Fast PPP convergence using multi-constellations and triple-frequency ambiguity resolution

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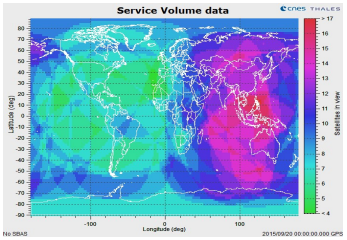
Introduction

PPP is a relatively new but powerful technique for positioning. The main difference between PPP and standard positioning is the use of the carrier-phase measurements, whose noise is lower by two orders of magnitude than the code measurements. It is now widely accepted that PPP techniques can achieve centimeter accuracy globally in real-time, in particular when they are combined with phase integer ambiguity resolution. However, one important drawback of the PPP is the convergence time. Dual-frequency PPP convergence is long, tens of minutes, which makes it impracticable for many applications.

However, with the development of the modernized GPS, Galileo and the Beidou constellations, a third frequency is now available on a growing number of satellites. For example, for a user located in the Asia-Pacific region, there can be nowadays more than 15 triple-frequency satellites in view.

In this poster, we explore the different measurements combination possibilities offered by the new triple-frequency signals, namely with the availability of "widelanes-only" intermediate combinations. By performing a noise analysis based on actual measurements, we show that the different characteristics of the combinations are compatible with a very fast ambiguity resolution, on all the constellations.



Number of triple-frequency satellites in view for a given location (september 2015)

Noise and combination analysis

Choice of frequencies

Frequency	GPS	Galileo	Beidou
A	G1	E1	B1
B	G2	E5a	B3
C	G5	E5b	B2

Wavelengths of interesting combinations

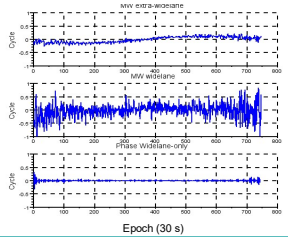
Combination	GPS WaveLength (m)	Galileo WaveLength (m)	Beidou WaveLength (m)
MW Extra-widelane (B, C)	5.86	9.76	4.88
MW Widelane (A,B)	0.86	0.75	1.02
MW Widelane (A,C)	0.75	0.71	0.85
Widelane only[1]	3.40	3.21	4.52
Widelane only Iono[2]	1.98	1.84	2.84

1) Combination of phase widelanes that eliminates the ionosphere component, assuming the extra-widelane is fixed
2) Combination of phase widelanes that eliminates the geometry component, assuming the extra-widelane is fixed

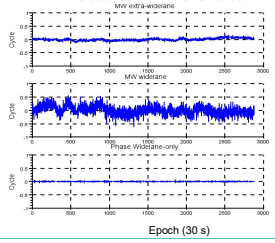
Noise amplification factors (widelane-only combination)

Frequency	GPS	Galileo	Beidou
A	3.4	3.2	4.5
B	-20.7	28.8	-21.2
C	17.3	-32	16.7

GPS combinations noise



Beidou combinations noise

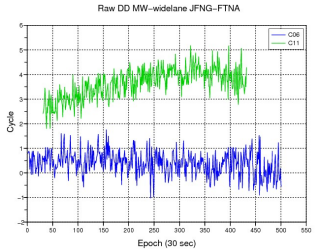


Conclusion

- The noise of GPS and Beidou measurements is compatible with ambiguity resolution on all frequencies
- Widelane-only phase combination is promising for triple-frequency-AR:
- Involves only differences of phase measurements
- Large wavelengths, fast convergence
- No dependency on wind-up effect

Beidou code anomaly

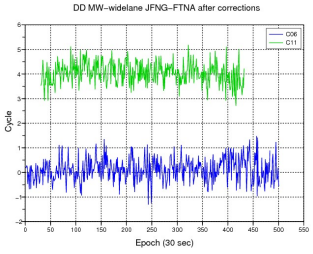
Raw Beidou MW-Widelane (Double-differences)



Possible explanation

- Wanninger 2014: Elevation-dependent code variations
- Amplitude ~1 meter
- Nature of this bias not fully understood yet
- Can be mitigated using predefined corrections
- Corrections tables are given for IGSO and MEO

Corrected Beidou MW-Widelane (Double-differences)



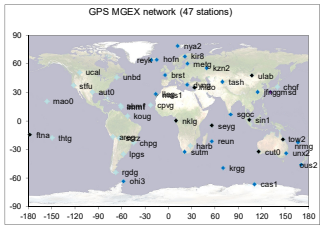
Conclusion

- The proposed calibration works for the MW-Widelane combination
- Integer property of phase ambiguity is conserved
- Geo corrections are tricky to evaluate
  - Constant elevation angles
- For the moment, no RTCM message to account for theses biases

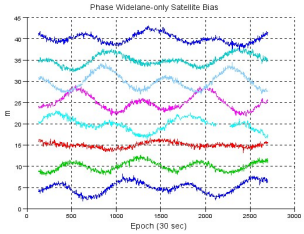
Satellite biases estimation (widelane-only combination)

These biases are defined as the phase widelane-only combination of individual phase biases as defined in the RTCM phase bias message

GPS network

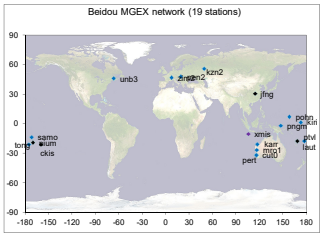


GPS biases



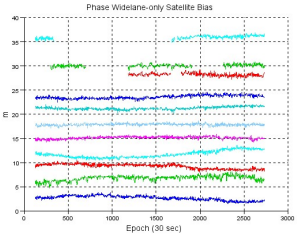
- Continuous estimation with 47 stations and 8 satellites
- The relatively high noise is consistent with the noise amplification factor of the combination

Beidou network



- Small number of triple-frequency Beidou MGEX stations
- Upgrade of the CNES/Regina network for triple-frequency compatibility

Beidou biases



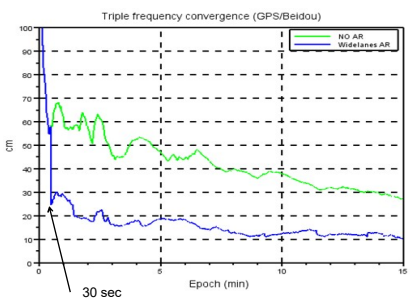
- Continuous estimation with 19 stations and 8 satellites (GEO and IGSO)
- Discontinuity for 3 MEOs outside Asia region

User-side results

Methodology

- Network side: Computation of SSR representation for phase biases
  - RTCM format
  - Post-processed
- User-side: use of the PPP-Wizard client
  - Real-time conditions in replay mode

User convergence time (JFNG, average over 10 runs)



Conclusions

- Partial ambiguity fixing with triple-frequency measurements is already possible over Asia
- Widelane-only phase measurements is a good candidate for fast convergence in the triple-frequency context
- For Beidou, an elevation-dependent code variation must be taken into account
- Satellite biases computation for the widelane-only combination is possible using the current MGEX network, for both GPS and Beidou
- At the user-level, quasi-instantaneous ambiguity resolution is achieved, leading to a very fast convergence at the decimeter level
- The proposed RTCM message for phase biases is compatible with this approach

References

Formulation

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