Beam Pointing Deviation Calculation Method for Large Antennas at Any Position Based on Track Roughness

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At present, most large radio telescopes at home and abroad adopt the design of wheel-rail seat frame. Due to the limited precision of rail manufacturing and installation, the large antenna serving in harsh environments also needs to carry out the azimuth pitch movement and support such a monster through the wheel rail, inevitably resulting in the unevenness of the track surface, which will seriously affect the antenna beam pointing. As the working frequency band of the antenna increases, the antenna beam pointing accuracy even becomes sensitive to slight track irregularities. Usually, the antenna beam pointing deviation caused by the track unevenness is as high as 2 arc-seconds, which can't be ignored for the antenna with high precision pointing requirements.

Therefore, this paper establishes the antenna pointing model based on the track irregularity, and accurately calculates the beam pointing deviation due to the track irregularity of the large antenna at any position, which is used to quantitatively evaluate the influence of the track irregularity on the beam pointing of large antennas, so as to guide the adjustment and compensation of the antenna performance when the antenna is in service.

Suppose that the best fitting function of the track irregularity is:

$$f(x) = a_0 + a_1 x + a_2 x^2 + \ldots + a_k x^k \tag{1}$$

Where x represents the track position, $f(x)$ represents the corresponding track height value, k is the highest exponent of the fitting function, and $a_0, a_1, a_2 \ldots a_k$ is the undetermined coefficients in the fitting function.

Through the least square principle and the measured height of the track, the undetermined coefficients in the best fitting function of the track irregularity can be obtained, as shown in Figure 1. According to the distribution of the azimuth seat frame and the wheel rail of the antenna, the azimuths of the points corresponding to the four wheels is respectively $Az+\frac{\pi}{4}$, $Az-\frac{\pi}{4}$, $Az-\frac{3\pi}{4}$ and $Az+\frac{3\pi}{4}$, and then the corresponding track height of the antenna wheel is:

$$f\left(Az+\frac{\pi}{4}\right), f\left(Az-\frac{\pi}{4}\right), f\left(Az-\frac{3\pi}{4}\right), f\left(Az+\frac{3\pi}{4}\right).$$

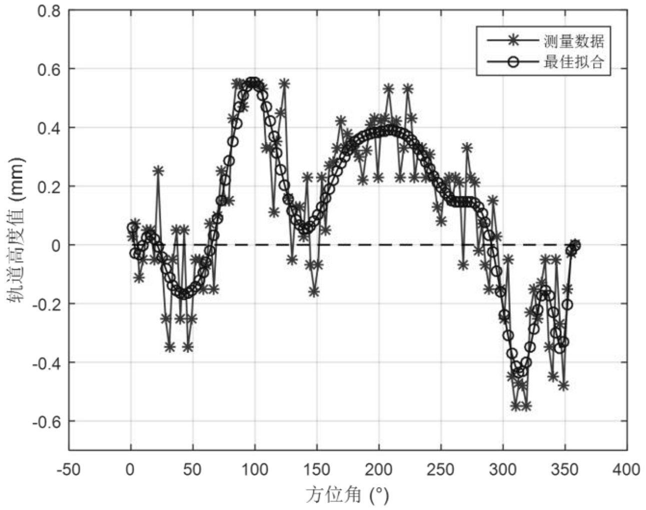

Fig.1 The measured values and the best fitting curve of an antenna track

Therefore, it is possible to calculate the beam pointing deviation when the antenna in service is at the azimuth angle Az and pitch angle El:

$$\begin{bmatrix}\Delta Az\\ \Delta El\end{bmatrix}=\begin{bmatrix}0 & \tan El & -1\\ -1 & 0 & 0\end{bmatrix}\begin{bmatrix}\frac{1}{2\sqrt{2}r} & -\frac{1}{2\sqrt{2}r} & -\frac{1}{2\sqrt{2}r} & \frac{1}{2\sqrt{2}r}\\ -\frac{1}{2\sqrt{2}r} & -\frac{1}{2\sqrt{2}r} & \frac{1}{2\sqrt{2}r} & \frac{1}{2\sqrt{2}r}\\ -\frac{s}{2r^2} & \frac{s}{2r^2} & -\frac{s}{2r^2} & \frac{s}{2r^2}\end{bmatrix}\begin{bmatrix}f\left(Az+\frac{\pi}{4}\right)\\ f\left(Az-\frac{\pi}{4}\right)\\ f\left(Az-\frac{3\pi}{4}\right)\\ f\left(Az+\frac{3\pi}{4}\right)\end{bmatrix} \tag{1}$$

Where the beam pointing unit is radian, r is the radius of the track, and s is the height of the pitch axis in the antenna mount coordinate system.

The beam pointing deviation should be output to an antenna control system (ACU), and then the antenna can be adjusted and compensated.

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