Estimation of the Atmospheric Refractivity using a Polarimetric Weather Radar in C-Band

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Abstract

- The aim of this work is to estimate the atmospheric refractivity and to analyse its statistical properties. Refractivity estimates are obtained from phase measurements of the radar response to stationary targets. The required data are obtained with the polarimetric weather Radar in C-Band of Meteogalicia.

Introduction

- The atmospheric refraction is the anomalous propagation phenomenon that describes how the electromagnetic waves path departs from a straight line through the air due to variation of the temperature, the water vapor pressure (humidity) and the air pressure. It is obtained by estimating the index of refraction n. Near of surface, the index of refraction is slightly higher than 1 and its variations are on the order 10^{-5}. Consequently, a derived parameter, referred to as refractivity N, is often used and it is defined as

$$N = 10^6(n-1)$$

- The refractivity is related to meteorological parameters through the following expression

$$N = 77.6\frac{p}{T} + 3.73\ 10^5\frac{e}{T^2}$$

where p is the air pressure (hPa), T is the absolute air temperature (K) and e is the water vapor pressure (hPa).
- Knowledge of temporal and spatial variations of the refractivity in the lowest part of the atmosphere is of importance in numerous fields, such as meteorology and electromagnetic wave propagation.
- In order to estimate the refractivity, the C-band polarimetric weather radar of Meteogalicia located at Monte Xesteiras (Galician Region, Spain) will be used to implement that algorithm.

Methodology

- Stationary targets will be found through analysis of the phase variations of the received echoes. Stationary targets (Gates #38-#42) will exhibit highly correlated phases in time while non-stationary targets (Gate #43) will present completely uncorrelated phases in time.

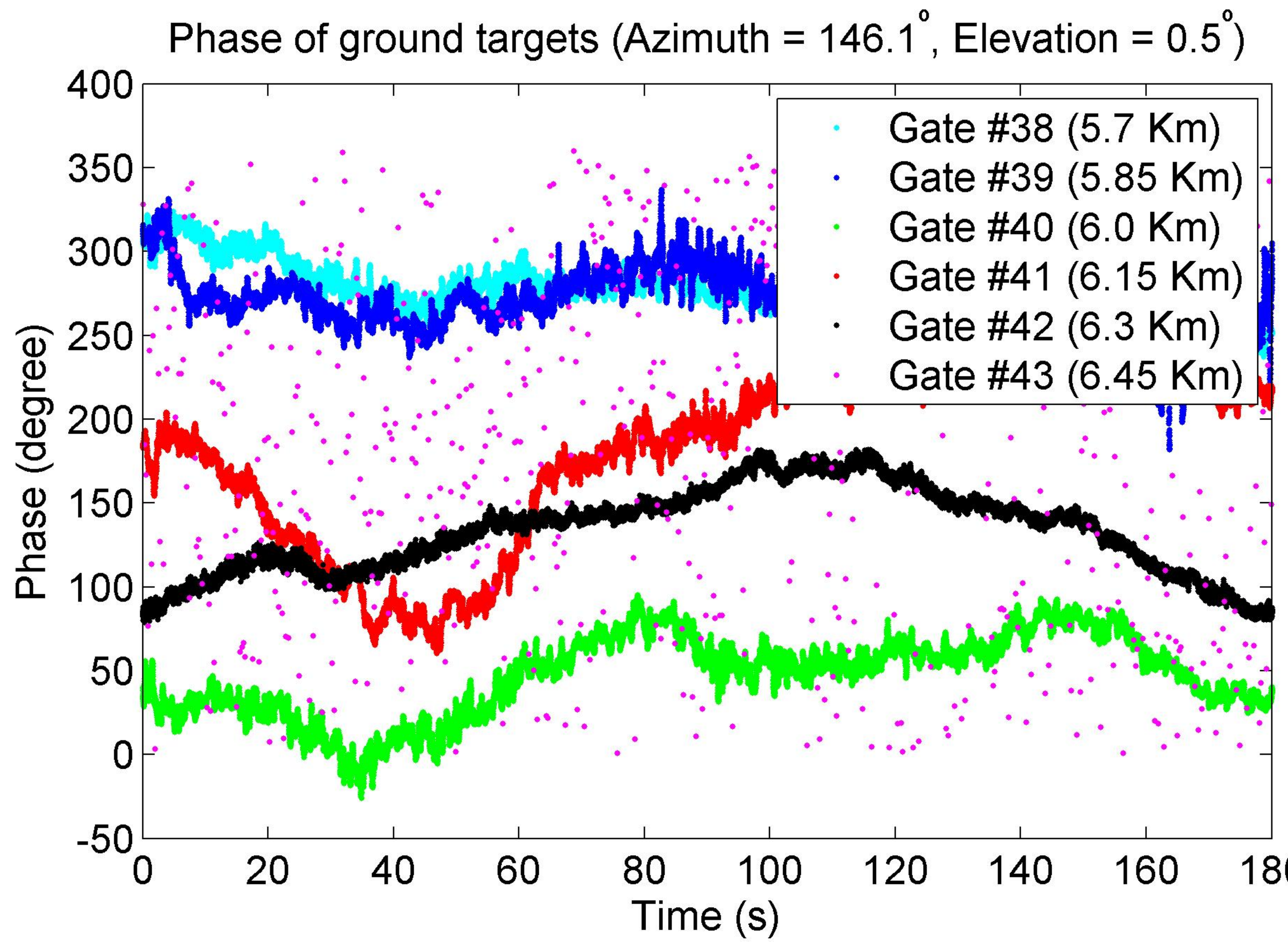

Figure 1: Phase of grounds targets

- Obtaining of the phase of two stationary targets which are aligned with the radar and separated a small enough range $\Delta r = r_1 - r_0$ for an instant of reference time t_0.

$$\phi(r_0,t_0) = \frac{4\pi f}{c} n_0(t_0) r_0 + \phi_{B1}$$

$$\phi(r_1,t_0) = \frac{4\pi f}{c}\left[n_0(t_0)r_0 + n_1(t_0)\Delta_r\right] + \phi_{B2}$$

- Obtaining of the spatial phase variation between two stationary targets.

$$\phi(r_0,t_0) - \phi(r_1,t_0) = \frac{4\pi f}{c} n_1(t_0)\Delta_r + \phi_{B1} - \phi_{B2} = \Delta\phi(t_0)$$

- Repeating the previous equations for a second scan in other instant of time t_1.

$$\phi(r_0,t_1) - \phi(r_1,t_1) = \frac{4\pi f}{c} n_1(t_1)\Delta_r + \phi_{B1} - \phi_{B2} = \Delta\phi(t_1)$$

- Obtaining of the temporal phase variation between two instants of time.

$$\Delta(\Delta\phi) = \Delta\phi(t_1) - \Delta\phi(t_0) = \frac{4\pi f}{c}\left[n_1(t_1) - n_1(t_0)\right]\Delta_r$$

Results (Theoretical)

- The refractivity variation derived from the phase variation is given by

$$\Delta N_1(t_1,t_0) = \left[n_1(t_1) - n_1(t_0)\right]10^6 = \frac{c}{4\pi f \Delta_r}10^6\Delta(\Delta\phi)$$

- Recall that on the one hand, it is desirable to choose Δr as long as possible to remove noisy term and to obtain an accuracy estimate of the refractivity variation.
- But on the other hand, the phase variation between successive spatial and temporal samples can only be measured within the interval $[0, 2\pi]$ and an aliasing problem (unwrapping) will happen if the phase variation exceeds this interval, leading to an incorrect estimation of the refractivity. One way to mitigate this unwrapping is to limit Δr. Therefore, the maximum unambiguous estimate of the refractivity variation is limited to

$$\Delta N_{Max} = \frac{c}{2f\Delta_r}10^6$$

Results (Figure)

- The temporal refractivity variation may be caused by variations of the meteorological parameters (propagation delay), the shape of the target and how it is illuminated by the radar beam while the spatial refractivity variation is due mainly to the quality of the target, the range to the radar and the increase of its height about radar level.

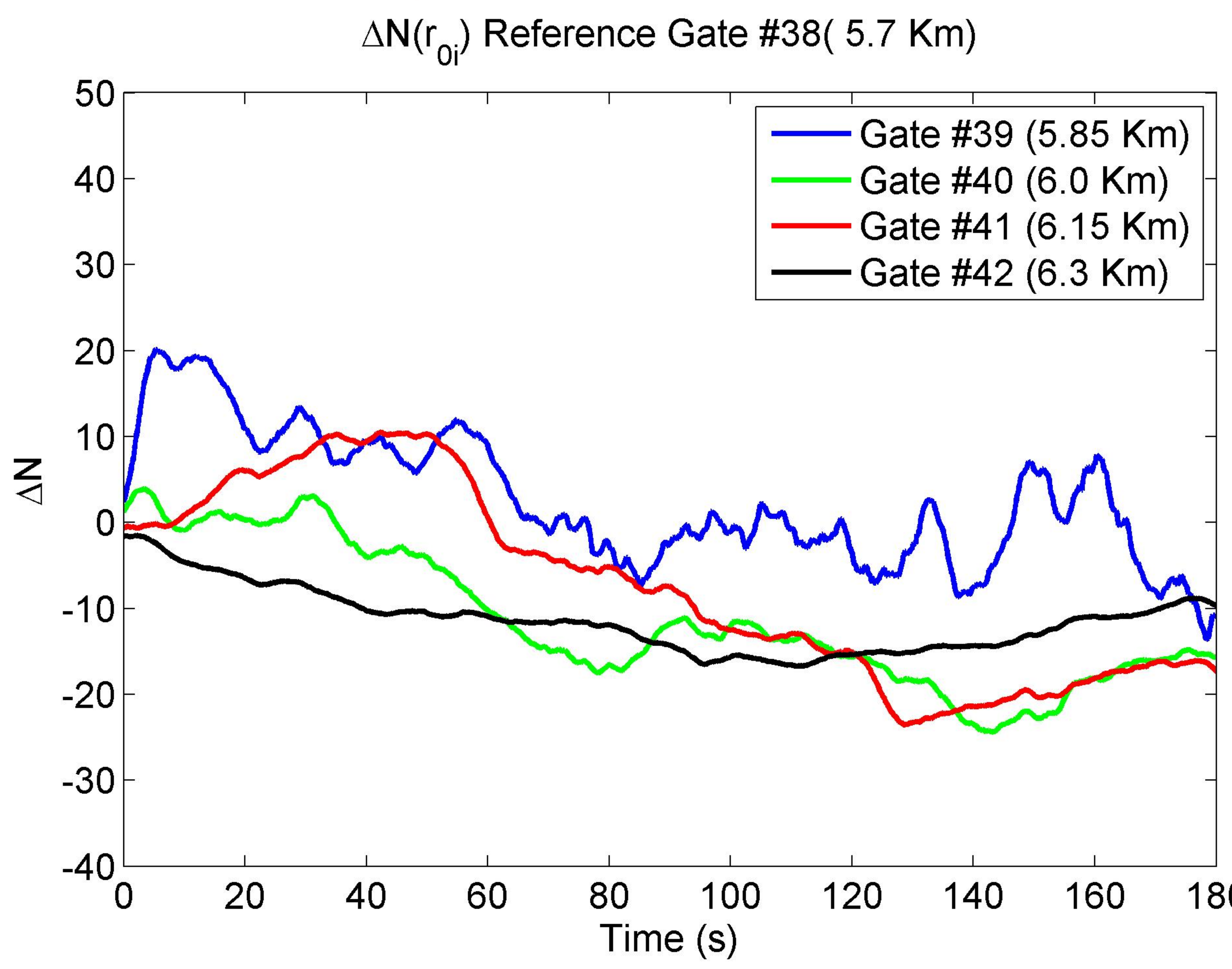

Figure 2: Average Refractivity Variation between stationary targets

Future work

- To analyze the quality of a target from the phase and the received power of their echoes to identify meteorological changes about each profile.
- So far, the vertical refractivity variation is not analyzed since the radar and the stationary targets are aligned at the same height. However, over complex terrain, this alignment is rarely with natural targets and the phase difference due to the spatial variability of the vertical structure will be higher than due to the horizontal variability. Hence, in the future, different targets heights are considered to estimate the refractivity variation.
- Considering the statistical properties of the different targets returns, the statistical characteristics of the estimated refractivity will be analyzed.

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