

SSRoverDAB+

NAVISP-EL2-069 “SSRoverDAB+”

Final Presentation

29th June 2023, 10:00 – 11:30 CET

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- 1) **Project motivation**
- 2) Project goals, tasks and structure
- 3) Outcome of the project
- 4) Product opportunities
- 5) Benefits of working with ESA
- 6) Questions and answers



Project motivation – precise GNSS market today

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- RTK networks operated by governmental institutions and private companies have been established as an **infrastructure for precise location-based applications throughout Europe**.
- Regional RTK networks as the **German SAPOS Service** supplement the European GNSS augmentation services EGNOS and Galileo High Accuracy Service (HAS) in the accuracy range of < 10 cm.
- The RTK corrections are transmitted in a bi-directional way via **mobile Internet** using **internationally standardised** data formats (e.g., RTCM 3.2 MSM) and protocols (e.g., Ntrip).
- There are GNSS **modules, sensors and complete systems** on the market that support these formats and protocols.
- Open standards lead to **competition in the market** and SMEs as Alberding GmbH have an opportunity to build own solutions.



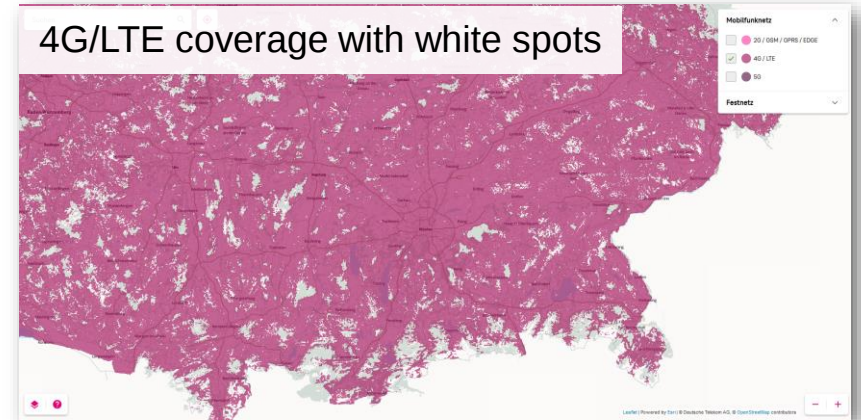
Alberding telemetry & positioning sensors

Project motivation – service provider perspective

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- The growing demand for precise real-time corrections puts an increasing **computational** and **bi-directional communication burden** on network RTK service providers.
- The provision of GNSS corrections to an **unlimited number** of users without significant investments into the **service infrastructure** requires a transition to a unidirectional broadcasting approach.
- A PPP-RTK service could solve this problem because the data format is **broadcastable** without a loss on accuracy over larger regions (e.g., Germany).
- PPP-RTK corrections can be transmitted via data channels with lower bandwidth as the terrestrial **Digital Audio Broadcasting DAB+** channel.

Example area: southern Bavaria



https://t-map.telekom.de/tmap2/coverage_checker/

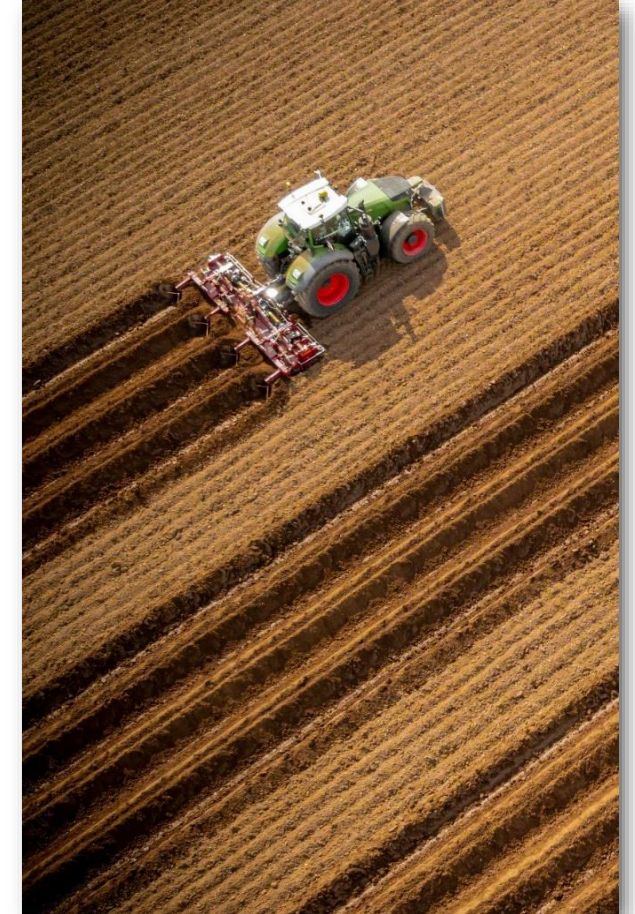


<https://www.dabplus.de/empfang/>

Project motivation – market perspective

SSRoverDAB+

- More and more digitisation and automation applications in **agriculture** and **automotive** require continuous, highly accurate, real-time GNSS position information – **as often as possible**.
- The **GNSS correction data** is often not available to users due to **mobile internet dead spots**.
- Worldwide operating GNSS companies try to overcome this problem by transmitting corrections via **geostationary satellites** in company proprietary data formats.
- The availability of real-time correction becomes a **key selling factor** for GNSS software and system solutions.
- **European SME** as Alberding GmbH need precise GNSS corrections in standardised formats to compete against complete close shop solutions (service, hardware, software).



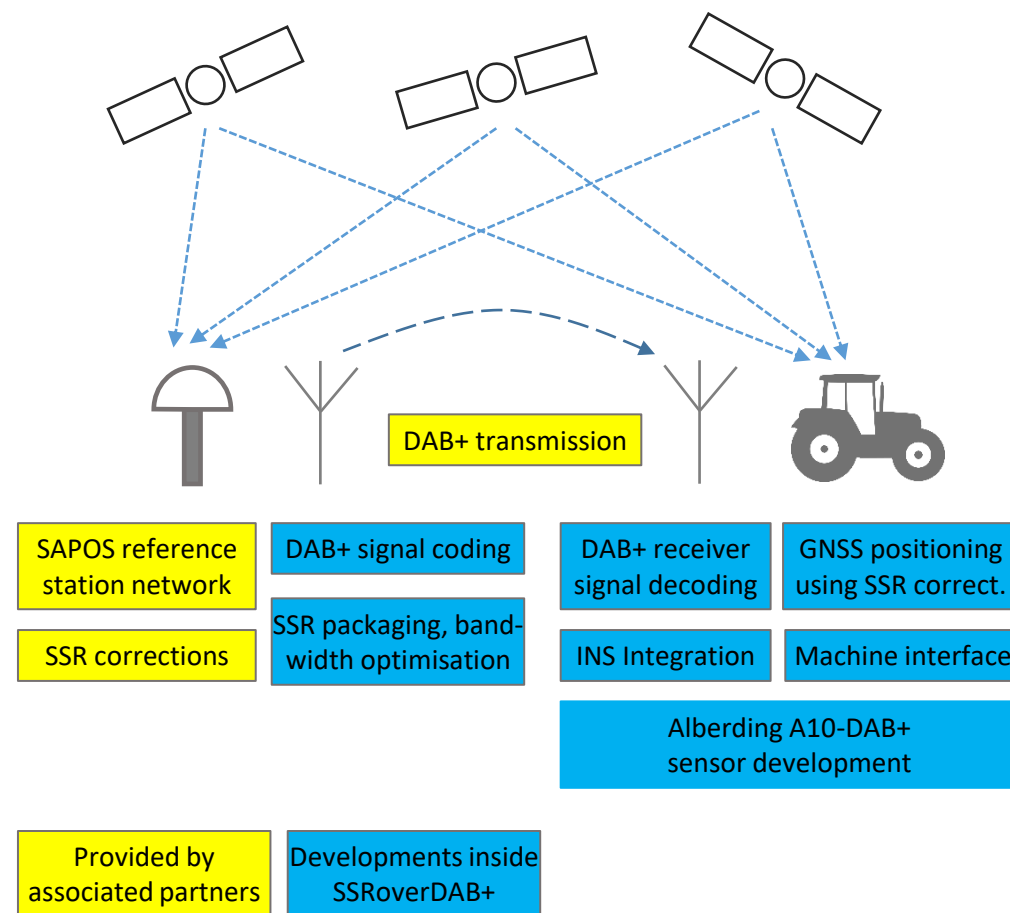
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Project goals

- **Increase the availability** of high-accuracy GNSS corrections in rural regions using DAB+ transmission
- **Overcome** computational and bi-directional communication **limitations of network RTK**
- Compute and compare **different SSR-based GNSS positioning solutions**
- Use of the **open published SSRZ** data format of Geo++
 - Indirectly via SSR2OBS conversion tool of Geo++
 - Directly by developing a new SSRZ interpreter
- Practical RTK field demonstration using **PPP-RTK** corrections received via **DAB+** with a prototype sensor based on the Alberding A10-RTK sensor platform

SSRoverDAB+



Alberding GmbH (DE)



- Project management
- Product provider
- Machine interface
- Field tests

Geo++ GmbH (DE)

- SSR correction generation
- SSR2OBS processing



LDBV (DE)*

- Reference network provider
- Correction service provider



Fraunhofer

IIS

Fraunhofer IIS (DE)

- Galileo E5AltBOC position solution
- DAB+ encapsulation and decoding
- Sensor fusion

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"SSRoverDAB+"



inPosition gmbh (CH)

- Receiver independent PPP-RTK solution



Bundesamt für
Kartographie und Geodäsie

BKG (DE)*

- DAB+ data channel provider (Bundesmux)

BayWa

BayWa AG (DE)*

- Support of agricultural field tests

* Associated partners

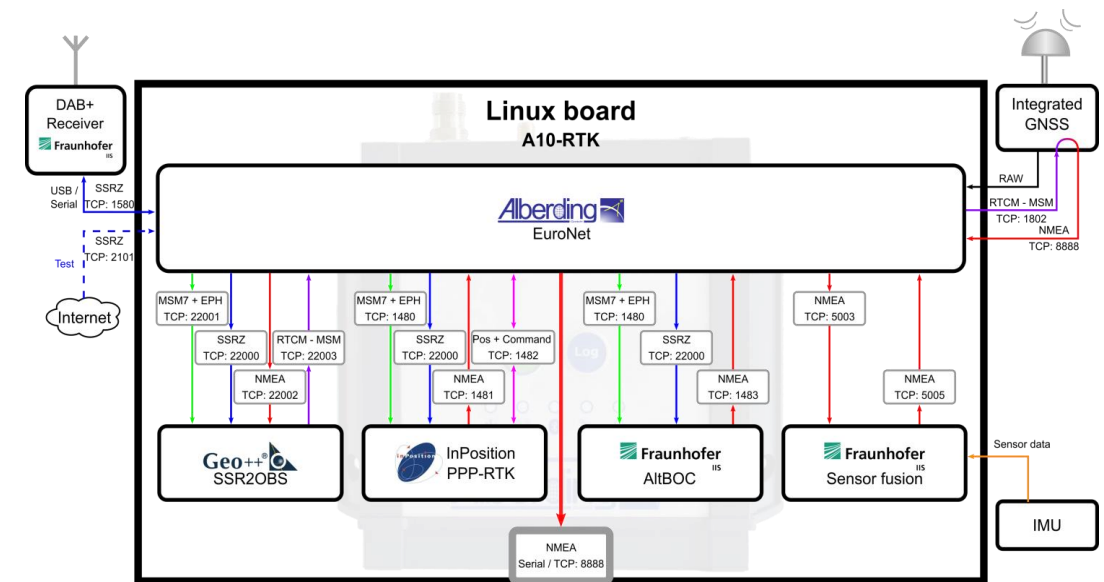


Fraunhofer



Project tasks

- Optimisation of the bandwidth and the DAB+ transmission of a broadcast-capable **SSR (PPP-RTK) correction** data stream
- Development and adaptation of **algorithms for precise** real-time **positioning**
 - SSR2OBS optimisation (improvement of the corrections)
 - PPP-RTK rover positioning algorithm using SSR corrections
 - Galileo E5AltBOC processing with SSR correction data
- Development of a **sensor fusion** algorithm to transform the GNSS position from the roof to the wheels of the machine
- Implementation of software modules on the embedded computer of the Alberding **A10-RTK** GNSS sensor
- Development of a **mobile DAB+ test receiver** for the integration in the A10-DAB+ prototype receiver
- Conducting agricultural **field tests**

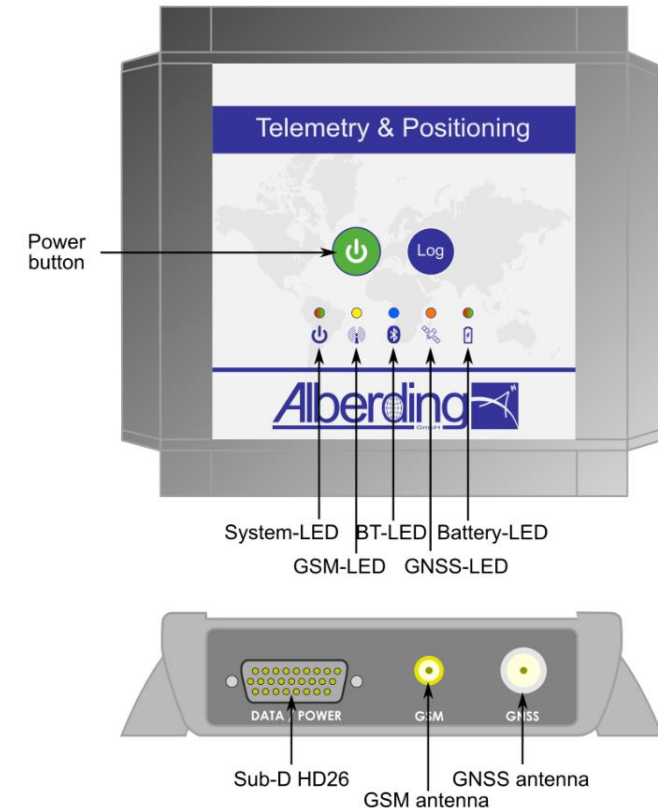


Linux board of the A10-RTK sensor

Alberding A10-RTK – the test platform

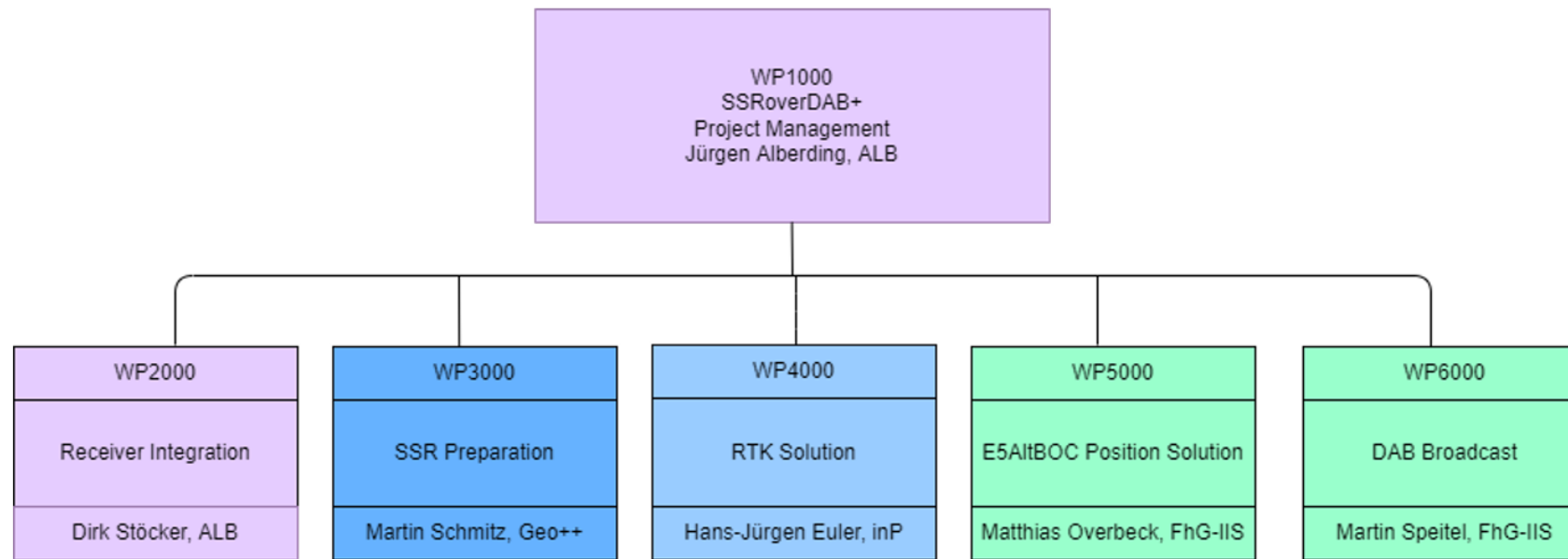
SSRoverDAB+

- Alberding A10- RTK – a versatile GNSS sensor
 - Integrated multi-frequency GNSS RTK-board
 - Supported GNSS modules: Septentrio / Trimble / u-blox / others
 - Integrated 4G LTE modem, memory, BT + WiFi module
 - Integrated Cortex M4 processor for the data management
 - 26-pin connector with multiport adapter (Ethernet, RS232, power)
 - External GNSS- and GSM-Antenna (heading optional)
- Optional embedded PC with Linux OS and EuroNet software
 - Data conversion (e.g. signal decoding, **SSR2OBS**)
 - Sensor fusion algorithms
 - Monitoring applications



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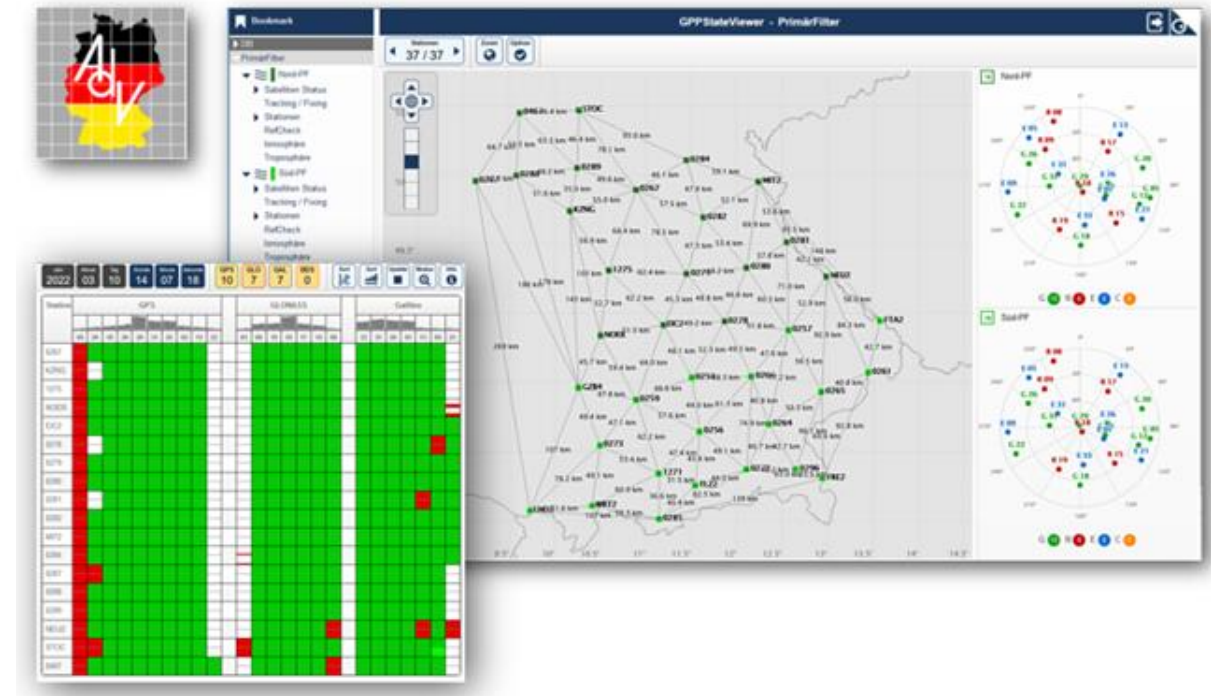


WP3000 - SSR Preparation

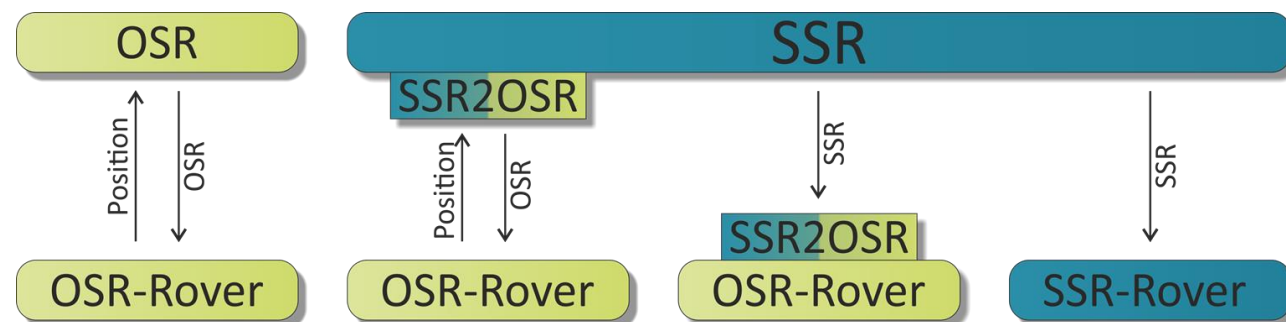
Geo++ GmbH | Hannover

Dr Martin Schmitz

- **SAPOS** GNSS reference station data provided by **LDBV**
 - SSR networking of Bavarian reference stations using two sub-networks North and South
- **Providing** high-accuracy **SSR corrections** with Geo++ GNSMART
- Generation of **broadcast-capable SSRZ** correction with **optimized bandwidth for DAB+** dissemination
- **Support of Galileo E5AltBOC** corrections in SSR service
- Successful **dissemination** and application of SSRZ over **DAB+** provided by the **BKG**



- **Open SSR format Geo++ SSRZ**
 - supporting precise real-time positioning
 - including atmospheric SSR corrections
 - extended specific for bandwidth reductions
 - SSRZ Version 1.1.2, 2022-11-11 (<https://www.geopp.de/ssrz>)
 - decoding code, Geo++ SSRZ Python Demonstrator (<https://github.com/GeoppGmbH?tab=repositories>)
- Geo++ **SSR2OBS** for **SSR to OSR conversion** of SSRZ corrections into RTCM MSM
 - support of conventional rover algorithm
- **Integration** of **SSR2OBS** in Alberding **A10** RTK-receiver
- **Enhancement** of **SSR2OBS** algorithms for ionospheric correction



GNSS correction concepts:

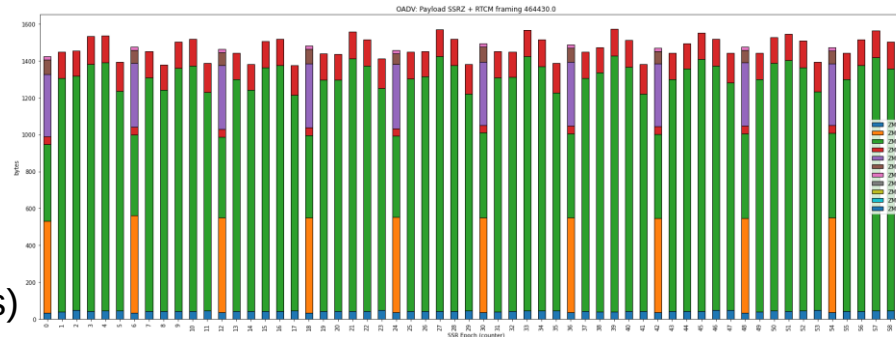
SSR – state space representation

OSR – observation space representation

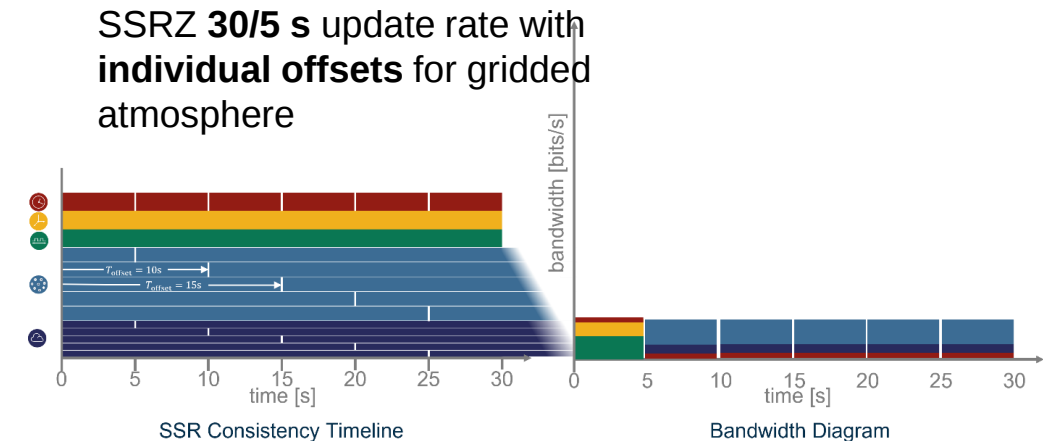
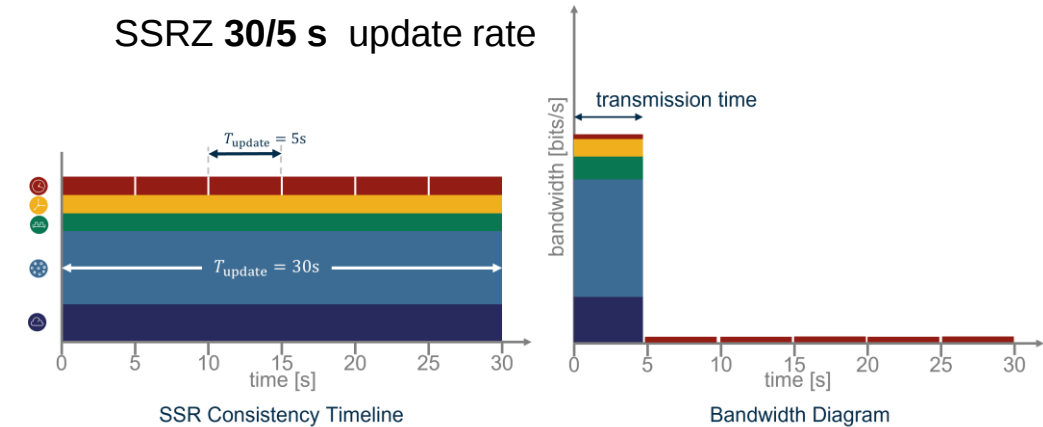
SSR Preparation

SSRoverDAB+

- Generation of a **broadcast-capable SSR** (PPP-RTK) correction with **optimized bandwidth for DAB+** dissemination
 - fast changing SSR parameters with 5s update rate
 - slowly changing SSR parameters 30s update rate
 - individual offsets for atmospheric correction
- **DAB+ bandwidth** requirements **supported by SSRZ format**
- **tested** in post-processing with data from the **German-wide PPP-RTK** Project Network of the **AdV** based on 279 stations and 17 sub-networks within 4 kbps



German-wide SSRZ:
state parameters and
RTCM framing (~3 kbps)
without metadata (~0.6 kbps)



WP4000 - RTK Solution

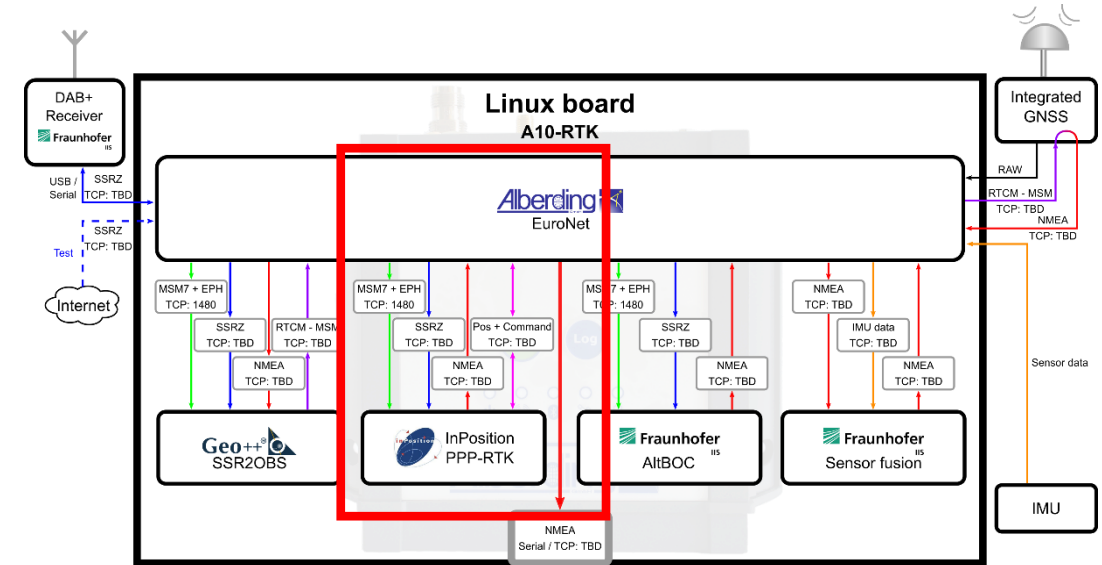
inPosition gmbh | Heerbrugg/Schweiz

Dr Hans-Jürgen Euler

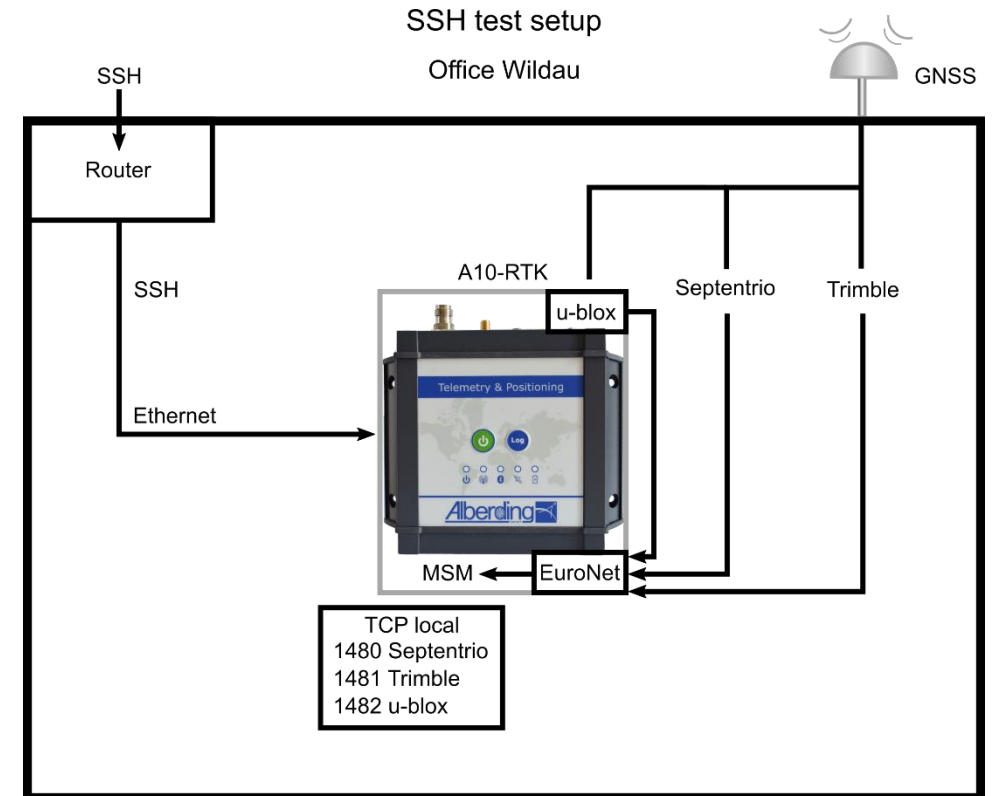
RTK Solution – Objectives

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- Integration inPosition's algorithms on A10 embedded board
- RTK solution on embedded board
- Precise Point Positioning (PPP)
 - Extension based on inPosition's PPP float solution
 - Use of primary frequency processing instead of ionospheric-free combinations
- Definition and implementation of solution interface
 - EdgeRtkPpp to A10 firmware
- Implementation of SSRZ decoding
- Integration of seamless SSRZ correction for direct use up to PPP integer fixed solution

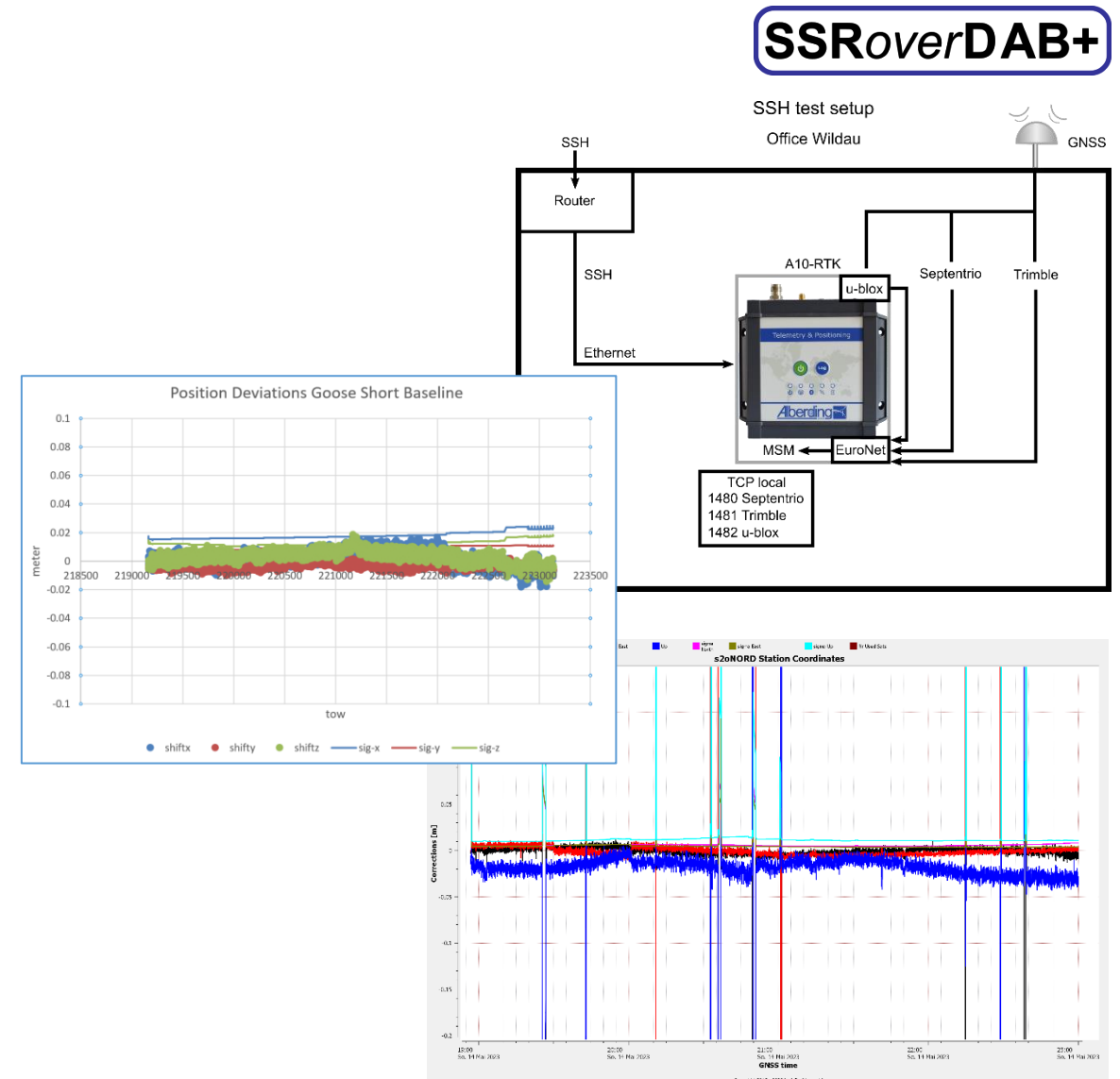


- inPosition's EdgeRtkPpp ported to Ubuntu Linux
 - Cross-compilation for A10's embedded board on Linux
- Implementation of SSRZ message structure
 - Reception of messages
 - Decoding
 - Application of corrections
- Implementation of numerically compatible models
 - Tropospheric model with Boehm mapping
 - Use of identical numeric parameters
 - Verification
 - Spherical harmonics for global ionospheric model
 - Adjustment of earth tide model
 - Shapiro relativity effect
- Fine-Tuning of algorithm parameter
- Use of SSRZ with AltBOC of Fraunhofer's GOOSE platform



RTK Solution – Results

- Ported algorithms of EdgeRtkPpp tested and verified on accessible A10 in Wildau
 - RTK tested with two receiver boards directly connected
 - PPP solution tested with different receiver boards and SSRZ of Brandenburg
- Ported EdgeRtkPpp tested on Fraunhofer's GOOSE platform
- EdgeRtkPpp tested and verified through available Ntrip SSRZ correction streams
 - SSR2OBS as artificial receiver
 - Erlangen station used as real receiver
 - Basic PPP functionality with fixed ambiguities verified

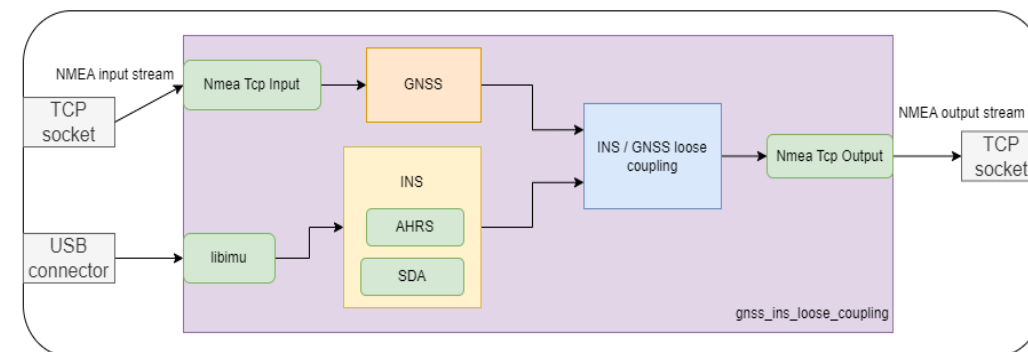
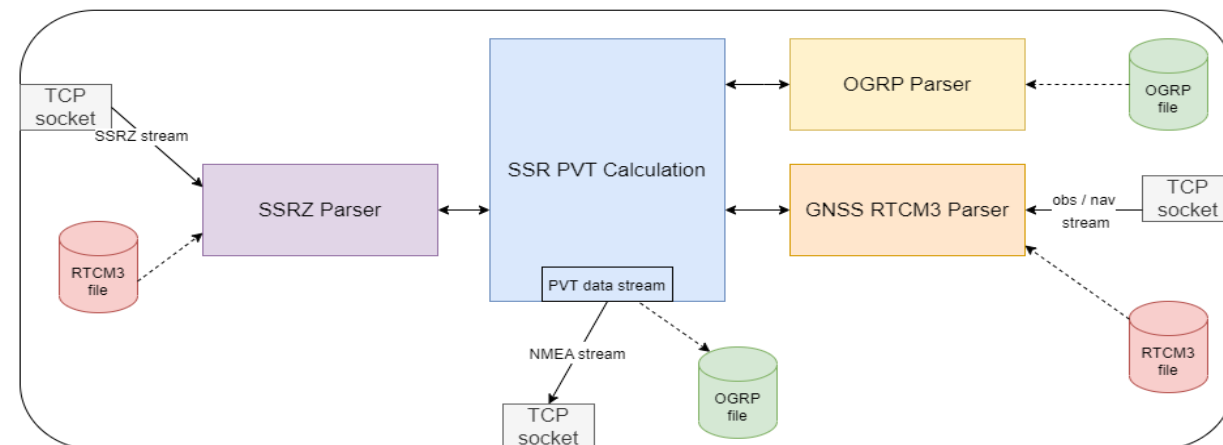


WP5000 - E5AltBOC Solution

Fraunhofer IIS | Nürnberg

Dr Fabio Garzia

- E5AltBOC-only PVT solution
 - GOOSE Receiver
 - Analysis E5 AltBOC pseudorange and carrier phases
 - Optimization of single-frequency E5 AltBOC PVT
 - A10-RTK receiver
 - RTCM3 TCP interface for E5 observation and Ephemeris
 - NMEA output interface
- E5AltBOC-only PVT with SSRZ corrections
 - RTCM3 TCP interface for SSRZ
 - Parsing of SSRZ messages for satellite clock, satellite orbits and atmospheric corrections
 - Application of SSR corrections to pseudoranges
- GNSS/INS Fusion
 - Orientation estimation from IMU and derivation of point-of-interest position
 - Optimization for real-time on A10-RTK



- SW apps for Linux
 - Developed in C++
 - Compiled for ARMv7 (GOOSE SBC/A10-RTK) and x86 (GOOSE PC)
 - Support real-time and post-processing modes

```
A10-50134:~ # ssrz_pvt --help
SSRZ PVT SW options:
--help                Show this help message

--debug-enu           print ENU on the console
--ssrz-log            print SSRZ info in a log file
--ssrz-file arg       SSRZ correction file
--ogrp-file arg       GOOSE ogrp file
--rtcm3-file arg      GNSS RTCM3 file
--gnss-ip-address-in arg (=127.0.0.1) IP address of input TCP RTCM3 stream
                                from GNSS RX
--gnss-ip-port-in arg (=1480) IP port of input TCP RTCM3 stream from
                                GNSS RX
--ssrz-ip-address-in arg (=127.0.0.1) IP address of input TCP SSRZ RTCM3
                                stream
--ssrz-ip-port-in arg (=1490) IP port of input TCP SSRZ RTCM3 stream
--nmea-ip-port-out arg (=5010) IP port of output TCP NMEA stream
--gps-l1              Enable GPS L1CA
--gps-l5              Enable GPS L5
--galileo-e1          Enable Galileo E1B
--galileo-e5a         Enable Galileo E5A
--galileo-e5b         Enable Galileo E5B
--galileo-e5          Enable Galileo E5 AltBOC
--rec-xyz arg         ECEF (x,y,z) receiver position
--rec-llh arg         Latitude, longitude and height receiver
                                position
--elevation-mask arg (=10) Elevation mask for PVT calculation
--no-ssr              If set, do not use SSR corrections
--ogrp-output         If set, create OGRP file with PVT
                                messages

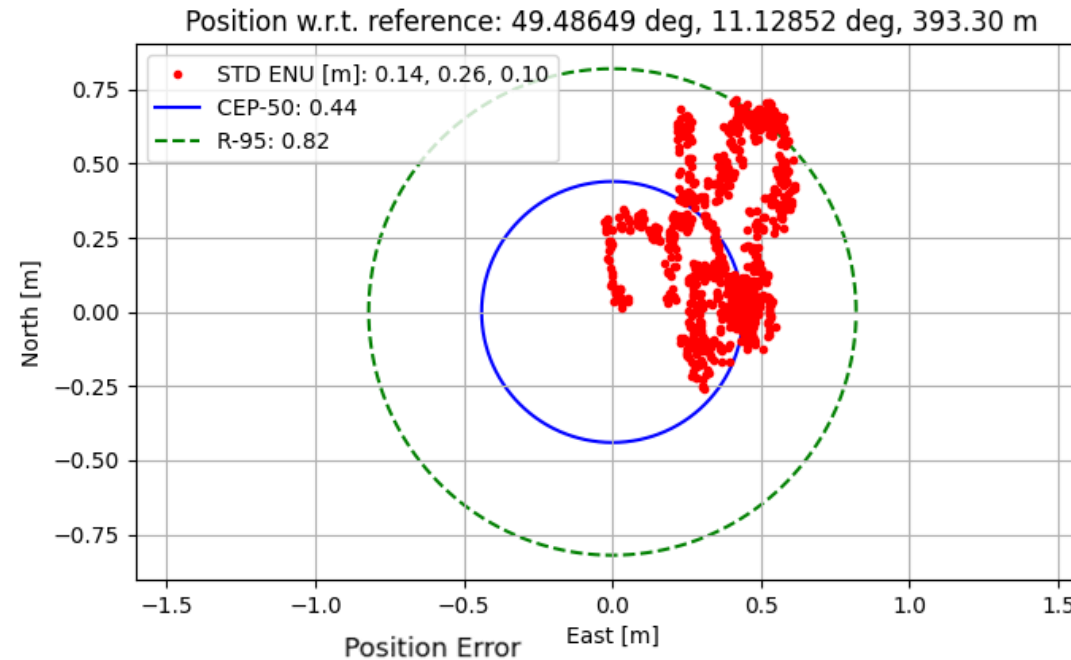
Please select only one GNSS signal!
```

```
A10-50134:~ # gnss_ins_loose_coupling --help
GNSS/INS Fusion SW options:
--help                Show this help message

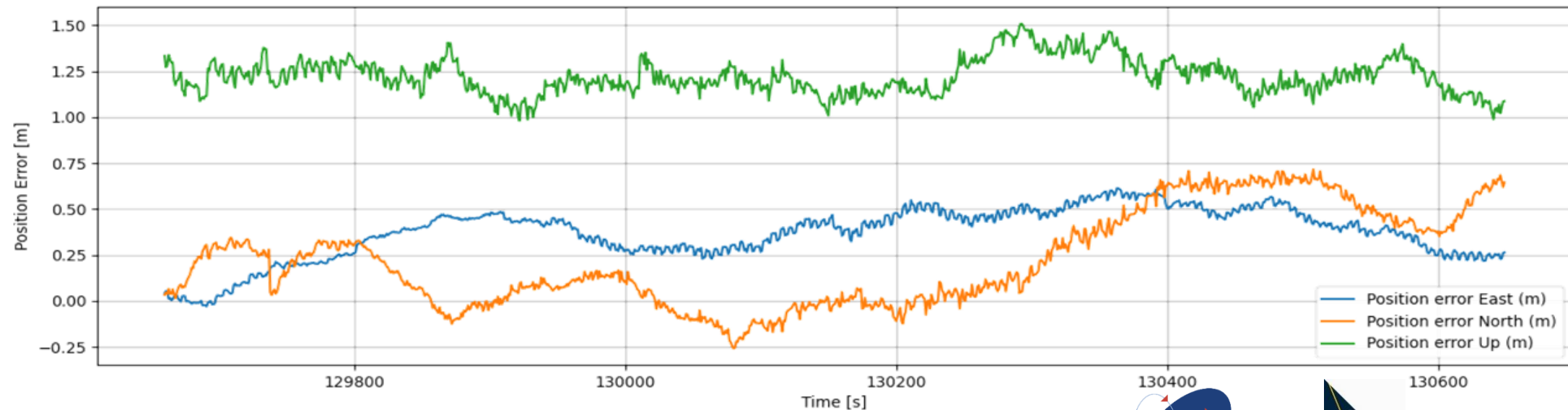
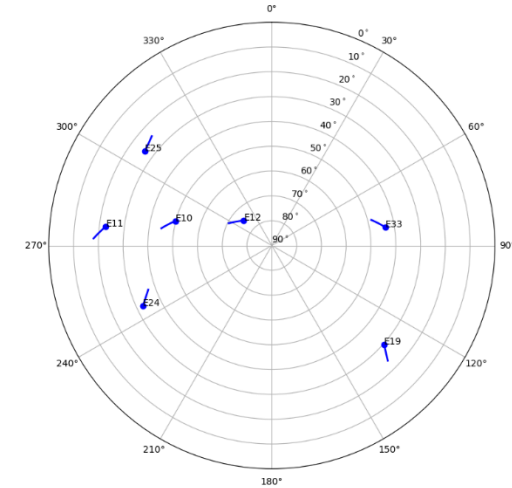
--debug-log           enable additional debug logs
--pvt-rate-hz arg (=1) PVT rate in Hz
--imu-rate-hz arg (=205) IMU measurement rate in Hz
--imu-downsampling-factor arg (=1) Downsample incoming IMU messages
--imu-g-acc           If set, the IMU acceleration data are
                                provided in G instead of m/s^2
--imu-deg-gyro        If set, the IMU gyroscope data are
                                provided in degrees instead of radians
--imu-z-axis-up       If set, the IMU z-axis is directed up
                                instead of down
--gnss-lever-arm arg  Position(x,y,z) of GNSS antenna in body
                                frame considering IMU as origin
--poi-lever-arm arg   Position(x,y,z) of point of interest in
                                body frame considering IMU as origin
--ip-address-in arg (=127.0.0.1) IP address of input TCP stream
--ip-port-in arg (=5003) IP port of input TCP stream
--ip-port-out arg (=5005) IP port of output TCP stream
--acc-bias-unc arg (=10) Acceleration bias uncertainty in micro
                                G
--gyro-bias-unc arg (=0.100000000000000001) Gyro bias uncertainty in deg/h
--gnss-pos-unc arg (=10) GNSS position uncertainty
--gnss-vel-unc arg (=10) GNSS velocity uncertainty
--debug-imu          Enable additional IMU debug logs
                                through TCP
--ip-port-debug-out arg (=5006) IP port of debug output TCP stream
--imu-csv-recorded-data arg IMU csv test file with recorded data
--recorded-data-timestamp arg Initial timestamp of recorded data,
                                needed to correctly set the date
--nmea-recorded-data arg NMEA test file with recorded data; no
                                realtime processing if this is set
--min-gnss-vel-for-heading-m-s arg (=1) Specify minimum GNSS velocity in m/s to
                                be used to initialize heading
--ip-port-rmc arg     Specify separate IP port for TCP NMEA
                                RMC stream (heading init through GNSS)
--ogrp-output arg (=1) Generate OGRP PVT messages; Settings:
                                0: console output, 1: GNSS only on TCP
                                port <ip-port-out> + 1 and GNSS/INS on
                                <ip-port-out> + 2; 2: output to files
```

E5AltBOC Solution

- E5AltBOC-only PVT with SSRZ corrections
 - CEP 0.44 by GDOP < 3
 - Std dev 0.14m East, 0.26m North



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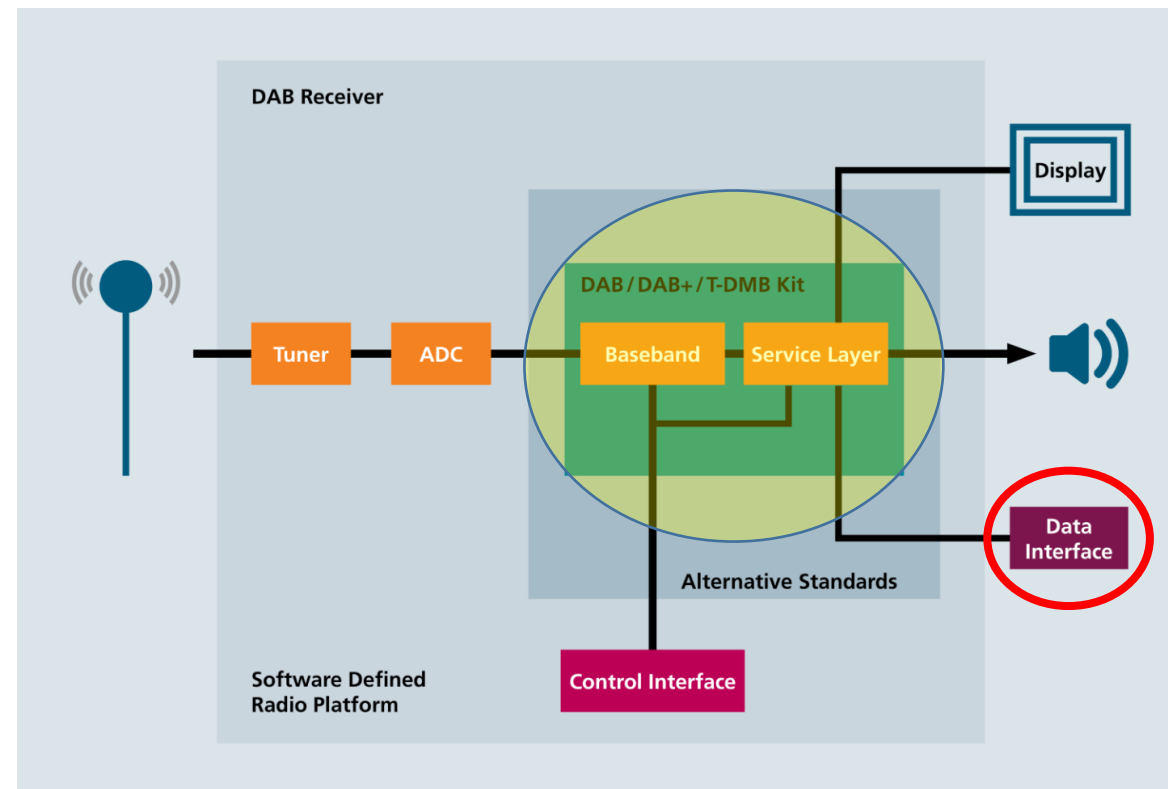
WP6000 - DAB+ Broadcast

Fraunhofer IIS | Erlangen

Christian Fiermann

DAB+ Broadcast - Objectives

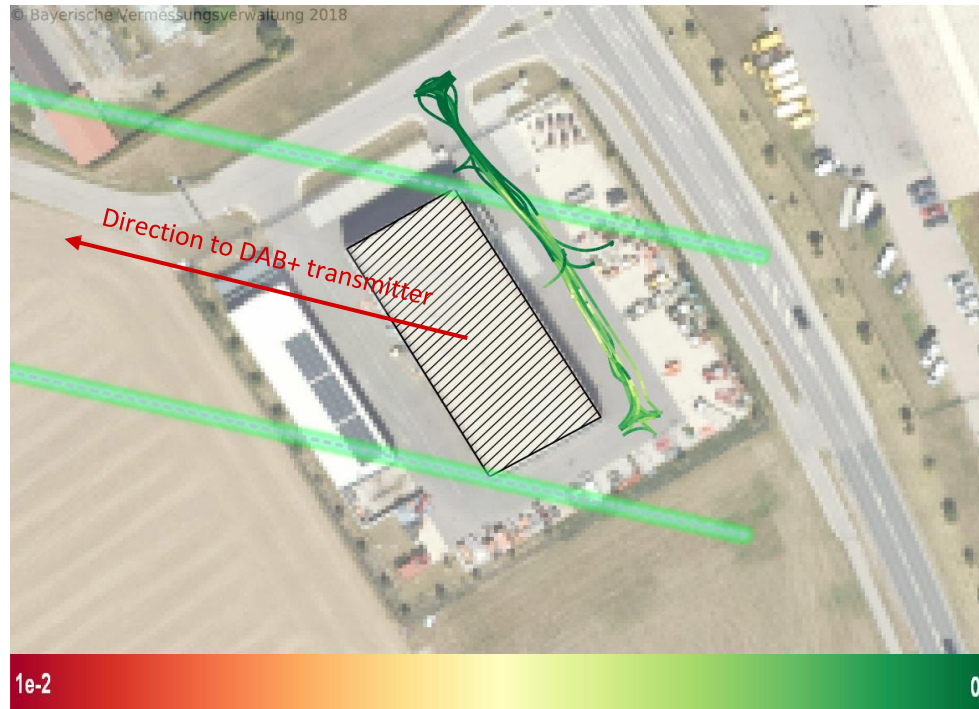
- Develop an integrated DAB+ receiver for receiving and decoding the data on channel 5C (178.325 MHz) based on the Fraunhofer IIS SDR platform
- Develop a robust high performance receiver solution
- Provide the decoded data to the Alberding A10-RTK receiver
- Support standardization of SSR over DAB+



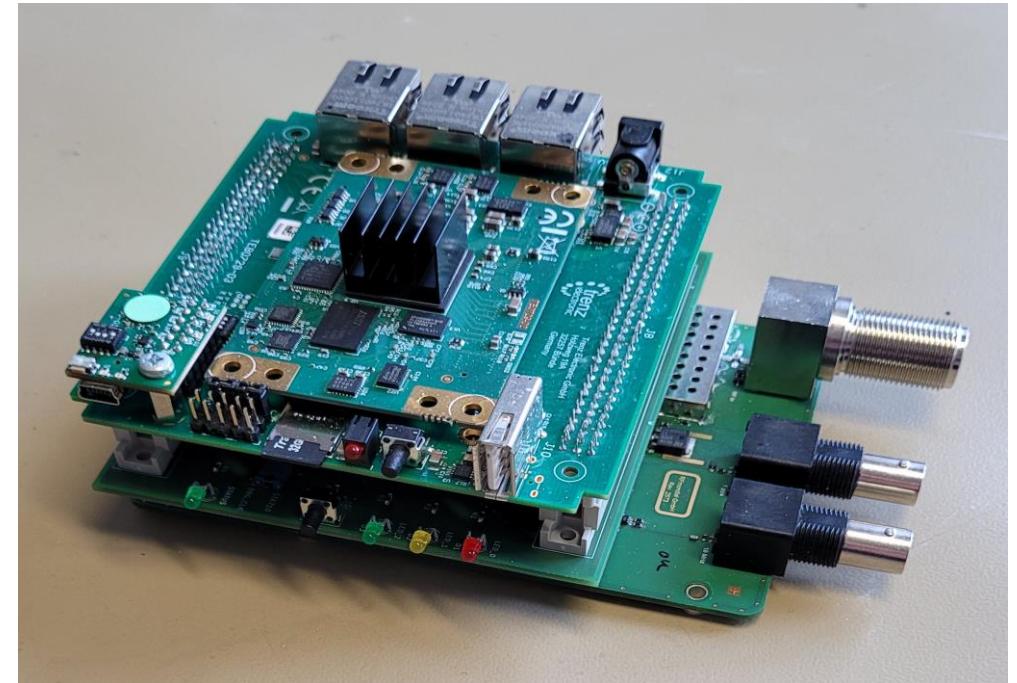
DAB+ Broadcast - Work

SSRoverDAB+

- Selection of a suitable receiver architecture
- Development of a prototype hardware platform based on Xilinx Zynq 7000 SoC with integrated ARMv7 cores
- Port of the Fraunhofer IIS DAB+ SDR software stack to the platform
- Lab and field tests for receiver and different VHF antennas



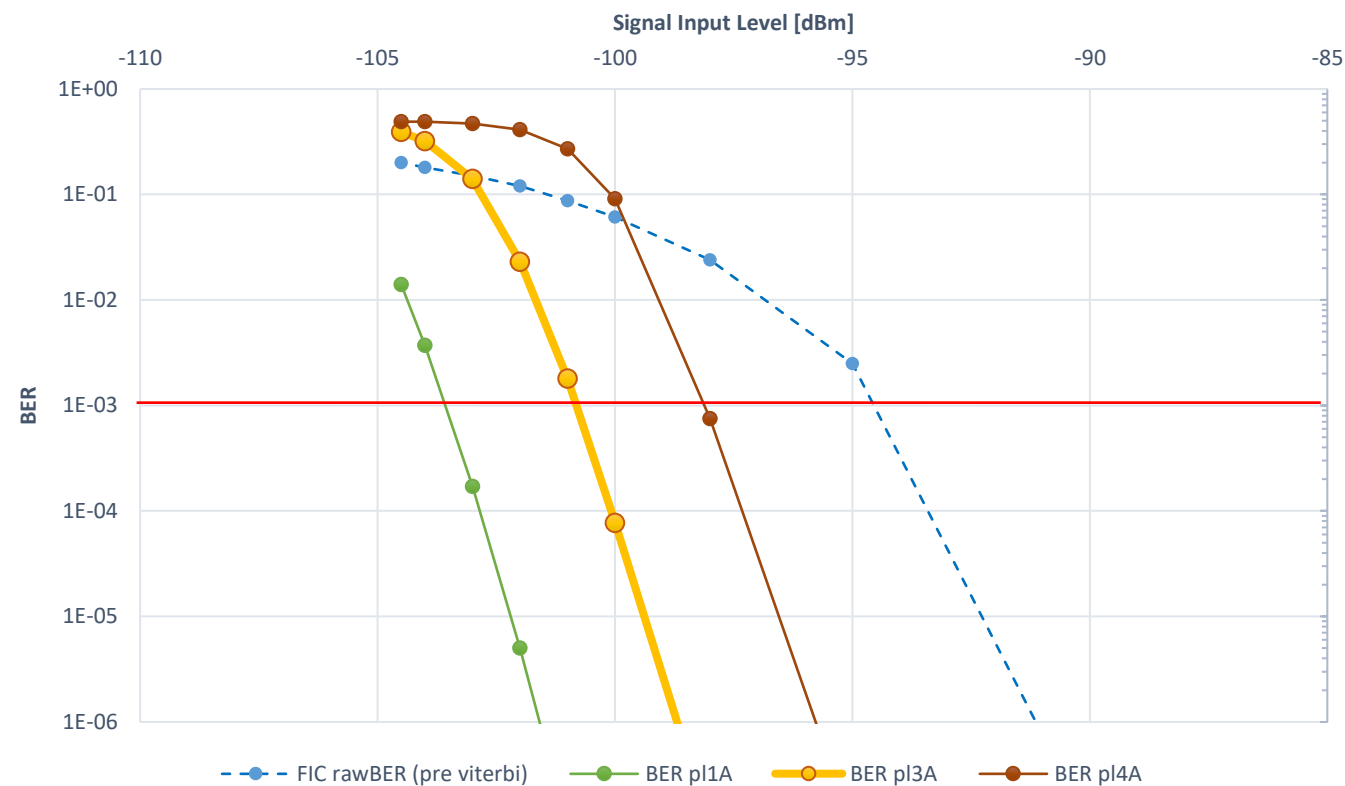
Field test BER (pre viterbi) measurement results at BayWa Feldkirchen
photo copyright Bayerische Vermessungsverwaltung, EuroGeographics



DAB+ Broadcast - Results

SSRoverDAB+

- The developed hardware platform works as expected.
- The overall performance of the system is comparable to state-of-the-art automotive solutions.
- Decoding is possible even under weak signal conditions.
- Application type for SSR data could be re-activated in the DAB+ standard.



WP2000 Receiver Integration

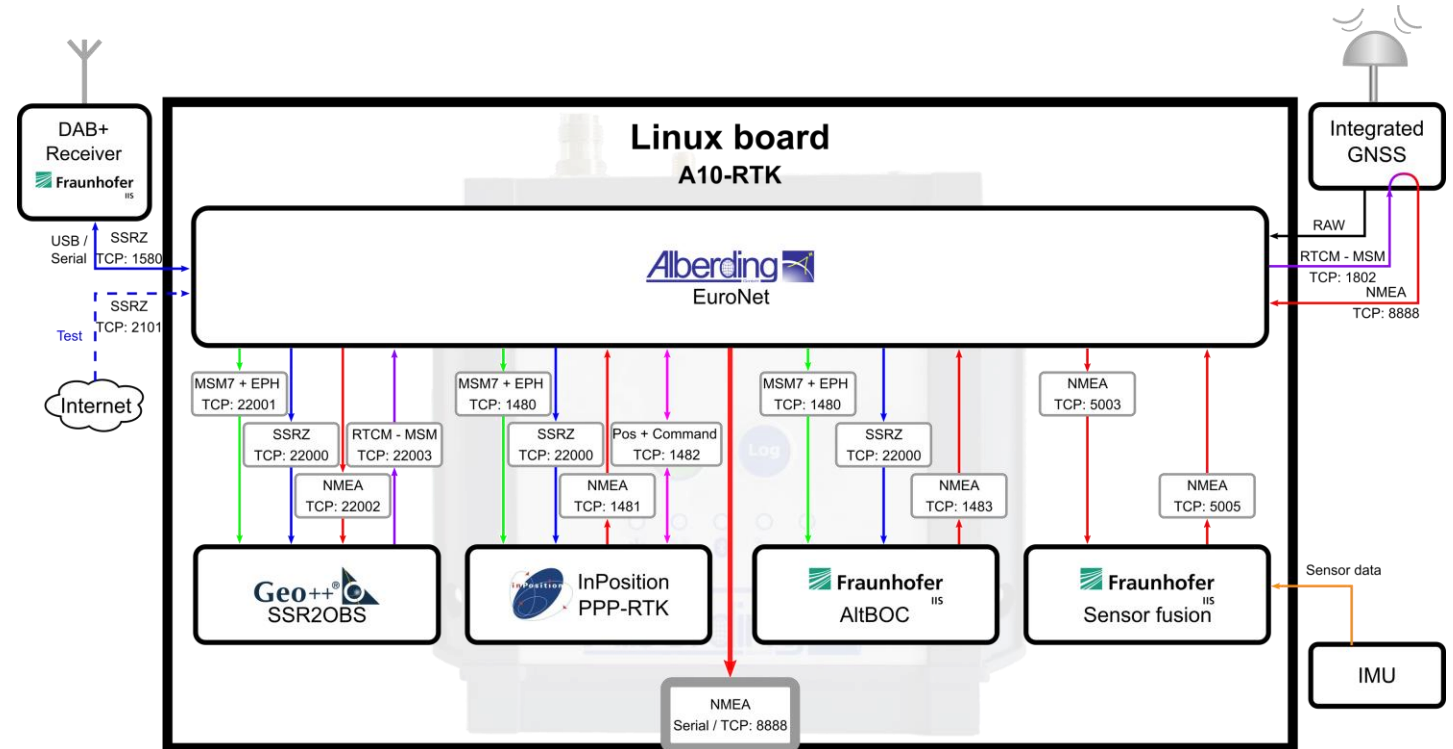
Alberding GmbH | Wildau

Dirk Stöcker

Receiver Integration – Objectives

SSRoverDAB+

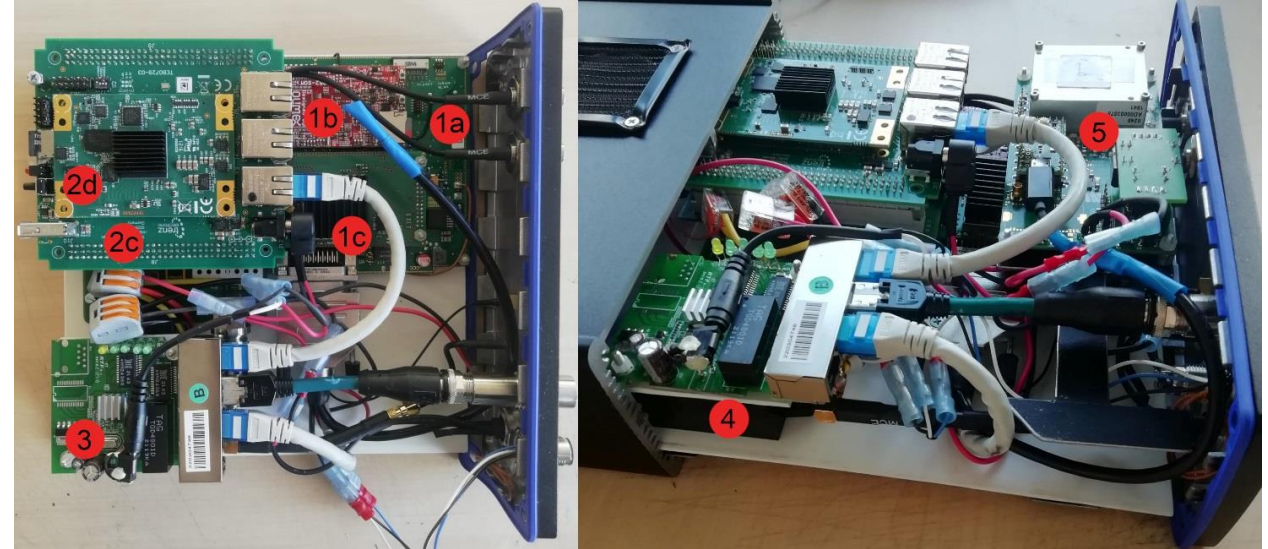
- Use A10-RTK for DAB+ reception
- Install updated SSR2OBS
 - Feedback channel integrated
- Install new software
 - inPRTK
 - FHG Sensorfusion
 - FHG E5AltBOC solution
- Create interface to agricultural machines
- Test data flow and position solutions



Receiver Integration – DAB+, LTE, GNSS receiver

SSRoverDAB+

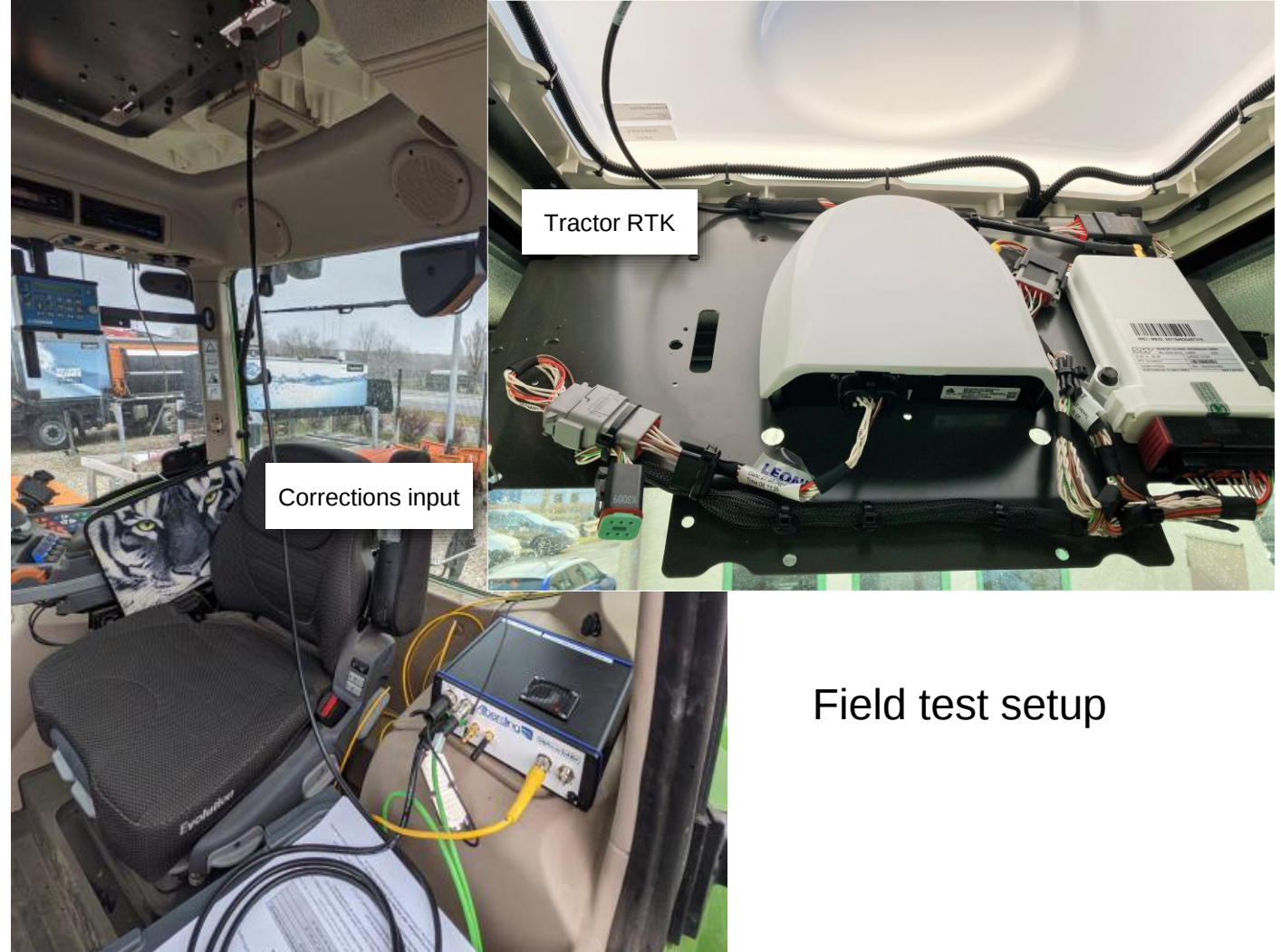
- A10-RTK system updated
- Prototype hardware developed for DAB+ reception and with internal INS
- New SSR2OBS version packaged and tested
- New packages for
 - inPRTK
 - FHG SensorFusion
 - FHG E5AltBOC
- Software tested and and issues reported/fixed
- Hardware machine interface for Fendt created
- Individual tests setup (position monitoring)
- Final field tests executed



Receiver Integration – Tests

SSRoverDAB+

- A10-RTK prototype hardware works
 - Reliable DAB+ reception
 - SSRZ data extraction
 - Ephemeris + Feedback data from internal GNSS
 - Conversion to RTCM3-MSM
 - Output to agricultural machine
 - Input of external position for logging
 - Switching between different data sources
 - Field tests have proven concept
- **Prototype hardware works**



Conclusions

SSRoverDAB+

- The communication between the four project partners was very intensive.
- All three associated partners supported the project during the whole project period of 14 months.
- We got a very good impression on the complexity of future interoperability tests for the SSR data format standardisation.
- Every working package delivered the expected results.
- The processing algorithms have been integrated to the Alberding A10-RTK sensor.
- The A10-DAB prototype sensors have been successfully used in practical field tests.
- **All project goals have been reached.**



Kick-Off Meeting 07 July 2022 in Nuremberg, Fraunhofer IIS

Agenda

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Next steps for a product development

SSRoverDAB+

- Development of a **DAB+ receiver module** in a smaller form factor for system integration
- Development of a new Alberding sensor platform with more **processing power** to run the DAB+ decoding and processing in parallel
- Development of a DAB+ **antenna solution** for mobile applications (surveying and GIS)
- Development of a **telemetry box** for re-transmitting the DAB+ corrections via BT and WiFi
- Production of **second generation** hardware prototypes in higher volume to expand the test to a larger number of test participants
- Development of a **highly integrated board** that can produced in numbers and sold to end users and system integrators



Re-transmitting of DAB+ corrections
Foto: LDBV, Bavaria

Requirements for the product

SSRoverDAB+

- Introduction and operation of an open data **SAPOS PPP-RTK** service in Germany
- Long-term provision of precise SSR corrections via the **DAB+ data channel** (rental contract by BKG)
- **Availability** and **usage** of a standardised PPP-RTK correction data format (RTCMSSR)
- Expansion of the transmission of SSR-based corrections via DAB+ service to a **larger service area** (e.g., Europe)
- Availability of **suitable mobile user hardware** for an excellent DAB+ reception
- Availability of high-precision GNSS modules that **accept** external correction data at all and for an **attractive** price

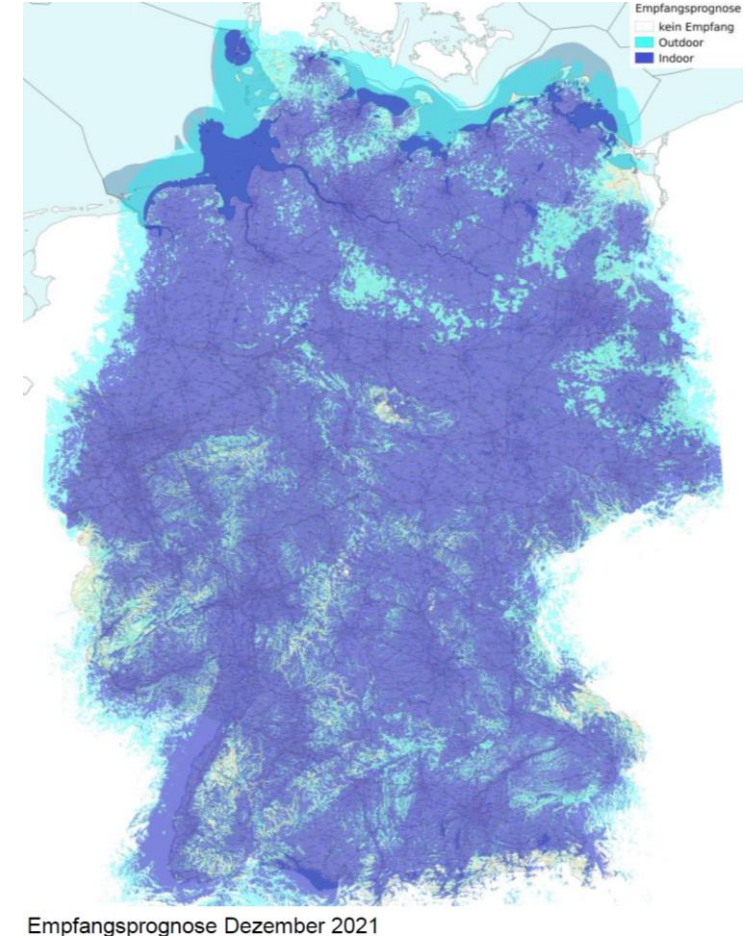


Airspy – mini DAB+ receiver
Foto: www.airspy.com

Competitive characters of the product

SSRoverDAB+

- **Correction data reception**
 - Coverage area of DAB+ in Germany
 - No costs for the data reception (data volume)
 - Existing hardware (DAB+ antenna) may be used
- **Security**
 - Data generation and provision is controlled by the (German) government
 - Broadcast solution - no user positions have to be transferred to the server
- **Flexibility and redundancy**
 - The same data stream can be received via DAB+ and mobile Internet (switching option)



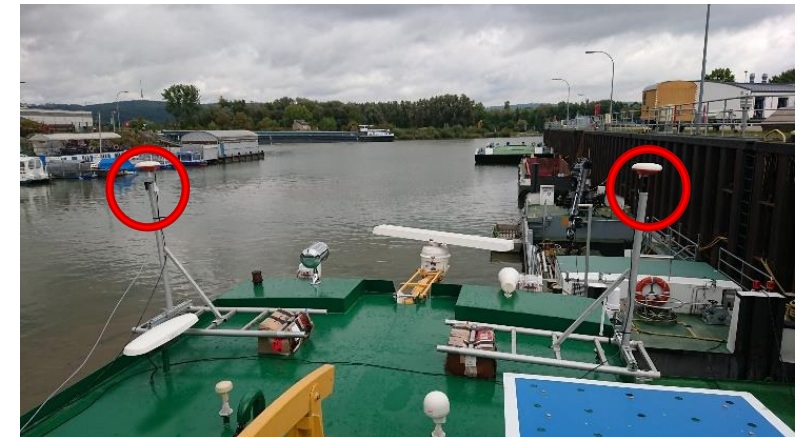
Potential markets for a future product

SSRoverDAB+

- Machine applications
 - Agriculture, forestry and construction
 - Automotive, railways and inland waterways
 - UAV, robotic, precise IoT
- Geodetic applications
 - Surveying, precise GIS
 - Geo-monitoring
- Others



icons: image courtesy of Flaticon



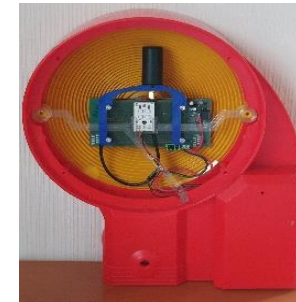
Impact of the project on Alberding GmbH

SSRoverDAB+

- Chance to stay in the precise GNSS market because of competitiveness in pricing and performance
- Growth of the company with the growing market of precise GNSS applications (IoT, automation, digitalisation, robotic)
- Recognition and reputation of Alberding GmbH will increase in the GNSS market by leading successfully research and innovation projects
- International companies and organisations will recognise Alberding GmbH as a potential partner for:
 - Developments and system integration
 - Buying and distributing Alberding products
 - Research projects
- Visibility of technology development expertise in Europe



GEO-MICHEL



A08-Bake



Intelligent buoy



Geo-Monitoring

Agenda

SSRoverDAB+

- 1) Project motivation
- 2) Project goals, tasks and structure
- 3) Outcome of the project
- 4) Product opportunities
- 5) Benefits of working with ESA**
- 6) Questions and answers



- Advantages of the support of ESA
 - International view on the applications
 - Overview on ongoing research developments
 - Experiences in project management
 - Strength, weaknesses and project focus
 - European visibility of the project
 - International approach for the products
 - Help to address the right markets
- Thank you very much for the funding of this project.

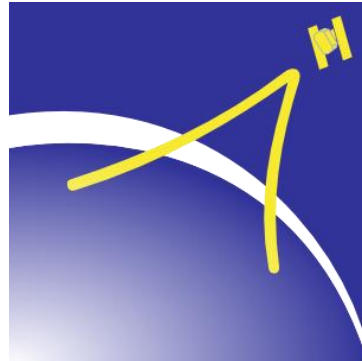


Agenda

SSRoverDAB+

- 1) Project motivation
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- 4) Product opportunities
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