Prelaunch Performance Evaluation of MWRI-II Onboard FengYun-3H

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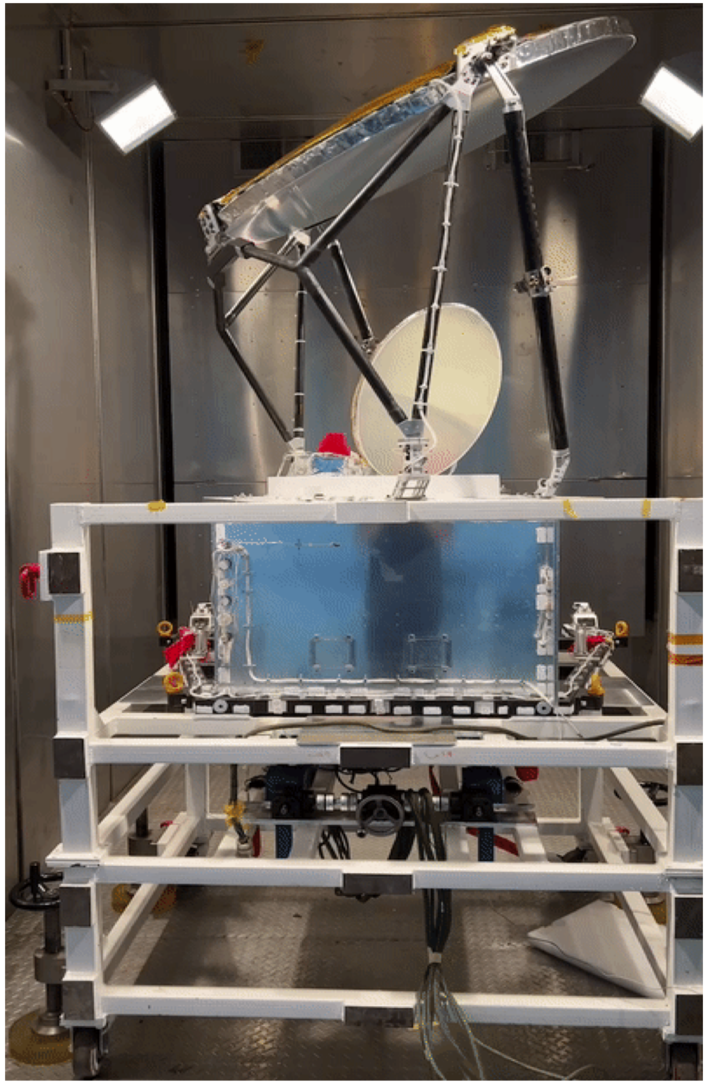
The MWRI-II instruments are dual-polarized, conical scanning, passive microwave radiometers.



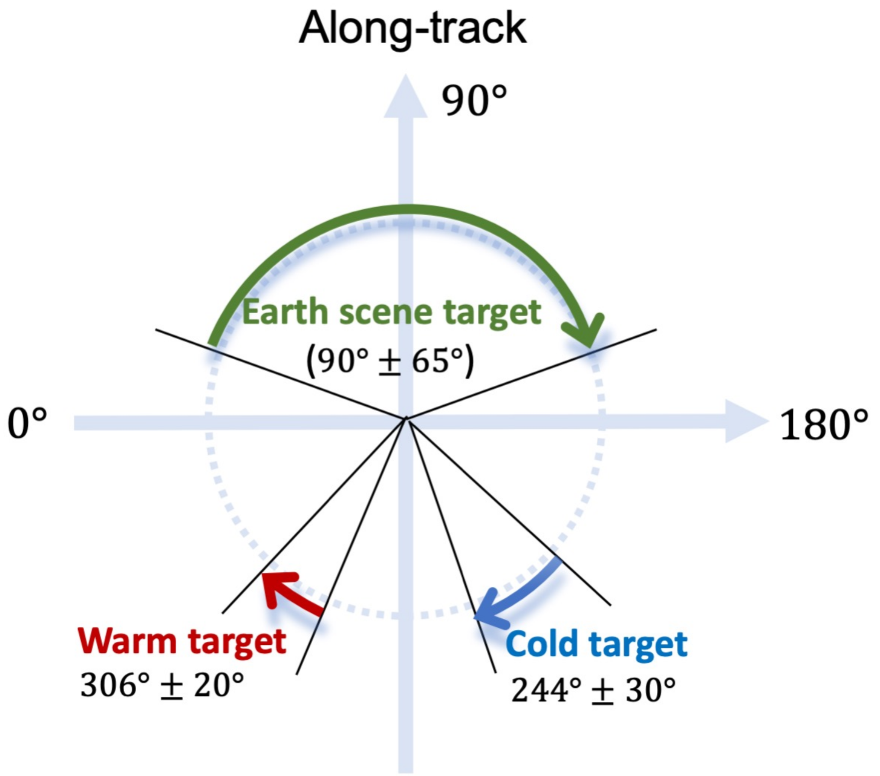
The Microwave Radiation Imager (MWRI) is widely used in numerical weather prediction and geophysical parameters monitoring, including soil moisture, snow depth, sea surface temperature, sea ice and ocean wind speed.

The second-generation MWRI-II has been carried on Fengyun 3F and Fengyun 3G. This one will be launched on Fengyun 3H, as the successor of Fengyun 3D.

The 22 instrument channels are summarized in the following table.

Band [GHz]	Polarization	Band [GHz]	Polarization
10.65	V, H	53.75	V, H
18.7	V, H	89	V, H
23.8	V, H	118.75±3.2	V
36.5	V, H	118.75±2.1	V
50.3	V, H	118.75±1.4	V
52.61	V, H	118.75±1.2	V
53.24	V, H		

MWRI-II adopts a two-point in-flight calibration scheme to derive antenna temperature, the Radiometer transfer function can be described as：



$$R = R_w + (R_w - R_c)\left(\frac{C_s - C_w}{C_w - C_c}\right) + \frac{\mu (C_s - C_w)(C_s - C_c)}{G^2}$$

$$R = a_0 + a_1 C_s + a_2 C_s^2$$

nonlinear parameter

in-board calibration parameters，related to μ

μ is related to instrument temperature, shown as:

$$\mu = a + b T_r + c T_r^{\,2}$$

coefficients

To be tested in TVAC

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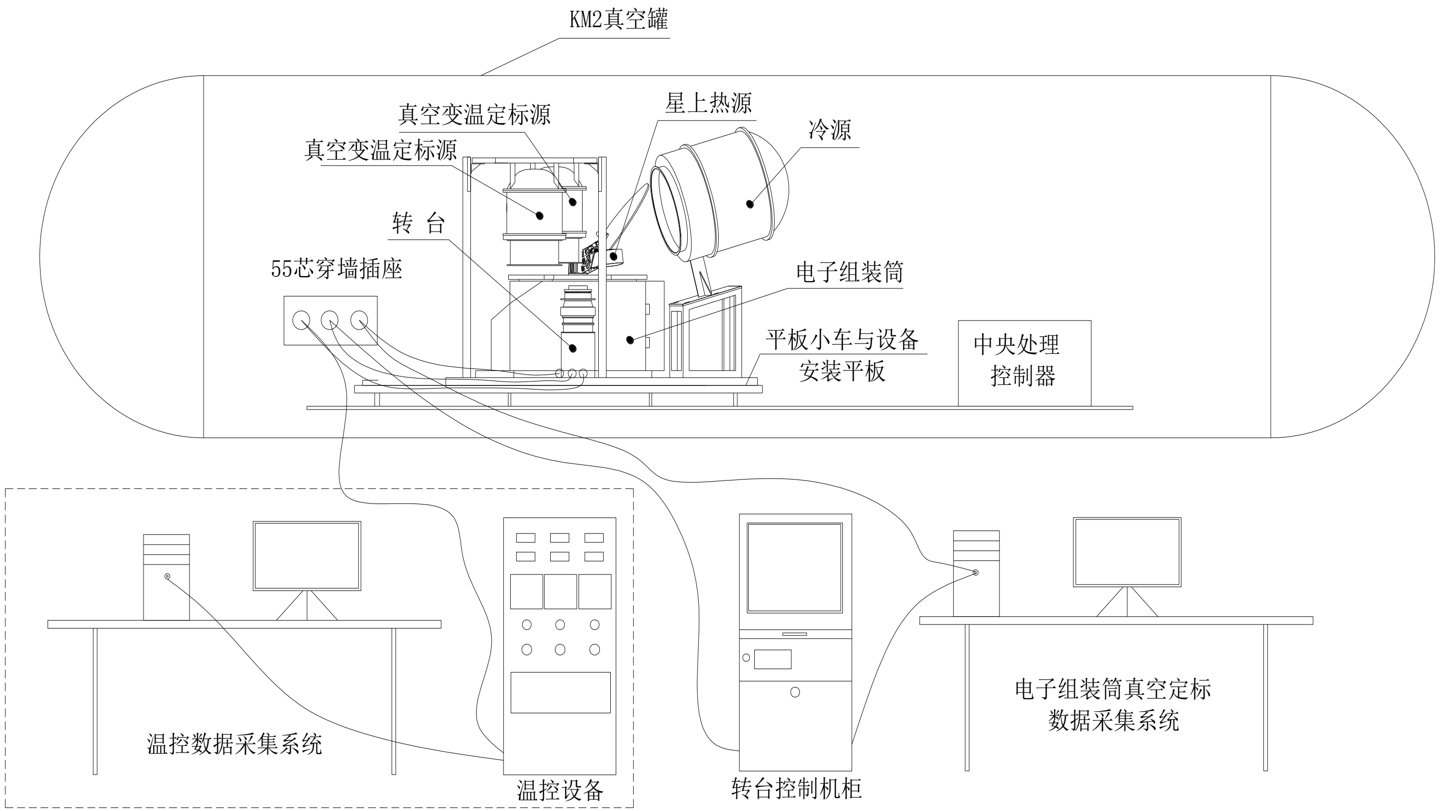
Ground TVAC Calibration

The aims of MWRI-II ground TVAC test are:

1. to test the instrument radiometric characteristics.

2. to evaluate its prelaunch performance, such as NedT.



The receiver is placed inside the KM2 vacuum tank. The temperature is controlled externally and the turntable rotates. Temperature control data and electronic assembly cylinder data are collected for experimental analysis.

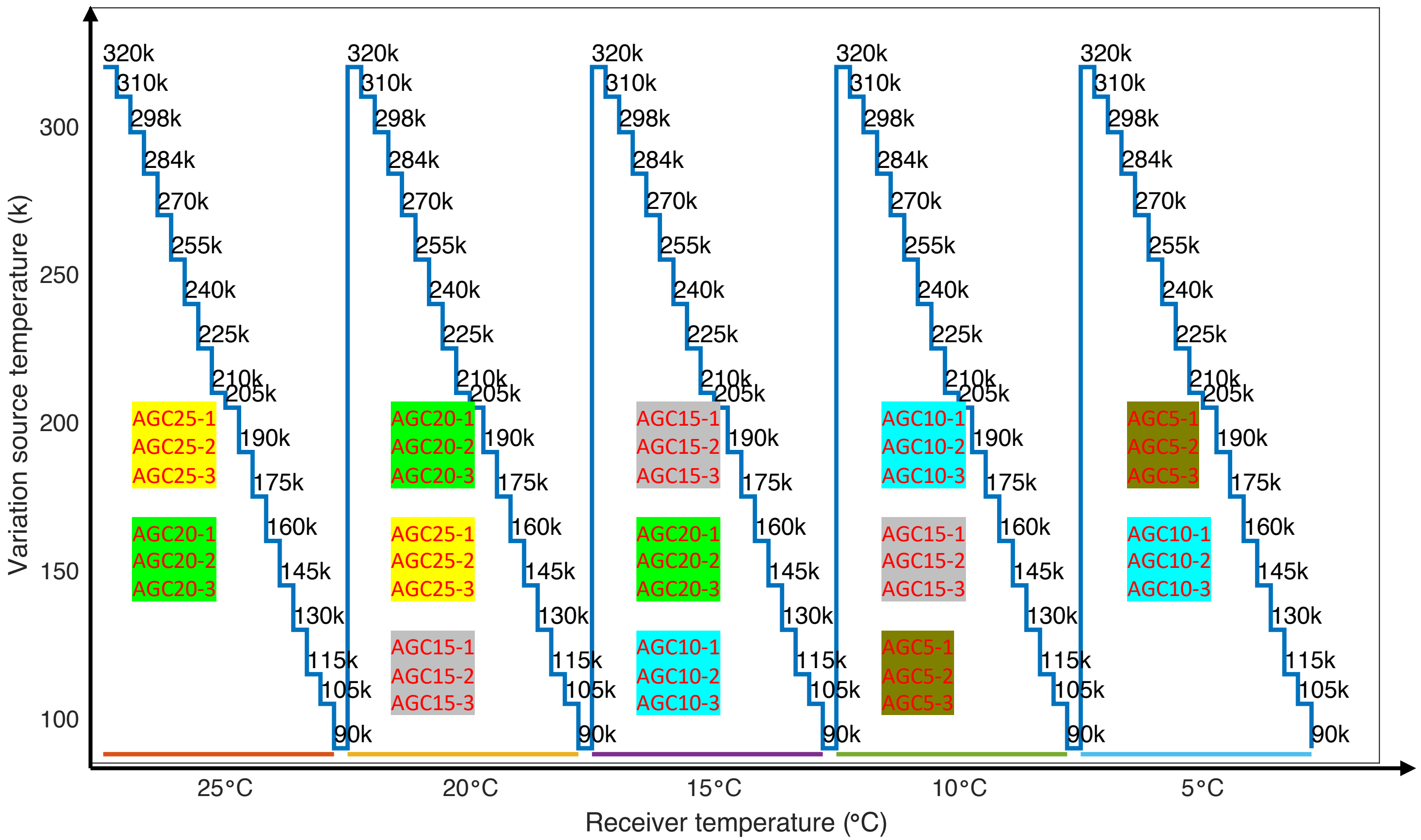
Experimental Scheme

Target temperature

- Cold-target : at 90K ；
- Warm-target : at 298K
- Temperature-varying target : Vary from 90 to 320 K with an increment of 15 K
- Instrument temperature : at 5℃、10℃、15℃、20℃、25℃

Automatic gain control (AGC)

- Three different AGC voltages for each channel are set at instrument temperatures of 5 ◦C, 10 ◦C, 15 ◦C, 20 ◦C and 25 ◦C.



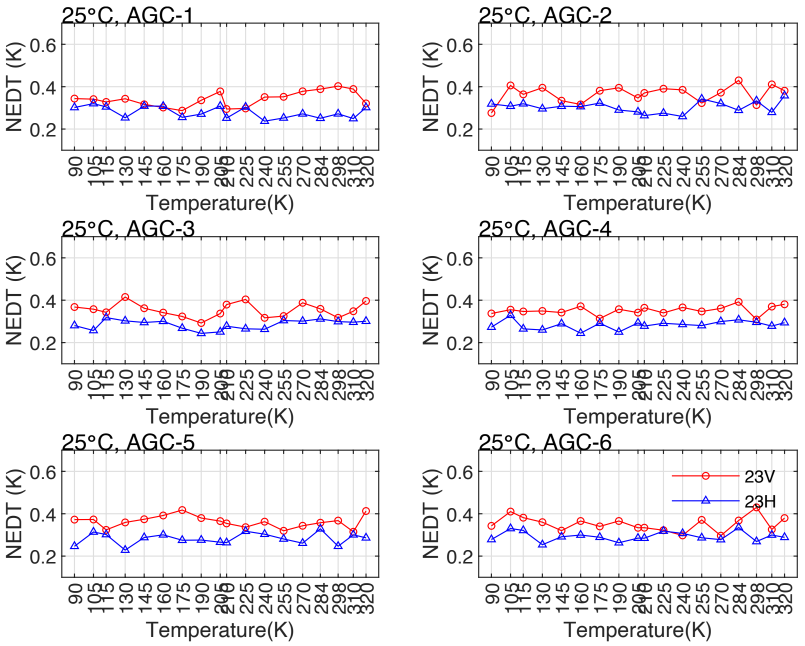
- In ground TVAC test, not only the exactly 3 AGC voltages at the corresponding instrument temperature, the AGCs at the adjacent temperature are also tested.

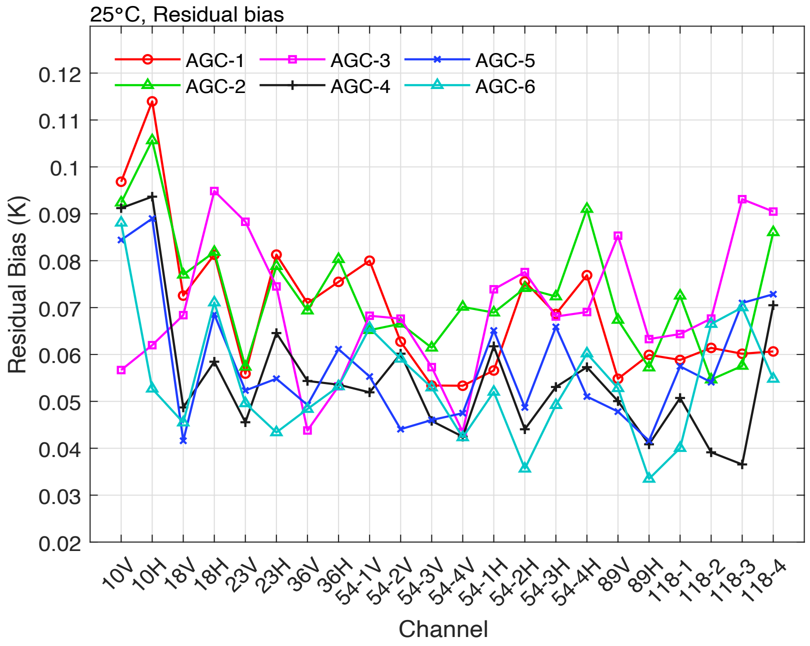
AGC Effect

Under the same instrument temperature and scene temperature, AGC can affect the sensitivity and nonlinearity of the radiometric characteristics.

Select optimal AGC ： Considering the instrument responses in non-linear residuals, sensitivity, linearity, gain, and other factors, the optimal AGC voltage can be selected for each channel at each receiver temperature.

Using the same set of optimal AGCs to analyze radiative characteristics for receivers with similar temperatures. 3 set of optimal AGCs for instrument temperature of 5~15℃, 10~20 ℃, 15~25 ℃ are used.



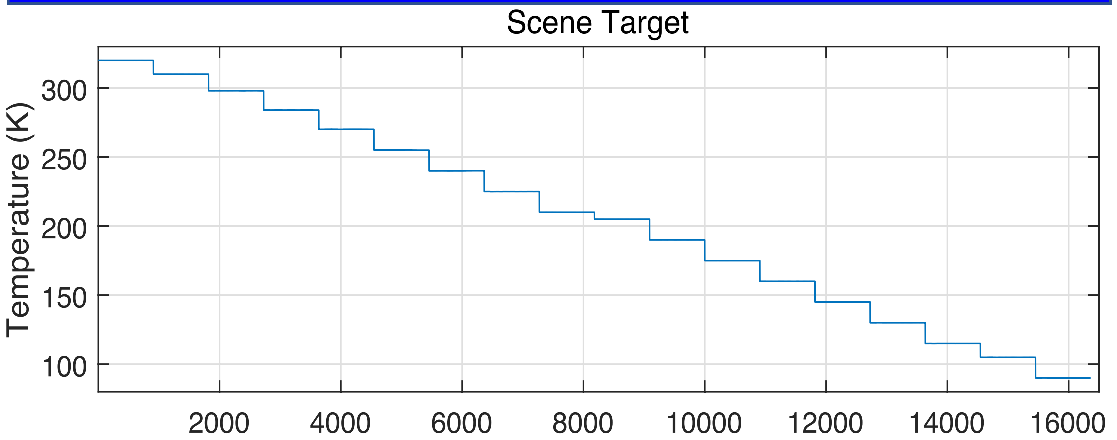


Temperature Control

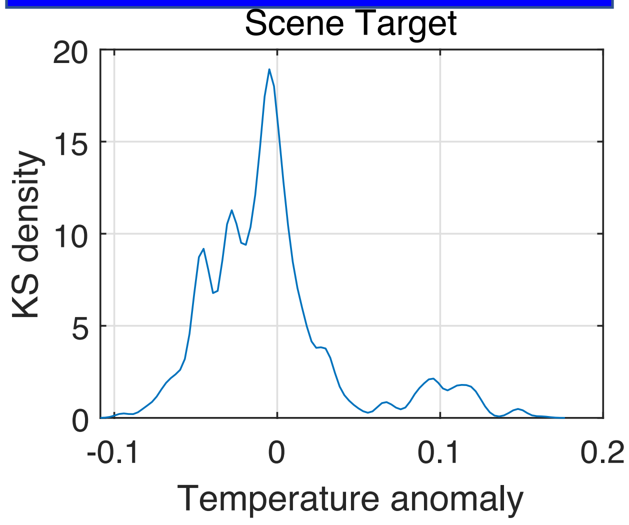
Scene target：

- Accuracy：Temperature varies from 320K to 90K；
- Homogeneity：PRT range within 0.2K;
- Stability：the temperature fluctuates within 0.15K at each temperature point.

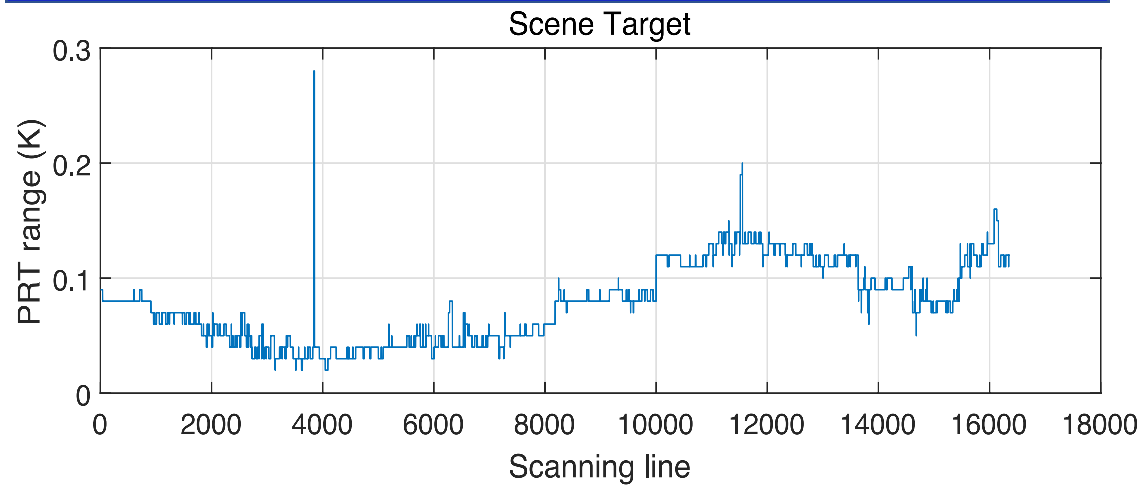
Accuracy



Stability



Homogeneity

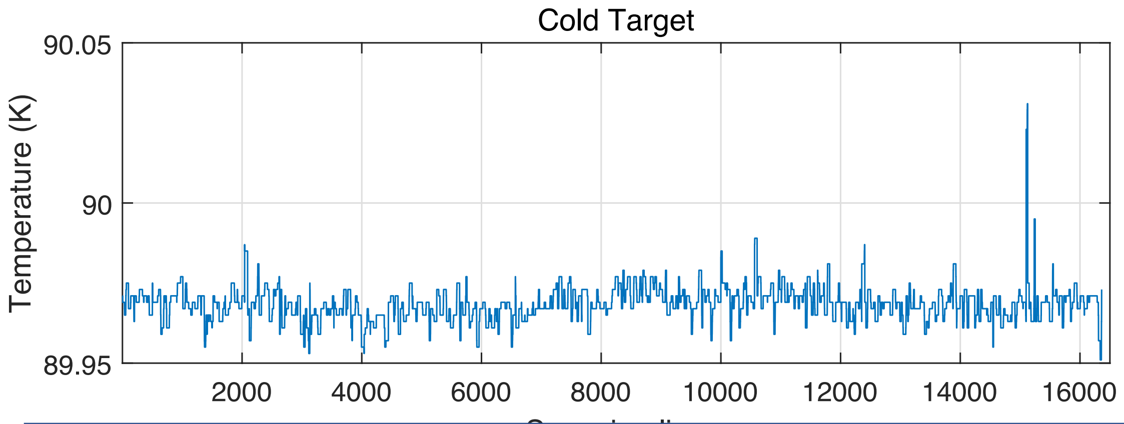


Temperature Control

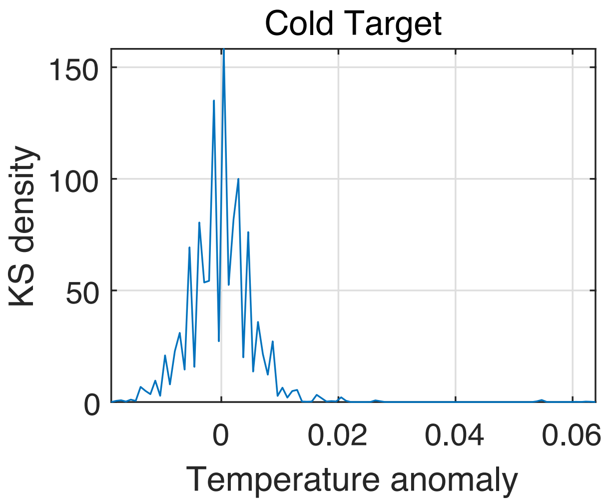
Cold target：

- Accuracy： Temperature varies from 89.95K to 90K；
- Homogeneity： PRT range within 0.2K;
- Stability： the temperature fluctuates within 0.02K at different scanning lines.

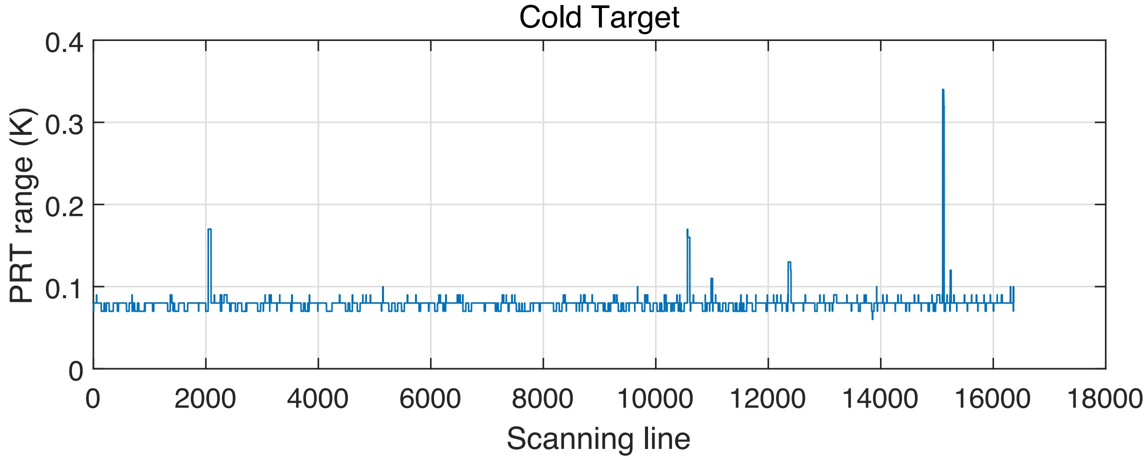
Accuracy



Stability



Homogeneity

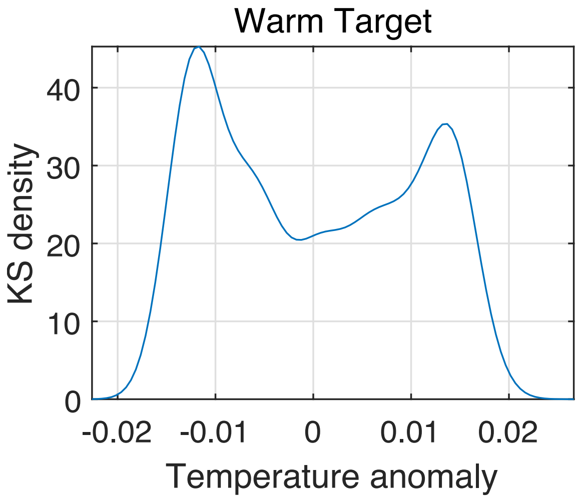


Temperature Control

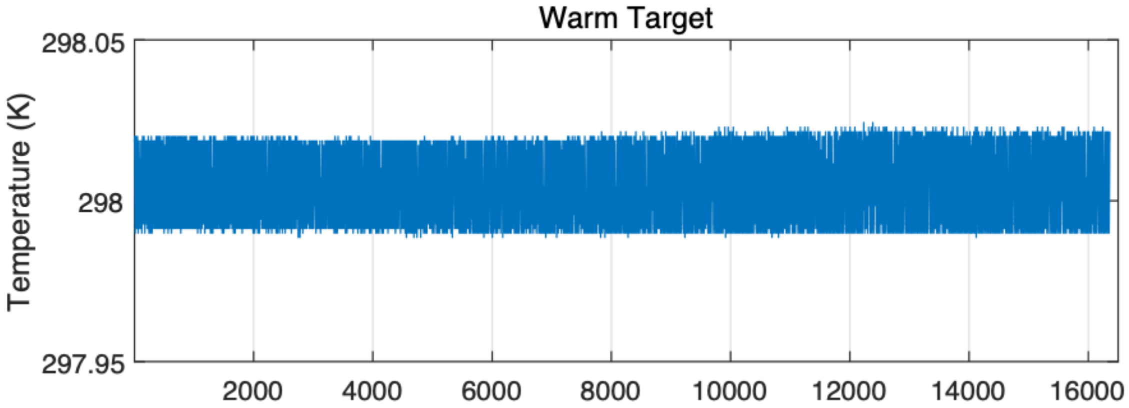
Warm target：

- Accuracy： Temperature varies from 297.99K to 298.02K；
- Homogeneity： PRT range within 0.13K;
- Stability： the temperature fluctuates within 0.02K at different scanning lines.

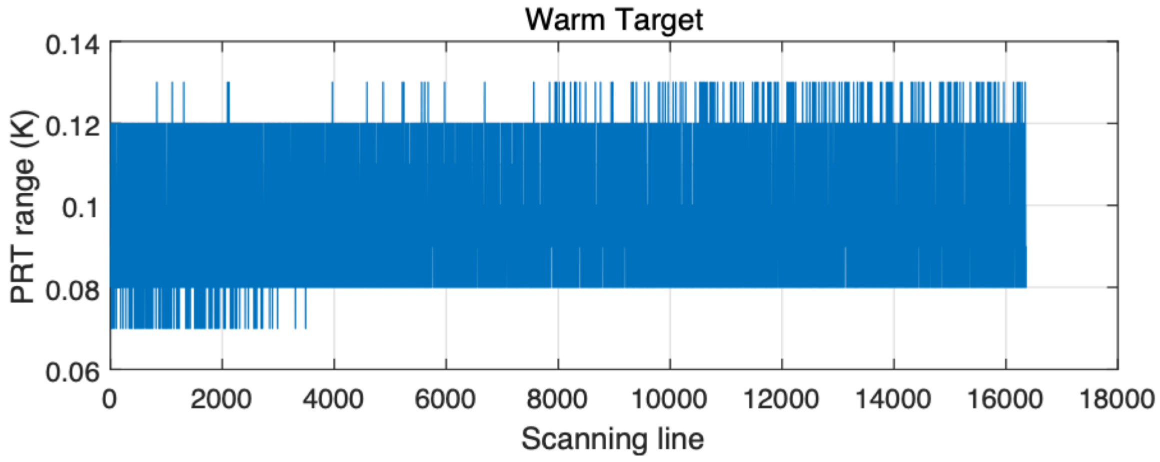
Stability



Accuracy



Homogeneity



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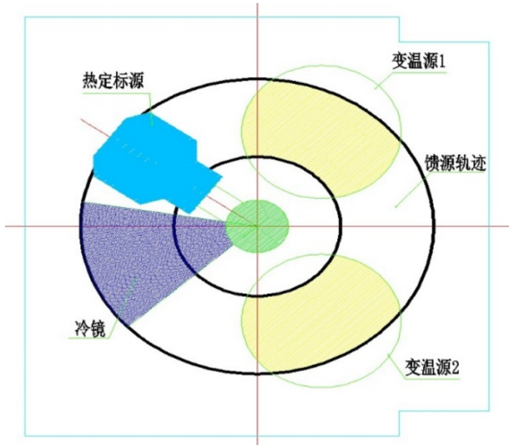
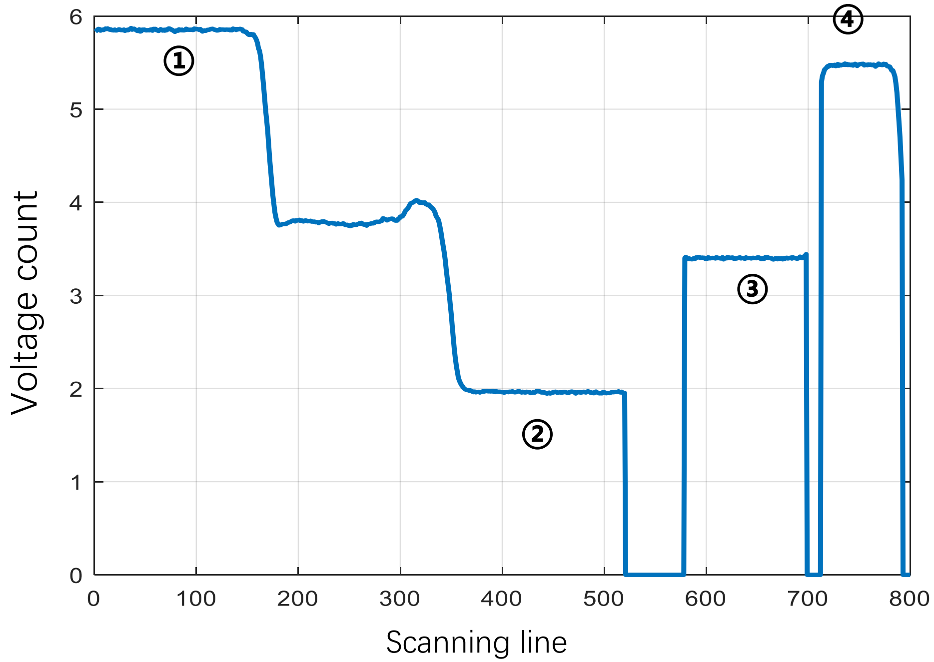
Stable FOVs

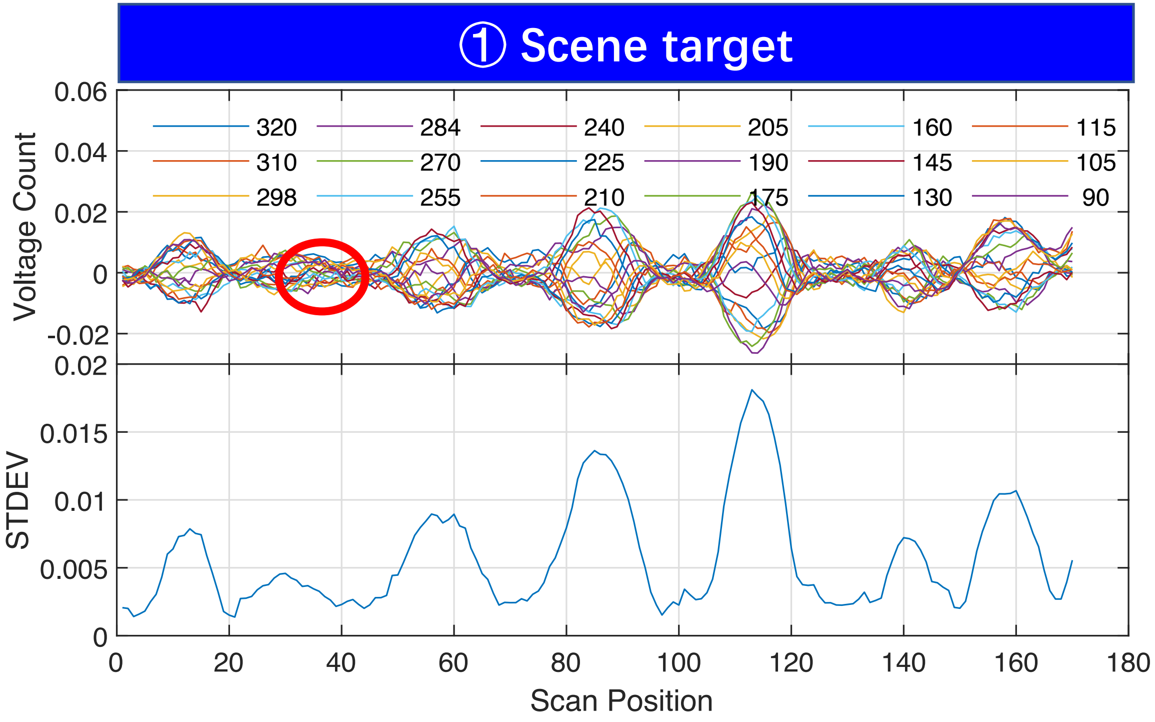
Constrained by the sizes and structures of sources, relatively stable FOVs are selected for nonlinear parameter analysis.

- **Selection criteria: low voltage anomaly and low voltage fluctuation.**

Scene target : approximately from the 38th to the 45th FOV.

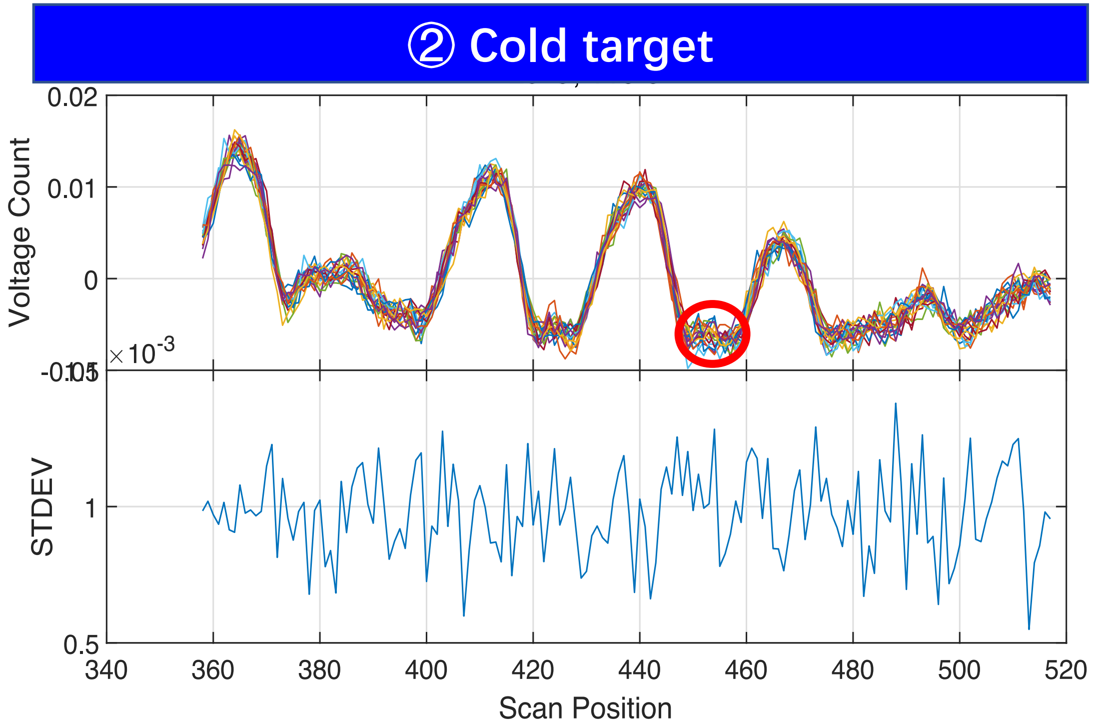


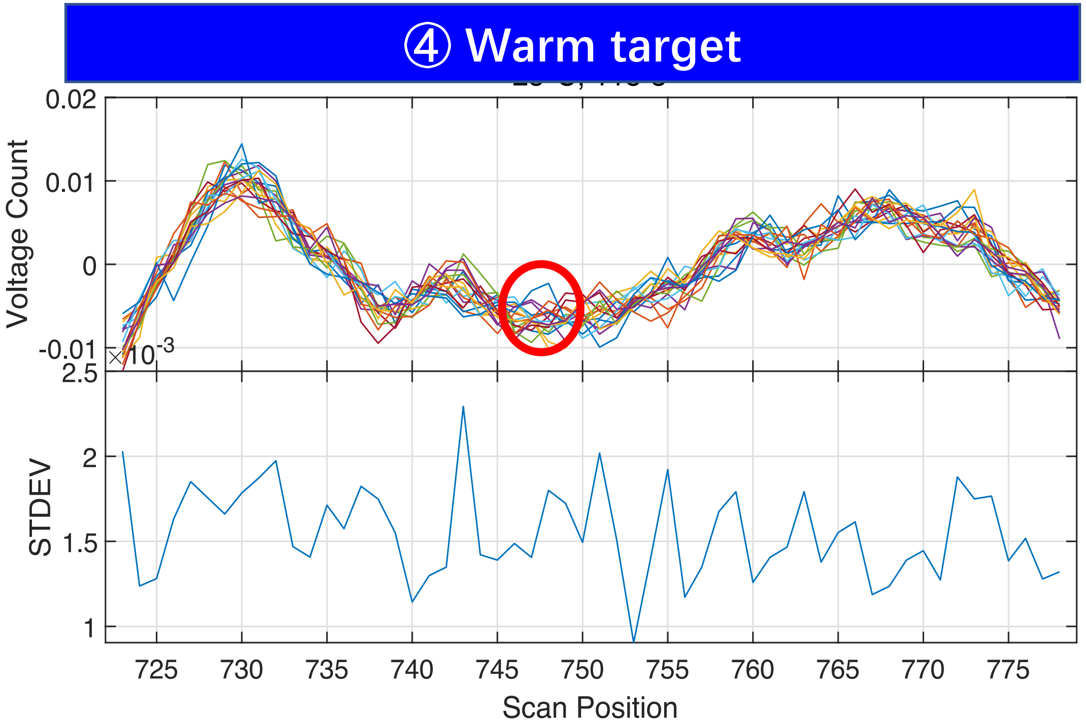




Stable FOVs

- **Cold target :** approximately from the 445th to the 458th FOV.
- **Warm target :** approximately from the 747th to the 750th FOV.





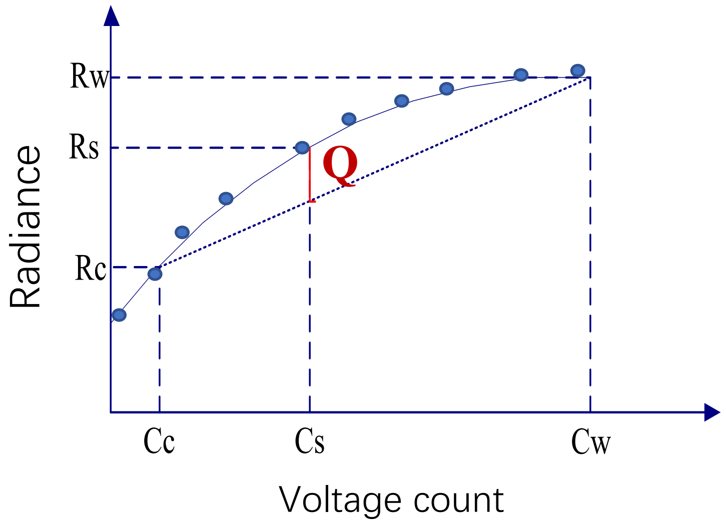
Nonlinear response

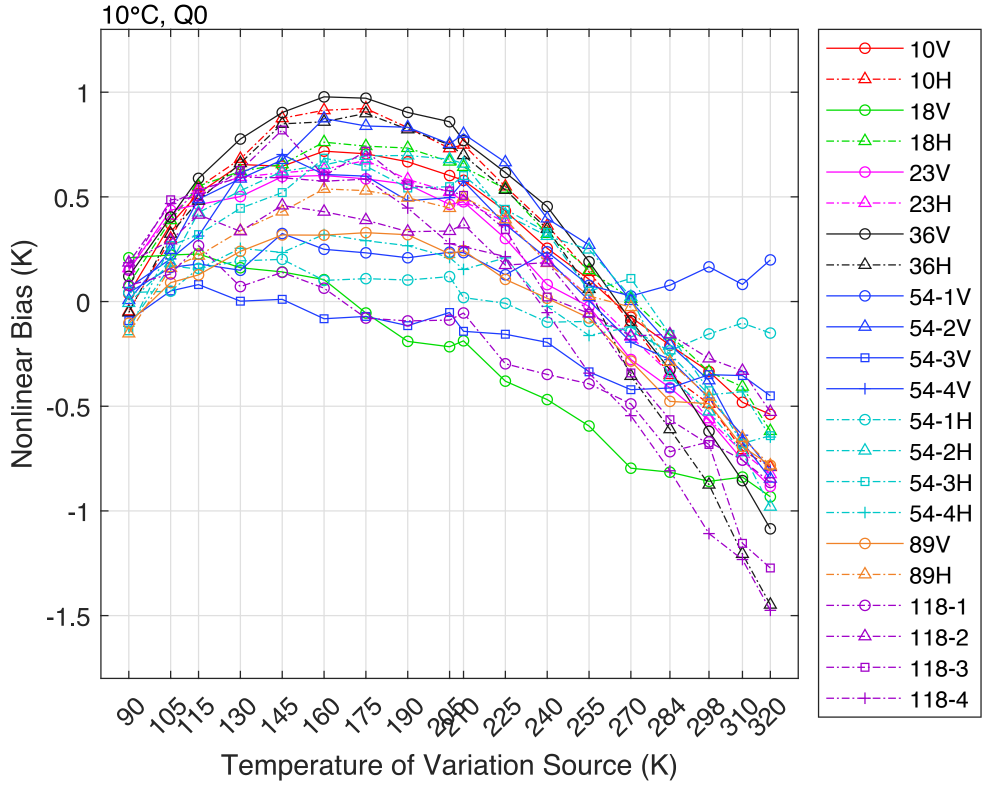
Nonlinear part

$$G = (V_H - V_C)/(T_H - T_C)$$

$$T_{A,lin} = (V_A - V_H)/G + T_H$$

$$Q = T_A - T_{A,lin}$$





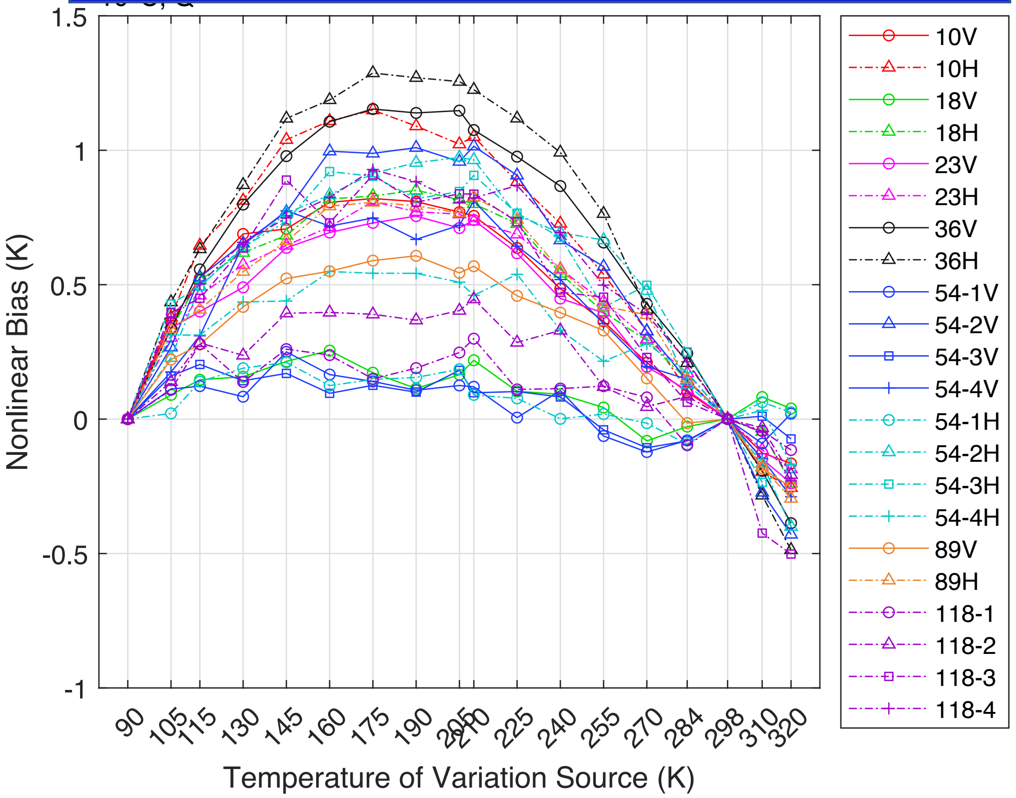
Because of different sources, the nonlinear part is not 0 at temperature 90K and temperature 298K. In order to analyze the response characteristics of the receiver, we correct them to 0.

Nonlinear response

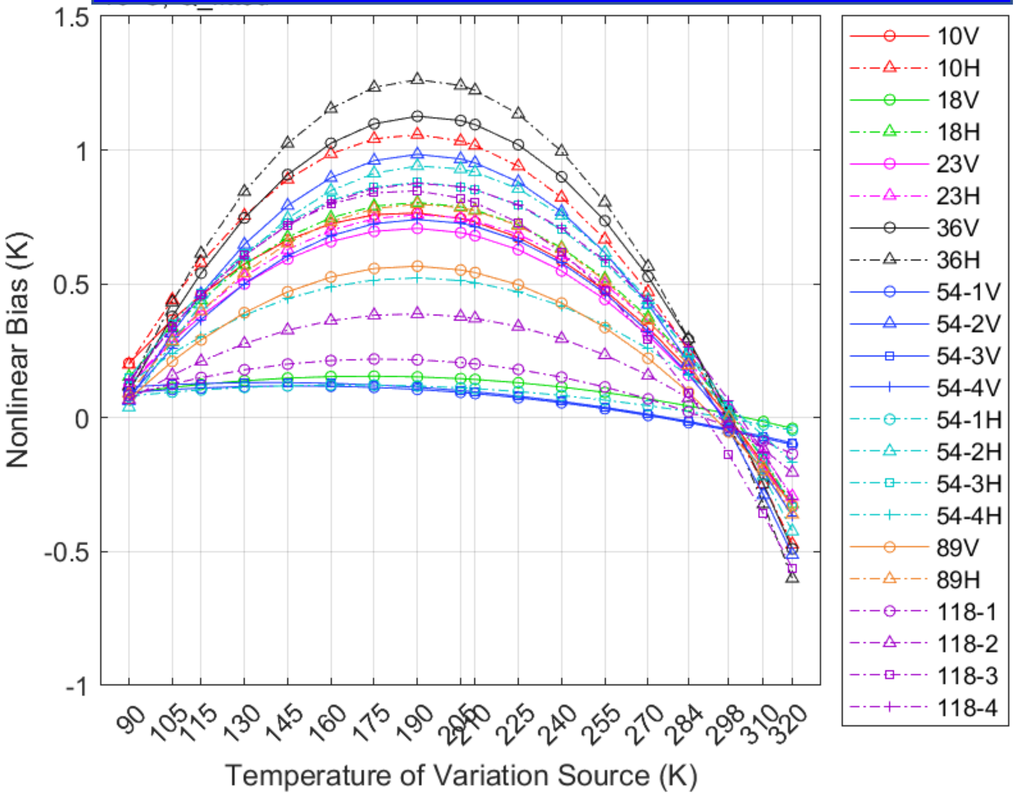
Nonlinear part

After corrected, the relationship between the nonlinear part and temperature can be approximated as a quadratic function.

Q_corrected



Q_fitted

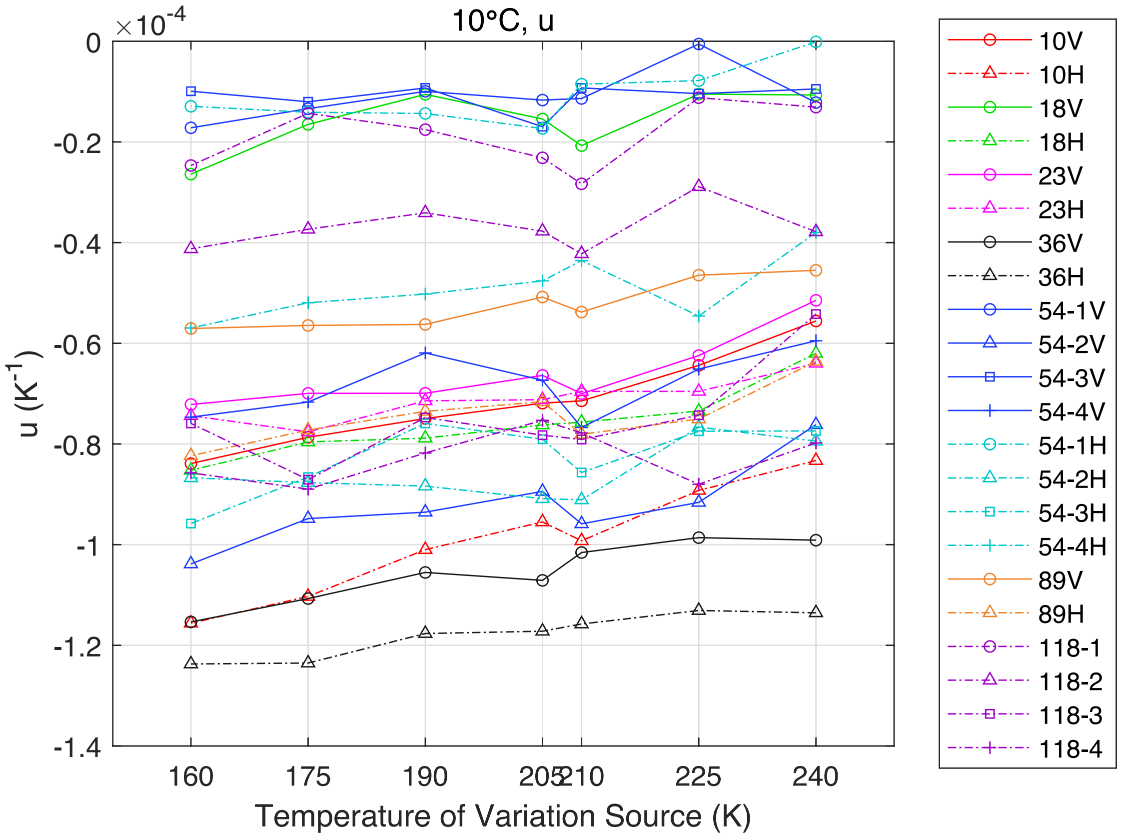


Nonlinear Parameter

$$Q_{corrected} = \mu (V_A - V_H)(V_A - V_C)/G^2$$

$$\mu = Q_{corrected} \cdot G^2 /(V_A - V_H)(V_A - V_C)$$

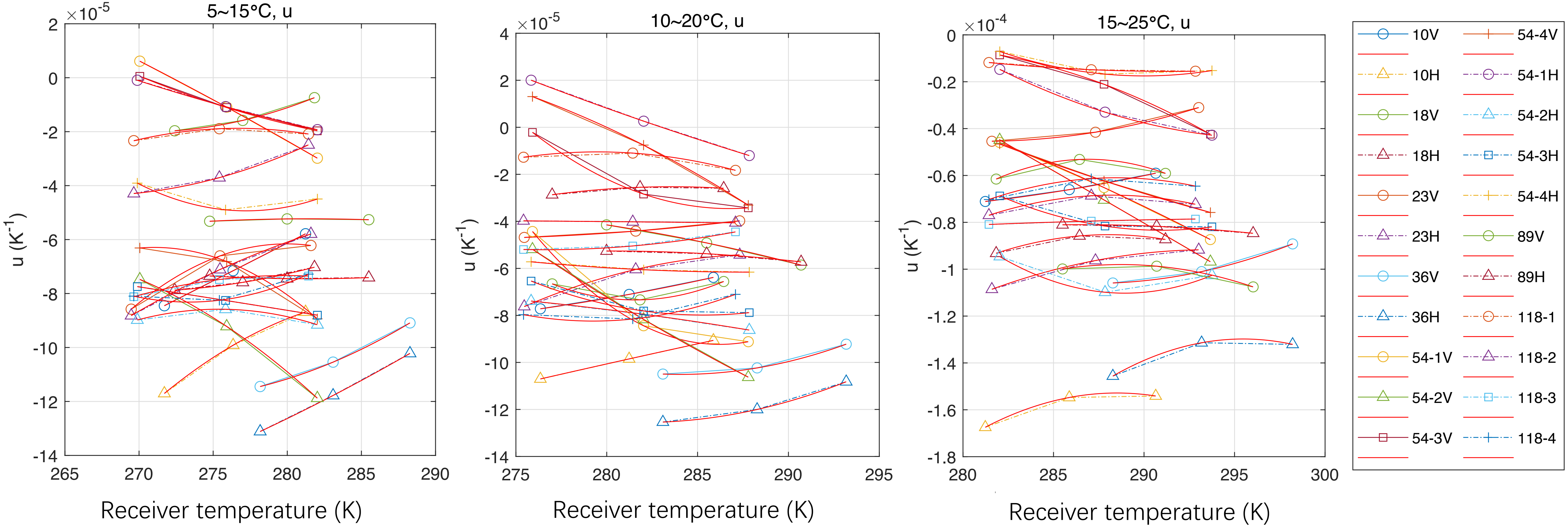
- μ can be obtained at each scene temperature.
- The range of μ is between -9.4×10^{-7} and -1.6 ×10^{-4}.
- The averaged μ is used as the nonlinear parameter .



Nonlinear Parameter

Under each set of optimal AGC, we can obtain the relationship between nonlinear parameter μ and receiver temperature.

$$\mu = a + bT_{REC} + cT_{REC}^2$$

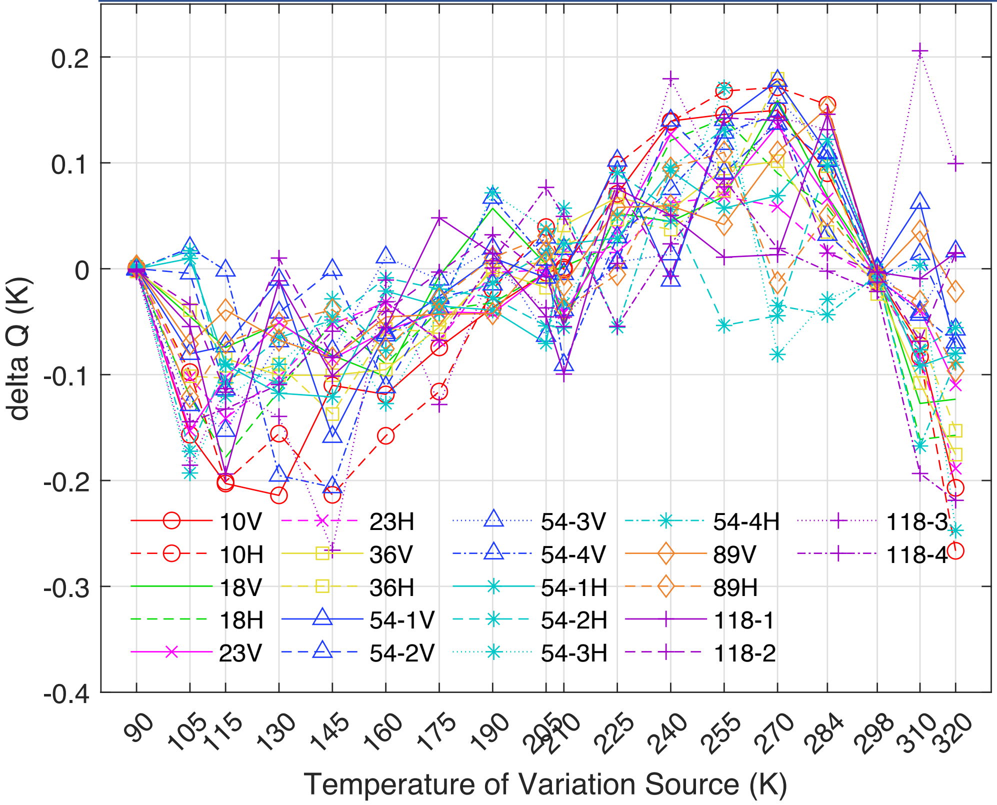


Nonlinear Residual

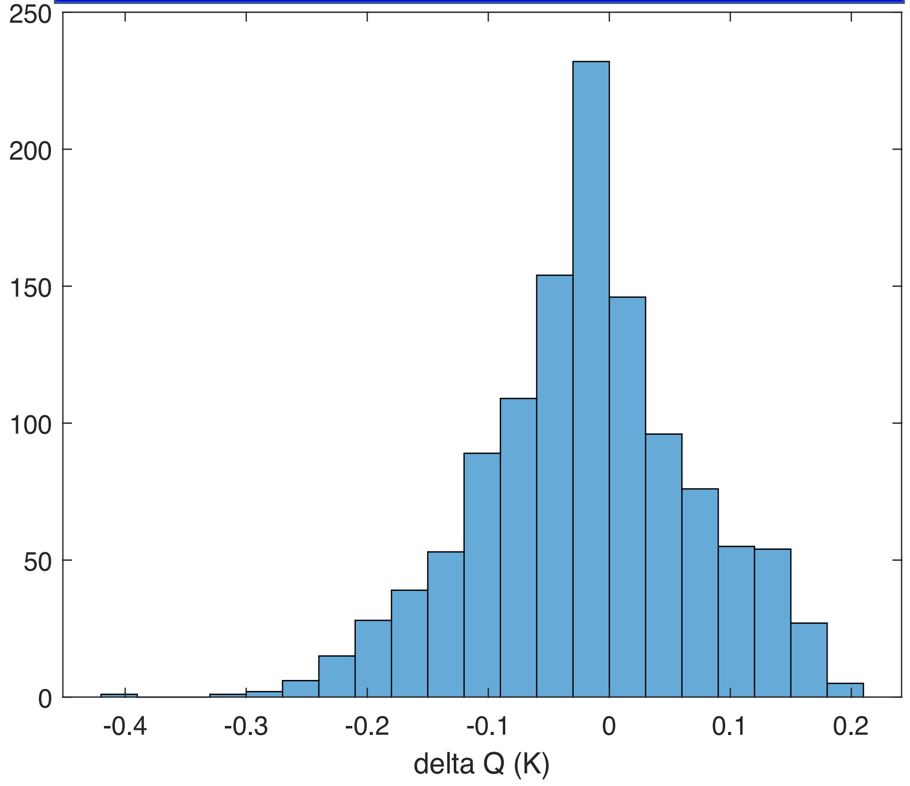
$$Residual = Q_{corrected} - Q_{fitted}$$

The residual ranges from -0.3 to 0.2, with 90% distributed between ± 0.15

Residual



Distribution



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Prelaunch Performance

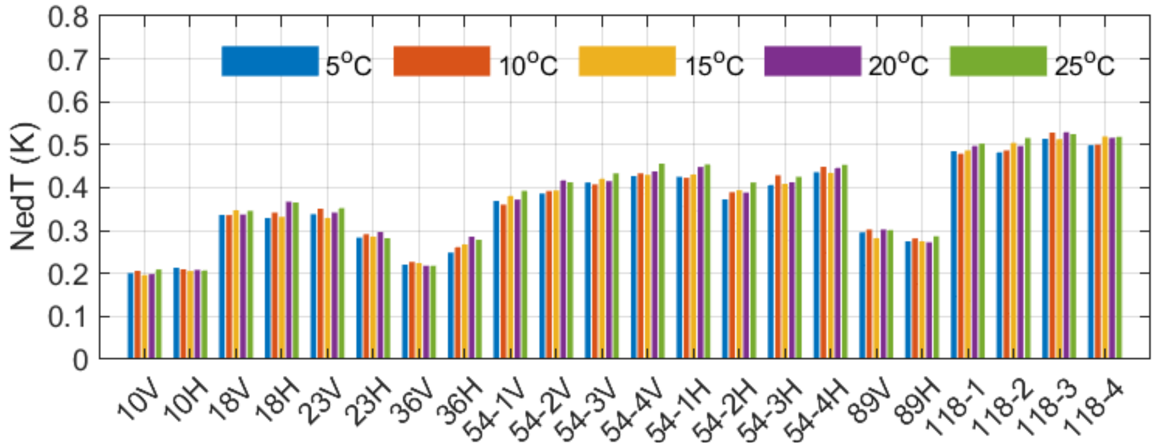
Sensitivity

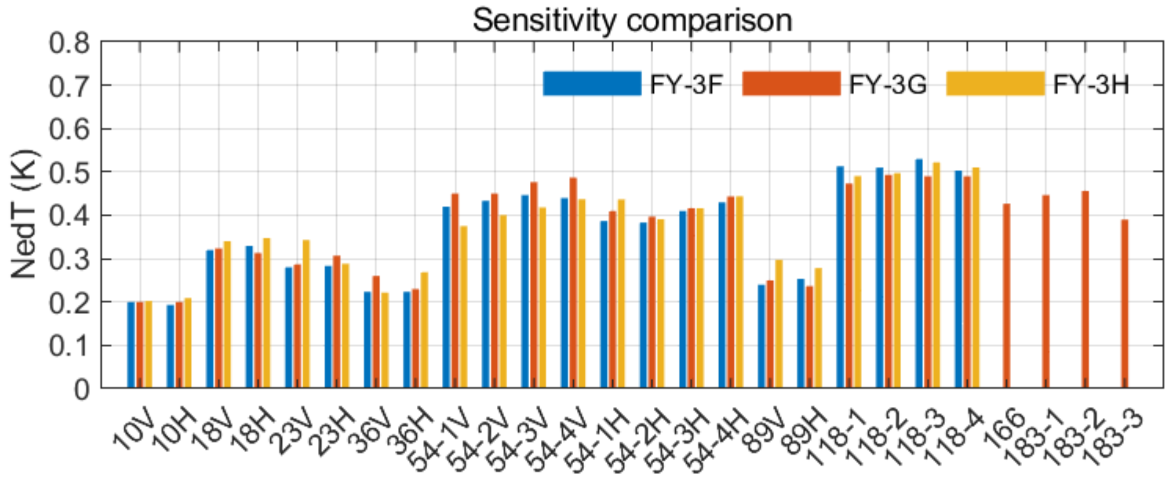
$$NEDT_c = \frac{T_2 - T_1}{C_2 - C_1} \times \sqrt{\frac{1}{n-1} * \sum_{i=1}^{n} (C_{1i} - \overline{C_1})^2}$$

$$NEDT_h = \frac{T_2 - T_1}{C_2 - C_1} \times \sqrt{\frac{1}{n-1} * \sum_{i=1}^{n} (C_{2i} - \overline{C_2})^2}$$

$$NEDT = \sqrt{\frac{NEDT_c^2 + NEDT_h^2}{2}}$$

- The sensitivity is basically stable at different instrument temperature.
- The sensitivity of channel 1 to channel 18 is below 0.5K, channel19 to channel 22 is below 0.6K.



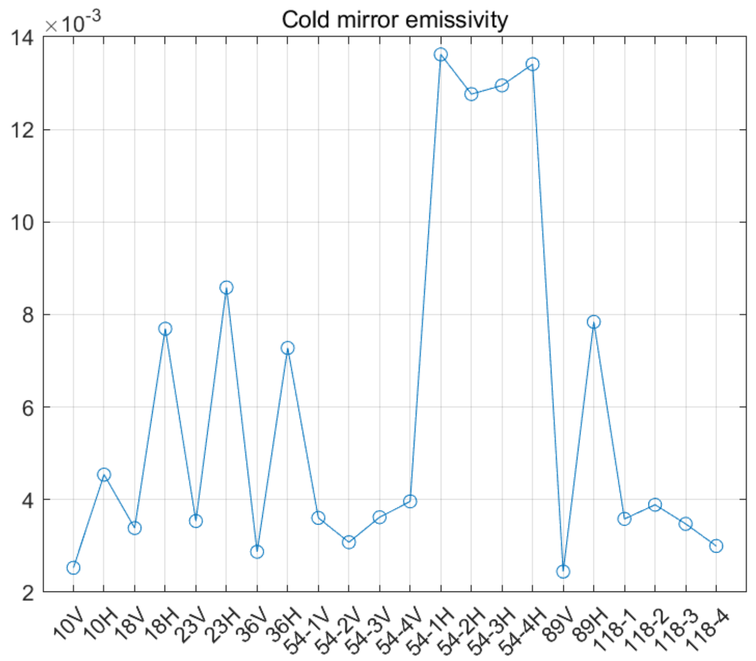


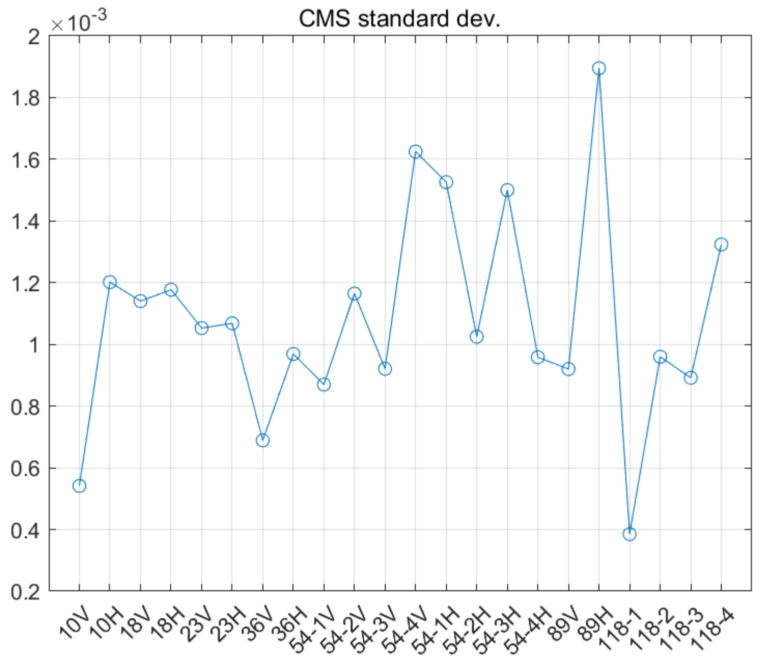
- The sensitivity is comparable with the FY-3F/MWRI and FY-3G/MWRI.

Cold Mirror Emissivity

Theoretically, when the BT of the observed target on the reflective surface is the same as that of the cold or warm target, the difference between the observed BT and the actual target BT is only linearly related to the emissivity.

In vacuum calibration, we set the temperature of the reflective surface observation target to be the same as that of the calibration source, and the emissivity can be measured by changing the physical temperature of the cold mirror.





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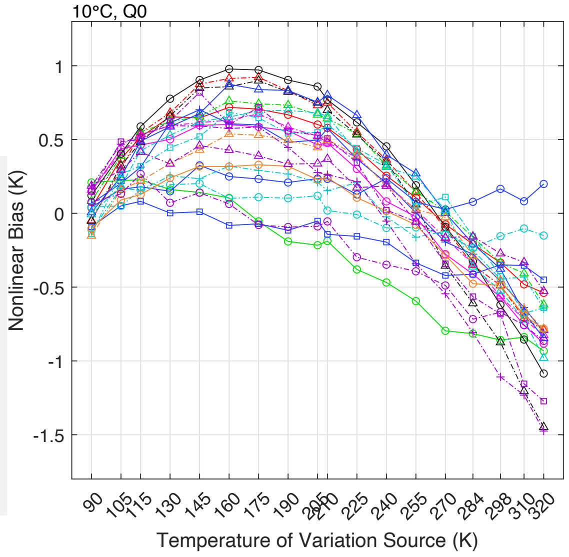
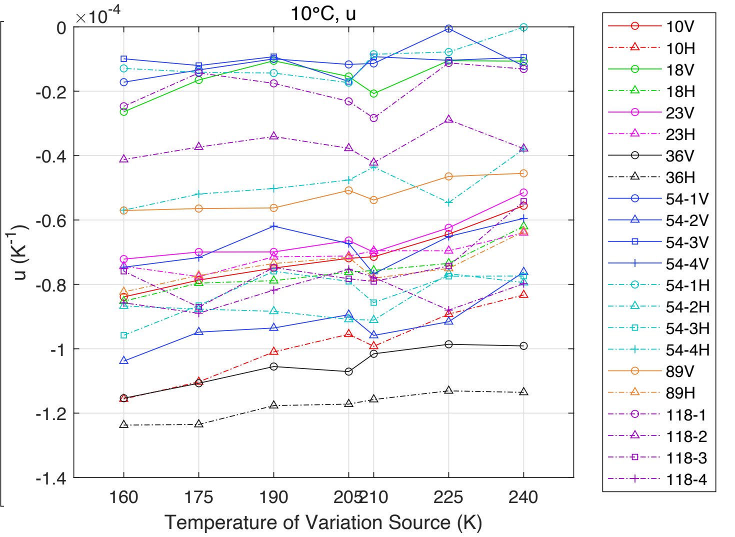
Summary

1. TVAC test achieves strict temperature control level. Temperature accuracy reaches 0.05K, homogeneity within 0.2K and stability within 0.15K.
2. The nonlinear parameter μ of the instrument is about 1×10^{-5}, comparable with that of FY-3F. The residual ranges from -0.3 to 0.2, with 90% distributed between ± 0.15.
3. The sensitivity of Channel 1 to channel 18 is below 0.5K, that of channel19 to channel 22 is below 0.6K.

Discussion

1. Pay more attention to the characteristics of calibration sources.
2. The nonlinear coefficient μ is linearly related to the scene temperature for 10 GHz channels





THANK YOU！

Speaker ：Pengjuan Yao

Major : Calibration and validation for microwave radiometer

National Satellite Meteorological Center, CMA