ANCORTEK

SDR SYSTEM EVALUATION KIT

USER MANUAL

ANCORTEK INC
Fairfax, VA 22030
USA

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TABLE OF CONTENTS

1 System Specification

1.1 Scope

Ancortek Inc has built compact-size, light-weight and low-power software defined RF modules and FPGA-based processor modules in S, C, X, and K bands operating at 2.4 GHz, 5.8 GHz, 6.2 GHz, 9.8 GHz and 25 GHz. Our SDR Evaluation Kits offer the ability of integrating transmitter-receiver systems for applications to industry automation, medical monitoring, public safety and security and academic research.

1.2 Features

- Support FMCW, FSK, and CW Signal Waveforms.
- Expandable Bandwidth.
- Selectable Operation Parameters.
- Selectable Stream Filtering.
- Selectable Display Mode.
- Recording of Complex (I & Q) Data.
- USB 2.0 Interface to Host Computer.
- Multifunctional Graphical User Interface (GUI).

1.3 Parameters

- An overview of the current SDR-KITs is shown in Table 1.
- The parameters of 2.4 GHz, 5.8 GHz, 6.2 GHz, 9.8 GHz and 25 GHz SDR-KITs are illustrated in Table 2-6.
- The parameters of the FPGA-based SDR-PM processor module are listed in Table 7.

Table 1 Overview of the SDR-KITs

SDR Evaluation Kits	SDR-KIT 240B	SDR-KIT 580B	SDR-KIT 620B	SDR-KIT 980B	SDR-KIT 2500B
Waveforms	FMCW/FSK/CW	FMCW/FSK/CW	FMCW/FSK/CW	FMCW/FSK/CW	FMCW/FSK/CW
Frequency Range	2.25 - 2.65 GHz	5.6 - 6.0 GHz	6.0 - 6.4 GHz	9.6 – 10.0 GHz	24 – 26 GHz
Expandable Frequency Range	2.05 - 2.65 GHz	5.2 - 6.0 GHz	5.6 – 6.4 GHz	9.2 – 10.2 GHz	23 – 26 GHz
Beam Width Horz/Vert	Patched Antenna 38°/38°	Patched Antenna 40°/20°	Patched Antenna 40°/20°	Patched Antenna 40°/20°	Horn Antenna 30°/20°
Bandwidth	100/150/300/400 MHz	100/150/300/400 MHz	100/150/300/400 MHz	100/150/300/400 MHz	0.5/0.75/1.5/2 GHz
Expandable Bandwidth	600 MHz	800 MHz	800 MHz	1 GHz	3 GHz
Power Output	22 dBm	19 dBm	19 dBm	18 dBm	16 dBm
Noise Figure	2.8 dB	3.4 dB	3.4 dB	3.4 dB	6.4 dB
Application	Through-Wall, Ground Penetration	Industry, Medical, Security, Through-Wall	Industry, Medical, Security, Through-Wall	Industry, Medical, Security	Industry, Medical, Security

Table 2 SDR-RF 240 Module Parameters

Parameter	Min.	Typ.	Max.	units
Frequency Range	*2.25*		*2.65*	*GHz*
Expandable Frequency Range	*2.05*		*2.65*	*GHz*
Tune Voltage	*0*		*5*	*V*
Tuning Sensitivity @RF Port		*0.1*		*GHz/V*
Power Output	*21*	*22*	*23*	*dBm*
SSB Phase Noise @10KHz offset		*-80*		*dBc*
SSB Phase Noise @1MHz offset		*-130*		*dBc*
Conversion Gain Over Rx Channel	*28*	*30*	*32*	*dB*
Noise Figure over Rx channel	*2.6*	*2.8*	*3.0*	*dB*
Maximum input power		*10*		*dBm*
Input 1dB power compression		*-15*		*dBm*
Supply voltage	*4.75*	*5*	*5.25*	*V*
Supply current	*650*	*670*	*700*	*mA*
Operating temperature	*-40*		*85*	*C°*
Storage temperature	*-65*		*150*	*C°*
Dimensions	*L=79 W=56 H=13*			*mm*

Table 3 SDR-RF 580 Module Parameters

Parameter	Min.	Typ.	Max.	units
Frequency Range	*5.6*		*6.0*	*GHz*
Expandable Frequency Range	*5.2*		*6.0*	*GHz*
Tune Voltage	*0*		*5*	*V*
Tuning Sensitivity @RF Port		*0.13*		*GHz/V*
Power Output	*18*	*19*	*20*	*dBm*
SSB Phase Noise @10KHz offset		*-80*		*dBc*
SSB Phase Noise @1MHz offset		*-130*		*dBc*
Conversion Gain Over Rx Channel	*26*	*28*	*30*	*dB*
Noise Figure over Rx channel	*3.2*	*3.4*	*3.6*	*dB*
Maximum input power		*10*		*dBm*
Input 1dB power compression		*-11*		*dBm*
Supply voltage	*4.75*	*5*	*5.25*	*V*
Supply current	*650*	*670*	*700*	*mA*
Operating temperature	*-40*		*85*	*C°*
Storage temperature	*-65*		*150*	*C°*
Dimensions	*L=79 W=56 H=13*			*mm*

Table 4 SDR-RF 620 Module Parameters

Parameter	Min.	Typ.	Max.	units
Frequency Range	*6.0*		*6.4*	*GHz*
Expandable Frequency Range	*5.6*		*6.4*	*GHz*
Tune Voltage	*0*		*5*	*V*
Tuning Sensitivity @RF Port		*0.13*		*GHz/V*
Power Output	*18*	*19*	*20*	*dBm*
SSB Phase Noise @10KHz offset		*-80*		*dBc*
SSB Phase Noise @1MHz offset		*-130*		*dBc*
Conversion Gain Over Rx Channel	*26*	*28*	*30*	*dB*
Noise Figure over Rx channel	*3.2*	*3.4*	*3.6*	*dB*
Maximum input power		*10*		*dBm*
Input 1dB power compression		*-11*		*dBm*
Supply voltage	*4.75*	*5*	*5.25*	*V*
Supply current	*650*	*670*	*700*	*mA*
Operating temperature	*-40*		*85*	*C°*
Storage temperature	*-65*		*150*	*C°*
Dimensions	*L=79 W=56 H=13*			*mm*

Table 5 SDR-RF 980 Module Parameters

Parameter	Min.	Typ.	Max.	units
Frequency Range	*9.6*		*10.0*	*GHz*
Expandable Frequency Range	*9.2*		*10.2*	*GHz*
Tune Voltage	*0*		*5*	*V*
Tuning Sensitivity @RF Port		*0.2*		*GHz/V*
Power Output	*17*	*18*	*19*	*dBm*
SSB Phase Noise @10KHz offset		*-80*		*dBc*
SSB Phase Noise @1MHz offset		*-130*		*dBc*
Conversion Gain Over Rx Channel	*26*	*28*	*30*	*dB*
Noise Figure over Rx channel	*3.2*	*3.4*	*3.6*	*dB*
Maximum input power		*10*		*dBm*
Input 1dB power compression		*-13*		*dBm*
Supply voltage	*4.75*	*5*	*5.25*	*V*
Supply current	*650*	*670*	*700*	*mA*
Operating temperature	*-40*		*85*	*C°*
Storage temperature	*-65*		*150*	*C°*
Dimensions	*L=79 W=56 H=13*			*mm*

Table 6 SDR-RF 2500 Module Parameters

Parameter	Min.	Typ.	Max.	units
Frequency Range	*24*		*26*	*GHz*
Expandable Frequency Range	*23*		*26*	*GHz*
Tune Voltage	*0*		*5*	*V*
Tuning Sensitivity @RF Port		*1.5*		*GHz/V*
Power Output	*14*	*16*	*18*	*dBm*
SSB Phase Noise @1MHz offset		*-100*		*dBc*
Conversion Gain Over Rx Channel	*18*	*26*	*31*	*dB*
Noise Figure over Rx channel		*6.4*		*dB*
Maximum input power		*0*		*dBm*
Input 1dB power compression		*-12*		*dBm*
Supply voltage	*4.75*	*5*	*5.25*	*V*
Supply current	*750*	*800*	*850*	*mA*
Operating temperature	*-40*		*85*	*C°*
Storage temperature	*-65*		*150*	*C°*
Dimensions	*L=79 W=56 H=13*			*mm*

Table 7 SDR-PM 402 Module Parameters

Parameter	Min.	Typ.	Max.	units
Supply voltage	*4.75*	*5*	*5.25*	*V*
Supply current	*180*	*200*	*220*	*mA*
Operating temperature	*-40 to +85*			*C°*
Storage temperature	*-65 to +150*			*C°*
Dimensions	*L=79*	*W=76*	*H=13*	*mm*

2 Operation Instruction

2.1 Equipment List

The Ancortek SDR Evaluation Kit comes with SDR-RF module and SDR-PM processor module.

For complete operation and data collection, you will also need

1. AC/DC power adapter +5V.
2. USB 2.0 A to Mini-B cable.
3. SMA-M to SMA-M cables.
4. Transmitting and receiving antennas.
5. Ancortek Graphical User Interface: SDR-GUI or MATLAB-based SDR-GUI.
6. PC Windows Operating System.

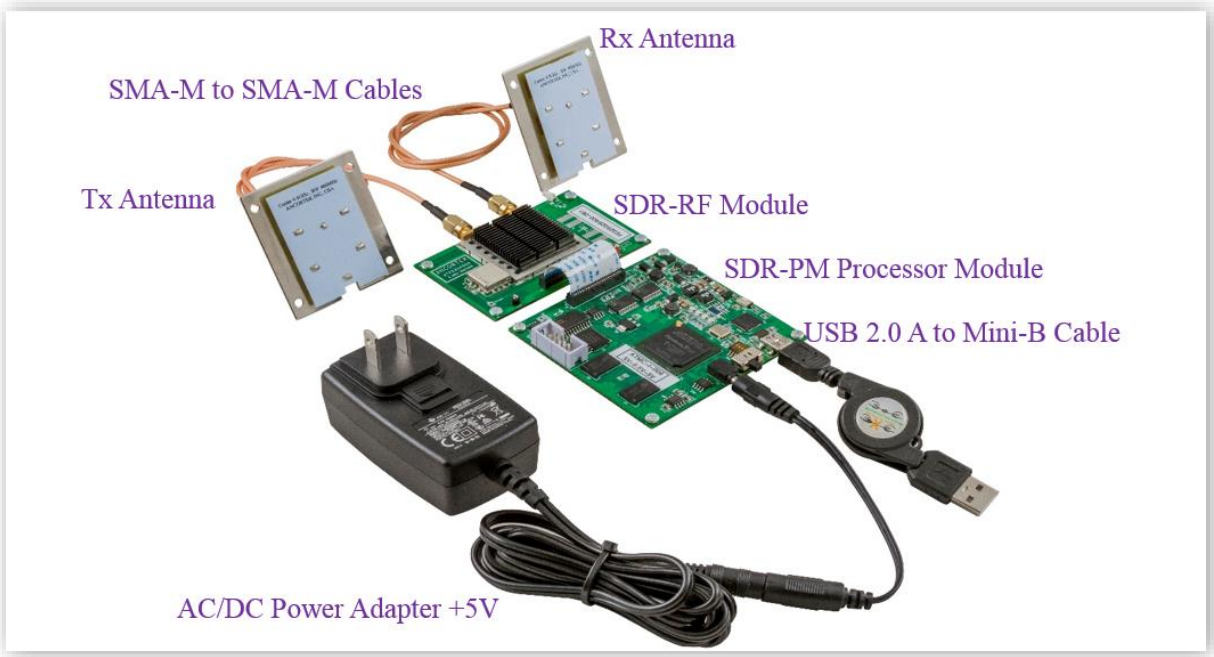

Figure 1 - Equipment List.

2.2 System Description

Figure 2 is a high level block diagram of the SDR Evaluation Kit. A graphical user interface (SDR-GUI) is used to control the configuration of the SDR via a USB 2.0 cable. Digital samples of control voltage are generated by the FPGA firmware. After D/A converter, an analog control voltage is directly sent to the voltage controlled oscillator (VCO). The output of the mixer in the receive chain is digitized and streamed to host computer for further processing.

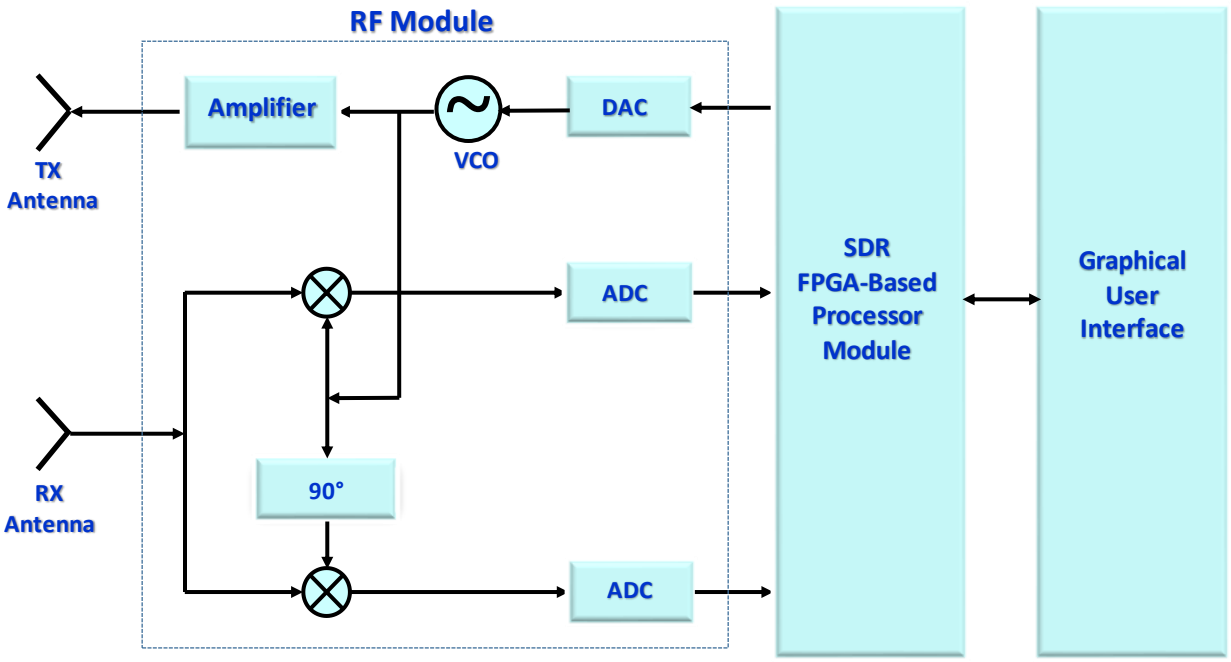

Figure 2 - System Block Diagram.

2.3 Getting Started

1. Run setup.exe to install the Ancortek SDR-GUI.
2. Plug in the Ancortek transceiver and go to the "Device Manager" (see Figure 3), right click "Unknown Device".

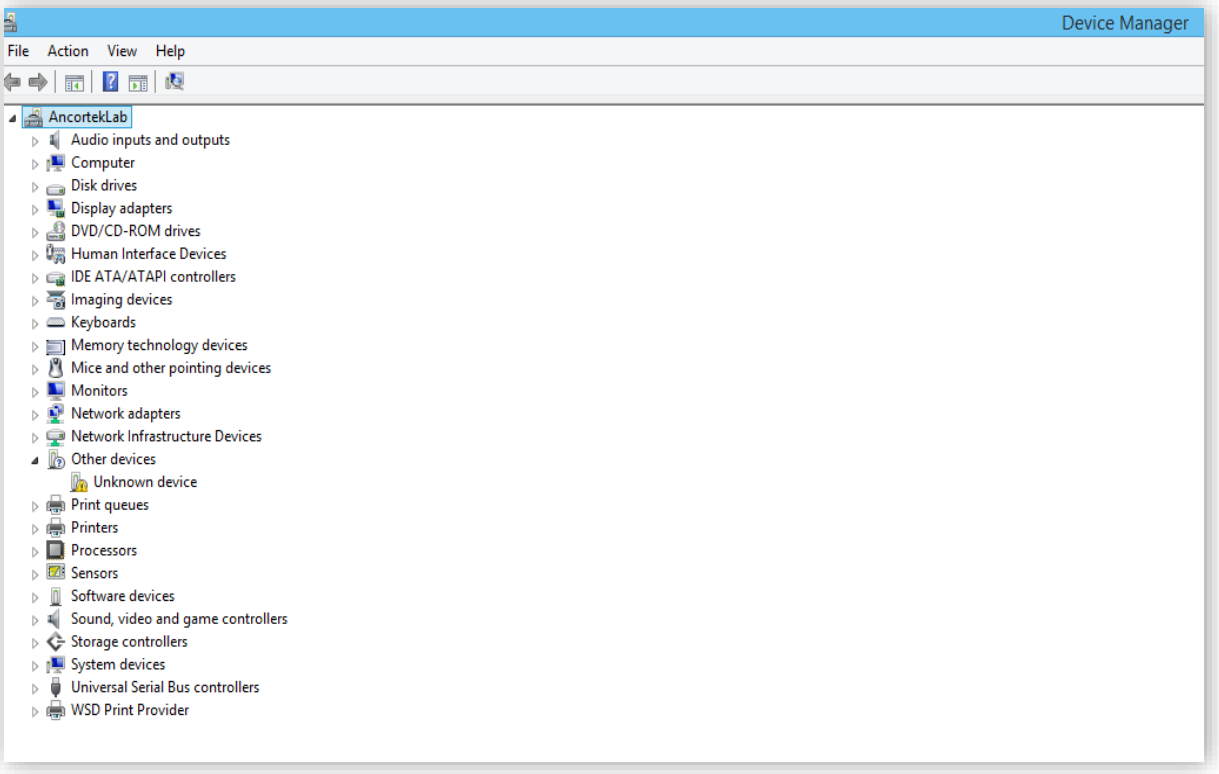

Figure 3 - Device Manager Window.

3. Click “Update Driver” (see Figure 4).

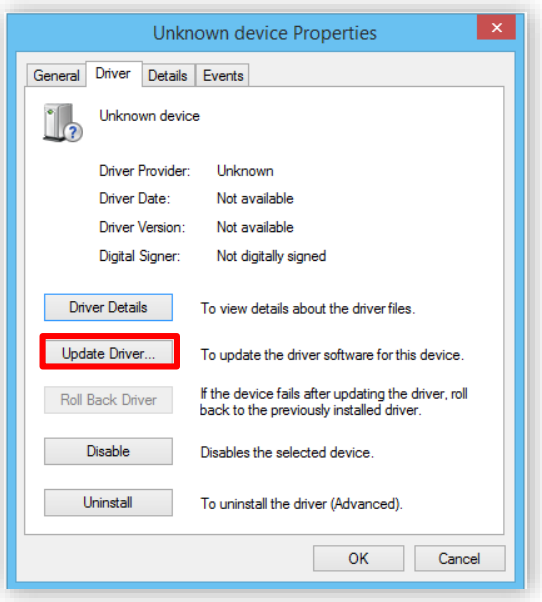

Figure 4 - Update Driver.

4. Click “Browse my computer for driver software” (see Figure 5).

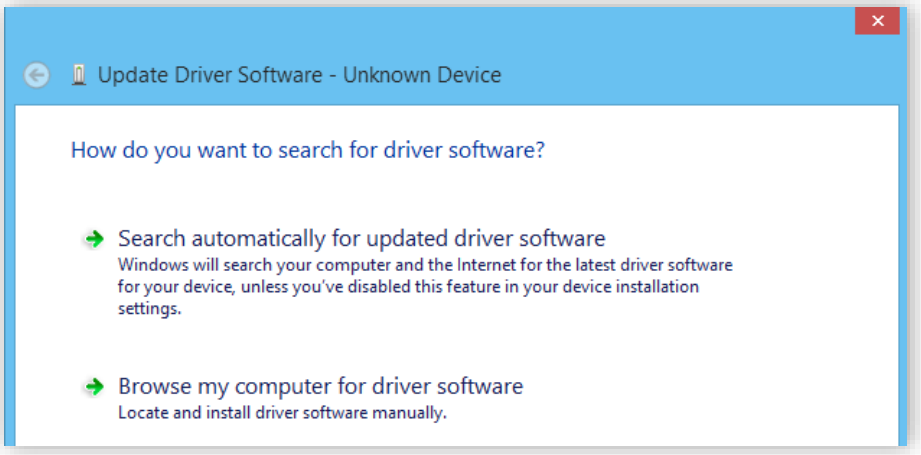

Figure 5 - Browse Computer for Driver Software.

5. Select the driver in the installation directory “Ancortek SDR/driver” according to Figure 6 below.

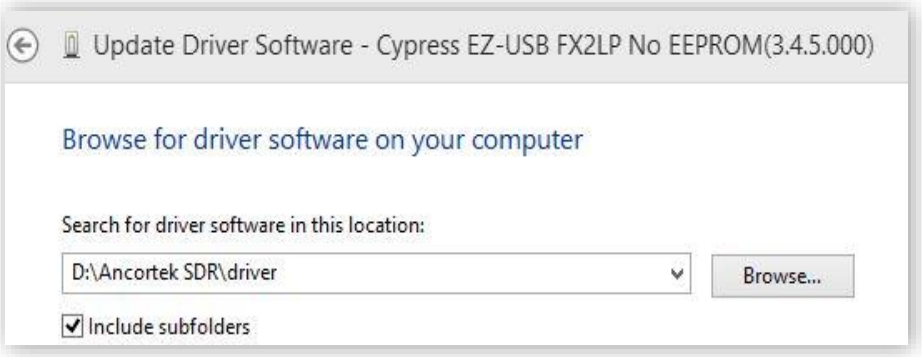

Figure 6 - Update Driver Software.

6. Driver software installed successfully.

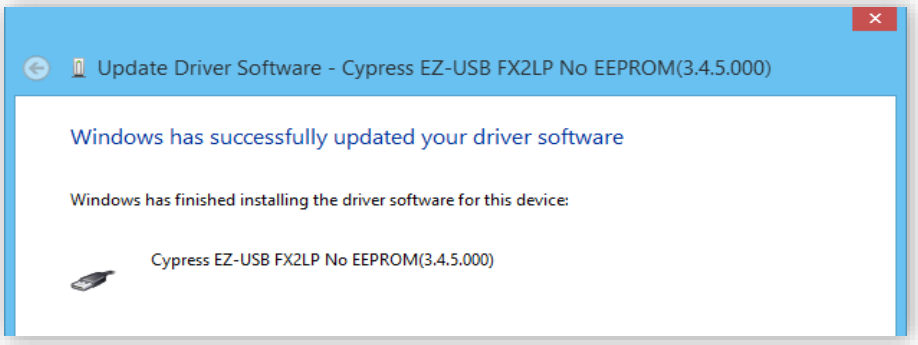

Figure 7 - Driver Software Installed Successfully.

7. Open the SDR-GUI.
8. MATLAB-based SDR-GUI is available for academic research groups upon request.

2.4 Graphical User Interface

2.4.1 Ancortek SDR-GUI

After running setup.exe and updating the driver software, Ancortek SDR-GUI, as shown in Figure 8, will appear. The GUI gives users access to selecting of waveforms, operating parameters, filtering types, and recording. It is capable of showing graphical representation of signals in time and frequency domain.

1. Control Panel

The Control Panel includes selecting of waveforms, operating parameters, filtering types, and recording.

- **Active Device**

  1) The upper-left pop-up menu: List of detected Ancortek devices.

  2) The upper-right pop-up menu: Center frequency or channel selection. Please choose the corresponding center frequency of the SDR-KIT before activating it. When using SDR-2400AD2, please choose CH1 or CH2 to select which channel to display.

  3) Activate: Start the data stream and plotting. This button is also used to stop the data stream or plotting.

  4) Refresh: Find Ancortek devices and list them in the upper-left pop-up menu.

- **Operating Parameters: Operating Mode**

  1) FMCW Sawtooth: Range and Doppler measurements.

  2) FSK: Range and Doppler measurements of moving targets.

  3) CW: Doppler measurement.

- **Operating Parameters: Signal Parameters**

  1) Bandwidth: Sweep bandwidth for FMCW Sawtooth waveform.

  2) Samples per Sweep: Number of time samples per sweep.

  3) Sweep Time: Length of one sweep. Changing the Sweep Time and Samples per Sweep will change the sampling rate.

- **Operating Parameters: Display Mode**

  1) Range & Time Scope: Range obtained by FFT of the beat signal in FMCW Sawtooth mode.

  2) Velocity Scope: Velocity obtained by FFT of the complex signal in FSK & CW modes.

  3) Range-Velocity Map: Range-Doppler map in FMCW Sawtooth mode.

  4) Range Waterfall: Waterfall of Range & Time Scope in FMCW Sawtooth mode and waterfall of detected range in FSK mode.

  5) Velocity Waterfall: Waterfall of Velocity in FMCW Sawtooth, FSK, and CW modes.

- **Stream Filtering**

  1) DC Subtraction: Remove the mean value of the signal waveform.

  2) Amplitude Correction: Normalize the amplitude of signal waveform.

  3) Hamming Window: Using Hamming Window before taking FFTs.

  4) Direct Clutter Cancellation: Background subtraction for FMCW-Sawtooth mode.

  Please make sure that there is no target of interest on the scene at the very beginning to collect clutter data when Direct Clutter Cancellation is enabled.

  5) Outdoor Range Weighting: Correct range-based signal attenuation via radar equation.

  6) Range Windowing: Select range to be displayed.

  7) Velocity Windowing: Select velocity to be displayed.

- **Display Parameters: Dynamic Range**

  1) Dynamic Range Auto: Automatic calculate the color limits using minimum and maximum data values.

  2) Dynamic Range: Sets the color limits to specified minimum and maximum values when Auto is unchecked.

  Note: Data values less than minimum or greater than maximum map to minimum and maximum, respectively. Values between minimum and maximum linearly map to the current color map.

- **Display Parameters: Update Rate**

  Update Rate: Set update rate of graphical plots. Data processing time will affect the actual update rate.

- **Display Parameters: Doppler Parameters**

  Sweep Count: Number of pulses collected for signal processing. Decrease this value will ease processing burden, thus, may increase update rate of graphical plots.

- **Display Parameters: Waterfall Parameters**

  1) History Size: Number of rows in data for waterfall display.

  2) Display Method: Resampling algorithm used for matrix data.

  3) Color Scheme: Change the color map.

  Note: In FSK mode, we suggest using Standard or B&W color scheme for Range Waterfall.

- **Export**

  1) Screen Capture: Save the Top or Bottom View of graphical results into a file.

  2) Duration: Raw data length to record.

  3) Record Data Stream: Start recording. The raw data will be saved into .dat file for post-processing. Below listed is MATLAB sample codes for reading the *.dat file. Data is the raw data in (I + j Q) format.

```
filename = '2015-03-25-10-08-12.dat'; % File name
fileID = fopen(filename, 'r');
dataArray = textscan(fileID, '%f');
fclose(fileID);
radarData = dataArray{1};
clearvars fileID dataArray ans;

fc = radarData(1); % Center frequency
Tsweep = radarData(2); % Sweep time in ms
NTS = radarData(3); % Number of time samples per sweep
Bw = radarData(4); % FMCW Bandwidth. For FSK, it is frequency step;
For CW, it is 0.
Data = radarData(5:end); % raw data in I+j*Q format
```

  For SDR-KIT 2400AD2, please use the following codes:

```
% 24GHz two channel radar data read
filename = '2016-04-25-16-22-16.dat'; % File name
fileID = fopen(filename, 'r');
dataArray = textscan(fileID, '%f');
fclose(fileID);
radarData = dataArray{1};
clearvars fileID dataArray ans;

fc = radarData(1); % Center frequency
Tsweep = radarData(2); % Sweep time in ms
NTS = radarData(3); % Number of time samples per sweep
Bw = radarData(4); % FMCW Bandwidth. For FSK, it is frequency step; For
CW, it is 0.
```

```
Data = radarData(5:end); % raw data in I+j*Q format
Data_1 = Data(1:2:end); % Data of channel 1
Data_2 = Data(2:2:end); % Data of channel 2
```

4) Record Status: When recording and saving are done, success information will appear.

- **Camera Controls**

  1) Current Camera: Refresh Devices to show available cameras, and choose one from the listed cameras.

  2) Camera Status: Press DISABLED to activate the camera. Press ENABLED to deactivate.

  NOTE : Please resize the Camera window to your preferred size at start up. You could drag the Camera window or Radar Controls window to a different position.

2. Graphic Panel

The Graphic Panel shows the graphical representation of signals in time and frequency domain.

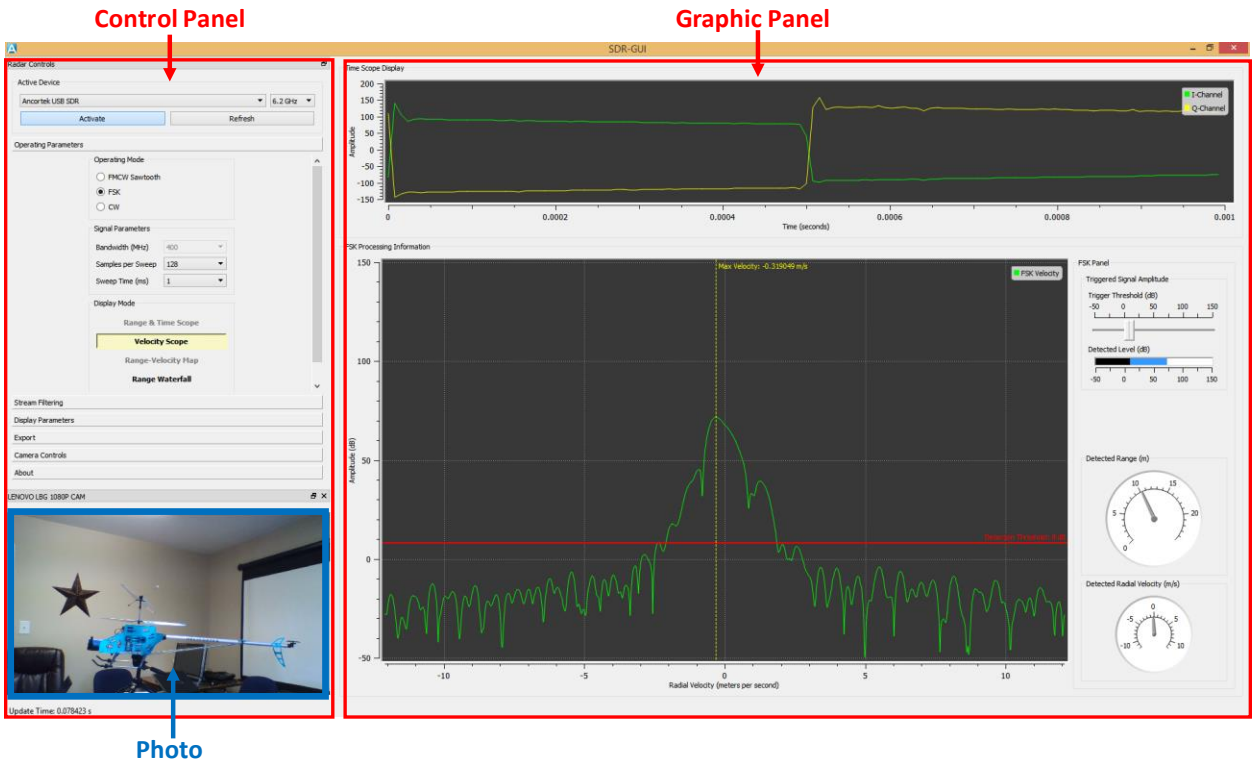

Figure 8 - Ancortek SDR-GUI.

2.4.2 MATLAB-based SDR-GUI

MATLAB-based SDR-GUI is available upon request. It is shown in Figure 9.

1. Control Panel

The Control Panel includes selecting of waveforms, operating parameters, filtering types, and recording.

- **Start/Stop**

  Start: Start the data stream and plotting. Please remember to choose the right center frequency from the pop-up menu on the right. When using SDR-2400AD2, please choose CH1 or CH2 to select which channel to display.

Stop: Stop the data stream or plotting.

- **Waveforms**

  1) FMCW_Sawtooth: Range and Doppler estimation.

  2) FMCW_Triangle: Range and Doppler estimation without range-Doppler coupling effect.

  3) FSK: Range and Doppler estimation of moving targets.

  4) CW: Doppler estimation.

- **Parameters**

  1) Bandwidth: Sweep bandwidth for FMCW.

  2) Sweep Time: Length of one sweep or pulse.

  3) Sampling Number: Number of time samples per sweep. Changing the Sweep Time and Sampling Number will change the sampling rate.

  4) Frequency: Frequency of transmitted signal.

- **Filtering**

  1) Direct Clutter Cancellation: Background subtraction for FMCW-Sawtooth and FMCW-Triangle. Please make sure that there is no target at the scene at the very beginning to collect clutter data when Direct Clutter Cancellation is enabled. Just after a few milliseconds, the target could enter the scene.

  2) Range Notch Filter: Filter out the clutter nearby when the target of interest is far from the transceiver for FMCW-Sawtooth and FMCW-Triangle. Please change notch width according to the distance of target of interest.

  3) Doppler Notch Filter: Filter out unwanted Doppler for range-Doppler map of FMCW-Sawtooth. Please change notch width according to the velocity of target of interest.

- **RawData**

  1) Record: Record up to 8 seconds worth of raw data. Micro-Doppler analysis of the recorded raw data will appear in the Graphic Panel.

  2) Save: Save the recorded raw data into .mat file for post-processing. Below is Matlab sample codes for reading the .mat file. Data is the raw data in (I+jQ) format.

```
raw = load('fmcw.mat');
Data = raw.DATA;
SweepTime = raw.SWEEPTIME;
NTS = raw.samplenumberpersweep;
BandWidth = raw.BANDWIDTH;
```

```
samp_rate =1/SweepTime*NTS*1000;
```

For SDR-KIT 2400AD2, please use the following codes:

```
% 24GHz two channel radar data read
raw = load('two_channel.mat');
Data_1 = raw.DATA1; % data of channel 1
Data_2 = raw.DATA2; % data of channel 2
SweepTime = raw.SWEEPTIME;
NTS = raw.samplenumberpersweep;
BandWidth = raw.BANDWIDTH;
samp_rate =1/SweepTime*NTS*1000;
```

3) Replay: Reshow the micro-Doppler analysis of the selected raw data.

2. Graphic Panel

The Graphic Panel includes selecting of graphical representation of signals in time and frequency domain.

- **FMCW_Sawtooth graphical results**

  1) Stream: I & Q data.

  2) Waterfall: Waterfall of range profile.

  3) Range Profile: Range obtained from FFT of the beat signal.

  4) Range Doppler: Range-Doppler map.

- **FMCW_Triangle graphical results**

  1) Stream: I & Q data.

  2) Range History: History of detected range.

  3) Velocity History: History of detected velocity.

- **FSK graphical results**

  1) Stream: I & Q data.

  2) Velocity History: History of detected velocity.

  3) Range History: History of detected range.

- **CW graphical results**

  1) Stream: I & Q data.

  2) Waterfall: Waterfall of velocity profile.

  3) Velocity Profile: Velocity obtained from the FFT of the (I + jQ)

4) Velocity History: History of detected velocity.

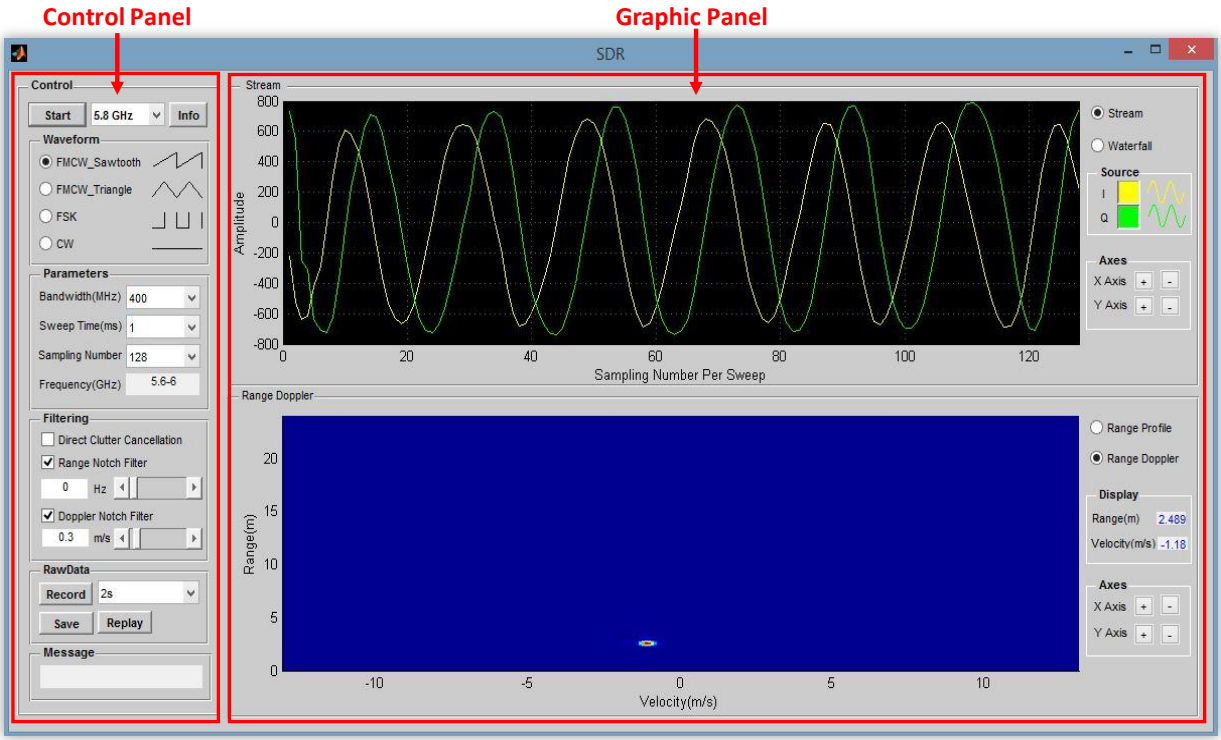

Figure 9 - MATLAB version of the SDR-GUI.