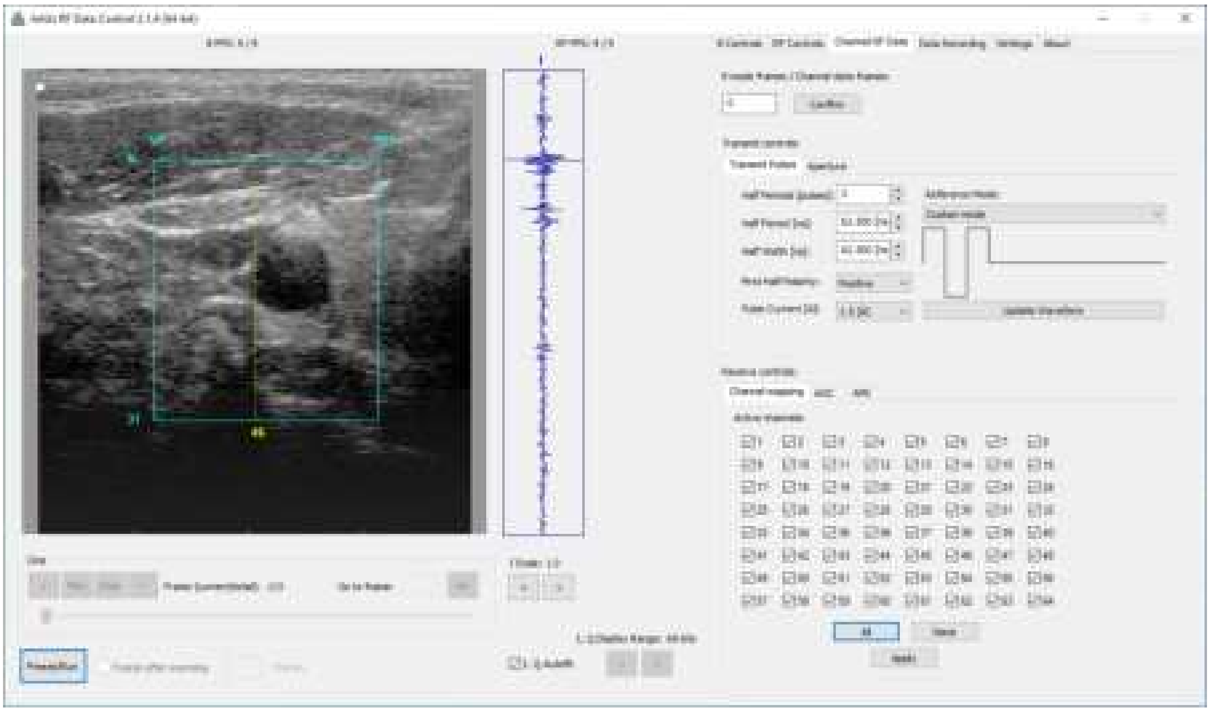
ArtUs RF Data Control II

User Manual



TELEMED

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Introduction

The document describes ArtUs RF Data Control II program from the release of the 2.1.4 version. The program is dedicated to the real-time acquisition of raw ultrasound data (channel RF data and beamformed RF) by using new unique configuration TELEMED scanner ArtUs. It's a continuation of the predecessor just the structure of the interface controls was reorganized into tabs and new functionality to receive raw channel data in real-time and to control related acquisition parameters (active channels selection, transmit delays programming, programming of excitation pulses, etc.) was implemented.

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

1. To program custom transmit delay values for individual channels and apertures. Fully custom transmit focusing in terms of delays available.
2. To choose active channels from 64 available (trade-off between frame rate and image quality).
3. To program custom transmit pulses for all channels of electronics (Tri-state pulser +A, 0, -A).
4. To select arbitrary beams to scan (custom sequence of working apertures) from the available range of beams.
5. Analog front-end parameters will be available for the users (high-pass filter cut-off, input resistance, and gain).
6. Possibility to adjust custom analog depth-dependent amplification of received echoes.

You cannot:

1. To program different in terms of amplitude and shape excitation pulses (Tx), analog front-end parameters and analog amplification values and depths for individual channels of electronics.
2. Channel data supporting scanner operates only in B (brightness) mode, other modes like Doppler are not supported.

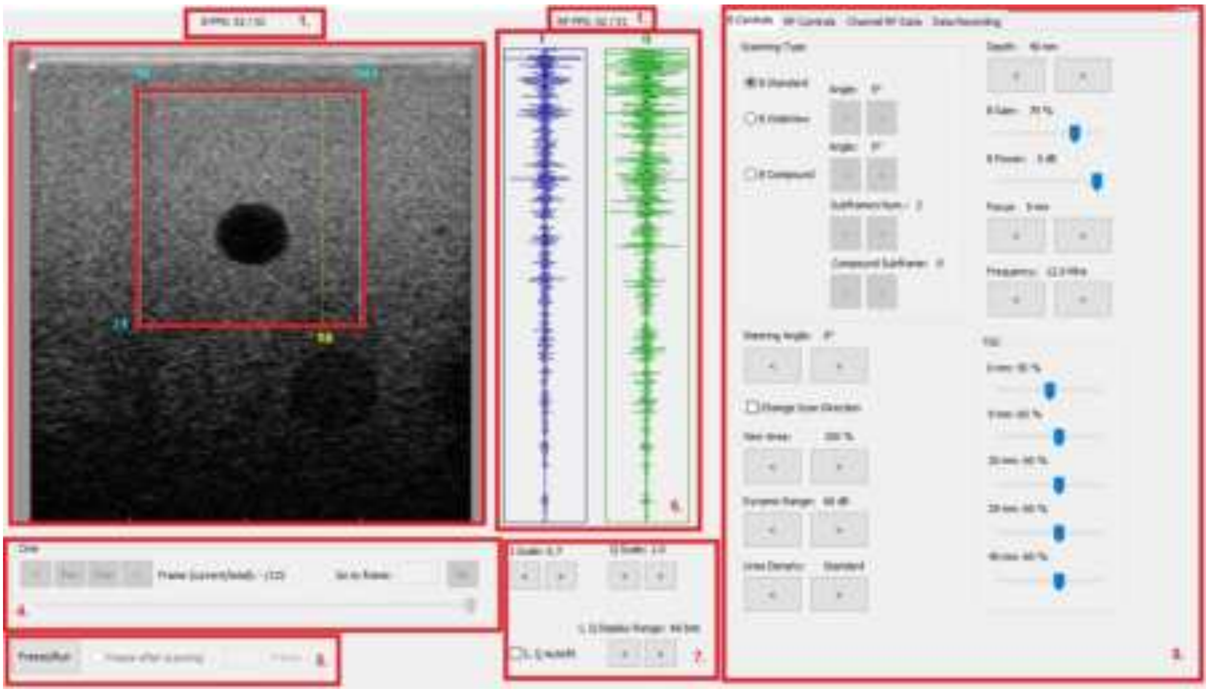
1. Structure of ArtUs RF Data Control II User Interface

Currently, ArtUs RF Data Control II program contains 6 tabs with different categories of ultrasonography controls:

- B controls
- 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. The majority (all except post-processing algorithms which are applied on B-mode image) of B-mode imaging parameters available in the Echo Wave II application are also available for 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

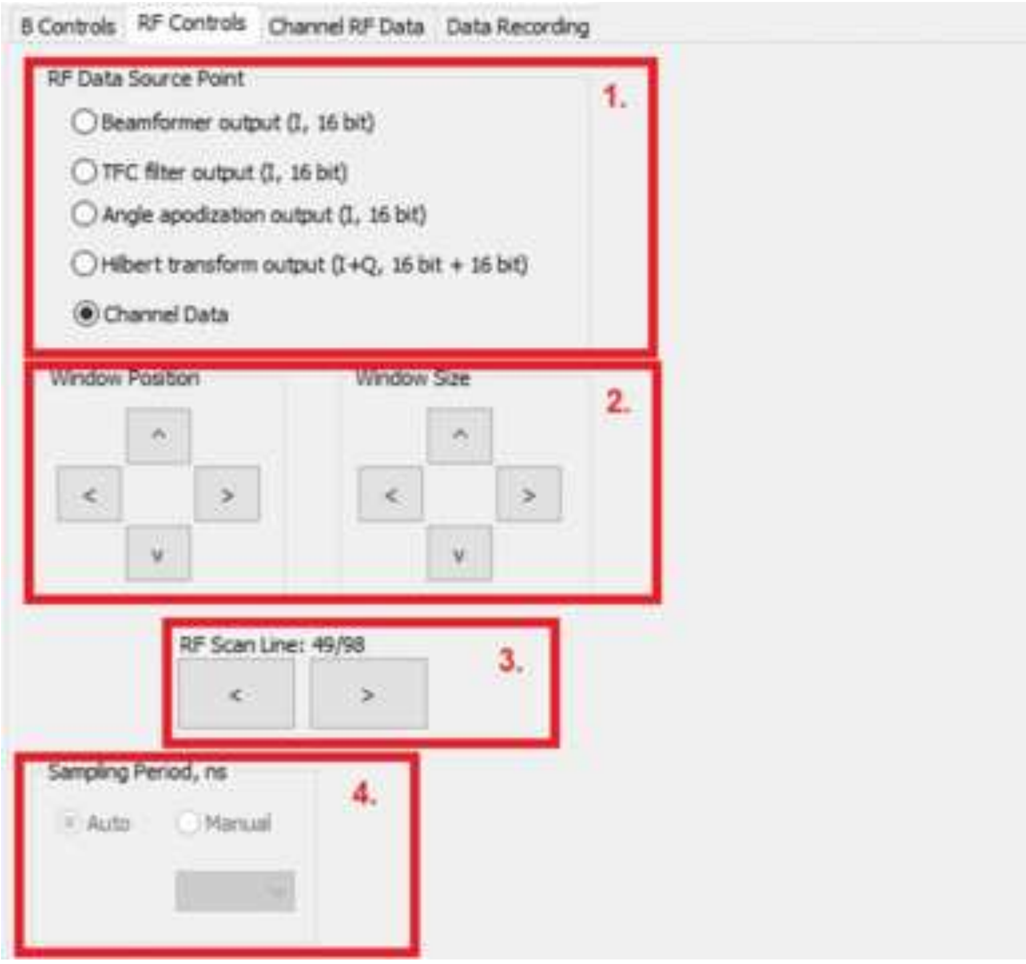
		of RF data to be transferred and the relative position of the RF output window in the B-mode image frame.
4	**Cine Loop controls**	Cine loop options. Allows to **play** recorded sequence and to watch it frame by frame. It is possible to jump to the desired frame by entering **Go to frame:** value and 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 then 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 will be scanned by marking the checkbox **Freeze after scanning** and entering a number of frames value.
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**) allow for adjusting the scale of the shown raw Channel of 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:
		    o **B Standard**,
		    o **B Wide View** (possibility to adjust the **angle** by control),
		    o **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 probes),
		• **Change scan direction** control – checkbox allows to change 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:
		    o Standard,
		    o Standard S (the same number of scanlines as for standard, just scanning speed is higher due to the use of parallel beamforming technique),
		    o Medium – number of scan lines twice lower in comparison to standard,
		    o Low – number of scan lines three times lower in comparison to standard,
		    o High – number of scanlines twice higher than standard.
		• **Depth, mm** – imaging depth,
		• **B Gain, %** – amplification of received signal (affects B-mode and beamformed RF data, but not channel data),
		• **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).

1.2. RF Controls Tab

RF Controls Tab allows 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.

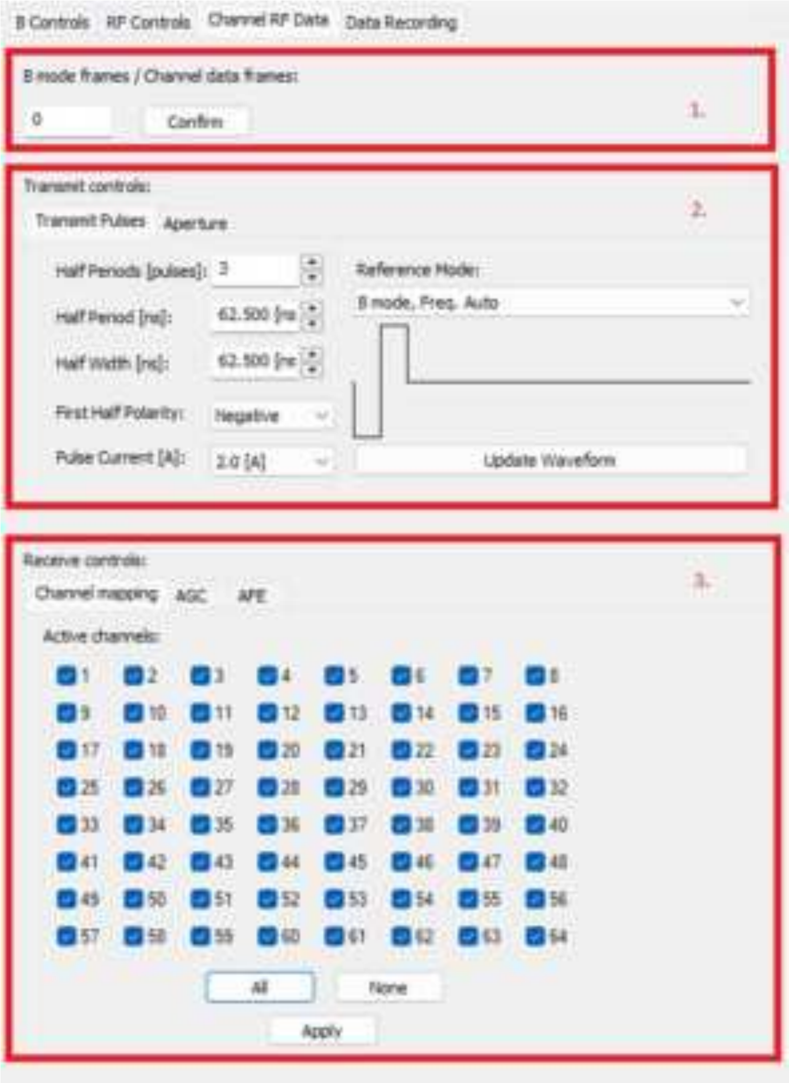


Num	Component	Description
1	**RF Data Source Point**	RF data is received as an array of 16-bit integers. This option allows to select the point of the beamformer from which raw data will be received. For the ArtUs ultrasound scanner, the following raw data types are available: • Beamformer output (*I*, 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 for ArtUs USS-1H/2H scanners only

2	**RF Window Controls**	The position and size of the RF window could be adjusted by the 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. Indicator
4	**Sampling period selection**	The controls allow to select sampling period Manually (25, 50, 100, 200 ns) or Automatically (25 ns for shallow depths and 50 ns for higher depths than 16 cm (8192 points)). Currently maximal 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 channel data-supporting device.**

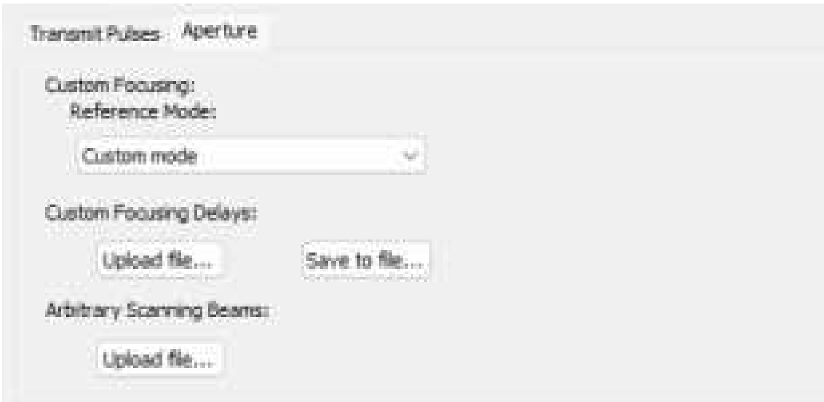
1.3. Channel RF Data Tab

Channel RF Data Tab contains controls that affect raw channel data. The controls are divided into taking effect on 1) Transmit control and 2) Receive control of channels. NOTE: by entering into custom modes in Transmit control you can alter acoustic output values so you cannot use the device with biological organisms!!!! The screenshot of Channel RF Data controls is shown below:



<table>
<tr><th>Num</th><th>Component</th><th>Description</th></tr>
<tr><td>1</td><td>B-mode frames/Channel Data frames</td><td>The control allows adjustment of how many B-mode images are received for Channel data frames. 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 1:1 proportion, 1 means 2:1 (two channel data frames followed by single B frame), and so on.</td></tr>
<tr><td>2</td><td>Transmit controls</td><td>There are two Tabs under the Transmit Controls section:
1) Transmit Pulses – control of excitation waveform

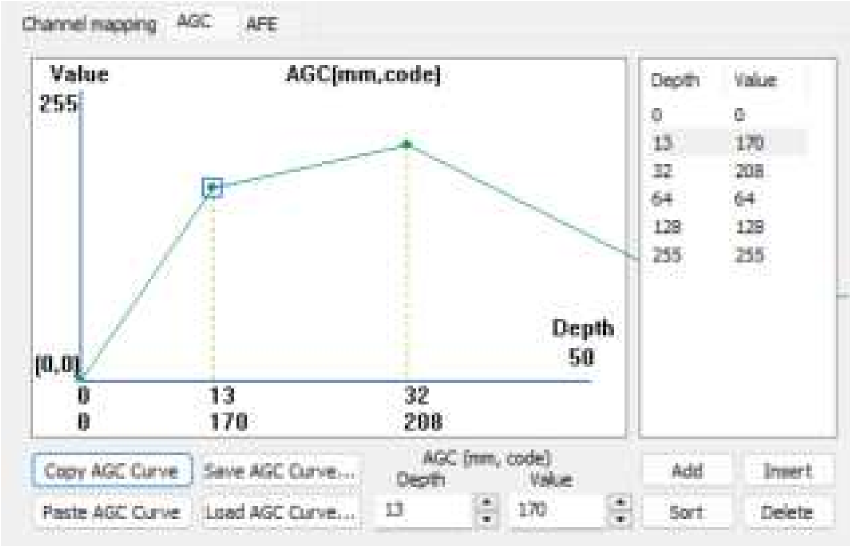
Half Periods [pulses] – number of half periods of pulse repetitions in an excitation sequence,
Half Period [ns] – the duration of a single excitation half period,
Half Width [ns] – indicates high-level voltage duration of the excitation pulse,
First Half Polarity – the polarity of the first half period might be Positive or Negative.
Pulse Current [A] – the amperage of pulser.

For setting Custom pulses the Reference mode control must be set to Custom, otherwise, the parameters are the same as one of the Reference mode from the list (i.e. B-mode). Transmit pulse control affects only channel RF data, but not B-mode data.
2) Aperture:


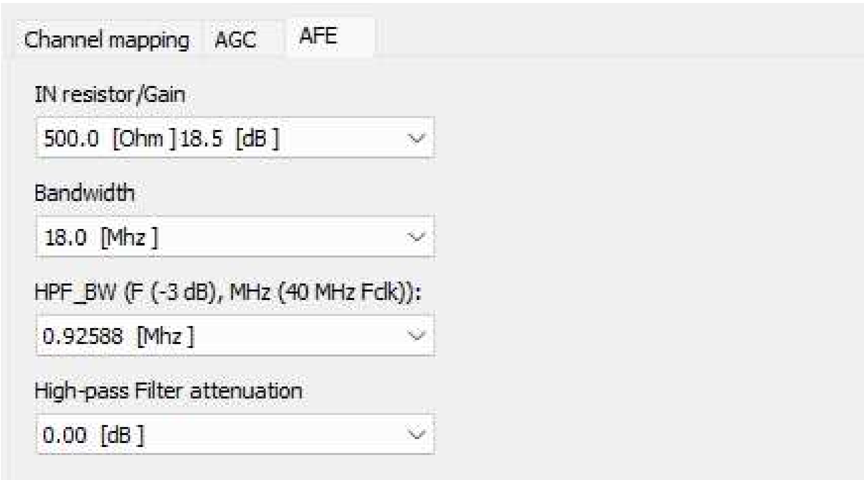
Custom focusing delays – possibility to use custom transmit focusing by uploading *.txt file of transmit delays for individual channels. The structure of the *.txt files with the delays for different scanning cases are provided and possibilities are described in Appendix I. In the beginning, it is possible to store 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 the file 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 the example is provided and possibilities are 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.</td></tr>
</table>

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's a compromise between FPS and image quality which could be restored by using 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 – analog depth-dependent gain control curve allows to adjust 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 the right mouse click nearby point to delete. The points could be added by using 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! AGC curve are connected with B Gain Control, Gain control shifts the programmed AGC curve down if decreased from 100 % linearly. 100 % gain means AGC as it is programmed, lower gain levels mean attenuated AGC by proportion to percent level.
3) AFE – analog front-end controls which effect on channel data could be controlled as well:



For the Artus scanner, there are 4 parameters:

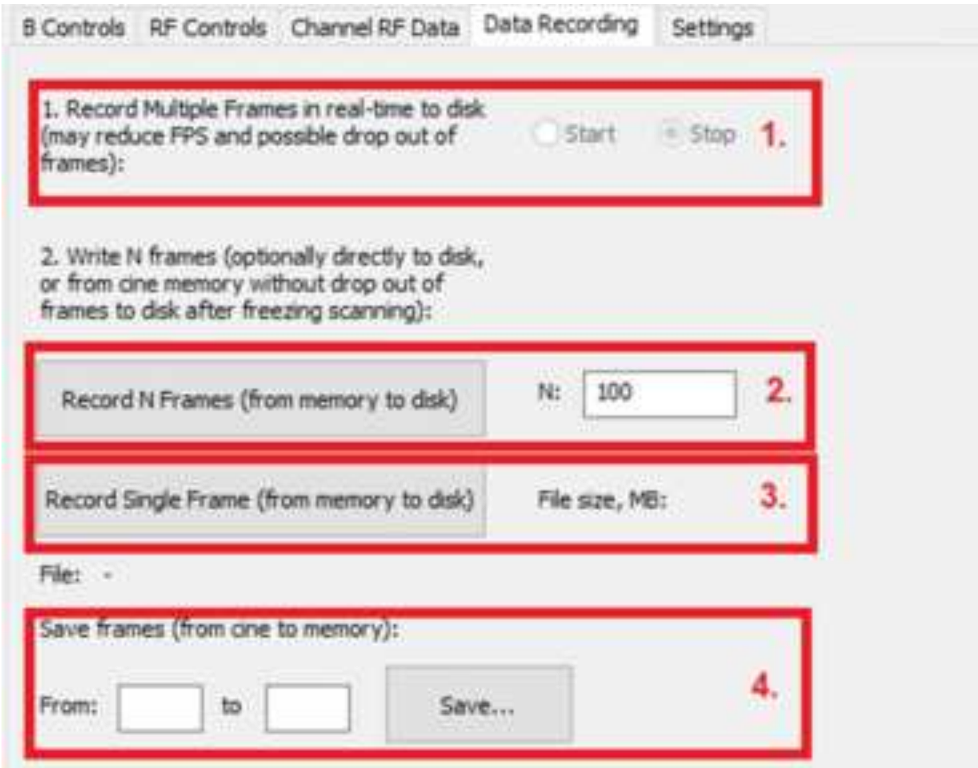
- In resistor value and gain [Ohm, dB] combined parameter, there are 8 allowed combinations of {R_{in}, Gain} in Artus AFE:
  { 100, 12.5},
  { 200, 12.5},
  { 400, 12.5},
  {1000, 12.5},
  { 50, 18.5},
  { 100, 18.5},
  { 200, 18.5},
  { 500, 18.5}.
- Low-pass anti-aliasing filter bandwidth [MHz], (4 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 0dB, -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.

1.4. Data Recording Tab

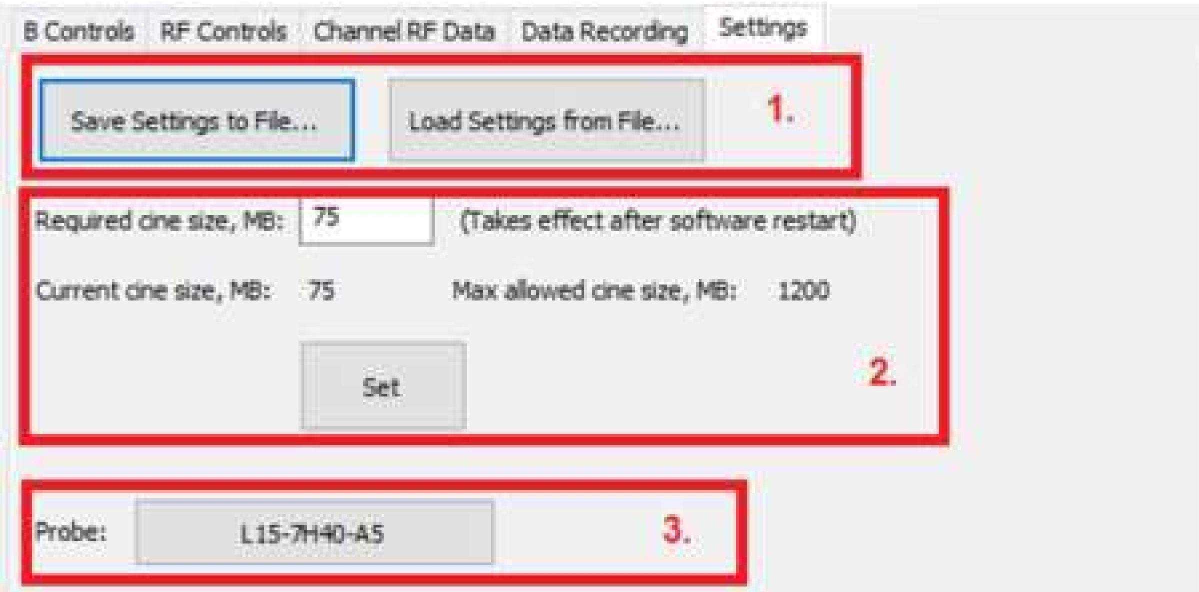
ArtUs RF Data Control II software allows recording raw data into *.bin files. There are two different structures of the files: 1) channel data and 2) beamformed RF data. Channel data can only be recorded retrospectively when scanning is frozen from Cine Loop memory, meanwhile for beamformed RF Data it is possible to record RF Data in real-time, just 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** allow to 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 could be controlled by observing indications of 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 disc in real-time during scanning, decrement of 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. For channel data mode active only after Freezing scanning.
3	**Record Single Frame**	There is an option to record a single RF frame (button Record Single Frame) which could be selected from a cine loop or just an actual frame during real-time scanning. For channel data mode active only after Freezing scanning.
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).

1.5. Settings Tab

Settings Tab allows to adjust Cine Loop size and to Save/Load used imaging settings into/from file, to choose probe if two ports Artus scanner is used



Num	Component	Description
1	**Save/Load Settings**	**Save Settings to File...** button creates the *.ini configuration file in the DIR where the *.exe file of the ArtUs RF Data Control program is located. The *.ini file contains used imaging parameters. Example of the file fragment:

<table>
<tr><td></td><td></td><td>

….
Load Settings from File button allows to reproduction of previously stored scanning settings by uploading the *.ini configuration file.</td></tr>
<tr><td>2</td><td>Cine buffer size</td><td>Possible to increase/decrease the size of the Cine Loop buffer (in MBs).

Note! Takes effect only after software restart.</td></tr>
<tr><td>3</td><td>Probe button</td><td>The Probe button lists the code of the active probe and options for probe selection for ArtUs with 2 ports (if two probes are connected).</td></tr>
</table>

1.6. About Tab

About Tab discloses contact info of TELEMED manufacturer.

2. Recording of RF data files

Currently, ArtUs RF Data Control II software allows the recording of the RF data to binary files for channel mode and for 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 some data acquisition parameters and information that is mandatory 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 could be recorded into binary files (*.bin). The filename contains acquisition time and date information, and the probe type code (**HH.MM.SS_DD-MM-YYYY_probe_code.bin**, i.e. "16.34.00_27-10-2017_L18-10H30-A4.bin"). The ***ArtUs*** RF Data Control SDK allows the recording of the 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 could 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 smaller window size allows to achieve 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 **RF0004**).
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
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 used scanning probe 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, at present 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
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 probe's surface (angle = 0 for linear array probes); 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 could 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 (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 discrete of Timestamp = 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 timestamp counter begins count from zero. Timestamps are in samples.
frame	int16	Number_of_RF_rows × Length_of_RF_row (Number_of_RF_rows × Length_of_RF_row × 2 bytes) for *source_ID=1, 2, 3;* *and* 2 × Number_of_RF_rows × Length_of_RF_row (2 × Number_of_RF_rows × Length_of_RF_row × 2 bytes) for *source_ID=4*	Single sub-frame RF data in 1D vector format (int16);

2.2. Structure of the channel data file

Channel data BIN file as beamformed RF data file contains 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 information that is mandatory for B-mode image beamforming from channel data. Channel data could only be written after freezing scanning – retrospectively from Cine Loop memory to preserve data transfer speed. The file structure for channel data is defined as follows:

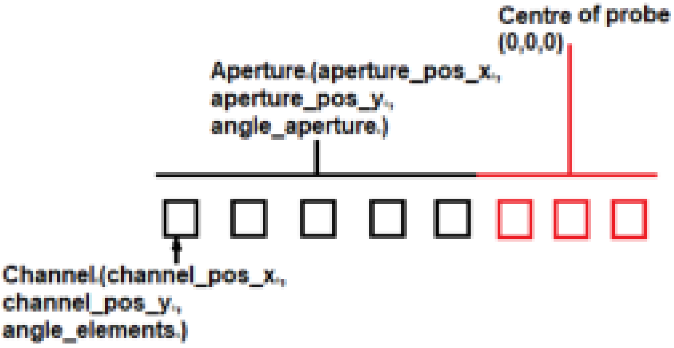
Contents of the file	Data type	Number of elements (bytes)	Description
RF file type	char	1 (6 bytes)	Channel RF file version (currently **CH0001**).
flag	int32	1 (4 bytes)	Flag which indicates if the tag of beam vectors position and start depth information exists (if exists flag = 1, otherwise flag = 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 final beam. This structure member is used when several beams are captured from the same position with different scanning set. 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 subframe actual for 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 4^{th} 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)	Maximal 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) respective to centre of the probe, • aperture_pos_y (in μm) respective to centre of the probe, • angle_aperture (in radians multiplied by 1000000) respective to centre of the probe, • dummy channels (if the channels are outside the aperture, what is actual for beams closer to probe edge, the number is negative and number of channels are declared, 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 are 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): • chanel_idx (0 – ChannelsPerBeam – 1), • channel_pos_x (in μm) respective to centre of aperture,

			• channel_pos_y (in µm) respective to centre of aperture, • angle_elements (in radians multiplied by 1000000) respective to centre of aperture. The information for each channel is arranged in the following order ($chanel\_idx_0$, $channel\_pos\_x_0$, $channel\_pos\_y_0$, $angle\_elements_0$, $chanel\_idx_1$, $channel\_pos\_x_1$, $channel\_pos\_y_1$, $angle\_elements_1$, …).
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 (value exists only if not custom transmit delays are selected)	int32	1 (4 bytes)	Start depth index in samples for the RF data window.
beam_postion_and_orientation (array exists only if not custom transmit delays are selected)	int32	BeamsPerFrame × SubFramesNumber × 3× 4 bytes	Information of position and orientation for each ultrasound beam: • beam_position_x (in µm) respective to centre of probe, • beam_position_y (in µm), respective to centre of probe, • beam_angle (in radians multiplied by 1000000), respective to centre of probe. 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

For channel data mode few 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. This subsection provides a drawing below how these coordinates are related (example for linear probe). 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 respective to the center of the probe (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 probe center coordinates.


Centre of probe
(0,0,0)
Aperture.(aperture_pos_x.,
aperture_pos_y.,
angle_aperture.)
Channel.(channel_pos_x.,
channel_pos_y.,
angle_elements.)

3. Installation notes and PC requirements

Requirements for the programming environment are as follows:

- To successfully run ArtUs RF Data Control II software the x64-bit Windows (8, 10, 11) operating system must be installed on your computer.
- i5/i7/i9 CPU
- 16 GB RAM or more
- USB 3.0
- Connected one of TELEMED ultrasound scanners:
  - ArtUs EXT-1H with RF module, beamformed RF data support
  - ArtUs EXT-2H with RF module, beamformed RF data support
  - ArtUs USS-1H, beamformed and channel RF data support
  - ArtUs USS-2H, beamformed and channel RF data support
- ArtUs properly installed drivers (for installation requirements please check 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. Volkov
1.0.3	08/07/2024	Added more explicit description on sampling of RF data	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. By turning on one of these modes, you will receive certain limitations for custom delays file uploading. For B Standard and B Compound modes, only the same set of custom delays for each scanned beam could be applied, 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 probes.
	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 is actual 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 used probe. 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 could be applied for each beam and this number is N.
	SubFrames Number	Actual for 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 (actual in case of compound scanning, otherwise 0), Beam.N – beam index, SubBeam.N – subbeam index. After the indexing information goes list of aperture elements and delay in samples for each, 0 delay – means that the element will not be active in a transmission, non-zero integer number delay turns excitation on. The sample is 6.25 ns. (for obtaining delay in time units you must multiply i.e. 800*6.25). The possible range of delays in samples 1 – 4096.

- 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.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=0
Element.9=0
Element.10=0
Element.11=0
Element.12=0
Element.13=0
Element.14=0
Element.15=0
Element.16=0
Element.17=0
Element.18=0
Element.19=0
Element.20=0
Element.21=0
Element.22=0
Element.23=0
Element.24=0
Element.25=0
Element.26=792
Element.27=795
Element.28=797
Element.29=798
Element.30=799
Element.31=800
Element.32=800
Element.33=799
Element.34=798
Element.35=797
Element.36=795
Element.37=792
Element.38=0
Element.39=0
Element.40=0
Element.41=0
Element.42=0
Element.43=0
Element.44=0
Element.45=0
Element.46=0
Element.47=0
Element.48=0
Element.49=0
Element.50=0
Element.51=0
Element.52=0
Element.53=0
Element.54=0
Element.55=0
Element.56=0
Element.57=0
Element.58=0
Element.59=0
Element.60=0
Element.61=0
Element.62=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.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=0
Element.9=0
Element.10=0
Element.11=0
Element.12=0
Element.13=0
Element.14=0
Element.15=0
Element.16=0
Element.17=0
Element.18=0
Element.19=0
Element.20=0
Element.21=0
Element.22=0
Element.23=0
Element.24=0
Element.25=0
Element.26=645
Element.27=645
Element.28=645
Element.29=645
Element.30=645
Element.31=645
Element.32=956
Element.33=952
Element.34=947
Element.35=942
Element.36=937
Element.37=931
Element.38=0
Element.39=0
Element.40=0
Element.41=0
Element.42=0
Element.43=0
Element.44=0
Element.45=0
Element.46=0
Element.47=0
Element.48=0
Element.49=0
Element.50=0
Element.51=0
Element.52=0
Element.53=0
Element.54=0
Element.55=0
Element.56=0
Element.57=0
Element.58=0
Element.59=0
Element.60=0
Element.61=0
Element.62=0
Element.63=0
[Frame.0.Beam.1.SubBeam.0]
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=0

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

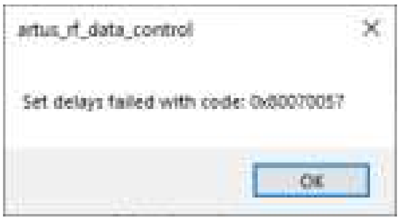
- B Compound scanning mode example

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

[Frame.0.Beam.0.SubBeam.0]
Element.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=0
Element.9=0
Element.10=0
Element.11=0
Element.12=0
Element.13=0
Element.14=0
Element.15=0
Element.16=0
Element.17=0
Element.18=0
Element.19=0
Element.20=0
Element.21=0
Element.22=0
Element.23=0
Element.24=0
Element.25=0
Element.26=823
Element.27=820
Element.28=816
Element.29=812
Element.30=808
Element.31=803
Element.32=798
Element.33=792
Element.34=786
Element.35=779
Element.36=772
Element.37=764
Element.38=0
Element.39=0
Element.40=0
Element.41=0
Element.42=0
Element.43=0
Element.44=0
Element.45=0
Element.46=0
Element.47=0
Element.48=0
Element.49=0
Element.50=0
Element.51=0
Element.52=0
Element.53=0
Element.54=0
Element.55=0
Element.56=0
Element.57=0
Element.58=0
Element.59=0
Element.60=0
Element.61=0
Element.62=0
Element.63=0
[Frame.1.Beam.0.SubBeam.0]
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=0
Element.9=0
Element.10=0
Element.11=0
Element.12=0
Element.13=0
Element.14=0
Element.15=0
Element.16=0
Element.17=0
Element.18=0
Element.19=0
Element.20=0
Element.21=0
Element.22=0
Element.23=0
Element.24=0
Element.25=0
Element.26=808
Element.27=808
Element.28=807
Element.29=806
Element.30=804
Element.31=802
Element.32=799
Element.33=796
Element.34=792
Element.35=788
Element.36=783
Element.37=778
Element.38=0
Element.39=0
Element.40=0
Element.41=0
Element.42=0
Element.43=0
Element.44=0
Element.45=0
Element.46=0
Element.47=0
Element.48=0
Element.49=0
Element.50=0
Element.51=0
Element.52=0
Element.53=0
Element.54=0
Element.55=0
Element.56=0
Element.57=0
Element.58=0
Element.59=0
Element.60=0
Element.61=0
Element.62=0
Element.63=0
[Frame.2.Beam.0.SubBeam.0]
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=0
Element.9=0
…………….

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



Appendix II. Arbitrary beams file structure

File structure for arbitrary beams is comparatively similar as in the case of 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, 152, and 153. Indices correspond to certain spatial positions.

```
[Beams_header]
Scan Type=0
Beams Number=5
[Beams Indexes]
Beam.0=32
Beam.1=96
Beam.2=160
Beam.3=152
Beam.4=153
```

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