Signal improvement of GNSS for Cislunar SSV

14th Meeting of the International Committee on
Global Navigation Satellite Systems

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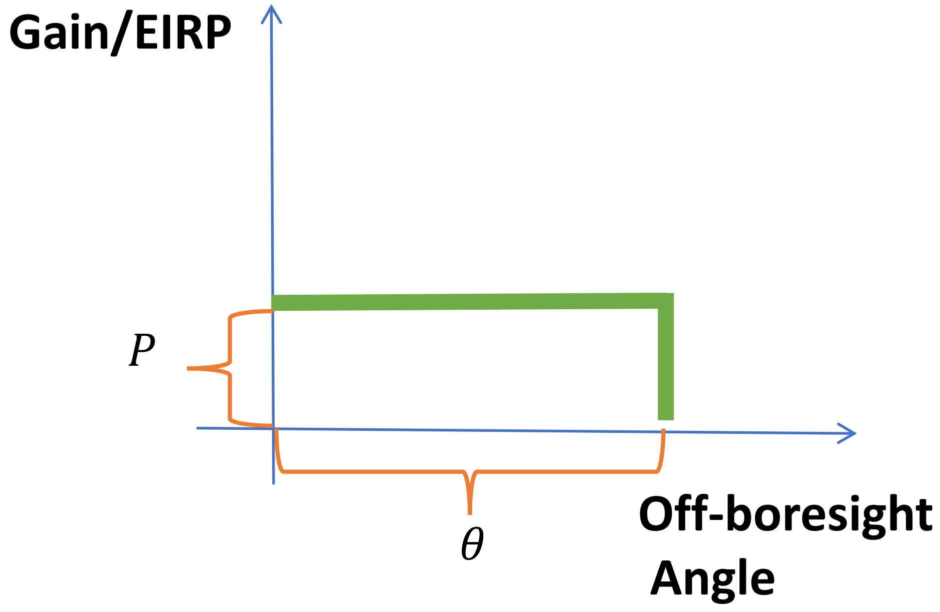
CONTENT

01

BOOKLET UPDATE

I. A New Model GNSS Satellite Transmit Antenna Pattern

- **In Booklet 1.0, the approach of evaluate signal availability is based on the simplified 2-parameter antenna model:**



- **P- represents the assumed EIRP or The Minimum Radiated Transmit Power (MRTP) which is inverse calculated based on the minimum received signal power at GEO and free space loss.**
- **θ- represents the reference off-boresight angle or the beam-width of the simplified antenna pattern**

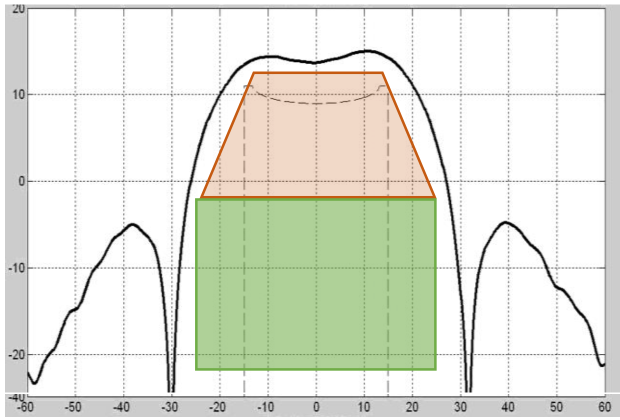
A conservative approach which both parameters of the antenna model derived by template input from providers.

I. A New Model GNSS Satellite Transmit Antenna Pattern

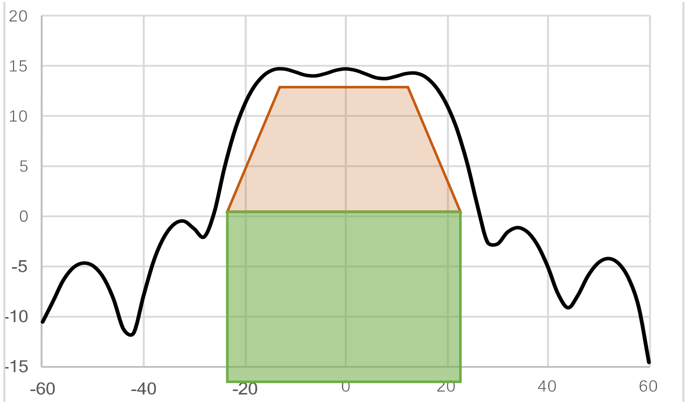
- **If compare the 2-parameter model (the green region) with the typical navigation transmit antenna patterns (as shown in the right), it can be seen the red region which can also contribute to space users are missed.**
- **To describe this red region 2 more parameters can be introduce to the model:** $\Delta\mathrm{P}, \theta_E$

Antenna Patterns of

B2 Signal (BDS-2 MEO)

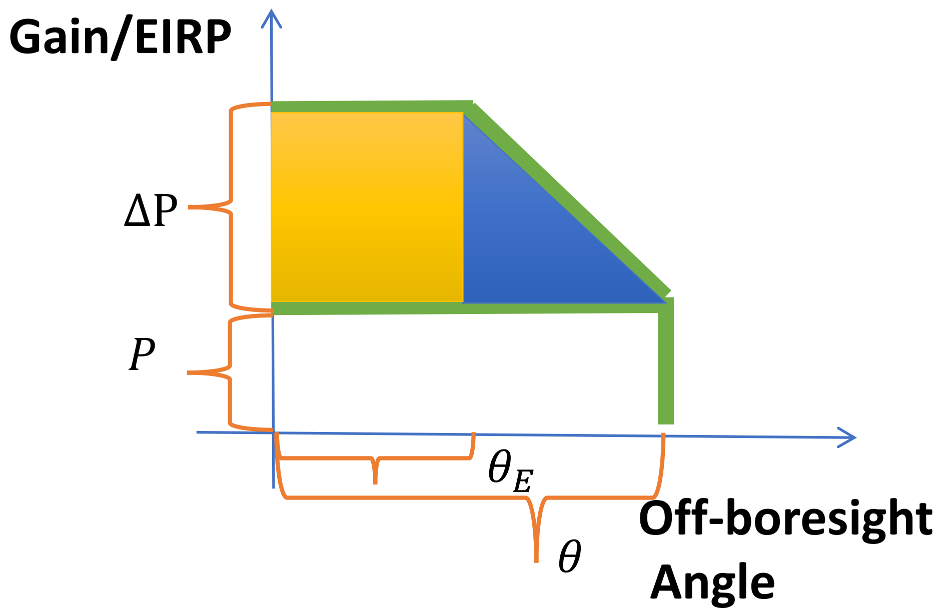


L2 Signal (GPS-IIR)



I. A New Model GNSS Satellite Transmit Antenna Pattern

➢ **In the new 4-parameter antenna model:**

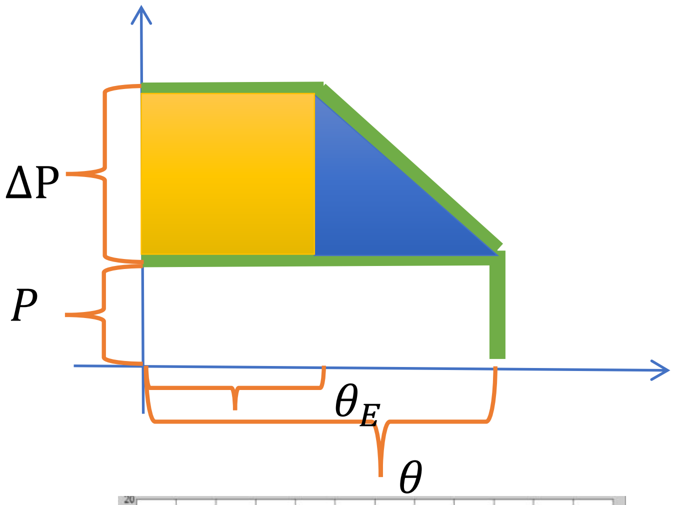


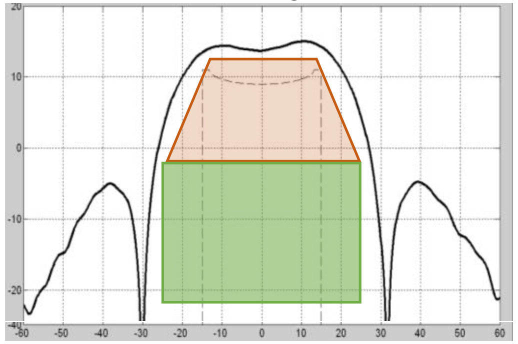
- θ_E - represents the edge of earth angle of the identified GNSS satellite
- $\Delta\mathrm{P}$- represents the power difference between the minimum EIRP inside θ_E and MRTP

θ_E can be also derived by input from providers.
By choosing value of $\Delta\mathrm{P}$, the new model remains a conservative approach since the ladder-shaped region still inside the envelope of real antenna patterns .

I. A New Model GNSS Satellite Transmit Antenna Pattern

➢ **In the new 4-parameter antenna model:**





- ☐ **By choosing a conservative value of ΔP, the new model remains a conservative approach with higher fidelity since the ladder-shaped region still inside the envelope of real antenna patterns .**
- ☐ **Based on observation of typical antenna patterns of GNSS, choosing 10dB as the value of ΔP is recommended.**

I. A New Model GNSS Satellite Transmit Antenna Pattern

➢ Implementation of the new antenna model

- ☐ The new model can be adopted to simulation scenario of globally averaged, mission- specific or both. The user will benefit from the new model with increased C/N0.
- ☐ Performance in the Lower SSV remain unchanged because it is not sensitive to the power gain in the new model.

➢ Why consider only the main-lobe in the model

- ☐ Antenna gain inside the main-lobe (or from EOE to reference OBA) is approximate monotonous and constant in all azimuth sections, which ensure the evaluation a conservative one.
- ☐ Antenna gain of the side-lobes varies tremendously in different azimuth sections, thus hard to characterize and remain conservative in the model.

02

Overview and current status in Cislunar SSV

02 Overview and current status in Cislunar SSV

I. Overview

- GNSS are maturing in the positioning applications of low Earth orbit, medium Earth orbit and geostationary satellites.
- SSV Booklet- The Interoperable GNSS Space Service Volume V1.0:
  - For lower SSV user: single of multiple GNSS can provide 100% available 4 satellites simultaneous visible service.
  - For upper SSV user: multiple GNSS can provide 99%. Single GNSS, can provide 4.2%(Galileo)~ 60.3%(GLONASS).

I. Overview

- **SSV Booklet- The Interoperable GNSS Space Service Volume V1.0:**
  - **For Cislunar SSV user: multiple GNSS can provide 16% availability within half Earth-moon distance.**
  - **The minimum sensitivity of a typical receiver is 20dB-Hz. The navigation signal transmitted by the Beidou, GPS, and Galileo systems is close to the receiver sensitivity limit at half of the average distance between the Earth and the moon.**

I. Overview

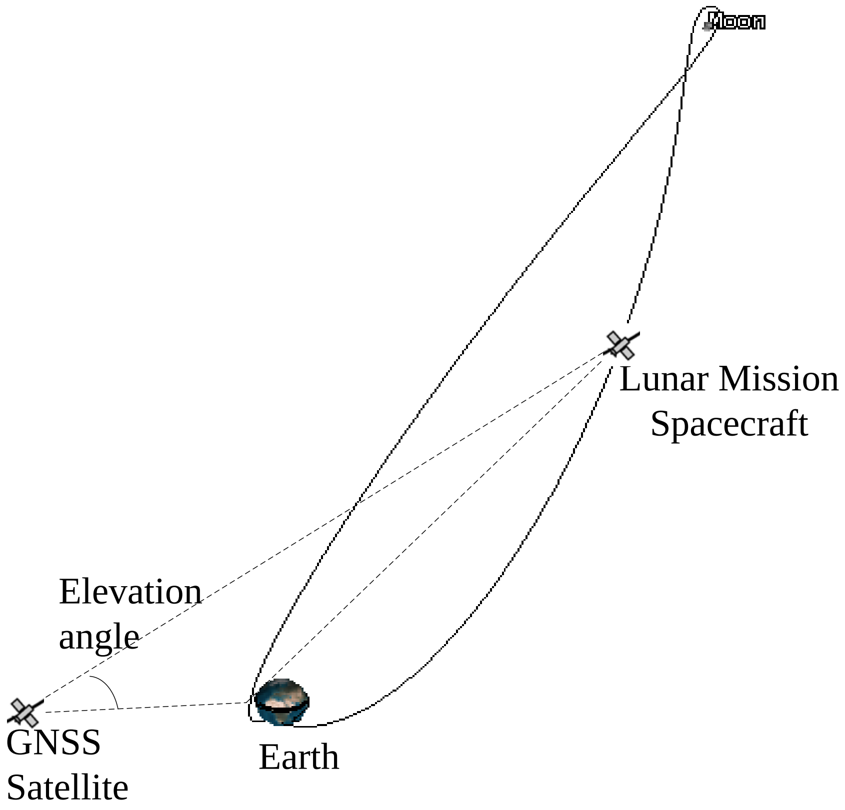
- **SSV Booklet- The Interoperable GNSS Space Service Volume V1.0:**
  - **If minimum sensitivity of a receiver is 15 dB-Hz, navigation signals transmitted by GNSS can also be received near the moon.**

II. Current status

- In the Cislunar SSV, the navigation signals of the GNSS system are directly used for navigation and positioning services. The power of the signal and the sensitivity of the receiver can meet the requirements of use.
- The main constraint factors are the visible number of navigation satellites and their spatial geometry.

III. Improvement method

- Consider deploying power-enhanced antennas on GNSS satellites, transmitting narrow-beam navigation power-enhanced signals, and enlarge the elevation angle movement of enhanced signals to extend the application of navigation satellites in the Cislunar SSV.



03

PDOP analysis of improved signals in Cislunar SSV

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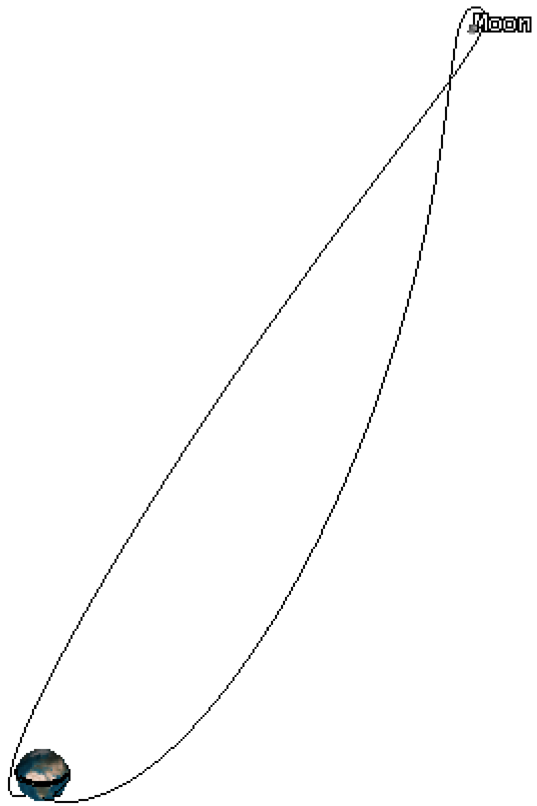
I. Parameter setting of the earth-moon transfer orbit:

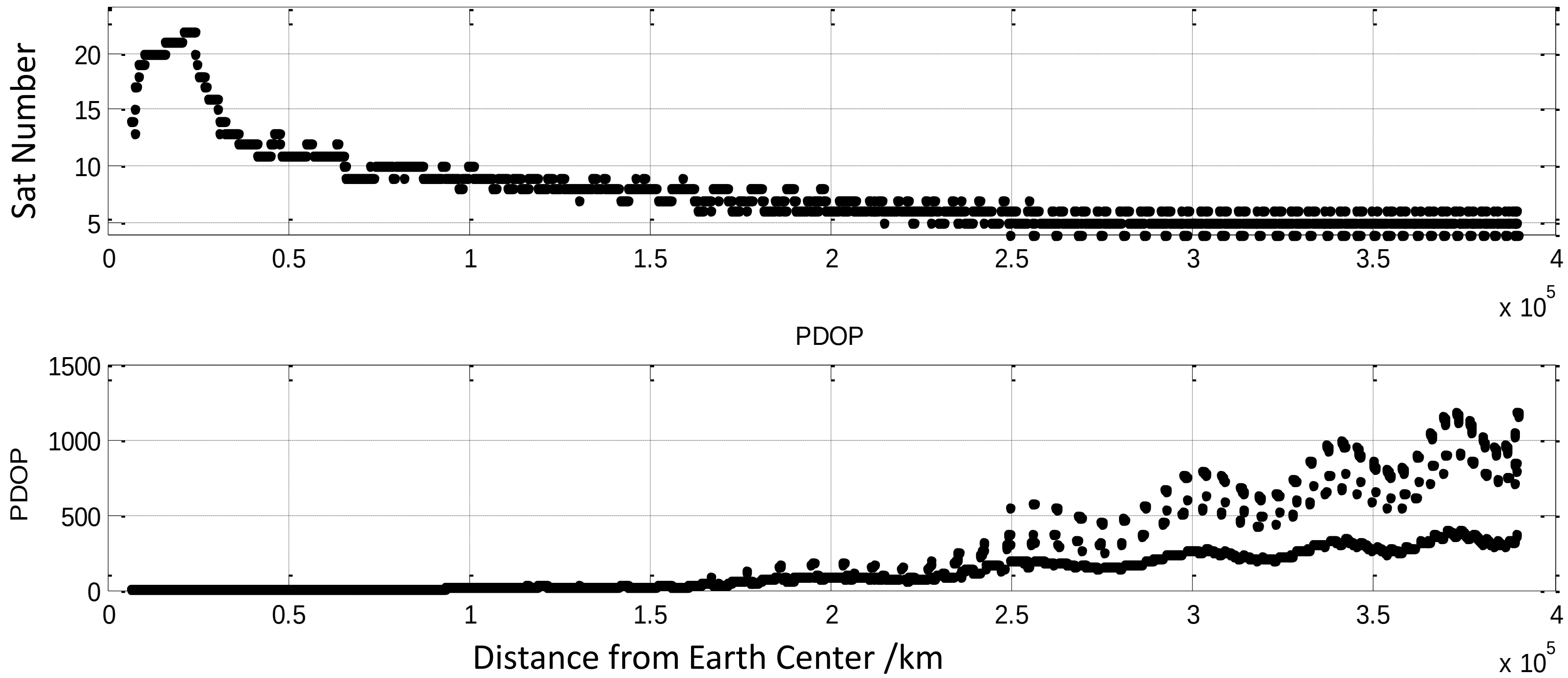
Time	2014 Dec. 1st，UTC 0h
J2000.0 ECI Position	X = -2295.556524km Y = -5708.797775km Z = -2782.097679km
J2000.0 ECI Velocity	Vx = 9.335116km/s Vy = -3.689306km/s Vz = -3.945018km/s



PDOP analysis of improved signals in Cislunar SSV

II. PDOP analysis of BDS with improved signal to earth-moon transfer orbit

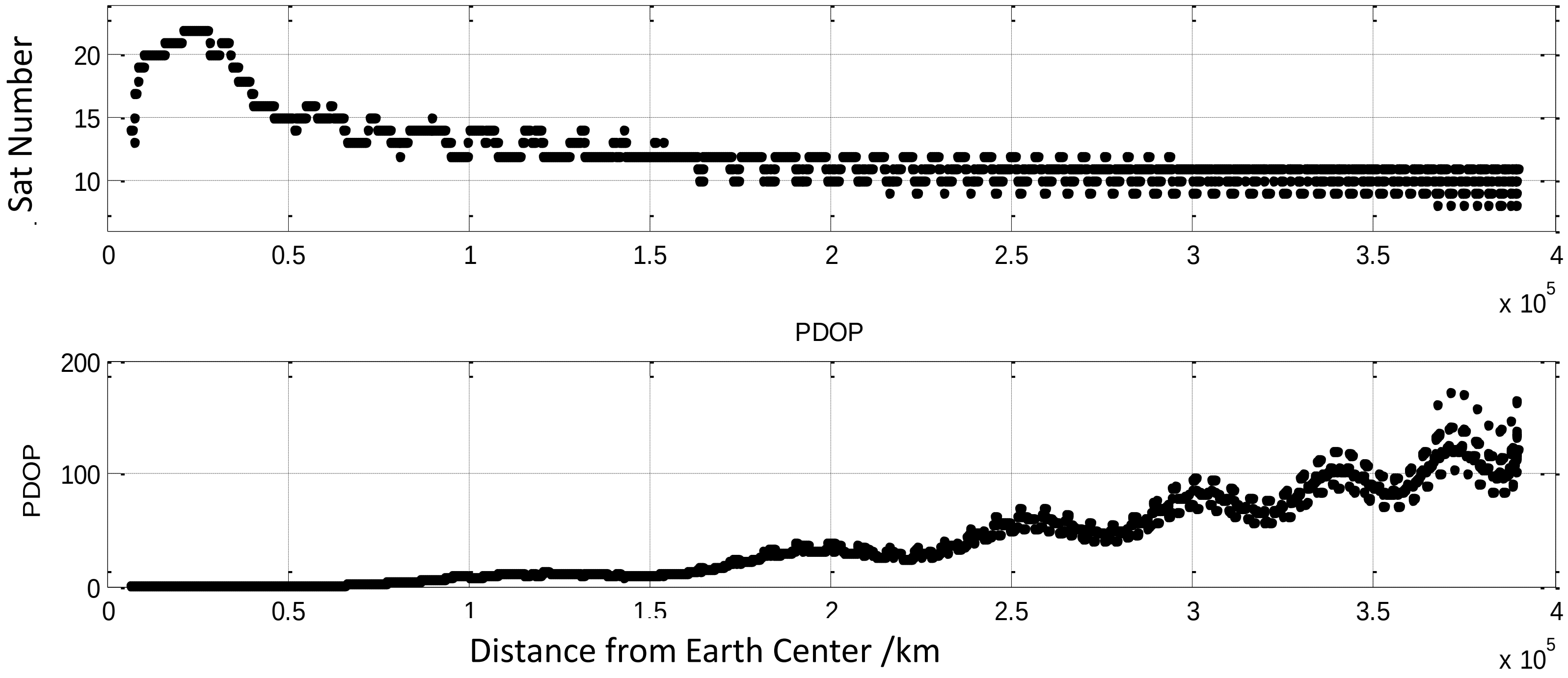
➢ **The elevation angle can be moved to ±60 degrees**



03 PDOP analysis of improved signals in Cislunar SSV

II. PDOP analysis of BDS with improved signal to earth-moon transfer orbit

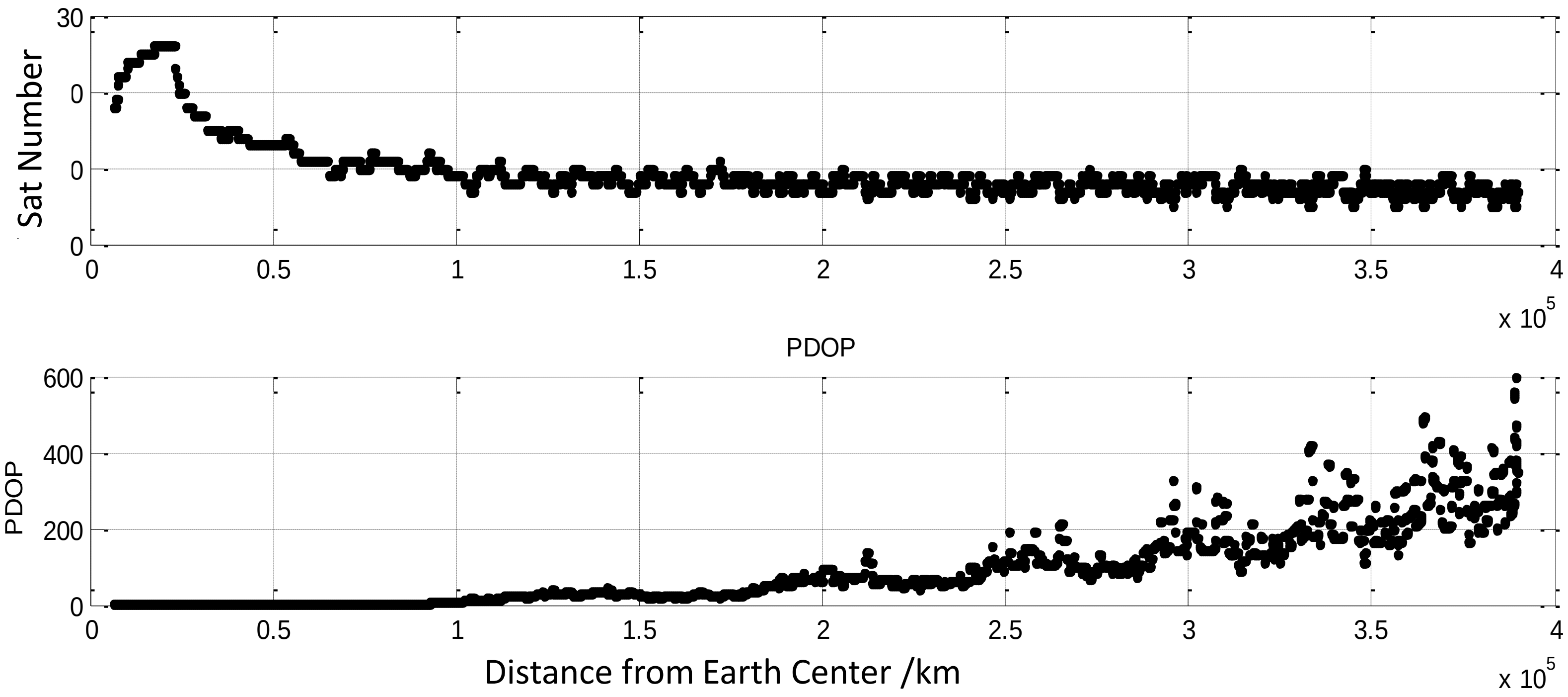
- **The elevation angle can be moved to ±80 degrees**



PDOP analysis of improved signals in Cislunar SSV

III. PDOP analysis of GPS with improved signal to earth-moon transfer orbit

- **The elevation angle can be moved to ±60 degrees**



PDOP analysis of improved signals in Cislunar SSV

III. PDOP analysis of GPS with improved signal to earth-moon transfer orbit

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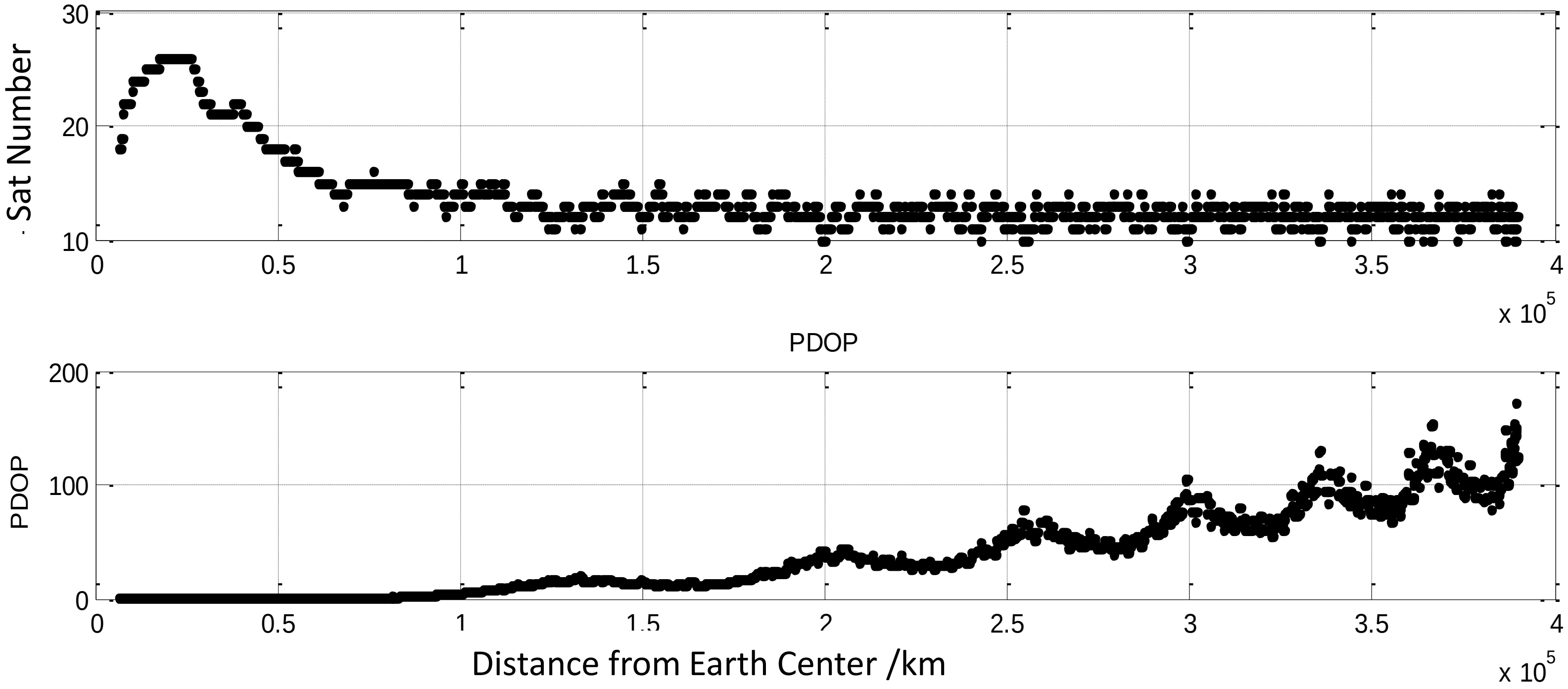
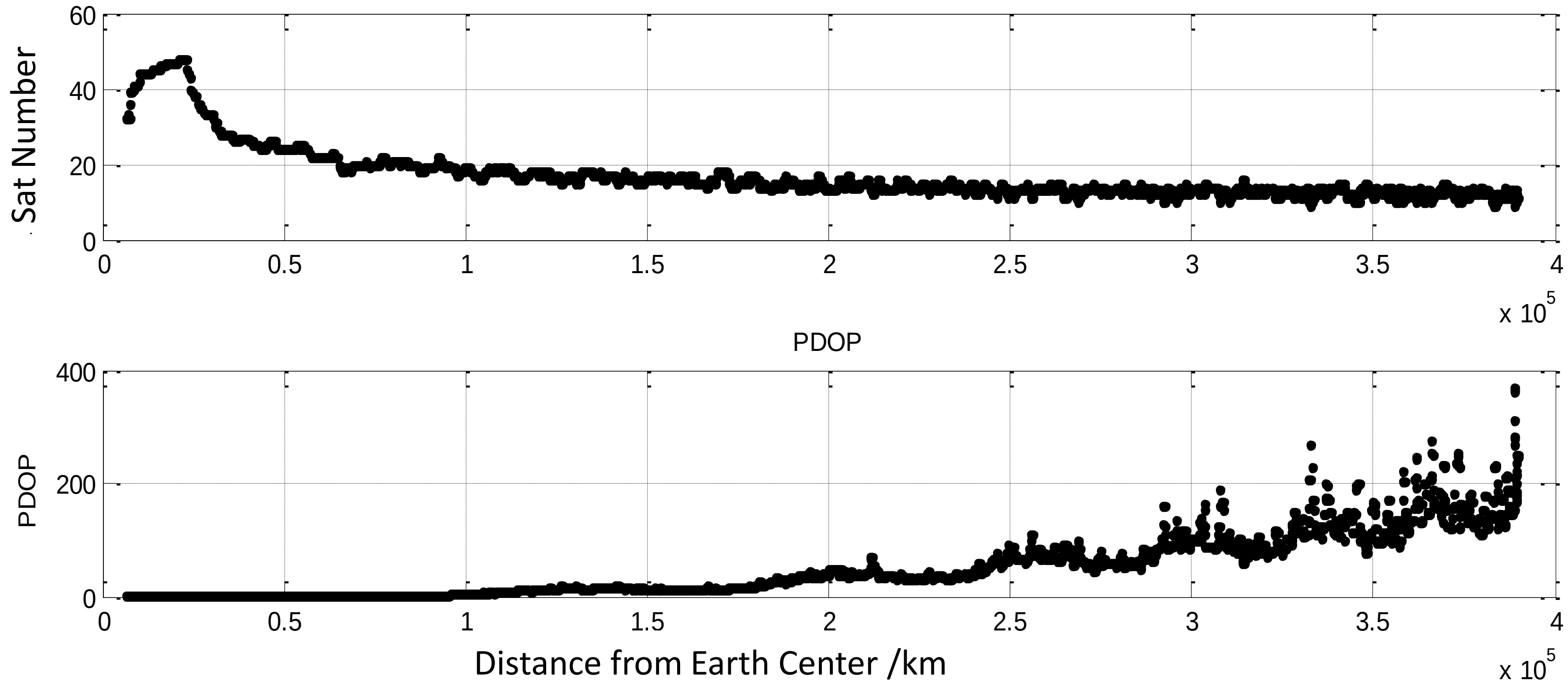


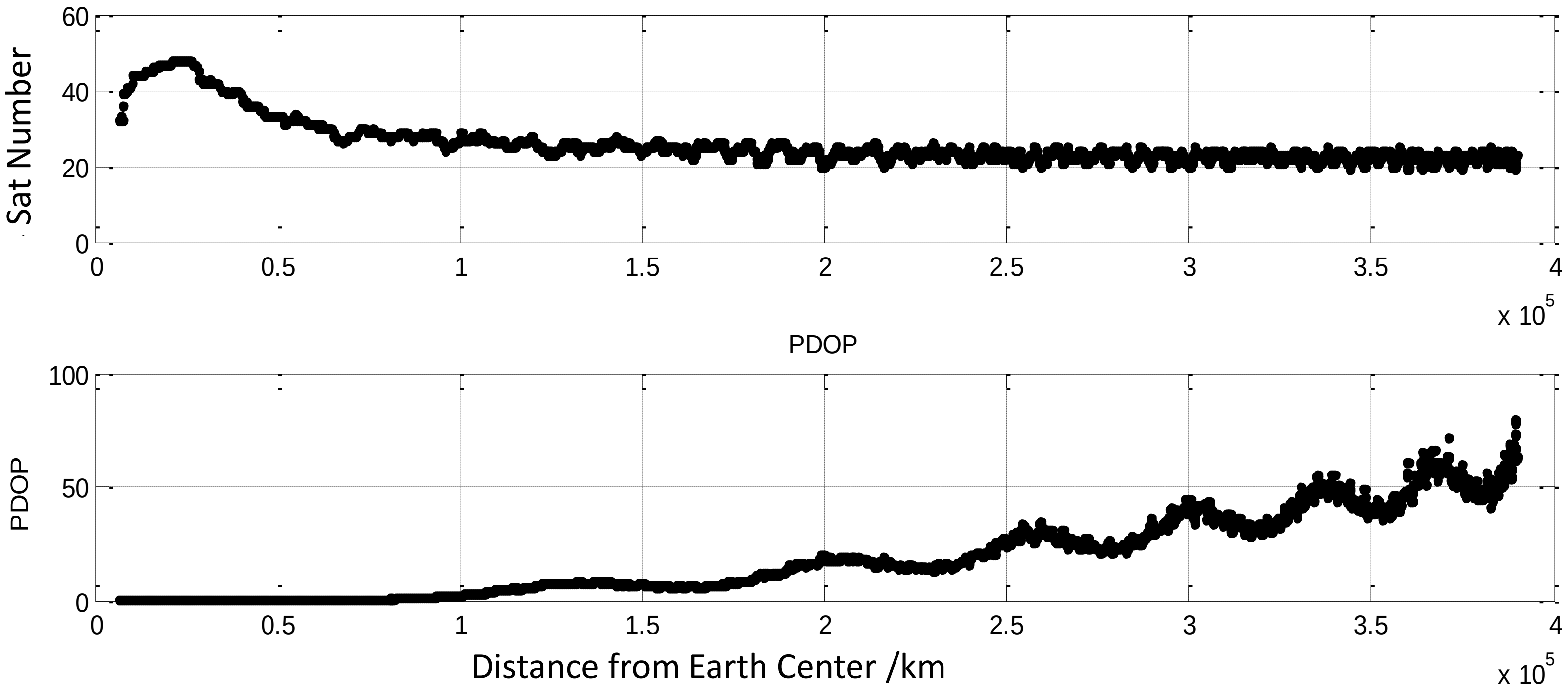
IV. PDOP analysis of BDS+GPS with improved signal to earth-moon transfer orbit

- ➢ **The elevation angle can be moved to ±60 degrees**



IV. PDOP analysis of BDS+GPS with improved signal to earth-moon transfer orbit

➢ **The elevation angle can be moved to ±80 degrees**



04

Conclusion

04 Conclusion

- **Enlarge the elevation angle of the enhanced signal can promote the GNSS availability in Cisluar SSV.** For single GNSS, the elevation angle reach ±80 degrees, the positioning accuracy of the Cislunar spacecraft near the moon can reach 0.15~0.17km (URE 1.0 meter).
- **Cooperative working mode can achieve better performance**, for the BDS+GPS, the positioning accuracy of the Cislunar spacecraft near the moon can reach within 100 meters.