Chirp-based pulse compression for duty cycle optimization in SOPHy X-band weather radar

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Abstract

The SOPHy weather radar, developed by the IGP, is a dual-polarization radar system operating in the X-band, with a maximum range of up to **60 km** and a **r**esolution of **60 m**. Its transmission technology is primarily based on solid-state amplifiers and initially employed a **phase-coding** technique based on **complementary code** signals, which prevented the amplifier from operating at maximum efficiency, achieving only **4% of the available *duty cycle***. To overcome this limitation, a **pulse compression** technique based on ***chirp*** waveforms is developed and evaluated, enabling more efficient use of the transmitted power and achieving a ***duty cycle* of up to 12%**. This improvement in the *duty cycle* enhances the detection capabilities of the radar system and contributes significantly to the observation and study of atmospheric phenomena in Peru.

1. Introduction

- Longer **complementary codes** produce higher sidelobe levels and restrict the maximum pulse width to **4% *duty cycle***.
- **Two coherent integrations** are needed for sidelobe suppression producing a **±10 m/s unambiguous radial velocity**.

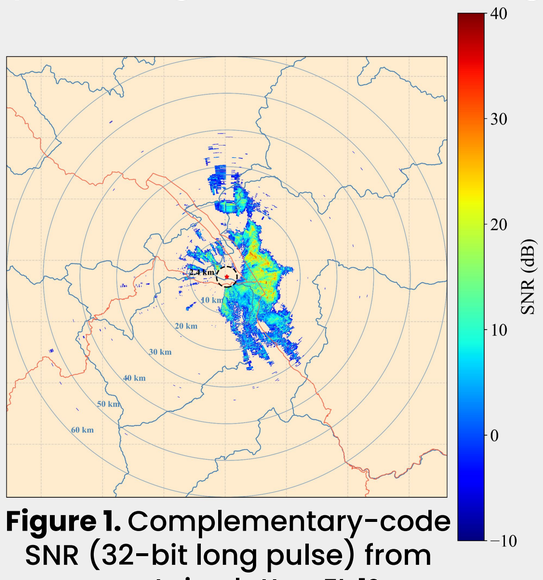

Figure 1. Complementary-code SNR (32-bit long pulse) from mountain clutter, EL 1°.

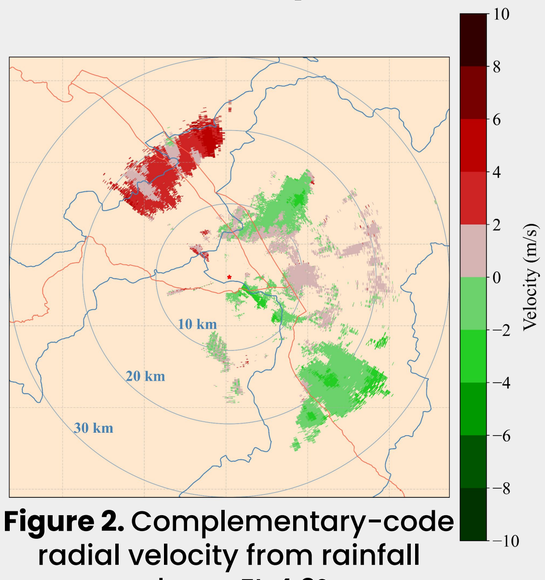

Figure 2. Complementary-code radial velocity from rainfall echoes, EL 4.2°.

2. Methodology

- Long ***chirp*** waveform enables a ***duty cycle* of up to 12%** while mitigating the blind range with a short *chirp* at **1% *duty cycle***.
- Use of **Blackman window** for sidelobes suppression.

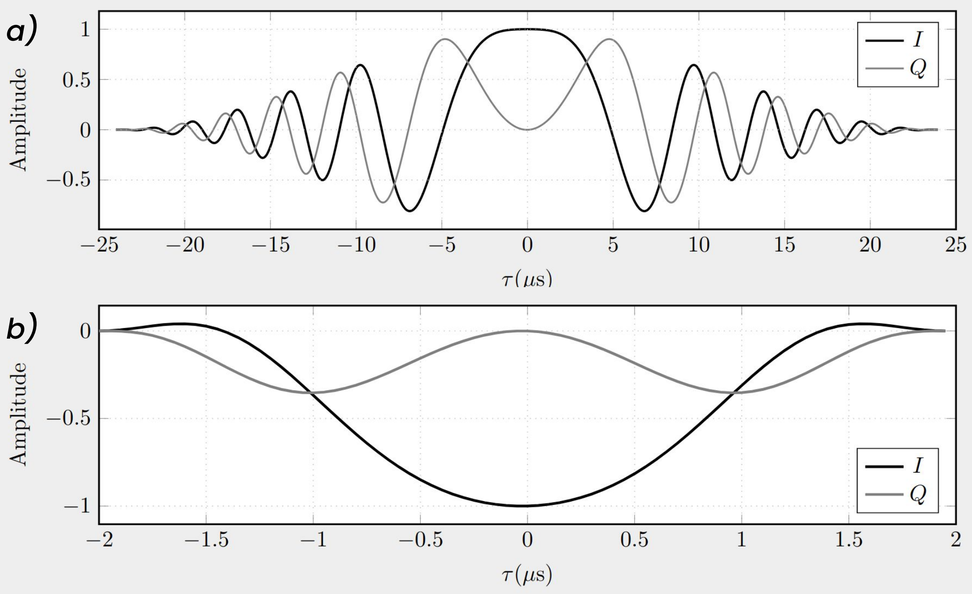

Figure 3. *Chirp* pulse compression waveforms. a) Long-pulse and b) short-pulse.

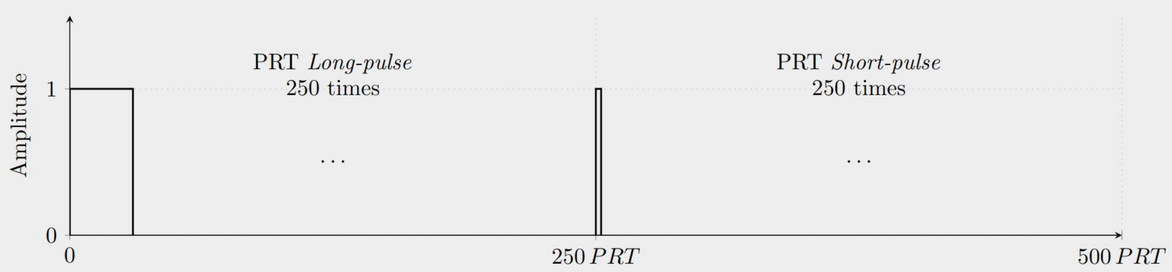

Figure 4. Transmission pulse scheme.

3. Results

- **Average SNR** increased by **13.8 dB**.
- **Blind range** reduced to approximately **505 m**.
- **Unambiguous radial velocity** extended to **±20 m/s**.

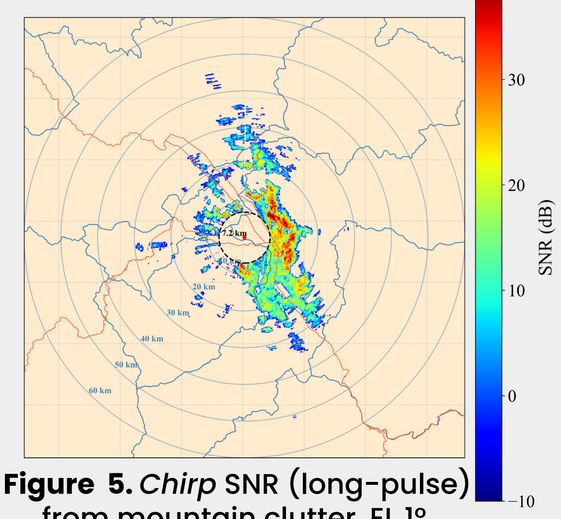

Figure 5. *Chirp* SNR (long-pulse) from mountain clutter, EL 1°.

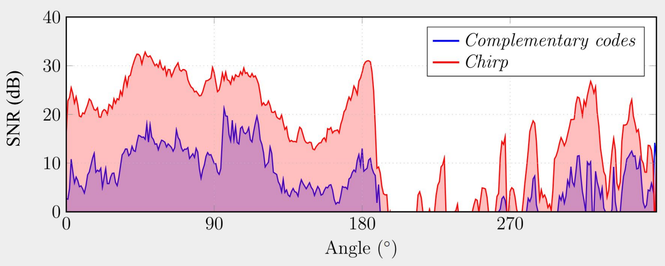

Figure 6. Long-pulse average SNR comparison.

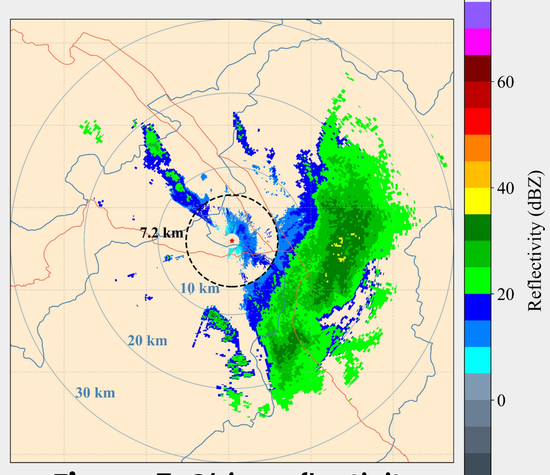

Figure 7. *Chirp* reflectivity from rainfall echoes, EL 4.2 °.

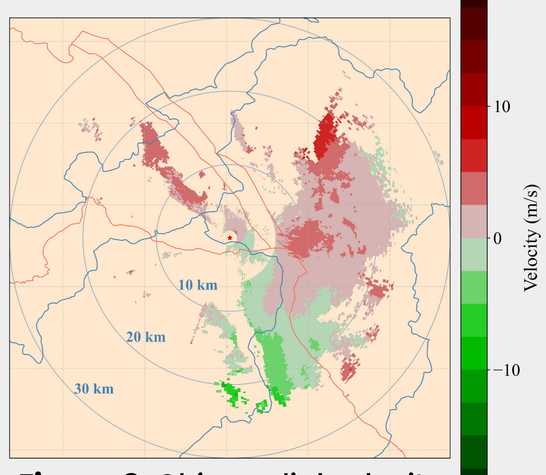

Figure 8. *Chirp* radial velocity from rainfall echoes, EL 4.2°.

4. Future works

The implementation of new blind-range mitigation techniques can be developed in the SOPHy weather radar system to optimize and improve radar performance in regions close to the radar and within the transition zone between the short and long pulses.

5. Acknowledgments

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6. References

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[2]Cheong, B. L., Kelley, R., Palmer, R. D., Zhang, Y., Yeary, M. B., & Yu, T.-Y. (2013). *PX-1000: A solid-state polarimetric X-band weather radar and time-frequency multiplexed waveform for blind range mitigation*. IEEE Transactions on Instrumentation and Measurement, 62(11), 3064–3072. https://doi.org/10.1109/TIM.2013.2270046