Comparison of Phase Calibration methods for TomoSAR Imaging and Applications over Forested Areas

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Abstract

Synthetic aperture radar tomography (TomoSAR) is a three-dimensional imaging technique developed on the basis of multi-baseline InSAR. In the imaging and applications based on TomoSAR over forested areas, proper phase calibration is necessary to avoid severe sidelobe effects or complete defocusing, which can be caused by factors such as baseline errors and changing atmospheric conditions.

In the study, we compared the calibration methods based on polynomial fitting (PF) and entropy minimization (EM), as well as proposed a novel approach combine the two methods. All three methods are tested based on airborne P-band MB-InSAR data, and the accuracy of the forest height extracted based on the proposed method is verified with light detection and ranging (LiDAR) data. The results indicate that the proposed approach outperforms the other two methods in term of tomography imaging and can accurately determine forest height with an accuracy of over 80%.

Methods

- **Phase calibration based on polynomial fitting (PF)**
  - The calibration method for single-baseline InSAR, can be used in the TomoSAR data based on a common primary image.
  - Isolating the phase errors based on external DEM and conducting the interferogram filter to reduce the effect of noise phase.
  - Extraction of the phase errors by polynomial fitting as follow:

$$\varphi^{PF}_{error,n}(x,r) = a_0 + a_1x + a_2x^2 + a_3xr + a_4r + a_5r^2$$

  - **Shortcoming**: The fitting ability of polynomial function and mismatch between external DEM and phase centers restrict its performance.
- **Phase calibration based on entropy minimization (EM)**
  - The EM method estimated phase errors by minimizing the entropy of tomography profile as follow:

$$\underset{\vec{\varphi}^{EM}_{error}}{argmin}\, S_2[\mathcal{P}(z_m, \vec{\varphi}^{EM}_{error})]$$

  - **Shortcoming**: The method may introduce unwanted vertical shifts in the retrieved tomograms without proper initial guessing.
- **Proposed method combining PF and EM**

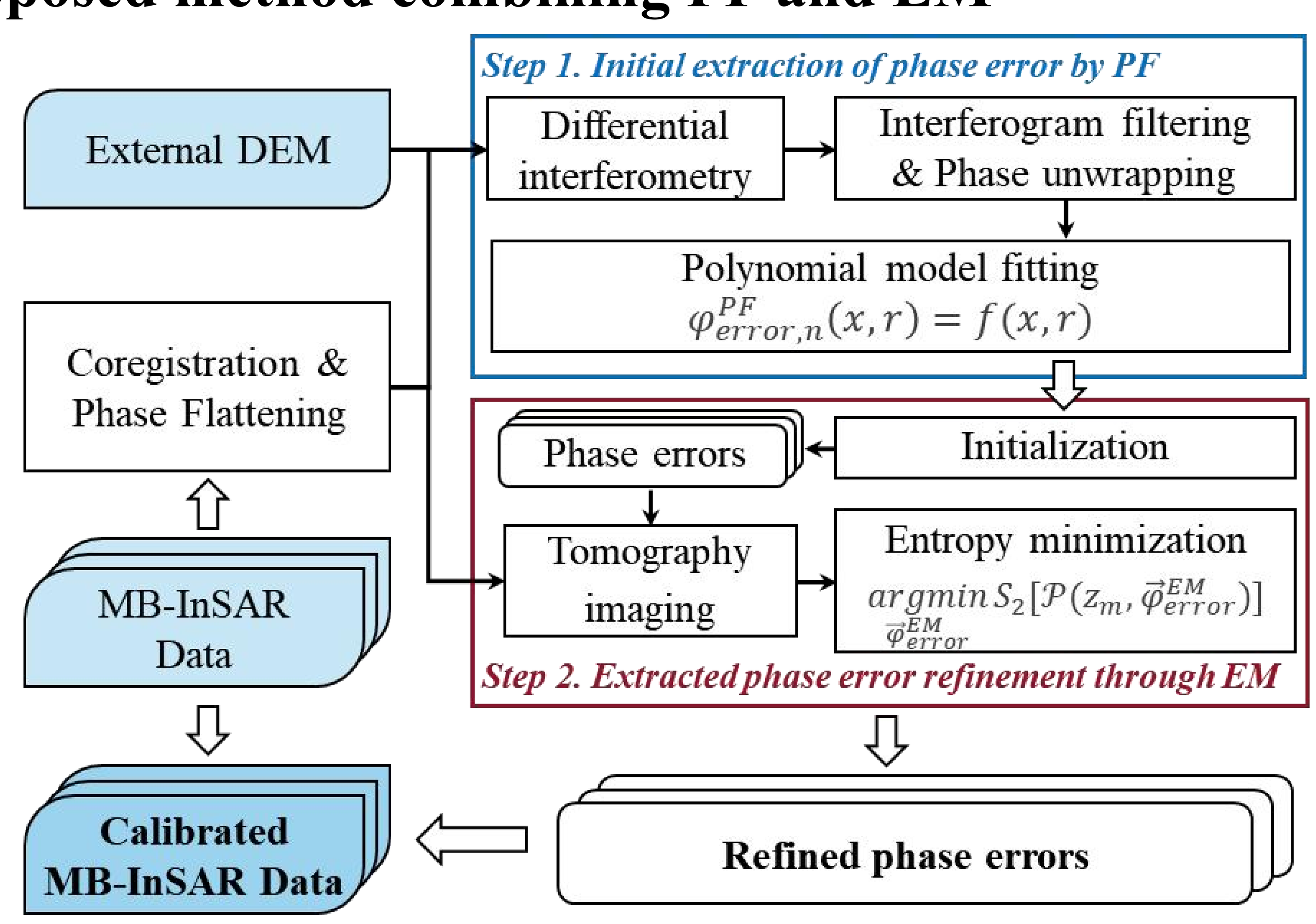
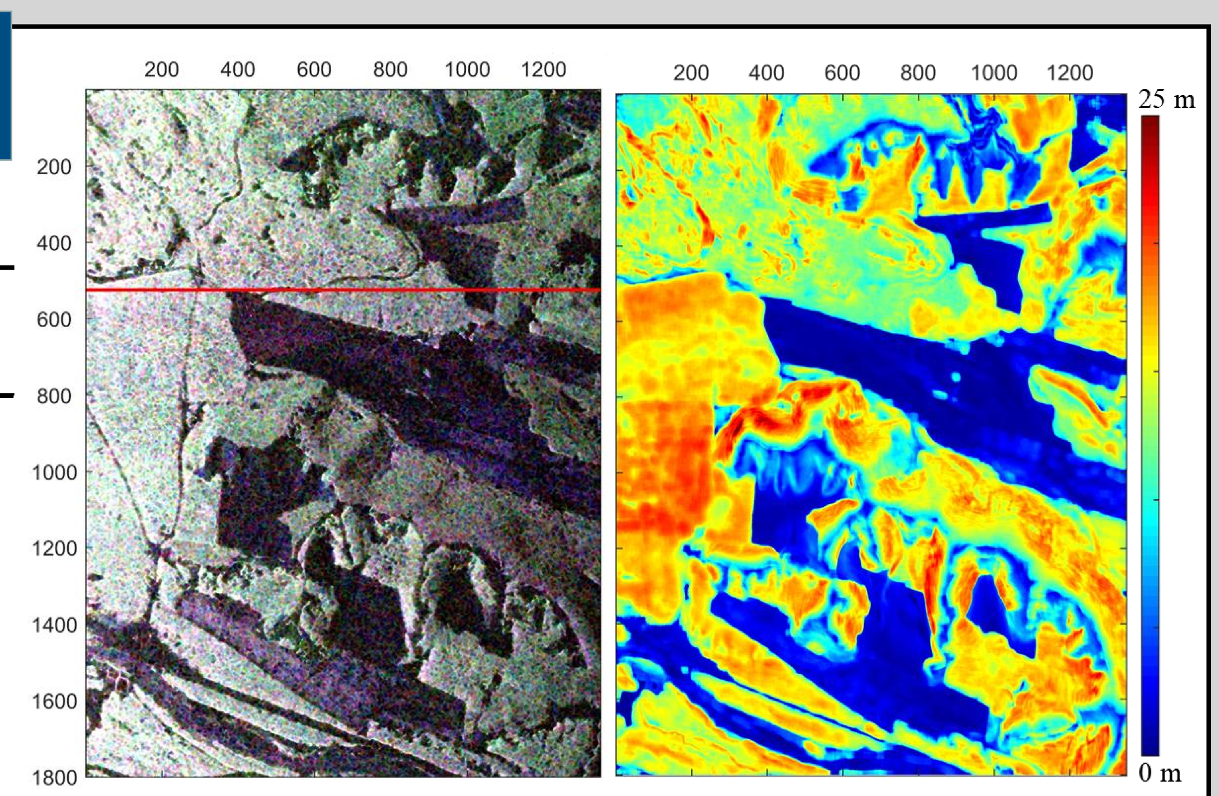


Fig. 1 Flow chart of proposed PF-EM phase calibration method

Test Data

Table.1 Parameters of test data

Parameters	Quantity
Frequency	450 MHz
Incidence angle	33° ~54°
Resolution azimuth×range	1.5×1.4 m
Baseline	[−83, −51, −21, 0, 40, 101] m

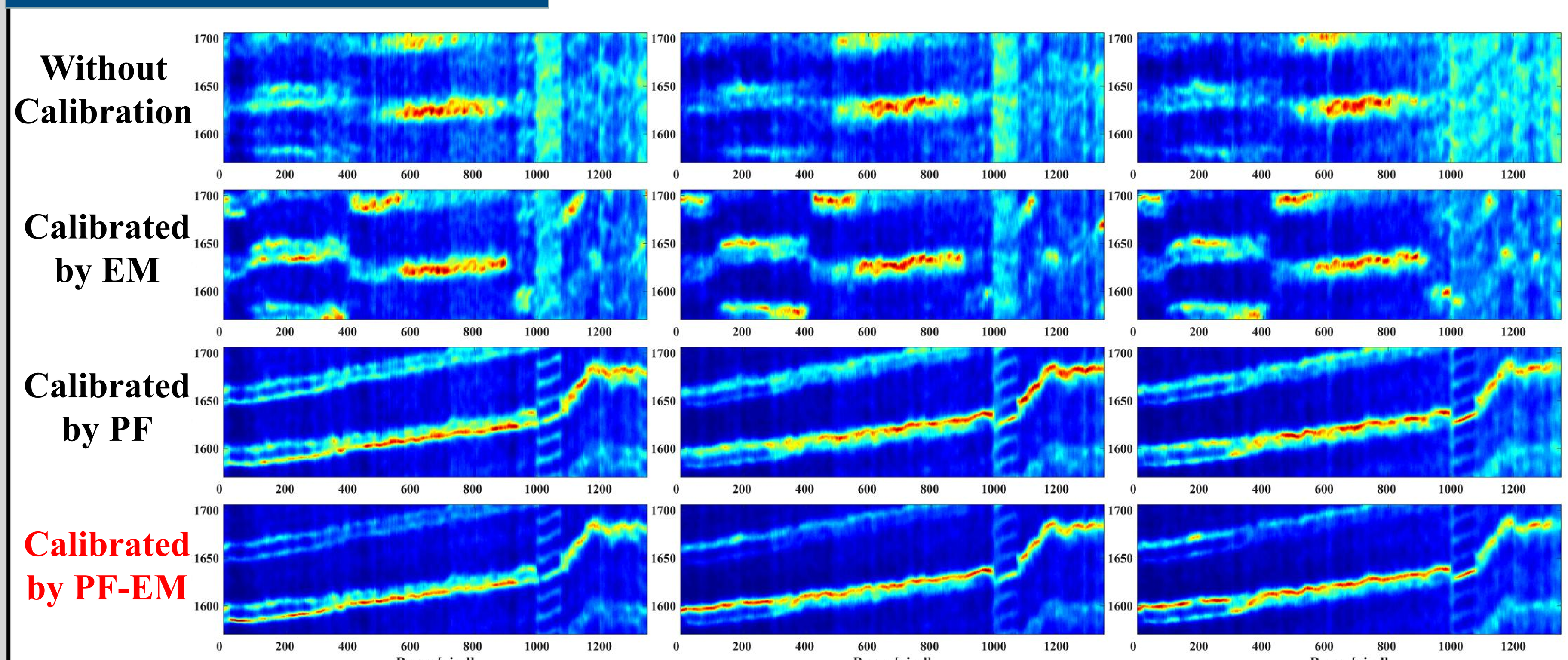


(a) Primary image (b) LiDAR CHM

Fig. 2. Test MB-InSAR data and LiDAR CHM

The test site is located in the Saihanba Forest Farm. Both coniferous forest and broad-leaved forest are distributed in the area. The test P-band MB-InSAR data was acquired on Oct. 29, 2019, based on an airborne P-band SAR system. The initial flying height of the acquisition is about 4000 m. And the vertical distance between two adjacent observations was approximately 30 meters.

Results



(a) HH polarization (b) HV polarization (c) VV polarization

Fig. 3. TomoSAR profile of Capon based different phase calibration methods

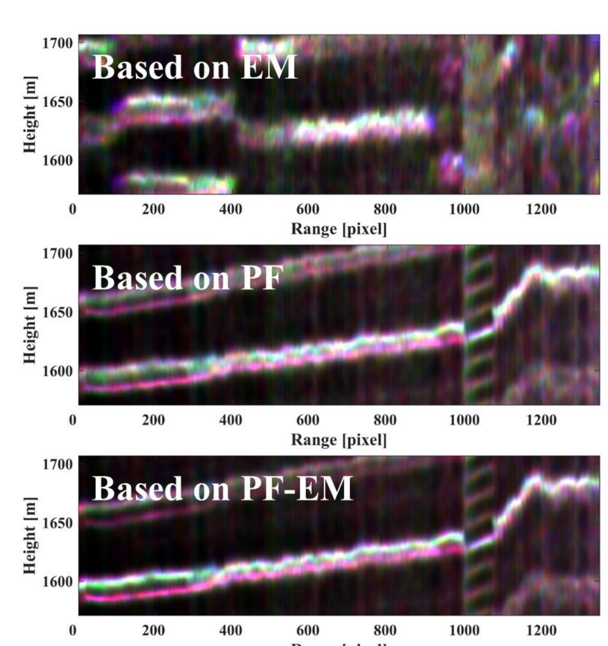
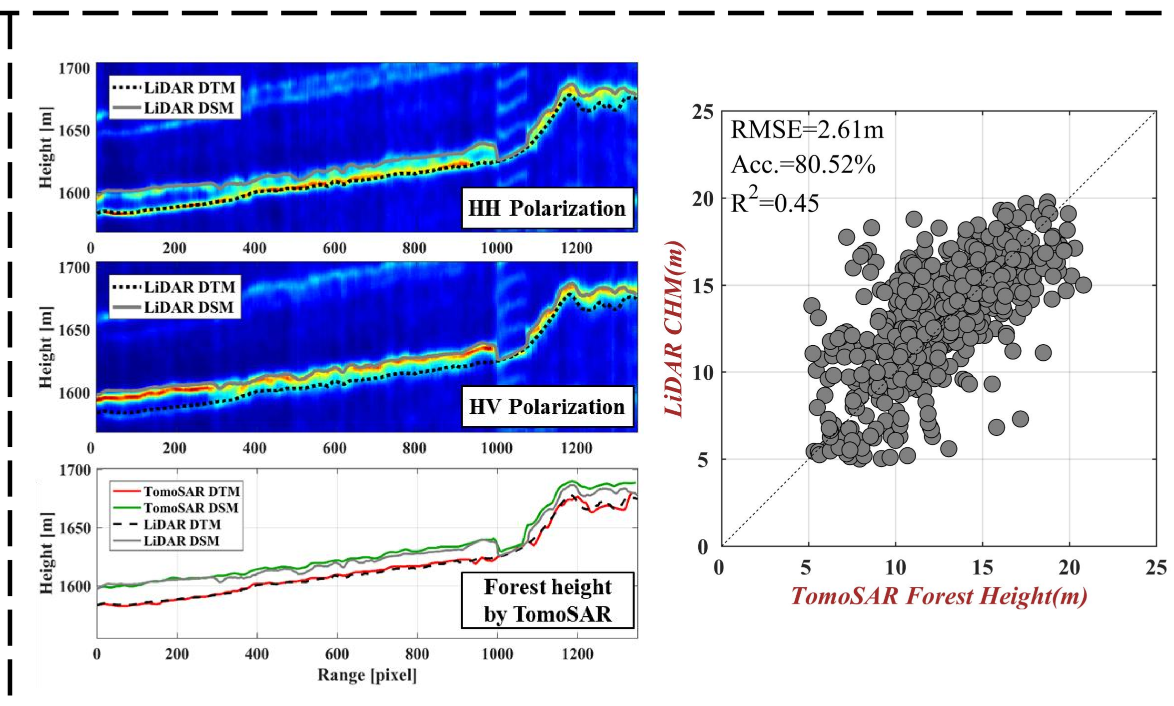


Fig. 4 Pauli RGB display of TomoSAR profile



(a) Profile with LiDAR data (b) Accuracy

Fig. 5. Forest height extraction based on proposed method

Conclusion & Disscusion

- Among three phase calibration methods, the proposed PF-EM method demonstrated the best performance when it came to suppressing noise and sidelobes. In Addition, the PF method was also able to produce a well-focused tomography profile but with some noise and sidelobes. However, the EM method had a tendency to produce imaging results that were discontinuous and suffered from unwanted vertical shifts.
- Our proposed method for calibrating the tomography profile produced forest height result which is highly consistent with the LiDAR CHM. The accuracy of the extraction was found to be over 80%.

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