User's Guide

mmWave Studio GUI

This document outlines the mmWaveStudio Graphical User Interface details and instructions for software start up. Operating procedures for Radar API and Post-Processing utility is also explained briefly in this user's guide.

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1. Introduction

The mmWaveStudio GUI is designed to characterize and evaluate the TI Radar devices. The mmWave device is configured and controlled from the mmWaveStudio by sending commands to the device over SPI. ADC data is captured using DCA1000 EVM or the TSW1400 EVM board and the data is processed in Matlab and the results are displayed in the GUI.

mmWaveStudio GUI utilizes C DLL and a set of API's to communicate from the GUI to the device through FTDI FT4232H device. The FT4232H is a USB 2.0 Hi-Speed (480 Mb/s) to UART IC. It has the capability of being configured in a variety of industry standard serial or parallel interfaces. The FT4232H features 4 UARTs. Two of these have an option to independently configure an MPSSE engine; this allows the FT4232H to operate as two UART/bit-bang ports plus two MPSSE engines used to emulate JTAG, SPI, I2C, bit-bang or other synchronous serial modes.

Key features of the mmWaveStudio GUI are

- Board Control (SOP Change, Reset Control)
- RS232 connection to device
- Firmware download over the RS232 interface
- Configuring the TI Radar device using the Radar API commands
- Interaction with DCA1000 EVM or TSW1400 EVM for raw ADC data capture
- Post-Processing of ADC data and visualization of the processed data

Refer to the TSW140x High Speed Data Capture/Pattern Generator Card User's Guide (SLWU079) for more information regarding the usage aspect of TSW1400 EVM and the related Software

Refer to DCA1000 EVM Capture Card User's Guide (SPRUIJ4) for more information regarding the usage aspect of DCA1000 EVM.

2. mmWaveStudio Installation and Startup

2.1 Installation

The following software should be installed before starting the mmWaveStudio

1. Install mmWaveStudio from the installer package
2. Install Matlab Runtime Engine (Version 8.5.1): It is used to run the Post-Processing utility within mmWaveStudio. https://in.mathworks.com/supportfiles/downloads/R2015a/deployment_files/R2015aSP1/installers/win32/MCR_R2015aSP1_win32_installer.exe
3. Install FTDI Drivers: FTDI USB Driver (mmwave_studio_<ver>\mmWaveStudio\ftdi) necessary to work with Radar device is installed. See section 2.3 for FTDI driver installation.

4. Install following software if you are using TSW1400 EVM

   a. Install HSDC Pro Software (for TSW1400 EVM only): It is used to work with TSW1400 EVM http://www.ti.com/tool/dataconverterpro-sw

> **NOTE:** HSDC Pro Software should be installed in Administrator Mode

   b. Install HSDC Pro radar device specific files

      i. If you are working with a single XWR1243 device

         - Copy ADC_FIRMWARE.rbf from mmwave_studio_<ver>\ mmWaveStudio\HSDCProFiles to ‘1400 details\Firmware’ folder in the HSDCPro installation. Don’t worry if the existing files are overwritten.
         - Copy AWR12xx_lvds_4Channel_ddr_4bit_par_centre_xx_bit.ini files from mmwave_studio_<ver>\ mmWaveStudio\HSDCProFiles to ‘1400 details\ADC files\’ folder in the HSDCPro installation

      ii. If you are working with XWR1642 device

         - Copy AWR1642_FIRMWARE.rbf from mmwave_studio_<ver>\ mmWaveStudio\HSDCProFiles to ‘1400 details\Firmware’ folder in the HSDCPro installation. Don’t worry if the existing files are overwritten.
         - Copy AWR16xx_lvds_4Channel_ddr_4bit_par_centre_xx_bit.ini files from mmwave_studio_<ver>\mmWaveStudio\HSDCProFiles to ‘1400 details\ADC files\’ folder in the HSDCPro installation

   c. Copy TSW1400_IID_Lookup.csv from mmwave_studio_<ver>\ mmWaveStudio\HSDCProFiles to ‘1400 details\’ folder in the HSDCPro installation

2.2 Startup

1. After the installation is complete, the GUI executable and associated files will reside in the following directory: C:\ti\mmwave_studio_<ver>\mmWaveStudio

2. Power up the xWR1xx DevPack (or DCA1000 EVM) and the xWR1xxx BOOST-EVM.

3. To start the GUI, click on the file called “mmWaveStudio.exe", located under C:\ti\mmwave_studio_<ver>\mmWaveStudio\RunTime folder.

> **NOTE:** mmWave Studio should to be started in Administrator Mode

> **NOTE:** If mmWave Studio shortcut has been created already, update the shortcut to the new installation path.

> **NOTE:** If you see the error message as shown in FIGURE 1 during opening mmWaveStudio in its output window, follow the steps mentioned below to solve this

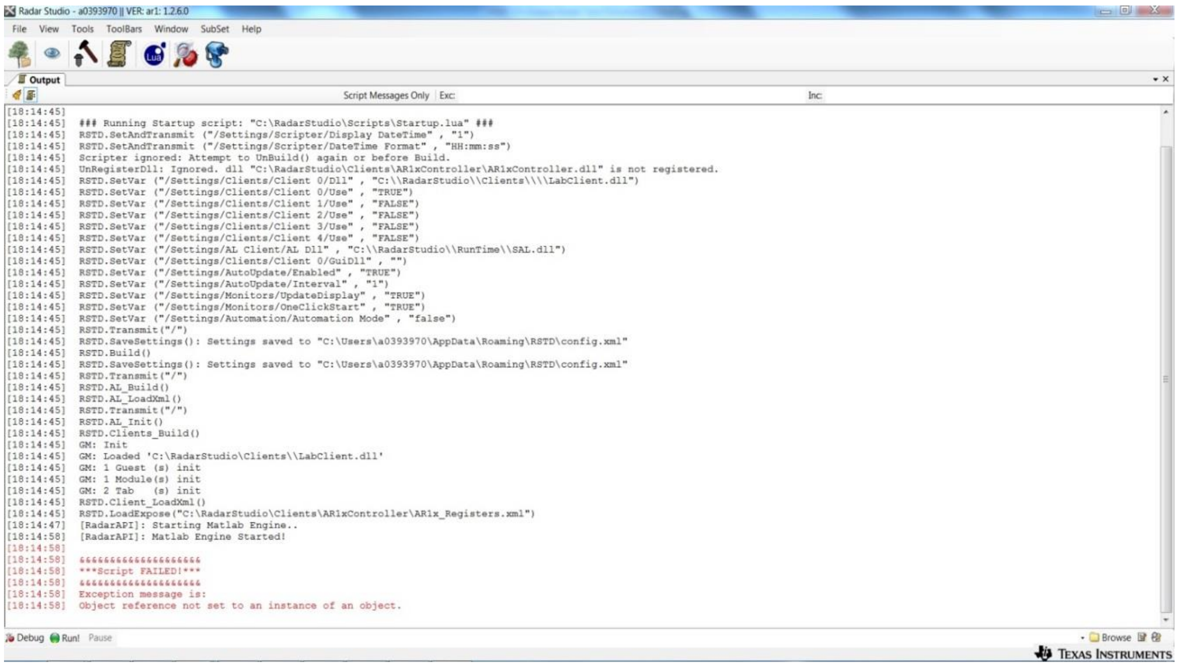


Figure 2.1. mmWaveStudio startup error message

a. Uninstall HSDC Pro

b. Install it again while TSW1400 board is connected through USB

c. Re-launch the mmWaveStudio GUI

2.3 USB Interface and Drivers

Once the USB is connected to the XWR1xx Dev Pack (or DCA1000 EVM), ensure to install the FTDI USB Drivers (mmwave_studio_<ver>\ftdi). After completion of the driver installation, COM ports will be available in Windows Device Manager as shown in FIGURE 2.6.

Once xWR1xxx EVM is connected to the MMWAVE-DEVPACK or DCA1000 EVM, connect DevPack or DCA1000 to PC using the USB cable provided and connect the power cable. Once done, there should be 4 additional COM Ports as shown in Figure 2.5

When the DevPack or DCA1000 EVM is connected for the first time to the PC, Windows maybe not be able to recognize the device and would come up as 'Other devices' in device manager as shown in Figure 2.2

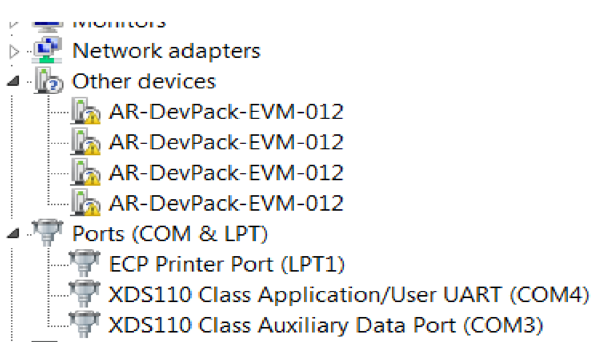


Figure 2.2. Device Manager (Other Devices)

In Windows device manager, right-click on these devices and update the drivers by pointing to the location of the FTDI driver as show in Figure 2.3

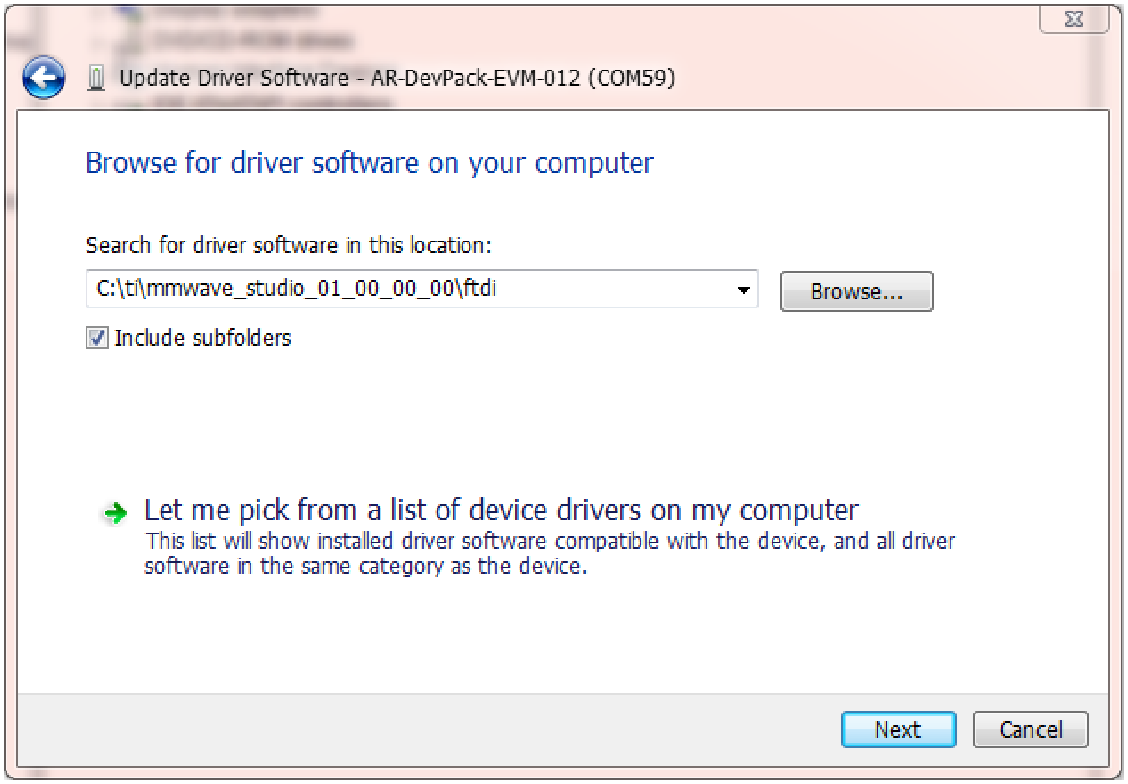


Figure 2.3 FTDI driver update

This must be done for all four COM ports. If after updating the FTDI driver, device manager still doesn't show 4 new COM Ports, as shown in Figure 2.4, you would need to update the FTDI driver once again.

Figure 2.4. Device Manager (USB Serial Port)

When all four COM ports are installed, the device manager recognizes these devices and indicates the COM port numbers, as shown in Figure 2.5

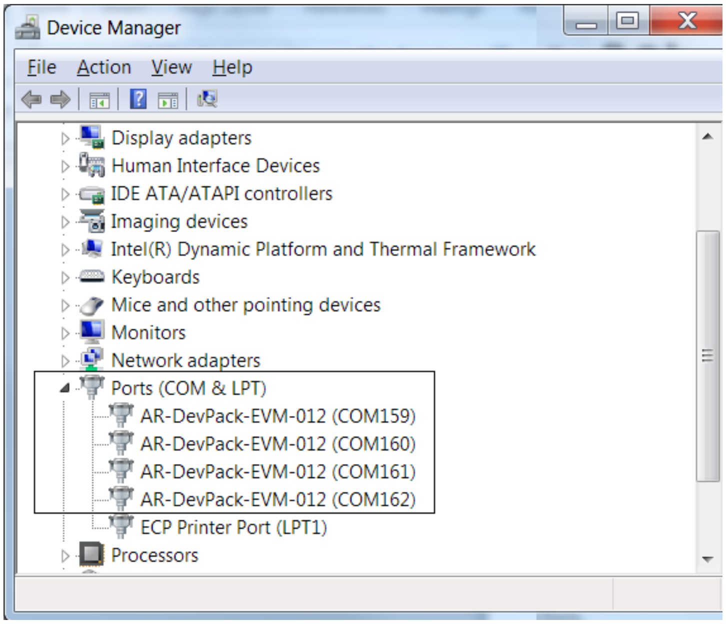


Figure 2.5. MMWAVE-DEVPACK or DCA1000 COM Ports

Next connect the USB cable from the XWR1xxx EVM to the PC. 2 COM ports will be enumerated with name XDS110. The mmWaveStudio should be connected to COM port numbered alongside the name XDS110 Class Application/User UART. In the following example, it is COM11. For more details, please refer to XWR12/XWR14/XWR16 EVM User Guide.

> **NOTE:** To update XDS110 USB driver, download and install XDS emulator software from this link [http://processors.wiki.ti.com/index.php/XDS_Emulation_Software_Package]

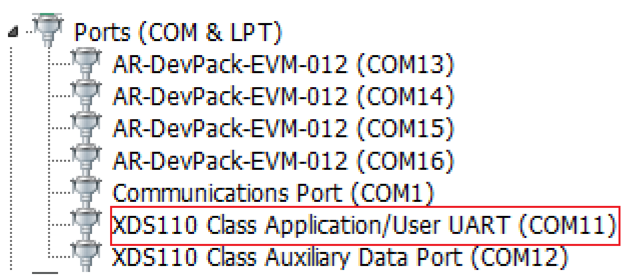


Figure 2.6. XWR1xx Dev Pack and EVM USB Enumeration

3. Using the DCA1000 EVM for capturing the raw ADC data

The DCA1000 EVM receives the LVDS data from XWR1xxx device and transfers the raw ADC data to the target PC via the Ethernet interface. The default destination Ethernet port address configured in the DCA1000 EVM is 192.168.33.30 and socket number is 4098. User has to ensure that target PC is set with this IP address to receive the raw ADC data from the DCA1000 EVM.

3.1 Raw ADC data capture

The LVDS data captured by the DCA1000 EVM is packetized and transferred over the Ethernet interface as UDP datagrams. These UDP datagrams are received by the target PC and it is written into file on the target PC. These UDP data grams contains meta data like packet sequence number, number of data bytes received until now which helps in determining if there were any packets which were not received in order or if there were any packets which were dropped.

The file name to store the raw ADC data is given by the user in the SensorConfig Tab. The DCA1000 EVM appends "Raw_n" to the file name given by the user. After 1 GB of capture, the DCA1000 EVM will start capturing the data into another file. Each subsequent file will have the test "Raw_n" appended to the user given filename where n is a number starting from 0. For example, if the user given filename is adc_data.bin, after the capture, user will see adc_data_Raw_0.bin, adc_data_Raw_1.bin etc. files in the mmWaveStudio\PostProc (default location of the raw ADC data files) folder.

3.2 Packet reorder and zero fill utility

Due to the Ethernet protocol, the file received by the DCA1000 EVM may not contain the UDP packets in correct order. There could be scenarios when the data is missed and not captured in the file. The packet reorder and zero fill utility will scan through the raw captured file and re-arrange the packets in correct order and in case of any missing packets; it will fill an equal amount of zeros in the file. This utility also removes the meta data and the output now contains the raw ADC data as transferred by the XWR1xxx device. The output of the packet reorder and zero fill utility is then given to matlab post processing for further processing and visualization.

NOTE: The matlab post processing utility in mmWaveStudio processes only the first captured raw ADC file successfully. For processing other files, user will have to develop his own processing and visualization routines.

The user can remove the packet header and packet sequence number from the received data using the mmwave_studio_<ver>\mmWaveStudio\PostProc\Packet_Reorder_Zerofill.exe utility. The usage of the script is as follows

Packet_Reorder_Zerofill.exe <InputFileName> <OutputFilename> <LogFile>

The format of the raw captured file after removing the meta data is explained in Section 22.

4. mmWaveStudio User Interface

Invoke mmWaveStudio.exe from C:\ti\mmwave_studio_<ver>\ mmWaveStudio\RunTime\mmWaveStudio.exe. When the mmWaveStudio GUI software is started, the initial setup screen appears and the main window appears as shown in FIGURE 4.1.

The GUI version is reported in the upper left corner of the GUI.

NOTE: If Matlab RunTime 8.5.1 is not installed prior to mmWave Studio invocation, error will be displayed saying Matlab Post Processing cannot be performed.

The mmWave Studio Main window has the following sections:

- Radar API Window
- Output Window

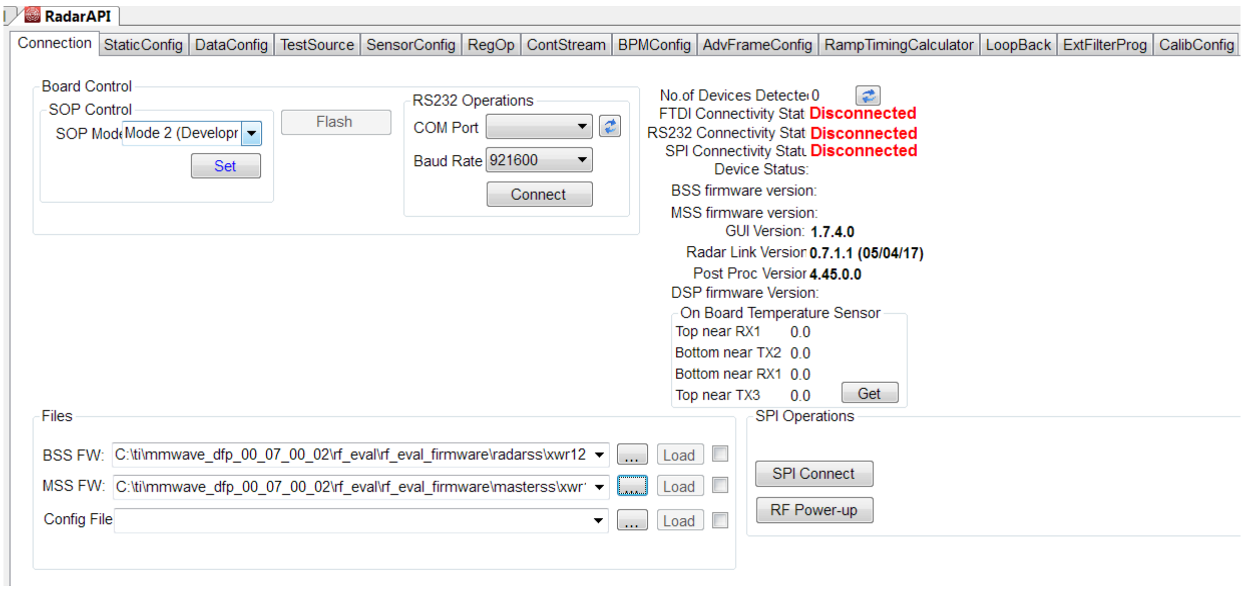


Figure 4.1. mmWaveStudio Main Window

Each of the above sections is described in detail in the forthcoming sections.

4.1 Menu Bar

The mmWaveStudio Main window has the following options in the Menu bar

4.1.1 File Menu

Exit: Exits the application and saves the setup (all current API configurations are stored locally in the PC which can be loaded back again).
Exit without saving layout: Exits without saving the current application setup.

4.1.2 View Menu

- The View menu opens the output window and LUA Shell window
- It also shows and hides toolbars and the status bar.

4.1.3 Tools Menu

Lock layout: Locks and unlocks the current layout. Once the layout is locked, the windows cannot be moved around.

Register DLLs to LUA: Using this option, any module developed in either C/LUA/C# can be loaded as a DLL. The APIs available (exposed) in the module can be called though LUA Shell. Refer to MSDN and LUA Help for creating libraries to be callable by LUA.

4.1.4 ToolBars Menu

Using this option, user can create shortcut buttons to associate frequent used actions in the form of LUA scripts. The below procedure details creating user defined button using the ToolBars menu.

1. Click *New.* The following dialog appears as shown in

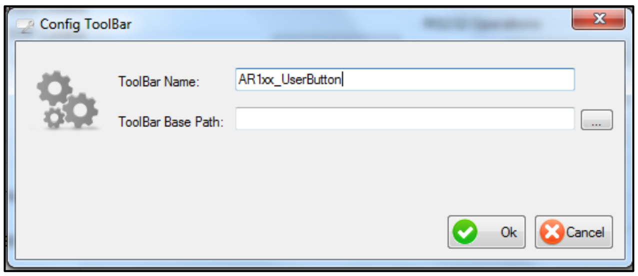


Figure 4.2. Config ToolBar

ToolBar Name – Sets the name for the ToolBar.

ToolBar Base Path – (optional) Defines a base path to search for the scripts which will be called via the toolbar's buttons.

> **NOTE:** Each Toolbar's configuration is saved in an XML file under %AppData%\RSTD\ToolBars folder

2. Set the ToolBar Name and click the OK button.
3. Click on the <new> button in the newly created toolbar.

Figure 4.3. Edit Button

4. This opens the User Button Configuration window

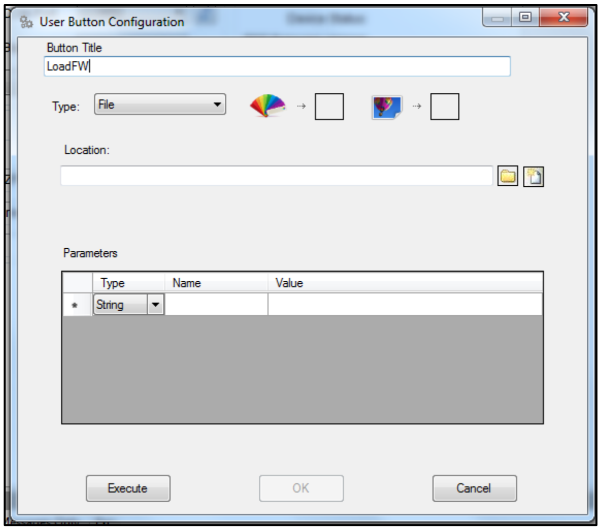


Figure 4.4. Button Config

5. Fill in the **Button Title** with a name for the button, and **Location** with the full path of the script you wish to run and click the **OK** button.
6. Clicking on the newly created button will execute the script it references.
7. Right-clicking on it will open a menu dialog with several options.

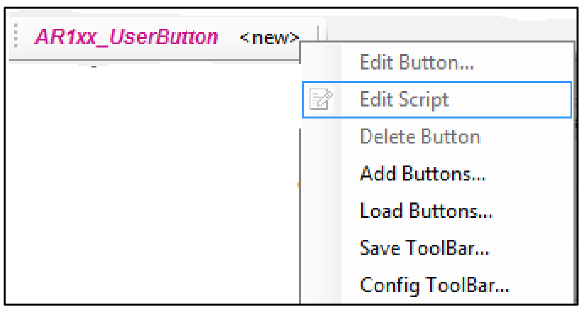


Figure 4.5. Edit User Defined Script

- **Edit Button** - Change the button's settings.
- **Edit Script** – Open the referenced script in your default text editor.
- **Debug Script** – Open the referenced script in the text editor.
- **Delete button** – Delete the user button.
- **Add Buttons** – Add buttons from another toolbar configuration file.
- **Load Buttons** – Load buttons from another toolbar configuration (clears existing buttons)
- **Save Toolbar** – Save the toolbar configuration to selected location (in xml format).
- **Config Toolbar** – Change the toolbar settings.

4.1.5 *Window Menu*

The Window menu shows open windows in the application.

4.1.6 *Help Menu*

The Help menu shows information about the current version of the application.

4.2 Radar API Window

As soon as the mmWaveStudio GUI is opened, the Radar API window appears as shown in FIGURE 4.6. Radar API Window is the primary tab through which the mmWave device's functionality can be verified. Also, the mmWave device is configured and controlled from the mmWaveStudio by sending commands to XWR1xxx device over SPI by interfacing through C DLL. Once the ADC data is captured using TSW1400 board, the post processing is done and plots are available in the GUI by interfacing with Matlab DLL.

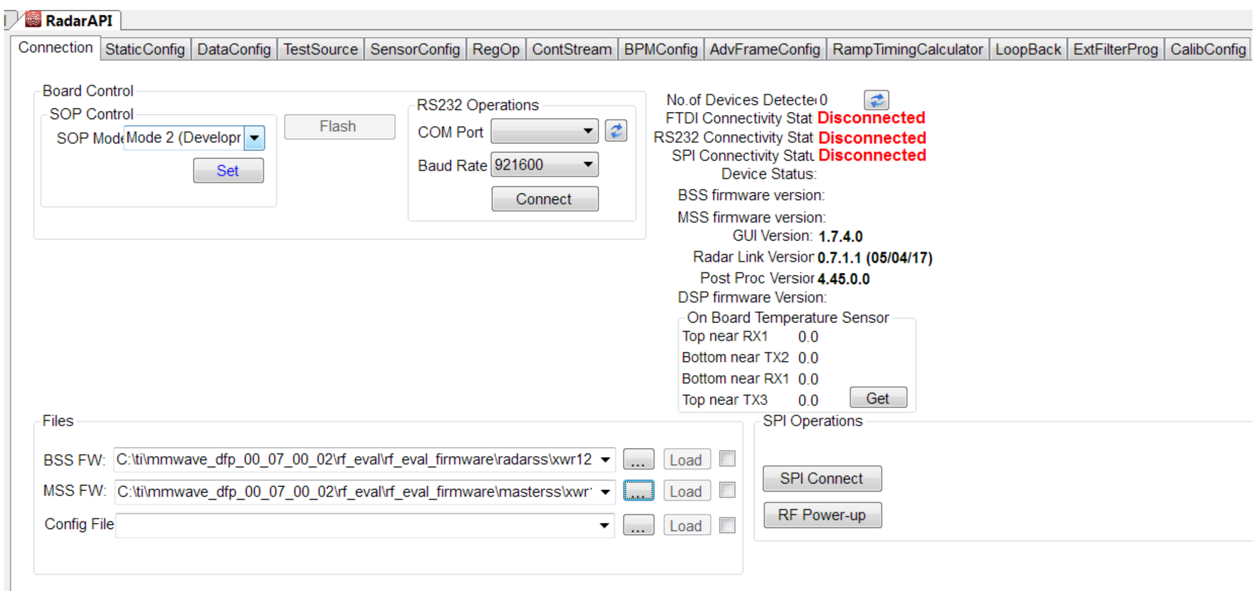


Figure 4.6. Radar API Window

In the Radar API window, the following tabs are available for communication with the Radar Device:

1. Connect
2. Static Config
3. Data Config
4. Sensor Config
5. RegOp
6. ContStream
7. BPM Config

8. AdvFrame Config
9. Calib Config
10. RampTimingCalculator
11. LoopBack
12. Calib Config

4.3 Output Window

The mmWaveStudio GUI components are dockable. Click View from the Menu bar, select output option. The output window also appears along with the main window. Select the output tab and drag to the section where you wish to dock. The output window docking is shown in the FIGURE 4.7.

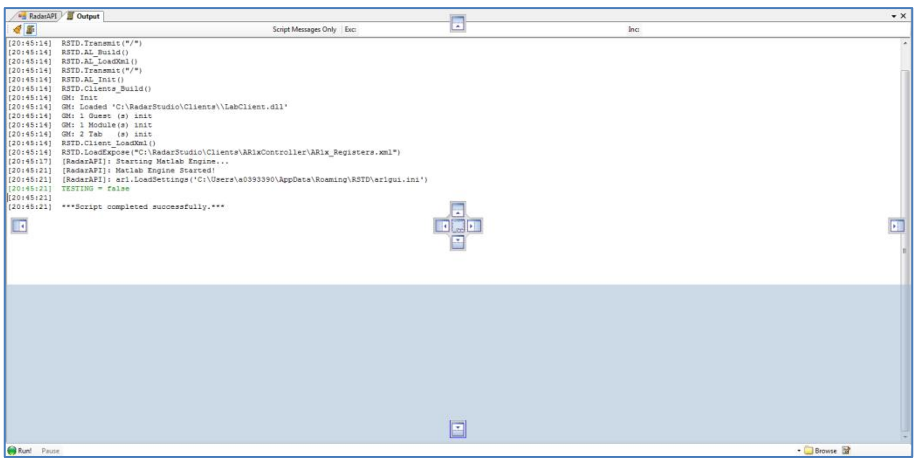


Figure 4.7. Output Window Docking

- The Output Window captures the user initiated actions along with timestamp.
- Both the logs and the script commands are available in the Output window.
- The script commands can be used to create custom LUA scripts and later run from the Run toolbar
- Also, upon an error or if the application is not responding, the error logs can be accessed by Right Clicking on the Output window.

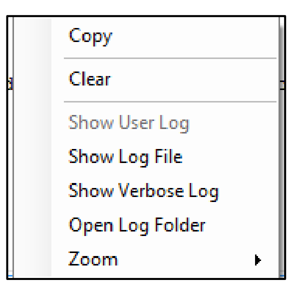


Figure 4.8. Output Window Log

4.4 LUA Shell

LUA Shell is used to execute LUA script commands, perform LUA operations. Click **View → LUA Shell** in the mmWaveStudio main window. The LUA Shell window appears as follows:

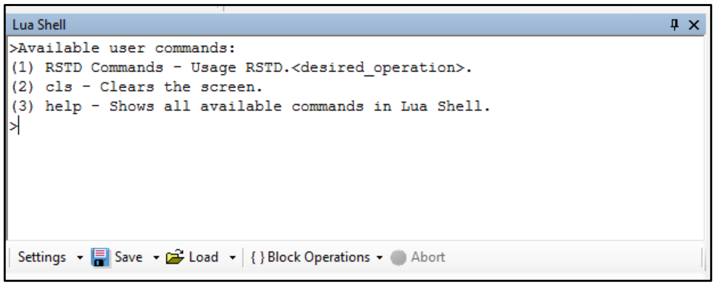


Figure 4.9. LUA Shell window

1. Running "help ar1" in the Lua Shell will list the functions contained under the ar1 module specific to Radar.
2. Running "help RSTD" in the Lua Shell will list the functions contained under the mmWaveStudio module.
3. Pressing Escape key - while the mouse cursor is on the last line deletes this line (last line only)
4. Running the 'help' command on each function name will display information on that function (e.g. "help ar1.Connect")

NOTE: The LUA shell supports auto-completion with the tab key.

History command – Typing history command in the LUA Shell prompt shows all the commands being used by the user in current LUA Shell. By pressing Up-Arrow (↑) and Down-Arrow (↓), the recent commands can be accessed.

5. Automation/Scripting

The XWR1xx interface exposes functions to LUA, which can be used to test predefined sequences and automate functionality on the device. All these functions can be found under the ar1 module.

1. Whenever a command is issued in the GUI window, the equivalent script commands can be taken from the Output window and formed an automation script. For example, In the Static Config tab, when Channel and ADC Config command is sent, in the Output window, the script command is logged.

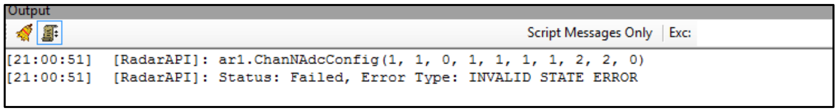


Figure 5.1. Command creation

2. The script commands start with ‘ar1’. The commands can be saved as a LUA file and used for automation.

3. To execute the LUA scripts, Browse and Select the script file and click Run

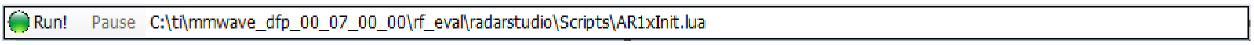


Figure 5.2. LUA Script execution

For more information on LUA Scripting language, please refer to: http://lua-users.org/wiki/ - The Lua wiki (See the Lua Directory inside for Lua tutorials) http://www.lua.org/manual/5.1/manual.html - Lua official Reference Manual

6. Radar API Tab Operations

The following sections briefly describe the operations in each tab of RadarAPI window

6.1 Connection Tab

When the mmWaveStudio is invoked, the Connect Tab appears as shown in FIGURE 6.1.

Figure 6.1. Connect Tab

Using this tab, user can perform

- Board control operations
- RS232 Operations
- Connectivity Status and content versions
- Firmware Download
- SPI Connection

CAUTION:

Before starting with any action on mmWaveStudio please make sure that GUI detects the device connected to PC. Value of ‘No of devices detected’ must be 1 else click on till it detects the device.

6.1.1 Board Control Operations

mmWaveStudio does board control operation of XWR1xxx device through XDS110 port on the XWR1xxx EVM.

SOP Control

NOTE: SOP control is only applicable when working with MMWAVE-DEVPACK. When using a DCA1000 EVM, use the jumpers on the XWR1xxx BOOST to control the SOP settings.

The XWR1xxx device implements a sense-on-power (SOP) scheme to determine the device operation mode. The device can be configured to power up in one of the three following modes:

- SOP2: Development Mode. This mode should be used for RF evaluation.
  - Set SOP Mode 2. For characterization and evaluation of XWR1xxx devices, always use SOP2 mode
  - Connect over RS232
  - Perform MSS (masterss) & BSS (radarss) Firmware Download
  - Perform SPI Connect
  - Issue API to the device

Once the USB connections to the board is intact, Select the SOP Mode and Click Set button. For SOP setting to be effective, Reset is also performed by the GUI.

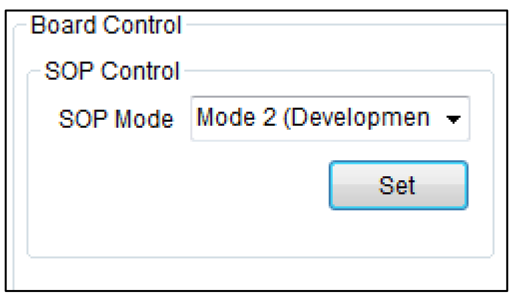


Figure 6.2. SOP Control

6.1.2 RS232 Operations

The serial port mode provides a direct PC connection of the XWR1xx device through the RS232 interface through the XDS110-USB interface. This mode allows firmware download and enables the device for characterization purposes. The serial port mode is also the default debug option on the Windows platform used to operate the device in TX and RX mode and using the read/write registers.

Once the SOP Mode is set, select the COM Port enumerated as 'XDS110 Class Application/User UART' for RS232 operations and click **Connect** button. The XDS110 port enumerates two ports as explained in USB interfaces and drivers section.

NOTE: Use the default Baud Rate of 921600 bps.

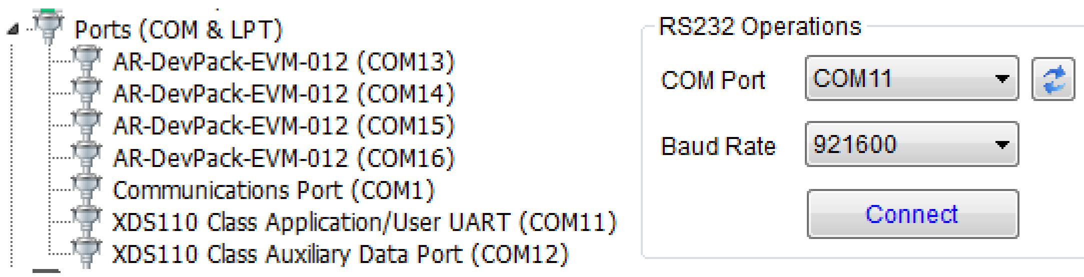


Figure 6.3. Serial Port Control and selecting the COM port for RS232 operations

Since the default baud rate configured in the device is 115200 bps, mmWaveStudio attempts to connect in 115200 baud rate, and then configures the RS232 module to re-establish connection in 921600 baud rate.

6.1.3 Firmware Download

The XWR1xx firmware is downloaded by the mmWaveStudio to the XWR1xx device while in Development mode (**SOP2**). The development mode provides a debug connection to the device using the dedicated RS232 interface such as writing and reading registers.

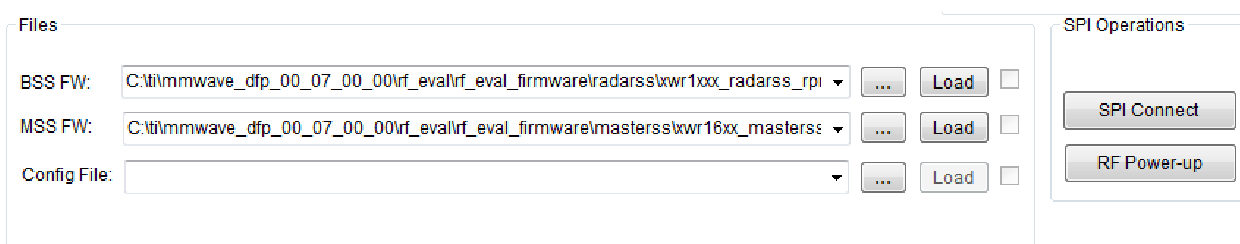


Figure 6.4. Firmware Download

The firmware download steps are as follows:

1. Select SOP Mode 2 (SOP selection is not needed when using DCA1000 EVM. User has to set the jumpers on xWR1xxx BOOST to set the device in SOP2 mode. Jumpers on SOP0 and SOP1 should be closed and SOP2 should be left open to set the device in SOP2 mode)

2. Connect over RS232

3. In the files area of the Connect tab, set the BSS and MSS firmware. Click the ... button and browse to the location of the file (e.g.

   mmwave_studio_<ver>\rf_eval_firmware\radarss\xwr16xx_radarss_rprc.bin for XWR16xx and

   mmwave_studio_<ver>\rf_eval_firmware\radarss\xwr12xx_xwr14xx_radarss_.bin for XWR12xx/XWR14xx devices

4. For MSS, load the binary file (e.g.

   mmwave_studio_<ver>\rf_eval_firmware\masterss\xwr16xx_masterss_rprc.bin for XWR16xx and mmwave_studio_<ver>\rf_eval_firmware\masterss\xwr12xx_xwr14xx_masterss.bin for XWR12xx/XWR14xx devices).

5. Click Load next to the BSS firmware. The mmWaveStudio application begins downloading the firmware files entered in the previous steps.

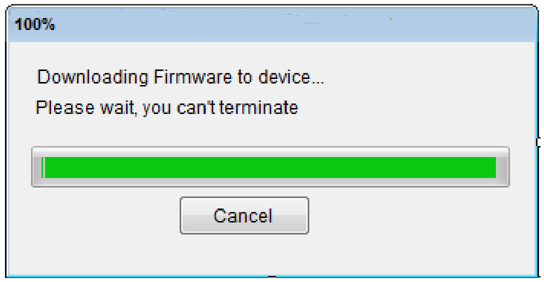


Figure 6.5. Firmware Download Progress

6. Once the BSS firmware download is complete, the Firmware version gets updated in the Status section

7. Click Load next to the MSS firmware update. The MSS Firmware version gets updated upon successful download.

6.1.4 SPI Connection & RF Power Up

The mmWave radar device communicates with the external host processor using the SPI interface. The mmWave device is configured and controlled from the external host processor by sending commands to mmWave device over SPI.

1. Once the MSS firmware boot up is complete, Click SPI Connect.

2. The SPI Connect button becomes SPI Disconnect indicating a success. If SPI connect does not succeed you may need to erase the serial flash and try again using the Uniflash tool.

3. Once SPI Connection is successful, Click RF PowerUp button. This command initiates BIST SS power up. Now, the user can issue commands to the device over SPI Communication interface. Go to section 7 to issue commands to the Radar device for RF evaluation.

7. Static Config Tab Operations

Using this tab, the user can set the following static device configurations:

1. RX and TX channel(s) needed for device operation

2. The data format of the ADC output (including the digital filtering)

3. RF LDO bypass option (Not used on EVMs)

> **NOTE:** RF LDO bypass option should not be enabled on EVMs. If RF LDOs are enabled, EVM may get damaged.

4. Low power options in the Sigma Delta ADC root sampling clock rate (reducing rate to half to save power in small IF bandwidth applications).
5. Frequency limits of operation
6. Trigger basic calibrations and RF initializations

After successful SPI Connection and RF Power Up, the Set buttons can be clicked in the order shown below:

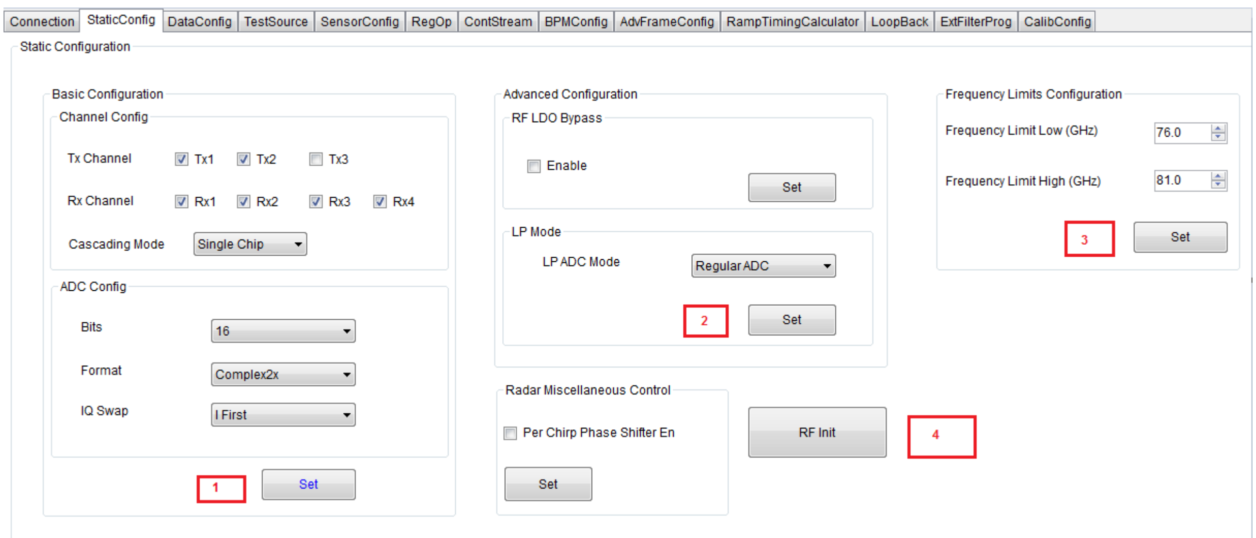


Figure 7.1. Static Config Tab

8. Data Config Tab Operations

Using this tab, the user can set the following Data Path configuration:

1. Data path format to transfer the captured ADC samples received over the receive chain to be transferred out to an external host.
2. Lane Configuration of the LVDS path to transfer Radar information to an external host.
3. Clock configurations of the LVDS lanes

Once the Static Configuration is complete, configure the Data Path by clicking Set button as follows

NOTE:

1. Matlab post processing supports data capture only in following modes
   a. 4 RX channel, 4 LVDS lanes
   b. 2 RX channels, 2 LVDS lanes
   c. 1 RX channel, 1 LVDS lane
2. Also, note that the RX channel number and LVDS lane number should match. For e.g. if user wants data from RX channels 1 and 3, then enabled LVDS lanes should be 1 and 3

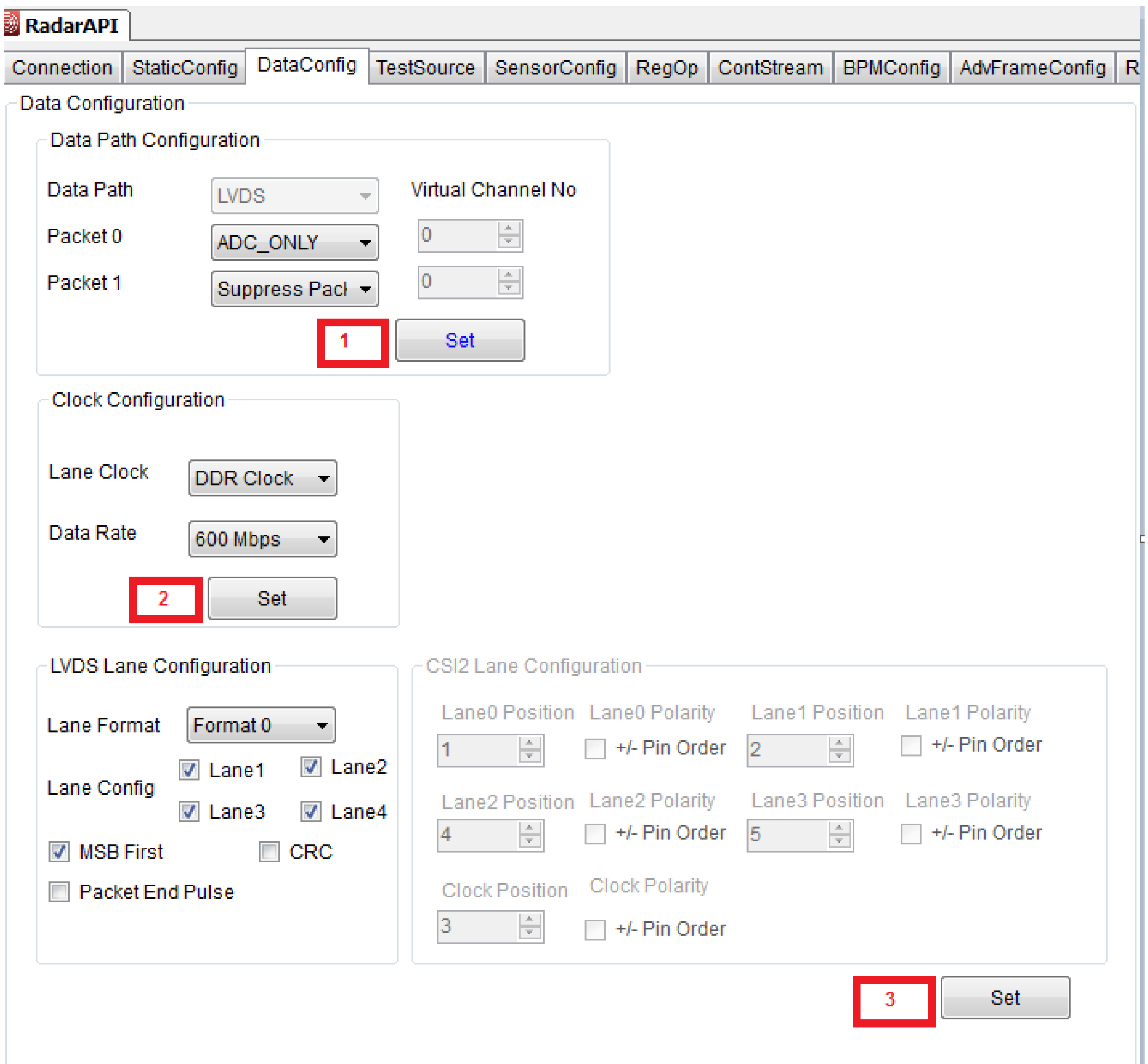


Figure 8.1. Data Config Tab

9. Sensor Config Tab Operations

Using this tab, the user can configure the chirp, profile parameter, associating defined profile to chirp index, frame configuration and other RF parameters.

9.1 Profile Config

Sets FMCW radar chirp profiles or properties (FMCW slope, chirp duration, TX power etc.). Since the device supports multiple profiles, each profile is defined in this sub block. Internal RF and analog calibrations may be triggered upon receiving this sub block and ASYNC_EVENT response sent once completed.

9.2 Chirp Config

This sub block contains chirp to chirp variations on top of the chirp profiles defined in the Profile config API. E.g. which profile is to be used for each chirp in a frame, and small dithers in FMCW start frequency and idle time for each chirp are possible and are defined here.

9.3 Frame Config

This sub block defines a frame, i.e. a sequence of chirps to be transmitted subsequently, the no. of frames to be transmitted, frame periodicity and how to trigger them.

> **NOTE:**
>
> 1. Ensure to open the HSDCPro software before issuing the Frame Configuration.
> 2. Matlab RunTime Engine (Version 8.5.1) and HSDCPro Software are pre-requisites for using the Post Processing utility available in mmWaveStudio GUI
> 3. Number of frames is zero for infinite samples

Follow the sequence as numbered in Sensor Configuration window as shown

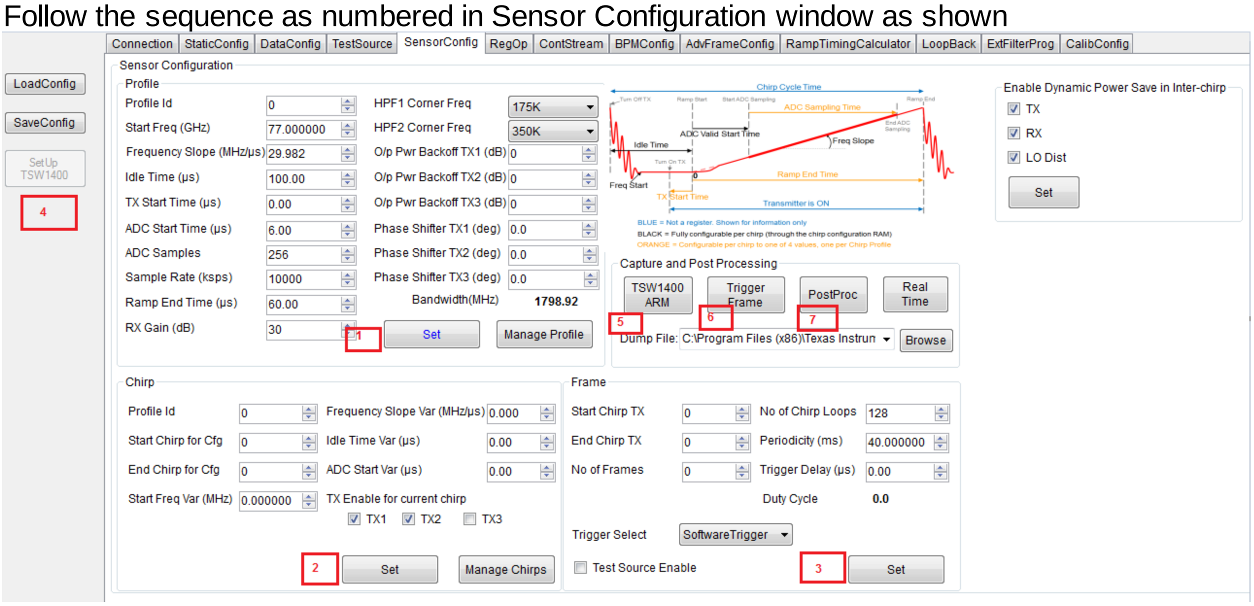


Figure 9.1. Sensor Config Tab

1. Open HSDCPro Software

2. Configure Profile
3. Configure Chirp
4. Configure Frame

> **NOTE:**
>
> 1. To capture raw ADC data in TSW1400, do not enable infinite framing mode (no. of frames = 0)
> 2. TSW1400 captures frames only for 10 seconds. Hence, ensure that total period of data capture (= frame periodicity x No. of frames) < 10 seconds

5. Set up TSW 1400 (ADC capture card). Wait until the setup completes.

   In case of DCA1000, follow these additional steps as shown below

   a. Set the PC IP address to 192.168.33.30
   Set Sub Net Mask as 255.255.255.0

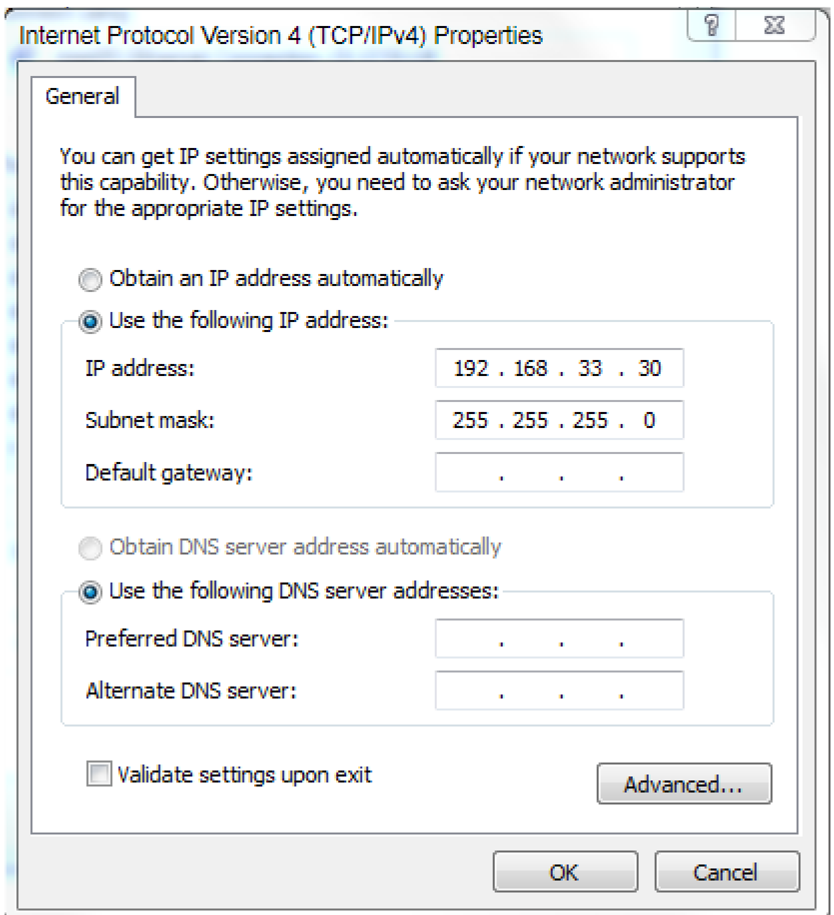


Figure 9.2. IP address configuration in case of DCA1000 EVM

   b. Click on Setup DCA1000 from the Connection tab

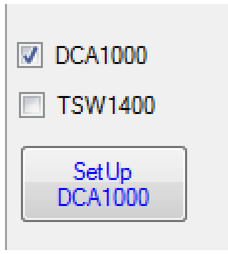


Figure 9.3. Setup DCA1000 configuration button from Connection tab

c. Ensure that FPGA version is read by the GUI as shown below

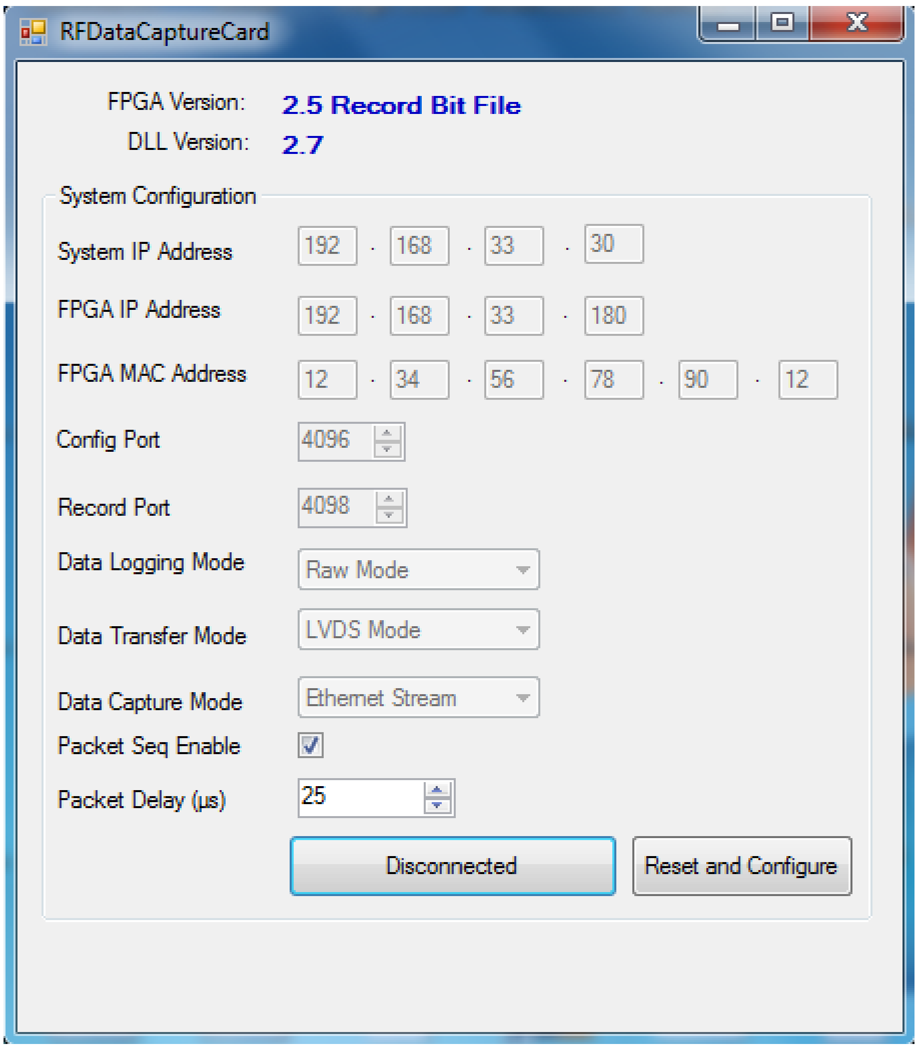


Figure 9.4. DCA1000 configuration window

6. ARM TSW1400 or DCA1000 ARM. Wait one second. Note that the text input field called 'dump file' allows one to select the file to which captured ADC data is to be stored.

7. Trigger Frame

8. Post Processing. Opens a 'radar post processing' tool that reads the 'dump file' and processes it, and finally displays a series of useful plots. The basic post processing window appears as follows

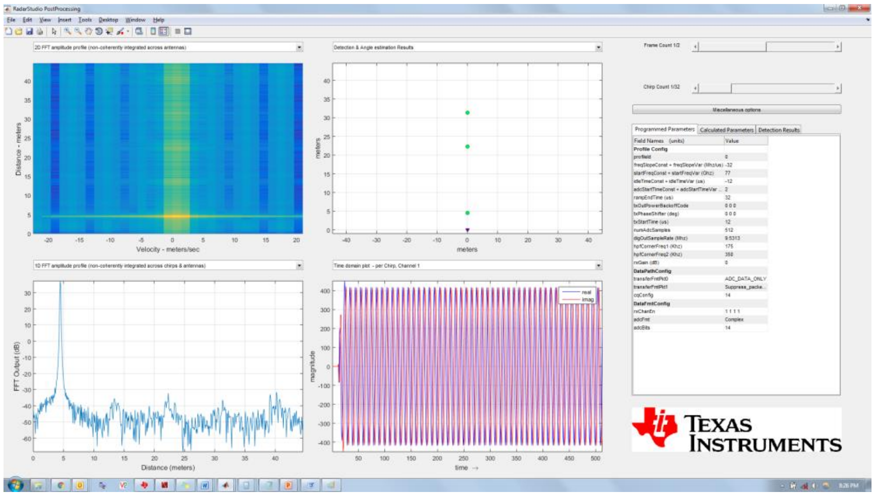


Figure 9.5. Post Processing in Matlab

> **NOTE:**
>
> 1. Steps 6, 7, 8 can be run multiple times.
> 2. If the number of samples to be collected changes (for e.g. if the number of frames is modified), then step 5 (setup TSW1400) needs to be retriggered.
> 3. The tool TSW1400 can only capture samples in multiples of 4096 (real samples per channel). If you have an odd number of samples to collect, please increase the number of frames, so that at least 4096 samples.
> 4. If the number of frames (in the frame config) is zero, then the number of frames that will be captured is 300. This will take a long time, so it is recommended that you provide a finite number of frames in the frame config

10. RegOp Tab

10.1 Register Operations Tab

Using RS232 communication interface, the device registers can be accessed using Register Operations tab. Also, the debug signals like APLL, synth can be configured using the Debug Signals section.

> **NOTE:** The Register Operation is enabled only upon successful connection over RS232 to XWR1xx device

<u>Register Read/Write</u>

Read/Write can be performed through bit fields and also 32-bit values.

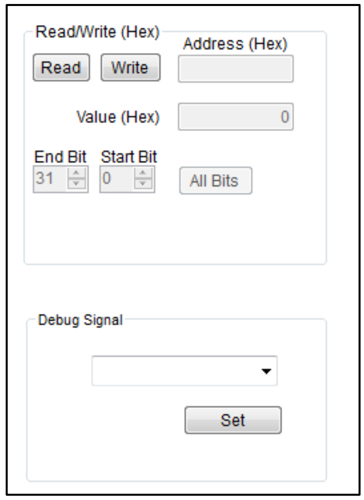


Figure 10.1. Register Read/Write

The figure shows the read/write registers, which is used to read and modify specific registers using their address and start/end bits for masking. Enter the address (in hex) and click the **Read** button to read it or set a value (in hex) and click **write** button to modify it. Click the All Bits button to mask the entire register.

10.2 Debug Signals

Select the debug signal and Click **Set** button. The debug signals available are:

1. NO MUX
2. APLL OUT
3. SYNTH OUT(2.5G)
4. SYNTH OUT(5G)

10.3 GPIO_0

The GPIO_0 can be used to bring out ADC valid signal which can be used to trigger the external instrument for synthesizer related measurements.

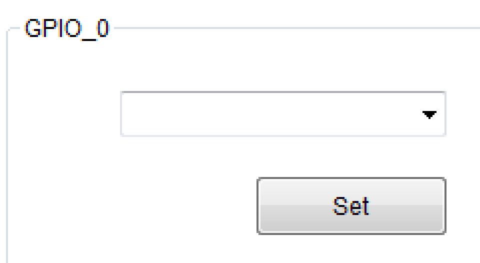


Figure 10.2. GPIO_0 option selection box

11. Continuous Streaming Tab Operations

The Continuous Streaming tab can be used for RF measurements. This tab contains the configurations of the data path to transfer the captured ADC samples continuously without missing any sample to an external host.

1. Set the StreamConfig parameters
2. Enable Continuous Streaming
3. Select Capture (to capture ADC samples) and then (optionally) select Display to process and display the captured ADC samples in the Radar Post Processing GUI.
4. Note: The number of samples to capture can be configured in the 'Basic Configuration for Analysis tool' Tab.
5. The remaining items in the 'Basic Configuration for Analysis tool' are not used by the 'Post Processing tool' but by the 'Analysis tool' which is a series of APIs used for 'Signal Analysis'.

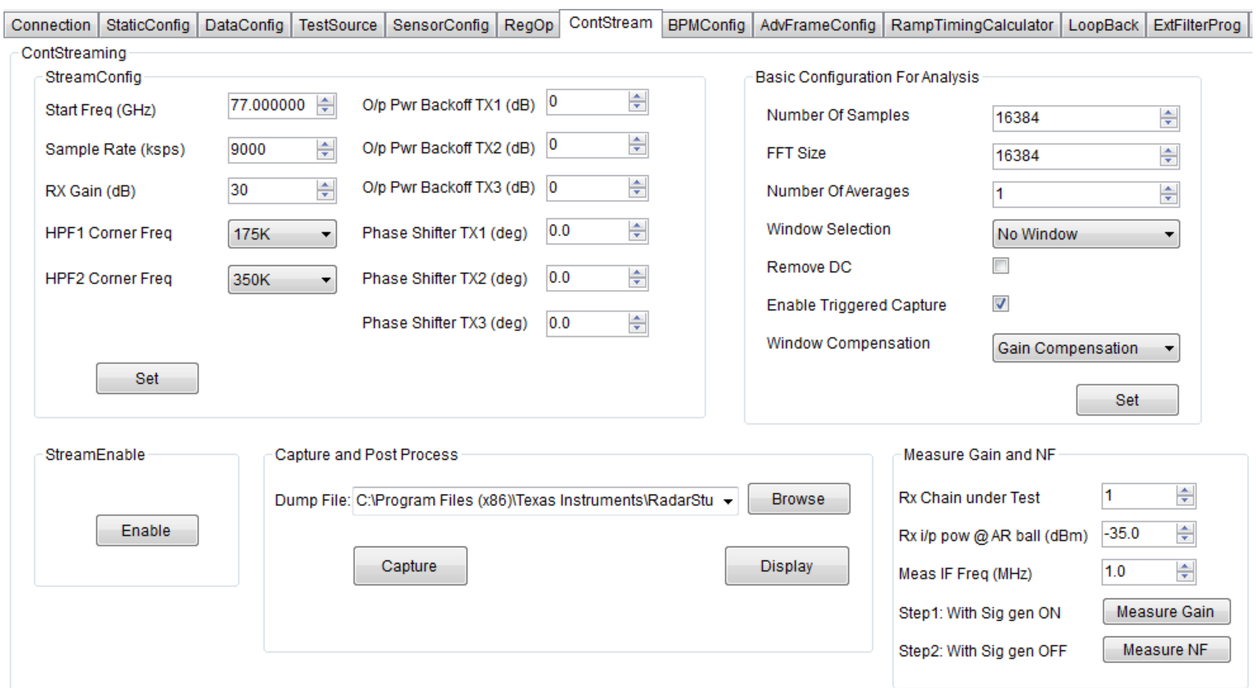


Figure 11.1. Continuous Streaming Tab

12. BPM Config Tab Operations

Using the BPM tab, static configurations related to BPM (Binary Phase Modulation) feature in each of the TXs is performed. Select the Start and End Index. Configure TX and Click **Set** button.

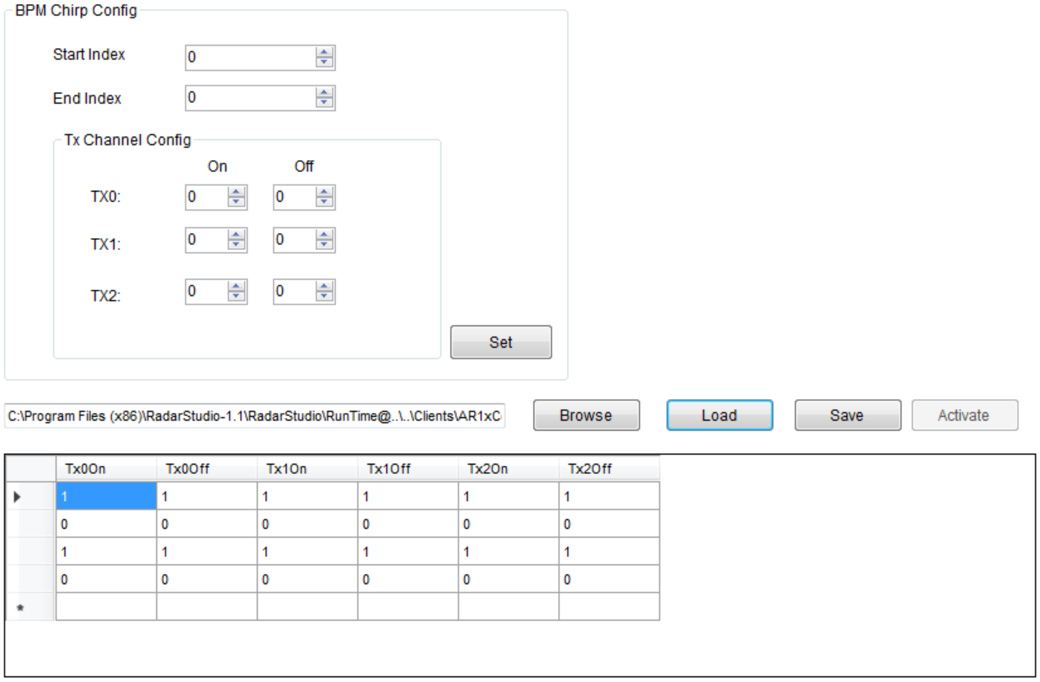


Figure 12.1. BPM Config Tab

13. Event Monitor Tab

This tab allows the users to read temperature sensor information and to read the external inputs fed to GPADC. Also, this tab allows reading of DFE statistics from the last frame.

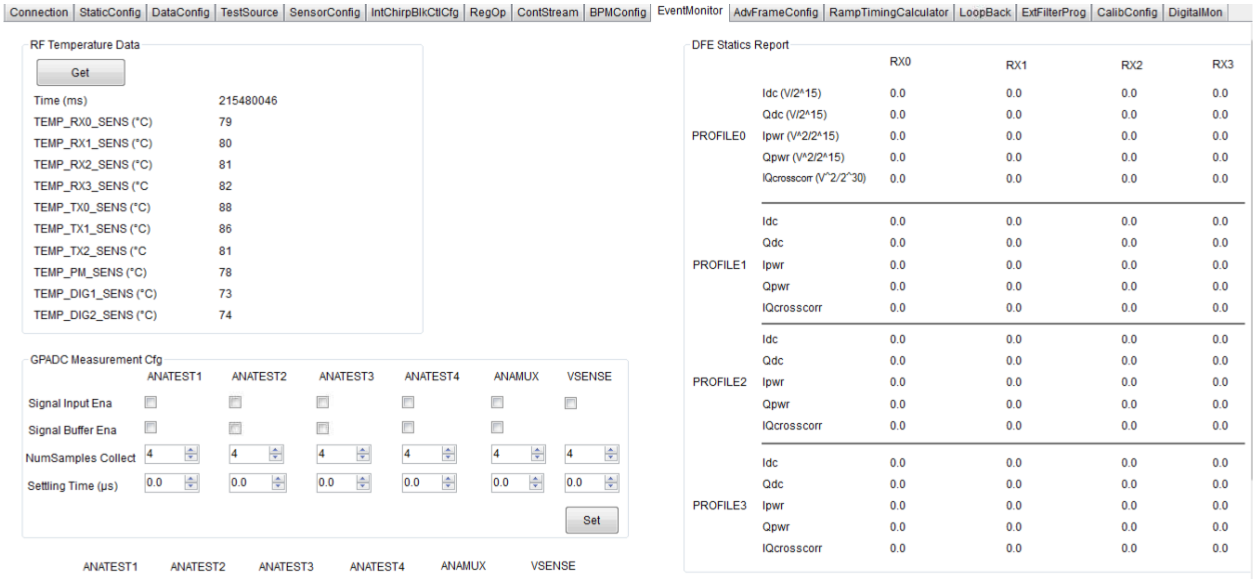


Figure 13.1. Event Monitor Tab

14. Advanced Frame Config Tab operations

This tab allows users with advanced frame configuration. Configuration options include sub-frames, bursts within each sub-frame, program burst loops, selection of chirp start index for the first chirp within the burst, configuration of sub-frame periodicity and burst periodicity. Also there are options to force a particular chirp profile within a sub-frame, selection of trigger source software/hardware and to program a trigger delay

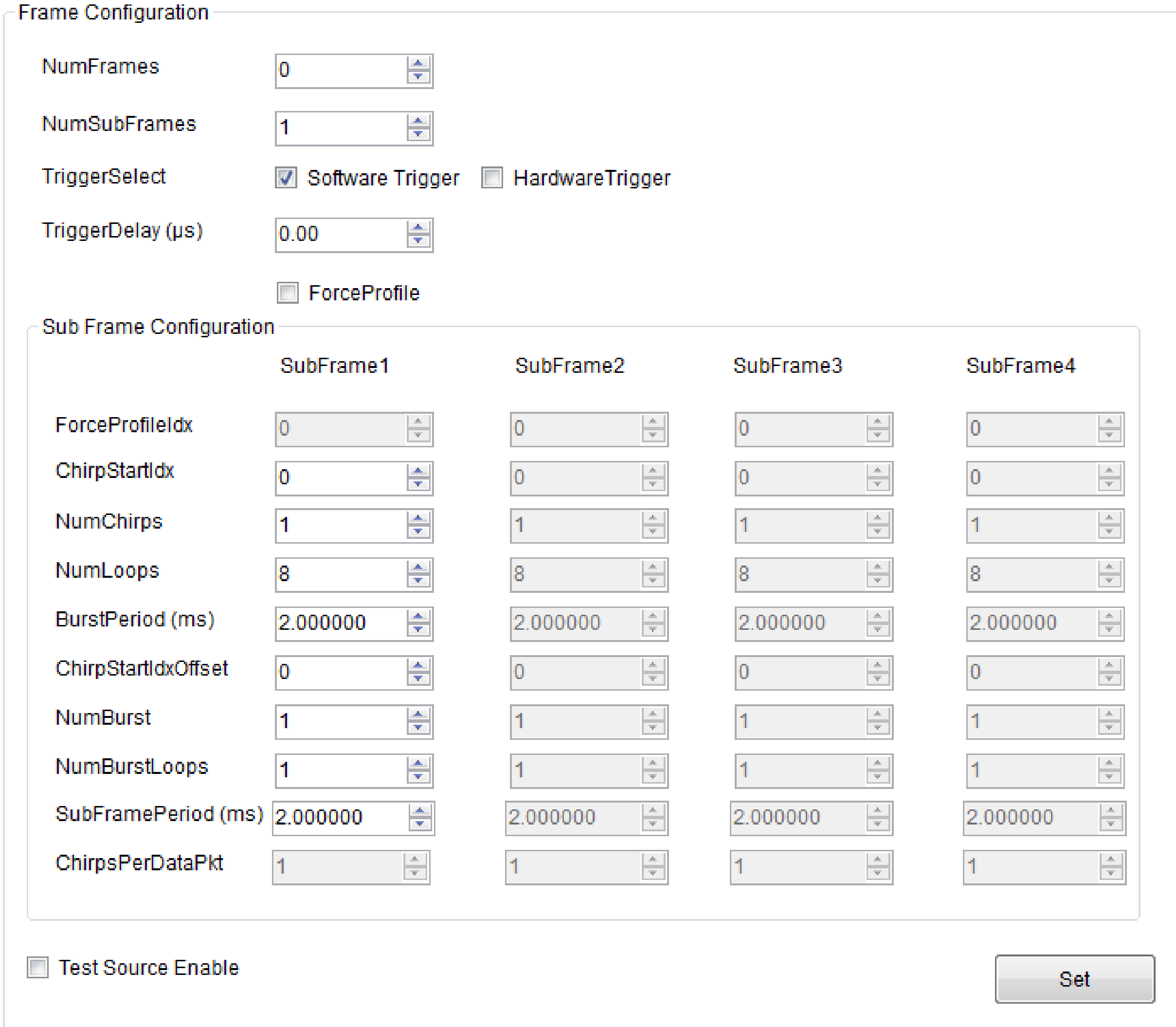


Figure 14.1. Advanced frame config tab

15. Rampgen Timing Calculator Tab

This tab gives the recommended timing parameters of the different chirp parameters like idle time, ADC start time, ramp end time and inter-chirp time etc. based on following inputs: ADC operating mode, DFE mode, slope, HPF corner frequencies and sampling rate. These calculations do not take into account the high speed transfer rate (CSI2/LVDS) requirements.

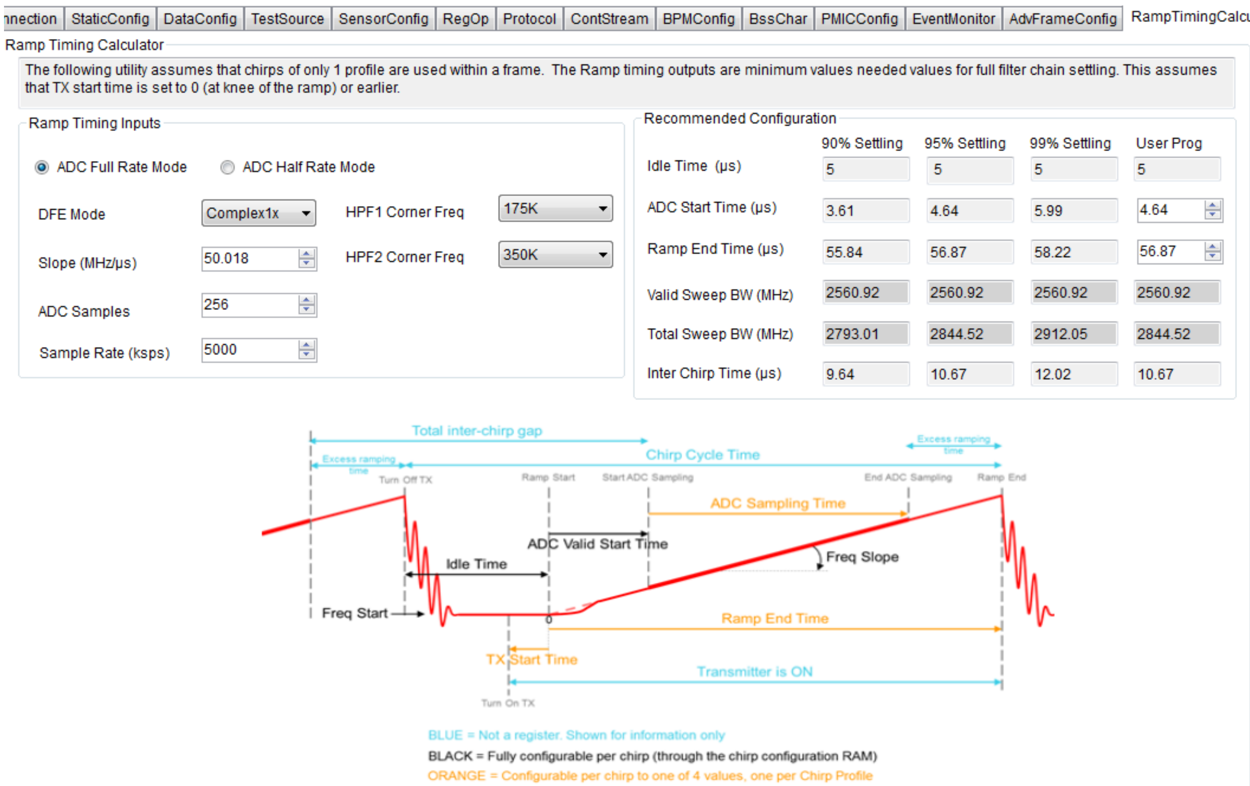


Figure 15.1. Rampgen Timing Calculator

16. Loopback Tab Operations

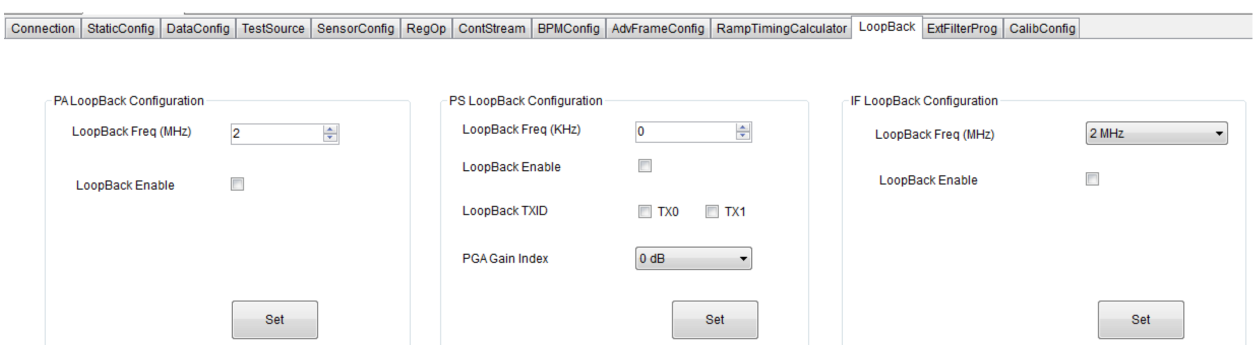


Figure 16.1. Loopback Config Tab

Loopback Tab supports following loopback options

1. PA Loopback
2. Phase Shifter loopback
3. IF loopback

The loopback APIs are intended to be issued after profile config and chirp config are issued to the device and before frame config API. The entire frame triggered from then on will have loopback enabled. To disable loopback, the loopbacks can be disabled in this tab and frames triggered from then on will have loopbacks disabled.

> **NOTE:** All profiles in the frame will have loopback paths enabled as long as the loopback is enabled.

17. CalibConfig Tab Operations

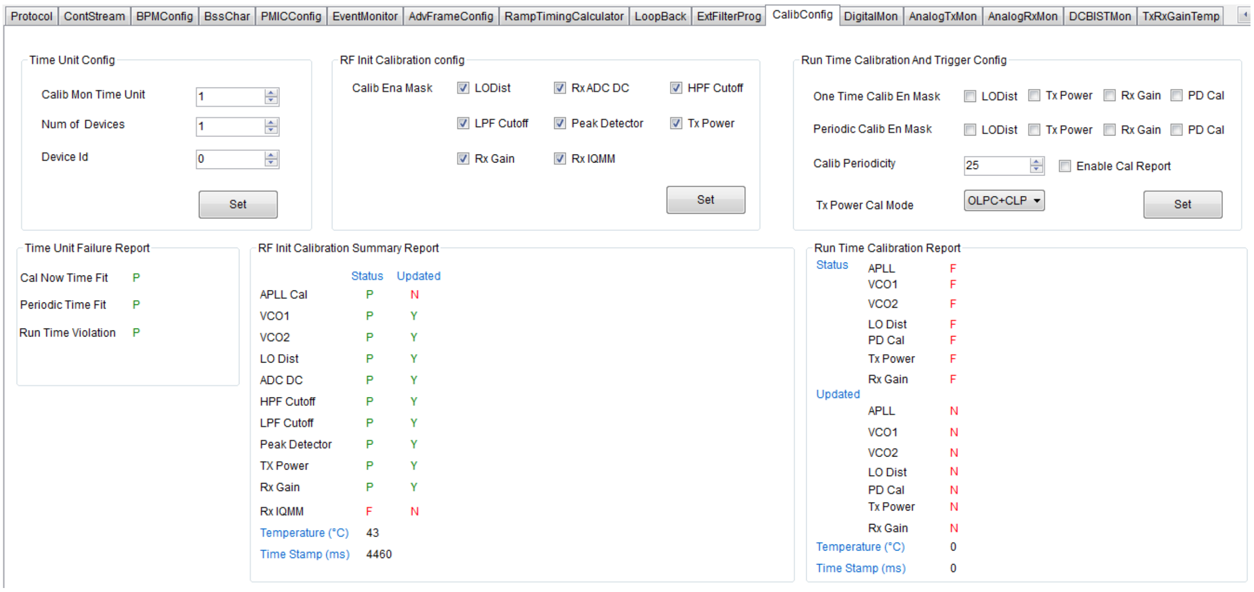


Figure 17.1. CalibConfig Tab

The CalibConfig Tab allows users to control the RF Init calibrations and Runtime calibrations which are scheduled by the firmware.

17.1 Time Unit Config

This allows configuration of the Calibration/Monitoring Time Unit in units of frames. No. of devices should be set to 1 if only 1 device is used

17.2 RF Init Calibration Config

This allows control of calibrations which will be triggered at RF Init. Default operation is will all calibrations enabled

17.3 RunTime Calibration and Trigger Config

This allows either 'One Time calibration' which will be triggered instantaneously or 'Periodic calibrations based on a Calibration Periodicity (in units of CalibMonTimeUnits) which will be triggered periodically when the frames are transmitted. Periodic calibrations are not triggered are frames are not ongoing.

17.4 Time Unit Failure report

This indicates a failure if the inter-frame/inter-burst idle time is not sufficient to trigger periodic calibrations/monitoring as specified by the user. The failure message is sent after frame config message is sent to the device.

17.5 RF Init Calibration Summary Report

This indicates the status of RF Init calibrations and if the results were applied in hardware. Along with this report, the boot time temperature and the time stamp is also indicated.

17.6 Runtime Calibration Report

This indicates the status of run time calibrations and if their results were applied in the hardware. Along with this information, the current device temperature and the timestamp at which the calibration results were applied is also indicated. If the user does not enable 'Cal Report' in the 'Run Time Calibration and Trigger Config', then the periodic Run Time calibration reports will not be sent by the device.

18. Monitoring

18.1 Digital monitoring

The entire digital monitoring boot up test status, latent fault tests and periodic tests can be triggered through this tab. This is not functional in the firmware now, but will be made available in future releases.

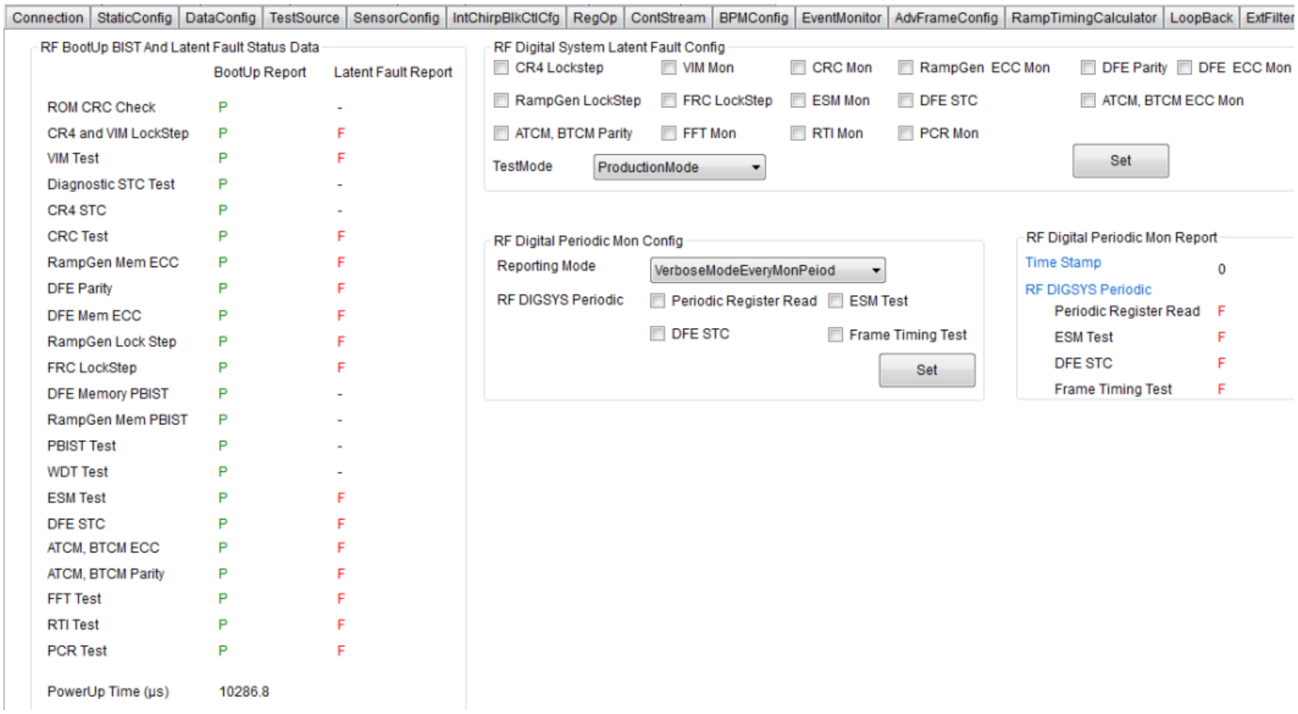


Figure 18.1. Digital monitoring configuration

18.2 Analog monitoring enables

This is included in AnalogTxMon tab. There is a checkbox for each analog monitoring feature

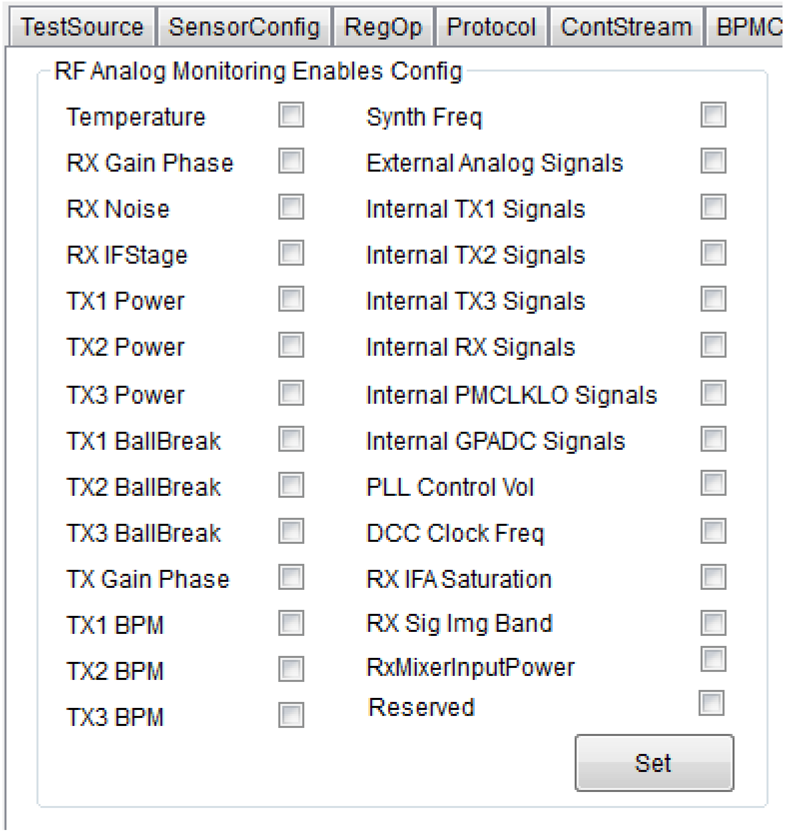


Figure 18.2. RF Analog monitoring consolidated enables

18.3 TX monitoring

The entire analog TX monitoring configurations are available in AnalogTxMon tab. This includes

1. TX power monitor
2. TX ball break monitor
3. TX BPM monitor
4. TX gain and phase monitor

The details of these monitor configurations are given in the Radar Interface Control Document.

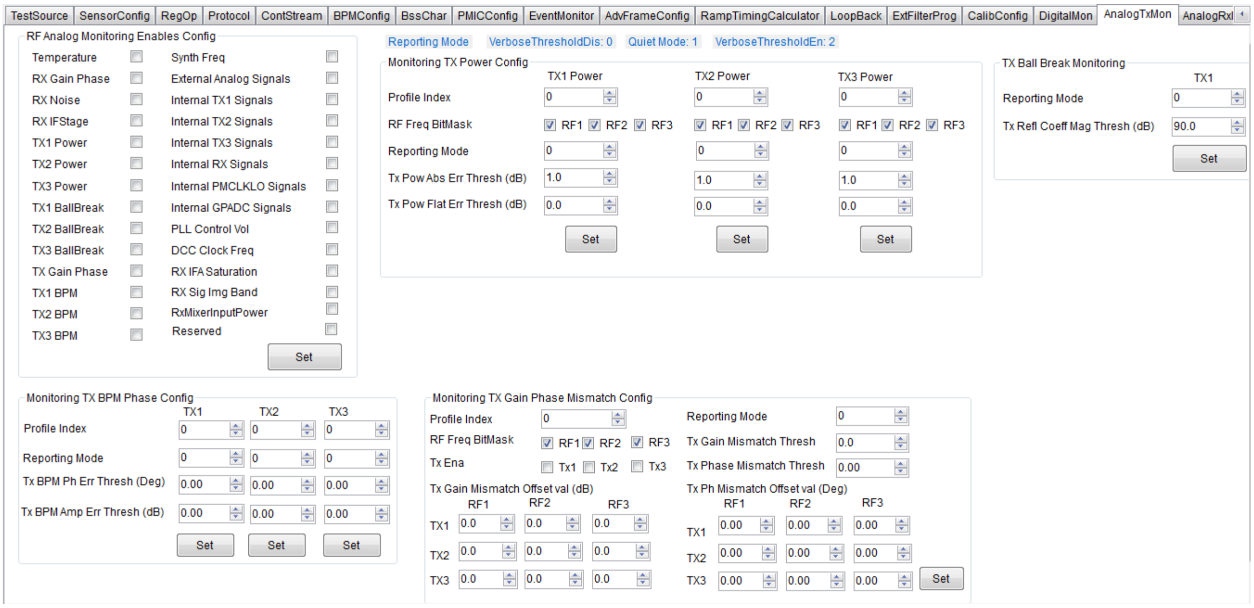


Figure 18.3. Analog TX monitoring configuration

18.4 RX monitoring

The entire analog RX monitoring configuration is available in the AnalogRxMon tab. This includes the configurations for following monitors

1. RX gain phase monitor
2. RX noise figure monitor
3. RX IF stage monitor
4. RX saturation detector monitor
5. RX signal and image band monitor

This tab also includes the temperature monitor and synthesizer frequency error monitor configurations.

The details of these monitor configurations are given in the Radar Interface Control Document.

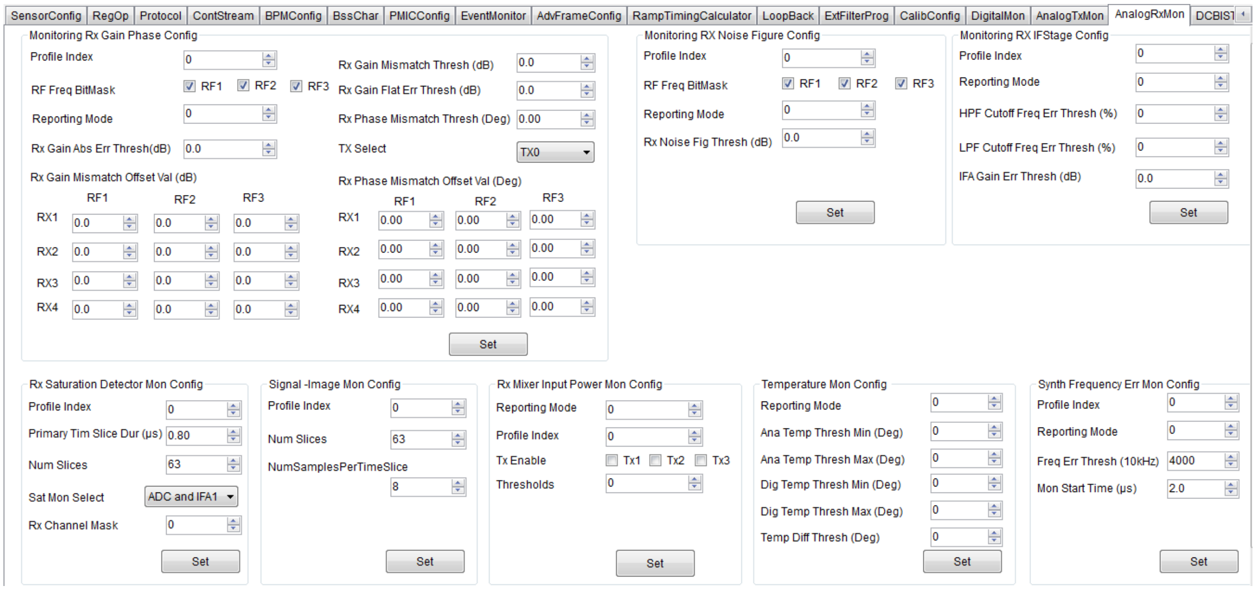


Figure 18.4. Analog RX monitoring configuration

18.5 DCBIST monitoring

The entire DCBIST monitor configurations are available in DCBISTmon tab. This includes the configurations for following monitors

1. External analog signals monitor
2. Internal TX signals monitor
3. Internal RX signals monitor
4. Internal PMCLKLO signals monitor
5. GPADC monitor
6. PLL control voltage monitor
7. DCC based clock monitor

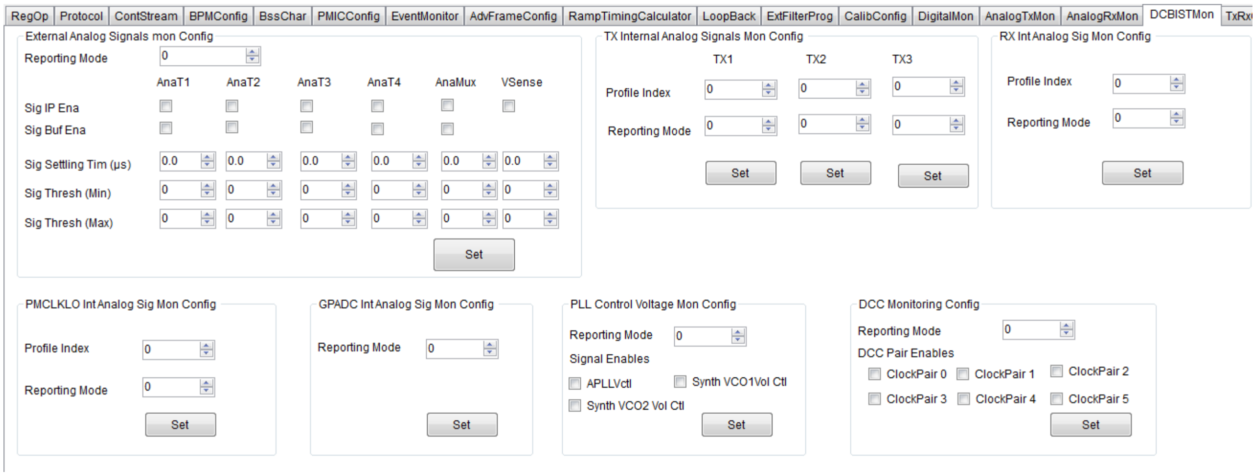


Figure 18.5. DCBIST monitor

The details of these monitor configurations are given in the Radar Interface Control Document.

Note that all configurations need to be done after profile configuration has been defined and before starting the frames. After triggering the frames, the monitoring reports are stored in the MonitoringReport.txt file under the mmwavestudio\PostProc folder.

Note: Since mmWaveStudio uses FTDI for SPI emulation, the SPI speed is limited to 3.75Mbps. Hence the throughput on data transfer is limited by this interface. To avoid any loss of monitoring data, keep the inter-frame idle time as high as 200 ms. This limitation does not apply to the silicon where SPI can be used at a higher clock rate.

19. RX and TX gain LUT

Users have the option to read the RX and TX gain LUTs (for a given profile) used in the firmware to correct for temperature variations. If the user wishes to override the LUT used by the firmware, he/she can modify these LUTs and inject them back into the device. The firmware will then use the user injected LUT instead of its internally generated LUT.

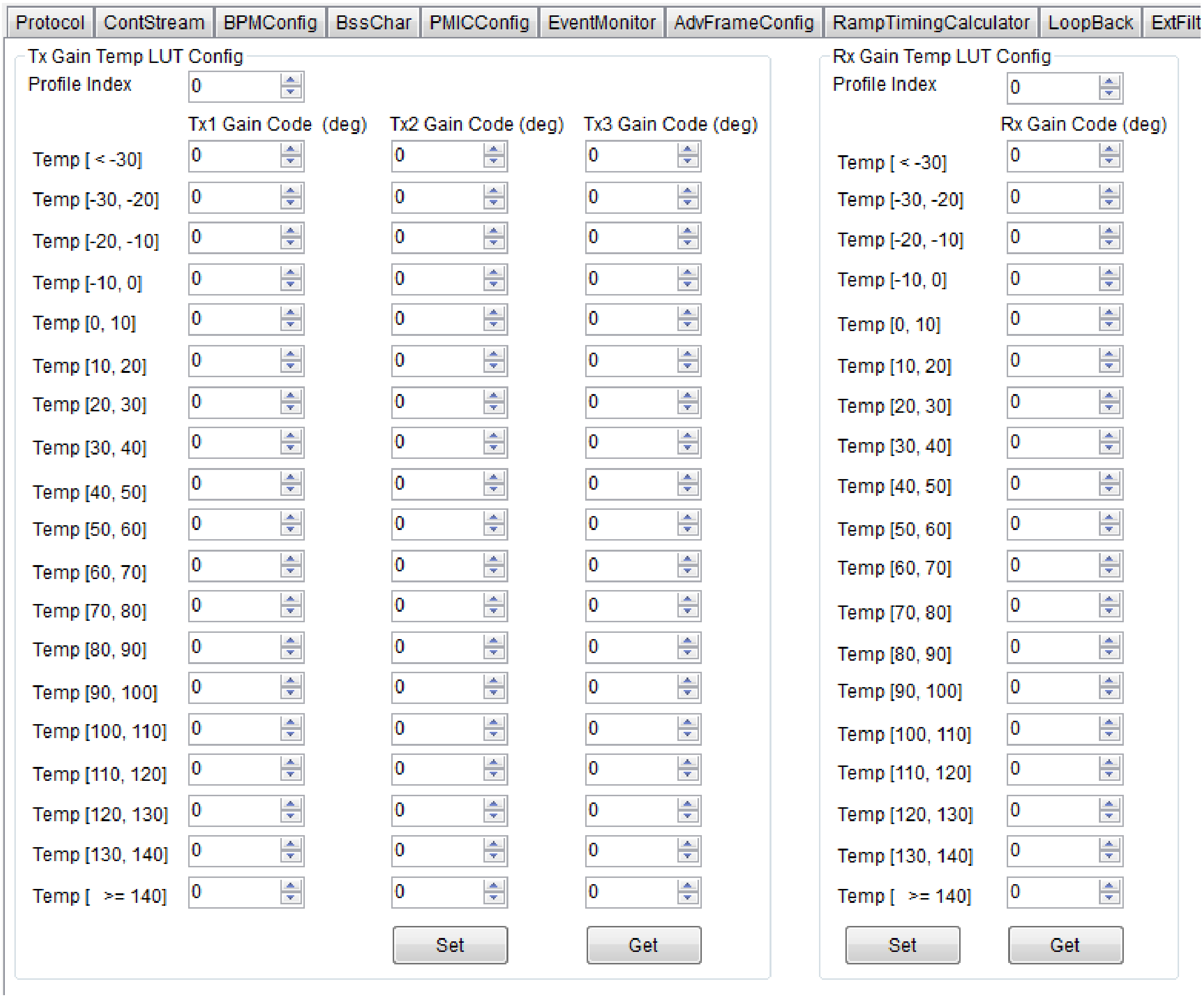


Figure 19.1. RX and TX LUT (read and write)

20. Radar post processing

The radar post processing (or PostProc) tool is used to visualize the adc data collected on the PC. It works using two inputs - the first is the raw LVDS capture (stored as .bin file) and the second is the sequence of APIs that were used to program the radar device (stored as .log file). Using these two sources of information, PostProc is able to interpret the data that the radar device collects and provide meaningful plots.

Note that mmWaveStudio automatically provides the dump file, and the sequence of APIs to the Matlab PostProc tool. So there is no need to manually provide these two inputs.

The following image shows how PostProc looks (with annotations) when you launch it first:

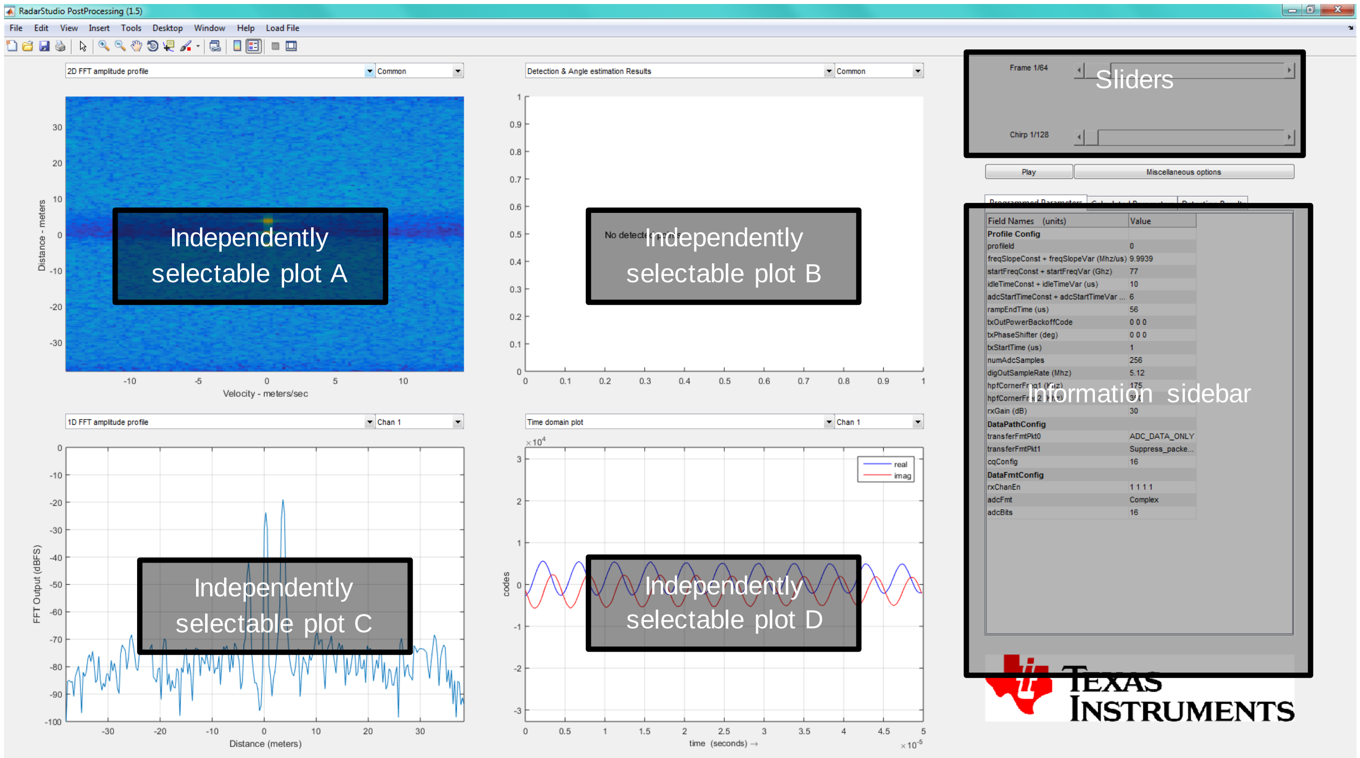


Figure 20.1. PostProc Basic

There are four different independently selectable plots. Each of these plots can be configured to different channels and different kinds of plots. Some of these plots are valid for all channels and some are simply a common measurement for all channels. Some plots are per-chirp and others are per frame. Each optionally is described later in the 'List of plots' section.

There is a set of sliders (on the top-right) that allow one to move around in the captured scenario, and display any frame, as well any of the chirps of the frame. If you are using the advanced frame configuration, the sub-frames, the bursts, the burst-loops are also individually selectable using the sliders.

Below the sliders, are two buttons, the 'play' button 'plays' the captured scenario, moving through each frame and updating the plots. 'Playing' through a captured scenario is a good way to see and correlate the captured scenario with what the different plots show, and see if there are issues.

While the default plots are a useful way to understand the radar data, some modification (to the plots) is sometimes required. So a number of 'less-common' options to modify the different plots are provided in a separate menu. This menu can be accessed using the 'Miscellaneous options' button.

Finally, below the 'Play' and 'Miscellaneous options' buttons is series of spreadsheets which provide the important parameters that were used to plot these graphs.

20.1 List of plots

Note: This list will be updated as more capability is added to PostProc.

20.1.1 Basic plots

20.1.1.1 2D FFT profile

The Range-velocity 'mesh' graph computed by performing a 2D-FFT of one frame of the captured scenario is shown in this plot. The x-axis shows the velocity (in meters/second) and the y-axis shows the range (in meters). Strong-reflectors are shown in brighter colours, and the noise floor is shown in dark blue.

Each channel can be independently selected, using the channel selector. If the common option is selected, then a sum of the

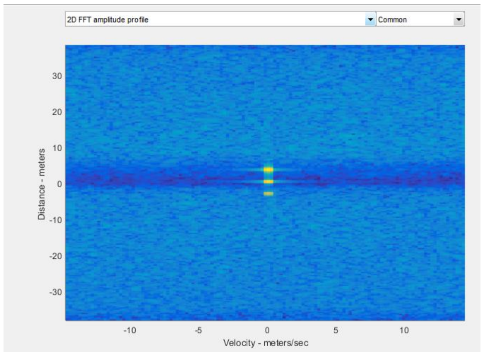


Figure 20.2. 2D FFT Profile

20.1.1.2 Range Angle plot

This plot shows a top-down view of the range-angle mesh. Targets are shown in brighter colours. The processing assumes a 1-Tx 4-Rx antenna configuration, with all 4 Rx antennas lying on the same plane (separated by $\lambda/2$, where λ is the starting wavelength of the FMCW ramp).

No calibration is performed in this step. Note that since only 4 antennas are used in the 3rd dimension processing, only a crude estimation of the angles are possible.

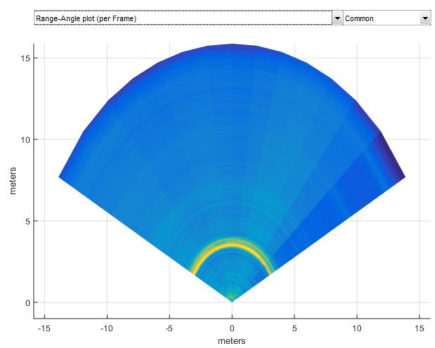


Figure 20.3. Range Angle plot

20.1.1.3 Detection and Angle estimation Results

A simple 2D-CFAR-CA (Constant false alarm – cell averaging) algorithm is used to detect targets in the scene. The parameters of the CFAR can be modified in the 'Miscellaneous Options' menu.

Targets are shown as green dots. As in the range-angle plot, the antenna configuration assumes 4-Rx antennas separated by $\lambda/2$ organised as a linear array, the third dimension processing is simply a 3D-FFT followed by a peak search. Hence only a single target is detected per range-velocity bin.

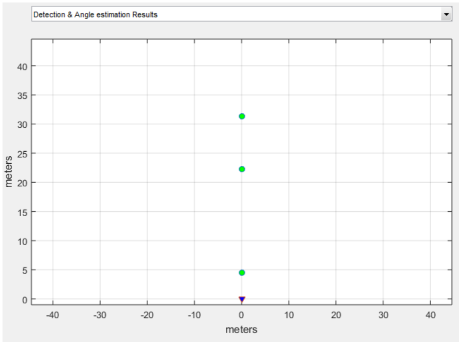


Figure 20.4. Detection and Angle Estimation results

20.1.1.4 Chirp Config Picture

This is a graphical depiction of the chirps that have been configured on the device. The x-axis is time (in seconds), and the y-axis is the ramp frequency. Using the 'miscellaneous options' menu, the plot can be modified to show all the chirps of a complete frame.

Since the chirp is common to all the rx channels on the device, only 'common' option is allowed on the channel selection dropdown.

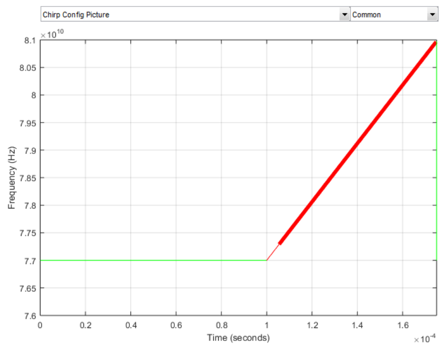


Figure 20.5. Chirp Config Picture

20.1.1.5 1D FFT amplitude profile

This is the '1D-FFT' amplitude profile. The x-axis can be configured (using the 'miscellaneous options' menu) to be in meters or in Hz (IF frequency) or in samples. The y-axis is given in dBFS.

Also, in the 'miscellaneous options' menu are options to do 'non-coherent' sum across chirps (per frame) and across antennas, as well as options to select the window (by default the Hann window is used).

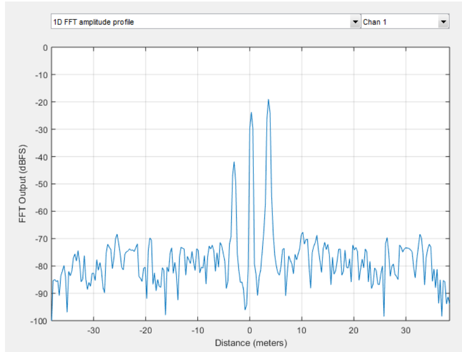


Figure 20.6. 1D FFT Profile

20.1.1.6 Time domain plot

This plot has the 'Raw ADC data' per chirp is plotted. The x-axis can be either time or 'instantaneous ramp frequency' or 'sample number'. The y-axis is in either ADC codes or in (1/full-scale).

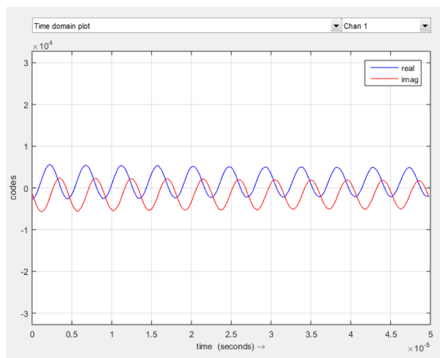


Figure 20.7. Time domain plot

20.1.2 CQ plots (chirp quality metrics) – (under development)

Chirp quality metrics are used to identify regions of a chirp affected by interference. It is still under development. The metrics used are namely

1. Wide band energy monitor
2. ADC/IF Saturation Indicator
3. DFE Energy monitor.

20.1.3 Characterization plots

20.1.3.1 Phase stability across chirps

Phase stability is an important concern when measuring vibration frequency, and also in low velocity measurement. This plot shows the phase (of the strongest reflector) as a function of the chirps of a frame. The x-axis is in 'chirp number' and the y-axis is in degrees. Note that the y-axis label also tells where the strongest reflector is present (in meters).

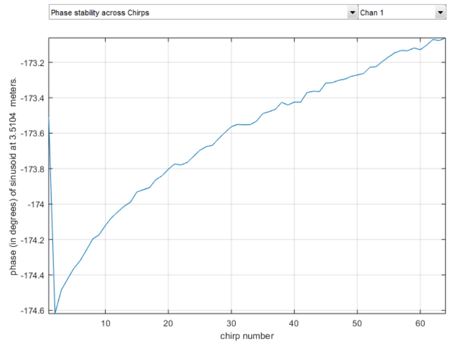


Figure 20.8. Phase Stability

20.1.3.2 Amplitude stability across chirps

Amplitude stability is a good measure of how stable the transmit power is across a Frame. This plot shows the amplitude of the strongest tone in the chirp. The position of the strongest reflector (in meters) is shown in the y-axis label.

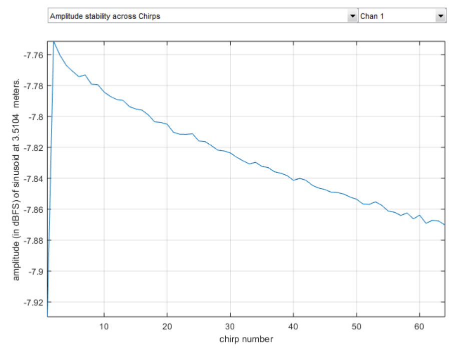


Figure 20.9. Amplitude stability

20.1.3.3 Zero-velocity bin vs High velocity bin

In a stationary scene, all energy from reflectors will be concentrated on the zero-velocity range bins. High-velocity range-bins will essentially be showing the thermal noise floor. This plot displays the Zero-velocity and the High velocity bins for an easy estimate of the SNR.

The 'high velocity bin' graph is generated from the '2D-FFT' by averaging the velocity bins from '$max_{velocity}/2$' to '$max_{velocity}$' and '-$max_{velocity}/2$' to '-$max_{velocity}$'.

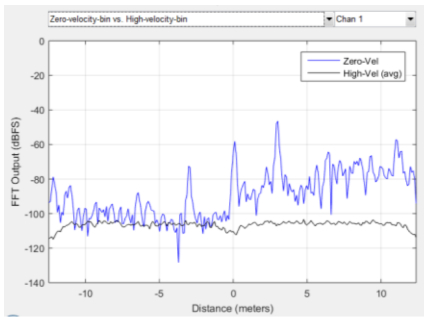


Figure 20.10. Zero-velocity bin vs High velocity bin.

20.2 Channel select

Some of these plots use all the Rx antennas to create the plot (1a, 1b, 1c, 2a, 2b, 2c), some have a per Rx measurement (1e, 1f, 3a, 3b), some aren't associated with the Rx plot (1d).

For measurements that are associated with a particular Rx, the channel select option can be used to select the channel whose measurement is to be shown.

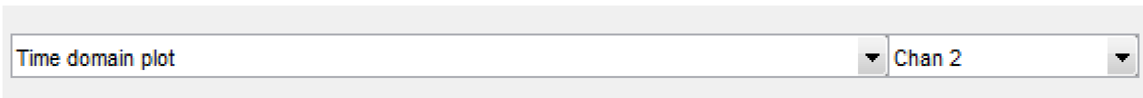


Figure 20.11. Channel select

PostProc will automatically select the first channel when changing from a common measurement to a per-channel measurement and vice-versa.

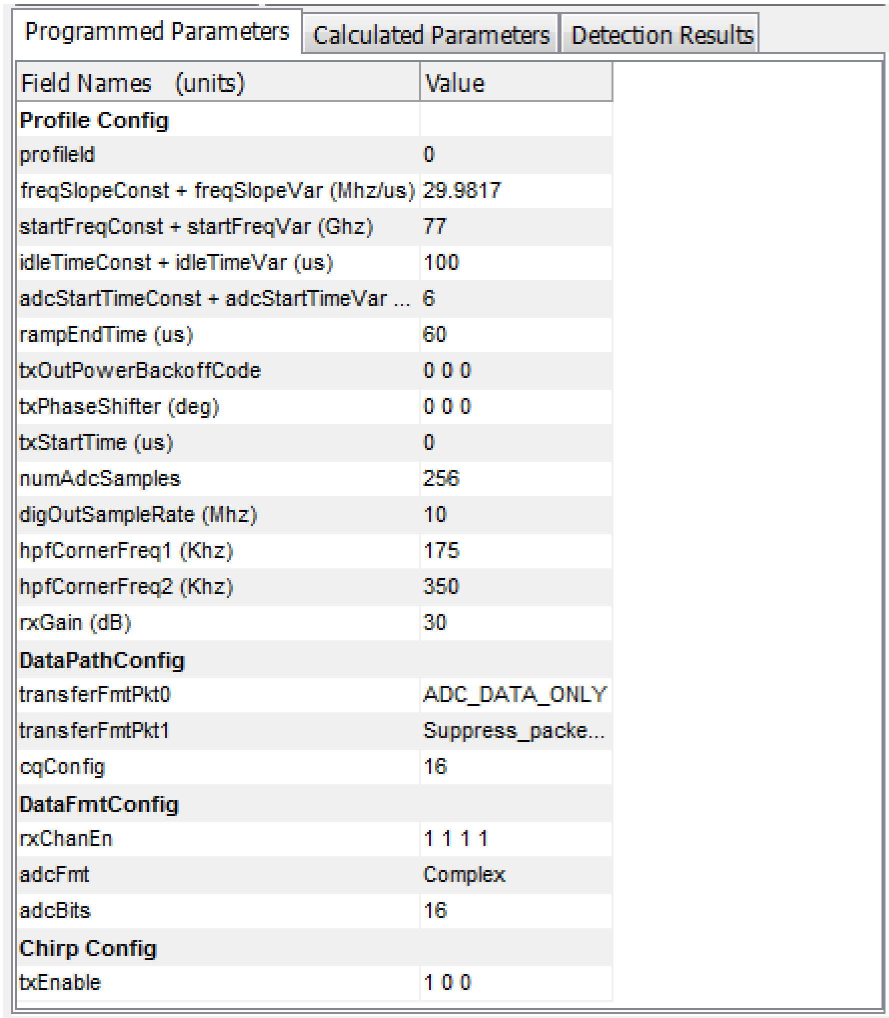
20.3 Frame /Profile /Chirp sliders

These slides allow exploring the different frames of the ADC dump. Within a frame, the different chirps can also be selected. If multiple 'chirp config' are selected as part of the frame, each is shown separately in the profile slider. Note that if the Advanced Frame Config is used, additional sliders will appear to allow the selection of 'sub-frames', 'bursts', 'burst-loops' which are configurable only through the Advanced Frame Config.

Figure 20.12. Sliders

20.4 Information sidebar

The sidebar has (as of now) three separate tabs.



Field Names (units)	Value
Profile Config	
profileId	0
freqSlopeConst + freqSlopeVar (Mhz/us)	29.9817
startFreqConst + startFreqVar (Ghz)	77
idleTimeConst + idleTimeVar (us)	100
adcStartTimeConst + adcStartTimeVar ...	6
rampEndTime (us)	60
txOutPowerBackoffCode	0 0 0
txPhaseShifter (deg)	0 0 0
txStartTime (us)	0
numAdcSamples	256
digOutSampleRate (Mhz)	10
hpfCornerFreq1 (Khz)	175
hpfCornerFreq2 (Khz)	350
rxGain (dB)	30
DataPathConfig	
transferFmtPkt0	ADC_DATA_ONLY
transferFmtPkt1	Suppress_packe...
cqConfig	16
DataFmtConfig	
rxChanEn	1 1 1 1
adcFmt	Complex
adcBits	16
Chirp Config	
txEnable	1 0 0

Figure 20.13. Information sidebar

These tabs are -

20.4.1 Programmed parameters

This gives a short list of the parameters that were programmed using the APIs. This is the data that the post-proc tool uses to analyse the data.

20.4.2 Calculated parameters

This is a useful list of parameters that are calculated using the programmed parameters. They include

d. True start frequency ramp. The programmed start frequency doesn't take into account the ADC start time. When the ADC start time is taken into consideration, the true start of the ramp happens a few microseconds after the programmed start.

e. Bandwidth. The bandwidth provided here correctly takes into account the ADC start time and the number of samples to be collected.

f. Range resolution

g. Velocity resolution

20.4.3 *Detection results*

Up to five detected measurements are shown, along with their SNR, velocities and ranges.

20.5 Play

If the ADC data has multiple frames, the play button plays through the frames one by one, allowing one to see the evolution of the scene.

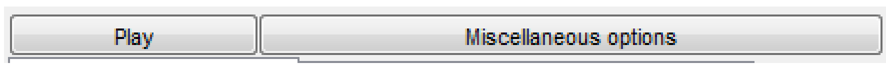


Figure 20.14. Play

20.6 Miscellaneous options

This window holds a list of options to modify and alter the plots. Options are organised in different 'boxes', with each box corresponding to a particular type of plot. The current 'boxes' are.

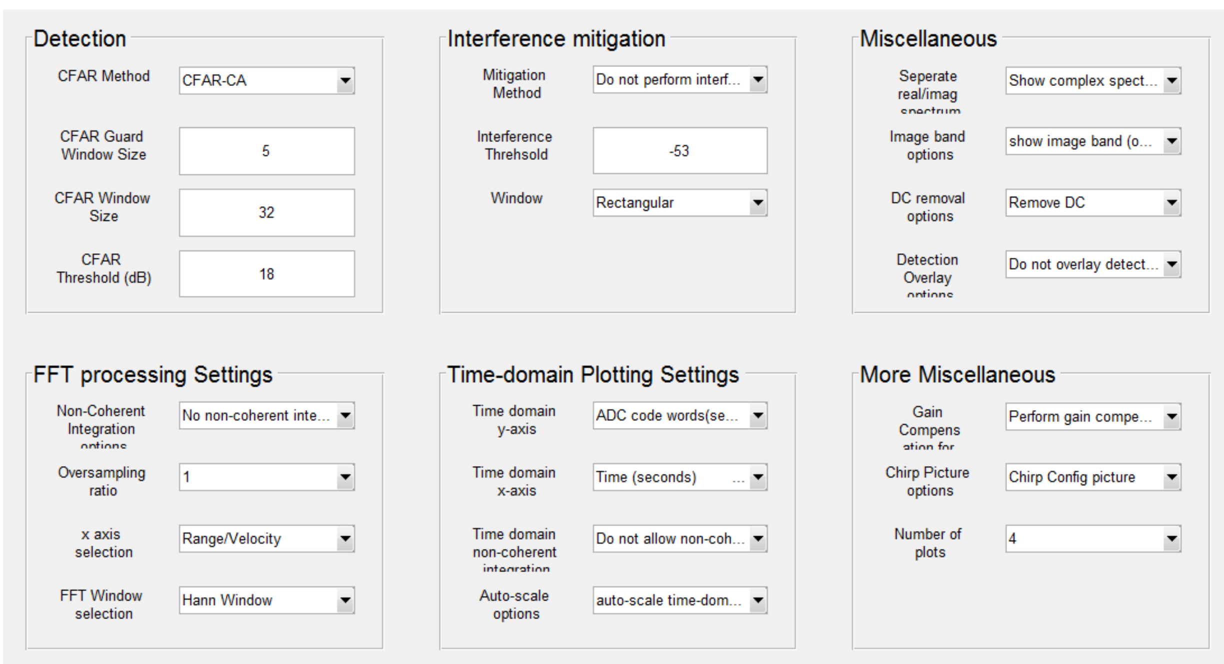


Figure 20.15. Miscellaneous options

20.6.1 *Detection*

The detection algorithm is 2D-CFAR-CA.

a. **CFAR method.** There are three different variants of CFAR that can be selected.

iii. CFAR-CA computes the noise floor considering samples that lie in a window that spans both sides of the CUT (cell under test). The noise floor is simply the mean of the energy in that window.

iv. CFAR-CA-SO selects the 'smaller of' (hence -SO) the noise-floor computed using samples that lie on left-side of the CUT and the noise floor computed using samples that lie on the right of the CUT.

v. CFAR-CA-GO selects the 'greater of' (hence -GO) the noise-floor computed using samples that lie on left-side of the CUT and the noise floor computed using samples that lie on the right of the CUT.

b. **CFAR guard-window size.** The guard window is used to reduce the effect of adjacent targets (or leakage) when measuring the noise floor. Essentially the samples that lie within the guard-window are omitted from the computation of the noise-floor.

c. **CFAR window size.** The size of the window determines the number of samples that are used to compute the noise-floor. The larger the window size, the better the noise floor estimate. However, the larger the window, the more probable that multiple targets will occur in the same window and result in a raised noise floor.

d. **CFAR Threshold.** Once the noise floor has been computed, it is compared against the CUT. If the CUT is greater than the noise-floor by the CFAR threshold, then CUT is declared as a valid target. Reducing the detection threshold will help increase the number of detected targets.

20.6.2 FFT processing settings

a. **Non-coherent Integration options**. Allow non-coherent integration across chirps and across chirps and antennas for the '1D FFT amplitude plots' and the 'time domain plots'. Allowing non-coherent integration improves the 'look' of the noise floor (in the '1D FFT amplitude profile'), and shows the envelope of complex signals in the time domain plot.

b. **Oversampling ratios**. Setting the 'oversampling ratio' higher than one creates zero-padded FFTs which improve bin-resolution (Note : zero-padding is done only in range not in velocity). Be aware that setting larger oversampling ratios, require proportionally more RAM to compute the FFT and also to display it.

c. **x-axis selection**. Changes the x-axis from meters (default) to hz. This is useful when doing looking at the IF spectrum, as opposed to an actual target.

d. **FFT-window selection**. Different FFT windows have different uses. By default we use the Hann window, which has a reasonable tradeoff between main lobe expansion and suppression of side-lobes. There are three other options, no-window (no energy loss, least main lobe expansion, no suppression of side lobes), and Blackman-Harris (high main lobe expansion, better suppression of side lobes (as compared to Hann)) and flat-top window (primarily used in characterization).

20.6.3 Miscellaneous

a. **Separate real/imag**. In the '1-D FFT amplitude profile' plot optionally separate the imaginary and real parts of the FFT.

b. **Image band options**. In the 'complex 2X' mode, the image band (i.e. negative frequencies) is visible. However, since no target can lie 'behind' the radar, the image band is of no interest in field tests. It is only useful in interference detection, and in monitoring.

c. **DC removal option.** This option can remove DC on a per-frame basis. By default DC is removed as it will result in cleaner images.

d. **Detection overlay options**. Allow the detection results to be displayed over the '2D FFT profile' plot, and the range-angle plot.

20.6.4 Time domain options

a. **Time domain x-axis**. The x-axis can be changed from time (seconds) to 'instantaneous ramp frequency' (Hz) or 'sample number'.

b. **Time domain y-axis**. The y-axis can be changed from ADC codewords to 1/fullscale.

c. **Time domain non-coherent integration options.** In conjunction with non-coherent integration options can construct the envelope of a complex time domain signal by computing $\sqrt{I^2 + Q^2}$

d. **Auto scale options**. The y-axis can be optionally allowed to auto-scale. This is useful for cases where the ADC swing is very low.

20.6.5 More miscellaneous options

a. **Window compensation options**. Applying a window prior to FFT causes a change in the absolute output level of the FFT (This change is called the windowing loss). These set of options allow two different methods of compensating for the windowing loss – Gain-compensation or Energy-compensation.

   Both methods differ only in the compensation factor. When using Gain-compensation the each fft output is divided by a factor given by $\sum_{i=0}^{N-1} w_i / N$.

   When using Energy-compensation the factor is given by $rms([w_0\ w_1 \ldots w_{N-1}])$.

b. **Chirp picture options**. This option selects between different plots in the 'Chirp Picture'. For example a 'single chirp's picture' can be plotted or a 'complete frame's worth of chirps' can be plotted.

c. **Number of plots.** By default 4 plots are shown on the main window. This dropdown can change that to 1, 2, 4, or 9 independently configurable plots.

20.7 Notes on Setting up PostProc for Characterization

The tool is 'by default' configured for characterization so no changes need to be done. There is no reason to access the 'miscellaneous options' menu.

21. Controlling mmWaveStudio from Matlab

1. From mmWaveStudio's Lua Shell, call the RSTD.NetStart() command

   This command starts a listening server on port 2777 by default.

   (you can also add this command to "C:\ti\mmwave_studio_01_00_00_01\ mmWaveStudio\Scripts\Startup.lua" so that it is called automatically)

2. There are two Matlab scripts shown below. Copy them and create scripts with names RSTD_Interface_Example.m and Init_RSTD_Connection.m. You can modify the path to the RtttNetClientAPI.dll in RSTD_Interface_Example.m, and then call the RSTD_Interface_Example from Matlab. This script demonstrates how to connect to mmWaveStudio from Matlab and allow Lua commands to be sent to mmWaveStudio. The script internally calls Init_RSTD_Connection.m to establish the connection to port 2777, and then displays a green message in the mmWaveStudio Output window.

   See lines 41-47 in Init_RSTD_Connection.m for an example of sending a single Lua Command. Basically, you construct the Lua command as a string in Matlab and pass it to the RtttNetClientAPI.RtttNetClient.SendCommand API. Also see commented lines 12-15 in RSTD_Interface_Example.m for an example on how to get mmWaveStudio to run an external Lua Script.

RSTD_Interface_Example.m

```
    %% RSTD Interface Example.m
1   addpath(genpath('.\'))
2
3   % Initialize mmWaveStudio .NET connection
4   RSTD_DLL_Path =
    'C:\ti\mmwave_studio_01_00_00_01\mmWaveStudio\Clients\RtttNetClientControl
    ler\RtttNetClientAPI.dll';
5
6   ErrStatus = Init_RSTD_Connection(RSTD_DLL_Path);
7   if (ErrStatus ~= 30000)
8       disp('Error inside Init_RSTD_Connection');
9       return;
10  end
11
12  %Example Lua Command
13  %strFilename =
    'C:\\ti\\mmwave_studio_01_00_00_01\\mmWaveStudio\\Scripts\\Example_script_
    AllDevices.lua';
14  %Lua_String = sprintf('dofile("%s")',strFilename);
15  %ErrStatus =RtttNetClientAPI.RtttNetClient.SendCommand(Lua_String);
```

Init_RSTD_Connection.m

```
    %% Init_RSTD_Connection.m
1   function ErrStatus = Init_RSTD_Connection(RSTD_DLL_Path)
2   %This script establishes the connection with mmWaveStudio software
3   %   Pre-requisites:
4   %   Type RSTD.NetStart() in mmWaveStudio Luashell before running the script.
    This would open port 2777
```

```
%   Returns 30000 if no error.
if (strcmp(which('RtttNetClientAPI.RtttNetClient.IsConnected'),'')) %First time the code is run after opening MATLAB
    disp('Adding RSTD Assembly');
    RSTD_Assembly = NET.addAssembly(RSTD_DLL_Path);
    if ~strcmp(RSTD_Assembly.Classes{1},'RtttNetClientAPI.RtttClient')
        disp('RSTD Assembly not loaded correctly. Check DLL path');
        ErrStatus = -10;
        return
    end
    Init_RSTD_Connection = 1;
elseif ~RtttNetClientAPI.RtttNetClient.IsConnected() %Not the first time but port is disconnected
% Reason:
% Init will reset the value of Isconnected. Hence Isconnected should be checked before Init
% However, Isconnected returns null for the 1st time after opening MATLAB (since init was never called before)
    Init_RSTD_Connection = 1;
else
    Init_RSTD_Connection = 0;
end

if Init_RSTD_Connection
    disp('Initializing RSTD client');
    ErrStatus = RtttNetClientAPI.RtttNetClient.Init();
    if (ErrStatus ~= 0)
        disp('Unable to initialize NetClient DLL');
        return;
    end
    disp('Connecting to RSTD client');
    ErrStatus = RtttNetClientAPI.RtttNetClient.Connect('127.0.0.1',2777);
    if (ErrStatus ~= 0)
        disp('Unable to connect to mmWaveStudio');
        disp('Reopen port in mmWaveStudio. Type   RSTD.NetClose() followed by RSTD.NetStart()')
        return;
    end
    pause(1);%Wait for 1sec. NOT a MUST have.
end

disp('Sending test message to RSTD');
Lua_String = 'WriteToLog("Running script from MATLAB\n", "green")';
ErrStatus = RtttNetClientAPI.RtttNetClient.SendCommand(Lua_String);
if (ErrStatus ~= 30000)
    disp('mmWaveStudio Connection Failed');
end
disp('Test message success');
end
```

22. Format of the raw captured file

This section provides a quick description of the format of the binary files collected by TSW1400 EVM and DCA1000 EVM from the xWR12xx, xWR14xx and the xWR16xx devices. There are subtle differences between the data generated by xWR16xx and xWR12xx/xWR14xx, and also differences when the number of channels is changed, as well as when the number of LVDS lanes is changed, and when the type of data (from complex to real) is changed.

Each combination therefore needs to be separately described. Since the number of combinations is very large, only the most useful combinations are described.

Next, we describe the notation used in the rest of the section. We then describe the 'Sample Format' – how to interpret each sample. We then describe the arrangement of data for xWR16xx's capture first, followed by xWR12xx/xWR14xx's capture.

22.1 Preliminaries

22.2 Notation

- Rx***k***I***n*** : The **n**th in-phase sample corresponding to **k**th receive channel
- Rx***k***Q***n*** : The **n**th quadrature-phase sample corresponding to **k**th receive channel
- **N**: The number of samples per chirp

22.3 Sample Format

Every sample captured by TSW1400 is **2 bytes** long and in the 'offset binary format'. In other words, every sample has an extra 2^{15} added to it. To get the true '2s complement' number, perform the following operation on every sample 'x' read from the file.

$$x = x - 2^{15}$$

Data captured from DCA1000 does issue. Each sample is in 2s complement format.

22.4 TSW1400 EVM xWR16xx file formats

22.4.1 2 LVDS Lanes, complex data, variable number of channels, chirping mode

Chirp 1	Rx*0*I*0*	Rx*0*Q*0*	Rx*0*I*1*	Rx*0*Q*1*	…	Rx*0*I*N-1*	Rx*0*Q*N-1*
	Rx*1*I*0*	Rx*1*Q*0*	Rx*1*I*1*	Rx*1*Q*1*	…	Rx*1*I*N-1*	Rx*1*Q*N-1*
	Rx*2*I*0*	Rx*2*Q*0*	Rx*2*I*1*	Rx*2*Q*1*	…	Rx*2*I*N-1*	Rx*2*Q*N-1*
	Rx*3*I*0*	Rx*3*Q*0*	Rx*3*I*1*	Rx*3*Q*1*	…	Rx*3*I*N-1*	Rx*3*Q*N-1*
Chirp 2	Rx*0*I*0*	Rx*0*Q*0*	Rx*0*I*1*	Rx*0*Q*1*	…	Rx*0*I*N-1*	Rx*0*Q*N-1*
	Rx*1*I*0*	Rx*1*Q*0*	Rx*1*I*1*	Rx*1*Q*1*	…	Rx*1*I*N-1*	Rx*1*Q*N-1*
	Rx*2*I*0*	Rx*2*Q*0*	Rx*2*I*1*	Rx*2*Q*1*	…	Rx*2*I*N-1*	Rx*2*Q*N-1*

	Rx3I0	Rx3Q0	Rx3I1	Rx3Q1	…	Rx3IN-1	Rx3QN-1

In the above diagram, each green block refers to one 16-bit number. Data is arranged in **row-major-order**. Note also, that each chirp consists of ***N*** complex samples.

If the number of enabled channels is two or one, then the rows corresponding to the disabled channels are removed in the above diagram. There is no support for three channels on 2 lanes. As an example with two channels (say, 1 and 3), then the 'data format' will look as follows.

Chirp 1	Rx1I0	Rx1Q0	Rx1I1	Rx1Q1	…	Rx1IN-1	Rx1QN-1
	Rx3I0	Rx3Q0	Rx3I1	Rx3Q1	…	Rx3IN-1	Rx3QN-1
Chirp 2	Rx1I0	Rx1Q0	Rx1I1	Rx1Q1	…	Rx1IN-1	Rx1QN-1
	Rx3I0	Rx3Q0	Rx3I1	Rx3Q1	…	Rx3IN-1	Rx3QN-1

22.4.2 2 LVDS Lanes, real data, variable number of channels, chirping mode

Chirp 1	Rx0I0	Rx0I2	Rx0I1	Rx0I3	…	Rx0IN-2	Rx0IN-1
	Rx1I0	Rx1I2	Rx1I1	Rx1I3	…	Rx1IN-2	Rx1IN-1
	Rx2I0	Rx2I2	Rx2I1	Rx2I3	…	Rx2IN-2	Rx2IN-1
	Rx3I0	Rx3I2	Rx3I1	Rx3I3	…	Rx3IN-2	Rx3IN-1
Chirp 2	Rx0I0	Rx0I2	Rx0I1	Rx0I3	…	Rx0IN-2	Rx0IN-1
	Rx1I0	Rx1I2	Rx1I1	Rx1I3	…	Rx1IN-2	Rx1IN-1
	Rx2I0	Rx2I2	Rx2I1	Rx2I3	…	Rx2IN-2	Rx2IN-1
	Rx3I0	Rx3I2	Rx3I1	Rx3I3	…	Rx3IN-2	Rx3IN-1

22.4.3 2 LVDS Lanes, complex data, variable number of channels, continuous streaming mode

Random number of samples	x	x	x	x	…	x	x	
	x	x	x	x	…	x	x	
	x	x	x	x	…	x	x	
	x	x	x	x	…	x	x	
Sync Pattern	$2047+2^{15}$	$2048+2^{15}$	$2047+2^{15}$	$2048+2^{15}$	$2047+2^{15}$	$2048+2^{15}$	$2047+2^{15}$	$2048+2^{15}$
Data Packet 1	Rx0I0	Rx0Q0	Rx0I1	Rx0Q1	…	Rx0I1023	Rx0Q1023	
	Rx1I0	Rx1Q0	Rx1I1	Rx1Q1	…	Rx1I1023	Rx1Q1023	
	Rx2I0	Rx2Q0	Rx2I1	Rx2Q1	…	Rx2I1023	Rx2Q1023	
	Rx3I0	Rx3Q0	Rx3I1	Rx3Q1	…	Rx3I1023	Rx3Q1023	

Sync Pattern	$2047 +2^{15}$	$2048+2^{15}$	$2047+2^{15}$	$2048+2^{15}$	$2047+2^{15}$	$2048+2^{15}$	$2047+2^{15}$	$2048+2^{15}$
Data Packet 2	Rx0I0	Rx0Q0	Rx0I1	Rx0Q1	…	Rx0I1023	Rx0Q1023	
	Rx1I0	Rx1Q0	Rx1I1	Rx1Q1	…	Rx1I1023	Rx1Q1023	
	Rx2I0	Rx2Q0	Rx2I1	Rx2Q1	…	Rx2I1023	Rx2Q1023	
	Rx3I0	Rx3Q0	Rx3I1	Rx3Q1	…	Rx3I1023	Rx3Q1023	

In the continuous streaming mode, a sync packet precedes every LVDS data packet. In order to make sense of the data, first, find the sync packet and then collect $(n4)$kB, (where n is the number of channels). The next data packet begins after $(n4)$ kB. It will also have a sync pattern in its start.

The sync packet is actually just the following numbers with each number being 2 bytes long, and the entire packet being 128 bits.

2047	2048	2047	2048	2047	2048	2047	2048

However, since HSDC Pro converts the samples to 'offset binary, we add 2^{15} to the sync pattern, and then search for it.

If the number of enabled channels is two or one, then the rows corresponding to the disabled channels are removed in the above diagram. There is no support for three channels on 2 lanes. As an example, the following diagram shows the data format when only two channels (1 and 3) are enabled.

Random number of samples	x	x	x	x	…	x	x	
	x	x	x	x	…	x	x	
	x	x	x	x	…	x	x	
	x	x	x	x	…	x	x	
Sync Pattern	$2047 +2^{15}$	$2048+2^{15}$	$2047+2^{15}$	$2048+2^{15}$	$2047+2^{15}$	$2048+2^{15}$	$2047+2^{15}$	$2048+2^{15}$
Data Packet 1	Rx1I0	Rx1Q0	Rx1I1	Rx1Q1	…	Rx1I1023	Rx1Q1023	
	Rx3I0	Rx3Q0	Rx3I1	Rx3Q1	…	Rx3I1023	Rx3Q1023	
Sync Pattern	$2047 +2^{15}$	$2048+2^{15}$	$2047+2^{15}$	$2048+2^{15}$	$2047+2^{15}$	$2048+2^{15}$	$2047+2^{15}$	$2048+2^{15}$
Data Packet 1	Rx1I0	Rx1Q0	Rx1I1	Rx1Q1	…	Rx1I1023	Rx1Q1023	
	Rx3I0	Rx3Q0	Rx3I1	Rx3Q1	…	Rx3I1023	Rx3Q1023	

22.5 TSW1400 xWR12xx/xWR14xx file format

22.5.1 n LVDS Lanes, complex data, n channels, chirping/continuous streaming mode

Chirp 1	Rx0I0	Rx0Q0	Rx1I0	Rx1Q0	Rx2I0	Rx2Q0	Rx3I0	Rx3Q0
	Rx0I1	Rx0Q1	Rx1I1	Rx1Q1	Rx2I1	Rx2Q1	Rx3I1	Rx3Q1
	…		…		…		…	…
	Rx0IN-1	Rx0QN-1	Rx1IN-1	Rx1QN-1	Rx2IN-1	Rx2QN-1	Rx3IN-1	Rx3QN-1
Chirp 2	Rx0I0	Rx0Q0	Rx1I0	Rx1Q0	Rx2I0	Rx2Q0	Rx3I0	Rx3Q0
	Rx0I1	Rx0Q1	Rx1I1	Rx1Q1	Rx2I1	Rx2Q1	Rx3I1	Rx3Q1
	…		…		…		…	…
	Rx0IN-1	Rx0QN-1	Rx1IN-1	Rx1QN-1	Rx2IN-1	Rx2QN-1	Rx3IN-1	Rx3QN-1

In the above diagram, each green block refers to one 16-bit number. Data is arranged in **row-major-order**. Note that the data format is a *transpose* of the xWR16xx format.

The data format remains unchanged in the 'continuous streaming' mode where one can think of the data collected as belonging to a single large chirp. There is no sync packet at the start of an LVDS packet, as there is one lane for each channel, so we will always know which lane has which channel.

If the number of enabled channels is less than four, then the columns corresponding to the disabled channels will have zeroes in it. For example, if only channels 1 and 3 are enabled, then the data format will look as follows.

Chirp 1	0	0	Rx1I0	Rx1Q0	0	0	Rx3I0	Rx3Q0
	0	0	Rx1I1	Rx1Q1	0	0	Rx3I1	Rx3Q1
	…		…		…		…	…
	0	0	Rx1IN	Rx1QN	0	0	Rx3IN	Rx3QN
Chirp 2	0	0	Rx1I0	Rx1Q0	0	0	Rx3I0	Rx3Q0
	0	0	Rx1I1	Rx1Q1	0	0	Rx3I1	Rx3Q1
	…		…		…		…	…
	0	0	Rx1IN	Rx1QN	0	0	Rx3IN	Rx3QN

22.5.2 *n* LVDS Lanes, real data, *n* channels, chirping/continuous streaming mode

Chirp 1	Rx0I0	Rx2I0	Rx0I1	Rx2I1	Rx1I0	Rx3I0	Rx1I1	Rx3I1
	Rx0I2	Rx2I2	Rx0I3	Rx2I3	Rx1I2	Rx3I2	Rx1I3	Rx3I3
	…		…		…		…	…
	Rx0IN-2	Rx2IN-2	Rx0IN-1	Rx2IN-1	Rx1IN-2	Rx3IN-2	Rx1IN-1	Rx3IN-1
Chirp 2	Rx0I0	Rx2I0	Rx0I1	Rx2I1	Rx1I0	Rx3I0	Rx1I1	Rx3I1
	Rx0I2	Rx2I2	Rx0I3	Rx2I3	Rx1I2	Rx3I2	Rx1I3	Rx3I3

	…		…		…		…	…
	Rx0IN-2	*Rx2IN-2*	*Rx0IN-1*	*Rx2IN-1*	*Rx1IN-2*	*Rx3IN-2*	*Rx1IN-1*	*Rx3IN-1*

22.6 DCA1000 EVM capture format (xWR12xx/xWR14xx complex, 4 channel, 4 lanes [Interleaved])

Chirp 1	Rx0I0	Rx1I0	Rx2I0	Rx3I0	Rx0Q0	Rx1Q0	Rx2Q0	Rx3Q0
	Rx0I4	Rx1I4	Rx2I4	Rx3I4	Rx0Q4	Rx1Q4	Rx2Q4	Rx3Q4
	…		…		…		…	…
	Rx0IN-1	Rx1IN-1	Rx2IN-1	Rx3IN-1	Rx0QN-1	Rx1QN-1	Rx2QN-1	Rx3QN-1
Chirp 2	Rx0I0	Rx1I0	Rx2I0	Rx3I0	Rx0Q0	Rx1Q0	Rx2Q0	Rx3Q0
	Rx0I4	Rx1I4	Rx2I4	Rx3I4	Rx0Q4	Rx1Q4	Rx2Q4	Rx3Q4
	…		…		…		…	…
	Rx0IN-1	Rx1IN-1	Rx2IN-1	Rx3IN-1	Rx0QN-1	Rx1QN-1	Rx2QN-1	Rx3QN-1

S

22.7 DCA1000 EVM capture format (xWR12xx/xWR14xx real, 4 channel, 4 lanes [Interleaved])

Chirp 1	Rx0I0	Rx1I0	Rx2I0	Rx3I0	Rx0I1	Rx1I1	Rx2I1	Rx3I1
	Rx0I4	Rx1I4	Rx2I4	Rx3I4	Rx0I5	Rx1I5	Rx2I5	Rx3I5
	…		…		…		…	…
	Rx0IN-2	Rx1IN-2	Rx2IN-2	Rx3IN-2	Rx0IN-1	Rx1IN-1	Rx2IN-1	Rx3IN-1
Chirp 2	Rx0I0	Rx1I0	Rx2I0	Rx3I0	Rx0I1	Rx1I1	Rx2I1	Rx3I1
	Rx0I4	Rx1I4	Rx2I4	Rx3I4	Rx0I5	Rx1I5	Rx2I5	Rx3I5
	…		…		…		…	…
	Rx0IN-2	Rx1IN-2	Rx2IN-2	Rx3IN-2	Rx0IN-1	Rx1IN-1	Rx2IN-1	Rx3IN-1

22.8 DCA1000 EVM capture format (xWR16xx complex, 4 channel, 2 lanes [Non-Interleaved])

Chirp 1	Rx0I0	Rx0I1	Rx0Q0	Rx0Q1	Rx0I2	Rx0I3	Rx0Q2	Rx0Q3
	Rx0I4	Rx0I5	Rx0Q4	Rx0Q5	Rx0I6	Rx0I7	Rx0Q6	Rx0Q7
	…		…		…		…	…
	Rx3IN-4	Rx3IN-3	Rx3QN-4	Rx3QN-3	Rx3IN-2	Rx3IN-1	Rx3QN-2	Rx3QN-1
Chirp 2	Rx0I0	Rx0I1	Rx0Q0	Rx0Q1	Rx0I2	Rx0I3	Rx0Q1	Rx0Q3
	Rx0I4	Rx0I5	Rx0Q4	Rx0Q5	Rx0I6	Rx0I7	Rx0Q6	Rx0Q7
	…		…		…		…	…
	Rx3IN-4	Rx3IN-3	Rx3QN-4	Rx3QN-3	Rx3IN-2	Rx3IN-1	Rx3QN-2	Rx3QN-1

22.9 DCA1000 EVM capture format (xWR16xx real, 4 channel, 2 lanes [Non-Interleaved])

Chirp 1	Rx0I0	Rx0I1	Rx0I2	Rx0I3	Rx0I4	Rx0I5	Rx0I6	Rx0I7
	Rx0I8	Rx0I9	Rx0I10	Rx0I11	Rx0I12	Rx0I13	Rx0I14	Rx0I15
	…		…		…		…	…
	Rx3IN-8	Rx3IN-7	Rx3IN-6	Rx3IN-5	Rx3IN-4	Rx3IN-3	Rx3IN-2	Rx3IN-1
Chirp 2	Rx0I0	Rx0I1	Rx0I2	Rx0I3	Rx0I4	Rx0I5	Rx0I6	Rx0I7
	Rx0I8	Rx0I9	Rx0I10	Rx0I11	Rx0I12	Rx0I13	Rx0I14	Rx0I15
	…		…		…		…	…
	Rx3IN-8	Rx3IN-7	Rx3IN-6	Rx3IN-5	Rx3IN-4	Rx3IN-3	Rx3IN-2	Rx3IN-1

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