Target Detection Using FM Chirp and GNU Radio-Based FMCW Radar

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Introduction

- Radar technology is widely used in various applications, such as aviation, meteorology and military.
- One of the radar techniques used for target detection is FMCW radar, which uses a continuous wave signal that is modulated in frequency.
- By combining GNU Radio with SDR hardware, it is possible to implement a custom radar system that can perform radar target detection and tracking, providing a cost-effective and flexible solution for various applications.

Problem Description

- Traditional radar systems often require expensive, custom hardware, which can be a barrier to entry for many applications.
- Additionally, they are often limited in terms of flexibility and adaptability, making it difficult to modify the system for different applications.
- They often get affected by environmental factors such as weather and terrain.

Challenges

- Complex signal processing:

  Requires advanced signal processing techniques. Designing an effective signal processing chain that can handle the high-frequency signals of radar systems can be challenging.

- High-frequency design:

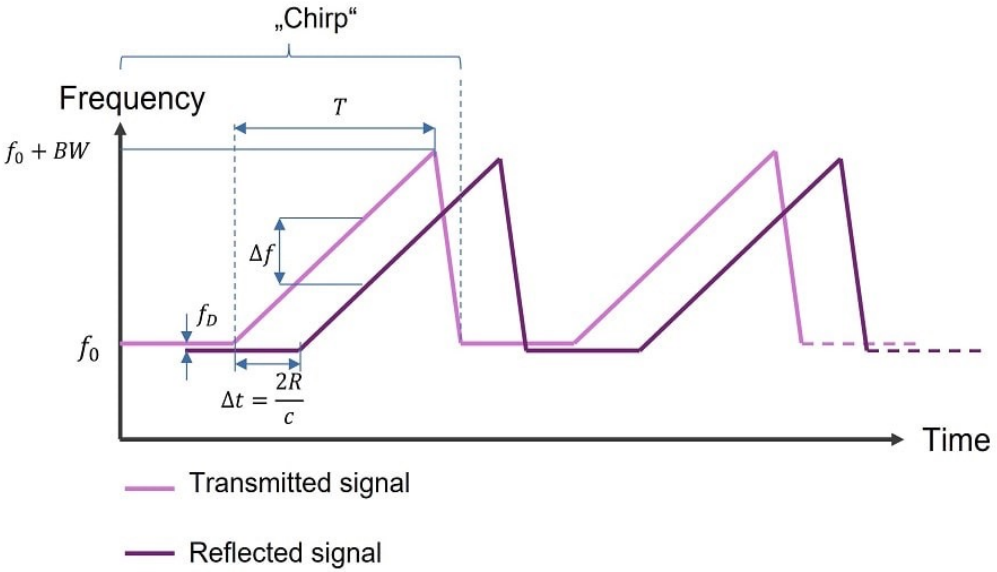
  Operate at high frequencies. Furthermore, building and testing hardware components for high-frequency applications can be expensive.

- Noise and interference:

  Susceptible to noise and interference from various sources, including other radar systems, electronic devices, and natural phenomena which leads in accuracy reduction.

FMCW Radar

- Frequency-Modulated Continuous Wave.
- Measures range and velocity of the targets.
- High accuracy and reliability.
- Velocity - Doppler shift.
- Range - the difference between transmitted and received signals.



https://www.renesas.com/us/en/blogs/basics-fmcw-radar

Advantages:

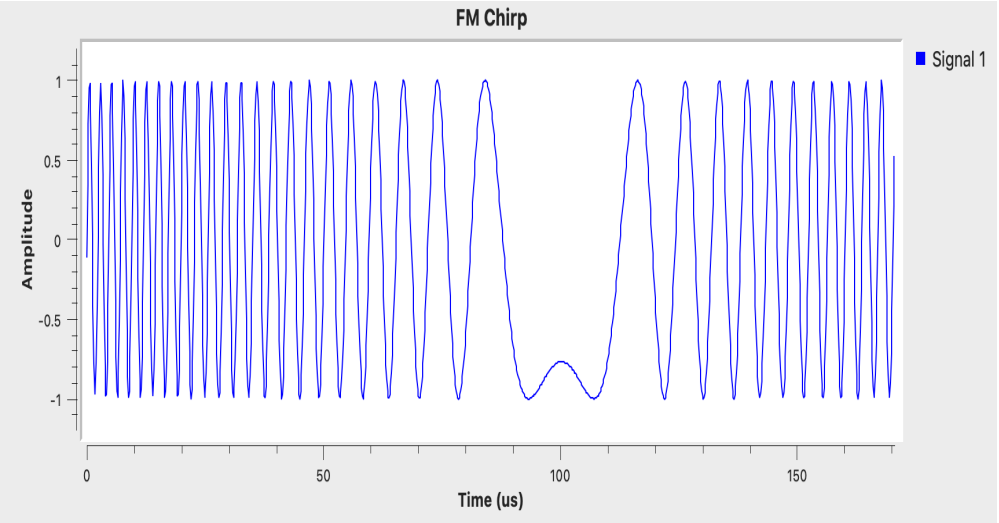
- High resolution
- Low power consumption
- Immunity to interference

Disadvantages:

- Limited range
- Sensitive to target velocity & acceleration

FM Chirp

- Frequency changes linearly.
- Chirp - a sound made by certain birds
- Measurement - chirp rate
- FM chirp generation: VCOs, DDS & SDR



Applications: Radar, Sonar Systems, Medical Imaging

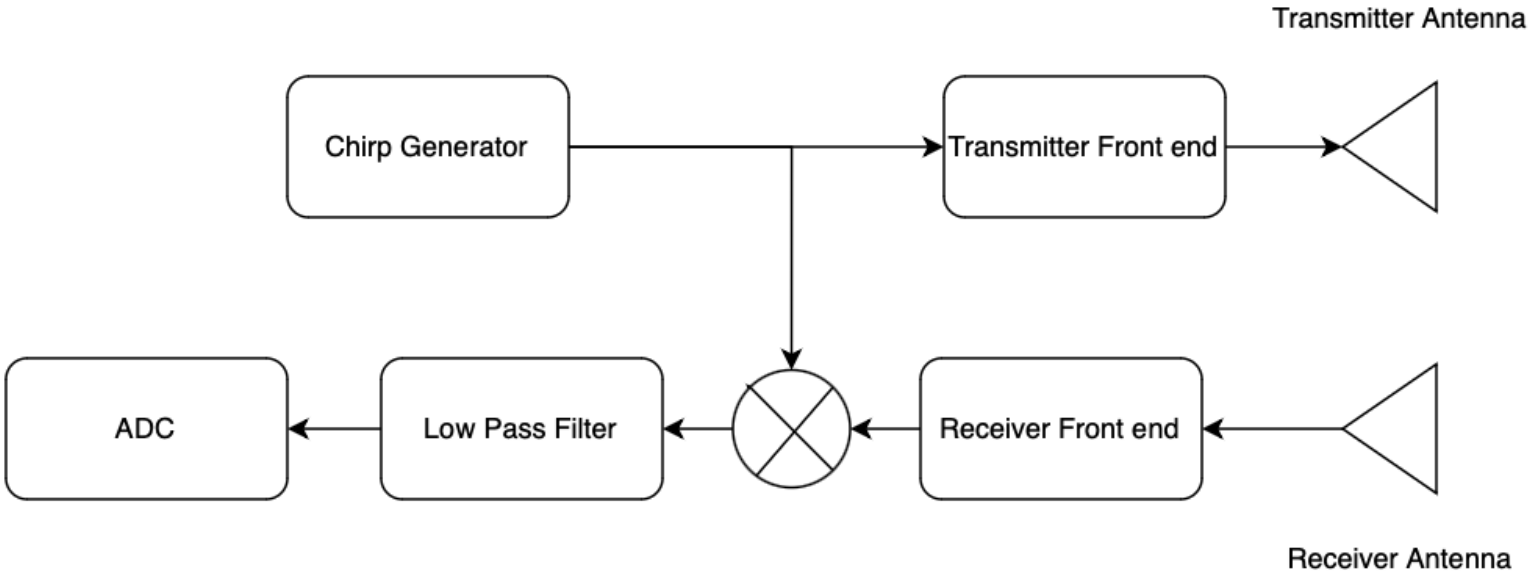
Advantages:

- High resolution
- Immunity to interference

Disadvantages:

- Limited bandwidth
- Sensitive to phase noise

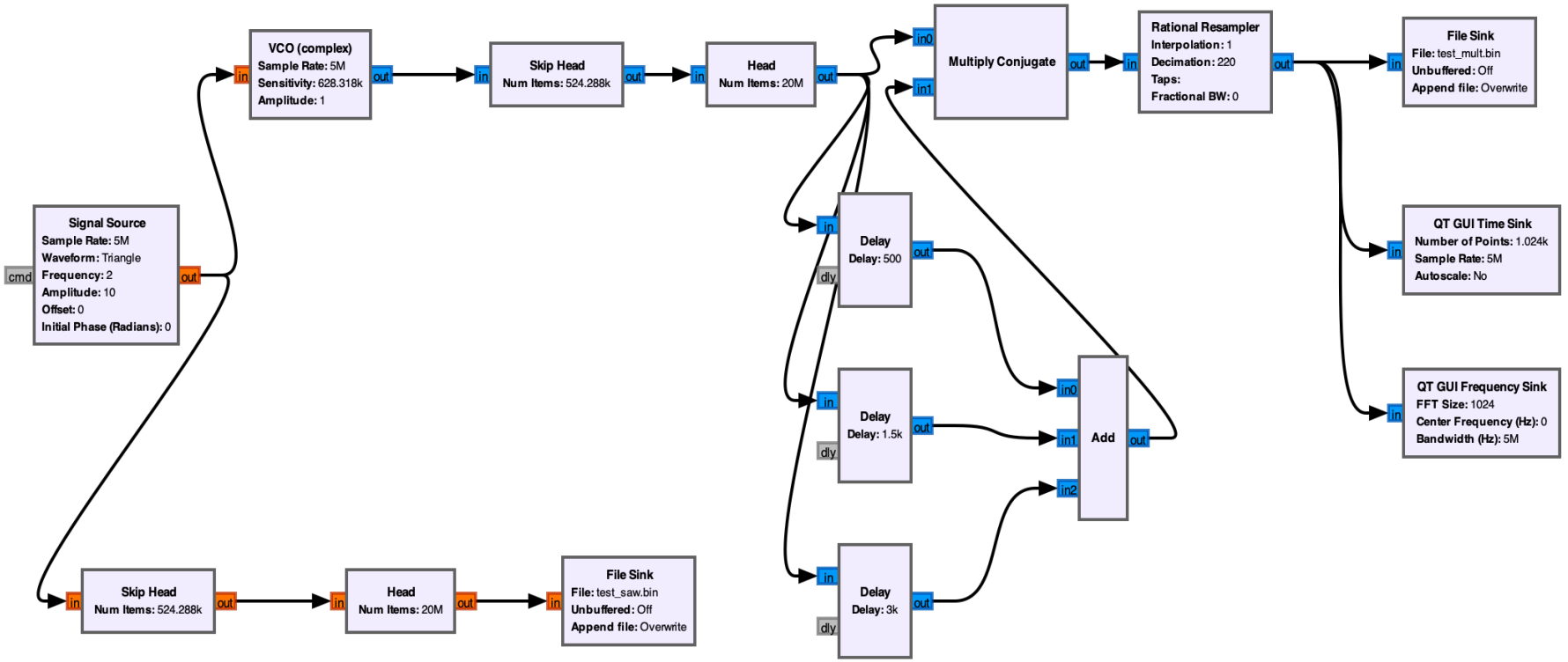
FMCW Radar System Design



A. Prabaswara, A. Munir and A. B. Suksmono, "GNU Radio based software-defined FMCW radar for weather surveillance application," *2011 6th International Conference on Telecommunication Systems, Services, and Applications (TSSA)*, Denpasar, Indonesia, 2011, pp. 227-230, doi:10.1109/TSSA.2011.6095440.

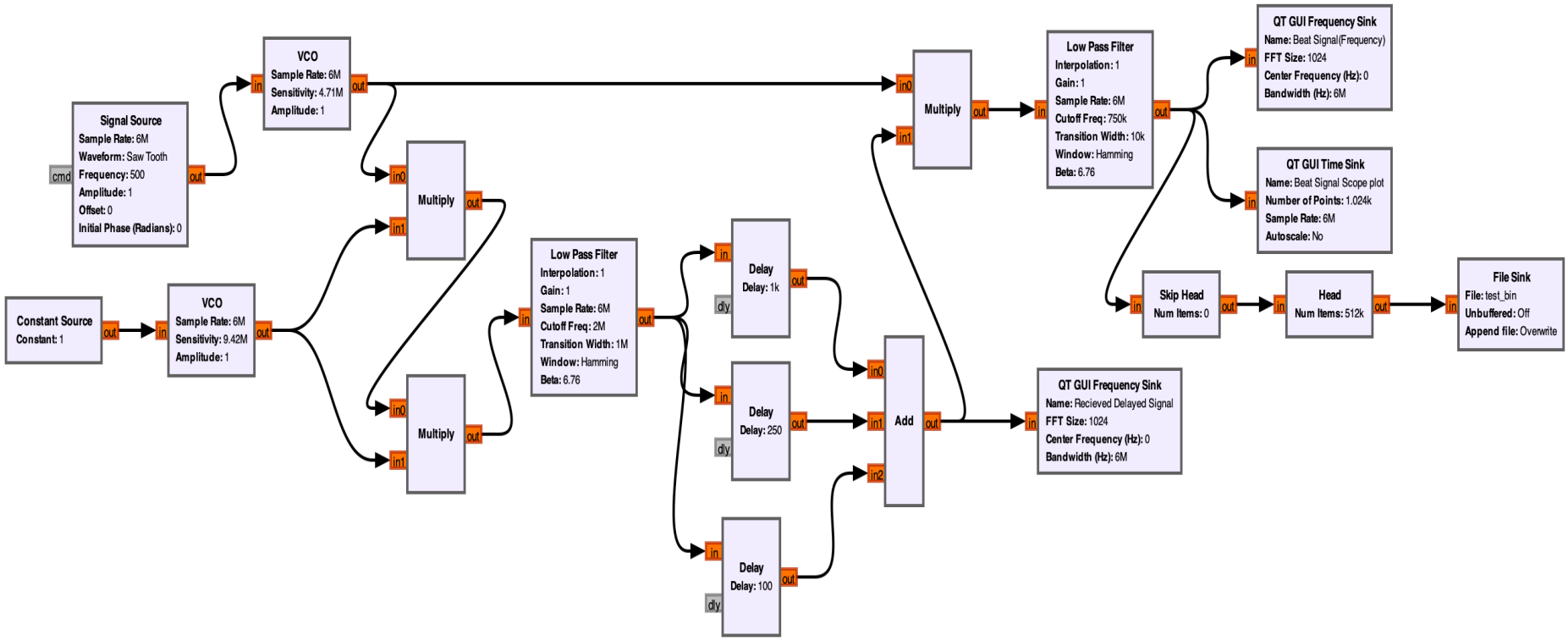
Target Detection Using Chirp in FMCW Radar

- Target detection using chirp



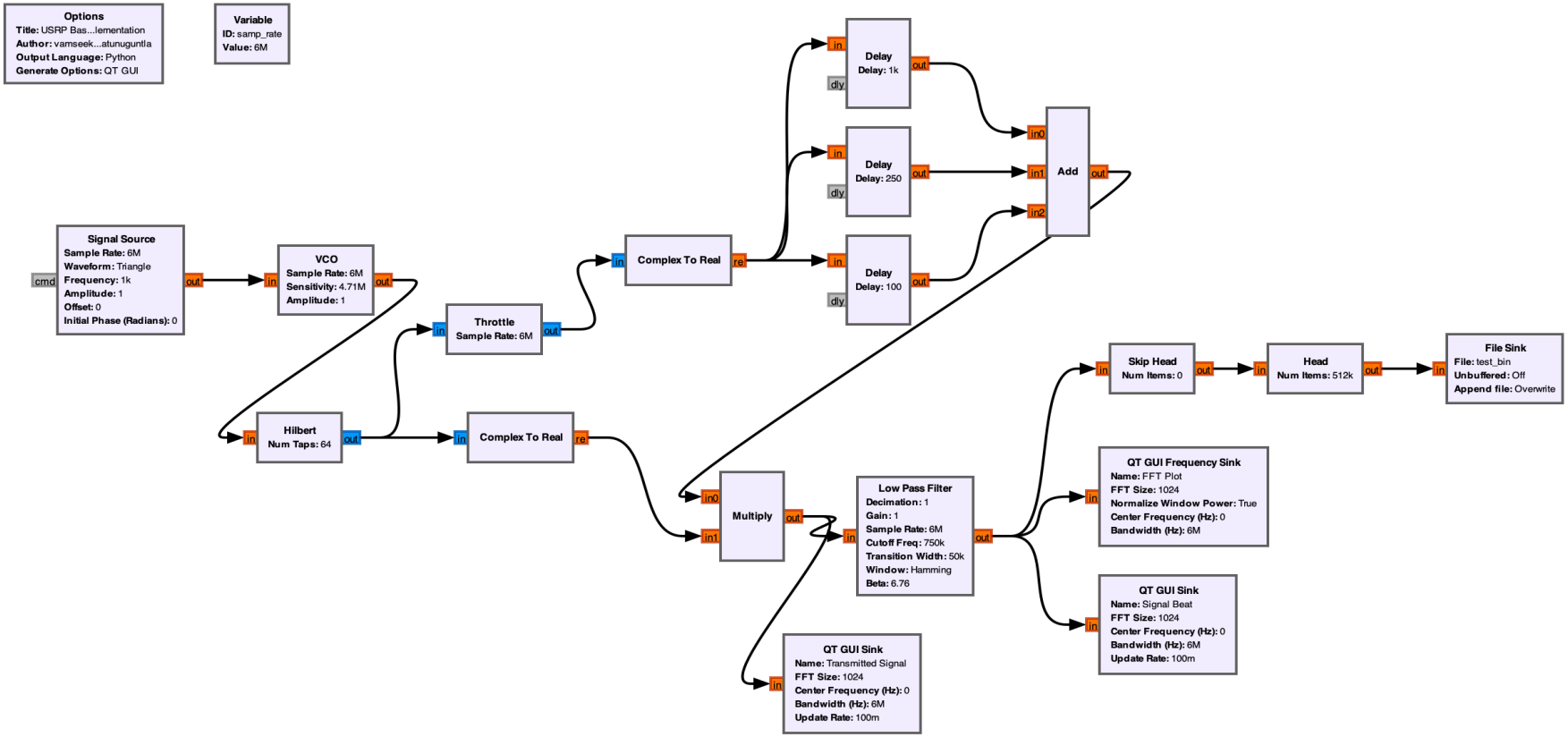
GNU Radio and FM Chirp FMCW Radar

- Real condition simulation



GNU Radio and FM Chirp FMCW Radar

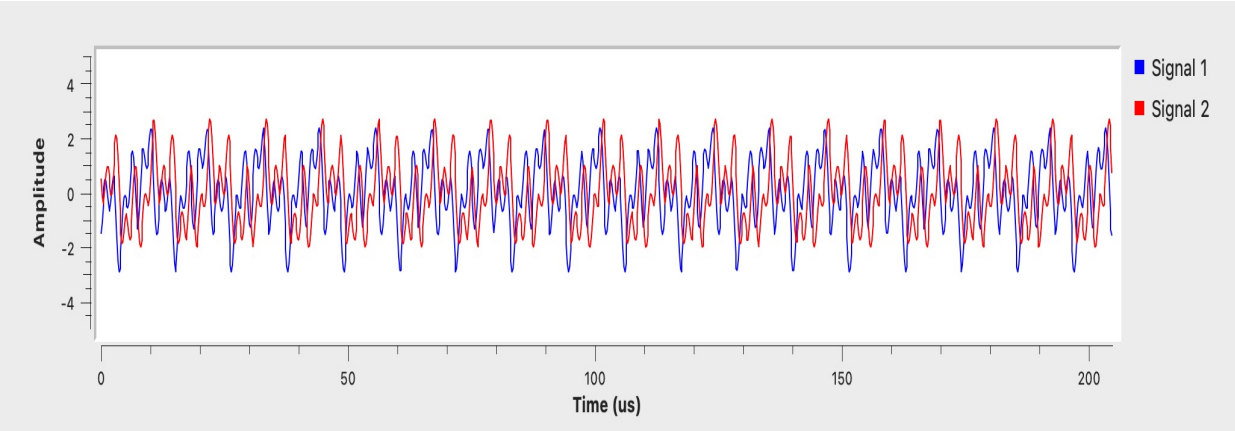
- USRP based simulation



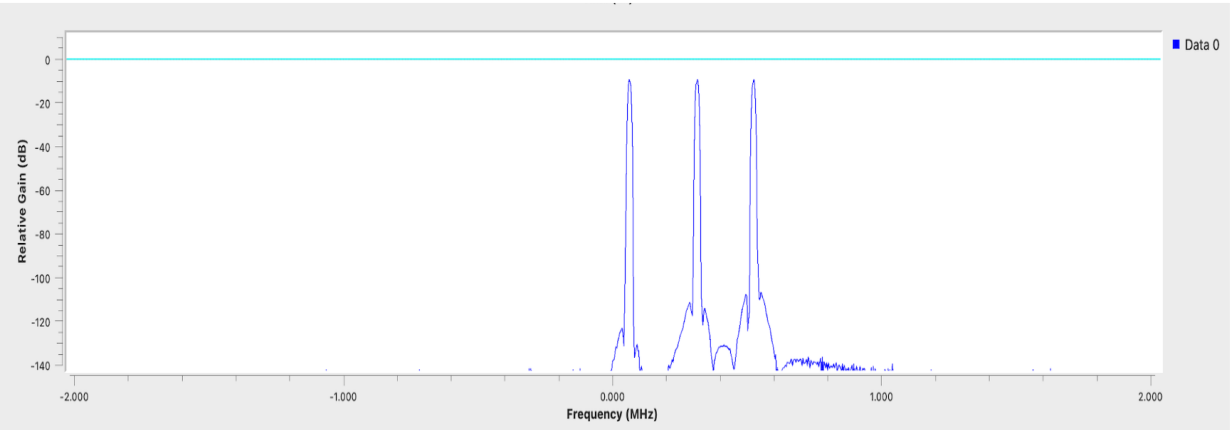
Simulation Results

- Target detection using chirp

Beat signal for 3 targets



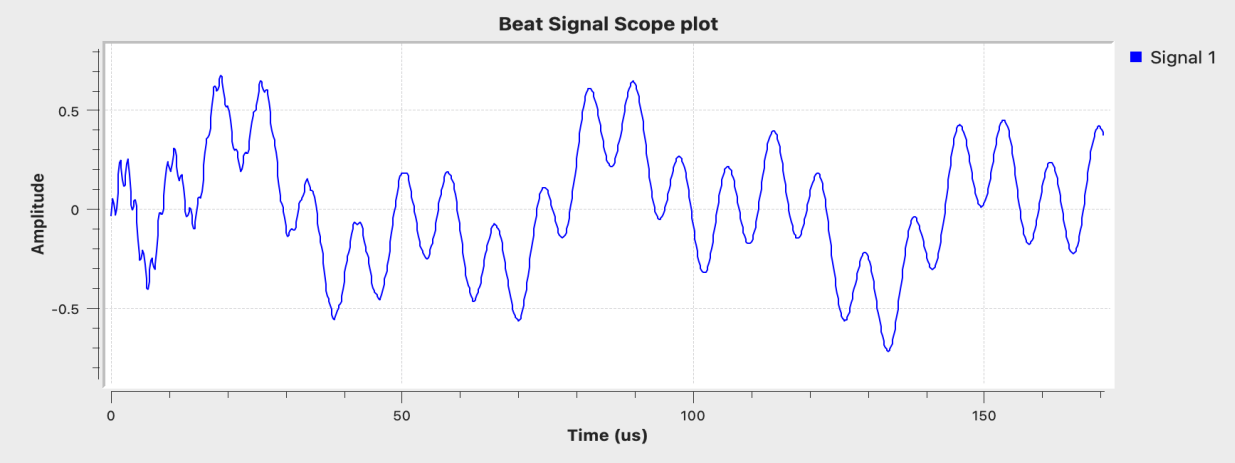
Beat frequency spectrum for 3 targets



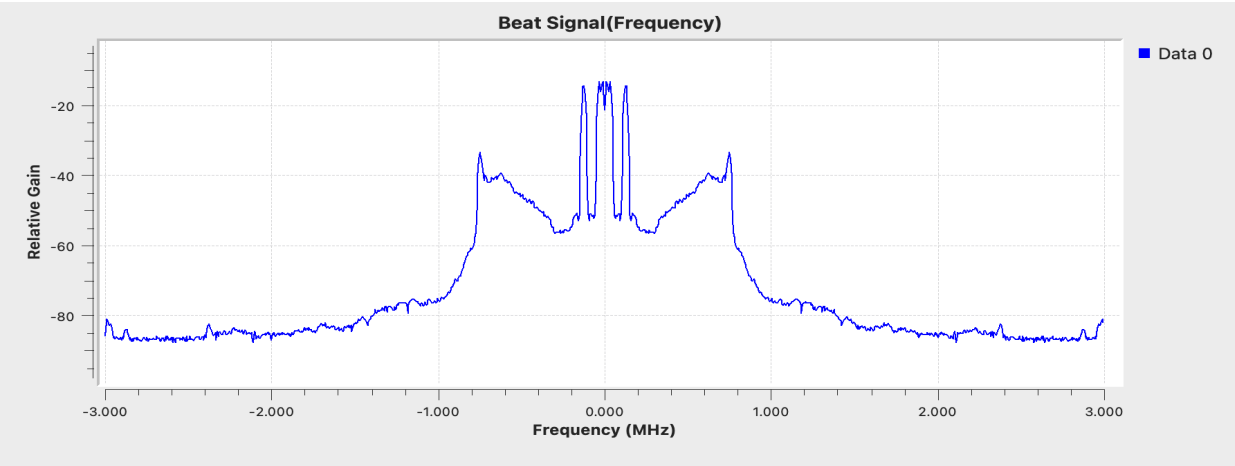
Simulation Results

- Real condition simulation

Beat signal scope plot



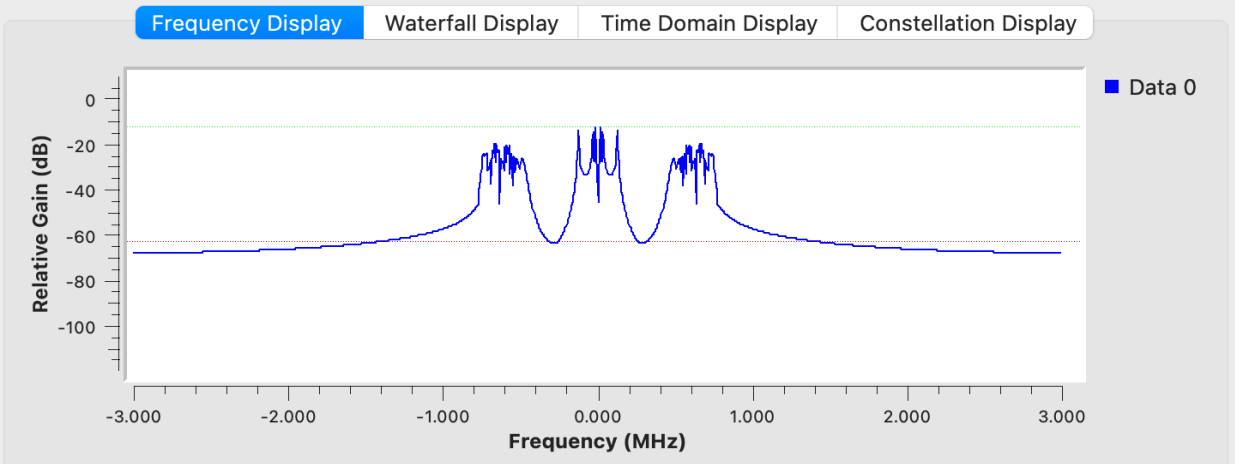
FFT beat signal



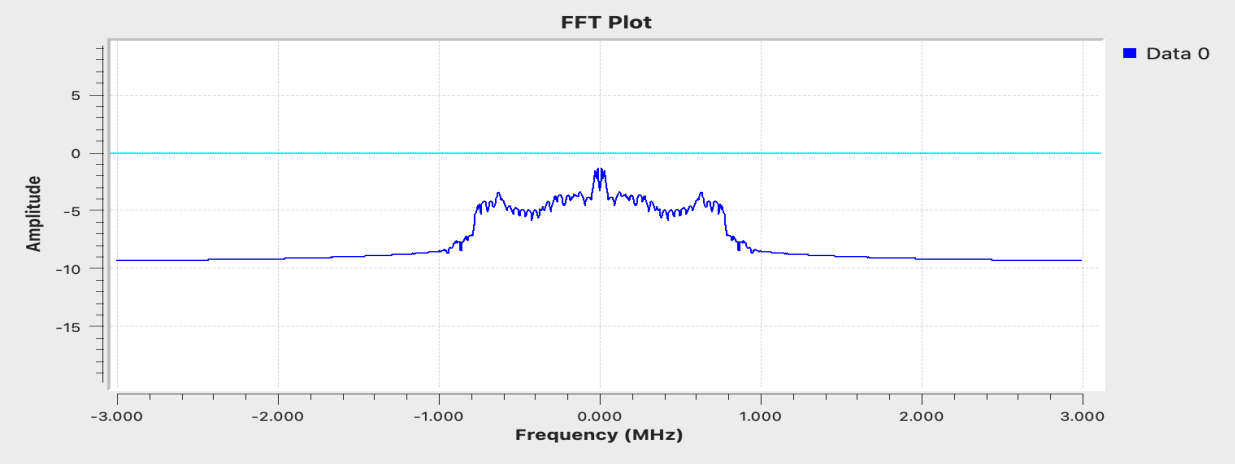
Simulation Results

- USRP based simulation

Beat signal scope plot



FFT beat signal



Accuracy Analysis for FM Chirp Generator

- 3 types of waveforms are being used:

  Sinusoidal - non-linear

  Triangular – linear

  Sawtooth - linear

- Simulations are performed using GNU Radio.

Accuracy Analysis for FM Chirp Generator

- Real condition simulation

Waveforms	Time Step	Distance(Theoretical)	Distance(GNU Radio)	Accuracy
Triangular	1000	25	25.2	99.2
	250	6.25	6.36	98.2
	100	2.5	2.7	92.5
Sawtooth	1000	25	25	100
	250	6.25	6.35	98.4
	100	2.5	2.53	98.8
Sinusoidal	1000	25	25.8	96.89
	250	6.25	6.47	96.59
	100	2.5	2.68	93.28

Accuracy Analysis for FM Chirp Generator

- USRP based simulation

Waveforms	Time Step	Distance(Theoretical)	Distance(GNU Radio)	Accuracy
Triangular	1000	25	25.32	98.7
	250	6.25	6.32	98.8
	100	2.5	2.6	96.15
Sawtooth	1000	25	25	100
	250	6.25	6.35	98.4
	100	2.5	2.5	100
Sinusoidal	1000	25	25.6	97.6
	250	6.25	6.38	97.9
	100	2.5	2.56	97.6

Conclusions

- Investigation of FM chirp accuracy in GNU radio-based FMCW radar for target detection.
- Characterisation of distance detection using carrier frequency of 1.5 MHz and 6 Msps sample rate.
- Results show the superiority of the USRP-based implementation method in terms of average accuracy.
- The sawtooth waveform exhibits the highest average accuracy among the three waveforms.

References

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