuation for the selected material.

## 5.2.10 Wedge Area

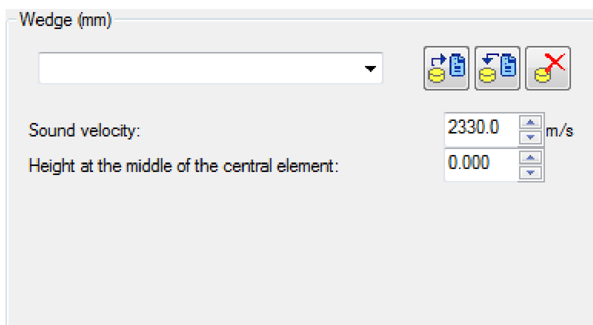


**Figure 5-13 The Wedge area for annular arrays**

The **Wedge** area (see Figure 5-13 on page 113) contains the following:

**Wedge** database

Allows the use of the **Wedge** database:

 **Load from database**

Allows one to load a wedge configuration from the wedge database.

**Save in database**

Allows one to save the active wedge configuration in the wedge database.

**Delete from database**

Allows one to delete a wedge configuration from the wedge database.

**Sound velocity (m/s)**

Defines the sound velocity in the wedge.

**Height at the middle of the central element (mm)**

Defines the height at the middle of the central element, relative to the material surface.

## 5.3 Creating Depth Beams for Annular Arrays

**Depth** beams are used to generate a set of ultrasound beams that focus at different depths.

To illustrate the use of the calculator for creating **Depth** beams for a 1-D annular array probe, the following typical application is given as an example.

### Example 1: Fresnel annular array

The following configuration is considered:

- Single 1-D annular array probe, Fresnel type with the following characteristics: nominal frequency 5 MHz, 16 elements, first radius 5 mm, and spacing between elements 2 mm
- A Rexolite wedge with the following characteristics: wedge velocity 2330 m/s, height at the middle of the central element 10 mm
- A flat carbon steel part with a wall-thickness of 100 mm
- The probe generates compression wave beams in pulse-echo mode at 0°, focusing between a true-depth distance of 10 mm to 90 mm with a depth resolution of 10 mm; all 16 elements of the probe are to be used to generate the beam.

In order to generate this set of **Depth** beams, the input parameters must be set as shown in Figure 5-14 on page 115.

Note that the database has been used to save probe, wedge, and material parameters (see section 10 on page 133).

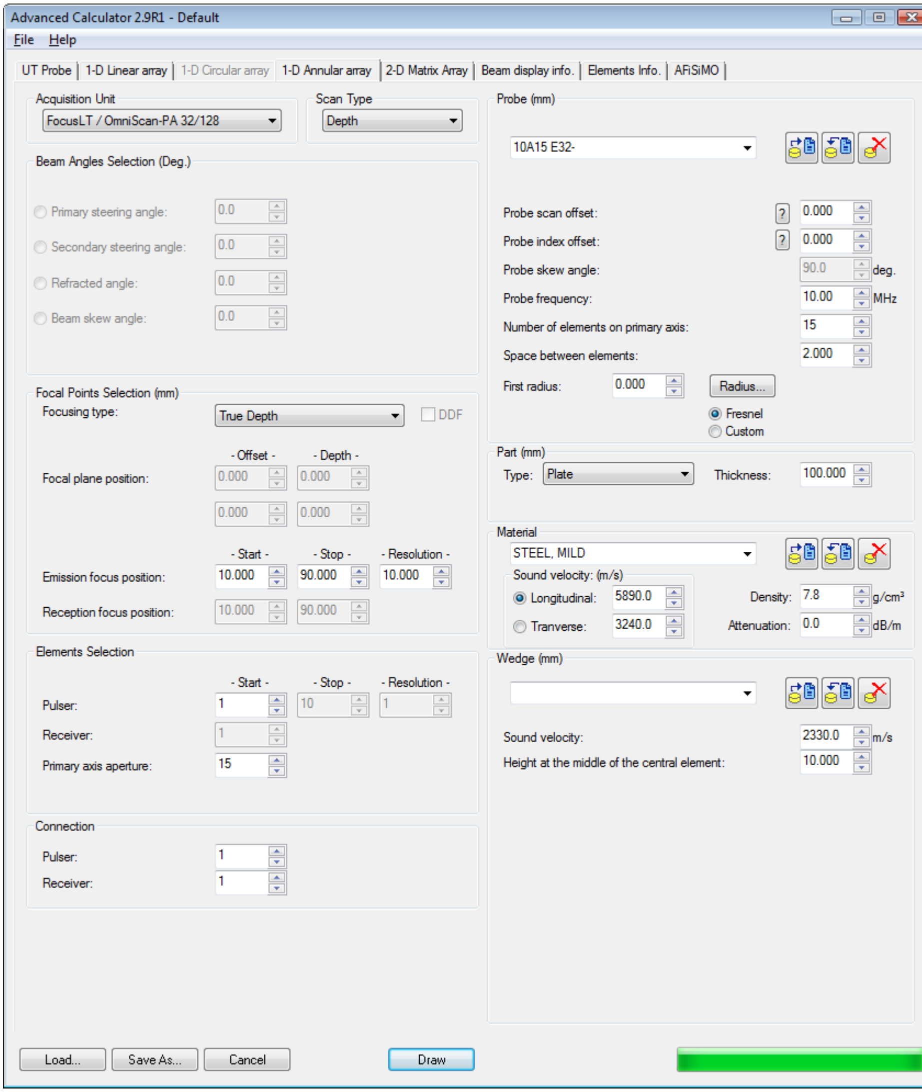


**Figure 5-14 Fresnel annular array: Depth beam input parameters**

Graphical and numerical information concerning the generated laws can be found on the corresponding **Beam Display Info.** tab (see Figure 5-15 on page 116).

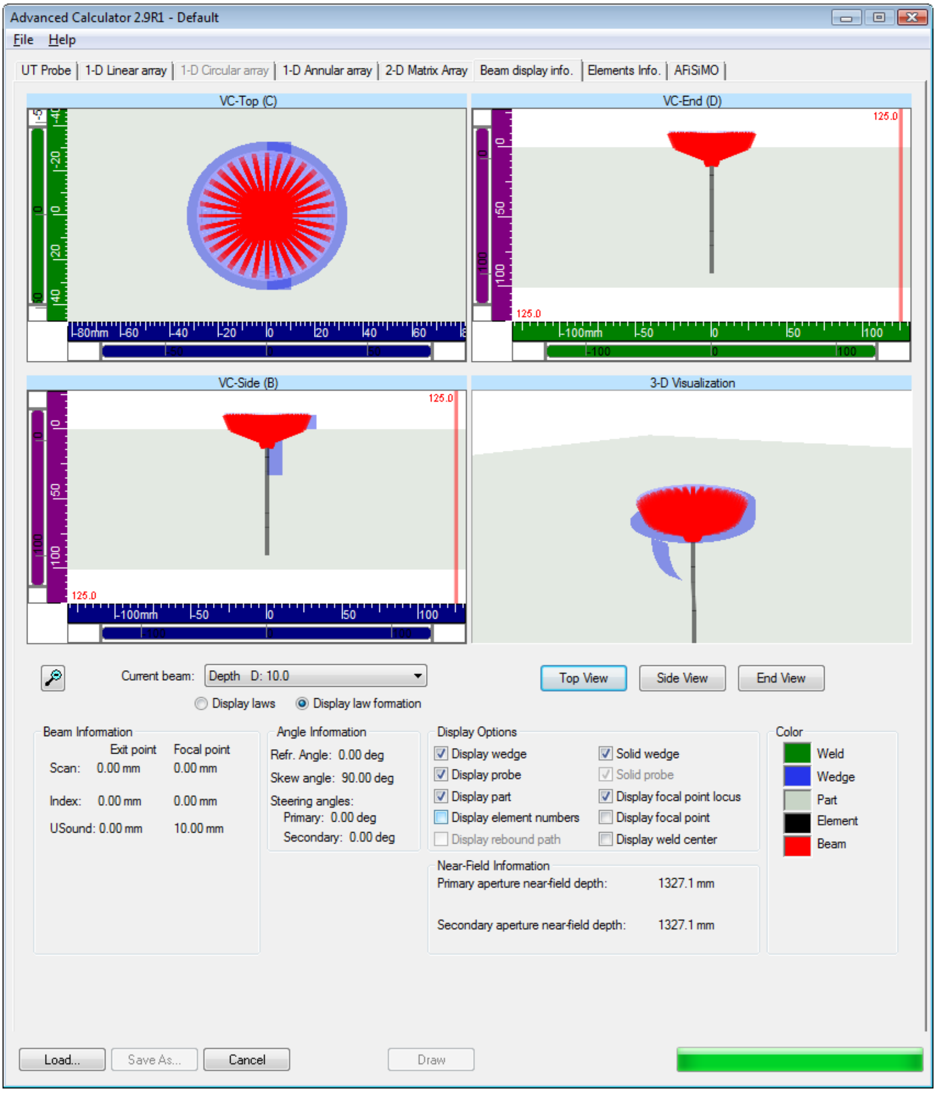


**Figure 5-15 Fresnel annular array: Depth beam visualization**

# 6. The 2-D Matrix Array Tab

This section describes how to create beams when inspecting parts using a 2-D matrix probe.

Sectorial beams are used to generate, at a fixed focusing distance and with a fixed primary aperture, a set of ultrasound beams of different inspection angles (refracted angles and/or skew angles).

The following is an example of configuration of sectorial beams.

The probe, part, and wedge parameters are as follows:

- Two 2-D matrix probe 5 MHz, 16 elements organized as follows: 4 elements on the primary axis and 4 on the secondary axis. The primary and secondary axis pitches are 2 mm. The probe configuration is of the type 1 (as defined in the Advanced Calculator).
- The part is a flat steel part having a thickness of 50 mm. The sound velocity in the part is 3200 m/s.
- A wedge, having a sound velocity of 2330 m/s, is angled at 30°. The height at the middle of the first element is 4 mm and the primary axis offset of the first element is 3 mm. The secondary axis offset of the first element is also 3 mm. The wedge is 12 mm long and 12 mm wide.

The inspection parameters are as follows:

- The inspection is done in the pulse-echo mode, using longitudinal waves.
- The ultrasound unit is true-depth and the beam is focused at 10 mm.
- The probe motion is parallel to the scanning axis (skew 0°).
- The steering angles ranges from –10 ° to 10 ° in steps of 2 ° on both primary and secondary axes.
- The aperture uses all the elements of the probe.

Figure 6-1 on page 118 presents the parameters to be entered to create the linear beams.

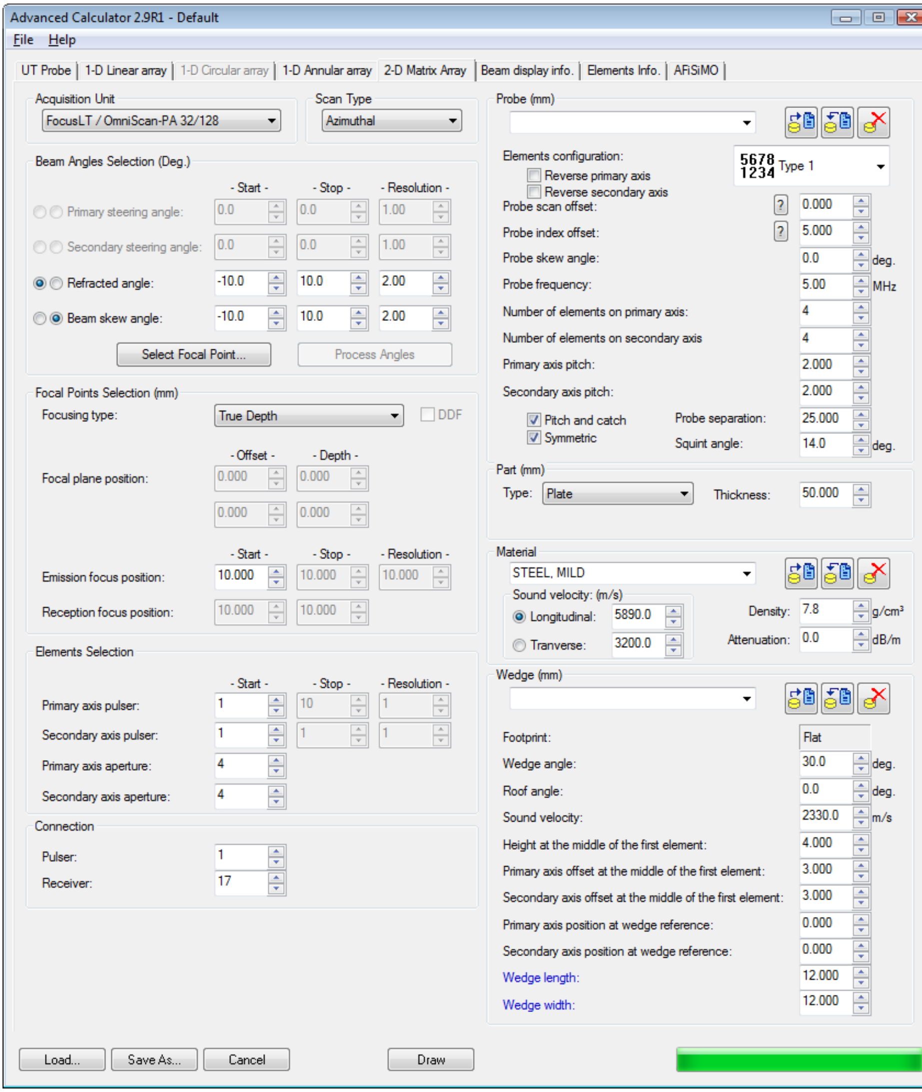


**Figure 6-1 Example of parameters of sectorial beams for a 2-D matrix probe**

The result can be examined in the graphic representation on the **Beam Display Info.** tab (see Figure 6-2 on page 119).

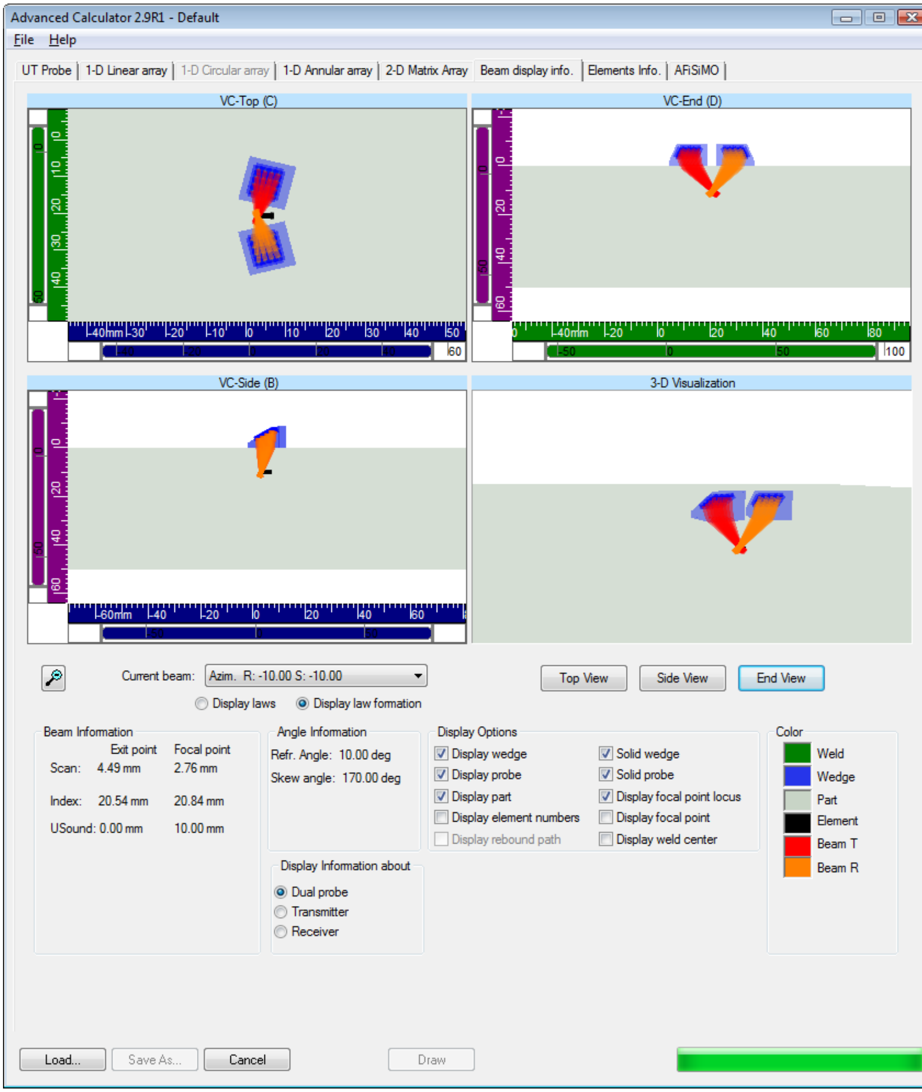


**Figure 6-2 Graphic representation of the sectorial beams for a 2-D matrix probe**

# 7. The Beam Display Info. Tab

The **Beam Display Info.** tab (see Figure 7-1 on page 122) can be used to verify and validate the inputs and the resulting beams for any of the supported array types. In addition to a graphical representation of the defined probe, wedge, and part, it also provides detailed numerical information for each of the created delay laws: position of beam exit point and focal point, beam refracted angle and skew angle, etc.

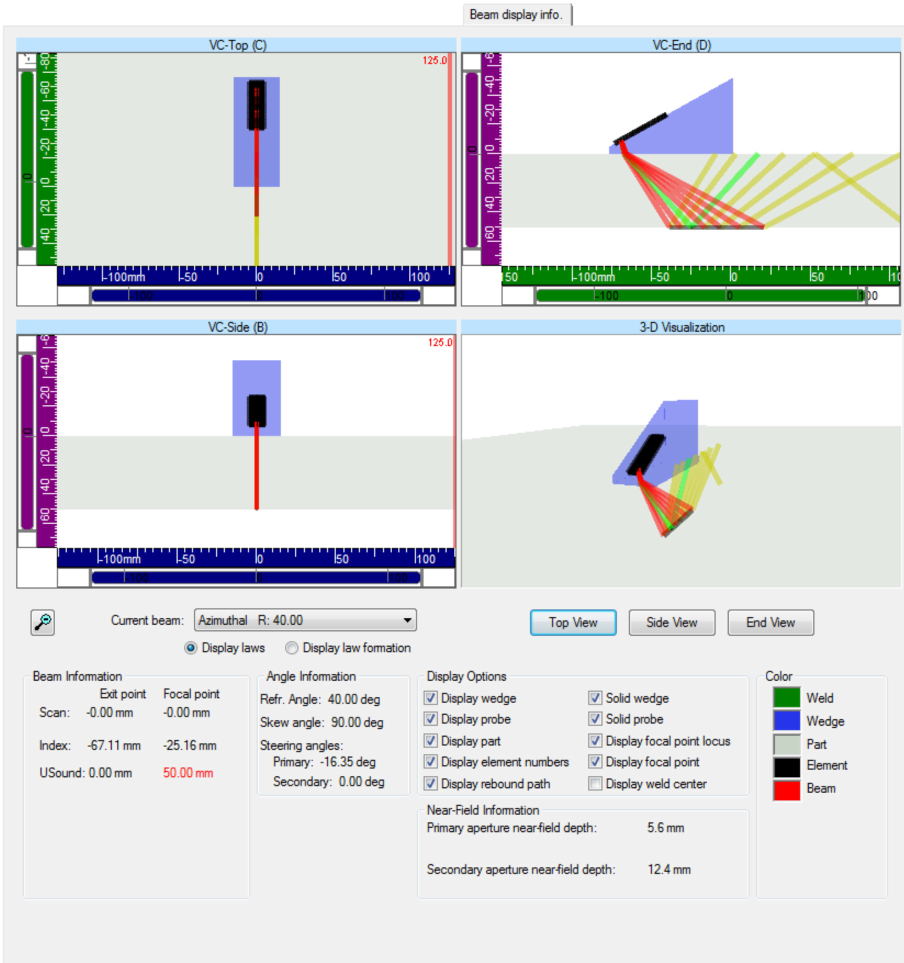


**Figure 7-1 The Beams Display Info tab**

The **Beam Display Info.** tab (see Figure 7-1 on page 122) contains the following:

### VC-Top (C)

This volume corrected view is a two-dimensional (2-D) graphical representation of the top view of the defined probe and part. One of the axes is the scan-axis, and the other is the index-axis. The defined probe and wedge can be displayed along with the ray tracing of the beams.

**VC-Side (B)**

This volume corrected view is a 2-D graphical representation of the side of the defined probe and part. One of the axes is the scan-axis, and the other is the ultrasound (Usound) axis. The defined probe and wedge can be displayed along with the ray tracing of the beams.

**VC-End (D)**

This volume corrected view is a 2-D graphical representation of the end of the defined probe and part. One of the axes is the index-axis, and the other is the ultrasound (Usound) axis. The defined probe and wedge can be displayed along with the ray tracing of the beams.

**3-D**

This view is a 3-D representation of the defined probe, wedge, and part.

The **Top View** button automatically readjusts the zoom and repositions the pane content in order to get a representation from the top of the part.

The **Side View** button automatically readjusts the zoom and repositions the pane content in order to get a representation from the side of the part.

The **End View** button automatically readjusts the zoom and repositions the pane content in order to get a representation from the end of the part.

In the **3-D Visualization** view:

- Click and drag to rotate the 3-D model.
- Right-click and drag to move the 3-D model.
- Click the wheel button and drag to zoom in or out of the view.

**Fit Image to Pane** ()

This button simultaneously un-zooms the content of the four views.

**Current beam**

Identifies the current beam.

**Sectorial** laws, depending on the **Beam angle selection**, are identified as follows:

Sectorial **A:** angle

Sectorial **St:** steering angle

Sectorial **Sk:** skew angle

**Linear** laws are identified as follows:

**Linear L: 1-16**, where **1** and **16** represent the first and the last element used to generate the law

**Depth** laws are identified as follows:

**Depth D: 45**, where **45** represents the focalization depth

**Static** laws are identified as follows:

**Static A: 30**, where **30** represents the refracted angle

**Beam information**

Indicates the beam **Exit point** and **Focal point** in Cartesian coordinates (**Scan**, **Index**, and **Usound**) and, for cylindrical coordinates (**Circumferential**, **Axial**, and **Depth**) for the current beam.

**Angle information**

Indicates the **Refr. Angle** (refracted angle), the total **Skew angle** (beam skew angle + probe skew angle), the **Primary**, and the **Secondary Steering angle** of the current beam.

**Display options**

Allows one to display the following options:

- Wedge (wire frame) or solid wedge
- Probe (wire frame) or solid probe
- Part
- Element numbers
- Focal point
- Focal point locus
- Rebound path
- Weld center

The user-defined options are saved upon closing the calculator.

**Color**

Allows one to define the color of the following components:

- **Wedge**
- **Part**
- **Element**
- **Beam**

The user-defined colors are saved upon closing the calculator.

**Near-Field information**

Indicates the **Primary Aperture Near-Field Depth** and the **Secondary Aperture Near-Field Depth.**

# 8. The Elements Info. Tab

The **Elements Info.** tab presents lists for the pulser and the receiver elements (see Figure 8-1 on page 128). The lists contain the calculated delays for each element number for the beam selected in the **Current Beam** area.

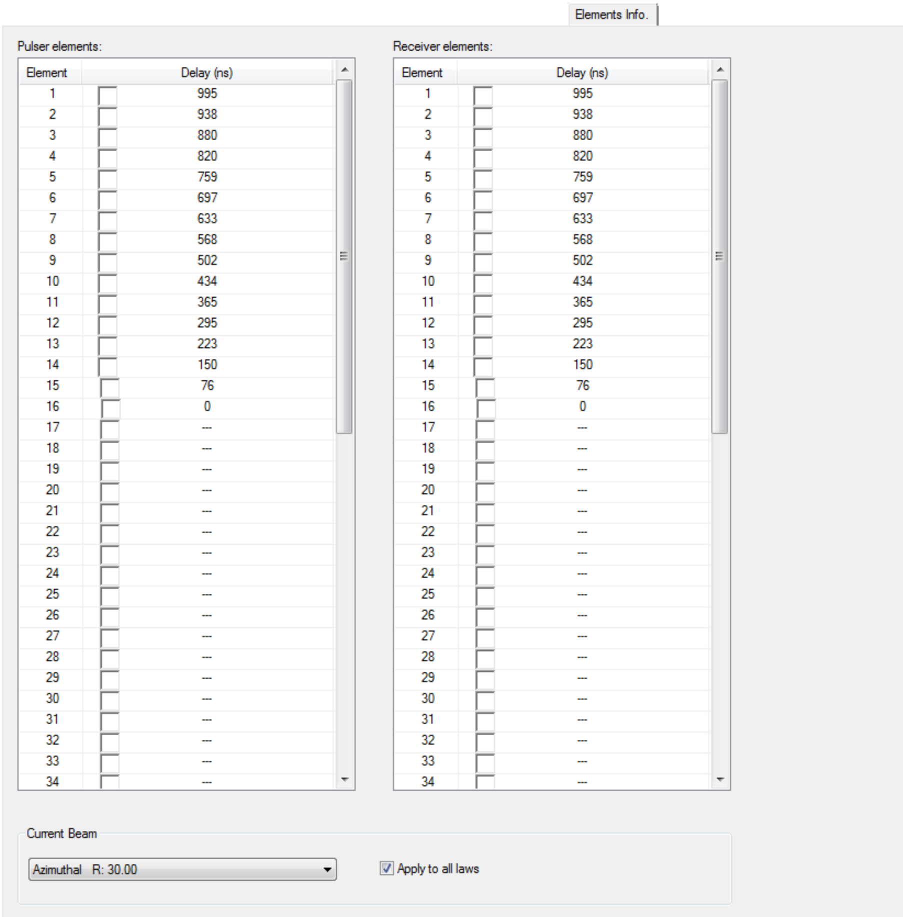


**Figure 8-1 Example of the Element Info. tab**

# 9. The AFiSiMO Tab

The Acoustic Field Simulation Module (AFiSiMO) is available as an option in the Advanced Calculator. It is used to simulate spatially diffracted fields in 2-D or 3-D. This component is particularly useful when defining new inspection techniques.

With this module you can:

- Validate inspection settings
- Measure beam width
- Display LW (longitudinal waves) and SW (shear waves)
- Simulate cylindrically focused probes
- Support linear and conventional UT probes

The **AFiSiMO** tab presents a large graphical visualization view, view selection buttons, and simulation parameters (see Figure 9-1 on page 130).

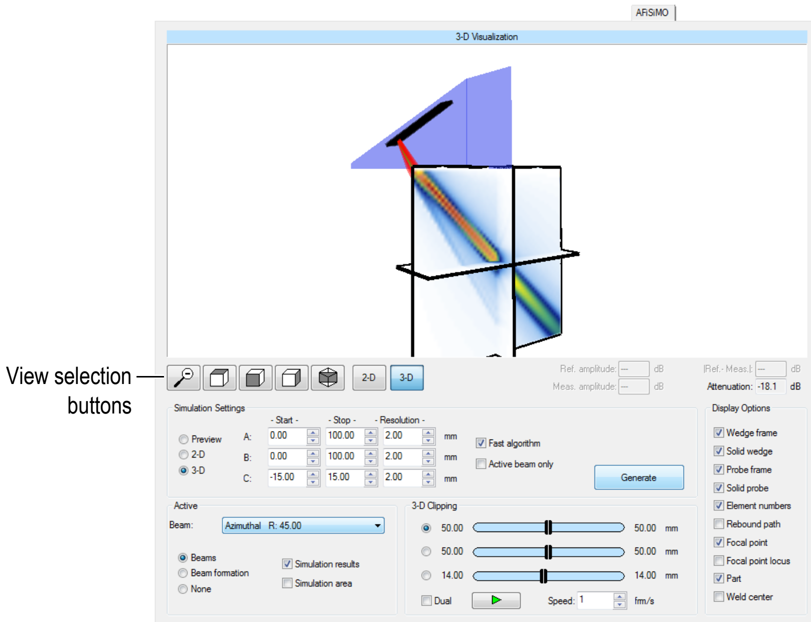


**Figure 9-1 Example of the AFiSiMO tab**

## 9.1 Creating Acoustic Field Simulations

The following procedure describes how to create acoustic field simulations.

---

**TIP**

When you want to create acoustic field simulations for several configurations, consider using the batch processing by selecting **File > Run AFiSiMo Batch** on the menu (see section 1.2.1 on page 14 for details).

---

### To create an acoustic field simulation

1. Use the appropriate Advanced Calculator tab (**UT Probe**, **1-D Linear array**, or **2-D Matrix Array**) to define the probe, wedge, part, and inspection parameters that you want to simulate.

2. Click **Draw** at the bottom of the tab.
   The Advanced Calculator calculates the beams as defined by your parameters.
3. In the **AFiSiMO** tab:
   *a)* In the **Simulation Settings** area, select the type of simulation that you want to perform. The available choices are:
   - **Preview**: to calculate a 2-D simulation with predefined start, stop, and resolution values using the fast algorithm.
   - **2-D**: to calculate the simulated acoustic field on a two-dimension plane.
   - **3-D**: to calculate the simulated acoustic field for volume.

   *b)* Set the values for the **Start**, **Stop**, and **Resolution** parameters to determine the scope of the simulation.
   *c)* Select the **Fast algorithm** check box to reduce the calculation time.
   *d)* Select the **Active beam only** check box to limit the simulation to the beams selected under **Active**. Clear the check box to perform the simulation on all beams.
   *e)* Click **Generate**.
4. When the simulation calculation is complete, use the view selection buttons to visualize the simulation results in various 2-D and 3-D (see Figure 9-2 on page 131).

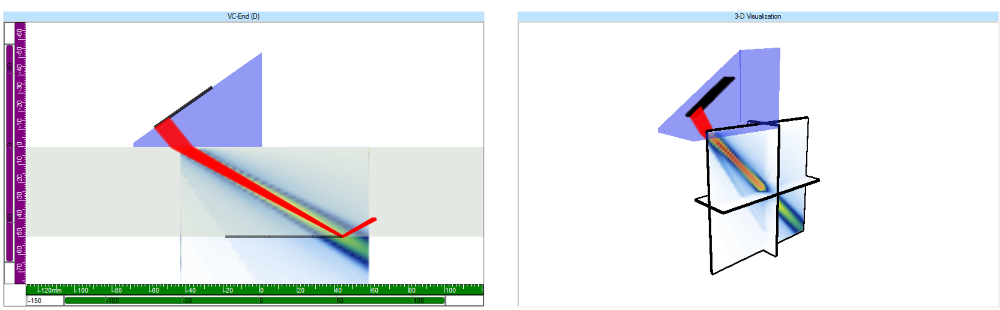


**Figure 9-2 Example of 2-D and 3-D simulation visualizations**

5. With the 2-**D** view selection button selected, in the visualization view:
   - Click, drag, and release to zoom to the drawn area.
   - Use the ruler and zoom bars to zoom in and out.
   - Click the zoom out button () to restore a full model view.

6. With the **3-D** view selection button selected, in the visualization view:
   - Click and drag to rotate the 3-D model.
   - Right-click and drag to move the 3-D model.
   - Click the wheel button and drag to zoom in or out of the view.
7. After generating a 3-D simulation, the controls in the **3-D Clipping** area are enabled, allowing you to visualize planes of the 3-D simulation:
   - Click and drag the any of the sliders to move the respective plane in the 3-D view.
   - Select one of the sliders, set the **Speed** and click the play button () to start an animation of the plane movement.

## 9.2 Verifying the AFiSiMO Availability

The AFiSiMO is an optional feature that needs to be purchased separately. Contact your local Evident representative for more information.

### To verify the AFiSiMO availability

1. When using the Advanced Calculator with TomoView, start TomoView.
2. In the **Start Selection** dialog box, verify that **Acoustic Field Simulation: Enabled** appears in the **Add On** area (see Figure 9-3 on page 132).

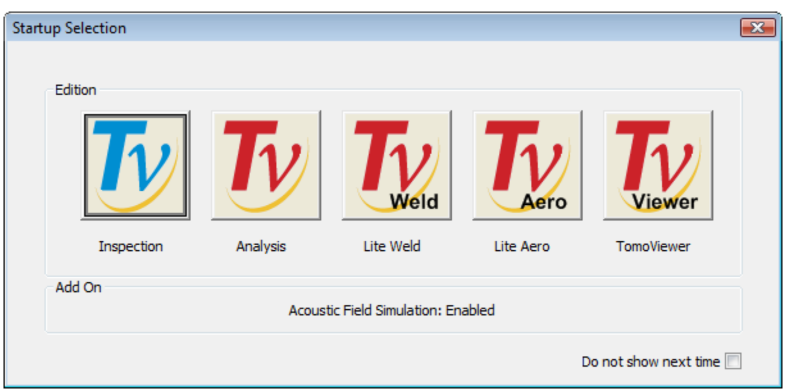


**Figure 9-3 The TomoView Startup Selection dialog box with the enabled AFiSiMO add on**

# 10. Using the Databases

The Advanced Calculator uses a database to store the information related to the probes, the material and the wedges. The database file is located in a folder under the Advanced Calculator folder. The default location is:

[Installation Folder]\TomoView29\Database

The Advanced Calculator installer creates the following files in the database folder:

UtDatabase.mdb

Active database file containing factory default information used by the Advanced Calculator.

UtDatabase-InstallationBackUp-xxxx.tmp.mdb

If a previous version of the Advanced Calculator was installed, a copy of the existing UtDatabase.mdb is created with this name, where xxxx is an automatically generated unique ID for the file. Rename this file to `UtDatabase.mdb` if you want to restore the content of the database as it was for the previous version of the Advanced Calculator.

# 10.1 Probe Database

The **Probe** database allows you to save and to load a user-defined probe configuration.

### To save a probe configuration in the Probe database

1. Enter the probe parameters with an appropriate probe name (see Figure 10-1 on page 134).

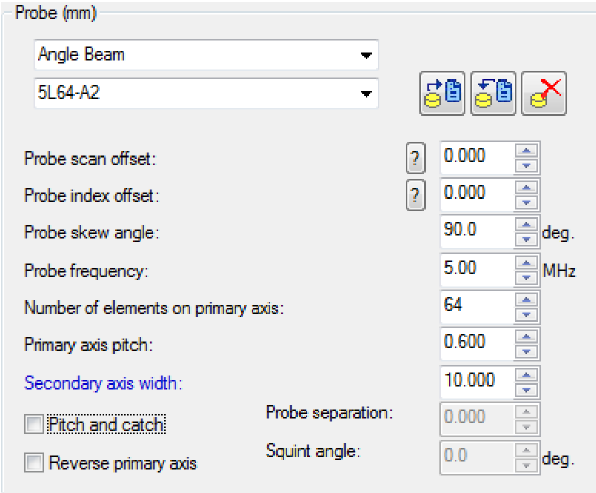


**Figure 10-1 Probe parameters**

2. Click  (Save in database button), and then click **OK** (see Figure 10-2 on page 135).

   The probe configuration is automatically saved in the **Probe** database.

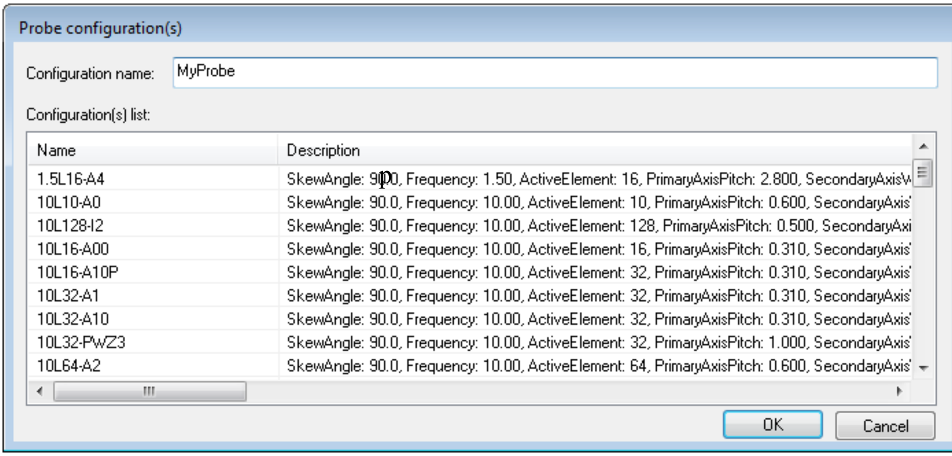


**Figure 10-2 Saving with the Probe Configuration dialog box**

### To load a probe configuration from the Probe database

1. In the **Advanced Calculator**, click  (Load from database button).
2. In the **Probe Configuration** dialog box, select the desired probe configuration, and then click **OK**.

   The probe configuration is automatically loaded from the **Probe** database.

### To delete a probe configuration from the Probe database

1. In the **Advanced Calculator**, click  (Delete from database button).
2. In the **Probe Configuration** dialog box, select the probe configuration that you want to delete, and then click **Delete**.
3. Click **OK** to close the dialog box (see Figure 10-3 on page 136).

   The probe configuration is automatically deleted from the **Probe** database.

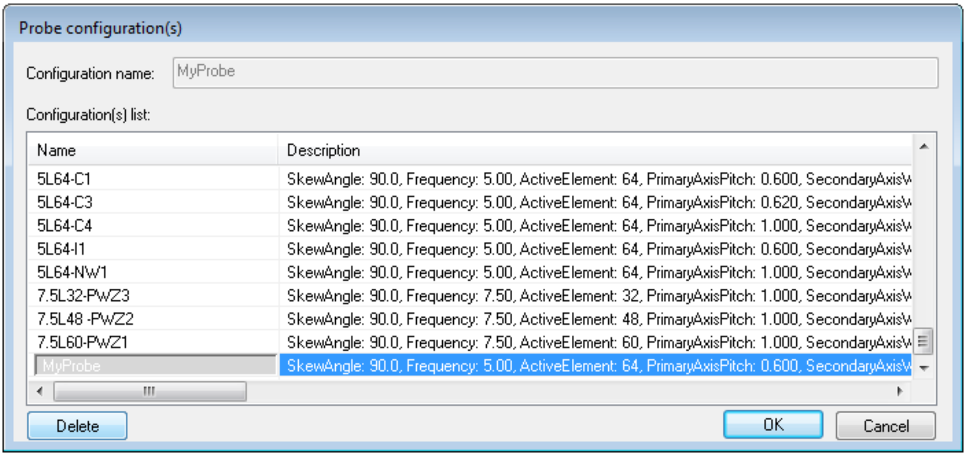


**Figure 10-3  Deleting with the Probe Configuration dialog box**

## 10.2 Material Database

The **Material** database allows you to save and to load a user-defined material configuration.

### To save a material configuration in the Material database

1. Enter the material parameters with an appropriate material name (see Figure 10-4 on page 136).

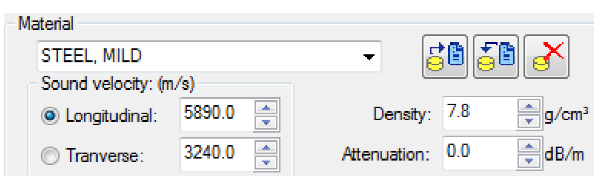


**Figure 10-4  Material parameters**

2. Click  (Save in database button), and then click **OK** (see Figure 10-5 on page 137).

The probe configuration is automatically saved in the **Material** database.

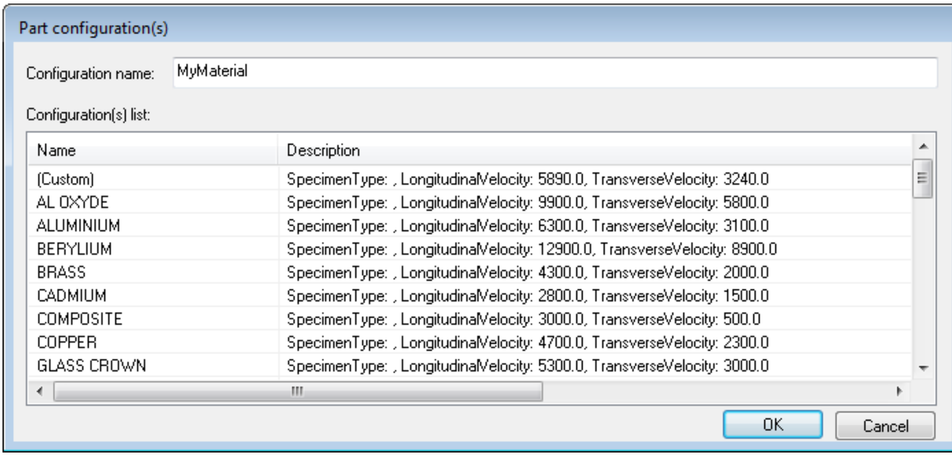


**Figure 10-5 Saving with the Material Configuration dialog box**

### To load a material configuration from the Material database

1. In the **Advanced Calculator**, click (Load from database button).
2. In the **Material Configuration** dialog box, select the desired material configuration, and then click **OK**.

   The material configuration is automatically loaded from the **Material** database.

### To delete a material configuration from the Material database

1. In the **Advanced Calculator**, click (Delete from database button).
2. In the **Material Configuration** dialog box, select the material configuration that you want to delete, and then click **Delete**.
3. Click **OK** to close the dialog box (see Figure 10-6 on page 138).

   The material configuration is automatically deleted from the **Material** database.

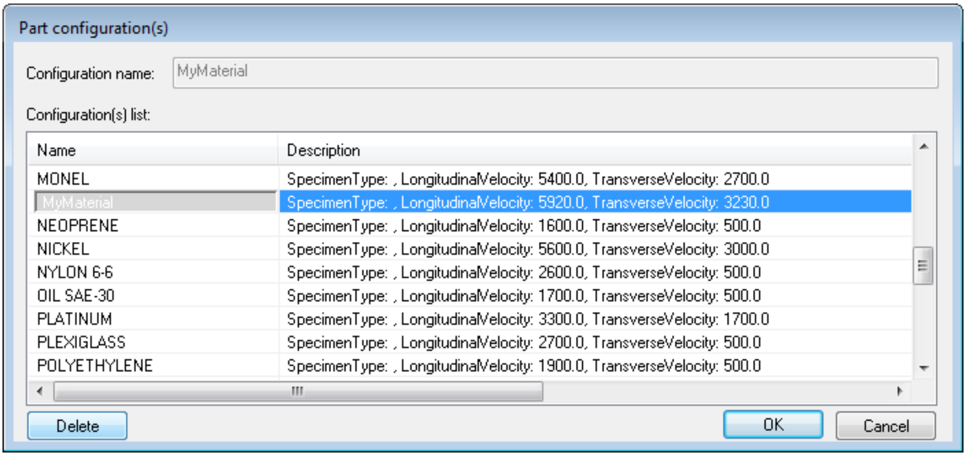


**Figure 10-6 Deleting from the Material Configuration dialog box**

## 10.3 Wedge Database

The **Wedge** database allows you to save and to load a user-defined wedge configuration.

### To save a wedge configuration in the Wedge database

1. Enter the wedge parameters with an appropriate wedge name (see Figure 10-7 on page 139).

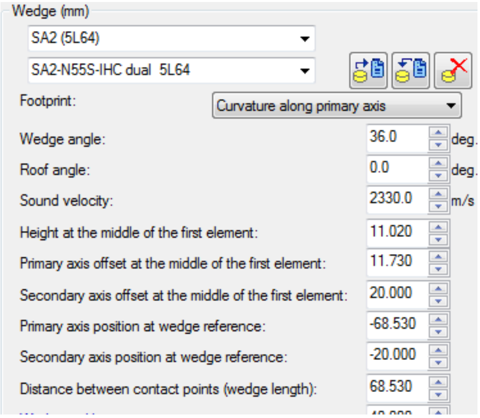


**Figure 10-7 Wedge parameters**

2. Click  (Save in database button), and then click **OK** (see Figure 10-8 on page 139).

   The wedge configuration is automatically saved in the **Wedge** database.

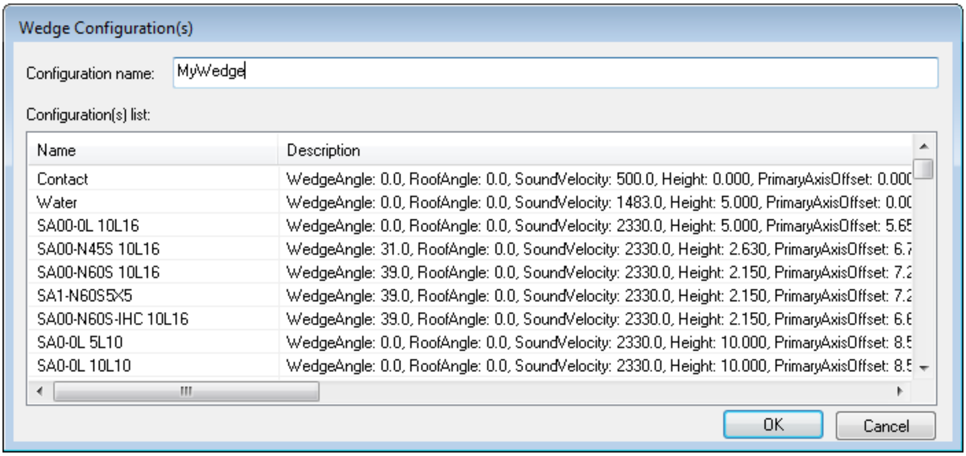


**Figure 10-8 Saving with the Wedge Configuration dialog box**

### To load a wedge configuration from the Wedge database

1. In the **Advanced Calculator**, click  (Load from database button).
2. In the **Wedge Configuration** dialog box, select the desired wedge configuration, and then click **OK**.

   The wedge configuration is automatically loaded from the **Wedge** database.

### To delete a wedge configuration from the Wedge database

1. In the **Advanced Calculator**, click  (Delete from database button).
2. In the **Wedge Configuration** dialog box, select the wedge configuration that you want to delete, and then click **Delete**.
3. Click **OK** to close the dialog box (see Figure 10-9 on page 140).

   The wedge configuration is automatically deleted from the **Wedge** database.

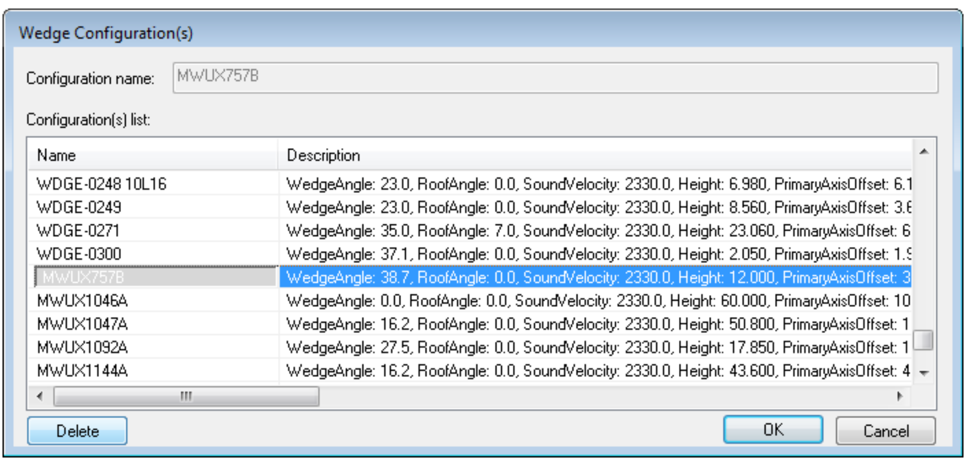


**Figure 10-9 Deleting with the Wedge Configuration dialog box**

# Appendix A: Theoretical Considerations on Law Delay Accuracy

The Advanced Calculator calculates beam delays to electronically generate an ultrasonic probe for which the active surface is a Fermat surface for the considered focal point in the material. This means that the rays from the individual elements (centre points) of the probe to the focal point should have equal flight times (FT). The errors are therefore expressed in time units, typically nanoseconds (ns). This approach is very similar to the optical path difference (OPD) parameter, expressed in number of wavelengths, used for quantitative assessment of the quality of optical systems (lenses, etc.).

In optics, it is assumed that a system with a maximum OPD error, smaller than a quarter of the wave length, generates a “sensibly” perfect image (see Warren J. Smith, *Modern Optical Engineering*, Chapter 11 “Image Evaluation,” 1966, McGraw Hill). This criterion is called the Rayleigh Limit, and is used for evaluation of aberrations (errors) in precision optics (microscopes, telescopes…).

When applying this criterion to the calculation of beam delays for ultrasonic array probes, a maximum difference of a quarter of a wavelength can be allowed, compared to an ideal Fermat surface. For typical probe frequencies used in nondestructive testing, the criterion yields the following allowable maximum delay differences:

- For a 10 MHz probe: 25 nanoseconds
- For a 5 MHz probe: 50 nanoseconds
- For a 2.25 MHz probe: 111 nanoseconds

For comparison purposes, a delay difference of 50 nanoseconds is equivalent to a mechanical accuracy of 0.06 mm (0.0025 in.) in the fabrication of the wedge, or an accuracy of approximately 0.1 degree for the wedge angle.

# Appendix B: Dynamic Depth Focusing (DDF)

In the case of conventional focused probes (and also standard focusing), the focusing is restricted to the region around the focal point, a region known as the *depth of field*. The depth of field is inversely proportional to the square of the array aperture at a given focal distance.

The advantage of the phased array probe over a conventional focused transducer is its capability to change the position of the depth of field by using different delays (focal laws) and then obtain a depth of field at different depths.

However, for the working range of a given phased array transducer, one beam is requested for each position of the depth of field. This involves one pulse/receive operation for each depth of field. To reduce the number of beams needed to cover a large thickness range with a constant depth of field position at different depths, the dynamic depth focusing (DDF) technique is introduced. The term “dynamic depth focusing” stands for dynamically changing the focusing depth at reception of the signals. At the emission of the beam, this technique behaves exactly as standard focusing: a given beam is applied to the elements of a phased array probe. This yields a focused beam with a given focal depth at emission. During reception (see Figure B-1 on page 144), a large number of beams are applied in real time using time-dependent delays to produce only one resulting A-scan. Knowing the propagation speed and the element positions, the time of reception of a given signal source is known for each element. At the time corresponding to the reception of the signal coming from point F1, the delay law L1 is applied. L2 is applied at the time corresponding to the reception of the signal coming from point F2. For clarity reasons only two laws are drawn in Figure B-1 on page 144, in reality a large number of laws are applied.

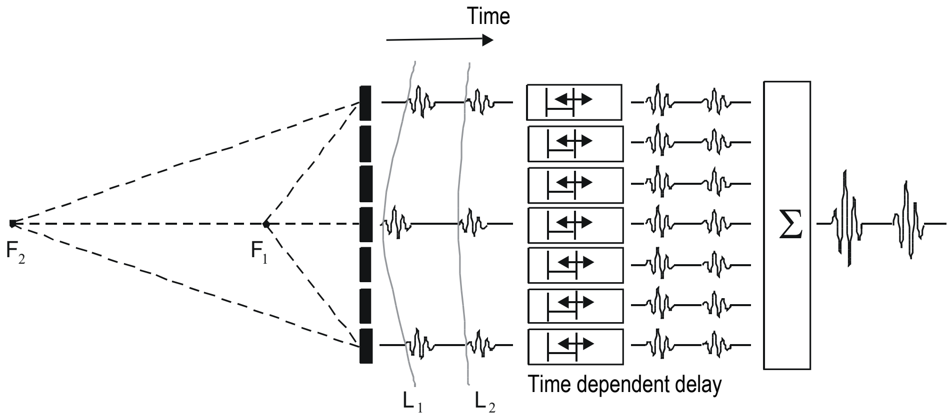


**Figure B-1 Dynamic depth focusing at reception**

Using phased array results in a significant increase of the depth of field while only one pulse/receive operation is needed. In practice, the obtained beam corresponds to the convolution of the emitted beam with separate "focused beams" at reception. Figure B-2 on page 144 shows this principle for a conventional focused probe or a phased array probe. Figure B-3 on page 145 shows this principle for DDF.

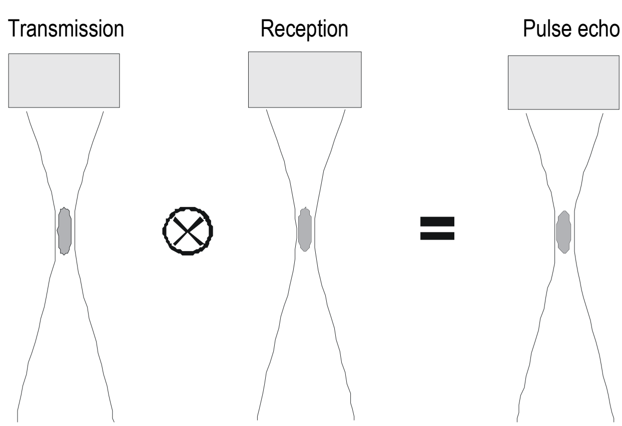


**Figure B-2 Standard focusing: convolution of transmitted and received beam**

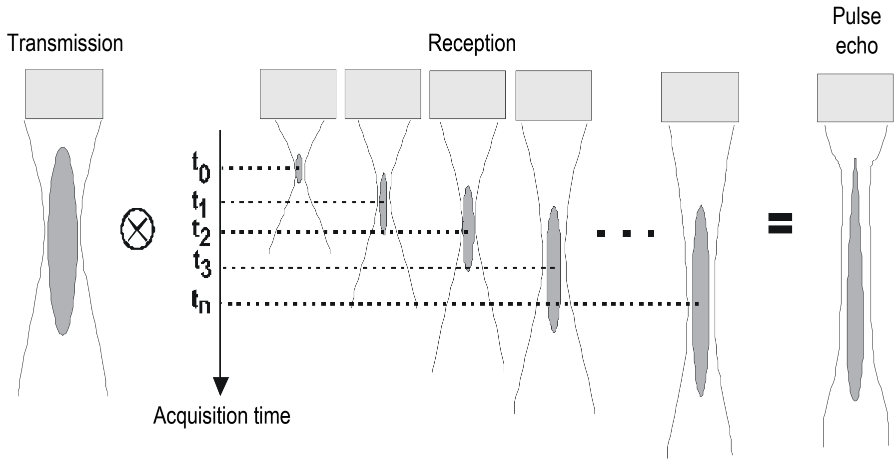


**Figure B-3 Dynamic depth focusing: resulting beam by convolution**

The choice of the transmitted beam (focal point and shape) will influence the resulting beam.

# Appendix C: Description of the .law File Format

This appendix describes the **.law** file format. This file is a text file, used to create specific beam configurations. These files can be loaded directly in TomoView or in the OmniScan.

The use of the **.law** file format supposes that the user has good background knowledge of phased array technology in general, and of the hardware and software in particular.

## C.1 Conventions

The following conventions are used in the file format description:

< >

Parameter delimiter

[ ]

Optional parameter

crlf

Carriage return and line feed

sep

<space> 1 <tab>

**J**

Specifies to repeat the content between the braces (depending on the number of laws and elements).

Normal characters (example N_Elements): represent a number.

Bold italic characters (example ***DDF***): represent a keyword.

Underlined characters (example G_Delay): represent TomoView parameters which can also be redefined in the UT Settings of TomoView without changing the law formation.

Italic characters (example *Frequency*): represent not used parameters.

# C.2 General Format

## C.2.1 Format

```
<Version> <sep> <N_Laws> [<Max_Channels>] <crlf>

J{<N_ActiveElements> <sep> <Frequency> <sep> <Cycles> <sep> <SumGain> <sep>
    <Mode> <sep> <Filter> <sep> <R_Angle> <sep> <S_Angle> <sep> <T_First> <sep>
    <R_First> <sep> <Scan_Offset> <sep> <Index_Offset> <sep> <G_Delay> <sep>
    <F_Depth> <sep> <M_Velocity> <crlf>

J{<E_number> <sep> <FL_Gain> <sep> <T_Delay> <sep> <R_Delay> <sep> <Amplitude>
    <sep> < P_width > <crlf>}}
```

## C.2.2 Example

An example of a .law file containing two beams using 10 elements, as generated by the TomoView Advanced Calculator, is given hereunder:

```
V5.0 2
10 1000 1 24 1 0 400 0 1 1 20304 0 14829 38303 3230
1 0 564 564 180 50
2 0 517 517 180 50
3 0 466 466 180 50
4 0 411 411 180 50
5 0 352 352 180 50
6 0 289 289 180 50
7 0 223 223 180 50
8 0 153 153 180 50
9 0 78 78 180 50
10 0 0 0 180 50
10 1000 1 24 1 0 500 0 1 1 22350 0 15314 32139 3230
1 0 168 168 180 50
2 0 162 162 180 50
3 0 153 153 180 50
4 0 140 140 180 50
5 0 125 125 180 50
6 0 107 107 180 50
7 0 85 85 180 50
```

```
8 0 60 60 180 50
9 0 32 32 180 50
10 0 0 0 180 50
```

# C.3 Object Description

## C.3.1 General Parameters

This section includes parameters that are related to the .law file format.

Version

<V> <number> <'.'> <number>.

N_Laws

The total number of beams defined in the file.

Max_Channels

Not applicable in version V5.0

## C.3.2 Law Parameters

This section includes parameters that are related to the beams defined in the law file.

N_ActiveElements

The number of active elements used to generate the given beam. The number shall be between 1 and 32 and shall fit to the limits of the hardware.

*Frequency*

Used for EMAT (electro-magnetic acoustic transducer) only. Pulse train frequency for the given law. The figure is given in kilohertz (kHz) and may vary between 300 kHz and 2000 kHz.

*Cycles*

Used for EMAT only. The number of cycles in the pulse train for the given law. The figure may vary between 1 and 15.

SumGain

Gain working range, expressed in decibels (dB), for a given law. The value is calculated according to the following formula:

Sum gain = 44 – [20 * Log(N)]
where N is the number of active elements used.

In TomoView, the **Sum gain** can be modified on the **Receiver** tab of the **UT Settings** dialog box (see Figure C-1 on page 150).

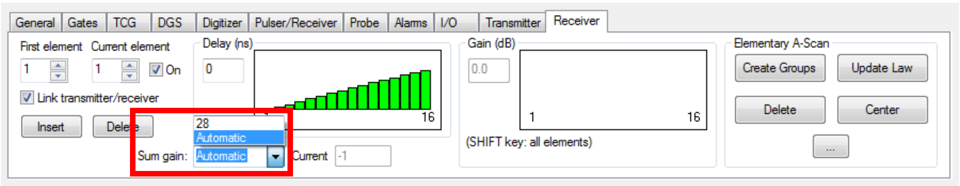


**Figure C-1 The Sum gain on the Receiver tab of the UT Settings dialog box**

Mode

The inspection mode for the given law:
0 = T/R (different pulser and receiver elements), or
1 = Pulse-echo (same pulser and receiver elements)

Filter

Specifies the filter applied at reception.
0 = no filter (0.5–20 MHz)
1 = 0.5–5 MHz
2 = 2–10 MHz
3 = 5–15 MHz
In TomoView, the Filter can be modified on the **Pulser/Receiver** tab of the **UT Settings** dialog box (see Figure C-2 on page 150).

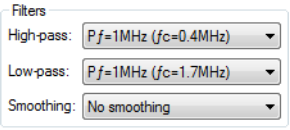


**Figure C-2 The Filters area of the Pulser/Receiver tab of the UT Settings dialog box**

R_Angle

The refracted angle for the given law expressed in tenths of degrees. This figure shall be between 0 and 900 (positive sign).
In TomoView, the **Refracted angle** can be modified on the **Probe** tab of the **UT Settings** (see Figure C-3 on page 151).

S_Angle

The skew angle for the given law expressed in tenths of degrees (number between 0 and 3599, positive sign).
In TomoView, the **Skew angle** can be modified on the **Probe** tab of the **UT Settings** dialog box (see Figure C-3 on page 151).

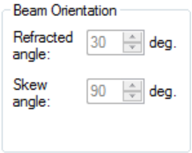


**Figure C-3 The Refracted angle on the Probe tab of the UT Settings dialog box**

T_First[1]

Specifies the number of the first pulser (≡ first pulser hardware connection) that will be used for transmission. This number must be between 1 and the maximum allowed by the hardware (for instance, 16, 32, 64, 128, …) or by the probe array.
In TomoView, the **First element** can be modified on the **Transmitter** tab of the **UT Settings** dialog box (see Figure C-4 on page 151).

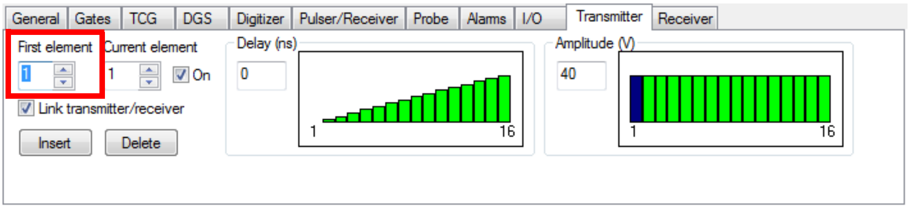


**Figure C-4 The First element on the Transmitter tab of the UT Settings dialog box**

R_First[2]

Specifies the number of the first receiver (≡ first receiver hardware connection) that will be used at reception. This number must be between at 1 and the maximum allowed by the hardware (for instance, 16, 32, 64, 128, …) or by the

1.It is important to notice that if this parameter is redefined in the UT settings of TomoView, then the wedge delay calculated by the TomoView Advanced Calculator will be incorrect.
2.Idem.It is important to notice that if this parameter is redefined in the UT settings of TomoView, then the wedge delay calculated by the TomoView Advanced Calculator will be incorrect.

probe array.
In TomoView, the first receiver can be modified on the **Receiver** tab of the **UT Settings** dialog box (see Figure C-5 on page 152).

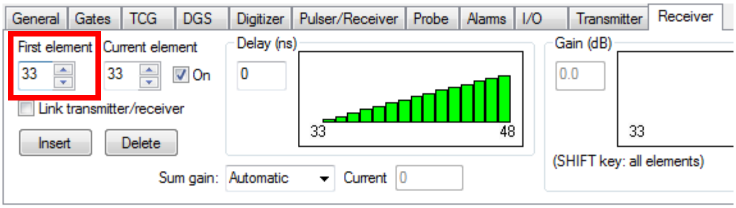


**Figure C-5 The First element on the Receiver tab of the UT Settings dialog box**

Scan_Offset

The Scan axis offset of the exit point for the given law relative to the mechanical reference point, expressed in *micrometers*.
In TomoView, the **Scan Offset** can be modified on the **Probe** tab of the **UT Settings** dialog box (see Figure C-6 on page 152).

Index_Offset

The Index axis offset of the exit point for the given law, relative to the mechanical reference point, expressed in *micrometers*.
In TomoView, the **Index Offset** can be modified on the **Probe** tab of the **UT Settings** dialog box (see Figure C-6 on page 152).

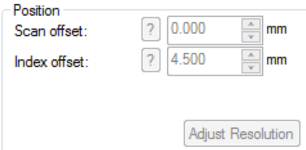


**Figure C-6 The Scan axis offset on the Probe tab of the UT Settings dialog box**

G_Delay

Specifies the global delay (GD) expressed in nanoseconds (ns).
GD = ED + WD + LD
ED: electronic delay. This delay is proper to the hardware and typically 1700 for the FOCUS and Tomoscan III PA systems.
WD: total wedge delay (transmission and reception).

LD: law delay (global delay introduced by the specified law).
In TomoView, the **Wedge delay** can be modified on the **Probe** tab of the **UT Settings** dialog box (see Figure C-7 on page 153).

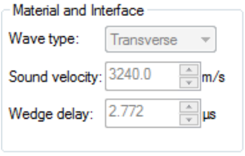


**Figure C-7 The Wedge delay on the Probe tab of the UT Settings dialog box**

*F_Depth*

Focusing true depth expressed in *micrometers*.

M_Velocity

Specifies the propagation velocity in the material, expressed in meters per second (m/s).
In TomoView, the **Sound velocity** can be modified on the **Probe** tab of the **UT Settings** dialog box (see Figure C-7 on page 153).

Element parameters

Parameters that are related to individual elements used in a defined beam.

E_number

The number identifying the individual element of the phased array probe relative to the first pulser and to the first receiver (see T_First and R_First). All numbers shall be consecutive (1, 2, 3, …). Non active elements shall be disabled by setting the delay to 65535 (see T_Delay and R_Delay).

FL_Gain

Beam Gain. The gain applied for the considered beam expressed in decibels (dB). Admitted range: 0–80. Elements of the same beam must have the same focal law gain.
For **.law** files generated in offline mode (that is, without phased array equipment connected), this parameter has the default value 0.
In TomoView, the **Beam** gain can be modified on the **General** tab of the **UT Settings** dialog box (see Figure C-8 on page 154). Make sure that **All laws** check box is cleared before modifying the focal law gain.

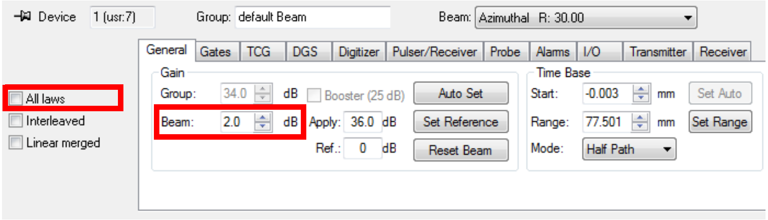


**Figure C-8 The Focal law gain on the General tab of the UT Settings dialog box**

T_Delay

Specifies the transmission delay for the specified active element. The delay is expressed in nanoseconds and must be between 0 and 25600. The transmission is deactivated when 65535 is used.

R_Delay

Specifies the reception delay for the specified active element. The delay is expressed in nanoseconds and must be between 0 and 25600. The reception is deactivated when 65535 is used.

Amplitude

The excitation amplitude for the specified active element, expressed in volts (range: 50–200). The value shall be the same for all defined elements and defined beams.
For **.law** files generated in offline mode (that is, without phased array equipment connected), this parameter has the default value 180.
In TomoView, the **Voltage** can be modified on the **Pulser/Receiver** tab of the **UT Settings** dialog box (see Figure C-9 on page 155).

P_width

The pulse width applied to the specified active element, expressed in nanoseconds (range: 50–500). The value shall be the same for all defined elements and beams used in the same law file.
For **.law** files generated in offline mode (that is, without phased array equipment connected), this parameter has the default value 50.
In TomoView, the **Pulse width** can be modified on the **Pulser/Receiver** tab of the **UT Settings** dialog box (see Figure C-9 on page 155).

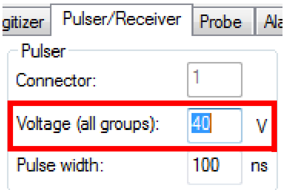


**Figure C-9  The Voltage on the Pulser/Receiver tab of the UT Settings dialog box**

# Appendix D: Description of the .pac file format

This appendix describes the .pac file format. This file is a text file, used to create specific DDF law configurations that cannot be done in TomoView.

The use of the **.pac** file format supposes that the user has good background knowledge of phased array technology in general and of the hardware and software in particular.

**NOTE**

The **.pac** file format should ONLY be used to save DDF beams. It is strongly recommended not to change any parameters in the .pac file.

## D.1 Conventions

The following conventions are used in the file format description.

< >

Parameter delimiter

[ ]

Optional parameter

crlf

Carriage return and line feed

sep

<space> 1 <tab>

**J**

Specifies to repeat the content between the accolades (depending on the number of laws and elements).

Normal characters (example N_Elements): represent a number.

Bold italic characters (example ***DDF***): represent a keyword or an abbreviation.

Underlined characters (example G_Delay): represent Tomoview parameters which can also be re-defined in the **UT Settings** of TomoView without changing the law formation.

Italic characters (example *Frequency*): represent not used parameters.

# D.2 General format

## D.2.1 Format

```
<Version><crlf>
PT<space><PodType>,<N-MaxActiveElements><crlf>

J{DF<Law_number_S>,<N_ActiveElements>,<Type>,<P_width>,
    <Burst>,<Mode>,<SumGain>,<R_Angle>,<S_Angle>,<Scan_Offset>,
    <Index_Offset>,<G_Delay>,<F_Depth>,<M_Velocity><crlf>

J{<E_number>/<FL_Gain>,<Amplitude>,<Filter>,<T_Delay>,<R_Delay>
    <T_element_number>,<_R_element_number ><crlf>}

J{DD<space><Dyn_start>,<Dyn_nbr>,<Dyn_div><crlf>
EF<Law_number_E><crlf>}}

PD<Selfifo>,<Swpdel><crlf>
FD<#Module>,<Dynamic_Hex>

DS<0>,<T_LawNumber>
LS <T_LawNumber>
```

## D.2.2 Example of .pac File for Non-DDF Laws

An example of a **.pac** file for non-DDF laws, containing two beams using 10 elements (the same configuration as described in Appendix C on page 147), as generated by the TomoView Advanced Calculator is given hereunder:

```
V2.1
```

```
PT Focus,32
DF1,10,1,50,1,1,24,400,0,20304,0,14829,38303,3230
DF1/0,180,0,564,564,1,1
DF2/0,180,0,517,517,2,2
DF3/0,180,0,466,466,3,3
DF4/0,180,0,411,411,4,4
DF5/0,180,0,352,352,5,5
DF6/0,180,0,289,289,6,6
DF7/0,180,0,223,223,7,7
DF8/0,180,0,153,153,8,8
DF9/0,180,0,78,78,9,9
DF10/0,180,0,0,0,10,10
EF1
DF2,10,1,50,1,1,24,500,0,22350,0,15314,32139,3230
DF1/0,180,0,168,168,1,1
DF2/0,180,0,162,162,2,2
DF3/0,180,0,153,153,3,3
DF4/0,180,0,140,140,4,4
DF5/0,180,0,125,125,5,5
DF6/0,180,0,107,107,6,6
DF7/0,180,0,85,85,7,7
DF8/0,180,0,60,60,8,8
DF9/0,180,0,32,32,9,9
DF10/0,180,0,0,0,10,10
EF2
DS0,2
LS2
```

### D.2.3 Example of .pac File for DDF Laws

An example of a **.pac** file for DDF laws, containing two beams using 8 elements, as generated by the TomoView Advanced Calculator is given hereunder:

```
V2.1
PT Focus,32
DF1,8,1,50,1,1,26,400,900,0,-50812,14095,50000,3230
DF1/0,180,0,438,438,1,1
DF2/0,180,0,385,386,2,2
DF3/0,180,0,328,330,3,3
DF4/0,180,0,269,271,4,4
DF5/0,180,0,206,208,5,5
DF6/0,180,0,141,142,6,6
DF7/0,180,0,72,73,7,7
DF8/0,180,0,0,0,8,8
DD F7AD,FFF0,81EF
EF1
DF2,8,1,50,1,1,26,450,900,0,-49832,14341,50000,3230
DF1/0,180,0,280,280,1,1
DF2/0,180,0,248,248,2,2
```

```
DF3/0,180,0,213,214,3,3
DF4/0,180,0,176,177,4,4
DF5/0,180,0,136,137,5,5
DF6/0,180,0,93,95,6,6
DF7/0,180,0,48,49,7,7
DF8/0,180,0,0,0,8,8
DD F72A,FFEE,01EF
EF2
PD 400,fffe
FD 1,0000
FD 1,0000
FD 1,0000
FD 1,0000
FD 1,0000
FD 1,0000
FD 1,0000
FD 1,0000
FD 1,0000
FD 1,0000
FD 1,0000
FD 1,0000
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FD 1,0000
FD 1,0000
FD 1,0000
FD 1,0000
FD 1,0000
FD 1,0000
FD 1,0000
FD 1,0000
FD 1,0000
FD 1,0000
FD 1,0000
FD 1,0000
FD 1,0000
FD 1,0000
DS0,2
LS2
```

# D.3 Object Description

## D.3.1 General Parameters

This section includes parameters that are related to the .pac file format.

Version

<V> <number> <'.'> <number>:
V2.1 is the only version supporting the FOCUS LT pod family.

N_MaxActiveElements

PT <PodType>,<N_MaxActive|Elements>:
Focus or FOCUS LT. Type used for DDF only.
Identifies the total number of active elements, allowed by the hardware, that could be used to generate the beam. The number is 16, 32, or 64.

## D.3.2 Law Parameters

This section includes parameters that are related to the beams defined in the .pac file.

Law_number_S

<DF><Law_number>:
Indicates the current focal law number

N_ActiveElements

The number of active elements used to generate the given beam. The number shall be between 1 and 64 and shall fit to the limits of the hardware.

Type:

Defines the kind of element:
1 = for Piezo
The value should always be set to 1.

P_width

The pulse width applied to the specified active element, expressed in nanoseconds (range: 50–500). The value shall be the same for all defined elements and beams used in the same law file.
For **.pac** files generated in offline mode (that is, without phased array equipment connected), this parameter has the default value 50.
In TomoView, the **Pulse width** can be modified on the **Pulser/Receiver** tab of the **UT Settings** dialog box (see Figure D-1 on page 162).

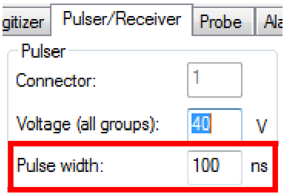


**Figure D-1 The Pulser area of the Pulser/Receiver tab of the UT Settings dialog box**

Burst

Defines the number of burst:
The value should always be set to 1.

*Mode*

The inspection mode for the given law: 0 = T/R (different pulser and receiver elements), or 1 =. Pulse-echo (same pulser and receiver elements).

SumGain

Gain working range, expressed in dB, for a given law. The value is calculated according to the following formula:
Sum gain = 44 – [20 * Log(N)]
where N is the number of active elements used.
In TomoView, the **Sum gain** can be modified on the **Receiver** tab of the **UT Settings** dialog box (see Figure D-2 on page 162).

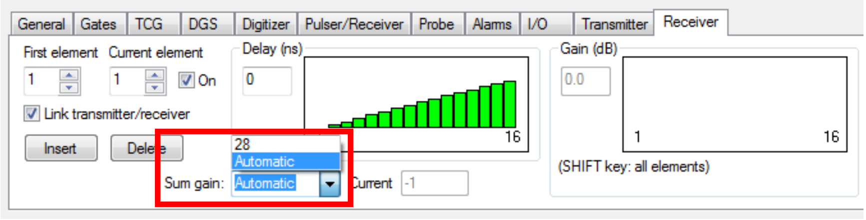


**Figure D-2 The Sum gain on the Receiver tab of the UT Settings dialog box**

R_Angle

The refracted angle for the given law expressed in tenths of degrees. This figure shall be between 0 and 900 (positive sign).

In TomoView, the **Refracted angle** can be modified on the **Probe** tab of the **UT Settings** dialog box (Figure D-3 on page 163).

S_Angle

The skew angle for the given law expressed in tenths of degrees (number between 0 and 3599, positive sign).
In TomoView, the **Skew angle** can be modified on the **Probe** tab of the **UT Settings** (see Figure D-3 on page 163).

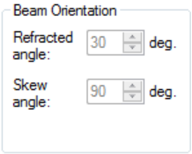


**Figure D-3 The Refracted angle on the Probe tab of the UT Settings dialog box**

Scan_Offset

The Scan axis offset of the exit point for the given law relative to the mechanical reference point, expressed in *micrometers*.
In TomoView, the **Scan Offset** can be modified on the **Probe** tab of the **UT Settings** dialog box (see Figure D-4 on page 163).


**Figure D-4 The Scan axis offset on the Probe tab of the UT Settings dialog box**

Index_Offset:

The Index axis offset of the exit point for the given law, relative to the mechanical reference point, expressed in *micrometers*.
In TomoView, the **Index Offset** can be modified on the **Probe** tab of the **UT Settings** dialog box (see Figure D-4 on page 163).

G_Delay

Specifies the global delay (GD) expressed in nanoseconds (ns).
GD = ED + WD + LD
ED: electronic delay. This delay is proper to the hardware and typically 1700 for the FOCUS and Tomoscan III PA systems.
WD: total wedge delay (transmission and reception).
LD: law delay (global delay introduced by the specified law).
In TomoView, the **Wedge delay** can be modified on the **Probe** tab of the **UT Settings** (see Figure D-5 on page 164).

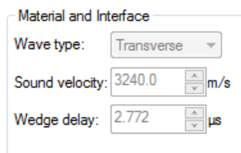


**Figure D-5 The Wedge delay on the Probe tab of the UT Settings dialog box**

*F_Depth*

Focusing true depth expressed in *micrometers*.

M_Velocity

Specifies the propagation velocity in the material, expressed in meters per second (m/s).
In TomoView, the **Sound velocity** can be modified on the **Probe** tab of the **UT Settings** dialog box (see Figure D-5 on page 164).

## D.3.3 Element Parameters

This section includes parameters that are related to individual elements used in a defined beam.

E_number

<DF><E_number>:
The number identifying the individual element of the phased array probe relative to the pulser and to the receiver number (see T_element_number and R_element_number). All numbers shall be consecutive (1, 2, 3, …). Non active elements shall be disabled by setting the delay to 65535 (see T_Delay and R_Delay).

FL_Gain

Focal Law Gain. The gain applied for the considered focal law expressed in decibels (dB). Admitted range: 0–80. Elements of the same focal law must have the same focal law gain.
For **.pac** files generated in offline mode (that is, without phased array equipment connected), this parameter has the default value 0.
In TomoView, the **Beam** gain can be modified on the **General** tab of the **UT Settings** dialog box (see Figure D-6 on page 165). Make sure that **All laws** is cleared before modifying the focal law gain.

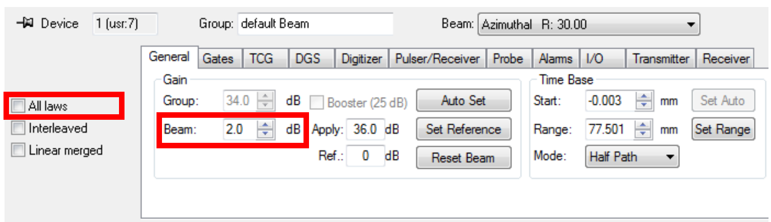


**Figure D-6 The Focal law gain on the General tab of the UT Settings dialog box**

Amplitude

The excitation amplitude for the specified active element, expressed in volts (range: 50–200). The value shall be the same for all defined elements and defined beams.
For **.pac** files generated in offline mode (that is, without phased array equipment connected), this parameter has the default value 180.
In TomoView, the **Voltage** can be modified on the **Pulser/Receiver** tab of the **UT Settings** (see Figure D-7 on page 165).

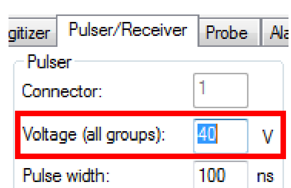


**Figure D-7 The Voltage on the Pulser/Receiver tab of the UT Settings dialog box**

Filter

Specifies the filter applied at reception.
0 = no filter (0.5–20 MHz)
1 = 0.5–5 MHz
2 = 2–10 MHz
3 = 5–15 MHz
In TomoView, the Filter can be modified on the **Pulser/Receiver** tab of the **UT Settings** dialog box (see Figure D-8 on page 166).

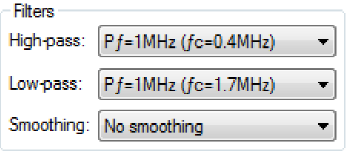


**Figure D-8 The Filters area of the Pulser/Receiver tab of the UT Settings dialog box**

T_Delay

Specifies the transmission delay for the specified active element. The delay is expressed in nanoseconds and must be between 0 and 25600. The transmission is deactivated when 65535 is used.

R_Delay

Specifies the reception delay for the specified active element. The delay is expressed in nanoseconds and must be between 0 and 25600. The reception is deactivated when 65535 is used.

T_element_number[1]

Specifies the number of the current pulser (≡ current pulser hardware connection) that will be used for transmission. This number must be between 1 and the maximum allowed by the hardware (for instance, 16, 32, 64, 128, …) or by the probe array.
In TomoView, the first pulser can be modified on the **Transmitter** tab of the **UT Settings** dialog box (see Figure D-9 on page 167).

1.It is important to notice that if this parameter is re-defined in the UT settings of TomoView, the wedge delay calculated by the TomoView Advance PA Calculator will be incorrect.

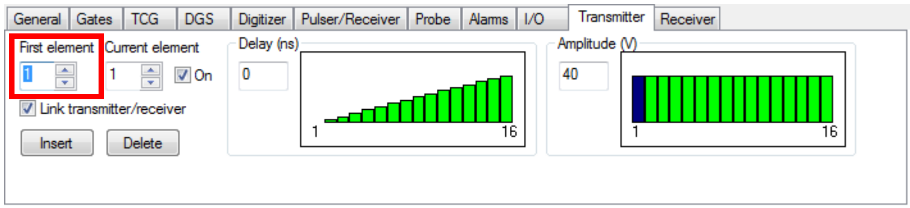


**Figure D-9  The First element on the Transmitter tab of the UT Settings dialog box**

R_element_number[1]

Specifies the number of the current receiver (≡ current receiver hardware connection) that will be used at reception. This number must be between at 1 and the maximum allowed by the hardware (for instance, 16, 32, 64, 128 …) or by the probe array.

In TomoView, the first receiver can be modified on the **Receiver** tab of the **UT Settings** dialog box (see Figure D-10 on page 167).

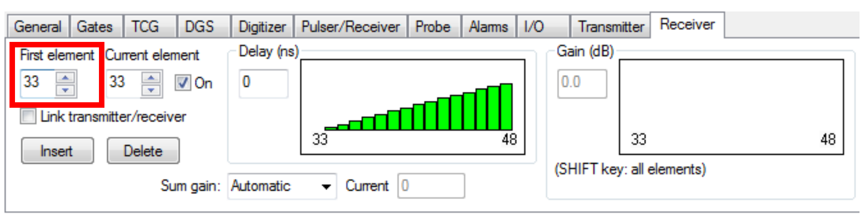


**Figure D-10  The First element on the Receiver tab of the UT Settings dialog box**

Law_number_E

<EF><Law_number>:

Indicates the end of the definition of the current focal number.

T_LawNumber

Indicates the total beams defined in the **.pac** file.

1.Idem.

### D.3.4 DDF Parameters

This section includes parameters that are related to the dynamic depth focusing algorithm.

Dyn_start

Indicates the start point from where the dynamic depth focusing should be applied. The value is expressed in hexadecimal.

Dyn_nbr

Indicates the number of sliding steps used in the dynamic depth focusing algorithm. The value is expressed in hexadecimal.

Dyn_div

Indicates the divider of the sliding step used in the dynamic depth focusing algorithm. The value is expressed in hexadecimal. Maximum 2 bytes. Higher two bytes are reserved for special bit field settings. Bit fields do not have the same meaning for Tomoscan III and FOCUS LT pods.

---

**NOTE**

For the Tomoscan III, the values of Dyn_start, Dyn_nbr, and Dyn_div are expressed as a negative count. For example, a Dyn_start of 0x0004 is expressed as 0xFFFB. For the FOCUS LT, the values are expressed normally. For example, a Dyn_start of 0x0004 is expressed as 0x0004.

---

Selfifo

Activates the dynamic depth focusing in the hardware chip.

Wpdel

Initial value of the delays before the dynamic depth focusing algorithm is applied. The value is expressed in hexadecimal.

#Module

Number of module to be programmed.

Dynamic_HEX

Defines the value in hexadecimal of the dynamic shift that must be applied.

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