Error Analysis of Simultaneous Full-polarization Radar

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1 ABSTRACT

The simultaneous full-polarization radar for observing air-moving targets is a new type of full-polarimetric radar system. It was firstly developed at the beginning of this century. This type of radar system has the ability to measure dynamical scattering matrix of aerial targets. The simultaneous full-polarization radar can be applied to many important fields such as military field (air defense & anti-missile), civil field (meteorological target observation) and other fields. The calibration of simultaneous full-polarization radar is a key technology for accurate measurement of transient polarization characteristics of aerial targets. Nowadays, the research on the calibration technique of this kind of radar is still in its infancy, and the technology is not mature enough nor systematic. The existing calibration and correction methods add some constraints and assumptions, which have many limitations. This research aimed at the characteristics of the simultaneous full-polarization radar system, analyzing the error source and its influence systematically, and hence to support the relevant calibration and correction methods.

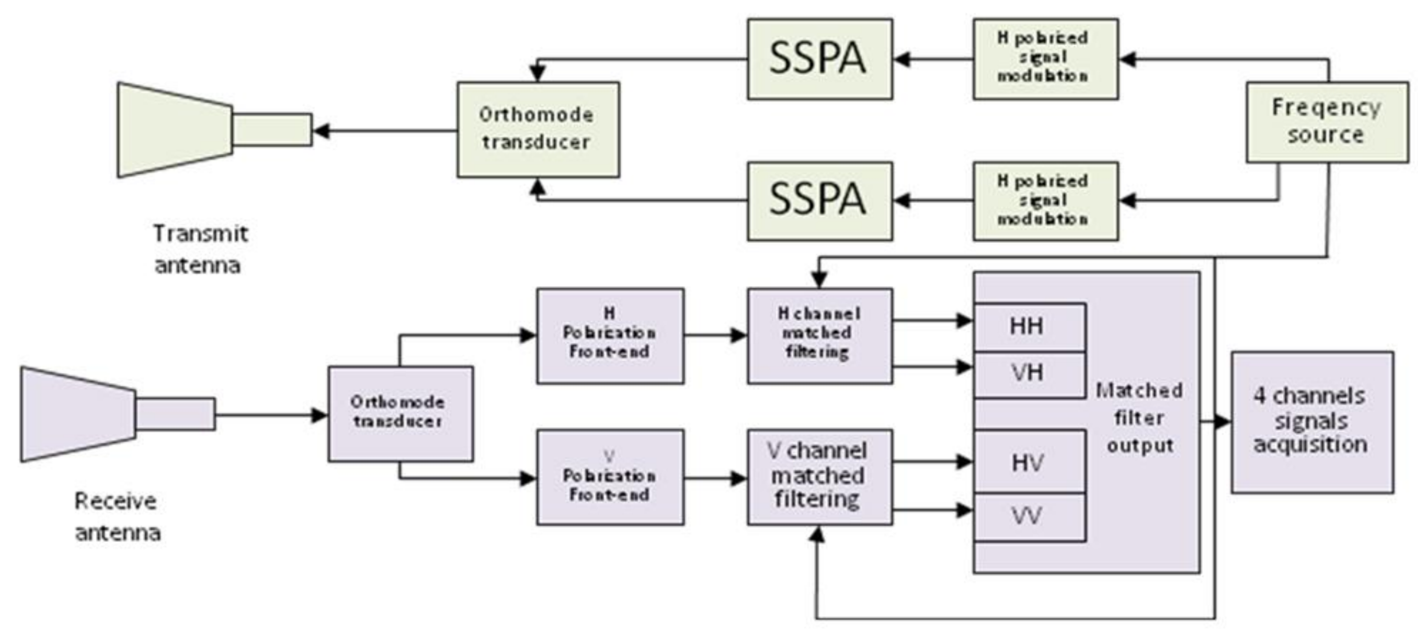

Fig1. A simplified block-diagram of simultaneous full-polarization radar

2 INTRODUCTION

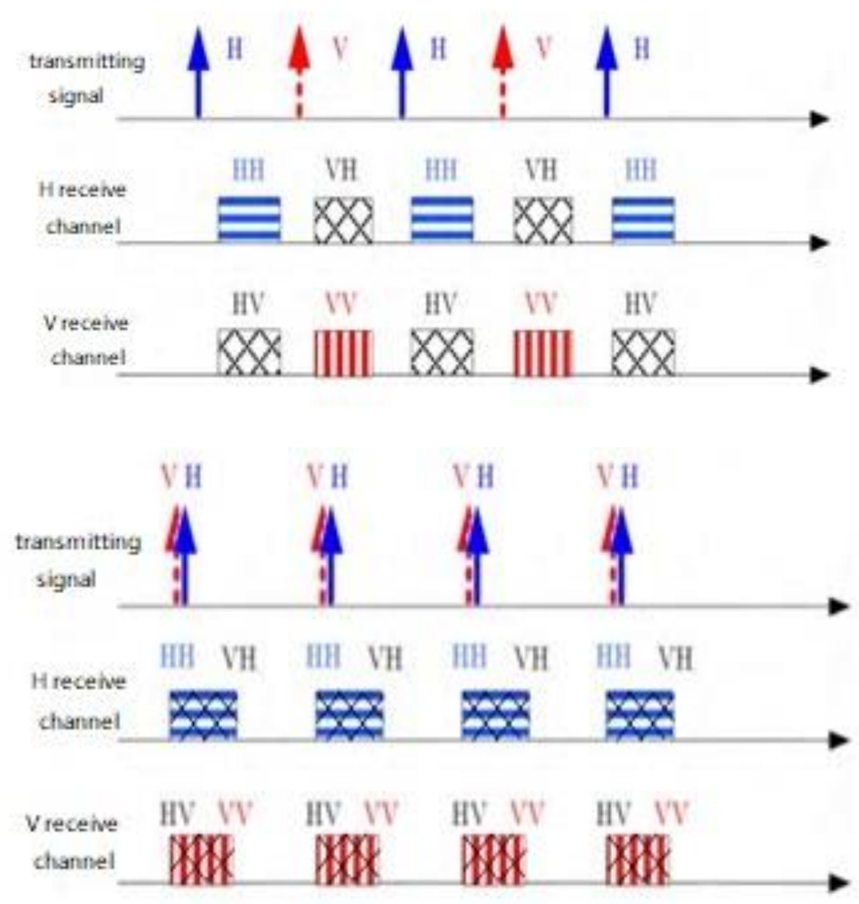

Fig2. Sequence diagram of traditional radar and simultaneous radar

In 1990, Giuli D proposed a method to measure the target scattering matrix elements simultaneously. In 2003, Titin-Schnaider C, Attia S calibrated the MERIC radar data acquired from the field experiment and analyzed the data after calibration. In 2010, National University of Defense Technology made a prototype of simultaneous polarization radar. Delft University of Technology also made some research on calibrating this kind of radar.

Simultaneous full-polarimetric radar system makes use of two separate transmitters, simultaneously transmitting two independent pulses through two separate orthogonally polarized channels feeding the same antenna.

Then, both received signals are simultaneously correlated on two branches with both the delayed replicas of transmitted signals, and then acquired the four elements of target scattering matrix.

According to Fig1, the received signal can be derived as follows[4]:

$$\boldsymbol{M} = \boldsymbol{RSTH} + \boldsymbol{n} = \begin{bmatrix} 1 & \delta_1 \\ \delta_2 & f_1 \end{bmatrix} \begin{bmatrix} S_{hh} & S_{hv} \\ S_{vh} & S_{vv} \end{bmatrix} \begin{bmatrix} 1 & \delta_4 \\ \delta_3 & f_2 \end{bmatrix} \begin{bmatrix} 1 & \delta_{h1} \\ \delta_{h2} & f_h \end{bmatrix} + \boldsymbol{n} \quad (1)$$

3 OBJECTIVE

Calibration work mainly concentrated on calibrating the errors caused by system and other factors. Throughout error analysis, we can base the calibration work and get a better understanding of simultaneous full-polarimetric radar. The early stage of our work is concentrated on analysis the SNR, Doppler frequency and time delay's impact on the work after calibration.

4 METHOD

Polarimetric calibration methods include point target calibration method and distributed target calibration method. There are a lot of successfully calibration methods with its own personality.

This work concentrated on point target calibration method. Most of the air-moving targets act as a point target in a SAR image. So we made a simulation based on van Zyl's model and National University of Defense Technology's model[4]. All experiments were carried out based on simulation data.

First we simulated the received data under different SNR. Then we used the van Zyl's calibration method to calibrate the simulation data. Through adjusting the targets' moving parameters and SNR, we got the SNR's and Doppler frequency's influence on the amplitude and phase of calibrated data.

There were three kinds of error sources considered:

- SNR
- Doppler frequency
- Time delay

5 RESULTS

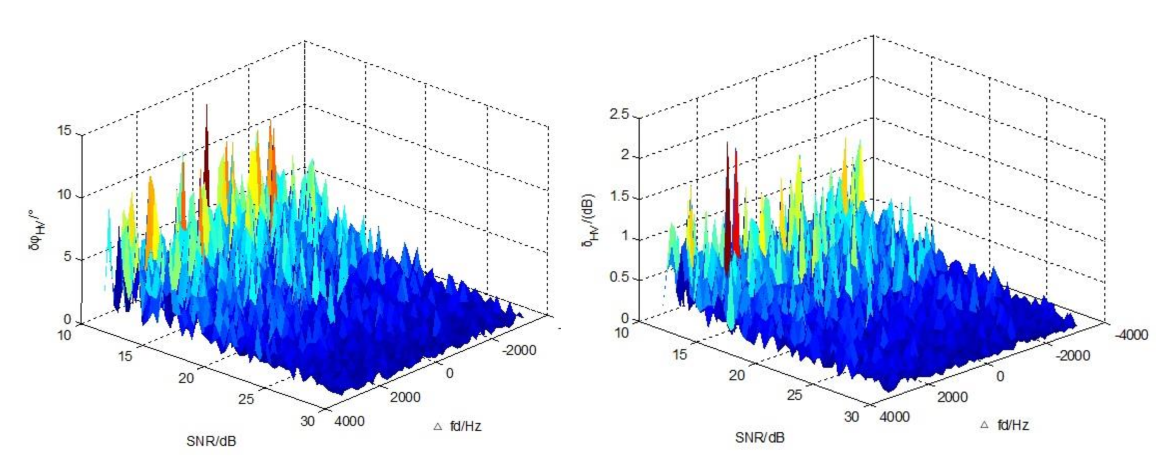

Fig3. Amplitude error of S_{HV} and phase error of S_{HV} after calibration, the x-label represents different signal-to-noise ratios (SNR), y-label represents radial velocity estimation error.

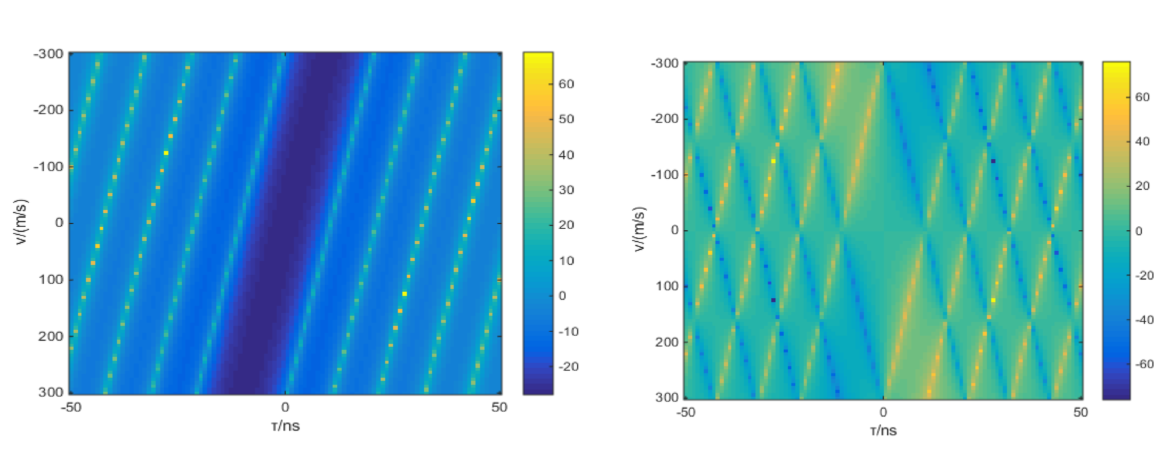

Fig4. Relationship between Moving parameters and H matrix elements, H matrix's expression can be seen in equation(1)

6 DISCUSSION

- Range estimation error:

When only concerning the change of range, the calibration results were much more different from above. The range occupied a large part of the error. The amplitude error of S_{HV} is about 5dB when the range deviation is 10 meters. In contrary, the radial velocity only had an effect on the results when radial velocity estimates changed the range estimates. The simulation results means that the phase and amplitude is mainly distorted by range deviation.

- Target depolarization coefficients:

The target depolarization coefficients also had an influence on the calibration results. Its influence substantially came from the non-orthogonality of the transmitted signals. Some literatures have given the conclusion under normal circumstances: if the product of band width and pulse duration of transmitted orthogonal signal was greater than 30dB, the signal non-orthogonality could be omitted. While we found that if target's scattering matrix elements S_{HV} was a large number that conclusion might not be reliable according to simulation results.

7 CONCLUSION

According to the simultaneous polarimetric radar simulation, we attained the detail relationship between radial velocity, range estimation and target's depolarization coefficients, which had great influences on the accuracy of polarimetric scattering matrix acquired by simultaneous polarimetric radar.

8 MAJOR REFERENCES

[1] Giuli D, Fossi M, Facheris L. Radar Target Scattering Matrix Measurement Through Orthogonal Signals[J]. IEE Proceedings-F, 1993, 140(4):233–242.

[2] Titin-Schnaider C, Attia S. Calibration of the MERIC full-polarimetric radar: theory and implementation[J]. Aerospace Science and Technology, 2003, 7 (2003): 633~640.

[3] Krasnov O A, Ligthart L P, Li Z, et al. The PARSAX- Full Polarimetric FMCW Radar with Dual-Orthogonal Signals[C]. European Radar Conference, Delft, Netherlands, 2008: 84-87.

[4] Wang F, Li C, Pang C, et al. A Method for Estimating the Polarimetric Scattering Matrix of Moving Target for Simultaneous Fully Polarimetric Radar.[J]. Sensors, 2018, 18(5):1418.