gr-pdw

An OOT Module for Pulse Descriptor Word (PDW) Generation

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GRCon 2024

Georgia Tech Research Institute

OUR MISSION

As a University Affiliated Research Center (UARC), the Georgia Tech Research Institute (GTRI) is the nonprofit, applied research unit of the Georgia Institute of Technology (Georgia Tech). GTRI leverages the science and engineering base of Georgia Tech to enhance the impact of our collective research output. Collaboratively, we advance technology and provide innovative solutions to:

- **Enhance economic impact for the State of Georgia**
- **Serve national security**
- **Improve the human condition**
- **Educate future technology leaders**

History of Service to the State and Nation

1946 – The name "Georgia Tech Research Institute" is given to a non-profit corporation created to handle EES contract and patent issues.

1973 – The Agricultural Technology Research Program is established to support Georgia's economically important poultry industry.

1984 – EES celebrates its 50th Anniversary by, among other things, changing its name to the Georgia Tech Research Institute (GTRI).

1930s | 1940s | 1950s | 1960s | 1970s | 1980s | 1990s | 2000s

FY23 – $941M in Research Awards & 2,966 Workforce

1952 – EES personnel help found Scientific Atlanta, later renowned for its satellite Earth stations and cable TV equipment.

1979 – The Huntsville Research Laboratory begins operations, giving EES a presence at Redstone Arsenal that continues to this day.

1995 – **GTRI** is designated a University Affiliated Research Center (**UARC**) by the Director of Defense Research and Engineering (DDR&E), Office of the Secretary of Defense (OSD).

1940 – Federal funding linked to World War II begins bringing in more projects, including work in wind-tunnel testing and communications technology.

1934 – The State Engineering Experiment Station (EES) opens in Georgia Tech's Old Shop Building, with a little more than **$5,000 in state funding** and **13 part-time faculty researchers.**

90 years of problem solving for Georgia and the nation

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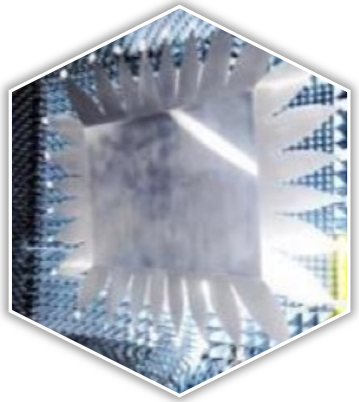
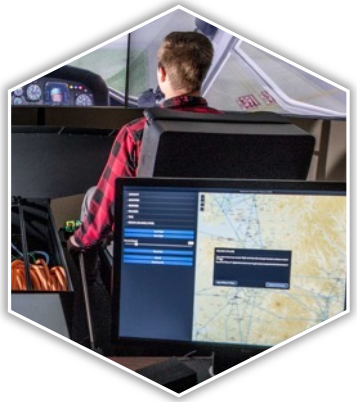
GTRI Laboratories



Advanced Concepts

Aerospace, Transportation & Advanced Systems



Applied Systems

Cybersecurity, Information Protection & Hardware Evaluation

Electronic Systems

Electro-Optical Systems

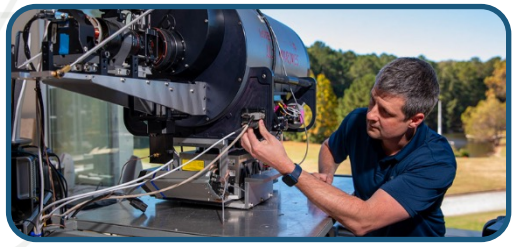
Information & Communications

Sensors & Electromagnetic Applications

Spectrum Warfare and Operations Research Division (SWORD)

A Diverse Base of Applied Innovation

GTRI Research Portfolio Groups



SENSORS

- Electromagnetic Spectrum Operations (EMSO)
- Intelligence, Surveillance, and Reconnaissance (ISR)
- Robotics and Autonomy

INFORMATION

- Command, Control, and Communications (C3)
- Cybersecurity
- Decision Superiority
- Information and Data Science

SYSTEMS

- Aerospace
- Air and Missile Defense (AMD)
- Threat Systems Analysis
- Training, Test, and Evaluation

TECHNOLOGY FOR SOCIETY

- Educate Future Technology Leaders
- Enhance Economic Impact for the State of Georgia
- Improve the Human Condition

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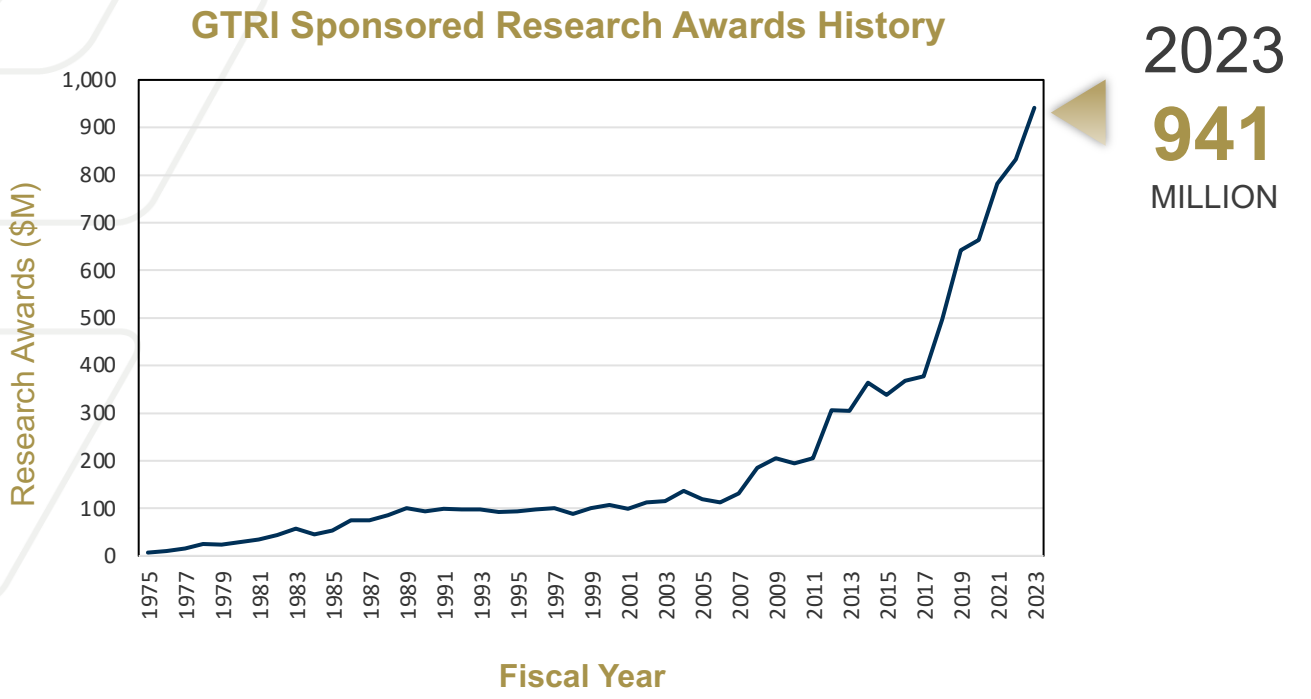
GTRI by the Numbers

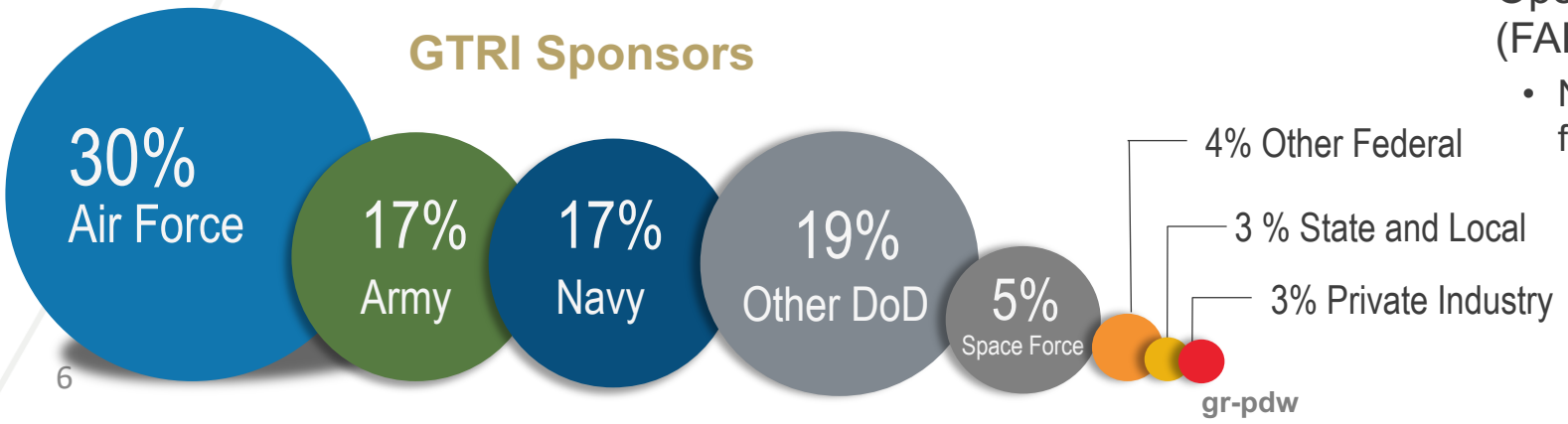


2023
941
MILLION

	GT FY23	GTRI FY23
Sponsored Research Awards	$1.42B	$941M
Economic Impact to State	FY22 $4.2B	FY22 $2.1B
Full-time Faculty and Staff	9,659	2,479
Total Faculty	4,658	1,851

Army's Largest University Affiliated Research Center (UARC)

- Second largest of 14 UARCs
- Operates under Federal Acquisition Regulation (FAR) 31.2
  - Non-profit electing to operate under cost principles for commercial organizations where fee is collected



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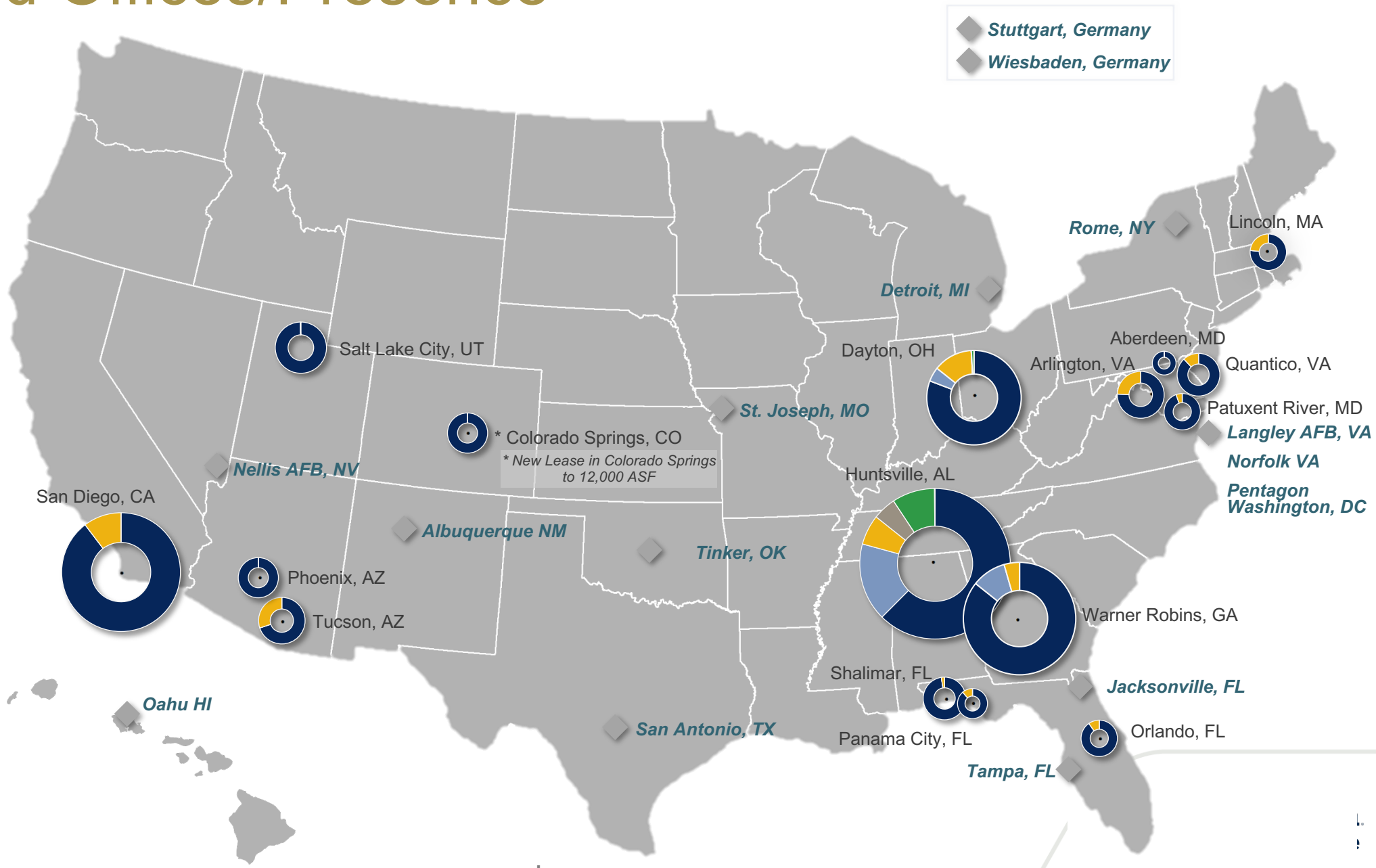
GTRI Field Offices/Presence

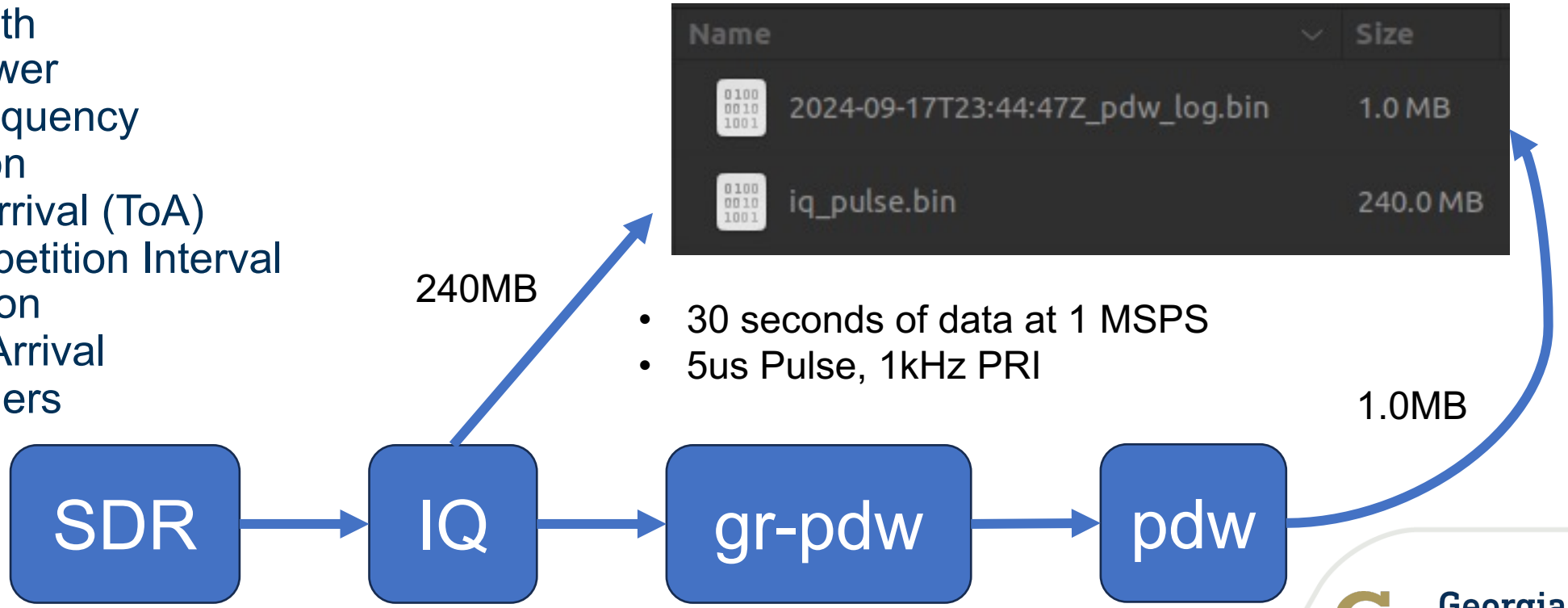
Field Offices (# of occupants)	Total ASF
Aberdeen, MD (2)	1,711
Arlington, VA (13)	7,308
Colorado, CO (21)	5,347
Dayton, OH (31)	16,347
Huntsville, AL (107)	60,000
Lincoln, MA (13)	6,596
Orlando, FL (18)	3,361
Panama City, FL (3)	2,016
Patuxent River, MD (8)	6,355
Phoenix, AZ (15)	6,236
Quantico, VA (7)	6,058
Salt Lake City, UT (13)	11,300
San Diego, CA (75)	17,414
Shalimar, FL (18)	5,992
Tucson, AZ (21)	4,780
Warner Robins (63)	19,832



Pulse Descriptor Word (PDW)

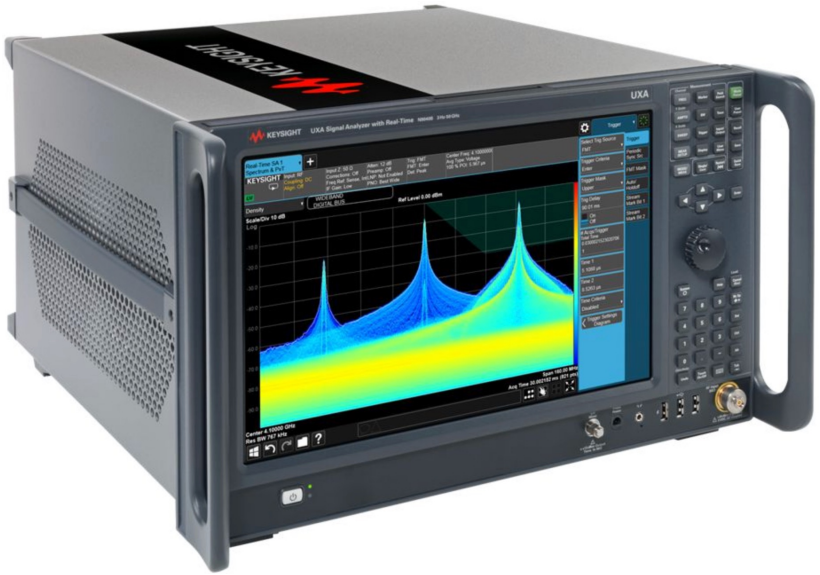
- Measurements that describe a pulse
- Generates pulse meta-data without requiring all of the I/Q to be stored. Real-time pulse analysis.
  - Considerable reduction in amount of data recorded

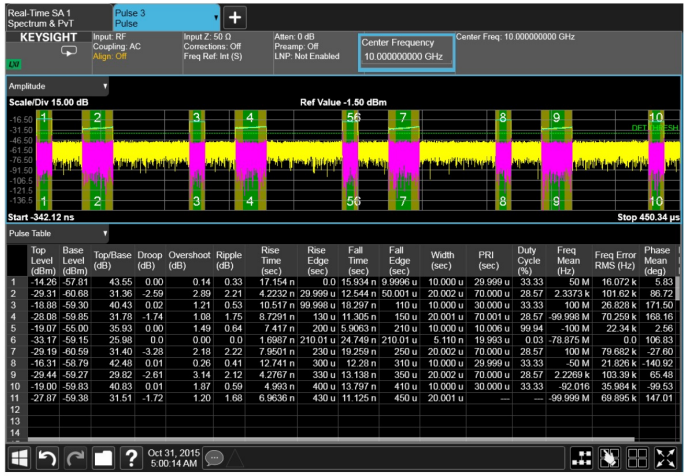
- Measurements Can Include:
  - Pulse width
  - Pulse Power
  - Pulse Frequency
  - Modulation
  - Time of Arrival (ToA)
  - Pulse Repetition Interval
  - Polarization
  - Angle of Arrival
  - Many Others



Motivation

- Field Tests / Exercises / Lab
- Signal externals are often used to characterize pulse emissions (radar, digital communications) but this capability is typically limited to:
  - Custom hardware / firmware:
    - Very cost prohibitive
    - Often has mission critical tasks
  - COTS Test Equipment:
    - Very cost prohibitive (Hardware and software)
    - Not suitable for rugged environments (temperature, dust, fast maneuvers)
    - Difficult to move around





Rugged Environments?

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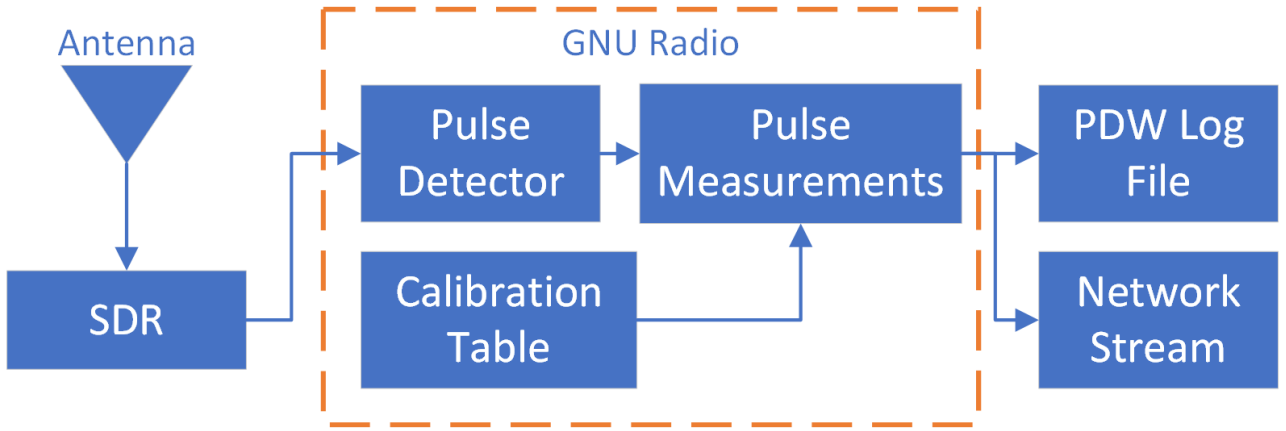
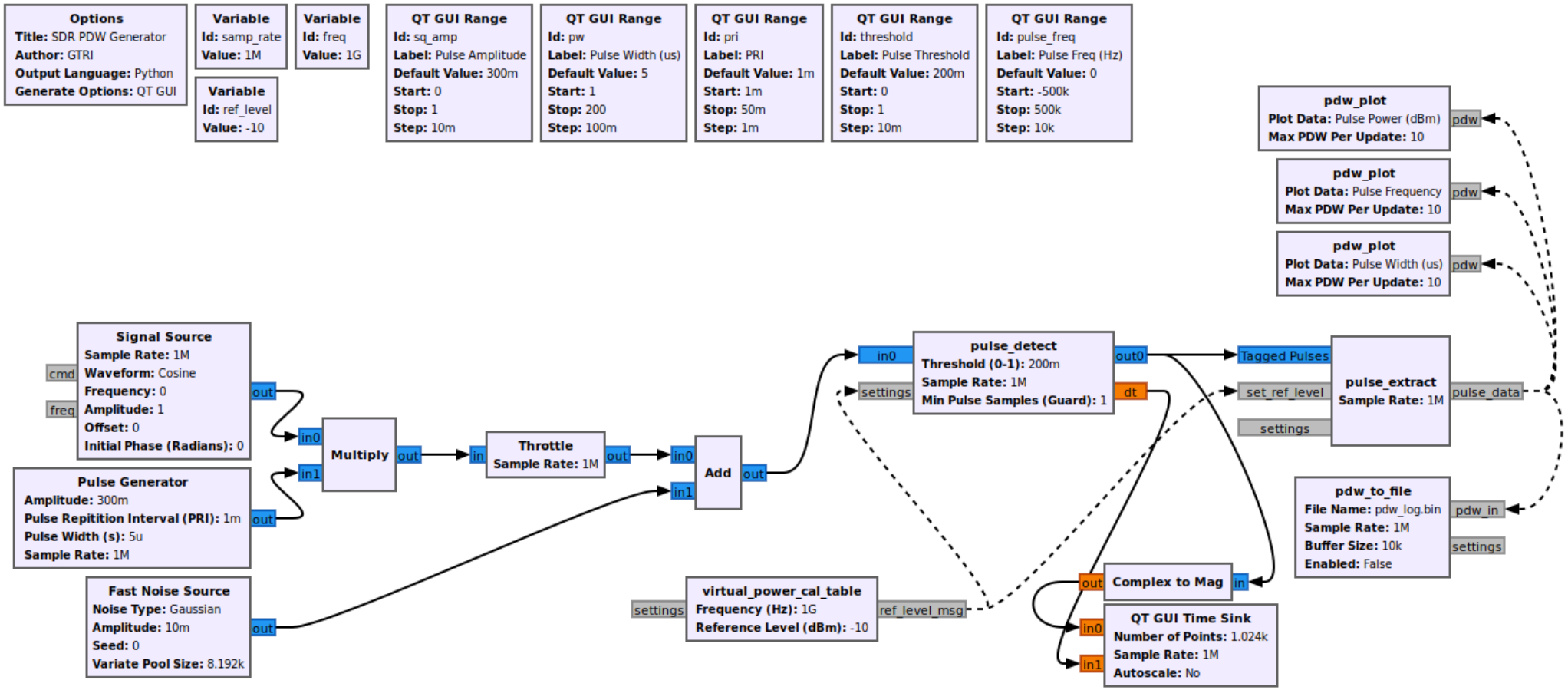
- Out of tree Module (OOT) for GNU Radio to perform pulse descriptor word (PDW) measurements
- Goal: Give any SDR ability to characterize pulses in real time
- Blocks:
  - **Pulse Detector**: Tags start and stop of pulses based on threshold
  - **Pulse Extraction**: Extracts IQ from Tagged Stream, calculates PDW measurements
  - **PDW to File**: Store PDW measurements to a file (tool included to read file)
  - **Calibration Table**: Scale pulse amplitude to calibrated power measurement
  - **PDW Plot**: PDW Measurement visualizations

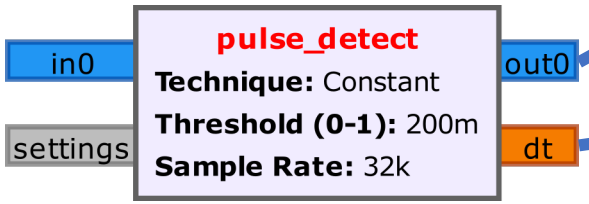


Typical Flowgraph

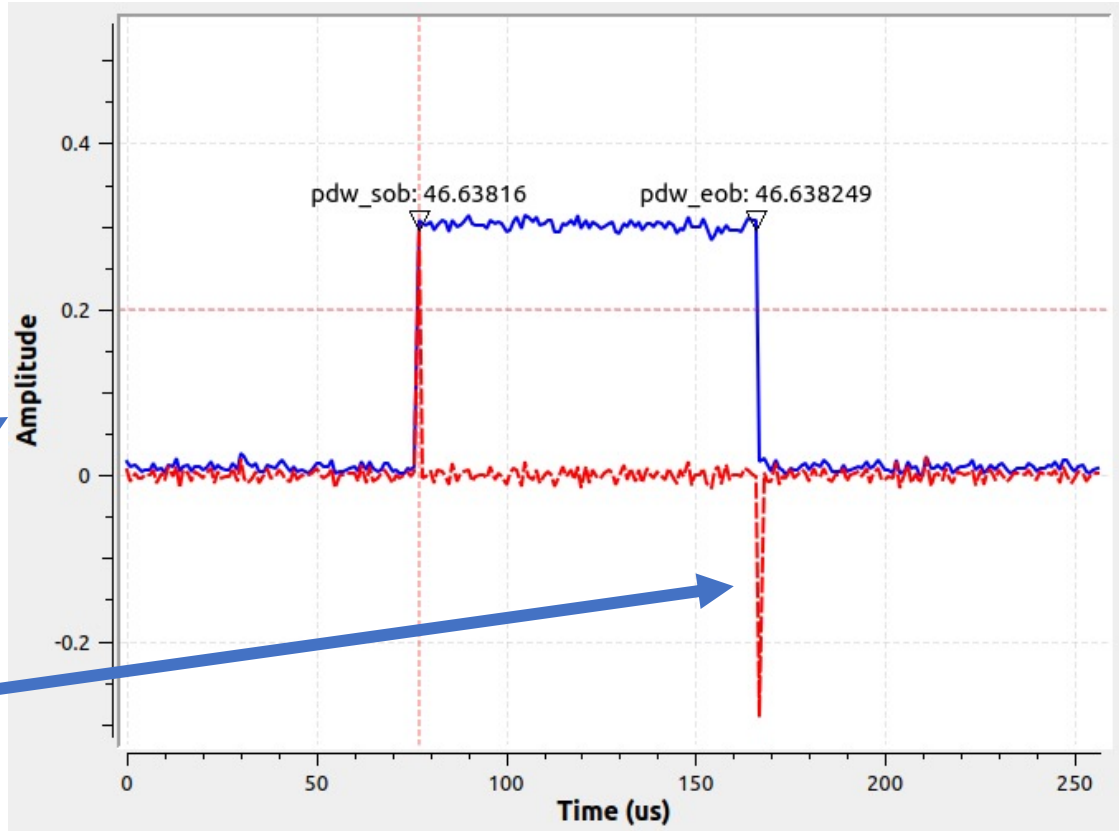


Block: Pulse Detection

- Constant threshold applied to the input signal.
- Threshold:
  - Assumes Range: 0 – 1
  - Can adjust while running
- Tags:
  - Start: pdw_sob
  - End: pdw_eob

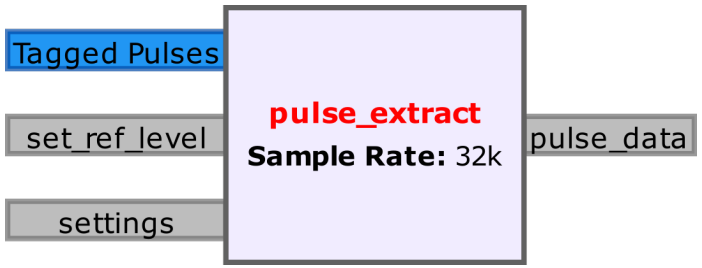


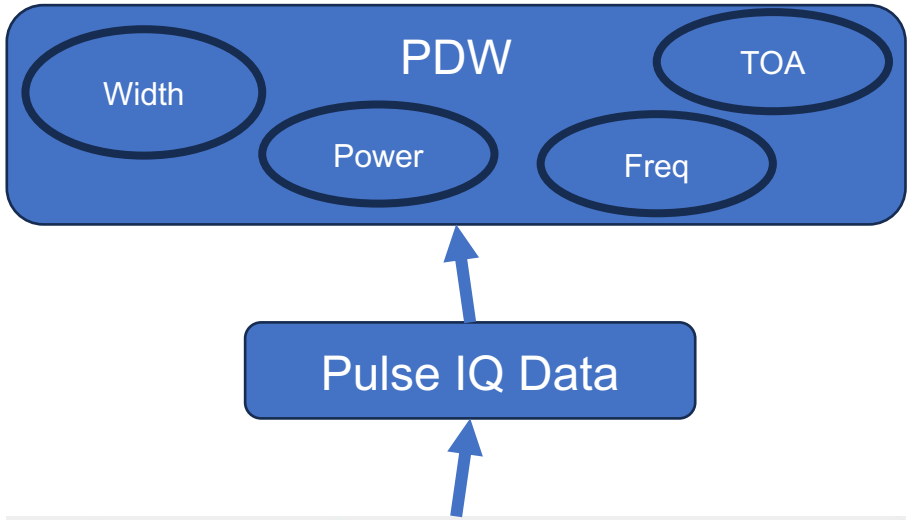
Debug Signal (Derivative of Input Signal)

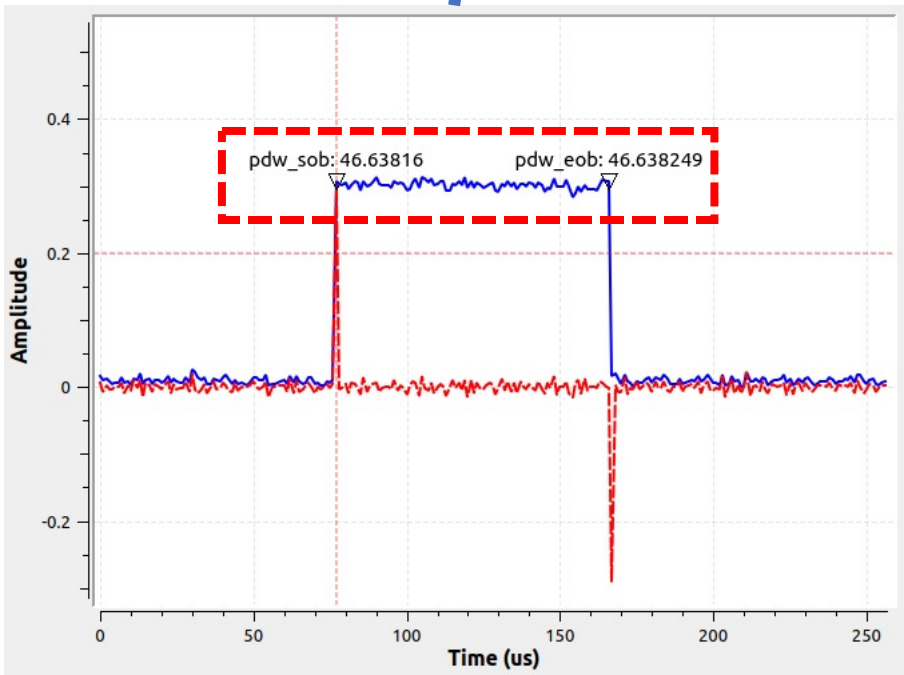


Block: Pulse Extraction

- Extracts I/Q in input tagged stream
  - Between: pdw_sob ↔ pdw_eob
- Measurements Performed on Each Subset of I/Q
  - Pulse Width
  - Pulse Power
  - Pulse Frequency
  - SNR



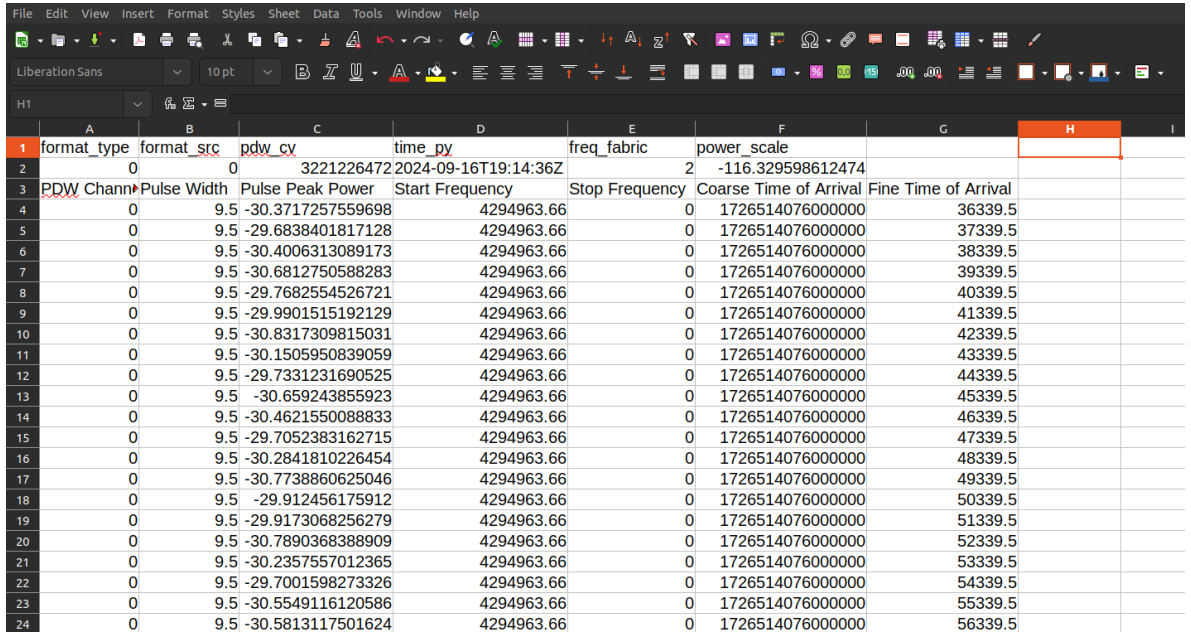




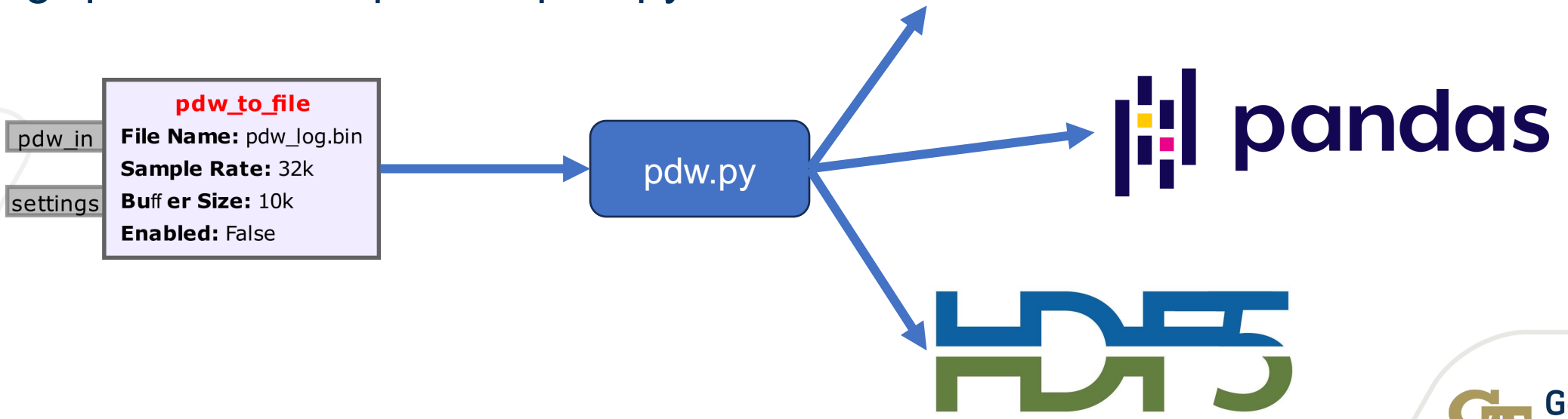
Block: PDW to File

- Writes PDW measurements to a binary file for offline analysis

- Tool Provided to Read / Write / Manipulate PDW Files:
  - gr-pdw → Examples → pdw.py

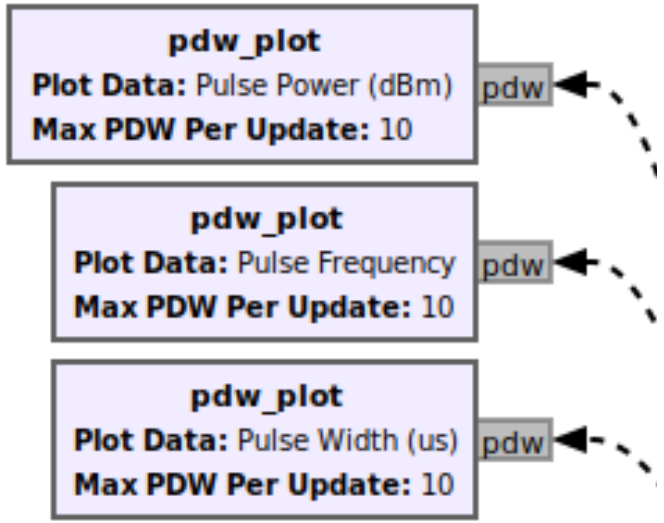


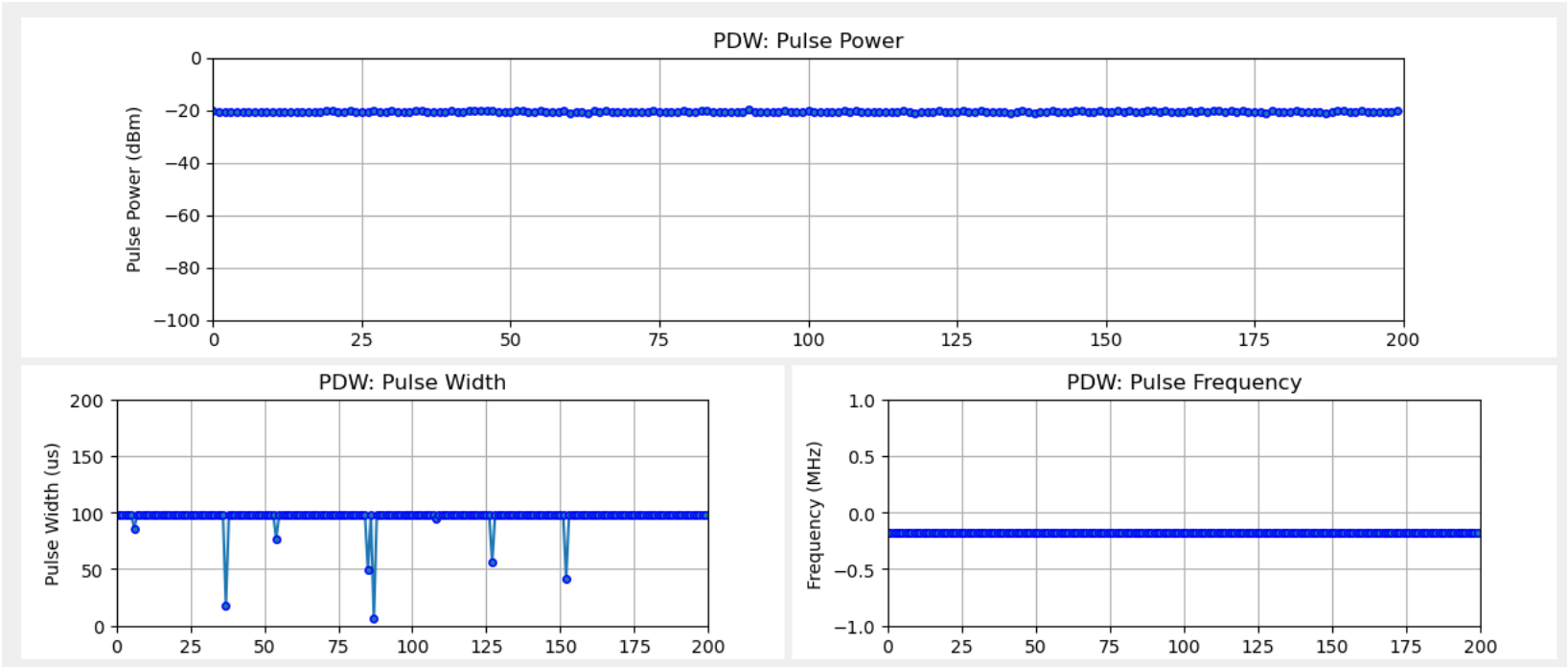
	A	B	C	D	E	F	G	H
1	format_type	format_src	pdw_cv	time_py	freq_fabric	power_scale		
2	0	0	3221226472	2024-09-16T19:14:36Z	2	-116.329598612474		
3	PDW Chann	Pulse Width	Pulse Peak Power	Start Frequency	Stop Frequency	Coarse Time of Arrival	Fine Time of Arrival	
4	0	9.5	-30.3717257559698	4294963.66	0	1726514076000000	36339.5	
5	0	9.5	-29.6838401817128	4294963.66	0	1726514076000000	37339.5	
6	0	9.5	-30.4006313089173	4294963.66	0	1726514076000000	38339.5	
7	0	9.5	-30.6812750588283	4294963.66	0	1726514076000000	39339.5	
8	0	9.5	-29.7682554526721	4294963.66	0	1726514076000000	40339.5	
9	0	9.5	-29.9901515192129	4294963.66	0	1726514076000000	41339.5	
10	0	9.5	-30.8317309815031	4294963.66	0	1726514076000000	42339.5	
11	0	9.5	-30.1505950839059	4294963.66	0	1726514076000000	43339.5	
12	0	9.5	-29.7331231690525	4294963.66	0	1726514076000000	44339.5	
13	0	9.5	-30.659243855923	4294963.66	0	1726514076000000	45339.5	
14	0	9.5	-30.4621550088833	4294963.66	0	1726514076000000	46339.5	
15	0	9.5	-29.7052383162715	4294963.66	0	1726514076000000	47339.5	
16	0	9.5	-30.2841810226454	4294963.66	0	1726514076000000	48339.5	
17	0	9.5	-30.7738860625046	4294963.66	0	1726514076000000	49339.5	
18	0	9.5	-29.912456175912	4294963.66	0	1726514076000000	50339.5	
19	0	9.5	-29.9173068256279	4294963.66	0	1726514076000000	51339.5	
20	0	9.5	-30.7890368388909	4294963.66	0	1726514076000000	52339.5	
21	0	9.5	-30.2357557012365	4294963.66	0	1726514076000000	53339.5	
22	0	9.5	-29.7001598273326	4294963.66	0	1726514076000000	54339.5	
23	0	9.5	-30.5549116120586	4294963.66	0	1726514076000000	55339.5	
24	0	9.5	-30.5813117501624	4294963.66	0	1726514076000000	56339.5	



Block: PDW Plot

- Plots selected measurements from PDW:
  - Pulse Power (dBm)
  - Pulse Frequency (MHz)
  - Pulse Width (μs)





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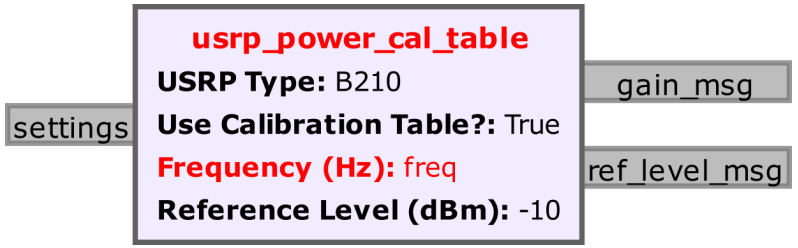
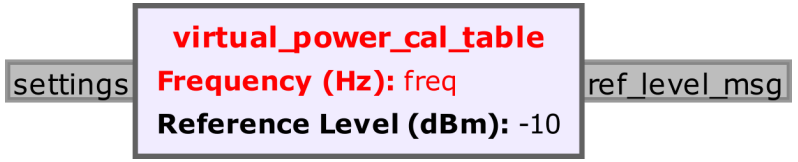
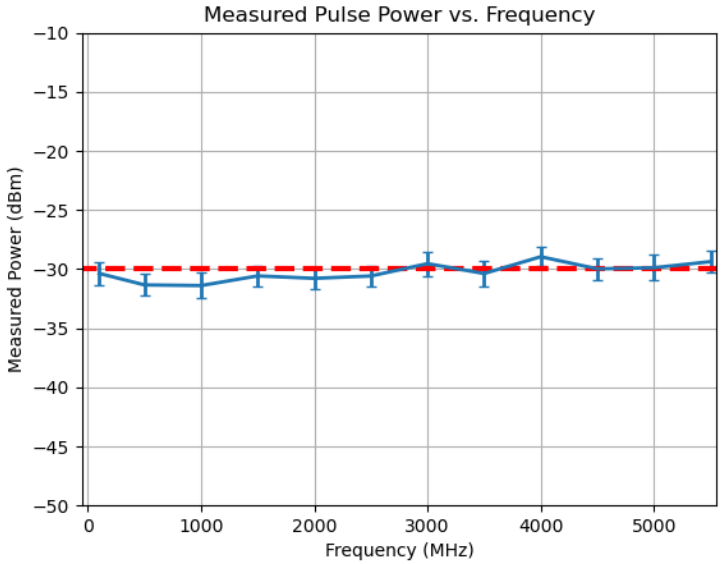
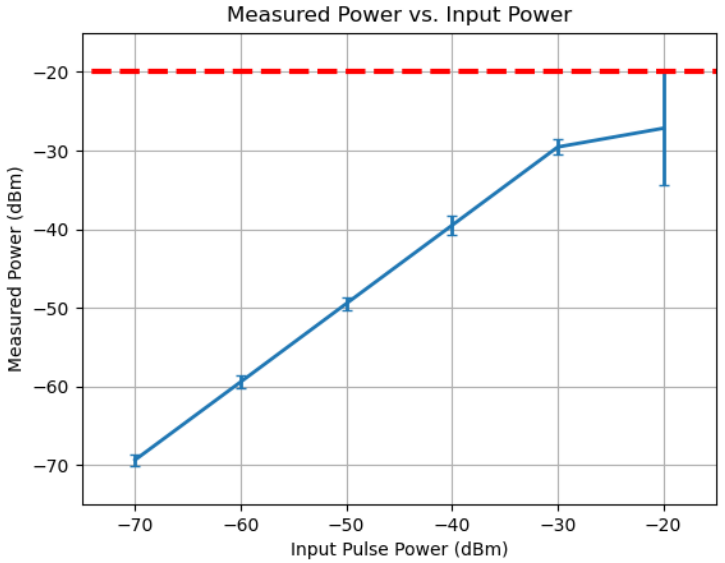
Block: Calibration Tables

- USRP Power Calibration utility
  - uhd_power_cal.py
  - Save calibration table as .pickle
- R&S Signal Generator
  - Automated Calibration
- User selects reference level
  - Block outputs a gain setting for USRP









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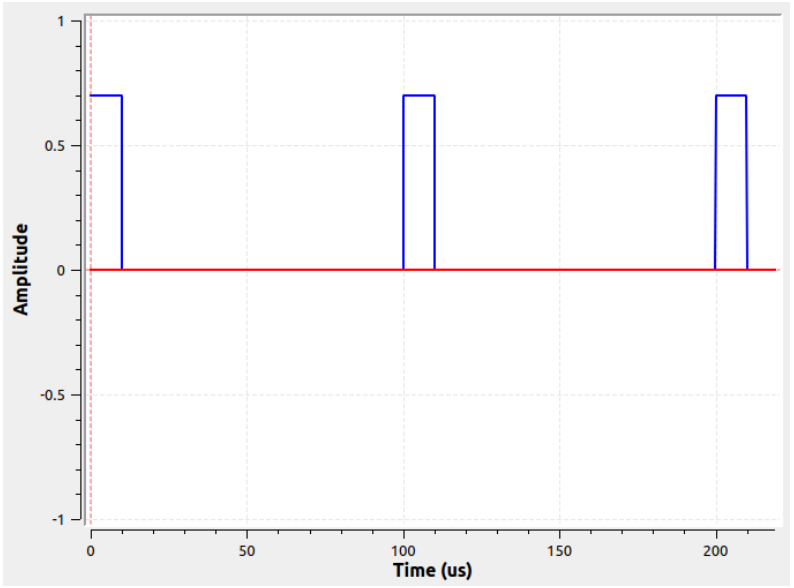
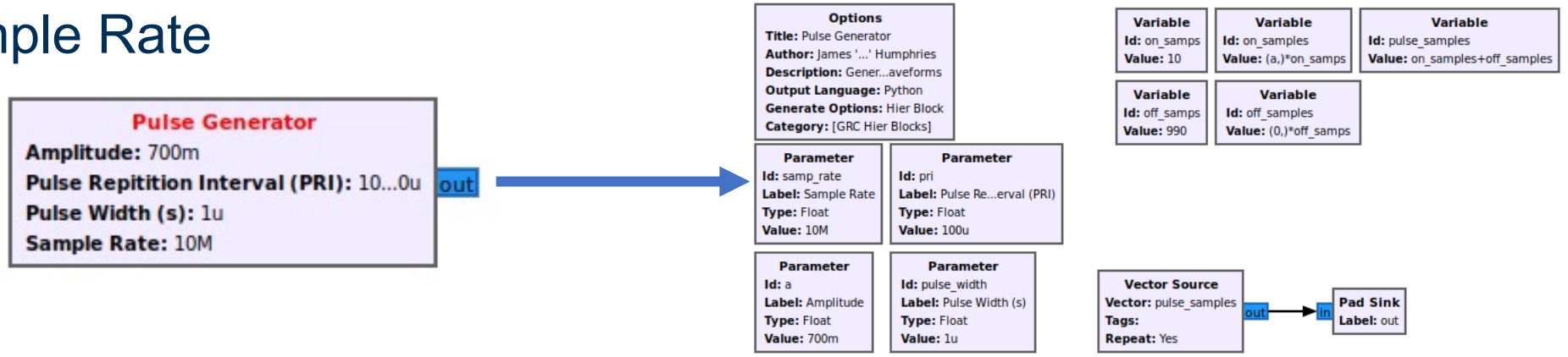
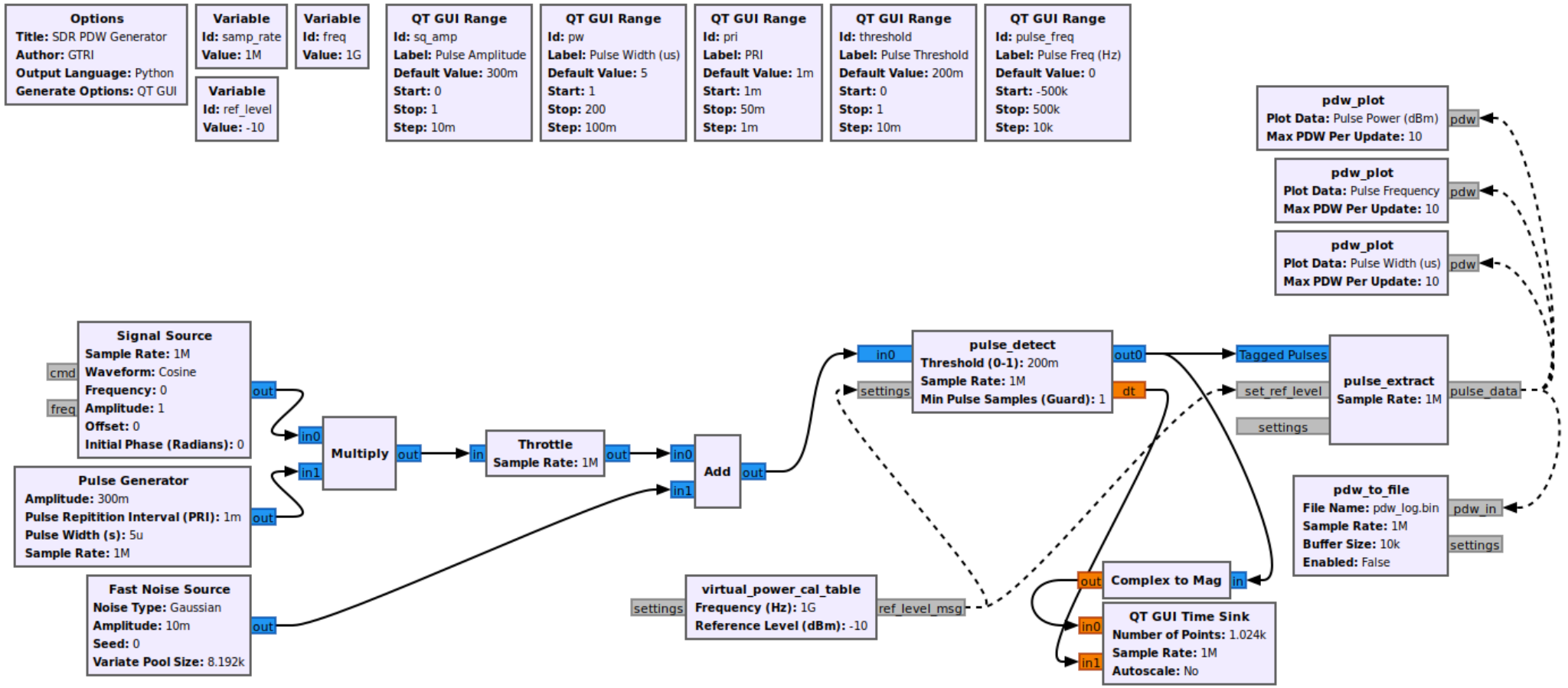
Extras: pulses.grc

- Hierarchal block to generate simple pulsed waveforms
- Inputs:
  - Amplitude
  - Pulse Repetition Interval (PRI)
  - Pulse Width
  - Sample Rate

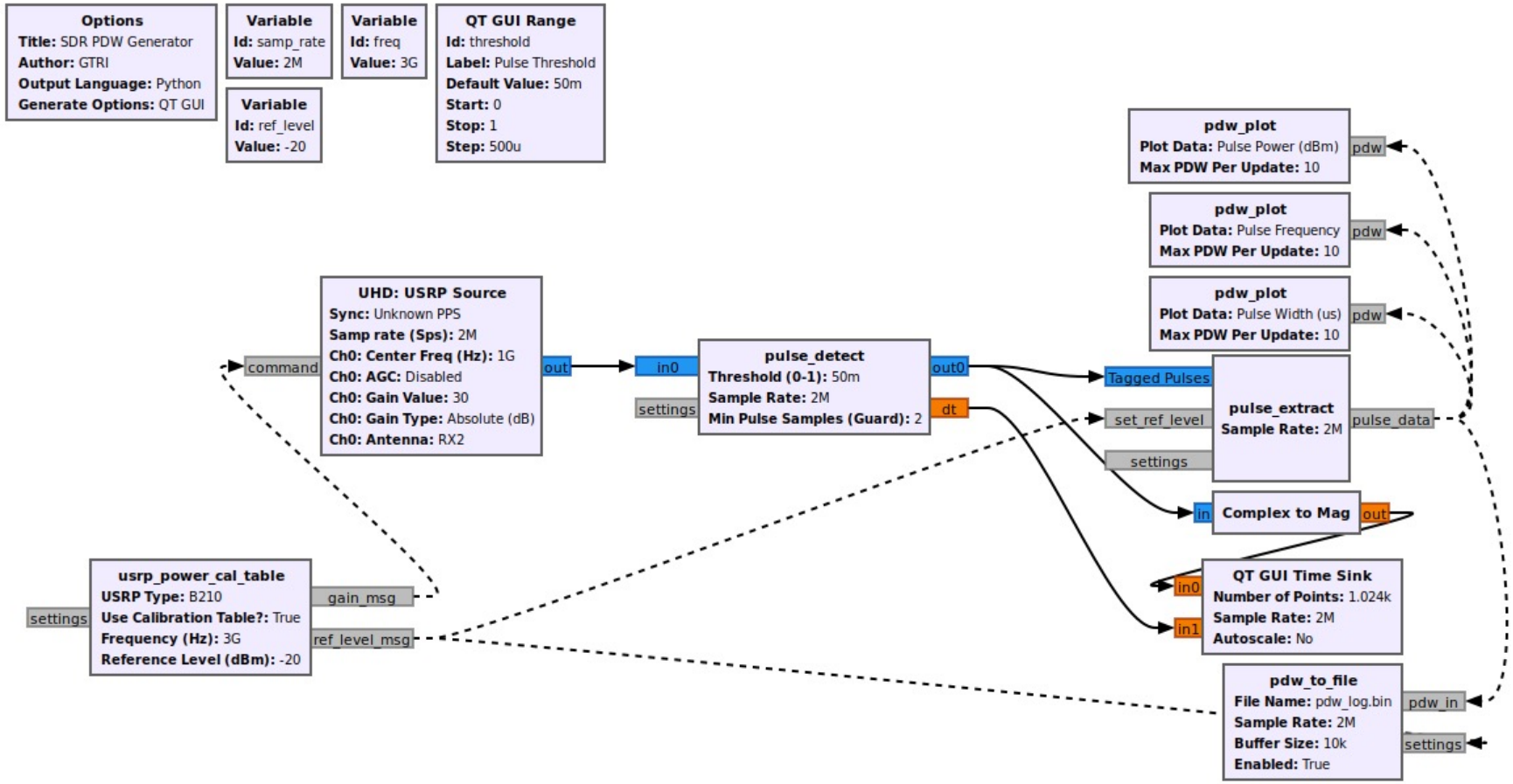




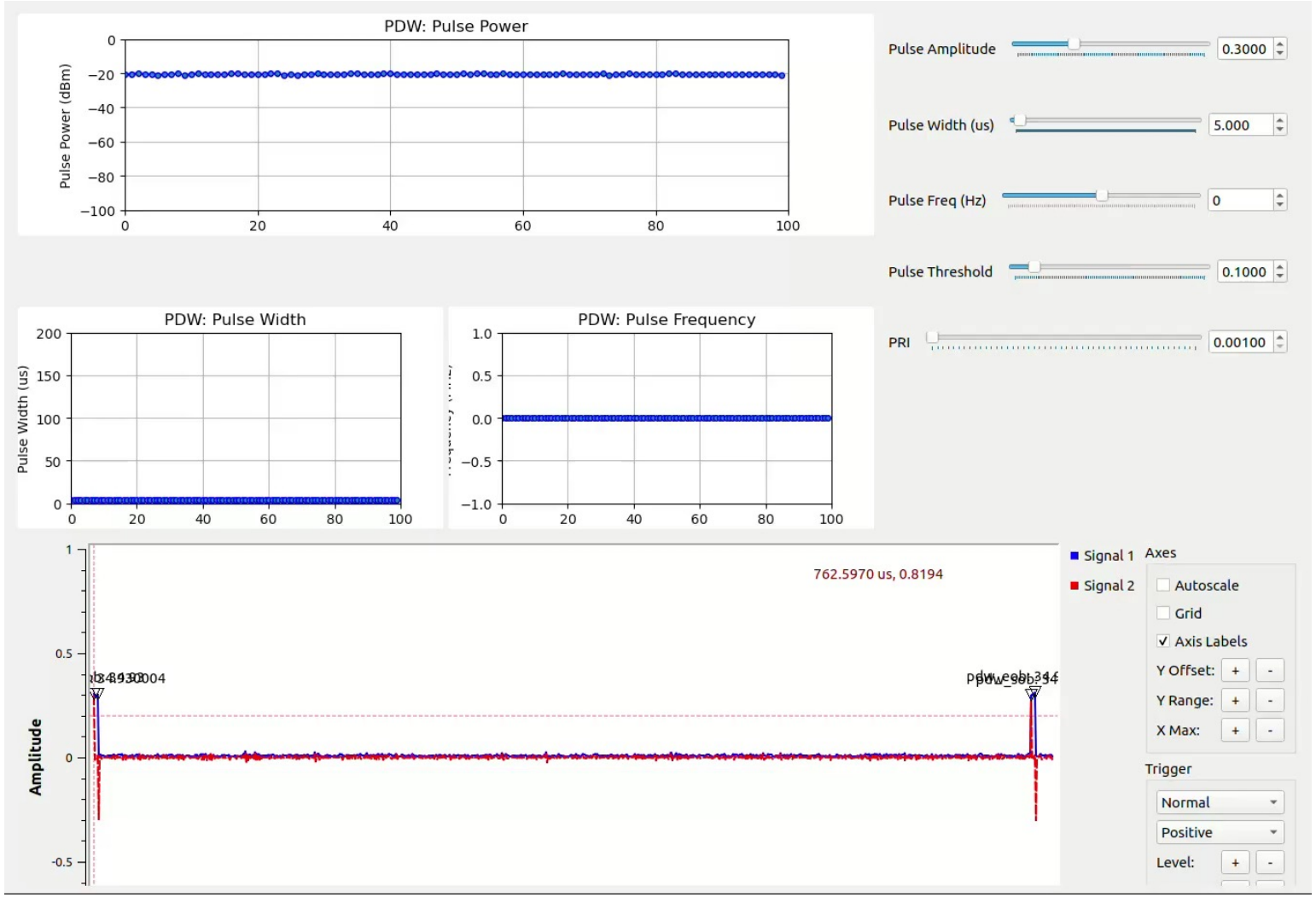
Example Flowgraph: Virtual Mode



Example Flowgraph: USRP

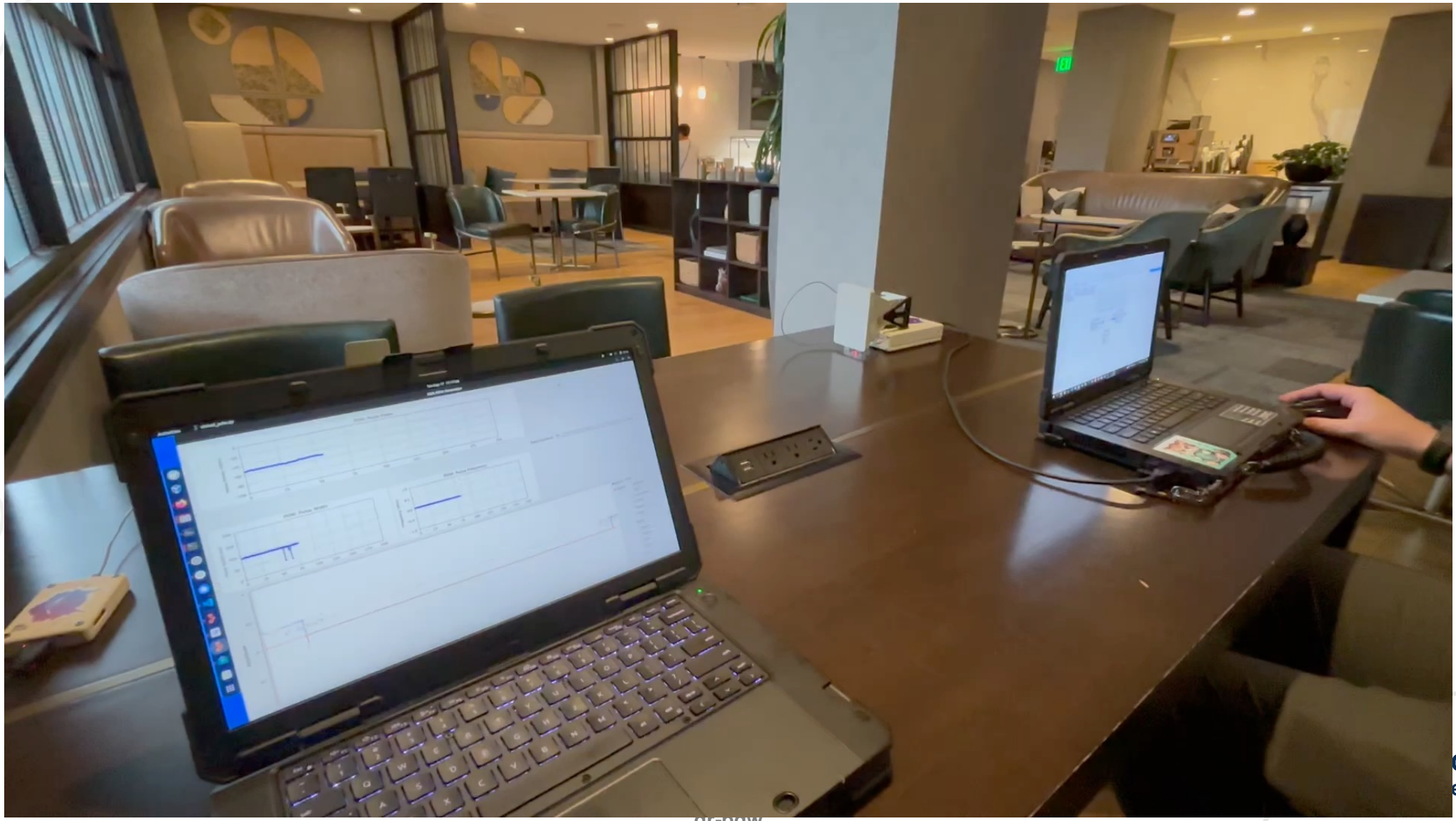


Demo (Video)



Demo: Test Setup

Demo: Wireless PDW Measurements



gr-pdw: Available on GitHub

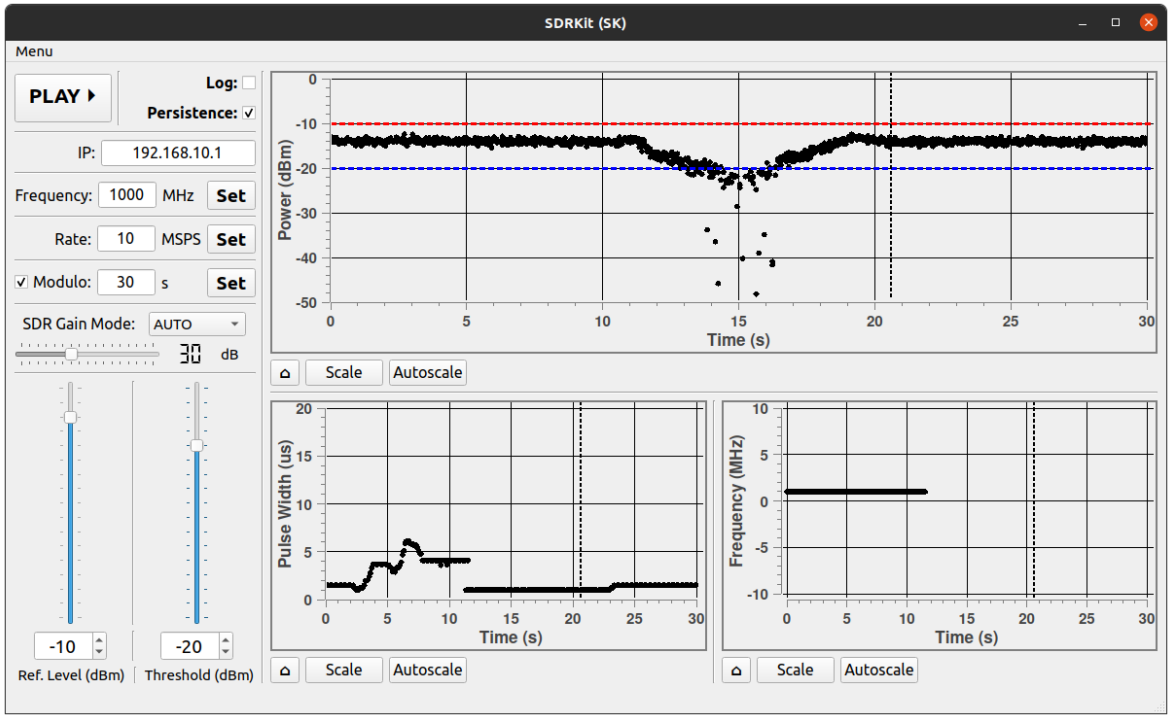
SOON™

https://github.com/gtri/gr-pdw

Pull requests are VERY welcome

Future Plans

- Port blocks to C++
- Improved plotting / visualization tools
- Modulation detection
- Pulse I/Q export
- PDW Streaming (Network)
- Firmware / RFNoC PDW generation (High Bandwidth)
- PDW Replay



Qt based GUI to display network PDW stream

Questions?

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