

UltraVision Classic

How To Guide – Release 3.10R20 & Higher

Frequency Filter Tool

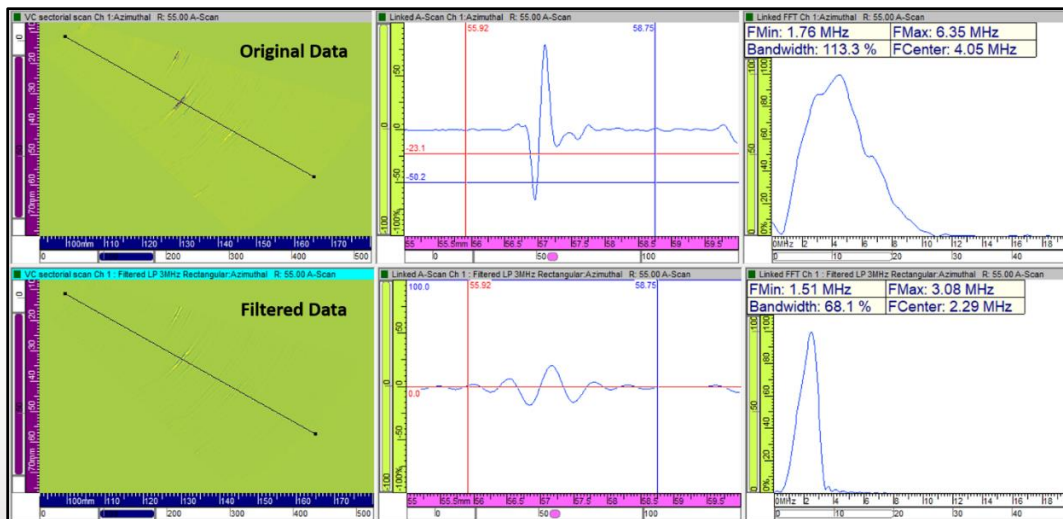
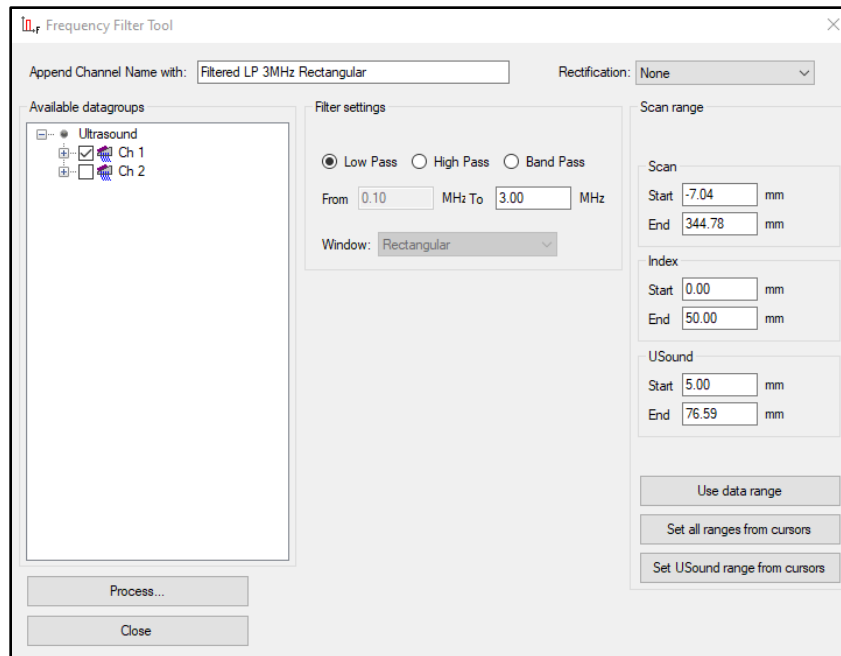


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1 Introduction

The **Frequency Filter Tool** is a data processing tool available in the analysis mode of the UltraVision Classic software. This tool allows the user to define and apply a customizable frequency filter on RF (non-rectified) data recorded with Zetec data acquisition systems.

The **Frequency Filter Tool** can be useful for applications where the user wants to:

- Investigate the influence of the ultrasonic frequency on the response of different reflector types or damage mechanisms (e.g. HTHA)
- Evaluate if the frequency responses of specific reflectors and material noise are different, e.g. to find ways to improve the global SNR of ultrasonic data

For data groups containing RF (non-rectified) signals, a certain range of the frequency spectrum of the selected datagroup(s) is filtered out, based on the user defined parameters. The following filter types are available:

- **Low Pass (LP)** filter, blocking frequencies higher than the filter frequency; this filter is available with a rectangular window function
- **High Pass (HP)** filter, blocking frequencies lower than the filter frequency; this filter is available with a rectangular window function
- **Band Pass (BP)** filter, blocking frequencies outside of the filter range; this filter is available with either a rectangular or a Gaussian window function

Once the processing is completed, new datagroup(s) are created and added to the list of channels. These data can be visualized and further processed like the original data. The data generated by the **Frequency Filter Tool** can also be stored in the **UVExtension** file accompanying the **UVData** file.

The **Frequency Filter Tool** can be used in combination with other data processing tools in UltraVision Classic, e.g. the **Geometric Echo Removal**, as long as non-rectified data are considered.

The second section of this document provides a short overview of the user interface and the operations performed within the **Frequency Filter Tool**.

The third section of this document illustrates the use of the offline filtering process and other frequency domain tools for a “Typical User Case”.

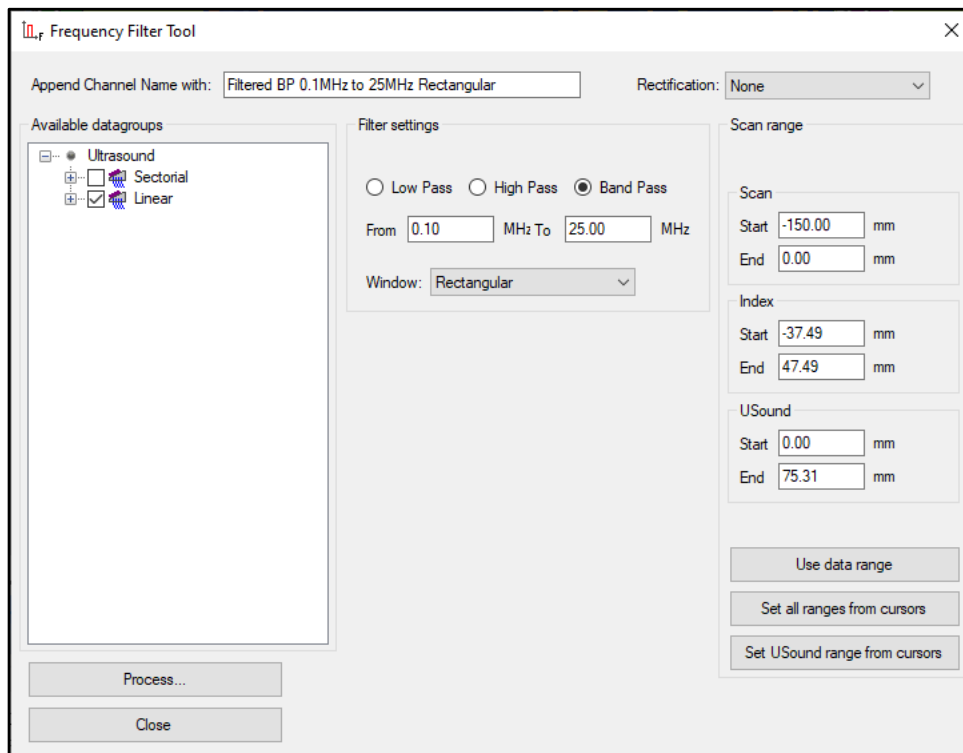
Finally, in the fourth section “Reference Guide”, the various options and parameters of the **Frequency Filter Tool** will be listed and explained chronologically.

2 Frequency Filter Tool - Overview

2.1 User Interface

The user interface of the **Frequency Filter Tool** allows the user:

- to select the datagroup(s) to be processed,
- to define the parameters of the filter,
- to define the area of interest which will be processed,
- to select whether (or not) the processed data will be rectified,
- (if required) to modify the structured name of the new datagroup, automatically generated when setting the filter parameters.



2.2 Processing

The following operations will be executed during processing by the **Frequency Filter Tool**:

1. Converting RF A-Scan signals from their original time domain to the frequency domain
2. Multiplication of all frequency domain signals by a filter transfer function with amplitude 1, and with the following -6 dB limits:

- For LP, from 0.1 MHz to user-defined upper cut-off frequency
- For HP, from user-defined lower cut-off frequency to 25 MHz (i.e. higher than bandwidth of existing Zetec units)
- For BP, from user-defined lower cut-off frequency to user-defined cut-off upper frequency

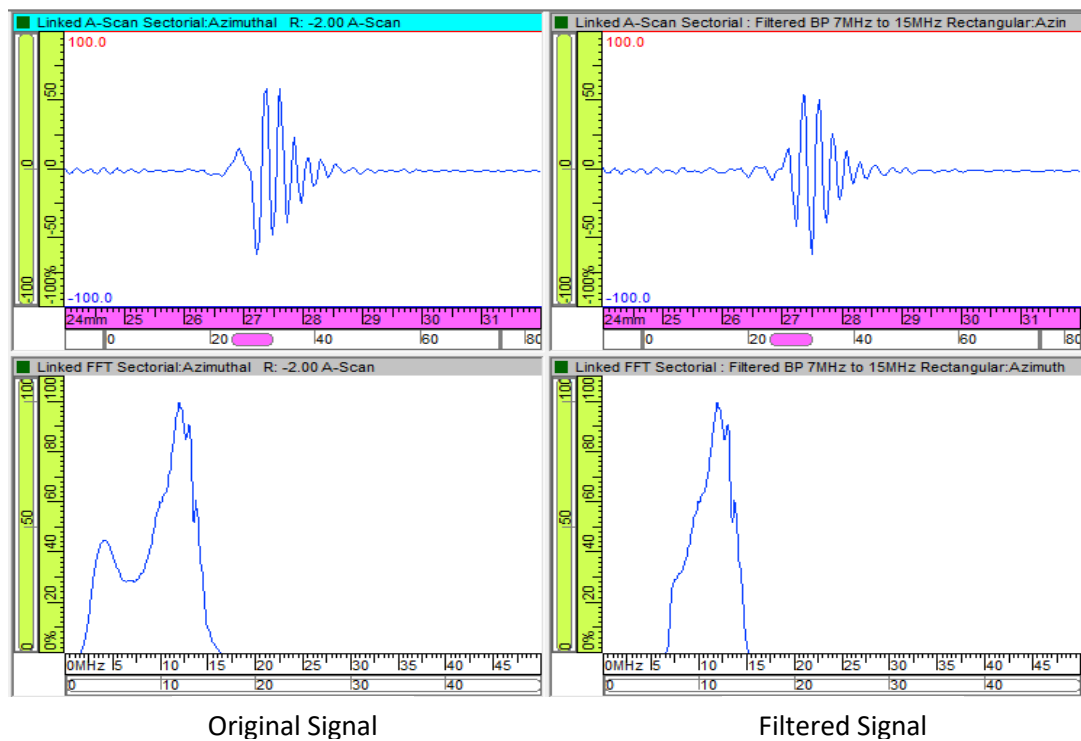


Values below 0.1 MHz and above 25 MHz are not allowed; this frequency range includes and exceeds the bandwidth of all existing Zetec units.



For **UVData** channels recorded with a digitizing frequency of 25 MHz, the upper cut-off frequency cannot exceed 12.5 MHz.

3. Converting the processed signals back from the frequency domain to the time domain to generate filtered RF A-scans signals for the new datagroup
4. Software rectification will be applied to the new datagroup if this option is selected by the user

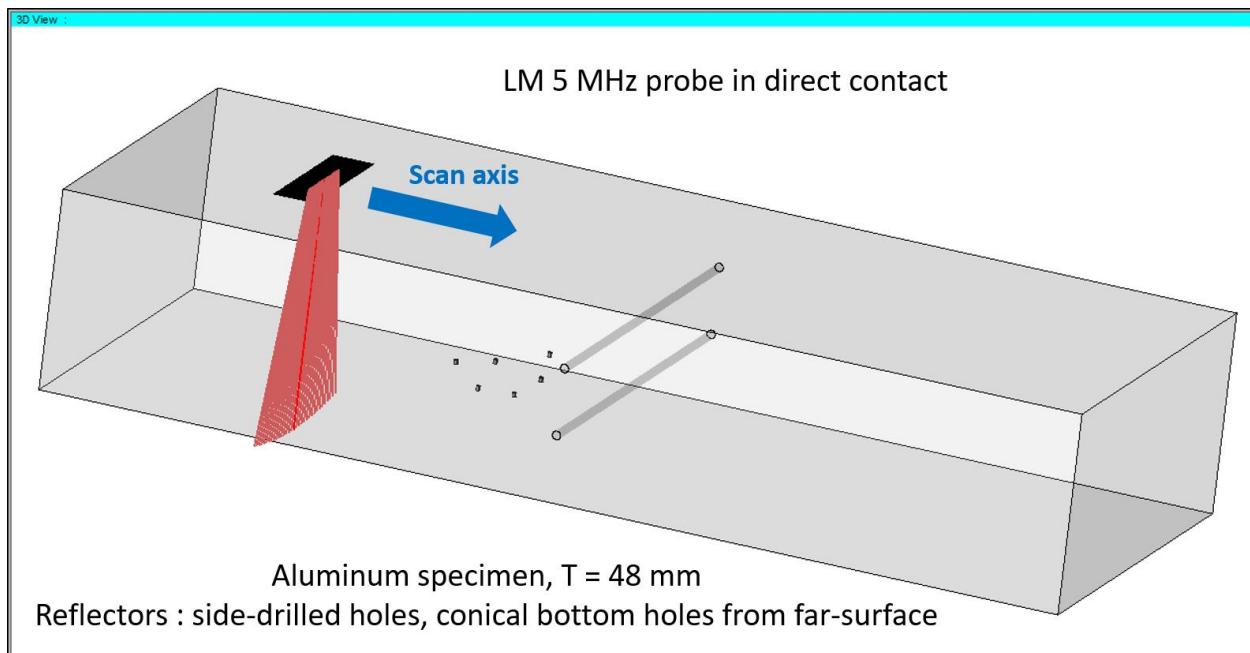


The figure above shows the result of rectangular BP filtering from 7.00 MHz to 15.0 MHz, on a broad-band signal with two maxima in the frequency spectrum.

3 Typical User Case

The data file for this user case was recorded on an aluminum reference specimen with various reflector types: infinite flat reflector (far-surface), side-drilled holes, and regular conical holes (drilled from far-surface).

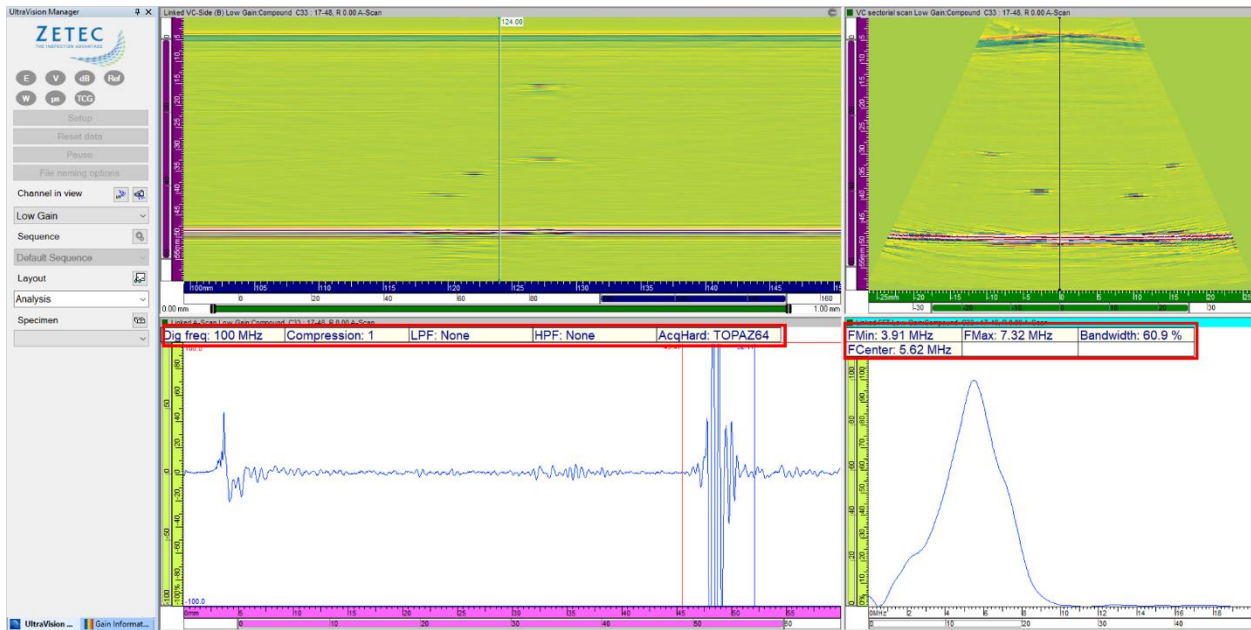
An LM 5 MHz probe was used in direct contact, while the hardware filter of the TOP Δ Z⁶⁴ unit was set to **None**, to allow for using the full bandwidth of the probe. A compound sweep was used from -16 to 16 degrees LW, with a resolution of 0.5 degrees and an active aperture of 32 elements. The compound sweep is combined with a one-line mechanical scanning movement to fully cover the region of interest.



The image below shows a typical screen lay-out for visualizing the raw RF data: Linked VC-Side (B) view, VC-Sectorial scan view, Linked A-Scan view for a given focal law and Linked FFT view for the same focal law.

View Information fields are used to show some relevant UT Settings of the data file, and frequency spectrum information of the backwall signal in the displayed A-Scan.

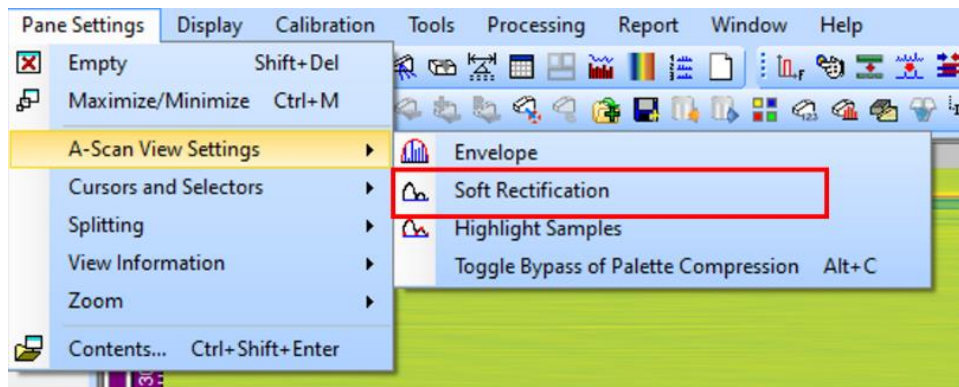
It is important to mention that the gain for this data group was carefully chosen in order NOT to generate saturated signals, but 24 dB soft gain was used to display the data, and to show the weak responses from the conical holes.

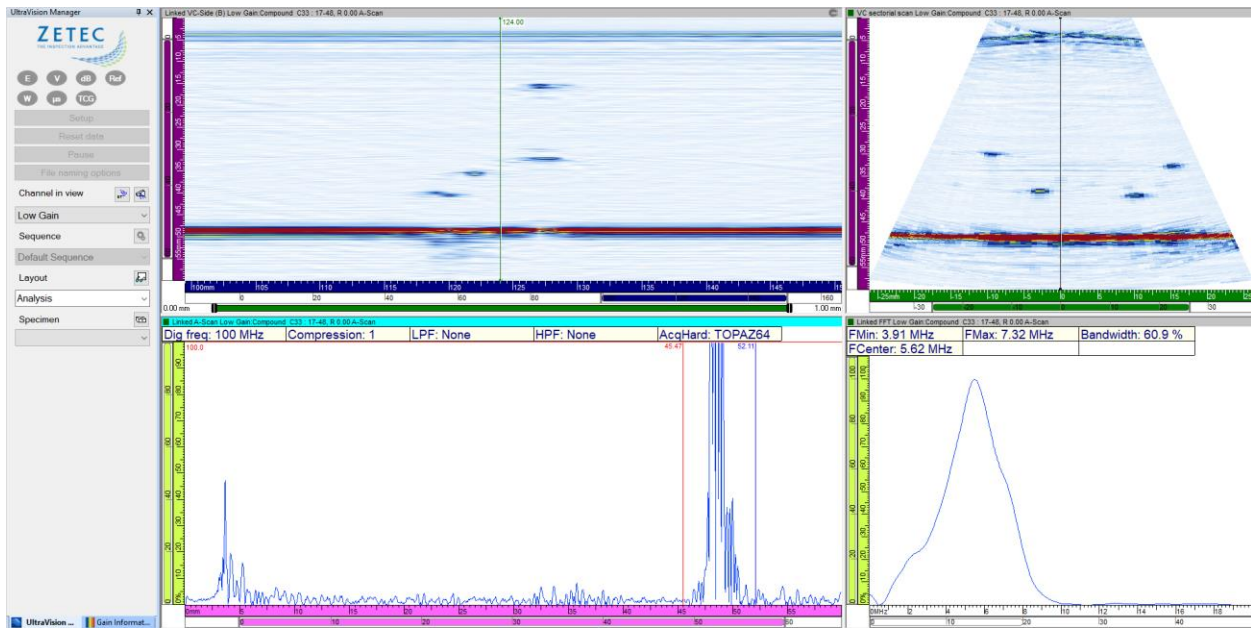


It can be observed that the center frequency of the back-wall signal is around 5.6 MHz, with 6 dB cut-off values of 3.9 and 7.3 MHz. The signal has a bandwidth of roughly 60 % which is typical for standard PA UT probes.

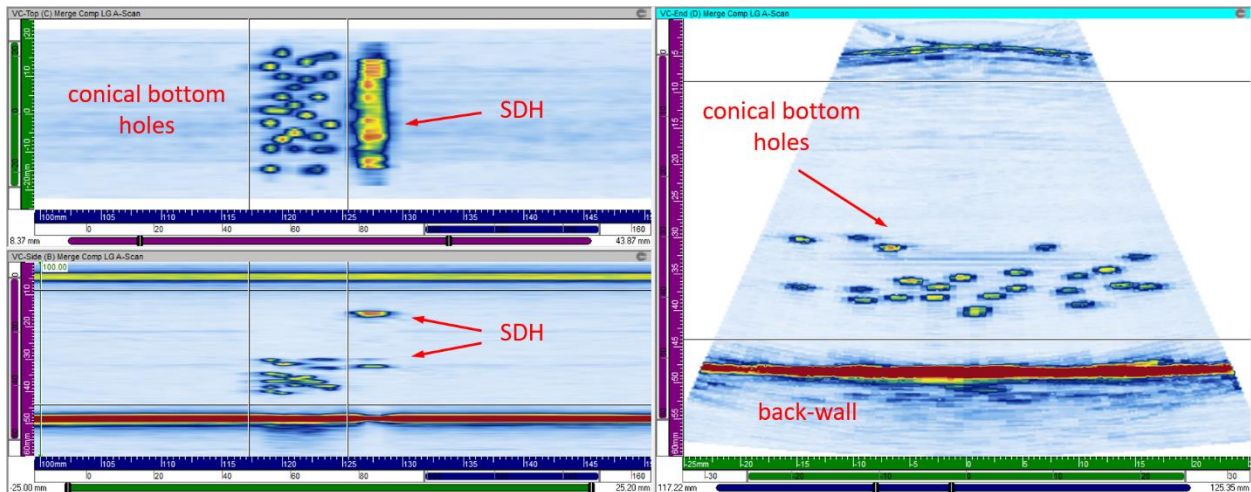
Even if the raw data is unrectified, the user can get the more familiar rectified visualization of the data, by using the **Soft Rectification** available in the **Pane Settings**, or from the dedicated icon in the toolbar.

The FFT and the related information remains available after the software rectification.





After performing a Volumetric Merge on the raw data, the new data group can be displayed using the VC-Top (C), VC-Side (B) and VC-End (D) views. The images clearly show the signals from the conical holes, the two side-drilled holes and the back-wall. Again, 24 dB soft gain was used to display the data.

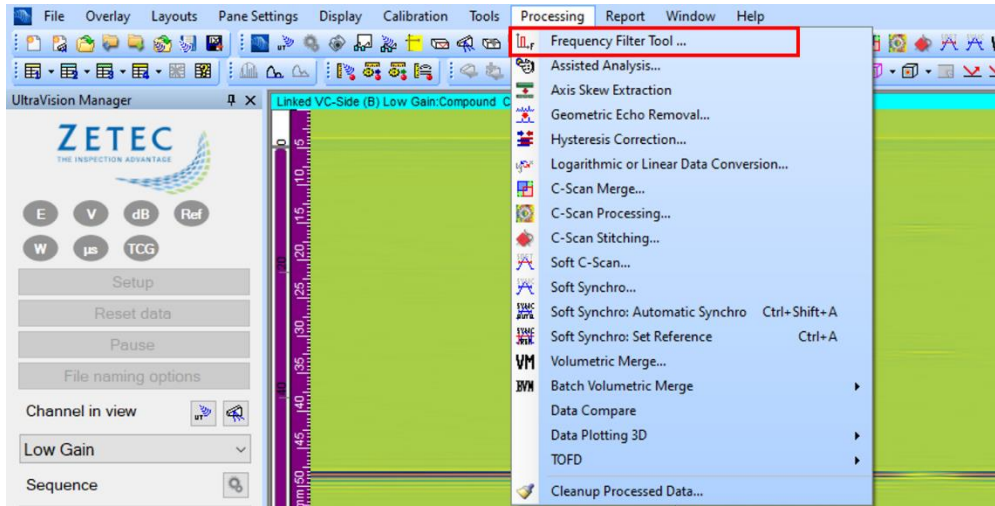


The **Frequency Filter Tool** will now be used to apply several filter settings to the raw data and compare the results. In addition, the original data and the processed data will serve to create merged data groups that are typically used for efficient flaw detection and sizing.

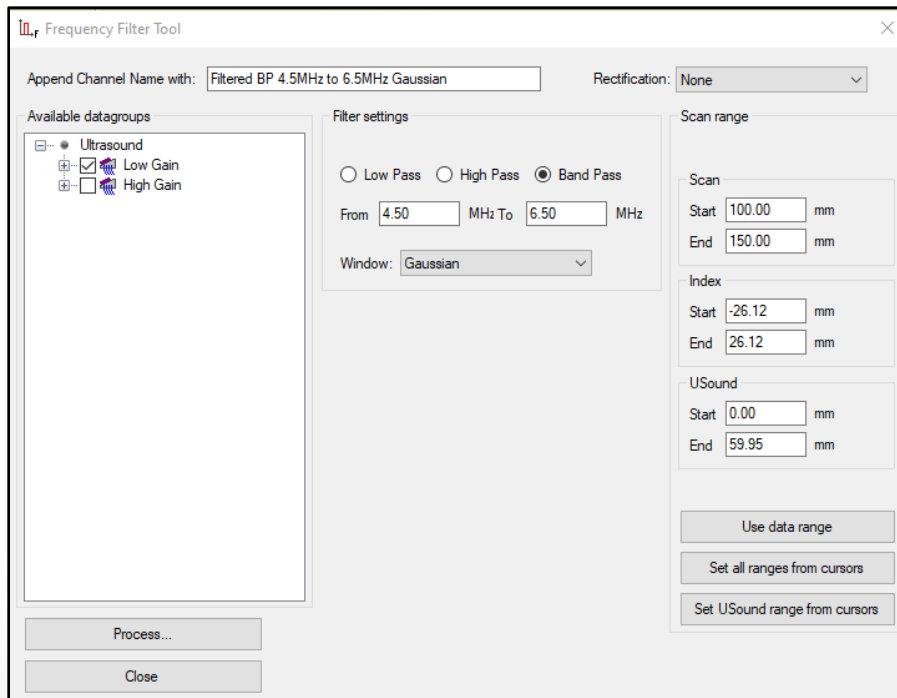
3.1 Using a Band Pass Filter

For the first filtering operation, a Band Pass filter around the center frequency of the spectrum will be used, from 4.5 MHz to 6.5 MHz with a Gaussian window function.

Select **Frequency Filter Tool** in the **Processing** menu, or directly click the icon in the **Processing** toolbar.



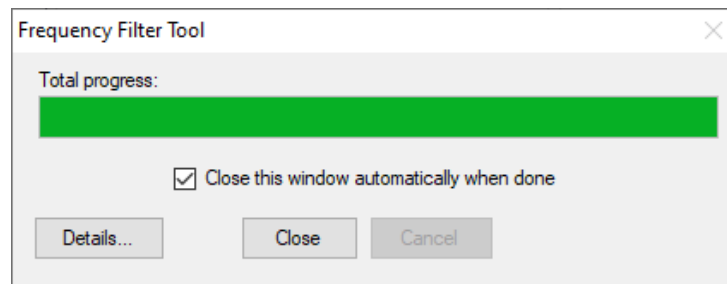
In the **Frequency Filter Tool** window, enter the following settings:



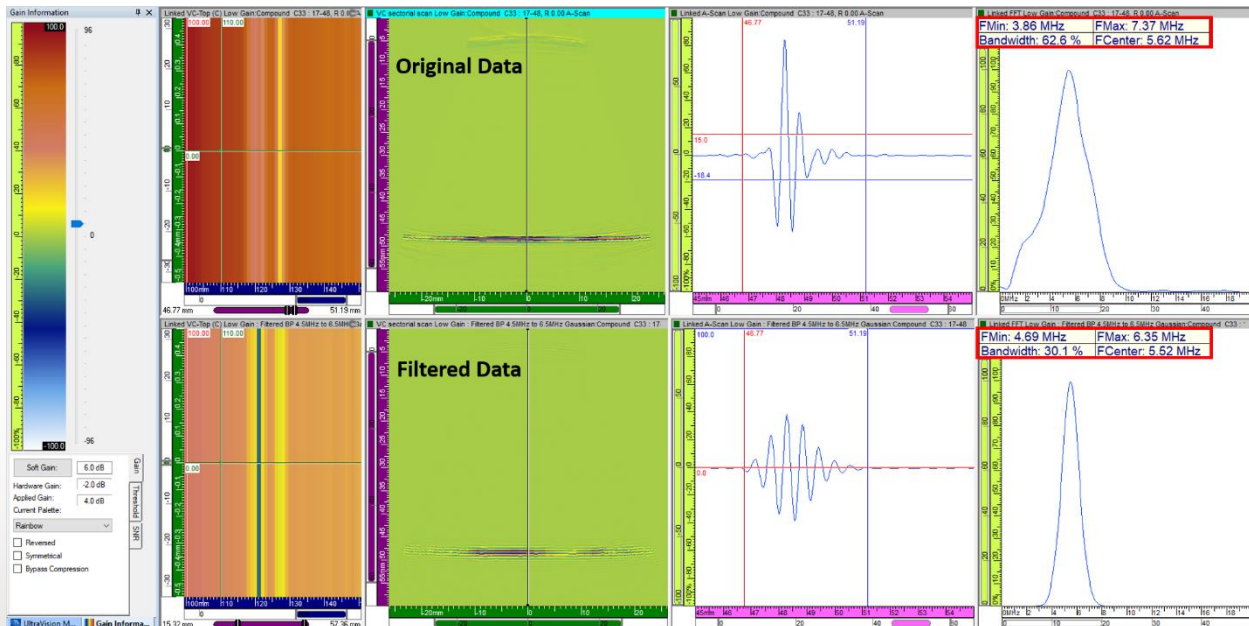
1. Under the **Available datagroups**, the box for the **Low Gain** datagroup is checked; *note that only the RF data groups included in the data file will be available for selection*
2. In the **Filter settings** section, the **Band Pass** option is selected.
3. In the **From** and **To** fields, 4.5 and 6.5 MHz values are entered.
4. From the dropdown list of **Window** parameters, **Gaussian** is selected.
5. The **Rectification** parameter is set to **None** (to again obtain an RF data group)
6. In the **Scan range** section, the default values correspond to the **Use Data Range** setting, meaning that the complete range will be processed.

During the entry of the parameters, the **Append Channel Name with** field will automatically adapt the structured name that will be added as a suffix to the name of the selected channel(s), to create the name of the new processed channel.

Then hit the **Process Summation** button, and the data will be processed.

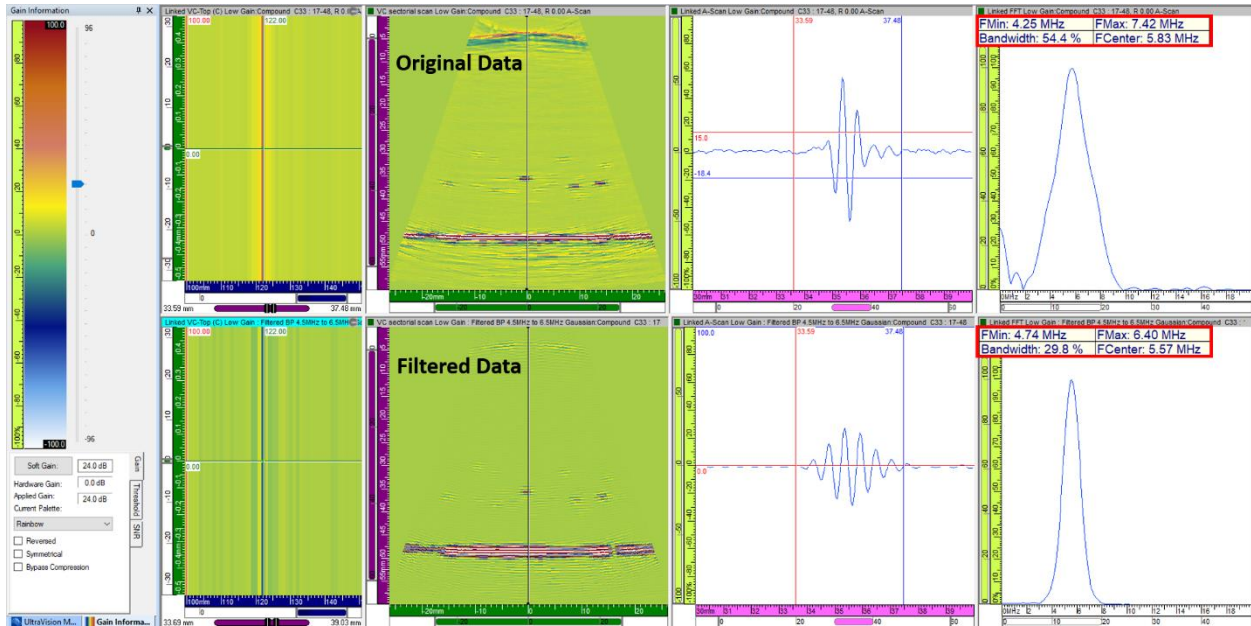


After processing, the reconstructed channel will appear in the **UltraVision Manager**, and can be visualized together with the original channel. The image below shows the frequency responses of the back-wall echo for the original channel (above) and the Band Pass filtered channel (below) for the 0 degree LW law and at the same probe position. The same soft gain setting has been applied for both channels.

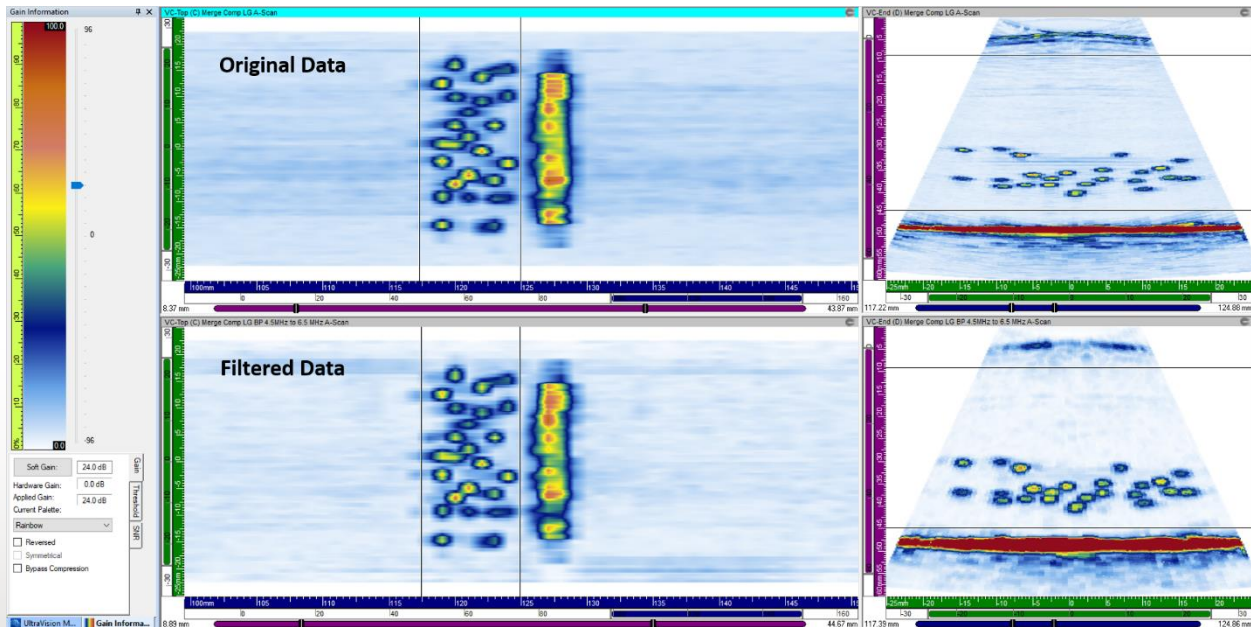


We can observe that the bandwidth of the back-wall signal in the Band Pass filtered channel has indeed been reduced according to the user-defined filter settings, and this also results in a longer (more resonant) echo signal in the A-scan.

The next image (with more soft gain) shows that the influence of the filter on the signal from a conical hole is quite similar as for the back-wall echo.



After performing a Volumetric Merge on the filtered data, the next image shows the comparison of the merged original data (above) and the merged BP filtered data (below) : VC-Top (C) and VC-End (D) views are presented, with 6 dB extra soft gain for the BP filtered data group.

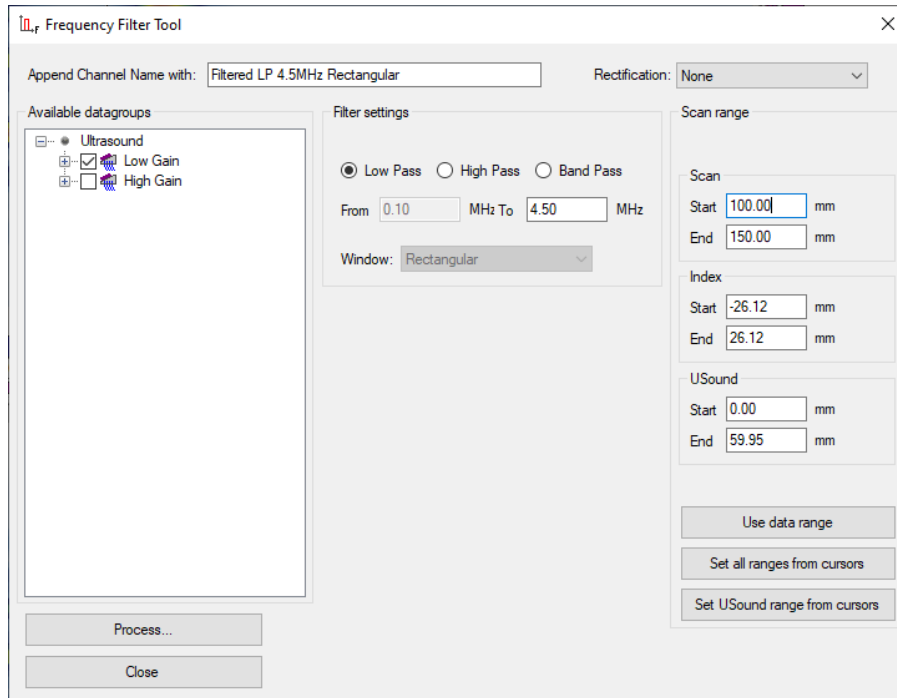


The images are quite similar, but the longer pulses in the A-scans of the filtered channel results into slightly less depth resolution in the merged data.

3.2 Using a Low Pass Filter

For the second example a Low Pass filter cutting off at 4.5 MHz will be applied, with a rectangular window function.

In the **Frequency Filter Tool** window, enter the following settings:



1. Under the **Available datagroups**, the box for the **Low Gain** datagroup is checked; *note that only the RF data groups included in the data file will be available for selection*
2. In the **Filter settings** section, the **Low Pass** option is selected.
3. In the **From** and **To** fields, the lower value of 0.1 MHz is fixed, and the higher value of 4.5 MHz is entered
4. From the dropdown list of **Window** parameters, **Rectangular** is selected.
5. The **Rectification** parameter is set to **None** (to again obtain an RF data group)
6. In the **Scan range** section, the default values correspond to the **Use Data Range** setting

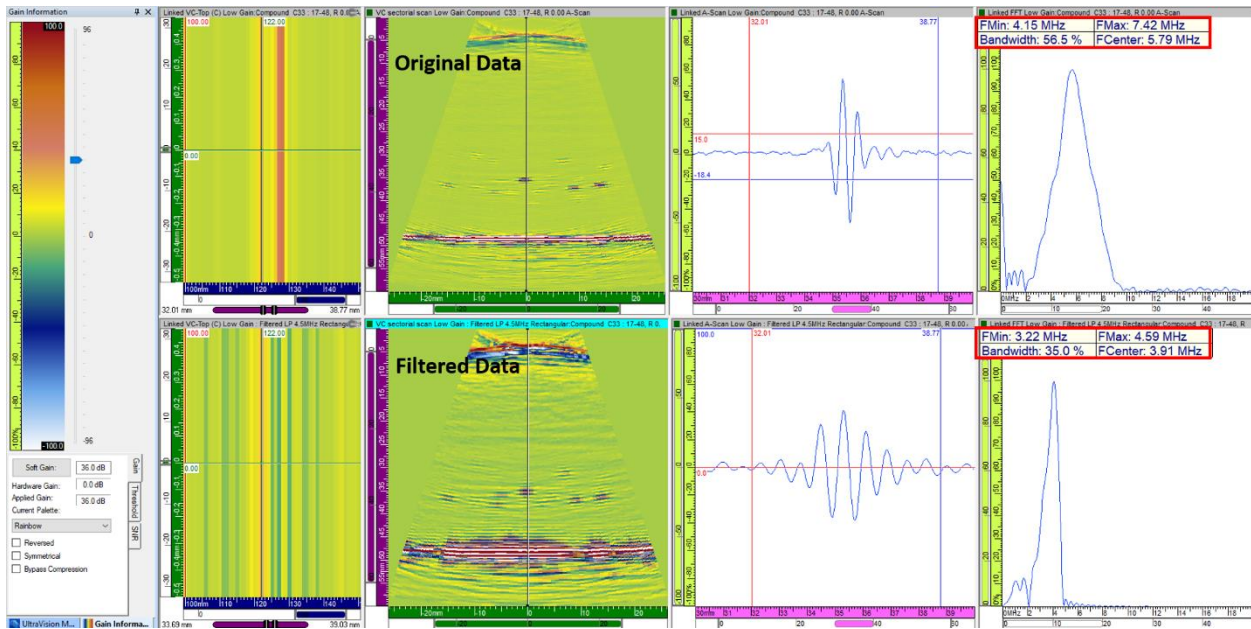
During the entry of the parameters, the **Append Channel Name with** field will automatically adapt the structured name that will be added as a suffix to the name of the selected channel(s), to create the name of the new processed channel.

Then hit the **Process Summation** button, and the data will be processed.

After processing, the reconstructed channel will appear in the **UltraVision Manager**, and can be visualized together with the original channel.

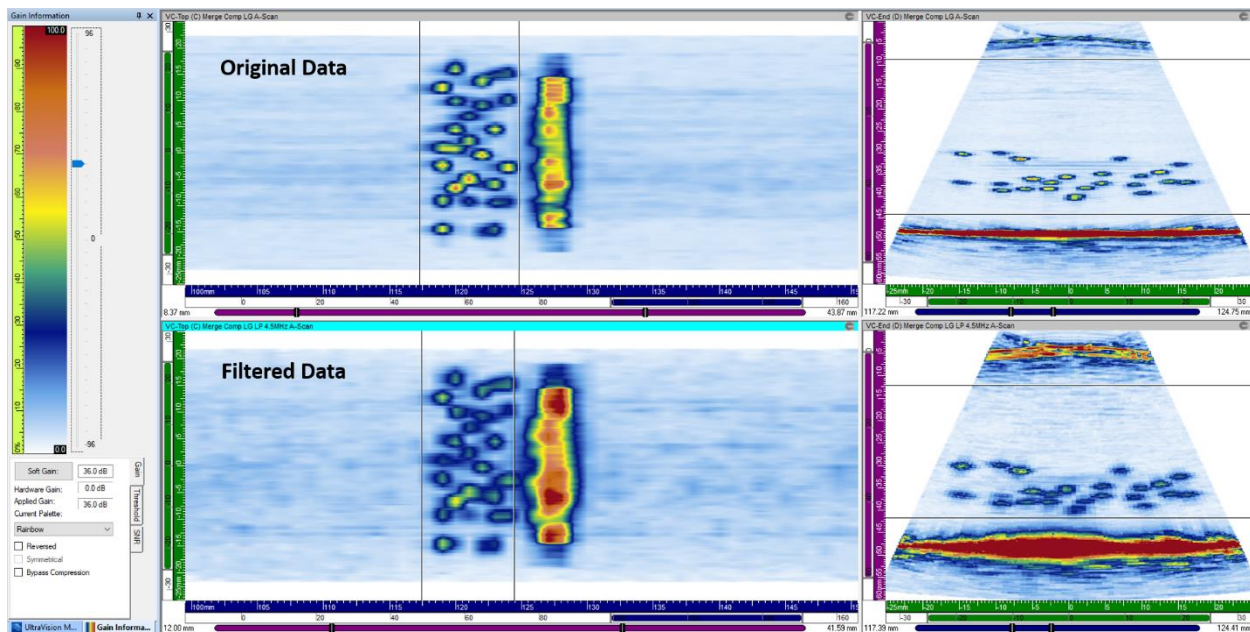
The image below shows the influence of the low pass filter on the signal from a conical hole. The soft gain of the filtered channel has been increased to get a similar amplitude on this reflector.

We can observe that bandwidth of the signal has again been reduced, this time cutting off the high frequency content. Comparing the Sectorial scan views, it is clear that a low pass filtering operation does not improve the detection capability on the small reflectors.



After performing a Volumetric Merge on the filtered data, the next image shows the comparison of the merged original data (above) and the merged LP filtered data (below) : VC-Top (C) and VC-End (D) views are presented, with 12 dB extra soft gain for the LP filtered data group.

It is confirmed that LP filtering doesn't improve the detection capability and SNR for small reflectors. This is obviously why high-frequency probes with a large bandwidth are typically preferred for such inspections.

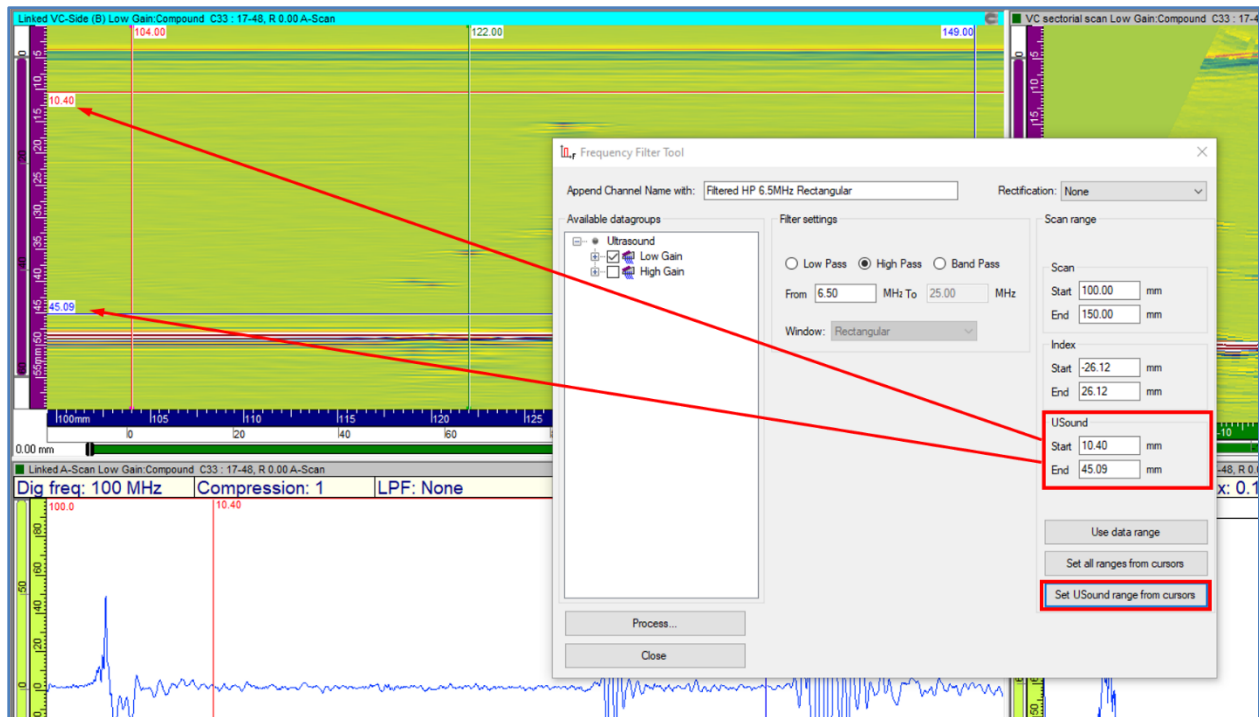


3.3 Using a High Pass Filter

In the last example a High Pass filter starting at 6.5 MHz will be applied, with a rectangular window function. We will also illustrate that a custom data range can be applied, to eliminate unwanted signals (e.g. saturation).

In the **Frequency Filter Tool** window, enter the following settings:

1. Under the **Available datagroups**, the box for the **Low Gain** datagroup is checked; *note that only the RF data groups included in the data file will be available for selection*
2. In the **Filter settings** section, the **High Pass** option is selected.
3. In the **From** and **To** fields, the lower value of 6.5 MHz is entered and the higher value of 25 MHz is fixed
4. From the dropdown list of **Window** parameters, **Rectangular** is selected.
5. The **Rectification** parameter is set to **None** (to again obtain an RF data group)
6. Position the cursors on the VC-Side (B) or Sectorial scan view to exclude the “entry signal” and the back-wall signal
7. Click the **Set USound range from cursors** button to adjust the **Scan Range** in the USound axis

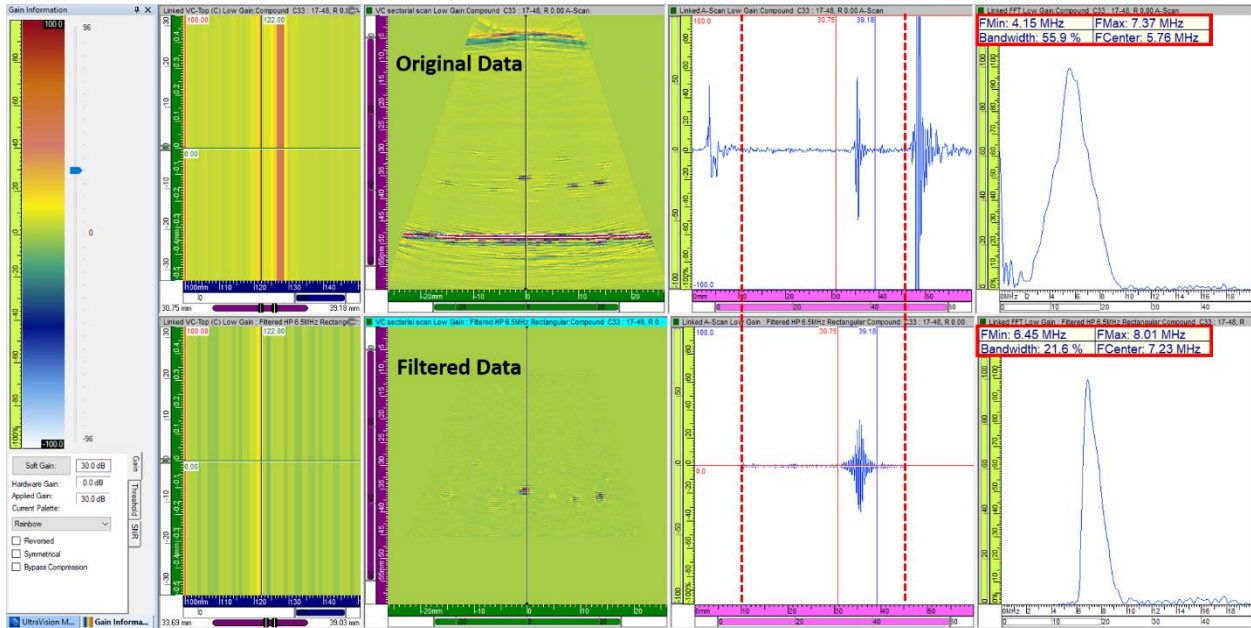


Then hit the **Process Summation** button, and the data will be processed.

After processing, the reconstructed channel will appear in the **UltraVision Manager**, and can be visualized together with the original channel.

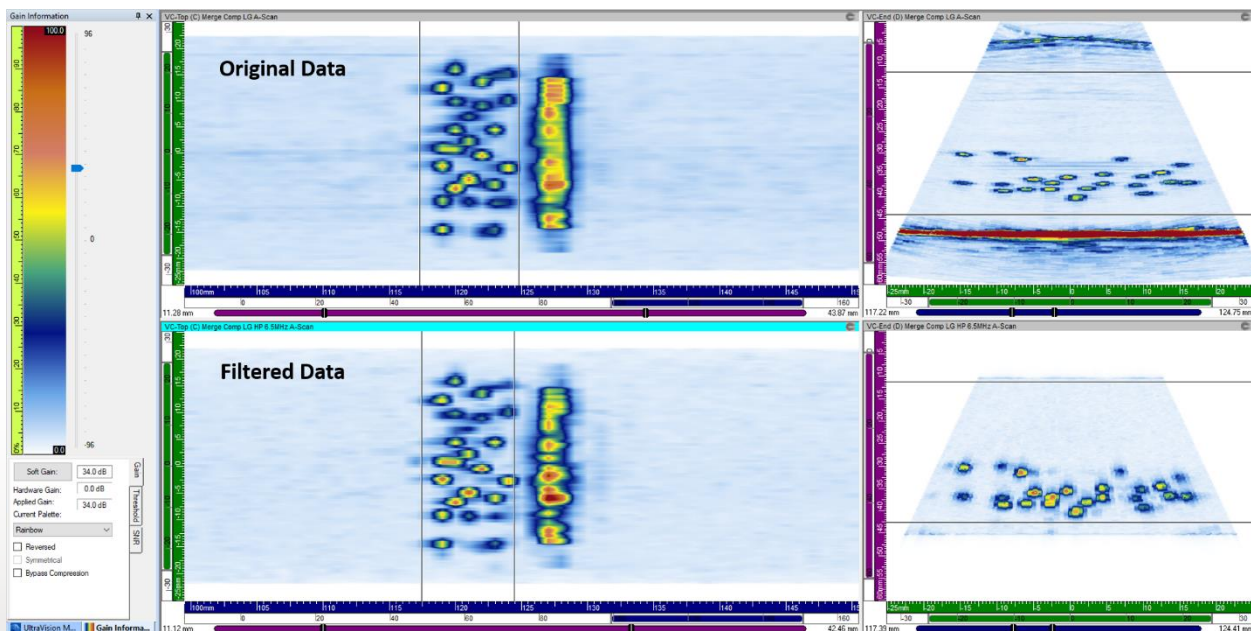
The image below shows the influence of the high pass filter on the signal from a conical hole. The soft gain of the filtered channel has been increased to get a similar amplitude on this reflector.

We can observe that the range along the USound axis has been truncated as requested, and that the remainder of the A-Scan signal is correctly positioned in the time-domain. Also, the bandwidth of the signal has again been reduced, cutting off the low frequency content. Comparing the Sectorial scan views, we can see that the high pass filtering operation has almost no influence on the detection capability for small reflectors.



After performing a Volumetric Merge on the filtered data, the next image shows the comparison of the merged original data (above) and the merged HP filtered data (below) : VC-Top (C) and VC-End (D) views are presented, with 10 dB extra soft gain for the HP filtered data group.

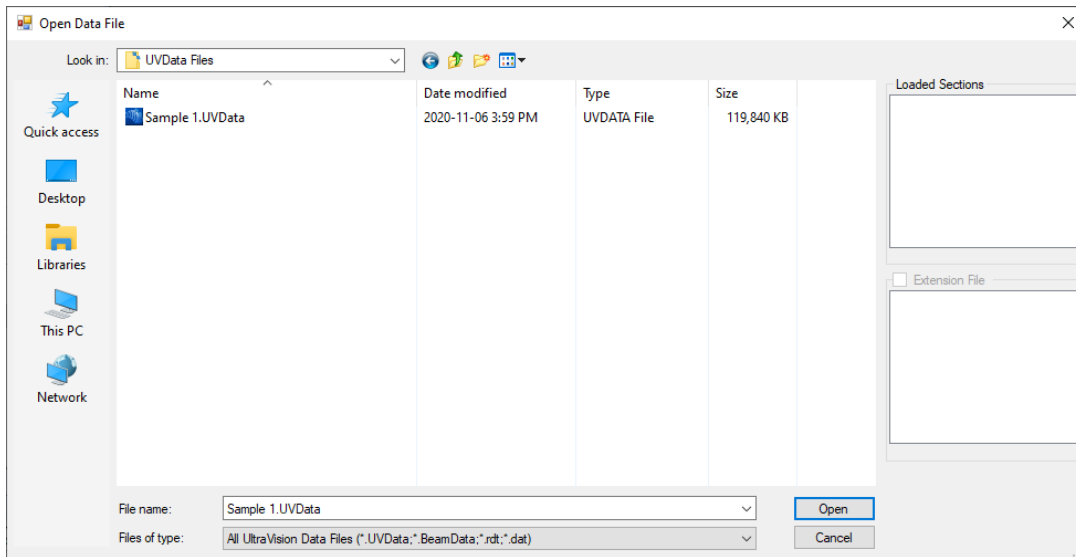
In this case study, HP filtering results in almost similar detection capability and SNR for small reflectors. But as for the BP filter the longer pulses in the A-scans of the filtered channel result into slightly less depth resolution in the merged data.



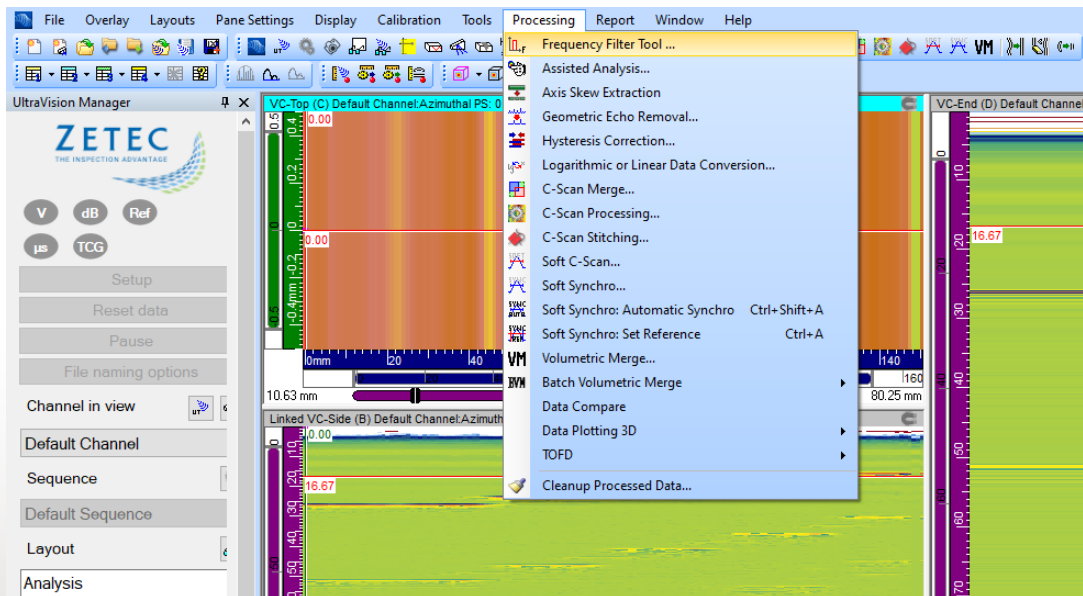
4 Reference Guide

This section provides detailed information on the parameters of the **Frequency Filter Tool** and summarizes the required steps to perform the offline filtering process in UltraVision Classic.

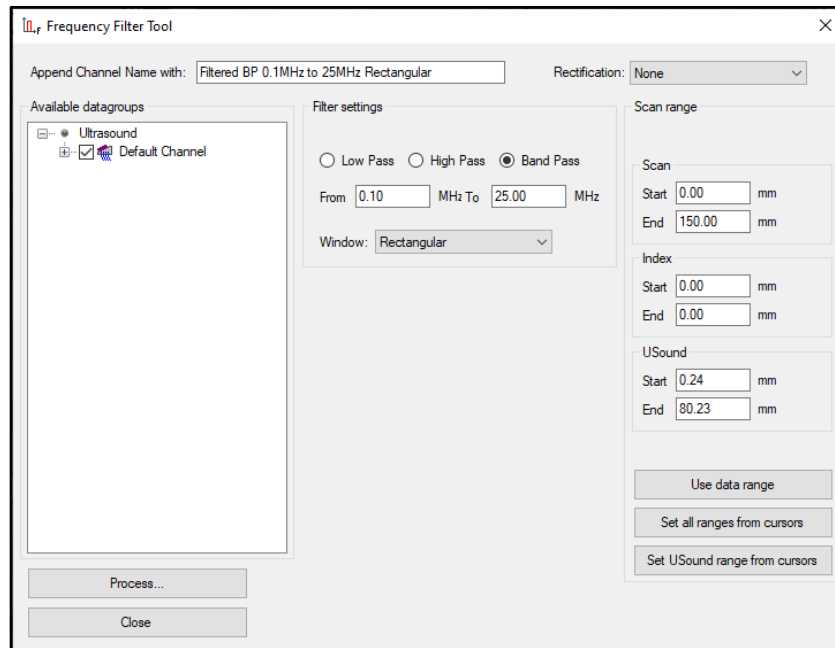
1. Run UltraVision 3.10R20 (or higher) in Analysis mode.
2. Open the data file of interest.



3. From the **Processing** menu, select **Frequency Filter Tool**. (**Processing** > **Frequency Filter Tool**)



4. The **Frequency Filter Tool** window opens. This window contains buttons, editable fields, and dropdown lists allowing the user to configure the parameters of the filtering process:



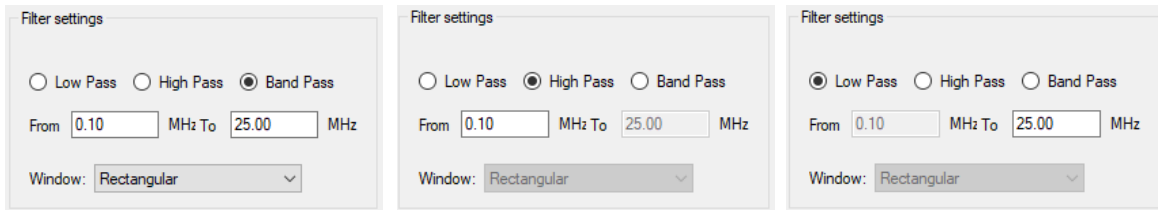
- **Append Channel Name with:** Displays the phrase which is added as a suffix to the name of the channel(s) selected to be filtered in order to create the name of the new filtered channel.
 - **Available datagroups:** Displays the list of available data for the filtering process. This list allows the user to select datagroup(s) to be processed.
 - **Filter settings:** Allows the user to define the filter type, frequency range and the window function.
 - **Scan Range:** Allows the user to define the volume of data that will be filtered.
 - **Rectification:** Allows the user to select whether or not the tool applies rectification to the resulting filtered data.
5. Using the list of **Available datagroups**, select the datagroup(s) of interest by checking the appropriate box.



Only datagroups acquired in the RF mode appear in the list of “Available datagroups”. FMC datagroups, including the FMC data acquired by TOPAZ64 and DYNARAY, do not appear in the list.

6. In the **Filter settings** box, select the filter type of interest (Low Pass, High Pass, Band Pass) by clicking on the appropriate radio button.

7. Enter the cut-off frequency value(s) in the **From** and **To** fields:
 - When **Band Pass** is selected, the user should enter the lower and upper cut-off frequencies in the **From** and **To** fields, respectively.
 - When **Low Pass** is selected, since the user should enter only the upper cut-off frequency, the **From** field is grayed out. The filtering process uses 0.1 MHz as the lower cut-off frequency.
 - When **High Pass** is selected, since the user should enter only the lower cut-off frequency, the **To** field is grayed out. The filtering process uses 25 MHz as the upper cut-off frequency (i.e. higher than bandwidth of existing Zetec units).

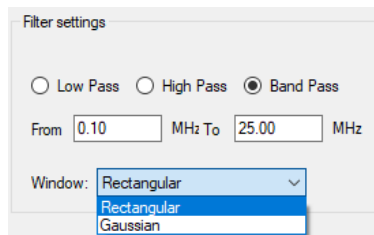


Values below 0.1 MHz and above 25 MHz are not allowed; this frequency range exceeds the bandwidth of existing Zetec units.



For **UVData** channels recorded with a digitizing frequency of 25 MHz, the upper cut-off frequency cannot exceed 12.5 MHz.

8. If the **Band Pass** filter type is selected, the Window list allows the user to select the window function type (Rectangular or Gaussian)



For the **Low Pass** and **High Pass** filter types, only the rectangular window function is available.

9. In the **Scan range** box, enter the boundaries of the data volume to be processed by the **Frequency Filter Tool** using one of the following options:

- Manually entering the values in the Start and End fields for Scan, Index, and USound axes.
- Pressing the “**Use data range**” button sets the **Scan range** parameters to include the total extent of the selected datagroup(s).
- Pressing the “**Set all ranges from cursors**” button sets the **Scan range** parameters according to the current cursors position within the display layout.
- Pressing the “**Set USound range from cursors**” button only sets the data range in the USound axis according to the current cursors position within the display layout. The data ranges in the Scan and Index axes do not change when using this button.

Scan range

Scan

Start mm

End mm

Index

Start mm

End mm

USound

Start mm

End mm



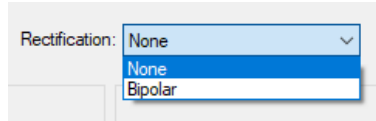
The portion of data volume which is out of the selected data range will not be included in the filtered channel.



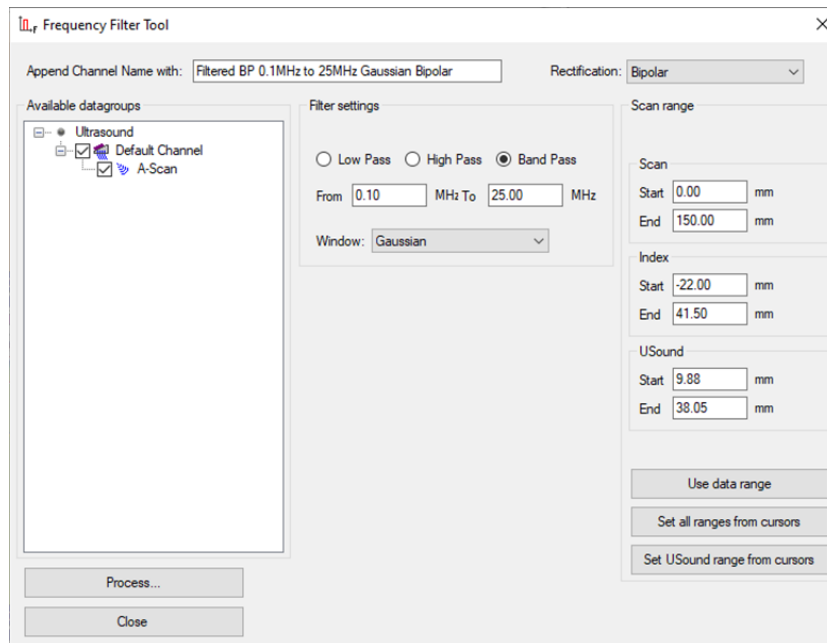
The displayed data range for all three axes is adapted to the axis' unit type of the active view upon opening the **Frequency Filter Tool**.

10. Using the **Rectification** dropdown list, specify whether or not signal rectification is applied to the filtered data:

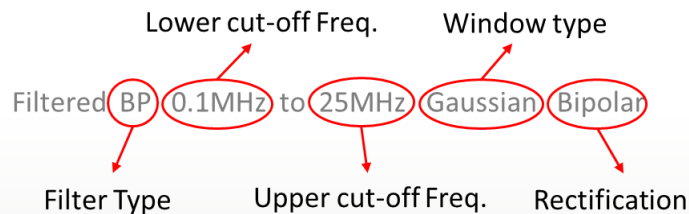
- **None:** No rectification is applied to the processed data. The new filtered data will be in the RF mode.
- **Bipolar:** After applying the selected filter, the signal rectification is applied. Upon selecting this option, the negative amplitude components of the processed data are brought back in the positive part.



11. Verify the **Append Channel Name with** field displaying the suffix which will be added to the name of the selected channel(s) to create the name new channel(s). This field is automatically updated to reflect the selected filter settings, but the user can also manually make any modification in the suffix when all the filter and data range parameters are set.

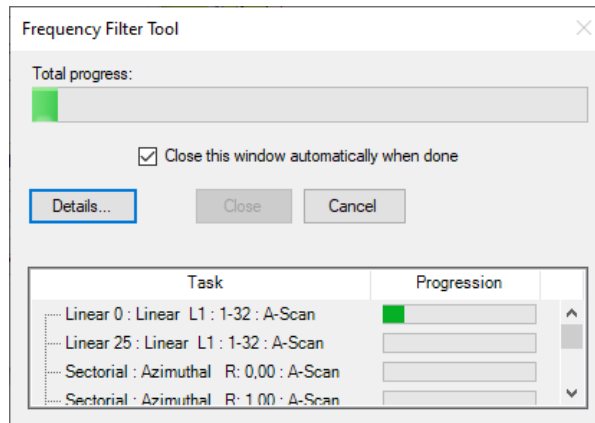


Nomenclature of the automatically appended suffix:

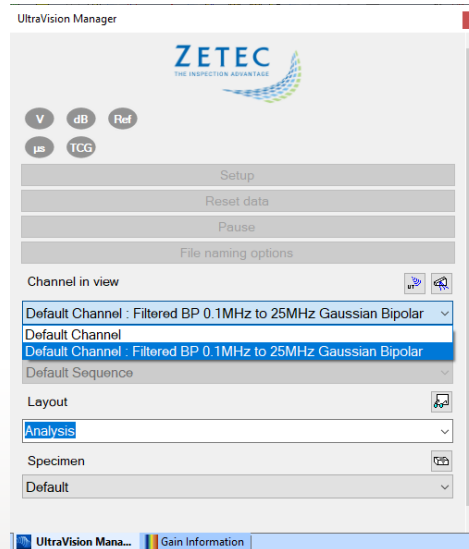


For example in the case illustrated in **Error! Reference source not found.**, the name of the filtered channel will be “Default Channel : Filtered BP 0.1MHz to 25MHz Gaussian Bipolar”.

12. If it is required to close the **Frequency Filter Tool** window without running the filtering process, press the **Close** button.
13. Press the **Process...** button to confirm the selected parameters and to start the filtering process. Upon pressing the **Process** button, a new window pops up displaying the progress of the filtering process.
14. Press the **Details...** button to see the progress of individual tasks of the frequency filtering process. If it is required to cancel the frequency filtering process, press the **Cancel** button.



15. Close the progress window, once the frequency filtering process is completed.
16. The processed datagroups are created and added to the list of channels which can be seen in the dropdown list of **Channel in view** in the **UltraVision Manager** menu.



17. The processed datagroups can be stored in a **UVExtension** file accompanying the **UVData** file.

5 Algorithms Used in the Frequency Filter Tool

The Frequency Filter Tool uses FFT (Fast Fourier Transform) and inverse FFT algorithms to convert RF A-Scan signals from their original time domain to the frequency domain, and back to the time domain after filtering.



FFT and inverse FFT algorithms may introduce “artifacts” when used on saturated A-Scan signals (amplitude > 100 %FSH), and therefore this may not produce correct filtered A-Scans; it is therefore recommended to use adequate hard gain settings to avoid saturation

6 Limitations

- **Frequency Filter Tool** can only be used in offline mode.
- The processed datagroups can be saved in the .UVExtension file.
- **Frequency Filter Tool** is applicable to datagroups in UVData files, containing conventional UT data and phased array UT data in RF mode.
- **Frequency Filter Tool** is **not** applicable to live TFM and FMC datagroups.
- **Frequency Filter Tool** does not support legacy *.RDT and *.DAT files.

Quality

Zetec Quality Program complies with ISO 9001:2015 and ISO/IEC 17025:2017

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