Super Resolution in GNSS coherent scattering

T. Beltramonte[1], M. di Bisceglie[1], C. Galdi[1],
I. M. Russo[1], C. Zuffada[2]

[1]Università degli Studi del Sannio, Benevento, Italy
[2]JPL/Caltech, Pasadena

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Purpose

Aim of the work: to gain better understanding of the signal scattered by land surface and inland water. Precisely:

- to improve resolution of GNSS-R in coherent scattering.
- to determine what is the dominant scattering regime for the observed surface.
- to optimize coherent and incoherent integration in GNSS-R signal processing.

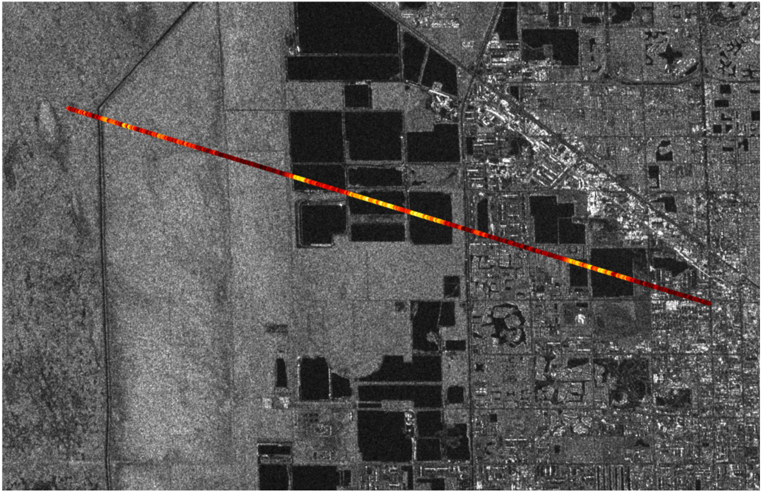
Preliminary analysis

We consider a Sentinel SAR image acquired over Florida, close to Miami Coast Buffer Water Preserve Area with superimposed CYGNSS collocated 1 ms spaced specular-point power returns.

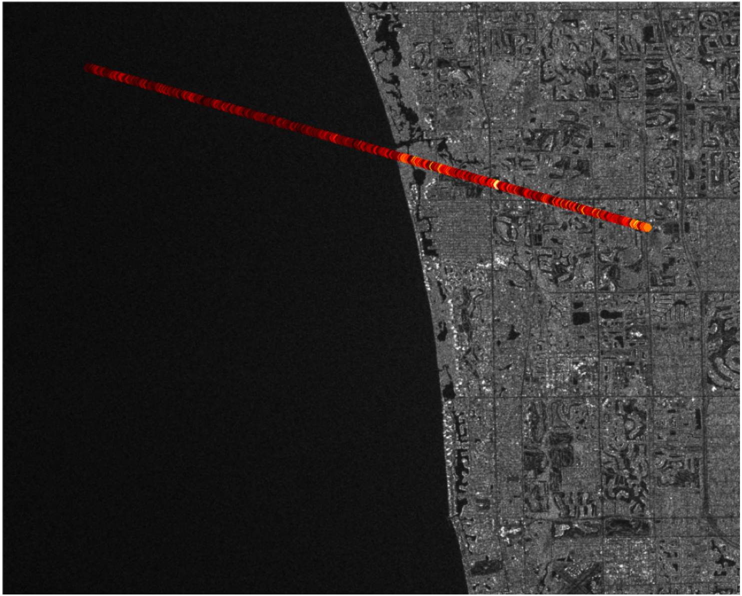
Datasets

- CYGNSS dataset: Raw-IF track acquired on January 11th 2019 at 10:47 AM, processed with a Matlab Software processor. Data are oversampled at 16.036 MHz;
- Sentinel-1 image: Acquired on January 9th 2019.

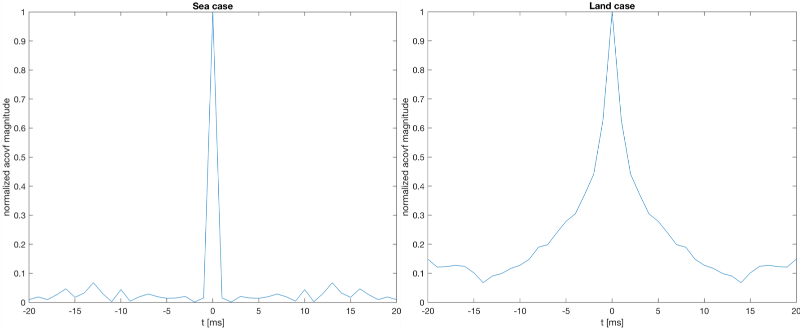
....Preliminary analysis



....Preliminary analysis



Results: Along-track correlations



Comments

- Figure highlights that 1 ms spaced reflections are highly correlated with the nature of the surface.
- The resolution is essentially determined by the electromagnetic scattering (i.e. first Fresnel zones);
- The along track specular points are finely spaced and could be used to investigate the coherence time of the surface reflections.

Resolutions

Shown in table are the sample spacing, spatial resolution and size of Fresnel zones

Sample spacing at 1 ms lag	6 m
Resolution cell size	26 km
n^{th} Fresnel Zone #	Major axis $[m]$
1	677
2	958
3	1173
4	1355
5	1515
6	1659
7	1792
8	1915
9	2032
10	2141

Superresolution method

This technique is well known in angle-of-arrival determination. It is based on subspace approach.

- We start from complex zero-Doppler 1 ms delay profiles (zero Doppler correlations)
- The autocorrelation matrix of the complex delay profiles is calculated. In this example we have used 50 delay waveforms.
- The eigenvectors span a signal subspace and a noise subspace. Arranging the eigenvalues and the corresponding eigenvectors in descending order, two subspaces are determined by splitting the eigenvalues in two classes: the first greatest D eigenvalues belongs to the signal subspace, the remaining $M - D$ to the noise subspace.

...Superresolution method

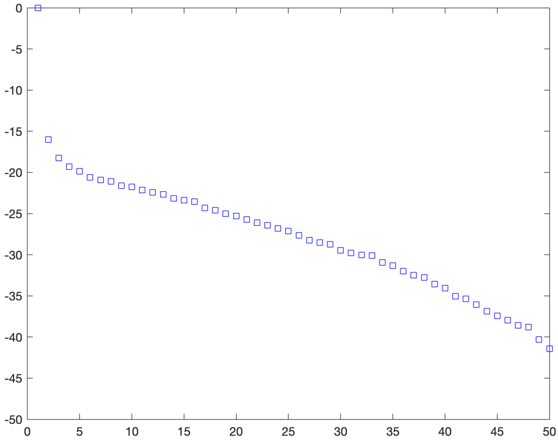
- The *Super resolution Delay Profile* (**SDP**) is calculated as

$$\mathsf{SDP}(\tau) = \frac{\mathbf{r}_c(\tau)\mathbf{R}^{-1}\mathbf{r}_c^T(\tau)}{\left|\sum_{i=D+1}^{M} \mathbf{r}_c^T(\tau)\mathbf{e}_i\right|}$$

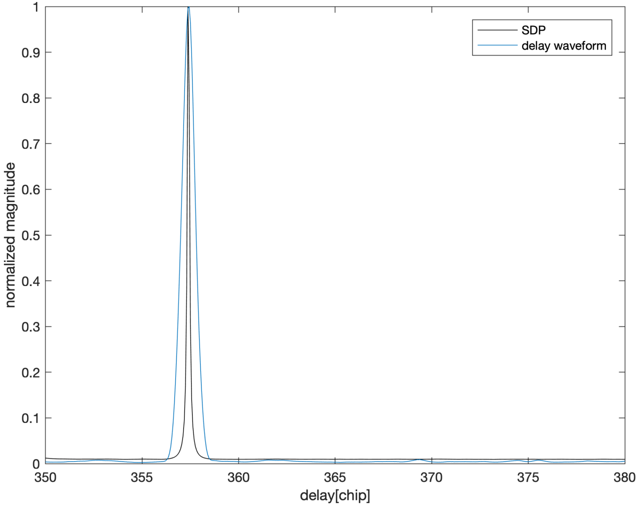
  where τ is the sample spacing, $\mathbf{r}_c(\tau)$ is the shifted autocorrelation of the PRN, $\mathbf{R}$ is the autocorrelation matrix, $\mathbf{e}_i$ are the eigenvectors.

Results: Eigenvalues

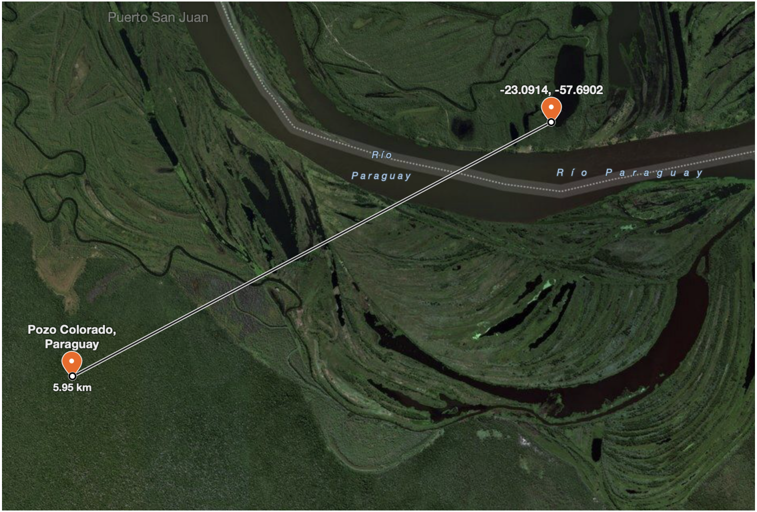
Example in case of coherent reflection.



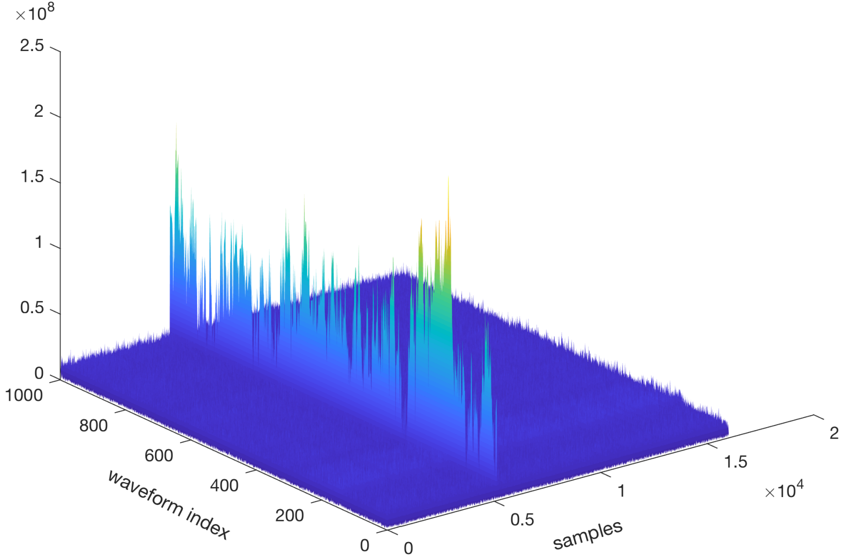
Results: Superresolution delay profile



Results: SD profile



Results: SD profile



Conclusions

- The presence of dominant eigenvalues can be used to determine if we reflection is coherent or not.
- The number of dominant eigenvalues is tied to the size of the scattering region.
- The along track correlation can be used for optimizing the coherent and incoherent processing.

Grazie di tutto