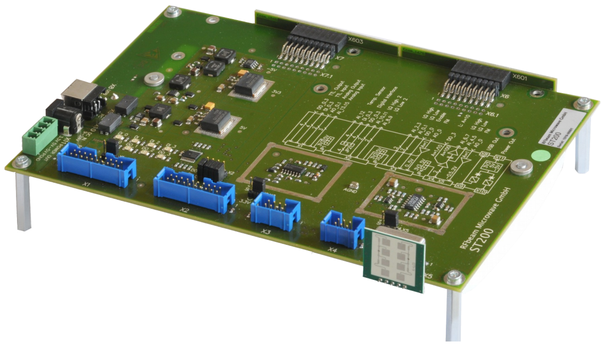
ST200 Radar Evaluation System

User Manual

Features



- Supports Doppler, FMCW, FSK, Monopulse
- USB Interface to Host Computer
- Onboard Low Noise Power Supplies
- Connectors for Different Radar Devices
- Amplifiers for Native Doppler Transceivers
- High Performance 16Bit Data Processing
- 250kSamples/s ADC and DAC
- Compact and Rugged Construction
- Powerful Signal Explorer PC Software
- NI LabVIEW ® DAQmx USB Interface

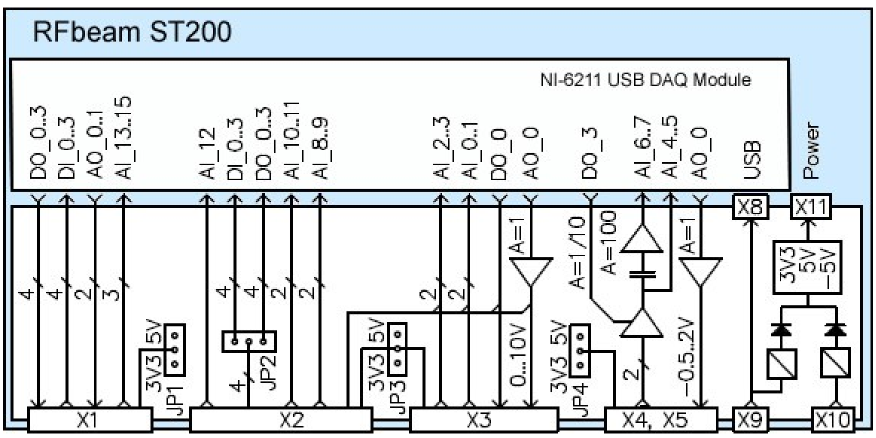
Applications

- Evaluation of Advanced Shortrange Radar Applications
- Development of Own Data Processing Algorithms
- Signal Analysis and Logging
- Learning and Exploring Radar Basics

Description

ST200 is a 16Bit data acquisition and processing system with a total 250k/s sampling rate. It contains all hardware necessary for acquiring Radar signals of RFbeam Transceivers.
ST200 contains a motherboard with power supply, amplifiers and I/O connectors. Data acquisition is performed by a NI-USB-6211 16Bit multifunction DAQ module from National Instruments mounted on the backside.
The easy to handle RFbeam Signal Explorer software features many basic Radar functions including an exciting FSK (Frequency Shift Keying) operation mode for high resolution distance measurements of moving objects.

ST200 Block Diagram



Radar Connectors:
X1: General purpose I/O
X2: Mixed I/O
X3: 4 Channel An. Inputs
X4: 2 Channel An. Inputs
X5: 2 Channel An. Inputs

Computer Interface:
X9: USB PC Port

Power:
X10: Optional DC In
X11: Low Noise DC Out

Getting Started

Please install software prior to connect ST200 to the USB port.

Equipment Needed

- ST200 Hardware
- ST200 Signal Explorer Software Installer on CD, USB stick or downloaded on HD
- USB cable
- K-LC2 sensor connected to connector X5
- PC running on Windows xp or never

Installing Signal Explorer Software

ST200 software comes with a setup procedure containing all necessary components into one single package:

- RFbeam ST200 Signal Explorer Software
- National Instruments DAQmx ® driver software
- National Instruments LabVIEW ® runtime systerm

1. Start RFbeam Signal Explorer `setup.exe` from your intallation media
   If your computer does not already contain a LabVIEW runtime engine and DAQmx driver, you will be prompted to accept licences of National Instruments.
2. If possible, accept all default program locations. Troubleshooting will be simplified like this.
3. Please be patient while LabVIEW runtime system and DAQmx driver are being installed.
   This may take some minutes...
4. Restart your computer, if asked so.
5. You will find SignalViewer under START->PROGRAMS->RFbeam->Signal Explorer and a shortcut icon on the Desktop.

Test Configuration and Go!

We will now take a first impression by using the Doppler mode and observe movement of persons.

Please refer to the screen shot in Fig. 1

1. Plug in a K-LC2 radar sensor into connector X5 of the ST200.
2. Connect ST200 hardware to you computer. There should appear a “New USB Hardware Found” message from Windows.
3. Windows will probably ask you for a hardware driver. Select to find it aoutomatically.
4. Start SignalExporer under START->PROGRAMS->RFbeam->SignalExplorer
   After some seconds the main screen of the Signal Explorer should appear.
5. Select the most important controls according to Fig. 1 below.
6. Drag all 3 cursors as shown in Fig. 1 . If cursors are not visible, press cursor "Reset" button.
7. Now move your hands in front of the K-LC2 sensor. You will see the frequency and speed in the upper graph and the time signal (oscilloscope) in the bottom graph.
8. Explore and become familiar with the effect of the 3 cursors.
9. Try to switch to Doppler-Phase screen by using the left tab in the bottom half of the screen. You will see the direction of your movement (Cursors must be set according to Fig. 1).

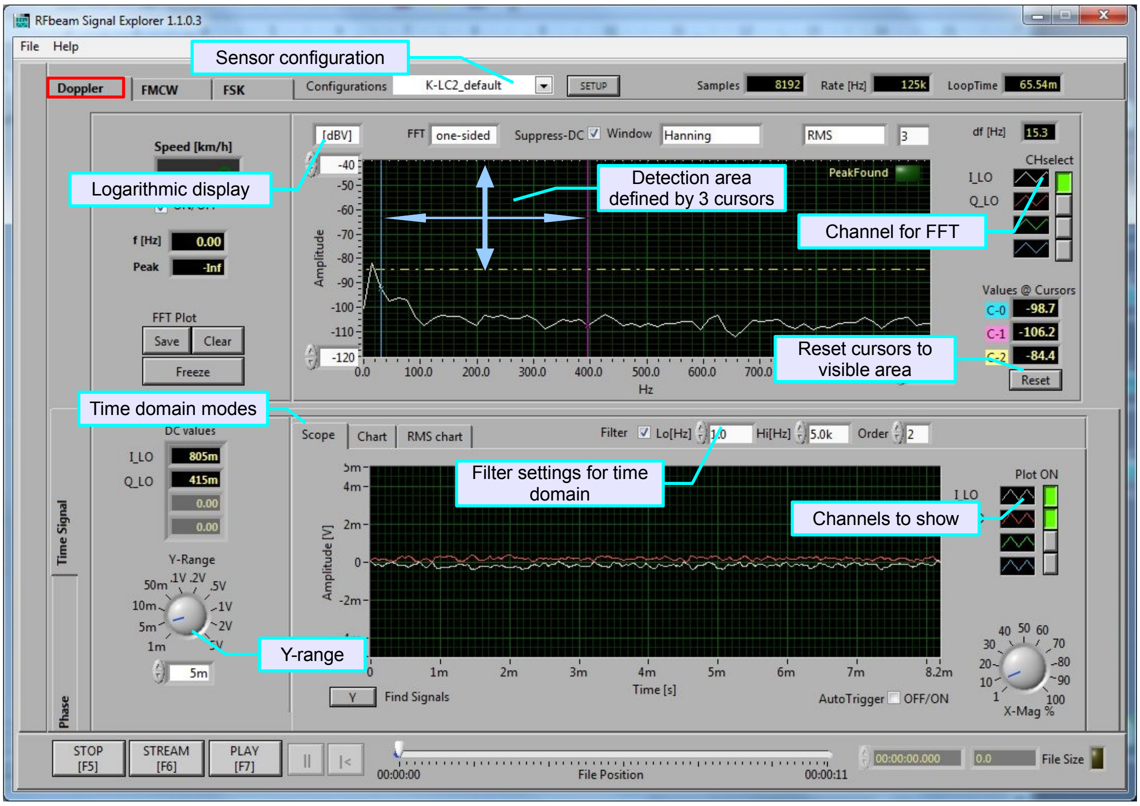


Fig. 1: Start Screen. Try to set all marked controls according to this figure

ST200 Hardware

ST200 consists of a mother board and a 16 Bit USB data acquisition system with 250kHz sampling rate. The mother board contains 5V and 3.3V low noise power supplies and analog buffers and amplifiers.

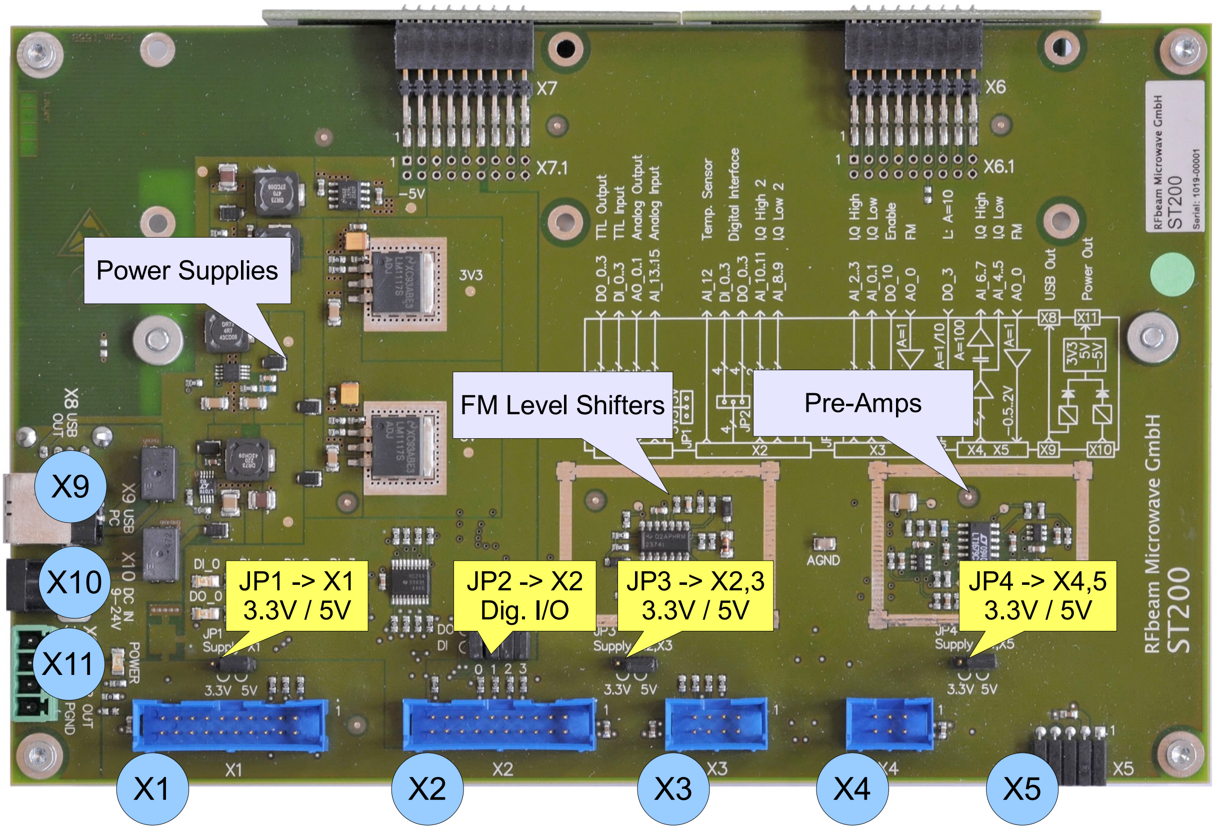


Fig. 2: Connector Arrangement

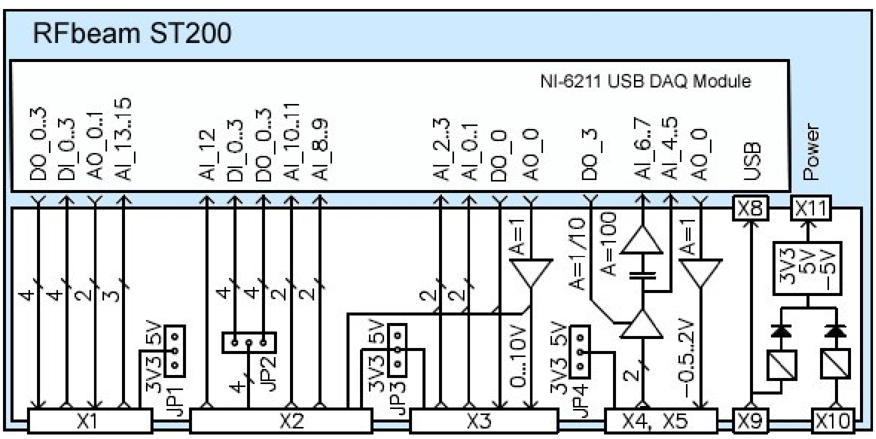


Fig. 3: Block Diagram

Sensor Connectors:
X1: General purpose I/O
X2: Mixed I/O
X3: 4 Channel An. Inputs
X4: 2 Channel An. Inputs
X5: 2 Channel An. Inputs

Computer Interface:
X9: USB PC Port

Power:
X10: Optional DC In
X11: Low Noise DC Out

Typical Sensor Connections

Please refer to Fig. 3 and to chapter Sensor Connectors for more details on tzhe connectors.
Sensors with higher current consumption (>120mA like K-MC4) need more power than USB can deliver.
An external DC 12V power supply with >0.5A should be plugged into X10 of the ST200 system.

K-LCx Series → X5 or X4

Sensors of the K-LCx series with no internal amplifiers can directly be plugged into X5.
For remote connecting K-LCx sensors, a 6 pin ribbon flat cable my be connected to X4.
X5 or X4 provide 2 channels with amplifiers.

K-MCx and K-HC1 Series → X3

K-MCx sensors provide internal amplifiers and are typically connected to X3.
X3 provides 2 channels and is directrly routed to the DAQ system.
Notes:
- K-HC1 needs an own, separate power supply and a special adapter cable.
- K-MC4 can only be operated with an external 12VDC power supply connected to X10.

Other Sensors

Please contact RFbeam for instructions on connecting special sensors.

Signal Explorer Software

Overview

Getting Help

Most controls and readouts provide a context help on mouse over.
Select Help - Show ContextHelp from main menu. This opens a floating window containing a brief description of the object pointed by the mouse cursor.

Operation Modes

ST200 Signal Explorer provides 3 main operation modes:

- Doppler Mode: Speed and direction measurements
- FMCW Mode: Distance measurements of statical and moving objects
- FSK Mode: Distance measurements with high resolution for moving objets

User interface includes selecting of operation modes and sensor types, setting of filter types and bandwidth, sampling rates, graphical representation of signals in time and frequency.

User inteface screen is devided into 3 sections:

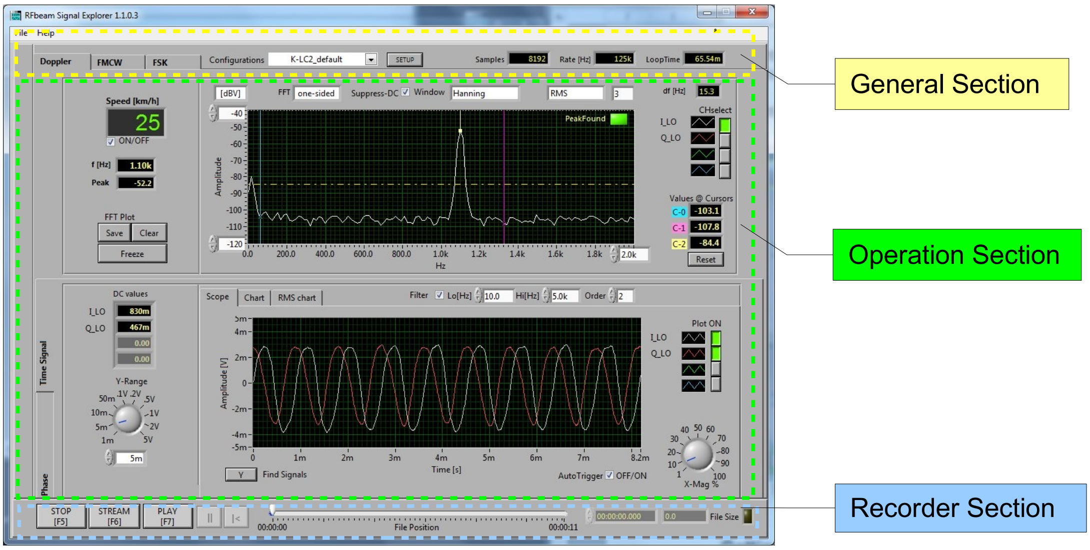


Fig. 4: Screen Sections

General Section

Settings and readouts in the general screen section (see Fig. 4) are accessible in all operation modes.

Readouts

Samples: Number of samples per channel as input for the signal processing (FFT).
Rate: ADC sampling rate per channel.
Loop Time: Time to read the samples defined in the selected configuration. It is calculated by

$$loop\,time = \frac{number\ of\ samples}{sampling\,Rate}$$

Configurations Selector

Many key settings are stored as so called configurations. Existing configurations may be selected at any time. After selecting, Signal Explorer jumps back into operation mode Doppler.

Configuration naming convention:

```
K-LC2_X4-5_IQH.cfg
    |       |   |_ connector inputs
    |       |____ connector name(s)  (refer to chapter Sensor Connectors)
    |___________ sensor type
```

Configurations Setup

You may alter or copy existing configurations. New configurations may be generated.
Refer to chapter Settings for more details.

Operation Section

This is the real time signal section (see Fig. 4).
Select the operation mode with the horizontal tabs on the top. Some modes allow selecting sub-modes by the vertical tabs in the bottom left part of the operation section.

Recorder Section

ST200 Signal Explorer allows real time recording and playback of signals captured in the Doppler and in the FSK mode.

Using Signal Explorer Software

Doppler Mode

About Doppler Radar

A more precise tiltle would be 'CW (Continuous Wave) Doppler Radar', when using RFbeam Radar sensors. These sensors do not produce pulses, but send continuously in the K-band (24.125 GHz). The sensors are also called Radar transceivers, because they include a *Trans*mitter and a Re*ceiver.* Doppler Radar is used to detect moving objects and evaluate their velocity. More details on the principle can be read here:

http://en.wikipedia.org/wiki/Doppler_radar
http://www.radartutorial.eu/11.coherent/co06.en.html

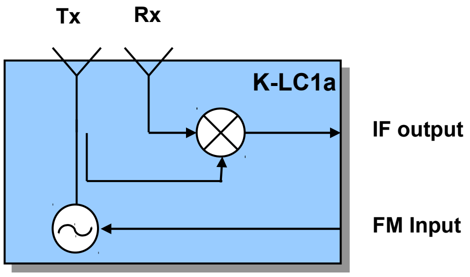


Fig. 5: Typical Radar Transceiver

RFbeam Radar transceivers return a so called IF signal, that is a mixing product of the transmitted (Tx) and the received (Rx) frequency. An moving object generates a slightly higher or lower frequency at the receiver. The IF signal is the absolute value of the difference between transmitted and received frequency.
These transceivers operate in the CW (Continuous Wave) mode as opposed to the pulse radars, that measure time of flight. CW radars can operate with very low transmit power (< 20dBm resp. 100mW).

Calculating the Doppler frequency

$$f_d = \frac{2 \cdot f_{Tx} \cdot v}{c_0} \cdot \cos \alpha \quad (1)$$

or

$$v = \frac{c_0 \cdot f_d}{2 \cdot f_{Tx} \cdot \cos \alpha} \quad (2)$$

- f_d Doppler frequency
- f_{Tx} Transmit frequency (24GHz)
- c_0 Speed of light ($3 * 10^8$ m/s)
- v Object speed in m/s
- α Angle between beam and object moving direction

At a transmit frequency of f_{Tx} = 24.125GHz we get a Doppler frequency for a moving object at the IF output of

$$f_d = v[km/h] \cdot 44\text{Hz} \cdot \cos \alpha \quad \text{or} \quad f_d = v[m/s] \cdot 161\text{Hz} \cdot \cos \alpha \quad (4)$$

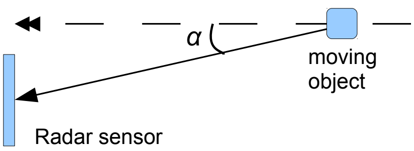


Fig. 6: Definition of angle *α*

Angle *α* reduces the measured speed by a factor of cos *α.*
This angle varies with the distance of the object.
To evaluate the correct speed, you need a trigger criteria at a known point. This can be accomplished by measuring the distance with the radar sensor (e.g. using FSK technology) or by measuring the angle using a monopulse radar such as K-MC4.

ST200 Doppler Mode

Note the difference between logarithmic (upper figure) and linear (bottom figure) FFT display. Smaller peaks in logarithmic display disappear in linear display.

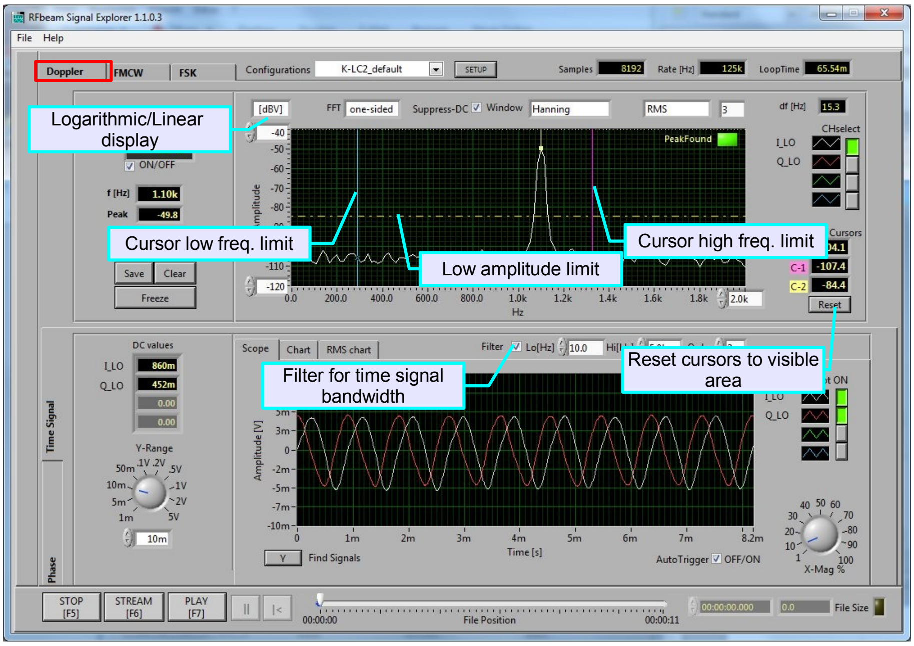


Fig. 7: Logarithmic FFT scale

Note the difference: in linear mode, small signals and noise disappear.

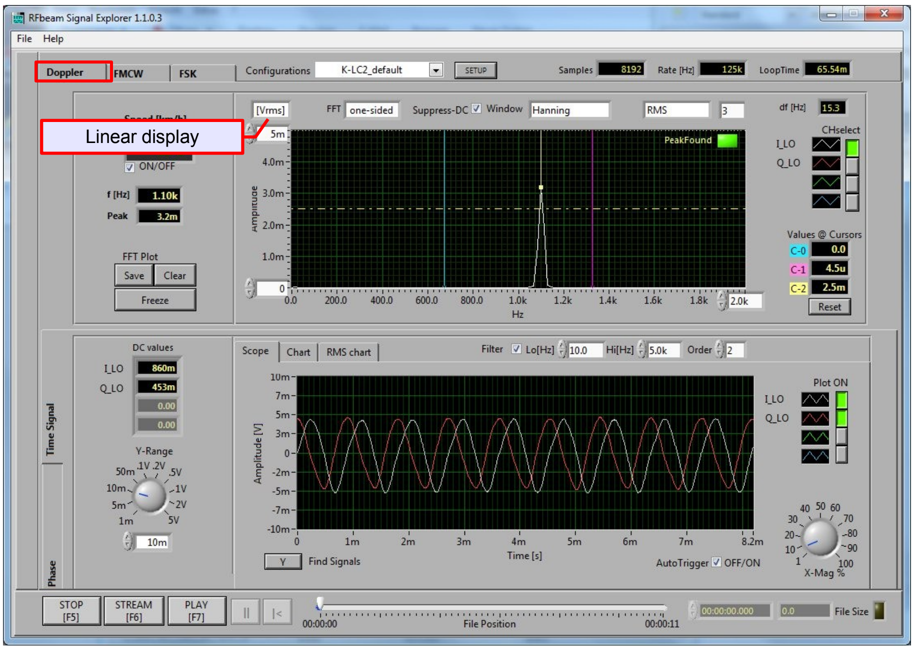


Fig. 8: Linear FFT scale

Remember to reset cursors after switching between logarithmic and linear mode.

Chart Modes

Besides the classical scope modes, ST200 allows “chart” modes for viewing slow signals.

Zooming and shifting charts

Data for the charts come from the signal buffer. Scaling is performed on display level and not on signal level. This allows scrolling and zooming.
Charts may be zoomed by changing the Y range and/or by changing the horizontal chart speed.
Charts may be “freezed”. Freezed charts may be horizontally scrolled over a history of around 1 million samples.

Signal chart mode

The “Signal chart mode” (Fig. 9) is similar to the scope mode, but writes the signal on a slow moving chart. This is useful for visualization of very slow signals.

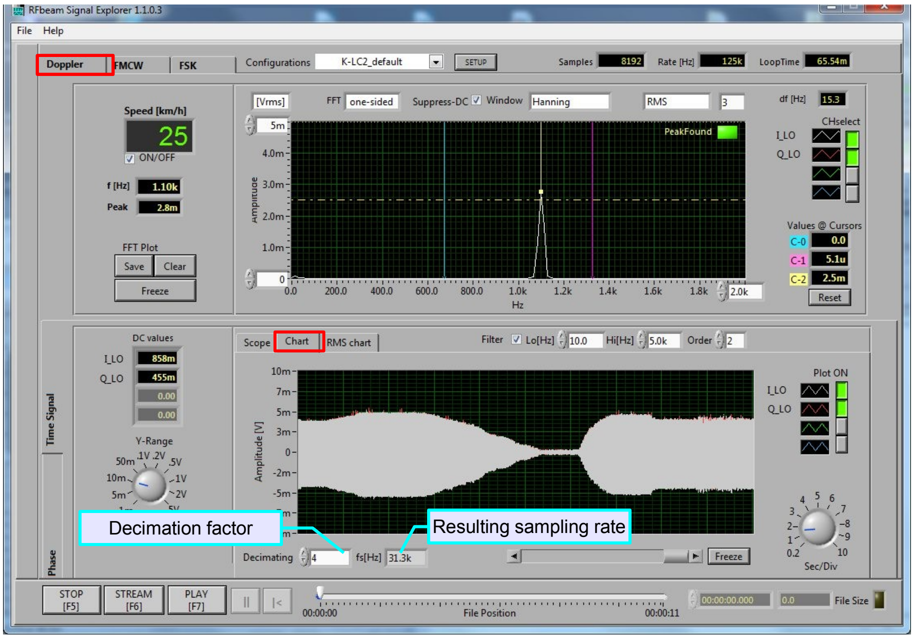


Fig. 9: Signal chart mode. Slow chart, high frequency → Envelope chart

You may (and should) downsample the signal, so that not all the signal buffer will be written to the chart. Set the decimation factor to the highest possible value, but smaller than the number of samples (in this example 8192) defined in the configuration.
This process is called decimation or resampling. It includes anti aliasing adapted to the new sampling rate:

$$f_s(chart) = \frac{sampling\ rate\ per\ channel}{decimation\ factor}$$ → Example in Fig. 9 $$\frac{125\text{kHz}}{4} = 31.25\text{kHz}$$

The reduced sampling rate limits upper frequency in chart to 0.4 * fu = 12.5kHz in our example.

Signal chart mode - very slow signals

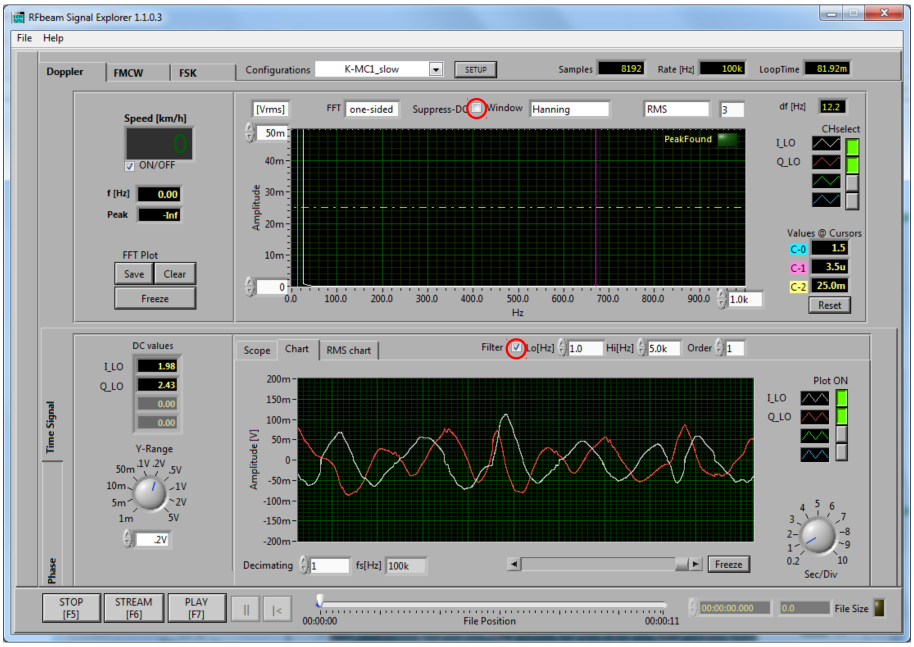


Fig. 10: Signal chart mode, very low frequency (record of human breathing)

Note: "Suppress DC" checkbox should be uncheckt. Otherwise slow signal will be interpreted as DC and removed or distorted.

RMS chart Mode

The “RMS chart mode” traces the RMS amplitude of the selected peak in a chart.

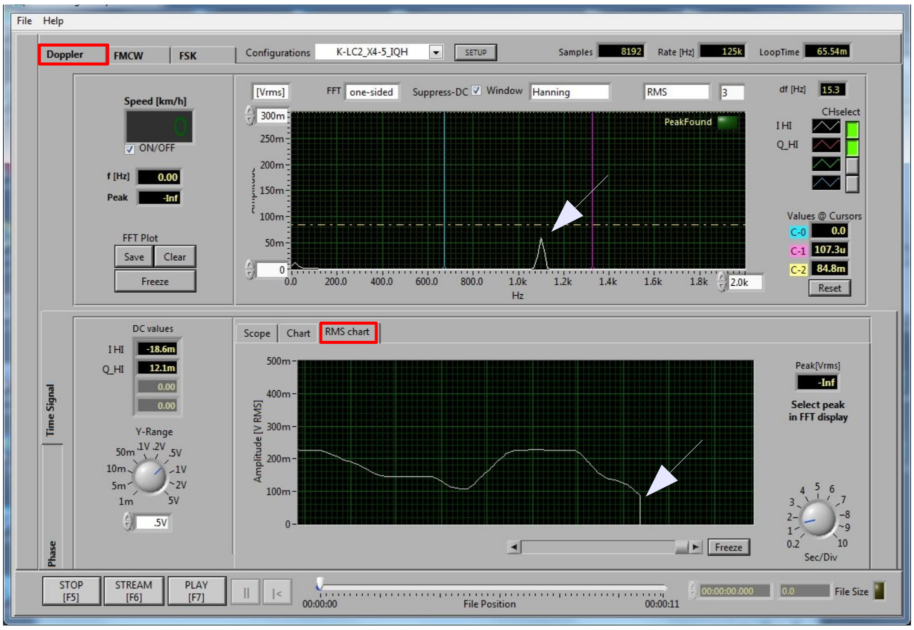


Fig. 11: RMS chart mode. Traces the selected peak's RMS amplitude

Fig. 11 shows an RMS amplitude chart of a selected peak. The amplitude drops to 0, as soon as the peak in the FFT falls outside the selected area. In our example, it dropped under the minimum level selected by the horizontal cursor.

Exploring the phase relation

Phase relaion bewtween two channels can be evaluated by using "cross FFT" algorithms (Fig. 12) or by using "complex FFT" (Fig. 13).

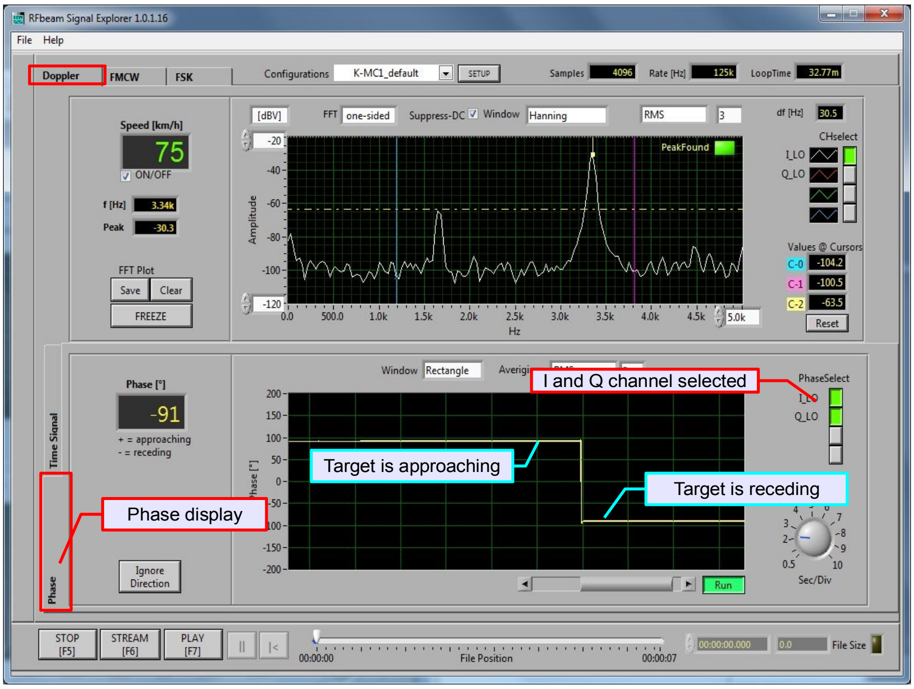


Fig. 12: Display I and Q phase relation to evaluate moving direction

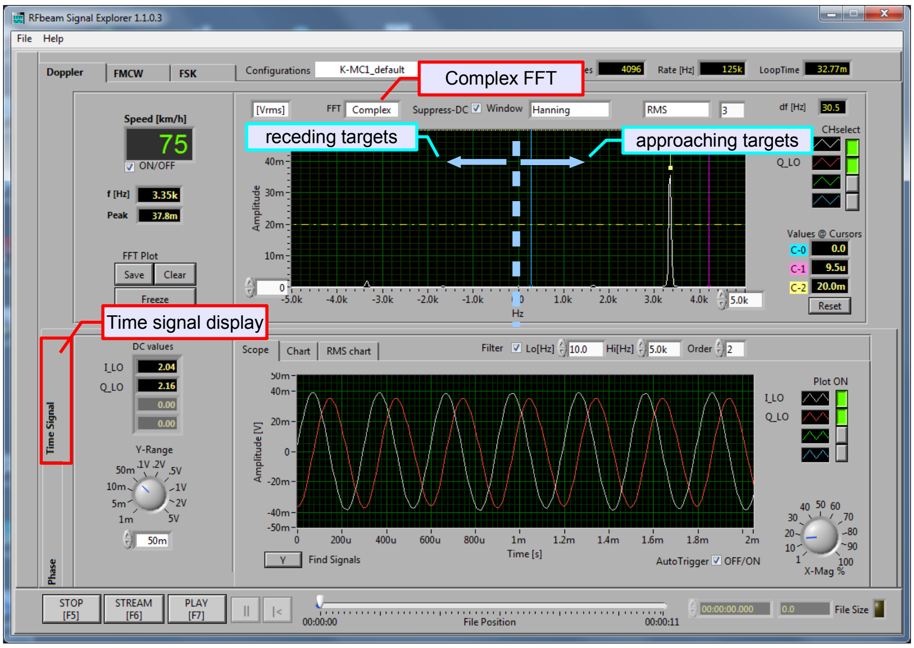


Fig. 13: Complex FFT with one approaching target: peak on right side

FMCW Mode

About FMCW

FMCW stands for Frequency Modulated Continuous Wave. This technique allows detection of stationary objects. FMCW needs Radar sensors with an FM input. This input accepts a voltage that causes a frequency change. There are also sensors with digital frequency control based on digital PLL designs. Modulation depth is normally a very small amount of the carrier frequency. In the K-band, most countries allow a maximum frequency range of 250MHz.
Descfription of many effects such as velocity-range unambiguities go beyond the scope of this paper. Please refer to Radar literature for more detailed explanations of FMCW and FSK techniques.

Sawtooth Modulation

Transmit frequency is modulated by a linear ramp. Fig. 14 shows a typical signal f_{Rx} returned by stationary and constantly moving objects. Note, that the difference frequency f_b is constant throughout nearly the whole ramp time.
At the output of the Radar transceiver we get the low frequency signal f_b called beat frequency. This is the result of mixing (=multiplying) transmitted and received frequencies (refer to Fig. 5).

Sawtooth modulation has important disadvantages:

- It is very difficult to get reliable results for moving objects
- The very sharp down ramp can disturb the amplified signals (ringing, saturation)

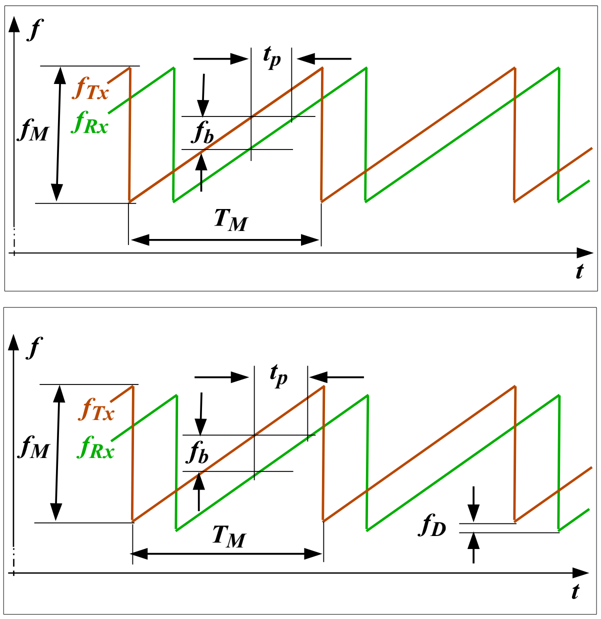


Fig. 14: Sawtooth modulation
Above: Stationary object, Below: Moving object

Returned echo from stationary object

f_M	Modulation depth
T_M	Modulation period
f_{Tx}	Transmitted frequency
f_{Rx}	Received frequency
t_p	Signal propagation time (time of flight)
f_b	Beat frequency f_{Tx} - f_{Rx}
f_D	Doppler shift frequency

Returned echo from moving object

Received frequency f_{Rx} is shifted by f_D .
This is the Doppler frequency caused by a receding object moving at a constant speed.

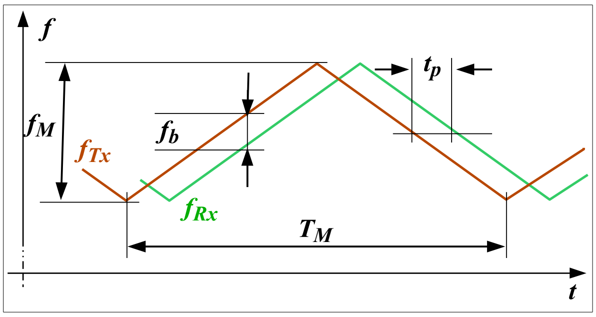
Distance can be calculated as follows:

$$R = \frac{c_0}{2} \cdot \frac{f_b}{f_M} \cdot T_M \qquad (5)$$

For legend refer to Fig. 14 above
R Range, distance to target
c_0 Speed of light ($3 * 10^8$ m/s)

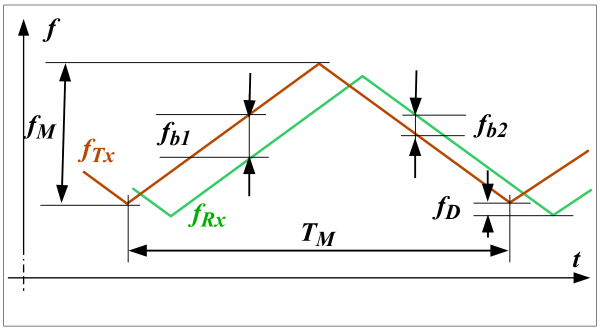
Triangle Modulation

Transmit frequency is modulated by a linear up and down ramp. Fig. 15 shows a typical signal f_{Rx} returned by stationary and constantly moving objects. Note, that the difference frequency f_b is constant throughout nearly the whole ramp time.
At the output of the Radar transceiver we get the a low frequency signal f_b called beat frequency. This is the result of mixing (=multiplying) transmitted and received frequencies (refer to Fig. 5).



Returned echo from stationary object

f_M Modulation depth
T_M Modulation period
f_{Tx} Transmitted frequency
f_{Rx} Received frequency
t_p Signal propagation time (time of flight)
f_b Beat frequency $f_{Tx} - f_{Rx}$
f_D Doppler shift frequency



Returned echo from moving object

Received frequency f_{Rx} is shifted by f_D .
This is the Doppler frequency caused by a receding object moving at a constant speed.

By measuring during up and down ramp, Doppler frequency f_D is the diffence between f_{b1} and f_{b2} .

Fig. 15: Triangle modulation
Above: Stationary object, Below: Moving object

Distance can be calculated as follows:

$$R=\frac{c_0}{2}\cdot\frac{f_b}{f_M}\cdot\frac{T_M}{2} \qquad (7)$$

For legend refer to Fig. 15 above
R Range, distance to target
*c_0 Speed of light (3 * 10^8 m/s)*

Maximum unambiguous range:

$$R_{max}=\frac{c_0}{2}\cdot\frac{T_M}{2} \qquad (8)$$

For legend refer to Fig. 15 above
R_{max} Max. unambiguos target distance
*c_0 Speed of light (3 * 10^8 m/s)*

Advantages of triangle modulation:

- Doppler frequency can be determined
- IF amplifiers are less stressed than with sawtooth modulation

Advanced FMCW Modulation Techniques

Triangle modulation may be extended with phase of constant frequency to allow Doppler detection.
You find examples in chapter Exploring FMCW.

Distance and Resolution

In K-Band (24GHz), maximum allowed frequency modulation depth f_M is < 250MHz. We also have to take in account tolerances and temperature influences. This limits the usable frequency shift f_M to typically 150MHz

For measuring f_b to evaluate distance we need at least one period of f_b during T_M , range resolution is limited to

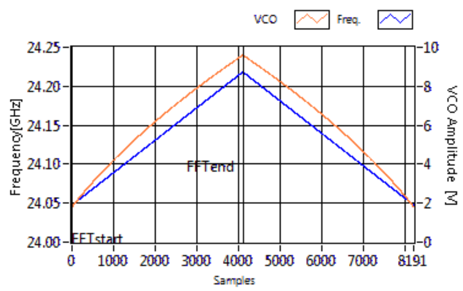
$$R_{min} = \frac{c_0}{2 \cdot f_M} = \frac{3^8\, m/s}{2 \cdot 250\text{MHz}} = 0.6\text{m} \quad (6)$$

This is a theoretical value, because we have to take in account drifts and tolerances in order to stay in the allowed frequency band.

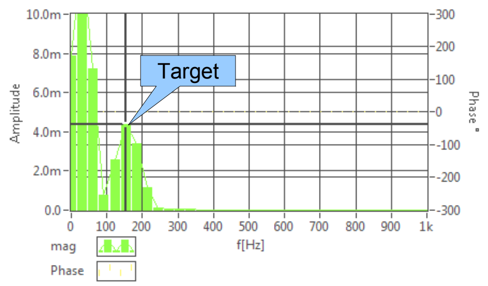
Working with the more realistic value of f_M = 150MHz, we get a minimum distance and resolution of R = 1m .
Resolution may be enhanced by using phase conditions, correlation and other sophisticated algorithms.

Real World EffectsSelf-Mixing Crosstalk

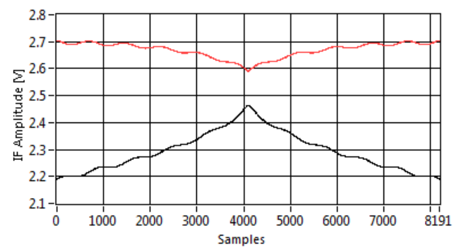
FM modulation with radar transceivers can produce side effects. Most annoying effect is caused by the feed through of the modulation signal to the IF output. This effect is caused by the limited isolation between transmitter and receiver path and can be called self-mixing. This effect limits the minimal detectable distance. This signal also limits the maximum signal amplification.



a) VCO modulation signal



c) FFT of the signal sensor output signal b)



b) Resulting sensor output with target in 5m

Left picture b) shows the I and Q signals of a K-MC1 sensor. Target has a distance of 5m. Self mixing signal is much higher than the reflected sinus signal of the target.
FFT in picture c) shows, that target signal is very close to the self mixing signal.

Fig. 16: FMCW effect of self mixing

Similar effects may be caused by poor quality of the cover in front of the sensor antenna. The cover is often called **RADOM** (from Radar Dome). The reason is different reflectivity at different frequencies. Please contact RFbeam for more informations on Radom.

Linearity

Non-linearity reduces resolution and sensitivity in FMCW ranging applications.
Linearity of the frequency ramps is crucial for reliable distance information. Varactor based open loop oscillators suffer of non linearities, that must be corrected by the FMCW VCO voltage generator.
RFbeam Signal Explorer offers tools to calculate and compensate non linearities. We will explain this later.

Exploring FMCW

FMCW may be best explored by using RFbeam K-MCx sensors. These sensors have enough sensitivity and beam focussing to demonstrate FMCW for many applications.
Best experience can be obtained by placing the Radar sensor outdoor. Fig. 17 shows an example of a signal from a sensor placed outside an office window.
Please note that some window types may absorb Radar signals, if they contain metallic components.

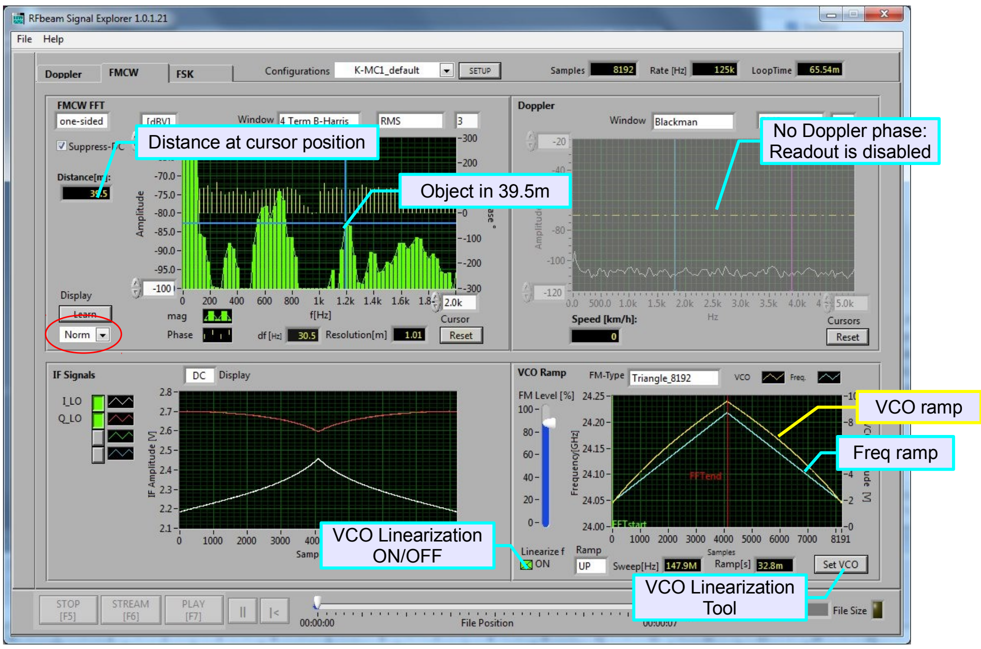


Fig. 17: ST200 FMCW Screen Overview using a K-MC1 sensor.

Bottom right graph in Fig. 17 demonstrates a calculated VCO ramp (yellow) to get a linear frequency ramp (blue). For more details on linearization refer to chapter FM Linearization.
Doppler FFT is displayed only, if VCO ramp contains a third, constant frequency block (called "3-blocks" FM Type).

In FMCW mode, the number of samples is defined by the definition of the VCO ramp. Refer to chapter FM Ramp Definitions.

Try using "Learn" button to mask out the momentary FMCW objects in FFT readout.
Select then "Diff" display. In this mode with linear FFT (Vrms) readout, be sure to extend range of Y axis to negative values also.
This allows better viewing changed situations in the environment.

FSK Mode

FSK stands for Frequency Shift Keying. FSK uses two discrete carrier frequencies f_a and f_b, (Fig. 18) while FMCW uses linear ramps.

For each carrier frequency, separate IF signals must be sampled in order to get 2 buffers for separate FFT processing.
Due to the very small step f_a - f_b a moving target will apear at the nearly the same Doppler frequency at both carriers, but with a different phase (Fig. 19) .
Phase shift due to the modulation timing and sampling must also be taken into account.

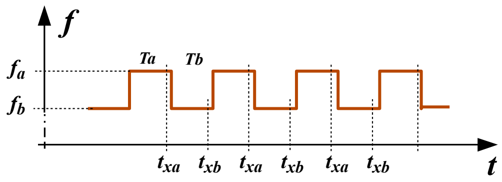


Fig. 18: FSK modulation scheme

f_a Carrier Frequency a
f_b Carrier Frequency b
t_{xa} Sampling point for Doppler a
t_{xb} Sampling point for Doppler b

Switching must be performed at a sampling rate high enough to meeting the Nyquist criteria for the Doppler signal acquisition.

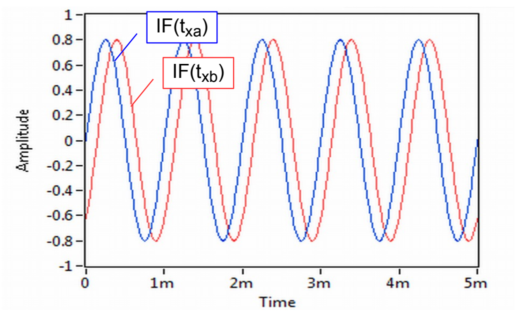


Fig. 19: Resulting Doppler frequencies

$IF(t_{xa})$ Sensor output signal at Carrier Frequency f_a
$IF(t_{xb})$ Sensor output signal at Carrier Frequency f_b

Doppler signals of the same moving target have same frequency, but are phase shifted by $\Delta\varphi$

For both IF signals, phase must be determined at the spectral peak of the object.

$$R = \frac{c_0 \cdot \Delta\phi}{4\pi \cdot (f_a - f_b)} \qquad (7)$$

$\Delta\varphi$ Phase shift of $IF(t_{xa})$ and $IF(t_{xb})$
φ ranges from 0 to 180°
Sign of φ indicates moving direction

The smaller the frequency step, the higher the maximum range.
With a frequency step of 1 MHz, you will get unambigous distance range of 75m.

- FSK can only be used for moving objects
- Multiple objects at different speeds may be detected
- Distance resolution depends manly on signal processing and is not limited by the carrier bandwidth limitations
- FSK has the advantage of simple modulation and does not suffer from linearity problems
- VCO signal generation is simple, but sampling and phase measurement is challenging

Exploring FSK

The power of FSK may be best explored by using the simple K-LC1a or other K-LCx series sensors. You may check the functionality by walking around in front of these sensors. Please note, that FSK allows even moving direction detection with the 1 channel K-LC1.

Technical Background

ST200 generates a continuous rectangular signal stream at the VCO input of the Radar sensor. With a strict and jitter free clock, two signal buffers, one for f_a, one for f_b (see Fig. 18), are generated from the sensor IF output. Sampling rate of each buffer is normally ¼ of the sampling rate of the analog output. This rate may be changed using the setup feature described in chapter Configurations Setup.
Both buffers are fed into the 2 inputs of a cross FFT, that allows measuring the phase for each spectral line.
Phase (=distance) is displayed on Signal Explorer for the highest level spectral peak only. But FSK would allows detecting distances of many targets with different speeds.
FSK is possible even with RFbeam's low cost sensor K-LC1a.

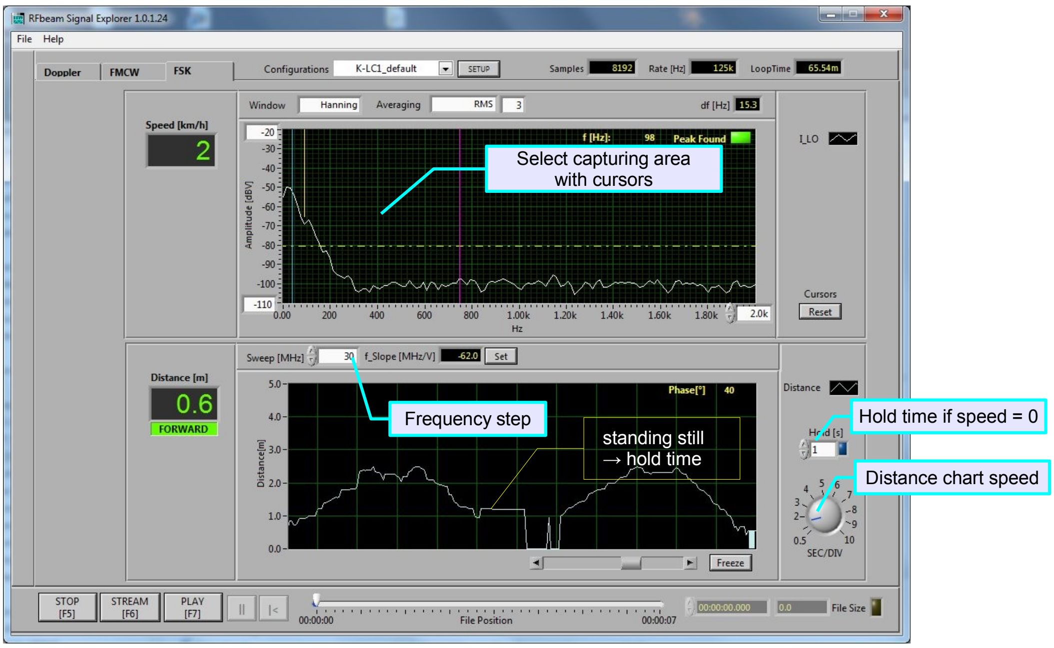


Fig. 20: FSK using K-LC1a: moving person, stopping for 1 second

Recording in FSK mode is possible. This allows analyzing situations under laboratory conditions.

Please select an appropriate area by means of the cursors in the FFT graph.
Phase calculation can be performed for each single frequency. In ST200, only the highest peak in the capturing area is taken in account.

Recording and Playback

ST100 allows recording and playing back Radar signals. Data is stored in multichannel TDMS files according to the National Instruments ® standard. There is no compression. Sampling rate in the file corresponds to the main sampling rate.

Following items are stored in the TDMS file:
Channel related:
- Channel (= Signal) Name
- Data length
- Samples/cycle
- Date/time of recording start

Administration:
- Sensor Name
- Author (user name of PC)
- Notes (not used yet)
- Configuration Name
- System Mode (Doppler, FSK)

FMCW recording is not supported in the current Signal Explorer version

Recording produces very long filels, depending on sampling rate, number of channels and recording duration.

Limiting file size

You may limit stream file size with different method:

1. Limit size by file size
2. Limit size by recording time
3. Split recording into multiple, size limited files. Multiple files will be numbered automatically.

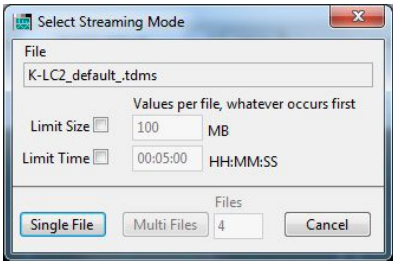


Fig. 21: Unlimited stream

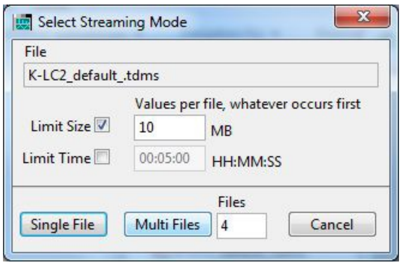


Fig. 22: 4 files limited to 10MB each

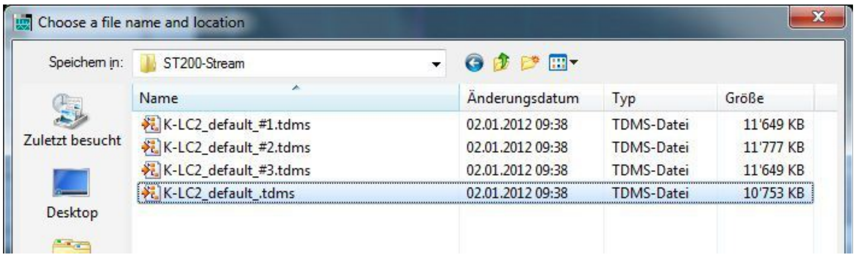


Fig. 23: Resulting files in Multi File mode selected as in Fig. 22

Please find more details on TDMS file format on http://zone.ni.com/devzone/cda/tut/p/id/3727.

Settings

Configurations

ST200 settings including sensor type are collected in configurations. You may generate as many configurations as you need.

Configurations Setup

You may alter or copy existing configurations. New configurations may be generated.

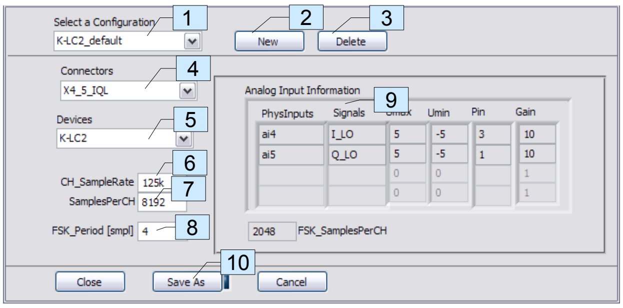


Fig. 24: Configuration Setup Dialog

Select predefined configurations from list box.
A configuration contains and defines:

- Sensor type
- Assigned connector
- Sampling per channel
- FSK period

Existing configurations may be overwritten (**be careful!**) or new ones may be generated.

Element		Description
1	Configuration selector	Select an existing configuration for viewing details or changing sampling parameters.
2	New configuration button	Select a new configuration based on the selected one.
3	Delete	Remove selcted configuration
4	Connectors	Select connector. Refer to chapter Sensor Connectors.
5	Devices	Select an existing sensor as defined by Radar Sensor Specification electronic datasheet.
6	Sampling Rate	ADC sampling rate per channel. Maximum is 250ks devided by number of chanels.
7	Samples per channel	Number of samples per channel as input for the signal processing (FFT).
8	FSK period	Period of one FSK cycle in samples. Minimum period is 4. -> 2 samples per carrier frequency
9	Connector information	Key data of the selected connector (not changable)
10	Save button	Active, whenever you have made changes

If generating new configurations, the system proposes a name root as follows.
You may change or complete it.

```
K-LC2_X4-5_IQH.cfg
  |     |  |_ connector inputs
  |     |____ connector name(s)  (refer to chapter Sensor Connectors)
  |__________ sensor type
```

Please do not change existing configurations, if you are not 100% sure about what you are doing. Unexpected behaviour may occur at inaccurate settings.
xx_default configurations can not be deleted.

Radar Sensor Specification

Radar Sensor specification makes part of the configuration. Each sensor is defined by an electronic datasheet `sensorname.ini`.

`[Comment]` `comment =`	*for future use*
`[ModuleConfig]` `stereo = TRUE` `MonoPulse = FALSE` `RxChannels = 1`	*These items define general sensor achitecture*
`[VCO]` `V_fmin = 1.000000` `V_f0 = 5.000000` `V_fmax = 10.000000` `V_FMmax = 10` `f_min = 24.036000` `f_0 = 24.105000` `f_max = 24.230000`	*Items affected automatically by* FM Linearization *Minimal VCO voltage* *Interpolation point at approx. ½ VCO range* *Maximal VCO voltage* *for future use* *Frequency @ VCO voltage V_fmin* *Frequency @ VCO voltage V_f0* *Frequency @ VCO voltage V_fmax*

Fig. 25: MC1.ini: Typical electronic datasheet for K-MC1

Naming convention

When creating a new configuration, this filename defines the sensor type. Example:
File MC1.ini → device name MC1.

Storage location

All device specifications are stored under `\ModuleSettings` as explained in chapter Working Files.

Adapting Existing Devices

Only items to change are the VCO characteristics. Changing the VCO data automatically affect the corresponding `sensorname.ini` file.

Generating New Devices

You may define new sensors by copying an existing file and editing by an ASCII editor like notepad or similar.
VCO values must be known and can be evaluated by using RFbeam K-TS1 test system (http://rfbeam.ch/fileadmin/downloads/datasheets/Datasheet_K-TS1.pdf)

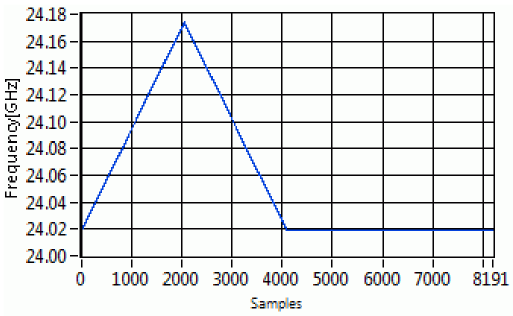
FM Ramp Definitions

FM ramp is defined in files:

[FMCW_Spec] UserWavePath = //Number of Samples UpRamp = 2048 DnRamp = 2048 Doppler = 4096	 *for future use* *Number of samples for up-chirp* *Number of samples for down-chirp* *Number of samples for doppler (0 = no doppler)*

Fig. 26: FMCW ramp description example '3-blocks-8192.ini'

This generates an FMCW period of total 8192 samples:

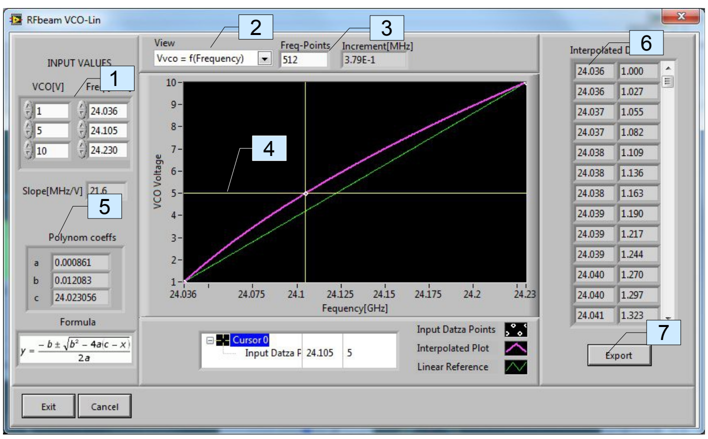


- Absolute voltage levels for 100% amplitude are given by the Radar sensor specification described in chapter Radar Sensor Specification.
- Frequency range depends on Radar Sensor Specification
  - Linearity compensation depends on FM Linearization
  - Sampling rate depends on configuration settings described in chapter Configurations.

FM Linearization

ST200 provides a tool "VCO-Lin" for interpolating the VCO characteristic from 3 known points. Output may be exported as csv file and can be used as table for your own FMCW system.

Call the tool by the [Set VCO] button in FMCW mode (see Fig. 17). You may get the 3 frequency points by measuring the sensor with RFbeam's K-TS1 test system.
VCO-Lin interpolates 3 points of the VCO courve to as many points (samples) as you wish.



1: Enter 3 value pairs Vvco - f[GHz].
These points are related to the Radar Sensor Specification

2: Select type of output:
Frequency vs VCO or
VCO vs. frequency

3: Number of interpolation poins

4: Dragable cursor

5: Polynom informations

6: Numeric output table

7: Export output table to a CSV file.

File and Directory Organisation

System Files

The files below **must not be edited** by the user. Configuration files found below are default files and will be copied to user storage space during installation.

[Programdir]\RFbeam\ST200_SignalExplorer\

ST200.exe ...		vital program files
Configurations\	AI_Config.ini 1) K-LC1_default.cfg K-LC1_X4-4IH.cfg ***.cfg	configuration files factory settings will be copied to user space during installation
FMCW-Settings\	3-blocks_8192.ini Triangle_4096.ini ***.ini	FMCW wave descriptions factory settings will be copied to user space during installation
ModuleSettings\	K-LC1.ini K-LC2.ini ***.ini	Radar sensor descriptions factory settings will be copied to user space during installation

Note 1) : AI_Config.ini contains hardware informations on the ST200 platform

Working Files

During installation, setup procedure copies the files below to user directories. Location depends on operating system. These files should not be changed directly, but are affected by the different setup options of Signal Explorer.

Windows xp
C:\Documents and Settings\user name\Local Settings\AppData\RFbeam\ST200
C:\Dokumente und Einstellungen\Benutzer name\Lokale Einstellungen\Anwendungsdaten\RFbeam\ST200

Windows Vista, Windows 7
C:\Users\user name\AppData\Local\RFbeam\ST200
Note: this directory may be hidden. For accessing, you need to change folder settings to "Show hidden files".

Appstats.ini		Statistics and installation history
System.ini		Last panel control settings
Configurations	AI_Config.ini 1) K-LC1_default.cfg K-LC1_X4-4IH.cfg ***.cfg	configuration files contain settings stored from Configurations Setup
FMCW-Settings	3-blocks_8192.ini Triangle_4096.ini ***.ini	FMCW wave descriptions
ModuleSettings	K-LC1.ini K-LC2.ini ***.ini	Radar sensor descriptions

Sensor Connectors

X1 Universal I/O

The universal connector X1 contains three analog inputs, two analog outputs and four digital in- and outputs for individual use.

X1 Pin Configuration

Pin	Signal	I/O	Description	Remark (with NI USB-6211)
1	AI13	I	Analog Input direct to AI13	Range of ±0.2V, ±1V, ±5V, ±10V
2	AGND	I/O		
3	AI14	I	Analog Input direct to AI14	Range of ±0.2V, ±1V, ±5V, ±10V
4	AGND	I/O		
5	AI15	I	Analog Input direct to AI15	Range of ±0.2V, ±1V, ±5V, ±10V
6	AGND	I/O		
7	DO0	O	Digital output direct from DO0	Max. 16mA
8	DO1	O	Digital output direct from DO1	Max. 16mA
9	DO2	O	Digital output direct from DO2	Max. 16mA
10	DO3	O	Digital output direct from DO3	Max. 16mA
11	DI0	I	Digital input direct to DI0	Pulldown 47kΩ
12	DI1	I	Digital input direct to DI1	Pulldown 47kΩ
13	DI2	I	Digital input direct to DI2	Pulldown 47kΩ
14	DI3	I	Digital input direct to DI3	Pulldown 47kΩ
15	AGND	I/O		
16	VCC	O	+5V, 400mA max	
17	AO0	O	Analog Output direct from AO0	±10V, ±2mA, Rout=0.2Ω
18	AGND	I/O		
19	AO1	O	Analog Output direct from AO1	±10V, ±2mA, Rout=0.2Ω
20	AGND	I/O		

X2 / X3 Direct Input

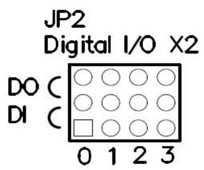
X3 is intended for use with sensors containing integrated IF amplifiers such as RFbeam K-MC1.
X2 contains all signals of X3 plus digital I/Os controlling future high complexity modules.

The modules on X2 and X3 can be supplied with 3.3V or 5V selected by JP3.

X2 Pin Configuration

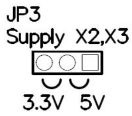
Connector X2 has a digital Interface with four digital I/O's. With the jumper JP2 the digital I/O's can be configured as inputs or as outputs.

Pin	Signal	I/O	Description	Remark (with NI USB-6211)
1	/Enable	O	Sensor /Enable Output	Buffered from DO0, 20mA
2	VCC	O	Supply configurable with JP3	+3.3V/0.4A or +5V/0.4A
3	GND	I/O		
4	Q_HI	I	Doppler Signal Q (quadrature) high gain	Analog input direct to AI3
5	I_HI	I	Doppler Signal I (in phase) high gain	Analog input direct to AI2
6	VCO	O	0 … 5V Output	Limited and buffered from AO0
7	I_LO	I	Doppler Signal I (in phase) low gain	Analog input direct to AI0
8	Q_LO	I	Doppler Signal Q (quadrature) low gain	Analog input direct to AI1
9	I2_LO	I	Doppler Signal I (in phase) low gain	Analog input direct to AI8
10	Q2_LO	I	Doppler Signal Q (quadrature) low gain	Analog input direct to AI9
11	I2_HI	I	Doppler Signal I (in phase) high gain	Analog input direct to AI10
12	Q2_HI	I	Doppler Signal Q (quadrature) high gain	Analog input direct to AI11
13	AGND	I/O		
14	DGND	I/O		
15	DIO0	I/O	Digital Input or Output	Configure with JP2 to DI0 or DO0
16	DIO1	I/O	Digital Input or Output	Configure with JP2 to DI1 or DO1
17	DIO2	I/O	Digital Input or Output	Configure with JP2 to DI2 or DO2
18	DIO3	I/O	Digital Input or Output	Configure with JP2 to DI3 or DO3
19	AI12	I	Analog Input direct to AI12	Range of ±0.2V, ±1V, ±5V, ±10V
20	VCC	O	+5V, 400mA max	



X3 Pin Configuration / Supply Selection

Pin	Signal	I/O	Description	Remark (with NI USB-6211)
1	/Enable	O	Sensor /Enable Output	Buffered from DO0, 20mA
2	VCC	O	Supply configurable with JP3	+3.3V/0.4A or +5V/0.4A
3	GND	I/O		
4	Q_HI	I	Doppler Signal Q (quadrature) high gain	Analog input direct to AI3
5	I_HI	I	Doppler Signal I (in phase) high gain	Analog input direct to AI2
6	VCO	O	0 … 5V Output	Limited and buffered from AO0
7	I_LO	I	Doppler Signal I (in phase) low gain	Analog input direct to AI0
8	Q_LO	I	Doppler Signal Q (quadrature) low gain	Analog input direct to AI1



X2 Pin Configuration

The connector X2 has a digital Interface with four digital I/O's. With the jumper JP2 the digital I/O's can be configured as inputs or as outputs.

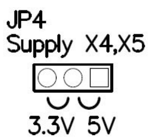
Pin	Signal	I/O	Description	Remark (with NI USB-6211)
1	/Enable	O	Sensor /Enable Output	Buffered from DO0, 20mA
2	VCC	O	Supply configurable with JP3	+3.3V/0.4A or +5V/0.4A
3	GND	I/O		
4	Q_HI	I	Doppler Signal Q (quadrature) high gain	Analog input direct to AI3
5	I_HI	I	Doppler Signal I (in phase) high gain	Analog input direct to AI2
6	VCO	O	0 … 5V Output	Limited and buffered from AO0
7	I_LO	I	Doppler Signal I (in phase) low gain	Analog input direct to AI0
8	Q_LO	I	Doppler Signal Q (quadrature) low gain	Analog input direct to AI1
9	I2_LO	I	Doppler Signal I (in phase) low gain	Analog input direct to AI8
10	Q2_LO	I	Doppler Signal Q (quadrature) low gain	Analog input direct to AI9
11	I2_HI	I	Doppler Signal I (in phase) high gain	Analog input direct to AI10
12	Q2_HI	I	Doppler Signal Q (quadrature) high gain	Analog input direct to AI11
13	AGND	I/O		
14	DGND	I/O		
15	DIO0	I/O	Digital I/O	Configure with JP2 to DI0 or DO0
16	DIO1	I/O	Digital I/O	Configure with JP2 to DI1 or DO1
17	DIO2	I/O	Digital I/O	Configure with JP2 to DI2 or DO2
18	DIO3	I/O	Digital I/O	Configure with JP2 to DI3 or DO3
19	AI12	I	Analog Input direct to AI12	Range of ±0.2V, ±1V, ±5V, ±10V
20	VCC	O	+5V, 400mA max	

X4 / X5 High Gain Inputs

X4 and X5 high gain inputs are optimized for using radar modules without IF amplifier (RFbeam K-LC1 e.g.). Four gains may be selected by digital output (DO3). Low gain often is used for FMCW operation, because high gain amplifiers will clip signals resulting from VCO sweep.
The modules on X4 and X5 can be supplied with 3.3V or 5V selected by JP4.

Pin Configuration / Supply Selection

Pin	Signal	I/O	Description	Remark (with NI USB-6211)
1	IF_Q	I	Doppler Signal Q (quadrature)	not used with 1 channel modules
2	VCC	O	Supply configurable with JP4	+3.3V/0.4A or +5V/0.4A
3	IF_I	I	Doppler Signal I (in phase)	used by single channel modules
4	GND	I/O		
5	VCO	O	-0.5 … 2V Output	Limited and buffered from AO0
6	NC	-	Not Connected	



Optional Gain Settings for X4, X5

Digital output DO3 allows selecting the gain of the first amplifier stage. This results in 20dB difference on both amplifier outputs. Please refer also to the block diagram.

DO3	AI4 (IF_Q)	AI6 (IF_Q)	AI5 (IF_I)	AI7 (IF_I)	Comment
Low	**20dB**	**60dB**	**20dB**	**60dB**	**default after power up**
High	0dB	40dB	0dB	40dB	not used in SignalExplorer Software

X10 Optional DC Power In

This input must be used, if USB does not deliver enough current to power ST200 including connected modules.

X11 Power Out

The power out connector X11 can be used to supply external devices with low noise supply voltages.

Pin Configuration

Pin	Signal	I/O	Description
1	VCC3V3	O	3.3V / 400mA max
2	VCC5V	O	5V / 400mA max
3	VCC-5V	O	-5V / 80mA max
4	PGND	I/O	

Document Revision History

Version 0.1	June 2011	Initial preliminary release
Version 0.2	July 15, 2011	Preliminary release
Version 1.0	Sept 20, 2011	1st official release, valid for software version 1.1 or later
Version 1.1	Jan 2, 2012	Added chapter Limiting file size. Corrected max. range in Exploring FSK These changes apply to software version 1.1.1 or later
Version 1.2	Jan 17, 2013	Formula (4) corrected

RFbeam does not assume any responsibility for use of any circuitry, principle or software escribed. No circuit patent licenses are implied. RFbeam reserves the right at any time without notice to change said system and specifications.