A RTK based array antenna positioning method of Chinese Meridian Project Phase II at Mingantu Observing Station

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Abstract

Method based on RTK of positioning the array antenna of the Chinese Meridian Project Phase II at Mingantu Observing Station are discussed. The results are presented.

1. Introduction

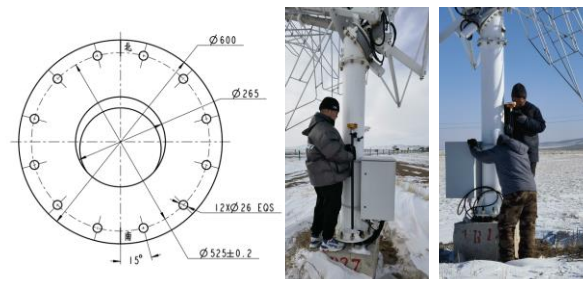
A new extended solar spectral radioheliograph named MUSER-III [1][2] has been constructed at Mingantu Observing Station. It works in meter to decameter wavelength (30-400MHz) and with 224 LPDAs antenna. MUSER-III is one of the most important solar dedicated equipment of the Chinese Meridian Project Phase II. The project is aimed to build a full-observing-chain from the sun to the earth, ground-based space environment monitoring system, providing deeper and wider information to study space weather and solar physics. The project is led by the National Space Science Center (NSSC), Chinese Academy of Sciences.

Accurate antenna position is key to obtain high quality image for a synthesis telescope. Two antenna form a pair correlation baseline. The correlation output corresponds to a parameter of synthetic aperture mapping. We have got a set of 224 antenna positions of MUESE-III based on Total Station measurement using existing control points. The 224 antenna include 100 movable LPDAs and 124 stationary LPDAs. These control points [3][4] built about 10 years ago spread on the grassland over about 10 square km. For the time being, some control points are damaged or notable skew. And another disadvantage of Total Station method is the intervisibility problem on the uneven grassland. And situation becomes worse after all the antenna have been set up. Fig.1 shows the center part of 124 stationary LPDAs.

Figure 1. Center part of stationary antenna of MUSER-III

RTK (Real-time kinematic) technique has the potential to solve the problems. When receiving good signal from satellite and from reference station, there are no transmission error using RTK to position the array antenna. Now in China, RTK reference stations cover almost allover the country. The nearest reference station is about 10km away from Mingantu Observing Station. The cost of CORS (Conti-nuously Operating Reference System) account is acceptable.

2. Positioning100 movable LPDAs using RTK



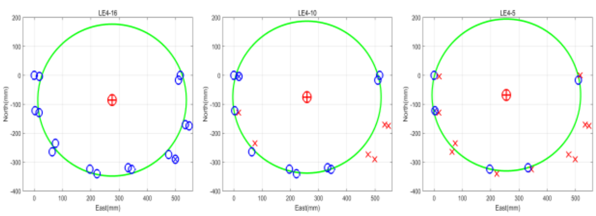


Figure 2. Positioning LPDAs using RTK

Positioning 8 of the 12 anchor bolts on LPDAs antenna basement by RTK are used to find the center of antenna structure. Each anchor bolt is measured two times. Bad measurements are gradually removed by Least Squares Method, with rms of the distance of remained points to the assumed center of the circle from ideal radius reduces gradually, and the rms is generally about 5mm.100 moveable LPDAs are measured in rare windless weather from Dec 29,2023 to Jan 18, 2024.The RTK model we used is Zhonghaida V300.the claimed plane error is ±(8+10^{-6}D) mm, D is distance between points to be measured. Figure 2 shows the measurement process.

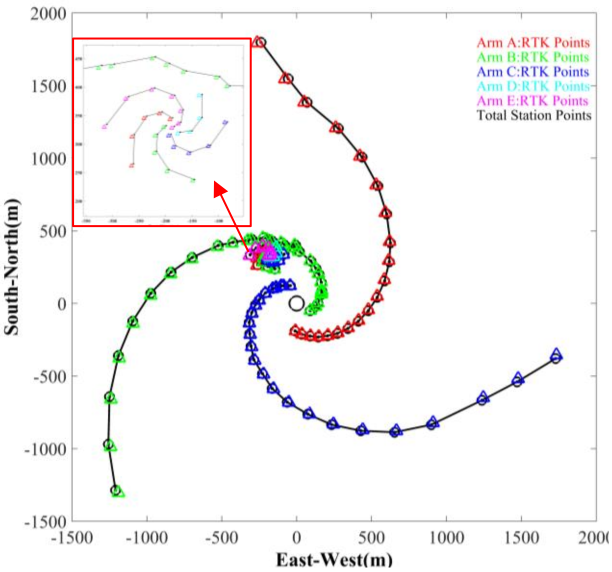


Figure 3. Overall layout of array antenna position

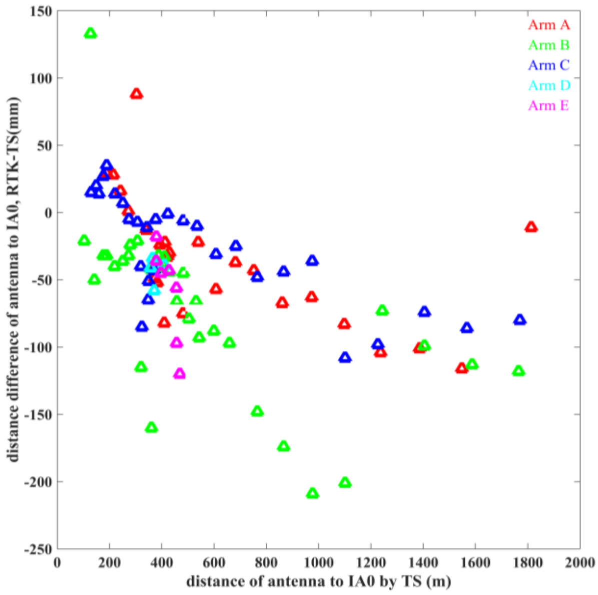


Figure 4. Distance difference between RTK and TS points to IA0 changes with distance

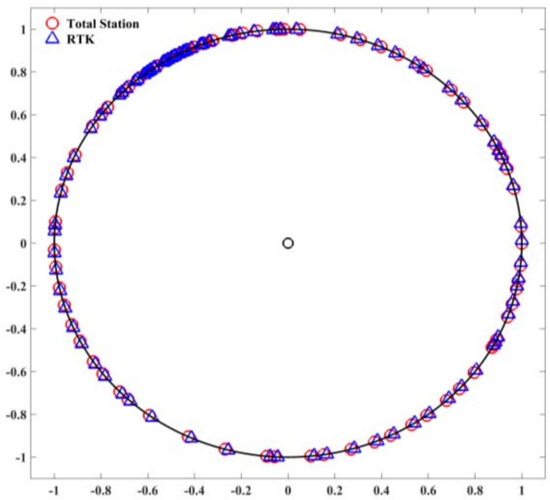


Figure 5. Angles between RTK and TS points take the same direction

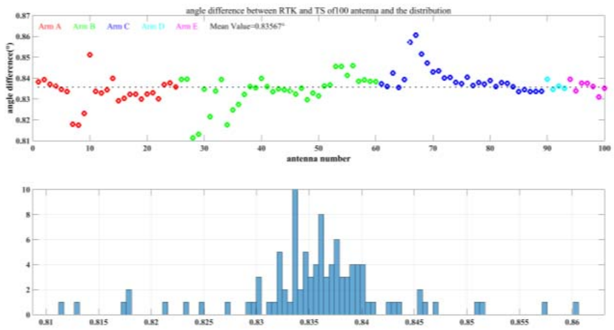


Figure 6. Distribution of angle difference of 100 RTK-TS points

3. Comparing positioning results of RTK and Total Station method

100 moveable LPDAs spread in 5 arms in MUSER-III center part, and 3 arms in outer part, see figure 3.

The coordinate system based on Total Station measurement is topocentric coordinates, with IA0 antenna of MUSER-I array as the coordinate origin, east as axis Y positive and north as axis X positive. By observing the Polaris to determine the directional reference. While RTK coordinate system here selected is CGCS 2000 (China Geodetic Coordinate System 2000), which is Geocentric coordinate. In the radioheliograph imaging process, topocentric coordinates is first changed into Geocentric coordinate, then changed into observing coordinate, see equations 1-3[5].

$$\begin{bmatrix}\Delta x\\ \Delta y\\ \Delta z\end{bmatrix}=\begin{bmatrix}x\\ y\\ z\end{bmatrix}-\begin{bmatrix}x_0\\ y_0\\ z_0\end{bmatrix} \qquad (1).$$

$$\begin{bmatrix}\Delta X\\ \Delta Y\\ \Delta Z\end{bmatrix}=\begin{bmatrix}-sinBcosL & -sinL & cosBcosL\\ -sinBsinL & cosL & cosBsinL\\ cosB & 0 & sinB\end{bmatrix}\begin{bmatrix}\Delta x\\ \Delta y\\ \Delta z\end{bmatrix} \qquad (2).$$

$$\begin{bmatrix}u\\ v\\ w\end{bmatrix}=\begin{bmatrix}sinH & cosH & 0\\ -sin\delta cosH & sin\delta sinH & cos\delta\\ cos\delta cosH & -cos\delta sinH & sin\delta\end{bmatrix}\begin{bmatrix}\Delta X\\ \Delta Y\\ \Delta Z\end{bmatrix}/\lambda \qquad (3).$$

Selecting IA0 as origin of new topocentric coordinate based on RTK measurement. From figure 3, RTK points and Total Station points are of cause significantly different. But the distances of RTK points and TS points to IA0 should be the same, if they are determined precisely. And there is a trend that the absolute value of distances difference increases with the distance of antenna to IA0. The biggest distance difference value is over 20cm for about 1km distance, which is well beyond the RTK precision. And the Total Station measurement is known to have bigger error with longer distance from control points, implying the Total Station measurements may having big error, especially for remote LPDA antenna.

In figure 5, angles between RTK and TS measurement points go the same way. The angles show approximate normal distribution, and the mean value is 0.83567degree. The RTK topocentric coordinate system needs to rotate anticlockwise an angle to change into Total Station topocentric coordinate system.

3. Results

After rotation an angle anticlockwise, array antenna positions in RTK and Total Station topocentric coordinate system show good consistence. See figure 8. And the remaining angle difference mean value is near zero.

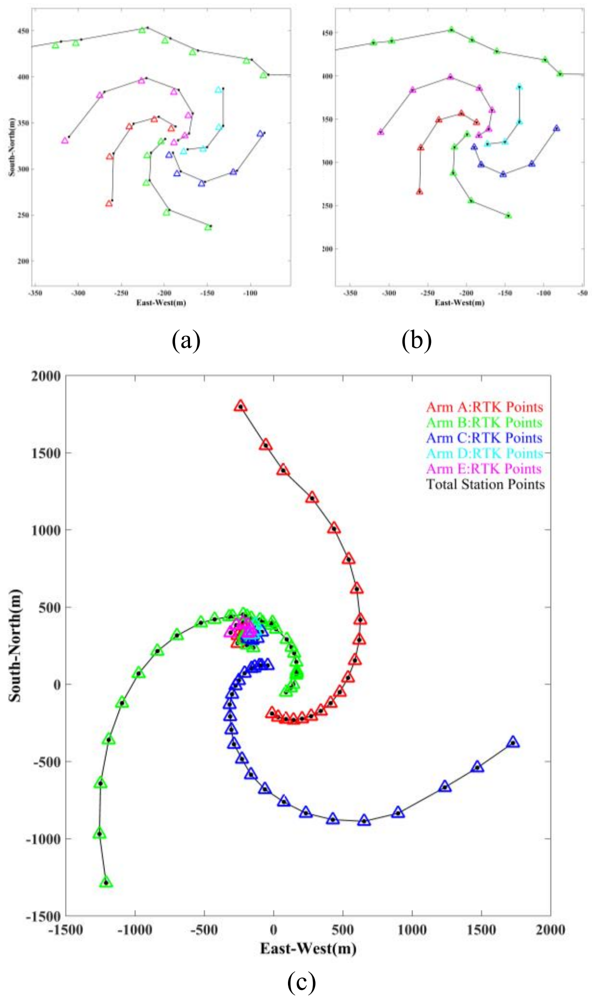


Figure 7. RTK and Total Station topocentric coordinate (a) center part antenna, before rotation, (b) center part, after rotation,(c) overall antenna, after rotation

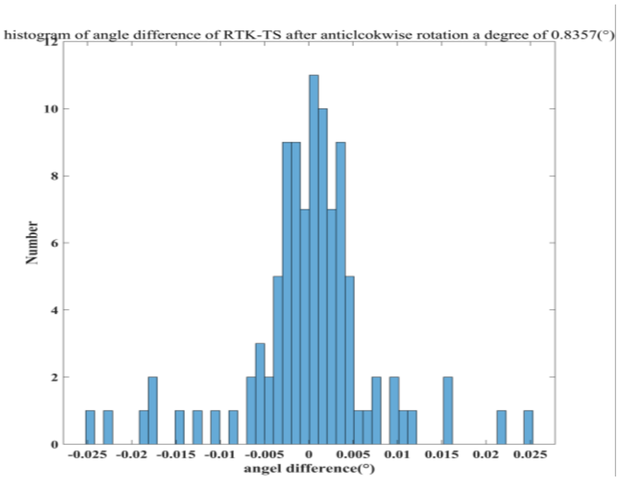


Figure 8. Histogram of remaining angle difference

4. Discussion and Conclusion

The working frequency band of MUSER-III is 30-400MHz, and the wavelength is 75cm-10m. In the situation of Mingantu Observing Station, using RTK instead of Total Station to position the structure center of the array antenna of MUSER-III seems practical with centimeter level accuracy. By shifting and rotating the RTK measurement results, we get a RTK topocentric coordinate system fitting well with existing topocentric coordinate system. And some of the Total Station measurement errors can be corrected.

Observing radio sources or satellites [6] to determine phase center of array antenna more precise is in process, but sometimes it is limited by the S/N and noise like FM broadcast. We are also trying to use UAV to position the array antenna [7].

5. Acknowledgements

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References

[1] Yihua Yan, Zhijun Chen, Wei Wang, et al., "Mingantu Spectral Radioheliograph for Solar and Space Weather Studies," *frontiers in Astronomy and Space Sciences*,29, March 2021, pp.1-13, doi:10.3389/fspas.2021.584043.

[2] Wang Chi, Xu Jiyao, Lu Daren, et al., "Construction Progress of Chinese Meridian Project Phase II," *Chin. J. Space Sci*., 2022, 42(4), pp.539-545, doi:10.11728 /cjss2022.04. yg09.

[3] Liu Donghao, Yan Yihua, Wang Wei, et al., "Baseline Measurement of the Antenna Array for the Chinese Spectral Radioheliograph in the Centimeter-to-Decameter Wave," *ASTRONOMICAL RESEARCH AND TECHNOLOGY*,2013,10(2), pp:128-133, doi:10. 3969/j.issn.1672-7673.2013.02.004

[4] Liu Donghao, Yan Yihua, Zhao An, et al., "A Delay Calibration for Chinese Spectral Radioheliograph in the decametric to centimetric wave range," *ACTA ELECTRONICA SINICA*, 2013, 41 (3), pp:570-574, Doi: 10.3969/j.issn.0372-2112.2013.03.025.

[5] Thompson A R, J M Moran, G W Swenson, "Interferometry and synthesis in radio astronomy," New York: Wiley, 2001.

[6] Wang Wei, Yihua Yan, Liu Donghao, et al., "Phase Calibration Using Satellite as Calibrator for Mingantu Spectral Radioheliograph," *ACTA ELECTRONICA SINICA*, Jun, 2019, 47(6), pp.1384-1387, doi:10.3969/j. issn.0372-2112.2019.06.028.

[7] Geng Lihong, Yihua Yan, Linjie Chen, et al., "Array antenna position measurement of Chinese Meridian Project Phase II at Mingantu Observing Station," *URSI GASS 2023*, DOI: 10.23919/URSIGASS57860.2023