NAVISP-EL2-069 “SSRoverDAB+”

Final Presentation

29th June 2023, 10:00 – 11:30 CET

J. Alberding, *Alberding GmbH*, **Dr. M. Schmitz**, *Geo++ GmbH,*

Dr. H-J. Euler, *inPosition GmbH*, **Dr. F. Garzia**, *Fraunhofer IIS,*

C. Fiermann, *Fraunhofer IIS*, **D. Stöcker**, *Alberding GmbH*

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

Fraunhofer inPosition Geo++ Alberding

Project motivation – precise GNSS market today

- 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.

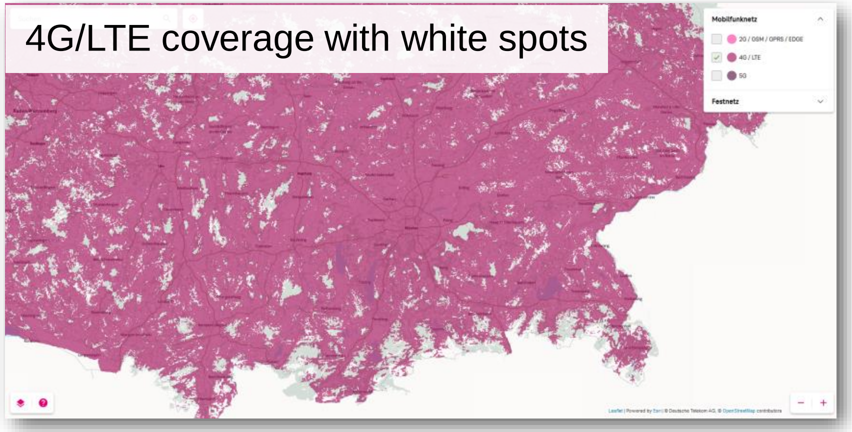
Alberding telemetry & positioning sensors

Project motivation – service provider perspective

SSRoverDAB+

- 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/

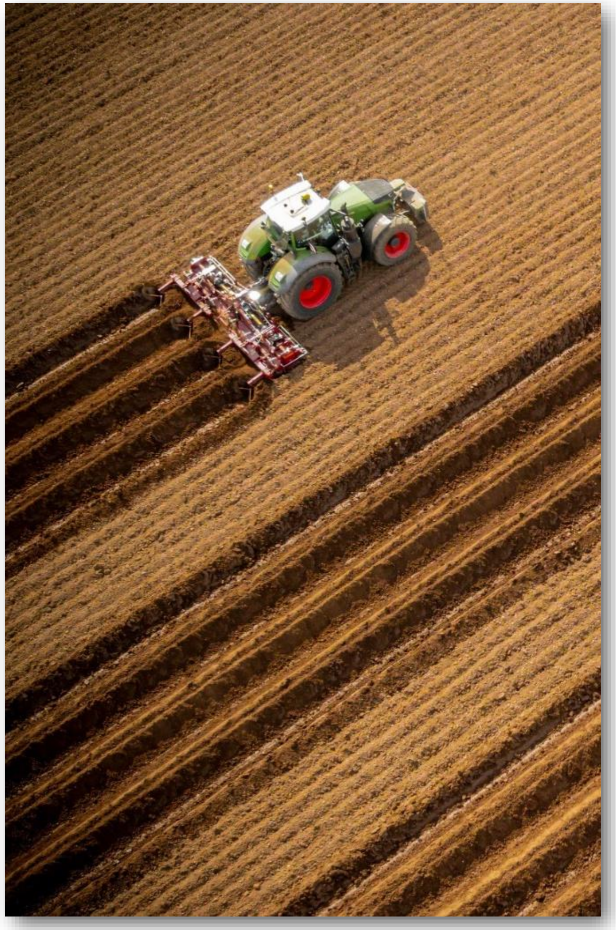
https://www.dabplus.de/empfang/

Fraunhofer · inPosition · Geo++ · Alberding

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).



Fraunhofer inPosition Geo++ Alberding

Agenda

SSRoverDAB+

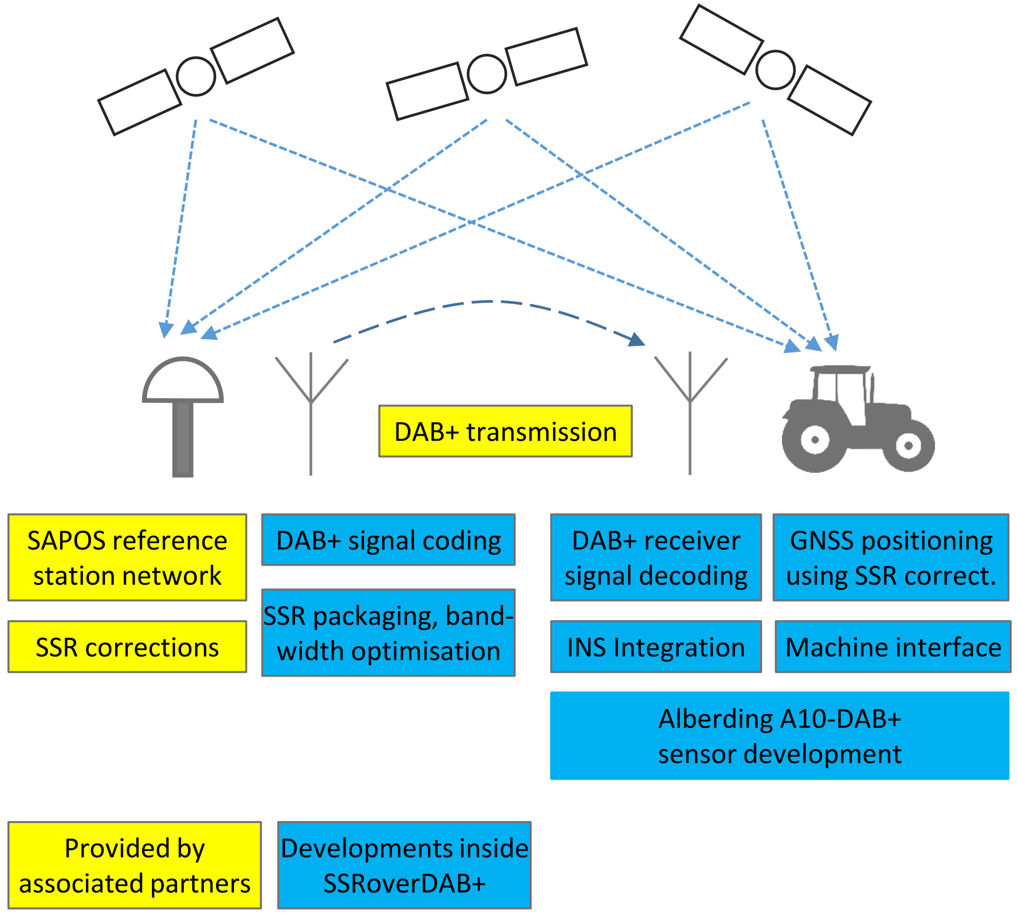
1) Project motivation
2) **Project goals, tasks and structure**
3) Outcome of the project
4) Product opportunities
5) Benefits of working with ESA
6) Questions and answers

Fraunhofer inPosition Geo++ Alberding

Project goals

SSRoverDAB+

- **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



Fraunhofer   inPosition   Geo++   Alberding

Project partners

SSRoverDAB+

NAVISP-EL2-069 "SSRoverDAB+"

Alberding GmbH (DE)

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

Fraunhofer IIS (DE)

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

inPosition gmbh (CH)

- Receiver independent PPP-RTK solution

Geo++ GmbH (DE)

- SSR correction generation
- SSR2OBS processing

BKG (DE)*

Bundesamt für Kartographie und Geodäsie

- DAB+ data channel provider (Bundesmux)

LDBV (DE)*

- Reference network provider
- Correction service provider

BayWa AG (DE)*

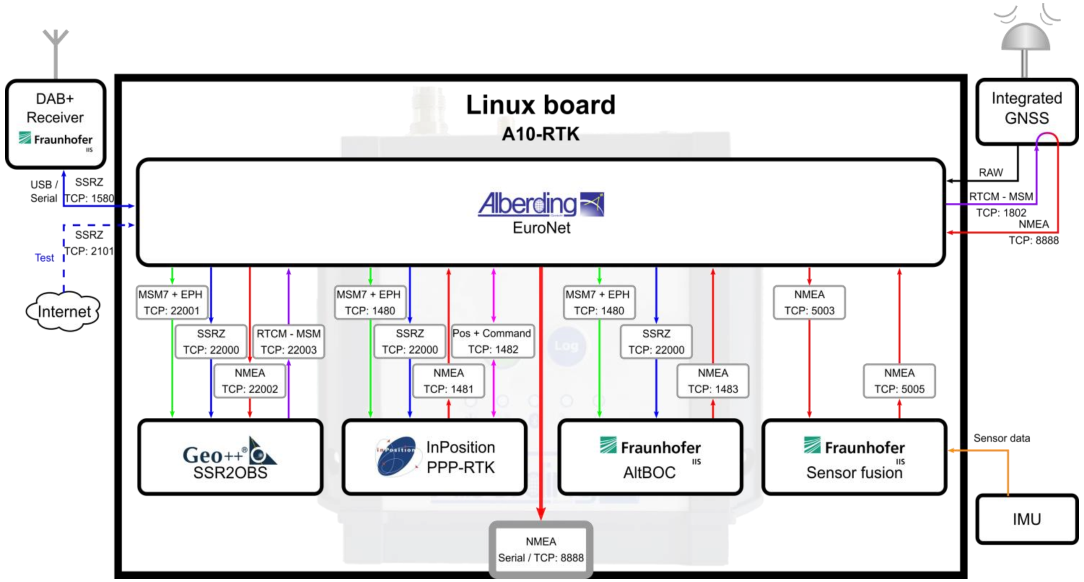
- Support of agricultural field tests

* Associated partners

Project tasks

SSRoverDAB+

- 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**



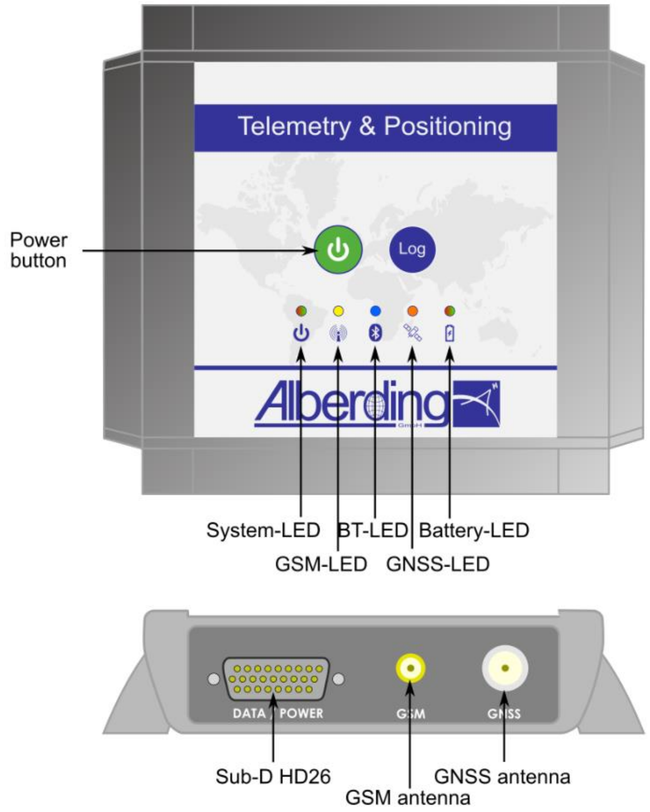
Linux board of the A10-RTK sensor

Fraunhofer
inPosition
Geo++
Alberding

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



Fraunhofer inPosition Geo++ Alberding

Agenda

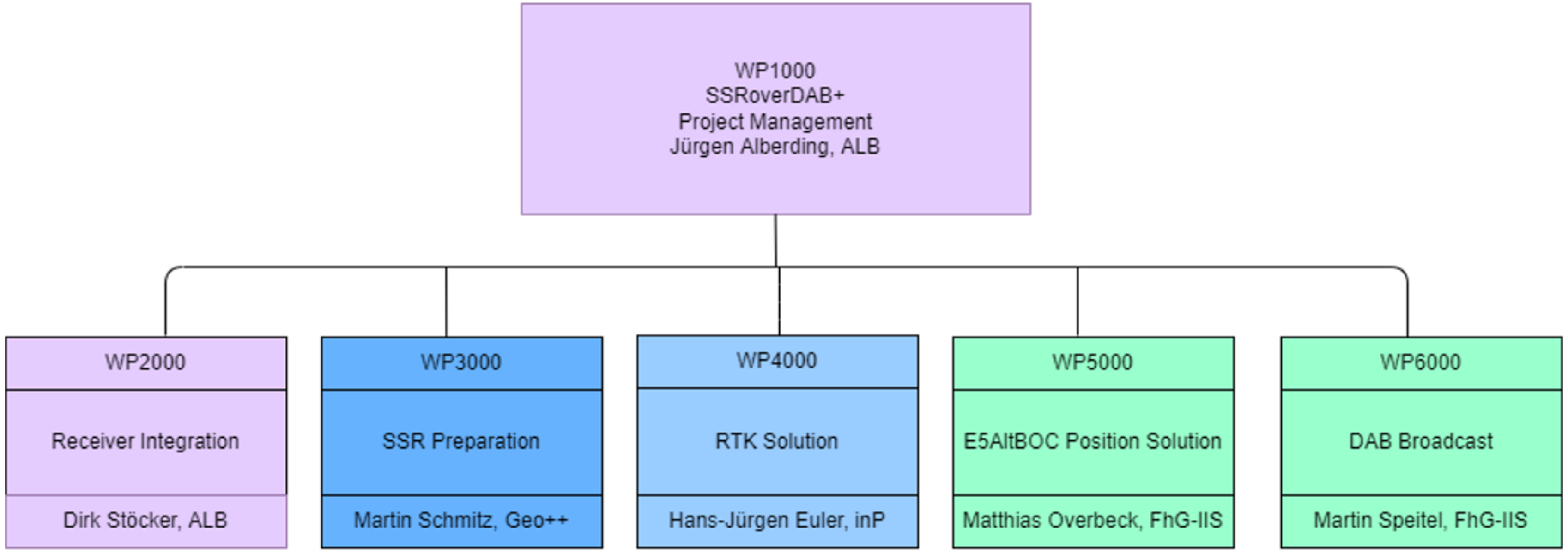
SSRoverDAB+

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

Fraunhofer inPosition Geo++ Alberding

Project structure

SSRoverDAB+



Fraunhofer inPosition Geo++ Alberding

Outcome of the project

WP3000 - SSR Preparation

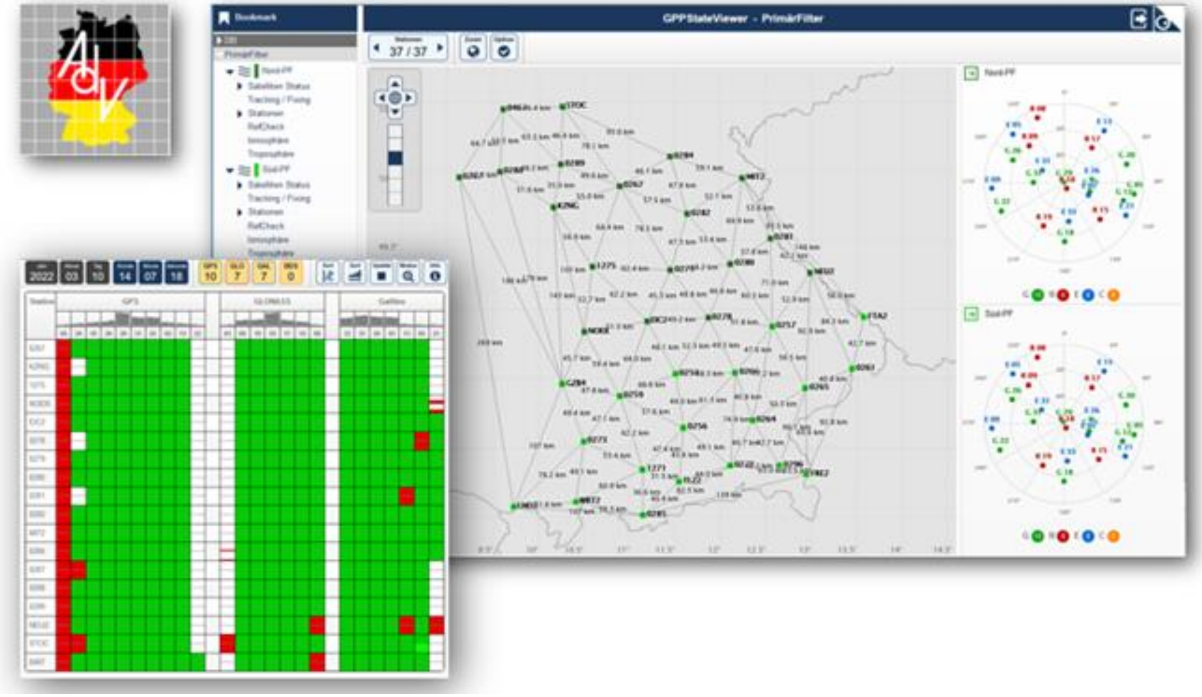
Geo++ GmbH | Hannover

Dr Martin Schmitz

SSR Preparation

SSRoverDAB+

- **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**

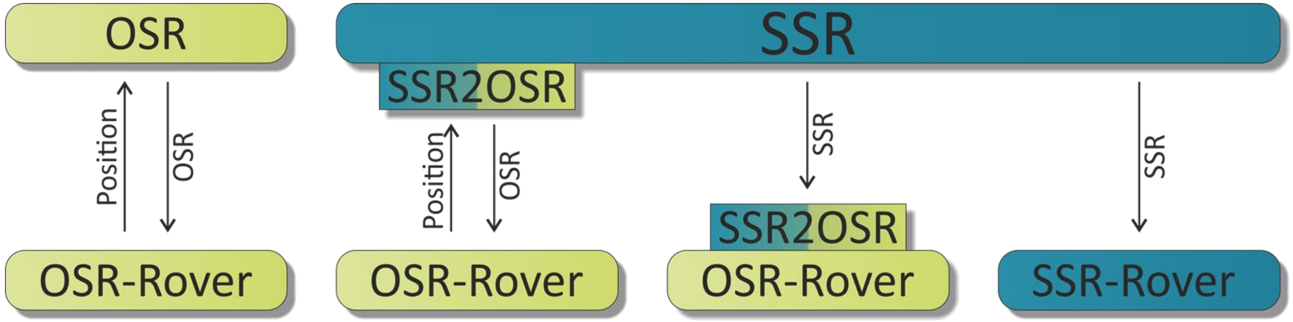


Fraunhofer inPosition Geo++ Alberding

SSR Preparation

SSRoverDAB+

- **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



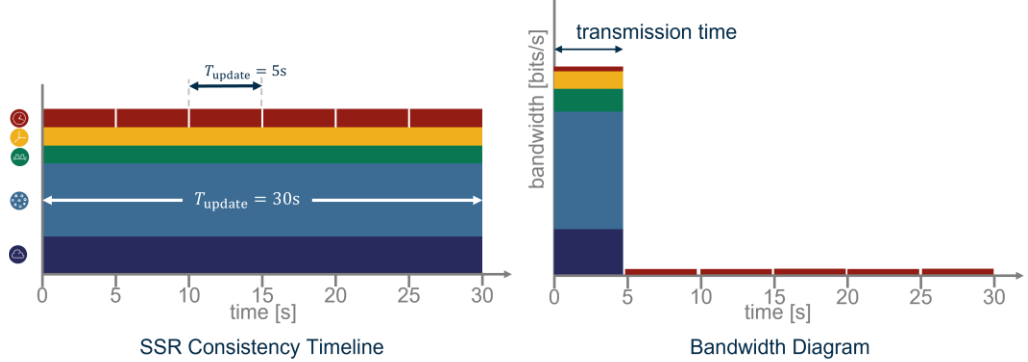
GNSS correction concepts:
SSR – state space representation
OSR – observation space representation

Fraunhofer | inPosition | Geo++ | Alberding GmbH

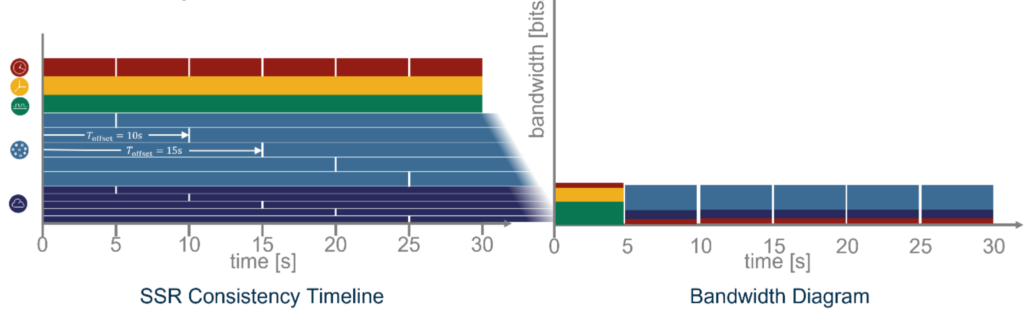
SSR Preparation

- 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

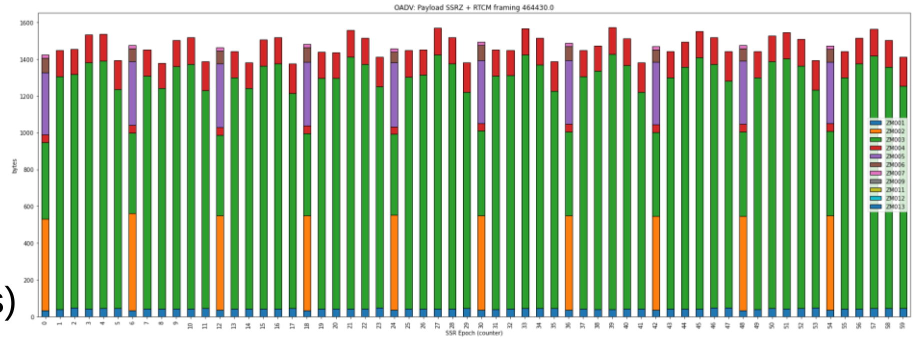
SSRZ **30/5 s** update rate



SSRZ **30/5 s** update rate with **individual offsets** for gridded atmosphere



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



Fraunhofer inPosition Geo++ Alberding

Outcome of the project

SSRoverDAB+

WP4000 - RTK Solution

inPosition gmbh | Heerbrugg/Schweiz

Dr Hans-Jürgen Euler

Fraunhofer

inPosition

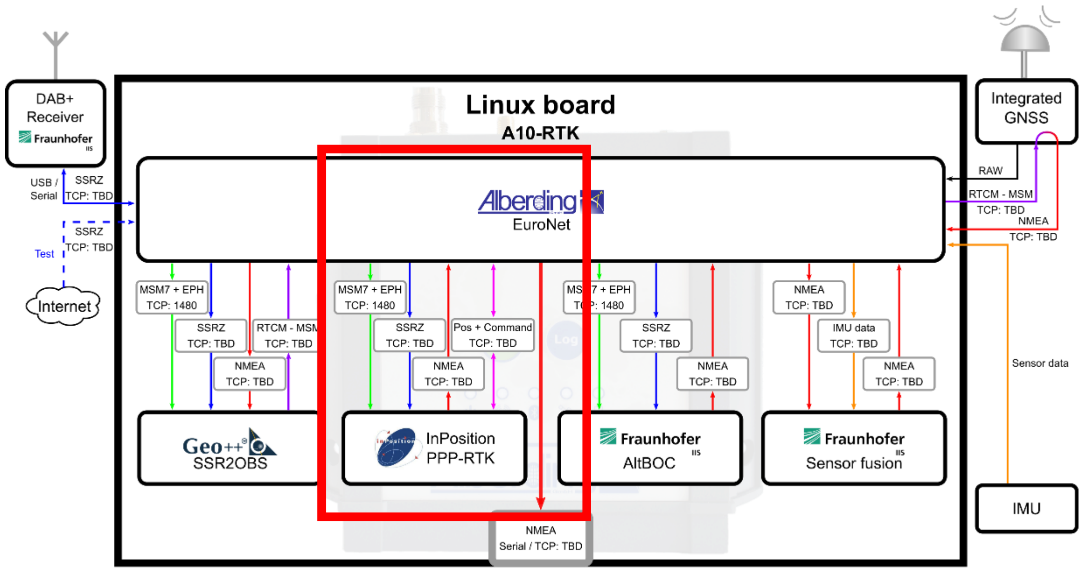
Geo++®

Alberding GmbH

RTK Solution – Objectives

SSRoverDAB+

- 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

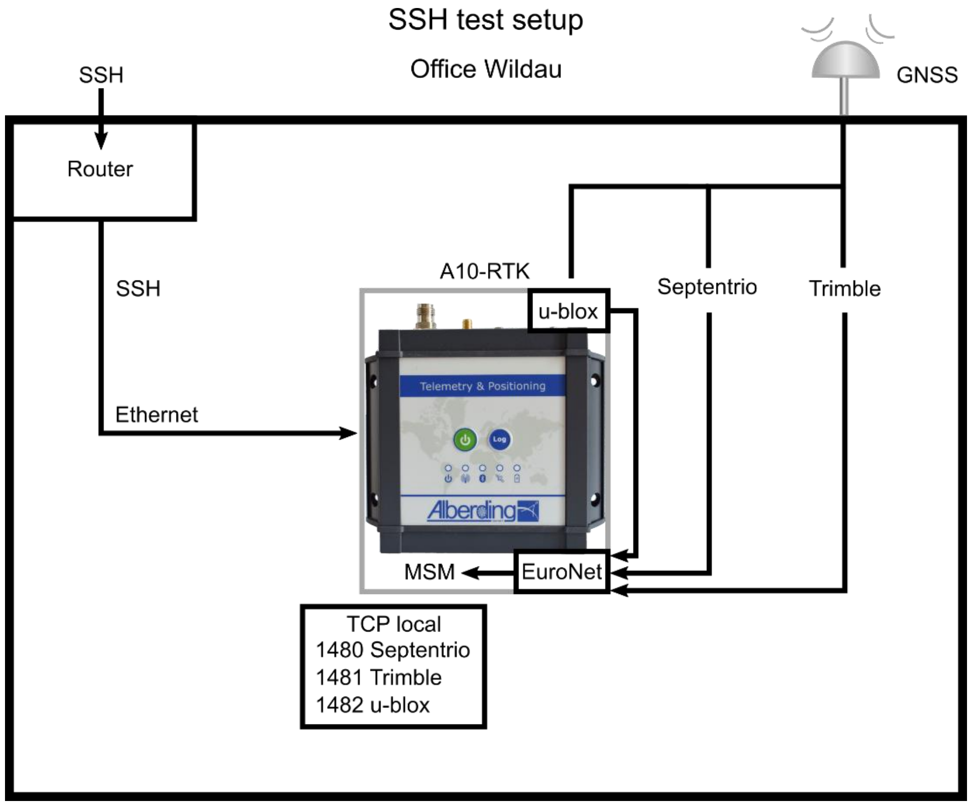


Fraunhofer inPosition Geo++ Alberding

RTK Solution – Work

SSRoverDAB+

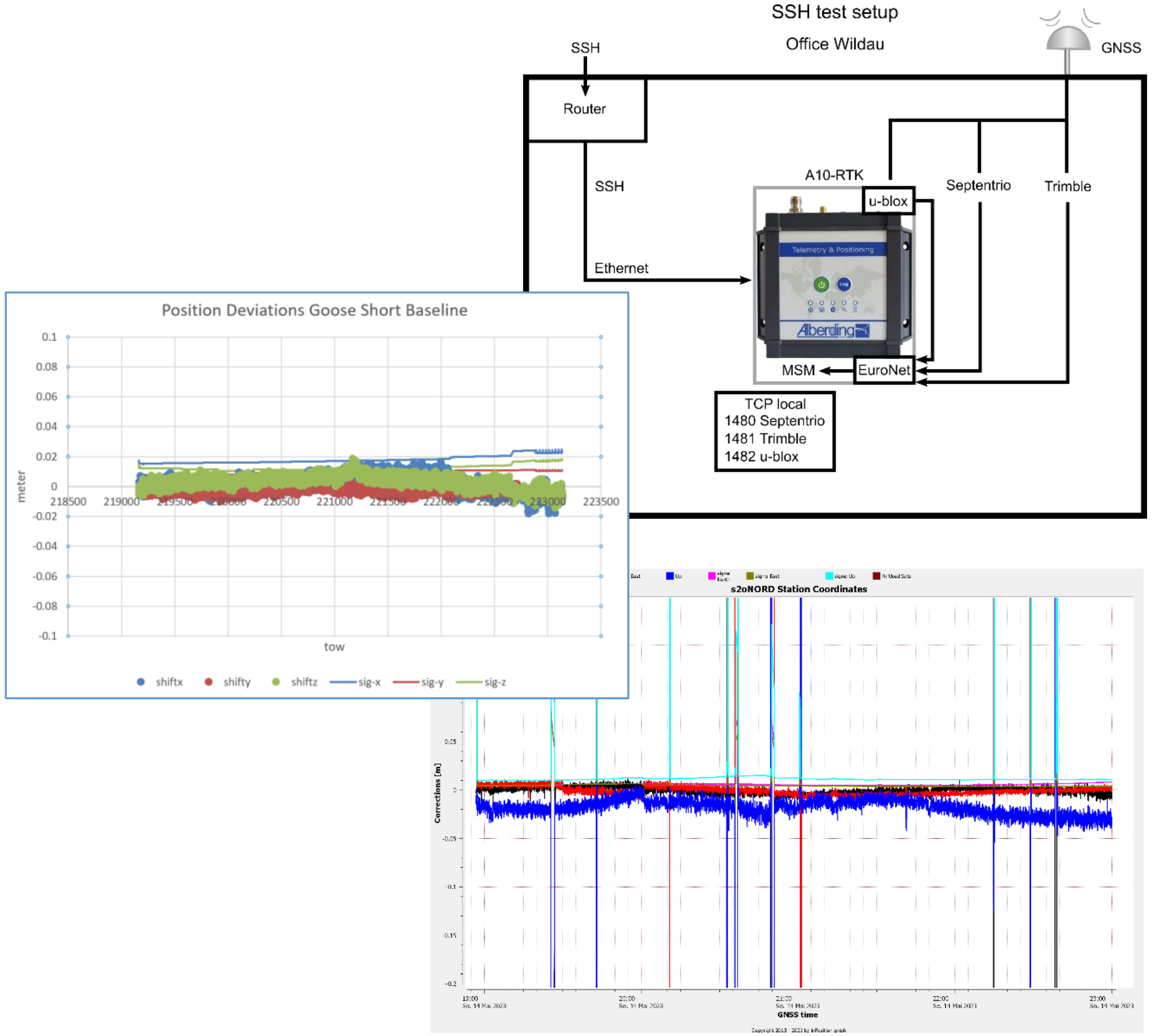
- inPosition's EdgeRtkPpp ported to Ubuntu Linux
  - Cross-compilation for A10's embedded board on Linux
- Implementation of SSRZ message structure
  - Reception of messages
  - Decoding
  - Application of corrections
- Implementation of numerically compatible models
  - Tropospheric model with Boehm 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



Fraunhofer

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



Outcome of the project

SSRoverDAB+

WP5000 - E5AltBOC Solution

Fraunhofer IIS | Nürnberg

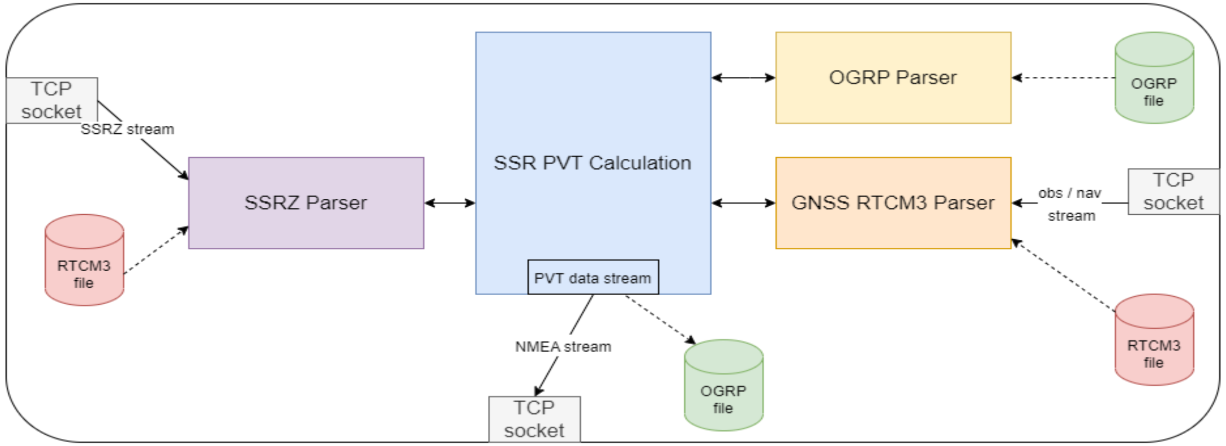
Dr Fabio Garzia

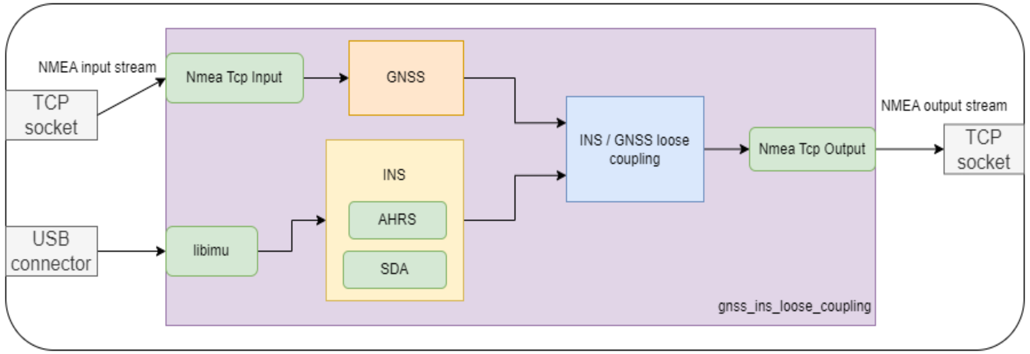
Fraunhofer inPosition Geo++ Alberding

E5AltBOC Solution

SSRoverDAB+

- 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





Fraunhofer inPosition Geo++ Alberding

E5AltBOC Solution

SSRoverDAB+

- 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

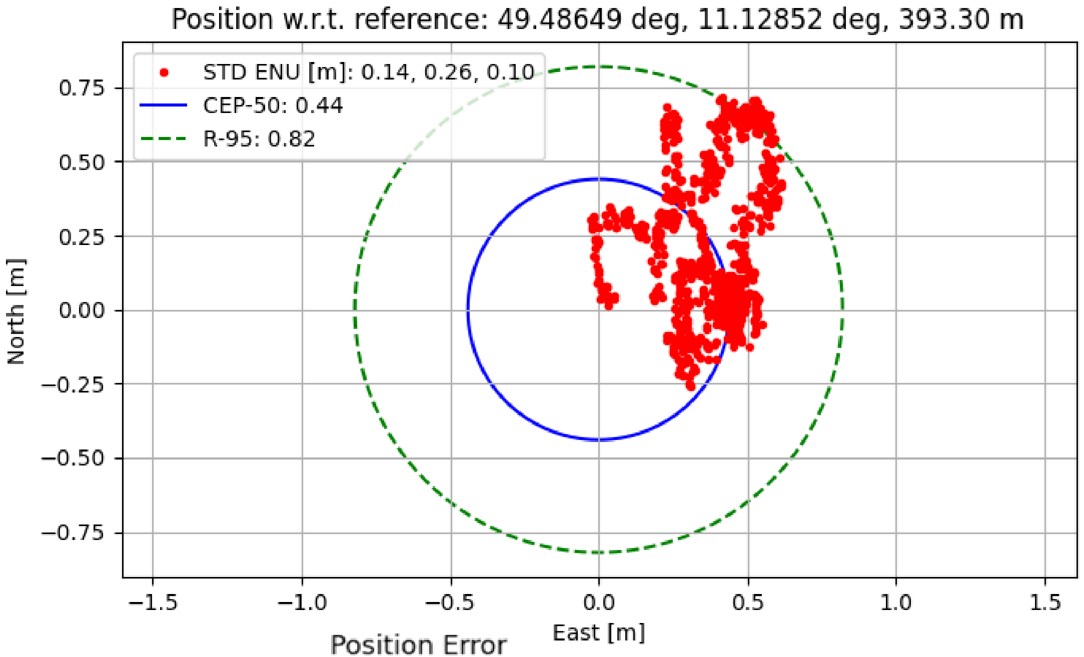
```
A10-50134:~ # ssrz_pvt --help
SSRZ PVT SW options:
  --help                               Show this help message

  --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!
```

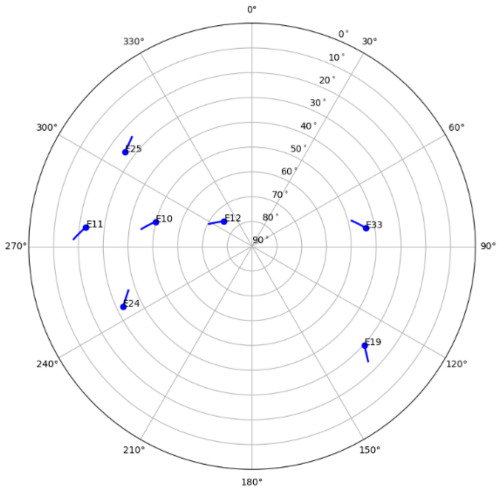
```
A10-50134:~ # gnss_ins_loose_coupling --help
GNSS/INS Fusion SW options:
  --help                               Show this help message

  --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 (=0.10000000000000001)
                                       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
```


Fraunhofer inPosition Geo++ Alberding

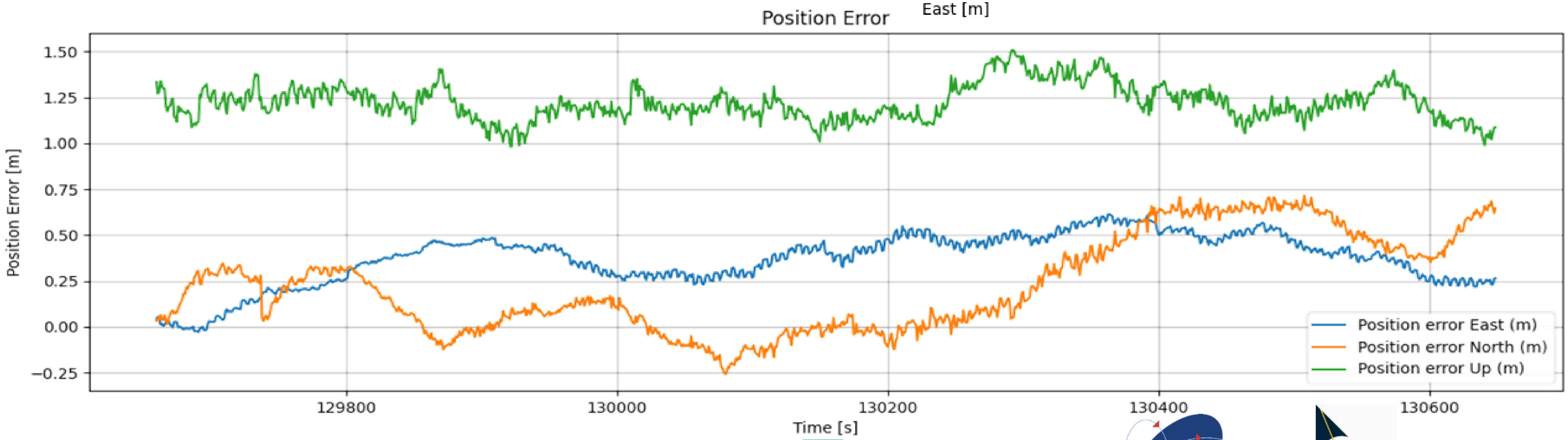
E5AltBOC Solution

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





SSRoverDAB+



Fraunhofer
inPosition
Geo++®
Alberding GmbH

Outcome of the project

WP6000 - DAB+ Broadcast

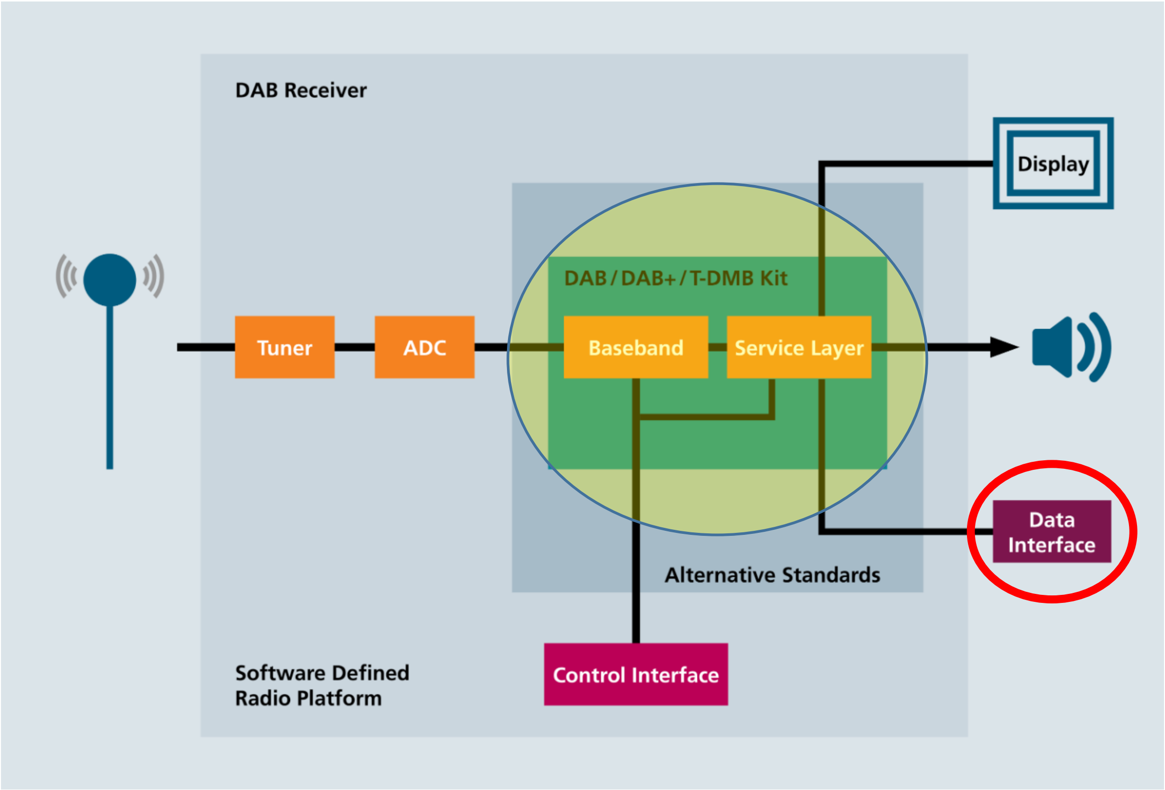
Fraunhofer IIS | Erlangen

Christian Fiermann

DAB+ Broadcast - Objectives

SSRoverDAB+

- 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+

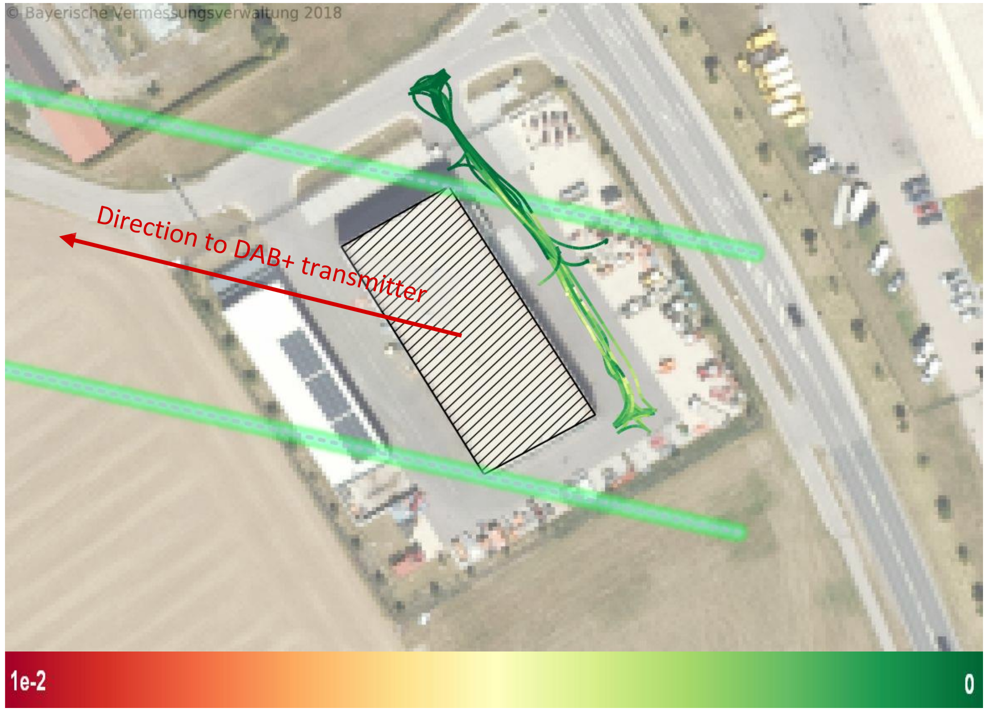


Fraunhofer inPosition Geo++ Alberding

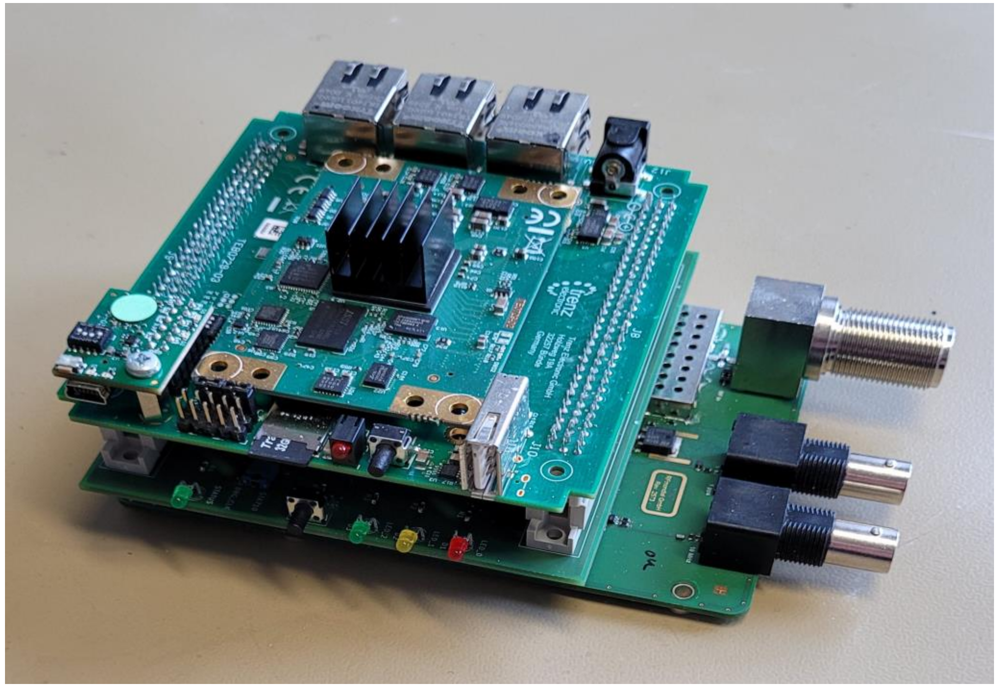
DAB+ Broadcast - Work

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

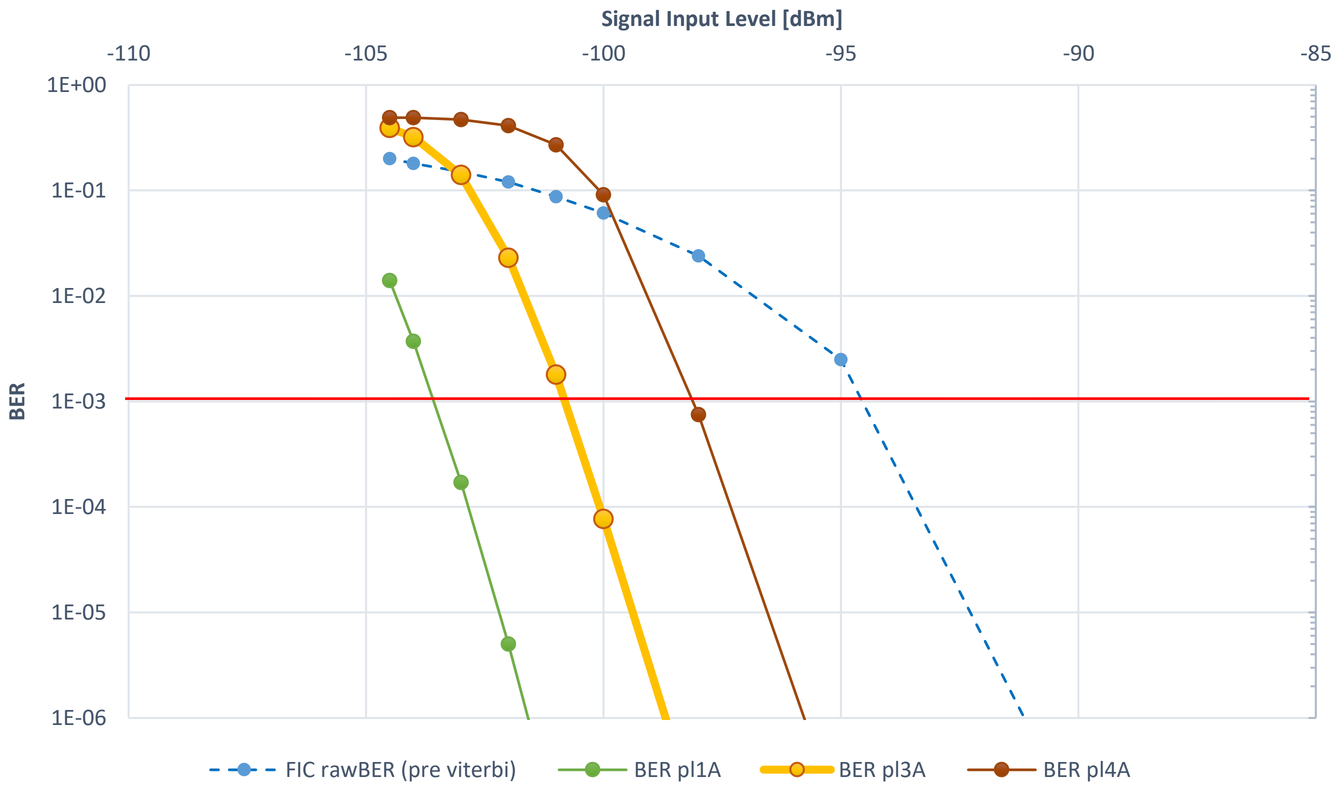


Fraunhofer inPosition Geo++ Alberding

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.



Fraunhofer inPosition Geo++ Alberding

Outcome of the project

SSRoverDAB+

WP2000 Receiver Integration

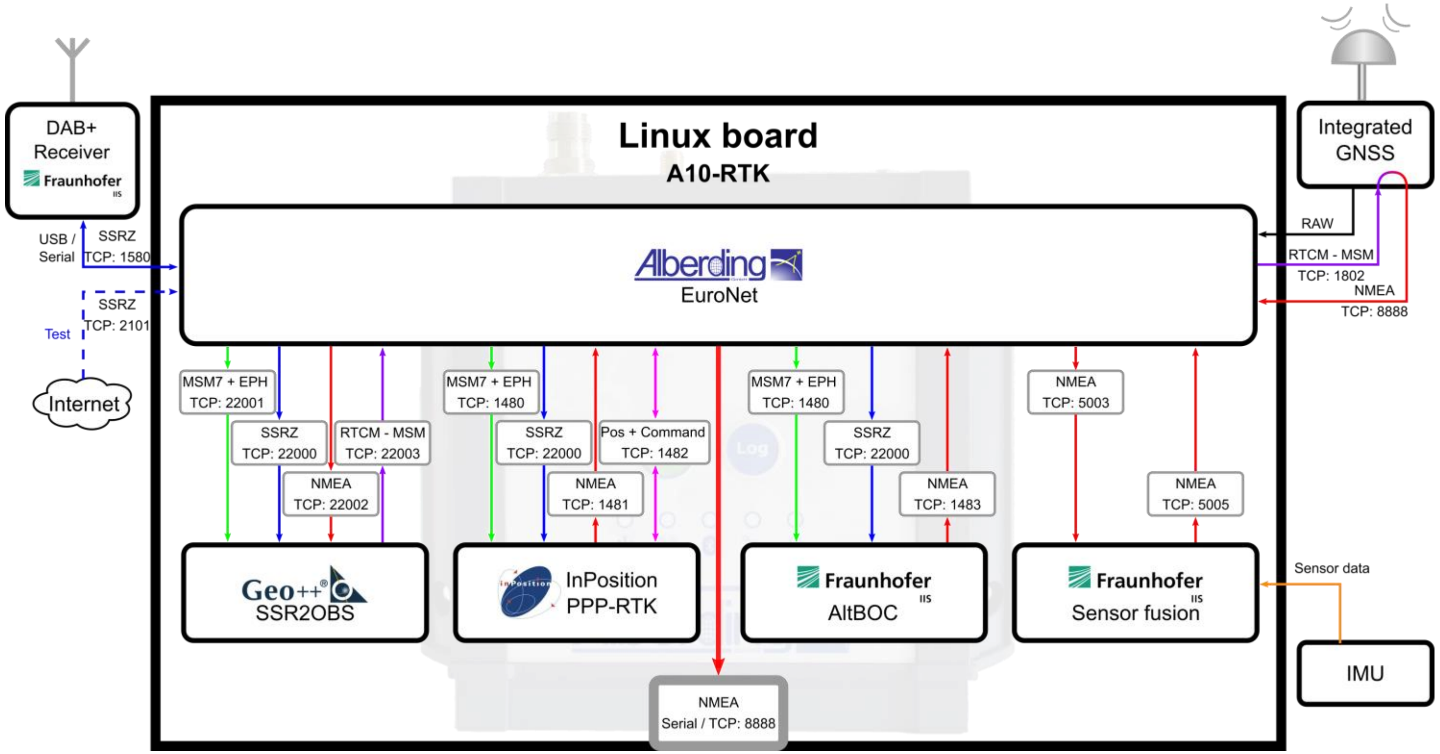
Alberding GmbH | Wildau

Dirk Stöcker

Fraunhofer inPosition Geo++ Alberding

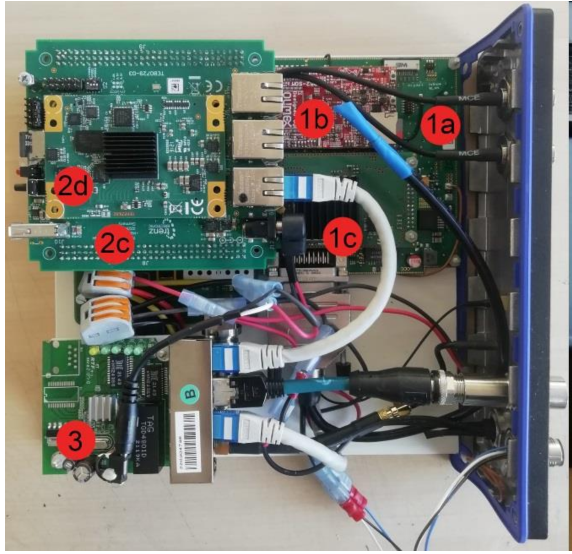
Receiver Integration – Objectives

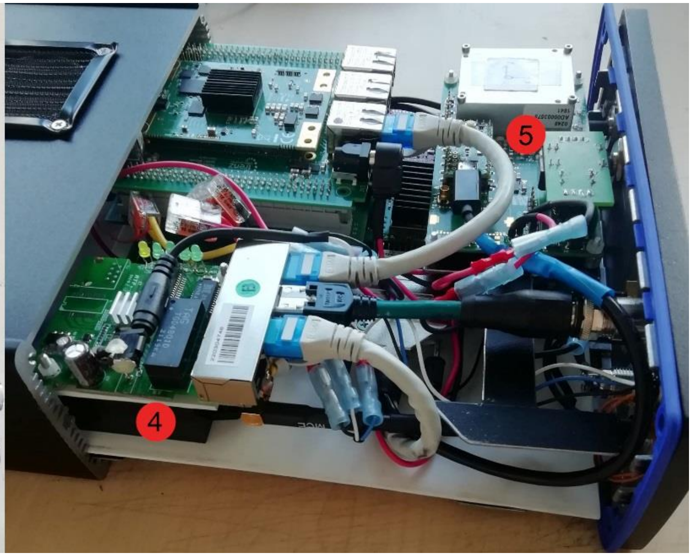
- Use A10-RTK for DAB+ reception
- Install updated SSR2OBS
  - Feedback channel integrated
- Install new software
  - inPRTK
  - FHG Sensorfusion
  - FHG E5AltBOC solution
- Create interface to agricultural machines
- Test data flow and position solutions



Receiver Integration – DAB+, LTE, GNSS receiver

- 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



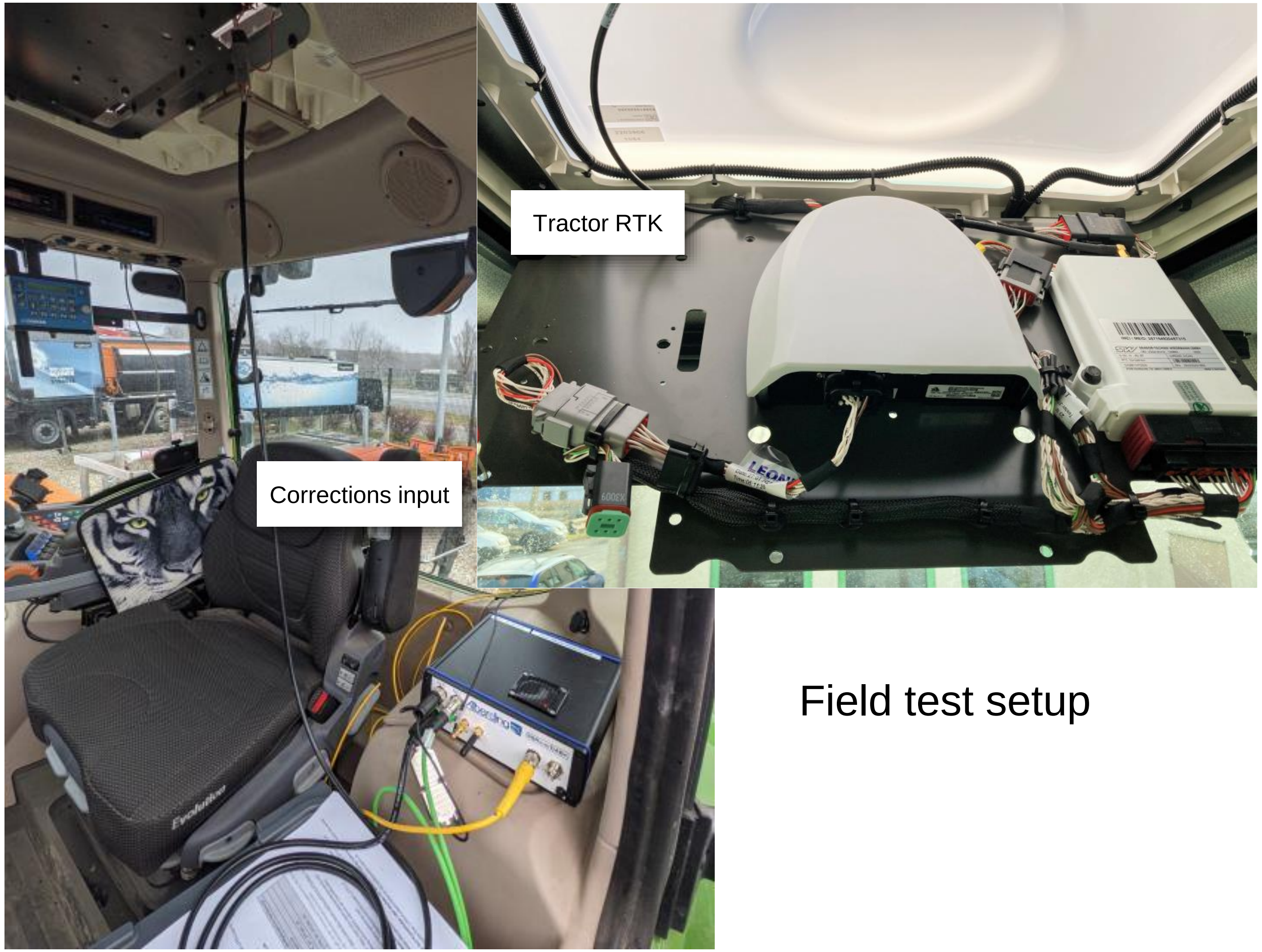


Receiver Integration – Tests

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**



Field test setup

Fraunhofer · inPosition · Geo++ · Alberding

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

Fraunhofer inPosition Geo++® Alberding GmbH

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

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

Fraunhofer inPosition Geo++ Alberding

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

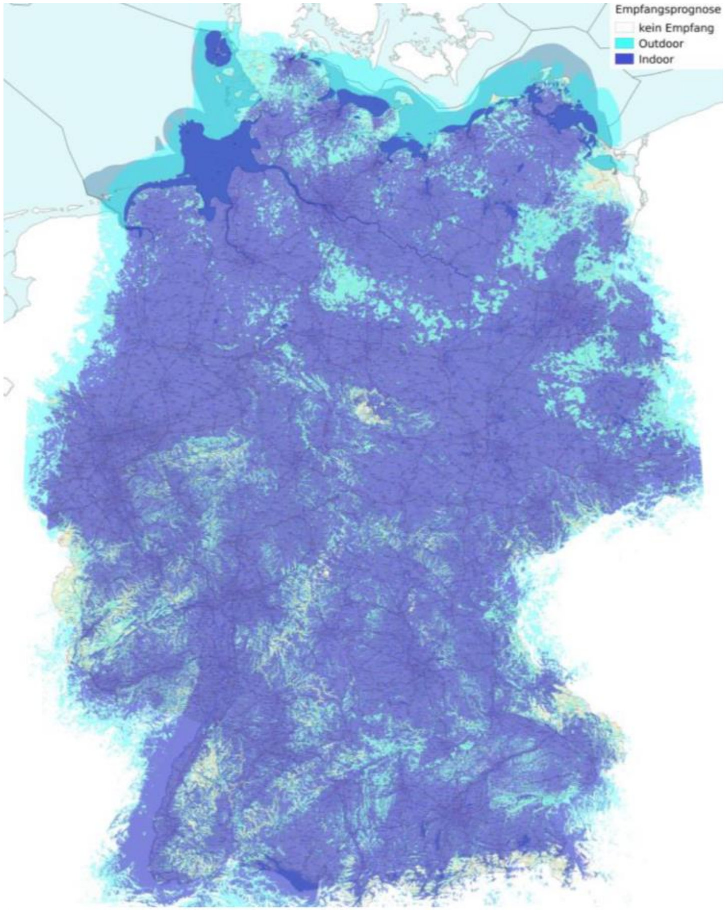
Airspy – mini DAB+ receiver
Foto: www.airspy.com

Fraunhofer inPosition Geo++ Alberding

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)



Empfangsprognose Dezember 2021

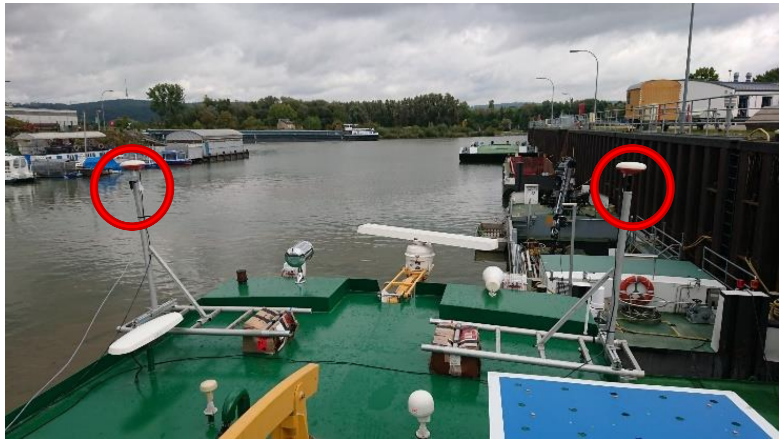
Fraunhofer · inPosition · Geo++ · Alberding

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

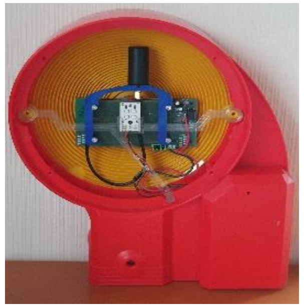


Fraunhofer inPosition Geo++ Alberding

Impact of the project on Alberding GmbH

- 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

Fraunhofer inPosition Geo++ Alberding

Working with ESA

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

Fraunhofer inPosition Geo++® Alberding

Questions and answers

Contact

SSRoverDAB+

Alberding GmbH (Project Lead)

Ludwig-Witthöft-Straße 14
D-15745 Wildau

Tel: +49 3375 2519 800
Email: info@alberding.eu
Web: www.alberding.eu

www.ssroverdab.eu

Fraunhofer inPosition Geo++® Alberding GmbH