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Institute of **Geodesy and Navigation**
Institut für **Erdmessung und Navigation**

MULTIPATH DETECTION AND MITIGATION

José Ángel Ávila Rodríguez, Stefan Wallner
Markus Irsigler, Matteo Paonni, Thomas Kraus and Bernd Eissfeller

Institute of Geodesy and Navigation
University FAF Munich, Germany

MULTIPATH DETECTION AND MITIGATION BY MEANS OF MULTI-CORRELATORS

- **A multi-correlator approach can be followed in order to realize**
  - Multipath Detection and Monitoring
  - Multipath Mitigation

- **By using the same basic principle (linear combination of the correlators' outputs) one can obtain:**
  - Multi-correlator-based real-time multipath monitoring system
    - Provide user with instant information regarding multipath affection of signals
    - **Implemented** in Matlab as RTMM (Real-Time Multipath Monitor)
  - Optimum S-Curve Shaping, by means of a coherent code phase discriminator defined as linear combination of the correlators output
    - Determine optimum S-Curve to mitigate multipath
    - **Implemented** for various GNSS signals in a real-time software receiver

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REAL-TIME MULTIPATH MONITOR - 1

- Real time multipath monitor based on **multi-correlator observations**
- Allows **instant detection** of multipath signals and thus to
  - **Exclude** the observations
  - **De-weigh** the affected observations
- Determining **optimum metric** (i.e. a suitable combination of correlator peak observations), the monitor can be made very sensitive
  - **Extremely weak multipath signals** can be detected

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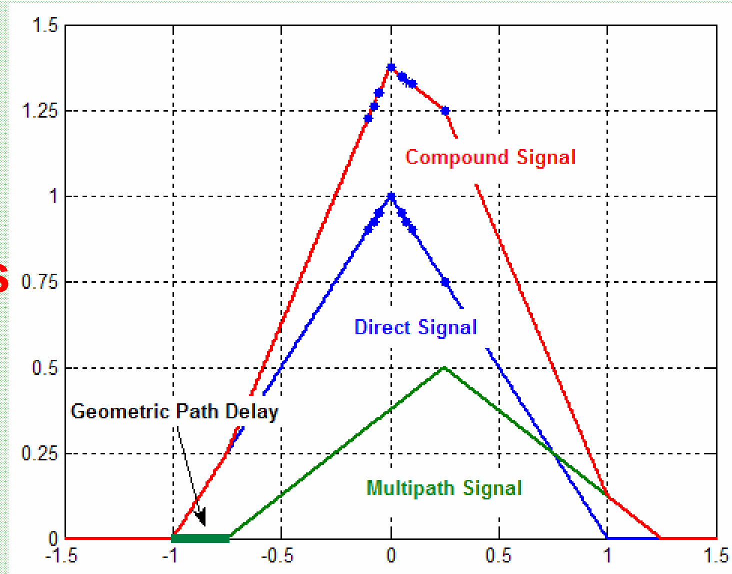
REAL-TIME MULTIPATH MONITOR - 2

- ✓ **Presence of multipath signals**
  - **→ Distortion of correlation function**
- ✓ **Use combination of multi-correlator outputs to set up a variety of test metrics**
- ✓ **Multipath distorts correlation function**
  - **→ Correlation values for indicated correlator positions are distorted**
  - **→ Test metrics itself are affected**



- ✓ **Idea of RTMM: Constantly monitor set of test metrics and compare to threshold**
- ✓ **Test metric exceeds corresponding noise level → multipath present**

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REAL-TIME MULTIPATH MONITOR - 3

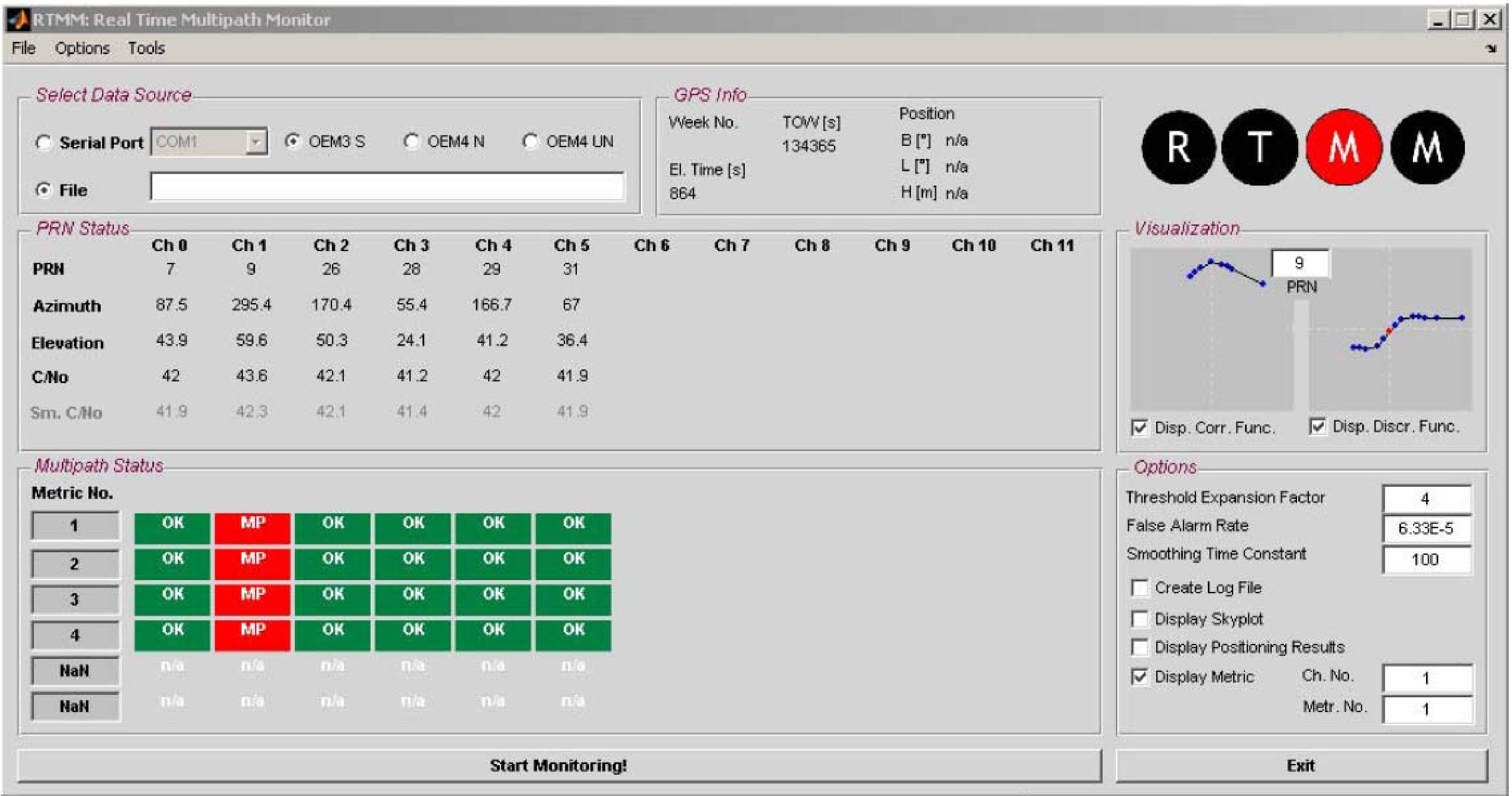
- **Huge variety of test metrics can be defined**
- **Examples**

Type of Test Metric	Formation	Example(s)
Delta-Tests	$\frac{(I_{-X} - I_{+X}) - (I_{-Y} - I_{+Y})}{I_Z}$	$\frac{I_{-0.075} - I_{+0.075}}{I_{+0.1}} - \frac{I_{-0.05} - I_{+0.05}}{I_{+0.1}}$
Symmetric Ratio Tests	$\frac{(I_{-X} - I_{+X})}{I_Y}$	$\frac{I_{-0.05} - I_{+0.05}}{I_{-0.075}}$
Simple Ratio Tests	$\frac{I_X}{I_Y}$ and $\frac{I_Y}{I_X}$	$\frac{I_{+0.25}}{I_{-0.1}}$ or $\frac{I_0}{I_{-0.075}}$
Differential Ratio Tests	$\frac{(I_X - I_Y)}{I_Z}$	$\frac{(I_{-0.1} - I_{+0.25})}{I_{+0.05}}$

- **Set of test metrics needs to be condensed in order to**
  - **Eliminate mutually depending metrics**
  - **Provide metrics sensitive to**
    - **Short/long delay multipath**
    - **Weak/strong multipath signals**

REAL-TIME MULTIPATH MONITOR - 4

✓ RTMM implementation



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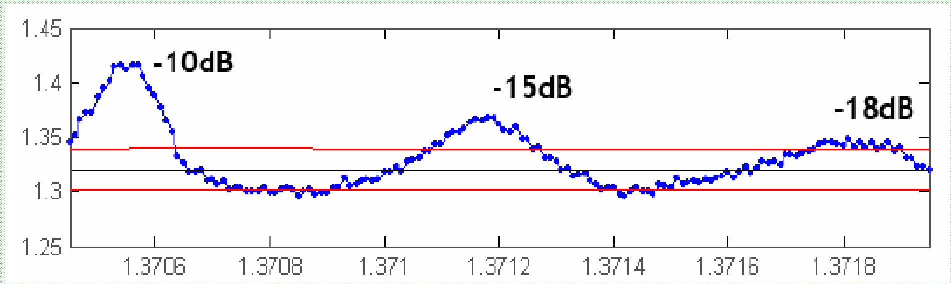
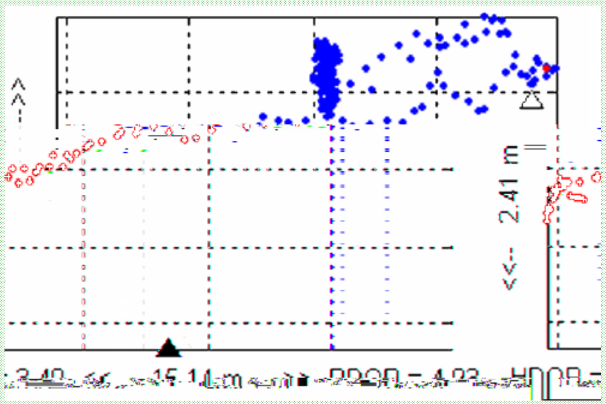
REAL-TIME MULTIPATH MONITOR - 5

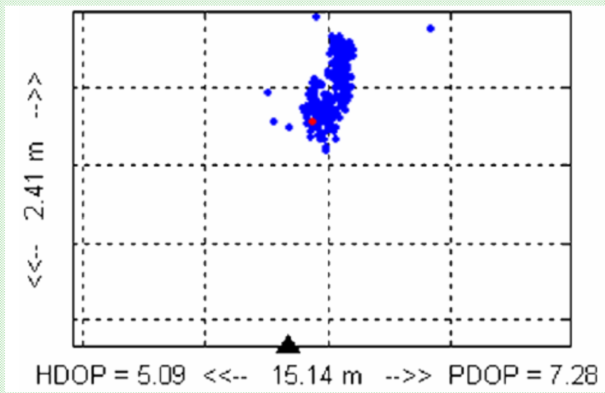
- ## Performance
  - **Detection of multipath signals with extremely low SMR**



  - **Exclusion or de-weighthing of multipath-affected signals**



No countermeasures



Signal exclusion based on RTMM

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REAL-TIME MULTIPATH MONITOR - 6

- **Benefits**
  - **Real-time capable, thus instant multipath monitoring**
  - **Unambiguous identification of multipath affected signals possible**
  - **Monitoring scheme easy to be implemented**
  - **Detection of weak multipath signals possible**

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OPTIMUM S-CURVE SHAPING FOR MULTIPATH MITIGATION

- **Multi-correlator approach can be applied to a conventional tracking loop structure to define an optimum coherent code phase discriminator aiming at mitigation of error introduced by multipath**
- **Coherent code phase discriminator defined as linear combination of correlators output**

$$\tilde{D}(\Delta\tau) = \sum_{i=1}^{N} \alpha_i R_i(\Delta\tau)$$

- **Basic idea:**
  - **Determination of Optimum S-Curve as goal of an optimization process**
  - **Choice of signal and pre-correlation bandwidth**
  - **Fitting of the optimum S-Curve**

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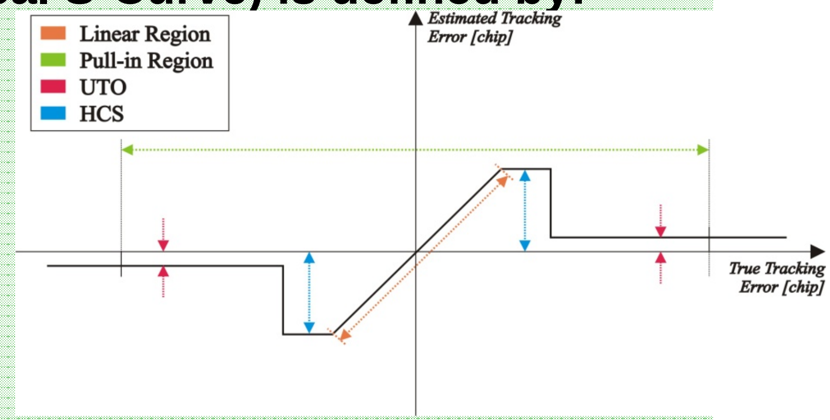
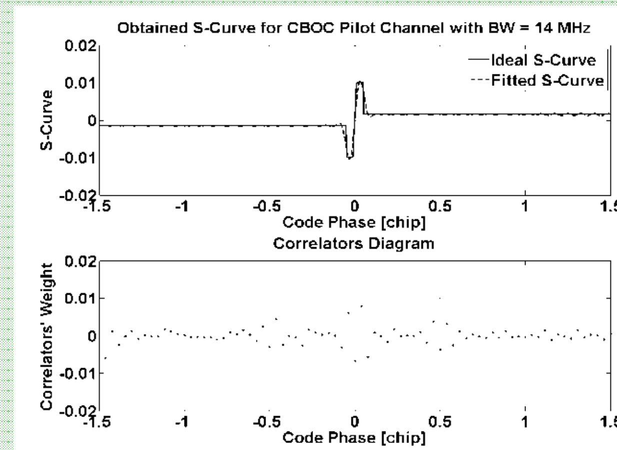
SHAPE AND FITTING OF THE OPTIMUM S-CURVE

- ✓ **The ideal coherent code discriminator (Ideal S-Curve) is defined by:**
  - **Linearity around tracking point**
  - **Zero value outside pull-in region**



- ✓ **To enhance performance characteristics are introduced**
  - **Unambiguous Tracking Offset (UTO)**
  - **High-Cut of the S-Curve (HCS)**
- ✓ **The fitting of the Optimum S-Curve is obtained by means of:**
  - **Definition of a fitting range**
  - **Resolution of the correlators**
  - **Derivation of the weights of the correlators**



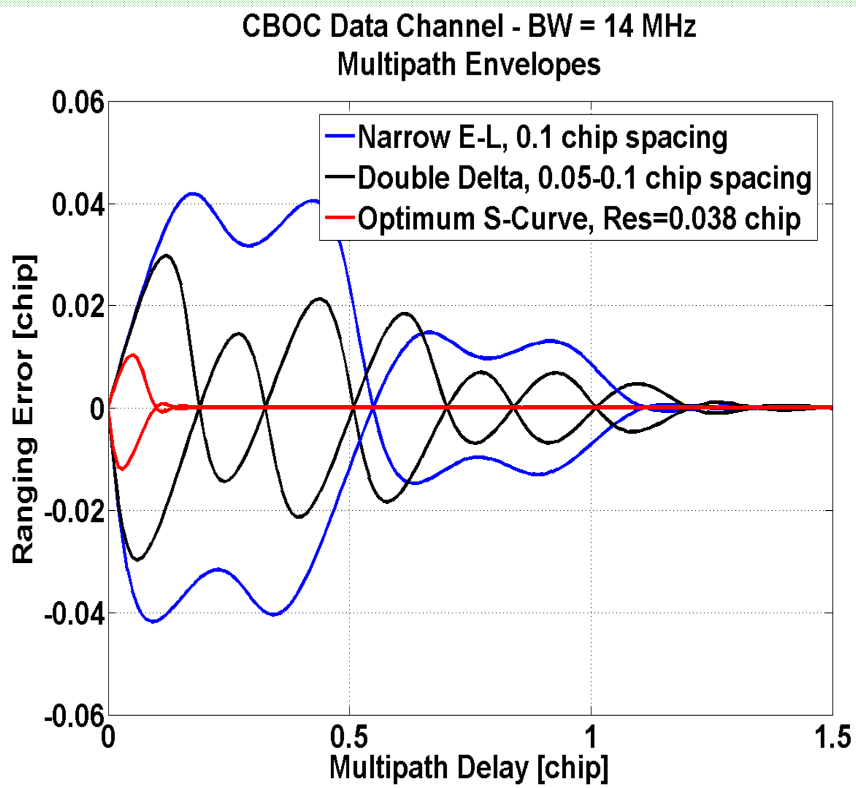
COST FUNCTION

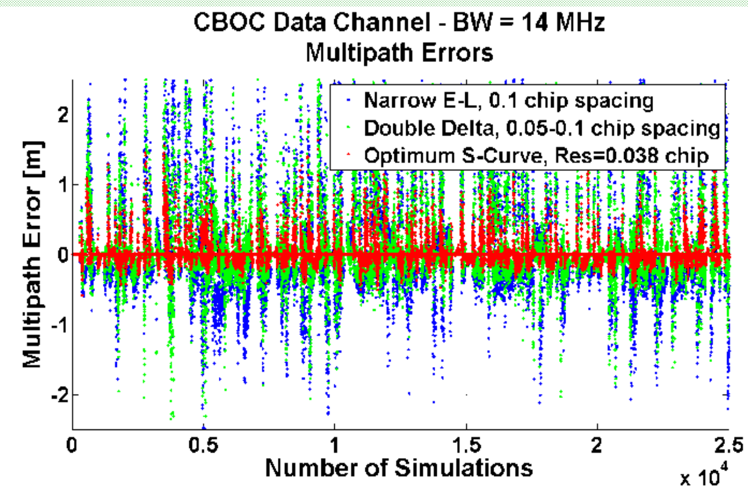
$$\sum\left[\tilde{D}(\Delta\tau)-\tilde{D}_{ID}(\Delta\tau)\right]^2$$

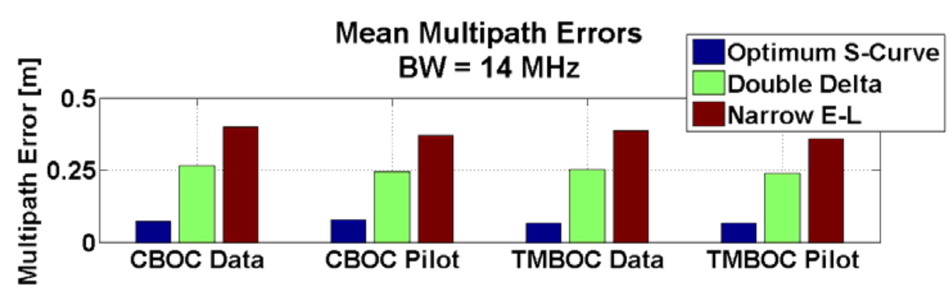
→ ***Linear combination of shifted replicas of the autocorrelation function***

OPTIMUM S-CURVE SHAPING
ASSESSMENT OF THE PERFORMANCE

Example of optimization for the tracking of the data channel of the Galileo E1-OS signal







SUMMARY

- ✓ **Instant multipath monitoring approach has been presented**
  - ✓ **Identification of weak multipath signals possible**
  - ✓ **Easy implementation at low-end receivers**
  - ✓ **Unambiguous identification of multipath-affected signals**
- ✓ **Optimization of S-Curve for minimum multipath error has been presented**
  - ✓ **Significant reduction of multipath error possible**
  - ✓ **Determination required only once depending on desired signal and receiver characteristics**

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THANKS FOR YOUR ATTENTION!

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