EFFECT OF ANTENNA POINTING ERRORS ON SPOTLIGHT SAR IMAGING CONSIDERING THE POINT TARGET LOCATION

Xin Zhang; Shijie Liu; Xiaohua Tong

Tongji University, China

CONTENTS

1 Background

Towards spaceborne SAR, external environment has an effect on the stability of SAR platform.

The antenna is regulated by the SAR system with specific regularity in the spotlight SAR、sliding spotling SAR、Scan SAR modes.

Antenna pointing error

Take the spotlight mode as a example

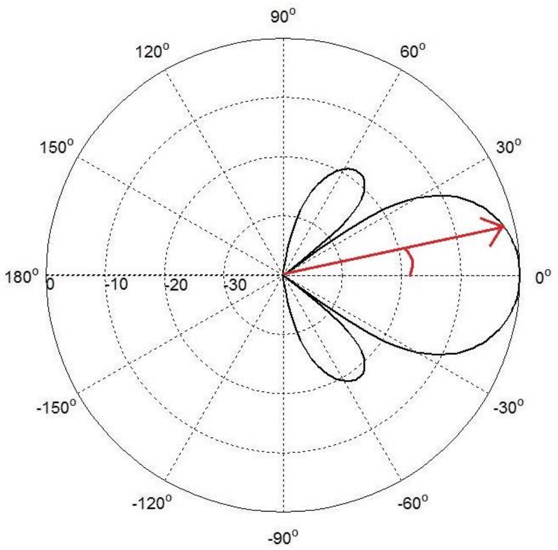


Figure 1. Antenna pattern

2 Primary Model

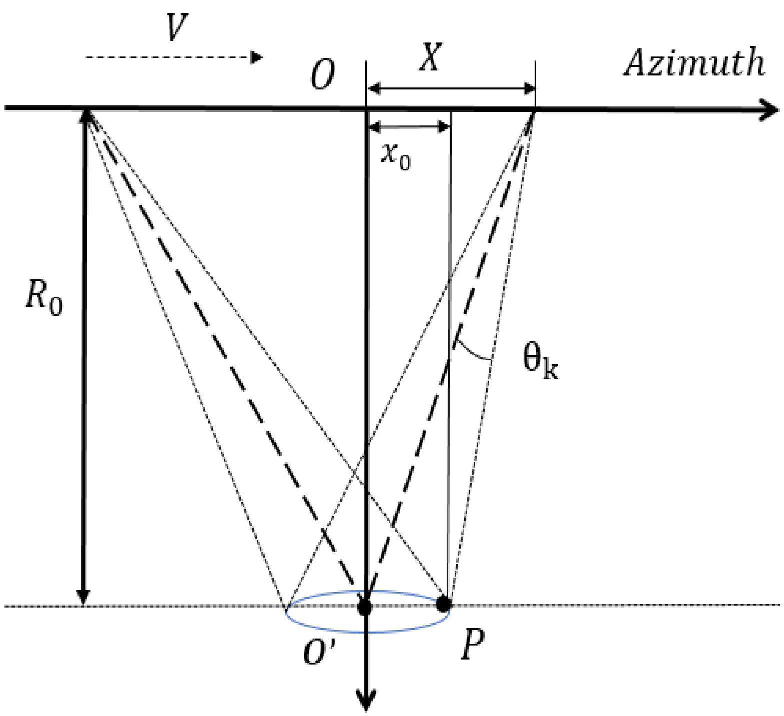


Figure 2. Illuminated geometry of the spotlight SAR

After the imaging process, the final echo can be simplified to the signal mode:

$$s(t) = w_a(t) w_r(t) e^{-j\pi f_r t^2}$$

After the phase compensation and antenna weighting processing in the imaging process, the final target signal is :

$$s_m(t) = e^{-j\pi f_r t^\wedge 2} \int_{-\infty}^{\infty} w_a(t) w_r(t) e^{-j2\pi f_r t.\tau} d\tau$$

$$\theta_k$$

2 Primary Model

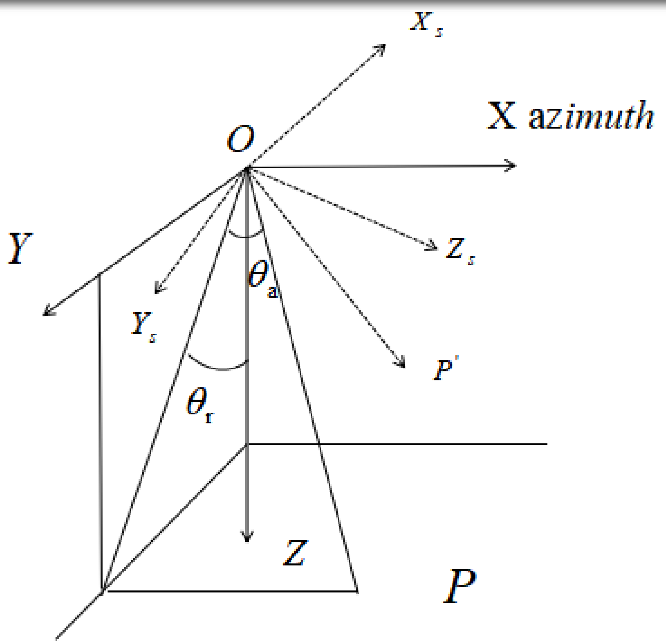


Figure 3. Antenna beam pointing change caused by attitude jitter

original azimuth antenna pointing θ_{a}

original range antenna pointing θ_{r}

+

yaw δ_y

pitch δ_p

roll δ_r

The relationship between three-axis attitude error and the antenna beam pointing errors is deduced:

$$\Delta\theta_{\mathrm{a}} = (\cos\theta_r \delta_p - \sin\theta_r \delta_y)$$

$$\Delta\theta_{\mathrm{r}} = \frac{(\delta_y \sin\theta - \cos\theta_a \cos\theta_r \delta_r + \cos\theta_a \sin\theta_r) \div \cos\theta - \sin\theta_r}{\cos\theta_r}$$

3 Analytic effect

Azimuth antenna pointing jitter

Suppose the direction of the antenna beam wobbles as follows:

$$\Delta\theta_a(t) = \theta_{am}\sin(\omega_0 t + \varphi_0)$$

The azimuth antenna gain is:

$$w_a(t) = w_a[\theta_{a0} + \theta_{am}\sin(\omega_0 t + \varphi_0)]$$

Where θ_{a0} is the Off-axis Angle of the target in azimuth direction, equal to θ_k when considered in the spotlight SAR mode.

Using a Taylor series expansion on θ_k and ignoring the high term, then $w_a(t)$ can be represented as:

$$w_{a1}(t) \cong w_a(\theta_k) + w_a{}'(\theta_k)\theta_{am}\sin(\omega_0 t + \theta_0)$$

Original antenna gain

Additional antenna gain

3 Analytic effect

Azimuth antenna pointing jitter

Set $w_r(\theta_{r0})$ as the antenna gain of range direction, the final target output signal can be expressed as:

$$s_{fa}(t) = w_r(\theta_{r0}) e^{j\pi f_r t^{\wedge}2} \int_{-\infty}^{\infty} w_{a1}(\tau) e^{-j2\pi f_r t.\tau} d\tau$$
$$= w_r(\theta_{r0}) e^{j\pi f_r t^{\wedge}2} \int_{-\infty}^{\infty} [w_a(\theta_k) + w_a{}'(\theta_k)\theta_{am} \sin(\omega_0 t + \theta_0)] e^{-j2\pi f_r t.\tau} d\tau$$

The azimuth antenna gain changes as the form of $w_a(\theta_k)$ over time in spotlight mode.

$$w_{a1}(t) \cong w_a(\theta_k) + w_a{}'(\theta_k)\theta_{am} \sin(\omega_0 t + \theta_0)$$

Azimuth Echo

Main echo

$$s_{ma}(t) = w_r(\theta_{r0}) e^{j\pi f_r t^{\wedge}2} \int_{-\infty}^{\infty} w_a(\theta_k) e^{-j2\pi f_r t.\tau} d\tau$$

changes over time

Additional echo

$$s_{wa}(t) = w_r(\theta_{r0}) e^{j\pi f_r t^{\wedge}2} \int_{-\infty}^{\infty} w_a{}'(\theta_k)\theta_{am} \sin(\omega_0 \tau + \theta_0)) e^{-j2\pi f_r t.\tau} d\tau$$

3 Analytic effect

Range antenna pointing jitter

The range direction off-axis angle towards certain target will not change as the SAR platform moving ahead.

$$W_r(t) \cong W_r(\theta_r) + W_r'(\theta_r)\theta_{rm}\sin(\omega_0 t + \theta_0)$$

Range Echo

- Main echo → $$s_{mr}(t) = e^{j\pi f_r t^2}\int_{-\infty}^{\infty}\omega_a(\tau)\omega_r(\theta_r)e^{-j2\pi f_r t\tau}d\tau$$
- Additoinal echo → $$s_{wr}(t) = e^{j\pi f_r t\wedge 2}\int_{-\infty}^{\infty}w_a(\tau)w_r'(\theta_r)\theta_{rm}\sin(\omega_0 t + \theta_0)]e^{-j2\pi f_r t.\tau}d\tau$$

$w_r'(\theta_r)$: constant value

4 Simulation results

The simulation parameters are shown as Table 1.

Table 1 Simulation parameters

Parameter (unit)	Value
Orbit altitude (km)	700
Wave length (m)	0.03
Velocity (km/s)	7.5
Antenna aperture (m）	10
Pulse repetition frequency (Hz)	5000

The angle of antenna direction is coupling with the attitude jitter angle, final antenna jitter angles of azimuth and range direction were given.

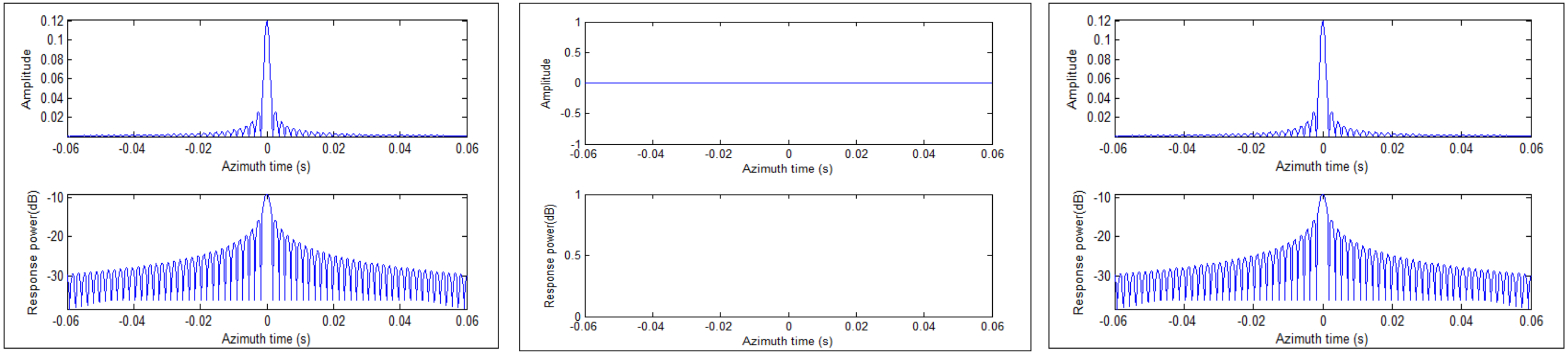
Refer to Chen et al., (2001), give the antenna jitter parameters that antenna jitter amplitude is 0.05deg, the frequency is 4 Hz, without loss of generality. $(0, Y_c)$ is the centre position of the target scene.

Chen et al., (2001) firstly did the research obout the influence of attitude jitter to stripmap SAR imaging .

4.1 Simulation results(target $(0,\ Y_c)$)

Azimuth antenna pointing jitter

When the target locates in the scene centre $(0,\ Y_c)$, the simulation results are displayed in Figure 4.



(a) Original echo

(b) Echo cause by antenna pointing jitter

(c) All echo

Figure 4

Simulation results of the echoes caused by azimuth direction pointing jitter towards target $(0,\ Y_c)$

Table 2. Compare of reference index

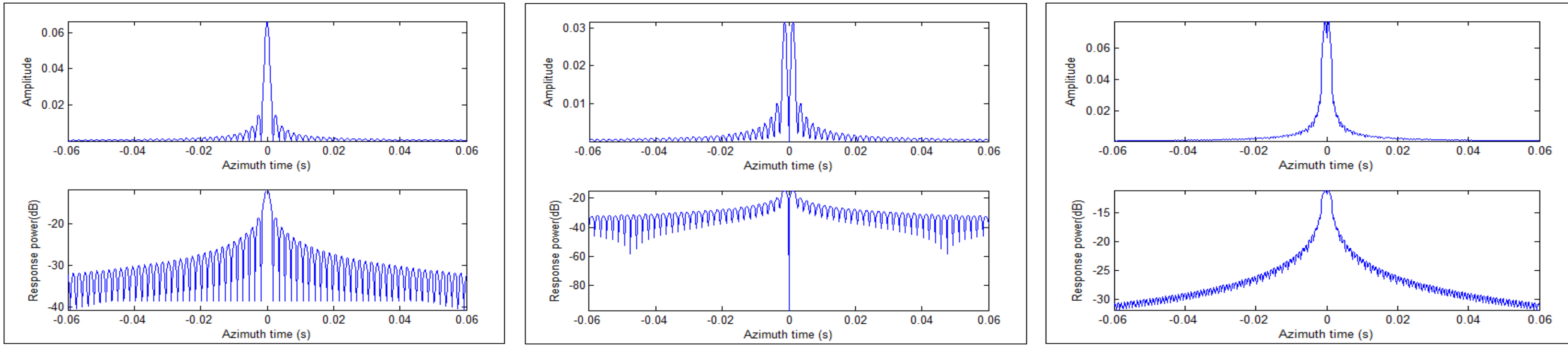
Statistical index	Original ideal echo	Echo after antenna pointing jitter
PSLR ISLR	-13.2740dB -10.6945dB	-13.2740dB -10.6945dB

Azimuth antenna pointing jitter almost cause no influence to the original echo.

4.2 Simulation results(target $(1000，Y_c)$)

Azimuth antenna pointing jitter

When the target locates in $(1000，Y_c)$, the simulation results are shown in Figure 5.



(a) Original echo

(b) Echo cause by antenna pointing jitter

(c) All echo

Figure 5

Simulation results of the echoes caused by azimuth direction pointing jitter towards target $(1000，Y_c)$

Table 3. Compare of reference index

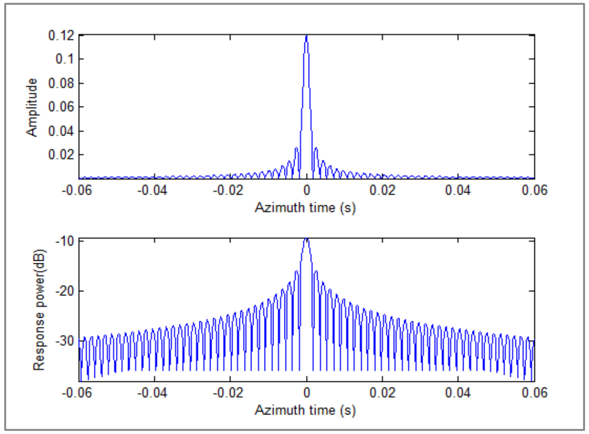
Statistical index	Original ideal echo	Echo after antenna pointing jitter
PSLR ISLR	-13.2740dB -9.1252dB	1.3013dB -6.3000dB

Additional echo caused by the antenna pointing jitter is obvious and symmetrical.

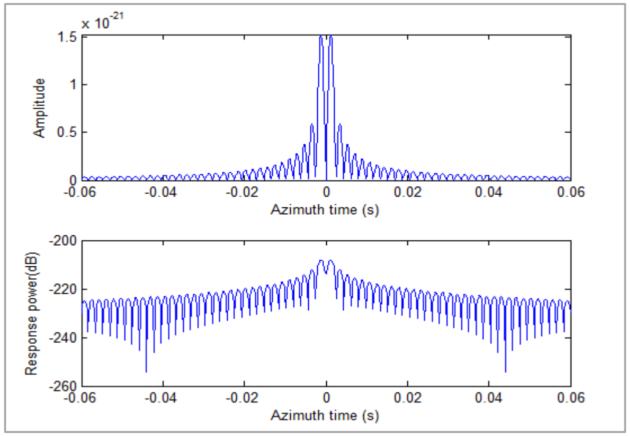
4.3 Simulation results(target $(0, Y_c)$)

Range antenna pointing jitter

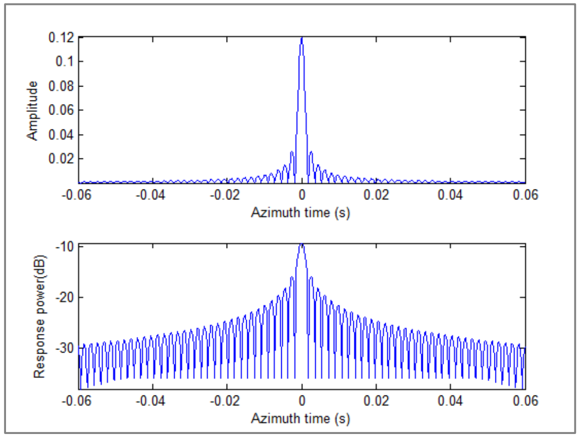
When the target locates in $(0, Y_c)$, the simulation results are shown in Figure 6.



(a) Original echo



(b) Echo cause by antenna pointing jitter



(c) All echo

Figure 6
Simulation results of the echoes caused by azimuth direction pointing jitter towards target $(0, Y_c)$

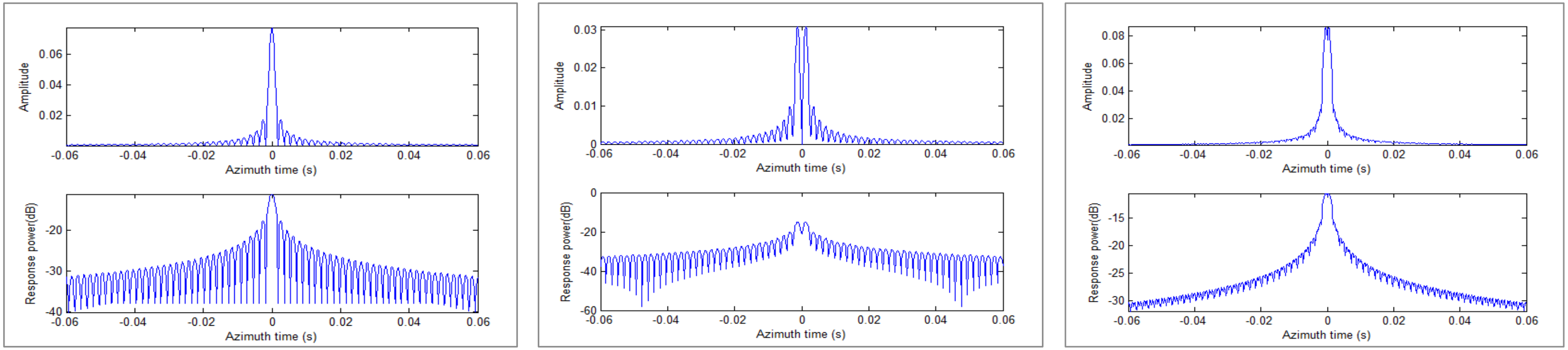
Table 4. Compare of reference index

Statistical index	Original ideal echo	Echo after antenna pointing jitter
PSLR ISLR	-13.2740dB -10.6945dB	-13.2740dB -10.6945dB

Range antenna pointing jitter almost cause no influence to the original echo.

4.4 Simulation results(target$(0, Y_c + 1000)$) Range antenna pointing jitter

When the target locates in $(0，Y_c + 1000)$, the simulation results are shown in Figure 7.



(a) Original echo

(b) Echo cause by antenna pointing jitter

(c) All echo

Figure 7

Simulation results of the echoes caused by azimuth direction pointing jitter towards target $(0, Y_c + 1000)$

Table 5. Compare of reference index

Statistical index	Original ideal echo	Echo after antenna pointing jitter
PSLR	-13.3313dB	0.97526dB
ISLR	-10.7627dB	-6.6643dB

Additional echo caused by the antenna pointing jitter is obvious and symmetrical

4.5 Simulation results

Azimuth antenna pointing jitter

The influence of the azimuth location to azimuth direction antenna pointing jitter - simulation result

Make the range coordinate in the centre, consider that the azimuth direction coordinate of the target location is from -1000m to 1000m.

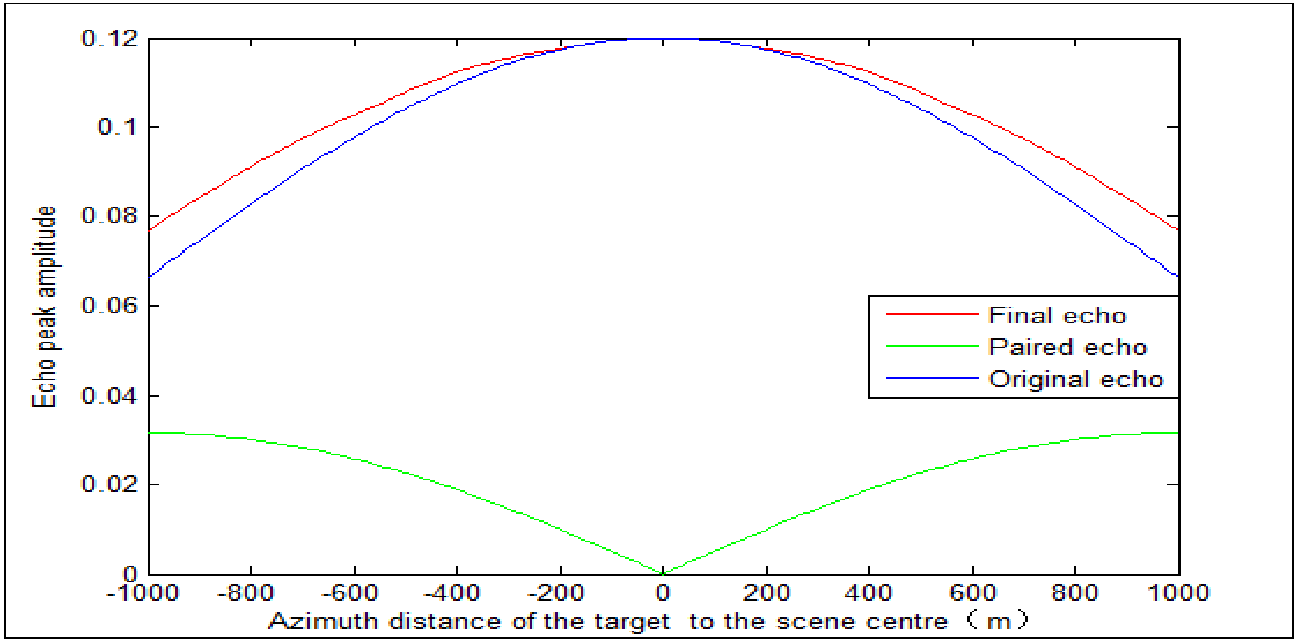


Figure 8. The influence of target azimuth direction position to the echo peak amplitude

4.6 Simulation results

Azimuth antenna pointing jitter

The influence of the range location to azimuth direction antenna pointing jitter ——simulation result

Make the azimuth coordinate 1000m, consider that the range direction coordinate of the target location change from Y_c -1000m to Y_c +1000m .

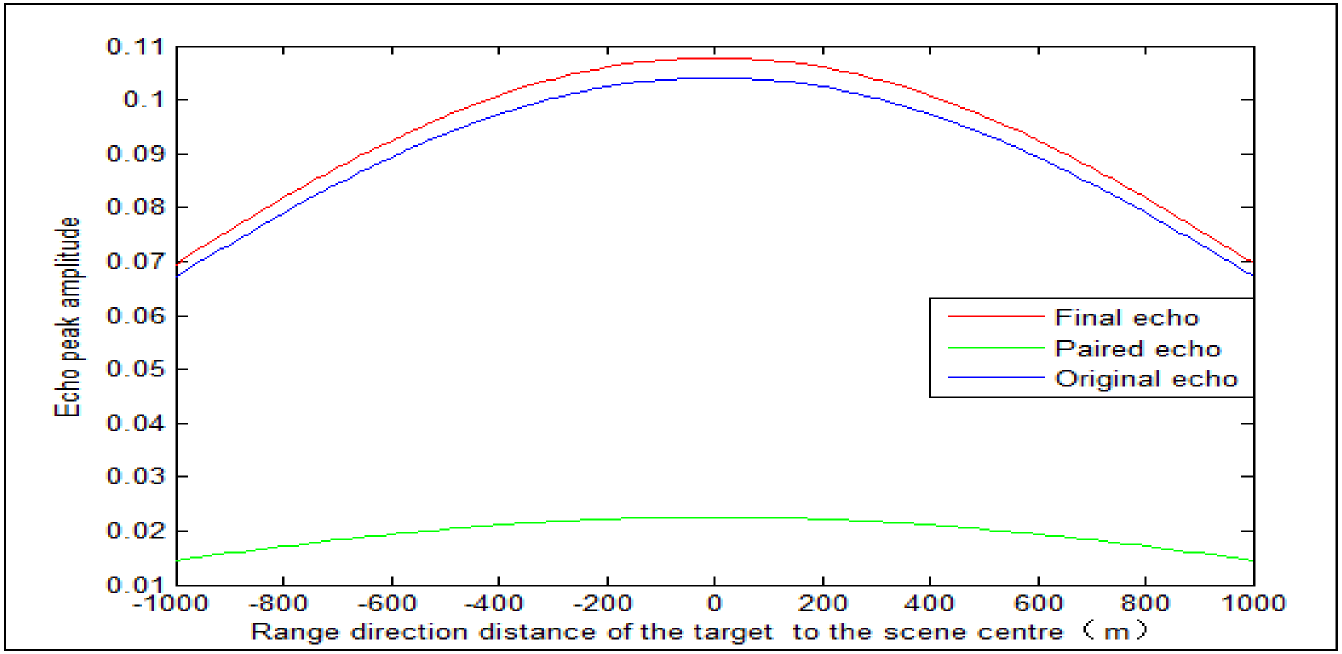


Figure 9. The influence of target range direction position to the echo peak amplitude

4.7 Simulation results

Range antenna pointing jitter

The influence of the azimuth location to range direction antenna pointing jitter—— simulation result

Make the range coordinate in the $Y_c + 1000$, consider that the azimuth direction coordinate of the target location changes from -1000m to 1000m.

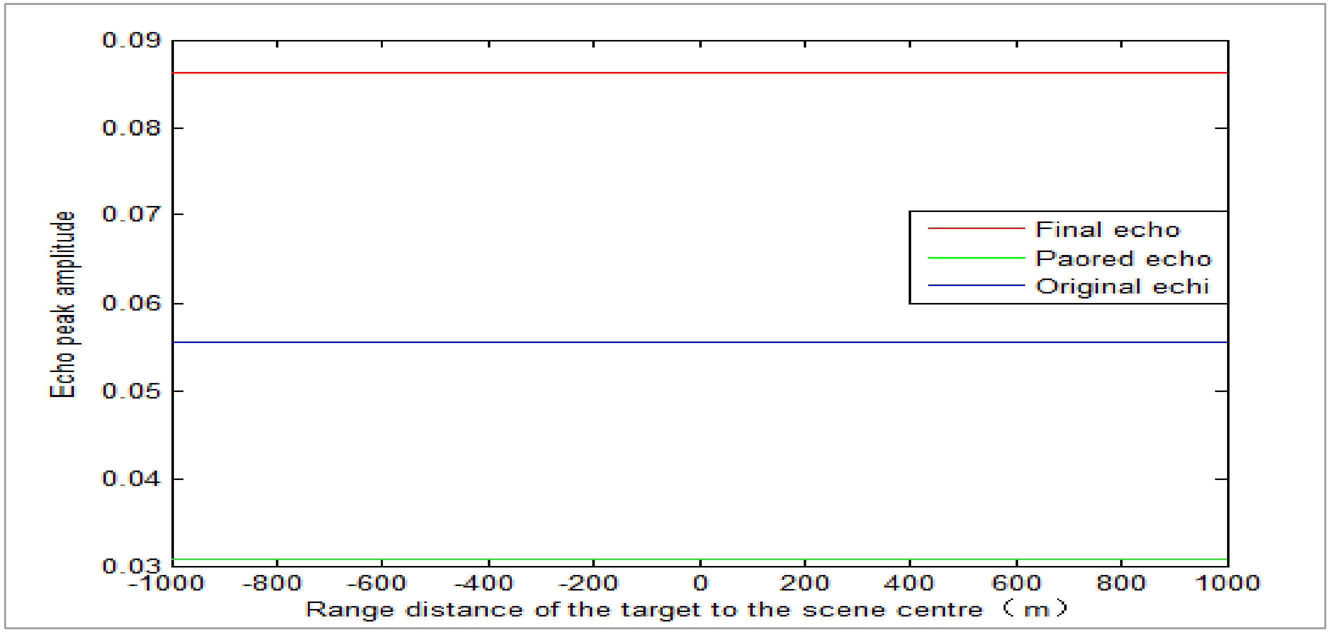


Figure 10. The influence of target azimuth direction position to the echo peak amplitude

4.8 Simulation results

Range antenna pointing jitter

The influence of the range location to range direction antenna pointing jitter ——simulation result

Make the azimuth coordinate 1000m, consider that the range direction coordinate of the target location is from Y_c -1000m to Y_c +1000m .

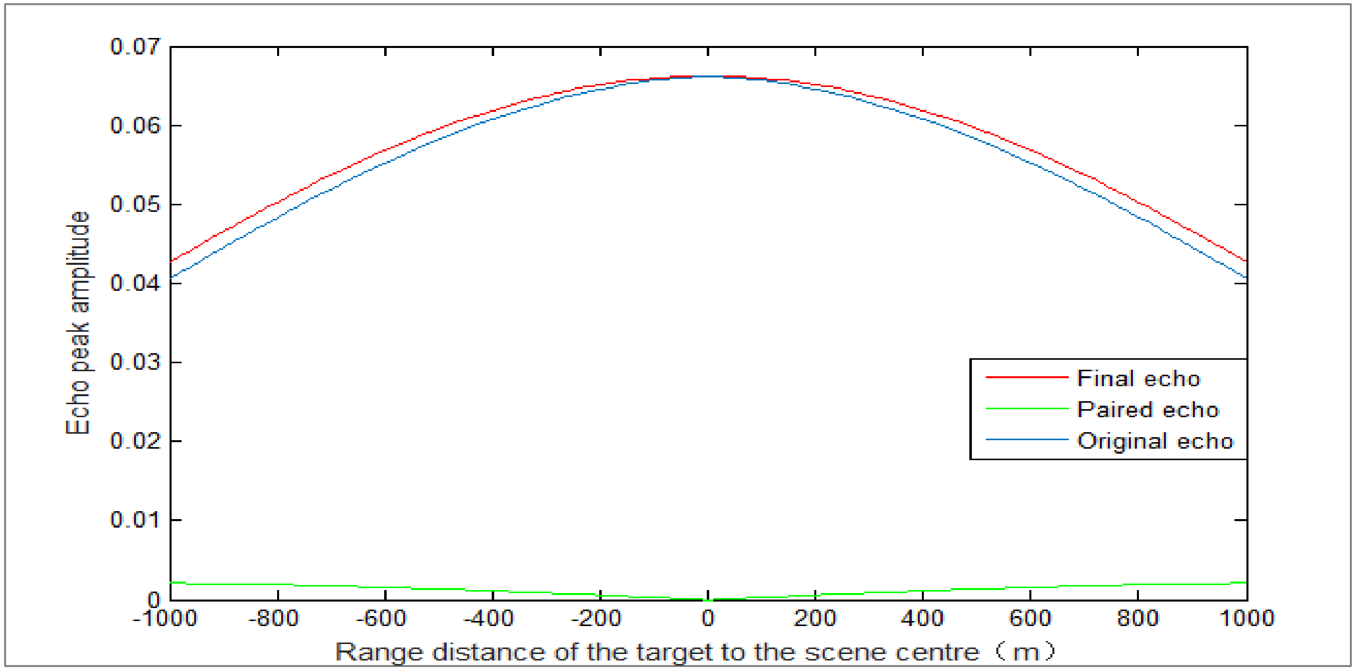


Figure 11. The influence of target range direction position to the echo peak amplitude

5 Conclusions

In the spotlight SAR mode,
the pointing errors of the antenna beam will influence the echo related to the target location in the illuminated scene, where the azimuth antenna jitter and range antenna jitter behave different laws as above analysis.

Future work

Multifrequency jitter and face target will be considered , and we need to seek a way to compensate the negative effect of the attitude jitter .

Thanks for your attention!