

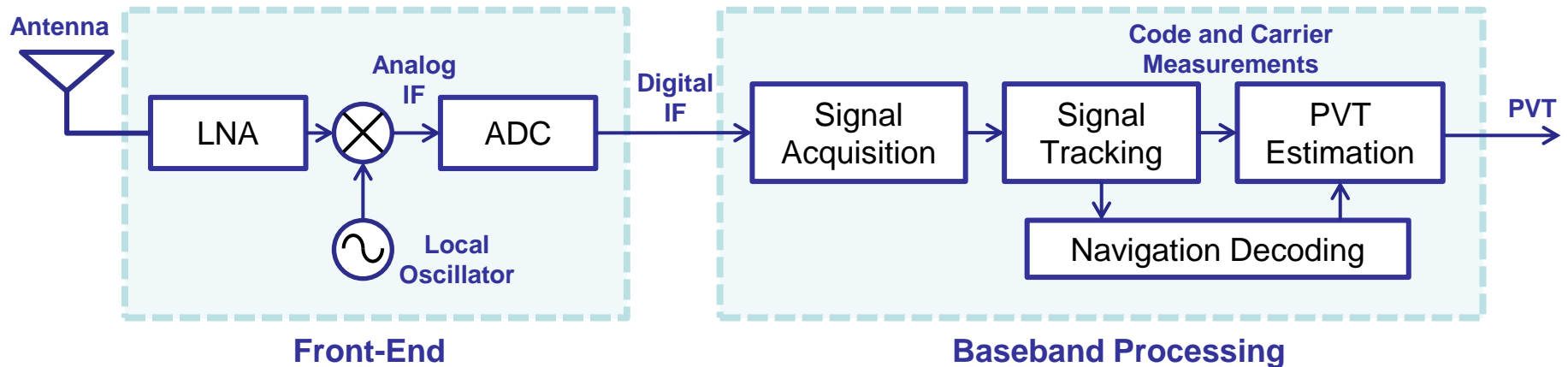


05: SDR Setup



Taro Suzuki

GNSS Front-end (1)



- ▶ What is important to choose front-end?
 - ▶ Price
 - ▶ How many bands? (How many front-ends?)
 - ▶ Sample rate
 - ▶ Signal bandwidth
 - ▶ Frequency range (Only LI or not?)
 - ▶ Data interface (USB2.0 / USB3.0 / Ethernet...)
 - ▶ Sampling bits
 - ▶ Oscillator accuracy

GNSS Front-end (2)



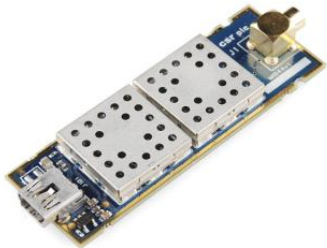
DVB-T dongle (RTL-2832U)

- **\$10**, Frequency: 24M-1.7GHz, Sampling: 2.56MHz
- Poor clock accuracy



Nuand BladeRF (LMS6002D)

- **\$420**, Frequency: 300Hz~3.8GHz, Sampling: ~40MSPS
- Tx function (transmitter)



SiGe GN3S sampler V2/V3 (SiGe4120)

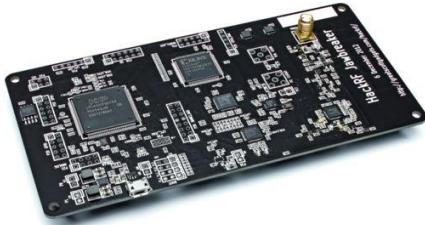
- **\$450**, Frequency: 1575.42MHz, Sampling: 4MHz
- For only GPS L1 signal



NSL STEREO (MAX2769b+MAX2112)

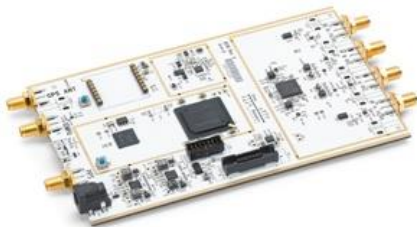
- **\$850**, Frequency: 300Hz~3.8GHz, Sampling: ~40MHz
- Two front-ends

GNSS Front-end (3)



HackRF (LMS6002D)

- **\$300**, Frequency: 30M-6GHz, Sampling: 20MHz
- Kick Starter project



Ettus USRP (AD9361)

- **\$1100**, Frequency: 300~3.8GHz, Sampling: 40Msps
- Tx function (transmitter)



SwiftNav Piksi (MAX2769)

- **\$525**, Frequency: 1575.42MHz, Sampling: 16Msps
- For only GPS L1 signal
- RTK GPS enable (FPGA based)



PocketSDR (MAX2771x2)

- **\$50**, 1.16G~1.61GHz (All GNSS signal frequency)
- **Two front-ends**
- **Open Source Project** <https://github.com/tomojitakasu/PocketSDR>

Which is Best?



RTL-SDR

- ▶ Most famous SDR front-end device
 - ▶ Using Elonics E4000 turner-chip
 - ▶ Using Realtek RTL2832U ADC
- ▶ Cheap (about \$10~\$20)
- ▶ Large community
 - ▶ <http://sdr.osmocom.org/trac/wiki/rtl-sdr>
- ▶ Active antenna cannot be used in default



Using GPS signal splitter and another GPS receiver



Using a bias-T network

Improved Version of RTL-SDR

RTL-SDR.com <http://www.rtl-sdr.com/buy-rtl-sdr-dvb-t-dongles>



Price: \$19.95

Improvements:

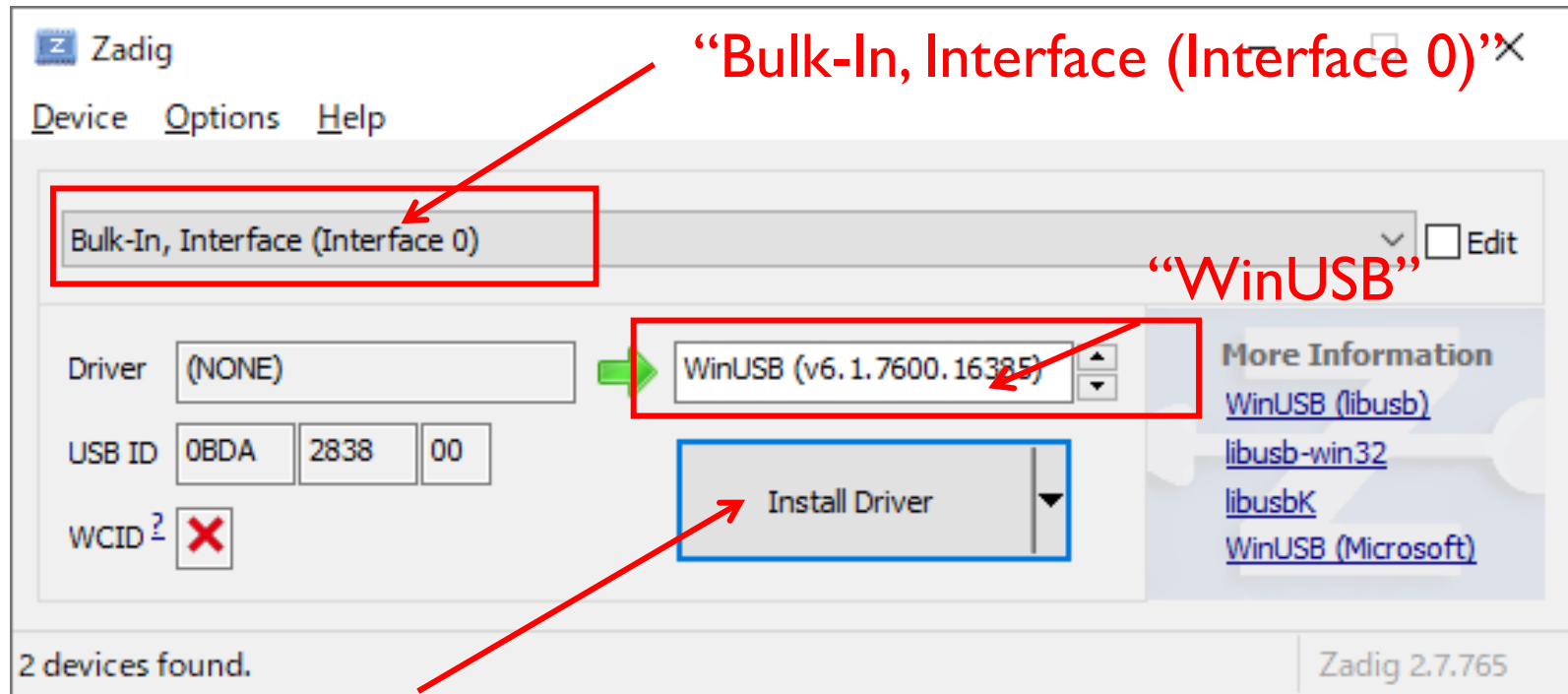
- ▶ Temperature compensated oscillator (TCXO)
- ▶ SMA female antenna port
- ▶ Improved component tolerances
- ▶ 4.5V USB powered bias tee

Install RTL-SDR Driver (1)

- ▶ Insert the **RTL-SDR** into an available USB port
- ▶ If your OS automatically installs a driver, wait until the OS finishes the installation before continuing.
- ▶ Run **Zadig.exe**
 - ▶ /05_SDR_Setup/rtlsdr/zadig/zadig-2.7.exe



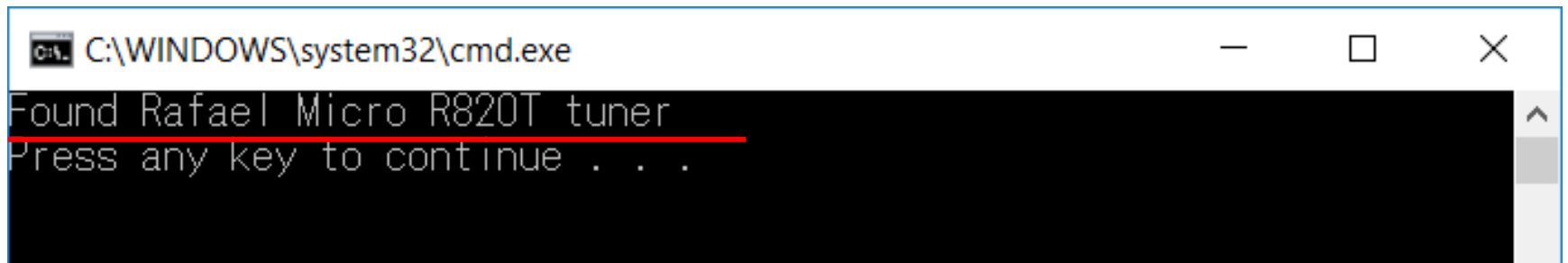
Install RTL-SDR Driver (2)



- ▶ Click "Install Driver"
- ▶ If nothing is displayed...
 - ▶ Options -> List All Devices

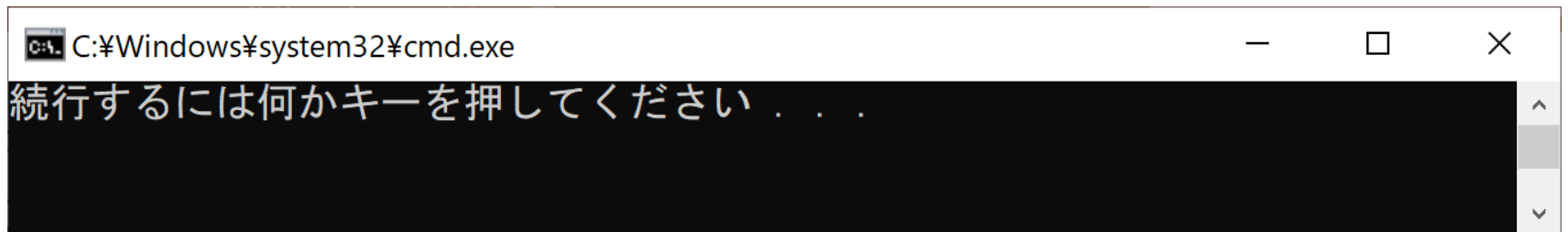
Install RTL-SDR Driver (3)

- ▶ Enable onboard Bias-T
- ▶ Open “**rtl-sdr**” folder and run “**l_bias_tee_on.bat**”



```
C:\WINDOWS\system32\cmd.exe
Found Rafael Micro R820T tuner
Press any key to continue . . .
```

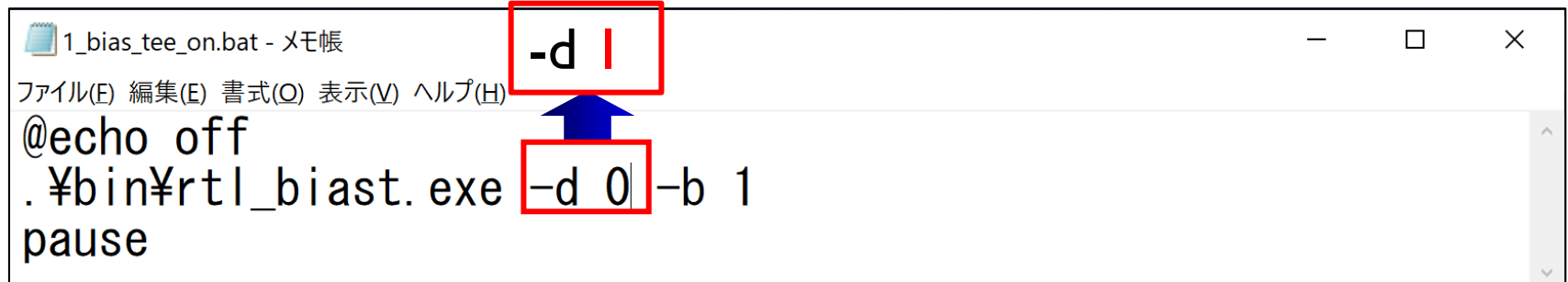
- ▶ If nothing is shown as follows, you need to change the device number of RTL-SDR



```
C:\Windows\system32\cmd.exe
続行するには何かキーを押してください . . .
```

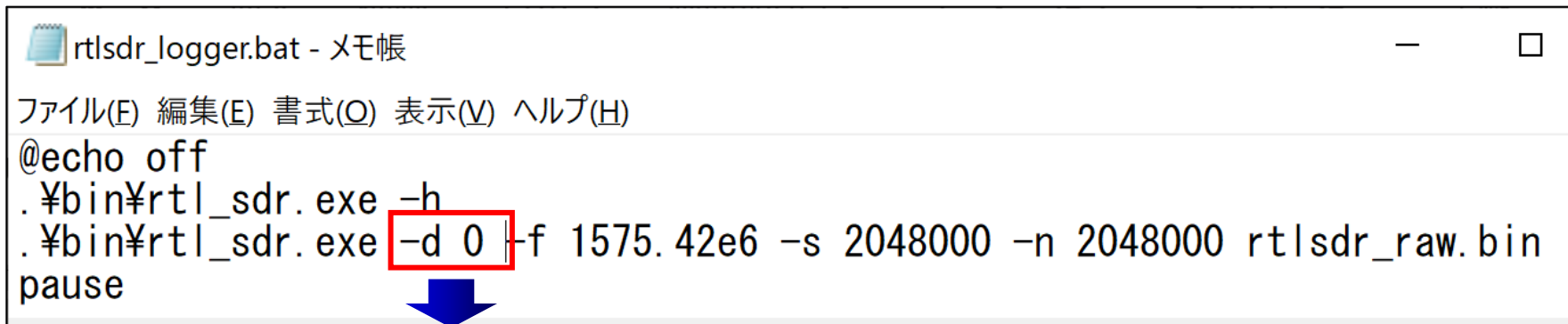
Install RTL-SDR Driver (4)

- ▶ If nothing is shown ...
- ▶ Edit “**1_bias_tee_on.bat**”



```
@echo off
.%bin%\rtl_biast.exe -d 0 -b 1
pause
```

- ▶ Edit “**2_rtl_sdr_logger.bat**”

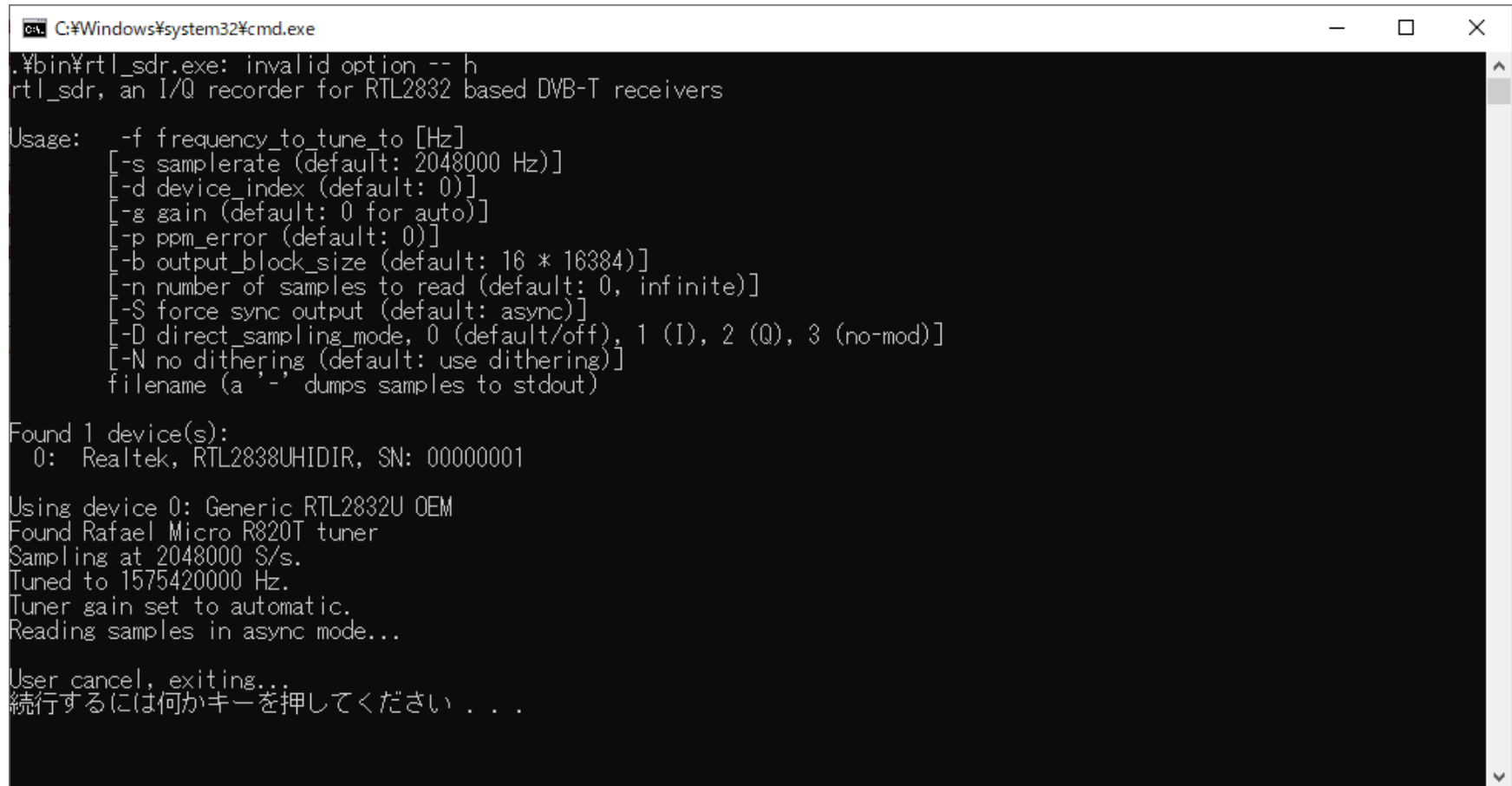


```
@echo off
.%bin%\rtl_sdr.exe -h
.%bin%\rtl_sdr.exe -d 0 -f 1575.42e6 -s 2048000 -n 2048000 rtl_sdr_raw.bin
pause
```

-d 1

Install RTL-SDR Driver (5)

- ▶ Open “rtl-sdr” folder and run “2_rtl_sdr_logger.bat”



```
C:\Windows\system32\cmd.exe
.\bin\rtl_sdr.exe: invalid option -- h
rtl_sdr, an I/Q recorder for RTL2832 based DVB-T receivers

Usage:  -f frequency_to_tune_to [Hz]
        [-s samplerate (default: 2048000 Hz)]
        [-d device_index (default: 0)]
        [-g gain (default: 0 for auto)]
        [-p ppm_error (default: 0)]
        [-b output_block_size (default: 16 * 16384)]
        [-n number of samples to read (default: 0, infinite)]
        [-S force sync output (default: async)]
        [-D direct_sampling_mode, 0 (default/off), 1 (I), 2 (Q), 3 (no-mod)]
        [-N no dithering (default: use dithering)]
        filename (a '-' dumps samples to stdout)

Found 1 device(s):
 0: Realtek, RTL2838UHIDIR, SN: 00000001

Using device 0: Generic RTL2832U OEM
Found Rafael Micro R820T tuner
Sampling at 2048000 S/s.
Tuned to 1575420000 Hz.
Tuner gain set to automatic.
Reading samples in async mode...

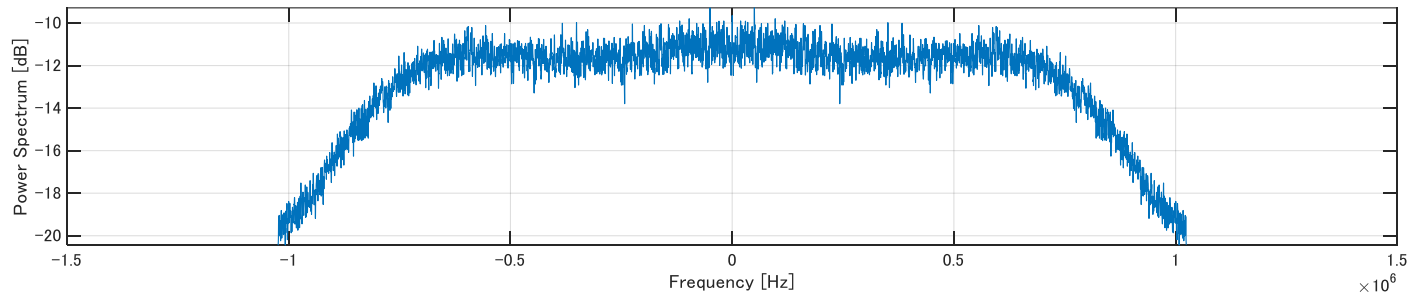
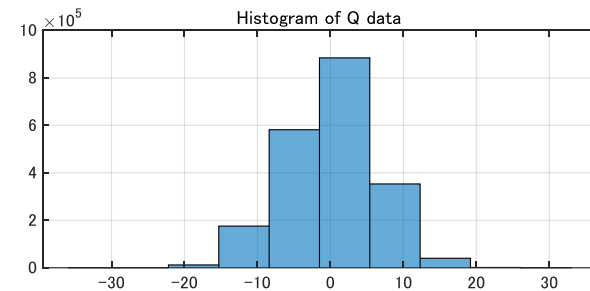
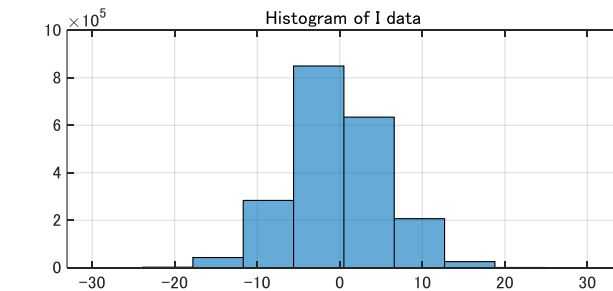
User cancel, exiting...
続行するには何かキーを押してください . . .
```

Exercise 1: Plot Data using MATLAB

- ▶ Open “**Ex1_run_plot_rfdata.m**” and Run



- ▶ **/05_SDR_Setup/matlab/Ex1_run_plot_rfdata.m**



- ▶ Try to plot RF data currently acquired

RF Data File Format

▶ rtlsdr_raw

- ▶ RTL-SDR: 8-bit I/Q samples



▶ int16

- ▶ Generic formats for I/Q samples



▶ int8

- ▶ PocketSDR: 2-bit I/Q samples



▶ Baseband File for MATLAB

- ▶ Variable data type



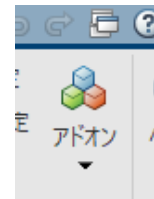
MATLAB Setup (1)

▶ Details:

<https://jp.mathworks.com/help/supportpkg/rtlsdrradio/ug/support-package-hardware-setup.html>

▶ Install addons

- ▶ Click addon in MATLAB menu
- ▶ Search “**rtl-sdr**” in addon explore
- ▶ Install “**Communications Toolbox Support Package for RTL-SDR Radio**”



Communications Toolbox Support Package for RTL-SDR Radio 作成者: MathWorks Communications Toolbox Team **STAFF**

Acquire RF data using RTL-SDR.

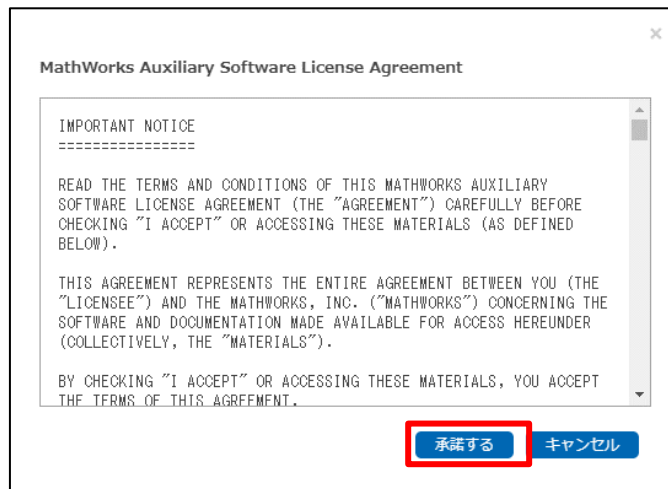
Design and verify practical **SDR** systems using Communications System Toolbox™ Support Package for **RTL-SDR** Radio. Support enables you to use the **RTL-SDR** USB radio as a standalone peripheral for

ハードウェア サポート

MATLAB Setup (2)

▶ Accept License and install

1



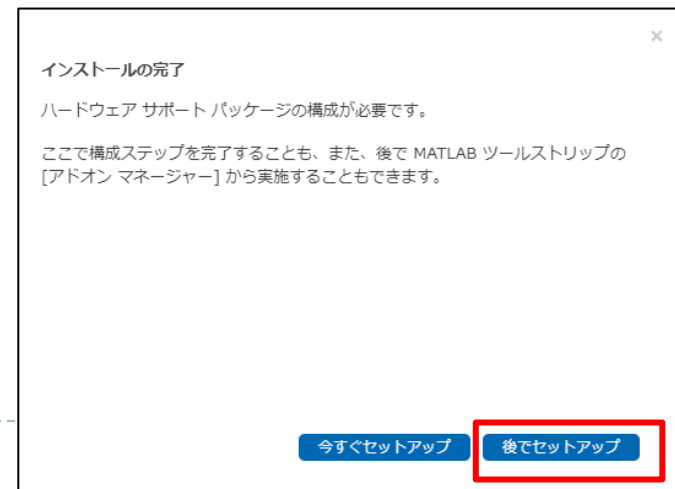
2



3



4



Exercise 2: Capture using MATLAB

- ▶ MATLAB
 - ▶ /05_SDR_Setup/matlab/**Ex2_run_rtlsdr_logger.m**
 - ▶ Int16 Binary file and Baseband file are captured
- ▶ Baseband file is RF data format for MATLAB
 - ▶ Baseband File Reader/Writer Blocks for Simulink
 - ▶ BasebandFileReader/Write functions

```
7  %% Setting
8  Fc = 1575.42e6; % Center frequency [Hz]
9  Fs = 2.048e6; % Sampling rate [Hz]
10 nsec = 1; % [sec]
11
12 % Output file name
13 bbfile = 'rtlsdr_matlab.bb';
14 binfile = 'rtlsdr_matlab.bin';
15
```

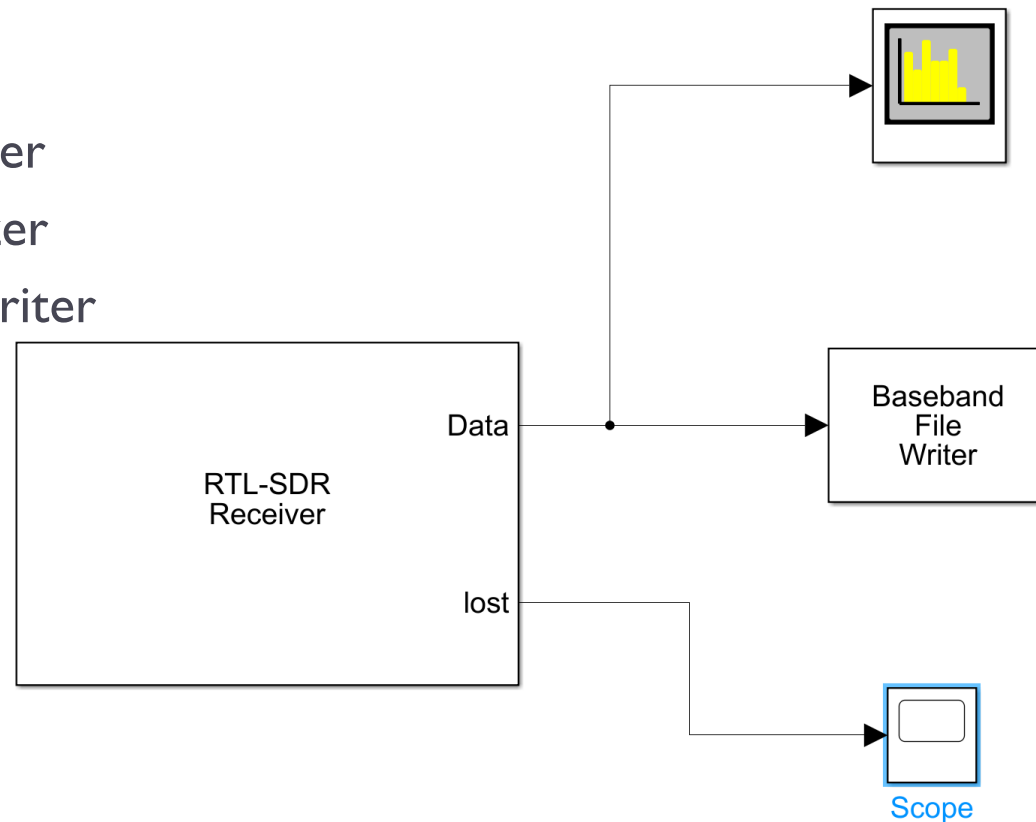
Exercise 3: Capture using Simulink (1)

▶ Simulink

▶ /05_SDR_Setup/simulink/**Ex3**/rtlsdr_logger.slx

▶ Blocks

- ▶ RTL-SDR Receiver
- ▶ Spectrum Analyzer
- ▶ Baseband File Writer
- ▶ Scope



Exercise 3: Capture using Simulink (2)

ブロック パラメーター: RTL-SDR Receiver

RTL-SDR Receiver (mask) (link)
Receive data from an RTL-SDR radio.

Radio Connection

Radio address: 0

Info

Radio Configuration

Source of center frequency: Dialog

Center frequency (Hz): 1575.42e6

Source of gain: AGC

Sampling rate (Hz): 2.048e6

Frequency correction (ppm): 0

Data Transfer Configuration

☐ Lost samples output port

☐ Latency output port

Output data type: int16

Samples per frame: 2048*10

☐ Enable burst mode

OK(O) キャンセル(C) ヘルプ(H) 適用(A)

スペクトル設定

メイン オプション

入力領域: 時間

タイプ: パワー密度

ビュー: スペクトル

サンプル レート (Hz): 継承

メソッド: ウェルチ

☒ 全周波数スパン

RBW (Hz): 自動

サンプル/更新: --

Baseband File Writer

rtlsdr_simulink.bb

Browse...

1575.42e6

struct()

inf

コード生成

OK(O) キャンセル(C) ヘルプ(H) 適用(A)

Exercise 4: Read Baseband File

▶ Simulink

▶ /05_SDR_Setup/simulink/Ex4/rtlsdr_reader.slx



▶ Advanced Challenge

- ▶ Visualization raw samples using Array Plot
- ▶ Compute Histogram using Histogram and Display
- ▶ Insert DC Blocker

Exercise 5: Convert RF file

▶ MATLAB

- ▶ `/05_SDR_Setup/matlab/Ex5_run_convert_rtlsdr.m`
- ▶ Convert rtl-sdr format (uint8) to int16 binary and Baseband file
- ▶ Plot and check converted data using
“`Ex1_run_plot_rfdata.m`”