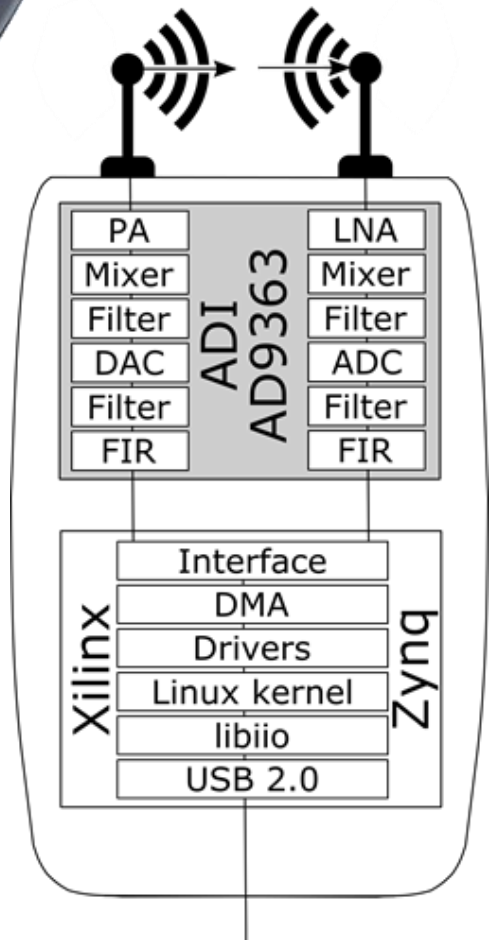
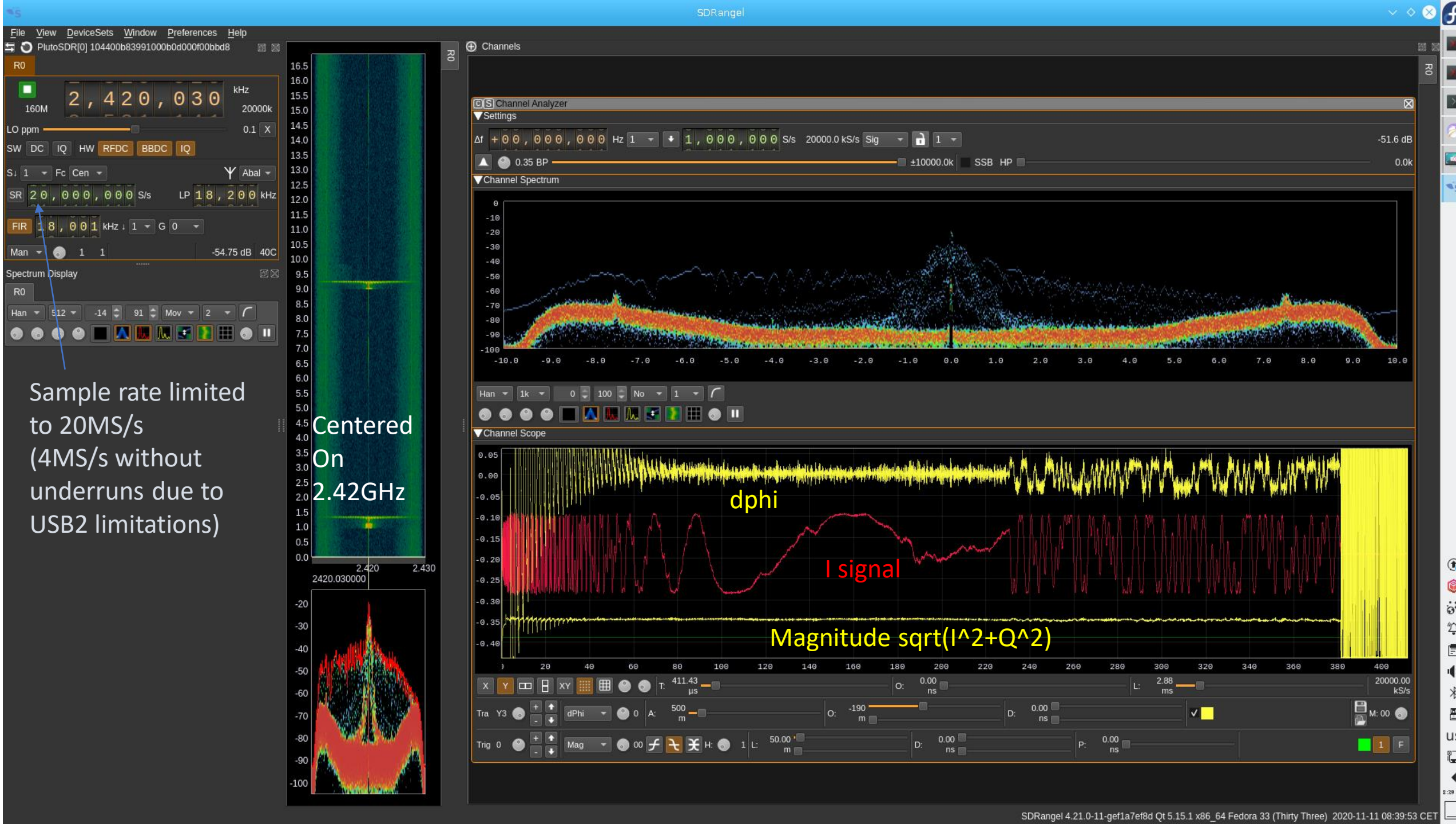
Software Defined Radio and (a bit) Synthetic Aperture Radar

2020-11-17 Martin Kielhorn

How does the remote control communicate with the drone?




SDRangel
File View DeviceSets Window Preferences Help
PlutoSDR[0] 104400b83991000b0d000f00bbd8
R0
2,420,030 kHz
160M
20000k
LO ppm
0.1 X
SW DC IQ HW RFDC BBDC IQ
Fc Cen
Abal
SR 20,000,000 S/s
LP 18,200 kHz
FIR 18,001 kHz
G 0
Man
-54.75 dB
40C
Spectrum Display
Han 512 -14 91 Mov 2
Sample rate limited to 20MS/s (4MS/s without underruns due to USB2 limitations)
Centered On 2.42GHz
2.420
2.430
2420.030000
Channels
Channel Analyzer
Settings
Δf +000,000,000 Hz
1,000,000 S/s
20000.0 kS/s Sig
-51.6 dB
0.35 BP
±10000.0k
SSB HP
0.0k
Channel Spectrum
Han 1k 0 100 No 1
Channel Scope
dphi
I signal
Magnitude sqrt(I^2+Q^2)
T: 411.43 µs
O: 0.00 ns
L: 2.88 ms
20000.00 kS/s
Tra Y3 dPhi 0
A: 500 m
O: -190 m
D: 0.00 ns
M: 00
Trig 0 Mag 00 H: 1
L: 50.00 m
D: 0.00 ns
P: 0.00 ns
SDRangel 4.21.0-11-gef1a7ef8d Qt 5.15.1 x86_64 Fedora 33 (Thirty Three) 2020-11-11 08:39:53 CET

Features and Benefits | Product Details

- Portable self-contained RF learning module
- Cost-effective experimentation platform
- Based on Analog Devices AD9363--Highly Integrated RF Agile Transceiver and Xilinx® Zynq Z-7010 FPGA
- RF coverage from 325 MHz to 3.8 GHz
- Up to 20 MHz of instantaneous bandwidth
- Flexible rate, 12-bit ADC and DAC
- One transmitter and one receiver, half or full duplex
- MATLAB®, Simulink® support
- GNU Radio sink and source blocks
- libiio, a C, C++, C#, and Python API
- USB 2.0 Powered Interface with Micro-USB 2.0 connector
- High quality plastic enclosure

github.com/analogdevicesinc/plutosdr-fw

analogdevicesinc / plutosdr-fw — Watch 54 | Star 135 | Fork 59

Code | Issues 4 | Pull requests | Actions | Projects | Wiki | Security

master | Go to file | Add file | Code

mhennerich PlutoSDR: Prepare for v0.32 release (part II) ... on Jul 6 117

buildroot @ 1daa690	PlutoSDR: Prepare for v0.32 release (part II)	4 months ago
hdl @ 847f0f2	PlutoSDR: Prepare for v0.32 release	5 months ago
linux @ 6edc6cd	PlutoSDR: Prepare for v0.32 release (part II)	4 months ago
scripts	legal: make the date, 3 years and 6 months + t...	5 months ago
u-boot-xlnx @ 469a0fd	PlutoSDR: Prepare for v0.32 release	5 months ago
.gitignore	.gitignore: add vim swap files	3 years ago
.gitmodules	build: remove default branch for buildroot sub...	2 years ago
LICENSE.md	LICENSE.md : Update with some wording twea...	3 years ago
Makefile	PlutoSDR: Prepare for v0.32 release	5 months ago
README.md	Update Readme.md with some badges	8 months ago

README.md

plutosdr-fw

PlutoSDR Firmware for the ADALM-PLUTO Active Learning Module

Latest binary Release : release v0.32 downloads 61k

Firmware License : license LGPL2+ license GPL2+ license BSD license apache and many others

About

PlutoSDR Firmware

plutosdr adalm-pluto sdr iio active-learning-module fpga hdl linux rf transceiver plutosdr-fw plutosdr-firmware

Readme

View license

Releases 22

v0.32 Latest on Jul 6

+ 21 releases

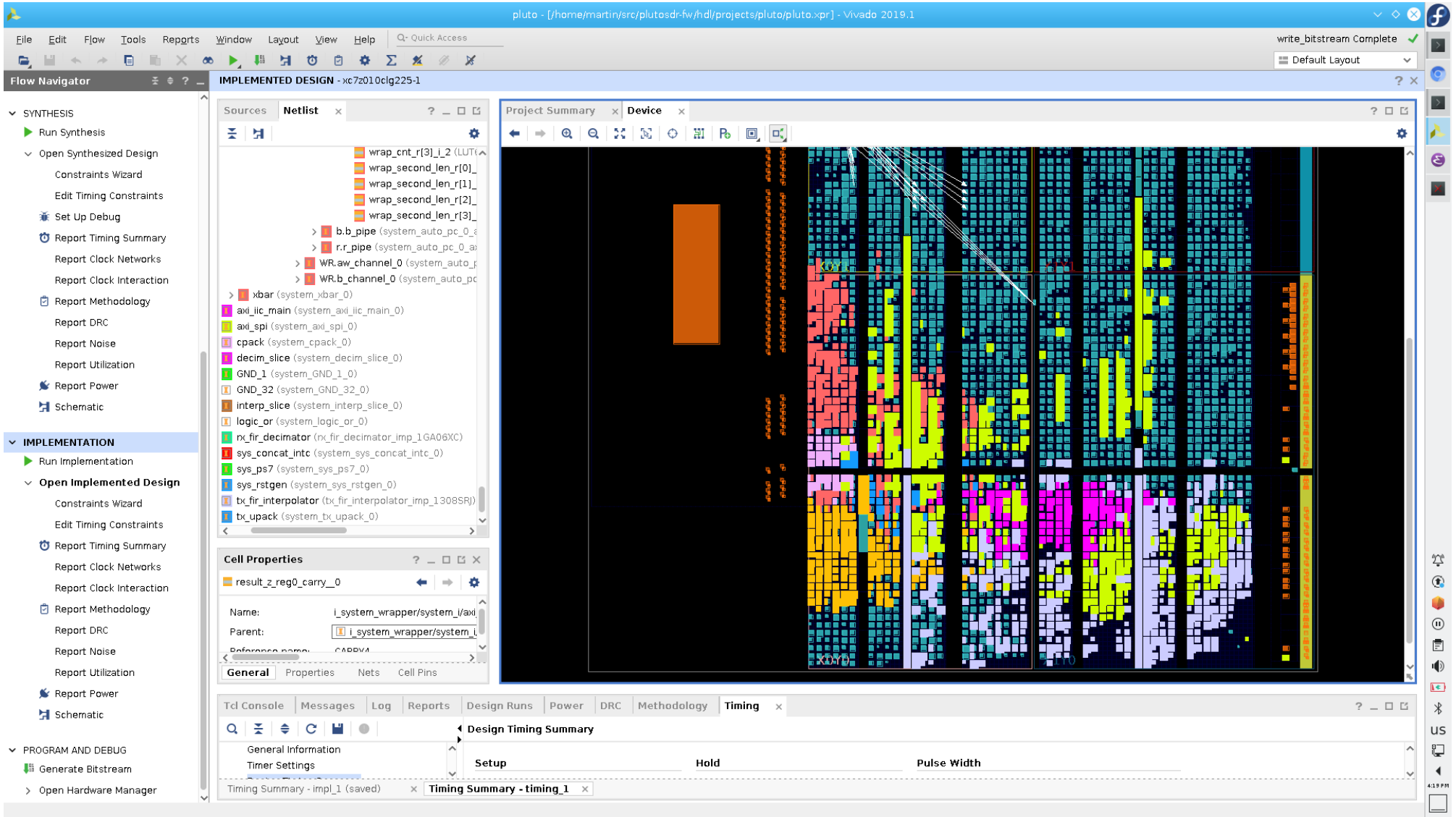
Packages

No packages published

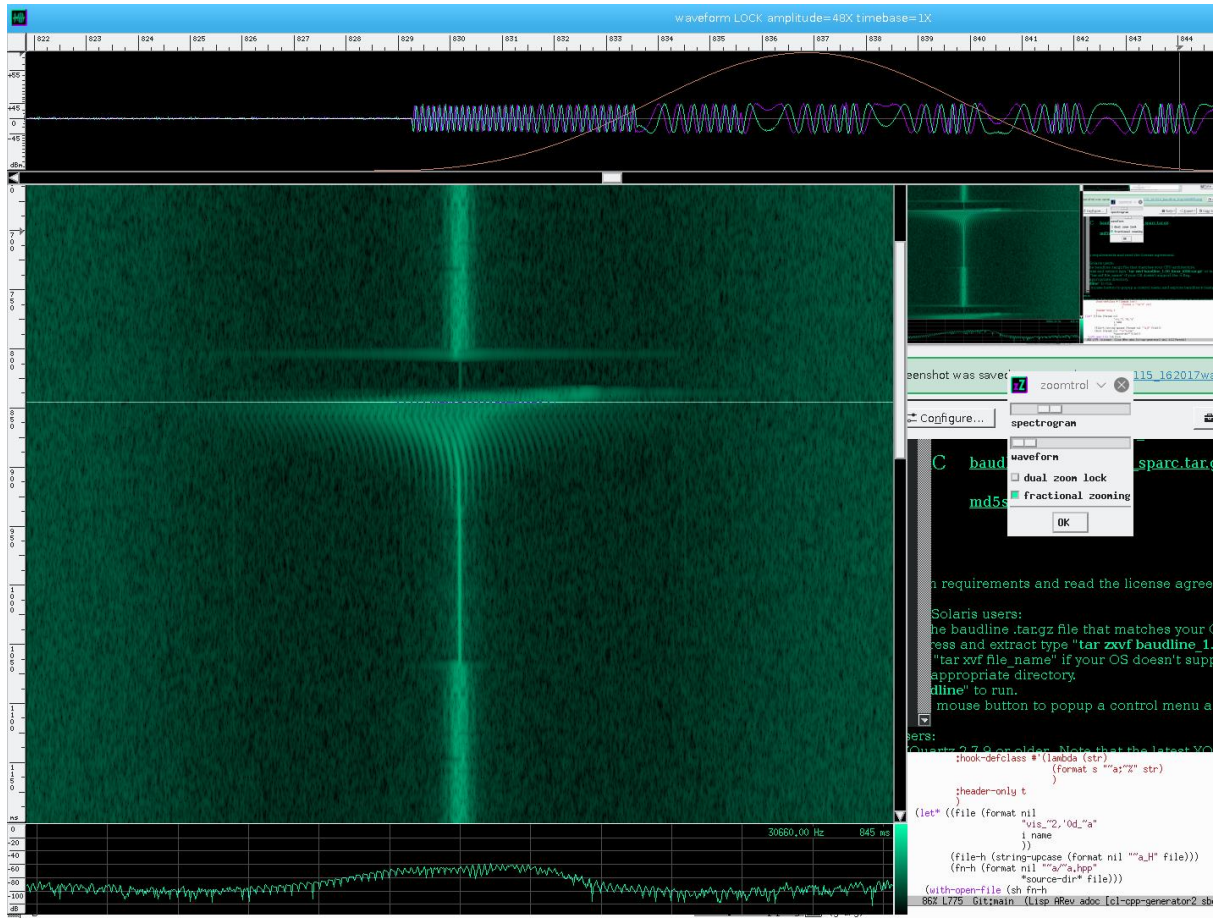
Contributors 6

Source code for firmware (Linux) and FPGA available and usable!

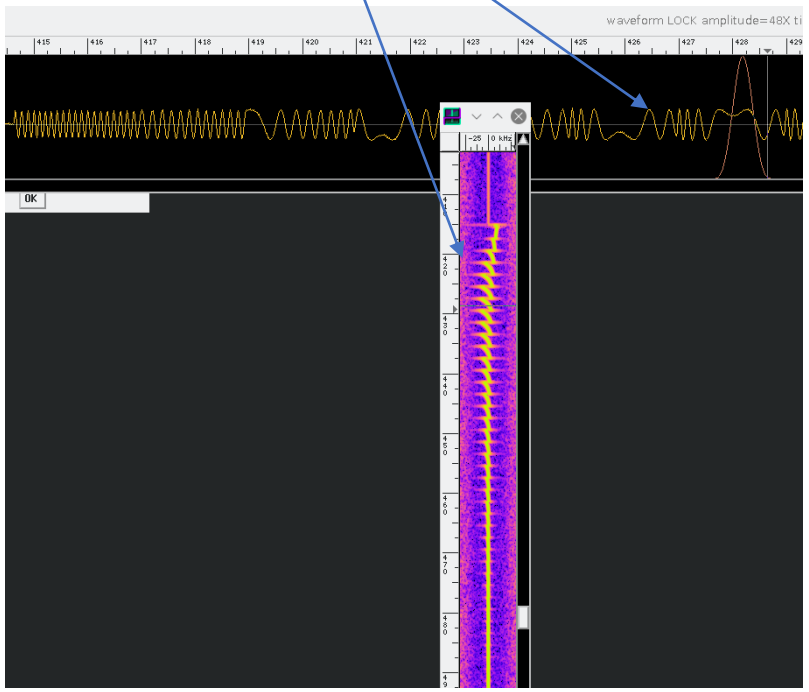
Building the FPGA firmware



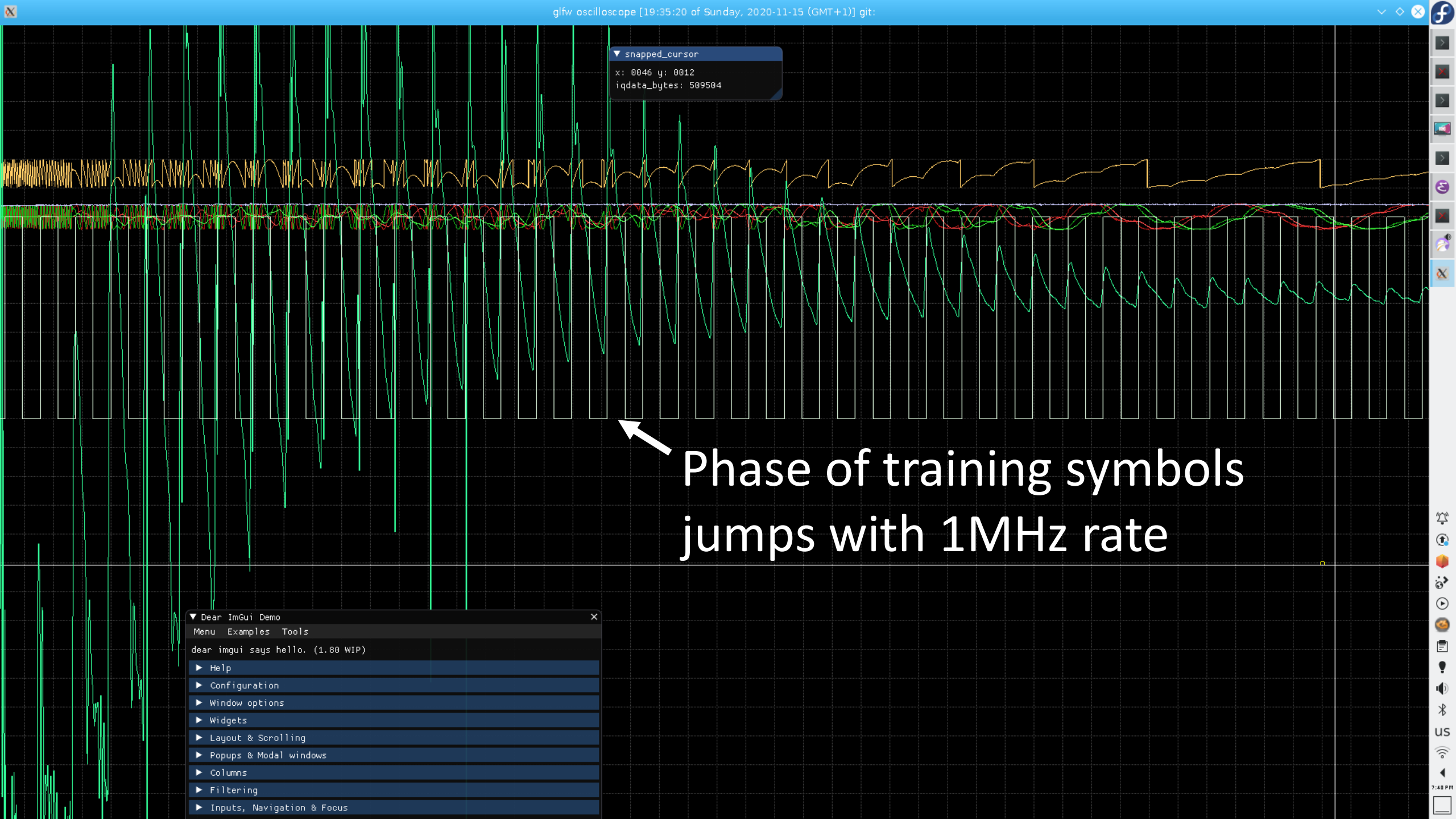
Cross-compile C++ program to capture data inside Zynq ARM Chip



Sample rate 61.44MS/s
Training symbols?



https://github.com/plops/build_pluto_firmware/blob/main/capture/source/vis_00_base.cpp


glfw oscilloscope [19:35:20 of Sunday, 2020-11-15 (GMT+1)] git:
snapped_cursor
x: 0046 y: 0012
iqdata_bytes: 509504
Phase of training symbols
jumps with 1MHz rate
Dear ImGui Demo
Menu Examples Tools
dear imgui says hello. (1.80 WIP)
Help
Configuration
Window options
Widgets
Layout & Scrolling
Popups & Modal windows
Columns
Filtering
Inputs, Navigation & Focus


glfw oscilloscope [22:34:51 of Sunday, 2020-11-15 (GMT+1)] git:
snapped_cursor
x: 0169 y: 0017
iqdata_bytes: 509504
sample_offset: -9.000000
sample_threshold: 0.010000
sample_binary size: 259
7f 55 1 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 1c f7 50
f5 5d a9 2c b0 30 fc 37 b0 47 6b c8 bb 42 a8 40
4 0 80 a8 bf aa aa aa aa 2a 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 86 39 0 78 86 0 2 8 8 fe 9 c8 81 10 e0
valid
ff ff fb ff ff ff bf ab aa aa aa 2a 8 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 ff ff ff
ff ff ff ff ff ff ff ff ff ff ff ff ff ff ff 7f
4 0 80 a8 bf ff ff ff ff 7f 55 55 55 55 55 1
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
80 f7 bd 57 7d d7 ab eb af ef ff ed ef dd da fb
Decoded data!
Dear ImGui Demo
Menu Examples Tools
dear imgui says hello. (1.80 WIP)
Help
Configuration
Window options
Widgets
Layout & Scrolling
Popups & Modal windows
Columns
Filtering
Inputs, Navigation & Focus

Document overview

I am most interested in red

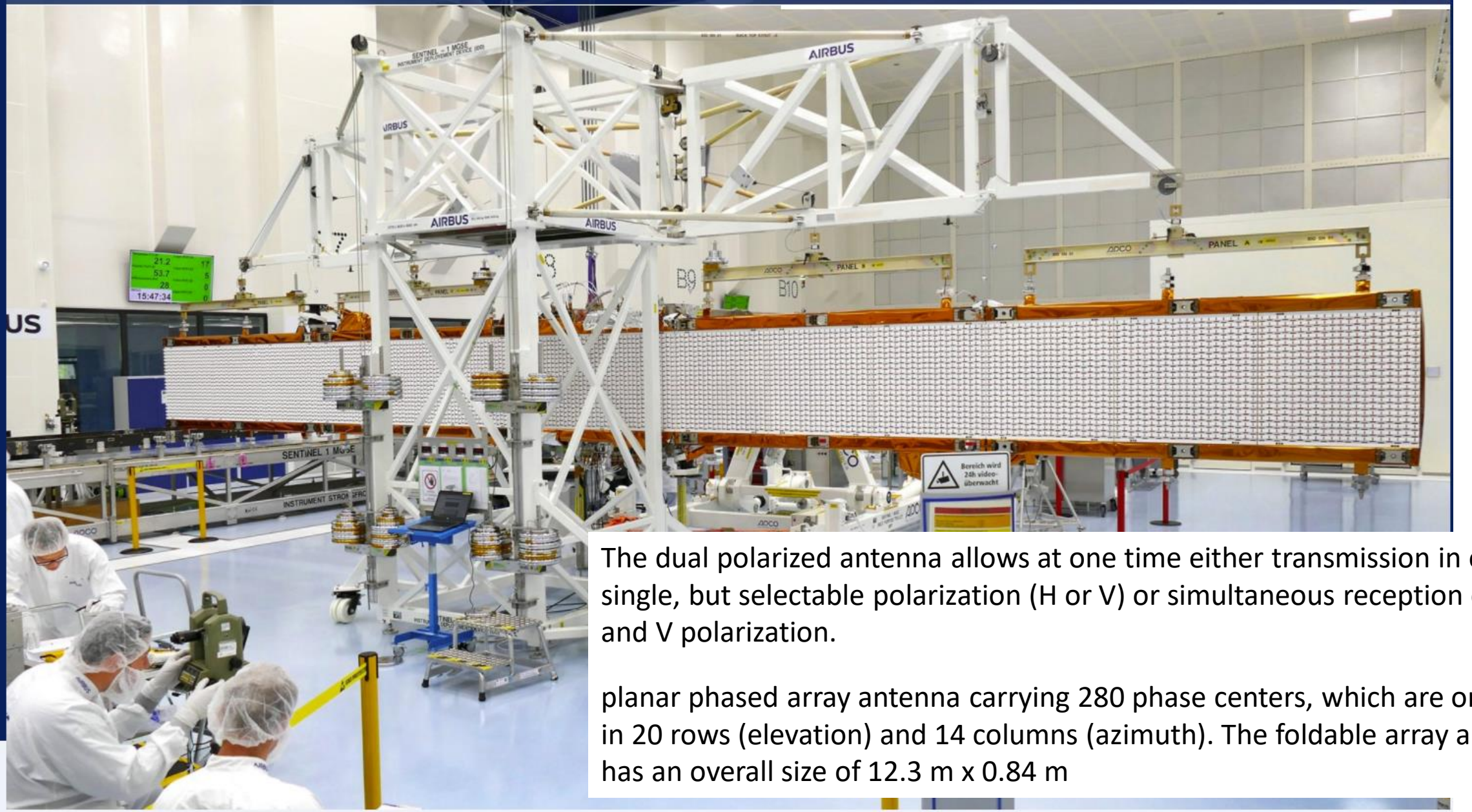
Blue .. ratiometric
Green .. format
Violet .. derived products
Yellow .. performance change
Red .. raw decoding

1	Sentinel_High_Level_Operations_Plan	20190722	Entire fleet, uk overseas territories, mining...
2	Sentinel-1-Ocean-Wind-Fields-OWI-ATBD.pdf	20190627	Wind gridding L2 processing
3	Sentinel-1-Product-Specification.pdf	20190627	Like 10
4	Sentinel-1-Level-1-Detailed-Algorithm-Definition	20190607	Focussing, header verification
5	Guide-to-Sentinel-1-Geocoding.pdf	20190326	Orbit and timing parameters, probably useful
6	Sentinel-1-masking-no-value-pixels-grd-products-note	20190129	Discrete sampling window start time near artifacts
7	Sentinel-1_IPF_Auxiliary_Product_Specification	20171221	Contains decoded data that they use for L1 process
8	Thermal-Denoising-of-Products-Generated-by-Sentinel-1-IPF	20171128	Additive noise noticable in regions of low signal
9	Sentinel-1-TOPS-SLC_Deramping	20170110	pulse
10	Sentinel-1_Product_Specification	20180419	L1 and l2, i might want their centroid estimates
11	Sentinel-1-Product-Definition	20160325	l1 and l2 descriptions
12	Sentinel-1A_TOPS_Radiometric_Calibration_Refinement	20151124	201508 s1a pol gain imbalance correction
13	Sentinel-1-IPF_EAP_Phase_correction	20150722	201503 phase in data change, now antenna
14	Sentinel-1-SAR-Space-Packet-Protocol-Data-Unit.pdf	20150622	Main spec, compression and data decoding
15	S1-Radiometric-Calibration-V1.0.pdf	20150521	Radar crossection in slc and grd products
16	Sentinel-1-Level-0-Data-Decoding-Package.pdf	20150128	Example data of decoding (maybe very useful)
16a	SAR calibration plan	20140909	documents calibration sequence
17	Sentinel-1_Level-0_Product_Format_Specification.pdf	20121220	filenames and zip contents

airbus.com/newsroom/press-releases/en/2020/08/sentinel1c-radar-antenna-has-spread-its-wings-for-the-first-time.html

AIRBUS

Commercial Aircraft Helicopters Defence Space Innovation Company Media



The dual polarized antenna allows at one time either transmission in one single, but selectable polarization (H or V) or simultaneous reception of both H and V polarization.

planar phased array antenna carrying 280 phase centers, which are organized in 20 rows (elevation) and 14 columns (azimuth). The foldable array antenna has an overall size of 12.3 m x 0.84 m

sentinel.esa.int/web/sentinel/missions/sentinel-1/instrument-payload

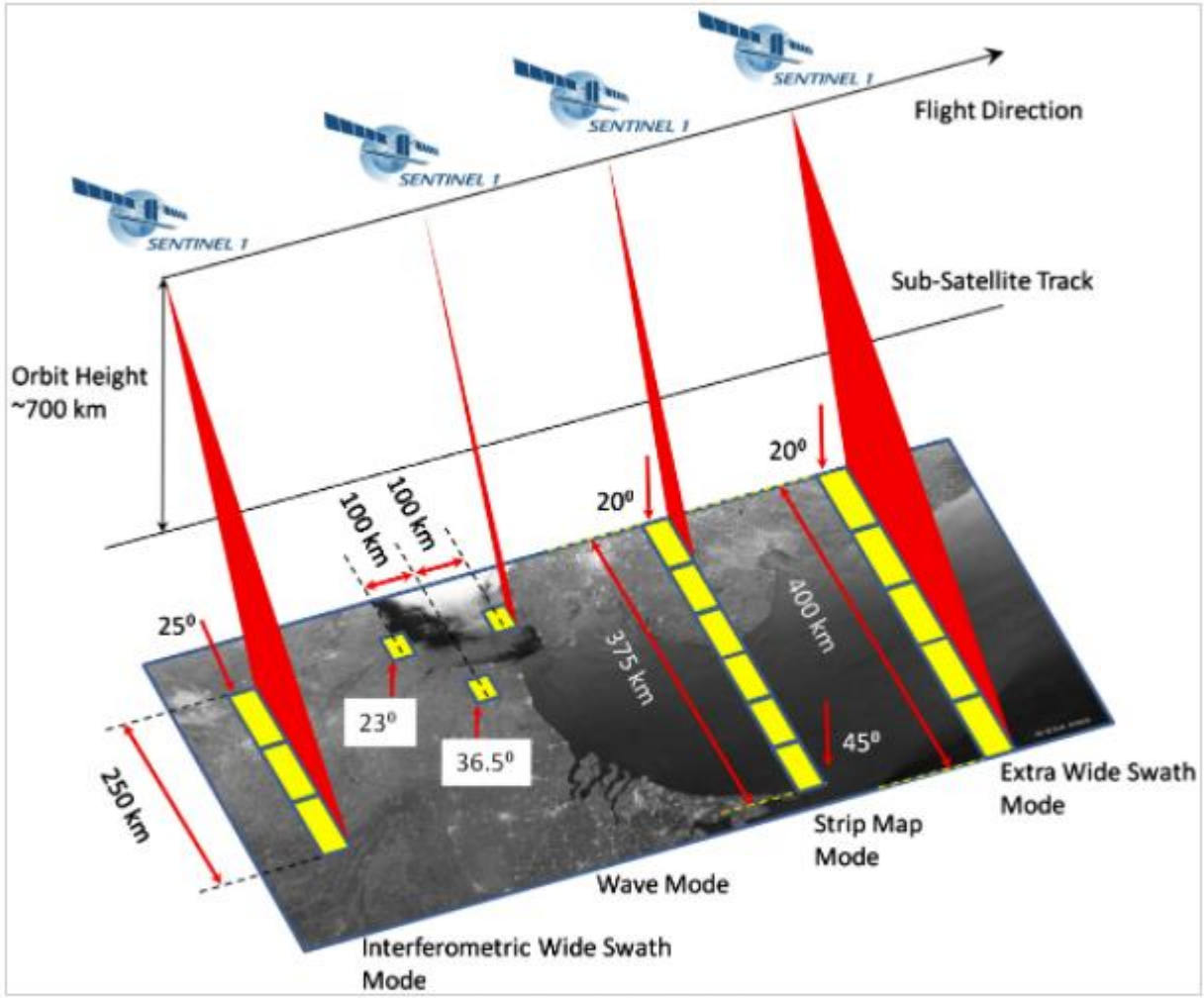


Figure 1: SENTINEL-1 Modes

The primary conflict-free modes are IW over land and WV over open ocean.

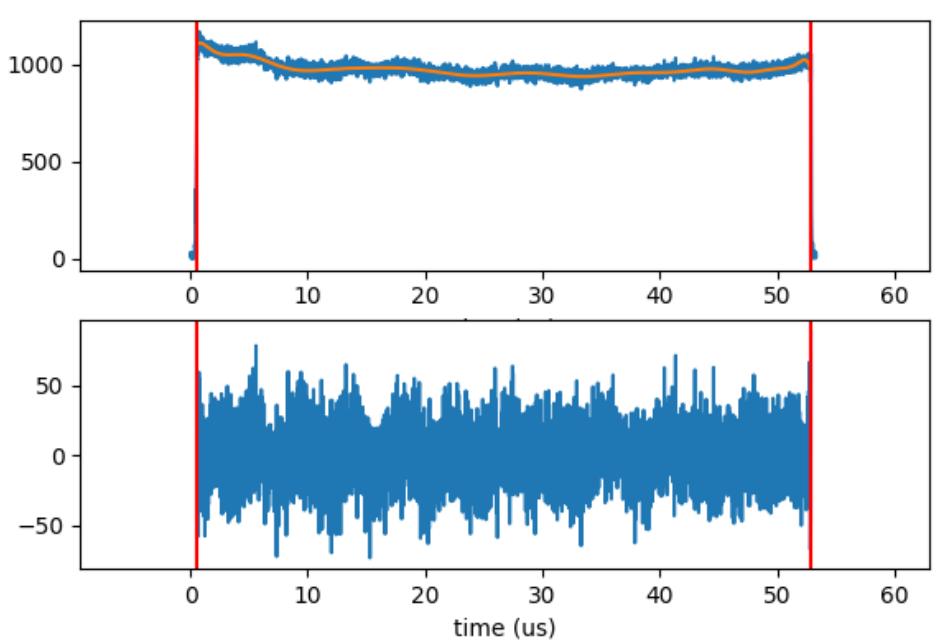
Stripmap Mode

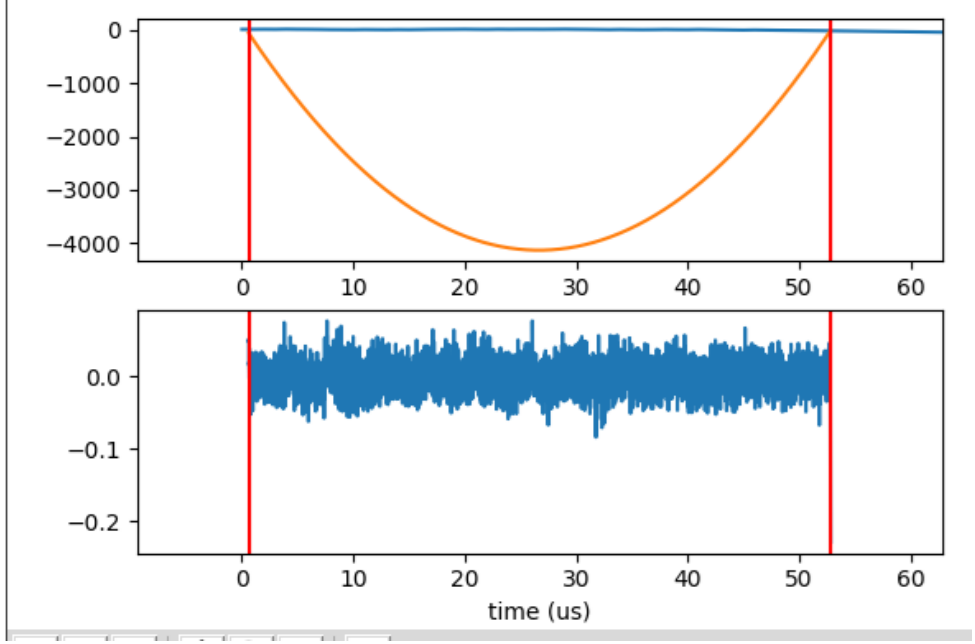
Stripmap imaging mode is provided for continuity with ERS and Envisat missions. Stripmap provides coverag with a 5 m by 5 m resolution over a narrow swath width of 80 km. One of six imaging swaths can be selected b changing the beam incidence angle and the elevation beamwidth.

Decode space packet
(unprocessed level 0 RF data as it is sent to the ground station)

```
PACKET-VERSION-NUMBER: 0
PACKET-TYPE: 0
SECONDARY-HEADER-FLAG: 1
APPLICATION-PROCESS-ID-PROCESS-ID: 65
APPLICATION-PROCESS-ID-PACKET-CATEGORY: 12
SEQUENCE-FLAGS: 3
SEQUENCE-COUNT: 2150
DATA-LENGTH: 16329
COARSE-TIME: 1225547582
FINE-TIME: 14395
SYNC-MARKER: 892270675
DATA-TAKE-ID: 90010464
ECC-NUMBER: INTERFEROMETRIC-WIDE-SWATH
IGNORE-0: 0
TEST-MODE: 0
RX-CHANNEL-ID: 0
INSTRUMENT-CONFIGURATION-ID: 6
SUB-COMMUTATED-INDEX: 18
SUB-COMMUTATED-DATA: 74
SPACE-PACKET-COUNT: 280678
PRI-COUNT: 283529
ERROR-FLAG: 0
IGNORE-1: 0
BAQ-MODE: 12
BAQ-BLOCK-LENGTH: 31
IGNORE-2: 0
RANGE-DECIMATION: 8
RX-GAIN: 8
TX-RAMP-RATE-POLARITY: 1
TX-RAMP-RATE-MAGNITUDE: 1605
TX-PULSE-START-FREQUENCY-POLARITY: 0
TX-PULSE-START-FREQUENCY-MAGNITUDE: 12335
TX-PULSE-LENGTH: 1967
IGNORE-3: 0
RANK: 9
PULSE-REPETITION-INTERVAL: 21859
SAMPLING-WINDOW-START-TIME: 3637
SAMPLING-WINDOW-LENGTH: 13985
SAB-SSB-CALIBRATION-P: 0
SAB-SSB-POLARISATION: 7
SAB-SSB-TEMP-COMP: 0
SAB-SSB-IGNORE-0: 0
SAB-SSB-ELEVATION-BEAM-ADDRESS: 6
SAB-SSB-IGNORE-1: 0
SAB-SSB-AZIMUTH-BEAM-ADDRESS: 525
SES-SSB-CAL-MODE: 0
SES-SSB-IGNORE-0: 0
SES-SSB-TX-PULSE-NUMBER: 6
SES-SSB-SIGNAL-TYPE: 0
SES-SSB-IGNORE-1: 0
SES-SSB-SWAP: 1
SES-SSB-SWATH-NUMBER: 10
NUMBER-OF-QUADS: 11943
IGNORE-4: 0
```

packet-version-number	4	4	X 0
packet-type	1	1	X 0
secondary-header-flag	0	0	X 1
application-process-id-process-id	0	0	X 65
application-process-id-packet-category	1	1	X 12
sequence-flags	0	0	X 3
sequence-count	12902	3266	X 2150
data-length	16329	3fc9	.
coarse-time	1225547582	490c5f3e	.
fine-time	14395	383b	.
sync-marker	892270675	352ef853	.
data-take-id	90010464	55d7360	.
ecc-number	8	8	maybe
ignore-0	0	0	.
test-mode	0	0	.
rx-channel-id	0	0	.
instrument-configuration-id	6	6	.
sub-commutated-index	18	12	.
sub-commutated-data	74	4a	.
space-packet-count	280678	44866	.
pri-count	283529	45389	.
error-flag	0	0	.
ignore-1	2	2	X 0
baq-mode	1	1	X 12
baq-block-length	31	1f	.
ignore-2	0	0	.
range-decimation	8	8	.
rx-gain	8	8	.
tx-ramp-rate-polarity	0	0	X 1
tx-ramp-rate-magnitude	17221	4345	X 1605
tx-pulse-start-frequency-polarity	0	0	.
tx-pulse-start-frequency-magnitude	6191	182f	X 12335
tx-pulse-length	1967	7af	.
ignore-3	1	1	X 0
rank	1	1	X 9
pulse-repetition-interval	21859	5563	.
sampling-window-start-time	3637	e35	.
sampling-window-length	13985	36a1	.
sab-ssb-calibration-p	0	0	.
sab-ssb-polarisation	0	0	X 7
sab-ssb-temp-comp	3	3	X 0
sab-ssb-ignore-0	1	1	X 0
sab-ssb-elevation-beam-address	2	2	X 6
sab-ssb-ignore-1	2	2	X 0
sab-ssb-azimuth-beam-address	269	10d	X 525
ses-ssb-cal-mode	2	2	X 0
ses-ssb-ignore-0	1	1	X 0
ses-ssb-tx-pulse-number	0	0	X 6
ses-ssb-signal-type	1	1	X 0
ses-ssb-ignore-1	0	0	.
ses-ssb-swap	0	0	X 1
ses-ssb-swath-number	10	a	.
number-of-quads	11943	2ea7	.
ignore-4	0	0	.





range, range rate, and range acceleration.

$$C(s) = \exp\left\{-i\,\frac{4\pi}{\lambda}\left[R_o + \dot{R}\,(s - s_o) + \ddot{R}(s - s_o)^2/2\right]\right\} \quad \text{(B5)}$$

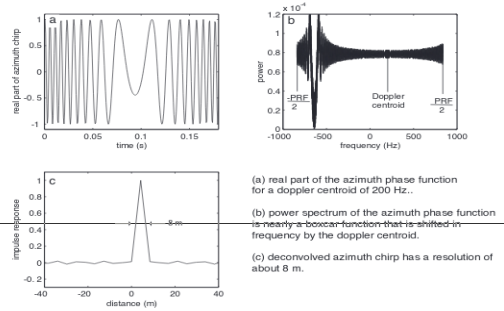
It is more common to describe the parameters for focusing the SAR image as the Doppler centroid f_{Dc} and the Doppler frequency rate f_R. The relationships are:

$$f_{Dc} = \frac{-2\dot{R}}{\lambda} \quad \text{and} \quad f_R = \frac{-2\ddot{R}}{\lambda} \quad \text{(B6)}$$

or

$$C(s) = \exp\left\{-i\,\frac{4\pi R_o}{\lambda}\right\} \exp\left\{i2\pi\left[f_{Dc}\,(s - s_o) + f_R(s - s_o)^2/2\right]\right\} \quad \text{(B7)}$$

Note that this function is another frequency-modulated chirp where the parameters are the Doppler centroid and the Doppler frequency rate. An example of this azimuthal chirp function for the ERS orbit/radar as well as its power spectrum and impulse response are shown in Figure B7.



(a) real part of the azimuth phase function for a doppler centroid of 200 Hz..

(b) power spectrum of the azimuth phase function is nearly a boxcar function that is shifted in frequency by the doppler centroid.

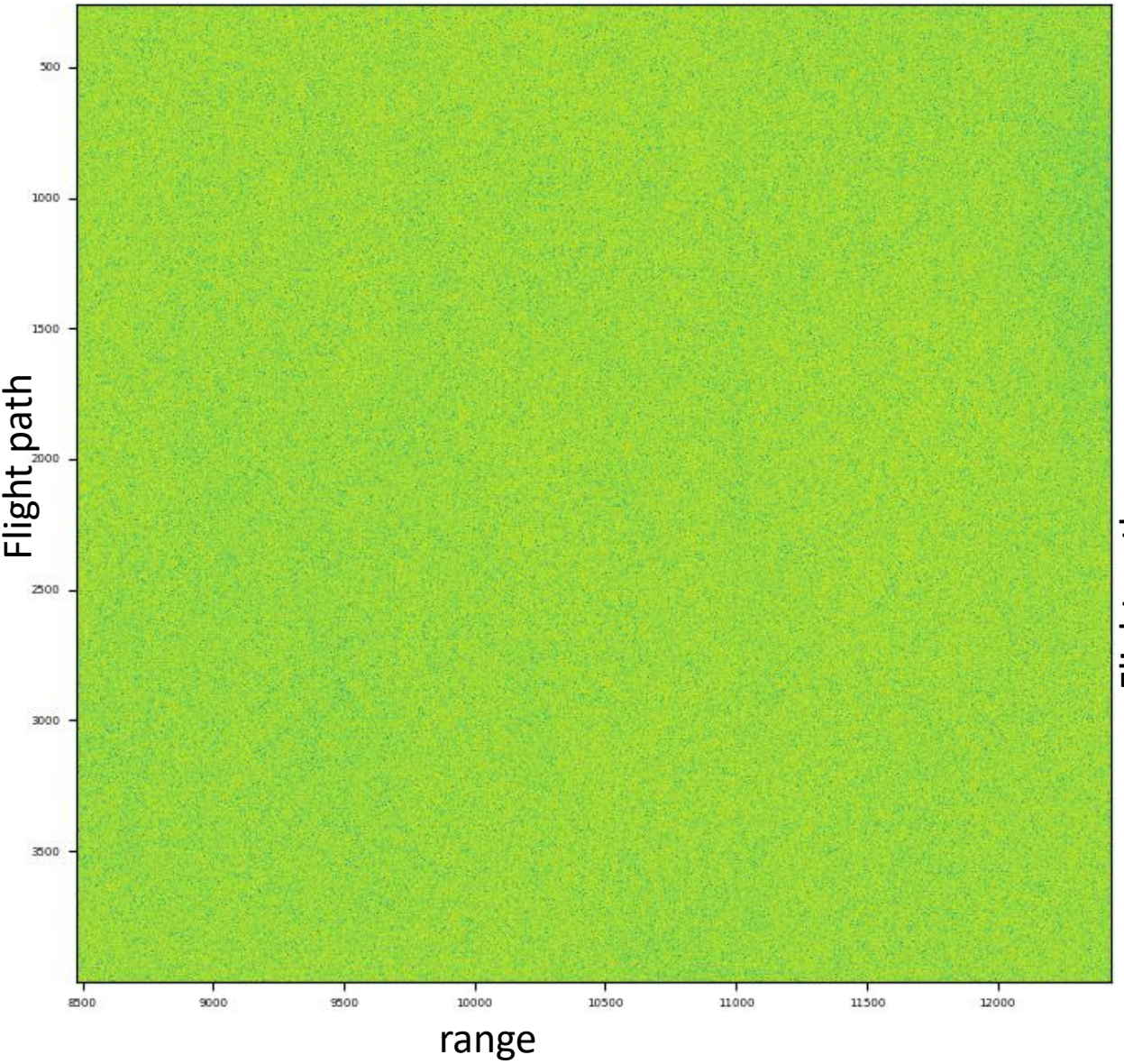
(c) deconvolved azimuth chirp has a resolution of about 8 m.

Compare measured calibration pulses and generated chirped pulse replicas
Decode (uncompress) raw data
Deconvolve with inverse chirp (pulse compression)

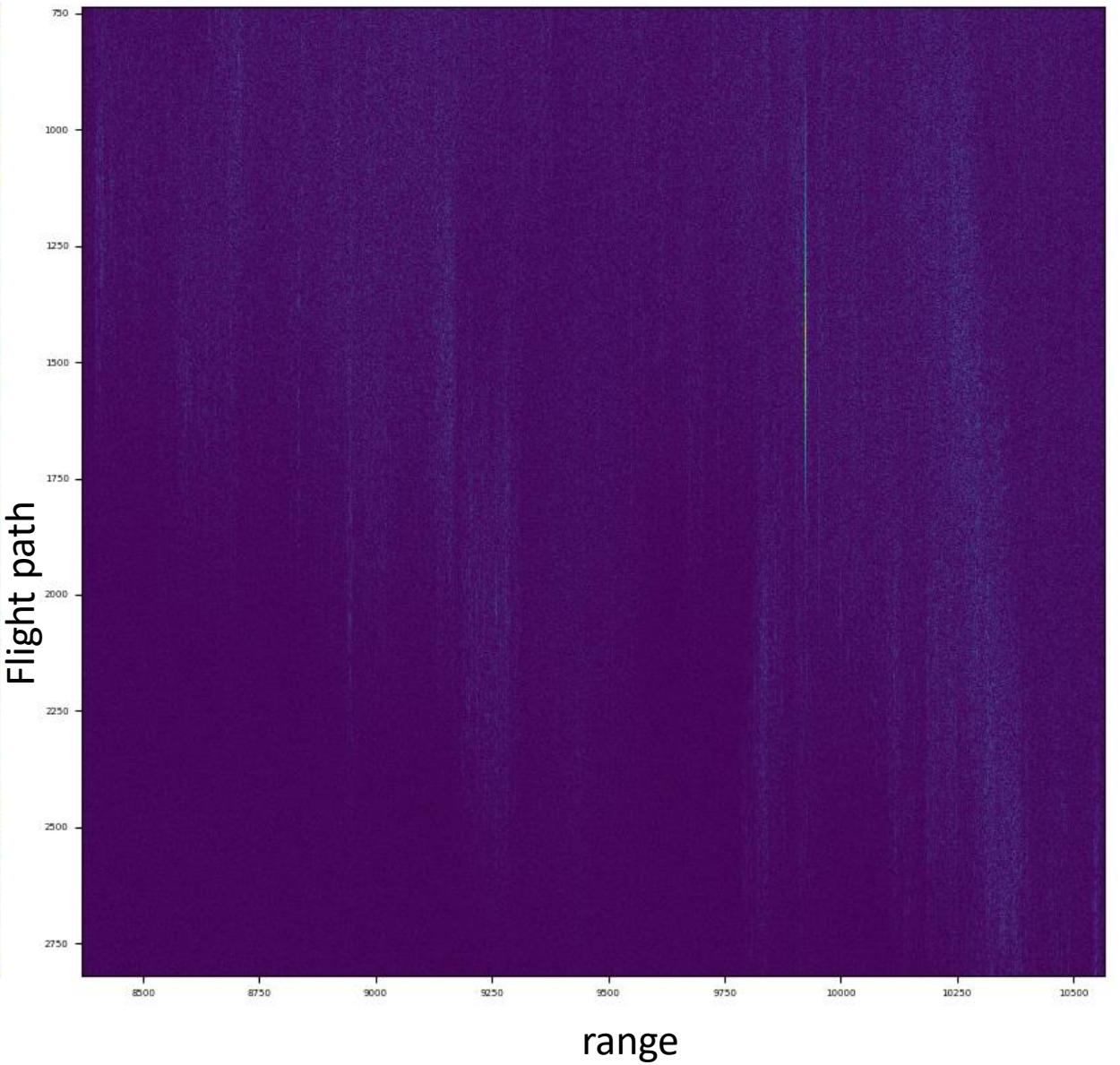
https://github.com/plops/cl-cpp-generator2/tree/master/example/08_copernicus_radar/source

https://topex.ucsd.edu/gmtsar/tar/GMTSAR_2ND.pdf

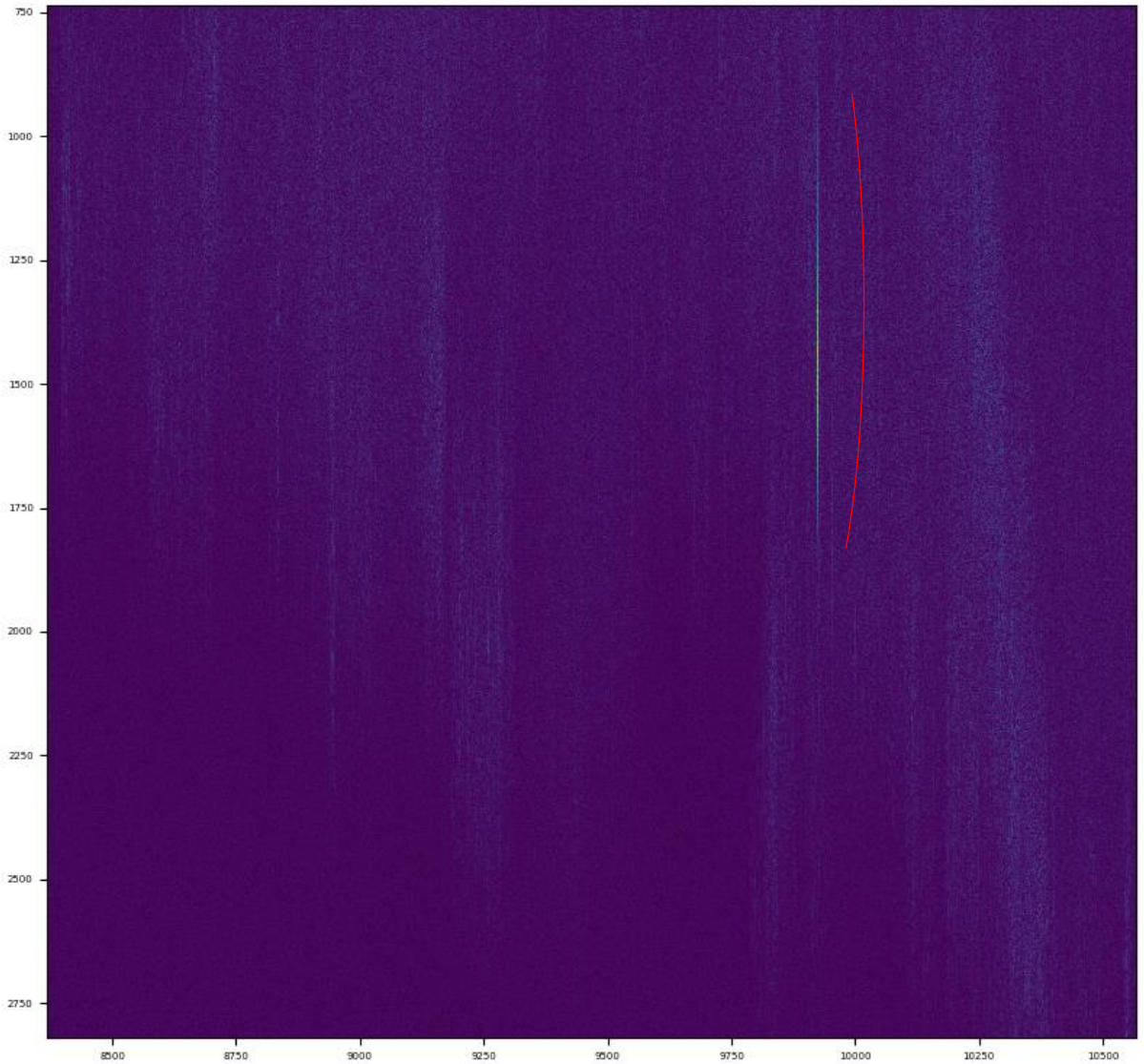
Unprocessed SAR data looks like noise most of the time!
(like digital holograms or ultrasound data)



Range compression
(deconvolve chirp)



Next step: azimuth compression
(integrate along parabola, or some shape depending on orbit)

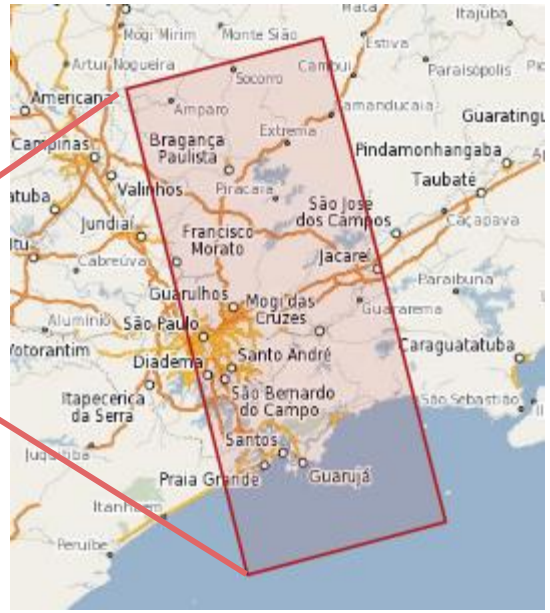


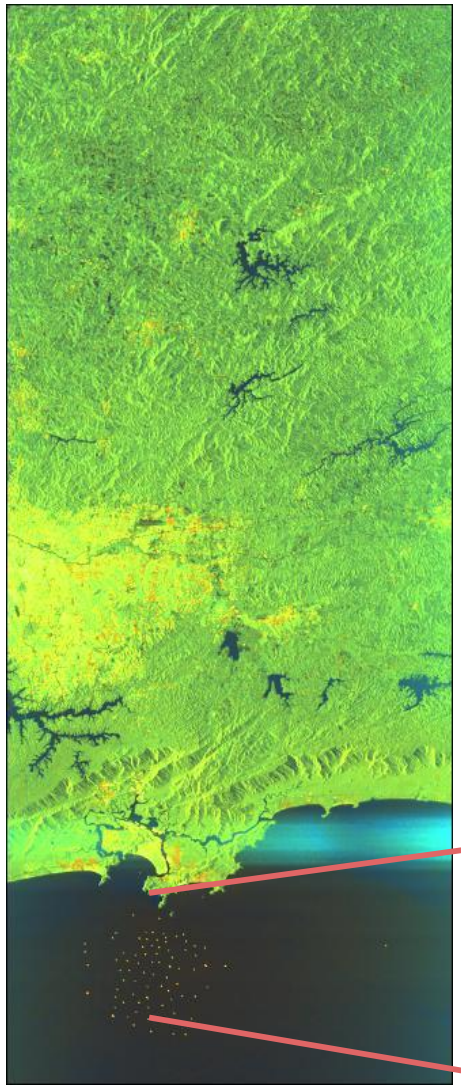
Search for data with sparse strong reflectors

(e.g. ships)

Ships around Singapore

Maximum of signal over 3 years
Shipping lane





S1B_S6_GRDH_1SDV_20200824T214315_20200824T214344_023070_02BCE0_D799