Radar HRRP Measurement of Ships

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ABSTRACT: High resolution range profile (HRRP) has become an important research direction in the field of radar target recognition. Measuring the one-dimensional HRRPs of targets and analyzing their characteristics have great significance and practical application value to target recognition. This paper has practically measured the HRRPs of ships in the sea surface utilizing the x-band phase-coherent pulse compression radar measurement platform, which lays a solid foundation for further research on ship target recognition.

1. Introduction
Radar high resolution range characteristics, namely the target's one-dimensional high resolution range profile (HRRP), are the coherent sum of the echoes of the target scatterers in each range unit[1], and represent the projection of the target scattering center’s complex echo signal on the radar line of sight (LOS) [2], which can reflect the target's shape and structure information. Because of its easy acquisition and accurate target recognition, it has become an important research direction in the field of radar target recognition [3]. As a key component of future reconnaissance system, strengthening the measurement and analysis of Radar high resolution range characteristics has extremely important military application value in target identification.

In this paper, the x-band phase-coherent pulse compression radar measurement platform was used to measure the high resolution range characteristics of ship targets on the sea surface.

Firstly, the paper introduces the background and significance of the measurement. Secondly, the paper introduces the software and hardware of the measurement platform. Thirdly, the measurement parameters and process are briefly introduced. Finally, the paper presents the high resolution range profiles of the ship targets based on the measured data.

2. Measurement Platform
The measurement platform adopts the advanced phase-coherent pulse compression system. The platform is composed of hardware and software.

2.1. Hardware of the measurement platform.
The hardware is mainly composed of antenna, phase-coherent transceiver system and main control computer (embedded data acquisition module), as shown in Fig.1. The receiving subsystem uses orthogonal demodulation scheme.
2.2. Software of the measurement platform.
The operating system is Windows XP 64bit. The development software is Microsoft Visual Studio 2010, which is used for the development and operation of measurement and control program; and Matlab 2014, which is used to complete the development and operation of pulse compression program.

3. Measurement parameters and measurement process

3.1. Measurement parameters

| Operation Band | Signal Bandwidth | Pulse Width | Pulse Repetition Frequency | Range Gate Width | Range Gate Delay |
|----------------|------------------|-------------|----------------------------|------------------|-----------------|
| X              | 150MHz           | 10μs        | 1kHz                       | 39us             | 12us            |

3.2. Measurement process

Step 1. Antenna alignment
Aim the antenna to the target ship
Step 2. System calibration
Select the working mode as "Calibration Mode" in the control interface of the platform, and record the calibration signal data for compensating the system broadband error, and for the reference of subsequent pulse compression processing.
Step 3. Echo acquisition
Select working mode as “Normal Mode”. The echo data of the sea were recorded
Step 4. Pulse compression
Start pulse compression program in MATLAB, and conduct pulse compression processing. Save the results.
Step 5. Profile extraction
Set the base noise level (-15dB) as the extraction threshold, and extract the target part exceeding the threshold in the pulse compression result, that is the HRRP of the ship.

4. Measurement results
This paper completes the acquisition and processing of echo data with one meter range resolution. The echo data are from one ship with different postures and different ships with the same posture.
4.1. HRRP of one ship with different postures

It can be seen from Fig.2-4 that the HRRPs of the same ship differ greatly with different postures [4]. In order to make this more objective, the scattering gravity center (SGC) [5] is calculated. Denoting the HRRP fragment as \( \hat{x}_{III} = [\hat{x}_{III}(n_1), \hat{x}_{III}(n_1+1), \ldots, \hat{x}_{III}(n_2)]^T \), then the SGC (ranges from 0 to 1) can be defined as

\[
SGC = \left( \frac{\sum_{n=n_1}^{n_2} n \cdot \hat{x}_{III}(n)}{\sum_{n=n_1}^{n_2} \hat{x}_{III}(n) - n_1} \right) / (n_2 - n_1)
\]

The SGCs of the above ship with different postures in Fig.2-4 are calculated and shown in Tab.2.

Tab.2 SGCs in different posture

| HRRP parameters | Posture1 | Posture2 | Posture3 |
|-----------------|----------|----------|----------|
| SGC             | 0.393    | 0.469    | 0.693    |

The reason of above phenomenon is that targets in optical region can be modeled as a set of discrete scattering points, and when the target posture changes, the relative radial distance between scattering points will change. As a result, all SGCs in a range resolution unit will change, namely HRRP posture sensitivity [6].
4.2. HRRP of different ships

![Ship image](image1.png)

(a) Ship image

![Result of range gate pulse compression](image2.png)

(b) Result of range gate pulse compression

(c) HRRP of Ship A

(d) HRRP of Ship B

(e) HRRP of Ship C

Fig. 5 HRRPs of three different Ships

It can be seen from Fig.5 that even the posture of the three different ships are the same, their HRRPs vary greatly.

The SGCs of the above three ships are also calculated and shown in Tab.3.

| HRRP parameters | Ship A | Ship B | Ship C |
|-----------------|-------|-------|-------|
| SGC             | 0.557 | 0.795 | 0.479 |

5. Conclusion

In this paper, the meter-level HRRPs of one ship with different postures and that of different ships with same posture are measured using the x-band phase-coherent pulse compression radar measurement platform. The results show that the HRRP of a ship has great relationship with its posture, that is to say, the HRRP of the same ship has a strong posture sensitivity, while the HRRP of different ships with the same posture is obviously different.

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