Codephase center corrections for multi GNSS signals and the impact of misoriented antennas

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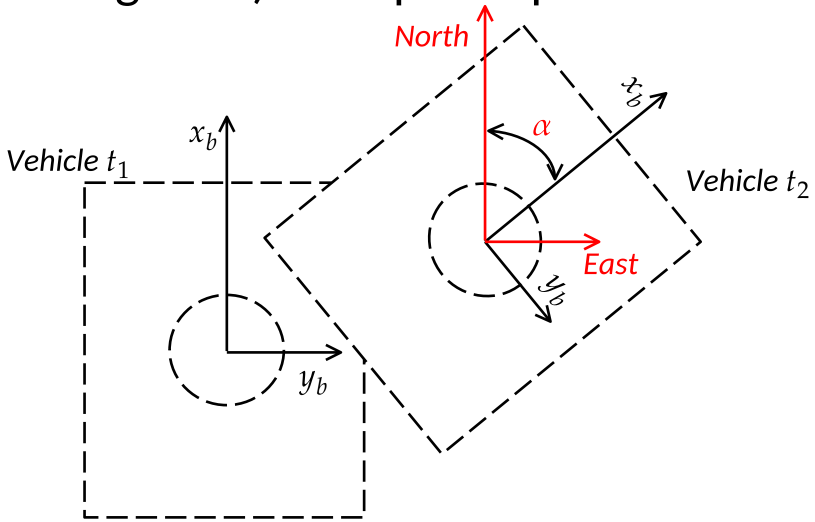
Motivation

- Consideration of phase center corrections (PCC) necessary for high precision GNSS applications
- Besides PCC for phase, also corrections for code exist, so called **codephase center correction (CPC)**
  - Antenna dependent delays of the received code
  - Varies with azimuth and elevation angles
  - Divided into a codephase center offset (PCO) and codephase center variations (CPV)
- Applying CPC in kinematic code applications (vehicle or aircraft navigation) to improve precision and accuracy
  - Issue: - Continuous change of antenna orientation
    - CPC only valid if antenna is orientated towards north
  - Idea: Rotated CPC pattern with angle α can compensate the impact of a misoriented antenna



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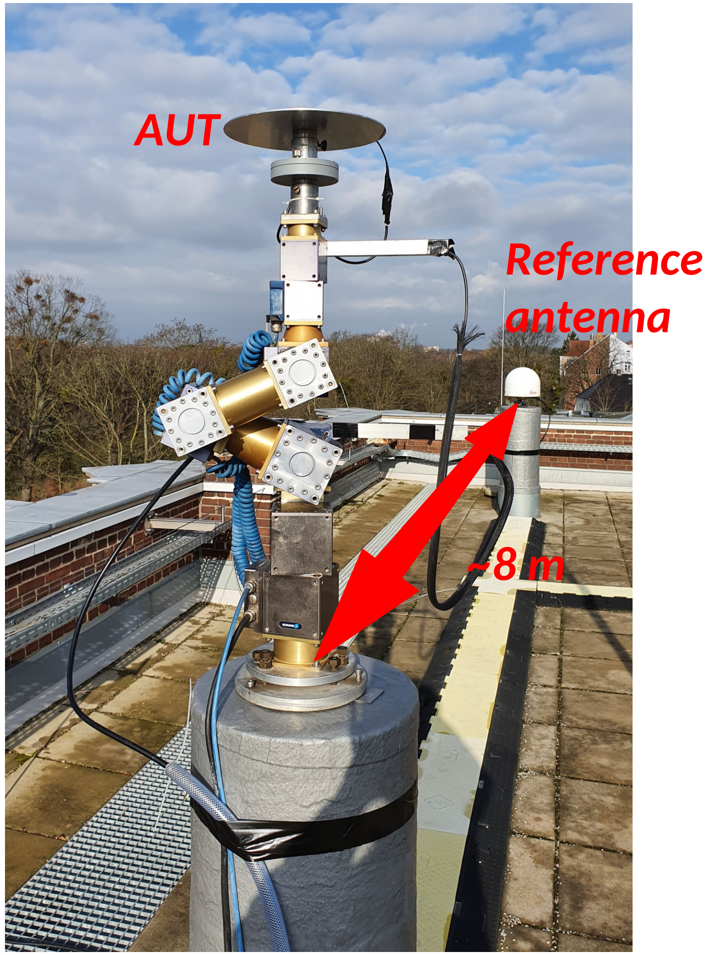
Method and estimation process

- Robot precisely rotates and tilts antenna under test (AUT) at a specific point in space
- Calculation of time differenced single differences (ΔSD)
  in a short baseline common-clock set up
  (use of external frequency standard)

  --> cancel out most of the effects, except CPC from AUT and unmodelled effects/noise
- Spherical harmonics (8,8) estimation of CPC based on *ΔSD*

$$CPC(\alpha^k, z^k) = \sum_{m=1}^{m_{max}} \sum_{n=0}^{m} \tilde{P}_{mn}(cos(z^k))(a_{mn}cos(n\alpha^k) + b_{mn}sin(n\alpha^k))$$

- Calculation of CPC grid with estimated parameters a_{mn}, b_{mn}
- Estimation of PCO from grid. Residuals indicate the CPV



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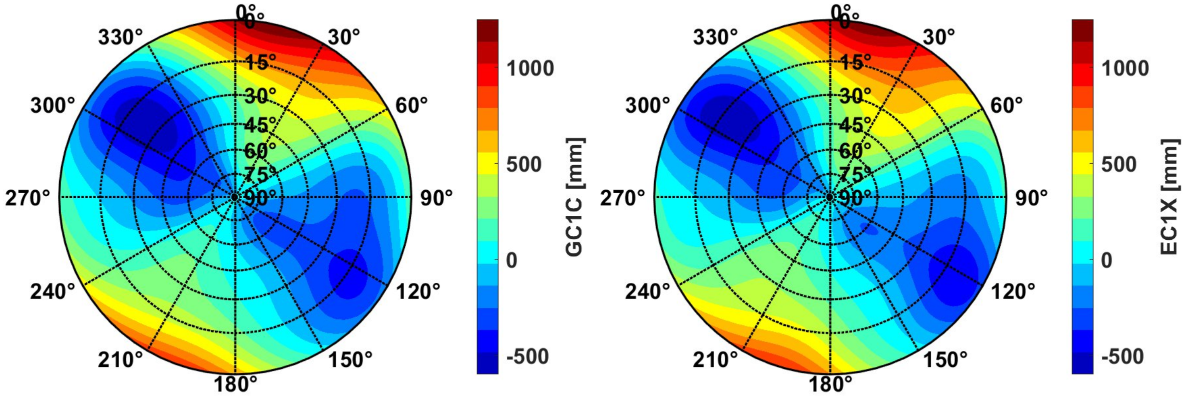
Calibration results - Ublox patch antenna

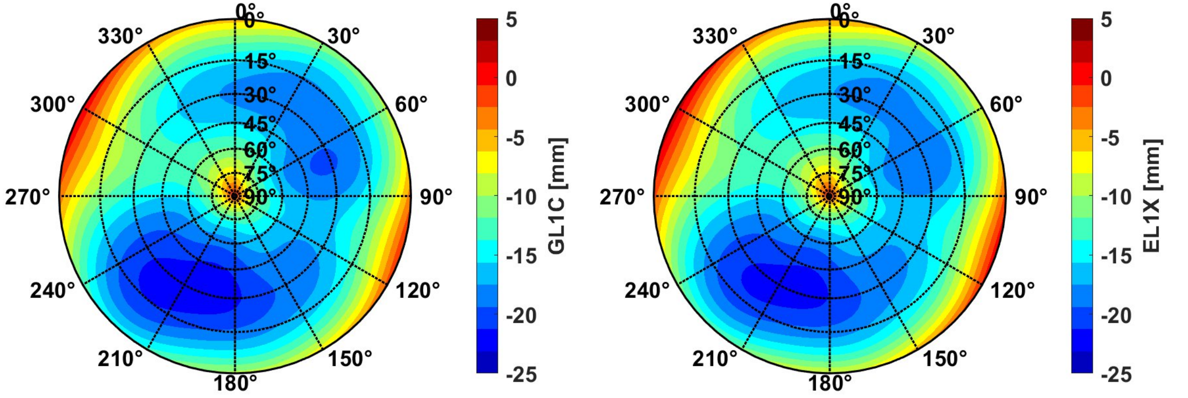
- 6 calibrations (July 2019)
- CPC between -50 cm and 120 cm
- PCC between -25 mm and 5 mm
- CPC/PCC show similar behaviour for same frequency of different satellite system
- Repeatability presented as RMS of difference pattern from two calibrations
- *ø RMS* is average RMS of all combined calibrations
- Repeatability for phase pattern is better by factor 100 than for code pattern

Signal	GC1C	EC1C	GL1C	EL1C
ø RMS [mm]	79.21	143.97	0.84	1.07

Estimated mean pattern



Codephase center correction for GPS C1 and Galileo C1



Phase center correction for GPS L1 and Galileo L1

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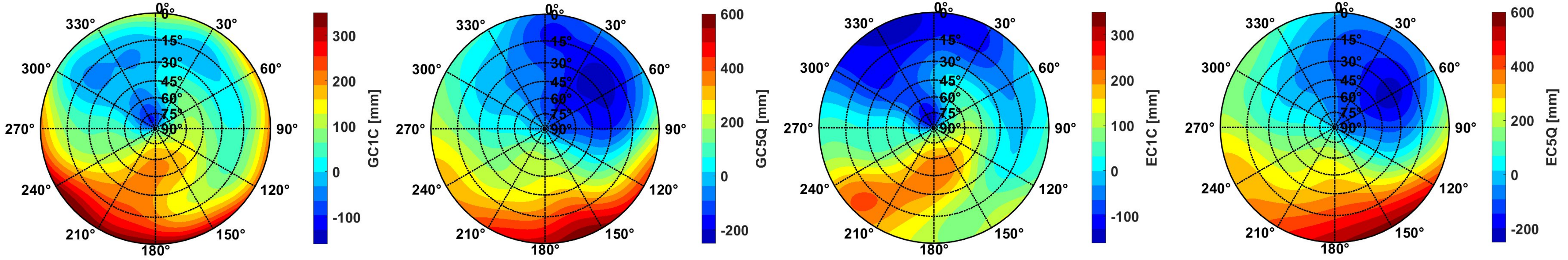
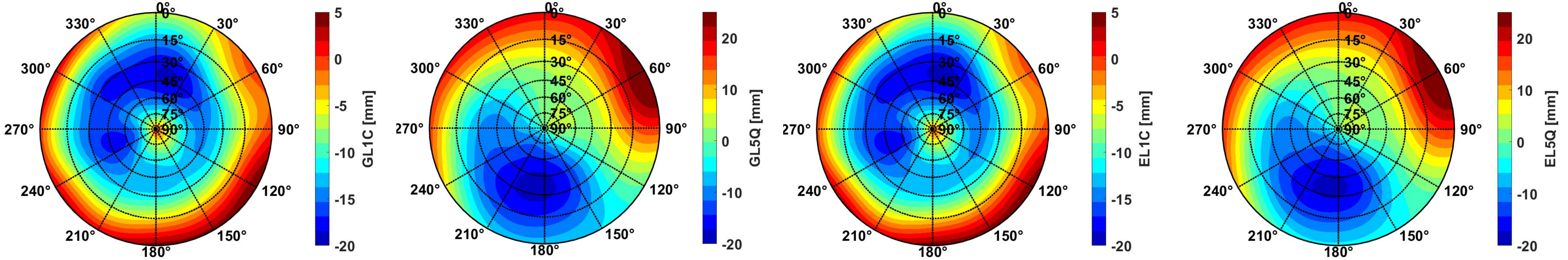
Calibration results - Tallysman patch antenna

Estimated mean pattern



Codephase center correction for GPS C1/C5 and Galileo C1/C5



Phase center correction for GPS L1/L5 and Galileo L1/L5

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Calibration results - Tallysman patch antenna

- 3 calibrations in March 2020
- CPC for GPS and Galileo

  C1: -15 cm to 35 cm

  C5: -20 cm to 60 cm
- PCC for GPS and Galileo

  L1: -20 mm to 5 mm

  L5: -20 mm to 20 mm

Signal *[Code]*	***ø RMS [mm]***	**Signal *[Phase]***	***ø RMS [mm]***
GC1C	56.05	GL1C	0.563
GC5Q	66.35	GL5Q	0.699
EC1C	33.63	EL1C	0.695
EC5Q	57.27	EL5Q	0.702

- Better repeatability than for ublox patch antenna (especially EC1C)
- Factor 100 between phase and code repeatability detectable

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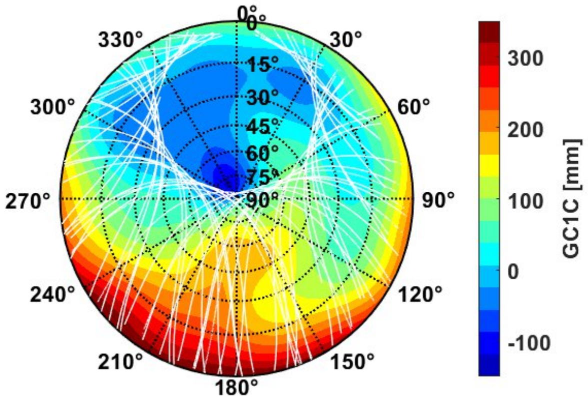
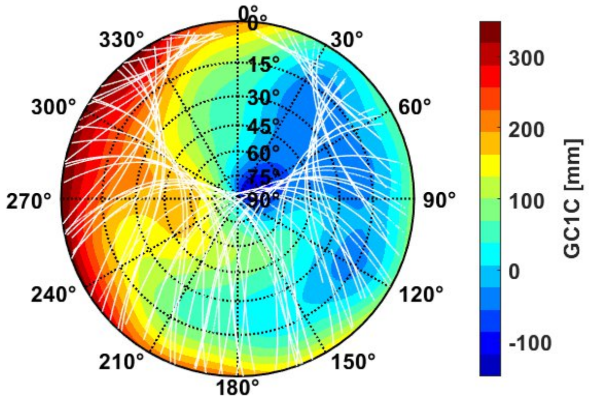
Impact of a CPC pattern (SPP - GPS C1)

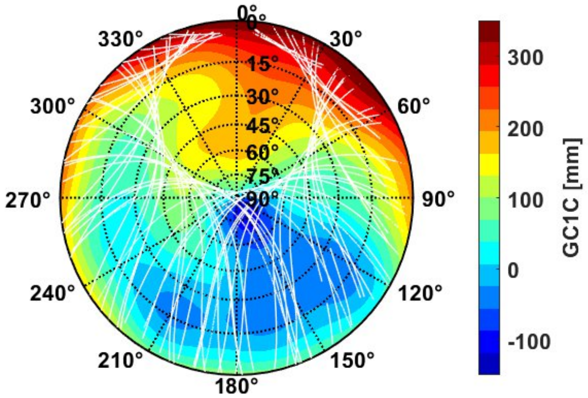
Rotated CPC with satellite visibility (white)



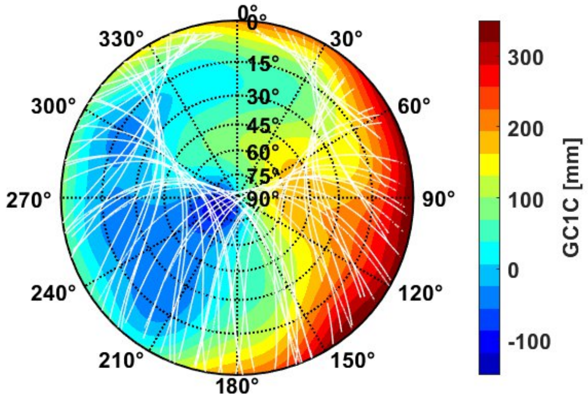
0 deg



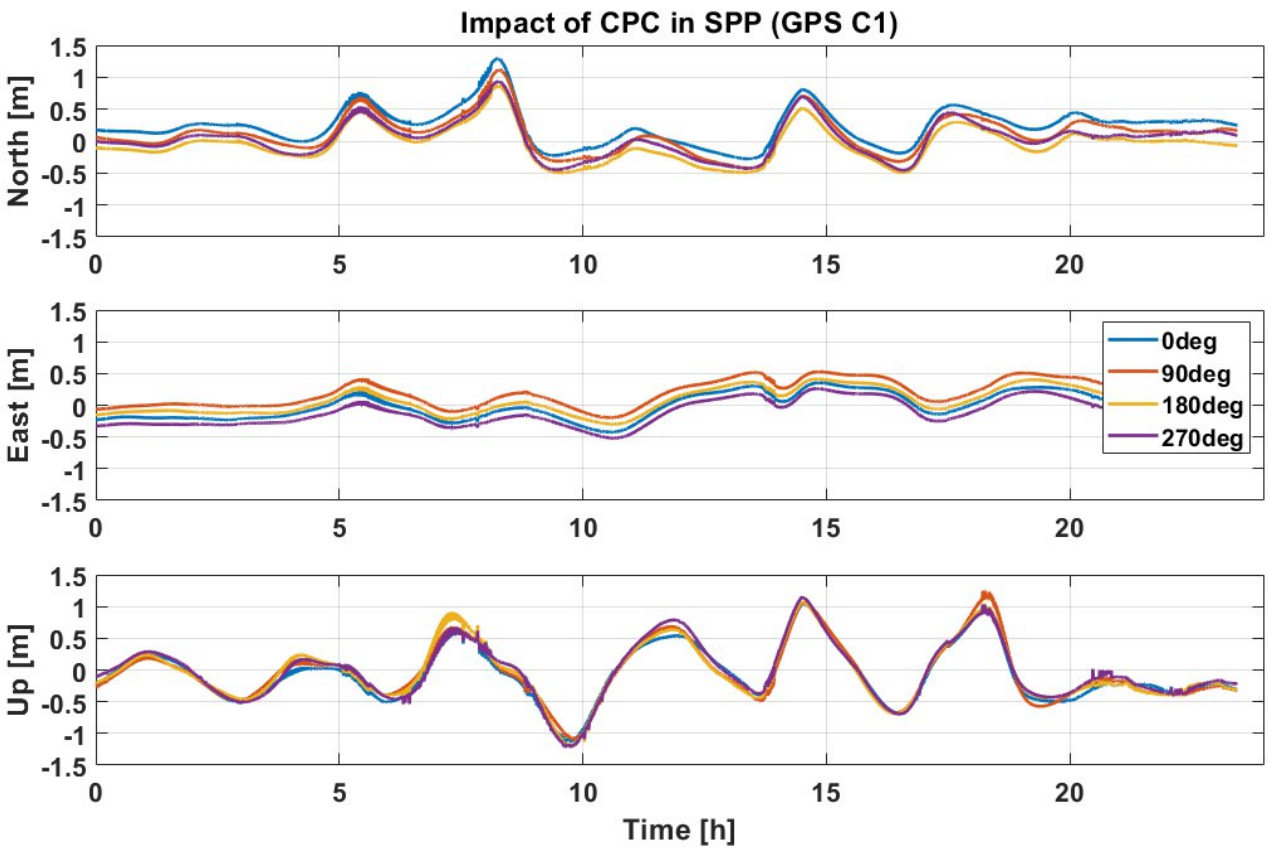
90 deg



180 deg



270 deg



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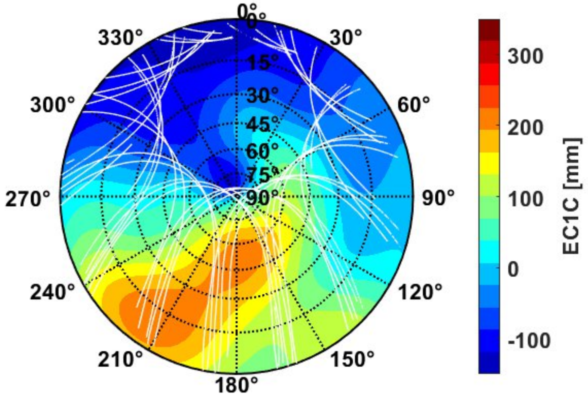
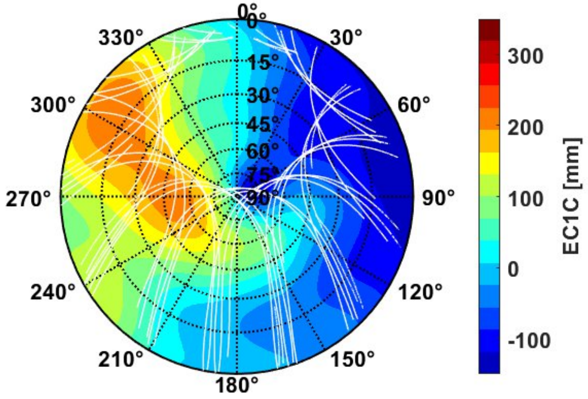
Impact of a CPC pattern (SPP - Galileo C1)

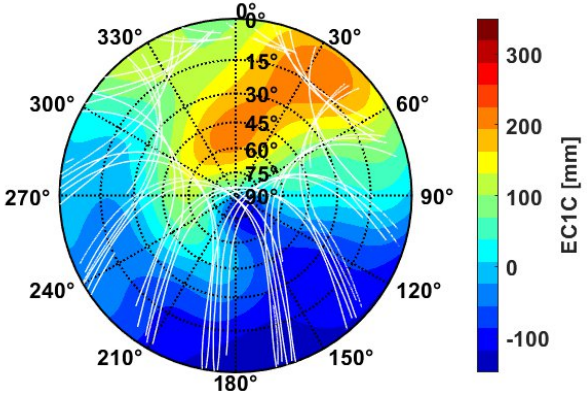
Rotated CPC with satellite visibility (white)



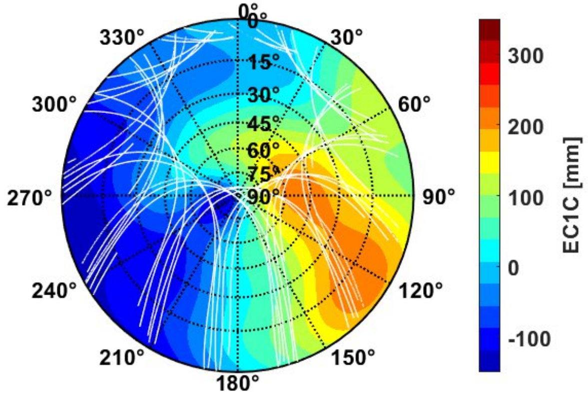
0 deg



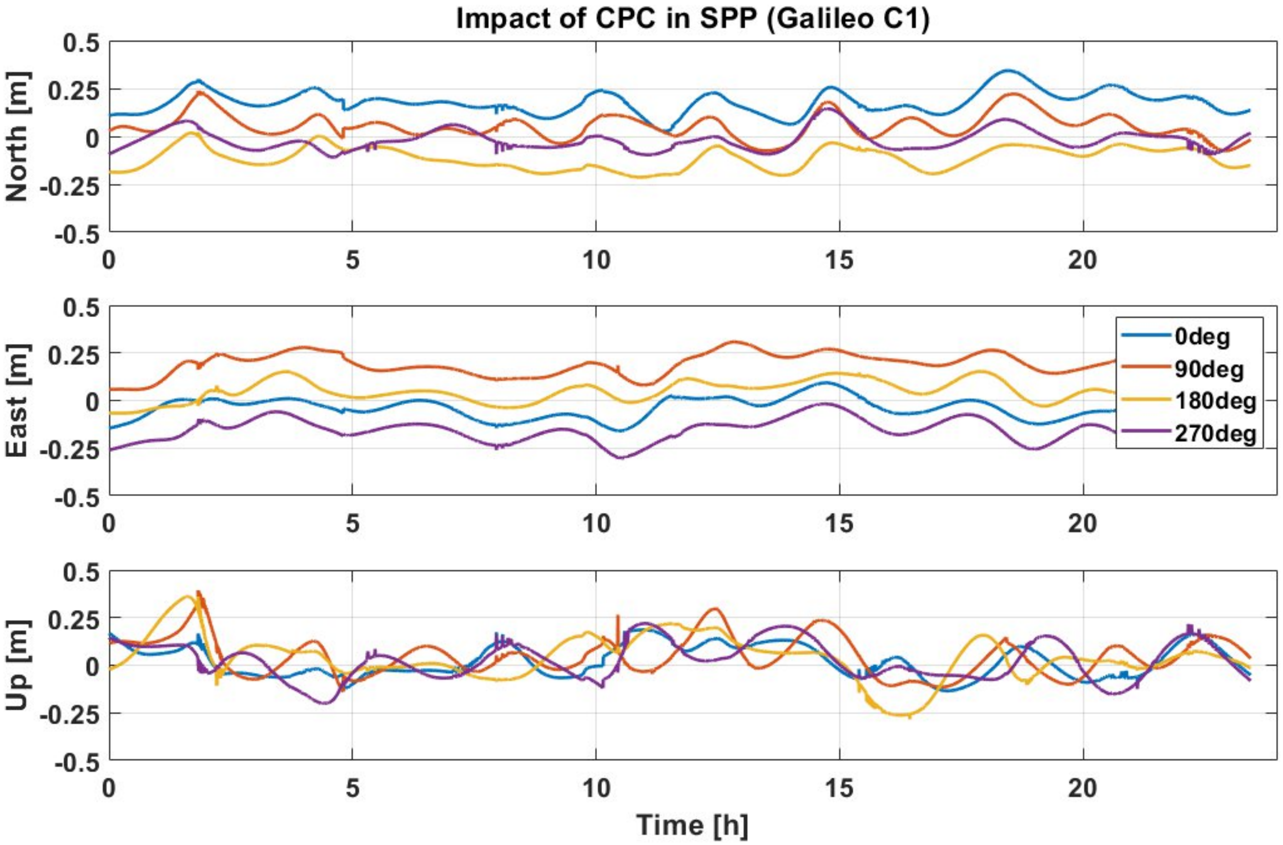
90 deg



180 deg



270 deg



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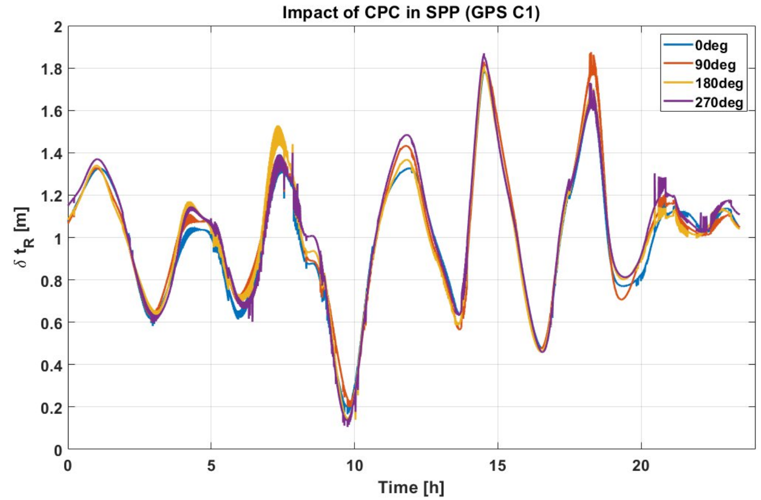
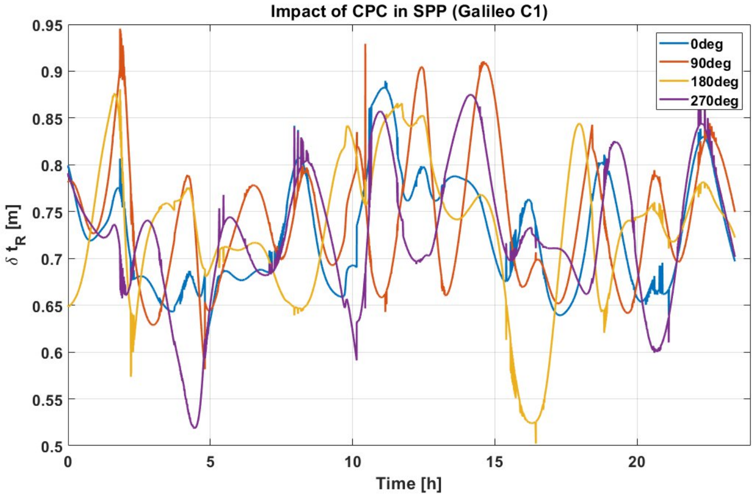
Impact of a CPC pattern (Receiver clock error)

- SPP solution was calculated
  - Without applying CPC
  - With applying rotated CPC pattern from Tallysman patch antenna
- Plots show differences of SPP solutions with respective pattern and no pattern
- A CPC pattern in a range of -20 cm to 40 cm leads to more than 1 meter position deviation and estimated receiver clock deviation
- Rotated CPC pattern change the impact
  - Mainly offset in North and East component
  - Different behaviour in Up component
  - Receiver clock error highly correlated with Up component
  - Depends on symmetry of CPC pattern and on satellite constellation





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Conclusion

- Estimated pattern for the two patch antenna are
  - Decimeter to meter range for CPC
  - Centimeter range for PCC
- Repeatability for phase pattern is about factor 100 better than for code pattern
- CPC pattern in decimeter range leads to more than 1 meter in positioning deviation
- Rotated pattern change the impact on estimated coordinates and clock
  - depends on pattern symmetry and satellite constellation
- In kinematic applications, with continuous change of the antenna orientation, it is important to rotate the CPC in the right direction to avoid faulty coordinate solution

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