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Research based on active reflector adjustment based on geometric method

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Abstract: In this paper, a mathematical model is established to achieve the best receiving effect of the electromagnetic wave reflected by the reflector.The aim is to make the working paraboloid close to the ideal paraboloid as much as possible by changing the different elevation and azimuth angles and adjusting the radial expansion of the actuator.The geometric model of the radius of the reference sphere and the focal length of the paraboloid is established.The expression of ideal parabolic function with azimuth Angle α and elevation Angle β and corresponding vertex are obtained by constructing rotation matrix.The effective nodes were judged according to the range of included Angle on the reflection surface,and the fitting degree was evaluated by the root mean square difference,and the fitting accuracy was finally obtained.

1. Background

With the development of radio and electronic information,reflector antenna has been widely used in electronic technology,military reconnaissance and astronomy in China.In recent years,reflector antennas have been widely used in astronomy,mainly for observing celestial bodies[1].It consists of active reflector system,feed support system,measurement and control system,receiver and terminal system.There is a certain gap between each reflection panel,in the process of adjusting the reflection panel,the panel will not be deformed because of tension and pressure.

2. Modeling and solving of problem 1

2.1 Model Establishment

The most important innovation point of FAST is active reflection,the use of computer control can achieve the reflection surface along the direction of view immediately generated 300m caliber parabola[2],parabolic focal plane formed by the focal plane and the ground state reflection sphere of its radius kR.As shown in the figure 1,C is the spherical center of the ground state reflecting surface,S is the object to be measured,P is the center of the receiving signal plane of the feed module,arc FNI is the basic parabola forming the ideal parabola,and arc JNK is the ground state reflecting surface.Given by the known conditions:

$$CF = R \tag{1}$$

$$FO = \frac{R}{2} \tag{2}$$

$$\angle FCO = 30^\circ \tag{3}$$

$$CP = R - F = (1 - k)R \tag{4}$$

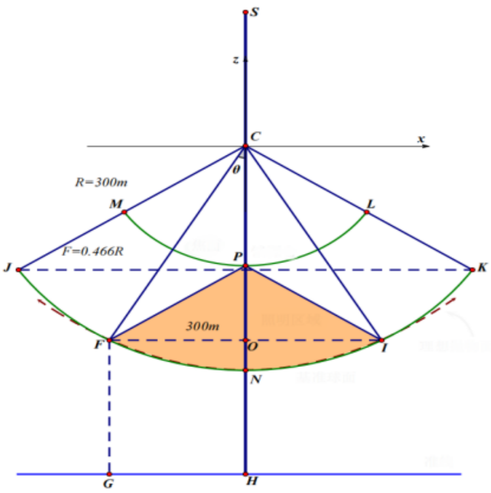

Figure 1: Profile map

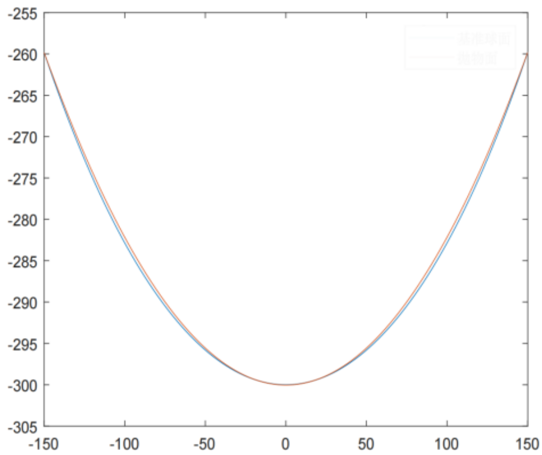

Figure 2: Comparison graph

So it can be concluded that:

$$PO = CO - CP = \left(\sqrt{3} - (1 - k)\right)R \tag{5}$$

$$PF = \sqrt{PO^2 + OF^2} = \sqrt{\left(\frac{R}{2}\right)^2 + (\sqrt{3}R - (1 - k)R)^2} \tag{6}$$

$$OP + GF = P \tag{7}$$

$$z = \frac{x^2}{2P} - \frac{P}{2} - (1 - k) \cdot R \tag{8}$$

The final ideal parabolic equation is:

$$z = \frac{x^2 + y^2}{2P} - \frac{P}{2} - (1 - k)R \tag{9}$$

2.2 Model solving

According to the output of the attachment,the actual reference spherical radius can be calculated as 300.4m.In this case,the reference spherical radius given is 300m.In order to improve the accuracy of the model,the real spherical radius of 300.4m is adopted in this paper,k = 0.466.It can be calculated that P = 280.04.

The specific parabolic equation can be obtained by substituting the data into the parabolic equation formula:

$$z = \frac{x^2 + y^2}{560.0814} - 300.434(m) \tag{10}$$

Finally, matlab was used to draw the comparison diagram between parabola and reference sphere, as shown in Figure 2.

3. Modeling and solving of problem 2

3.1 Model Establishment

After obtaining the rotating paraboloid, the radial distance between each node and the paraboloid can be calculated by geometric method according to the paraboloid equation, so as to get the length of each node expansion[3]. Specific practices are as follows:

Step1: Determine the valid node number:

$$\overrightarrow{NC} = (-x_n, -y_n, -z_n) \tag{11}$$

$$\overrightarrow{CS} = (\cos\beta\cos\alpha, \cos\beta\sin\alpha, \sin\beta) \tag{12}$$

$$\cos\theta = \frac{\overrightarrow{NC}\cdot\overrightarrow{CS}}{|\overrightarrow{CS}||\overrightarrow{CS}|} \tag{13}$$

Step2: Calculate the radial linear equation of the node:

$$\frac{x-x_n}{0-x_n} = \frac{y-y_n}{0-y_n} = \frac{z-z_n}{0-z_n} \tag{14}$$

Step3: Solve the intersection of the equation of the line and the ideal parabola:

$$\begin{cases} z = \frac{x^2+y^2}{2P} - \frac{P}{2} - (1-k)R \\ \begin{pmatrix} x \\ y \\ z \\ 1 \end{pmatrix} = M^{-1}\begin{pmatrix} x' \\ y' \\ z' \\ 1 \end{pmatrix} \\ \frac{x'-x_n}{0-x_n} = \frac{y'-y_n}{0-y_n} = \frac{z'-z_n}{0-z_n} \end{cases} \tag{15}$$

Step4: Calculate the distance between the intersection point and the node:

$$D = \sqrt{(x-x_n)^2 + (y-y_n)^2 + (z-z_n)^2} \cdot \mathrm{sym}(z-z_n) \tag{16}$$

Where sym(x) is the unsigned function.

Step5: Determine the expansion amount of each actuator:

$$d = \begin{cases} 0.6, & D \geqslant 0.6 \\ 0, & 0.6 \leqslant D \leqslant 0.6 \\ -0.6, & D \leqslant -0.6 \end{cases} \tag{17}$$

Step6: Update node coordinates:

$$\vec{n}_0 = \frac{\vec{P}-\vec{N}}{|\vec{P}-\vec{N}|} = \frac{(x-x_n, y-y_n, z-z_n)}{\sqrt{(x-x_n)^2+(y-y_n)^2+(z-z_n)^2}} \tag{18}$$

Update coordinates: $(x_{nu}, y_{nu}, z_{nu}) = (x_n, y_n, z_n) + \overrightarrow{n_0} \cdot |d_n|$

Step7: Determine the proximity evaluation amount of the working parabola.

Step8: Calculate RMS of close accuracy:

$$RMS = \sqrt{\frac{\sum_{n=1}^{N}(D_n-d_n)^2}{N}} \tag{19}$$

3.2 Model solving

The actual ideal parabola equation is calculated as follows:

$$\begin{cases} z' = \frac{x'^2+y'^2}{560.0814} - 300.4340 \\ \begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = M^{-1}[x,y,z]^T \\ M^{-1} = \begin{bmatrix} 0.986 & -0.01 & -0.647 \\ -0.01 & 0.992 & -0.123 \\ 0.164 & 0.123 & 0.979 \end{bmatrix} \end{cases} \tag{20}$$

Finally, through matlab programming, the obtained parabolic equations draw the ideal parabolic simulation diagram after the rotation Angle α = 36.795° and elevation Angle β = 78.169°.

Traverse each node, calculate the straight line equation of node and spherical center and then calculate the intersection point, calculate the distance between the intersection point and node according to the intersection point, finally calculate the expansion length according to the expansion limit, update node coordinate data as shown in the figure. The updated coordinate data was used to calculate the distance again and calculate THE RMS.According to the formula, the calculated result was 0.02326m, indicating that the parabolic adjusting model had a considerable fitting effect.

Number	List	Quantity (m)	x(m)	y(m)	z(m)
1	A0	0.348960881	0	0	-300.0510391
2	B1	0.44473431	6.098757562	8.394553657	-299.7757319
3	C1	0.411903276	9.869149012	-3.206597132	-299.8085432
4	D1	0.294348624	0	-10.38081832	-299.9260275
5	E1	0.254966488	-9.874311992	-3.208274642	-299.9653861
…	…	…	…	…	…
690	D267	0.091966965	-130.0191826	-147.5588113	-226.9499983
691	D268	0.085314732	-139.5291619	-139.8092824	-226.2164354
692	D269	0.053043965	-148.7872228	-131.8457149	-225.1383385

Figure 3: Partial results

4. Evaluation of Model

4.1 Advantages

(1) The model presented in this paper has high precision, and the error between the model and the actual data is within the tolerable range.

(2) The working paraboloid fits well with the ideal paraboloid, which has strong feasibility.

4.2 Disadvantages

(1) The model has not carried out in-depth research on the intelligent optimization algorithm, and the error has not yet converged.

(2) There is room to reduce the accuracy of the optimization model.

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