Calibration and Optimization Scheme of the Metal Ball of Weather Radar in Nanchang

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Abstract Calibration of weather radar is a main means to ensure the performance and data accuracy of weather radar. In the past, the calibration method was the static instrument calibration method of weather radar, but the full-link calibration and comparison calibration stations of external radiation sources have not been conducted. In order to achieve truth calibration and improve the accuracy and consistency of radar data in the whole network, the full link calibration of the metal ball was carried out in Nanchang radar station in August 2024. In this paper, conclusions on the calibration of the metal ball and the problems in the calibration process as well as some experience were introduced.

Key words Weather radar; Metal ball calibration; Conclusion; Experience

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The basic products detected by weather radar include reflectivity factor, velocity, spectral width, differential reflectivity, differential phase, differential phase shift, and correlation coefficient. How to ensure the measurement accuracy of the above basic products is one of the key tasks of weather radar.

Weather radar calibration is one of the main means to ensure the performance and data accuracy of weather radar. This means includes measuring the key parameters of radar with high precision, analyzing and finding problems, and accurately measuring various characteristic parameters such as precipitation, atmospheric wind field, temperature and humidity field, aerosol and clouds by adjusting each parameter of radar finally. The key parameters of radar subsystem such as transmitter, receiver, servo and signal processor algorithm are tested and calibrated by instruments. The key parameters of transmitter, receiver, servo and signal processor are tested and calibrated by instruments. This calibration method is applicable to the calibration of the static instrument in the weather radar, and the full-link calibration and comparison calibration stations of the external field radiation source has not been developed. In order to achieve truth calibration and improve the accuracy and consistency of radar data in the whole network, the Radar Meteorological Center of China Meteorological Administration proposed a calibration method combining dynamic and static data of meteorological radar, namely full-link calibration of metal balls.

1 Principle and method of metal ball calibration

1.1 Principle A metal ball scatters electromagnetic waves in all directions of space, and the radar irradiates the standard reflector with known cross-section area to obtain the echo signal of the standard reflector, so as to simulate the backscatter echo of the radar to clouds, rain and other meteorological particles and use the standard metal ball as the detection target of the radar. In order to ensure that the metal ball is effectively identified by weather radar to obtain accurate radar cross section (RCS), UAVs should be suspended with a metal ball of appropriate size and fly outside the far field range of the radar antenna. The radar beam center is aligned with the metal ball, and Z, ZDR and CC are calculated respectively. The measured and theoretical equivalent reflectivity factor (Z) should be close to differential reflectivity factor (ZDR), with a theoretical value of 0, while the theoretical value of correlation coefficient (CC) is 1. The principle of metal ball calibration is shown in Fig. 1.

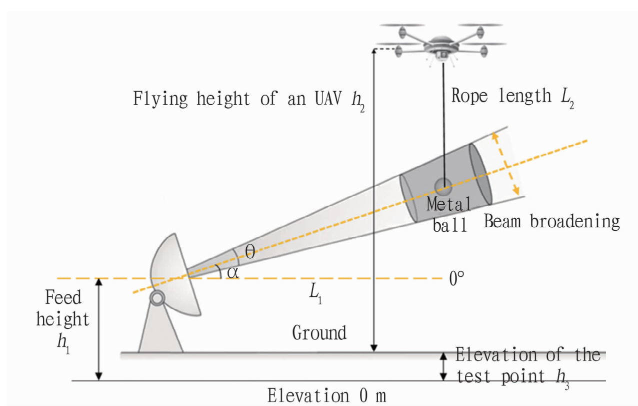

Fig. 1 Principle of metal ball calibration

1.2 Calculation of Z The measured value of the equivalent reflectivity factor of the metal ball observed by radar can be calculated according to the meteorological radar equation. The formula for calculating the echo peak power of a single target of the metal ball is as follows:

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$$P_r^{max} = \frac{P_t G^2 \sigma \lambda^2}{(4\pi)^3 R^4} \quad (1)$$

Thus, the equivalent reflectivity factor for a single target of the metal ball by meteorological radar observation can be calculated as follows:

$$10\lg Z = C + P_r^{max} + 20\lg R + RL_{at} \quad (2)$$

In the formula, P_r is the total power received by the antenna (KW); P_t is the transmitting power (KW); G is the antenna gain (dBi); L_ε is the total system feeder loss (dB).

2 Work arrangement before metal ball calibration

2.1 Site selection for UAV calibration The optimal linear distance between the metal ball and the radar feed is 2.5 – 3.5 km. There should be no shielding between the ball and the feed, and there should be no obvious interference sources on the periphery of the connection between the ball and the feed and on the extension line. Nanchang Radar, which is located in Daishan Street, Qingyunpu District, Nanchang City, was built in 2001. In recent years, with the economic development, the surrounding detection environment has been affected by human activities, and the low elevation detection of radar has been significantly interfered with. In this study, the azimuth angle without ground object interference in the radar 0.5° elevation was selected as the direction to survey the map environment within the range of 2.5 – 3.5 km. 3 suitable locations were selected, and then field investigation was carried out. Xianghu Wetland Park in the north-northwest direction was selected according to site size, crowd density and operation safety of UAV.

Table 1 Parameters of the receiver

Receiver	Dynamic range of vertical channel (external) // dB	Noise factor of vertical channel (internal) // dB	Noise factor of vertical channel (external) // dB	Dynamic range of horizontal channel (internal) // dB	Dynamic range of horizontal channel (external) // dB	Noise factor of horizontal channel (internal) // dB	Noise factor of horizontal channel (external) // dB
Measured value	100	2.22	2.2	100	96	2.42	2.21
Acceptance standard	≥95	≤3.0	≤3.0	≥95	≥95	≤3.0	≤3.0

2.2 Metadata approval before metal ball calibration The relative position was calculated by the metal ball calibration software installed on the radar RDA according to the latitude and longitude information of the metal ball and radar building, and the calculation results should be consistent with the actual situation to complete the accurate finding of the ball. Therefore, the first step of the experiment is to use the RTK UAV for the metadata approval of radar feed. The UAV was flown near the center of the radome to simulate the position of antenna feed, and the information of latitude and longitude and elevation displayed by the RTK UAV was compared with that set in the software.

2.3 Radar calibration before metal ball calibration In order to ensure the accuracy and reliability of the weather radar before calibration, the inside and outside of radar was calibrated according to the *Provisions of the Calibration of Weather Radar*. As shown in Table 2, the indicators of the transmitter, receiver and servo system meet the requirements of the provisions.

Table 2 Parameters of the transmitter

Transmitter	Transmit pulse width (wide pulse) // μs	Transmit pulse width (narrow pulse) // μs	Transmit pulse peak power (wide pulse) // kW	Transmit pulse peak power (narrow pulse) // kW	Limiting improvement factor (prionotron output) // dB
Measured value	4.78	1.64	737.86	700.27	56
Acceptance standard	4.70 ± 0.25	1.57 ± 0.10	≥650	≥650	≥55

3 Metal ball calibration

3.1 Metal ball tracking The first flight failed to find the ball. As shown in Fig. 2, according to the analysis of the surrounding environment of the radar station, the possible reason is that radar beam sidelobe was affected by ground objects to influence the experiment. The problem can be solved by increasing the flight altitude and narrowing the search range.

By adjusting the height of the metal ball and narrowing the scanning range to avoid interference, the ball was found successfully in the second flight. Two obvious wave peaks appeared in the high-angle scanning results of the pitch RHI, of which the high wave peak corresponds to the UAV, while the low wave peak corresponds to the metal ball. After the elevation of the metal ball was located, SEC scanning was conducted. As shown in Fig. 3 and Fig. 4, there were obvious wave peaks, showing that the ball finding was successful.

3.2 Comparison and analysis of theoretical and measured data The second ball finding was successful, but the experimental data deviated greatly from the theoretical data. Through on-the-spot communication between the flight group and the radar group, the possible causes of the deviation are determined as follows: firstly, the metal ball is close to the edge of the radar beam detection library; secondly, the distance between the ball and the ground building is still insufficient; thirdly, parameters corresponding to radar are not suitable. Updating the software, correcting transmitting power and adjusting the rope length were conducted on site, and the metal ball was moved in the direction of the radar beam towards the center of the detection library.

After adjustment, the effect was verified through an experiment. The theoretical value of decibel reflectivity factor (DBZ) is 51.3, and the calibration peak value of experimental RHI metal ball is 51.19; ZDR value is –0.16, and SEC scanning peak value is 51.71, while FIX scanning value is 51.57. ZDR values of SEC and FIX scanning are −0.12 and −0.16, respectively. The theoretical value of ZDR is 0, and the experimental values are all within 0.16. Both are basically consistent with theoretical values (Fig.4).

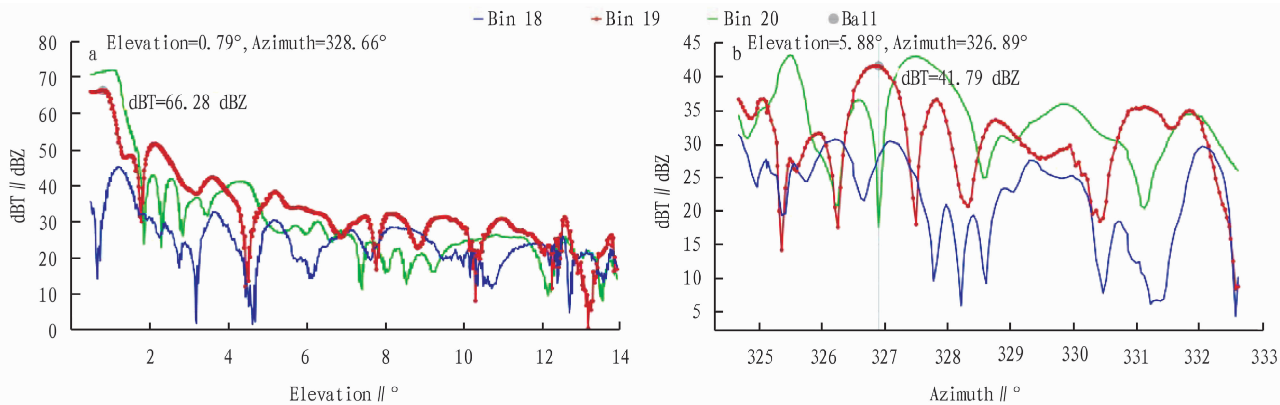

Fig.2 Elevation (a) and azimuth (b) of SEC scanning

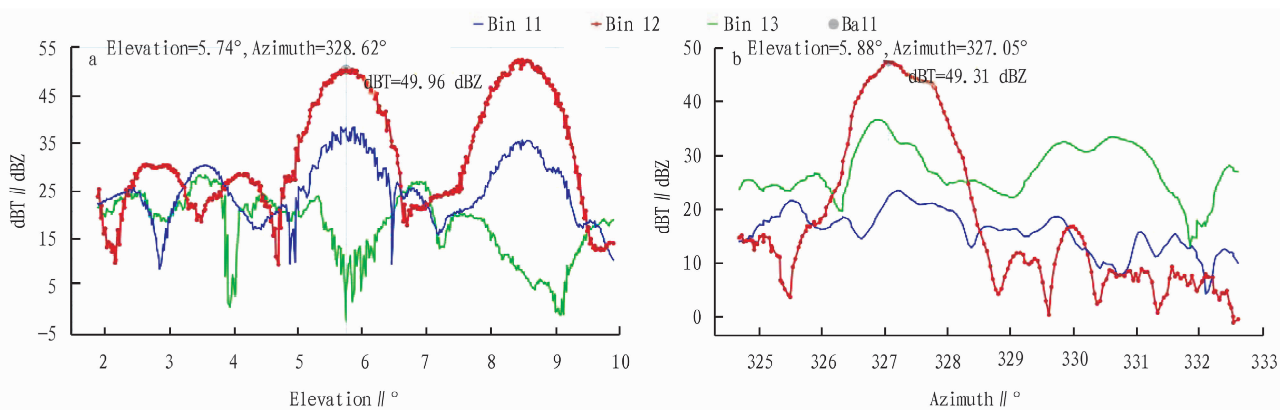

Fig.3 Elevation (a) and azimuth (b) of SEC scanning

4 Conclusions and optimization scheme

4.1 Conclusions Nanchang radar completed the experiment of metal ball calibration on August 2. The UAV took off and landed six times in total, and the base data and iq data were all archived. From the analysis of the experimental data, it is concluded that through on-site calibration of the radar, the overall calculation deviation of Z index in the metal ball experiment of Nanchang radar is within 1 dBZ, and the ZDR deviation of the metal ball is within 0.16 dBZ.

4.2 Experience The radar is located in the downtown area, where there are more ground objects, so it is needed to narrow the scanning range properly when looking for the ball. Due to the influence of the side lobe of radar electromagnetic wave, the interference free area required for the metal ball calibration experiment is larger, and if conditions permit, the height should be raised as far as possible when applying for UAV airspace.

The metal ball calibration software has a flash back phenomenon, which still exists after version updating, which is suspected to be related to the radar host operating system linux. According to the rules summarized in the radar calibration experiment in Nanchang, the software is restarted after the completion of a calibration, and then the next grab is conducted, which can effectively reduce the probability of the flash back.

When the sunlight is too strong, the h30 camera carried by the UAV fails to find the ball, and it is needed to focus manually.

The transmitted power of radar needs to be modified by calibration syscal for reflectivity according to the measured value.

4.3 Optimization scheme

4.3.1 Current situation of calibration. There are UAV and radar operation group, and communication is conducted mainly by mobile phone wechat. Existing problems are as follows: during the experiment, the communication link is not smooth, and the delay affects the flight time of UAV.

4.3.2 Optimization scheme. A small local area network between the outfield UAV and weather radar is constructed through the Internet, and the weather radar control software RDA is operated in the outfield by using VNC remote control software, so that the radar software is directly controlled in the outfield. The radar control computer can directly read the position information of UAV to realize the data interconnection between UAV and radar, which facilitates software calibration and saves the time of data interconnection. It is needed to the inefficient interconnection between the UAV field and radar calibration operation through wechat and telephone contact, cancel the radar operation group, increase the flight time of UAV and improve calibration efficiency.

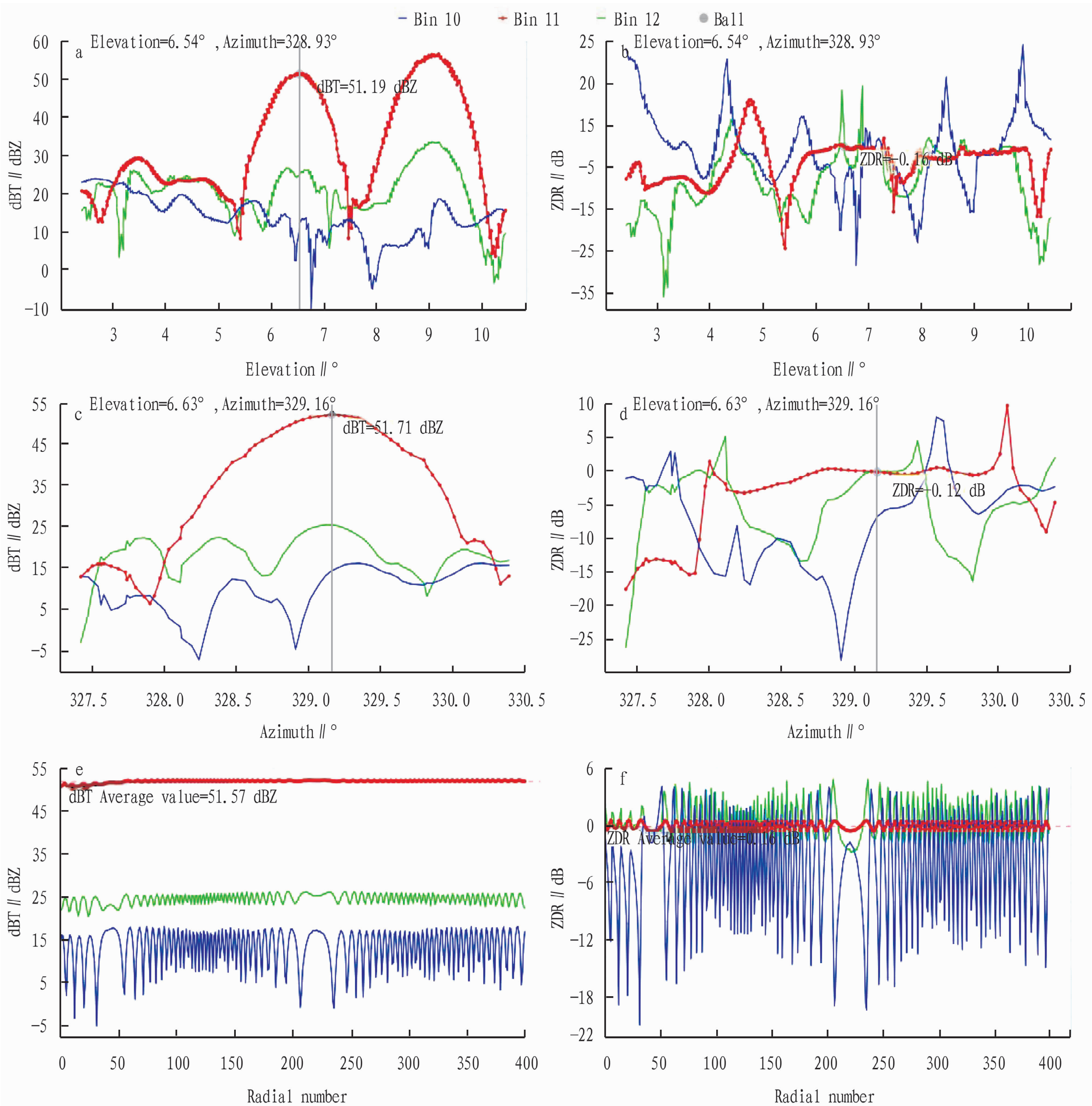

Fig. 4 Results of RHI, SEC and FLX scanning

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