A New Calibration Method for Two-coordinates Shipborn Search Radars

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Abstract: It is necessary for shipborn radars to be retangularily calibrated to ensure high indication accuracy. A new active calibration method for two-coordinates shipborn search radars is proposed, and its basic principles and implementation scheme of engineering are introduced, and the calculation arithmetic of real value of distance and bearing based on DGPS measurement and application effects are also been presented. Compared with the traditional calibration methods, it has the advantages of high precision and convenience for use.

Keywords: radar; active calibration; DGPS

1 Introduction

In order to ensure the radar detection precision, the shipborn radars must be calibrated by using the active calibration method after their first installation or repair. At the same time, in order to ensure the shipborn warfare system efficiency ,the shipborn radars' null-steering must be termly calibrated in order to eliminate the null-steering errors caused by the component aging, mechanical abrasion,etc. At present, the naval troops usually use the static calibration methods based on the calibration towers[1].These methods have many disadvantages: high requirements to the surroundings of the calibration towers, low precision, inconvenience on the implementation and etc. So these methods can't fulfill the recent demands of the naval troops. Therefore a new active calibration method for 2-coordinates shipborn search radars base on the GPS has been put forward and its realization as well as experimentation results have also been given.

2 Basic Principles of Active Calibration

The linchpin of radar calibration is to provide a set of measurable true value benchmarks to radars to be calibrated. After receiving the radar signal the active calibration equipment transmits a simulation echo signal during a certain time delay. And then these signals will form a target image same as the images produced by calibration towers in the radar screen. The transmission time delays of the active calibration equipment are controllable, so the distance of simulation images is also controllable, and then the noise cased by the nearby object can be eliminated. By using the GPS or earth measure methods, the position of the warship's equivalent radiation center and beaconing antennas can be calculated out. By accurately controlling the delay time of echo pulses', the distance and bearing true value can be provided. The active calibration equipments can be located at anywhere without barriers within 2 km away form the radar. The beaconing equipments should be designed as a broad band transmitter, in order to fulfill the requirements to calibrate different shipborn radars at the same time. The doppler frequency shift can also be added into the simulation echo, in order to calibrate radars while they work on the MTI mode.

3 Design of the Active Beaconing Equipment

The basic working principle of the beaconing equipment is to receive the radar signal and then transmit the storaged/modulated radar signal. After measuring the received radar signals, the equipment will transform the 2～18GHz broadband signals into the 128MHz intermediate frequency which is suitable for the digital memory.

In order to restrain the spurious noise and harmonic wave during the frequency conversion flow, the frequency conversion flow takes use of multilevel frequency conversion and intermediate frequency conversion technology. This equipment composes of: antenna, T/R switch ,receiving unit, frequency storage and signal simulation unit, emission unit, frequency synthesizer, control unit, display/control terminal and etc.

The structure chart of this equipment refers to figure 1.

The function of key parts:

1) Antenna System. This part is mainly used to receive the pulse of radars and to emit the simulation echo pulse. The antenna takes use of circular polarization in order to fit different radars.

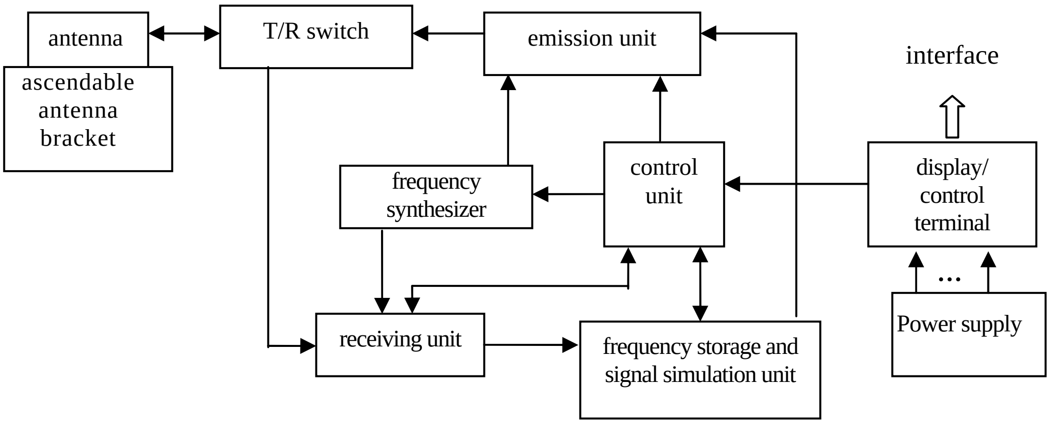

Figure 1. The Structure Chart of Active Beaconing Equipment

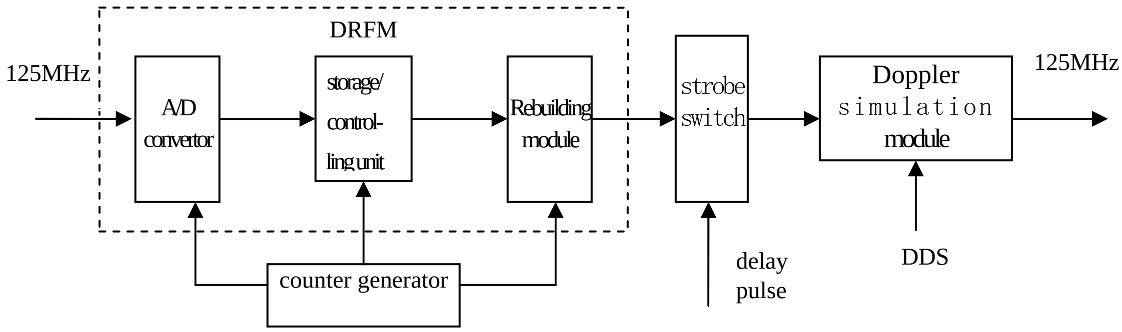

Figure 2. The Structure Chart of Frequency Storage and Signal Simulation

2) T/R Switch. This part is mainly used to is isolate the receiving and emission therefore improve the receiving/emission isolation and to protect the receiving unit during emission.

3) Receiving Unit. This part is mainly used to preselect the received signals, convert the frequency of the preselected signals and measure the detail parameters of them. All these work will be down on the base of the preseted radar working frequency which we want to calibrate. After these work, this part can provide the baseband and pulse time delay benchmark signals to the RF memory as well as the controlling unit.

4) Frequency Storage and Signal Simulation Unit. This unit is the core part of the equipment. It takes use of the amplitude quantization, full pulse storage numerical RF storage technology to store the pulse parameters coming from the receiving unit. While storaging the doppler modulation will also be added to the pulse parameters in order to simulate the real target return signals. Its structure figure refer to figure 2.

5) Emission Unit. This part is mainly used to do the frequency conversion, filter work, magnifying work and amplitude controlling to the signals come from the digital frequency memory.

6) Frequency Synthesizer. This part is mainly used to provide the local oscillator frequency for the receiving and emission unit for frequency conversion.

7) Control Unit. This part is mainly used to receive the controlling signals and data come from the display/control terminal to do the real time control for the other other units and modules.

8) Display/Control terminal. This part is mainly used to do the equipment setting , command signals and data sending. It can communicate with outside equipments via the ethernet work, USB net, serial interface and etc.

9) Power Supply. This part is mainly used to supply

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the power for all the units of this equipment.

4 Calculation of True Value

The true value measure equipments which take use of the DGPS can fulfill the precision requirements [2] .The navigation system will be turned on while the ships is in the berthing state. Two sets of DGPS receivers will be set at the ship's equivalent radiation center and the becoming machine's antenna. By minutes of observation the coordinates ($T_0(B_0, L_0, h_0)$)of ship's equivalent radiation center and target points ($T_1(B_1, L_1, h_1)$) can be measured out.

This measurement will use the sphere coordinates system which takes the ship's equivalent radiation center point as the coordinates system's origin point [3,4] .As a result this measurement must do the coordinate conversation work..

The conversation work will be done as follow:

step1: transform the data of GPS from WGS-84 earth coordinates system to the space-earth right-angle coordinates system;

step2: transform the converted data from the space-earth right-angle coordinates system to the radar right-angle coordinates;

step 3: transform the converted data from the radar right-angle coordinates to radar sphere coordinates.

1）WGS-84 earth coordinates data （B, L, h） convert to space-earth right-angle coordinates data （X, Y, Z）:

$$\begin{cases} X = (N+H)\cos B \cdot \cos L \\ Y = (N+H)\cos B \cdot \sin L \\ Z = [N \cdot (1-e^2) + H] \cdot \sin B \end{cases} \qquad (1)$$

$N = \dfrac{a}{\sqrt{1-e^2\sin^2 B}}$:the curvature radius of prime vertical cycle of reference ellipsoid;

a, b :reference ellipsoid's semi-major semi-axis;

$e = \sqrt{\dfrac{a^2-b^2}{a^2}}$:first eccentricity of reference ellipsoid.

2）space-earth right-angle coordinates （X, Y, Z） convert to radar right-angle coordinates （x, y, z）

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} -\sin B_0 \cdot \cos L_0 & -\sin B_0 \cdot \sin L_0 & \cos B_0 \\ -\sin L_0 & \cos L_0 & 0 \\ \cos B_0 \cdot \cos L_0 & \cos B_0 \cdot \sin L_0 & \sin B_0 \end{bmatrix} \cdot \begin{bmatrix} X - X_0 \\ Y - Y_0 \\ Z - Z_0 \end{bmatrix} \qquad (2)$$

$[X_0, Y_0, Z_0]^T$:the radar's space and earth right-angle coordinates;

B_0, L_0 is radar 's the latitude and longitude in the earth coordinates sytem.

3）radar 's right-angle coordinates (x, y, z) convert to radar sphere coordinates (D, β, ε) .

$$D = \sqrt{x^2 + y^2 + z^2} \qquad (3)$$

$$\beta = arctan\frac{y}{x} \qquad (4)$$

D :the distance between target and radar;

β :the bearing angle between calibrated radar and target;

5 Experimentation Results

In the experimentation, the time delays have been set as 30km，60km，90km, of each time delay we got 20 groups of real measured values. Distance and bearing errors have been displayed in the following figure 3 and 4.The useless data will be winkled out, their periodicity, placidity will also be checked according to the military data processing criterion[5]. Their random errors and system errors are listed in table 1.

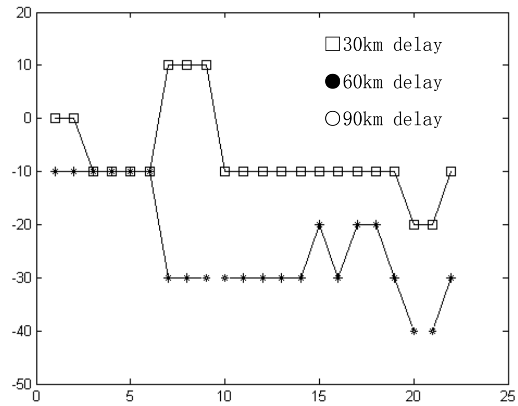

Figure 3. Distance errors

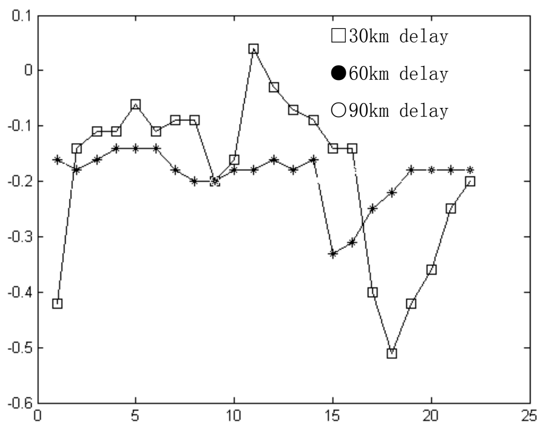

Figure 4. Bearing errors

Talbe 1. Real Demarcatation Results

Time Delay	Distance（m）		Bearing（°）	
	Random Errors	System Errors	Random Difference	System Difference
30km	1.7	-7	0.03	-0.05
60km	1.8	-8	0.03	-0.06
90km	1.8	-7	0.02	-0.06

The calibrated radar's distance finding precision is 50m,its bearing finding precision is 0.3º.They are all under the allowable error range, they needn't to be revised. If the calculated system error is out of the precision requirements, the radar distance finding and bearing finding benchmarks must be revised.

6 Conclusion

This active calibration method have already been applied in the demarcation of several 2-coordinates shipborn search radars. The calibrated radars have all do well in the target indication for shipborn weapons. This portable equipment can greatly improve the efficiency of radar calibration. It can also greatly save manpower and material resource. However, it can't be used for the phased array and 3-coordinates radar's calibration. This equipment's precision can not fulfill the precision requirements of tracking radars. So, it needs to be modified in the future.

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