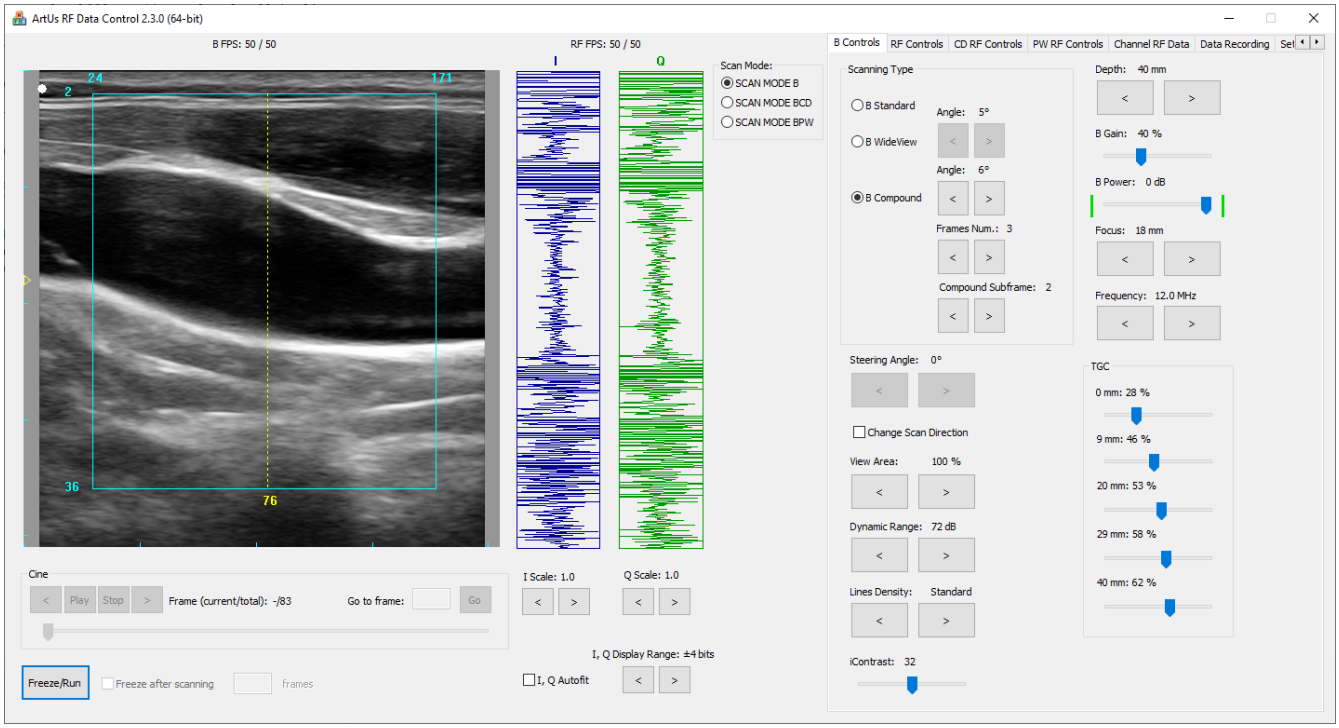
TELEMED
ULTRASOUND MEDICAL SYSTEMS

USER MANUAL

ArtUs RF Data Control II

Real-time acquisition of channel and beamformed RF data with TELEMED ArtUs ultrasound scanners



DOCUMENT VERSION	**1.0.6**
DATE	06/11/2026
SOFTWARE	ArtUs RF Data Control II, version 2.1.4 and later

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Contents

Introduction **3**

1. Structure of ArtUs RF Data Control II User Interface **4**

1.1. B Controls Tab and the other main components of GUI 4

1.2. RF Controls Tab 6

1.3. CD RF Controls Tab 7

1.4. PW RF Controls Tab 8

1.5. Channel RF Data Tab 10

1.6. Data Recording Tab 13

1.7. Settings Tab 14

1.8. About Tab 15

2. Recording of RF data files **16**

2.1. Structure of the beamformed RF data file 16

2.2. Structure of the channel data file 17

2.3. Coordinate system for B-mode image reconstruction 19

3. Installation notes and PC requirements **21**

4. Revision History **22**

5. References **23**

Appendix I. Transmit delays file structure **24**

Appendix II. Arbitrary beams file structure **29**

Appendix III. Scenarios for plane wave scanning and passive reception **30**

Introduction

This document describes the ArtUs RF Data Control II program, starting from version 2.1.4. The program is designed for real-time acquisition of raw ultrasound data (channel RF data and beamformed RF data) with TELEMED ArtUs scanners in a special configuration. It continues its predecessor: the interface controls are reorganized into tabs, and new functions are added to receive raw channel data in real time and to control the related acquisition parameters (selection of active channels, programming of transmit delays and excitation pulses, etc.).

By using the scanner and software equipped with channel data acquisition capabilities you get the following:

You can

✓ Program custom transmit delay values for individual channels and apertures – fully custom transmit focusing in terms of delays.

✓ Choose the active channels from the 64 available (a trade-off between frame rate and image quality).

✓ Program custom transmit pulses for all channels (three-level pulser: +HV, 0, −HV).

✓ Select arbitrary beams to scan (a custom sequence of working apertures) from the available range of beams.

✓ Adjust analog front-end parameters (high-pass filter cut-off, input resistance and gain).

✓ Adjust custom analog depth-dependent amplification of received echoes.

You cannot

✗ Set different excitation pulse amplitudes and shapes (Tx), analog front-end parameters, or analog amplification values and depths for individual channels.

✗ Use imaging modes other than B (brightness) mode: a scanner with channel data support operates only in B-mode; Doppler and other modes are not supported.

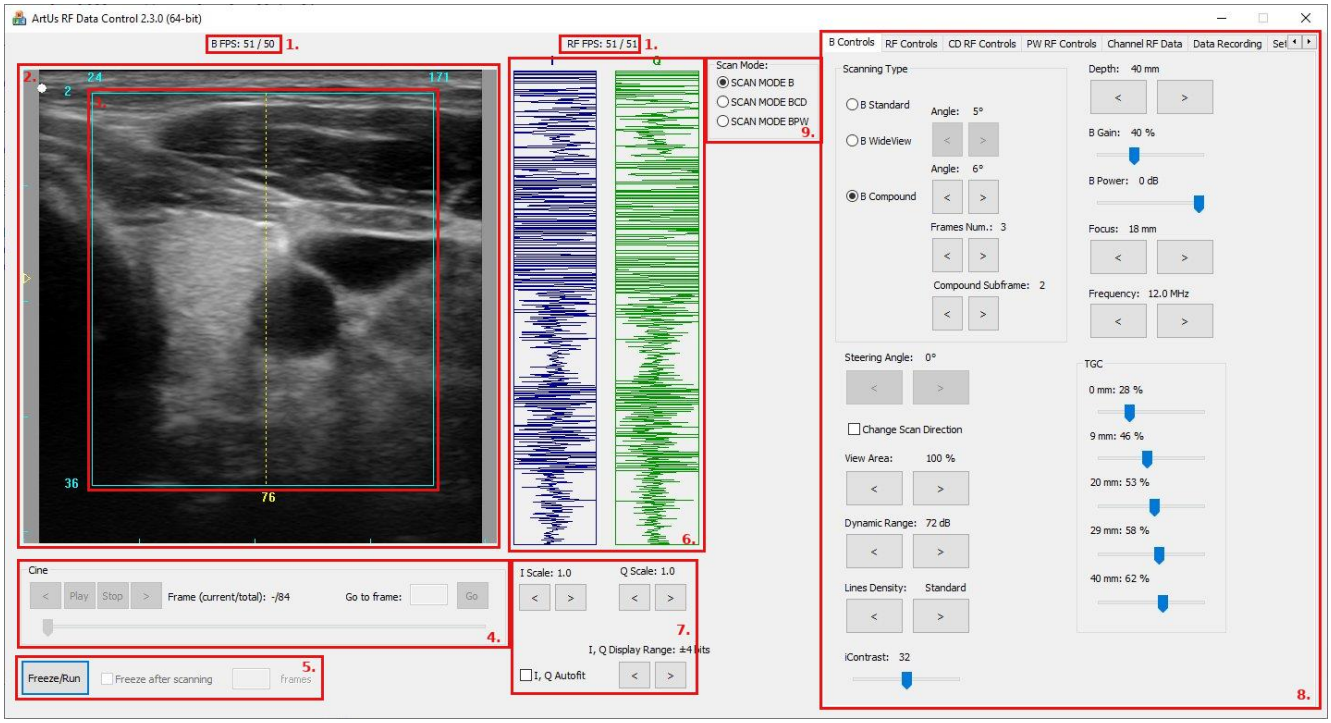
1. Structure of ArtUs RF Data Control II User Interface

The ArtUs RF Data Control II program contains eight tabs with different categories of ultrasound controls:

- B controls
- RF controls
- CD RF controls
- PW RF controls
- Channel RF Data
- Data Recording
- Settings
- About

1.1. B Controls Tab and the other main components of GUI

The subsection presents the B Controls Tab and other main components of GUI. Most B-mode imaging parameters available in the Echo Wave II application (all except the post-processing algorithms applied to the B-mode image) are also available in the ArtUs RF Data Control II program.



Num	Component	Description
1	**FPS indicators**	There are FPS indicators for B-mode and RF mode **B FPS: X / Y** and **RF FPS: X / Y** where: • X – screen rendering speed, depends on PC performance • Y – true scanning speed
2	**The main B-mode imaging window**	Displays full grayscale B-mode images and the superimposed boundary lines of adjustable RF window. The B-mode image serves for the navigation during raw data collection.

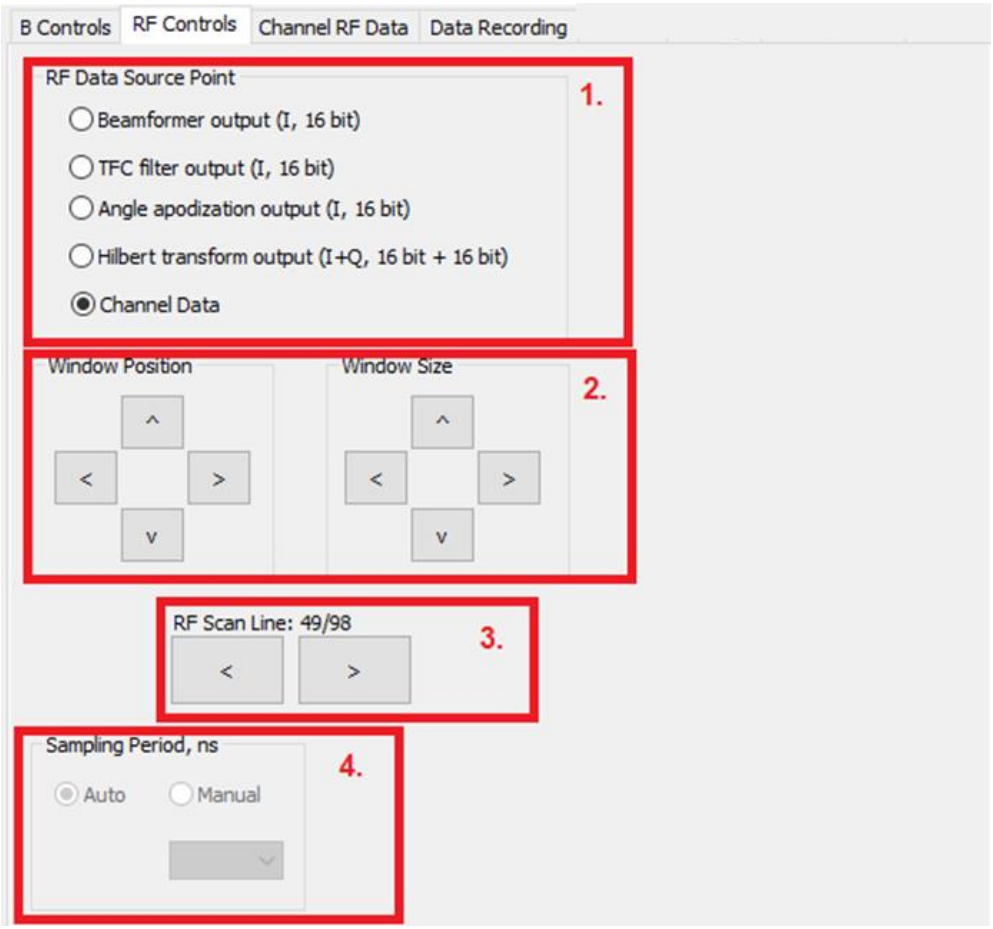
3	**RF window**	The contour (solid light blue lines) outlines the external boundaries of the RF window. The scanning line numbers and imaging depth for the RF window are displayed close to the border. RF window defines the amount of RF data to be transferred and the relative position of the RF output window in the B-mode image frame.
4	**Cine Loop controls**	Cine loop options. Allows you to **play** recorded sequence and to watch it frame by frame. It is possible to jump to the desired frame by entering **Go to frame:** value and pressing **Go**. Frame indicator shows a number of frames stored in the cine loop memory buffer and the number of actual frame. Cine loop controls are active only when ultrasound scanning is frozen.
5	**Main scanning controls**	Control starts (**Run**) and stops (**Freeze**) ultrasound scanning. It is possible to freeze the scanning after N frames by marking the checkbox **Freeze after scanning** and entering the number of frames.
6	**Raw data plot**	Displays the raw data of the single selected beam (the dashed yellow line superimposed on the B-mode image marks the scanline position). For channel data mode Raw data plot shows the first channel of the selected beam. The displayed RF signals are scaled by both axes to obtain well-visible waveforms.
7	**Raw data plot scale controls**	Controls (**I Scale, Q Scale**) adjust the scale of the displayed raw channel or beamformed RF signal. It is possible to set auto scale by checking **I, Q Autofit** or to select **I, Q Display Range** by setting limit values in bits.

8	**B Controls Tab**	The tab contains the majority of B-mode imaging controls available in ultrasound imaging systems, such as:
		• Scanning type:
		  ○ **B Standard**,
		  ○ **B Wide View** (possibility to adjust the **angle** by control),
		  ○ **B Compound** (possibilities to adjust maximal compound **Angle**, number of compounded **Subframes**, subframe number which are displayed superimposed on B-mode image, **Compound Subframe**),
		• **Steering angle** control (possibility to steer scanned beams by a certain angle, active for linear transducers),
		• **Change scan direction** control – the checkbox changes the scan direction (white filled circle marker on top indicates from which edge scanning starts),
		• **View Area %** - possibility to reduce imaging area,
		• **Dynamic Range, dB** – possibility to adjust the range from 36 – 102 dB,
		• **Line Density** control. Possible values:
		  ○ Standard,
		  ○ Standard S (the same number of scanlines as for standard, just scanning speed is higher due to the use of parallel beamforming technique),
		  ○ Medium – half the number of scan lines of Standard,
		  ○ Low – one third of the number of scan lines of Standard,
		  ○ High – twice the number of scan lines of Standard.
		• **Depth, mm** – imaging depth,
		• **B Gain, %** – amplification of received signal
		• **B Power, dB** (from -20 to 0 dB) – the power of excitation pulses (affects all levels of received data),
		• **Focus, mm** – transmission focal depth,
		• **Frequency, MHz** – scanning frequency of ultrasound waves,
		• **TGC** – time-gain compensation for amplification of signals received from different depths. (depth, mm, and amplification, % values are displayed near each TGC slider).

9	**Scan mode selector**	Control allows to select which RF data stream will be scanned and transferred: B mode RF, Color Doppler mode RF or PW mode RF. **Please Note:** Color Doppler and PW RF streams are available for ArtUs EXT-1H/2H starting from TDP 2.3.1b68 and USGFW2 SDK 4.4.1b55.

1.2. RF Controls Tab

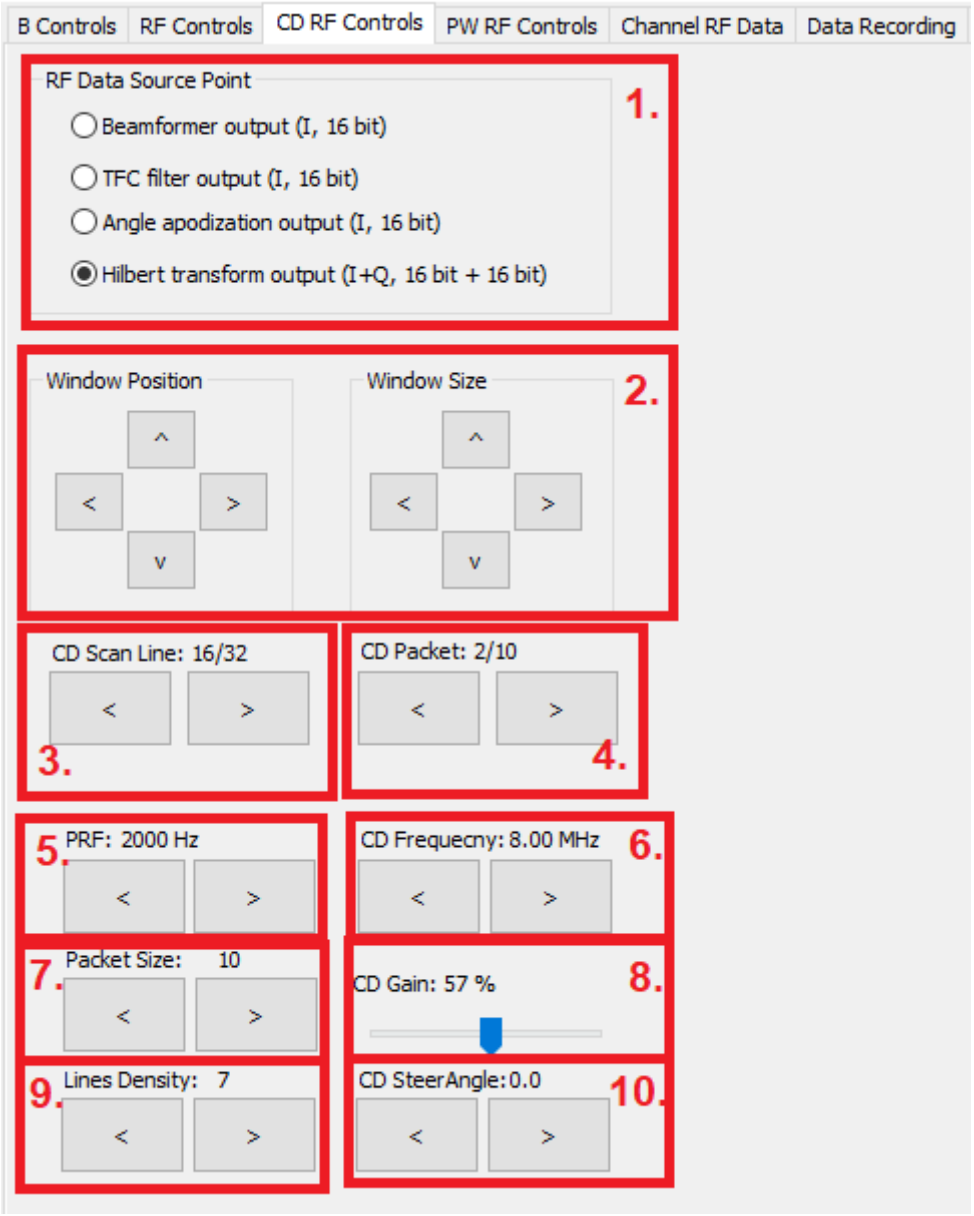
The RF Controls Tab allows you to: 1) select from which point of the beamformer raw data will be received, 2) adjust the Size and Position of the RF window which defines the amount of RF data to be transferred and the relative position of the RF output window in the B-mode image frame.



Num	Component	Description
1	**RF Data Source Point**	RF data is received as an array of 16-bit integers. This option selects the point of the beamformer from which raw data will be received. For the ArtUs ultrasound scanner, the following raw data types are available: • Beamformer output (*I*, 16-bit), • TFC (time-frequency control) filter output (*I*, 16-bit), • Angle apodization output (*I*, 16-bit), • Hilbert transform output (*I*+*Q*, 16-bit + 16-bit). • Channel data (16-bit). **Note!** Channel data functions are optional and available only for ArtUs USS-2H scanners.
2	**RF Window Controls**	The position and size of the RF window can be adjusted with these controls. There is a trade-off between RF window size and scanning speed (fps).
3	**RF Scan Line**	These controls allow the user to select the RF scanning line which will be displayed on the screen. For channel data mode the single channel for each beam will be displayed.
4	**Sampling period selection**	The controls allow you to select the sampling period manually (25, 50, 100, 200 ns) or automatically (25 ns for shallow depths and 50 ns for depths greater than 16 cm (8192 points)). Currently, the maximum number of depth points with the best digitization (25 ns) for channel data is 8192. **Note! Sampling period control is active and available only for devices with channel data support.**

1.3. CD RF Controls Tab

The CD RF Controls Tab allows you to: 1) select from which point of the beamformer raw data will be received, 2) adjust the Size and Position of the CD window which defines the amount of CD data to be transferred and the relative position of the CD output window in the B-mode image frame, 3) control other parameters affecting Doppler signal (frequency, Gain etc.).

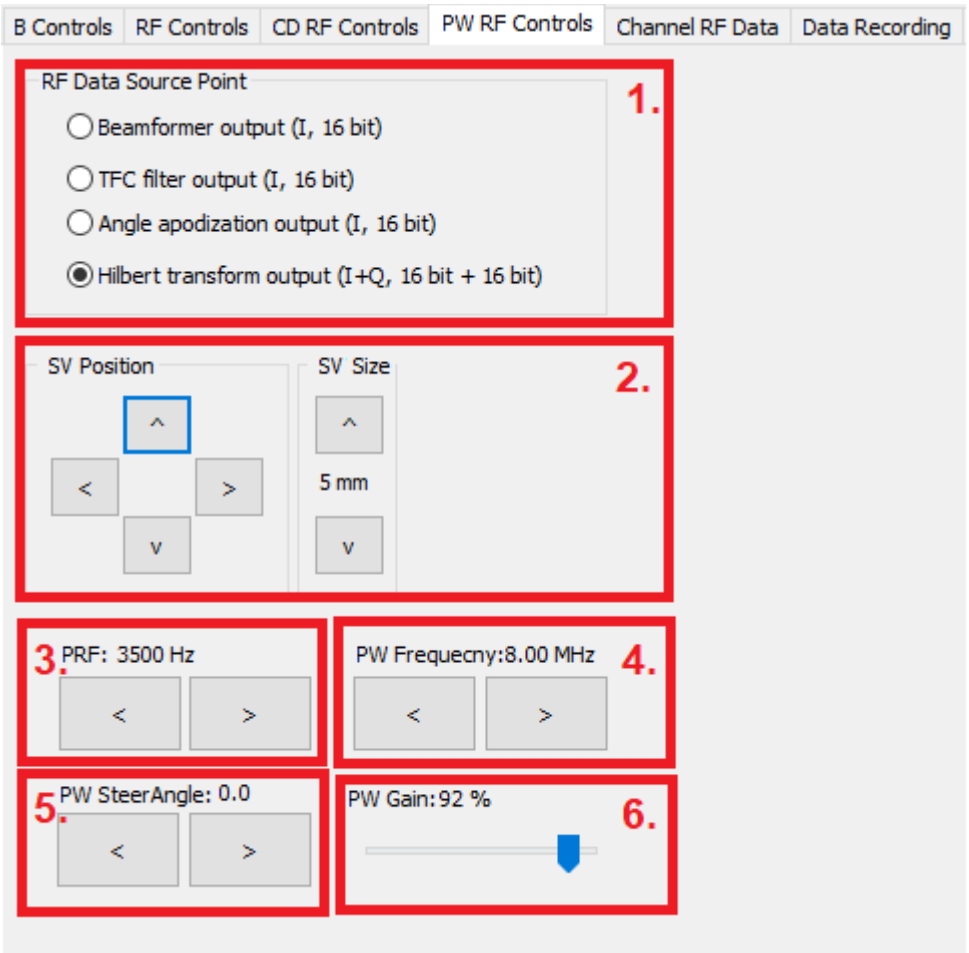


Num	Component	Description
1	**CD RF Data Source Point**	RF data is received as an array of 16-bit integers. This option selects the point of the beamformer from which raw data will be received. For the ArtUs ultrasound scanner, the following raw data types are available: • Beamformer output (*I*, 16-bit), • TFC (time-frequency control) filter output (*I*, 16-bit), • Angle apodization output (*I*, 16-bit), • Hilbert transform output (*I*+*Q*, 16-bit + 16-bit). Please note the control is common for both CD RF and PW RF.

2	**Color Doppler Window Controls**	The position and size of the Color Doppler data window can be adjusted with these controls.
3	**CD Scan Line**	These controls allow the user to select the Color Doppler scanning line which will be displayed on the screen.
4	**CD Packet**	These controls allow the user to select the Color Doppler scanning line from the specified packet which will be displayed on the screen.
5	**PRF control**	Pulse repetition frequency control for Doppler stream.
6	**CD Frequency control**	Excitation Frequency control for Color Doppler stream
7	**Packet Size control**	Packet size control determines a count of repetitions of scanned beam in the same direction.
8	**CD Gain control**	Amplification of Color Doppler signal in %.
9	**Lines Density control**	Control determines how many lines will be in a Color window, trade-off between imaging quality and FPS.
10	**CD Steering Angle Control**	Controls steering angle of Doppler beams, value in degrees.

1.4. PW RF Controls Tab

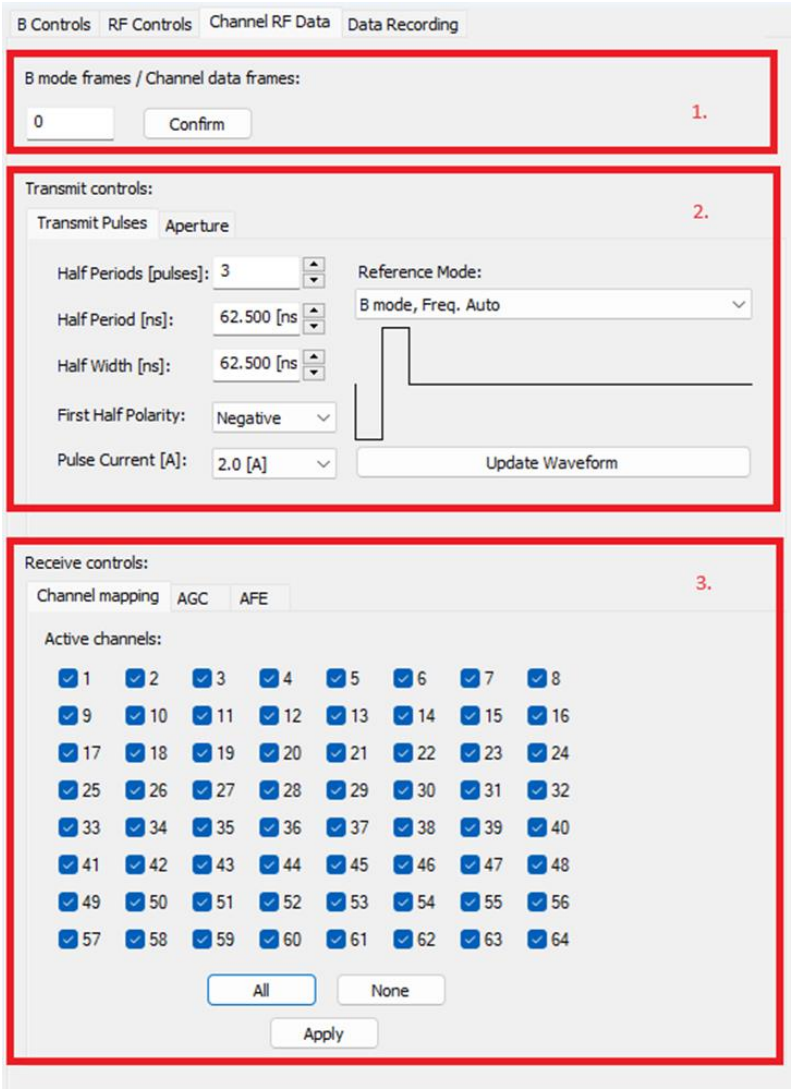
The PW RF Controls Tab allows you to: 1) select from which point of the beamformer raw data will be received, 2) adjust the Size and Position of the PW Sample Volume which defines the amount of PW data to be transferred and the relative position of the Sample Volume in the B-mode image frame, 3) control other parameters affecting Doppler signal (frequency, Gain etc.).



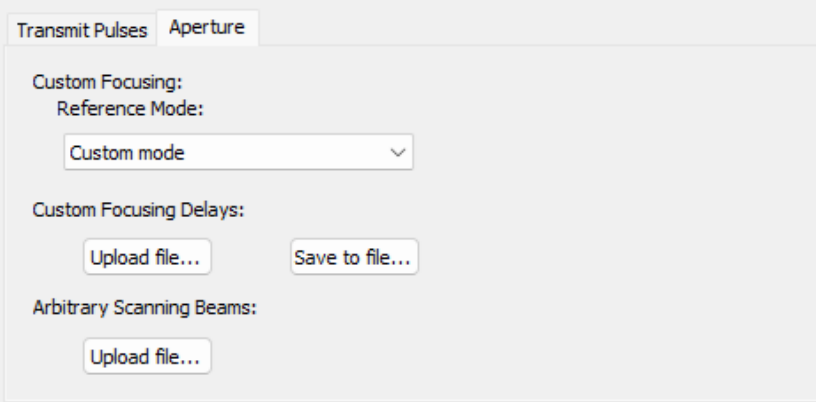
Num	Component	Description
1	**PW RF Data Source Point**	RF data is received as an array of 16-bit integers. This option selects the point of the beamformer from which raw data will be received. For the ArtUs ultrasound scanner, the following raw data types are available: • Beamformer output (*I*, 16-bit), • TFC (time-frequency control) filter output (*I*, 16-bit), • Angle apodization output (*I*, 16-bit), • Hilbert transform output (*I*+*Q*, 16-bit + 16-bit). Please note the control is common for both CD RF and PW RF.
2	**SV Position and Size Controls**	The position and size of the PW sample volume can be adjusted with these controls.
3	**PRF control**	Pulse repetition frequency control for PW Doppler stream.
4	**PW Frequency control**	Excitation Frequency control for PW Doppler stream
5	**PW Steering Angle Control**	Controls steering angle of PW beam, value in degrees.
6	**PW Gain control**	Amplification of PW Doppler signal in %.

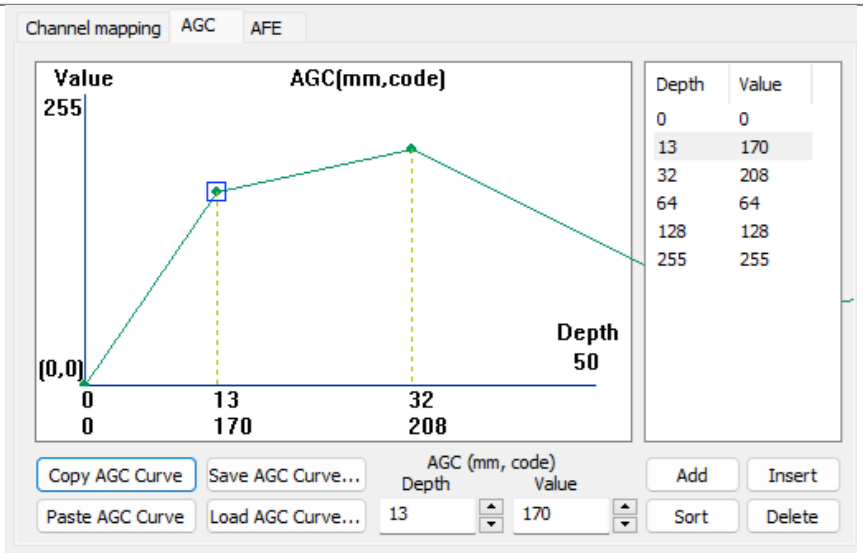
1.5. Channel RF Data Tab

Channel RF Data Tab contains controls that affect raw channel data. The controls are divided into 1) Transmit controls and 2) Receive controls. NOTE: custom modes in Transmit controls can change the acoustic output values, so in these modes the device must not be used on humans or animals! The screenshot of Channel RF Data controls is shown below:



Num	Component	Description
1	**B-mode frames/Channel Data frames**	The control sets the proportion of channel data frames and B-mode images. Currently, the scanning is performed in so-called “duplex” mode combining a selected proportion of B-mode images and channel data frames. The parameter is in the range 0 – 1023, where 0 means a 1:1 proportion, 1 means 2:1 (two channel data frames followed by a single B frame), and so on.
2	**Transmit controls**	There are two Tabs under the Transmit Controls section: **1) Transmit Pulses** – control of excitation waveform • **Half Periods** [pulses] – number of half periods of pulse repetitions in an excitation sequence, • **Half Period** [ns] – the duration of a single excitation half period, • **Half Width** [ns] – indicates high-level voltage duration of the excitation pulse,

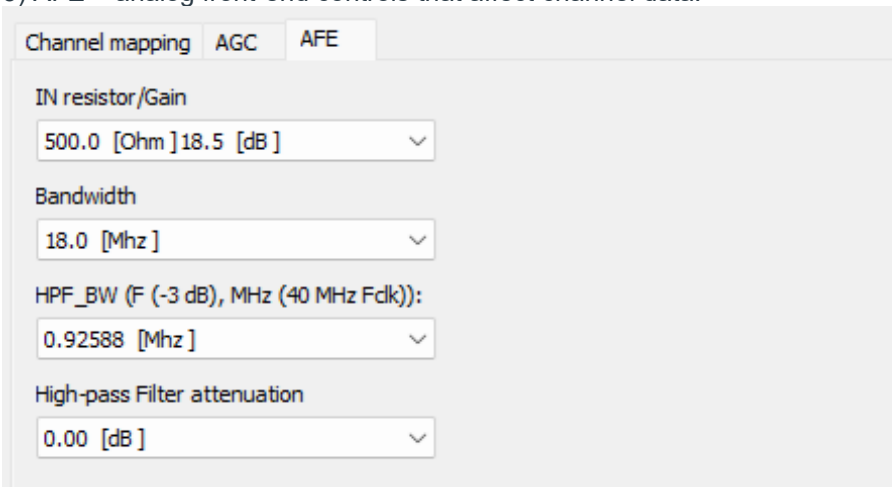
		• **First Half Polarity** – the polarity of the first half period might be **Positive** or **Negative**. • **Pulse Current [A]** – the pulser current. For setting Custom pulses the **Reference mode** control must be set to **Custom**, otherwise, the parameters are the same as in one of the reference modes from the list (e.g. B-mode). Transmit pulse control affects only channel RF data, but not B-mode data. 2) **Aperture**:  **Custom focusing delays** – possibility to use custom transmit focusing by uploading *.txt file of transmit delays for individual channels. The structure of the *.txt delay files for different scanning cases and the available options are described in **Appendix I**. First, you can save the delays used by implemented TELEMED scanning modes (B Standard, B Wide View and B Compound) by pressing the button **Save to file**… when the desired mode is selected in the **B controls** Tab. To load custom delays from a file, the button **Upload file**… must be used. For uploading custom transmit delays you must select **Custom mode** in the Combo box (**Note!** If Scan Type is changed and different *.txt files are uploaded sequentially you must turn on Custom mode in the combo box again). **Arbitrary scanning beams** – possibility to scan beams in arbitrary order (multiple repetitions of them etc.). Controlled by uploading *.txt file of beams indices to scan. The structure of the *.txt file, with an example, is described in **Appendix II**. For uploading the file you must select **Custom mode** in the Combo box. The disappearing RF Window on the B-mode image is the indicator that custom mode is turned off for both delays and arbitrary beams since you are no longer scanning well-defined beams and channel RF data.
3	**Receive Controls**	There are three Tabs under the Receive Controls section: 1) **Channel mapping** – possibility to select channels that are active for channel data transfer to PC. The lower number of active channels results in higher FPS. It is a trade-off between FPS and the image quality that can be reconstructed from a limited number of channels. There are three buttons **All** (all channels active), **None** (no channels are active), and **Apply** (confirm selection). Channel mapping control affects only channel RF data, but not B-mode data. 2) AGC – the analog depth-dependent gain control curve adjusts the amplification of channel data signals at different levels of scanning depth.



AGC control affects both B-mode images and channel RF data. The points can be created interactively by the left mouse click on the chart at the desired location and deleted by right-clicking near the point. Points can also be added with the edit fields (**Depth**, **Value**) and confirming by button **Add** (**Insert** button creates blank value). There is a possibility to **Sort** AGC points and **Delete** some points, to **Copy**, **Paste**, **Save,** and **Load** the AGC curve.

Note! The AGC curve is linked to the B Gain control: decreasing the gain below 100 % shifts the programmed AGC curve down linearly. 100 % gain means the AGC as programmed; lower gain levels attenuate the AGC in proportion to the percentage.

3) AFE – analog front-end controls that affect channel data:



For the ArtUs scanner, there are 4 parameters:

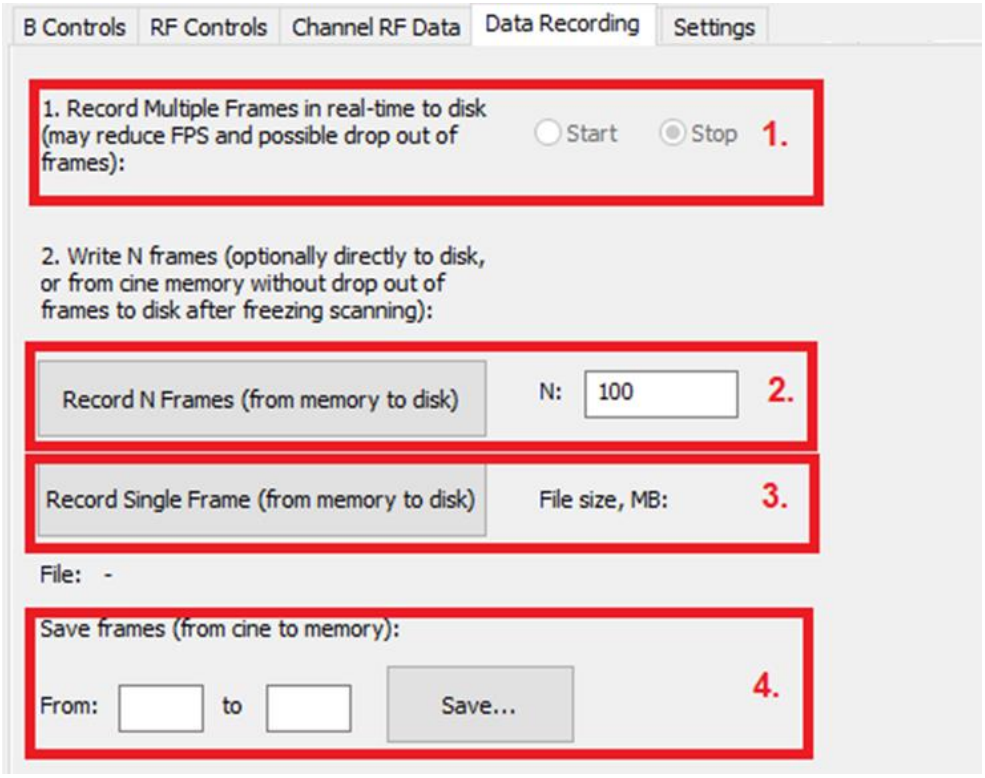
- Input resistor value and gain [Ohm, dB] – a combined parameter with 8 allowed combinations of {R_{in}, Gain} in the ArtUs AFE:
  { 100, 12.5},
  { 200, 12.5},
  { 400, 12.5},
  {1000, 12.5},
  { 50, 18.5},
  { 100, 18.5},
  { 200, 18.5},
  { 500, 18.5}.
- Low-pass anti-aliasing filter bandwidth [MHz], (4 possible values 9 MHz, 10 MHz, 15 MHz, 18 MHz).

		• Digital High-pass Filter cut-off [MHz], 11 possible selections: Bypass, 0.0987 MHz, 0.19520 MHz, 0.29168 MHz, 0.38606 MHz, 0.47912 MHz, 0.57088 MHz, 0.66138 MHz, 0.7507 MHz, 0.83886 MHz, 0.92588 MHz. • High-pass filter attenuation, [dB]. Three possible values: 0 dB, −0.58 dB, −1.16 dB. AFE control affects both B-mode images and channel RF data.

Note! For channel data mode ITHI frequency mode and Standard S line density options are not supported.

1.6. Data Recording Tab

ArtUs RF Data Control II software records raw data into *.bin files. There are two different structures of the files: 1) channel data and 2) beamformed RF data. Channel data can only be recorded retrospectively when scanning is frozen from Cine Loop memory, whereas beamformed RF data can also be recorded in real time, but such recording might result in a small number of missing frames and slightly reduced FPS. Data Recording Tab contains the following controls:

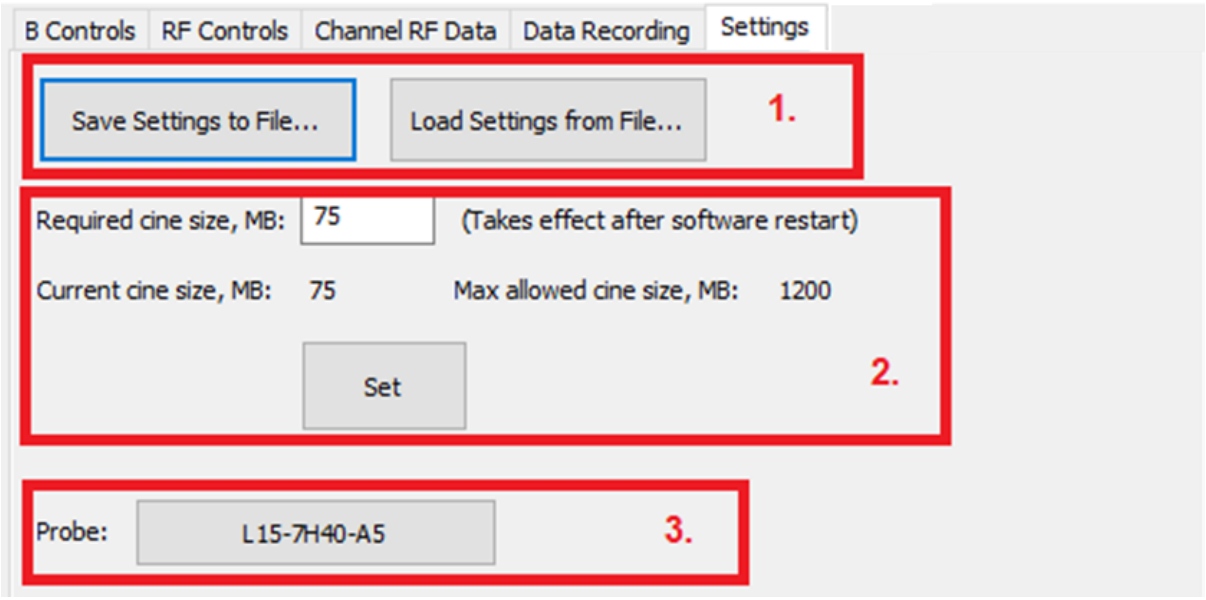


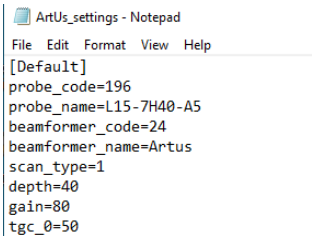
Num	Component	Description
1	**Record Multiple Frames**	Radio buttons **Start**/**Stop** record beamformed RF data into (*.bin) file from the selected data source point and RF window in real-time during scanning (active only while scanning is running and not for channel data mode). The file size can be monitored with the counter (size in MB). **Note! There is a small number of randomly skipped frames in RF data records when the file is recorded directly to the disk in real time during scanning; a decrease in FPS is also possible. It is recommended to save RF data from the Cine buffer after scanning when the freeze button is pressed. Such writing ensures that all collected RF data will be recorded without missing frames and reduction of FPS.**
2	**Record N Frames**	There is an option to record N frames (default value – 100) during real-time scanning or retrospectively from Cine Loop when the Freeze button is pressed. In channel data mode, available only after scanning is frozen.

3	**Record Single Frame**	There is an option to record a single RF frame (button Record Single Frame) which can be selected from the cine loop or just an actual frame during real-time scanning. In channel data mode, available only after scanning is frozen.
4	**Save frames**	**Save frames From :/To** allows recording of specific frames from the Cine Loop memory buffer to the *.bin file when scanning is frozen (retrospectively).

1.7. Settings Tab

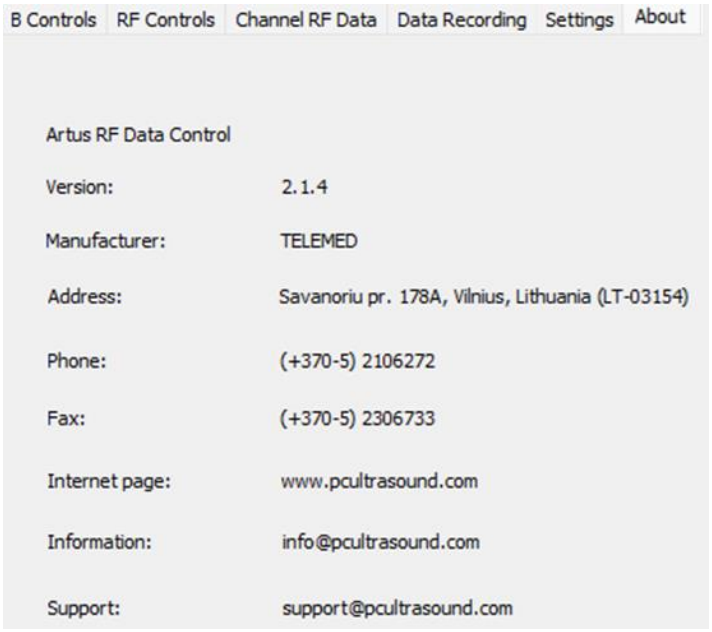
The Settings Tab allows you to adjust the Cine Loop size, save/load imaging settings to/from a file and choose the transducer if a two-port ArtUs scanner is used.



Num	Component	Description
1	**Save/Load Settings**	**Save Settings to File…** button creates the *.ini configuration file in the folder where the *.exe file of the ArtUs RF Data Control program is located. The *.ini file contains used imaging parameters. An example of a file fragment:  **Load Settings from File** button restores previously stored scanning settings from the *.ini configuration file.
2	**Cine buffer size**	Increases or decreases the size of the Cine Loop buffer (in MB). **Note!** Takes effect only after the software is restarted.
3	**Probe button**	The **Probe** button shows the code of the active transducer and lets you select the transducer on a two-port ArtUs (if two transducers are connected).

1.8. About Tab

The About Tab shows TELEMED contact information.



2. Recording of RF data files

ArtUs RF Data Control II software records RF data to binary files in channel data mode and in beamformed RF data mode. There are two different structures of files for different types of RF data (channel RF and beamformed RF). Both structures have header information and RF data. The header contains data acquisition parameters and the information required for B-mode image reconstruction from the recorded RF data.

2.1. Structure of the beamformed RF data file

The collected beamformed RF data and the main acquisition parameters needed for offline analysis and imaging can be recorded into binary files (*.bin). The filename contains acquisition time and date information, and the transducer code (**HH.MM.SS_DD-MM-YYYY_probe_code.bin**, e.g. "16.34.00_27-10-2017_L18-10H30-A4.bin"). The ***ArtUs*** RF Data Control SDK records RF data files of unlimited size (limited only by the capacity of the HDD).
Each recorded RF data frame contains header information and beamformed RF data from the corresponding RF window. The position and size of the window can be adjusted during scanning, and therefore the header of acquisition information is written to file for each frame in a recorded sequence. Please note that a smaller window allows higher frame rates. The file structure for a single frame is defined as follows:

Contents of the file	Data type	Number of elements (bytes)	Description
RF file type	char	1 (6 bytes)	RF file version is written only at the beginning of the file not before each frame (currently **RF0005**).
number_of_frames	int32	1 (4 bytes)	The number of RF frames recorded into the file (**!Note:** if the Record Multiple Frames Start/Stop option is used during the recording of RF data the field will be equal to 0).
header_size	int32	1 (4 bytes)	Size of header in bytes
frame_size	int32	1 (4 bytes)	Size of RF frame in bytes
mode	int32	1 (4 bytes)	Scanning mode (RF data): 0 – BRF, 1 – CFRF, 2 – PWRF.
source_ID	int32	1 (4 bytes)	RF data source ID: 1 – Beamformer output, 2 – TFC filter output, 3 – Angle apodization output, 4 – Hilbert transform output.
tx_frequency	int32	1 (4 bytes)	US wave transmission frequency, in Hz.
frame_rate	int32	1 (4 bytes)	The actual number of frames per second, since streaming started, depends on the transducer used and the size of the RF window. The frame rate is multiplied by 100.
Length_of_RF_row	int32	1 (4 bytes)	Number of RF signal samples in a single scanning row.
Number_of_RF_rows	int32	1 (4 bytes)	Number of RF scanning lines in a predefined RF window.
Sampling_period_ns	int32	1 (4 bytes)	Sampling period – defines the digitization resolution, in nanoseconds (ns). For the ArtUs system - 25 ns ~ 40 MHz sampling for depths up to 8192 samples, and 50 ns (20 MHz) for number of samples >8192.
Sample_size	int32	1 (4 bytes)	Number of bits, currently 16/32-bit for the RF data
start_depth	int32	1 (4 bytes)	Scanning start depth in mm (offset for each beam) used for imaging of the

			scanning window in the absolute coordinate system
DopplerPacketSize	int32	1 (4 bytes)	Doppler packet size for Color mode, if moide is not Color Doppler value will be = 1.
Start_point_position_and_orientation	int32	3 × Number_of_RF_rows (3 × Number_of_RF_rows × 4 bytes)	Start position coordinates and orientation angle of each beam are originally recorded in triplets (beam_x_i, beam_y_i, $angle_i$, where *i*-th scanning beam) for each scanning beam beginning from the left side of the sector. • angle – specifies the angle of the ultrasonic beam's direction (in radians multiplied by 1000000). The angle is given relative to the perpendicular to the center of the transducer surface (angle = 0 for linear array transducers); in the case of compound scanning mode (B compound) the parameter returns angle of beams for each compounded sub-frame (number of compounded sub-frames can be adjusted by Frames Num. control); • beam_x - start x coordinates of each beam, (in μm); • beam_y - start y coordinates of each beam, (in μm).
time_stamps	uint32	Number_of_RF_rows × *DopplerPacketSize* (Number_of_RF_rows × 4 bytes)	Time stamps for each ultrasound scanning line. Timestamp – time from the last start of scanning until the start of receiving of RF-data in present ultrasound line. One timestamp unit = sampling period (25 ns for 40 MHz sampling clock of ArtUs). Maximum time for 32-bit timestamp is 28606043.625 μsec (28.605043625 sec), after that, the timestamp counter restarts from zero. Timestamps are in samples.
frame	int16	Number_of_RF_rows × Length_of_RF_row × *DopplerPacketSize* (Number_of_RF_rows × Length_of_RF_row × *DopplerPacketSize* ×2 bytes) for *source_ID=1, 2, 3;* *and* 2 × Number_of_RF_rows × Length_of_RF_row × *DopplerPacketSize* (2 × Number_of_RF_rows × Length_of_RF_row × *DopplerPacketSize* × 2 bytes) for *source_ID=4*	Single sub-frame RF data in 1D vector format (int16);

2.2. Structure of the channel data file

Like the beamformed RF data file, the channel data BIN file contains a header and channel data. The main difference is that header information is written only once before channel data frames and not before each channel data frame contrary to beamformed RF data files. The header contains the information required for B-

mode image beamforming from channel data. Channel data can only be written after scanning is frozen – retrospectively from Cine Loop memory to preserve data transfer speed. The file structure for channel data is defined as follows:

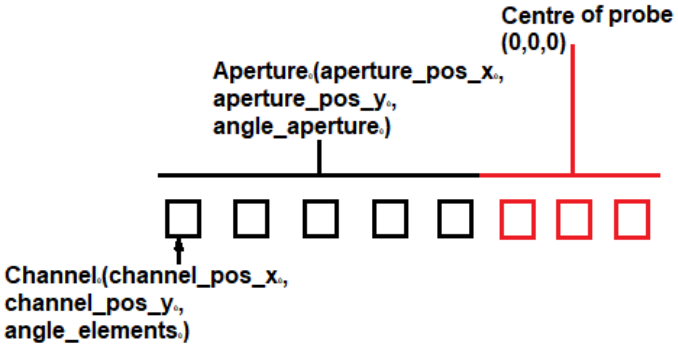
Contents of the file	Data type	Number of elements (bytes)	Description
RF file type	char	1 (6 bytes)	Channel RF file version (currently **CH0001**).
flag	int32	1 (4 bytes)	Flag which indicates if the tag of beam vectors position and start depth information exists (if exists flag = 1, otherwise flag = 0). The flag = 1 for TELEMED scanning modes (standard, wide view and compound), meanwhile for custom transmit delays or beams information on beam position and orientation and start depth are not provided.
sampling_period	int32	1 (4 bytes)	Sampling period value in nanoseconds.
BeamsPerFrame	int32	1 (4 bytes)	Number of scanned beams per frame.
SamplesPerChannel	int32	1 (4 bytes)	Number of samples for each channel.
ChannelsPerBeam	int32	1 (4 bytes)	Number of active channels for each beam.
SampleBitCount	int32	1 (4 bytes)	Number of bits of channel RF data.
FrameSize	int32	1 (4 bytes)	Size in bytes of channel RF Data frame.
SubFramesNumber	int32	1 (4 bytes)	Number of subframes (actual for compound mode)
SubBeamsNumber	int32	1 (4 bytes)	The number of beams that are used to calculate the final beam. This structure member is used when several beams are captured from the same position with different scanning sets. For example - in multibeam scanning mode, when several beams with different focus settings are captured from the same position.
SubFrameIndex	int32	1 (4 bytes)	Index of the subframe, used in compound mode (index of the first recorded channel RF data frame). For example, if compound frames number is equal to 5 and subframe index is equal to 3 that means that sequence of recorded subframes starts from the 4th frame.
number_of_frames_to_record	int32	1 (4 bytes)	Number of channel RF data frames recorded into the file.
aperture_size	int32	1 (4 bytes)	Maximum possible number of active channels (64 for ArtUs system).
mask_of_active_channels	int32	aperture_size × 4 byte (256 bytes for ArtUs)	Mask (array) of zeros and ones to indicate which aperture channel is active.
index_and_position_of_aperture_and_dummy_channels	int32	BeamsPerFrame × 5 × 4 bytes	BeamsPerFrame × 5 array containing information for each beam: • aperture index (0 – BeamsPerFrame-1), • aperture_pos_x (in µm) relative to the centre of the transducer, • aperture_pos_y （in µm) relative to the centre of the transducer, • angle_aperture (in radians multiplied by 1000000) relative to the centre of the transducer, • dummy channels (if the channels are outside the aperture, which happens for beams near the transducer edge, the number is negative and gives the number of such channels, for example if value is equal to -32, that means that for first 32 channels of the

			beam there is no channel RF Data). The information for each beam is arranged in the following order (aperture index$_0$, aperture_pos_x$_0$, aperture_pos_y$_0$, angle_aperture$_0$, dummy channels$_0$, aperture index$_1$, aperture_pos_x$_1$, aperture_pos_y$_1$, angle_aperture$_1$, dummy channels$_1$, …).
position_of_channels	int32	ChannelsPerBeam × 4 × 4 bytes	Each channel index, position and angle information (ChannelsPerBeam × 4 array): • channel_idx (0 – ChannelsPerBeam – 1), • channel_pos_x (in µm) relative to the centre of the aperture, • channel_pos_y (in µm) relative to the centre of the aperture, • angle_elements (in radians multiplied by 1000000) relative to the centre of the aperture. The information for each channel is arranged in the following order (channel_idx$_0$, channel_pos_x$_0$, channel_pos_y$_0$, angle_elements$_0$, channel_idx$_1$, channel_pos_x$_1$, channel_pos_y$_1$, angle_elements$_1$, …).
start_end_indices_channels	int32	ChannelsPerBeam×2× BeamsPerFrame×SubBeamsNumber× SubFramesNumber× 4 bytes	Array contains excitation pulse beginning and end indices for each channel which were active in transmission of ultrasound. Array contains information: • Start indexes, • End indexes.
Start_Depth (present only if custom transmit delays are not selected)	int32	1 (4 bytes)	Start depth index in samples for the RF data window.
beam_position_and_orientation (present only if custom transmit delays are not selected)	int32	BeamsPerFrame × SubFramesNumber × 3× 4 bytes	Information of position and orientation for each ultrasound beam: • beam_position_x (in µm) relative to the centre of the transducer, • beam_position_y (in µm), relative to the centre of the transducer, • beam_angle (in radians multiplied by 1000000), relative to the centre of the transducer. The information for each channel is arranged in the following order (beam_position_x$_0$, beam_position_y$_0$, beam_angle$_0$, beam_position_x$_1$, beam_position_y$_1$, beam_angle$_1$, …).
channel_data	int16	number_of_frames_to_record × FrameSize/2 × 2 bytes	Channel RF Data of N recorded frames. The data in the buffer are arranged as follows: *SamplesPerChannel* × *ChannelsPerBeam* × *BeamsPerFrame* × *number_of_frames_to_record.*

2.3. Coordinate system for B-mode image reconstruction

In channel data mode, several arrays describe the position and orientation of beams (not always present), apertures, and channels, meanwhile for beamformed RF only the position and orientation of beam arrays are given. The drawing below shows how these coordinates are related (example for a linear transducer). Coordinates and angle (***aperture_pos_x***, ***aperture_pos_y***, ***angle_aperture***) of the aperture are physical meanwhile if the scanning beam was steered by a certain angle, you must use beam position and orientation

arrays (*beam_position_x*, *beam_position_y*, *beam_angle*) for reconstruction. Please note the beam position and orientation information in the channel data file exists only if no custom transmit delays and beams are used during scanning. Both aperture coordinates and beam (if exist) coordinates are relative to the center of the transducer (0,0). For each aperture/beam, there are provided channel position and orientation arrays (*channel_pos_x*, *channel_pos_y*, *angle_elements*) which provide information on how to position each channel in aperture. The drawing shows an aperture that contains 5 channels (elements) and transducer center coordinates.



3. Installation notes and PC requirements

Requirements for the programming environment are as follows:

- Windows 10 or Windows 11, 64-bit (x64), is required to run ArtUs RF Data Control II software.
- i5/i7/i9 CPU
- 16 GB RAM or more
- USB 3.0
- One of the following TELEMED ultrasound scanners connected:
  - ArtUs EXT-1H with RF module, beamformed RF data support
  - ArtUs EXT-2H with RF module, beamformed RF data support
  - ArtUs USS-2H, beamformed and channel RF data support
- Properly installed ArtUs drivers (for installation requirements, see the readme file of the drivers package).
- Installed Usgfw2 SDK x64-bit redistributable files (usgfwsetup.exe).

4. Revision History

Version	Date	Description of Revision	Revision author
1.0.0	07/10/2022	Initial Release	A. Sakalauskas
1.0.1	11/06/2024	Updated description of Channel data controls Tab and removed limitations section	A. Sakalauskas
1.0.2	12/06/2024	Minor grammar corrections and updated PC requirements	A. Sakalauskas G. Volkovas
1.0.3	08/07/2024	Added more explicit description on sampling of RF data	A.Sakalauskas
1.0.4	25/09/2026	Added scenarios for plane wave scanning and passive reception programming: Appendix III.	A.Sakalauskas
1.0.5	26/10/2026	New document design; spelling, grammar and wording corrections; consistent terminology (transducer); PC requirements updated (Windows 10/11, 64-bit); corrected beam indices in the Appendix II example.	A.Sakalauskas G.Volkovas
1.0.6	06/11/2026	Added info about Color Doppler and PW Doppler RF data controls and updated info on beamformed RF data format.	A. Sakalauskas

5. References

[1] ArtUs RF Data Control User Manual.

Appendix I. Transmit delays file structure

There are 3 scanning modes for obtaining B image implemented in TELEMED ArtUs RF Data Control II software: 1) B Standard, 2) B Wide View, and 3) B Compound. Each of these modes sets certain limitations for uploading custom delay files. For B Standard and B Compound modes, only the same set of custom delays can be applied to every scanned beam, but for B Wide View mode you can program custom delays for each beam individually.

The table below describes the structure of delays files used for custom transmit focusing.

	Field	Description
[TX_header] – header information of transmit delays file	Scan Type	Indicates what type of scanning is used: 0 – for B Standard and B Compound scanning and 1 – for Wide View mode, 2 – for phased array transducers.
	Aperture Size	Number of elements in aperture, 64 – for ArtUs scanner.
	SubBeams Number	The number of SubBeams is a number of beams that are used to calculate the final beam. This field applies when several beams are captured from the same position with different scanning sets. For example - in multibeam scanning mode when several beams with different focus settings are captured from the same position or multifocus mode.
	Beams Number	Beams Number – number of beams with different transmit delays set. The maximum possible number is 192 and depends on the transducer used. For B Standard mode and B Compound mode Beams Number = 1 (all the beams are scanned with the same set of delays), for B Wide View mode different delays can be applied to each beam and this number is N.
	SubFrames Number	Applies to compound mode. It is a number of subframes used for compounding, possible range of compounded frames 2 – 5. The maximum possible number of subframes for compound mode is 5.
[Frame.N.Beam.N.SubBeam.N] – corresponding delays for each element.	Element.0=0 Element.1=0 Element.2=0 Element.3=0 Element.4=0 Element.5=0 Element.6=0 Element.7=0 Element.8=796 Element.9=800 … Element.63=0	Before a set of delays for each beam indexing information is provided: [Frame.N.Beam.N.SubBeam.N] – where: Frame.N – Subframe index (used in compound scanning, otherwise 0), Beam.N – beam index, SubBeam.N – subbeam index. The indexing information is followed by a list of aperture elements and the delay in samples for each: a delay of 0 means the element is not active in transmission; a non-zero integer delay turns the excitation on. One sample is 6.25 ns (to obtain the delay in time units, multiply, e.g. 800 × 6.25 ns = 5 μs). The possible delay range is 1–4096 samples.

- B Standard scanning mode example

[TX_header]	
Scan Type	0
Aperture Size	64
SubBeams Number	1
Beams Number	1
SubFrames Number	1

[Frame.0.Beam.0.SubBeam.0]							
Element	Delay	Element	Delay	Element	Delay	Element	Delay
Element.0	0	Element.16	0	Element.32	800	Element.48	0
Element.1	0	Element.17	0	Element.33	799	Element.49	0
Element.2	0	Element.18	0	Element.34	798	Element.50	0
Element.3	0	Element.19	0	Element.35	797	Element.51	0
Element.4	0	Element.20	0	Element.36	795	Element.52	0
Element.5	0	Element.21	0	Element.37	792	Element.53	0
Element.6	0	Element.22	0	Element.38	0	Element.54	0
Element.7	0	Element.23	0	Element.39	0	Element.55	0
Element.8	0	Element.24	0	Element.40	0	Element.56	0
Element.9	0	Element.25	0	Element.41	0	Element.57	0
Element.10	0	Element.26	792	Element.42	0	Element.58	0
Element.11	0	Element.27	795	Element.43	0	Element.59	0
Element.12	0	Element.28	797	Element.44	0	Element.60	0
Element.13	0	Element.29	798	Element.45	0	Element.61	0
Element.14	0	Element.30	799	Element.46	0	Element.62	0
Element.15	0	Element.31	800	Element.47	0	Element.63	0

- B Wide View scanning mode example

[TX_header]	
Scan Type	1
Aperture Size	64
SubBeams Number	1
Beams Number	192
SubFrames Number	1

[Frame.0.Beam.0.SubBeam.0]							
Element	Delay	Element	Delay	Element	Delay	Element	Delay
Element.0	0	Element.16	0	Element.32	956	Element.48	0
Element.1	0	Element.17	0	Element.33	952	Element.49	0
Element.2	0	Element.18	0	Element.34	947	Element.50	0
Element.3	0	Element.19	0	Element.35	942	Element.51	0
Element.4	0	Element.20	0	Element.36	937	Element.52	0
Element.5	0	Element.21	0	Element.37	931	Element.53	0
Element.6	0	Element.22	0	Element.38	0	Element.54	0
Element.7	0	Element.23	0	Element.39	0	Element.55	0
Element.8	0	Element.24	0	Element.40	0	Element.56	0
Element.9	0	Element.25	0	Element.41	0	Element.57	0
Element.10	0	Element.26	645	Element.42	0	Element.58	0
Element.11	0	Element.27	645	Element.43	0	Element.59	0
Element.12	0	Element.28	645	Element.44	0	Element.60	0
Element.13	0	Element.29	645	Element.45	0	Element.61	0
Element.14	0	Element.30	645	Element.46	0	Element.62	0
Element.15	0	Element.31	645	Element.47	0	Element.63	0

[Frame.0.Beam.1.SubBeam.0]

Element	Delay	Element	Delay	Element	Delay	Element	Delay
Element.0	0	Element.16	0	Element.32	**798**	Element.48	0
Element.1	0	Element.17	0	Element.33	**794**	Element.49	0
Element.2	0	Element.18	0	Element.34	**789**	Element.50	0
Element.3	0	Element.19	0	Element.35	**784**	Element.51	0
Element.4	0	Element.20	0	Element.36	**779**	Element.52	0
Element.5	0	Element.21	0	Element.37	**773**	Element.53	0
Element.6	0	Element.22	0	Element.38	0	Element.54	0
Element.7	0	Element.23	0	Element.39	0	Element.55	0
Element.8	0	Element.24	0	Element.40	0	Element.56	0
Element.9	0	Element.25	0	Element.41	0	Element.57	0
Element.10	0	Element.26	**488**	Element.42	0	Element.58	0
Element.11	0	Element.27	**488**	Element.43	0	Element.59	0
Element.12	0	Element.28	**488**	Element.44	0	Element.60	0
Element.13	0	Element.29	**488**	Element.45	0	Element.61	0
Element.14	0	Element.30	**488**	Element.46	0	Element.62	0
Element.15	0	Element.31	**802**	Element.47	0	Element.63	0

[Frame.0.Beam.2.SubBeam.0]

Element	Delay	Element	Delay	Element	Delay	Element	Delay
Element.0	0	Element.2	0	Element.4	0		
Element.1	0	Element.3	0				

… further entries follow the same structure

- B Compound scanning mode example

[TX_header]	
Scan Type	0
Aperture Size	64
SubBeams Number	1
Beams Number	1
SubFrames Number	5

[Frame.0.Beam.0.SubBeam.0]

Element	Delay	Element	Delay	Element	Delay	Element	Delay
Element.0	0	Element.16	0	Element.32	798	Element.48	0
Element.1	0	Element.17	0	Element.33	792	Element.49	0
Element.2	0	Element.18	0	Element.34	786	Element.50	0
Element.3	0	Element.19	0	Element.35	779	Element.51	0
Element.4	0	Element.20	0	Element.36	772	Element.52	0
Element.5	0	Element.21	0	Element.37	764	Element.53	0
Element.6	0	Element.22	0	Element.38	0	Element.54	0
Element.7	0	Element.23	0	Element.39	0	Element.55	0
Element.8	0	Element.24	0	Element.40	0	Element.56	0
Element.9	0	Element.25	0	Element.41	0	Element.57	0
Element.10	0	Element.26	823	Element.42	0	Element.58	0
Element.11	0	Element.27	820	Element.43	0	Element.59	0
Element.12	0	Element.28	816	Element.44	0	Element.60	0
Element.13	0	Element.29	812	Element.45	0	Element.61	0
Element.14	0	Element.30	808	Element.46	0	Element.62	0
Element.15	0	Element.31	803	Element.47	0	Element.63	0

[Frame.1.Beam.0.SubBeam.0]

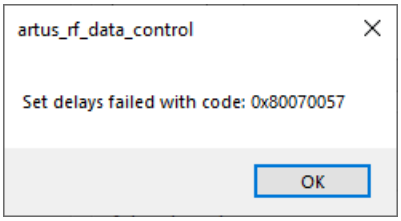
Element	Delay	Element	Delay	Element	Delay	Element	Delay
Element.0	0	Element.16	0	Element.32	799	Element.48	0
Element.1	0	Element.17	0	Element.33	796	Element.49	0
Element.2	0	Element.18	0	Element.34	792	Element.50	0
Element.3	0	Element.19	0	Element.35	788	Element.51	0
Element.4	0	Element.20	0	Element.36	783	Element.52	0
Element.5	0	Element.21	0	Element.37	778	Element.53	0
Element.6	0	Element.22	0	Element.38	0	Element.54	0
Element.7	0	Element.23	0	Element.39	0	Element.55	0
Element.8	0	Element.24	0	Element.40	0	Element.56	0
Element.9	0	Element.25	0	Element.41	0	Element.57	0
Element.10	0	Element.26	808	Element.42	0	Element.58	0
Element.11	0	Element.27	808	Element.43	0	Element.59	0
Element.12	0	Element.28	807	Element.44	0	Element.60	0
Element.13	0	Element.29	806	Element.45	0	Element.61	0
Element.14	0	Element.30	804	Element.46	0	Element.62	0
Element.15	0	Element.31	802	Element.47	0	Element.63	0

[Frame.2.Beam.0.SubBeam.0]

Element	Delay	Element	Delay	Element	Delay	Element	Delay
Element.0	0	Element.3	0	Element.6	0	Element.9	0
Element.1	0	Element.4	0	Element.7	0		
Element.2	0	Element.5	0	Element.8	0		

… further entries follow the same structure

If information in a *.txt delay file is wrong, you will receive an error message:



Appendix II. Arbitrary beams file structure

The file structure for arbitrary beams is similar to that of the transmit delays mode. The main two parameters are the count of beams (*Beams Number*) and the indices of beams to scan (*Beams Indexes*). The example below shows how to scan 5 beams with indexes 32, 96, 160, 152 and 153. Indices correspond to certain spatial positions.

[Beams_header]	
Scan Type	0
Beams Number	5

[Beams Indexes]	
Beam	**Index**
Beam.0	32
Beam.1	96
Beam.2	160
Beam.3	152
Beam.4	153

Appendix III. Scenarios for plane wave scanning and passive reception

This appendix describes how to configure the **ArtUs USS--2H** device for three operating modes:

1. Plane-wave scanning
2. Plane-wave compound scanning
3. Passive-receive scanning

Each scenario includes the required transmit-delay file format and recommendations for beam selection to optimize frame rate (FPS).

1. Plane-Wave Scanning Mode

To operate in basic plane-wave mode, upload a transmit-delay file in which **all elements have identical non-zero delay values**. A minimal example is shown below:

[TX_header]	
Scan Type	0
Aperture Size	64
SubBeams Number	1
Beams Number	1
SubFrames Number	1

[Frame.0.Beam.0.SubBeam.0]							
Element	Delay	Element	Delay	Element	Delay	Element	Delay
Element.0	800	Element.16	800	Element.32	800	Element.48	800
Element.1	800	Element.17	800	Element.33	800	Element.49	800
Element.2	800	Element.18	800	Element.34	800	Element.50	800
Element.3	800	Element.19	800	Element.35	800	Element.51	800
Element.4	800	Element.20	800	Element.36	800	Element.52	800
Element.5	800	Element.21	800	Element.37	800	Element.53	800
Element.6	800	Element.22	800	Element.38	800	Element.54	800
Element.7	800	Element.23	800	Element.39	800	Element.55	800
Element.8	800	Element.24	800	Element.40	800	Element.56	800
Element.9	800	Element.25	800	Element.41	800	Element.57	800
Element.10	800	Element.26	800	Element.42	800	Element.58	800
Element.11	800	Element.27	800	Element.43	800	Element.59	800
Element.12	800	Element.28	800	Element.44	800	Element.60	800
Element.13	800	Element.29	800	Element.45	800	Element.61	800
Element.14	800	Element.30	800	Element.46	800	Element.62	800
Element.15	800	Element.31	800	Element.47	800	Element.63	800

Important note on FPS

If only the delay file is uploaded, the device will still operate in **beam-scanning mode**. This means:

- Each delay set is applied to **every aperture position** across the transducer.

- For a 192-element transducer with standard line density, this results in **192 X 64 transmit events** per frame.
- The scan becomes redundant and FPS decreases significantly.

Reducing transmit count using arbitrary beams
To scan only a subset of apertures, use the **IUsgArbitraryBeams** interface and upload an arbitrary-beam index file. This allows you to fire only selected apertures while still covering the full transducer surface.

Example for a **192-element transducer** (three active apertures):

[Beams_header]	
Scan Type	0
Beams Number	3

[Beams Indexes]	
Beam	**Index**
Beam.0	32
Beam.1	96
Beam.2	160

For a **128-element transducer**, reduce the beam count to **2** and choose appropriate indices.
Selecting fewer beams reduces the number of transmit events to the minimum required and **significantly increases FPS**. If overlapping plane-wave acquisitions are desired, select more beams and corresponding indices.

2. Plane-Wave Compound Scanning Mode

Plane-wave compounding is enabled by selecting **B Compound** in the ***B Controls*** tab and choosing the desired number of subframes (range **2–5**). The system will then allow uploading transmit-delay files containing multiple delay sets—one per subframe.

Example below shows **five subframes** corresponding to steering angles: **0°, –2°, +2°, –4°, +4°**

[TX_header]	
Scan Type	0
Aperture Size	64
SubBeams Number	1
Beams Number	1
SubFrames Number	5

[Frame.0.Beam.0.SubBeam.0]

Element	Delay	Element	Delay	Element	Delay	Element	Delay
Element.0	800	Element.16	800	Element.32	800	Element.48	800
Element.1	800	Element.17	800	Element.33	800	Element.49	800
Element.2	800	Element.18	800	Element.34	800	Element.50	800
Element.3	800	Element.19	800	Element.35	800	Element.51	800
Element.4	800	Element.20	800	Element.36	800	Element.52	800
Element.5	800	Element.21	800	Element.37	800	Element.53	800
Element.6	800	Element.22	800	Element.38	800	Element.54	800
Element.7	800	Element.23	800	Element.39	800	Element.55	800
Element.8	800	Element.24	800	Element.40	800	Element.56	800
Element.9	800	Element.25	800	Element.41	800	Element.57	800
Element.10	800	Element.26	800	Element.42	800	Element.58	800
Element.11	800	Element.27	800	Element.43	800	Element.59	800
Element.12	800	Element.28	800	Element.44	800	Element.60	800
Element.13	800	Element.29	800	Element.45	800	Element.61	800
Element.14	800	Element.30	800	Element.46	800	Element.62	800
Element.15	800	Element.31	800	Element.47	800	Element.63	800

[Frame.1.Beam.0.SubBeam.0]

Element	Delay	Element	Delay	Element	Delay	Element	Delay
Element.0	777	Element.16	789	Element.32	800	Element.48	812
Element.1	778	Element.17	789	Element.33	801	Element.49	813
Element.2	778	Element.18	790	Element.34	802	Element.50	813
Element.3	779	Element.19	791	Element.35	802	Element.51	814
Element.4	780	Element.20	792	Element.36	803	Element.52	815
Element.5	781	Element.21	792	Element.37	804	Element.53	815
Element.6	781	Element.22	793	Element.38	805	Element.54	816
Element.7	782	Element.23	794	Element.39	805	Element.55	817
Element.8	783	Element.24	794	Element.40	806	Element.56	818
Element.9	784	Element.25	795	Element.41	807	Element.57	818
Element.10	784	Element.26	796	Element.42	807	Element.58	819
Element.11	785	Element.27	797	Element.43	808	Element.59	820
Element.12	786	Element.28	797	Element.44	809	Element.60	821
Element.13	786	Element.29	798	Element.45	810	Element.61	821
Element.14	787	Element.30	799	Element.46	810	Element.62	822
Element.15	788	Element.31	799	Element.47	811	Element.63	823

[Frame.2.Beam.0.SubBeam.0]

Element	Delay	Element	Delay	Element	Delay	Element	Delay
Element.0	823	Element.16	811	Element.32	799	Element.48	788
Element.1	822	Element.17	810	Element.33	799	Element.49	787
Element.2	821	Element.18	810	Element.34	798	Element.50	786
Element.3	821	Element.19	809	Element.35	797	Element.51	786
Element.4	820	Element.20	808	Element.36	797	Element.52	785
Element.5	819	Element.21	807	Element.37	796	Element.53	784
Element.6	818	Element.22	807	Element.38	795	Element.54	784
Element.7	818	Element.23	806	Element.39	794	Element.55	783
Element.8	817	Element.24	805	Element.40	794	Element.56	782
Element.9	816	Element.25	805	Element.41	793	Element.57	781
Element.10	815	Element.26	804	Element.42	792	Element.58	781
Element.11	815	Element.27	803	Element.43	792	Element.59	780
Element.12	814	Element.28	802	Element.44	791	Element.60	779
Element.13	813	Element.29	802	Element.45	790	Element.61	778
Element.14	813	Element.30	801	Element.46	789	Element.62	778
Element.15	812	Element.31	800	Element.47	789	Element.63	777

[Frame.3.Beam.0.SubBeam.0]

Element	Delay	Element	Delay	Element	Delay	Element	Delay
Element.0	755	Element.16	778	Element.32	801	Element.48	825
Element.1	756	Element.17	780	Element.33	803	Element.49	826
Element.2	758	Element.18	781	Element.34	804	Element.50	827
Element.3	759	Element.19	783	Element.35	806	Element.51	829
Element.4	761	Element.20	784	Element.36	807	Element.52	830
Element.5	762	Element.21	785	Element.37	809	Element.53	832
Element.6	764	Element.22	787	Element.38	810	Element.54	833
Element.7	765	Element.23	788	Element.39	812	Element.55	835
Element.8	767	Element.24	790	Element.40	813	Element.56	836
Element.9	768	Element.25	791	Element.41	814	Element.57	838
Element.10	769	Element.26	793	Element.42	816	Element.58	839
Element.11	771	Element.27	794	Element.43	817	Element.59	841
Element.12	772	Element.28	796	Element.44	819	Element.60	842
Element.13	774	Element.29	797	Element.45	820	Element.61	843
Element.14	775	Element.30	798	Element.46	822	Element.62	845
Element.15	777	Element.31	800	Element.47	823	Element.63	846

[Frame.4.Beam.0.SubBeam.0]

Element	Delay	Element	Delay	Element	Delay	Element	Delay
Element.0	846	Element.16	823	Element.32	800	Element.48	777
Element.1	845	Element.17	822	Element.33	798	Element.49	775
Element.2	843	Element.18	820	Element.34	797	Element.50	774
Element.3	842	Element.19	819	Element.35	796	Element.51	772
Element.4	841	Element.20	817	Element.36	794	Element.52	771
Element.5	839	Element.21	816	Element.37	793	Element.53	769
Element.6	838	Element.22	814	Element.38	791	Element.54	768
Element.7	836	Element.23	813	Element.39	790	Element.55	767
Element.8	835	Element.24	812	Element.40	788	Element.56	765
Element.9	833	Element.25	810	Element.41	787	Element.57	764
Element.10	832	Element.26	809	Element.42	785	Element.58	762
Element.11	830	Element.27	807	Element.43	784	Element.59	761
Element.12	829	Element.28	806	Element.44	783	Element.60	759
Element.13	827	Element.29	804	Element.45	781	Element.61	758
Element.14	826	Element.30	803	Element.46	780	Element.62	756
Element.15	825	Element.31	801	Element.47	778	Element.63	755

Beam-selection recommendations

The same FPS-optimization rules apply as in non-angular plane-wave mode:

- Use **IUsgArbitraryBeams** to reduce the number of apertures scanned.
- Select beam indices appropriate for the transducer element count.
- More beams → more overlap → higher compounding quality but lower FPS.

3. Passive-Receive Mode

Passive-receive mode is configured by uploading a transmit-delay file in which **all elements are muted**. This is achieved by setting every delay value to **zero**:

[TX_header]	
Scan Type	**0**
Aperture Size	**64**
SubBeams Number	**1**
Beams Number	**1**
SubFrames Number	**1**

[Frame.0.Beam.0.SubBeam.0]							
Element	Delay	Element	Delay	Element	Delay	Element	Delay
Element.0	0	Element.16	0	Element.32	0	Element.48	0
Element.1	0	Element.17	0	Element.33	0	Element.49	0
Element.2	0	Element.18	0	Element.34	0	Element.50	0
Element.3	0	Element.19	0	Element.35	0	Element.51	0
Element.4	0	Element.20	0	Element.36	0	Element.52	0
Element.5	0	Element.21	0	Element.37	0	Element.53	0
Element.6	0	Element.22	0	Element.38	0	Element.54	0
Element.7	0	Element.23	0	Element.39	0	Element.55	0
Element.8	0	Element.24	0	Element.40	0	Element.56	0
Element.9	0	Element.25	0	Element.41	0	Element.57	0
Element.10	0	Element.26	0	Element.42	0	Element.58	0
Element.11	0	Element.27	0	Element.43	0	Element.59	0
Element.12	0	Element.28	0	Element.44	0	Element.60	0
Element.13	0	Element.29	0	Element.45	0	Element.61	0
Element.14	0	Element.30	0	Element.46	0	Element.62	0
Element.15	0	Element.31	0	Element.47	0	Element.63	0

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