SNOW DEPTH ESTIMATION BASED ON MULTIPATH PHASE COMBINATION OF BDS TRIPLE-FREQUENCY SIGNALS

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Abstract

Snow depth measurements are essential both to study snow water equivalent and to predict drought, flooding, and water availability. This study investigates on snow depth measurements using linear phase combination of BDS triple-frequency signals (B1,B2,B3). This phase combination is geometry free and is not affected by ionospheric delays. Satellite signals collected by GNSS receiver of Trimble R9 was used to evaluate the method. The results demonstrate that there exists good agreement between BDS reflectometry based snow depth estimates and the ground-truth measurements.

Theoretical Modeling

- The multipath contribution to the phase (mm) :

$$\delta\phi(\theta;\alpha;H;\lambda) = \frac{\lambda}{2\pi}\cdot tan^{-1}\left[\frac{\alpha sin\left(4\pi\frac{H}{\lambda}sin\theta\right)}{1+\alpha cos\left(4\pi\frac{H}{\lambda}sin\theta\right)}\right]$$

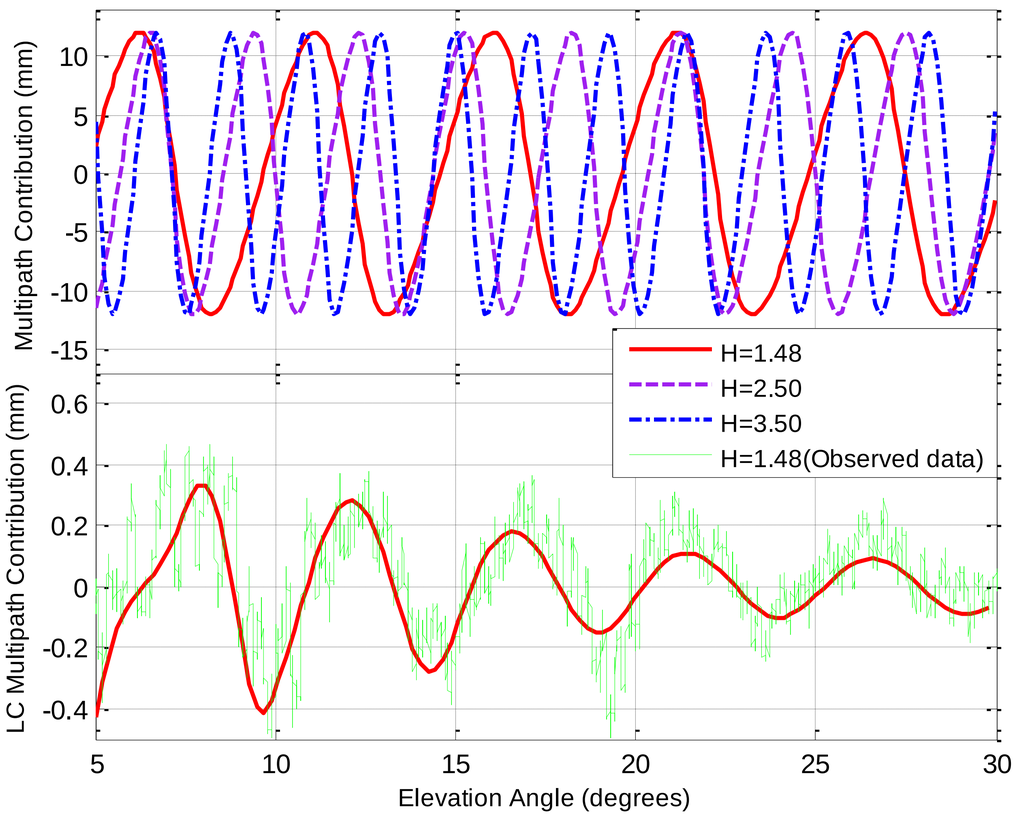
  - θ , the satellite elevation angle
  - α , the attenuation of the reflected signal
  - H, the antenna height
  - λ, the wavelength of the BDS B1, B2, or B3 band signal
- The triple-frequency phase linear combination (LC) of BDS signals:

$$k_1\widetilde{\phi_1} + k_2\widetilde{\phi_2} + k_3\widetilde{\phi_3} = k_1\delta\phi_1 + k_2\delta\phi_2 + k_3\delta\phi_3$$

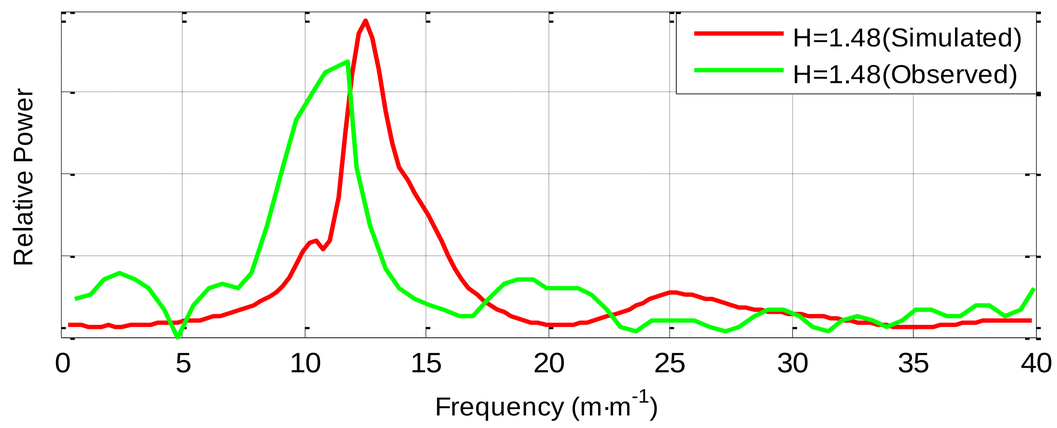
  - $\widetilde{\phi_i}$, the carrier phase observations
  - k_i, the constants derived from the values for λ_1 , λ_2 , and λ_3 :

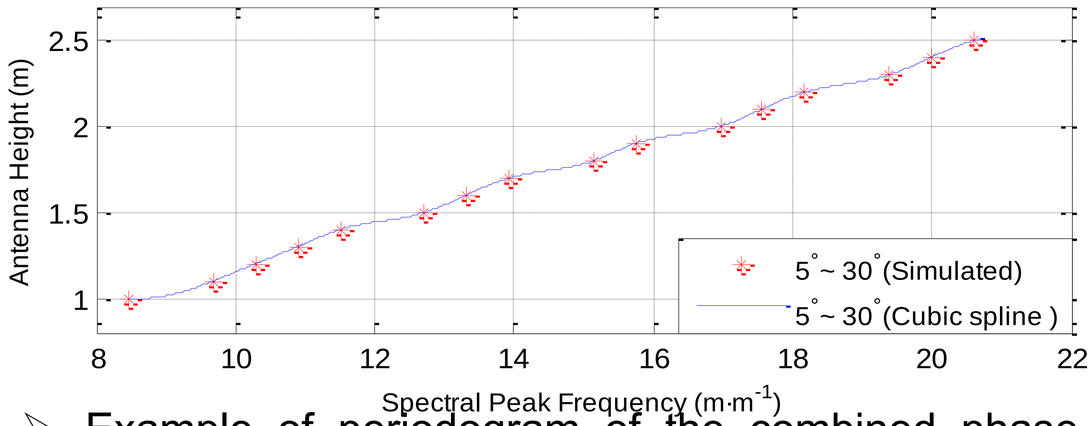
$$k_1 = (\lambda_3^2 - \lambda_2^2)$$
$$k_2 = (\lambda_1^2 - \lambda_3^2)$$
$$k_3 = (\lambda_2^2 - \lambda_1^2)$$

- Frequency analysis of the combined phase
- Conversion from peak frequency to antenna height



➢ Reflection excess phase of B2 signal under three antenna heights (upper) and linear combination phase simulated and observed under one antenna height (lower).





➢ Example of periodogram of the combined phase (upper). Relationship between antenna height and spectral peak frequency (lower).

Estimation Method

- Establish functional relationship between antenna height and spectral peak frequency of the combined phase
- Perform spectral analysis of the combined phase measurements and obtain the spectral peak frequency
- Retrieve antenna height with theoretical model, and then determine snow depth

Experimental Results & Summaries

- Experiment date: January 2017
- Location: Mudanjiang, Heilongjiang Province, China
- Average STD of snow depth estimates with three satellites over 10 days is 1.8 cm
- The average estimate with three BDS satellites tends to be smaller than the ground-truth data by 2.8 cm
- Phase combination of BDS triple-frequency signals is an effective snow depth estimation method