Estimation of Tree Height Under Transmission System using Interferometric SAR (InSAR)

Tamer ElGharbawi[1*], Junichi Susaki[2], Kamolratn Chureesampant[3], Chomchanok Arunplod[4], Juthasinee Thanyapraneedkul[5], Thip Limlahapun[6]

[1]Suez Canal University,
Ismailia, Egypt. tgh@eng.suez.edu.eg
[2]Kyoto University,
Kyoto, Japan. susaki.junichi.3r@kyoto-u.ac.jp
[3]Electricity Generating Authority of Thailand,
Nonthaburi, Thailand. kamolratn.c@egat.co.th
[4]Srinakharinwirot University,
Bangkok, Thailand. chomchanok@g.swu.ac.th
[5]Thammasat University,
Bangkok, Thailand. yok_japan@yahoo.com
[6]Kasetsart University,
Bangkok, Thailand. thip.limlahapun@gmail.com

Abstract: In this research, we are estimating trees heights around the power transmission system in Thailand using polarimetric interferometric synthetic aperture radar (Pol-InSAR). The results of this research should facilitate hazards management and mitigation for power transmission lines by employing the regularly acquired spaceborne SAR images. Estimating tree heights using spaceborne Pol-InSAR is very challenging due to serval issues. First, the very small vertical wavenumber makes the system very sensitive to any phase change or phase noise, second, the repeat pass system is inertly affected by temporal decorrelation which can be very significant for forest regions due to tree movements with wind or by simply growing.

We study tree heights in parts of Thailand using two Full-Pol ALOS PALSAR-2 L-band images and employing the Random Volume over Ground (RVoG) model, which assumes the canopy part as a layer of randomly distributed particles characterized by an exponential decay of the transmitted radar power. RVoG models the relation between the complex coherence and the radar scattering center using $\left[\gamma = e^{j\varphi_o}\frac{\gamma_v+\mu}{1+\mu}\right]$, were φ_o is the ground phase and μ is the ground contribution. The pure volume coherence $\left[\gamma_v = \frac{p_1(e^{p_2 h_v}-1)}{p_2(e^{p_1 h_v}-1)}\right]$ is modeled by relating tree heights (h_v) to decay rate (σ) and vertical wavenumber (k_z) using $p_1 = \frac{2\sigma}{\cos\theta}$ and $p_2 = p_1 + jk_z$. This model employs the

relation between the radar signal polarimetry and the location of the corresponding scattering center to estimate the height of the highest scattering center assuming to be the top of the canopy layer.

We used two L-band ALOS-PALSAR2 images acquired on 18th April 2016 and 13th June 2016 to estimate the complex coherence of our study area using different polarizations e.g. HH, HV, VV, HH-VV.. etc. However, in our study regions, we found the coherence values are very low due to temporal decorrelation. This prevented estimating the ground phase and canopy (pure volume) complex coherence by fitting a line in the complex plane. Therefore, we assumed the pure volume coherence to be the HV coherence, and the ground coherence to be the HH coherence. Then, we subtracted the ground phase from the canopy phase by complex conjugate the HV and HH complex coherences. The resulting phase is a representation of the canopy height, however, we found that it is affected by a ramp bias, therefore, we modeled and removed a surface of the first degree from the final phase to reduce the ramp effect. To estimate the final canopy height, we calculated the vertical wavenumber and incident angle for our study area and created a lookup table relating complex coherence to tree heights (h_v) and decay rate (σ).

By comparing the final results with LiDAR data, we found several issues preventing accurate canopy height estimation in our study region. First of all, the very low coherence values prevented dense spatial estimation as we use a coherence threshold of 0.25. Second, the rapid change in dielectric constant due to the heavy cloud cover and the rain season reduced the accuracy significantly. Third, the rough topography with slopes ranging from 5^o to 70^o affected the performance of the RVoG model. The steep slopes cause different canopy heights and ground radar responses to be mixed within a single pixel which makes identifying the actual canopy height very challenging. An additional source of error is the agriculture fields around the power transmission lines which are permitted for selected crops. The crops change the radar responses between acquisitions significantly due to, growing, irrigation, and harvesting. We believe that agriculture is the main source for phase decorrelation in our study regions. To evaluate the results, we isolated the pixels with an error of less than 2 meters, and we found that these pixels have low slopes rate and low temporal decorrelation. We found that estimating canopy height with high accuracy depends on the nature of the study area and the observation system characteristics. We believe that using repeat pass spaceborne L-band SAR images can be used to estimate canopy heights but with caution to the sources of phase decorrelation. We recommend modeling ground slopes and selecting the SAR images within the dry season to reduce the dialectic constant effect, especially in tropical regions. We believe that bistatic observations are the best solution to eliminate temporal phase decorrelation and provide regular canopy height monitoring.

Keywords: Pol-InSAR; Canopy Height; RVoG; Thailand.
Acknowledgment: We thank the Electricity Generating Authority of Thailand (EGAT) for funding this research.