ANALYSIS AND COMPENSATION FOR MOTION ERRORS IN FMCW SAR DATA

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ABSTRACT

Conventional monostatic and recent bistatic Synthetic Aperture Radar (SAR) systems all work in pulsed mode [1], ensuring a good isolation between transmit and receive signal, where transmitter and receiver share the same antenna. Continuous-Wave (CW) technology, however, requires less peak transmit power than the pulsed ones [2]-[3]. Thus, the combination of Frequency-Modulated Continuous-Wave (FMCW) technology and SAR techniques would offer all the benefits of a high resolution imaging sensor, additionally compact size, lightweight, etc. Since FMCW components are more and more becoming components "of the shelf" due to their wide application in automotive radar based driver assistance systems, this will enable a significant cost reduction in remote sensing applications. Hence FMCW SAR systems can play an important role in remote sensing, reconnaissance and surveillance applications, especially for the application of small-size unmanned aerial vehicles (UAVs).

For FMCW SAR, the variation of the instantaneous slant range introduced by the continuous motion during the pulse time is no longer negligible since the conventional start/stop approximation does not hold. Conceptually this start/stop approximation assumes that any transmitted pulse experiences a delay time which is constant during the pulse duration, and only varies from pulse to pulse (known as range migration), while in principle leading edge and trailing edge of any transmitted pulse experience different delay times introduced by the time varying slant range. Therefore, processing of FMCW SAR differs from the conventional pulsed SAR due to the fact that the range walk term and an additional range azimuth coupling are introduced by the continuous motion of the antenna while transmitting and receiving the signal. The range walk term is discussed in detail in [3], whereas the additional range azimuth coupling term is formulated for the first time in the FMCW SAR community in [2].

As far as the airborne FMCW SAR systems are concerned, trajectory deviation of sensor can strongly degrade the final image quality in form of geometrical inaccuracies and radiometric resolution losses [4]. To account for the deviations, flight parameters are measured onboard using the Global Positioning System (GPS), and Inertial Navigation System (INS) [4]-[5]. Using the measured position information, a motion compensation method can be applied to improve the quality of focused image. In [6], the conventional two-step compensation method was used to compensate for the motion errors of FMCW SAR data [7]. However, the in-pulse trajectory deviations are more complex compared with the pulsed mode SAR. Up to day, the effects of the continuous motion during pulse on the signal characteristics FMCW SAR have not been documented or mentioned in the scientific community so far. Especially, the coupling of the in-pulse trajectory deviation and range-azimuth coupling term needs to be paid for more attention.

The main objectives of this paper are to develop the accurate signal models to formulate the effect of the in-pulse motion errors on the signal characteristics of FMCW SAR, and further develop effective and efficient motion compensation approaches to deal with motion errors during pulse for FMCW SAR systems. Furthermore, we will integrate the motion approaches into the processing chains of the available FMCW processing algorithms [2].

We will validate the formulated signal model and compensation method by using real millimeter-wave (Ka-band) FMCW SAR data, acquired by using FHR's airborne millimeter-wave SAR system (i.e. MEMPHIS) [8]-[9], in April 2008. MEMPHIS is a unique experimental millimeter-wave synthetic aperture radar system which contains two front-ends: one operates at 35GHz (Ka-band) and another at 94 GHz (W-band). The radar system is mounted on a Transall C-160 aircraft with a flight altitude of 320m, velocity of 75 m/s, and looking angle of 70º. The preliminary result with our motion compensation model method is shown in Fig. 1.

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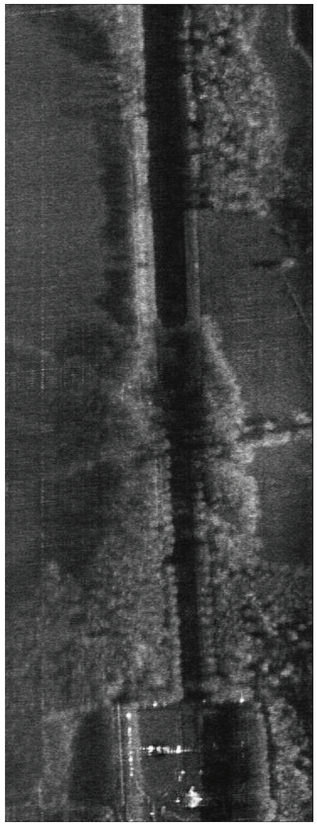

Fig. 1a. FMCW SAR image

Fig. 1b. Optical image from Google Earth

The processed image has a size of 331 m (Slant range) × 897 m (Azimuth) at Herrenchiemsee, Germany. (The horizontal and vertical directions denote the range and azimuth, respectively.)