Ionospheric delay estimation in SAR interferometry: Significance of the method using the split-spectrum double-difference interferogram

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Split-spectrum method is used as a useful method in reducing the ionospheric delay which is one of the major error factors in SAR interferometry (e.g., Brcic et al., 2010; Rosen et al., 2010; Gomba et al., 2016). This method divides chirp signal of SAR into high and low bands, and generates interferograms for each bands. The ionospheric delay and crustal deformation components are extracted from them. Generally, the ionospheric delay component phai,iono can be estimated from

$\Phi_{iono}=f_L f_H(\Phi_L f_H - \Phi_H f_L)/(f_0(f_H^2-f_L^2))$ -(1)

where f0, fl, fh are center frequencies of full, lower, and higher bands. phai,l phai,h are phase differences of interferograms for lower and higher bands. Empirically, for interferometric pairs with high coherence, the ionospheric delay component can be accurately estimated from this equation. However, that with low coherence, the accuracy degrades mainly due to the difficulty of unwrapping. Then Wegmüller et al. (2018) proposed the method using following equation,

$\Phi_{iono}=A\Phi_0 + B(\Phi_H-\Phi_L)$ -(2)

where phai,0 is phase difference of full-band interferogram, and A, B are coefficient derived from center frequencies. In general, the better coherence is obtained for interferometric pair with wider bandwidth, and therefore the first term is relatively easier to unwrap than that with divided frequencies. Since the second term falls within the value of $-\pi$ to $+\pi$ in most cases, it is possible to easily obtain the phase difference. Furthermore, since A is approximately 0.5, equation (2) can be approximated to

$2\Phi_{iono}=\Phi_0 + 2B(\Phi_H-\Phi_L)$ -(3)

As mentioned before, the second term can easily estimate the phase difference, and then it is possible to obtain an interferogram showing only the ionospheric delay component without unwrapping.

Now, we are developing ionospheric delay estimation tools based on the above three equations. In this presentation, we describe the results of test analysis on several pairs using tools under development. In this analysis, SAR images divided the band in half are used. For high and low frequency pairs, interferograms are generated. After removing orbital and topographic fringes, the spectrum filter (Goldstein and Werner, 1998) is applied to them. From these interferograms, ionospheric delay is estimated using each equation. An outlier removing filter and a Gaussian filter are applied to ionospheric delay image.

First, as a pair with relatively high coherence, the interferometric pair of ALOS-2/PALSAR-2 images which observed Azuma-yama on September 9, 2014 and August 11, 2015 was analyzed. About this pair, almost the same results were obtained from analysis using each equation. However, as a result from interferometric pair which observed on March 7, 2016 and April 18, 2016, included large crustal deformation associated with the 2016 Kumamoto earthquake, differences were obtained in results from analysis using each equation. In particular, in the analysis using Eq. (1), the unwrapping error in the vicinity of the fault seems to have a big influence. In manual analysis, if the error is correctly masked, it is considered that roughly the same result as equation (2) is obtained. In a result from equation (3), the ionospheric delay component was obtained even in the vicinity of the fault. However, in other interfering pairs with particularly poor coherence, the ionospheric delay could not be properly estimated by the analysis using Equation (3) in some cases.

Although there are few analysis cases at the present time and more case analysis is required, it is generally felt that the method based on equation (2) can estimate the ionosphere delay with relatively high accuracy. However, in cases where large crustal deformation are included such that unwrapping is difficult, the method based on equation (3) may be better. It may be necessary to select a method which is appropriate for a case.

Keywords: SAR, ionospheric delay, crustal deformation