

GNSS jamming detection using spectral variation

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Outline

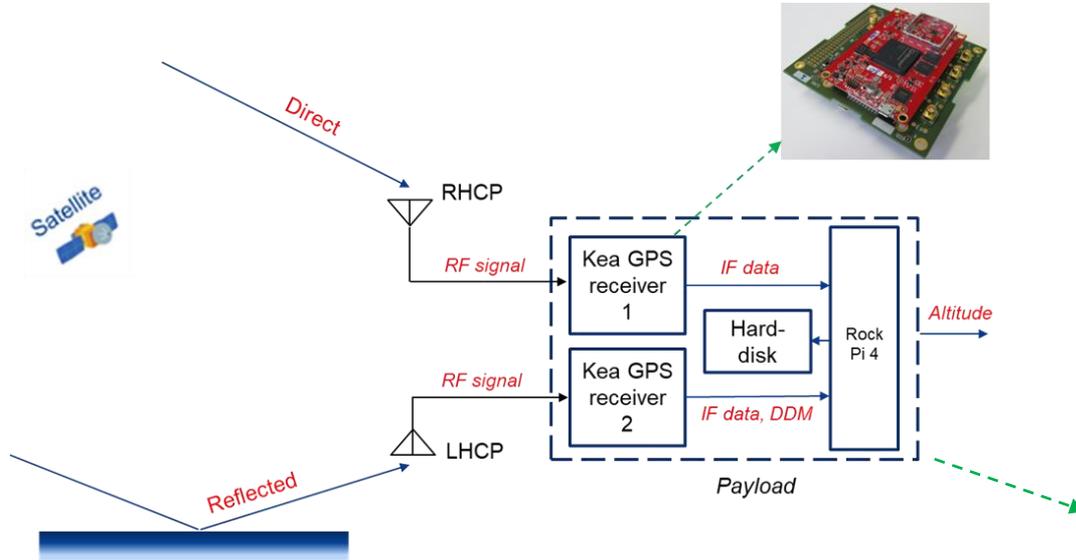
- Introduction
- Harry payload
- Experiment set up
- Spectral variation of GNSS signal
- Jamming detection method and result
- Jamming discriminative information distribution
- Conclusions

Introduction

- GNSS has been widely employed to provide positioning, navigation, and timing services
- Jamming can prevent the receiver from decoding the satellite signal to produce the accurate navigation solution
- Machine learning, frequency Doppler shift, signal direction of arrival, signal quality measurement, subspace methods, and random matrix theory have been introduced to detect jamming
- We proposed to use spectral variation of GNSS signal due to its simplicity hence much less computation processing requirement

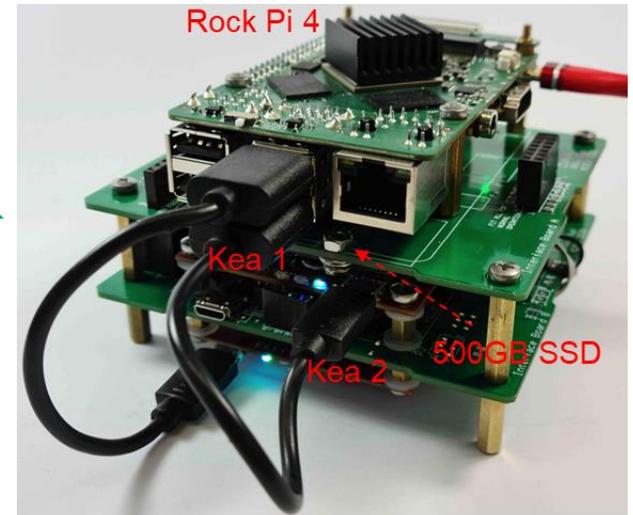


Harry payload

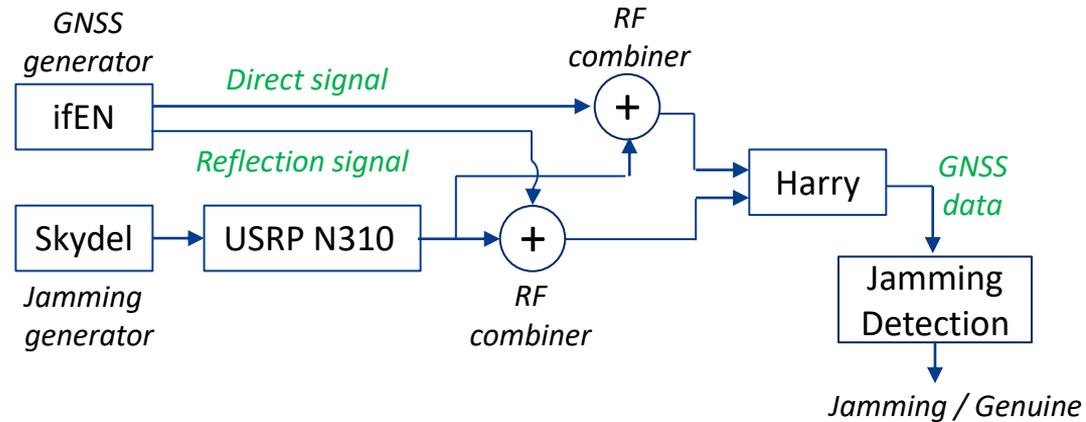


- GNSS data recording
- Can estimate the altitude of Aircraft, UAVs, and CubeSats

- Designed, built and tested by ACSER, UNSW & General Dynamics NZ
- RF to IF conversion, ADC, navigation, Delay Doppler Map (DDM) computation



Experimental set up at ACSER's laboratory



Receiver's position (longitude, latitude, altitude): [155.87°, -34.55°, 150m]

Jammer's position (longitude, latitude, altitude): [155.87°, -34.55°, 100m]

Skydel's configuration for jamming signals

Type	Enabled	Frequency (MHz)	Power (dB)	Group	
Chirp	<input type="checkbox"/>	1575.4200	40.00	2	Bandwidth: 10 MHz, Sweep Time: 10 μ s
Pulse	<input type="checkbox"/>	1575.4200	40.00	2	Duty Cycle: 50%, Pulse Rate: 10000 Hz
AWGN	<input type="checkbox"/>	1575.4200	40.00	2	Bandwidth: 1 MHz; Seed: 2114494358
BOC	<input type="checkbox"/>	1575.4200	40.00	2	Code Rate: 1.023 MChips/s; Code Length: 1 ms; Sub-carrier Rate: 2.046 MHz; Cosine: False
BPSK	<input type="checkbox"/>	1575.4200	40.00	2	Code Rate: 1.023 MChips/s; Code Length: 1 ms;
CW	<input type="checkbox"/>	1575.4200	40.00	2	Initial Phase: 0°

↑
jamming generator can be enabled or disabled

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same frequency and power level

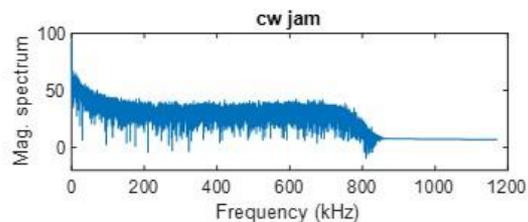
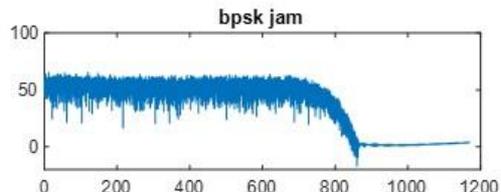
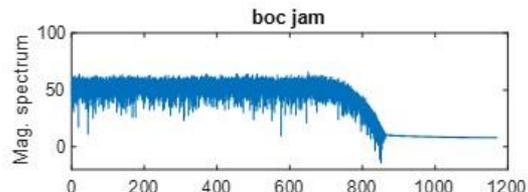
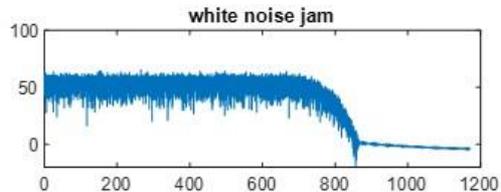
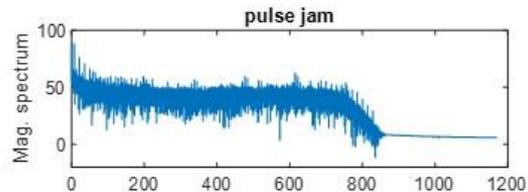
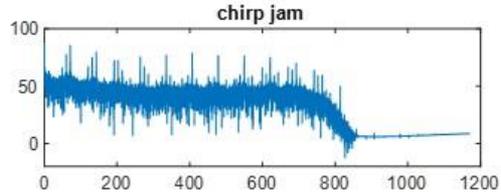
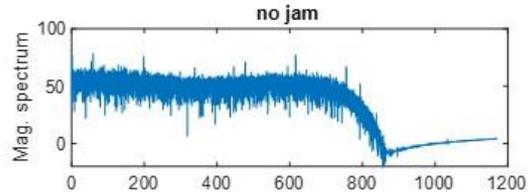
AWGN: Additive white Gaussian noise

BOC: Binary Offset Carrier

BPSK: Binary phase-shift keying

CW: Continuous wave

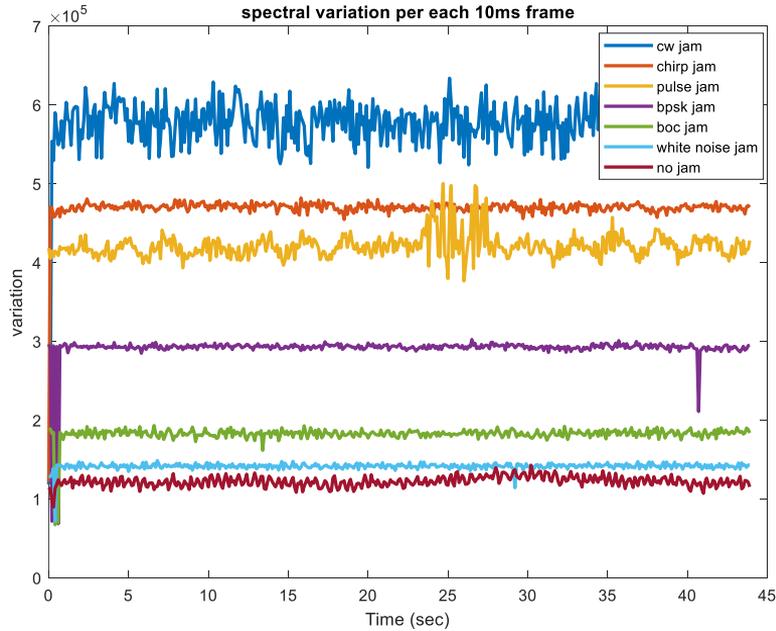
Magnitude spectrum of 10ms GNSS data frame



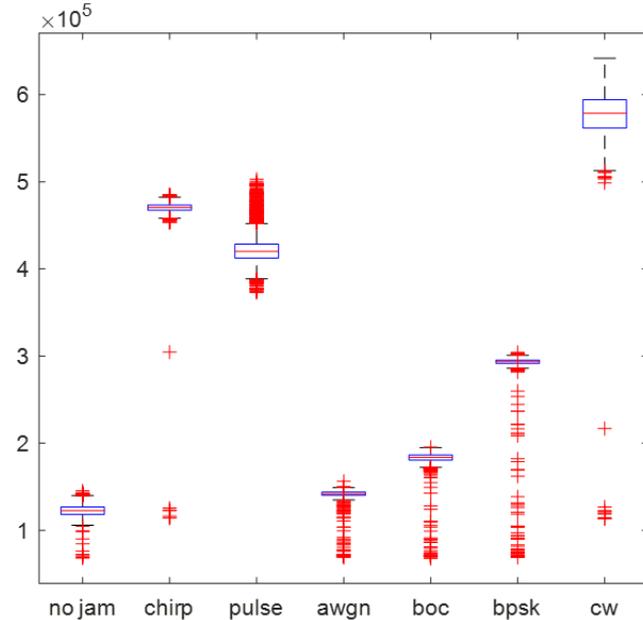
- Magnitude spectrum varies more significant under jamming corruption, especially if the jamming is not AWGN (white noise)

Spectral variation of GNSS data

Instantaneous

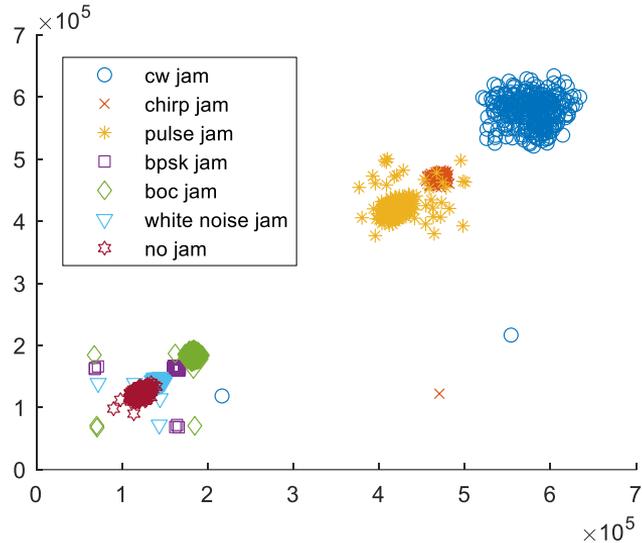


Statistical distribution



- Computed as variation of magnitude spectrum of individual 10 ms frame of GNSS data
- A potential discriminative feature for jamming detection

Scatter plot of spectral variation



- Spectral variation is a potential discriminative feature for jamming detection or classification
- More challenge to detect AWGN jamming
- Fisher's ratio is a measure for linear discriminating power

$$Fisher's\ ratio = \frac{(m_1 - m_2)^2}{v_1 + v_2}$$

where m_i and v_i are the mean and variance of the i th class

Normalized Fisher's ratio

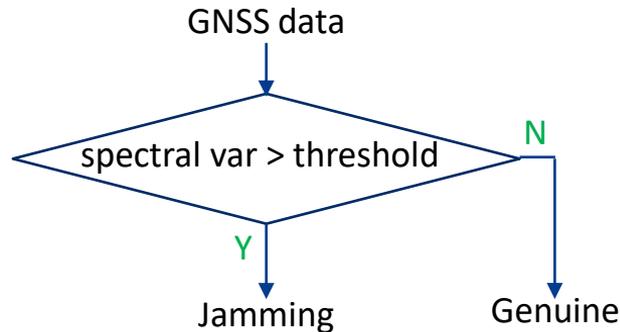
cw	chirp	pulse	bpsk	boc	awgn
1.0	0.87	0.8	0.51	0.14	0.02

- It is more challenge to detect the corruption of bpsk, boc, and especially awgn jamming

Proposed jamming detection method and result

- The jamming threshold was computed as the product of the spectral variation of a genuine GNSS signal and α , a coefficient empirically selected as 1.5

$$\text{jamming_threshold} = \text{spectral_variation_genuine} * \alpha$$

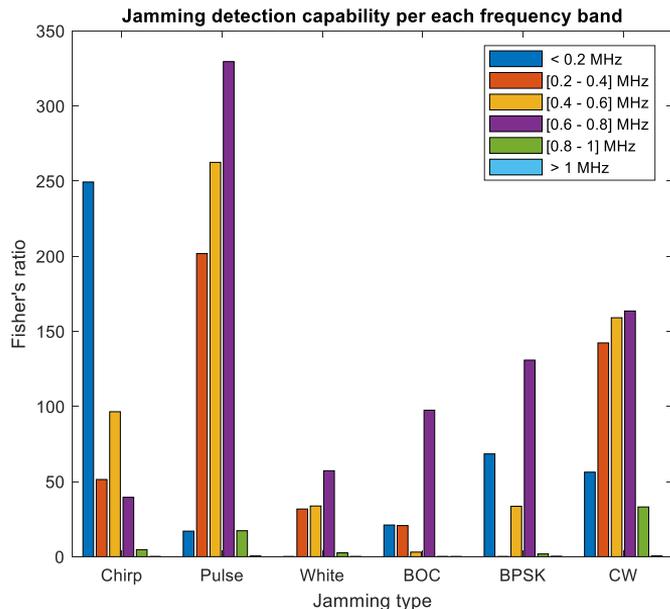
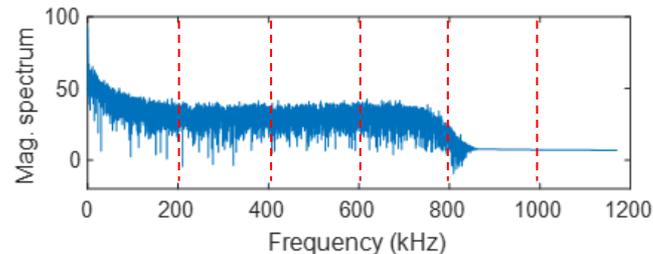


Accuracy of jamming detection

Jamming	cw	chirp	pulse	bpsk	boc
Accuracy(%)	99.89	99.93	100	99.58	98.17

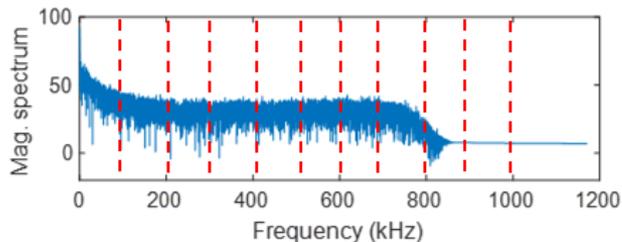
- Average accuracy across five popular jamming types is 99.5%
- For AWGN jamming, using only spectral variation may not be sufficient to detect jamming corruption hence the result was not included
- The performance of our proposed jamming detection method will be compared with that of other existing methods

Jamming discriminative information distribution

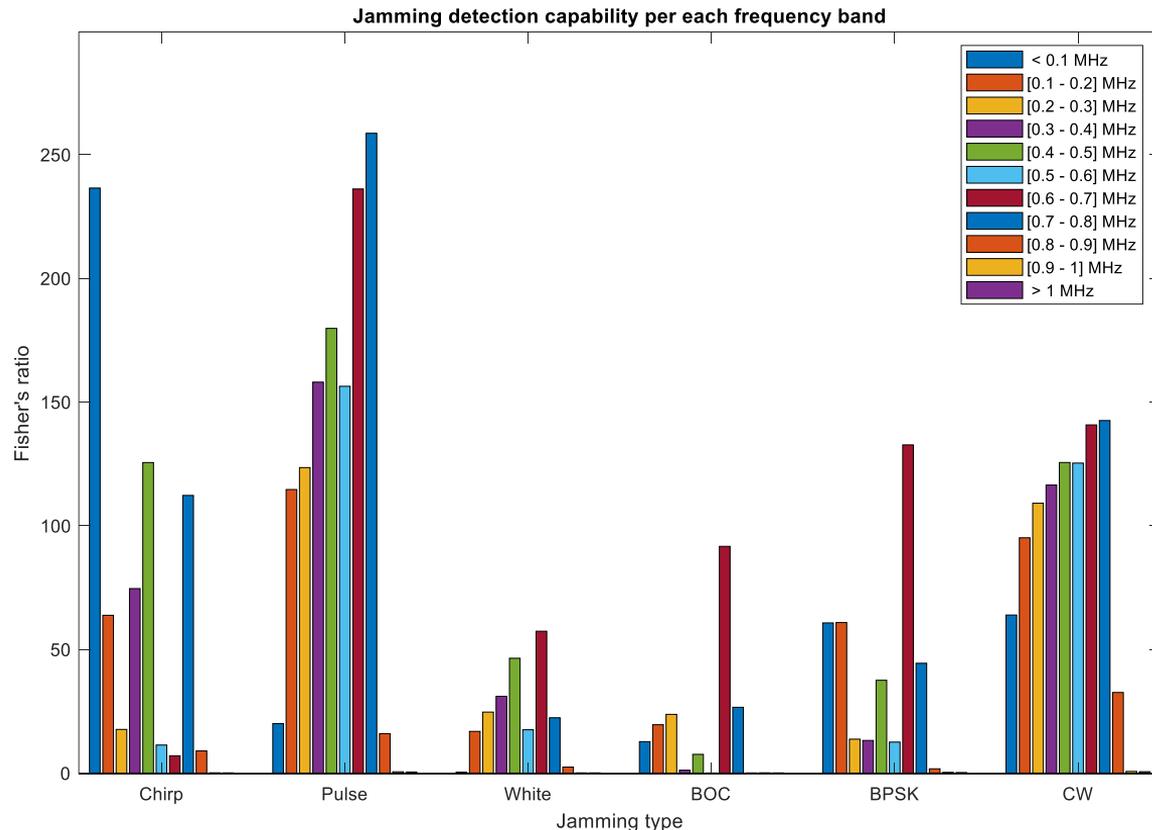


- Jamming discriminative information not uniquely distributed across frequency bands due to the distribution of GNSS and jamming information
- A sub-band approach may be more efficient than a full-band approach for jamming detection
- Fisher's ratio was computed for each sub-band based on the spectral variation in that band
- For chirp jamming the frequency band below 200 kHz is most important
- For pulse, awgn, boc, bpsk, and cw the frequency band from 600 to 800 kHz is the most important
- Information beyond 800MHz is negligible

Jamming discriminative information distribution



- Experimental result with 100 kHz subband approach is highly consistent with that of 200 kHz subband



- A subband approach and method to emphasizing feature in frequency band containing more jamming discriminative information will be investigated for jamming detection

Conclusions

- An GNSS receiver system under jamming corruption was successfully established at ACSER's laboratory based on our GNSS simulators, equipment and payload.
- Our proposed jamming detection method based on spectral variation of GNSS signal produced accurate result when testing with different popular types of jamming.
- The implementation of our method based on spectral variation is simpler than other existing methods hence requires less computation and more efficient for real time application.
- The performance of our proposed method will be more thoroughly evaluated by comparing with that of other methods in the literature.
- Jamming discriminative feature is not uniquely distributed across frequency. A subband approach employing a strategy to emphasize discriminative feature in important frequency band would be more efficient for jamming detection.