Improvement of center-correction reset between guide-model switching for shipborne radar

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Abstract. Antenna servo system of shipborne radar has added digital-guide model and mutual-guide model with the support of center correction in order to capture and track targets conveniently. However, the switching between these two models would create larger step change resulting from the non-reset of center-correction. To this point, this paper represents the working principle of digital guidance, mutual guidance and center correction, and analyses the reason of step change. Then an novel approach is presented to improve the reset of center-correction. The results of experiments indicate that it can avoid the step change caused by the existence of center-correction value, and it enhances the reliability of facility effectively.

1. Introduction
Due to the narrow launch beam and harsh working environment, shipborne radar adds greater difficulty to the offshore measurement and control task. In order to ensure that the radar can capture the target in time and track it as early as possible, it is usually considered to use digital guidance and mutual guidance between radars in design and use to improve the efficiency of search and acquisition. The radars used for measurement and control tasks built on the survey ship usually have more than two sets to meet the mutual guidance requirements. Therefore, in the target acquisition phase, if the digital guidance data has a large deviation, the radar with a narrow beam cannot detect the target, but at this time If the radar with the wide beam finds and has tracked the target, the former can choose to switch directly from the digital-introduction mode to the mutual-induction mode, so that the target can be tracked and captured quickly. At present, the center correction function is added to both guide modes, but the correction amount will not be automatically cleared with the switch of the guide mode, but will be superimposed on the latter mode to form a step. In view of this situation, this paper proposes an improved method of center correction and clearing, to ensure that when the mode is switched, the center correction of the previous mode can be automatically cleared, which will not affect the target capture in the new mode.

2. Shipborne radar guidance mode
2.1. Digital boot mode
Digital guidance mode is one of the important working methods of shipboard servo system. The current equipment adopts the digital guidance mode of the earth system. The ACU (antenna control unit) uses the earth coefficient index angle superimposed center correction amount as the command angle, and the earth angle formed by the antenna actual deck angle superimposed inertial navigation
data as the comparison angle. The current command is calculated in real time. The difference between the angle and the comparison angle, the error angle is obtained, and then the error angle is subjected to large-angle operation control or digital loop PID processing, and finally the real-time speed command is output to the servo drive to control the antenna rotation through D/A. The road structure is shown in Figure 1.

![Figure 1. Structure diagram of geodetic coefficient loop](image)

2.2. Mutual guidance mode between radars
The mutual guidance mode between radars is also one of the important working methods of shipboard servo systems. At present, a certain type of surveying ship is built with three sets of tracking and measuring radars and a set of optical measuring theodolites. After the coordinates in the dock work, the coordinates of the antenna deck system are basically the same, and they have mutual guidance conditions.

When the antenna is in the mutual guidance mode, the correction amount of the deck angle superposition center of the guidance antenna outside the ACU is the command angle, and the actual deck angle of the own antenna is used as the comparison angle to calculate the difference between the current command angle and the comparison angle in real time. Obtain the error angle, and then perform the PID processing of the error-free position loop, and finally output the real-time speed command through D/A to the servo drive to control the rotation of the antenna. Its loop structure is shown in Figure 2.

![Figure 2. Mutual guidance loop structure diagram](image)

3. Guidance mode correction and reset method

3.1. How the center correction works
The center correction is based on the digital guidance and mutual guidance modes, that is, based on the digital guidance trajectory angle or the actual operating angle of the outer guidance antenna, the
azimuth and pitch angle are superimposed by the handwheel to form the final control command. The difference between the center correction functions in the two modes is that digital guidance is based on superimposing the center correction on the basis of digital data, and the comparison angle is the geodetic system; mutual guidance is based on superimposing the center correction on the actual deck angle of the outer guidance antenna. The comparison angle is the deck system. During operation, press the "correction" button to activate the correction function; pop up the "correction" button to clear the correction amount; press the "correction" button again to restart the correction function.

The "correction" key signal is a Boolean signal. When the signal input to the control key board is "1", the center correction function in the software is realized. The antenna control software is developed by Borland Delphi. At present, the center correction function in the code distinguishes between digital guidance and mutual guidance mode. Taking the digital guidance mode as an example, the code to implement the center correction function is as follows:

```pascal
if GuideOffsetFlag then
begin
  AzSteerTotalAngle := AzSteerTotalAngle + AzSteerAddAngle;
  ElSteerTotalAngle := ElSteerTotalAngle + ElSteerAddAngle;
  AzCmdAngle := MACRecData.AzEarthGuideAngle + AzSteerTotalAngle;
  ElCmdAngle := MACRecData.ElEarthGuideAngle + ElSteerTotalAngle;
end;
```

In the code, taking the azimuth as an example, AzSteerTotalAngle represents the final azimuth center correction amount, and AzSteerAddAngle represents the incremental rotation of the code wheel.

### 3.2. Problem analysis

At present, shipborne radars generally use the center correction function for auxiliary scanning in the process of digital guidance and mutual guidance to improve the efficiency of target acquisition. However, after pressing the "correction" button, if you directly switch from the digital guidance mode to the mutual guidance mode without canceling the "correction" function, the correction amount in the previous mode will be directly superimposed on the command angle of the next mode. According to the operation requirements of the device, if the actual angle of the antenna differs greatly from the commanded angle, the actual angle of the antenna needs to be turned around the commanded angle to ensure the safety of the device. Therefore, if the difference between the digital guidance data and the external guidance antenna's mutual guidance data is large, during the mode switching process, the "correction" function must be cancelled first, and then the mode is switched. Such operations are easily overlooked in the tight task and cause corrections. The amount is superimposed, causing steps and target loss.

### 3.3. Improvement of center correction and zeroing method

Through researching the code, it is found that there is a piece of code as follows before entering the correction function:

```pascal
begin
  if GuideOffsetFlag then
  begin
    AzSteerTotalAngle := 0;
    ElSteerTotalAngle := 0;
  end;
end;
```

This code plays a certain role of correction and clearing, but as long as the "correction" button is pressed, GuideOffsetFlag is effective. After the mode is switched, only AzSteerTotalAngle and ElSteerTotalAngle are set to zero, and the code wheel increments AzSteerAddAngle and ElSteerAddAngle remain the same. The amount of change is the reason for the step.
Therefore, you only need to add the code that sets AzSteerAddAngle and ElSteerAddAngle to zero in the above code. The modified code is as follows:

```pascal
begin
  if GuideOffsetFlag then
  begin
    AzSteerTotalAngle :=0;
    ElSteerTotalAngle :=0;
    AzSteerAddAngle:=0.0;
    ElSteerAddAngle:=0.0;
  end;
end;
```

This code is the same in the running function of the digital boot mode and the mutual boot mode, just do the same. After processing in this way, you can switch between digital guidance and mutual guidance while keeping GuideOffsetFlag valid, without worrying about the superposition of the angle correction amount.

4. Implementation of revised zeroing method

In order to verify the availability of this change, two sets of S-band and C-band antennas are used to test and verify the ship at a standstill. The method of monitoring local transmission of digital guidance, ACU operation, and C-band servo monitoring computer are used to record data status. The S-band antenna selects the trajectory of a certain transit target and uses digital guidance throughout, as the external guidance source. The C-band antenna selects the trajectory of the same target, changes a certain parameter of the trajectory, adds a slight disturbance, and simulates the situation where the difference between the numerical index and the mutual guidance is large, as the experimental object. The experimental antenna superimposes the correction amount on the basis of the digital index, so that it closely follows the mutual guidance angle of the external guidance antenna. When the pitch angle of the ground reaches a certain angle, the correction is kept effective and the switch is switched to mutual guidance.

4.1. Original code experiment

Using the original code, choose to switch when the elevation angle of the experimental antenna is 8 °. During the experiment, it was found that when switching to mutual guidance, the actual angle of the experimental antenna has a significant step phenomenon. Select the monitoring computer to record some data as shown in Table 1.

| Minutes and seconds | ACU working method | Great location | Earth pitch angle | Index azimuth | Number index pitch angle |
|---------------------|--------------------|----------------|-------------------|---------------|--------------------------|
| 20:36:00.650        | Number index       | 21.111         | 7.963             | 20.636        | 7.355                    |
| 20:36:00.700        | Number index       | 21.107         | 7.975             | 20.631        | 7.367                    |
| 20:36:00.750        | Number index       | 21.102         | 7.991             | 20.624        | 7.383                    |
| 20:36:00.800        | Mutual citation    | 21.569         | 8.611             | 20.614        | 7.404                    |
| 20:36:00.850        | Mutual citation    | 21.562         | 8.643             | 20.599        | 7.432                    |
| 20:36:00.900        | Mutual citation    | 21.549         | 8.682             | 20.581        | 7.469                    |

It can be seen from Table 1 that the numerical data with perturbation and the original numerical data have a large gap near the pitch of 8 °. According to the experimentally established operation, the center correction amount is azimuth + 0.470 °, pitch +0.602 °, because the ship is stationary, the earth angle in the digital pilot mode can be regarded as the earth angle of the outer guiding antenna, regardless of the effect of the ship roll. When switching to the mutual guidance mode, the correction
amount is not cleared, causing the actual angle of the antenna to superimpose the correction amount, and the antenna deviates from the mutual guidance angle, forming a step.

4.2. Improved code experiment
Optimize the code and do the same. During the experiment, it was found that when switching to mutual guidance, the actual angle of the experimental antenna did not have a step phenomenon. Select the monitoring computer to record some data as shown in Table 2.

| Minutes and seconds | ACU working method | Great location | Earth pitch angle | Index azimuth | Number index pitch angle |
|---------------------|--------------------|----------------|-------------------|---------------|--------------------------|
| 20:54:03.250        | Number index       | 21.098         | 8.011             | 20.624        | 7.401                    |
| 20:54:03.300        | Number index       | 21.092         | 8.024             | 20.617        | 7.414                    |
| 20:54:03.350        | Number index       | 21.083         | 8.042             | 20.607        | 7.433                    |
| 20:54:03.400        | Mutual citation    | 21.071         | 8.060             | 20.593        | 7.457                    |
| 20:54:03.450        | Mutual citation    | 21.053         | 8.089             | 20.574        | 7.491                    |
| 20:54:03.500        | Mutual citation    | 21.028         | 8.127             | 20.549        | 7.536                    |

It can be seen from Table 2 that there is no obvious step in the switching process. The center correction amount is azimuth + 0.468 ° and pitch + 0.605 °. Obviously, when entering the mutual guidance calculation, the correction amount is cleared, and the angle of the antenna itself and the outer guidance antenna remain basically the same, so the antenna operates smoothly.

5. Conclusion
This paper aims at the problem that the current center correction amount cannot be automatically cleared when switching between digital guidance and mutual guidance modes, which may cause the antenna to form a large step during mode switching. An improvement measure is added, which is to increase the clear code statement of the code disc increment, so that the correction function can safely switch the mode while maintaining the validity. The experimental results show that this modification can effectively avoid a large step of the antenna. At the same time, the modified task software can simplify the operation steps, reduce the risk of human error, and greatly improve the reliability of the servo equipment.

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