# Generating Integrity Support Information Of The IGS Provided Precise Orbit, Clock And Bias Products

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## ◆ Motivation

In the field of Positioning Navigation and Timing (PNT) relating to human life safety, the continuity, integrity and availability of the positioning solutions are of crucial importance in addition to the accuracy. Within the IGS, the precise satellite orbit, clock as well as code/phase bias products have been provided by CODE, CNES, GFZ and WHU analysis centers. While those precise products can support the implementation of PPP-AR, the integrity monitoring at the user side cannot be guaranteed.

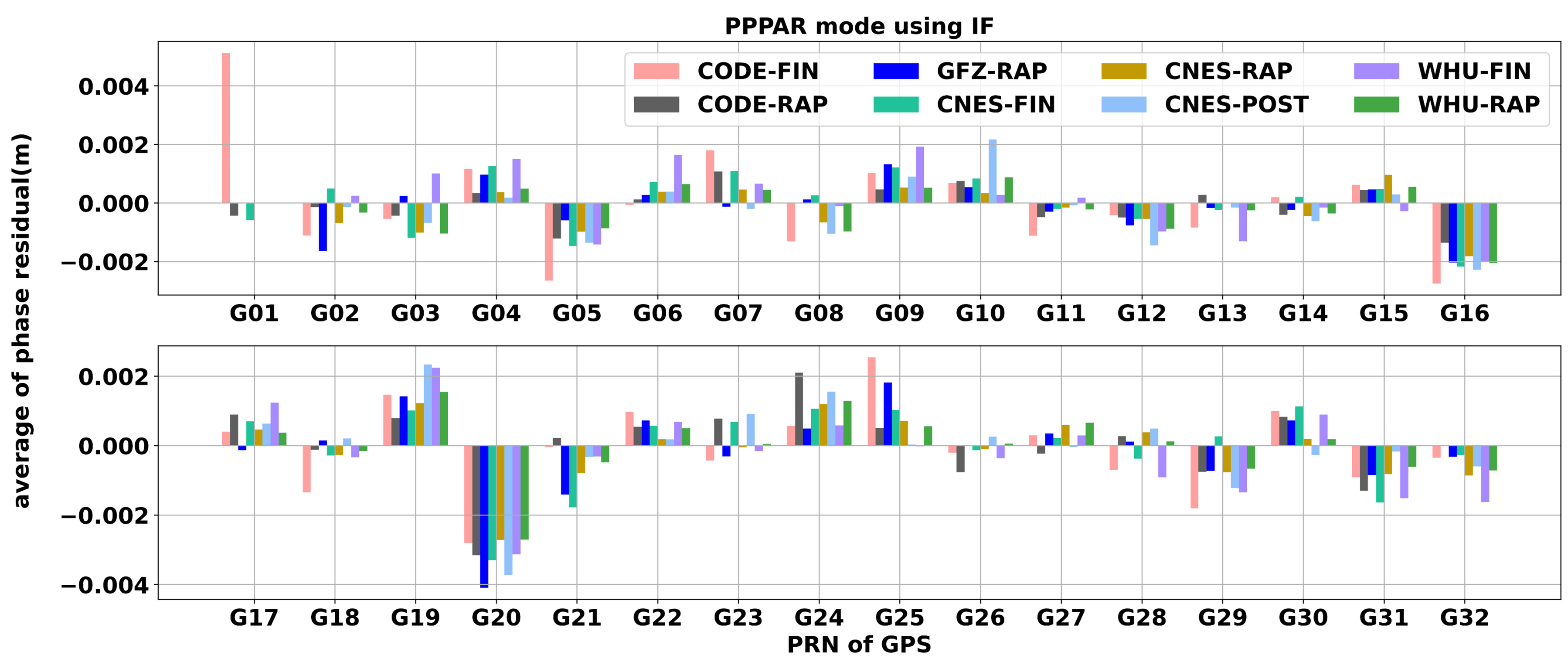
The method for GNSS signal-in-space (SIS) integrity monitoring can be mainly divided into two categories. The first one utilizes precise ephemeris as references and projects the satellite/clock errors onto the line-of-sight direction between satellite and stations to obtain the SIS User Range Error (SISURE). The second one, i.e., the method adopted within presented study, is to extract pseudo-range and/or carrier-phase observation residuals through the PPP-AR analysis. Note that the rapid/final precise orbit and clock products commonly exhibit notable time delay compared to those real-time products. As such, we emphasize the use of PPP-AR derived pseudo-range and carrier-phase residuals for the integrity monitoring of the IGS provided precise products, especially in the case of real-time applications.

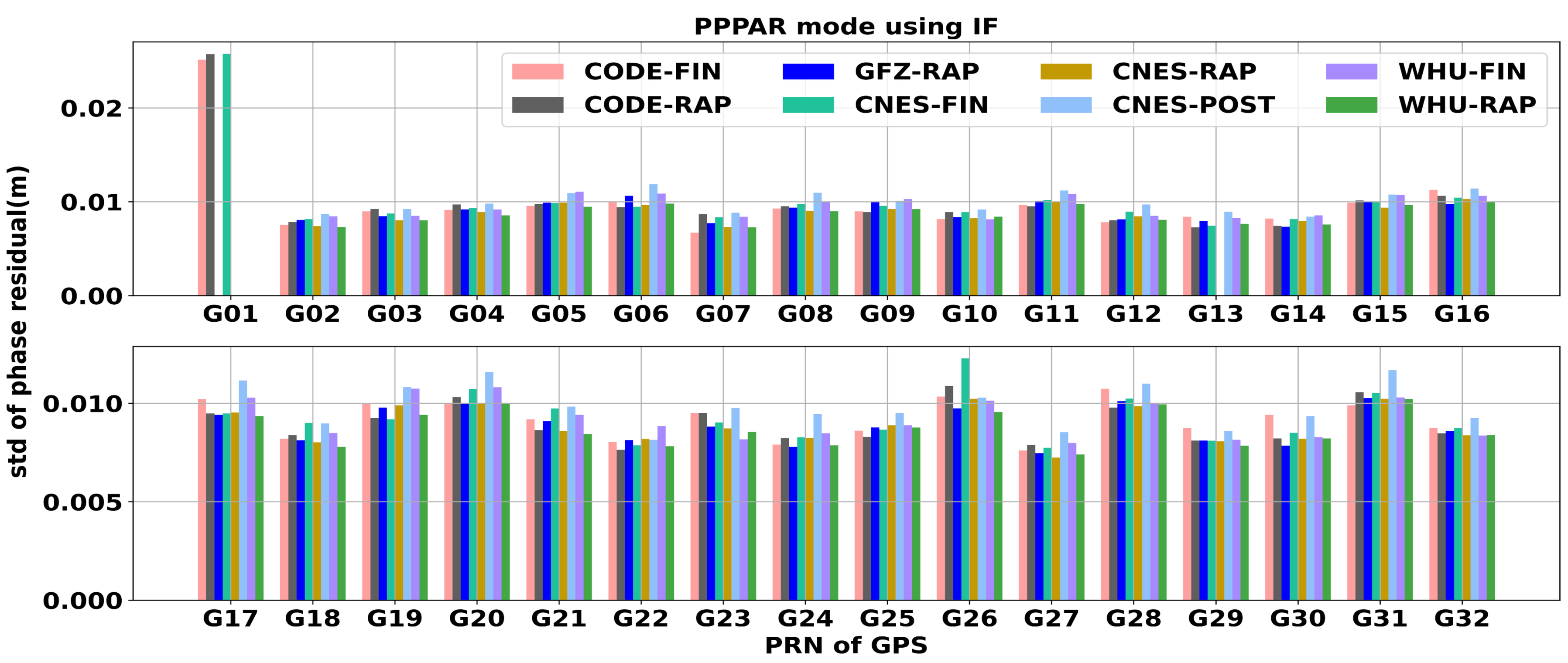
## ◆ ISM Computation

For the IGS provided precise orbit, clock and bias products, the associated integrity support information (ISM) can be calculated as follows:

**Ⅰ)** Generating pseudo-rang and carrier-phase residuals based on the ionosphere-free (IF) or Un-Combined (UC) PPP-AR analysis.

**Ⅱ)** Calculating Bias and standard deviation (STD) of the above observable residuals after performing the normal distribution fitting.




**Ⅲ)** Forming detection threshold based on the derived Bias and STD.

**Ⅳ)** Comparing observable residuals with the detection threshold. If the residual is larger than the detection threshold, it indicates integrity risk detected. The alarm index (AI) sets to 1, otherwise set to 0.

Clearly, the generated ISM mainly includes BIAS, STD as well as AI.

## ◆ Proposed ISM File Format

The proposed ISM file format consist of the file name, file header as well as file body.

**Ⅰ)** ISM File Name:

*AAA0MGXTTT_YYYYDDDHHMM_07D_07D_ISM.ISM*

*YYYY*: 4-digital year of start time
*DDD*: 3-digital day-of-year of start time
*HH*: 2-digital hour of start time
*MM*: 2-digital minute of start time

| *AAA* | *TTT* | *Descriptions* |
|---|---|---|
| *COD* | *FIN* | Derived ISM of CODE final product |
| *COD* | *RAP* | Derived ISM of CODE rapid product |
| *GRG* | *FIN* | Derived ISM of CNES final product |
| *GRG* | *RAP* | Derived ISM of CNES rapid product |
| *GRG* | *RTS* | Derived ISM of CNES real-time product |
| *GBM* | *RAP* | Derived ISM of GFZ rapid product |
| *WHU* | *FIN* | Derived ISM of WHU final product |
| *WHU* | *RAP* | Derived ISM of WHU rapid product |

**Ⅱ)** ISM File Header:

The file header consist of three parts: FILE/REFERENCE, FILE/COMMENT and ISM/DESCRIPTION.

**Ⅲ)** ISM File Body:

| *Parameters* | *Descriptions* |
|---|---|
| *PRN* | Satellite Pseudo-Random Noise |
| *OBS* | Observation type (Pseudo-range or Carrier-phase) |
| *COM* | Observation combination type (IF or UC) |
| *FRE1* | First frequency (GPS L1C; GAL E1; BDS B1I) |
| *FRE2* | Second frequency (GPS L2W; GAL E5a; BDS B3I) |
| *DATA_START* | Start epoch |
| *DATA_END* | End epoch |
| *BIAS* | ISM: BIAS |
| *UNIT* | Unit of Bias (Default: m) |
| *STD* | ISM: STD |
| *UNIT* | Unit of Std (Default: m) |
| *ALERM_INDEX* | ISM: AI |

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+ISM/SOLUTION
*PRN OBS__ COM FRE1 FRE2 DATA_START____ DATA_END______ BIAS__________________ UNIT STD__________________ UNIT ALARM_INDEX
 G01 CODE  IF  C1C  C2W  2024:001:00000 2023:007:86370 -2.630801475817479E-02 m     3.432167428973011E-03 m    0
 G01 CODE  UC  C1C       2024:001:00000 2023:007:86370 -2.826453110732762E-02 m     9.471271028201512E-03 m    0
 G01 CODE  UC       C2W  2024:001:00000 2023:007:86370  3.552648706524948E-02 m     9.751815931723794E-03 m    0
 G01 PHASE IF  L1C  L2W  2024:001:00000 2023:007:86370  2.559537538911441E-02 m    -9.570484315730582E-02 m    0
 G01 PHASE UC  L1C       2024:001:00000 2023:007:86370  3.204148987837763E-02 m     5.930239527511572E-02 m    0
 G01 PHASE UC       L2W  2024:001:00000 2023:007:86370  4.203668679488456E-02 m    -6.431570077000232E-02 m    0
 ...
 E01 CODE  IF  C1C  C5Q  2024:001:00000 2023:007:86370  2.471072713597058E-02 m     4.838447737340022E-03 m    0
 E01 CODE  UC  C1C       2024:001:00000 2023:007:86370 -3.637223465358441E-02 m    -7.808071748214529E-03 m    0
 E01 CODE  UC       C5Q  2024:001:00000 2023:007:86370 -3.160009796417366E-02 m     6.004983594792250E-03 m    0
 E01 PHASE IF  L1C  L5Q  2024:001:00000 2023:007:86370 -1.027212351822387E-02 m    -8.731948587478196E-02 m    0
 E01 PHASE UC  L1C       2024:001:00000 2023:007:86370 -4.065178285339088E-02 m    -3.609524953312974E-02 m    0
 E01 PHASE UC       L5Q  2024:001:00000 2023:007:86370 -4.124476157652524E-02 m    -6.752724259867302E-02 m    0
 ...
 C19 CODE  IF  C2I  C6I  2024:001:00000 2023:007:86370 -3.078579802324457E-02 m     9.788376873613776E-04 m    0
 C19 CODE  UC  C2I       2024:001:00000 2023:007:86370  8.776432792696368E-03 m    -2.076814588637604E-03 m    0
 C19 CODE  UC       C6I  2024:001:00000 2023:007:86370  4.448691461584151E-03 m     2.714102796828851E-03 m    0
 C19 PHASE IF  L2I  L6I  2024:001:00000 2023:007:86370 -2.016407475493755E-02 m     5.018334423498425E-02 m    0
 C19 PHASE UC  L2I       2024:001:00000 2023:007:86370  4.755705479532833E-02 m     8.611992976184937E-02 m    0
 C19 PHASE UC       L6I  2024:001:00000 2023:007:86370  1.432822174144699E-03 m     7.075498509125727E-02 m    0
 ...
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## ◆ Summary and Outlook

After ISM products are generated from different IGS ACs, users can utilize ISM together with associated precise products to achieve high-precision and high-integrity PPP-AR. BIAS and STD are used to optimize the stomatic model, while AI can be employed as a marker to exclude abnormal satellites.

The proposed ISM format would directly benefit those ground and space users leveraging on the IGS post-processing precise products, which can also be used for the GNSS real-time positioning applications after adapting it to the IGS-SSR format.