INTERFEROMETRIC ALIGNMENT OF SPACEBORNE DUAL-ANTENNA SAR SYSTEM

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1. INTRODUCTION

In spaceborne dual-antenna (i.e., single-pass mode) interferometric synthetic aperture radar (InSAR) system, the alignment of the master and slave antenna beam is crucial. In order to achieve the best interferometric performance, antenna beams should be coincided with each other between the master and slave. The beam alignment of the first spaceborne dual-antenna InSAR system, the Shuttle Radar Topography Mission (SRTM) with a 60 m deployable mast assembled on the Space Shuttle Endeavour, has been discussed in detail [1]. This can provide some technical reference for the InSAR beam alignment. However, compared with the SRTM beam alignment, the traditional satellite-borne mode of our InSAR system makes a different baseline configuration. Meanwhile, the Attitude and Orbit Determination Avionics (AODA) equipped in the SRTM system, which provides in-flight measurements to support antenna alignment, is absent in our InSAR equipment due to some systemic consideration. Therefore some techniques for real-time attitude measurement of the master and slave antennae are required.

In this paper, the alignment system of our InSAR system is described, especially for the satellite-borne baseline configuration and the adjustment of radar beam. Then a three-step alignment scheme, which is composed of coarse alignment, fine alignment and alignment maintenance, is proposed. The technical points for each step are briefly introduced, and an outstanding alignment performance is achieved.

2. ALIGNMENT SYSTEM DESCRIPTION

During the on-orbit operation of the satellite, the beam alignment between the master and slave antenna is affected by several factors, which are categorized into static and dynamic effects [1]. The beam alignment system is to eliminate these factors by measuring the relative beam bias after mast deployment (for the static effects) and by monitoring the alignment conditions during the radar working period (for the dynamic effects). Referred to the SRTM system, some modifications are made in our InSAR system and briefly discussed as follows.

2.1. Baseline configuration

In the SRTM system, the master (i.e., inboard) and slave (i.e., outboard) antenna are connected by a deployable mast (see Fig. 1(a)). Such a 60 m mast will not change the gravity center of the space shuttle for hundreds of tons weight. If such baseline configuration is directly applied in a satellite-borne InSAR system (usually several tons weight), the gravity center will shift towards the slave antenna and the whole system will be instable. Therefore, a horizontal tri-antenna baseline configuration is proposed. As shown in Fig. 1(b), two 40 m masts are horizontally deployed from two sides of the satellite. An equivalent 80-meter baseline is formed considering the signal interferometry of the two slave antennae. Such a baseline configuration makes a much more stable interferometric alignment in the satellite-borne InSAR system.

2.2. Adjustment of radar beam

The master antenna is composed of two-dimensional active phase array, which is about 9 m x 0.8 m corresponding to a 3dB beam width of about 6.7 º (range) by 0.2 º (azimuth). Meanwhile, the slave antenna is composed of one-dimensional active linear array, which is about 6.4 m x 0.3 m corresponding to a 3dB beam width of about 7.2 º (range) by 0.3 º (azimuth).

The master antenna can provide a beam adjustment both in the azimuth and range direction. In the azimuth direction, it provides a beam adjustment of ±1.8 º in theory; however, this is restrained for the radar image discontinuous or overlapped effect. In the range direction, it provides a beam adjustment of ±1.5 º, where ±1.0 º adjustment is due to the compensation of orbital drift.

The slave antenna can only provide a beam adjustment in the azimuth direction (±1.0 º). Meanwhile, with a mechanical adjustment in this direction, the response time is relatively long, which will further disturb the antenna and mast. Therefore the mechanical steering only works during the coarse alignment period.

As a conclusion, the beam adjustment capacity and step are listed in Tab. 1.

3. ALIGNMENT SCHEME

The procedure of beam alignment can be divided into three parts: the coarse alignment, the fine alignment, and the alignment maintenance. After deploying the mast, the platform of the slave antenna is first steered according to the pre-flight parameters. Then the slave beam is mechanically steered in order to coincide with the master beam at a certain extent. Then the fine alignment is accomplished with the Doppler centroid estimation. When the radars start working, the alignment is maintained by inspecting the relative attitude between the master and slave antenna (also use the Doppler centroid estimation). This technical scheme can align the radar beams without using the AODA information.

3.1. Coarse alignment

Two tasks need to be finished in coarse alignment. Since the slave antenna is receive-only, the first task is to mechanically steer the slave platform (range direction) and to adjust the slave phase array (azimuth direction) in order to receive the echo transmitted from the master one. In details, the searching step can be set to a relatively big value such as the master beam size to coincide with the master beam quickly. The next task is to coincide between the two radar beams as much as possible, especially in the range direction as it is assumed to be well aligned during the fine alignment, by using an efficient method. The ratio of the energy received by the master and salve antenna is selected as an index for this measurement. For the same scene, this ratio is proportional to the slave effective pattern, which is the superposition of the one-way diagram of both master and slave antenna. Fig.2 shows the two-way effective pattern of the slave antenna for an azimuth beam misalignment of 0.2 º, and this confirmed that the echo energy can verify the coarse alignment.

3.2. Fine alignment

After the coarse alignment, the range misalignment is less critical since it only reduces the gain in near or far ranges, whereas the azimuth misalignment should be well considered [1]. For a satellite with a speed of 7 km/s and an X-SAR system, a squint angle of 0.02 º will introduce a Doppler bias of 160 Hz, which can be easily estimated by using the conventional Doppler centroid estimation, e.g., MLBF [2] or MLCC [2]. In our previous work, an efficient Doppler estimation method, called sign-MLCC [3], has been proposed. This method signified the range-compressed signal and is more suitable for real-time processing on a satellite. Moreover, the forward prediction technique is also applied in our sign-MLCC method in order to estimate the Doppler centroid block by block. Fig. 3 shows the prediction of the signal aptitude processed in the sign-MLCC algorithm. Therefore it provides a continuous Doppler central estimation during the fine alignment.

3.3. Alignment maintenance

When the antenna beam is aligned, the interferometric system starts to work. During the working period, the bend and twist of the mast will affect the alignment system. If this influence can be negligible, e.g., within 0.05 º in azimuth and 0.25 º in range, no adjustment is required. This requires a robust mechanical property of the mast; otherwise some methods for dynamic compensation should be considered [4]. Other static effects can be eliminated by monitoring the fine alignment or even the coarse alignment at set intervals.

5. REFERENCES

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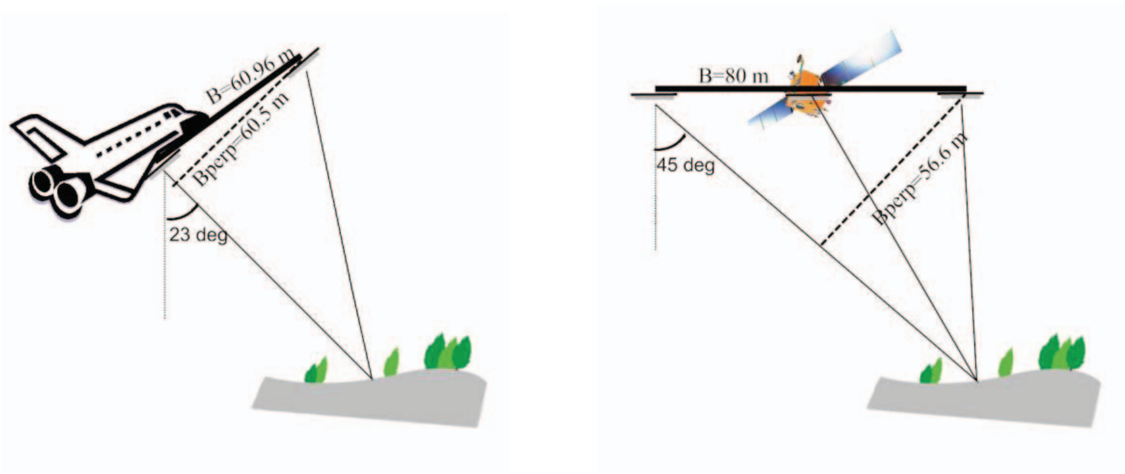


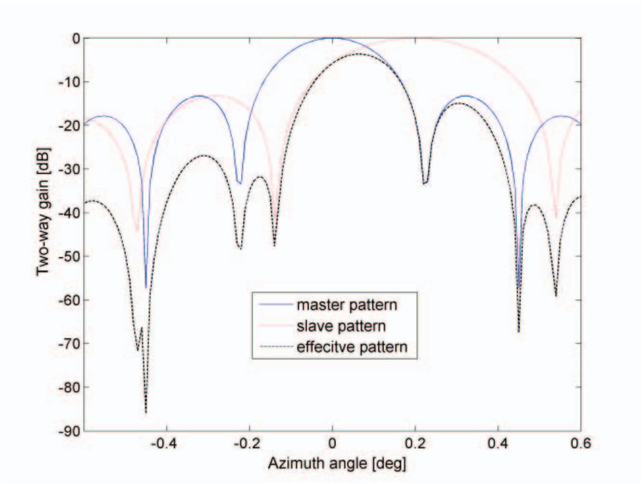
(a) **(b)**

Fig.1 Baseline configuration: (a) 45 ° baseline of SRTM system; (b) Horizontal baseline of satellite-borne system.

Tab.1 Adjustment abilities of the master and slave antenna.

Direction Method Antenna	Range				Azimuth			
	Mechanical steering		Electrical steering		Mechanical steering		Electrical steering	
	Capacity	Step	Capacity	Step	Capacity	Step	Capacity	Step
Master			±0.5 ° (2)-(3)	0.01 °				
Slave	120 ° (1)	0.2 °					±1.0 ° (1)-(3)	0.01 °

(1) Coarse alignment, (2) fine alignment and (3) alignment maintainance.



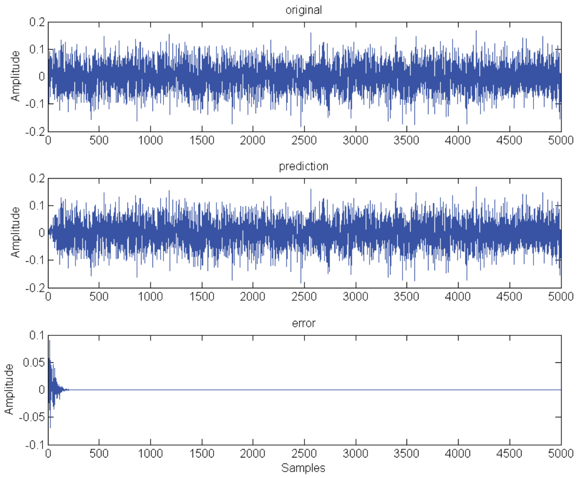


Fig.2 The effective pattern for an azimuth beam misalignment of 0.2 °.

Fig.3 Result of beam deviation prediction.