The 5th Report of Undergraduate Graduation Design

· Intergrator to forward the trajectory & Multipath noise

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Outline

Work summary of this week:

- Complete the intergrator to forward the trajectory
- Multipath noise
- PSD of stocks coefficients of oscillator and system noise

Bad news:

- Can't carry on the forward procedure.

Complete the intergrator to forward the trajectory

Problem encontered

- Unbalanced energy
- Big trajectory error from GRACE FO's

Possible reasons

- Coordinates transformation error
- Accelaration error

Accelaration formula are UNCORRECT!

Original formula from Zheng-tao Wang

$$
\begin{cases}
a_{X_{lm}} = \begin{cases} \dfrac{GM}{R_e^{\,2}}\left[-b_1 E_{l+1,1}\cdot \bar{C}_{l0}\right] & m=0 \\ \dfrac{GM}{2R_e^{\,2}}\left[\begin{matrix} b_2(-E_{l+1,m+1}\cdot \bar{C}_{lm} - F_{l+1,m+1}\cdot \bar{S}_{lm}) + \\ b_3(E_{l+1,m-1}\cdot \bar{C}_{lm} + F_{l+1,m-1}\cdot \bar{S}_{lm}) \end{matrix}\right] & m>0 \end{cases} \\
a_{Y_{lm}} = \begin{cases} \dfrac{GM}{R_e^{\,2}}\left[-b_1 F_{l+1,1}\cdot \bar{C}_{l0}\right] & m=0 \\ \dfrac{GM}{2R_e^{\,2}}\left[\begin{matrix} b_2(-F_{l+1,m+1}\cdot \bar{C}_{lm} + E_{l+1,m+1}\cdot \bar{S}_{lm}) + \\ b_3(-F_{l+1,m-1}\cdot \bar{C}_{lm} + E_{l+1,m-1}\cdot \bar{S}_{lm}) \end{matrix}\right] & m>0 \end{cases} \\
a_{Z_{lm}} = \dfrac{GM}{R_e^{\,2}}\left[b_4(-E_{l+1,m}\cdot \bar{C}_{lm} - F_{l+1,m}\cdot \bar{S}_{lm})\right]
\end{cases}
$$

$$
\begin{cases}
b_1 = \sqrt{\dfrac{(l+1)(l+2)(2l+1)}{2(2l+3)}} \\
b_2 = \sqrt{\dfrac{(l+m+1)(l+m+2)(2l+1)}{(2l+3)}} \\
b_3 = \sqrt{\dfrac{(l-m+1)(l-m+2)(2l+1)}{(2l+3)}} \\
b_4 = \sqrt{\dfrac{(l-m+1)(l+m+1)(2l+1)}{(2l+3)}}
\end{cases}
$$

In the above pictures, b_3 is WRONG!, because of the Dirichlet function.

Accelaration formula after correction

Corrected formula

$$b_3 = \sqrt{\frac{(n-m+1)(n-m+2)(2n+1)(1+\sigma_{1m})}{(2n+3)}} \tag{1}$$

Diriclet function to be used

$$\sigma_{1m} = \begin{cases} 1, & m = 1 \\ 0, & m \neq 0 \end{cases} \tag{2}$$

·Already finish the simulation work of all the error sources for KBR

Needed value

- Amplitude reduction factor ε.
- Distance between the reflection point and phase centre y.
- Cone angle θ.

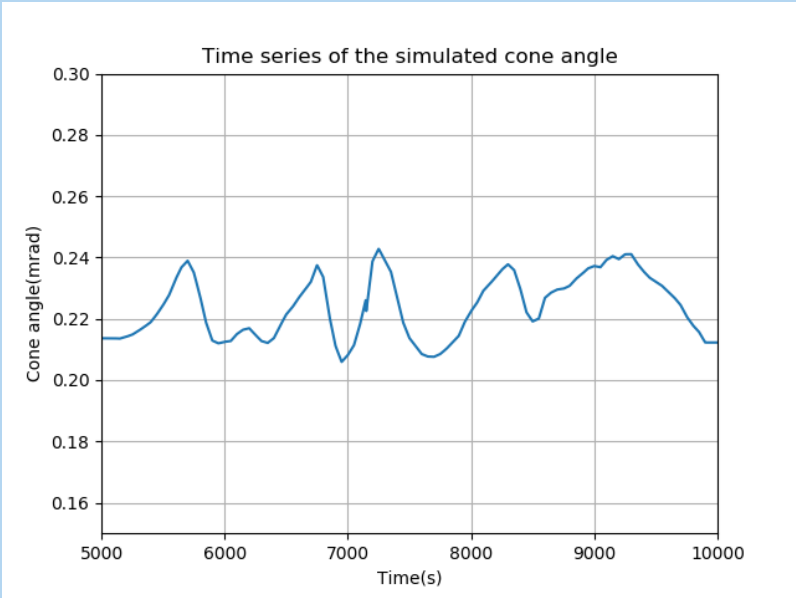
Formula

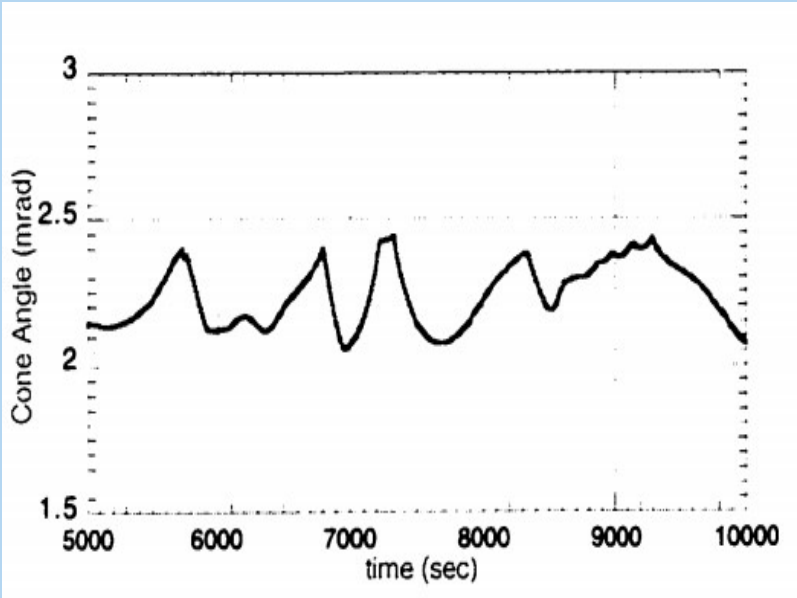
$$\Delta\rho = \sqrt{2}\varepsilon y\theta \quad or \quad \Delta\dot{\rho} = \sqrt{2}\varepsilon y\dot{\theta} \tag{3}$$

But I still can't derive the formula correctly! According to the reference, this multipath model has been simplified, I accept it!

Simulated cone angle, because the attitude data seem not be released . . .

Cone angle

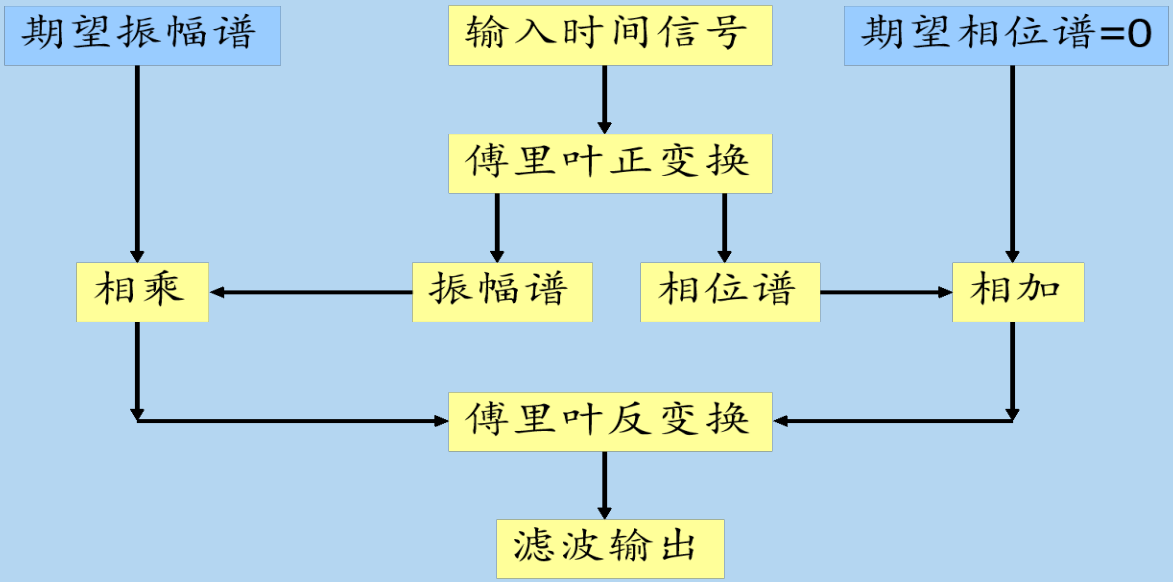




The left picture above is picked by machine-learning.

Because I don't know the producedure to determine attitude angles, this simulation using filtering is taken

Filter flow



Make a white noise time series to pass through the filter from the picked cone angle.

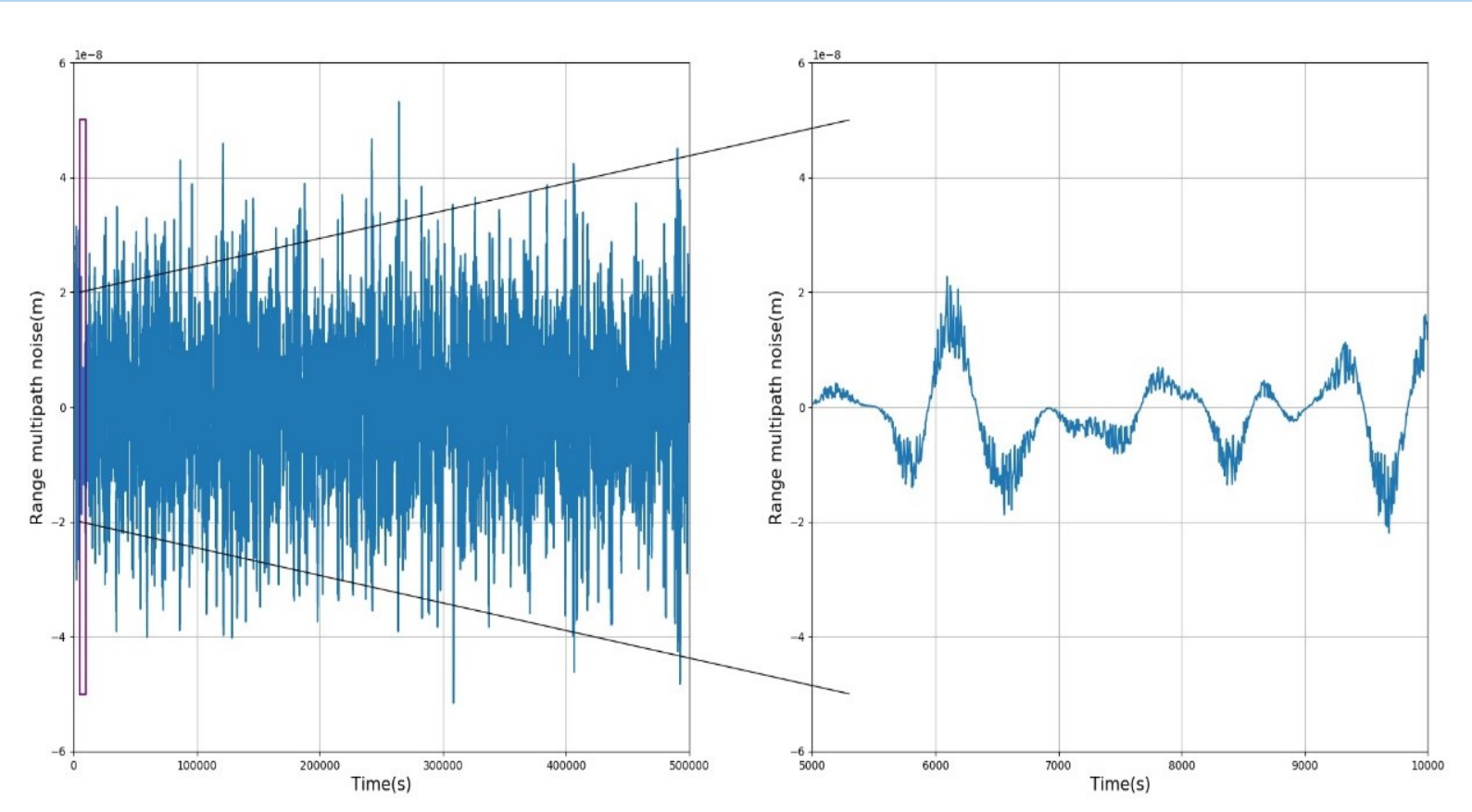
ε and y

How to determine

- The distance between the phase centre and the reflectio point is a random number between 0.777m and 0.275m.
- Determining the amplitude reduction factor is a trick. According to the reference, this value is obtained by testing. Since the related GRACE FO tests is unavilable, and the ANT-MULTIPATH performance is undoubtfully better than GRACE, the ε I assign is an order of magnitude smaller than the given one.

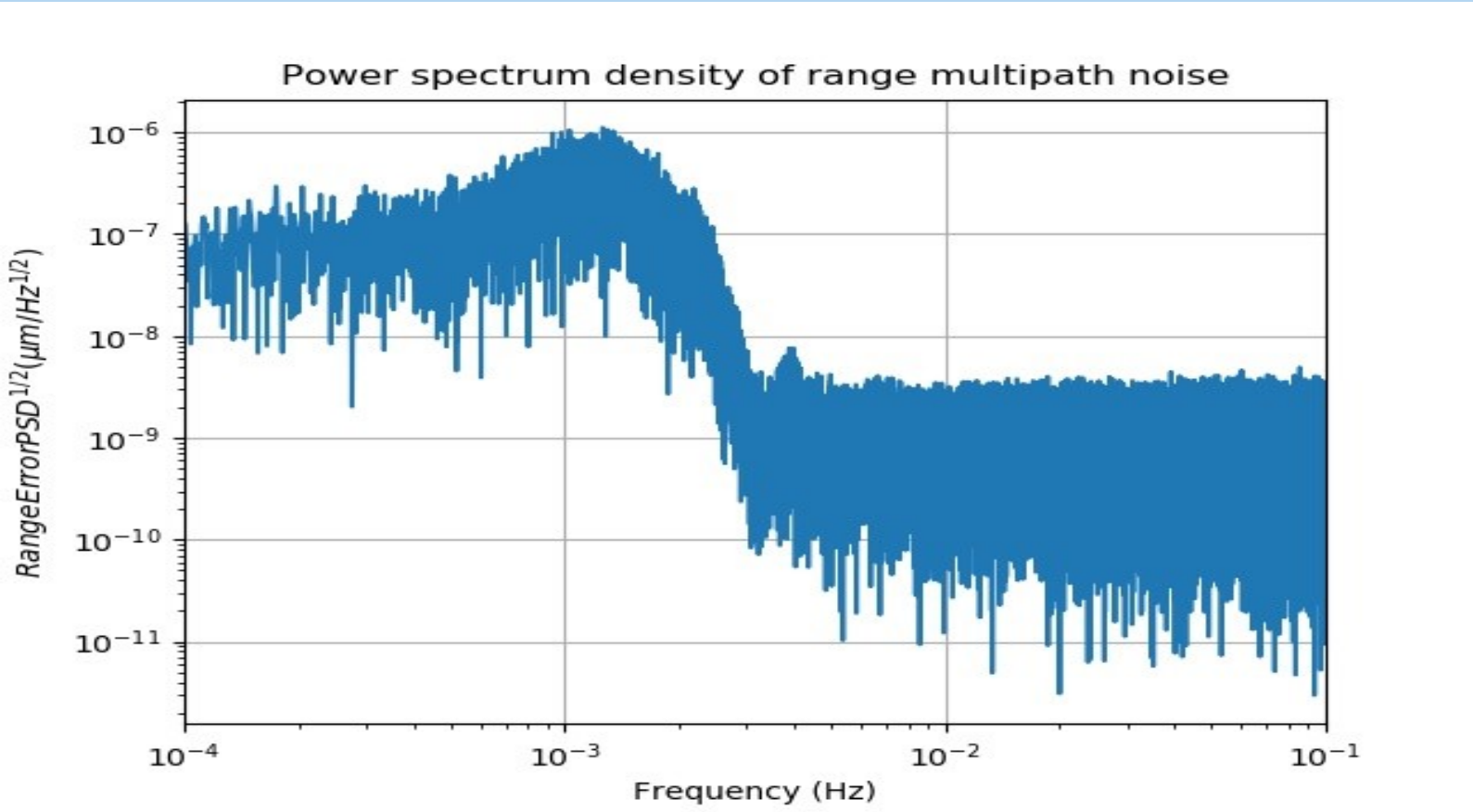
After filtering . . .

Range multipath noise



PSD, the concerned one

PSD of the range multuipath noise



Range-rate time series TO stocks coefficients

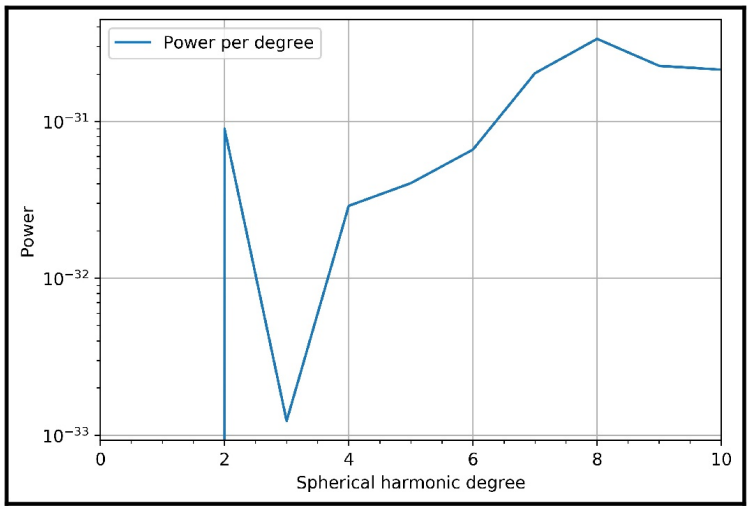
Principle

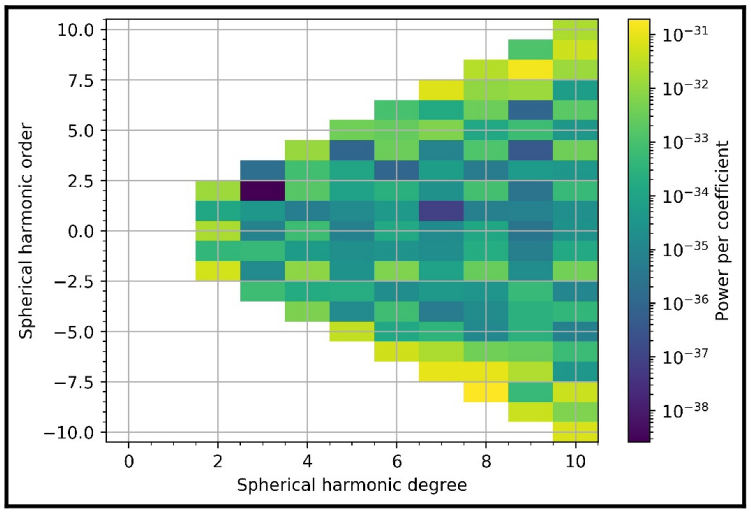
- Range rate noise caused by USO frequency drift and system noise is changed with time, as same as the gravity. Therefore, once a long time span of range-rate noise is got, the stocks coefficients can be attained by the same way to attain the geoid stocks coefficients.
- After getting the stocks coefficients, the error propagation formula is on the way to get the error level for different degree.

PSD of the stocks coefficients

Just a test using one-day data.

PSD 1D and 2D





Next step...

Plan of the next few weeks

- Finish the KBR error propagation work, which is pretty simple, because the formula is given, and the programme may not cost a long time.
- Getting coefficients of a higher degree requires a longer GRACE FO data. The internet speed may be a problem.
- Finish opening report.
- Finish a piece of translation. Wish instructors can offer some reference about LRI in GRACE FO, which I barely know and the optics can be really professional.

Some bad news . . .

We can perform the forward procedure, but...

1. Coordinates transformation is still a problem.
   - Cannot make sure the parts except the time-label part are 100% correct ...

   Solutions:
   - Unify the time system with GRACE FO.
2. Three-body pertuation is not available.
   - Cannot revise the complete program to a subroutine to be called in real time.
   - The time system may be a problem.

   Solutions:
   - Make sure the program can be rewrite.
   - Time system is really important.

Thank you!