PARIS Interferometric Technique - Proof of Concept
PIT-PoC

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Overview

Headline

We present a new GNSS-R signal processing technique which gives an order of magnitude better precision in delay determination w.r.t. the standard approach used so far.

To support this affirmation we will show you:

1. A comparison between the standard GNSS-R signal processing and the new approach;
2. The custom instrumentation we have constructed to test the new technique; and
3. Experimental results showing evidence of the announced improvement.

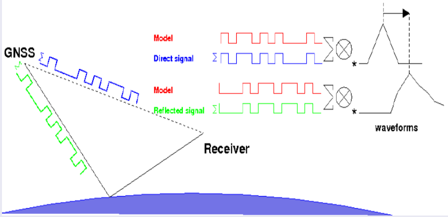
Outline

1. Model Correlation vs. PARIS Interferometric Technique
2. The PARIS Interferometric Receiver (PIR)
3. PIR Characterization with a GNSS Signals' Generator
4. The Zeeland Bridge Campaign
5. Conclusions

How to receive the GPS-Reflected Signals?

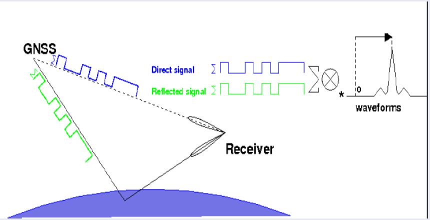
GNSS-R**s**: Standard Approach

- A local replica of the signal is generated on the receiver using well-known PRN codes and delay/Doppler info.
- Input signals are cross-correlated against local replicas.
- The two resulting cross-correlation functions, called waveforms, are the GNSS-R raw observables.



GNSS-R**i**: Interferometry Approach

- No replica or model is used to cross-correlate with.
- A selected reflected signal, obtained with a high-gain narrow-beam and correctly pointed antenna, is cross-correlated with the signals obtained by similar antenna pointing toward the transmitter (without reflection)

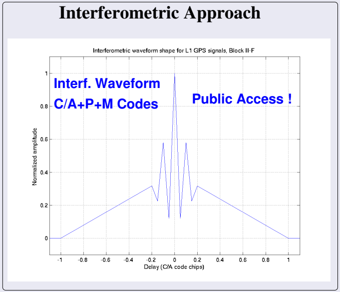


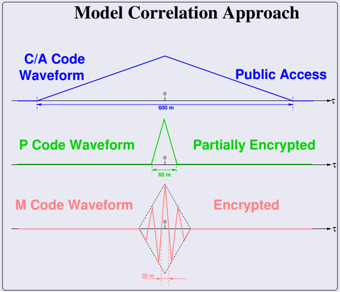
PARIS Interferometric Technique Advantages

Signal Processor Simplification

- Local code replicas not needed!
- Signal processing is valid for *any* signal: total flexibility.

Improvement in Delay Precision is Expected





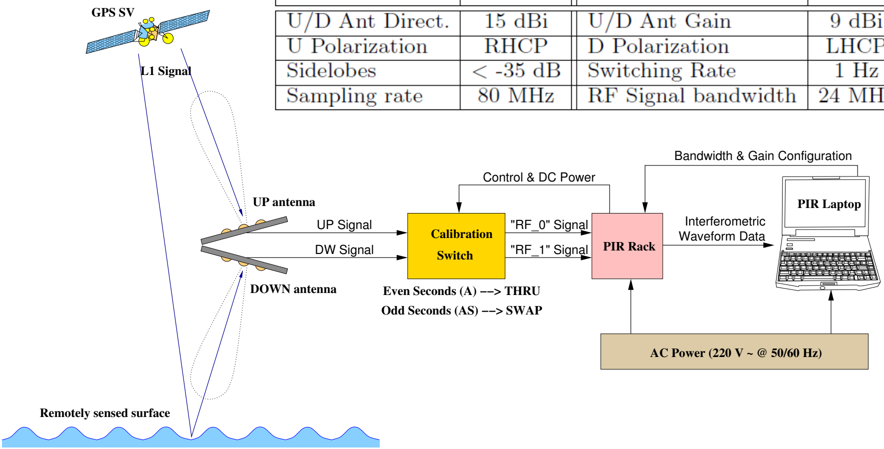
Public+encrypted codes contribute: increased power&bandwidth.

Outline

PIR Architecture

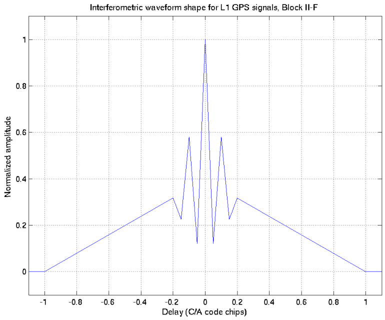
GNSS-Ri System Parameters

Parameter	Value	Parameter	Value
U/D Ant Direct.	15 dBi	U/D Ant Gain	9 dBi
U Polarization	RHCP	D Polarization	LHCP
Sidelobes	< -35 dB	Switching Rate	1 Hz
Sampling rate	80 MHz	RF Signal bandwidth	24 MHz

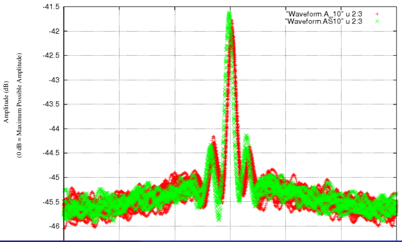


Interferometric Waveform Examples

Theoretical shape of an interferometric waveform



A real interferometric waveform from a urban environment



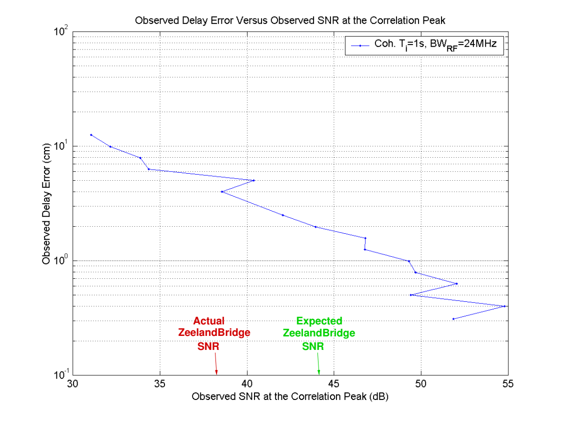
Outline

Test 1: Characterization of Delay Precision vs. SNR

Summary

- **Goal** determine dispersion in delay determination with varying SNR.
- **Procedure** while maintaining the relative delay constant, vary the input signal strength in steps, and observe SNR and delay dispersion on the output waveforms.

Results

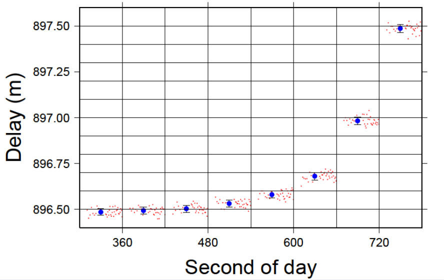


Test 2: Characterization of Delay Accuracy

Summary

- **Goal** determine biases in delay determination with varying delay of reflected waveform.
- **Procedure** while maintaining the signals strength constant, vary the synthesized relative delay, and compare with the actual observed delay on the output waveforms.

Results

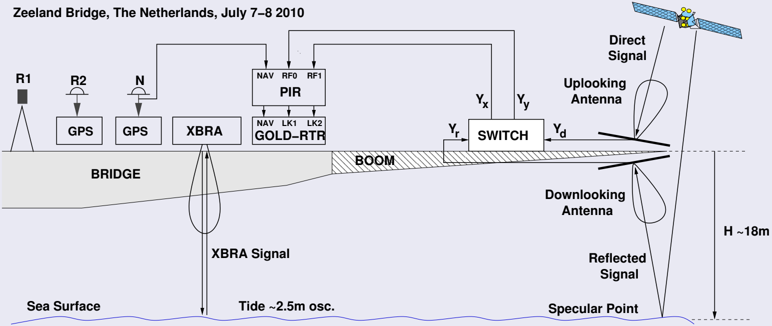


Time (SoD)	Synthesized Delay (cm)	Measured Delay (cm)	1s σ (cm)	Difference (cm)
300-359	ref	ref	1.8	ref
360-419	1	0.8	1.8	**0.2**
420-479	2	1.8	2	**0.2**
480-539	5	4.6	1.8	**0.4**
540-599	10	9.5	2	**0.5**
600-659	20	19.5	2	**0.5**
660-719	50	49.7	2.1	**0.3**
720-779	100	100	2.1	**0**

Outline

Campaign Overview

Experimental Setup



Goals

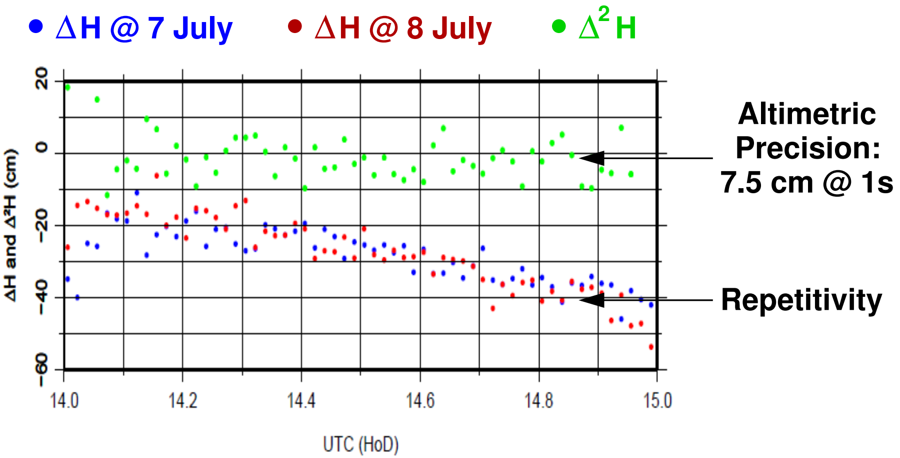
- Determine sea height with GNSS-Ri waveforms and compare with ground truth.
- Obtain delays with both GNSS-Rs/GNSS-Ri wavefroms and compare both techniques.

Campaign Execution Views

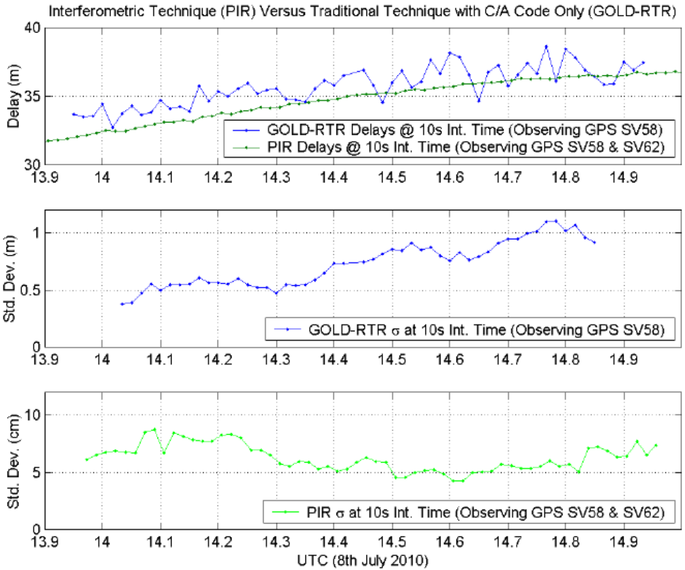
"An image is better than one thousand words"

And much the better if it is cinema!
See a small trailer summarizing the Zeeland Bridge campaign key facts.

$$\Delta H(t) = H^{PIR}(t) - H(t)$$
$$\Delta^2 H(t) = \Delta H(t + 1\ Sidereal\ Day) - \Delta H(t)$$



GNSS-Ri/GNSS-Rs Techniques Comparison



Outline

Conclusions

- Evidence that GNSS-Ri produces observable delays with uncertainties reduced one order of magnitude with respect to conventional GNSS-Rs;
- This has been proved using signals generated by GNSS simulators and data gathered in dedicated experiments aimed to measure the sea tide in the Zealand Bridge (The Netherlands);
- We have developped an end-to-end custom system, which includes antennas, calibration resources, digital signal processors and an associated control unit; and
- We consider that it has established a landmark which could be used as a reference to measure further developments in this field; but
- Not everything is done in GNSS-Ri!. There are still new scientific and technological challenges: experimental work with more representative geometries (higher, faster, ...) and the extension of our signal processor to match the requirements for a space instrument.

Thank you very much for your attention!