The pointing model of 4.5-m small radio telescope at NARIT

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Abstract. The efficiency of a radio telescope decisively depends on its pointing accuracy. Telescope's pointing model (PM) contains repeatable errors due to the antenna control system's imperfections, which can be corrected during observation. The 4.5m Small Radio Telescope (SRT's) has been developed for education and experiments at Astropark, National Astronomical Research Institute of Thailand (NARIT), Chiang Mai (18°N 51' 5" and 98°E 57' 27"). We have implemented a 10-cm optical camera system installed on the SRT's antenna structure to measure the offset of individual pointing covering all sky direction, which then are modeled, and the telescope's PM is obtained. Here, we report preliminary results of SRT's PM, where we obtain for each epoch -551.116 and -3811.549 arcsec for Azimuth encoder offset, and 1217.105 and -3343.866 arcsec for Elevation encoder offset. More accurate results can be obtained with better sky coverage observation.

1. Introduction

Pointing model is one of the methods to find the efficiency of utility by reporting in term of the encoder offset. Thus this method will be applied to the Thai National Radio Telescope (TNRT) after completely installed. Make sure that this method will be worked properly, we have applied the same manner with 4.5m Thai Small Radio Telescope (SRT's). This telescope is installed at Astro-Park, Chiang Mai, Thailand and used for educational purposes. Its located at 18°N 51' 5" and 98°E 57' 27" and above the mean sea level of 340 meters. The uncertainty of SRT's pointing is measured in term of the error of the stars by pointing them in both of radio frequency and visible light. The small optical telescope have been installed on the main surface of SRT's which track and point to the same direction with SRT's. We report preliminary results of SRT's pointing model in this report.

2. Pointing model

The pointing model is used to correct for miss-alignments from the radio telescope [1] in both of azimuth (Az) and elevation (El) which azimuth angle is the angle formed between a north celestial pole (determine at the north pole have azimuth is 0 degree) and a line from the observer to a point of interest projected along the horizon (maximum at 360 degree that is the north pole) and elevation is the angle of altitude of the object that maximum at 90 degree. The algorithm of pointing model which used for SRT's and TNRT's 40 meters is similar with ALMA [2] but add gravity term into the model [3]. This pointing model algorithm for azimuth error is given by

$$\delta Az = P_1 + P_2 \sec El + P_3 \tan El - P_4 \cos Az \tan El + P_5 \sin Az \tan El \quad (1)$$

But, this algorithm should be correct for cosine of elevation (cross-elevation), which is given by $\delta Az_{corr} = \delta Az \cos El$. The pointing model algorithm for elevation error is given by

$$\delta El = P_4 \sin Az + P_5 \cos Az + P_7 + P_8 \sin El + P_9 \cos El \quad (2)$$

where the individual pointing coefficients are defined in table 1.

Table 1. Explanation of the pointing coefficients whose pointing errors are described by equation (1) and (2).

Parameter	Physical meaning
P_1	Azimuth encoder offset, includes positioning error for receivers in the Nasmyth focus
P_2	Collimation error, includes positioning error for receivers in the Nasmyth focus
P_3	Lack of orthogonality between the azimuth and elevation axis, includes positioning error for receivers in the Nasmyth focus
P_4	Tilt of azimuth axis along a E-W direction
P_5	Tilt of azimuth axis along a N-S direction
P_6	Declination error of source, this parameter can be ignored as long as their positions have well-determined
P_7	Elevation encoder offset, includes positioning error for receivers in the Nasmyth focus
P_8	Gravitational effect, includes positioning error for receivers in the Nasmyth focus. Combines with P_9 and has no simple meaning
P_9	Gravitational effect, includes positioning error for receivers in the Nasmyth focus. Combines with P_8 and has no simple meaning

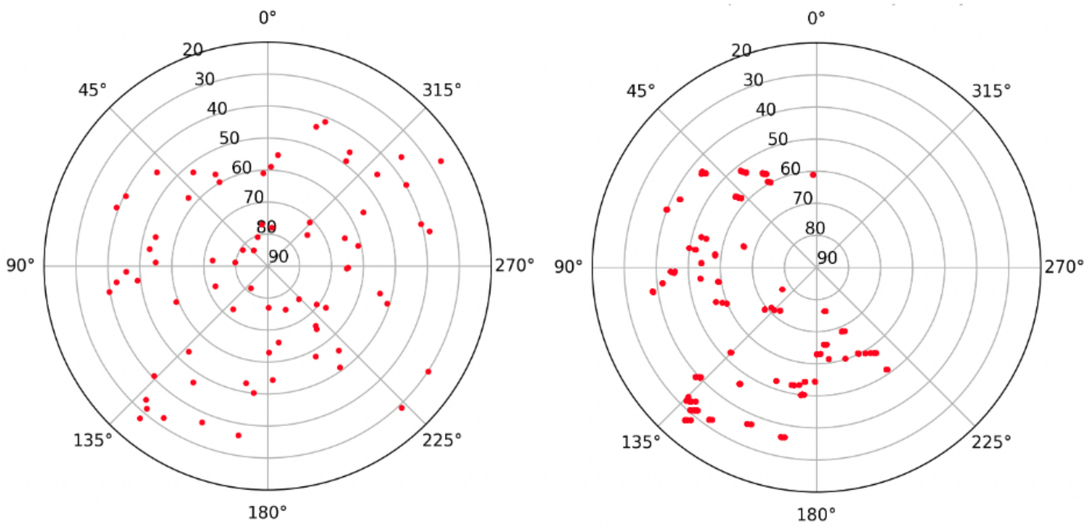
3. Planning observation and observable

We planned to observe the pointing model for 5 days along 1 month. But, we were able to observe only 2 out of 5 days (see the detail in table 2).

Table 2. Observation plan and what is happened in each day

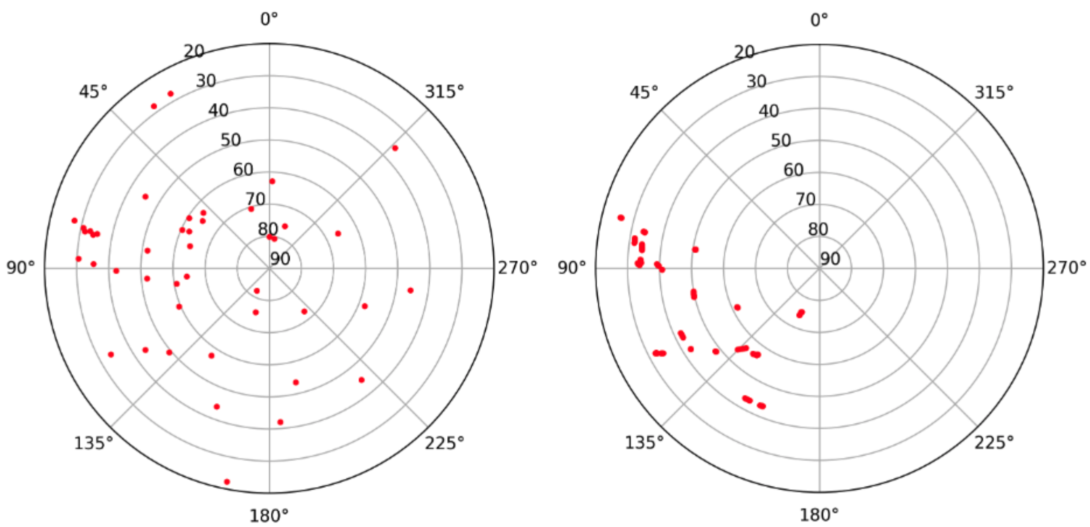
Date	Remarks
15^{th} January 2021	Complete data collection, but not cover the sky
21^{st} January 2021	Cancelled due to cloudy weather
22^{nd} January 2021	Cancelled due to cloudy weather
11^{th} February 2021	Cancelled due to the technical problem
16^{th} February 2021	Complete data collection, but not cover the sky

We determined the order of the observation in each object which depend on the position and time until we could observes whole sky. But, We could not observe the whole sky because the object disappeared out of optical telescope frame in some sky positions. We show positions of the observation plan and observable position in figure 1 and 2.



(a) Planning observation (b) Observable

Figure 1. (a) Planning observation on 15^{th} January 2021 which coverage position. (b) Observable position at 15^{th} January 2021 which observed in some area.



(a) Planning observation (b) Observable

Figure 2. (a) Planning observation on 16^{th} February 2021 which coverage position. (b) Observable position at 16^{th} February 2021 which observed in some area.

4. Results and discussion

When the observations were completed, we solved the pointing parameter by using equation (1) and (2) as shown the result in table 3. For SRT's, we focus on parameter P_1 and P_7 as only 2 parameters, which can be modified to the SRT's encoder. We get the result of both P_1 are -551.116 and -3811.549 arcsecond, respectively. And we get the result of both P_7 are 1217.105 and -3343.866 arcsecond, respectively. Neither plus nor minus signs have any physical meaning. On 15^{th} January 2021, we were able to observe the azimuth angle in range of 0 to 220 degrees, which estimate cover 60 percentage of the whole sky. On 16^{th} February 2021, we were able to observe the azimuth angle in range of 60 to 160 degrees, which estimate cover 27 percentage of the whole sky.

The pointing model parameters (P1 to P9) depend on a number of observable points (Regression). If there are a large number of observable points, We will get more accuracy results. In figure 1(b) or 15^{th} January 2021, could observe as a wider area or greater coverage position of the whole sky than figure 2(b) or 16^{th}.It is a reason why the pointing model parameters of 15^{th} January 2021 is better (get lower values) than 16^{th} February 2021.

Table 3. The pointing model parameters in each epoch which get from SRT's observation.

Parameter	15^{th} January 2021	16^{th} February 2021
P_1	-551.116	-3811.549
P_2	90.346	6570.450
P_3	614.102	-5184.783
P_4	-662.982	-988.760
P_5	-653.078	1919.906
P_7	1217.105	-3343.866
P_8	-1345.131	5076.639
P_9	-156.435	3931.304

5. Conclusion

We used a pointing model to find the efficiency of SRT's pointing. We planned to observe the pointing model for 5 days along 1 month. But, we were able to observe only 2 out of 5 days due to technical and weather issues. We get the pointing model parameters P_1 in each epoch are -551.116 and -3811.549 arcsecond, respectively. We get the pointing parameters P_7 in each epoch are 1217.105 and -3343.866 arcsecond, respectively. We get an encoder offset in both of azimuth and elevation angle on 15^{th} January 2021 less than on 16^{th} February 2021. If we need to get more accuracy results, we need to observe the whole sky. We will apply this result to enter a correction value to SRT's encoder in both of azimuth and elevation angle. The next observations should give a better result.

References

[1] de Vicente P and Barcia A 2007 Deconstructing a pointing model for the 40M OAN radiotelescope *Tech. Rep. IT-OAN 2007–26* pp 1–25

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