BayNavTech™ Satellite Navigation Centre Munich
The Competence Centre for Satellite Navigation and its Applications

Concept and Architecture of the Bavarian Navigation Signal Experimentation Facility (BaySEF™)

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The SNCM at the Ottobrunn site is an EADS Astrium GmbH initiative:
- to bundle navigation technology competences at Munich
- to cover key tasks for verification and monitoring of satellite navigation signals, navigation systems and services and navigation application systems

The Astrium initiative is supported and co-funded by the Bavarian Ministry for Economics, Infrastructure, Traffic and Technology.

The Team is formed under the lead of EADS Astrium GmbH together with:
- IfEN GmbH
- Institute for Communication & Navigation (IKN), German AeroSpace Centre (DLR)
- Institute for Physical Geodesy & Navigation (IfEN), FAF University Munich
- Research Centre for Satellite Geodesy (FESG), Technical University Munich

Duration: 01.01.2004 – 31.12.2007 (development & implementation)
The BayNavTech™ Facilities

- **BayNavTech™ Signal Experimentation Facility (BaySEF™)**
  BaySEF is a Flexible Software Receiver and Evaluation Platform for reception and processing of navigation signals as well as determination of the signals' performance parameters
  - focusing on signal performance  
    (code & carrier phase, Signal-to-Noise-Ratio, demodulated data bits).
  - Adjustable parameters allow settings from 'high-end' to 'low-end' receiver characteristics

- **BayNavTech™ Performance Assessment Facility (BayPAF™)**
  BayPAF is a Flexible Analysis Environment for determination of performance of system and application algorithms for navigation systems, application systems and services
  It is an Interactive Simulation and Demonstration Environment for development, research and training focusing on
  - navigation system processes  
    (orbit determination, time synchronization)
  - navigation system augmentation  
    (local integrity, navigation-related support data)
BayNavTech™ Overall Centre Architecture

Signal Data

Observation Data
Potential BayNavTech™ Users

BayNavTech™ Services Serving a Broad User Community

- **GNSS Programmes’ Key Players**
  … for key tasks in system design, development and verification

- **GNSS Operators and Concessionaires**
  … for verification, validation and (operational) monitoring

- **Application / Solution / Service Providers**
  … for development, optimisation, performance assessment, verification purposes

- **Navigation Hardware and Infrastructure Manufacturers**
  … contributions to verification of, e.g., receivers, signal generators

- **Standardisation and Certification Bodies**
  … by provision of GNSS performance and reference data

- **Research and Development Community and Institutions**
  … e.g., universities, research institutes, R&D departments

- **Educational and Training Institutions**
  … for demonstration and as “playground”
BaySEF™ – Concept

Flexible Offline & Realtime Receiver for non-encrypted Satellite-Navigation-Signals

Challenge:
- GPS signals in L1, L2 and L5
- GALILEO signals in E5, E6 and L1

Signal Generator, …
(Spirent, GATE, NSGU, Interferer…)

RF-Frontend System

DDCs

(Raw)-Data Recording System

(Offline)-Processing Facility

Real-Time Galileo GPS SW Receiver

Navigation Raw-Data per Satellite Signal:
• $C/N_0$
• Code-Phase ($\sigma + \text{bias}$)
• Carrier-Phase ($\sigma + \text{bias}$)
• Demodulated Data-Bits (BER/SER/FER)

... Format: CCSDS

Performance Evaluation

MMI, M&C

GPS, GIOVE, GALILEO IOV, Interferer, …
BaySEF™ – Navigation RCVR Main Functions

Further requirements:

- Flexibility wrt the input signal (Galileo/GPS/Pseudolites/Simulated)
- RF- bandwidth (24/40/90 MHz)
- Signal processing: flexible decimation and quantization of sampled signals (decimation down to 2 MHz)
- Reference signal generation (BPSK, BOC, AltBOC, ..)
- Coherent processing of pilot- & data channels
- SSB or DSB processing
- Flexible discriminators (type/order, loop-BW/integration time, correlator spacing)
- min. 5 correlators with adjustable delays
- REALTIME - and/or OFFLINE Signal Processing (min.1200 sec)
BaySEF™ - Navigation RCVR Architecture (1)

BaySEF Sub-Systems:
- RF-Frontend
- DDCDR (VSystems)
- M&C Unit
- ONPF
- RTR-Application
BaySEF™ – Architecture (2)

- **Antennas**: dual omni-directional spiral, active low noise, incl. interference rejection filter

- **RF Front-end**: E5-, E6-, L1-bands as well as E5a- & E5b-subbands, 70 MHz IF, low phase noise, low linear distortions

- **ADC/DDC**: up to 550 MSamples per band, up to 8 bit quantization, customized DDC core with variable decimation, equalization filters, variable output data formats/quantization

- **Data-Recorder**: COTS, four bands with 120 Mbyte/s each, recording capability > 20 min / band, typically several hours playback of recorded samples into Real-time Receiver

- **Real-time Receiver**: four bands, 12 channels each, all current GPS and Galileo signals, dual band synchronization
BaySEF™ – Architecture (3)

- **Monitor & Control:** H/W configuration controlled by APIs, remote control, GUI

- **Offline Navigation Processing Facility:** software receiver for acquisition & tracking (programmed in MATLAB & C)

- **Performance Evaluation Facility:** either standard EADS IT, or BayPAF, or external user

- **Auxiliary Equipments:** COTS-GPS RCVR, Reference Time Receiver, High Precision Frequency Standard

- **Mobile Support Equipment:** configured from another M&C PC and a mobile power generator

Each of the two systems (4-band receiver) is designed to be transportable by a van for mobile applications.
BaySEF™ - Example Results from a GPS C/A Code Demonstrator Operation (3)

**Code-Jitter vs C/No**

BL: 5 Hz, $T_{int}$: 1 ms, E-L-Space: 1.0 chips

**Normalized Mean Correlation Power vs Code Delay**

Averaged Correlation Function from 10.000 to 10.199 s

BL: 5 Hz, $T_{int}$: 1 ms, E-L-Space: 1.0 chips
BaySEF™ – Software Simulator Tool

Analysis

- CCF
- Ideal TD-Signal-generation & Multiplexing
- Ideal oversampled spreading code (Reference Signal)
- Filter (Pre-HPA)
- HPA
- Filter (Post-HPA)
- Atmosphere
- Demod
- Filter (RX-input)

Result

- CCF Correlation Loss
- Power Losses
- Code-/Carrier Bias
  - Ideal Code-Jitter
  - Multipath Envelopes
  - Max. MP-Error

Example:
- E6- Signal
- in Time Domain

Envelopes
- P/L-Signal in TD
- Spectral Separation
- Coefficients (SSC)
- Comparison of PSD and Envelopes

Assessment

- PSD + Spectral Masks
- Ideal Spectral Envelope-generation
- P/L Signal

Real Part

Imaginary Part

Amplitude vs. Time [ns]

Example: E6- Signal in Time Domain
BaySEF™ – Hardware Signal Generator & Analyzer Tools

Example Results

Signal Generator
(NSG 5100 EADS Astrium)
Example: E6-Band

Signal Analyzer (FSQ - R&S)
- RF-IF D/C & DDC
- I/Q Demodulation
- Storage & Display

Signal Post Processing:
(EADS Astrium)

I-channel:
C/Nav: BPSK(5) Data & Pilot

Q-channel:
G/Nav: BOC(10,5) Data & Pilot
GNSS Signal Generator NSG 5100

- Galileo, GPS, EGNOS, WAAS, Pseudolite signals
- Galileo
  - E5ab, L1, E6
- Fully user configurable
  - Programmable memory based PRN codes
  - Configurable message data rates
  - Transparent navigation message
- Supports high power output & pulsing of the signal
- User friendly graphical interface (GUI)
NSG 5100 Graphical User Interface

- GNSS selector
- GNSS Settings
- Simulation Scenarios
- Nav Message
- PRS
- Advanced Settings
- Monitoring
GNSS Signal Generator NSG 5100

- Applications
  - GNSS receiver & chipset development
  - Production testing (mobile phones/PDAs with GNSS receiver)
  - Galileo signal analysis (laboratory and outdoors)
  - Provision of additional ground based ranging signals (Pseudolite)

- Availability of NSG 5100
  - Prototype is available
  - Commercial version: Mid 2006
BaySEF™ Planning

- Overall System Development

- Offline Signal Processing Facility:
  - Basic functional elements: Feb. 2006

- Signal Evaluation Facility:
  - Basic functional elements: Sept. 2006
  - Further development on customer demands
Thank you for your attention...