Error Analysis of Planar Near Field for Antenna Phase Center Measurement

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Abstract

This paper expatiates on the definition and solution of antenna phase center in planar near field. It provides the method of error analysis modeling and the 18 error items of phase pattern. And the final boundary of the error is obtained by error synthesis method. Based on error matrix, Monte Carlo method is employed for error analysis of phase center.

Introduction

With the successfully launch of the last Beidou satellite, the navigation system has been fully operational.

To improve the navigation accuracy, the spacial coordinates of satellite is necessary. The invented coordinate of satellite signal relates to its antenna coordinate, which is based on antenna phase center.

The definition of antenna phase center is given according to the National Spacecraft Standard. It is a point as the sphere center of antenna radiation, the surface of far field radiated sphere in service range has the minimum RMS(Root Mean Square) on phase fluctuation of the radiated electric field in antenna co-polarization.(Test Method of Navigation Satellite Antenna Phase center Q/QJA229-2014)

Therefore, the accuracy of navigation satellite positioning is directly influenced by that of antenna phase center. Based on planar near field, this paper analyses and assesses the test error of antenna phase center.

Method

—— Direct measurement

For the 18 error items of near field, processing error, measurement area truncation and multiple reflection are estimated by direct measurement.

—— Modeling

The model should be built close to the antenna under estimated, like similar gain and beam width. In this paper, error items like sampling position error of probe, processing error and receiver random error, which are hard to estimated by measurement are analysed by modeling.

$$\bar{E} = C\sum_m\sum_n \frac{1}{r}e^{-jkr}\left[\hat{I}_{mn} - \frac{\hat{I}_{mn}\cdot\bar{r}}{r^2}\cdot\bar{r}\right]$$

$$\bar{F} = \bar{f}_0\sum_m\sum_n I_{mn}e^{-jk[m\cdot dx\cdot\sin\theta\cdot\cos\varphi + n\cdot dy\cdot\sin\theta\cdot\sin\varphi]}$$

Error synthesis

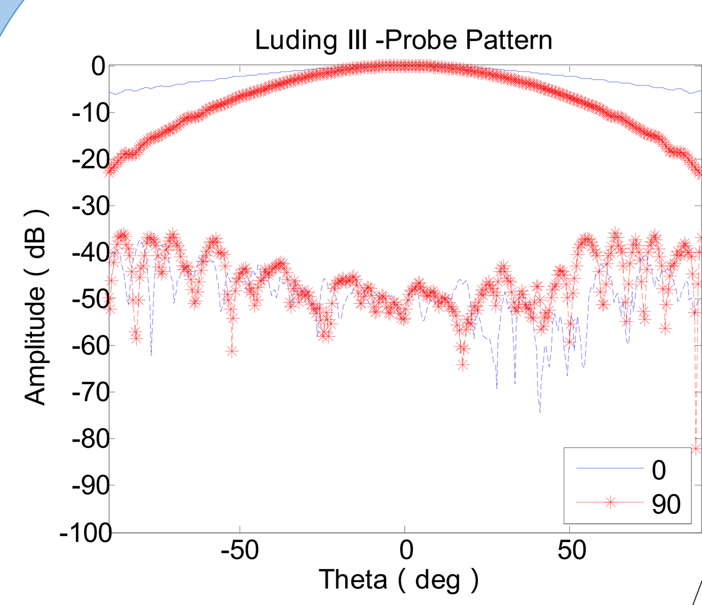

FIG.1. Measured pattern of open waveguide

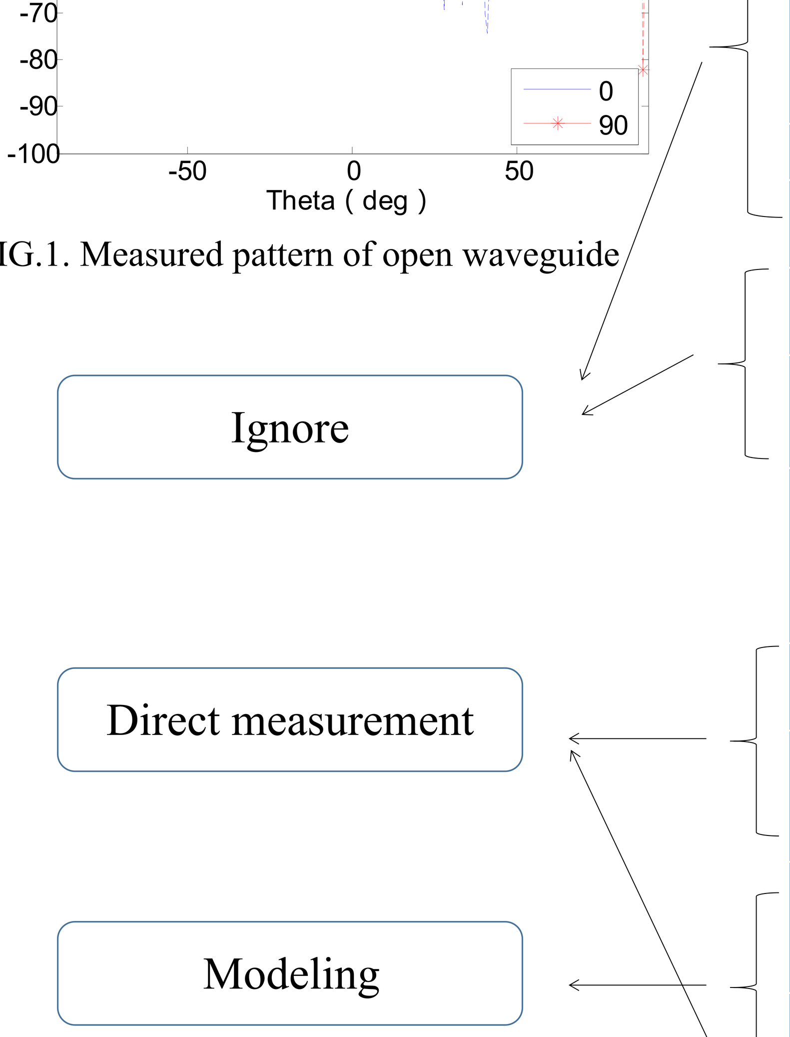

TABLE I. 18 Error Items

NO.	Source of error	Phase pattern error bound	Error distribution	Composition factor
1	Probe relative pattern	/	/	/
2	Probe polarization ratio	/	/	/
3	Probe gain	/	/	/
4	Probe alignment	/	/	/
5	Normalization constant	/	/	/
6	Impedance mismatch	/	/	/
7	AUT alignment	Influence phase center directly	Linear superposition	1
8	Processing error	0.150	Rectangular distribution	$\sqrt{3}$
9	Measurement area truncation	0.200	Rectangular distribution	$\sqrt{3}$
10	Probe X-Y position errors	0.050	Rectangular distribution	$\sqrt{3}$
11	Probe Z position errors	0.400	Rectangular distribution	$\sqrt{3}$
12	Multiple reflections	0.400	Rectangular distribution	$\sqrt{3}$
13	Receiver amplitude nonlinearly	0.100	Rectangular distribution	$\sqrt{3}$
14	System phase errors	0.280	Rectangular distribution	$\sqrt{3}$
15	Receiver dynamic range	0.002	Rectangular distribution	$\sqrt{3}$
16	Room scattering	0.010	Rectangular distribution	$\sqrt{3}$
17	Leakage & crosstalk	0.010	Rectangular distribution	$\sqrt{3}$
18	Random errors in amplitude and phase	0.220	Rectangular distribution	$\sqrt{3}$
	standard error	u	Normal distribution	3
	Combined error	U	Normal distribution	3

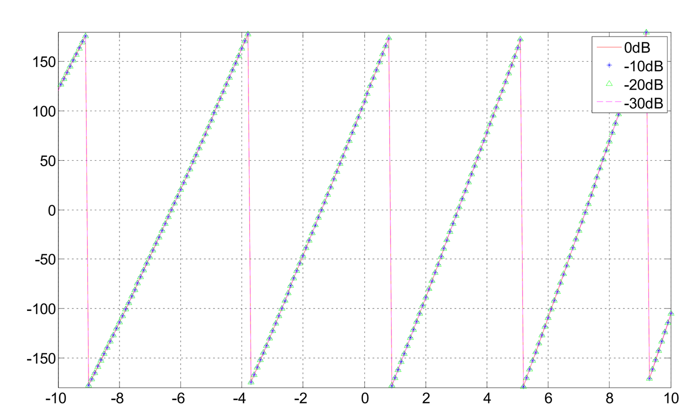
FIG.2. Phase pattern under different dynamic range

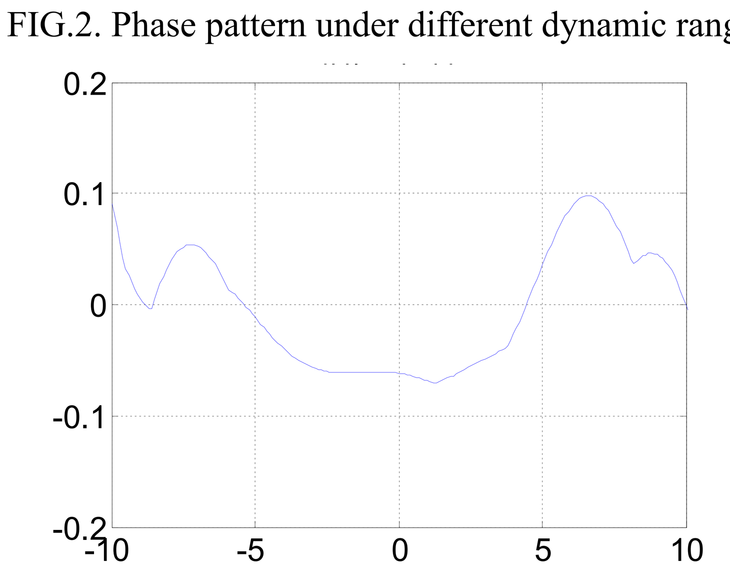
FIG.3. Peak to peak value of phase error

$$u = \sum_i U(x_i)/k_i \qquad U = ku$$

Phase Error Matrix

$$f(x) = \frac{1}{\sqrt{2\pi}\sigma}\exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right)$$

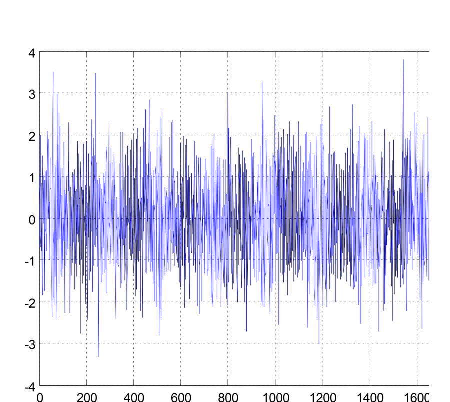
FIG.4. Phase error matrix

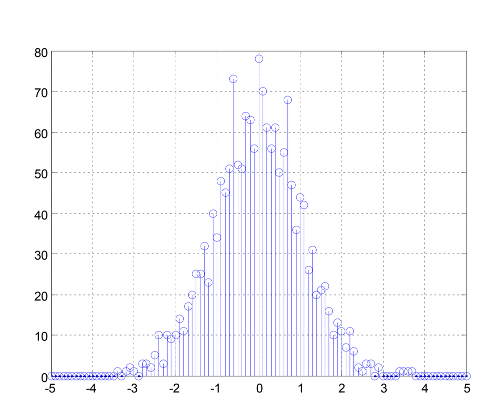
FIG.5. Probability density distribution of phase error matrix

According to Monte Carlo method, random error matrix more than 5000 times and phase center are calculated.

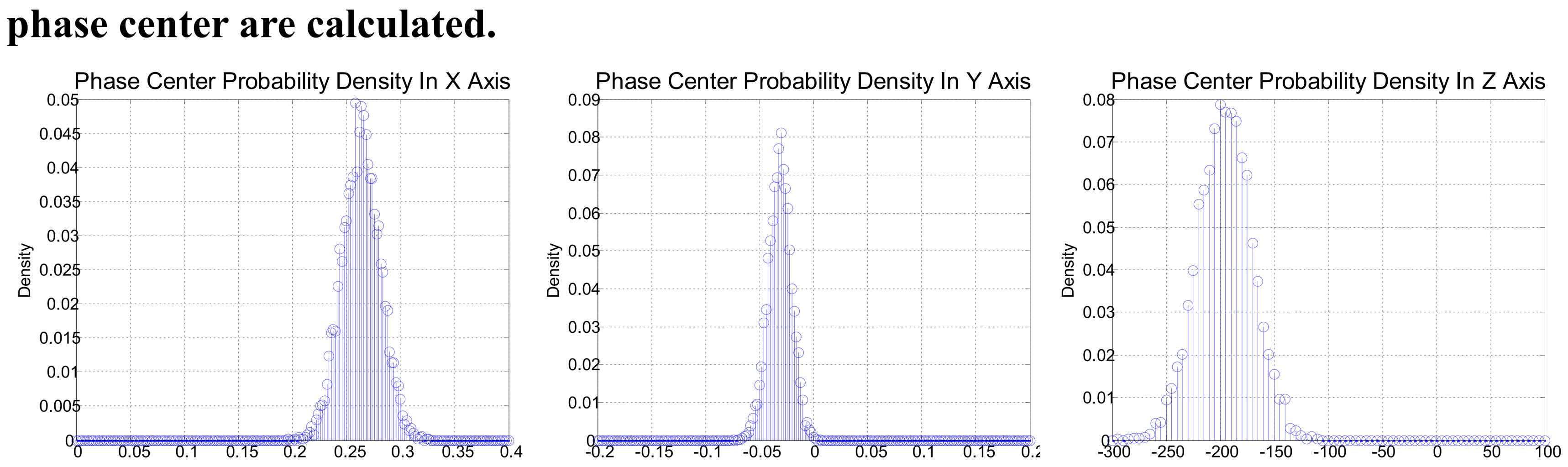

FIG.6. Probability density distribution of phase center

TABLE II. Phase Center Error on Different Axes

Axis	Error bound	Distribution
X	±0.07mm	
Y	±0.05mm	Normal
Z	±50mm	Normal

Result

AUT alignment is the factor that only affects test coordinate instead of test result.

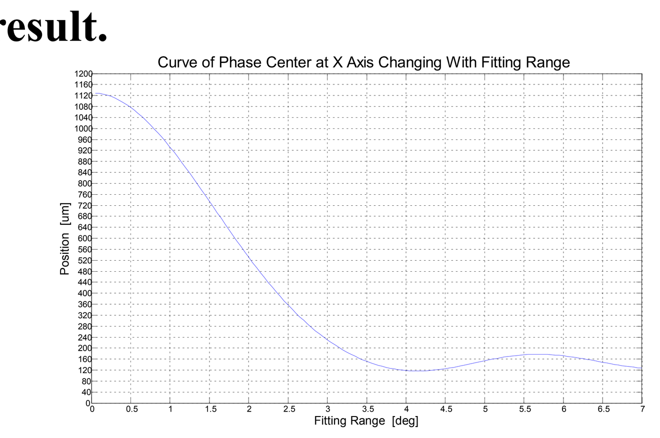

FIG.7. Phase center change caused by fitting range

TABLE III. AUT Alignment Error of Antenna Phase Center

Axis	Rotation 0.05°	Distance 150um	Final
X	0.005mm	0.15mm	0.155mm
Y	0.0016mm	0.15mm	0.152mm
Z	1.5mm	0.15mm	1.65mm

TABLE IV. Final Result of Phase Center Error

Axis	18 error items(except AUT alignment)	AUT alignment	Error
X	0.07mm	0.155mm	0.17mm
Y	0.05mm	0.152mm	0.16mm
Z	50mm	1.65mm	50.03mm

Conclusion

Planar near field is taken as an example for antenna phase center error analysis. Based on 18 error items, the error bound of phase pattern is acquired. Monte Carlo method is also employed for error synthesis. Combined with its particular items, we got the final result of phase center error analysis.

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