NAVISP2-EL-112

RESILIENT POSITIONING NAVIGATION AND TIMING BASED ON 5G BROADCAST

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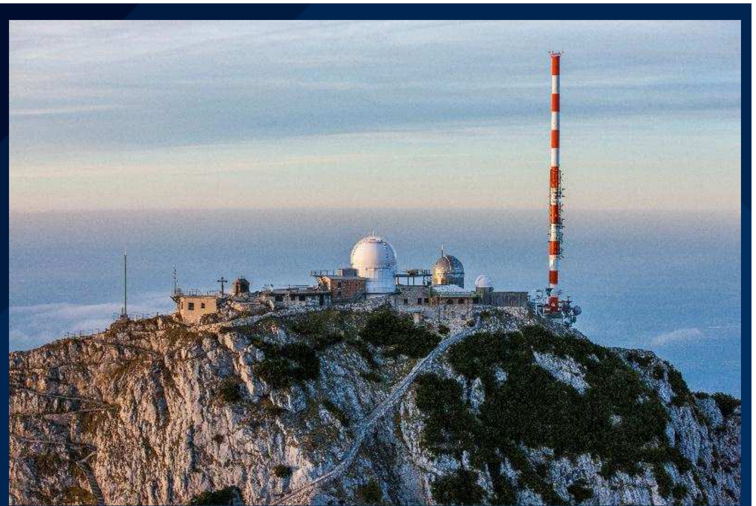
Make ideas real



AGENDA

- ► Introduction
- ► Control and Synchronization Segments
- ► User Segment
- ► Transmitter Segment
- ► Lab Integration and Field Tests
- ► Observations, Conclusions & Outlook

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INTRODUCTION

WHAT SHOULD A GNSS BACKUP SYSTEM LOOK LIKE?

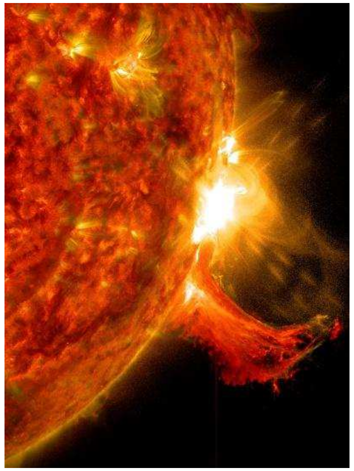
- High signal power → difficult jamming
- Low exposure to solar storms & space debris
- Low dependency on other infrastructure (e.g. power grid)
- A ***dissimilar*** backup system is desirable
  - Other frequency range (not L-band)
  - Other transmitter location (not MEO orbit)
- Cost effective to deploy and maintain
- Performance?
  - EU: technology demos requested that can achieve:

    < 100m (95%)

    < 1 µs UTC time sync (3-sigma)

    See also DEFIS/2020/OP/0007

A low-cost jammer
Source: some online shop



Solar eruption
Source: NASA/SDO/ Wiessinger

THE IDEA

- ► Use existing TV broadcasting infrastructure for timing and navigation
  - – Re-use towers, amplifiers, frequencies, antennas, …
  - – UHF band (~470-698 MHz)
  - – typ. ~10-100 kW ERP
- ► Use of worldwide 5G Broadcast standard
  - – UTC timestamp and positioning features available
  - – Easy integration in 5G chipsets for mass-market receivers
  - – Minimal overhead for navigation and timing, majority remains for broadcasting
- ► Minor upgrade for existing R&S TV transmitters

THE CHALLENGE & THE TEAM

- Improve jitter of TV transmitters to nano-second range (main focus of this project)
- Synchronize the transmitters
- Build a test receiver
- Demonstrate that concept is working
  - Lab test
  - Field test

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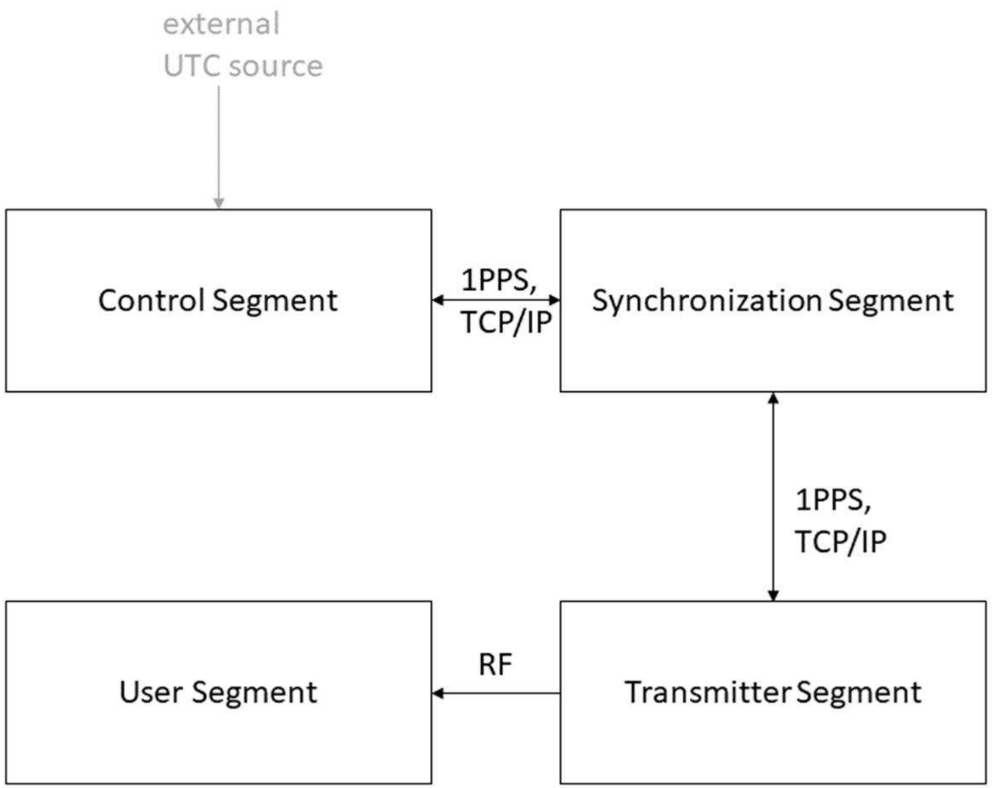
SYSTEM DESIGN

- Similar segments as in a GNSS, but much simpler
- Synchronization segment can be implemented in various ways, e.g. via PTP-capable fiber, microwave links or hardened GNSS receivers



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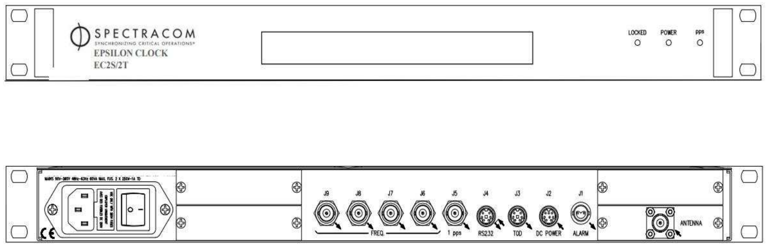
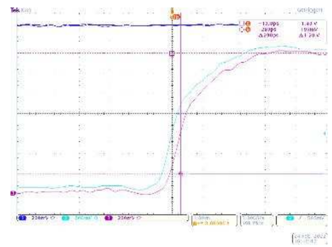
CONTROL AND SYNCHRONIZATION SEGMENTS

CONTROL & SYNCHRONIZATION

- ► Control segment main clock selection and integration
  - – Spectracom Epsilon Clock EC2S selected
  - – GPS Disciplined Rubidium oscillator

- ► Synchronization segment for lab tests
  - – PTP White Rabbit
  - – WR-LEN-KIT from SevenSolutions
  - – < 1ns jitter





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USER SEGMENT

TEST RECEIVERS

- Receiver A: R&S TSME Measurement receiver
  - ~10 ns TDOA accuracy, ~15 ns TOA accuracy
  - PPS-out for timing applications
- Receiver B: OBECA Open-source SDR based on LimeSDR
  - Affordable "starter-kit" for universities, students, …
- Position engine (used with both):
  - Based on open-source GPSTK
  - Weighted-Least-Squares Algorithm
  - Output: NMEA

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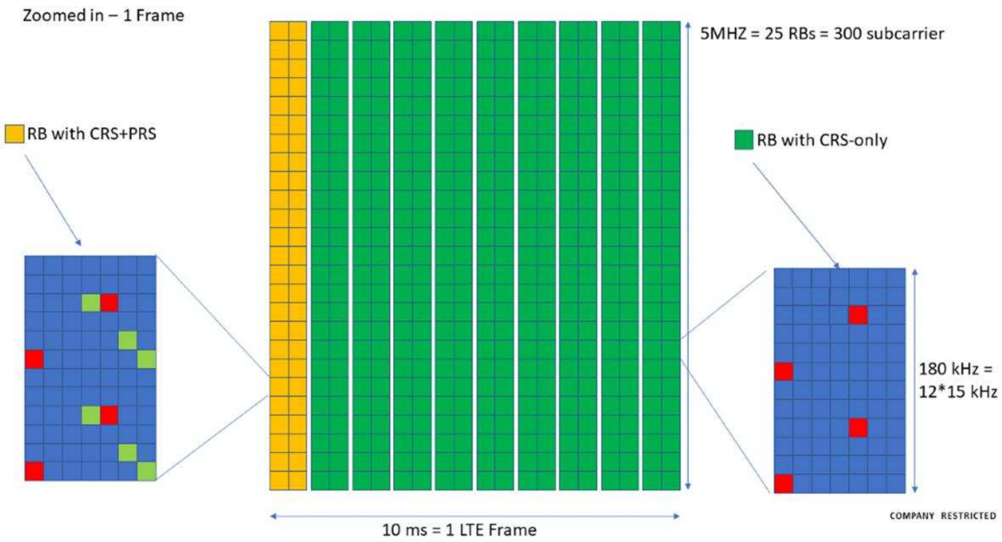
TRANSMITTER SEGMENT

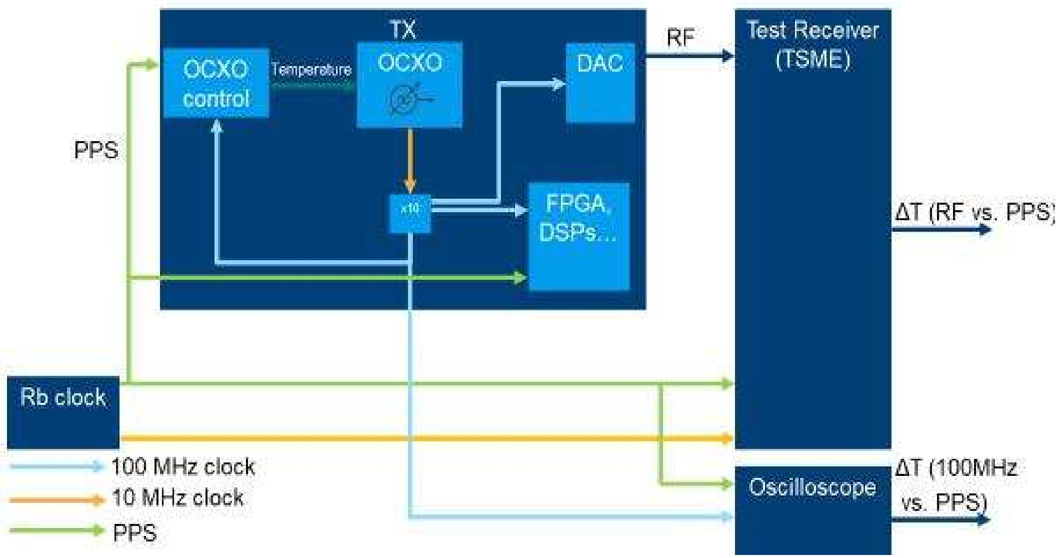
TRANSMITTER - ENHANCEMENTS

- Added PRS to FeMBMS encoder
- Implemented SIB16 for UTC timing
- Provisioned posSIBs (TX location, correction values). Identified necessary extensions in 3GPP for Broadcast



TRANSMITTER SEGMENT

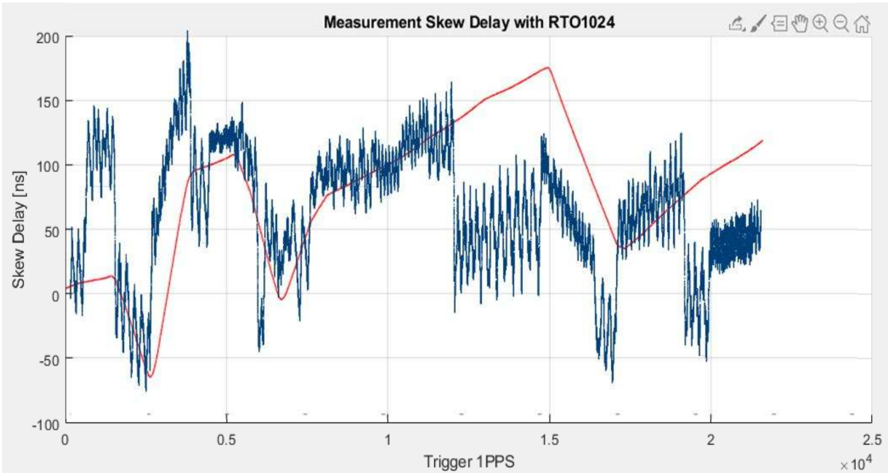
- Simplified TV transmitter diagram including measurement devices



TRANSMITTER ACCURACY – STATUS QUO

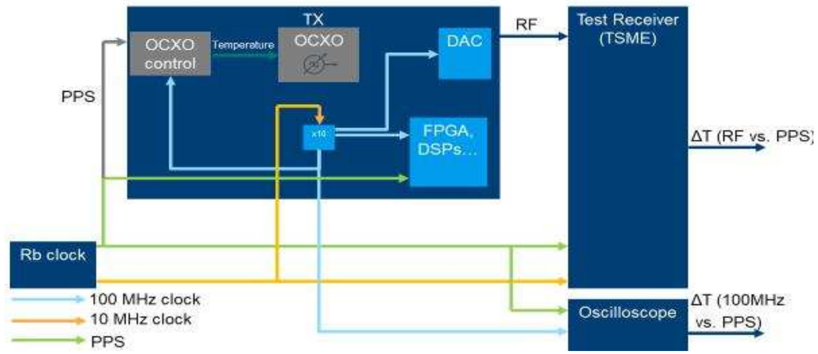
- The transmitter's OXCO error is the main error source of the RF signal's time inaccuracy
- Error contribution ~ 100 m (300 ns)
- Other Periodic and systematic errors visible
- Targeted Optimizations during this project:
  - Improve OCXO control
  - Improve SFN regulator

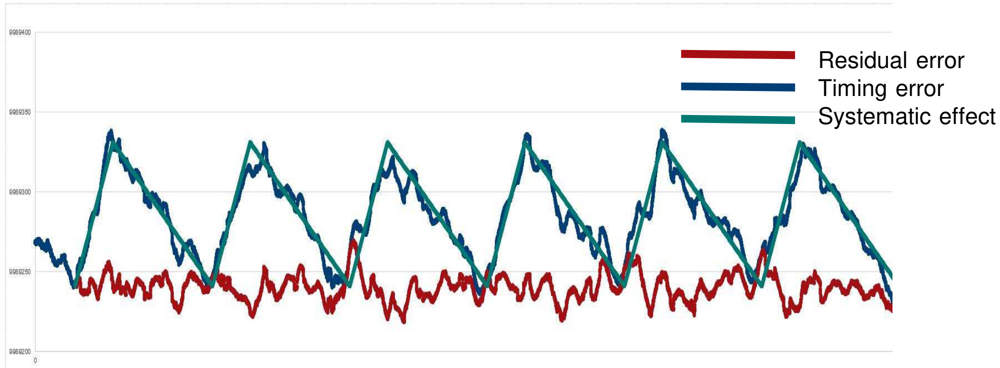
Accuracy-Analysis of RF Signal jitter (before this project)

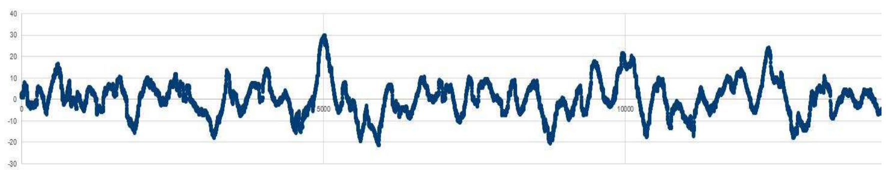


OCXO BYPASS

- If OCXO is bypassed, largest error removed, but still periodic 100 ns error visible
- SFN regulator causes periodic error. If mitigated, we would expect less than 50 ns error



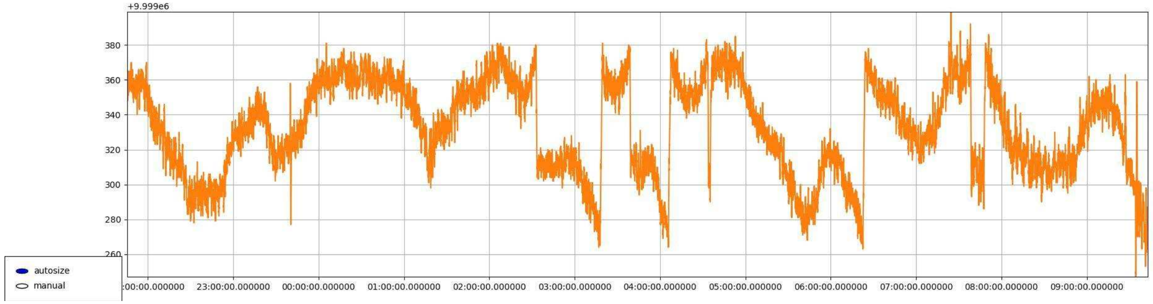




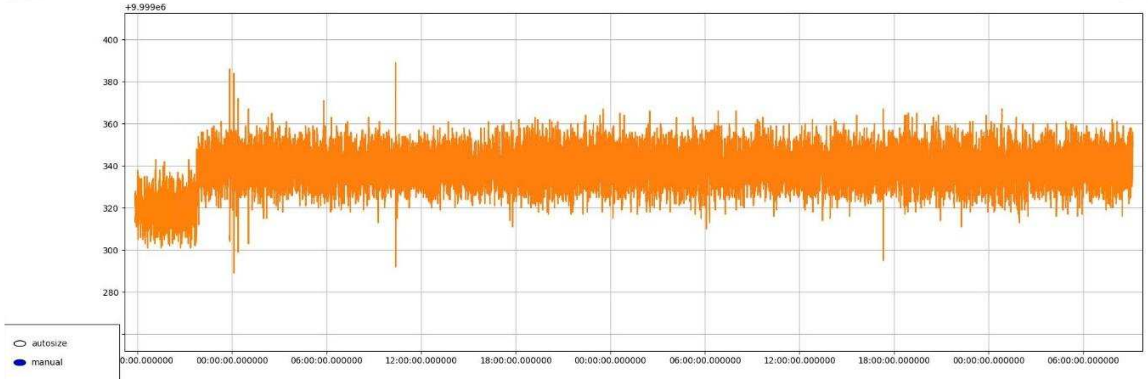
Residual error: 50 ns

OCXO AND SFN OPTIMIZATION

► Timing error < 40 ns



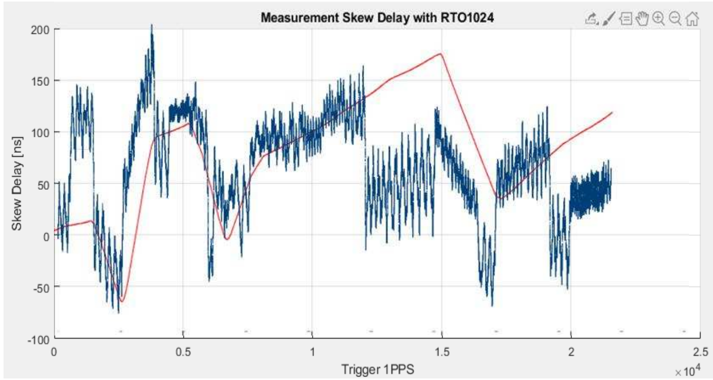
Remaining timing error (< 100 ns) after improvement of OCXO PID controller, without bypass

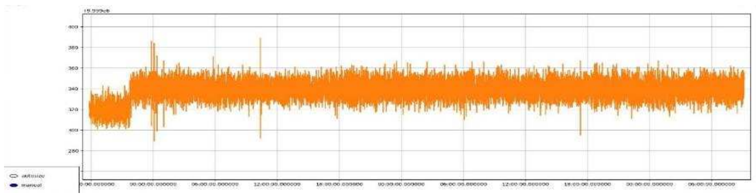


Remaining timing error (< 40 ns) after improvement of OCXO PID controller and SFN regulator

SUMMARY TRANSMITTER IMPROVEMENTS

- **TV transmitter jitter reduced from 100 m to 12 m**
- Further improvement technically possible





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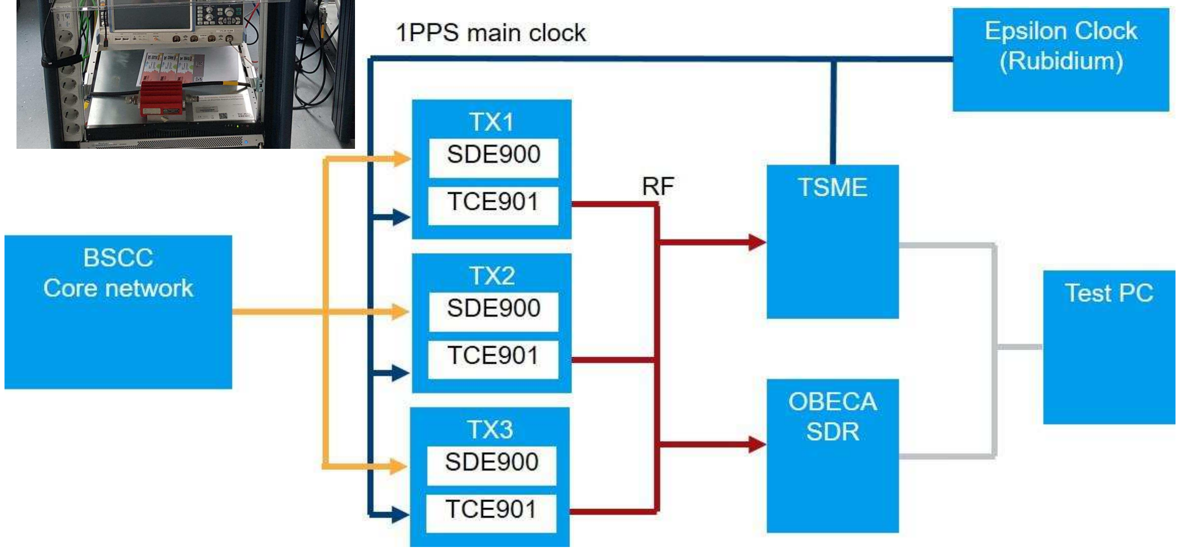
LAB INTEGRATION AND FIELD TESTS

LAB INTEGRATION

► Lab Testbed

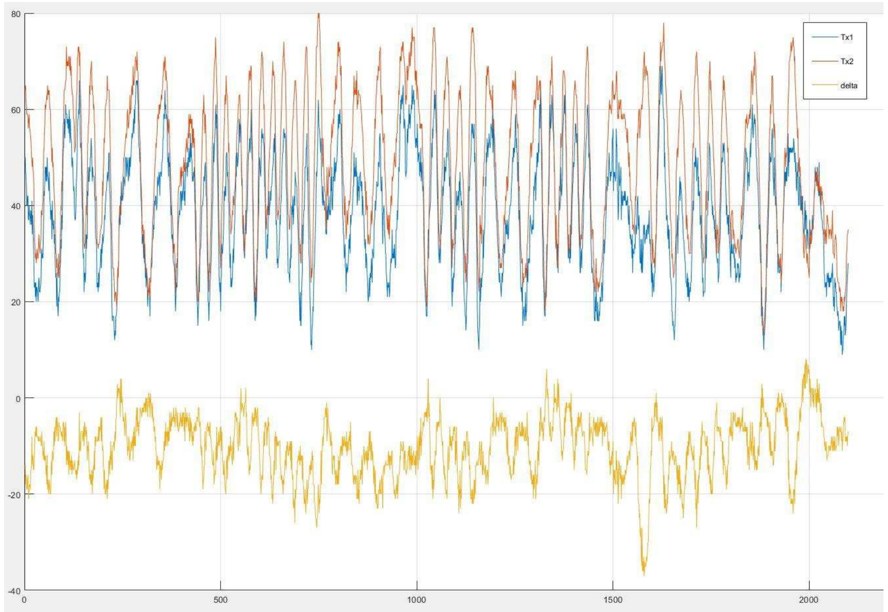
Transmitters

Receiver: TSME



SYNCHRONIZE TWO TRANSMITTERS

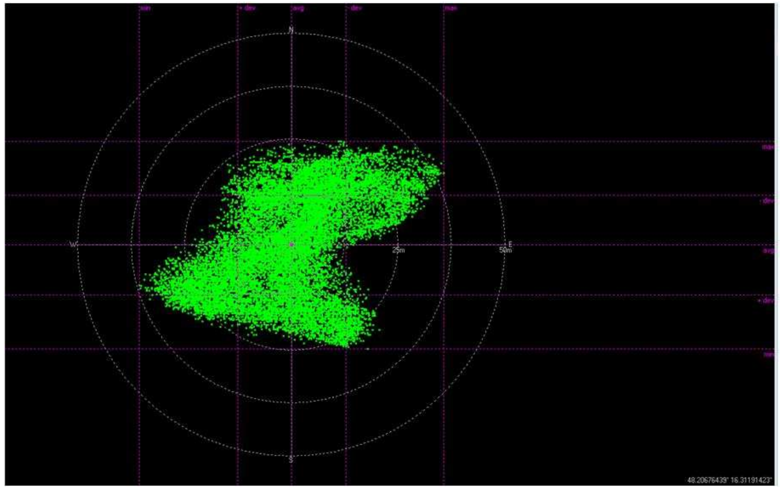
- Two transmitters and TSME are connected to the
  same 1PPS source
- Plot shows the LTE frame start vs. PPS signal of both transmitters and the difference between them
- The delta measurement of two transmitters shows a ~ 40 ns jitter
  - In line with the expectations

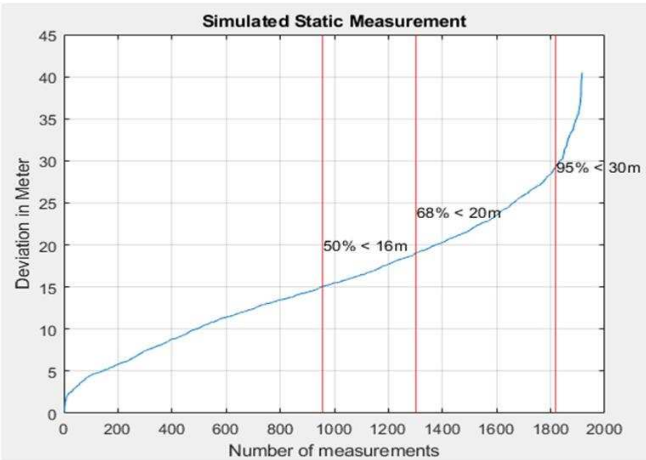


SYNCHRONIZE THREE TRANSMITTERS

- ► TSME-based receiver, geometrically in the middle of the 3 transmitters
- ► System performance under ideal conditions is well within the targeted accuracy goal.
  Error distribution:

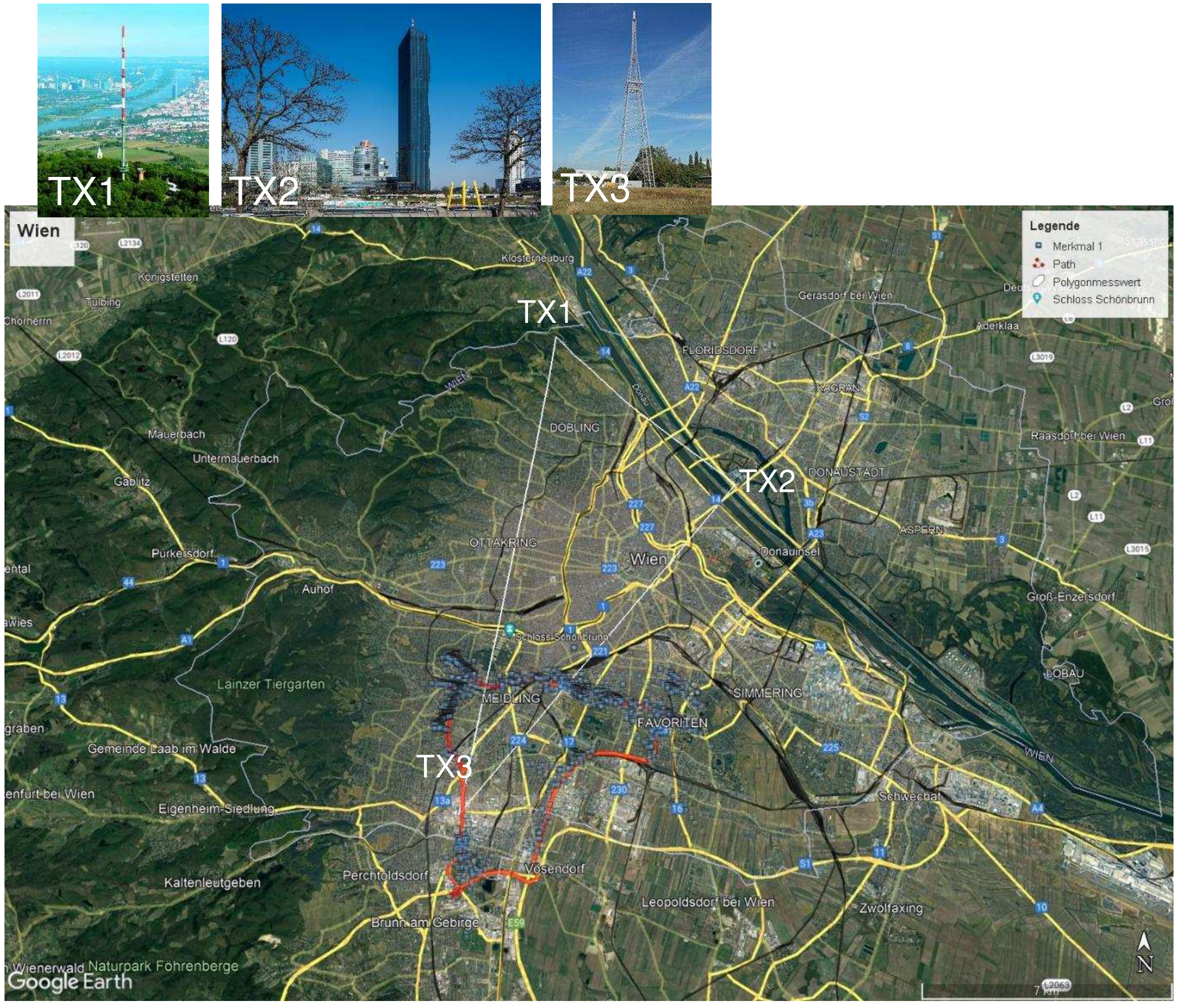
  95% < 29,4 m
  68% < 19,0 m
  50% < 15,1 m





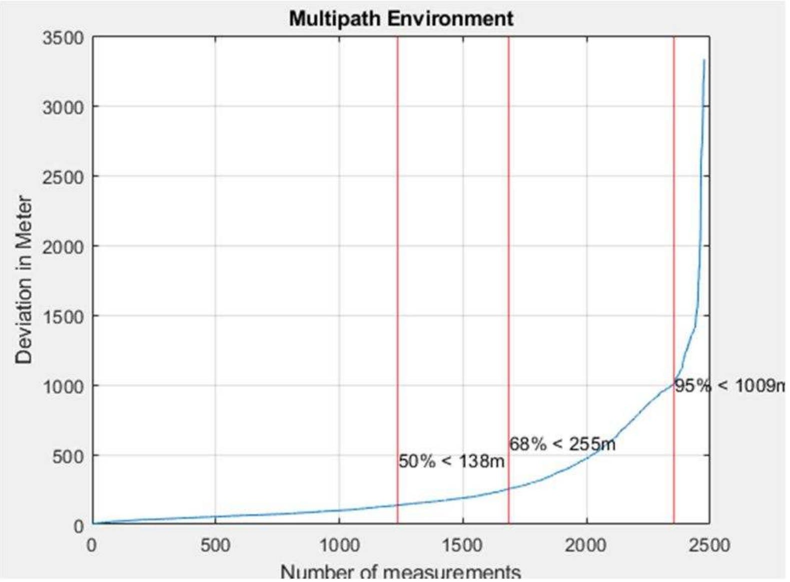
FIELD TESTS – VIENNA TEST BED

- ► 3 HPHT sites from ORS in Vienna:
  - TX1: Kahlenberg, ca. 40 kW ERP
  - TX2: DC Tower, ca. 10 kW ERP
  - TX3: Liesing, ca. 10 kW ERP
  - UHF band, 666 MHz
  - 5 MHz bandwidth



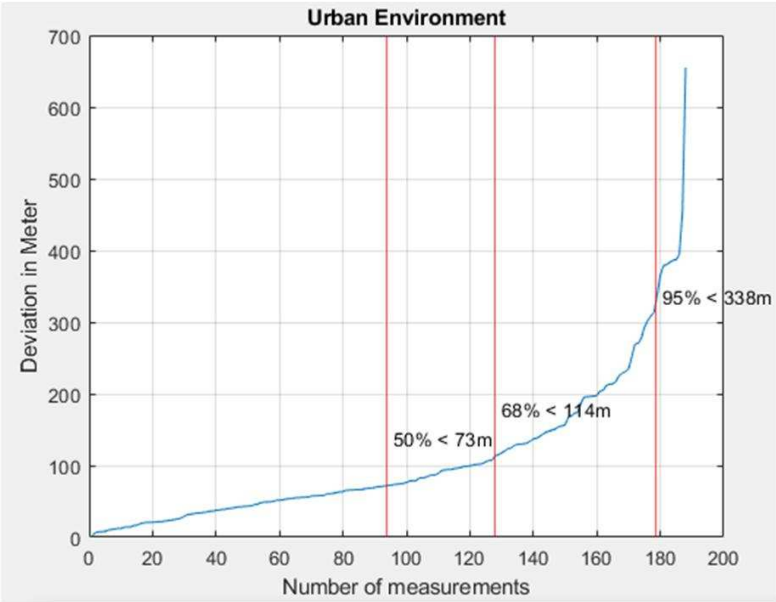
FIELD TESTS – MULTIPATH ENVIRONMENT

- A heavy multipath environment with a lot of tall buildings which can lead to reflections.
- Antenna on roof of moving car
- Transmitter sync via differential mode



FIELD TESTS – URBAN / SUBURBAN ENVIRONMENT

- An urban scenario (but without tall buildings) that is situated rather in the middle of the three transmitters.
- Antenna on roof of moving car
- Transmitter sync via differential mode

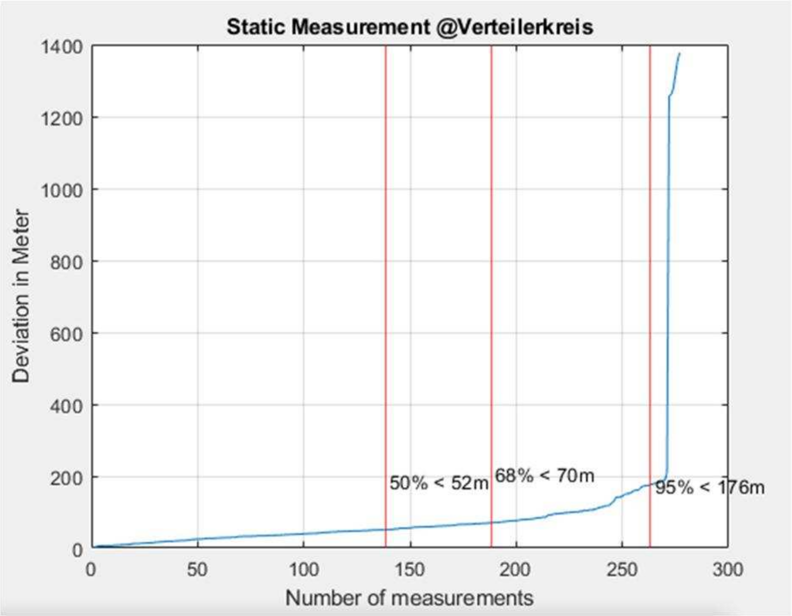


FIELD TESTS – URBAN / SUBURBAN ENVIRONMENT

► Scatter Plot at Küniglberg

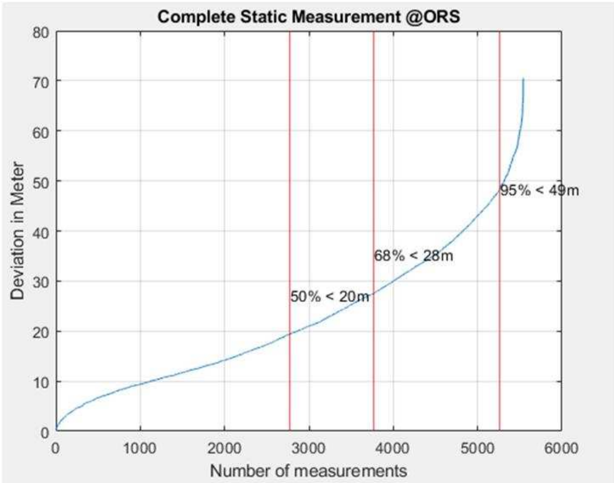
FIELD TESTS – STATIC MEASUREMENT IN VEHICLE

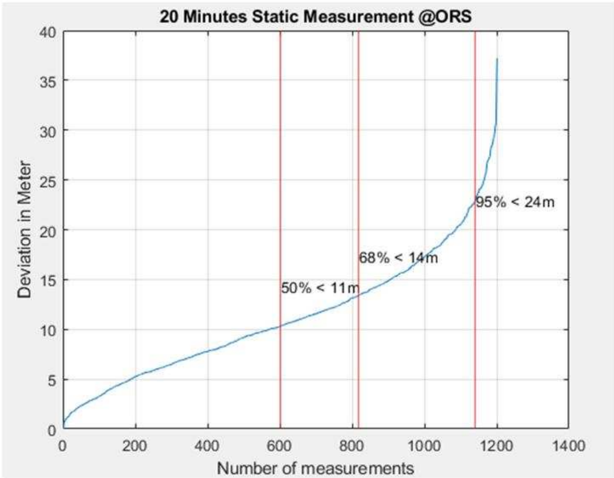
- Antenna on roof of moving car
- Measurements were taken while car was parked at a parking lot
- The high errors are most likely due to the poor geometry at the test site and the influence of multipath.
- Transmitter sync via differential mode



FIELD TESTS – STATIC MEASUREMENT AT ORF HQ

- Receiver at the rooftop of the ORF headquarter at a fixed position during the measurement
- Overall scatter cloud slowly moved over the time
- First 20 minutes of the test were also evaluated. The remaining uncertainty was only 11 m for 50% and 24 m for 95% of the valid fixes.



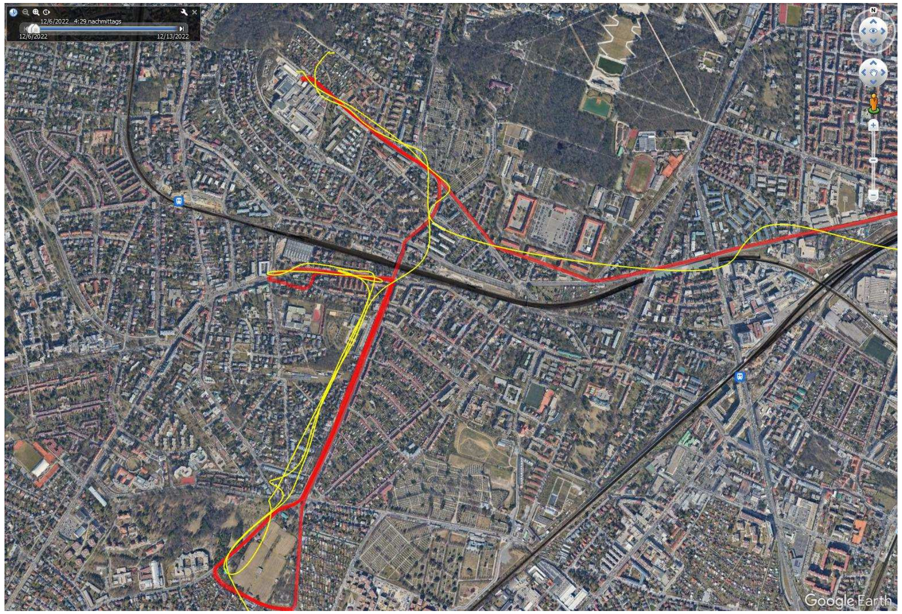


FIELD TESTS – STATIC LOCATION SCATTER PLOT

- Slowly moving due to uncompensated clock drift of non-ideally synchronized transmitters
  - Effect of external GPSDO, not the transmitters themselves
- Inaccuracy due to transmitter jitter is lower, estimated ~30 m

FIELD TESTS – SMOOTHED TRACK

- Using gaussian filter of length 51, the jitter is suppressed (yellow track) and positions follow the GNSS reference track (red), however with degraded accuracy



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OBSERVATIONS, CONCLUSION & OUTLOOK

OBSERVATIONS

Accuracy in static scenario within target (49 m vs. 100 m)

Moving scenarios significantly worse than static, presumably due to unmitigated multipath in test receiver

In 47% of time signals from all 3 transmitters could be received → coverage not yet sufficient for continuous navigation

In 99.5 % of time signal from at least one transmitter was received → good coverage for timing applications

Currently GPS disciplined clocks at transmitter sites are a major source of errors

System is working

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CONCLUSIONS AND OUTLOOK

Work on multipath mitigation in receiver would be beneficial	GNSS correction data broadcast could be integrated (RTK/PPP)	Integration of barometric pressure for z-axis
High dynamic range near transmitters could be addressed, e.g. using muting pattern	Usage of PTP for GNSS indepedent transmitter synchronization	Coverage prediction tool for navigation would be helpful for network planning

HOW TO GET IT OPERATIONAL?

- ► Invite Broadcast Network Operators to upgrade transmitter sites in regions where not all frequencies for DVB-T/T2 are currently used
- ► Invite chipset and end user equipment manufactures to support 5G Broadcast navigation signal
- ► Initial focus could be on distribution of precise time signal. Navigation support could be extended later.
- ► Invite operators of critical infrastructure to use alternative time sources

Source: http://www.dvb-t2hd.de/

Thank you!

Q & A