Ionospheric scintillation diagnostics

Mariusz Pożoga

LOFAR Ionospheric Workshop, Warszawa, 2-3 June 2016
Centrum Badań Kosmicznych PAN, Warszawa, Polska

Outline

1 Definition

2 Morphology

3 Measurement

4 Summary

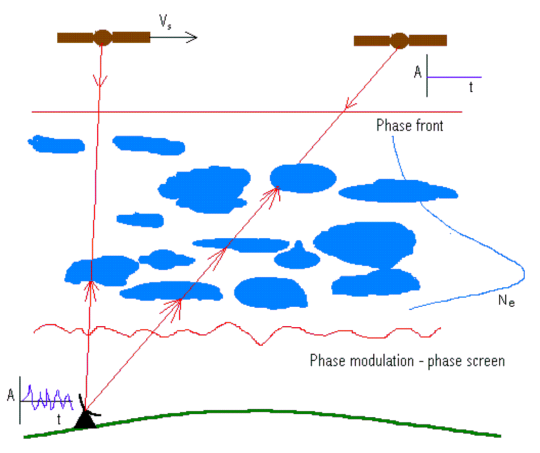
Definition

Ionospheric scintillation - fluctuation of radio signal parameters caused by refraction radio wave on ionospheric plasma irregularities. We can consider the fluctuation of amplitude, phase, receiving angle, polarization.

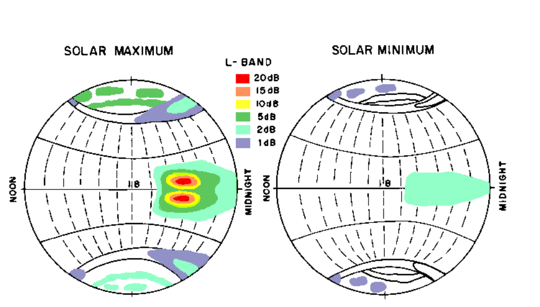
Definition

Ionospheric scintillation - fluctuation of radio signal parameters caused by refraction radio wave on ionospheric plasma irregularities. We can consider the fluctuation of amplitude, phase, receiving angle, polarization.
Problems: some of fluctuation only look like ionospheric scintillation - effect of antenna pattern, signal reflection, scintillation origin.

Formation mechanism



Morphology


SOLAR MAXIMUM
SOLAR MINIMUM
L- BAND
20dB
15dB
10dB
5dB
2dB
1dB
NOON
MIDNIGHT
18
NOON
MIDNIGHT
18

Scintillation parameters

- Scintillation index and r.m.s. phase

$$S_4 = \sqrt{\frac{< I^2 > - < I >^2}{< I >^2}}$$
$$\sigma_\phi = \sqrt{< \phi^2 > - < \phi >^2}$$

Strength and morphology of irregularities

- Phase scintillation spectrum - Shape of the irregularity spectrum from V_0/f_{min} down to V_0/f_{max} where f_{min} and f_{max} are the minimum and maximum observed frequencies
- Peak ant the Fresnel frequency of the amplitude spectrum - Scan velocity V_0 and if the scan velocity is known - the irregularities' transverse drift velocity or a distance to the irregularity slab

Measurement

- High frequency part of the amplitude scintillation - Shape of the irregularity spectrum at scale size form just above the Fresnel size down to V_0/f_{max}
- Behavior of the low frequency part of amplitude spectrum - Irregularity axial ration
- Mutual coherence function - Variance of the electron density fluctuation integrated over the propagation path and the other scale of turbulence (provided the scan velocity in known)
- Spaced-receiver correlation analysis - Average transverse drift velocity, its variance and irregularity axial ratio

Signal sources

- Radio sources
  - week signal
  - wide band
  - unknown signal
- Beacon signal
  - strong signal
  - well defined
  - narrow band
- GPS
  - well defined signal
  - high frequency (scintillation strength $\sim \lambda^{1.5}$)
  - not direct measurement

Spectral analysis

Signal spectrum:

$$w(f) = Tf^{-p}$$

Phase variance:

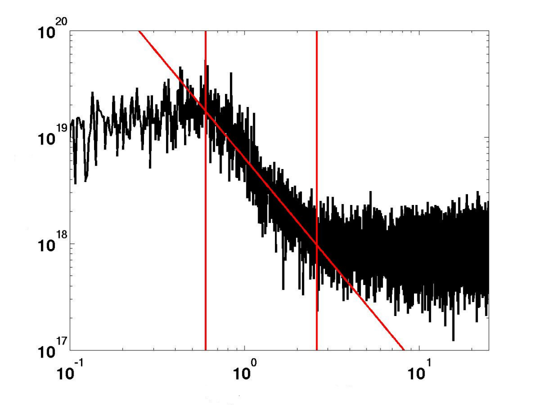
$$\sigma_\phi^2 = 2T \int_{1/\tau_c}^{\infty} f^{-p} = \frac{2T\tau_c^{p-1}}{p-1},$$

Spatial-frequency relation:

$$f_F = \frac{v_{eff}}{\sqrt{2\lambda z_R \sec\theta}}$$

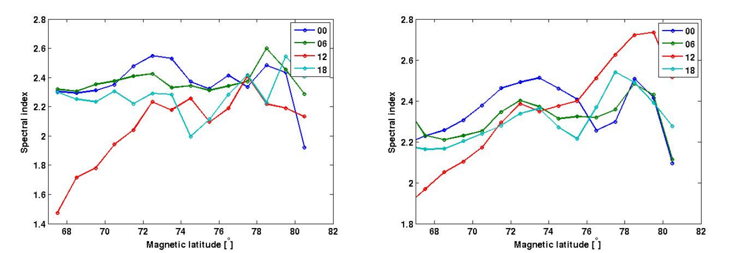
where $z_r = \frac{z_i z_s}{z_i + z_s}$

Example - spectrum



$p = 1.973$, $T = 6.3 * 10^{18}$ Range: $0.59 - 2.5$Hz

Examples - spectral index



Spectral index over Hornsund at summer, low and high activity.

Spaced-receiver

Use multiple receiver we can compare signal coming to us trough different path. Assuming static pattern moving over receiver we can calculate some parameter as velocity and irregularity shape.

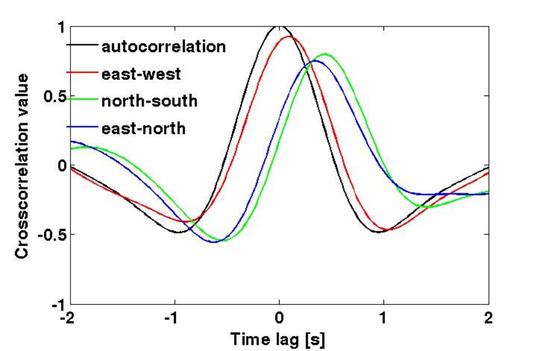
Spaced-receiver

Use multiple receiver we can compare signal coming to us trough different path. Assuming static pattern moving over receiver we can calculate some parameter as velocity and irregularity shape.
Crosscorrelation function:

$$\rho(\xi, \eta) = \rho(\mathrm{A}\xi^2 + \mathrm{B}\eta^2 + 2\mathrm{H}\xi\eta)$$

- Cross spectral analysis
  - information about scale or irregularities
- Correlation analysis
  - simple relationship between parameter or cross crorelation function and drift/irregularity parameter
  - lack of information about scale of irregularities

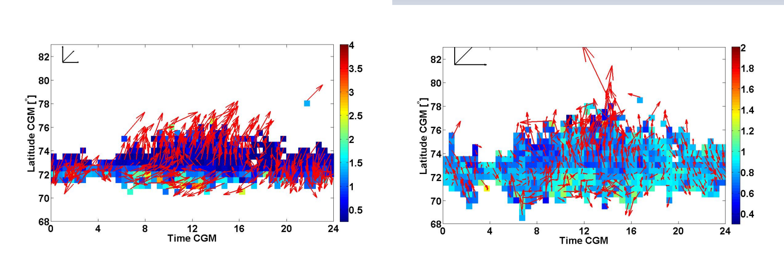
Example of crosscorrelation function



Problem:

- strong filtration needed
- no correlation between signal

Examples - drift pattern



Amplitude and phase drift pattern during high activity.

Summary

Summary

- Low frequency - stronger scintillation

Summary

- Low frequency - stronger scintillation
- Multiple antenna - anisotropy measurement

Summary

- Low frequency - stronger scintillation
- Multiple antenna - anisotropy measurement
- Middle latitude region

Question

- What parameter we can measure using LOFAR?
- How fast we can measure amplitude of radio source using 1 station?
- Is possible to get any information about ionosphere from pulsar observation?

Thank You