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To cite this article: Hongtu Xie *et al* 2018 *J. Phys.: Conf. Ser.* **960** 012037

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Experiment of Azimuth-invariant Bistatic UHF UWB SAR

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Abstract. Bistatic ultrahigh frequency ultrawideband synthetic aperture radar (UHF UWB SAR) has the well ability of the penetrating the foliage, high-resolution imaging and providing the increased information. In the paper, an imaging experiment of the azimuth-invariant bistatic UHF UWB SAR is described and the result is proposed. In August 2015, an along-track bistatic UHF UWB SAR experiment was conducted in China, and the raw data was collected. In this bistatic SAR system, the transmitter and receiver are both carried by a vehicle and separated by an invariable distance. The aim was to investigate the imaging property of the bistatic UHF UWB SAR system. Bistatic image was obtained using the subaperture spectrum-equilibrium method integrated with the fast factorized back projection algorithm (FFBPA). Experiment results prove the validity of the bistatic UHF UWB SAR experiment.

1. Introduction

Presently, a number of the remote sensing and geoscience applications are developed on the synthetic aperture radar (SAR) [1]-[3]. In recent years, the bistatic SAR imaging experiment was carried out by several countries in the military and civilian fields, and some experiment results were obtained [4]-[6].

Compared with the monostatic SAR, bistatic SAR has the complex configurations since it can be designed and deployed flexibly to satisfy different applications [7]-[9]. For the same scene, the bistatic SAR has the greater anti-jamming ability than the monostatic case. If the bistatic SAR system includes more than one transmitters or receivers, the imaging scene can be illuminated at the different angles, which can acquire the added information of scenes. Along-track bistatic SAR is an azimuth-invariant bistatic SAR system, whose transmitter and receiver are both carried by one platform and separated by an invariable distance. Along-track bistatic SAR not only inherits advantages of the general bistatic SAR, but also is easy to implement imaging, thus it has attracted the much attention.

Ultrahigh frequency (UHF) ultrawideband (UWB) SAR system operates in the UHF UWB signal with a large fractional bandwidth and the wide antenna beamwidth associated with a large integration angle, so it can provide the higher resolution SAR image [10]-[12]. Hence, it is a significant advantage



that the along-track bistatic SAR operates in the UHF UWB mode. Some countries have conducted the bistatic UHF UWB SAR experiments, and several results were obtained [13] [14].

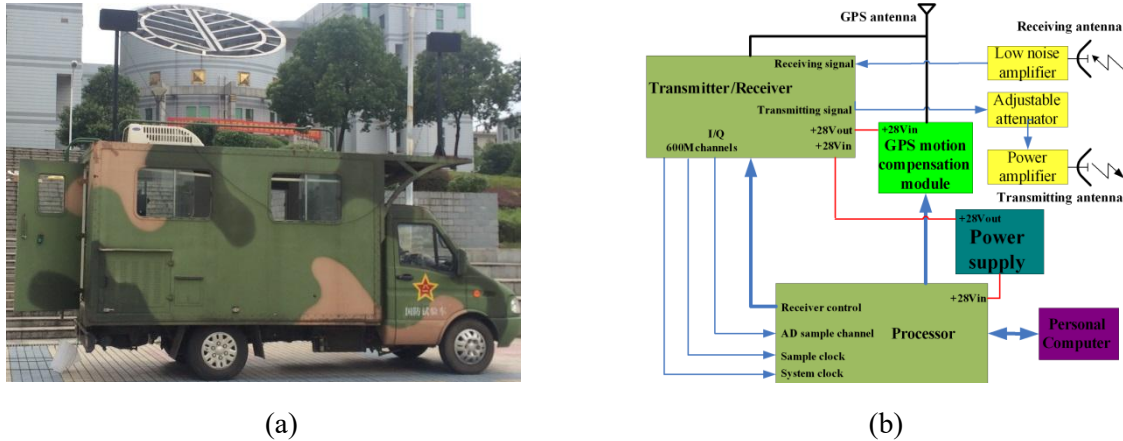


Figure 1. (a) Along-track bistatic UHF UWB SAR system; (b) Its block diagram.

However, the along-track bistatic UHF UWB SAR experiment also poses the various challenges, such as the synchronization between the transmitter and receiver, position measurement of the radars, polarimetric calibration, collection geometry planning and data processing. Most important challenge is the successful operation of the along-track bistatic UHF UWB SAR experiment.

The paper presents the experiment of the along-track bistatic UHF UWB SAR. In Section 2, the along-track bistatic UHF UWB SAR system is given, focusing on the collection ability of the bistatic UHF UWB SAR data. The along-track bistatic UHF UWB SAR imaging experiment and the data processing are discussed in Section 3. The experimental results are presented in Section 4.

2. Development of the along-track bistatic UHF UWB SAR

Monostatic UHF UWB SAR system was developed by National University of Defense Technology (NUDT) in 2008, operating at UHF-band with a fractional bandwidth of about 0.25 [3]. In 2011, a programme of the upgrades to add a bistatic collection ability to the monostatic UHF UWB SAR was commenced using the hardware and software of the monostatic UHF UWB SAR. In August 2015, the experiment of the along-track bistatic UHF UWB SAR was conducted in campus in Changsha, China. Figure 1(a) gives the along-track bistatic UHF UWB SAR system, which is fixed on the vehicle, and the transmitting and receiving antennas are mounted at the front and end of the top of the vehicle. The transmitter transmits the chirp signal to the scene, while the receiver illuminates the same region and receives the scattered signal of the scene. Figure 1(b) gives the block diagram of this bistatic SAR, which contains the transmitting and receiving antennas, global positioning system (GPS) antenna, transmitter/receiver, GPS motion compensation module, processor, power supply, personal computer (PC), etc. To void the antenna's coupling and interfere for the near-field imaging, the caliber coupling multilayer patch antennas used for transmitting the radar signal and receiving the scattered signal are mounted on the vehicle separately. The transmitting and receiving antennas have the 3 dB azimuth beamwidth from approximately 30° to 55° and 3 dB elevation beamwidth from approximately 70° to 90° . The transmitter and receiver have the center controller, GPS synchronization module, frequency synthesizer, wave generator, and so on. One pulse per second (1PPS) signal from the GPS receiver is transferred into the center controller to control the system timing reference, and GPS synchronization module provides the coherence frequency reference for the SAR system, and then it is used to drive a frequency synthesizer to produce various clock signals for different parts of this SAR system. Under the control of the center controller, the wave generator generates the chirp signal. It is then modulated into the radio frequency signal, attenuated by the adjustable attenuator and amplified by the power amplifier. Finally, it is transmitted by the transmitting antenna. Simultaneity, the receiving antenna receives the scattered signal of the scene. It is then transferred into the low noise amplifier, down-

converted into the intermediate frequency signal, filtered and amplified by the power amplifier, and demodulated into the in-phase and quadrature signals. Finally, the in-phase and quadrature signals are sampled by a high-speed sampler, converted by the analogue-to-digital converter, and recorded on the solid state electronic array and fed to PC. This bistatic SAR system's position is obtained by the GPS motion compensation module and recorded on the electronic array to offer the motion compensation.

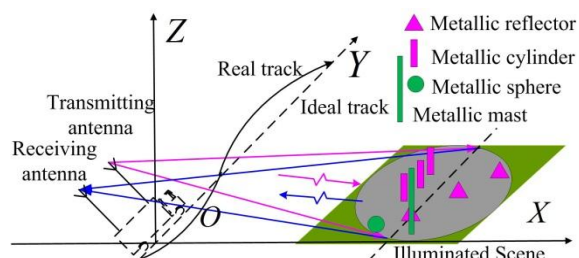


Figure 2. Geometry of the bistatic experiment.



Figure 3. Optical image of the imaging scene.

Table 1. Parameters of the along-track bistatic UHF UWB SAR system.

Parameter	Value	Parameter	Value
Signal frequency	UHF	Signal bandwidth	200MHz
Sampling frequency	220Hz	Pulse duration	1us
Pulse repetition frequency	500Hz	Incidence angle	82.3 °

3. Imaging experiment of the along-track bistatic UHF UWB SAR

3.1. Vehicle experiment

The bistatic data collection ability of the UHF UWB SAR system was exercised in August 2015. The along-track bistatic UHF UWB SAR system was performed well, simultaneously producing a set of collected bistatic scattered signal. Figure 2 shows the geometry of the bistatic experiment. The dashed line is the vehicle nominal track, and the solid curve is its actual track. The transmitting antenna continually illuminates the scene including several targets, and then the receiving antenna receives the bistatic scattered signal of the scene. Parameters of the along-track bistatic UHF UWB SAR system is listed in Table 1. The vehicle moves along the Y axis direction with the speed about 3.5m/s. Initial positions of the transmitting and receiving antennas are about (0, 2, 4)m and (0, -2, 4)m at zeros time.

To collect data over a range of the incidence angle, the distance of the scene center was varied: the typical distance ranged from 35m to 55m, which produces the incidence angle transmitting/receiving antenna from 80.3° to 80.8°. Finally, one data site was selected for the data processing: the scene was a flat area, which has the size about 50m in the X axis and 80m in the Y axis. The scene center is (45, 40, 0)m. Figure 3 shows the optical image of imaging scene, which includes some various targets, such as the metallic reflectors, metallic cylinders, as well as metallic sphere and metallic mast, were deployed at the scene prior to the imaging experiment, in order to validate the imaging property of the bistatic UHF UWB SAR system and scattering characteristics of various targets. The positions of the metallic reflectors are about (37.8, 38.8, 0)m, (48.2, 49.2, 0)m and (58.6, 59.6, 0)m, respectively. The positions of the metallic cylinders are about (32.7, 46.6, 0)m, (32.7, 49.2, 0)m and (32.7, 51.8, 0)m, respectively. The position of the metallic mast is about (40, 31, 0)m.

3.2. Data processing

Along-track bistatic UHF UWB SAR system is subject to some difficulties in the data processing, i.e., the huge amount of the scattered signal, serious range-azimuth coupling and complex motion errors, as well as the serious radio frequency interfere (RFI), which makes the data processing more complicated. The accurate disposal of these problems is an intractable issue for the frequency domain algorithms, but it can be precisely managed in the time domain back projection algorithm (BPA) [7]. To reduce its

high computation, the efficient implementation of the BPA has been applied for the bistatic SAR imaging, i.e., the fast factorized BPA (FFBPA) [15], which can be used for this bistatic SAR imaging.

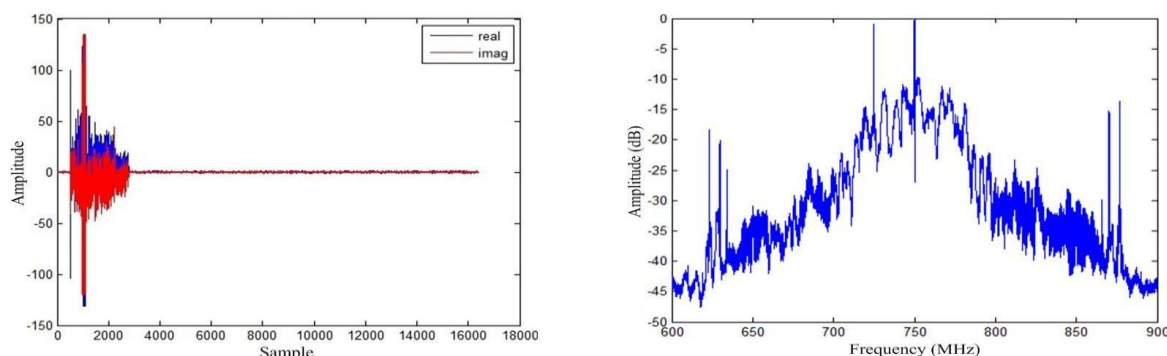


Figure 4. Bistatic scattered data of the illuminated scene. Left column: Bistatic scattered data from one transmitted radar pulse, including the real (blue line) and imaginary (red line) components; Right column: Sum of the frequency spectrum of the bistatic scattered data from 100 radar pulses.

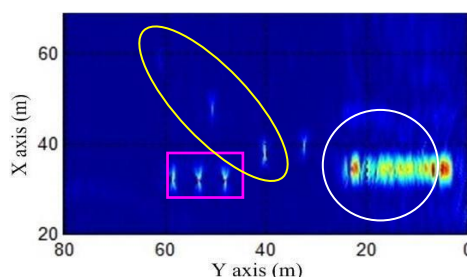


Figure 5. Bistatic UHF UWB SAR image obtained by the FFBPA

Besides, there is a strong radio frequency interference (RFI) saturated by the receiving antenna working in the UWB band. The influence of RFI signal may be extremely significant since their power is much higher than the reflected power of the bistatic UHF UWB SAR. To remove its influence, a subaperture spectrum equilibrium method [16] integrated with a FFBPA is used in the data processing.

Finally, before the RFI suppression is performed, the bistatic UHF UWB SAR data (including the GPS data) should be preprocessed. First, the GPS data should be upsampled and filtered, and then transferred into the Cartesian coordinate system to obtain the local position of the transmitting and receiving antennas. Then, the scattered data of the scene should be downsampled and filtered.

4. Experiment results

Figure 4 gives the bistatic scattered data of the scene in time-domain and frequency-domain. In the left of Figure 4, the real (blue line) and imaginary (red line) components of the bistatic scattered data is complicated due to the bistatic geometry. And, it can be seen that the scattered data of targets in the frequency domain in the right of Figure 4, since targets are deployed at the flat and open square, and the power of their scattered data is strong.

Figure 5 shows the bistatic UHF UWB SAR image obtained by the FFBPA, which is shown that the scene is well reconstructed. First, it is seen that the targets (the metallic reflectors, cylinders, mast and sphere) are well focused. Second, it can be found that the relative scattered power of the metallic cylinder (as well as metallic mast) in the yellow ellipse will become strong compared with the metallic reflectors in the red rectangle. Finally, we find that only a metallic sphere in the white circle is seen.

In order to quantitatively evaluate the focusing quality of the bistatic UHF UWB SAR image in Figure 5, the amplitude profiles of the imaging result of one metallic reflector in the X and Y axes are extracted from Figure 5. Moreover, the resolutions of the selected focused metallic reflector in the X and Y axes can be measured based on the width of the amplitude profiles at -3dB. The measured resolutions of the selected metallic reflector in the X and Y axes are 0.21m and 0.23m, respectively.

5. Conclusion

Imaging experiment of the azimuth-invariant bistatic UHF UWB SAR has been performed using the monostatic UHF UWB SAR system. After the processing of the acquired bistatic data, the high quality bistatic UHF UWB SAR image was obtained, which validates the imaging property of the bistatic UHF UWB SAR system. A more extensive of the bistatic UHF UWB SAR experiments with different operation modes will be carried out in the future.

Acknowledgments

This work was supported in part by the National Natural Science Foundation of China (No. 61571447), in full by Scientific Research Project of Education Department of Hunan (No. 16C1233), and in part by the Domain Foundation of Equipment Advance Research (No. 6140410301 and No. 6140410304).

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