Measurement of phase center for antenna with the method of moving reference point

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Abstract— **To locate or to measure antenna with high precision ,the error of antenna phase center is the main error source, so it is necessary to locate antenna phase center accurately. In this paper, based on the measured data of an antenna phase pattern and amplitude pattern, using the least square method ，we can compute the antenna phase center deviation. And with the measurement accuracy less than 1mm ，the proposed method can accurately and conveniently measure the phase center.**

Key words：antenna phase center； the least square method ；phase center deviation；

I. INTRODUCTION

For most antennas, there may be no such a phase center, but for many antennas, we can find such a reference point which makes the phase of an area field of main beam remain constant relatively, and this point is called "seeing phase center".

How conveniently, accurately calibrate antenna phase center? Schupler and others proposed to calibrate antenna phase center[1]in the microwave dark room for the first time. The calibration method requires that we must not stop to adjust antenna location manually until the phase pattern is symmetrical, this method not only wastes time and effort, but also operate difficultly. Antenna Measurement books [2] [3]detail a testing method about measuring phase centre, which also require to adjust the antenna location constantly, but the calibration errors of this method is high. Another method was proposed to calibrate antenna phase center in Literature [4], this method established the relationship between measurement results of the phase pattern and phase centre deviation, and solving equation team we can calculate phase center deviation. However, this method has certain limitations, it is only suitable for determining phase center antenna calibration. In literature [5],the method of moving reference point is used to calculate the antenna phase centre of angle conical horn antenna.

Based on the literature [4] [5], we propose a practical phase center measurement method which can accurately measure antenna phase center position error and does not require manual operation. And its measurement process can be compiled and automated, so this method has been applied in actual test system, and satisfying results can be obtained.

Ⅱ. THE METHOD OF MOVING REFERENCE POINT TO MEASURE ANTENNA PHASE CENTER

For any antenna, a component of the far field radiation in the spherical coordinates can be written as follows:

$$E = \hat{u}F_u\left(\theta,\phi\right)e^{j\varphi(\theta,\phi)}\frac{e^{-jkr}}{r} \qquad (1)$$

Where $F_u\left(\theta,\phi\right)$ represents the amplitude pattern, $\varphi\left(\theta,\phi\right)$ represents the phase direction, $k=\dfrac{2\pi}{\lambda}$ is the free space wave number. Antenna phase center might deviate from the rotating center or geometric center in measurement or application, as shown in Figure1.

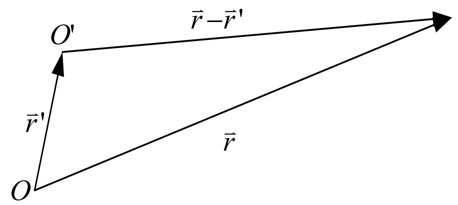

Fig.1.Sketch map of moving reference point

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Then according to far-field approximation,we can get the new far-field expression :

$$E = \hat{u}F_u(\theta,\phi)e^{j\varphi(\theta,\phi)}\frac{e^{-jk(|\vec{r}-\vec{r}'|+\vec{r}'\cdot\vec{r})}}{|\vec{r}-\vec{r}'|}$$

$$= \hat{u}\frac{e^{-jk|\vec{r}-\vec{r}'|}}{|\vec{r}-\vec{r}'|}F_u(\theta,\phi)e^{j[\varphi(\theta,\phi)-k\vec{r}'\cdot\vec{r}]} \qquad (2)$$

with $\psi(\theta,\phi)=\varphi(\theta,\phi)-k\vec{r}'\cdot\hat{r}$,the deviations between the phase center of the antenna and its turning center could be expressed by small vector $\vec{r}'$:

$$\vec{r}' = \Delta x\hat{x} + \Delta y\hat{y} + \Delta z\hat{z} \qquad (3)$$

The vector unit $\hat{r}$ can be shown as:

$$\hat{r} = \sin\theta\cos\phi\hat{x} + \sin\theta\sin\phi\hat{y} + \cos\theta\hat{z} \qquad (4)$$

$$\therefore \psi(\theta,\phi) = \varphi(\theta,\phi) - k(\Delta x\sin\theta\cos\phi + \Delta y\sin\theta\sin\phi + \Delta z\cos\theta) \qquad (5)$$

Equation (5) is the phase center pattern function with o' as its reference point, and $\varphi(\theta,\phi)$ is the phase pattern function when reference center and rotation center coincide with each other. By changing Δx , Δy , Δz ,that is, moving reference point, make the rate of change of $\psi(\theta,\phi)-\varphi(\theta,\phi)$ be smallest, so the phase center can be found.

Equation (5) show that the phase $\psi(\theta,\phi)$ is only sensitive to the shift of phase centre in the measurement plane, that is to say, when $\phi=0$, $\psi(\theta,0°)$ is only impacted by the change of Δx , Δz . And the phase $\psi(\theta,90°)$ is only impacted by Δy , Δz , in measurement plane $\phi=90°$ .This relationship can be used to determine Δx , Δy , Δz 。

Suppose measured antenna is ideal spherical wave source, we know that $\varphi(\theta,\phi)=$ constant, but most of the actual antennas is not an ideal spherical wave source, there exists divergence phase. But it can be considered that phase could be measured in a particular section where the main lobe $\varphi(\theta,\phi)=$ constant. It is assumed that phase pattern is measured in the planes of $\phi=90°$ and $\phi=0°$,so equation (5) can be rewritten as equation (6):

$$\psi(\theta)=\varphi(\theta)-k(\Delta t\sin\theta+\Delta z\cos\theta) \qquad (6)$$

Where Δt represents Δx or Δy (when $\phi=0°$, it represents Δx ; when $\phi=90°$, it represents Δy .) .Then in a section we get the relationship between Δt , Δz and the phase deviation.(Phase deviation represents the difference between the far-field phase and the phase of the maximum radiation direction):

$$\Phi(\theta)=-k(\Delta t(\sin\theta-\sin\theta_m)+\Delta z(\cos\theta-\cos\theta_m)) \qquad (7)$$

In Eq.(7), the phase deviation, Δt and Δz , can be calculated using the least squares method . But we can measure different value of Δz when $\phi=0°$ and $\phi=90°$ .And it is practiced that if we choose $\Delta z=\frac{\Delta z(0°)+\Delta z(90°)}{2}$, high accuracy will be available.

III. MEASUREMENT SYSTEMS AND PROCEDURES

Figure 2 shows the test system block diagram based on the principle forenamed. And the phase center of an antenna has been tested practically, the test steps were as follows：

1）As Figure 2, we connect every component of the system together, then give it power, allowing the system to normal. And ensuring position rotation axis perpendicular to receiving polarization rotation axis, then reset the two-dimensional dynamic system, make this position as the initial point; Then adjust source antenna to point to the antenna-under-test , as the zero point of measured angle.

2) Measure the data of amplitude and phase of a cross-section. Then according to Eq.(7), phase center devitions, Δt and Δz , can be derived with the least squares method.

3) If the value of Δt and Δz is still large, the program will control the 2-D-Control system automatically, in order to change the deviation. Then repeat the step 2).

4) By changing the polarization of receivers and transmitters for the polarization angle (angle ϕ), We can measure the phase center deviation of arbitrary antenna section.

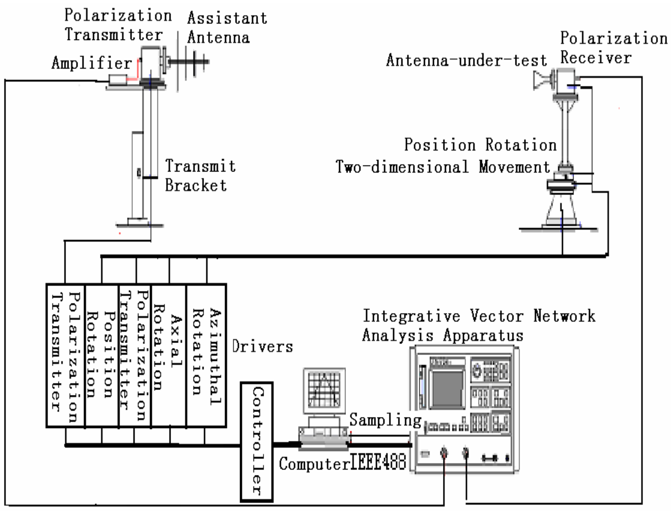
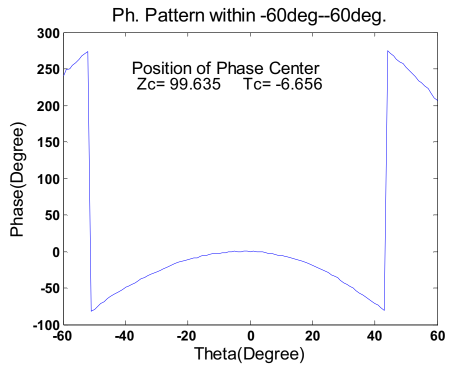


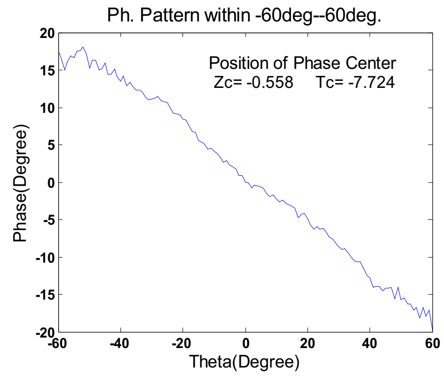
Fig.2. Diagram of Test System

Ⅳ. THE MEASUREMENT RESULT

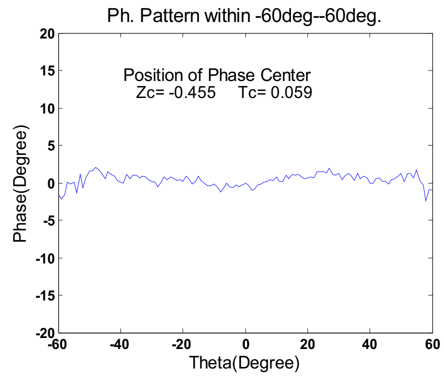
Figure 2 shows the test system block diagram based on the principle forenamed. And the phase center of an antenna has been tested practically, the test results were as follows: with the antenna loaded , in accordance with the first measured results of amplitude and phase pattern, we can get the results of the phase centre within [-60,60]angle, offset $\Delta x = -6.656mm$, $\Delta z = 99.635mm$ (Figure 3(a)); Then according to the offsets above, automatically control and move the two-dimensional movement system, repeat the measurement above and calculate the phase center offset $\Delta x = -7.724mm$, $\Delta z = -0.558mm$ (Figure 3(b))again, and the new offsets $\Delta x = 0.059mm$, $\Delta z = -0.455mm$ can be calculated (Figure 3(c)); From measuring graphics and calculation results, better results will be obtained through three measurements at most.



(a) The first measurement result



(b)The second measurement result



(c) The third measurement result

Fig.3 Actual measurement results

Ⅴ. CONCLUSION

With the development of communication, radar, artificial satellite and space navigation technology, the demands of precision is increasingly improving in antenna tracking and positioning. Only using amplitude beam method has unable to search and local accurately. While the method of antenna phase centre can be used to position and measure precisely. The study on antenna phase center, whether in the application of phase measurement and beam forming surveillance, or as a part of interferometer array modules or parabolic antenna feed, plays an important role increasingly. With the developed test system, according to the far antenna radiation field theory, antenna phase center can be measured accurately, with the measurement accuracy less than 1mm, by changing the reference point.

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