

Experiment with Radar Studio, TSW1400, Devpack, IWR1443 and measurement 2.7m RCS .5 target, measurement at 10meters.

Table of Contents	Page#
Section 1 - Purpose	1
Section 2 - Hardware Setup	1
Section 3 - Radar Key parameters – mmWave Sensing Estimator	3
Section 4 - Radar Studio operation	5
Section 5 – 10m measurement example IWR1642	24

Section 1 Purpose

This experiment utilizes the Sensing Estimator to extract parameters for use in Radar Studio. We then apply these radar parameters to Radar Studio, in order to process experiments, and illustrate what some of the key Radar Studio parameters are.

Note: References - The Radar Studio User Guide, Sensing Estimator User Guide, TSW1400 User Guide, and dfp Installation Instructions are all referenced. There is online training for using Radar Studio, with TSW1400 for mmWave, and a PPTX document.

Section 2 Hardware Setup

The TSW1400, Devpack, and Radar Sensor EVM are mounted together, using the short data cable, in a Panavise. Note: be careful not to crush components on the TSW1400 using the panavise.

Follow the TSW1400, Radar Studio user and Installation guide for hardware and software setup.

In my usage, I have a USB powered hub from the computer to the TSW1400, Devpack, and Radar Sensor IWR1443.

Figure 1 – Frontside TSW1400,Devpack, IWR1443 Radar Sensor EVM

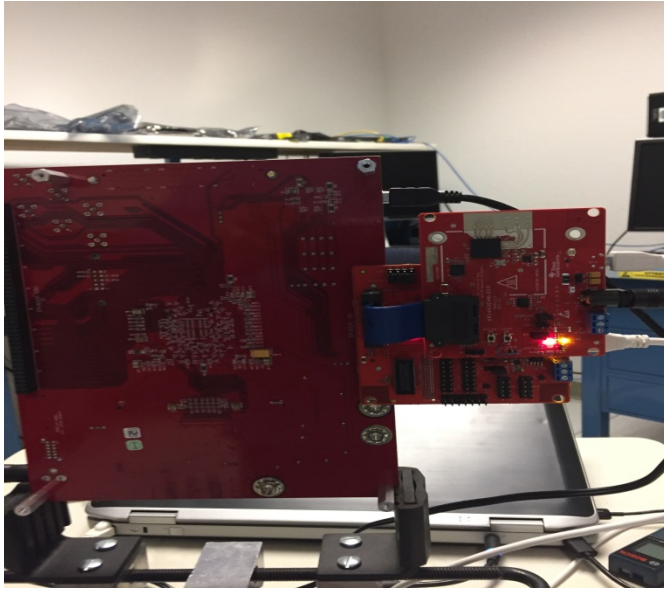
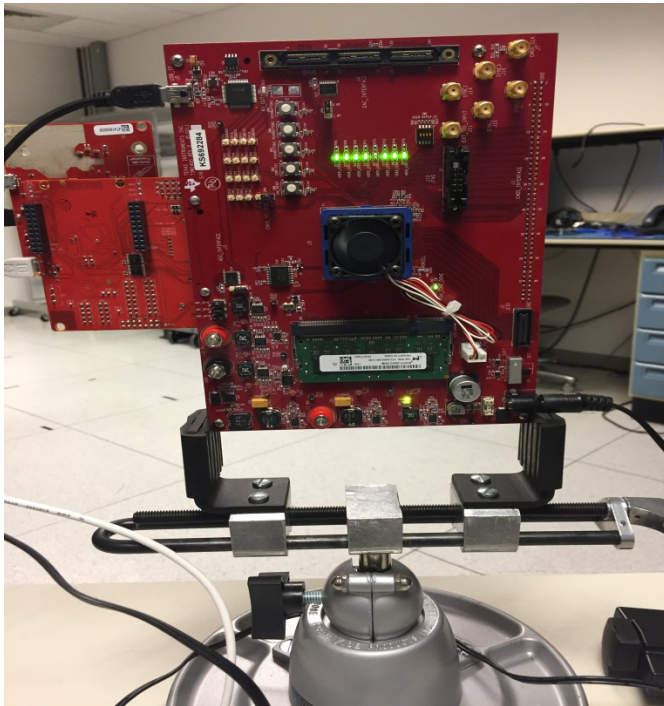


Figure 2 – Backside TSW1400,Devpack, IWR1443 Radar Sensor EVM



The RCS target is mounted on a tripod with Velcro. The RCS target is 2.7 meters from the radar sensor. See Figure 3.

Figure 3 – RCS Target



Section 3 Radar Key parameters – mmWave Sensing Estimator

The Radar Key parameters for this experiment are:

High Range Resolution, < 5cm

The Velocity max, and Velocity resolution are adjusted to get the desired number of FFT points, this is a range demonstration. Velocity is not a key value.

Range of 10 meters

Use of 1024 point FFT – highest native frequency bin resolution

Using the mmWave Sensing Estimator; the key parameters are shown in Figure 4, from mmWave Sensing Estimator Tool.

Load the provided configuration file into the Sensing Estimator -
test_range10m_rangeres4p1cm_1021samples.json

Figure 4 – mmWave Sensing Estimator

Assumptions and Inputs | Short Range Default

Device Specific Parameters

mmWave Sensor	xWR1443
# of Rx Antennas	4
# of Tx Antennas	1

Board Specific Parameters

Transmit Antenna Gain (dB)	8
Receive Antenna Gain (dB)	8

Regulatory Restrictions

Frequency Range (GHz)	77 - 81
Maximum Bandwidth (MHz)	4000
Transmit Power (dBm)	12

Scene Parameters

Ambient Temperature (deg Celcius)	20
Maximum Detectable Range (m)	10
Range Resolution (cm)	4.1
Maximum Velocity (km/h)	6.45
Velocity Resolution (km/h)	12.9
Measurement Rate (Hz)	10
Typical Detectable Object (m*2)	Adult 1

Additional Parameters

Detection Loss (dB)	2
System Loss (dB)	1
Implementation Margin (dB)	2
Detection SNR (dB)	12

Outputs and Chirp Design

Detectable Object Range

Max Range for Typical Detectable Object (m)	36.14
Min RCS Detectable at Max Range (m*2)	0.01

Chirp Design Parameters

Valid Sweep Bandwidth (MHz)	3658.54	Idle Time Minimum (us)	7
Ramp Slope Init (MHz/us)	7.17	Ramp End Time	523.70
Ramp Slope Parameter	1.49	ADC Valid Start Time Minimum (us)	10.70
Ramp Slope (MHz/us)	7.19	Max Chirp Repetition Period (us)	543
Inter-chirp Time (us)	20.20	Chirp Repetition Period (us)	530.70
Chirp time, Tc (us)	510.26	# of Range FFT Bins	1024
Number of Samples per Chirp	1021	Min # of Chirp Loops	2
Maximum Beat Frequency (MHz)	0.48	# of Doppler FFT Bins	2
Sampling Frequency Minimum (MSPS)	2	Active Frame Time (ms)	1.06
Total Sweep Bandwidth (MHz)	3767.33	Range Interbin Resolution (cm)	4.09
Carrier Frequency (GHz)	77.09	Velocity Interbin Resolution (m/s)	3.58
Lambda (mm)	3.89	Radar Cube Size (KB)	32

No errors are found.

SAVE CONFIG | LOAD CONFIG | RESET CONFIG

Note: if there are errors in the Sensing Estimator they would be displayed as red boxes, values, and have an error below the outputs and chirp design section.

Section 4 - Radar Studio operation

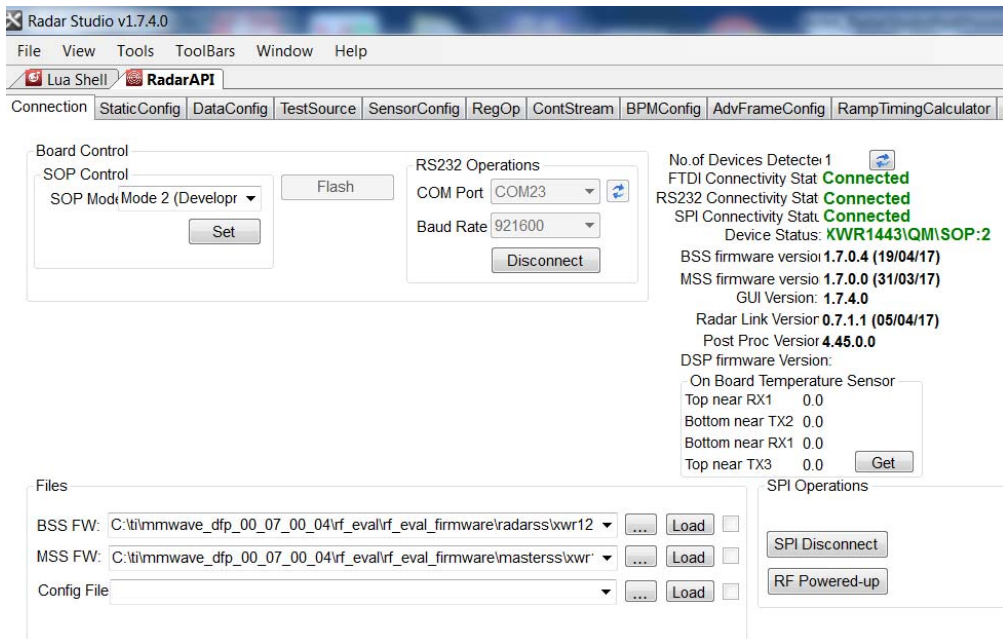
Radar Studio setup, is done by following the PPTX instructions, it is not clear in the graphics, there is a blue highlight for the different screens.

The normal setup is:

- Launch program
- Load configuration file
- Connection
- Static Configuration
- Data Configuration
- Ramp Timing Calculator
- Sensor Configuration
- Run Experiment and Post Processing

4.1 Launch Program

Figure 5 – Radar Studio - Connection



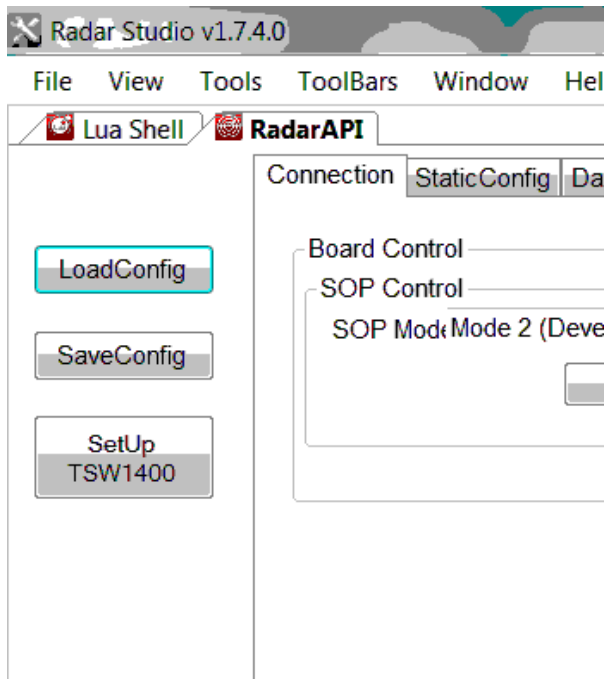
Follow through the initialization steps, Board Control Set, Connect RS232 Com Port (Control port).

Load the BSS FW, MSS FW, SPI Connect.

RF Power Up.

Load Configuration File, on the left of the display, use Load Config, navigate to setup file.

Figure 6 – Radar Studio – Connection – Load Configuration

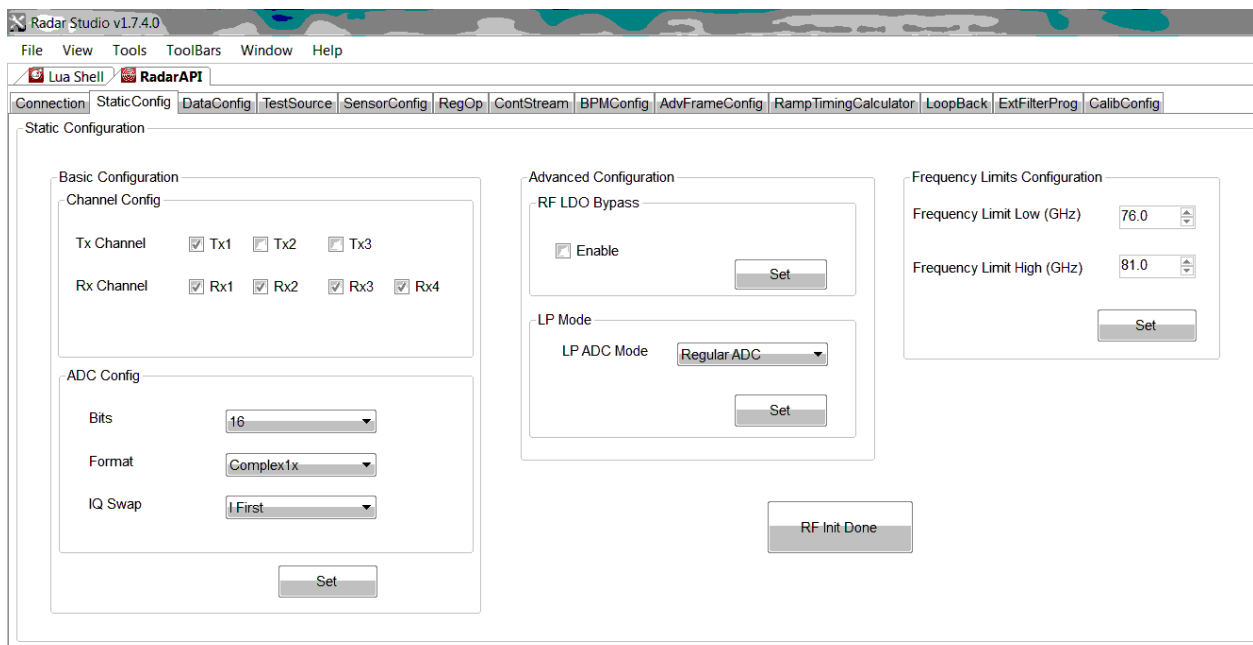


4.2 Static Config – select the Static Config tab

The Tx Channel, Rx Channel have to match the Sensing Estimator.

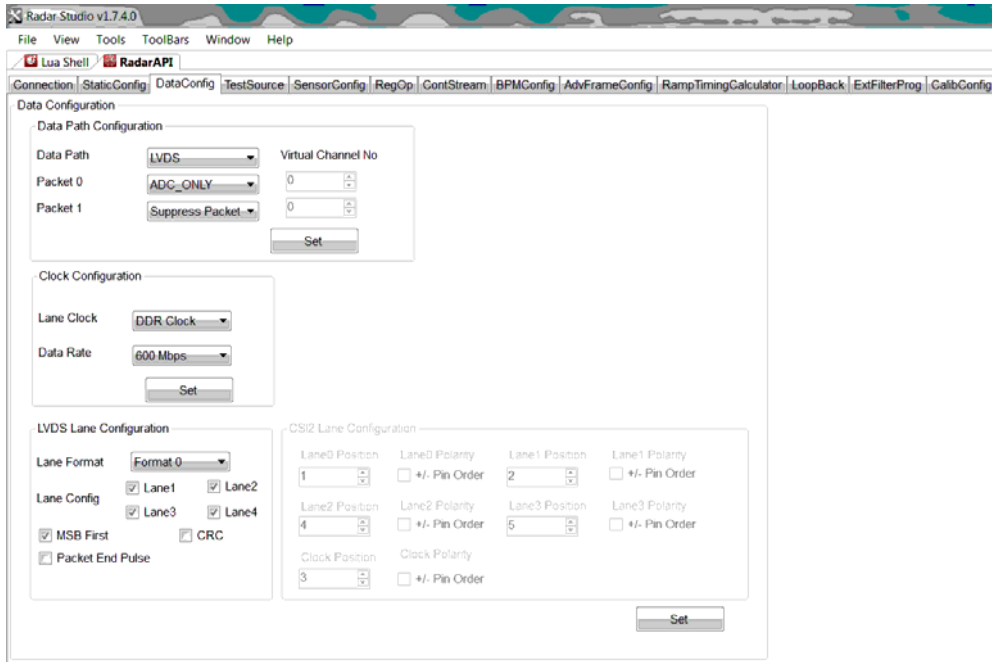
Set the Basic Configuration, LP Mode, and Select RF Init

Figure 7 – Radar Studio – Static Configuration



4.3 Data Config (LVDS output) – select the Data Config tab

Figure 8 – Radar Studio – Data Configuration



Normally the number of LVDS lanes matches the number of receivers active. We can lower the DDR clock rate, but then we need to calculate the chirp/frame time. Set the Data Path Configuration, Set the Clock Configuration, Set the LVDS Lane Configuration.

4.4 Profile, Chirp, and Frame Configuration

Note: The goal is to populate the Sensor Config tab. Some of the values calculated in Radar Studio are different from the Sensing Estimator, ADC Start time, Idle Time, Excess Ramp time. Currently you need to select the larger values.

Chirp, Profile, Frame configuration, is done in steps. Comparing the Sensing Estimator and the various tabs for Radar Studio.

Ramp Timing Calculator – open the Ramp Timing Calculator tab

You need to enter the ADC mode, DFE output mode, Synthesizer Slope, number of samples in Chirp, DFE output rate, HPF settings in the Ramp Timing inputs.

Normally the DFE Mode is Complex 1x.

Normally the ADC Mode is full rate, if the DFE output rate is < 5000kps it can be Half rate .

Synthesizer slope, ADC samples, come from the Estimator.

The HPF1, HPF2 analog High Pass filters, normally use the default values.

Figure 9 – Radar Studio – Ramp Timing Calculator

Ramp Timing Calculator

The following utility assumes that chirps of only 1 profile are used within a frame. The Ramp Timing Calculator assumes that TX start time is set to 0 (at knee of the ramp) or earlier. NOTE: This calculation does not take care of separately.

Ramp Timing Inputs

ADC Full Rate Mode ADC Half Rate Mode

DFE Mode: HPF1 Corner Freq:

Slope (MHz/ μ s): HPF2 Corner Freq:

ADC Samples:

Sample Rate (ksps):

You then need to record the recommended configuration for the 99% column.

Figure 10 – Radar Studio – Ramp Timing Calculator – Recommended Configuration

Ramp timing outputs are minimum values needed values for full filter chain settling. This calculation does not take into account the high speed lane rate requirements. These will have to be adjusted.

Recommended Configuration

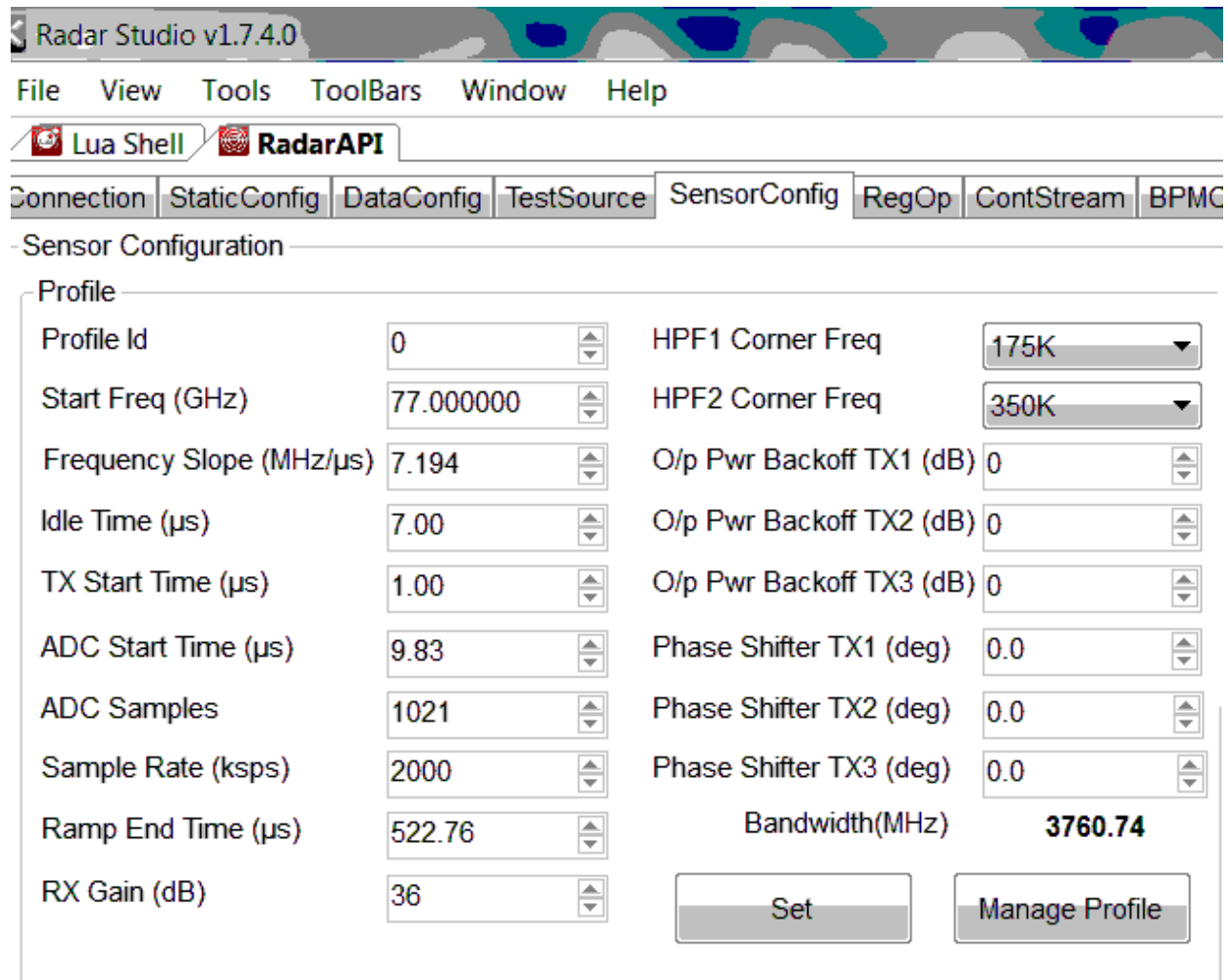
	90% Settling	95% Settling	99% Settling	User Prog
Idle Time (μ s)	<input type="text" value="7"/>	<input type="text" value="7"/>	<input type="text" value="7"/>	<input type="text" value="7"/>
ADC Start Time (μ s)	<input type="text" value="1.97"/>	<input type="text" value="5.38"/>	<input type="text" value="9.83"/>	<input type="text" value="5.38"/>
Ramp End Time (μ s)	<input type="text" value="514.9"/>	<input type="text" value="518.31"/>	<input type="text" value="522.76"/>	<input type="text" value="518.31"/>
Valid Sweep BW (MHz)	<input type="text" value="3672.54"/>	<input type="text" value="3672.54"/>	<input type="text" value="3672.54"/>	<input type="text" value="3672.54"/>
Total Sweep BW (MHz)	<input type="text" value="3704.19"/>	<input type="text" value="3728.72"/>	<input type="text" value="3760.74"/>	<input type="text" value="3728.72"/>
Inter Chirp Time (μ s)	<input type="text" value="11.4"/>	<input type="text" value="14.81"/>	<input type="text" value="19.26"/>	<input type="text" value="14.81"/>

You need to copy the chirp settings to the SensorConfig tab of Radar Studio.

- Idle Time
- ADC Start Time
- Ramp End Time
- Note: Tx start time is not calculated, we use 1us as a default.

Chirp Configuration

Figure 11 – Radar Studio – Chirp Configuration - Profile



If the initial case has > 1 Tx, you need to set different chirps, note: when the file is saved multiple chirps are not restored after save. Make sure you save a picture of the additional profile or chirp configurations, as you will have to enter them manually.

Note: Rx Gain is 24-48db, 30 is the default, 36 is a value here, most of the time we use 48.

After you have entered profile 0, depress Set.

Figure 12 – Radar Studio – Chirp Configuration - Chirp

Chirp

Profile Id	0	Frequency Slope Var (MHz/μs)	0.000
Start Chirp for Cfg	0	Idle Time Var (μs)	0.00
End Chirp for Cfg	0	ADC Start Var (μs)	0.00
Start Freq Var (MHz)	0.000000	TX Enable for current chirp	
<input checked="" type="checkbox"/> TX1 <input type="checkbox"/> TX2 <input type="checkbox"/> TX3			

Set Manage Chirps

In the chirp tab, we have the individual Tx set, since we have 1 Tx from the Sensing Estimator, we have one Chirp (simplified). We reference the RF profile entered above.

Depress Set when complete.

Frame Configuration

The frame configuration is the number of chirp sets * number of Frames from the Sensing Estimator.

The Sensing Estimator has 2 frames, typically we record 10.

Chirp period * 2 * number of chirp loops (128, min is 2) = Periodicity for Frame ms (note 2 is to maintain 50% dutycycle)

Figure 13 – Radar Studio – Chirp Configuration - Frame

The screenshot shows a dialog box titled "Frame" with the following configuration options:

Start Chirp TX	0	No of Chirp Loops	128
End Chirp TX	0	Periodicity (ms)	136.000000
No of Frames	10	Trigger Delay (μ s)	0.00
		Duty Cycle	49.9 %
Trigger Select	SoftwareTrigger		
<input type="checkbox"/> Test Source Enable	<input type="button" value="Set"/>		

4.5 Running the experiment and Post Processing

We then run radar Studio, setting the profile, chirp, frame configuration, we then Setup TSW1400 (left margin), arm TSW1400, and Trigger TSW1400.

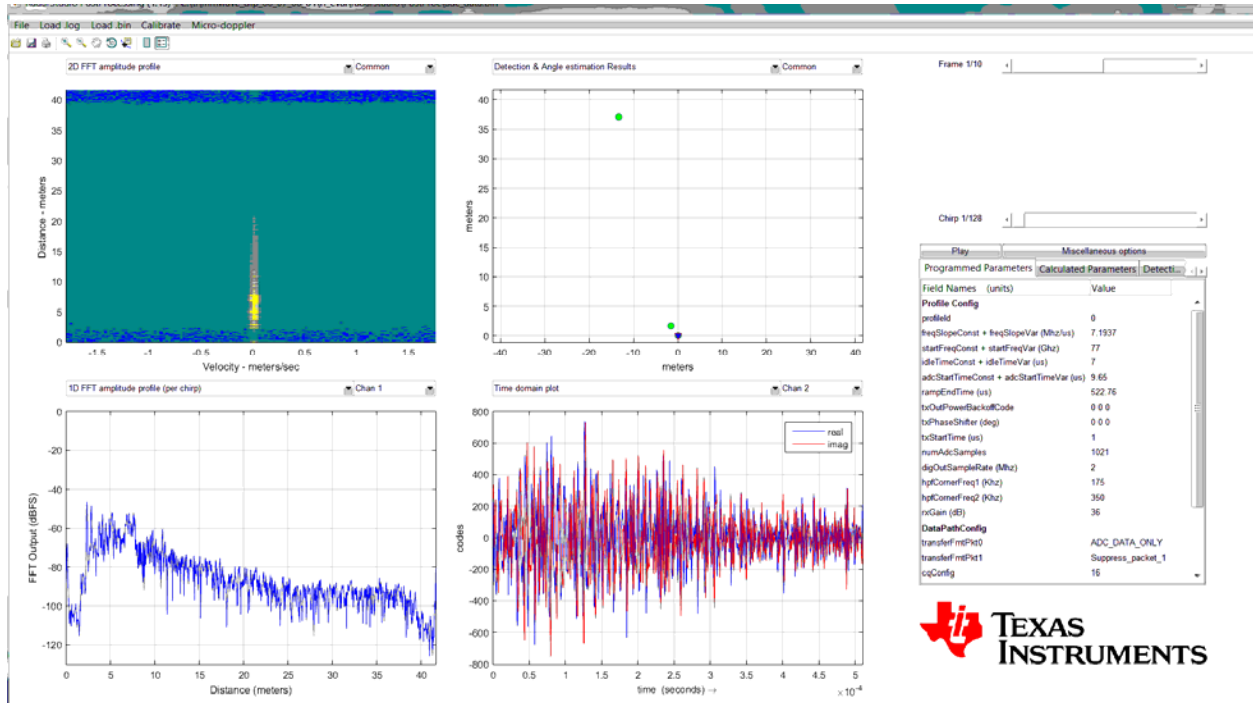
Wait for capture complete. Then push Post Process..

5.0 Matlab Post Processing Radar Studio

In the Sensor Configuration tab, there is a location for the file, that will be written by TSW1400, and then read for Post Processing.

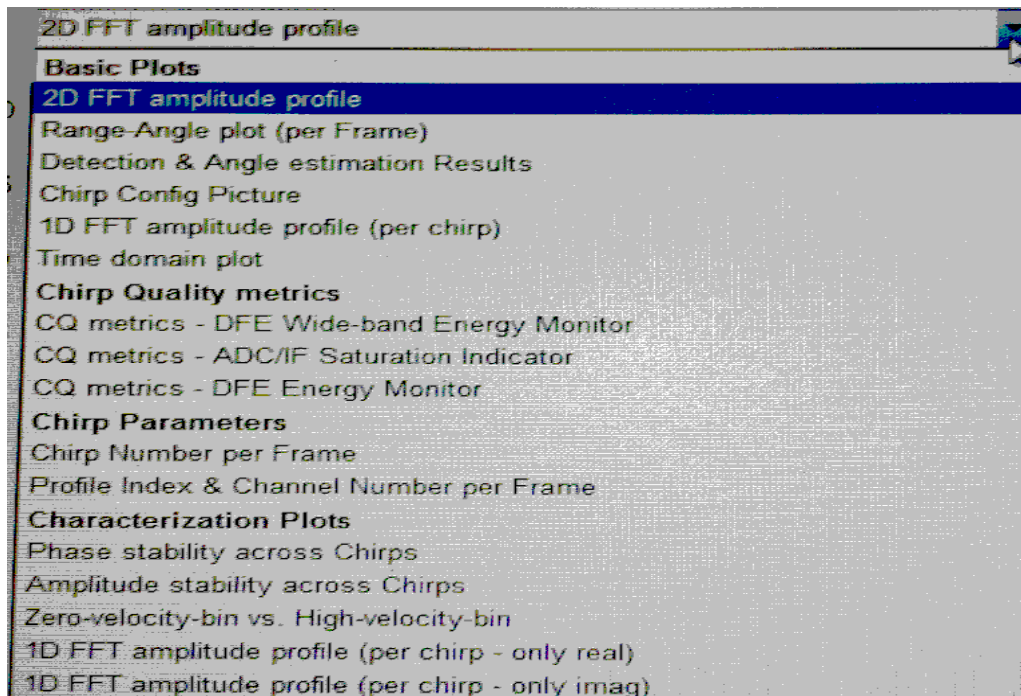
The Compiled Matlab GUI is run after post processing, look at the lower right status box on Radar Studio if there are error conditions during the experiment run, we don't expect post-processing to be successful.

Figure 14 – Radar Studio – Post Processing Matlab



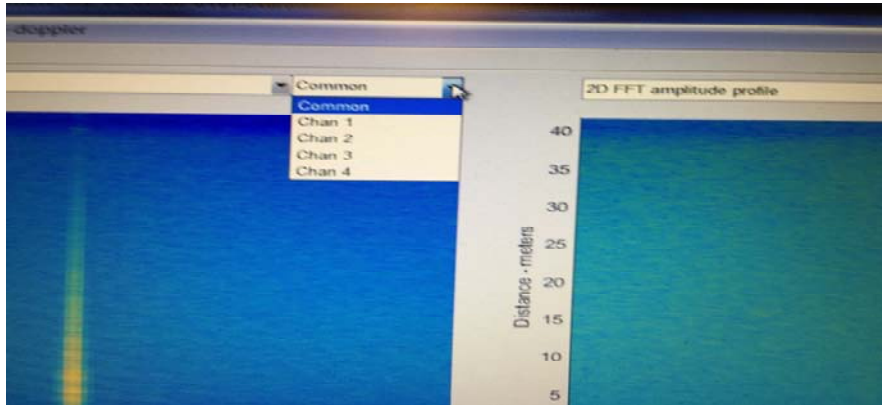
At the top of each selected graph, there are different graph types that can be selected. These are setup by default, then you can change them.

Figure 15 – Radar Studio – Post Processing Matlab – Plot Select



Under each graph section on the right side, we can have a collection of common or individual receiver channels.

Figure 16 – Radar Studio – Post Processing Matlab – Plot Select



On the right side of the graph, there are several data selectors, sets of parameters, and a miscellaneous option menu.

Frame Selector

Figure 17 – Radar Studio – Post Processing Matlab – Frame Select



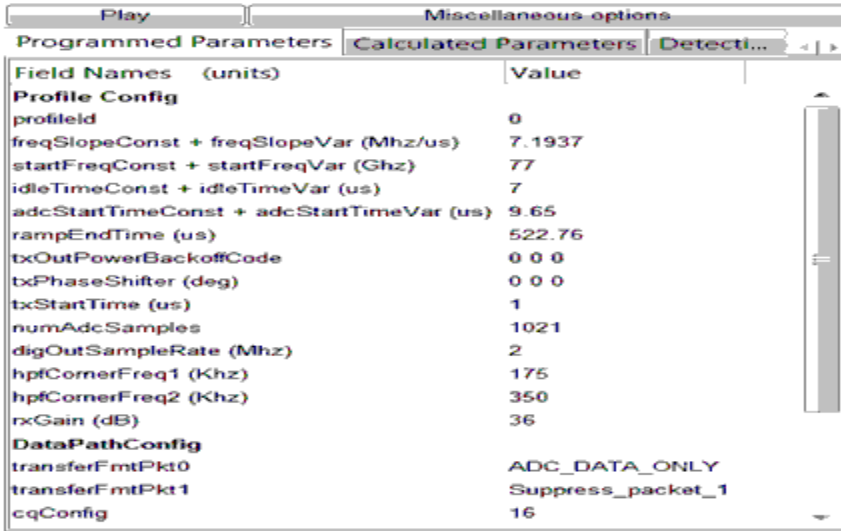
Chirp Selector

Figure 18 – Radar Studio – Post Processing Matlab – Chirp Select



The Frame, Chirp selectors can be used to select specific captured data for display.

Figure 19 – Radar Studio – Post Processing Matlab – Play, Miscellaneous, Programmed Parameters, Calculated Parameters, Detection



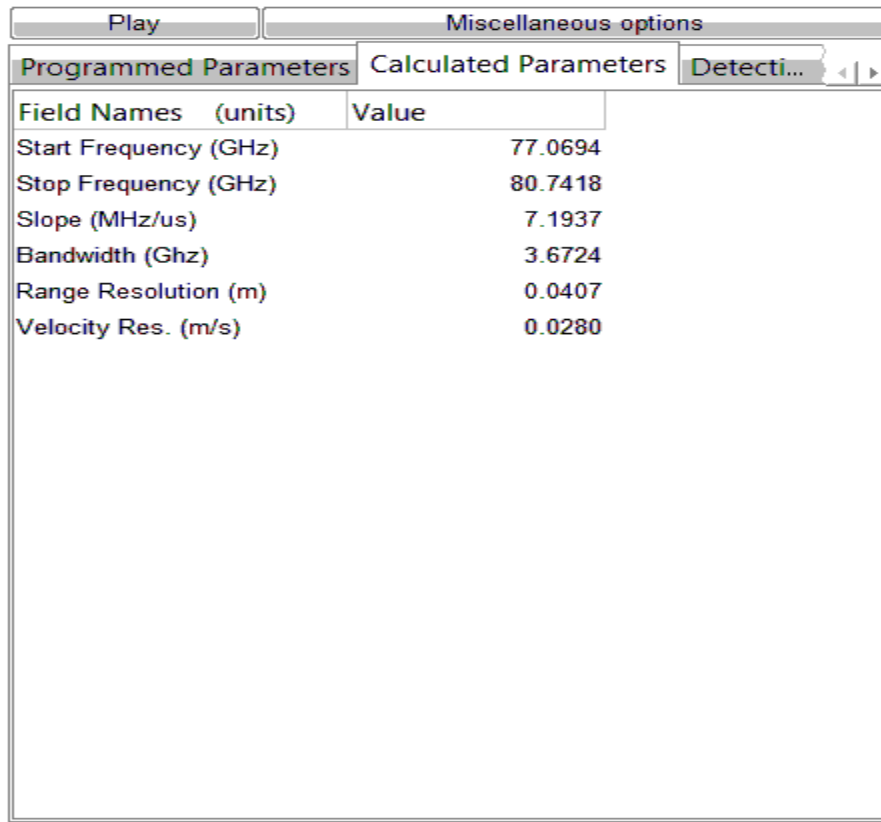
Field Names (units)	Value
Profile Config	
profileId	0
freqSlopeConst + freqSlopeVar (Mhz/us)	7.1937
startFreqConst + startFreqVar (Ghz)	77
idleTimeConst + idleTimeVar (us)	7
adcStartTimeConst + adcStartTimeVar (us)	9.65
rampEndTime (us)	522.76
txOutPowerBackoffCode	0 0 0
txPhaseShifter (deg)	0 0 0
txStartTime (us)	1
numAdcSamples	1021
digOutSampleRate (Mhz)	2
hpfCornerFreq1 (Khz)	175
hpfCornerFreq2 (Khz)	350
rxGain (dB)	36
DataPathConfig	
transferFmtPkt0	ADC_DATA_ONLY
transferFmtPkt1	Suppress_packet_1
cqConfig	16

The play button allows a specific selected chip to be played across multiple frames.

The Programmed Parameters – are passed from the Radar Studio setup to the Matlab script. They are shown in the above figure.

Calculated Parameters – these are computed from the Chirp, Profile parameters for Matlab.

Figure 20 – Radar Studio – Post Processing Matlab – Calculated Parameters

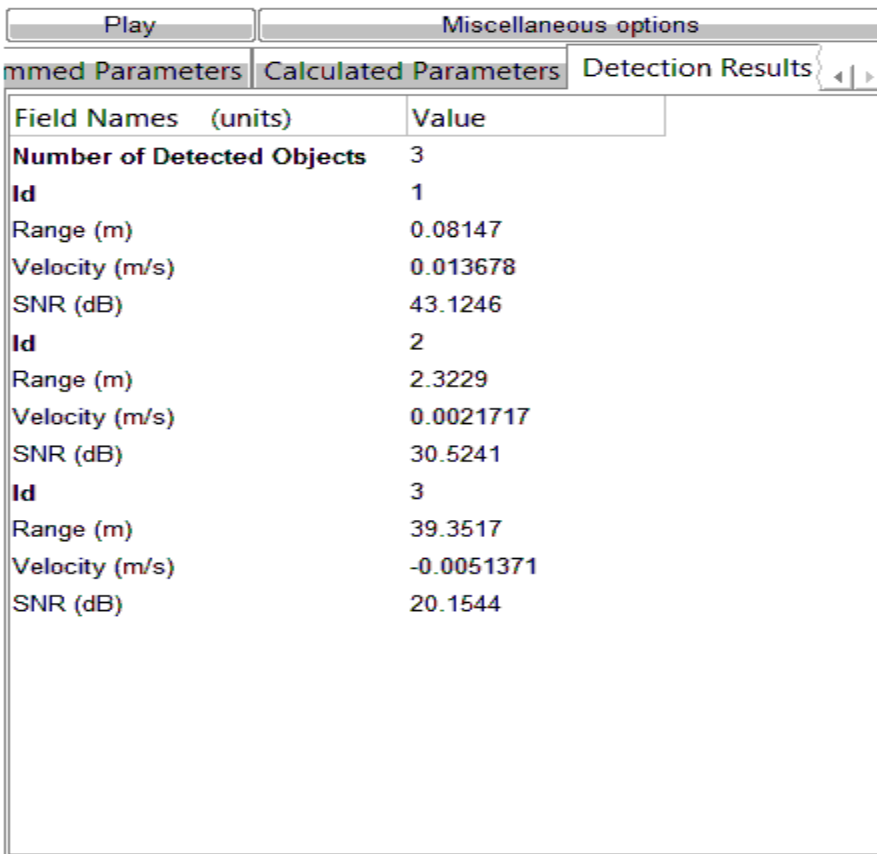


The screenshot shows the Radar Studio software interface. At the top, there are two buttons: "Play" and "Miscellaneous options". Below these are three tabs: "Programmed Parameters", "Calculated Parameters", and "Detecti...". The "Calculated Parameters" tab is active, displaying a table with the following data:

Field Names (units)	Value
Start Frequency (GHz)	77.0694
Stop Frequency (GHz)	80.7418
Slope (MHz/us)	7.1937
Bandwidth (Ghz)	3.6724
Range Resolution (m)	0.0407
Velocity Res. (m/s)	0.0280

We pass the ADC Buffer data from the radar sensor, through Radar Studio, to the recorded file. The recorded file is post processed, so that we can detect specific objects.

Figure 21 – Radar Studio – Post Processing Matlab – Detection



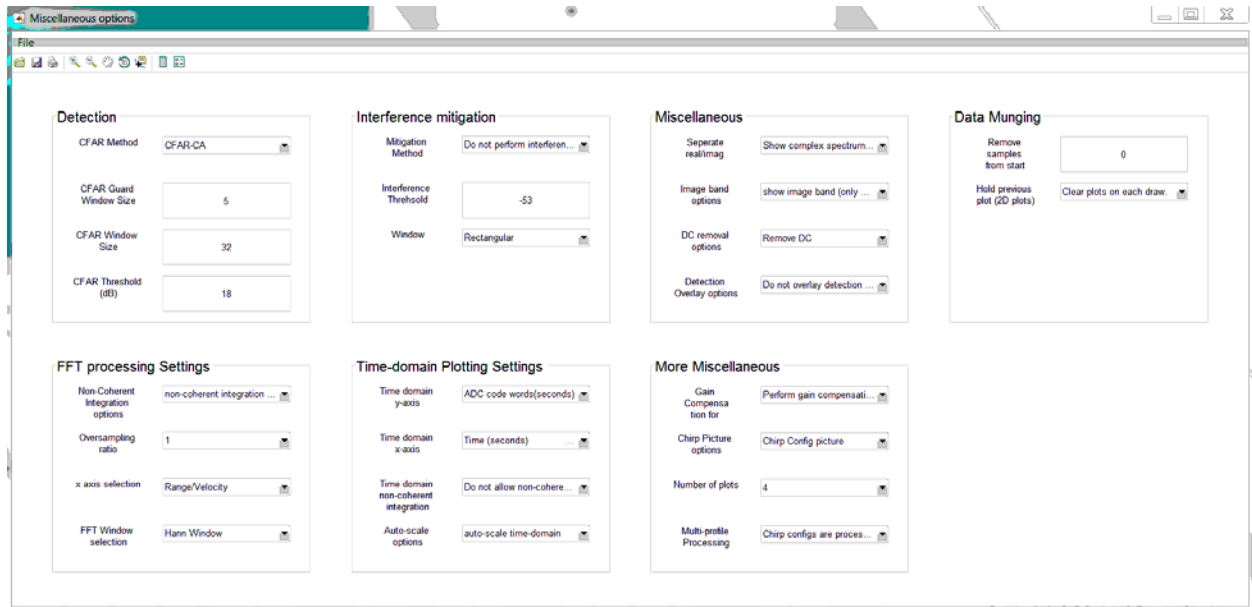
The screenshot shows the 'Detection Results' tab of the Radar Studio software. At the top, there are buttons for 'Play' and 'Miscellaneous options'. Below these are three tabs: 'Immed Parameters', 'Calculated Parameters', and 'Detection Results'. The 'Detection Results' tab is active and displays a table with two columns: 'Field Names (units)' and 'Value'. The table lists parameters for three detected objects, including their IDs, ranges, velocities, and SNR values.

Field Names (units)	Value
Number of Detected Objects	3
Id	1
Range (m)	0.08147
Velocity (m/s)	0.013678
SNR (dB)	43.1246
Id	2
Range (m)	2.3229
Velocity (m/s)	0.0021717
SNR (dB)	30.5241
Id	3
Range (m)	39.3517
Velocity (m/s)	-0.0051371
SNR (dB)	20.1544

The miscellaneous options, brings up another set of processing and graph selections. It is described in the following sections

Miscellaneous options

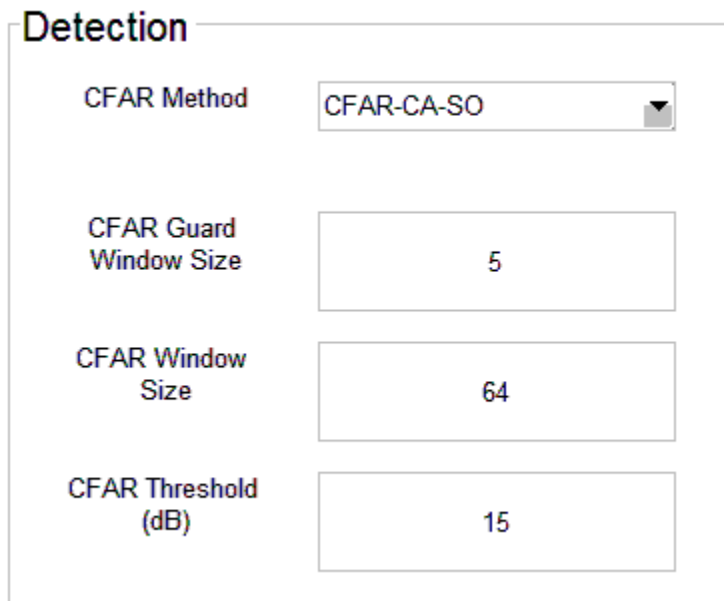
Figure 22 – Radar Studio – Post Processing Matlab – Miscellaneous options



Note: normally this can be left open, to reprocess the desired mode of the captured data.

a) Detection

Figure 23 – Radar Studio – Post Processing Matlab – Miscellaneous options - Detection



CFAR Method – the 3 modes are covered in Section 2.1 of Part 2 of the Hardware Accelerator User Guide. For the xWR1642, the equivalent DSP code is being described. Also covered in <http://www.radartutorial.eu/01.basics/False%20Alarm%20Rate.en.html>

CFAR-CA – default

CFAR_CAGO – looks for greater of the left or right samples, picks the larger for comparison with current

CFAR_CASO – looks for smaller of the left or right samples, picks the smaller for comparison with current
This is the 2nd choice.

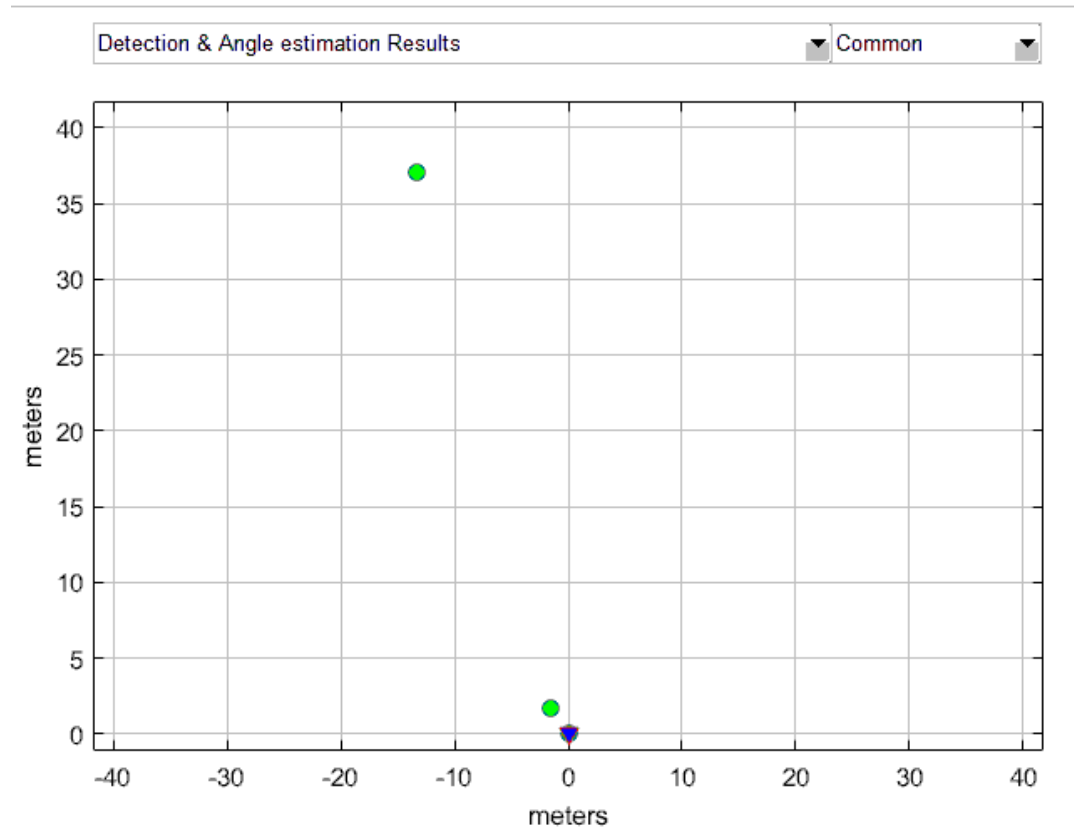
CFAR Guard Window – these are the samples around the peak-being-measured to exclude from the average

CFAR Window Size – the number of cells to include in the cell average.

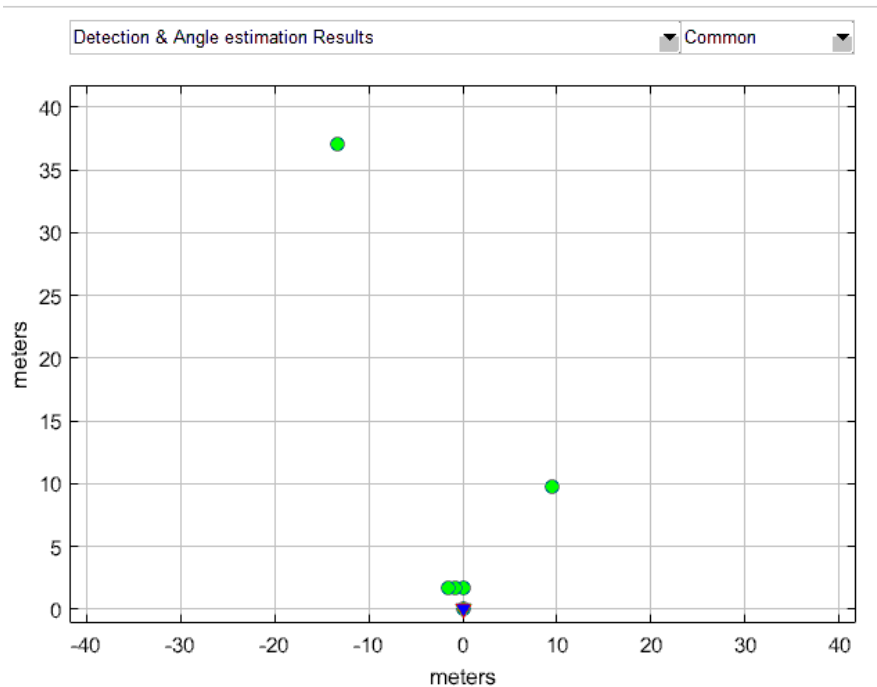
CFAR Threshold – how strong in db a peak must be above the average

Note: some references have additional CFAR capabilities, these could be built into the x1642 version, due to DSP coding, they are not in the HardWare Accelerator in the x1443 devices.

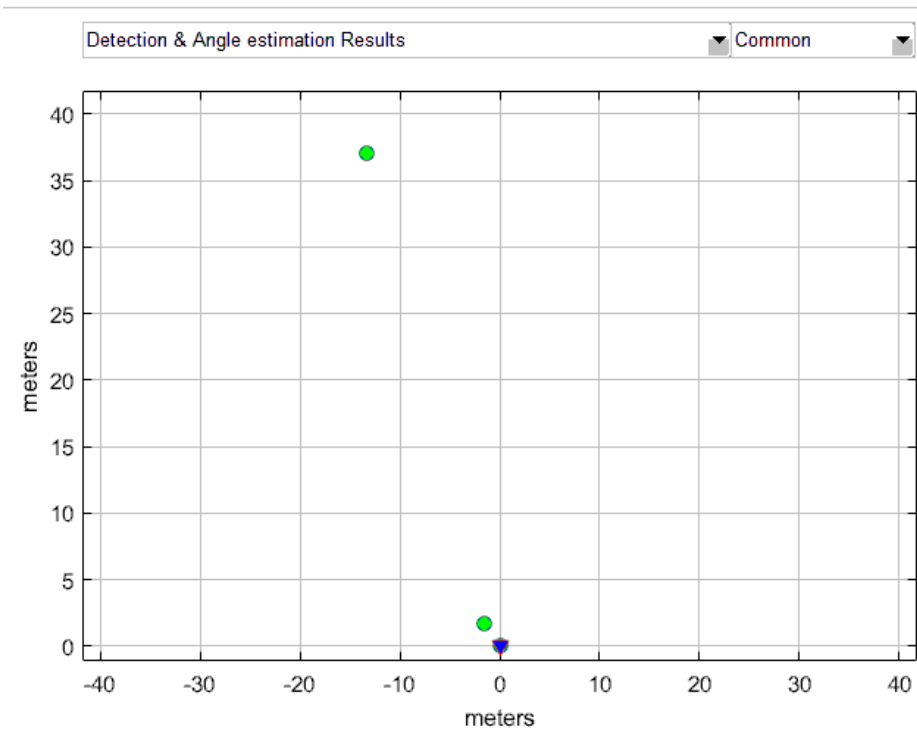
Reference default



Example change to CFAR_CASO, lower the detect SNR to 12



Changing the window size to 64 samples, changing the SNR back to 15



b) FFT Processing Settings

Figure 23 – Radar Studio – Post Processing Matlab – Miscellaneous options – FFT Processing

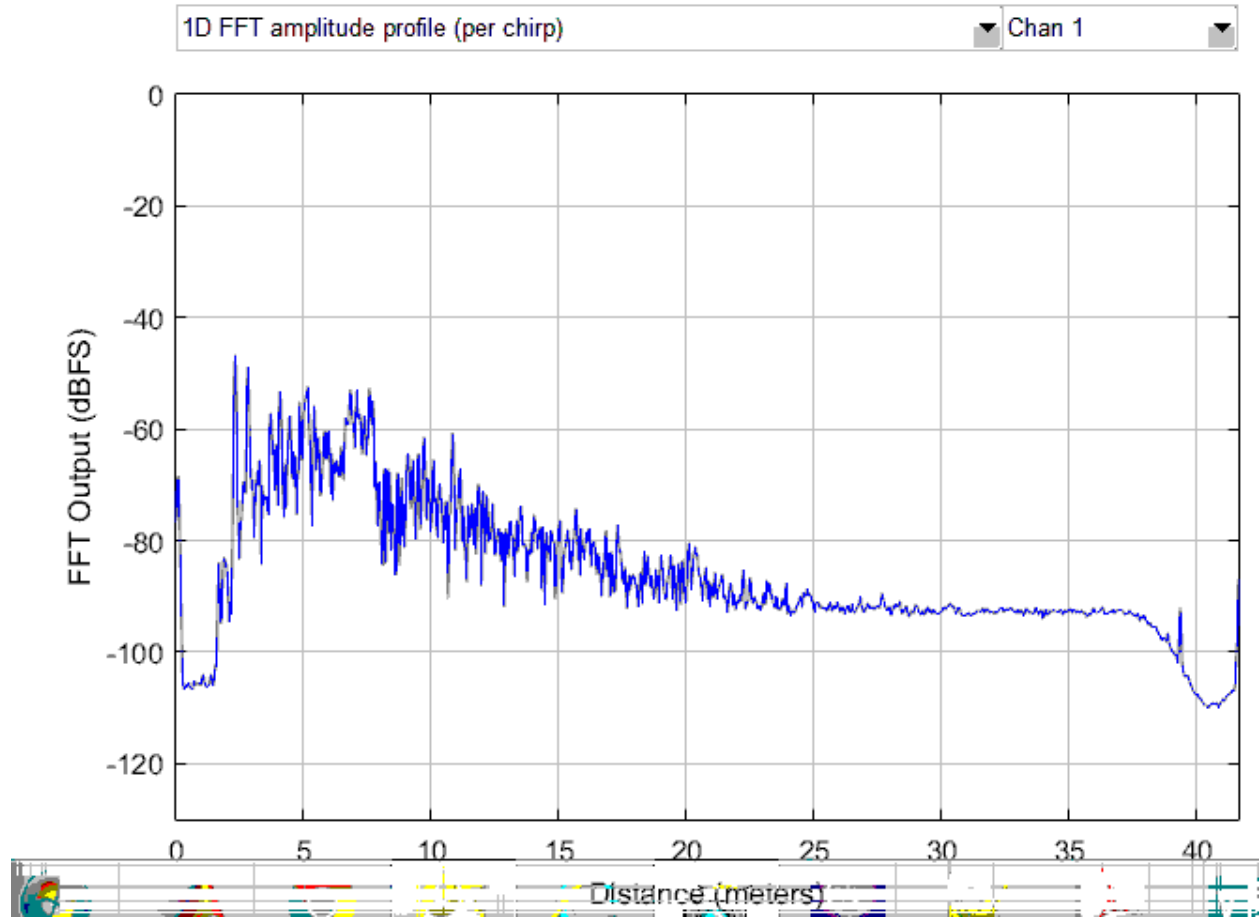
FFT processing Settings

Non-Coherent Integration options	No non-coherent integrat... ▼
Oversampling ratio	1 ▼
x axis selection	Range/Velocity ▼
FFT Window selection	Hann Window ▼

FFT processing Settings which affects the Lower left graph.

Integration across chirps, and receivers - Compare changes in the lower left graph for the option changes below. Selecting Non Coherent Integration across chirps, provides an averaging for each Receiver channel

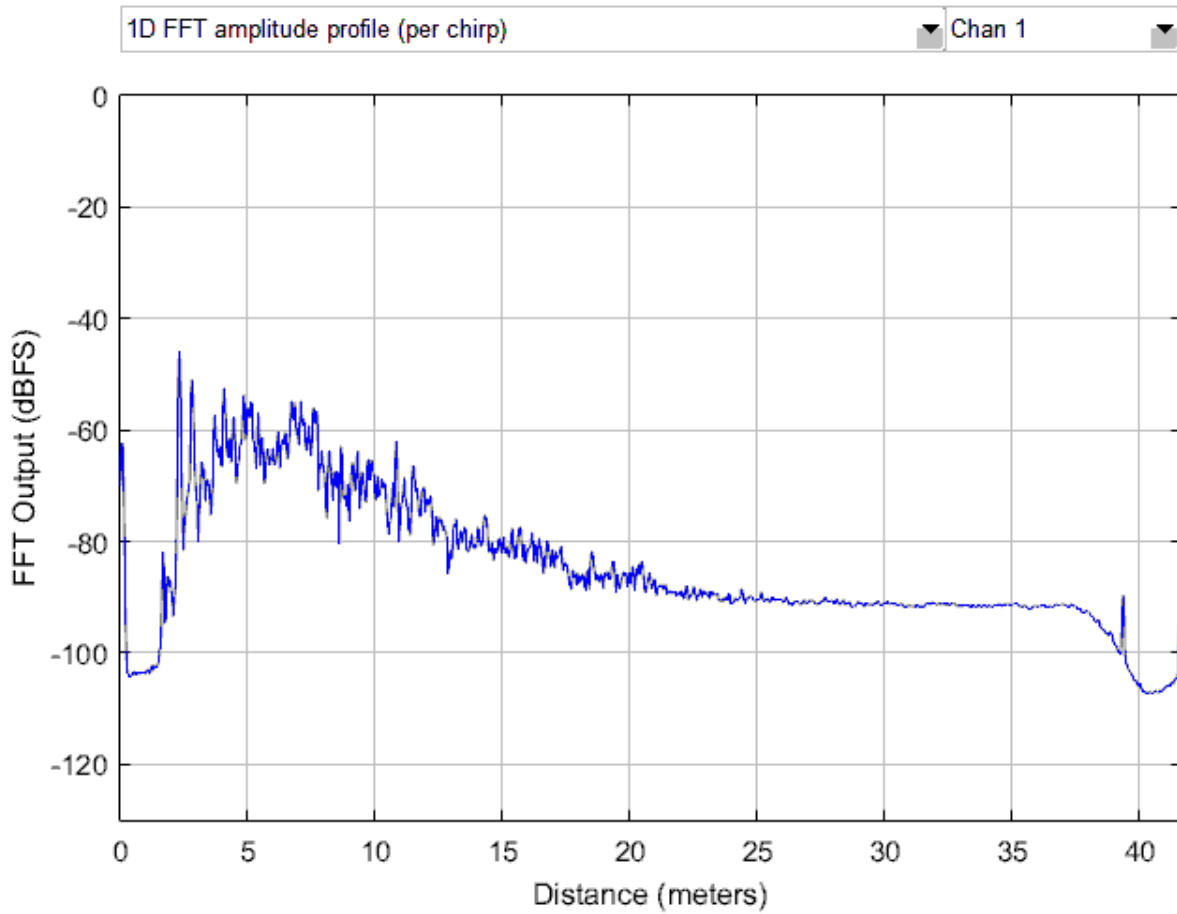
Figure 24 – Radar Studio – Post Processing Matlab – Miscellaneous options – FFT affects



You can still select each receiver channel above and to the right of the graph.

Selecting the Non Coherent Integration across chirps AND antennas, gives an average view of the receivers combined.

Figure 25 – Radar Studio – Post Processing Matlab – Miscellaneous options – FFT affects



Oversampling ratio applies a zero insertion technique for having more points for FFT processing. Normally it is set to 1.

X axis for FFT plot can be Distance, or Frequency using the selected value.

FFT Window selection provides the prewindowing for the ADC Buffer samples prior to the FFT. Hahn is normally selected.

Note: the FFT window selection also affects the heat map.

c) Interference Mitigation

Figure 26 – Radar Studio – Post Processing Matlab – Miscellaneous options – Interference Mitigation

Interference mitigation

Mitigation Method	Do not perform interferen... ▼
Interference Threhsold	-53
Window	Rectangular ▼

allows for detection if Interference (I think using the CQ data), this is not yet enabled – TBD, it may also require Complex 2x processing

d) Time Domain Plotting Settings

Figure 27 – Radar Studio – Post Processing Matlab – Miscellaneous options – Time Domain Plotting

Time-domain Plotting Settings

Time domain y-axis	ADC code words(seconds) ▼
Time domain x-axis	Time (seconds) ... ▼
Time domain non-coherent integration	Allow non-coherent integ... ▼
Auto-scale options	auto-scale time-domain ▼

Time Domain Y axis, can be IQ signed integers or x/fullscale normalized.

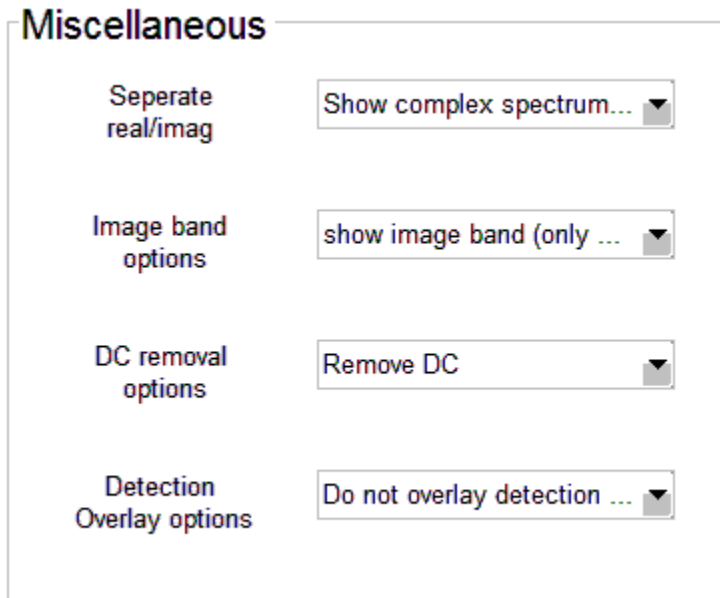
Time Domain X axis, can be Time, Ramp Frequency, or Sample number

Time incoherent integration – normal, or allows chirps to be averaged

Auto Scale – scale for sample size or not

e) Miscellaneous

Figure 28 – Radar Studio – Post Processing Matlab – Miscellaneous options – Miscellaneous



Separate real / imag – I leave this off

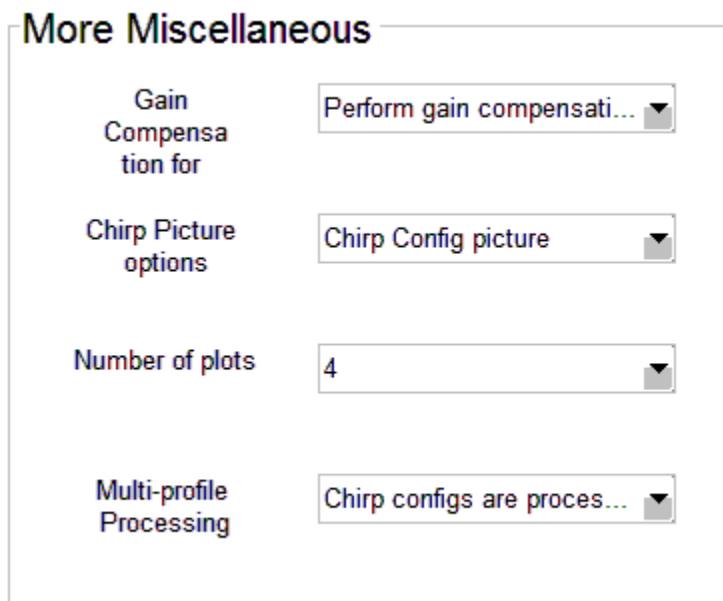
Image band options – if this is Complex 2x mode, can ignore the negative frequency section, not used for Complex 1x

DC removal options – normally DC is removed

Detection overlay options – overlays detection results on heat map plot

f) More Miscellaneous

Figure 29 – Radar Studio – Post Processing Matlab – Miscellaneous options – More Miscellaneous



Gain Compensation – the default is Perform Gain compensation. There is no gain compensation or energy compensation (I think this tries to reverse HPF1, HPF2).

Chirp Picture options – I don't see a difference with this selected.

There is a frame select, and chirp within a frame select slider on the main graph.

Number of plots 1,2,4,9 – using the selector above the plot you can select different plot values, common or specific Receiver plots.

Multi profile processing – the graph can selective plot different chirp-profile data, if there are multiple profiles.

Section 5 – 10m measurement example IWR1642