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Ambiguity Resolution with Multiband-Singleband Delay Differences

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VieVS Days 2026

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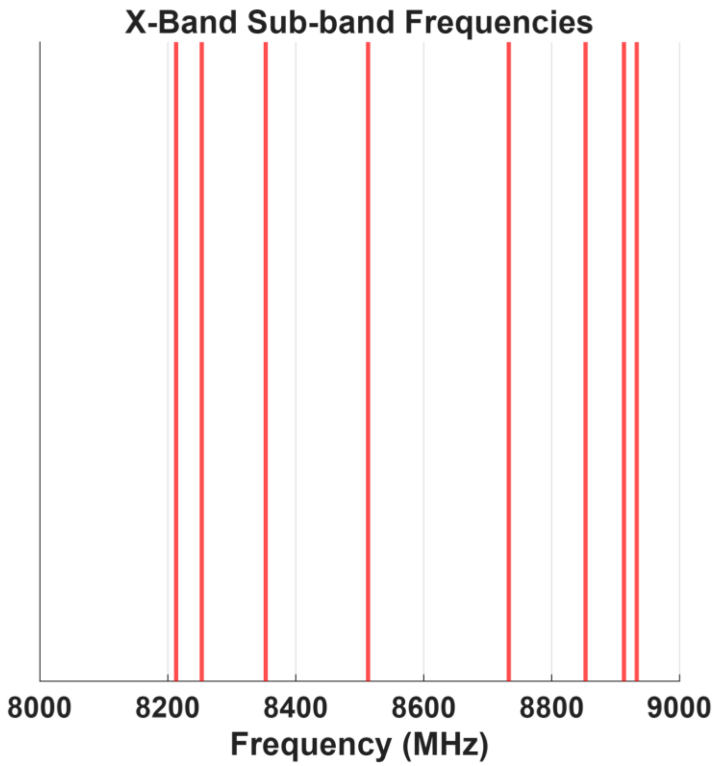
Session Processing

- Scheduling
- Observation
- Correlation
- Ambiguity Resolution
- Ionospheric Calibration
- VLBI Data Analysis

Preprocessing in VieVS

Singleband Delays (without Ambiguities)

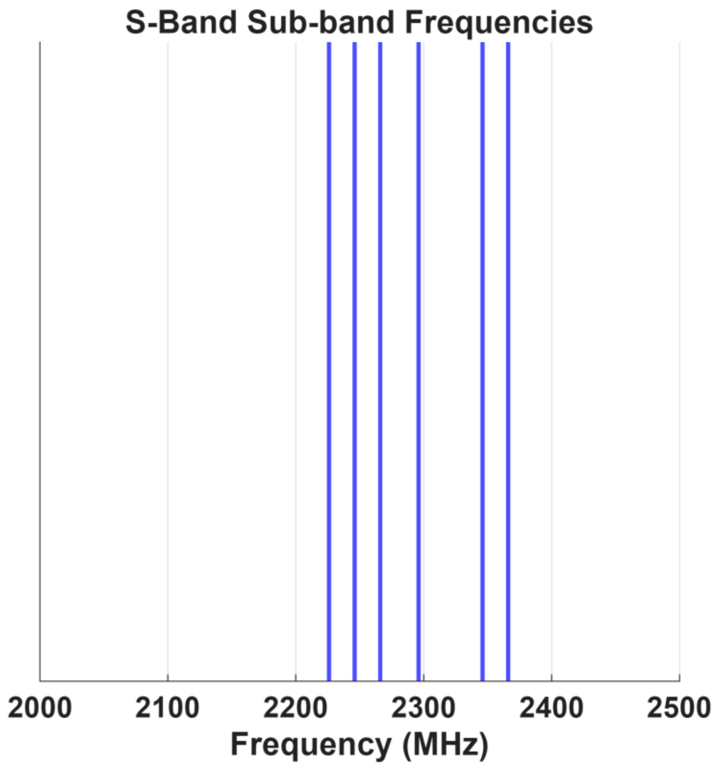
- Group delay is determined for each individual channel
- Final group delay is obtained by averaging the individual delays
- No ambiguities occur



Multiband Delays (included Ambiguities)

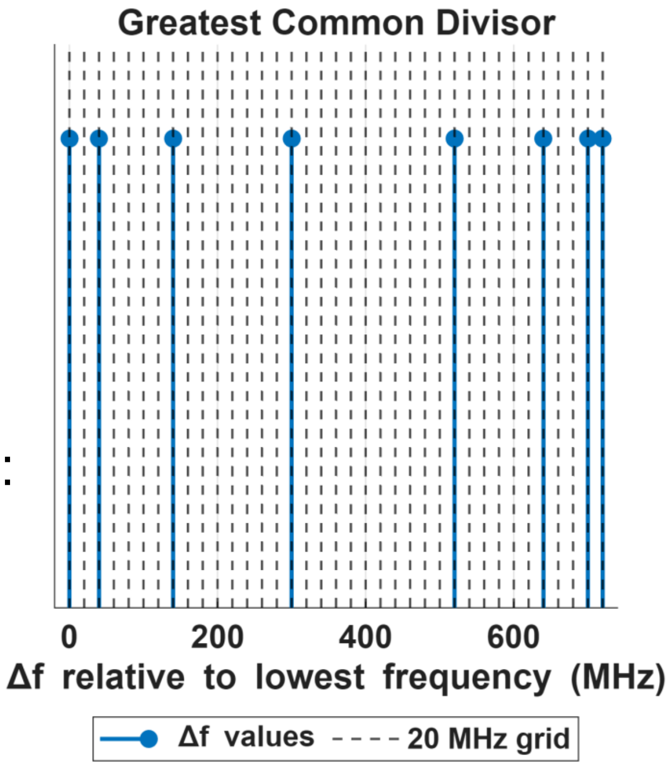
- Entire bandwidth is used to determine the group delay

- However, since the spectrum is only sparsely occupied by channels at certain frequencies, ambiguities occur



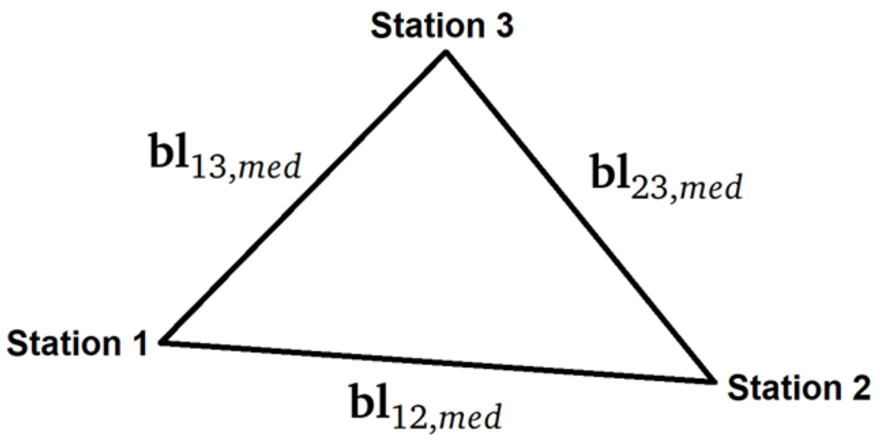
Ambiguity Spacing Example: X-band

- 8 sub-bands, ~720 MHz bandwidth
  - Given sub-band frequencies (MHz):
    8212.99, 8252.99, 8352.99, 8512.99,
    8732.99, 8852.99, 8912.99, 8932.99
  - Frequency differences (relative to the lowest frequency):
    40, 140, 300, 520, 640, 700, 720 MHz
    → Greatest common divisor (GCD): 20 MHz
  - Ambiguity spacing = inverse of GCD:
    1 / GCD = 1 / (20 MHz) = 50 ns



Ambiguity Resolution with Triangle Closures

- Ambiguities arise in multiband delay observations in the X/S-band
- Use triangle delay closures to resolve them
- Based on difference between:
  - Multiband delays (with ambiguities)
  - Singleband delays (without ambiguities)
- The calculated closure should be within the limit of half the ambiguity spacing



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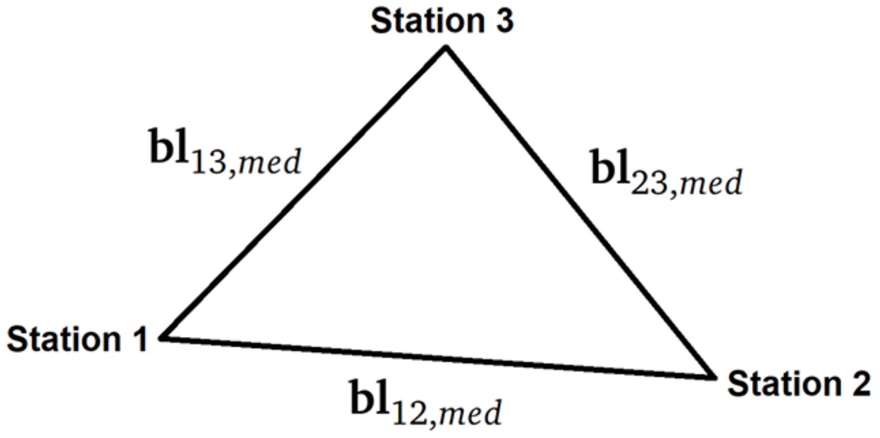
Ambiguity Triangle Solution: Example

- Closure = 55 ns
- Ambiguity spacing = 50 ns
- → Apply 50 ns to one baseline

$$\tau_{close} = (\mathbf{bl}_{12,med} + \mathbf{bl}_{23,med} - \mathbf{bl}_{13,med}) \cdot s_i$$



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References

- The presentation is mainly based on a presentation given by Peter Urban at the IVS GM2026: Urban, P., Krasna, H., & Nothnagel, A. (2026, April 28). Ambiguity Resolution with Multiband-Singleband Delay Differences. Zenodo. https://doi.org/10.5281/zenodo.19852331

- Nothnagel, A. (2025). Elements of Geodetic and Astrometric Very Long Baseline Interferometry. Vienna Center for VLBI, Version V4.2. https://doi.org/10.48436/3qkq9-rv841

- Urban, P. (2025). Ambiguity resolution and ionospheric calculations for VLBI CONT17 sessions with VieVS [Diploma Thesis, Technische Universität Wien]. reposiTUm. https://doi.org/10.34726/hss.2025.130063

Thank You for Your Attention!

Questions regarding ambiguity resolution in VieVS are welcome!

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Appendix

Ambiguity Spacing

- The inverse of the largest common devisor of all sub-band frequency differences

$$\tau_{amb} = \frac{1}{\Delta \nu_{max}}$$

Sign

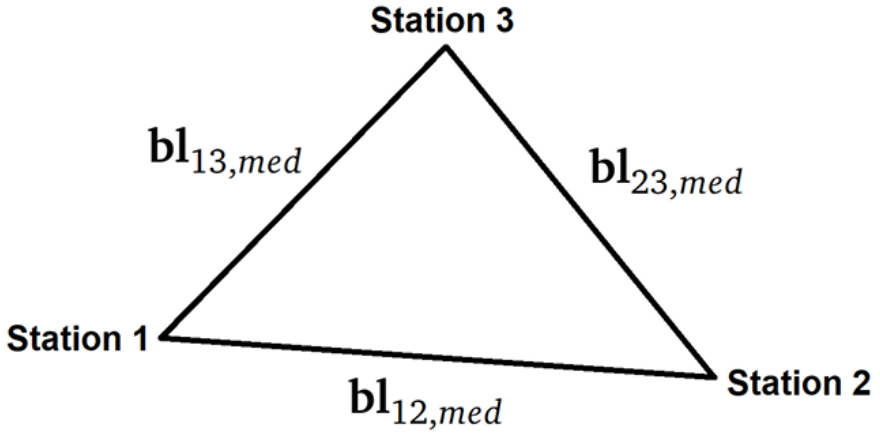
- b_{13}, b_{32}, b_{21} baselines between the stations
- P_1, P_2, P_3 3D-station coordinates
- s_i sign for the closure formula

$$\mathbf{b}_{13} = \mathbf{P}_3 - \mathbf{P}_1, \quad \mathbf{b}_{32} = \mathbf{P}_2 - \mathbf{P}_3, \quad \mathbf{b}_{21} = \mathbf{P}_1 - \mathbf{P}_2$$

$$s_i = \operatorname{sign}\left([\mathbf{b}_{13} \times \mathbf{b}_{32} + \mathbf{b}_{21} \times \mathbf{b}_{13} + \mathbf{b}_{32} \times \mathbf{b}_{21}] \cdot \underbrace{\frac{\mathbf{P}_1 + \mathbf{P}_2 + \mathbf{P}_3}{3}}_{\text{center of gravity}} \right)$$

Ambiguity Processing per Baseline

- Consider all observations per baseline
- Use observations with quality code 9
  - or best available quality code
- Compute the median value
- Median reduces influence of outliers



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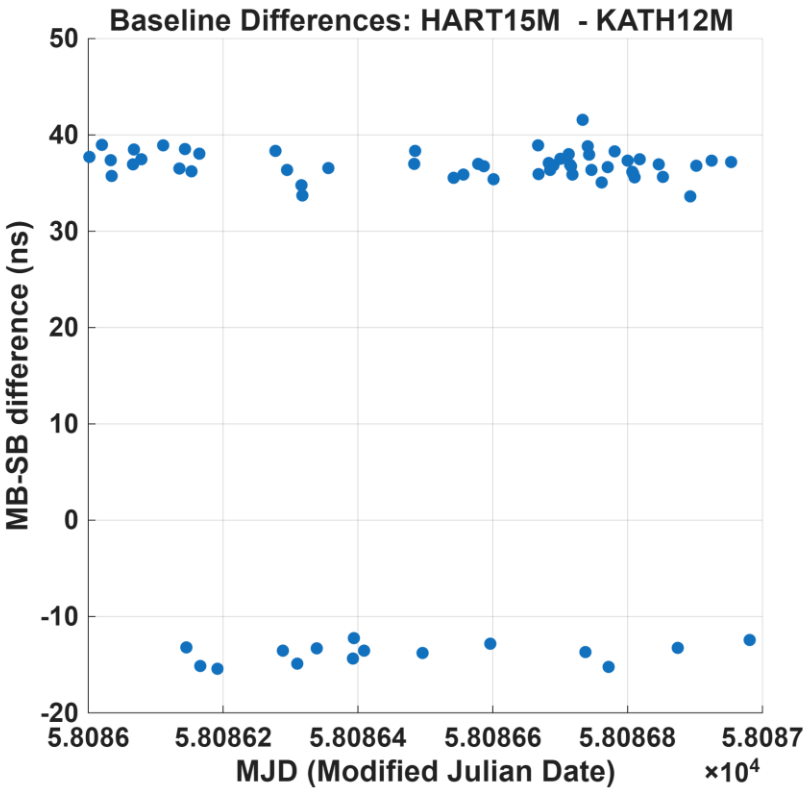
Ambiguities within a Baseline

- Example: baseline HART15M – KATH12M
- Session: 17NOV29XB (X-band)
- Median value of baseline: +40 ns
- Multiband–singleband delay differences: –10 ns
  - Apply ambiguity correction: +50 ns



Ambiguity Network Solution

- Solve ambiguities for the entire network
  - Includes all stations and baselines

- Max. 2 × ambiguity spacing per baseline

$$\tau_{close} = (\mathbf{bl}_{12,med} + \mathbf{bl}_{23,med} - \mathbf{bl}_{13,med}) \cdot s_i$$

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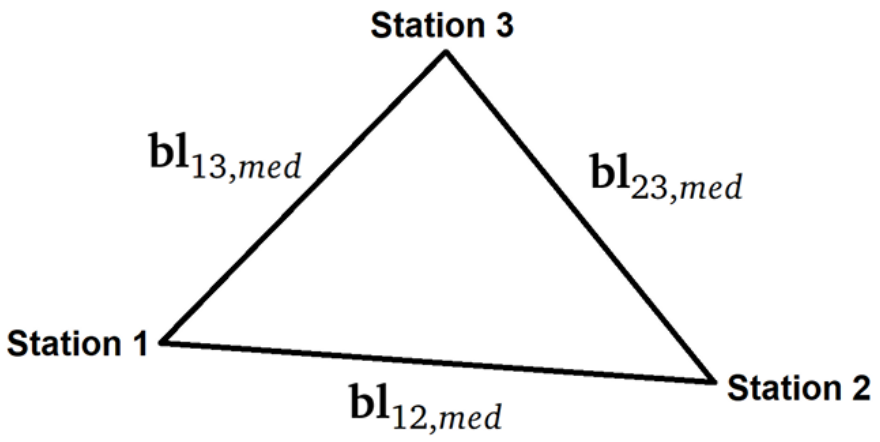

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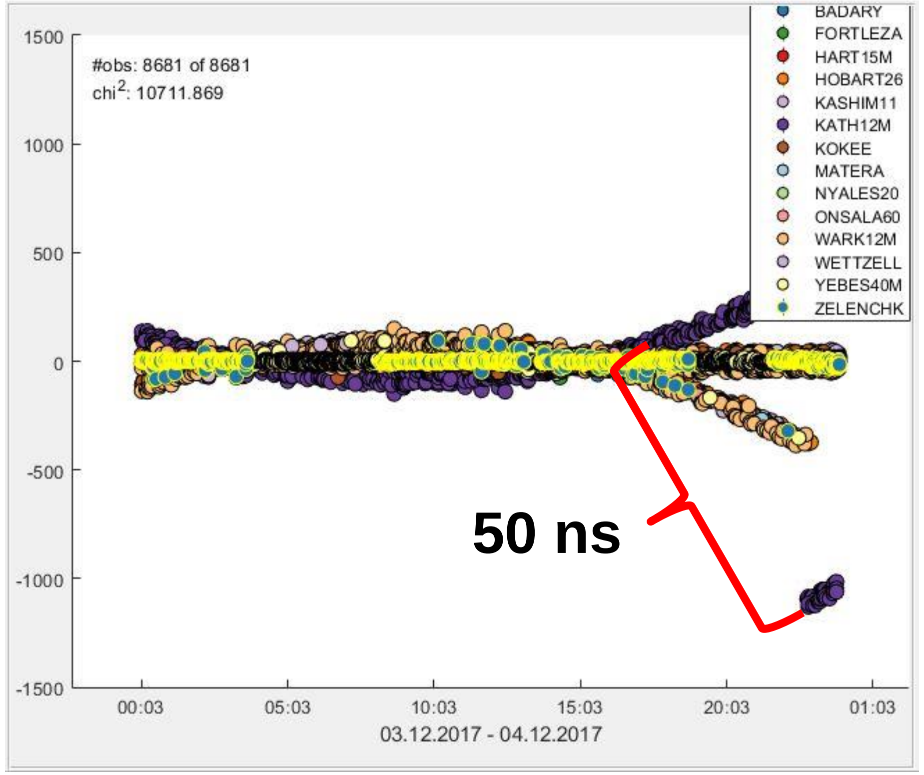
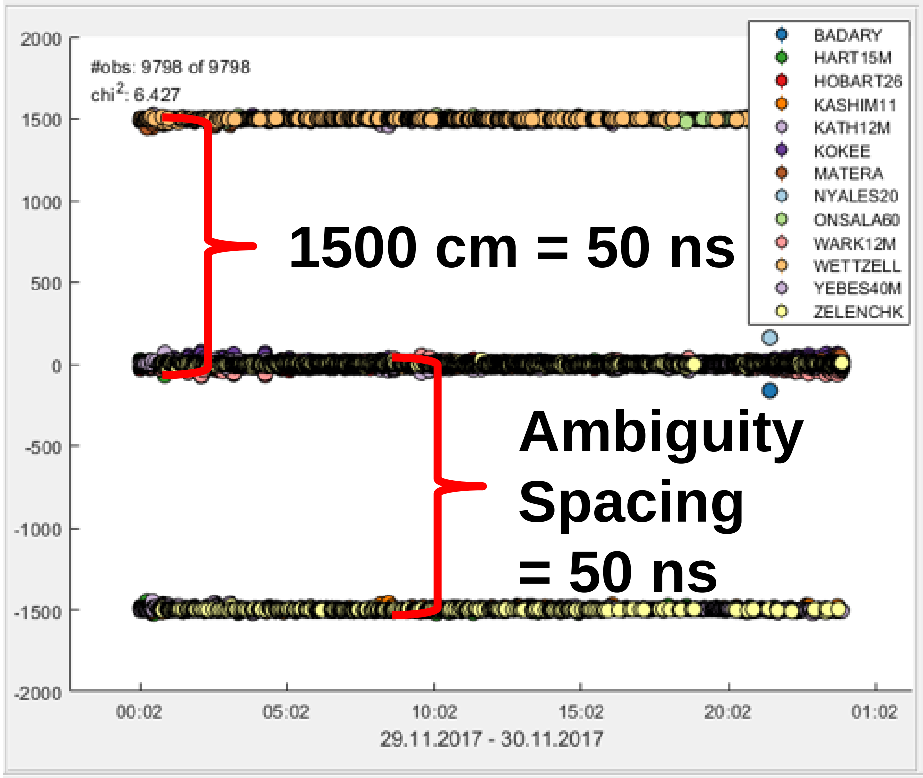
Automatic Ambiguity Solution

- Ambiguities might remain unresolved
- Manual ambiguity resolution in VieVS for a small amount of observations if necessary



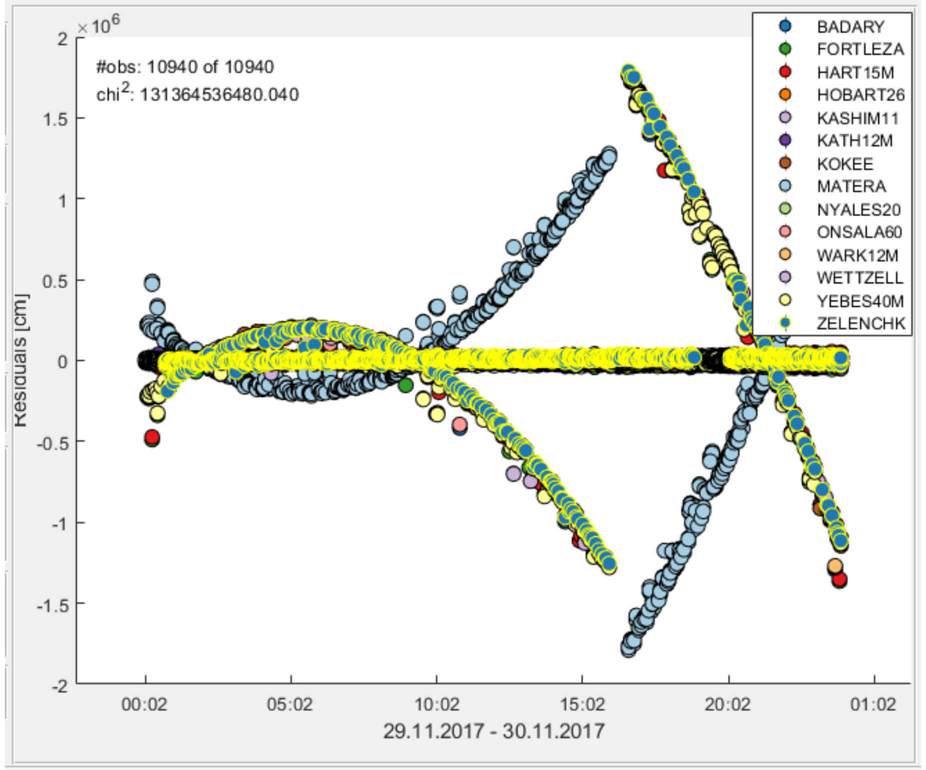
Manual Ambiguity Solution for the Entire Session

- More steps need to be applied:
  - Some stations or baselines have to be turned temporarily off
  - Choose the option of a down-weighting of non-independent baselines in VieVS
- → Very time consuming
- → Requires practice



Manual Ambiguity Solution for the Entire Session (2)

- First solution of 17NOV29XB without any ambiguity correction
- Clock break at the station Matera
- Clock break is independent solvable from the ambiguity solution



State-of-the-art Calculation

- L2-norm minimization provides the basis
- Iterative approach
- Functional model based on a second-order polynomial representation of the clock function