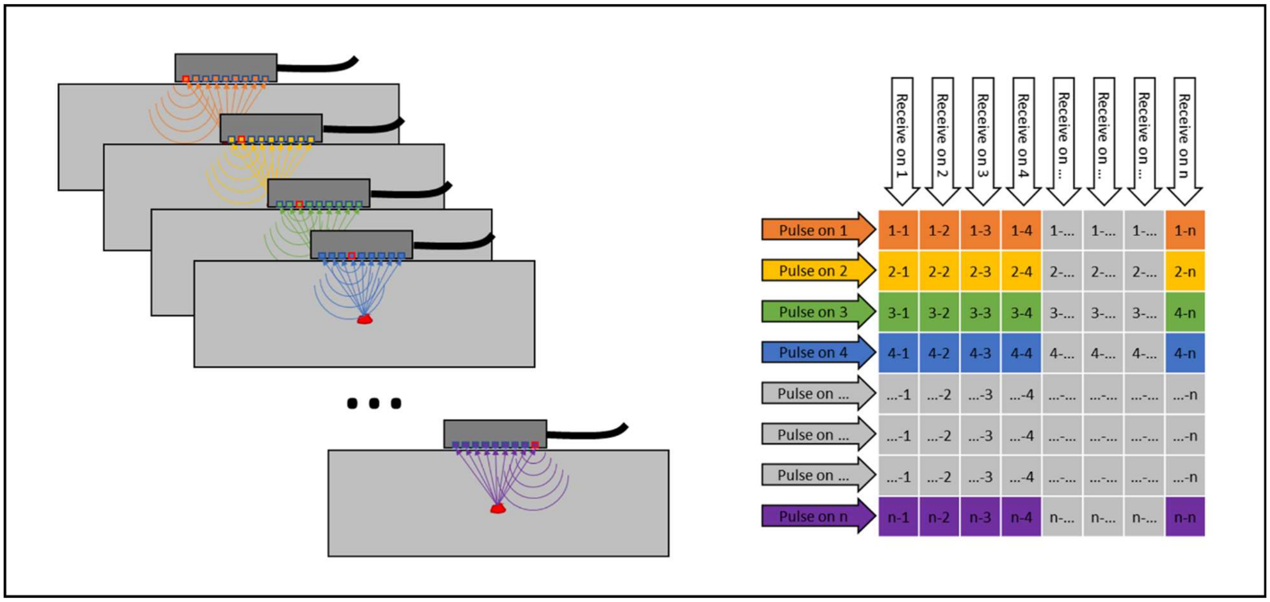
Eddyfi Technologies

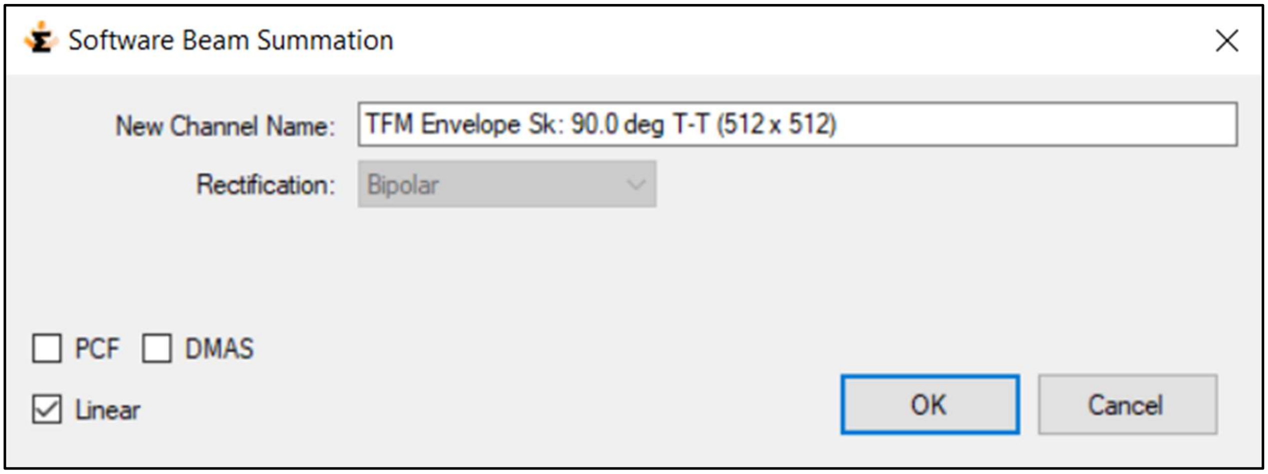
Delivering the Zetec Inspection Advantage

UltraVision Classic

How To Guide – Release 3.11R4 & Higher

FMC & PWI Raw Data Reconstruction





Revision History

Revision	*Modifications*	*Date*
1	Original	2020.11.16
2	• Modified UI for Software Beam Summation Tool • Added PWI raw data reconstruction • Added “Linear Unchecked” reconstruction	2023.04.05

Table of Content

1 Introduction - Purpose of the Tool

The EMERALD remote data acquisition unit and the TOPΔZ^{64} integrated phased array unit have the capability to record individual A-scans from FMC and PWI firing sequences, in addition to live TFM and phased array data.

The legacy DYNARAY remote data acquisition unit has the capability to record individual FMC A-scans in addition to live phased array data.

After recording, the UltraVision Classic software can be used to reconstruct various types of data groups from the raw FMC data, including standard phased array signals, TFM (Total Focusing Method) frames or TF (Total Focusing) images.

For raw PWI data, the reconstruction options are limited to TFM frames.

All FMC and PWI data reconstruction operations are performed using the **Process Summation** tool in the **Advanced Calculator.**

By recording the raw A-Scan data, the signals received by each individual element of the probe remain available for data analysis, and this allows the operator to fully exploit the benefits of various techniques, wave modes and advanced reconstruction algorithms.

FMC raw data saving on a complete weld is still a time-consuming process, but taking FMC Snapshots or Full Data on short scans in flawed or suspicious regions can be a valuable asset for the characterization and sizing of challenging flaws. In addition, the introduction of PWI firing has made the raw data saving process a more “industrial” option.

The second section of this document provides a brief explanation of the differences between FMC and PWI firing sequences.

The third section provides more detailed information about the advanced raw data reconstruction options in UltraVision Classic.

The fourth and the fifth section respectively illustrate the FMC and PWI raw data reconstruction processes in UltraVision Classic for some typical user cases , using relevant ultrasonic data.

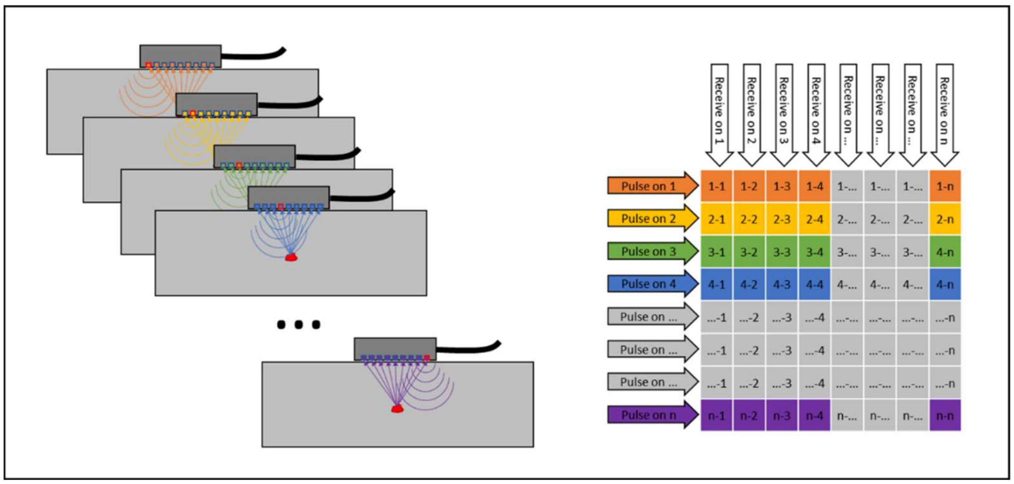
And in the last section “Reference Guide”, the various tools and options will be listed and explained in detail.

2 FMC & PWI Raw Data Reconstruction Options

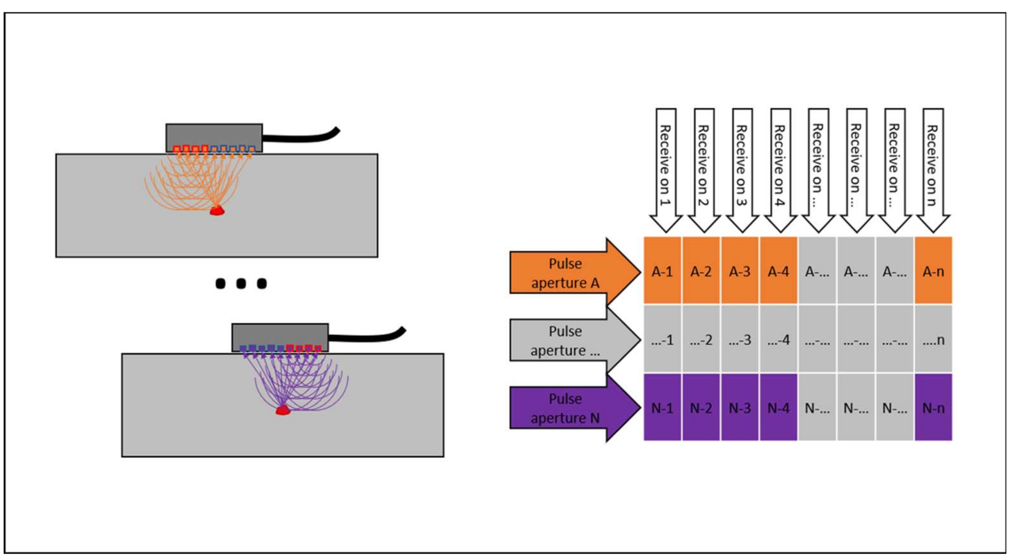
2.1 FMC Firing Sequence

The Full Matrix Capture (FMC) firing sequence consists in capturing and recording A-Scan signals from every transmitter-receiver pair in an array. Each element of the probe is fired sequentially, and for each element pulsed, every receiving element collects an individual A-scan.

At the end of the FMC firing sequence for a probe with 64 elements, a matrix of 4096 (64 x 64) A-scan signals is recorded.



2.2 PWI Firing Sequence



Plane Wave Imaging (PWI) is an alternative firing technique that uses a multi-element aperture for pulsing, instead of firing each element individually like FMC.

The PWI firing sequence consists of one or more focal laws, typically with varying refracted angle. After each pulse, the raw A-scans from the reception by each individual element of the probe will be collected. Obviously, by firing more pulses at a wider range of angles, more and better information from the reflectors in the region of interest will be captured.

At the end of the PWI firing sequence with 10 pulses (angles) for a probe with 64 elements, a matrix of 640 (10 x 64) A-scan signals is recorded.

PWI raw data recording has several benefits compared to FMC raw data recording:

- The emitted pulse from the full aperture has more energy and is more directional than a single element excitation; therefore, it provides greater sensitivity and potentially better SNR
- The firing sequence is significantly shorter (# pulses vs. # probe elements), which results in a higher PRF and scanning speed
- Less elementary A-scans need to be recorded and processed

So basically, PWI raw data recording has the potential to considerably increase the scanning speed, while conserving most of the benefits and the quality of classic FMC-TFM imaging.

3 FMC & PWI Raw Data Reconstruction Options

The UltraVision Classic software can be used to reconstruct various types of data groups from the raw data, including standard phased array signals, TFM (Total Focusing Method) frames or STF (Sectorial Total Focusing) images.

Standard phased array UT data group (only from FMC raw data)

In this case the FMC elementary A-scans are used to generate a sectorial, a linear or a compound sweep of A-scans, while applying the settings of the Advanced Calculator defined by the user. This is essentially the same calculation used during live phased array UT.

TFM (Total Focusing Method) data group (for both TFMC and PWI raw data)

TFM is the most commonly used advanced focusing algorithm.

The TFM algorithm sums all elementary A-scan signals acquired during the FMC or PWI firing sequence to generate a frame of pixels, where each pixel is computed using a dedicated focal law. The resulting TFM data group has the same characteristics as a merged data group.

In theory, ideal focusing is achieved in each point of the frame, but the focusing capability of this technique still depends on the acoustic wavelength and the total aperture of the array. Therefore, some conditions must be met to effectively obtain ideal focusing.

TF (Total Focusing) data group (only for FMC raw data)

The elementary A-scans from the FMC data recording can also be used to generate a sectorial (azimuthal), a linear or a compound sweep of A-scans, while focusing in each point along the sound path.

In the case of a sectorial sweep we will call this technique STF or "Sectorial Total Focusing", and its physical principle is very similar to a DDF (or Dynamic Depth Focusing) algorithm, applied both in transmission and in reception.

The algorithm has the benefit of generating a summed A-scan signal for each angle, identical to standard PA UT.

For reconstruction of TFM and TF data groups, UltraVision Classic offers a number of options:

DAS (Delay And Sum)

This is the most commonly used TFM and TF reconstruction algorithm. It basically applies appropriate delays to the individual pulser-receiver A-scan, and sums them afterwards.

DMAS (Delay Multiply And Sum)

This algorithm sums the delayed pulser-receiver A-Scans multiplied by each other. This process reduces the well-known TFM artifacts (isochrones) that are in fact "partially constructive" interferences, often occurring in the presence of large reflectors like the back-wall of a component.

PCF (Phase Coherence Factor)

TFM and TF with Phase Coherence Factor reduces the sidelobes of the image by modulating the amplitude of the signals with the phase information.

Envelope

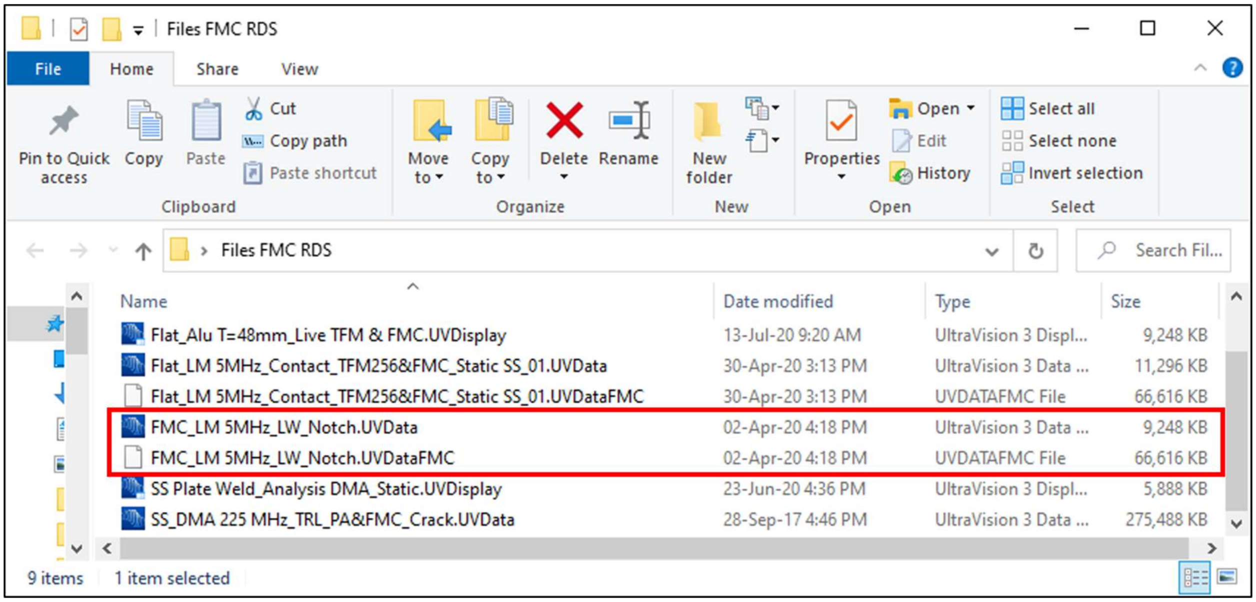
This algorithm processes analytic signals obtained from the pulser-receiver A-Scans using the Hilbert Transform. The "envelope" is obtained from the magnitude of the summed analytic signals. The resulting images look like phased array signals with a smoothing filter applied.

The Envelope can be combined with either DAS, DMAS or PCF.

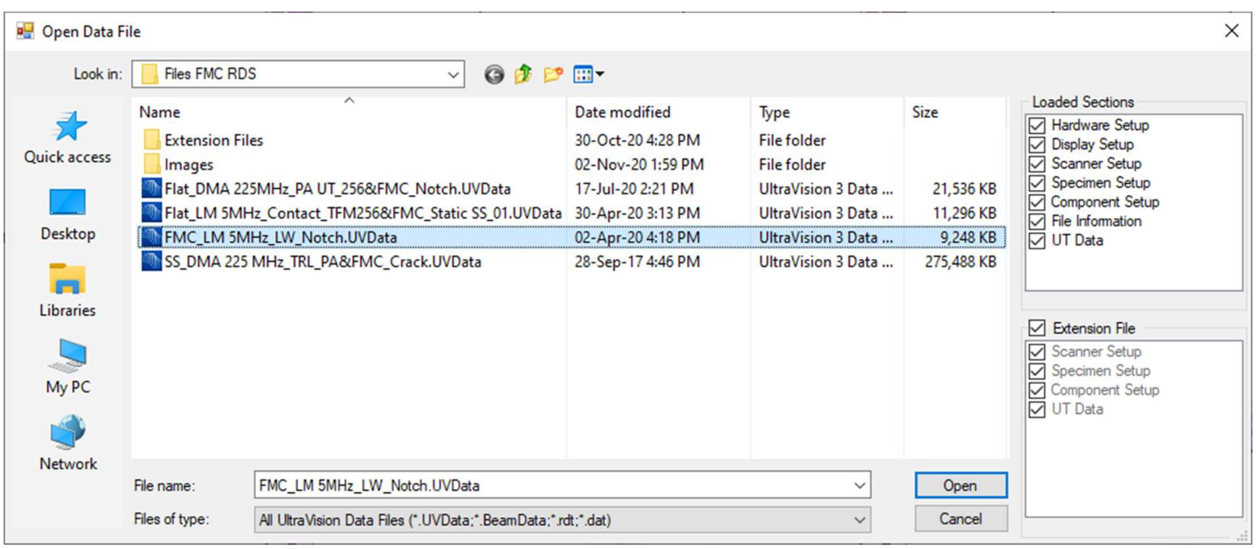
4 Typical User Cases - FMC Data Reconstruction

4.1 1D-Linear Probe, LW Wedge, Pulse-Echo Mode, recorded with TOPΔZ64

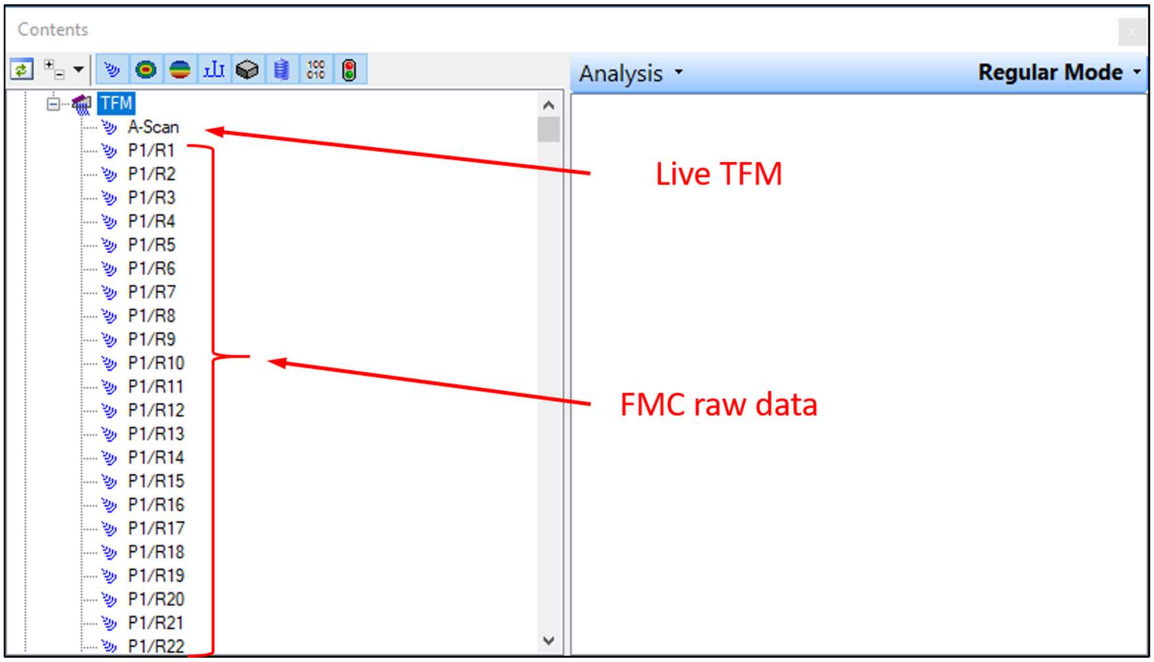
When FMC raw data are recorded with EMERALD or TOPΔZ64, the software generates 2 separate files, i.e. the regular **UVData** file that contains the phased array and/or live TFM data, and an additional **UVDataFMC** file with the same name that contains the raw FMC data.



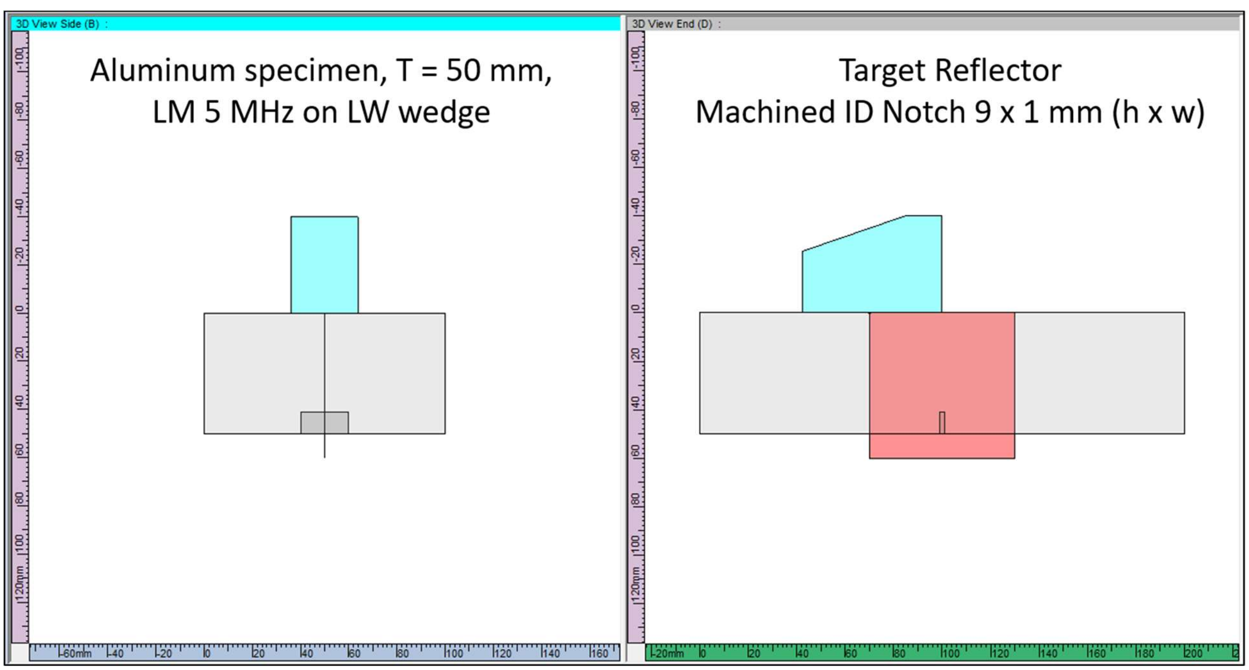
In order to process the raw data, both files must be in the same directory on the computer. Just open the regular UVData file in UltraVision Classic and the additional file will automatically be loaded.



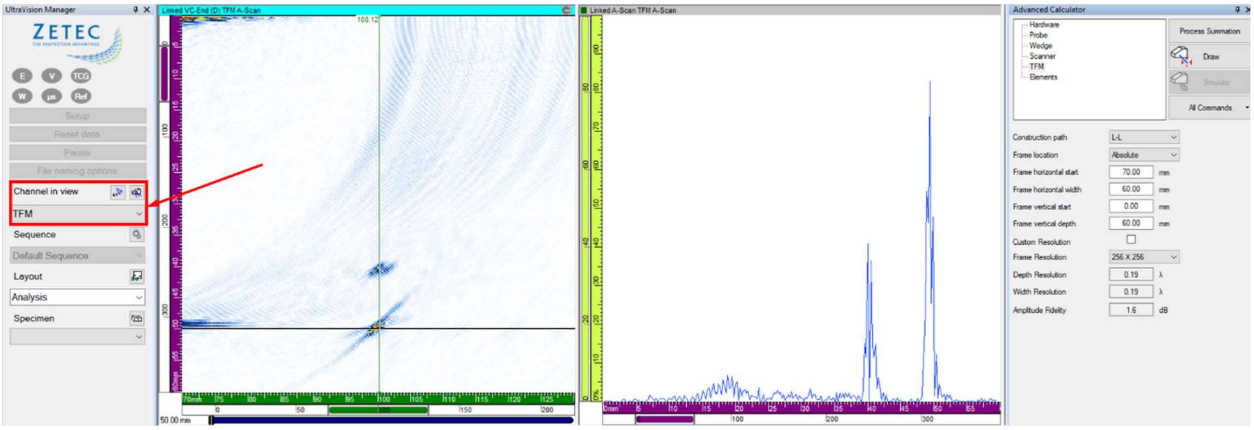
Once the file is loaded, the raw FMC A-scan data will show up in the **Contents** Pane



The file for this user case was recorded on a reference specimen with a machined notch, and contains a static TFM frame 256 x 256 in L-L mode, in addition to an FMC Snapshot containing 4096 (64 x 64) individual A-scans.



The Linked VC-End view (for skew 90, 270 configurations) or Linked VC-Side view (for skew 0, 180 configurations) together with the A-Scan view are typically used to visualize live TFM data.

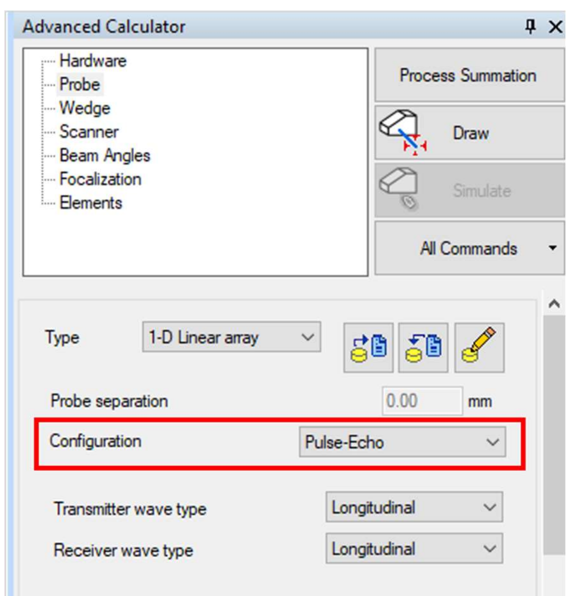


The TFM frame shows part of the back-wall echo, and tip and corner echoes from the machined notch.

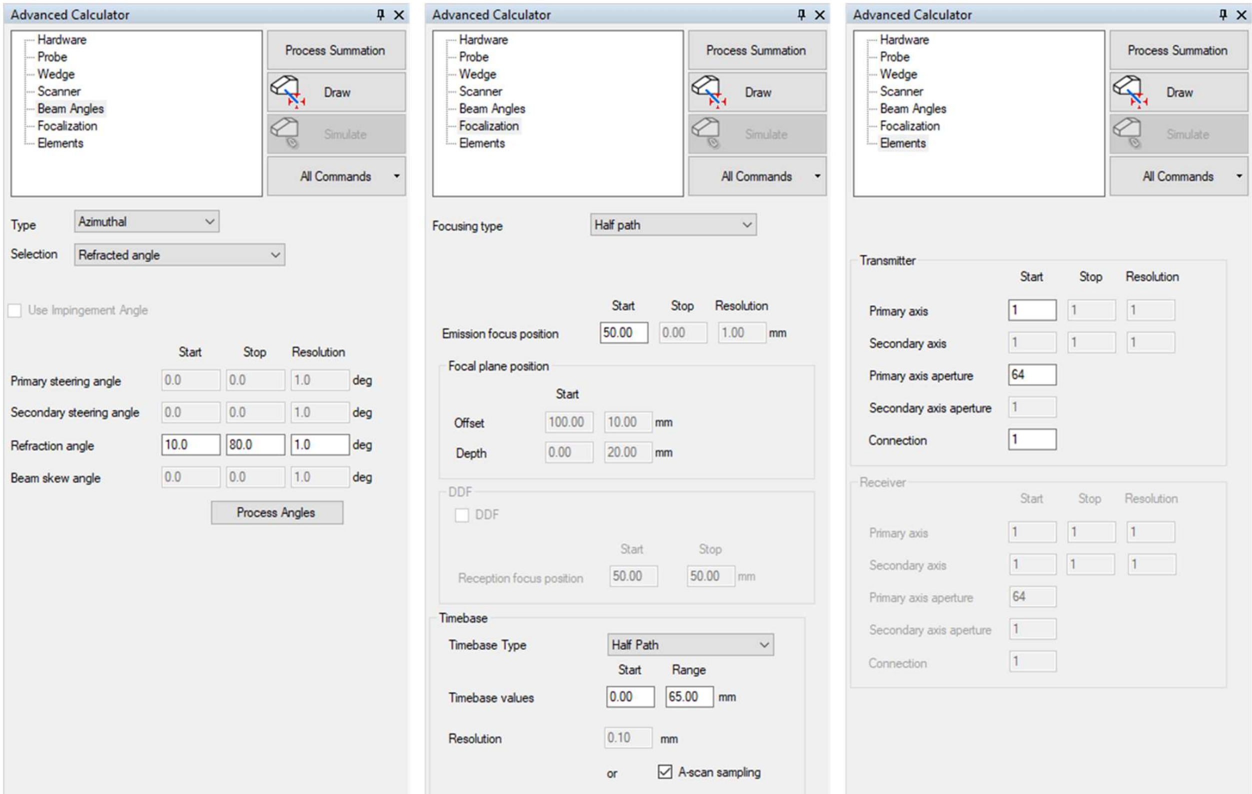
4.1.1 Standard PA UT Reconstruction

The reconstruction of raw FMC data is performed in the **Advanced Calculator** interface.

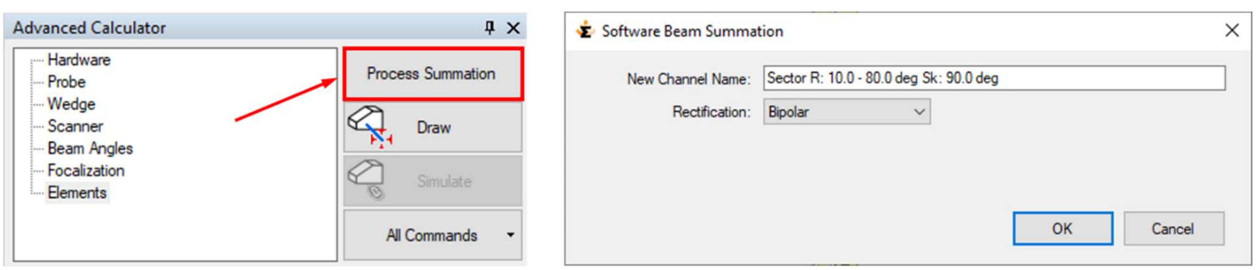
To reconstruct standard PA UT data, select **Configuration Pulse-Echo** in the **Probe tab**.



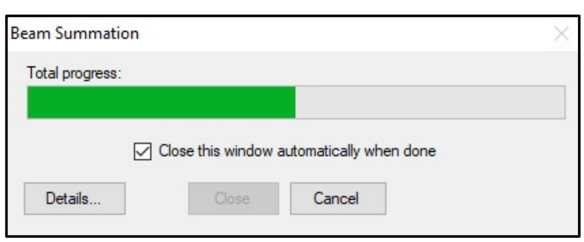
Then define the parameters of the Sector scan in the **Beam Angles**, **Focalization** and **Elements** tabs.



Then hit the **Process Summation** button, and the software will propose a structured name for the **New Channel** of reconstructed data. The user can modify this name.

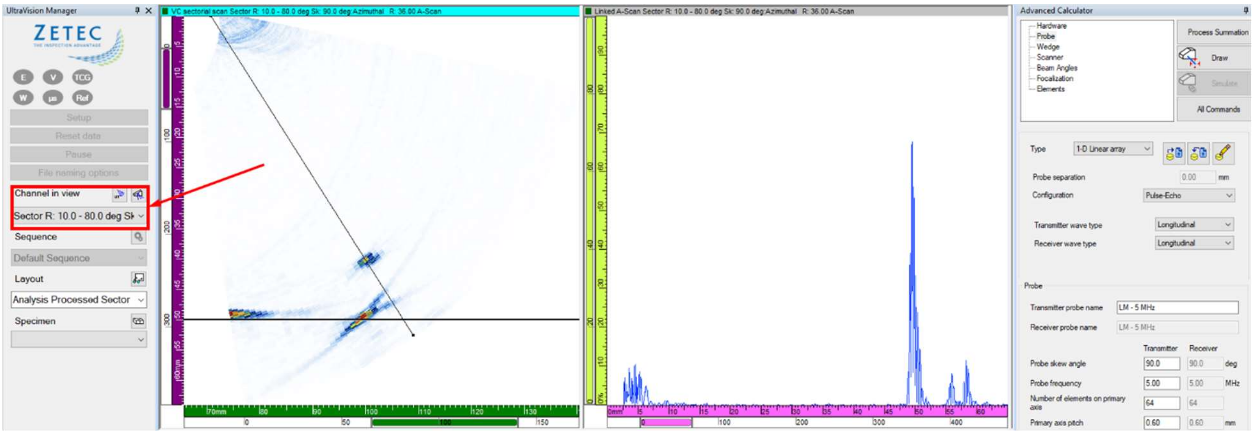


Upon hitting **OK** the data will be processed.



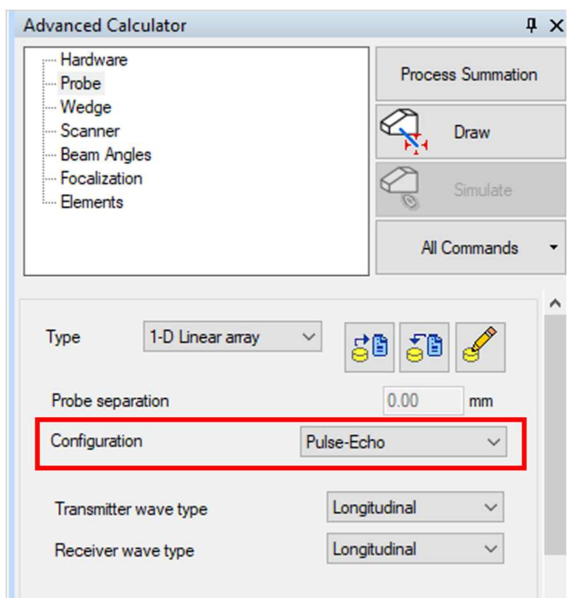
After processing, the reconstructed channel will appear in the **UltraVision Manager**, and can be visualized like regular standard phased array data (e.g. Sectorial scan and A-scan views). The sectorial scan from 10° to 80°LW focused at HP 50 mm shows part of the back-wall echo, and tip and corner echoes from the machined notch.

This reconstructed data group has exactly the same characteristics as a regular phased array data group and can be further used for **Volumetric Merge** operations and visualization.

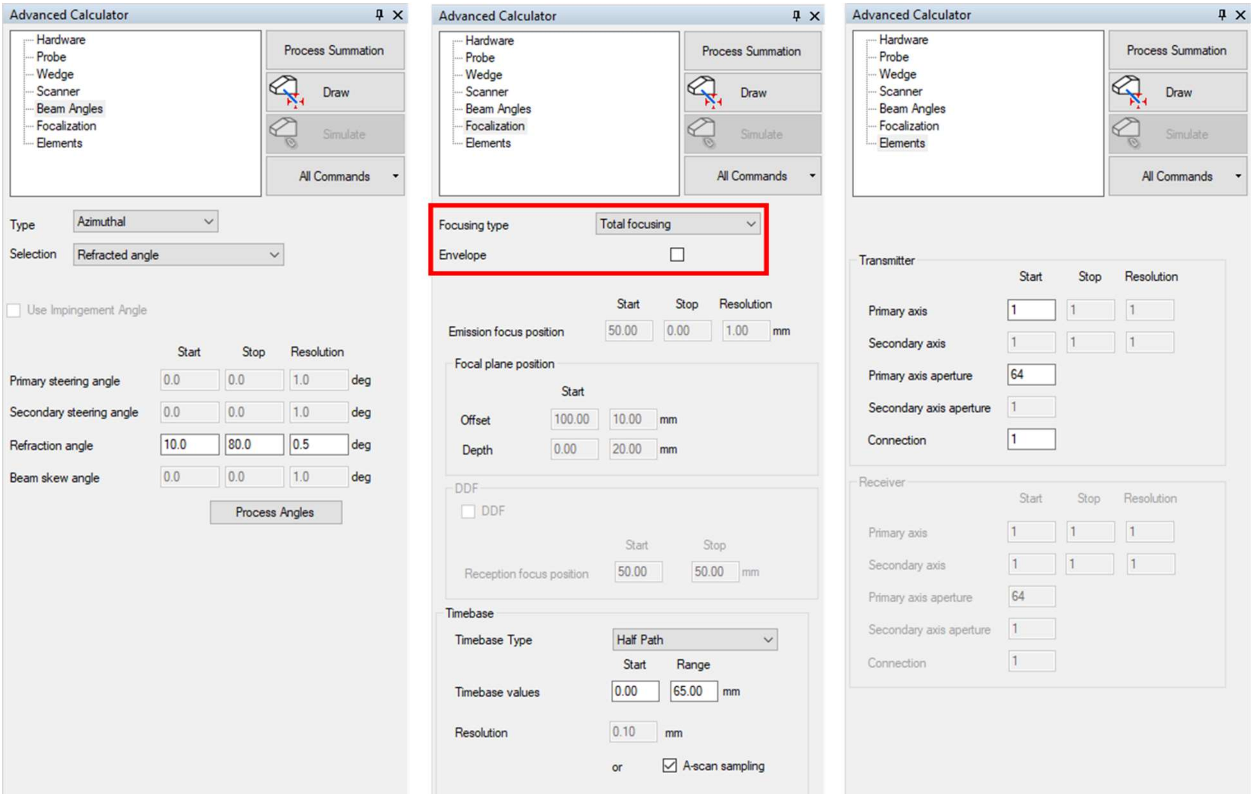


4.1.2 Sectorial Total Focusing Reconstruction

To reconstruct Sectorial Total Focusing data, select **Configuration Pulse-Echo** in the **Probe** tab.

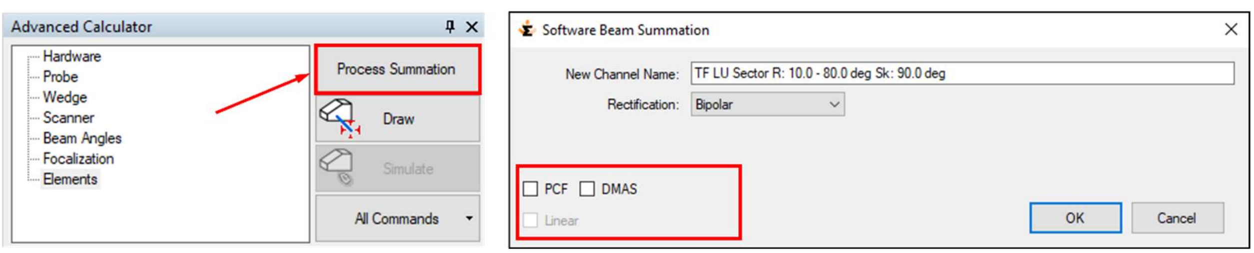


Then define the parameters of the Sector scan in the **Beam Angles**, **Focalization** and **Elements** tabs. In the **Focalization** tab select **Focusing Type Total Focusing.** In this tab the **Envelope** option can also be selected.



Then hit the **Process Summation** button, and the software will again propose a structured name for the **New Channel** of reconstructed data.

In the case of a data reconstruction with STF (Sectorial Total Focusing), the processing options appear: **PCF** (Phase Coherence Factor), **Envelope** and **DMAS** (Delay Multiply and Sum). If none of the options is checked, the common **DAS** (Delay and Sum) reconstruction algorithm is used.



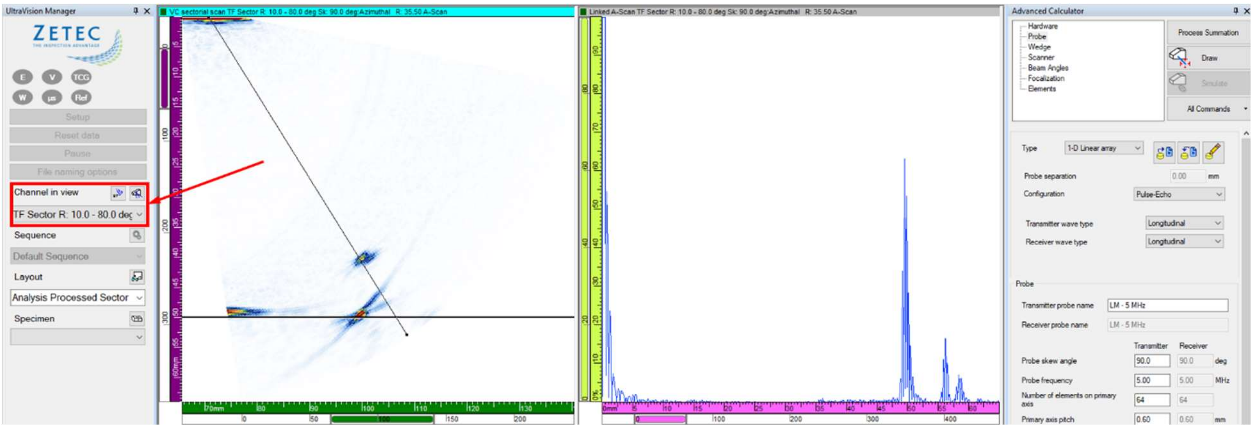
Important Note :

A sectorial data group has been selected here for reconstruction, meaning that the individual reconstructed A-scans will be accessible for e.g. Volumetric Merge. For that reason the “Linear” option is unchecked (and grayed out), and the proposed structured name includes the mention **“LU” (“Linear Unchecked”).**

Upon hitting **OK** and processing, the reconstructed STF channel will appear in the **UltraVision Manager**, and can be visualized like regular standard phased array data (e.g. Sectorial scan and A-scan views).

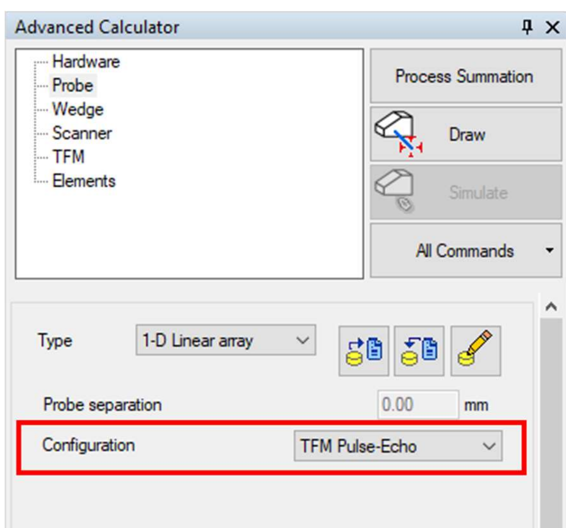
This reconstructed data group has exactly the same characteristics as a regular phased array data group and can be further used for **Volumetric Merge** operations and visualization.

In this example, the image from the reconstructed STF looks very similar to the reconstructed standard PA UT focused at HP 50 mm, because the notch is in the focusing range of the standard PA UT.



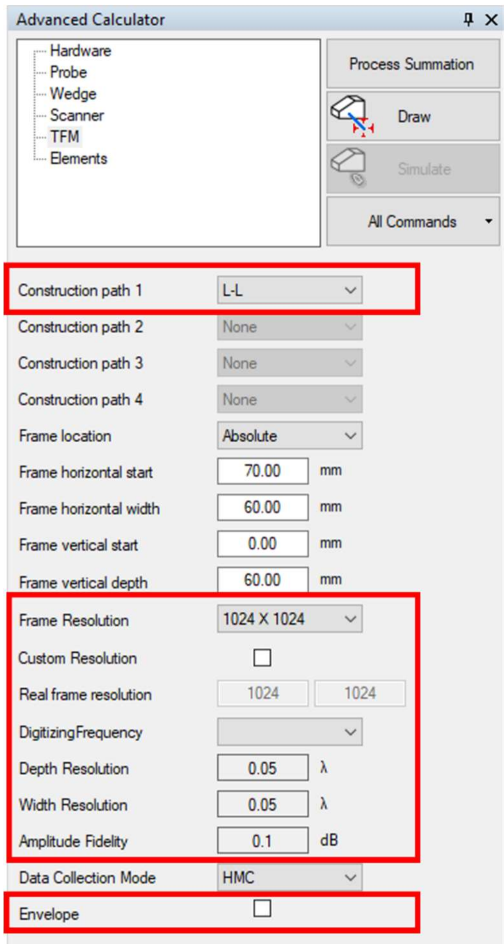
4.1.3 FMC-TFM Reconstruction

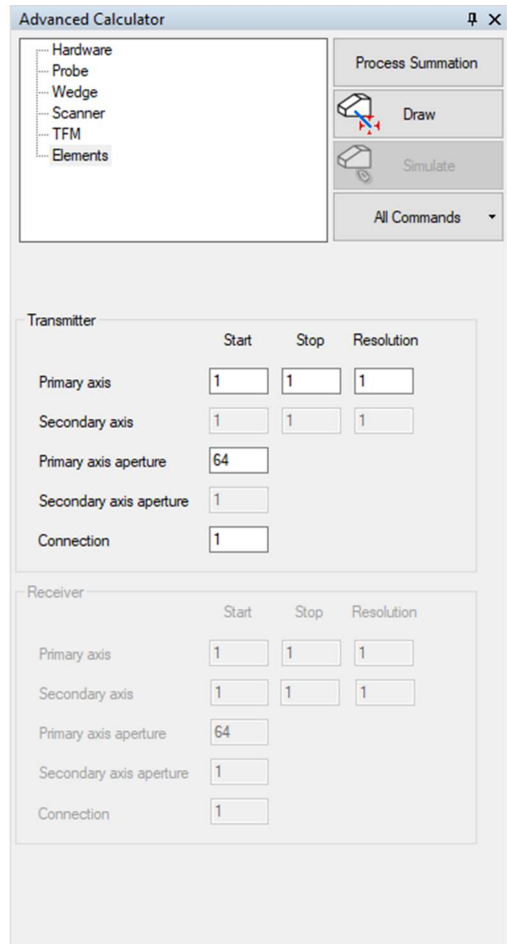
To reconstruct FMC-TFM data, select **Configuration TFM Pulse-Echo** in the **Probe tab**.



Then define the parameters of the TFM frame in the **TFM** and **Elements** tabs. The parameters for the definition of the reconstructed TFM data are similar as for the live TFM on TOPΔZ^{64} .

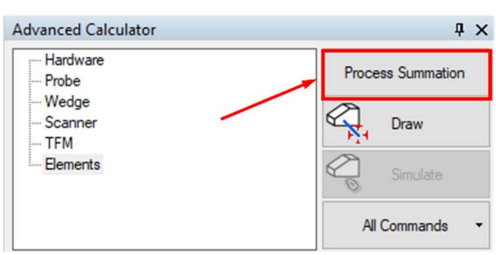
First, the **Construction path** will be set to **L-L**, just like the live TFM data, and also the frame extent will be selected identical. The **Frame Resolution** will set at 1024 x 1024, improving the **Amplitude Fidelity** from 1.6 dB to 0.1 dB. In this tab the **Envelope** option can also be selected.

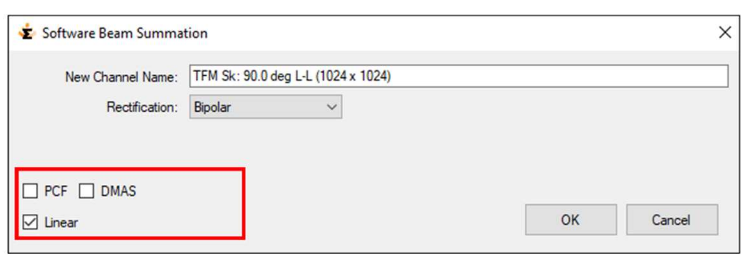




Then hit the **Process Summation** button, and the software will again propose a structured name for the **New Channel** of reconstructed data.

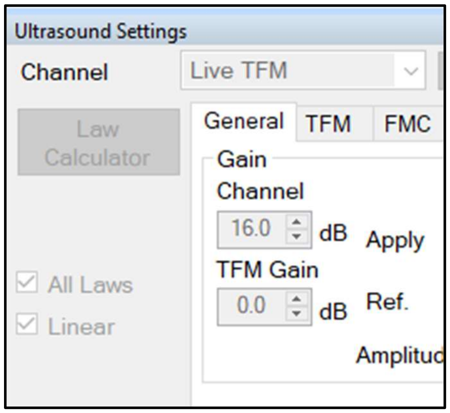
In the case of a TFM data reconstruction, the same options appear as for STF: **PCF** (Phase Coherence Factor), and **DMAS** (Delay Multiply and Sum). If none of these options is checked, the common **DAS** (Delay and Sum) reconstruction algorithm is used.





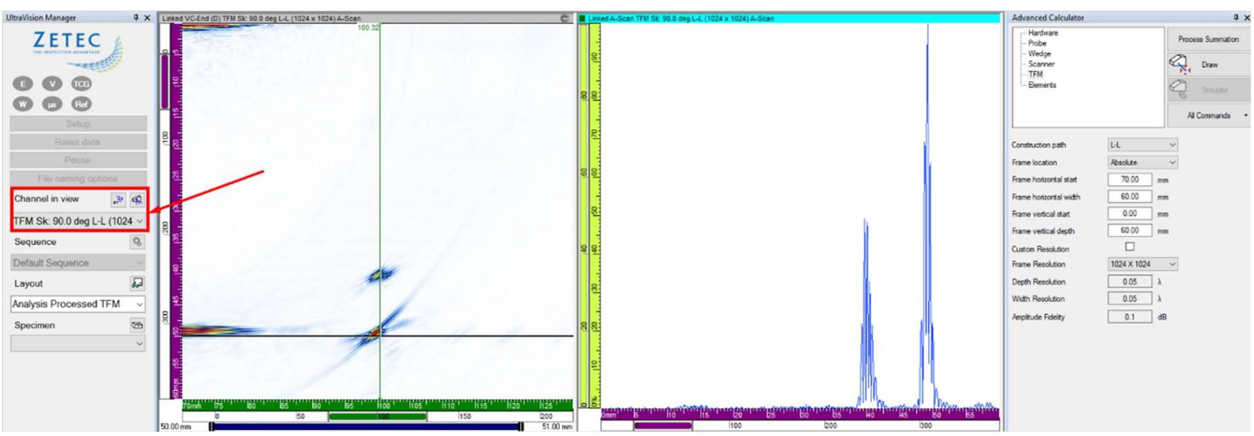
Important Note :

A TFM data group has been selected here for reconstruction. By default, live TFM data are recorded with the “Linear” option checked in the **UT Settings** , and behave like a “merged” data group. In that case, the reconstructed data will also be reconstructed as a “merged” data group, and the proposed structured name does not include the mention “LU”.



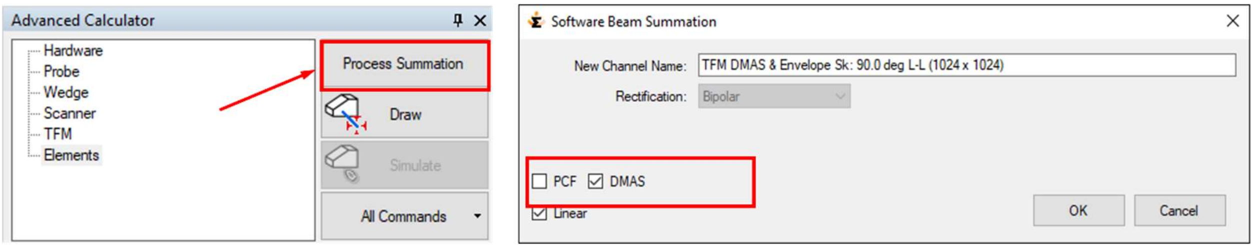
Before recording the live TFM and raw FMC or PWI data, the user can however decide to uncheck the “Linear” option and in that case the raw data can also be reconstructed with the “Linear Unchecked” option. This gives more flexibility for the Volumetric Merge process, e.g. different scan lines in a raster scan sequence can be merged individually.

Upon hitting OK and processing, the reconstructed TFM channel will appear in the **UltraVision Manager**, and can be visualized like live TFM data (e.g. Linked VC-End and A-scan views).



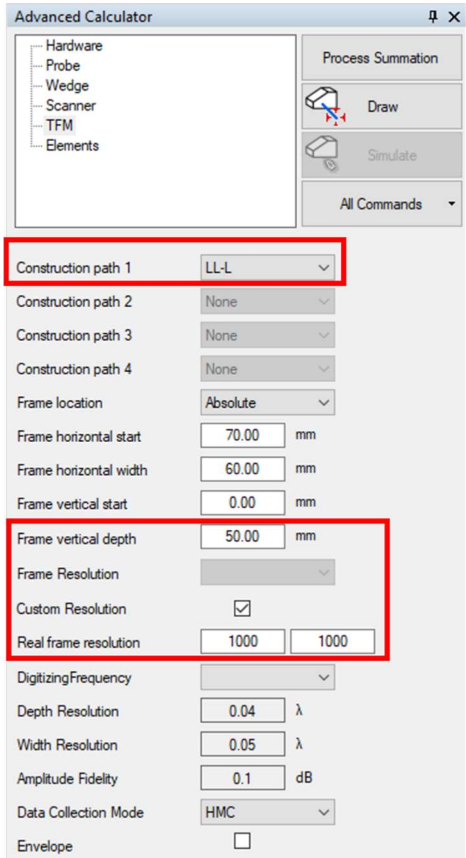
As for the live TFM, the reconstructed frame shows the back-wall echo, and tip and corner echoes from the machined notch, but with improved resolution because of the 1024 x 1024 (1 Megapixel) frame.

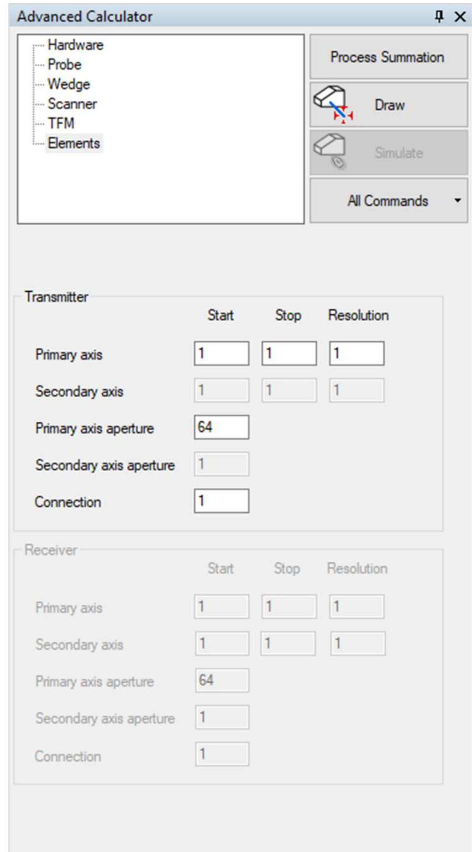
For the second FMC-TFM reconstruction, the options **Envelope** and **DMAS** are checked, and this is also reflected in the structured name for the **New Channel** of reconstructed data.



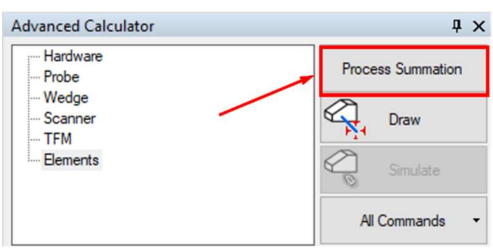
Upon hitting OK and processing, the reconstructed TFM channel will appear in the **UltraVision Manager** and can be visualized.

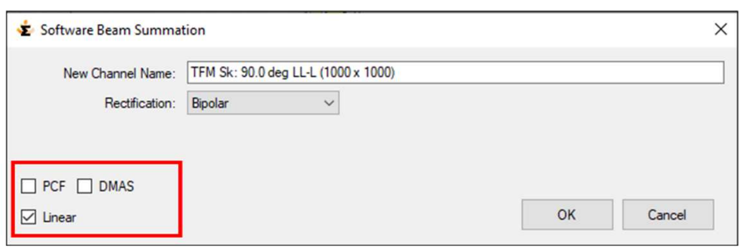
For the third FMC-TFM reconstruction, the **Construction path** is set to **LL-L**, and we can observe that the frame vertical extent is automatically limited to the specimen thickness. This is also the case for other indirect reconstructions paths (e.g. LL-LL, LL-T, …). The **Frame Resolution** is set at a **Custom Resolution** of 1000 x 1000, just to illustrate the presence of this option. The **Amplitude Fidelity** is obviously very similar at 0.1 dB.





Then hit the **Process Summation** button, and the software will again propose a structured name for the **New Channel** of reconstructed data, mentioning the **LL-L** wave mode.

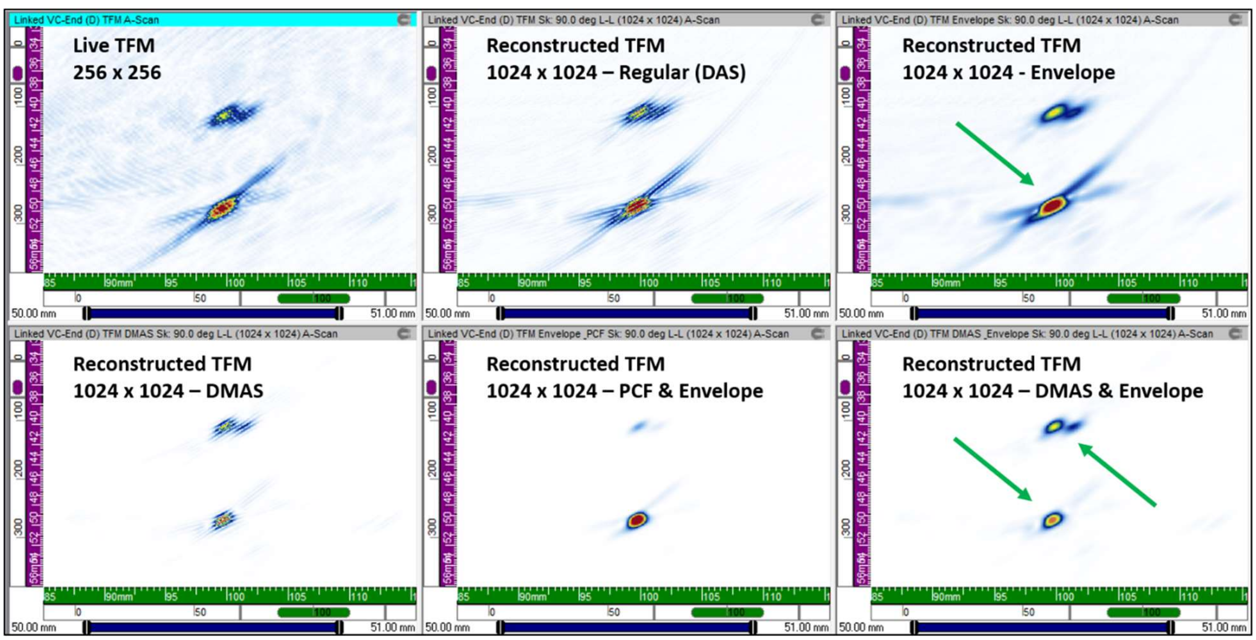




Upon hitting OK and processing, the reconstructed TFM channel will appear in the **UltraVision Manager**.

We can see that for this type of planar flaw, perpendicular to the ID surface, the LL-L wave mode provides a complete image of the surface of the flaw. This information is complementary with the image from the L-L wave mode.

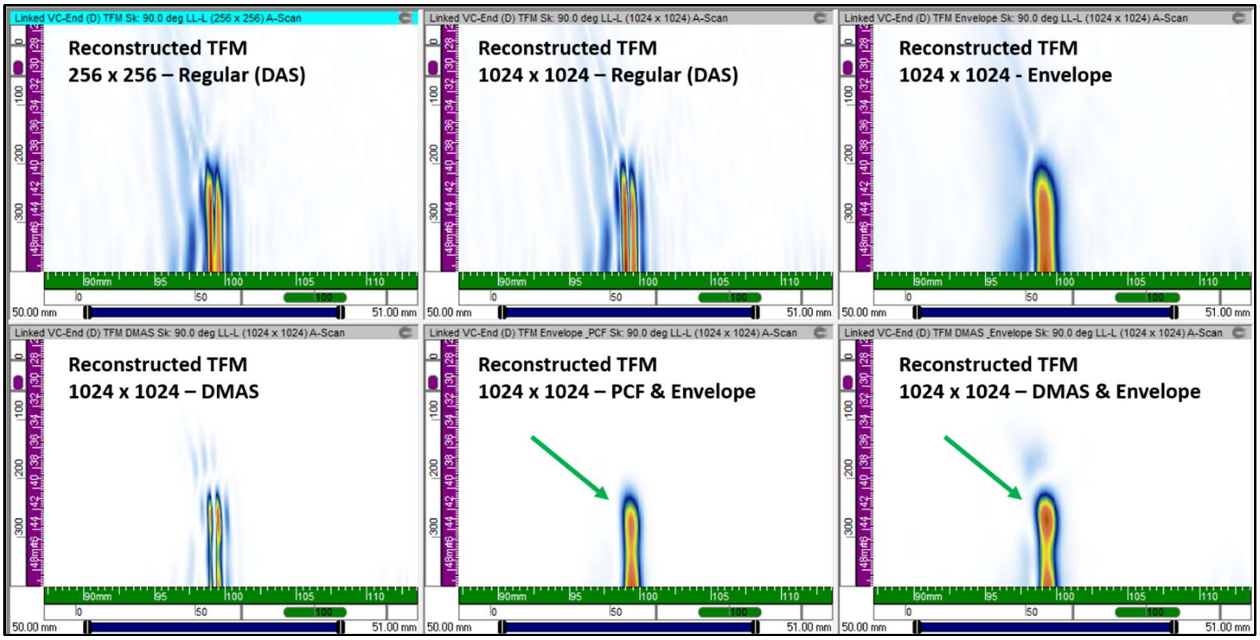
The image below shows images in the L-L wave mode, from live TFM and 5 different reconstruction algorithms. The live TFM in the upper left corner is a 256 by 256 frame, code-compliant but close to the 2 dB amplitude fidelity threshold. The reconstructed data are 1024 x 1024 frames. After reconstruction of the region of interest shown in the examples above, the images have been zoomed in on the notch.



It can be observed that the TFM envelope image (upper right corner) is smoother than the regular TFM, and may simplify data interpretation.

More obvious is that the DMAS and PCF algorithms strongly reduce the artifacts from the corner trap. In this example, the best image in the lower right corner is provided by combining DMAS and envelope processing. The height and even the width of the machined notch can be accurately measured.

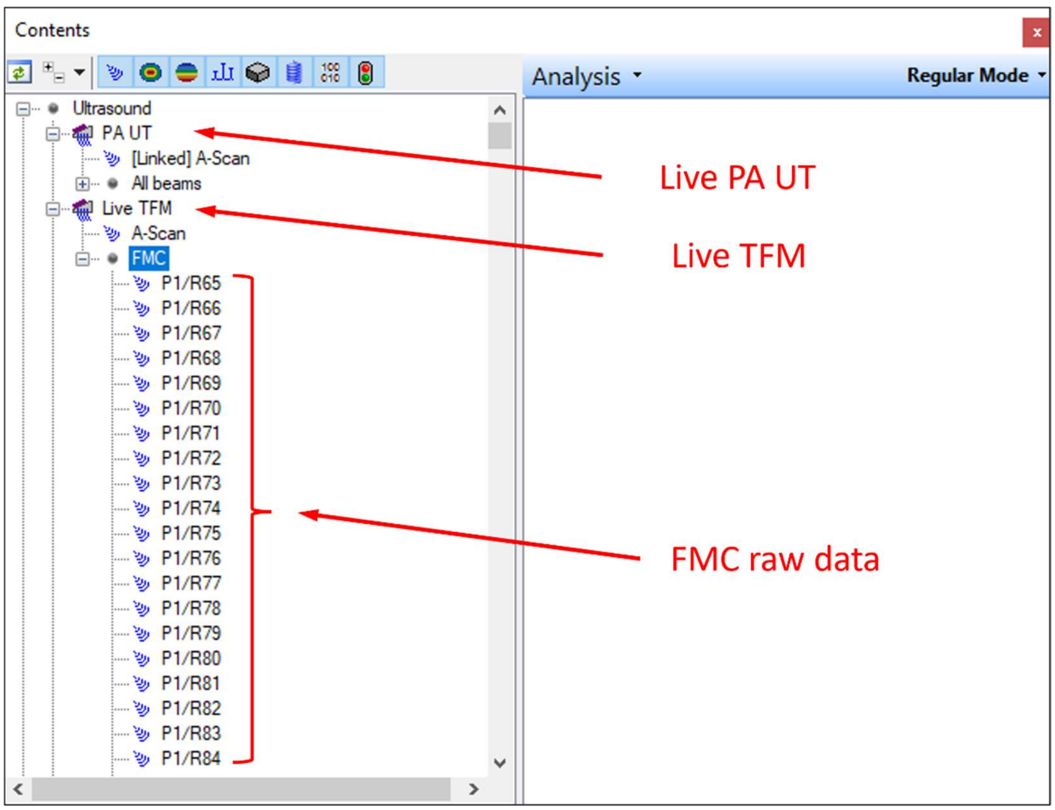
The next image shows the same algorithms applied for LL-L reconstruction of the raw FMC data of the machined notch. Again, it can be observed that DMAS and PCF in combination with the envelope eliminate a large part of the TFM artifacts and provide a clearer image of the flaw face.



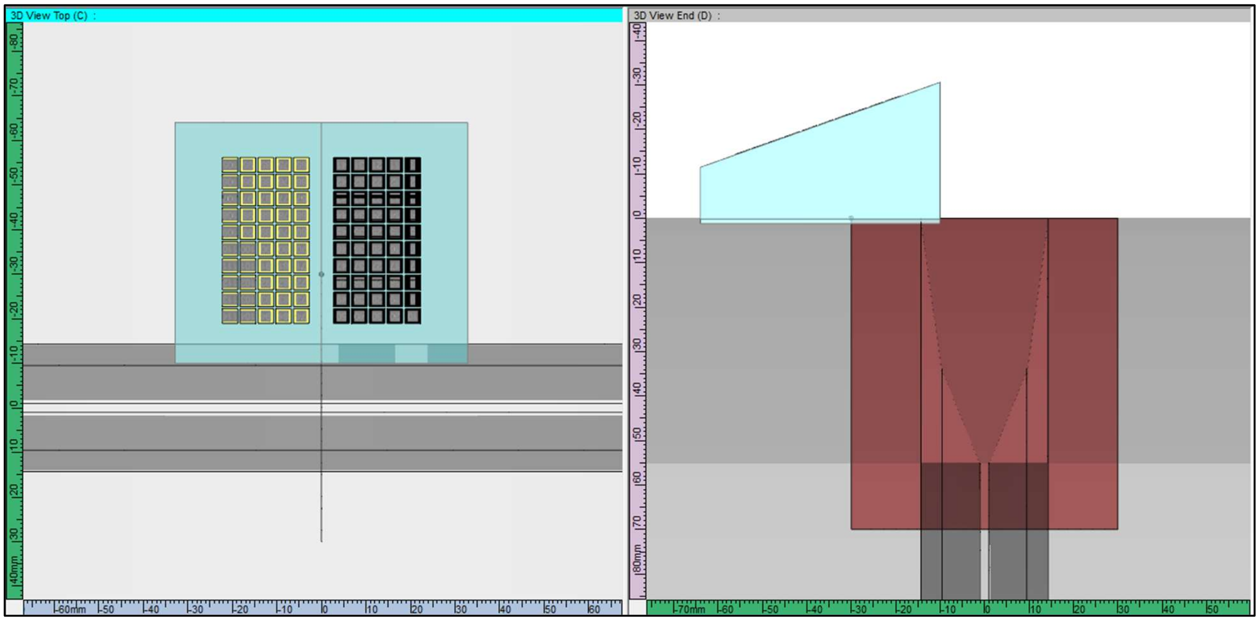
4.2 Dual 2D-Matrix Array (DMA), Pitch & Catch Mode, recorded with EMERALD

In this user case, the FMC raw data have been recorded with EMERALD. In order to process the raw data, just open the regular UVData file in UltraVision Classic and the additional UVDataFMC file will automatically be loaded as well. Once the file is loaded, the raw FMC A-scan data will show up in the **Contents** Pane.

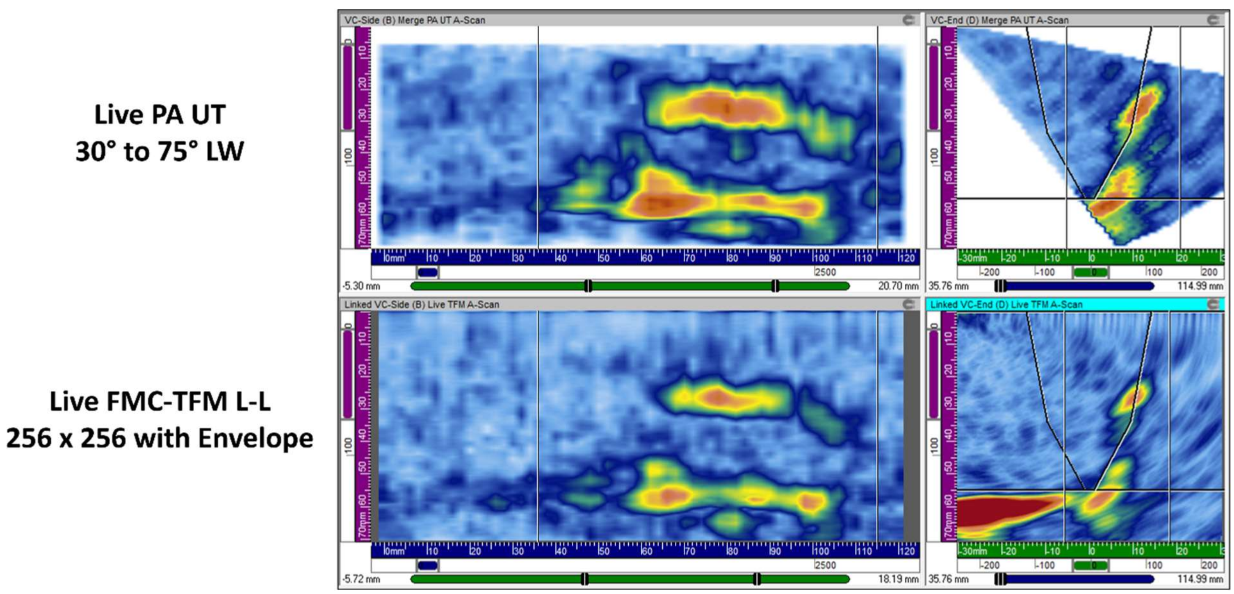
The file for this user case was recorded on a CASS (Cast Austenitic Stainless Steel) weld specimen with a real thermal fatigue crack, and contains a standard PA UT channel with an azimuthal sweep from 30° to 75°LW, a live TFM channel, and FMC raw data taken every 2 mm over a total distance of 120 mm.



The DMA probe assembly consists of two large 1 MHz 2D-matrix arrays with each 10 x 5 elements, fixed onto a TRL wedge. The image from the Advanced Calculator shows the DMA probe assembly.



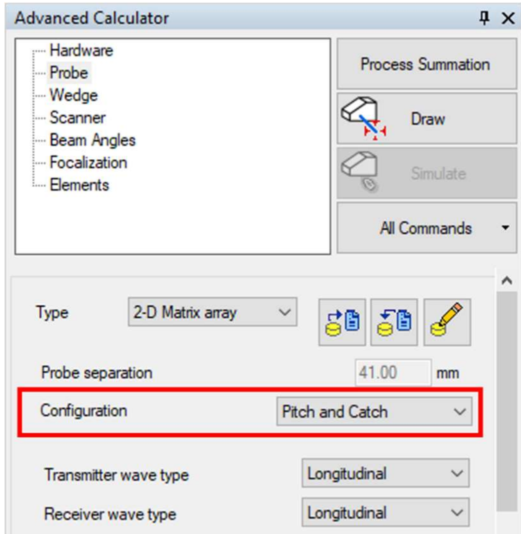
The merged standard PA UT data and the live FMC-TFM data are shown below (VC-Side and VC-End Views). The corner and tip signals from the crack can be clearly observed.



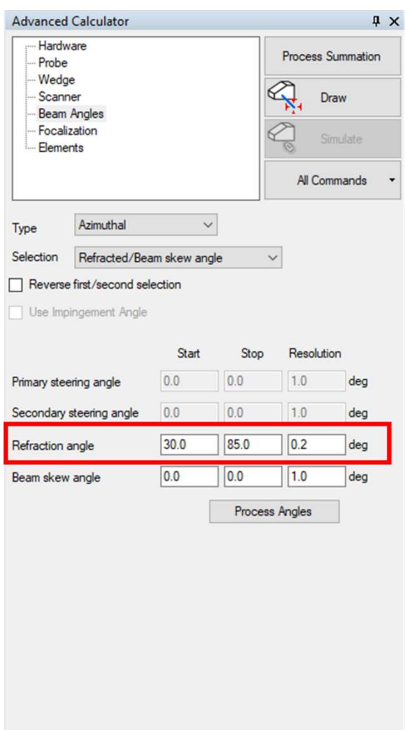
To perform the reconstruction from the FMC raw data, make sure that the live TFM channel is "active" by clicking on a view of this channel. If the standard PA UT channel is selected, the **Process Summation** button will NOT appear.

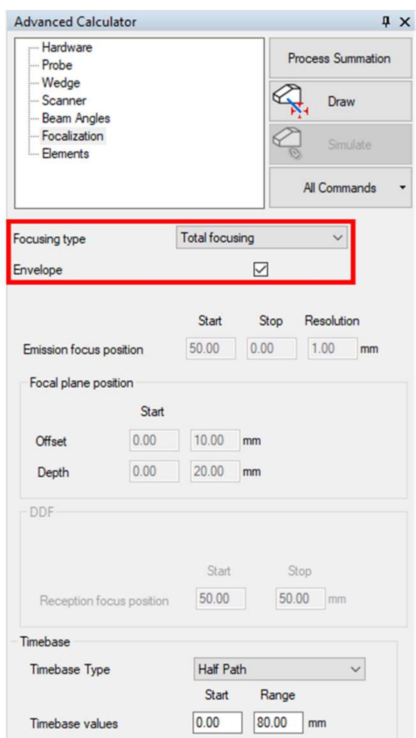
4.2.1 Sectorial Total Focusing Reconstruction

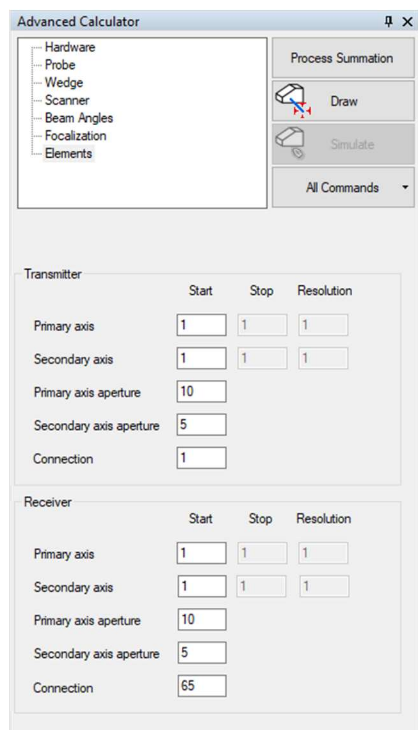
To reconstruct Sectorial Total Focusing data, select **Configuration Pitch & Catch** in the **Probe tab**.



Then define the parameters of the Sector scan in the **Beam Angles**, **Focalization** and **Elements** tabs. In the **Focalization** tab select **Focusing Type Total Focusing.** In this example, a very small angle resolution was chosen, to illustrate the capability to generate high resolution azimuthal sweeps.

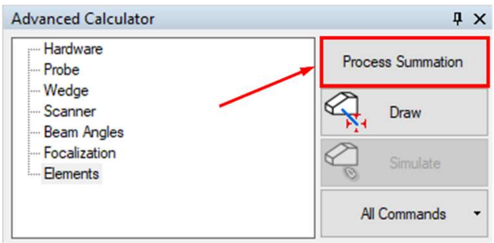


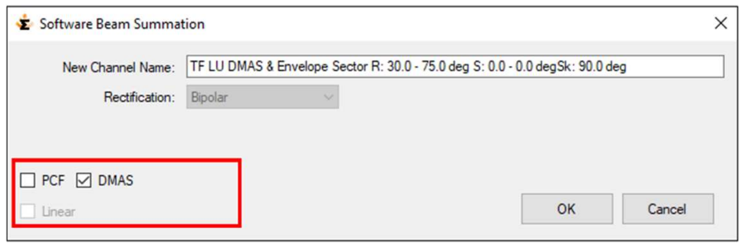




Then hit the **Process Summation** button, and the software will propose a structured name for the **New Channel** of reconstructed data.

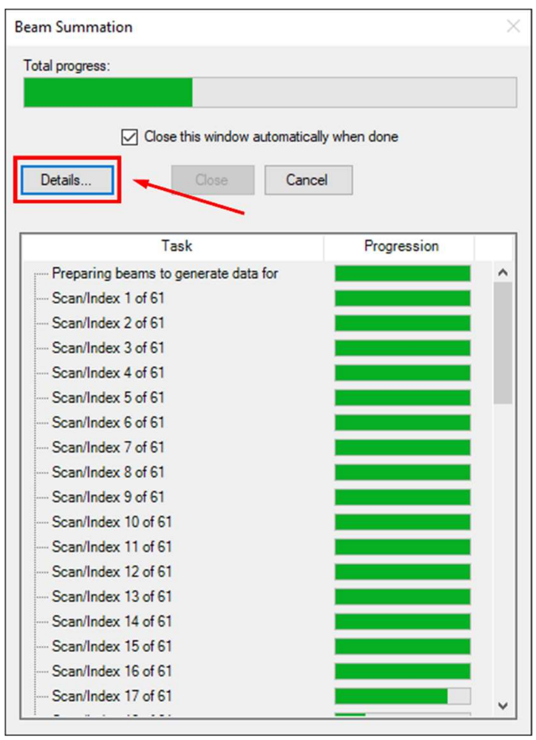
In the case of a data reconstruction with STF (Sectorial Total Focusing), the processing options appear: **PCF** (Phase Coherence Factor) and **DMAS** (Delay Multiply and Sum). In this case, the **DMAS** option was selected.



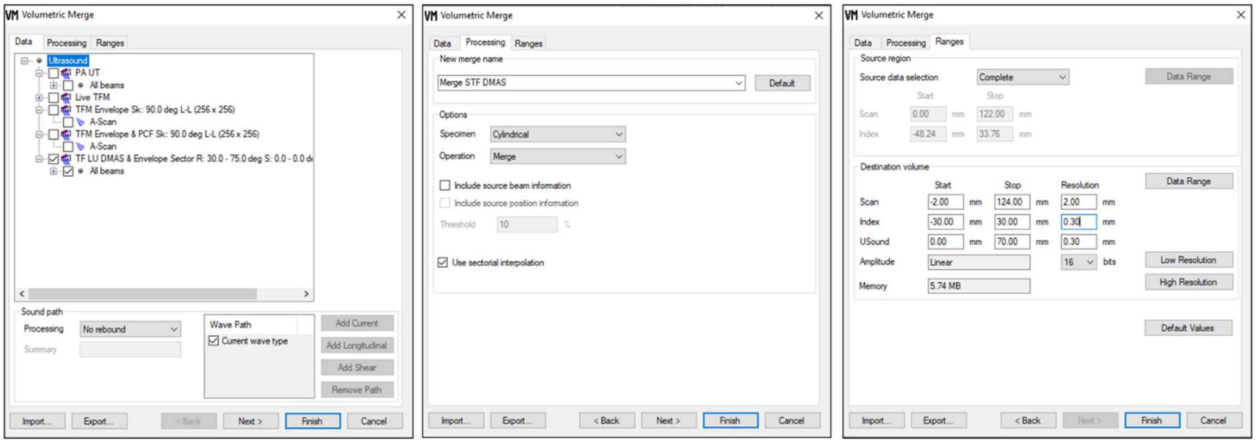


Upon hitting **OK** and processing, the reconstructed STF channel will be generated.

Since this is a larger data file, the processing time is longer. The user can monitor the progress of the operations, by hitting the Details button.

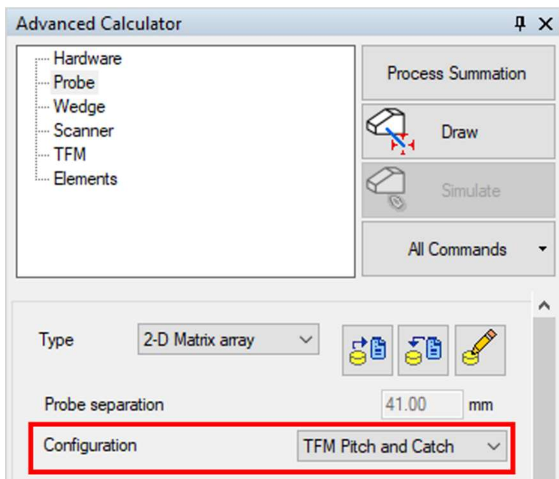


The Volumetric Merge tool can also be used on the reconstructed STF data group, with the parameters shown below. The merged data group is shown together with the reconstructed TFM from the next paragraph.



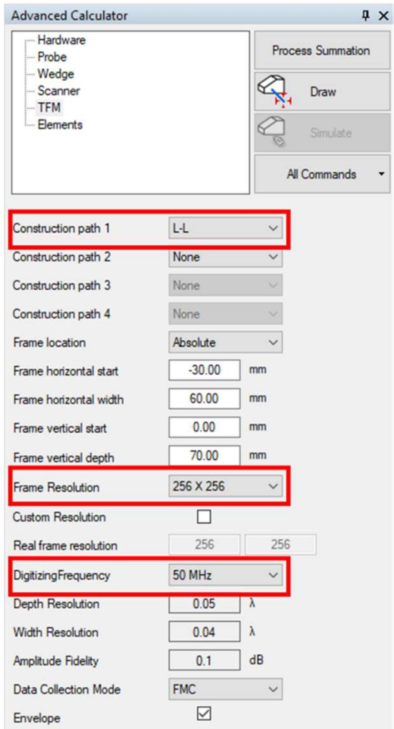
4.2.2 TFM Reconstruction

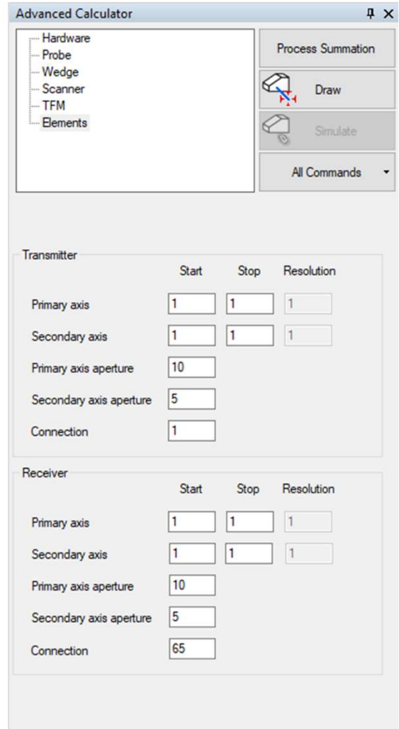
To reconstruct TFM data, select **Configuration TFM Pitch & Catch** in the **Probe tab**.



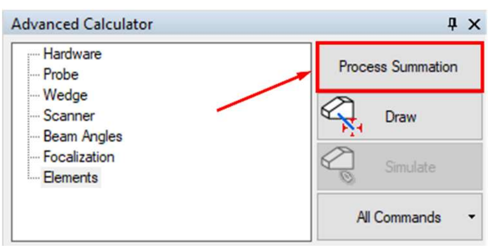
Then define the parameters of the TFM frame in the **TFM** and **Elements** tabs. The parameters for the definition of the reconstructed TFM data are similar as for pulse-echo TFM.

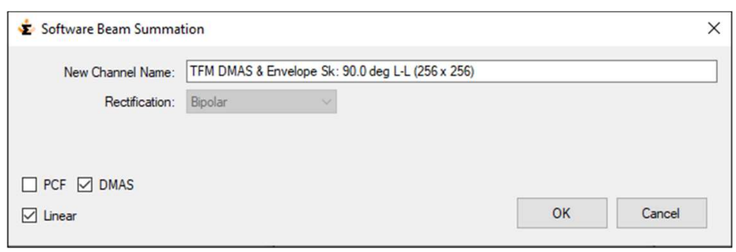
The **Construction path** is set to **L-L**, just like the live TFM data, and a **Frame Resolution** of 256 x 256 is used. It can be observed that since the release of UltraVision 3.12R18, the operator can adjust the **Digitizing Frequency** (possible values 100 MHz, 50 MHz, 25 MHz and 12.5 MHz) for the recording of raw data. For low-frequency probes, reducing the digitizing frequency allows to drastically increase the scanning speed while maintaining excellent raw data quality and reconstructed image quality.





Then hit the **Process Summation** button, and the software will again propose a structured name for the **New Channel** of reconstructed data.



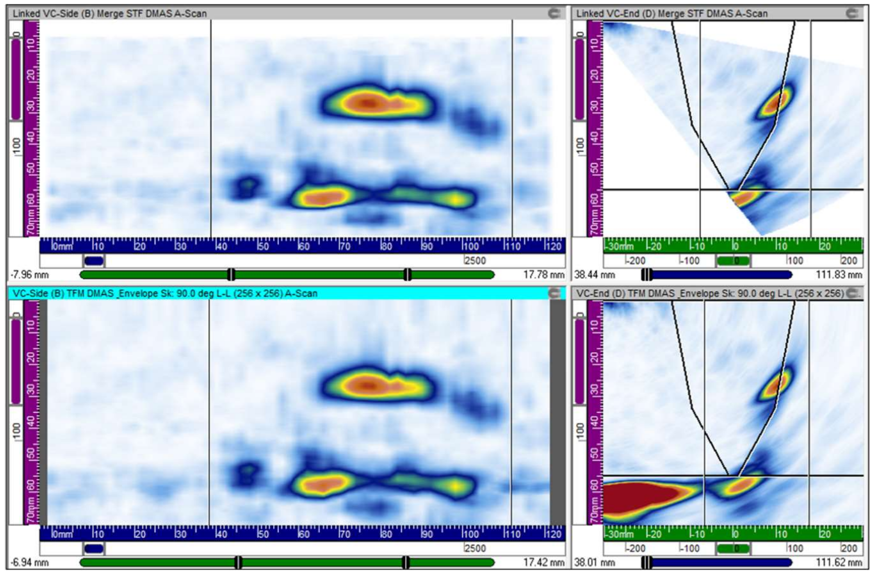


After hitting OK and processing, the reconstructed TFM channel will appear in the **UltraVision Manager**. This reconstructed data group has the same characteristics as a live TFM data group, i.e. the characteristics of a merged data group.

The image below shows the merged STF DMAS & Envelope data and the reconstructed FMC-TFM DMAS & Envelope data (VC-Side and VC-End Views). When comparing to the merged standard PA UT data and the live TFM, the corner and tip signals from the crack are still very clearly observed, and the overall noise level is drastically reduced for both reconstructed channels with the DMAS algorithm.

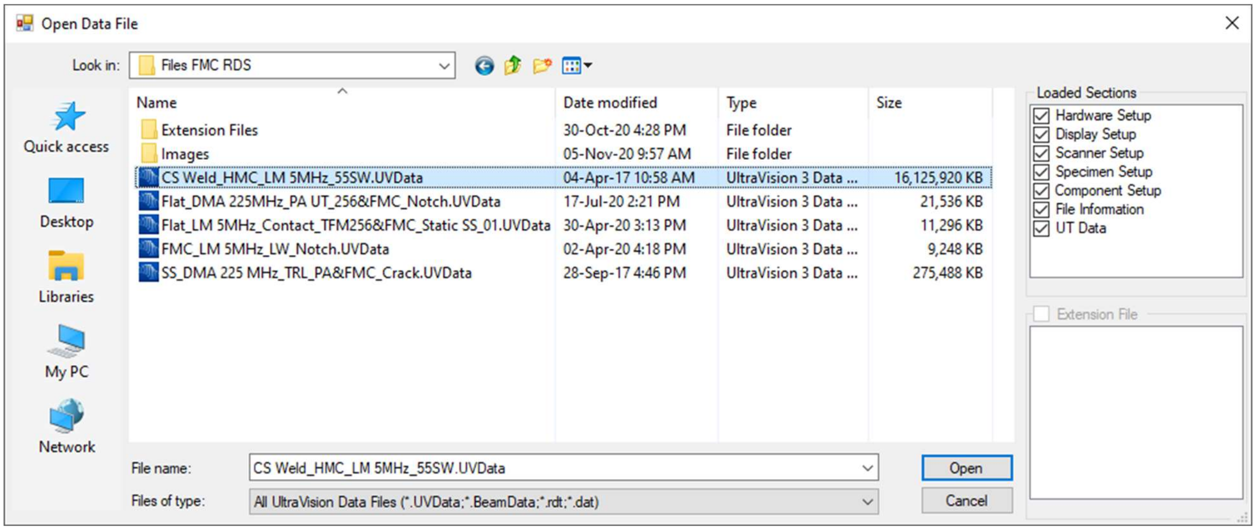
Merged STF
30° to 75° LW, res 0.2°
DMAS & Envelope

Reconstructed FMC-TFM
L-L 256 x 256
DMAS & Envelope

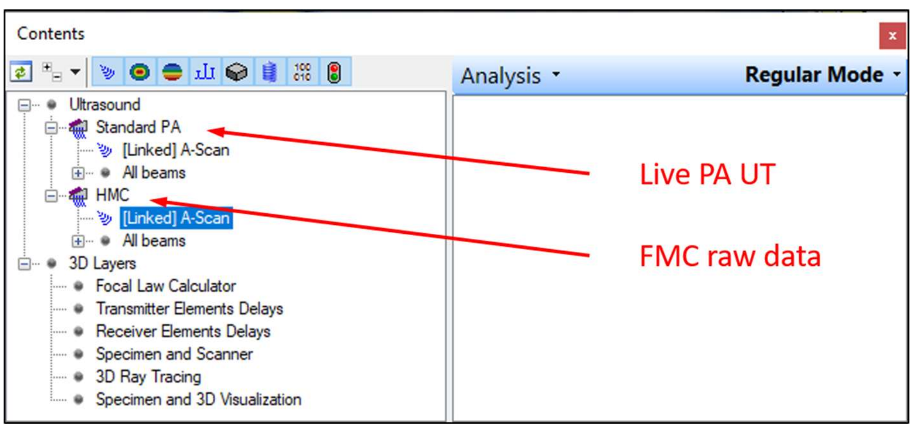


4.3 1D-Linear Probe, SW Wedge, Pulse-Echo Mode, recorded with DYNARAY

When FMC (or HMC) raw data are recorded with DYNARAY, the software generates a single file, the regular **UVData** file, and this file contains the phased array data and the raw FMC (or HMC) data. In order to process the raw data, just open the regular UVData file in UltraVision Classic.

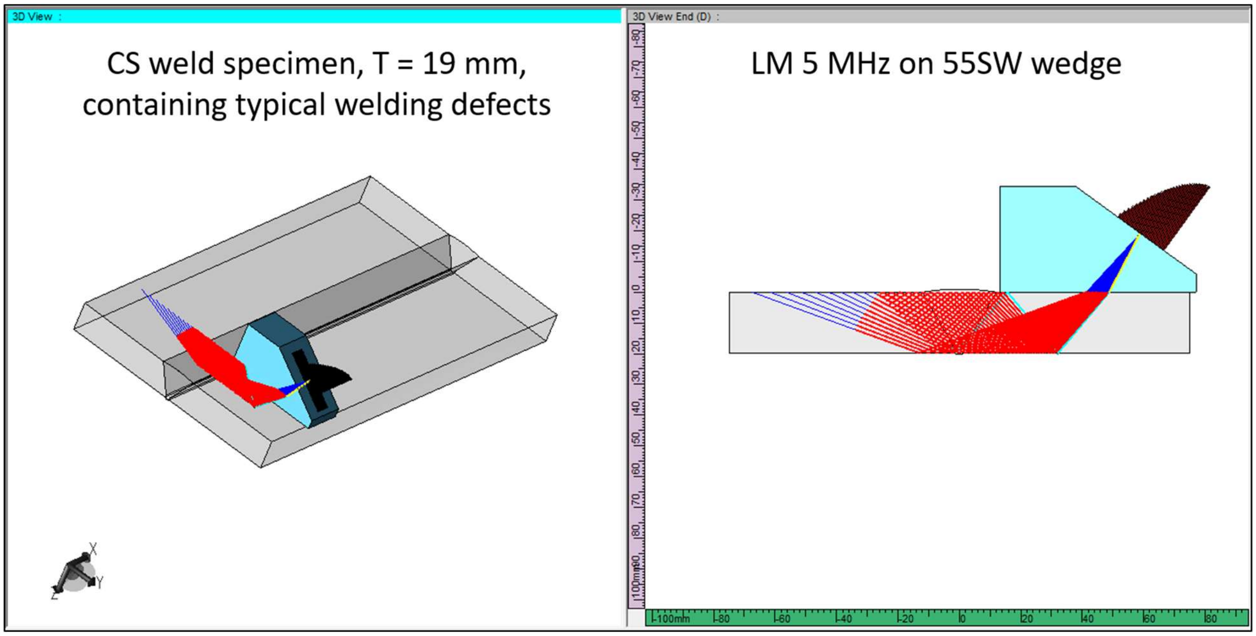


Once the file is loaded, the raw HMC A-scan data will show up in the **Contents Pane**

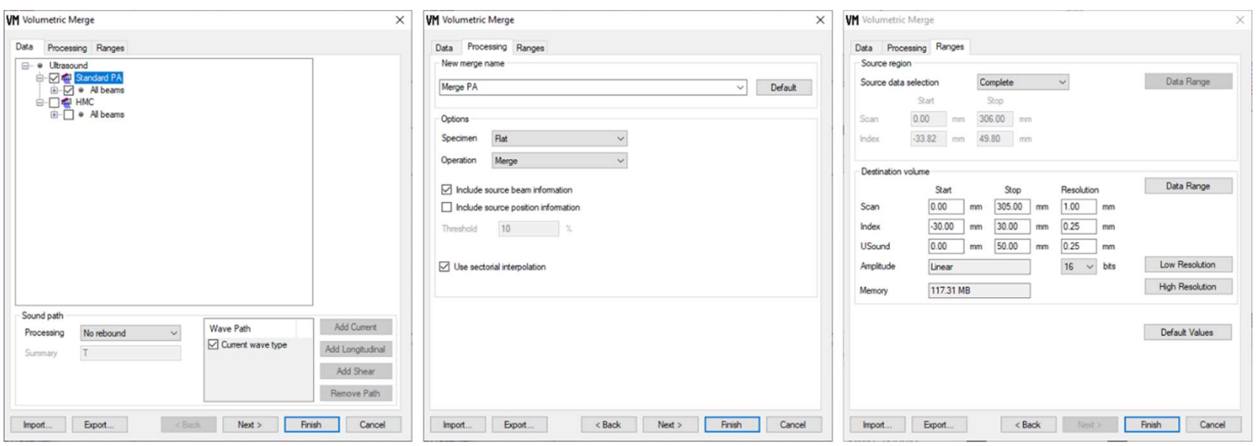


The file for this user case is a very large file (more than 16 GBytes), from a carbon steel weld sample with various welding flaws. The file contains a standard PA UT channel, with an azimuthal sweep from 40° to 70°SW, focused at **True Depth** 20 mm, in addition to a separate channel named “HMC” containing HMC data taken every mm along the 300 mm long sample.

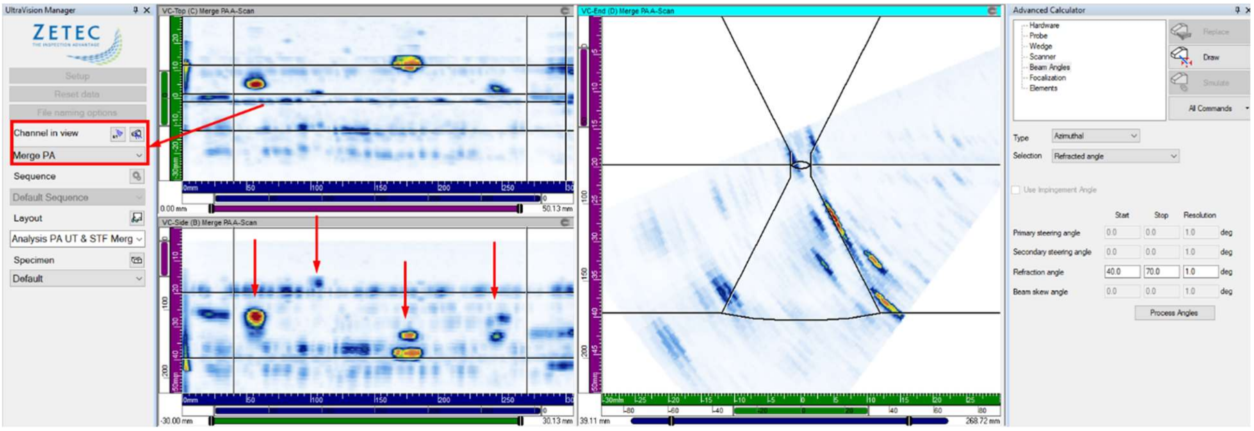
The image from the Advanced Calculator shows the probe assembly with SW wedge, a typical probe configuration used for carbon steel weld inspection. The probe is located so that the weld and HAZ volume are covered using the first and the second half skip of the ultrasound path.



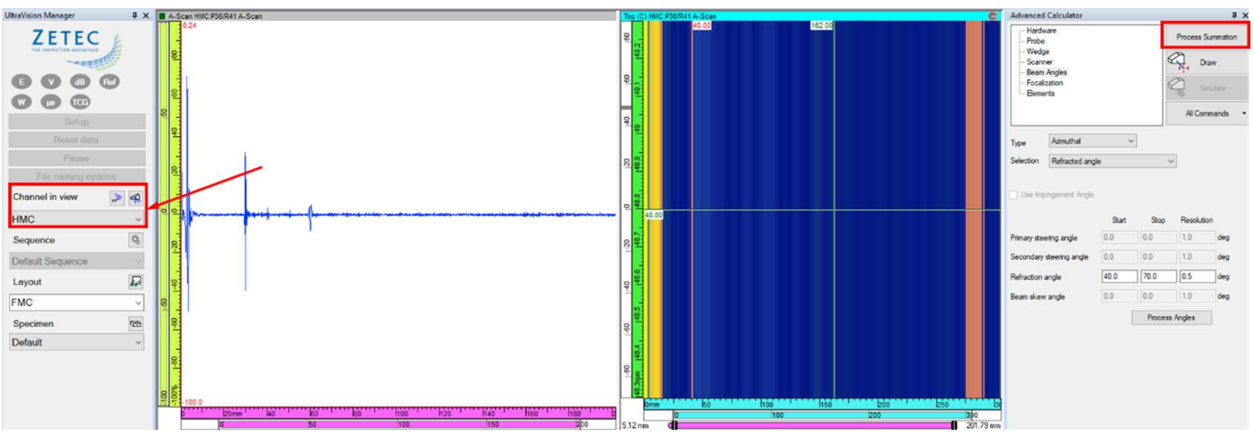
For easy data review and evaluation of standard phased array data, UltraVision Classic includes the Volumetric Merge tool. The parameters below have been used to generate the merged data group.



The merged data group is shown below, using the typical VC-Top, VC-Side and VC-End views. The weld sample contains 4 weld defects, a lack-of fusion, an incomplete penetration, a toe-crack and a cluster of porosity. All can be detected, but the low amplitude signals of the incomplete penetration and the cluster of porosity are not very well resolved. On the other hand, the corner and tip echoes from the toe-crack can be clearly observed.

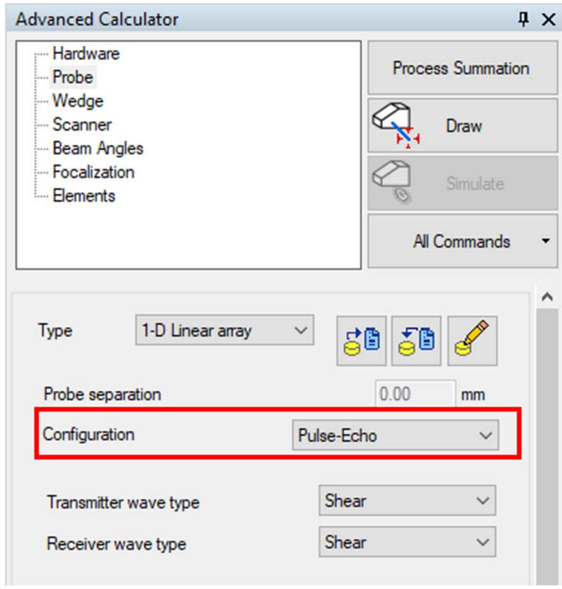


<u>To reconstruct the elementary A-scan data recorded with</u> ***<u>DYNARAY</u>****<u>, make sure that the separate "FMC" (or "HMC" channel is "active" by adding a view for this channel and selecting this view (see below)</u>*. If another channel is selected, the **Process Summation** button will NOT appear.

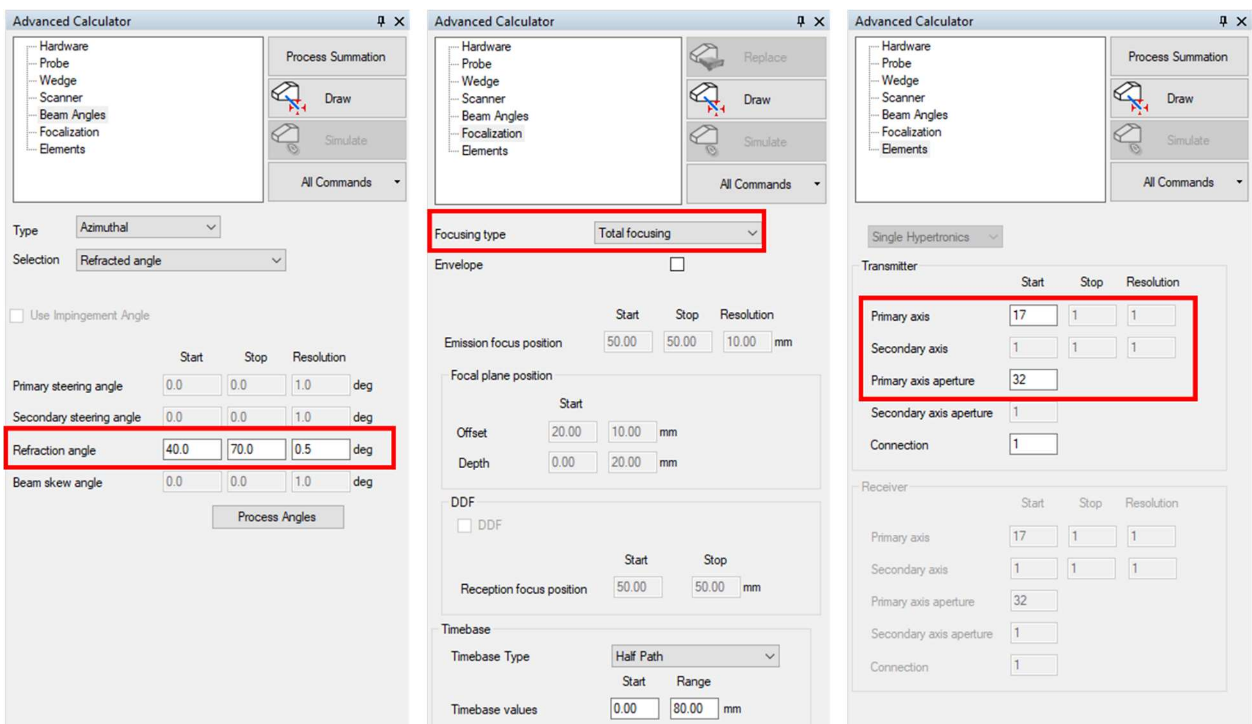


4.3.1 Sectorial Total Focusing Reconstruction

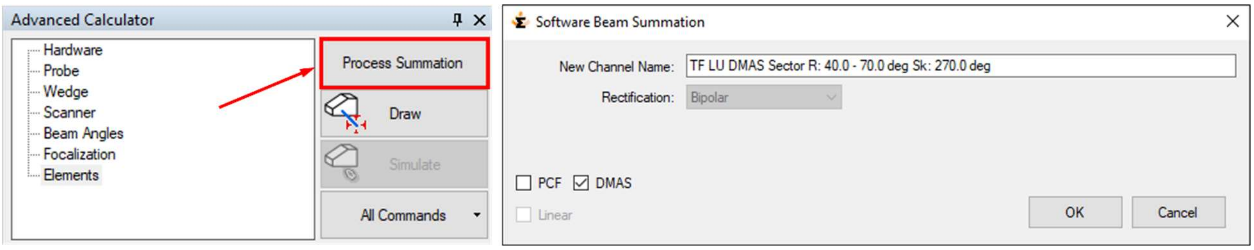
To reconstruct Sectorial Total Focusing data, select **Configuration Pulse-Echo** in the **Probe tab**.



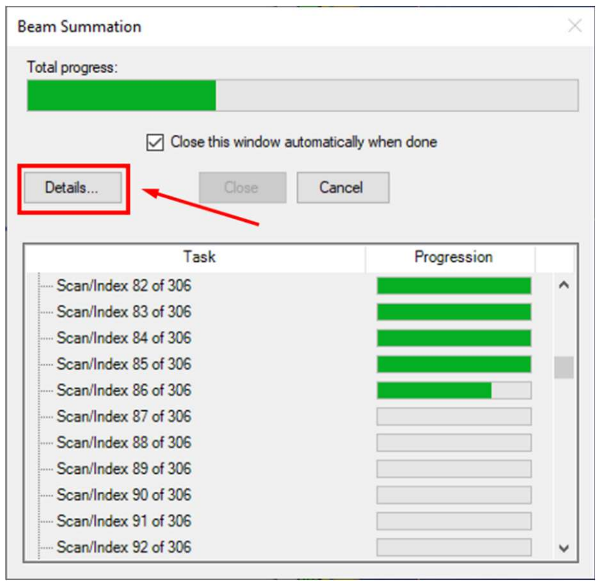
Then define the parameters of the Sector scan in the **Beam Angles**, **Focalization** and **Elements** tabs. In the **Focalization** tab select **Focusing Type Total Focusing.** In this example, the angle resolution is set at 0.5 degrees and the active aperture of the probe at 32 elements, similar to what is used for the standard phased array channel.



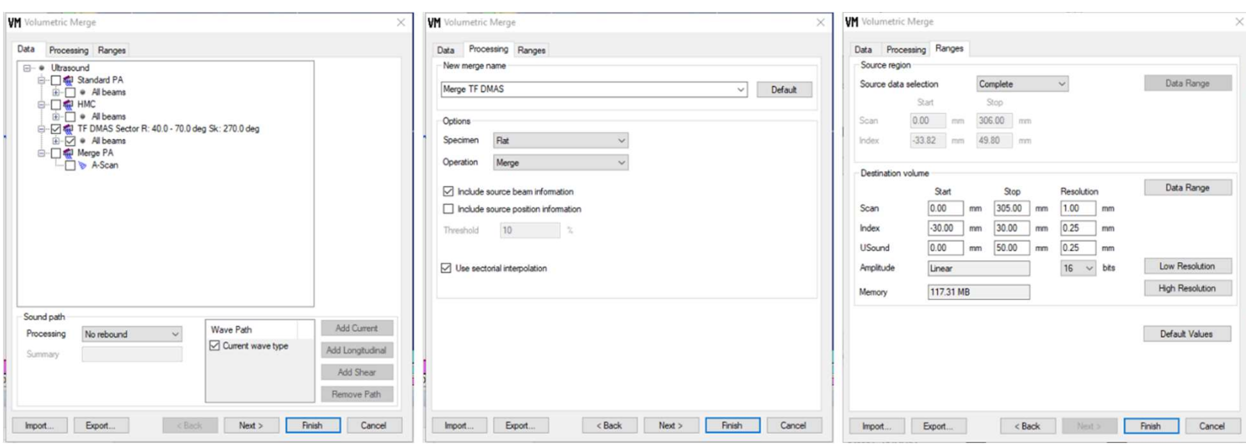
Then hit the **Process Summation** button, and the software will propose a structured name for the **New Channel** of reconstructed data. In this example, the reconstruction is with **DMAS**.



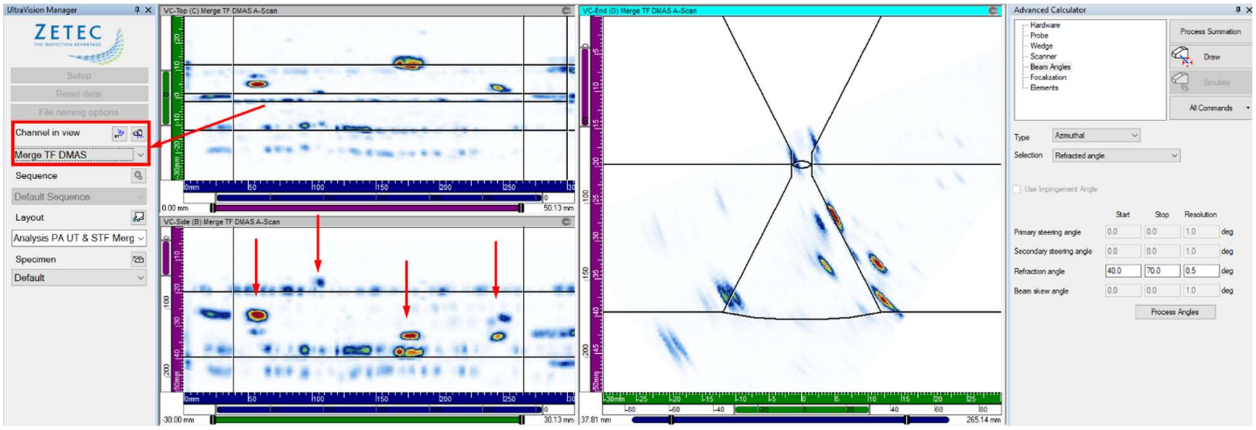
Since this is a very large data file, with HMC data at each probe location, the processing time is longer. The user can better monitor the progress of the operations, by hitting the Details button.



The Volumetric Merge tool can also be used on the reconstructed STF data group. Similar parameters are used to generate this new merged data group.

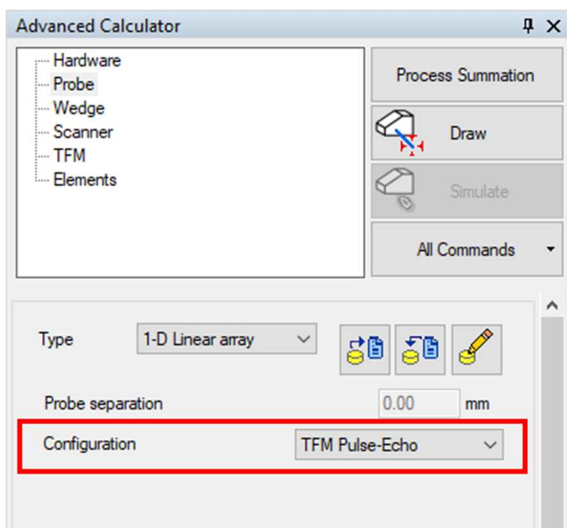


The merged data group from the STF DMAS reconstruction is shown below. Compared to the standard phased array data, the cluster of porosity is much better resolved, and the overall resolution and SNR are improved.



4.3.2 TFM Reconstruction

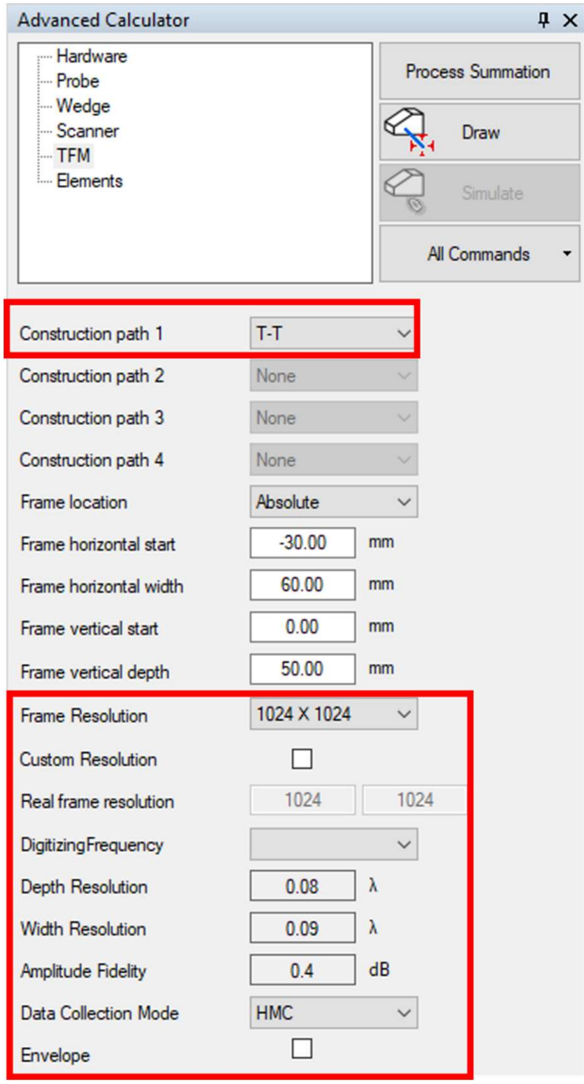
To reconstruct TFM data, select **Configuration TFM Pulse-Echo** in the **Probe tab**.

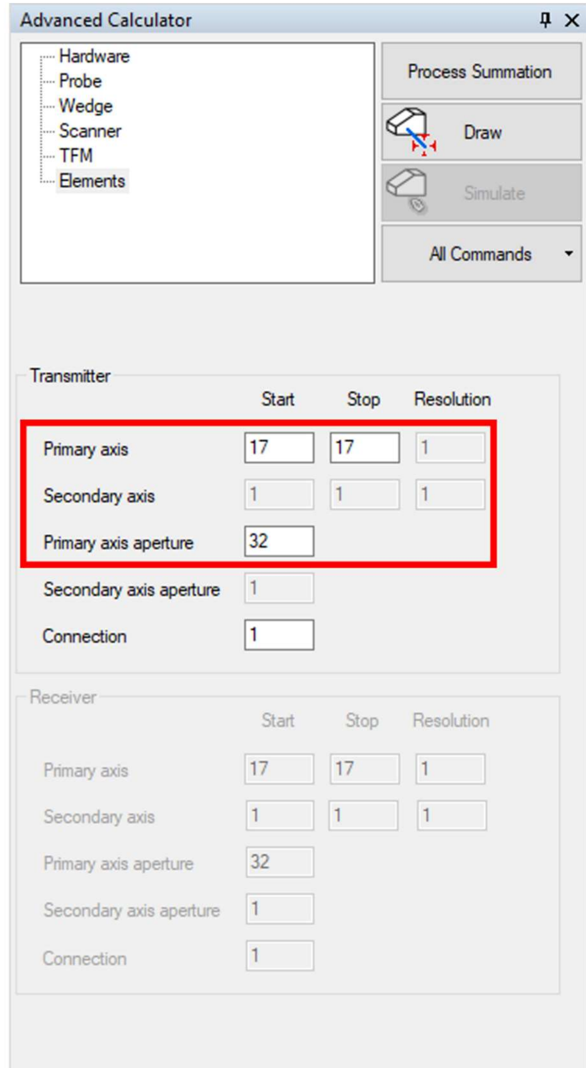


Then define the parameters of the TFM frame in the **TFM** and **Elements** tabs.

First, the **Construction path** will be set to **T-T**, the frame extent will be selected identical to the extent of the merged data groups from standard PA UT and reconstructed STF. The **Frame Resolution** will be set at 1024 x 1024, resulting in an **Amplitude Fidelity** of 0.4 dB.

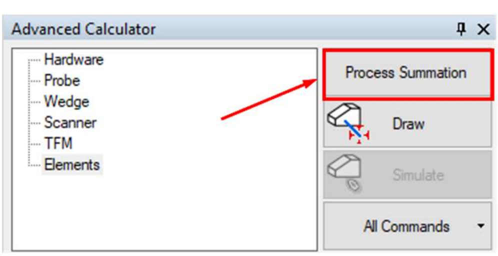
An active aperture of 32 elements is selected, similar to what is used for the standard phased array channel.

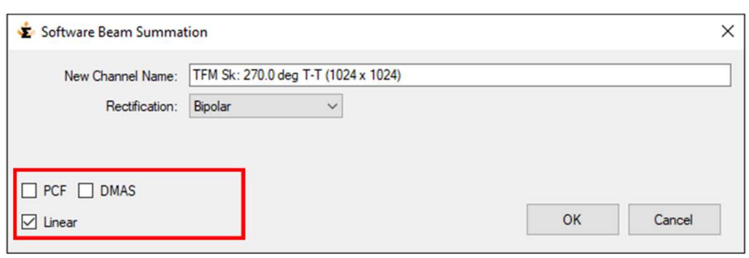




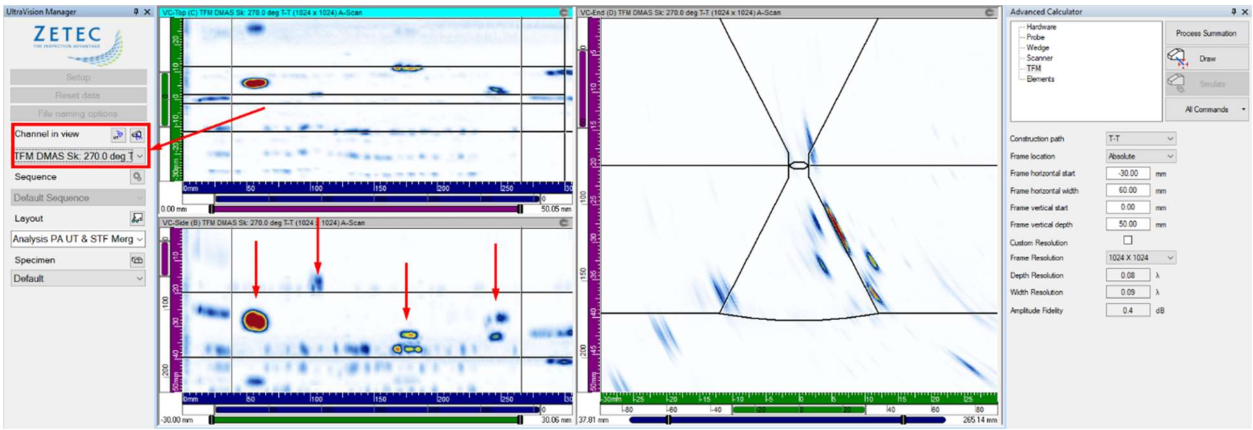
Then hit the **Process Summation** button, and the software will again propose a structured name for the **New Channel** of reconstructed data. With none of the options checked, the common **DAS** (Delay and Sum) reconstruction algorithm is used.

For raw FMC or HMC data acquired with DYNARAY, the "Linear" option is unchecked by default, but in this case study with a One-line scanning sequence there is no benefit of reconstructing with the "Linear Unchecked" option.

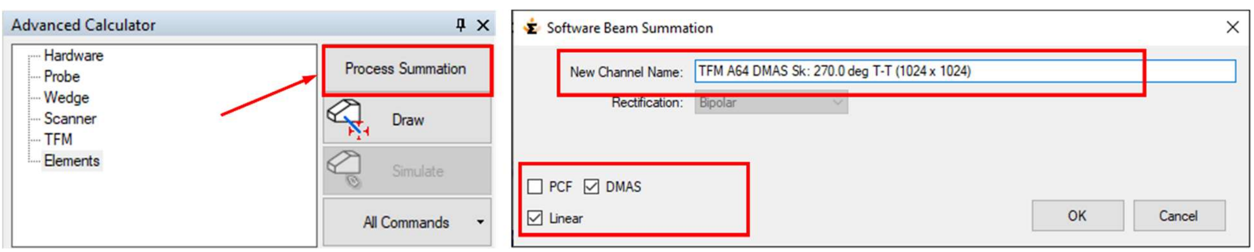




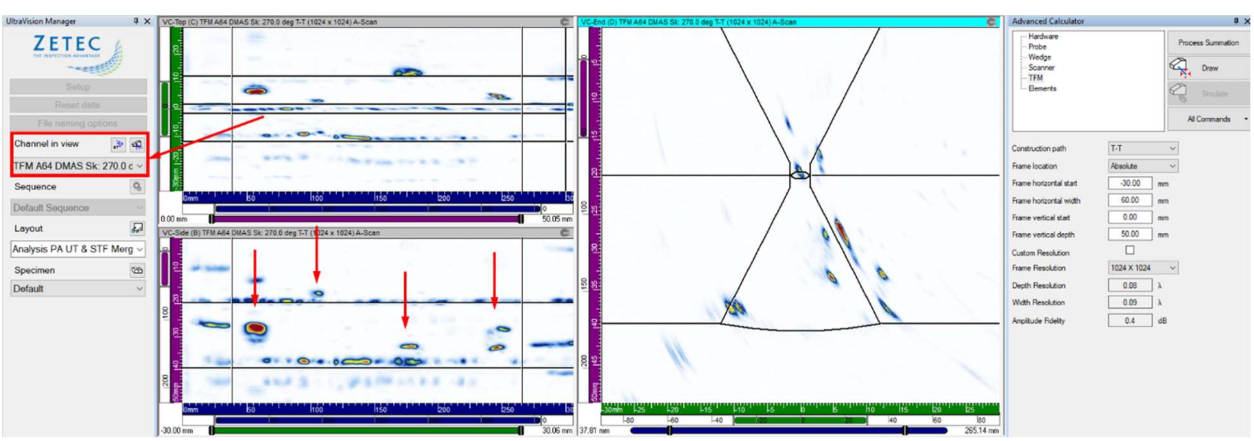
Upon hitting OK and processing, the reconstructed TFM channel will appear in the **UltraVision Manager**. This reconstructed data group has the same characteristics as a merged data group, so no additional merging operation is required. The data group is shown below. Compared to the standard phased array data, the cluster of porosity and the incomplete penetration are much better resolved, and the overall resolution and SNR are improved.



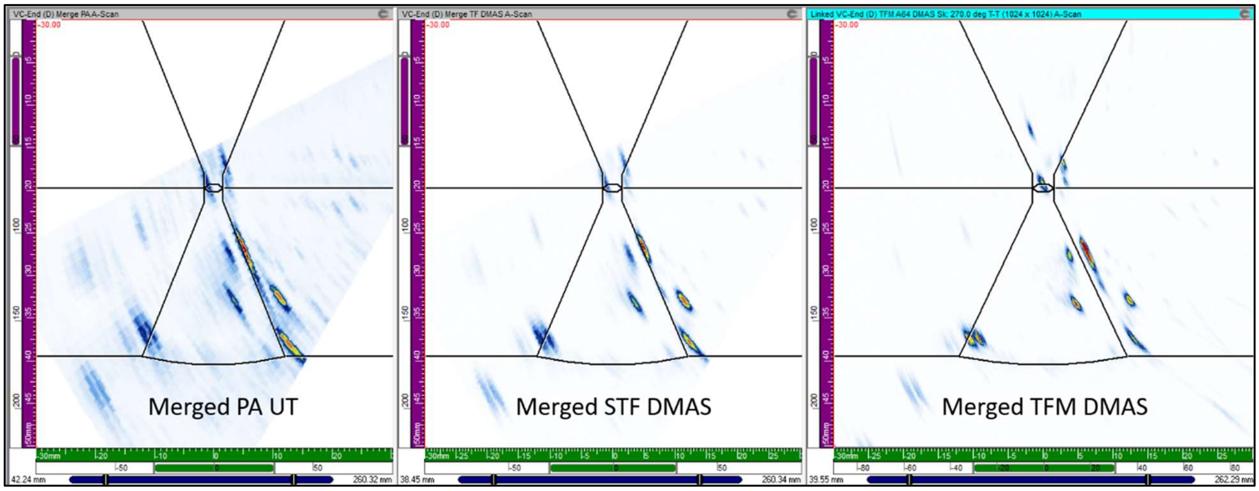
For the second TFM reconstruction, the **DMAS** reconstruction algorithm is used. Also, the active aperture is changed to 64 elements. The operator can manually modify the structured name for the **New Channel** of reconstructed data to reflect the modified aperture.



Upon hitting OK and processing, the reconstructed TFM channel will appear in the **UltraVision Manager** and can be visualized. The new TFM data group is shown below. The improved resolution provided by the larger aperture can be clearly observed. Also the DMAS algorithm further reduces the noise.

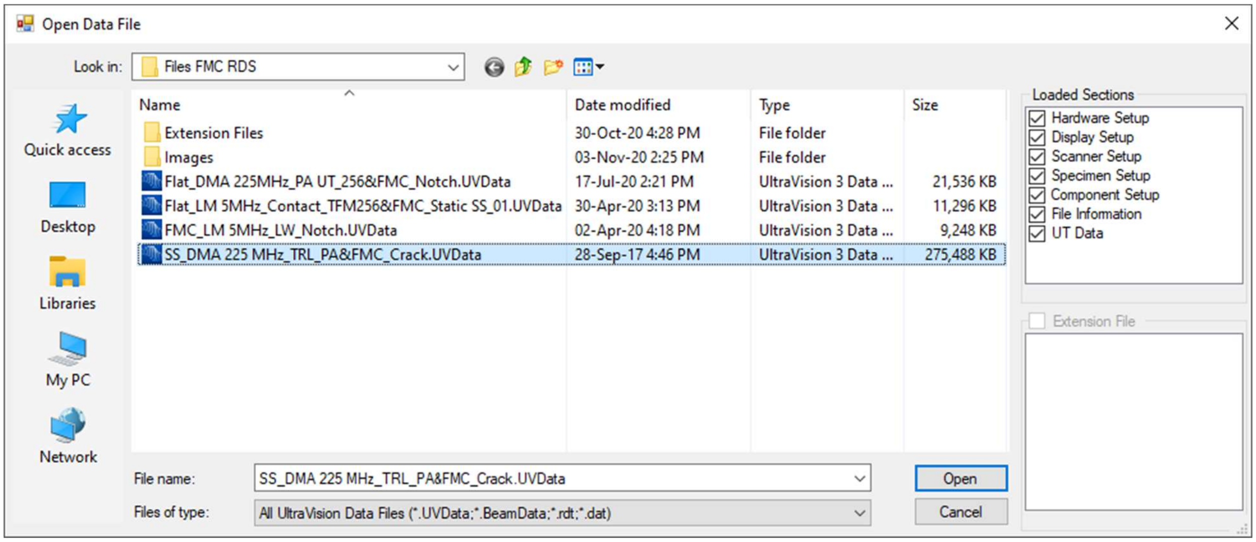


The image below compares the VC-End views of weld with the 4 flaws for merged PA UT (left), merged reconstructed STF DMAS (middle) with 32-element aperture and finally TFM DMAS (right) with 64-element aperture. This further illustrates the improved resolution and SNR provided by the advanced focusing algorithms and the large aperture.

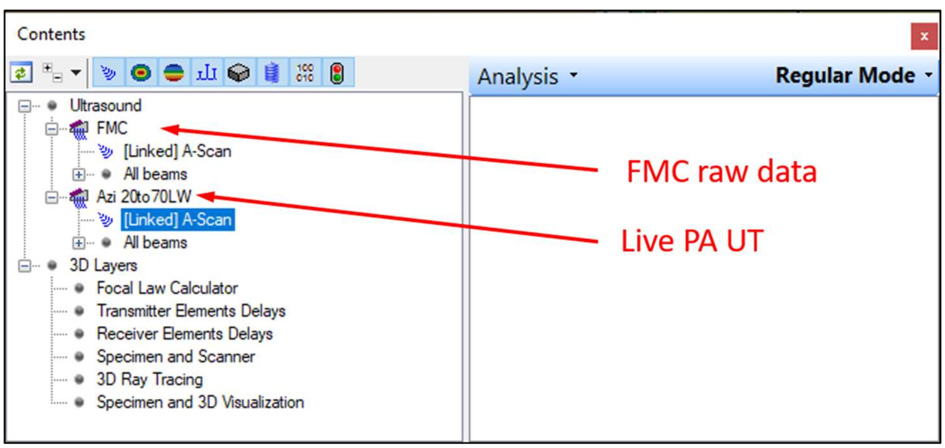


4.4 Dual 2D-Matrix Array (DMA), Pitch & Catch Mode, recorded with DYNARAY

When FMC (or HMC) raw data are recorded with DYNARAY, the software generates a single file, the regular **UVData** file, and this file contains the phased array data and the raw FMC (or HMC) data. In order to process the raw data, just open the regular UVData file in UltraVision Classic.

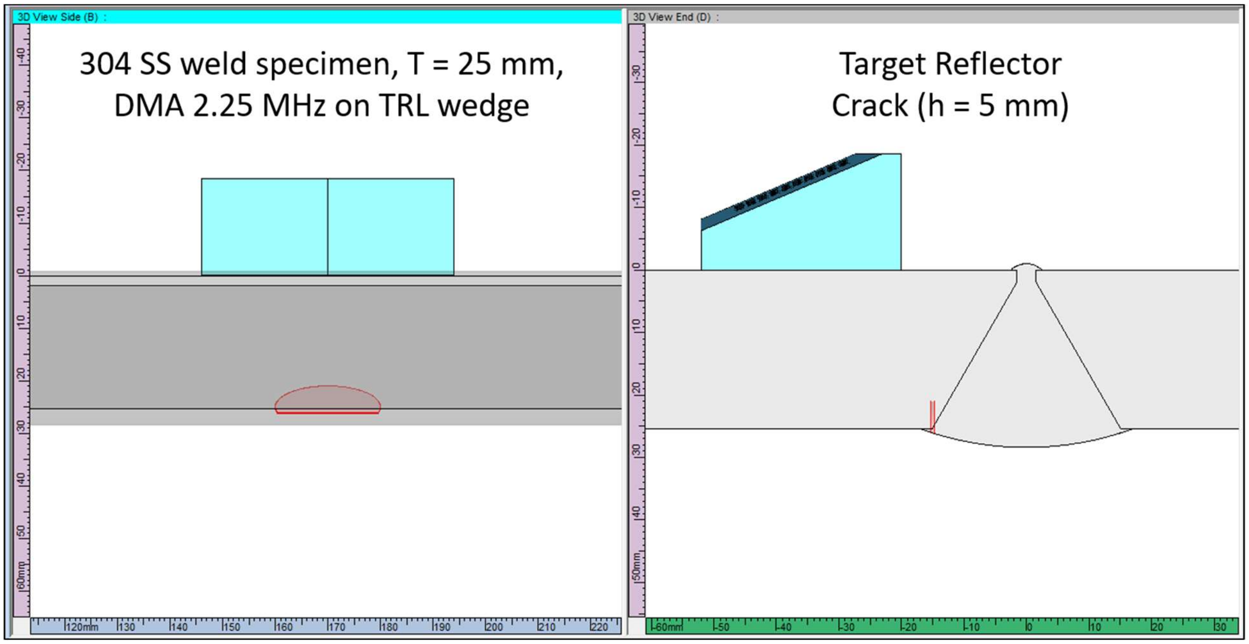


Once the file is loaded, the raw FMC A-scan data will show up in the **Contents Pane**

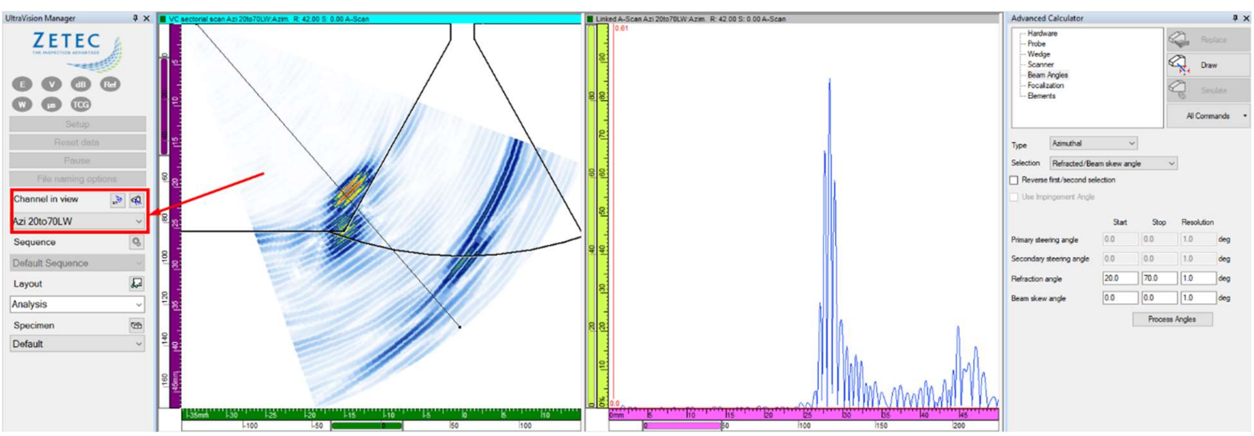


The file for this user case was recorded statically on a stainless steel weld with a crack, and contains a standard PA UT channel, with an azimuthal sweep from 20° to 70°LW, in addition to a separate channel named "FMC" containing an FMC Snapshot with 900 (30 x 30) individual A-scans (both transmitter and receiver arrays have 30 elements).

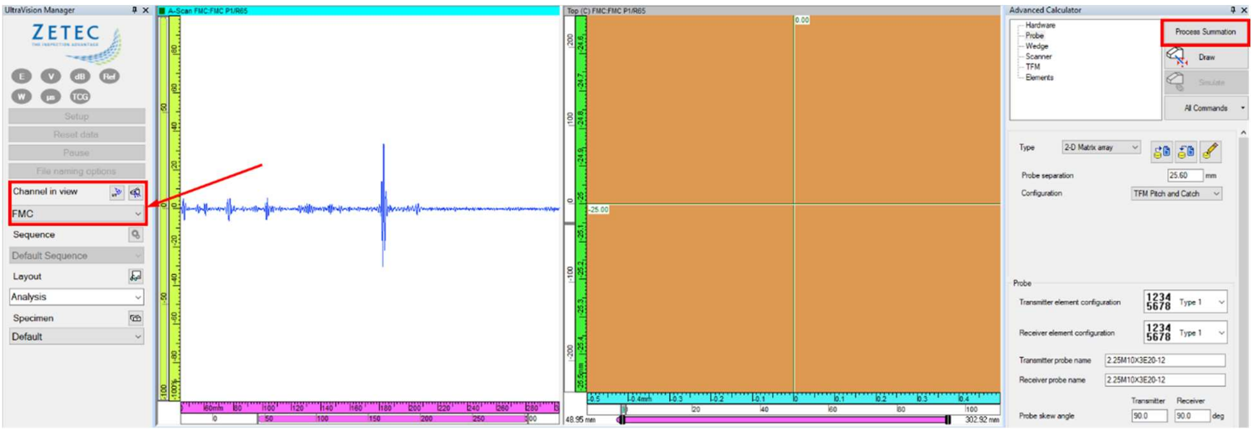
The image from the Advanced Calculator shows the DMA probe assembly with TRL wedge, a typical probe configuration used for stainless steel weld inspection.



The standard phased array data are shown below, using the Sectorial scan together with the A-Scan. The corner and tip echoes from the crack can be observed, as well as a strong mode-converted signal. It can also be observed that in this case no smoothing was used for the phased array data.

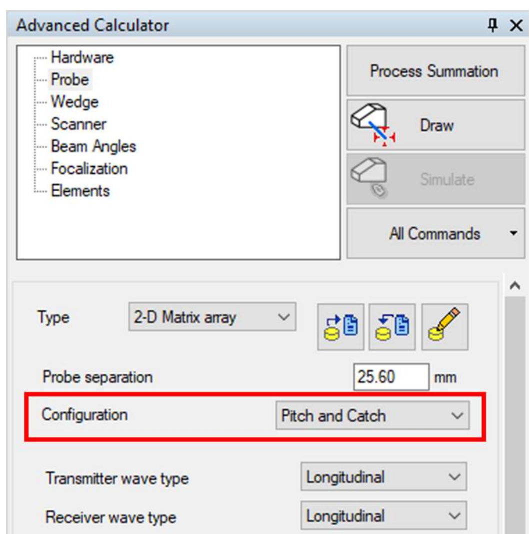


To reconstruct the elementary A-scan data recorded with DYNARAY, make sure that the separate "FMC" (or "HMC") channel is "active" by adding a view for this "FMC" channel and selecting this view (see below). If another channel is selected, the **Process Summation** button will NOT appear.

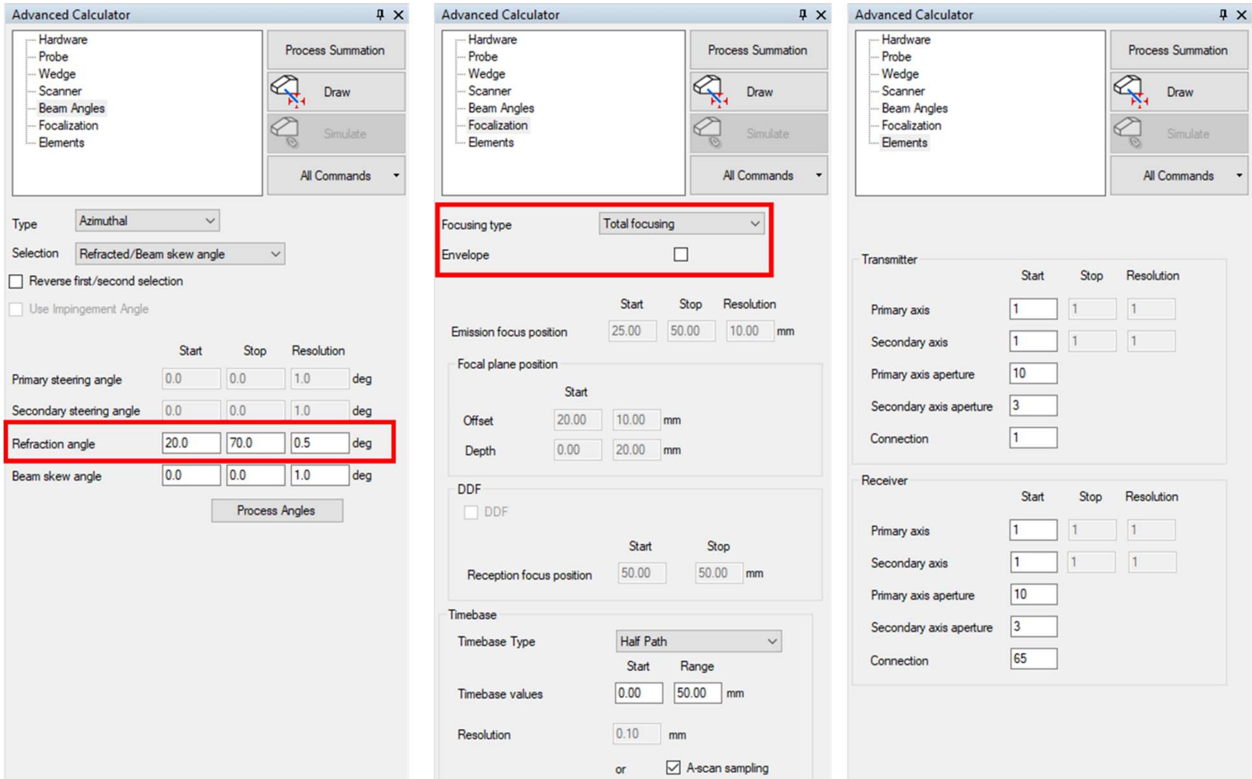


4.4.1 Sectorial Total Focusing Reconstruction

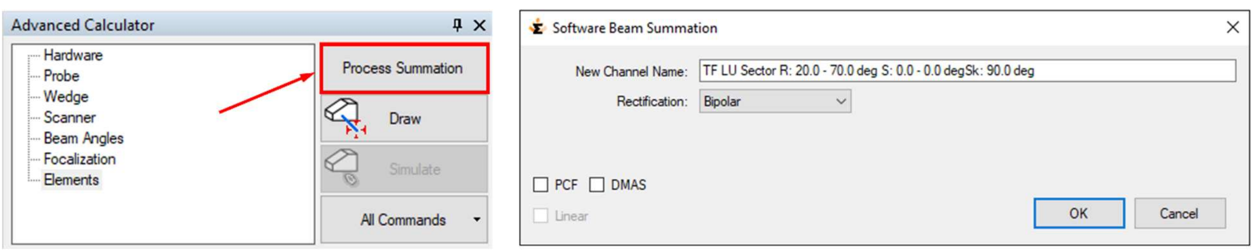
To reconstruct Sectorial Total Focusing data, select **Configuration Pitch & Catch** in the **Probe tab**.



Then define the parameters of the Sector scan in the **Beam Angles**, **Focalization** and **Elements** tabs. In the **Focalization** tab select **Focusing Type Total Focusing.**



Then hit the **Process Summation** button, and the software will propose a structured name for the **New Channel** of reconstructed data.

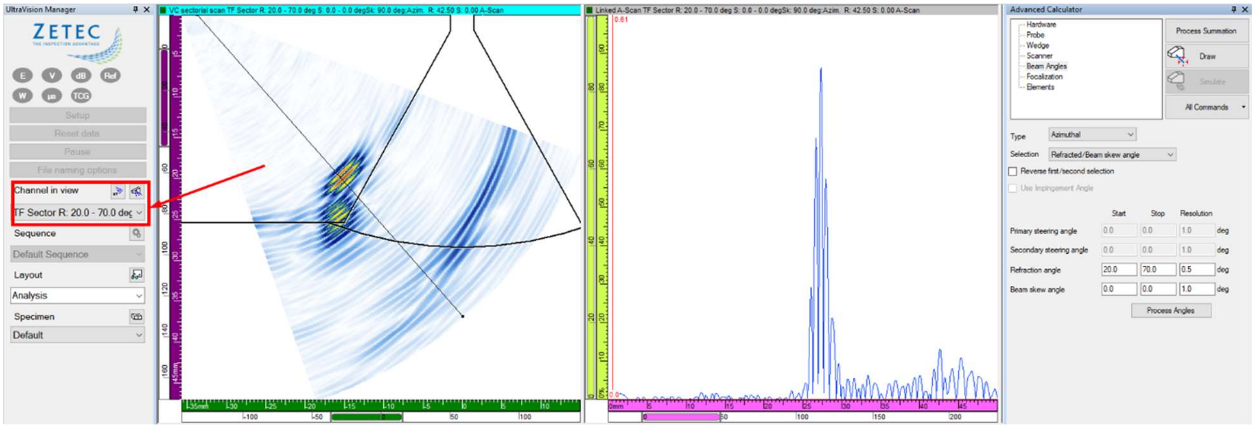


In this example, the reconstruction has been done with the regular **DAS** (first figure below), with a combination of **DAS** and **Envelope** (second figure below), and finally with a combination of **DMAS** and **Envelope** (third figure below).

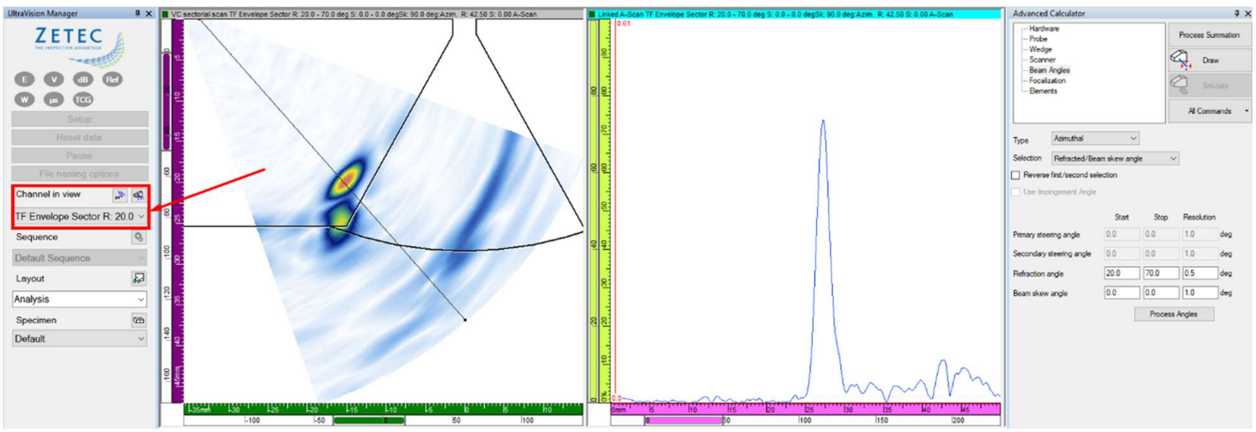
The influence of the **Envelope** (smoothing) is clearly visible on the sectorial scan and A-scan views.

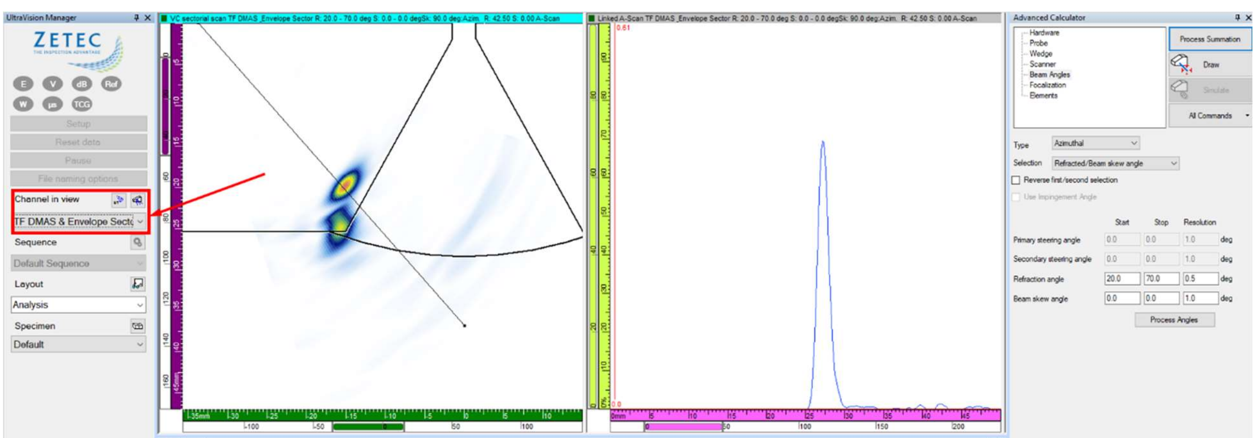
The STF reconstruction with DAS only provides an image that is very similar to the live standard phased array channel without smoothing. This is to be expected, because the standard phased array beam was focused in the region of the crack.

The reconstruction with DMAS shows far less intensity for the mode converted signal, and improves the overall SNR.


UltraVision Manager
ZETEC
Channel in view
TF Sector R: 20.0 - 70.0 deg
Sequence
Default Sequence
Layout
Analysis
Specimen
Default
Advanced Calculator
Process Summation
Draw
All Commands
Process Angles

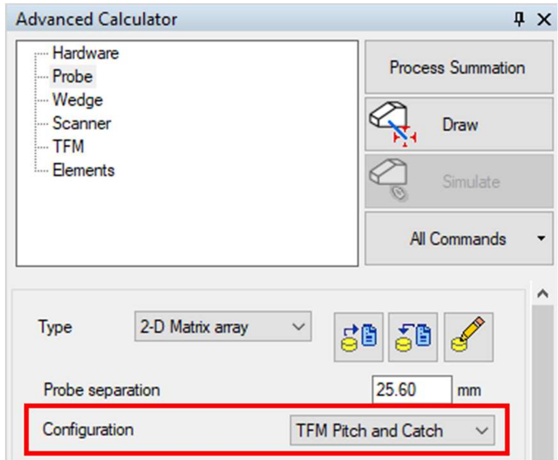
<


UltraVision Manager
ZETEC
Channel in view
TF Envelope Sector R: 20.0
Sequence
Default Sequence
Layout
Analysis
Specimen
Default
Advanced Calculator
Process Summation
Draw
All Commands
Process Angles

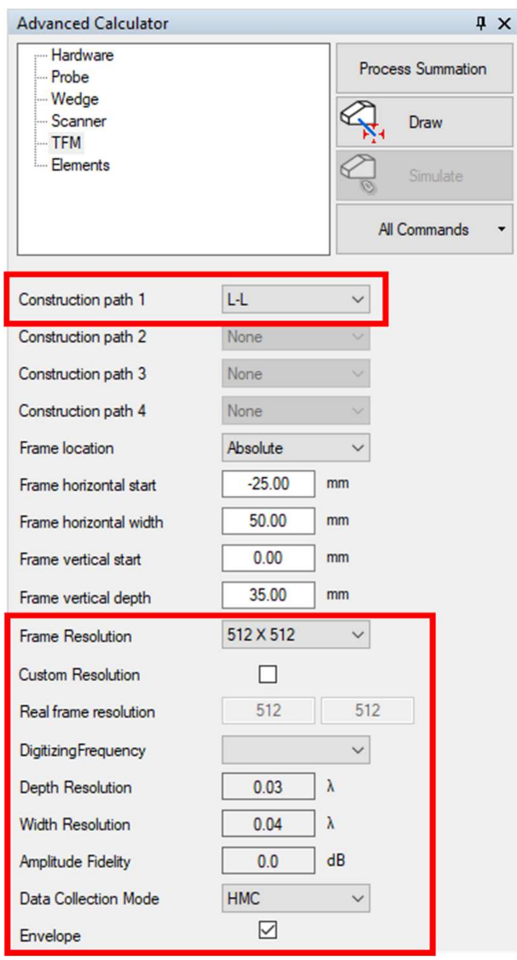

UltraVision Manager
ZETEC
Channel in view
TF DMAS & Envelope Secto
Sequence
Default Sequence
Layout
Analysis
Specimen
Default
Advanced Calculator
Process Summation
Draw
All Commands
Process Angles
View Properties

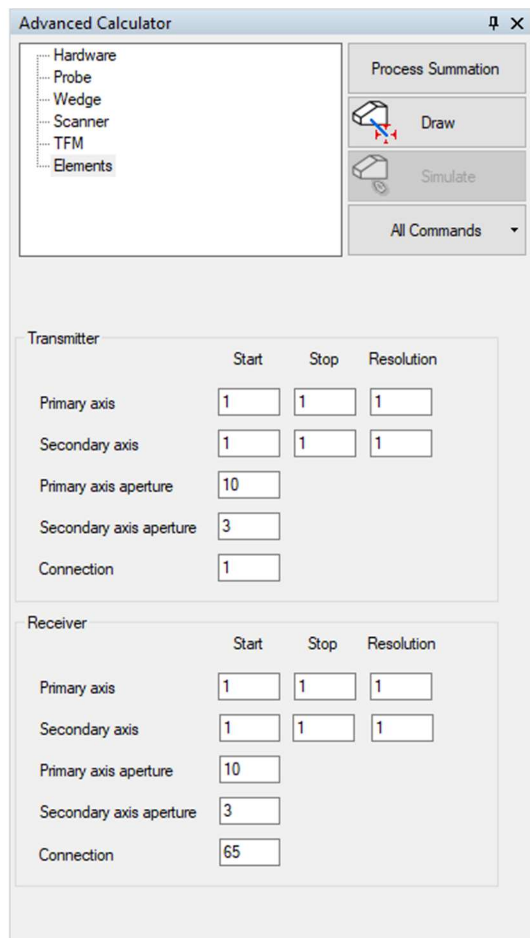
4.4.2 TFM Reconstruction

To reconstruct TFM data, select **Configuration TFM Pitch & Catch** in the **Probe tab**.



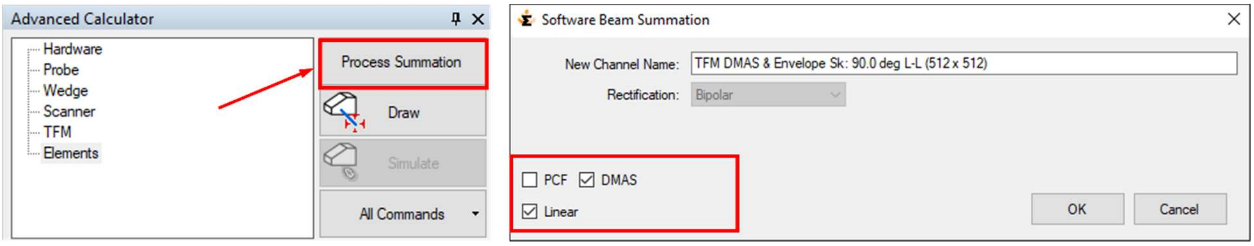
Then define the parameters of the TFM frame in the **TFM** and **Elements** tabs. The **Construction path** is set to **L-L**, and a **Frame Resolution** of 512 x 512 is used. For the considered 2.25 MHz probe and frame extent, this is results in an excellent **Amplitude Fidelity** of 0.1 dB.



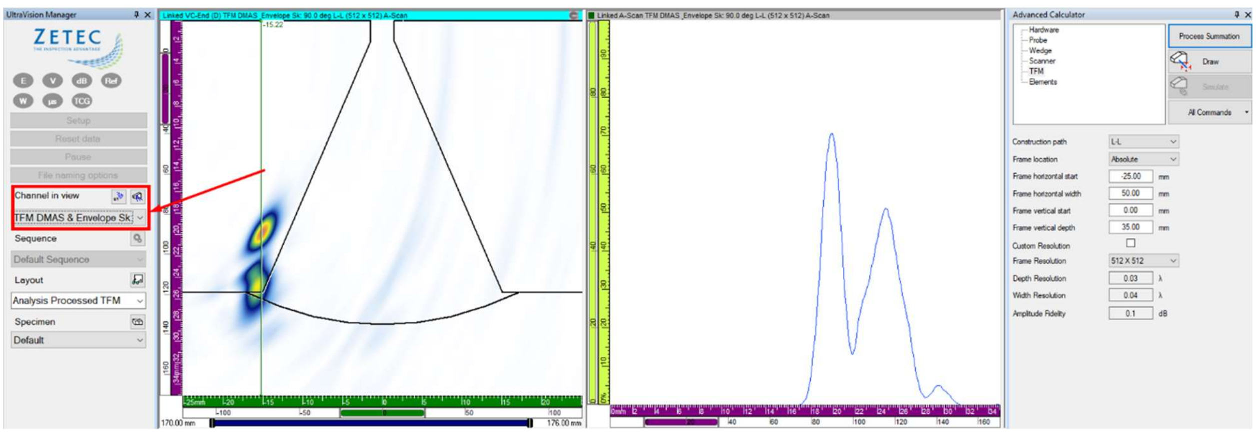


Then hit the **Process Summation** button, and the software will again propose a structured name for the **New Channel** of reconstructed data.

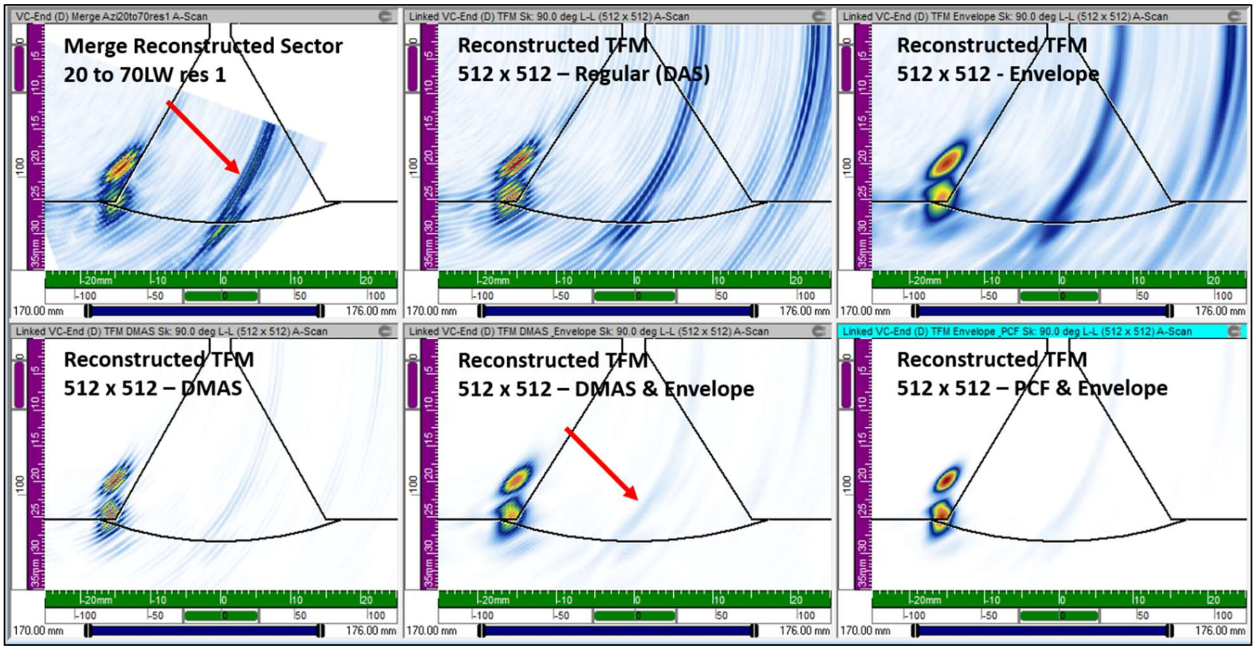
In this example, the reconstruction has been done with a combination of **DMAS** and **Envelope**.



Upon hitting OK and processing, the reconstructed TFM channel will appear in the **UltraVision Manager**, and can be visualized like a merged data group.

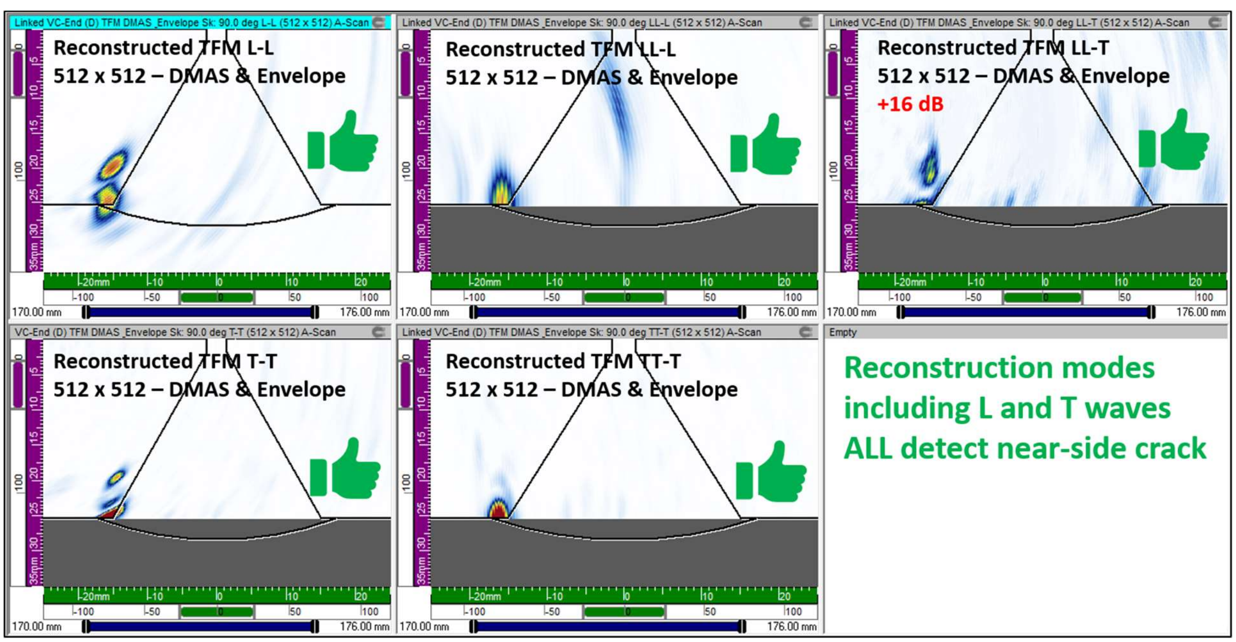


The image below shows images from a merged reconstructed standard phased array channel, and from 5 TFM 512 x 512 frames reconstructed in L-L wave mode with different algorithms.



Since the PA UT channel is well focused on the crack, the advanced focusing algorithms don't provide a lot of extra focusing capability or resolution. But typical behavior of each algorithm is confirmed. For example, **PCF** and **DMAS** show far less intensity for the mode converted signal, and an SNR improvement compared to regular (**DAS**) TFM.

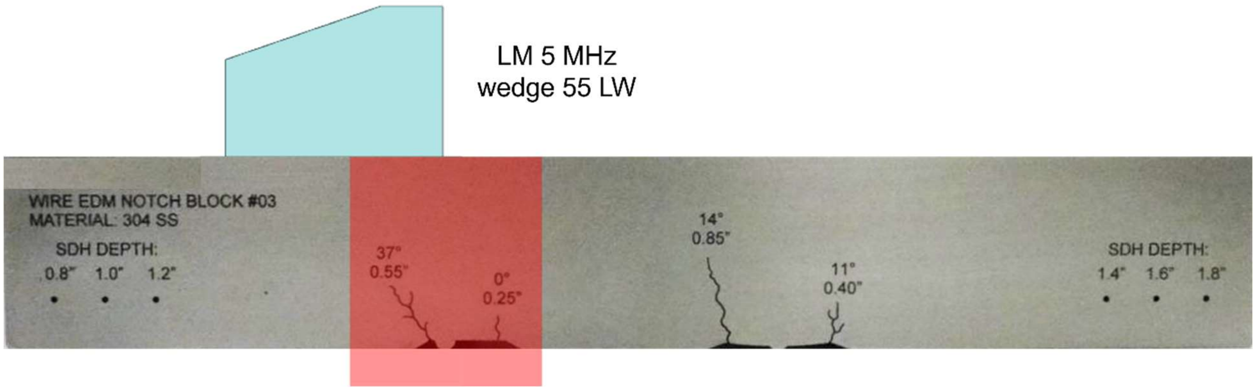
The next image shows TFM frame reconstructions with **DMAS** and **Envelope** for various direct and indirect wave modes. It can be observed that for the crack on the near-side of the stainless steel weld, all reconstruction modes, including both L and T waves, can somehow detect the crack.



5 Typical User Cases - PWI Data Reconstruction

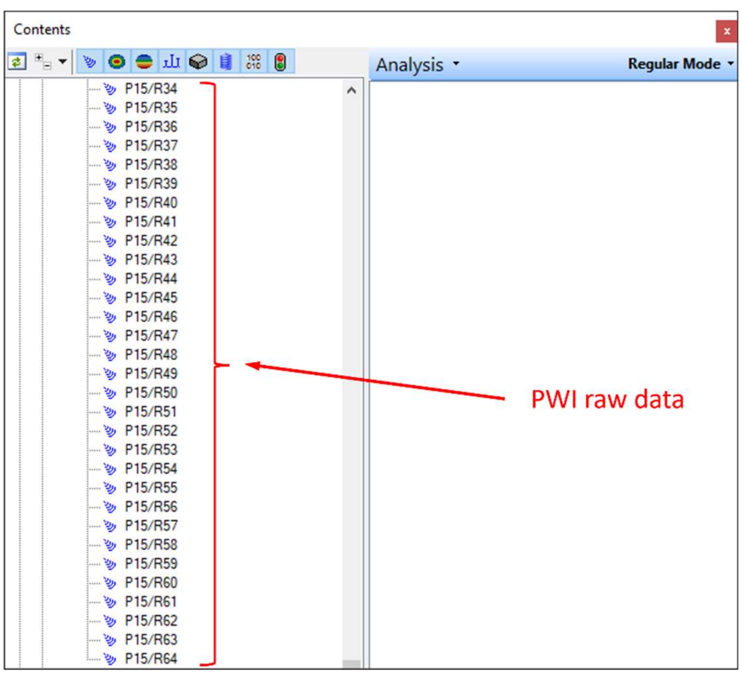
5.1 1D-Linear Probe, LW Wedge, Pulse-Echo Mode, recorded with EMERALD

The file for this user case was recorded on a reference specimen made of 304 stainless steel. The considered specimen is 50 mm thick and contains a number of simulated branched cracks, fabricated using wire EDM (see below). The base material has a relatively fine grain structure, so we were able to use the same 5 MHz pulse-echo probe and L-wave wedge of user case 4.1.



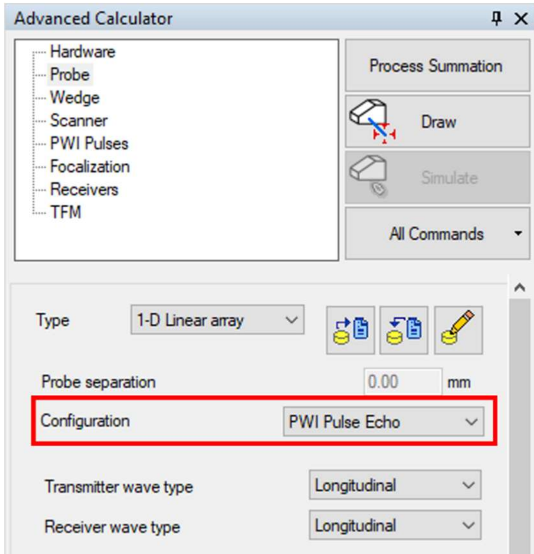
The recorded data file contains a static PWI-TFM frame 512 x 512 in L-L mode generated by a firing sequence of 15 pulses, in addition to an Snapshot containing 960 (15 x 64) individual A-scans.

Once the file is loaded, the PWI raw A-scan data will show up in the **Contents** Pane.



5.1.1 TFM Reconstruction

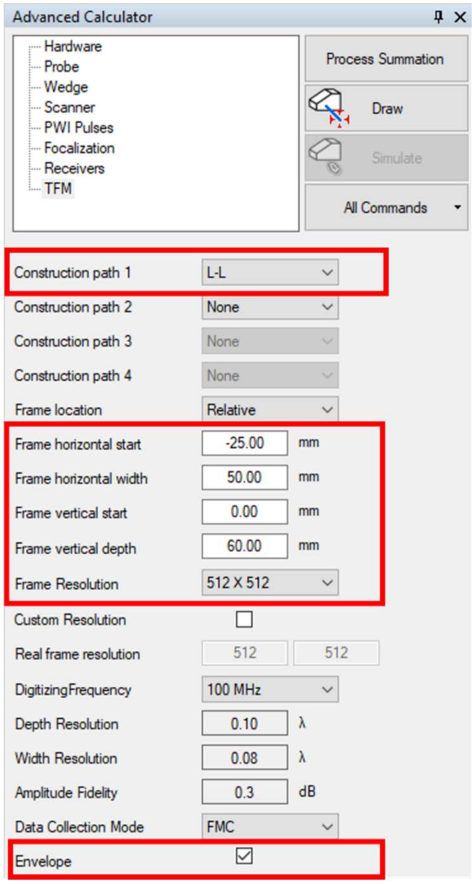
For PWI raw data, the only available option is to reconstruct TFM images. To reconstruct PWI-TFM data, select **Configuration PWI Pulse-Echo** in the **Probe tab**.

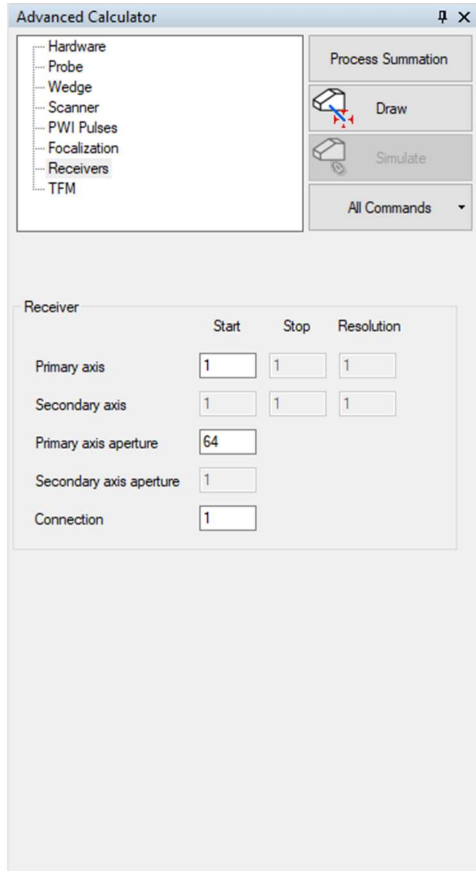


The **PWI Pulses** tab and the **Focalization** tab is available, for PWI the firing sequence was fixed before the recording and cannot be modified. All fields are therefore "grayed".

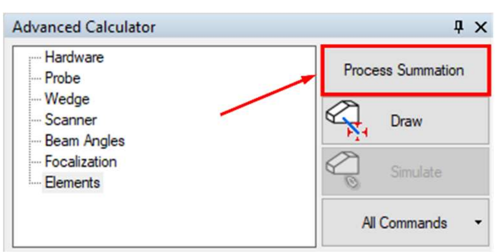
Then define the parameters of the TFM frame in the **TFM** and **Receivers** tabs.

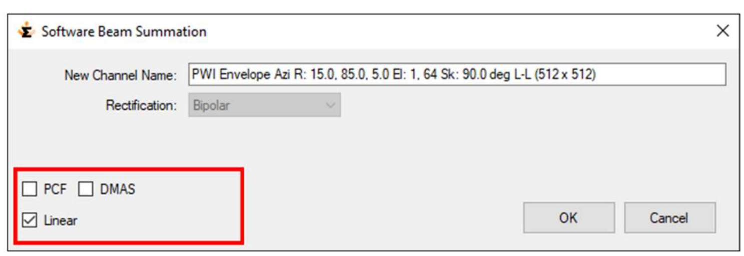
The **Construction path** will be set to **L-L**, just like for the live TFM data, and also the frame extent and **Frame Resolution** (512 x 512) will be selected identical. The **Envelope** option is also selected.





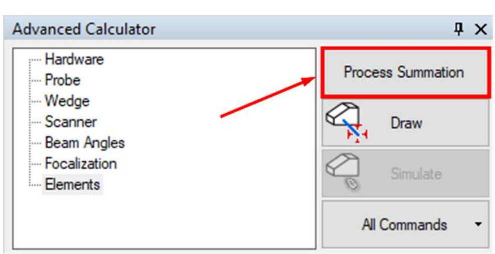
Then hit the **Process Summation** button, and the software will propose a structured name for the **New Channel** of reconstructed data.

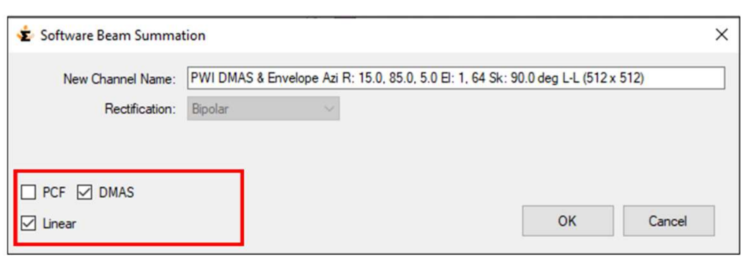




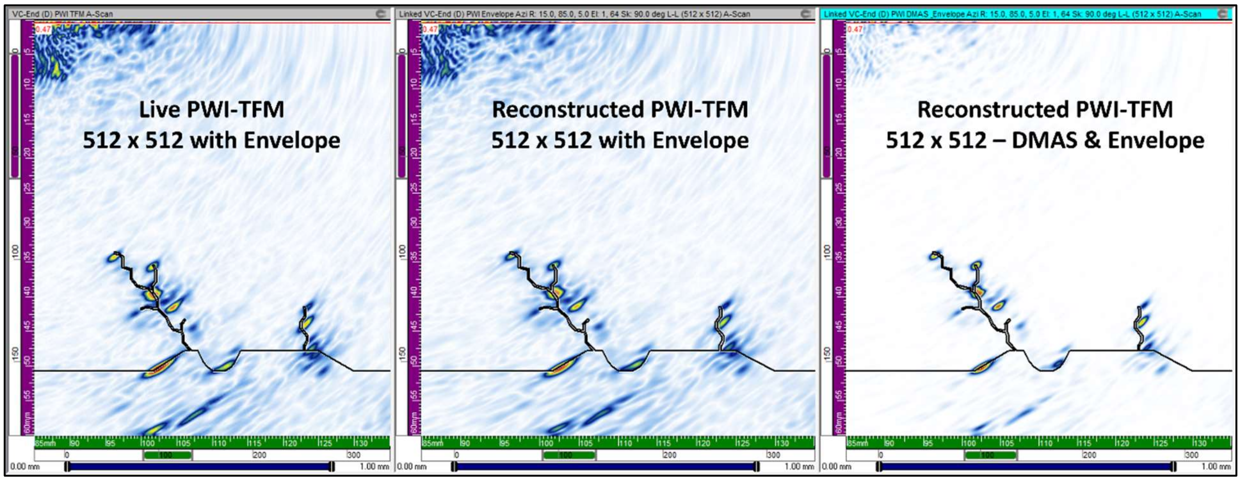
None of the options is checked, so the common **DAS** (Delay and Sum) reconstruction algorithm is used.

For the second PWI-TFM reconstruction, the options **Envelope** and **DMAS** are checked, and this is also reflected in the structured name for the **New Channel** of reconstructed data.

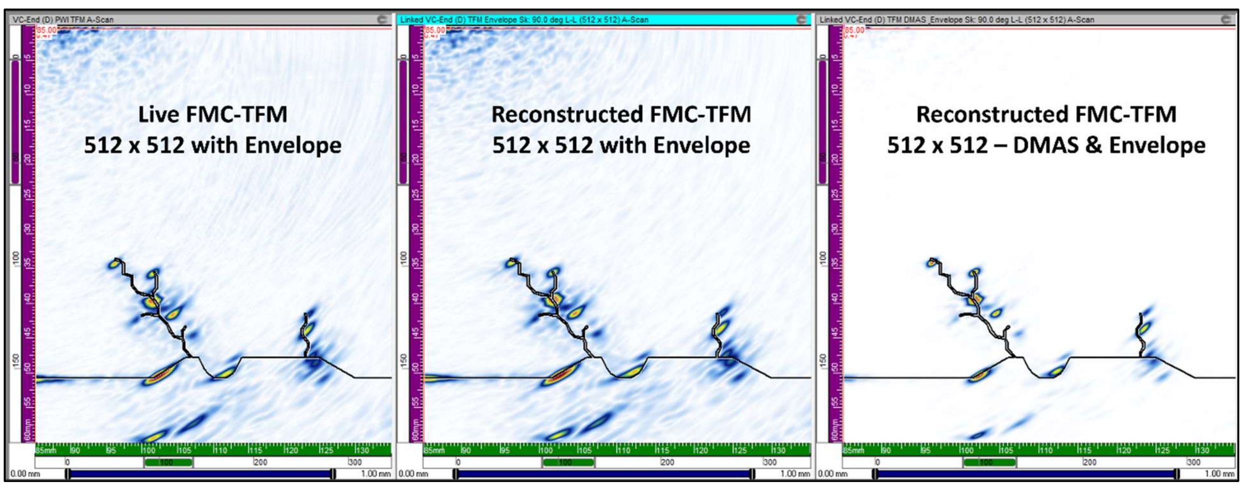




The image below compares the live PWI-TFM data and the reconstructed PWI-TFM data. It can be observed that the DMAS algorithm also improves the imaging quality for the PWI-TFM reconstruction.



The second image shows similar data, but from live FMC-TFM and FMC-TFM reconstructions. It can be observed that the quality of the PWI-TFM imaging is very close to the FMC-TFM imaging, provided that sufficient PWI pulses are used. The quality of the TFM imaging and the benefits for flaw characterization are clearly illustrated by the use of a DXF overlay of the specimen on the data.



5.2 Dual 2D-Matrix Array (DMA), Pitch & Catch Mode, recorded with EMERALD

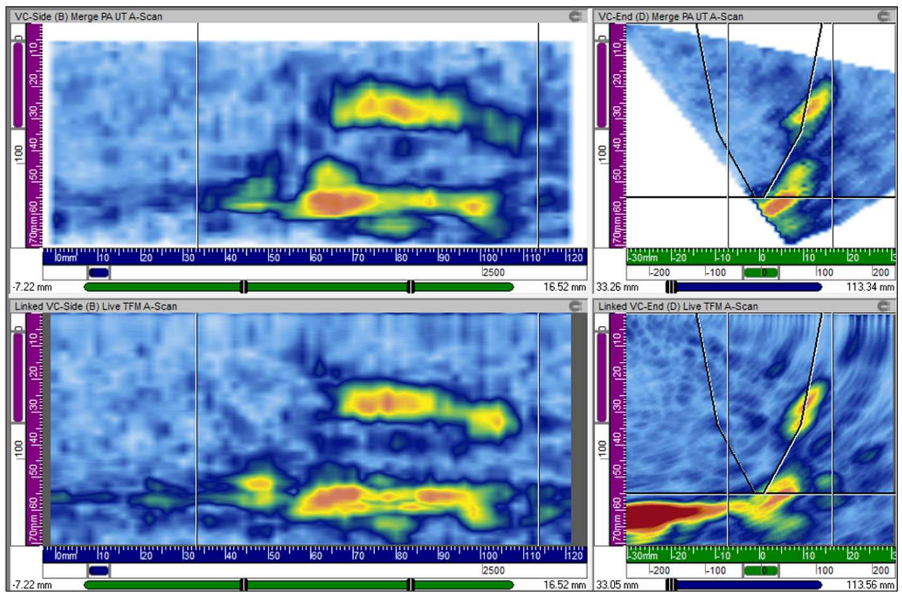
As for the previous user case, the PWI raw data have been recorded with the EMERALD unit. In order to process the raw data, just open the regular UVData file in UltraVision Classic and the additional UVDataFMC file will automatically be loaded as well.

For this user case, the same CASS weld specimen and the 1 MHz DMA probe of § 4.2 were used. This time the file contains a standard PA UT channel with an azimuthal sweep from 30° to 75°LW, a live PWI channel, and PWI raw data taken every 2 mm over a total distance of 120 mm. The PWI firing sequence included 8 angles between 5° and 75°LW.

The merged standard PA UT data and the live PWI-TFM data are shown below (VC-Side and VC-End Views). The corner and tip signals from the crack can be clearly observed.

Live PA UT
30° to 75° LW

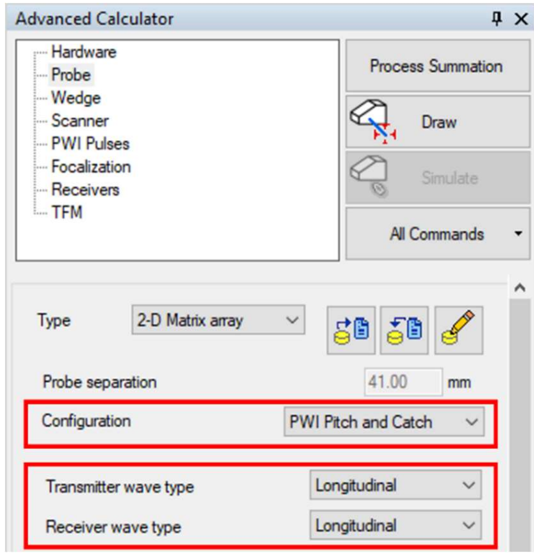
Live PWI-TFM L-L
256 x 256 with Envelope



To perform the reconstruction from the PWI raw data, make sure that the live PWI channel is "active" by clicking on a view of this channel. If the standard PA UT channel is selected, the **Process Summation** button will NOT appear.

5.2.1 TFM Reconstruction

To reconstruct PWI-TFM data, select **Configuration PWI Pitch and Catch** in the **Probe tab**, and at the same time select the appropriate wave type for transmitter and receiver.

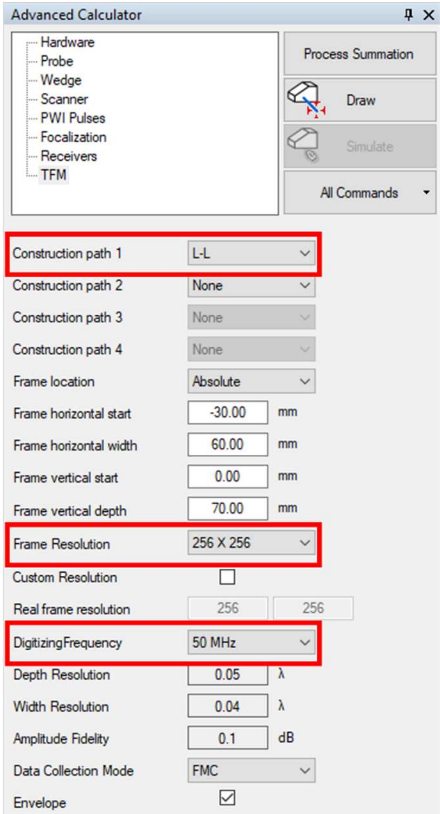


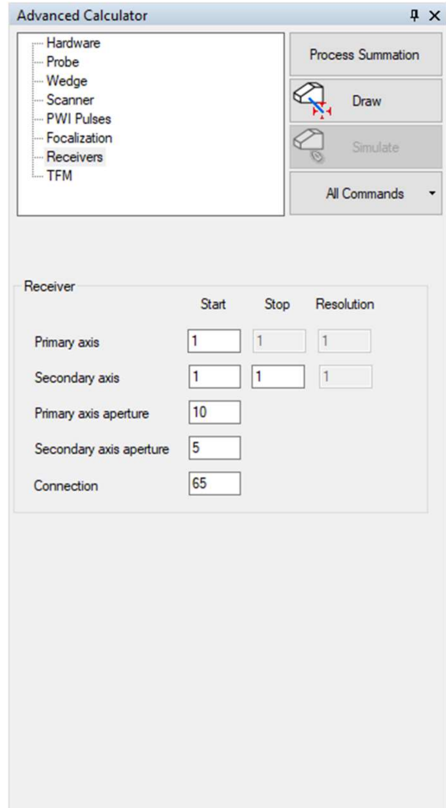
The **PWI Pulses** tab and the **Focalization** tab is available, for PWI the firing sequence was fixed before the recording and cannot be modified. All fields are therefore "grayed".

Then define the parameters of the TFM frame in the **TFM** and **Receiver** tabs.

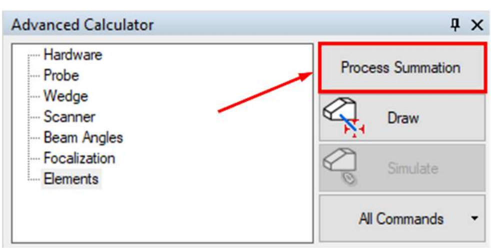
The **Construction path** is set to **L-L**, just like the live PWI data, and a **Frame Resolution** of 256 x 256 is used. It can be observed that since UltraVision 3.12R18, the operator can adjust the **Digitizing Frequency** (possible values 100 MHz, 50 MHz, 25 MHz and 12.5 MHz) for the recording of raw data. For low-frequency probes reducing the digitizing frequency allows to increase the scanning speed while maintaining excellent raw data quality and image quality.

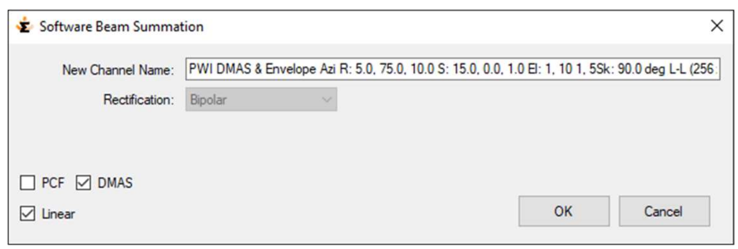
In the **Receiver** tab, typically all receiver elements will be selected for the reconstruction. It is however possible to modify this selection.





Then hit the **Process Summation** button, and the software will again propose a structured name for the **New Channel** of reconstructed data.



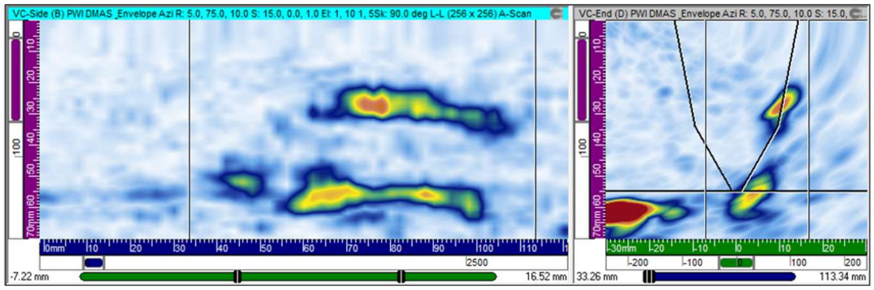


After hitting OK and processing, the reconstructed PWI-TFM channel will appear in the **UltraVision Manager**. This reconstructed data group has the same characteristics as a live PWI data group, i.e. the characteristics of a merged data group.

The image below shows the reconstructed PWI-TFM DMAS & Envelope data (VC-Side and VC-End Views). When comparing to the merged standard PA UT data and the live PWI, the corner and tip signals from the crack are still very clearly observed, and the overall noise level is drastically reduced for the reconstructed channel with DMAS.

When comparing the reconstructed PWI-TFM image with the reconstructed FMC-TFM image of § 4.2, we can observe little difference, even for a PWI firing sequence that included only 8 pulses, compared to 50 pulses (transmitter elements) for the FMC firing sequence. The number of raw A-scans recorded for the PWI firing was 400 (8 x 50), compared to 2500 (50 x 50) for the FMC firing.

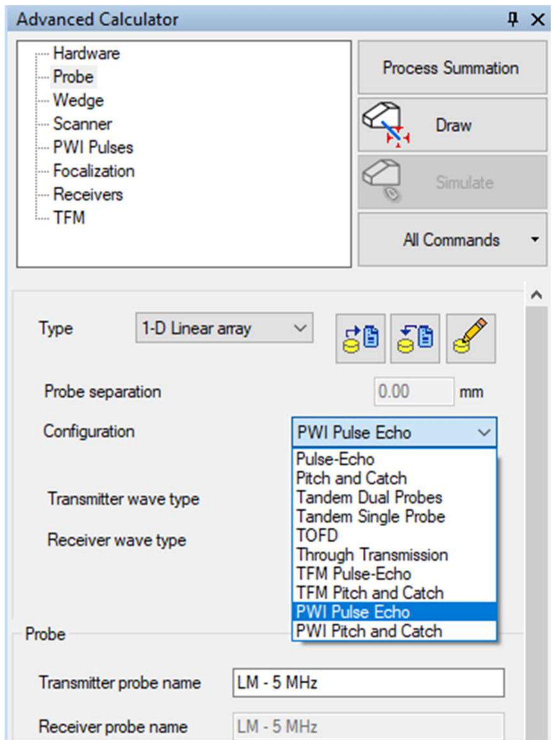
Reconstructed PWI-TFM
L-L 256 x 256
DMAS & Envelope



6 Reference Guide

The reconstruction of raw FMC of PWI data recorded with EMERALD and TOPΔZ64, and raw FMC or HMC data recorded with DYNARAY or DYNARAY Lite, is performed entirely in the **Advanced Calculator** interface of UltraVision Classic.

The configuration to be reconstructed can be selected from **Configuration** in the **Probe tab**.



The configurations available for FMC raw data reconstruction are:

- **Pulse-Echo**: to reconstruct a set of standard phased array focal laws or Total Focusing focal laws from a pulse-echo probe, e.g. **Azimuthal**, **Linear** or **Compound** sweep
- **Pitch & Catch**: to reconstruct a set of standard phased array focal laws or Total Focusing focal laws from a pitch & catch probe (dual linear array or dual matrix array), e.g. **Azimuthal**, **Linear** or **Compound** sweep
- **TFM Pulse-Echo**: to reconstruct TFM frames from a pulse-echo probe
- **TFM Pitch and Catch**: to reconstruct TFM frames from a pitch & catch probe (dual linear array or dual matrix array)

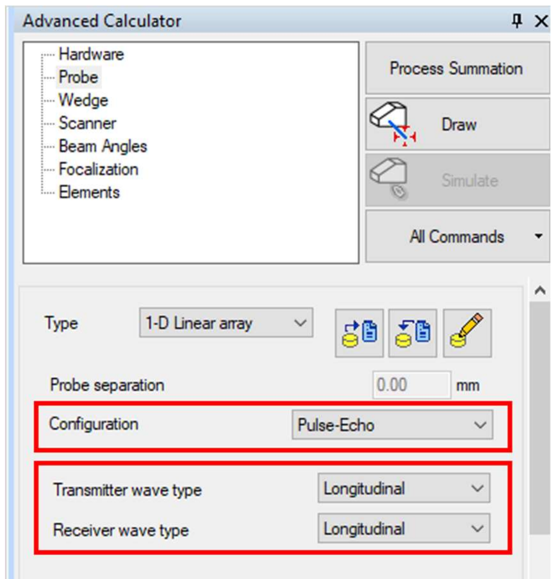
The configurations available for PWI raw data reconstruction are:

- **PWI Pulse-Echo**: to reconstruct TFM frames from a pulse-echo probe
- **PWI Pitch and Catch**: to reconstruct TFM frames from a pitch & catch probe (dual linear array or dual matrix array)

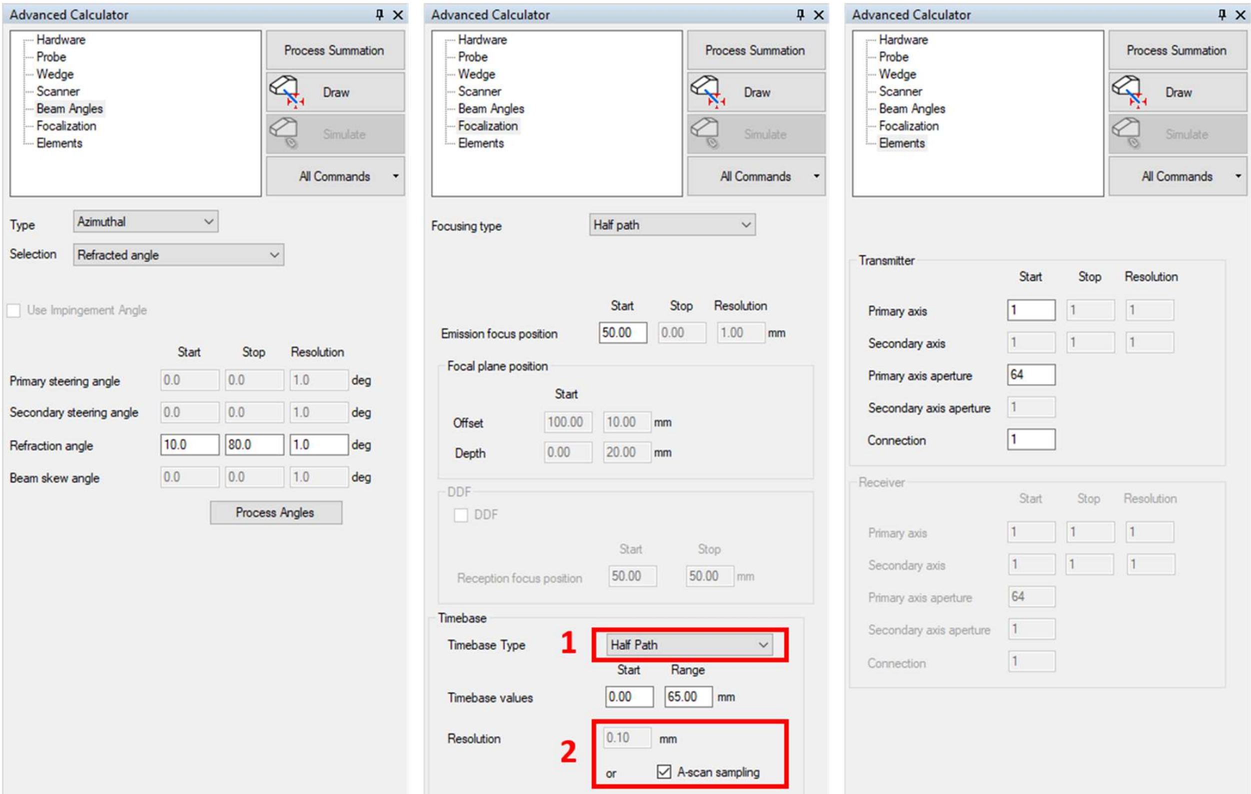
6.1 Standard PA UT reconstruction of FMC raw data

To reconstruct standard PA UT data, select **Configuration Pulse-Echo** or **Pitch & Catch**, in the **Probe tab**, and select the **Transmitter wave type** and **Receiver wave type.**

It is important to mention that the FMC data reconstruction can be performed for both **Longitudinal** and **Shear** waves no matter what the considered probe and wedge configuration is. *But obviously the quality of the reconstructed data will depend on the ability of the probe configuration to efficiently generate each wave type.*



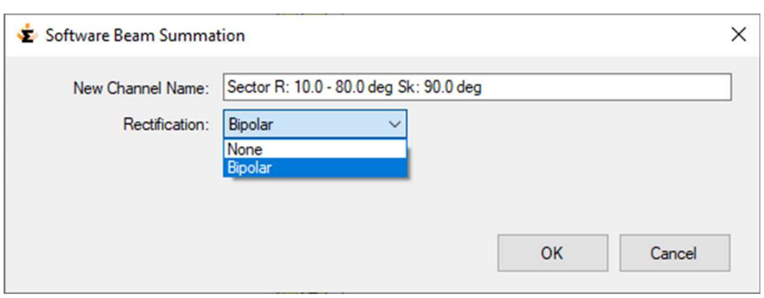
Then define the parameters of the required sweep in the **Beam Angles**, **Focalization** and **Elements** tabs, just as if you would be programming focal laws prior to a standard phased array inspection.

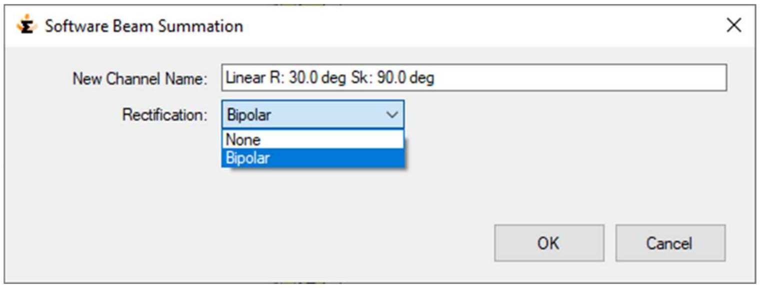


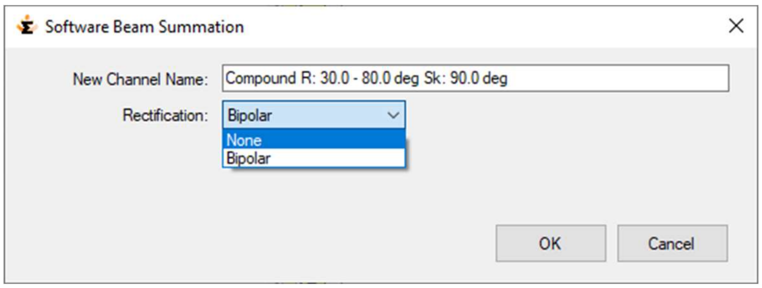
Important Notes

1. In the **Focalization** tab, the **Timebase Type** can be selected as **Half Path** of **True Depth**
2. In the **Focalization** tab, the **Timebase Resolution** is by default set to **A-scan sampling**, which means that the resolution of the raw FMC A-scans (highest possible resolution) will be used for the reconstructed signals; for standard phased array reconstruction the resolution cannot be changed

Depending on the sweep **Type** selection in the **Beam Angles** tab, (**Azimuthal**, **Linear** or **Compound**), after hitting the Process Summation button, the software will propose an appropriate structured name for the **New Channel** of reconstructed data. The user can modify this name.





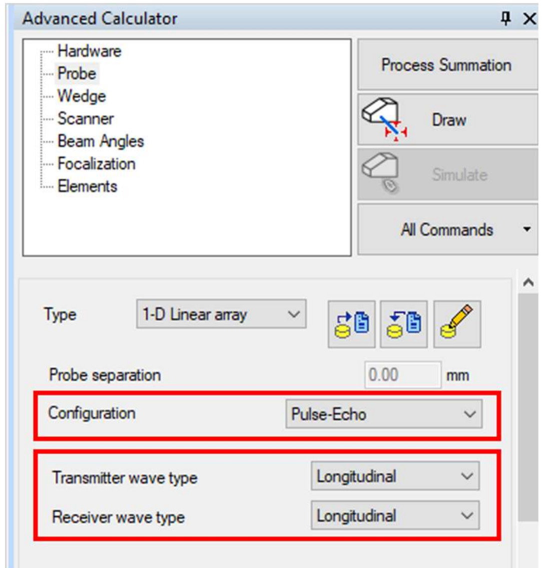


The **Rectification** option allows to select **None** to generate RF reconstructed data, or **Bipolar** for rectified reconstructed data.

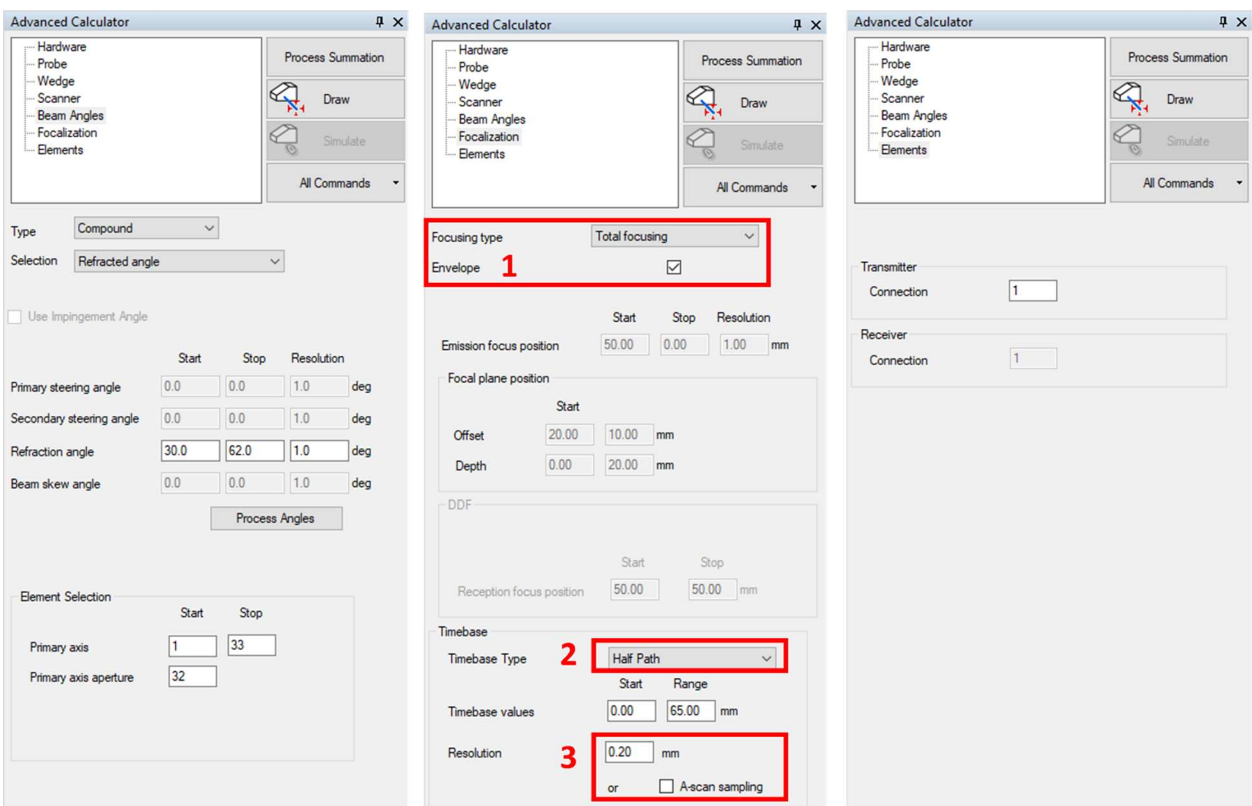
6.2 Total Focusing reconstruction of FMC raw data

To reconstruct Total Focusing data, select **Configuration Pulse-Echo** or **Pitch & Catch** in the **Probe tab**, and select the **Transmitter wave type** and **Receiver wave type.**

It is important to mention that the FMC data reconstruction can be performed for both **Longitudinal** and **Shear** waves no matter what the considered probe and wedge configuration is. *But obviously the quality of the reconstructed data will depend on the ability of the probe configuration to efficiently generate each wave type.*



Then define the parameters of the required sweep in the **Beam Angles**, **Focalization** and **Elements** tabs, just like for standard phased array reconstruction, except that in all cases, The **Focusing type** must be set to **Total Focusing.**



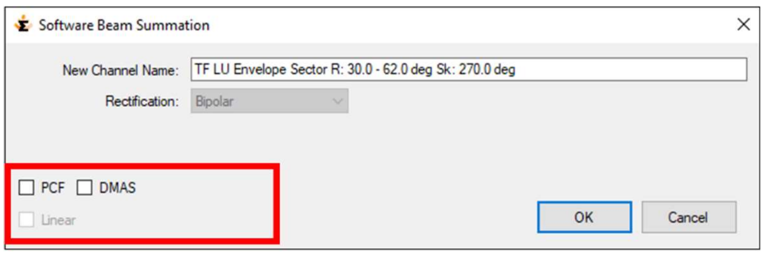
Important Notes

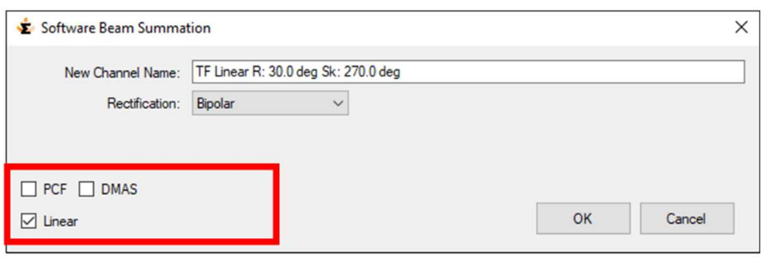
1. Since UltraVision 3.11R4, for **Total Focusing** reconstruction, the **Envelope** feature should now be selected in the **Focalization** tab

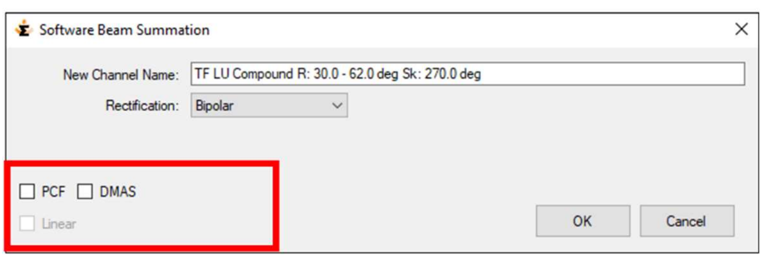
2. In the **Focalization** tab, the **Timebase Type** can ONLY be selected as **Half Path**

3. In the **Focalization** tab, the **Timebase Resolution** is by default set to **A-scan sampling**, (highest possible resolution), but can be modified to a lower resolution.

Depending on the sweep **Type** selection in the **Beam Angles** tab, (**Azimuthal**, **Linear** or **Compound**), after hitting the **Process Summation** button, the software will propose an appropriate structured name for the **New Channel** of reconstructed data. The user can modify this name.







The **Rectification** option allows to select **None** to generate RF reconstructed data, or **Bipolar** for rectified reconstructed data.

For **Total Focusing** reconstruction, the options **PCF** and **DMAS** are available. The options are explained in § 2 of this document. Checking one or more options will automatically reflect in the structured **New Channel Name** proposed by the software.

For Total Focusing reconstruction of an **Azimuthal** or **Compound** sweep, the option **Linear** is by default unchecked (and grayed out), and the individual reconstructed A-Scans (for each angle in the sweep) will be accessible for e.g. Volumetric Merge. The proposed structured name automatically includes the mention **"LU" ("Linear Unchecked").**

For Total Focusing reconstruction of a **Linear** sweep, the option **Linear** is by default unchecked, but the user can check it if he wants the reconstructed data group to be automatically merged. In this case, the proposed structured name does NOT include the mention **"LU" ("Linear Unchecked").**

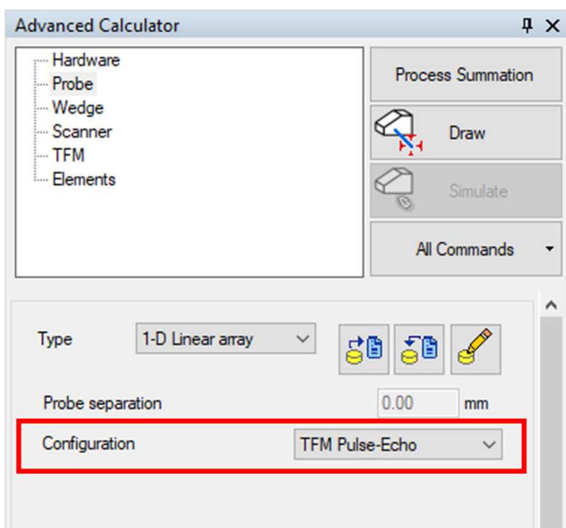
Important Note:

Data groups reconstructed with "LU" are unmerged data groups, with individual A-Scans available, and the End view is typically visualized using the **VC-Sectorial scan** view.

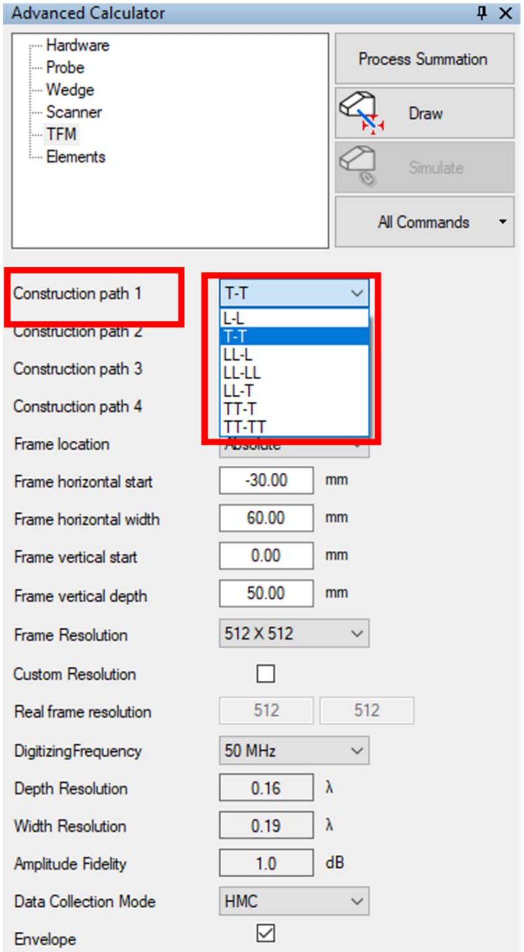
Data groups reconstructed without "LU" are merged data groups, with no individual A-Scans available, and the End view is typically visualized using the **Linked VC-End** view.

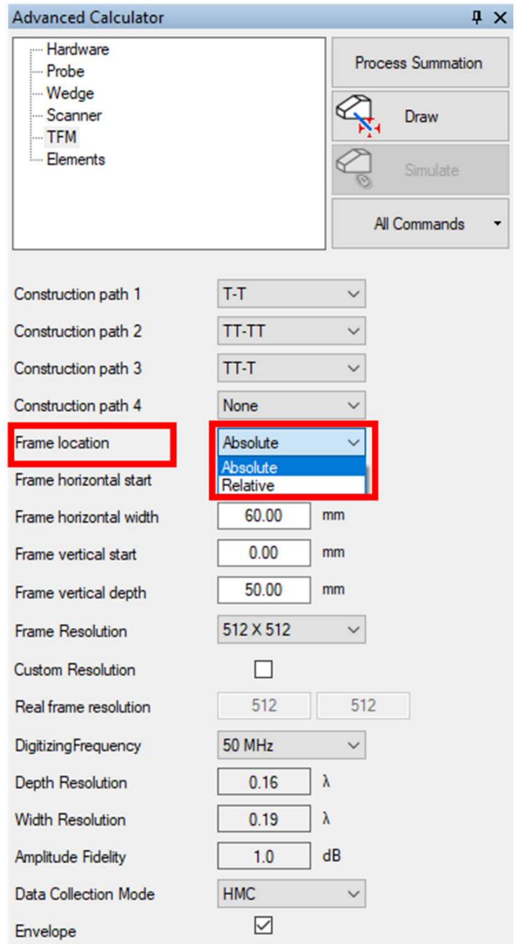
6.3 TFM Reconstruction of FMC raw data

To reconstruct TFM data, select **Configuration TFM Pulse-Echo** or **TFM Pitch & Catch** in the **Probe tab**.

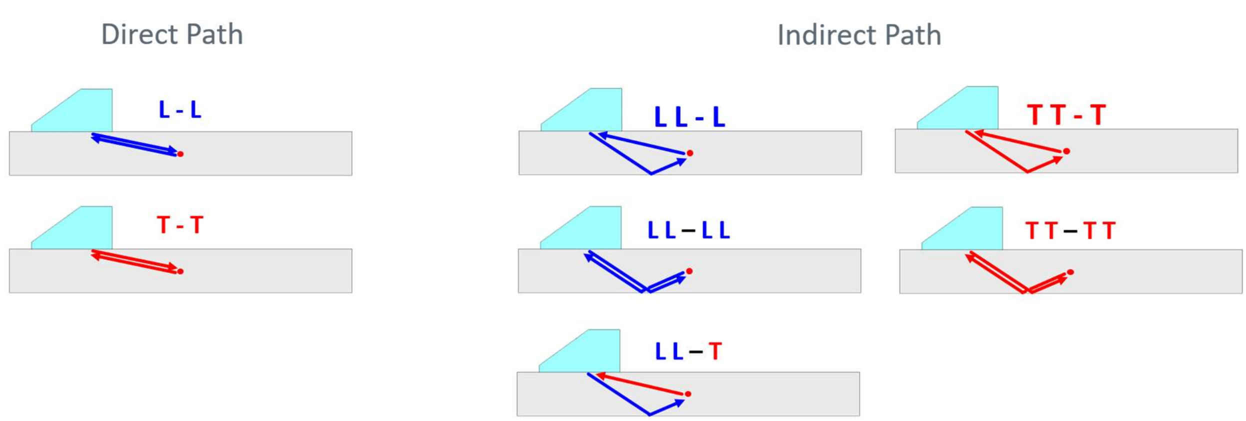


Then define the parameters of the TFM frame in the **TFM** and **Elements** tabs.





For the **Construction path**, direct paths **L-L** and **T-T** are supported as well as indirect paths **LL-L** , **LL-LL**, **LL-T**, **TT-T** and **TT-TT** (using reflection from the back-wall of the specimen before hitting the reflector).

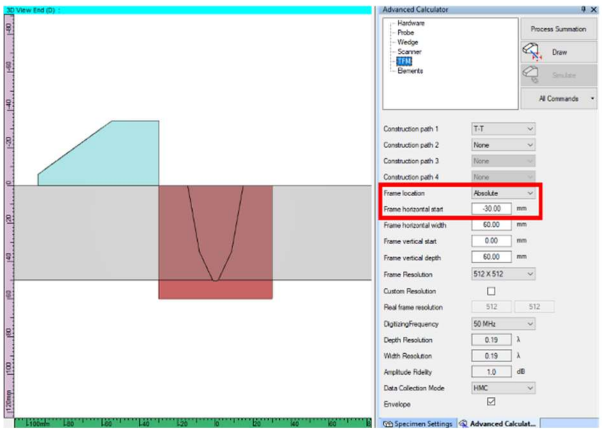


The **Frame location** allows the user to determine the reference for the location of the TFM frame:

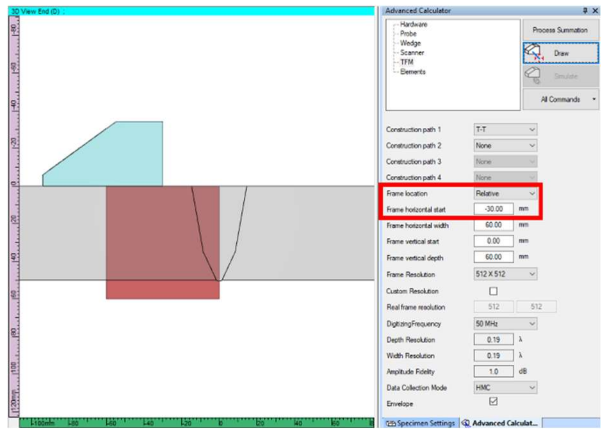
- **Absolute** means that the frame is reconstructed with reference to the specimen as defined in the software
- **Relative** means that the frame is reconstructed with reference to the probe reference as defined in the software

The figure below shows the effect of the reference for a given frame size definition.

Absolute

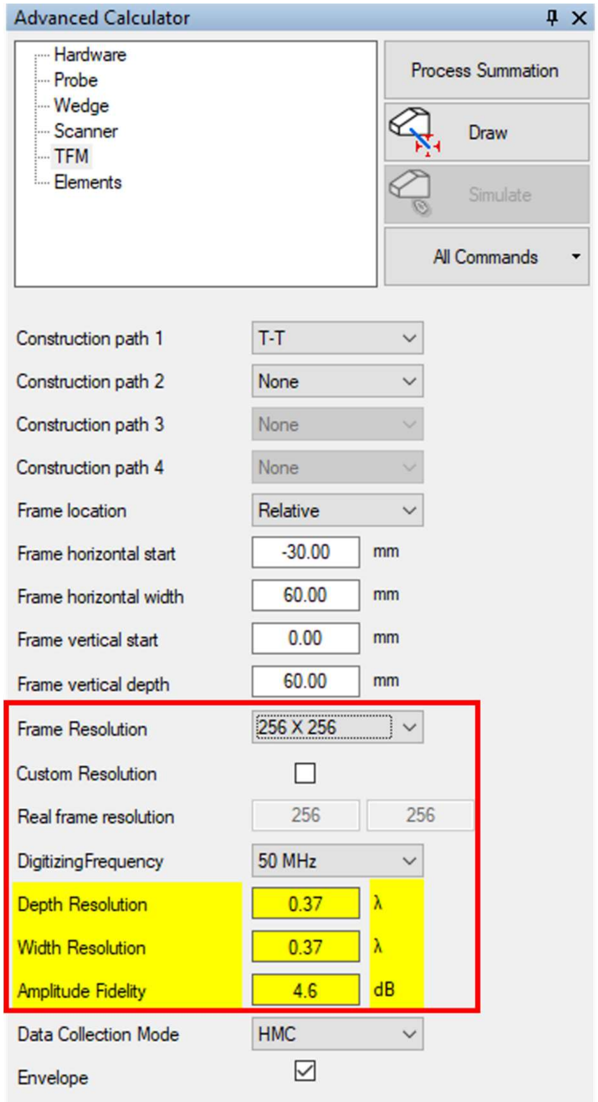


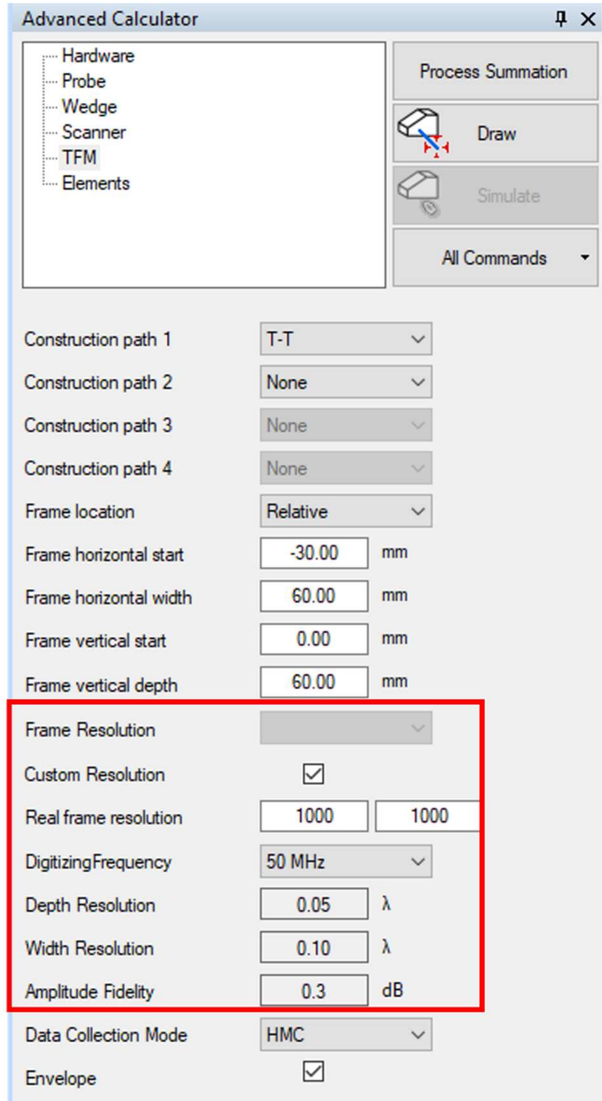
Relative



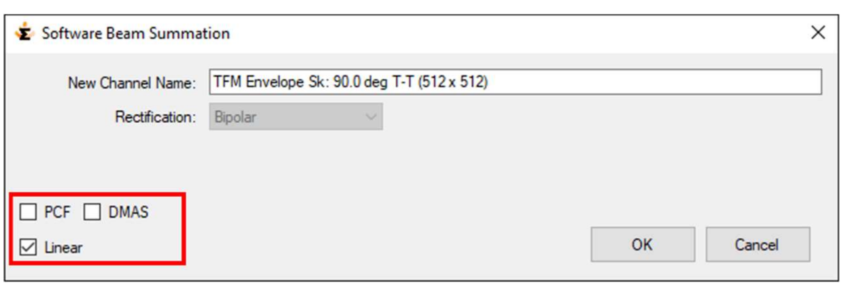
The **Frame Resolution** can be selected from a drop-down box (see below left), or it can be set as a **Custom Resolution** (see below right).

Whenever the selected **Frame Resolution** results in an **Amplitude Fidelity** higher than 2 dB, the field will be highlighted in yellow to suggest the operator to improve the **Frame resolution.**





Depending on the **Construction path** selection in the **TFM** tab, after hitting the **Process Summation** button, the software will propose an appropriate structured name for the **New Channel** of reconstructed data. The user can modify this name.



For **TFM** reconstruction, the options **PCF** and **DMAS** are available. The options are explained in § 2 of this document. Checking one or more options will automatically reflect in the structured **New Channel Name** proposed by the software.

For **TFM** reconstruction, the option **Linear** is by default unchecked, but the user can check it if he wants the reconstructed data group to be automatically merged. In this case, the proposed structured name does NOT include the mention **"LU" ("Linear Unchecked").**

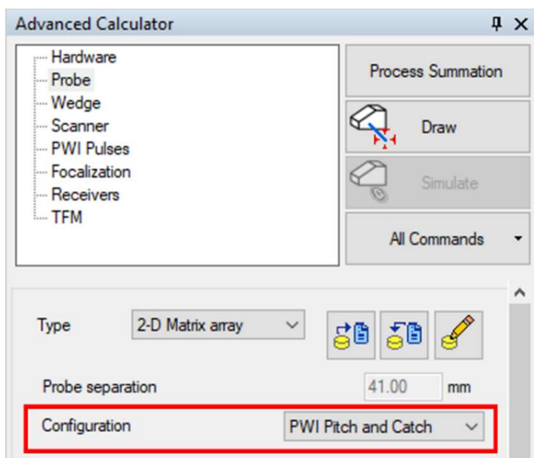
Important Note:

Data groups reconstructed with **"LU"** are unmerged data groups, with individual A-Scans available, and the End view is typically visualized using the **VC-Sectorial scan** view.

Data groups reconstructed without "LU" are merged data groups, with no individual A-Scans available, and the End view is typically visualized using the **Linked VC-End** view.

6.4 TFM Reconstruction of PWI raw data

To reconstruct TFM data, from PWI raw data generated by a PWI firing sequence, select **Configuration PWI Pulse-Echo** or **PWI Pitch and Catch** in the **Probe tab**.



All fields of the **PWI Pulses** tab and the **Focalization** tab are "grayed", because the parameters of the PWI firing sequence were fixed before the recording and cannot be modified.

Then define the parameters of the TFM frame in the **TFM** and **Receiver** tabs, as mentioned in § 5.1.1 and § 5.2.1.