Polarimetric and Interferometric SAR Calibration Verification Methods

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ABSTRACT

It is necessary to calibrate SAR data in order to use the data for science applications. When both polarimetric and interferometric data are collected simultaneously, these SAR data can be used for cross-calibration and verification. The frequency of polarimetric and interferometric data does not have to be the same for this purpose. For example, the NASA/JPL AIRSAR system can acquire C-band interferometric data and L-band polarimetric data simultaneously. The radiometric calibration of polarimetric data can be improved using the local slope information obtained from SAR interferometry. The accuracy of geophysical parameter estimation may be enhanced using true incidence angles derived from SAR interferometry. The calibration of interferometric SAR data can be verified by examining interferometric correlation coefficients. Both azimuth and range slopes estimated from an interferometric SAR DEM can be used to examine the polarization calibration accuracy. In this paper, we show several examples of cross-calibration verification between polarimetric and interferometric SAR data

I. INTRODUCTION

The NASA/JPL AIRSAR system is capable of collecting both polarimetric and interferometric SAR data. It can acquire three frequency (P-band, L-band, and C-band) polarimetric data and cross track interferometry data at both L- and C-band. The most popular mode acquires C-band cross track interferometric data and L- and P-band polarimetric data. When both polarimetric and interferometric data are collected simultaneously, these SAR data can be used for cross-calibration and verification. The frequency of polarimetric and interferometric data does not have to be the same for this purpose.

The most obvious application of interferometric SAR data is improving the radiometric calibration accuracy of polarimetric SAR data using the correct ground area. Using a topographic map generated from the cross track interferometric data, true incidence angles can be derived. Then, they can be used for geophysical parameter estimation techniques that utilize polarimetric SAR data. As an example, more accurate soil moisture can be estimated using true incidence angles, especially for high relief areas.

Recently, several researchers successfully estimated tree heights using the interferometric correlation coefficient [1,2]. In order to implement this method, one must remove the decorrelation effect due to SNR. The accuracy of this method depends on the ability to isolate the scattering related correlation coefficient. The resulting scattering correlation coefficient can also be used for verifying the quality of interferometric SAR data. Polarimetric SAR data can be used for estimating both range and azimuth slopes [3]. When polarimetric data are collected with interferometric data simultaneously, the slopes independently derived from interferometric SAR data can be used for evaluating the polarimetric calibration accuracy.

First, we discuss the interferometric correlation coefficient and propose a new method to separate the SNR correlation and the scattering related correlation. The effectiveness of this new method is demonstrated using an example. Then, we examine a way to verify the polarimetric calibration accuracy using geometric parameters derived from interferometric SAR data. Finally, we conclude this paper by summarizing the results.

II. INTERFEROMETRIC CORRELATION COEFFICENT VERIFICATION

The interferometric correlation coefficient (γ) is defined as

$$\gamma = \frac{\langle \psi_1 \psi_2^* \rangle}{\sqrt{\langle \psi_1 \psi_1^* \rangle \langle \psi_2 \psi_2^* \rangle}} \qquad (1)$$

where ψ_1 and ψ_2 are electromagnetic fields measured at two interferometric channels. For single pass interferometric SAR, the interferometric correlation coefficient can be written as

$$\gamma = \gamma_{Scat}\gamma_{SNR} \qquad (2)$$

where γ_{Scat} is the correlation coefficient due to the scattering geometry. The SNR related correlation coefficient (γ_{SNR}) can be expressed in terms of the measured backscattering cross section ($\sigma_0^{(m)}$) and the noise equivalent backscattering cross section (σ_n) as

$$\gamma_{SNR} = \frac{\sigma_0^{(m)} - \sigma_n}{\sigma_0^{(m)}} \qquad (3)$$

It is important to separate γ_{Scat} and γ_{SNR} to study interferometric phenomenology [1]. Here, we propose to use two adjacent interferometric data to estimate the noise equivalent backscattering cross section and γ_{Scat}. As an example, we used the NASA/JPL AIRSAR data collected over Rosamond, California to separate γ_{Scat} and γ_{SNR}. This area was chosen because it has flat topography without much vegetation. Even though the area is uniform in radar brightness, there is enough backscattering cross section variation, we can implement equations (2) and (3). Mathematically, the proposed technique can be written as

$$\frac{\gamma(2)}{\gamma(1)} = \frac{\gamma_{Scat}(2)}{\gamma_{Scat}(1)} \frac{\dfrac{\sigma_0^m(2) - \sigma_n}{\sigma_0^m(2)}}{\dfrac{\sigma_0^m(1) - \sigma_n}{\sigma_0^m(1)}} \qquad (4)$$

where 1 and 2 represent two areas along the same azimuth line. If both areas are similar in scattering geometry, then

$$\gamma_{Scat}(1) \approx \gamma_{Scat}(2) \qquad (5)$$

Using (2) and (4), we can estimate the noise equivalent backscattering cross section as

$$\sigma_n = \frac{X\sigma_0^m(1) - \sigma_0^{(m)}(2)}{X - 1} \qquad (6)$$

where

$$X = \frac{\sigma_0^m(2)\gamma(2)}{\sigma_0^m(1)\gamma(1)} \qquad (7)$$

Using this method, we estimate the noise equivalent backscattering cross sections at various incidence angles. The estimated noise equivalent backscattering cross sections are –32.8 dB, -31.1 dB, -34.3 dB, and –31.2 dB at 26^0, 32^0, 47^0, 60^0, respectively. The more interesting result is γ_{Scat} as shown in figure 1.

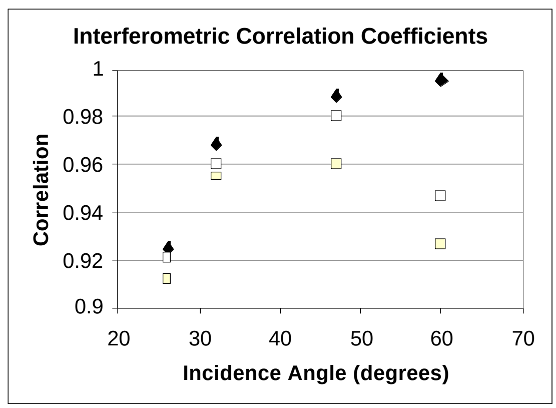

Figure 1. Interferometric correlation coefficients: γ_{Scat} (diamond) and γ (square).

Notice that γ_{Scat} monotonously increases as the incidence angle increase as expected from surface scattering decorrelation. Since the scattering correlation coefficient is close to 1 at 60 degrees incidence angle, the co-registration of two interferometric channels must be relatively accurate. The proposed method will be effective when we select homogeneous scattering areas correctly for estimating the noise equivalent backscattering cross section. Polarimetric SAR data are very useful for selecting these homogeneous scattering areas.

III. POLARIMETRIC SLOPE ESTIMATION

Both azimuth and range slopes can be estimated from interferometric SAR data by simply calculating derivatives from topographic data. These slope data can be used for verifying polarimetric SAR data. The polarization orientation angle shift can be estimated using [2]

$$\tan\alpha = \frac{\tan\varpi}{-\tan\phi\cos\theta + \sin\theta} \quad (8)$$

where α is the polarimetric orientation angle shift, ϖ is the azimuth slope, ϕ is the range slope, and θ is the radar look angle. From interferometric SAR data, we can estimate the orientation shift angle α using both range and azimuth slopes and the incidence angle. This verifies the accuracy of polarimetric SAR calibration. The interferometric data accuracy may have to be examined using ground control points when polarimetric orientation angle shift is systematically different from one derived from interferometric SAR data.

IV. CONCLUSIONS

In this paper, we presented several examples of the cross verification of polarimetric and interferometric SAR data. Several examples are given to demonstrate the effectiveness of these techniques. The scattering related correlation coefficient derived from interferometric SAR data can be used for verifying the quality of interferometric data. The polarimetric calibration accuracy can also be estimated using geometric parameters derived from interferometric SAR data. These techniques can be used for estimating various geophysical parameters when SAR data are correctly calibrated.

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REFERENCES

[1] E. Rodriguez, T. R. Michel, and D. J. Harding, “Interferometric Measurement of Canopy Height Characteristics of Coniferous Forests,” submitted for publication

[2] R. N. Treuhaft, S. N. Madsen, M. Moghaddam, and J. J. van Zyl, “Vegetation Characteristics and Underlying Topography from Interferometric Radar,” Radio Science, Vol. 31, No. 6, pp. 1449-1485, 1996.

[3] J. Lee, D. L. Schuler, T. L. Ainsworth, “Polarimetric SAR Data Compensation for Terrain Azimuth Slope Variation, IEEE Trans. Geosci. Remote Sens., Vol. 38, No. 5, pp. 2153-2163, 2000.