FM/DAB/DVB-T Multiband Multistatic Passive Radar System – Design Considerations and Lessons Learnt

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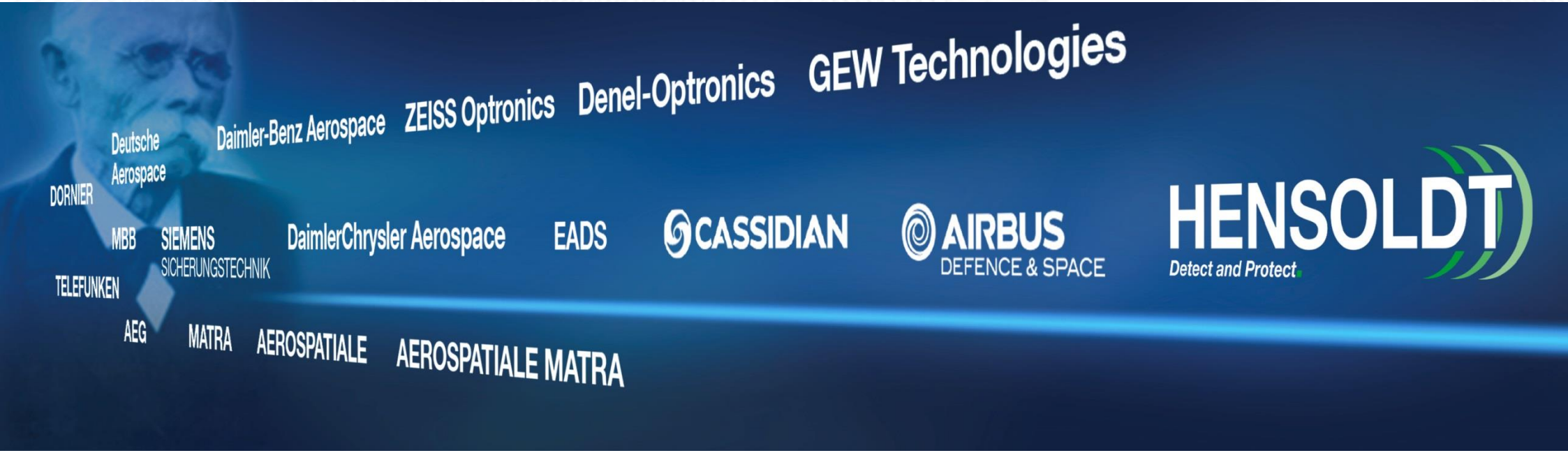
New Company effective March 1st, 2017: HENSOLDT



Airbus Defence & Space → carve-out of radar, optronics, EW and avionics business →

→ Airbus DS Electronics & Border Security → rebranding from March 1st, 2017 to → **HENSOLDT**

Passive Radar Design Study, System Overview and Lessons Learnt:

- Goal and Basic Design Considerations
- Analysis of Transmitter Network Structure for Germany and Network Model
- Passive Radar Design and System Overview
- Measurement Results
- Lessons Learnt and Conclusion

Basic Question and Activities

Can a conventional active air surveillance radar be replaced / augmented by a Passive Radar system, consisting of one or several receiver sites ?

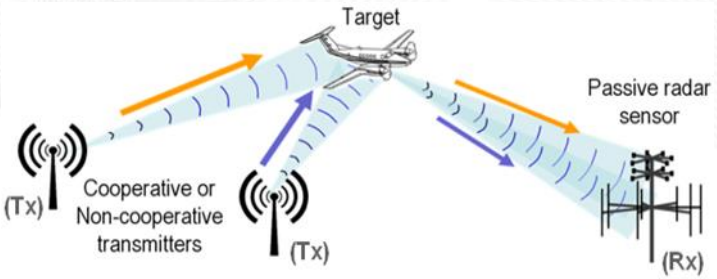
-> 360° az. coverage, ~ 60° el. coverage
-> range ~100km @ typical A/V RCS
-> handling, 3D-localization and separation of a great number of aerial targets

→ ***Analyse networks available as illuminators***

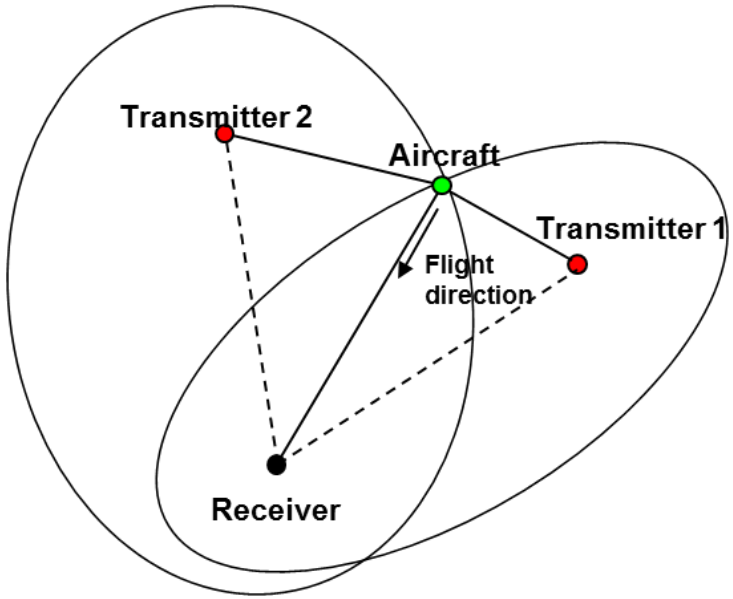
→ ***Design, built and test a prototype system and perform tests to gain experience***

Multistatic Passive Radar Principles & Problems

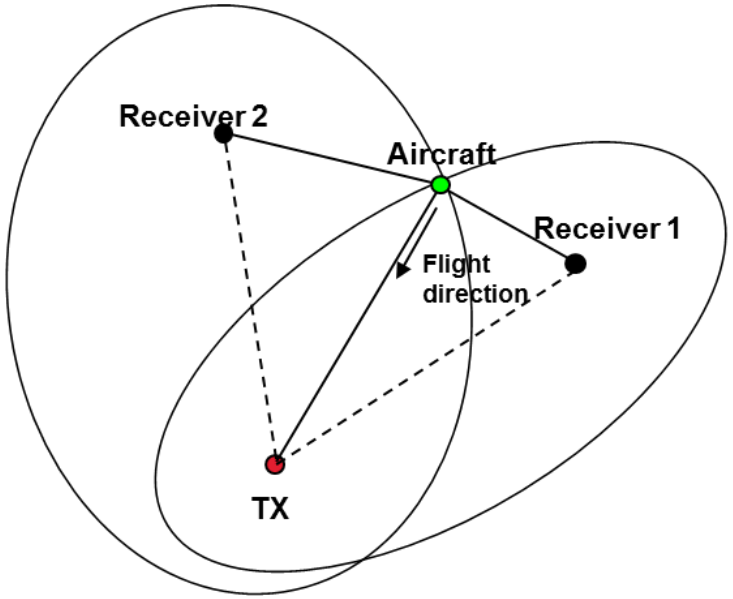
1. Ensure multistatic illumination of airspace & targets
2. Suppress strong ‘Direct Signals’ from Tx
3. Detect, fuse detections & separate targets, localize targets



Multiple Tx, Single Rx

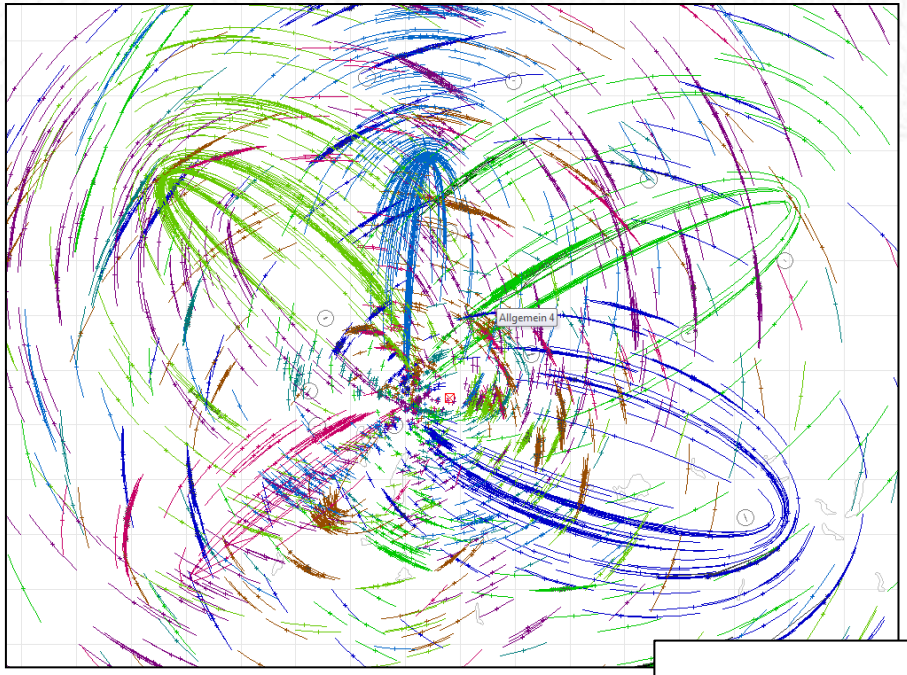


Multiple Rx, Single Tx

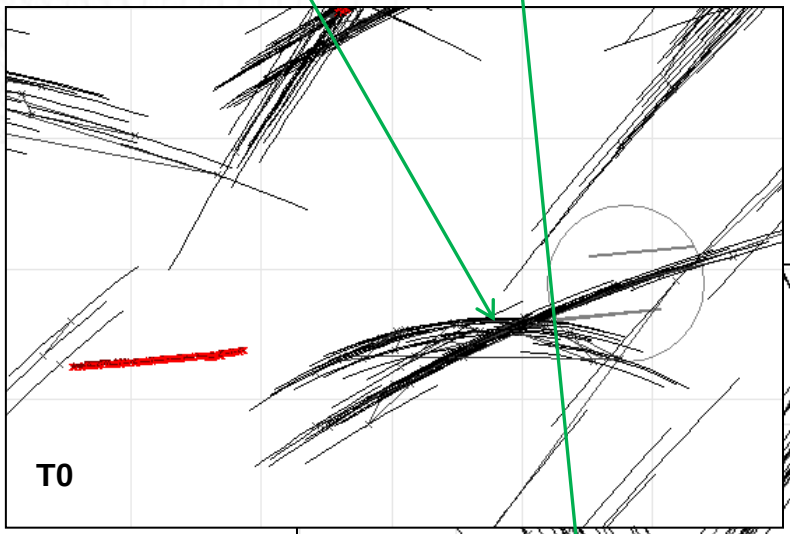


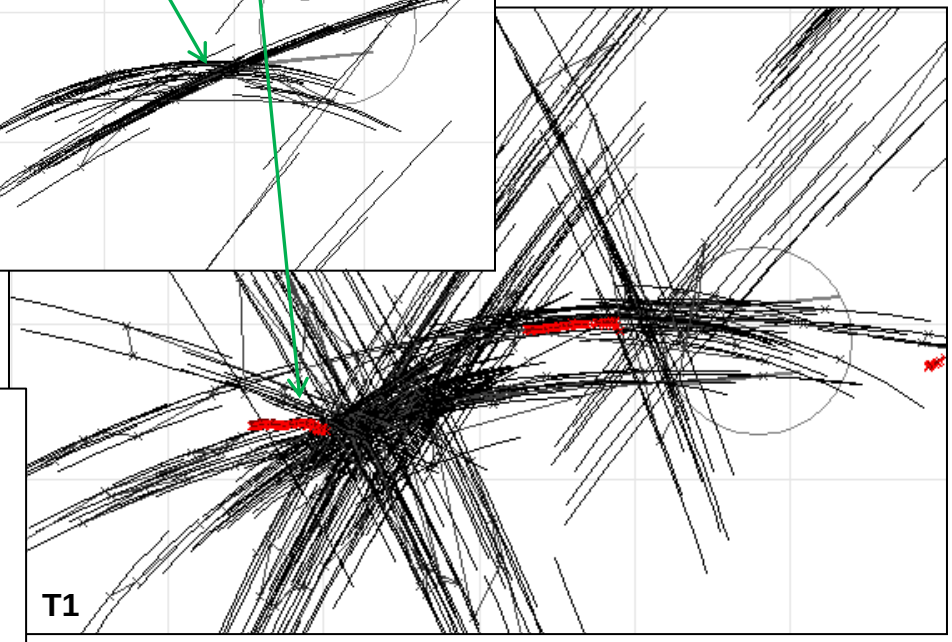
Impressions of Separation Problem in Multi-Target Scenarios

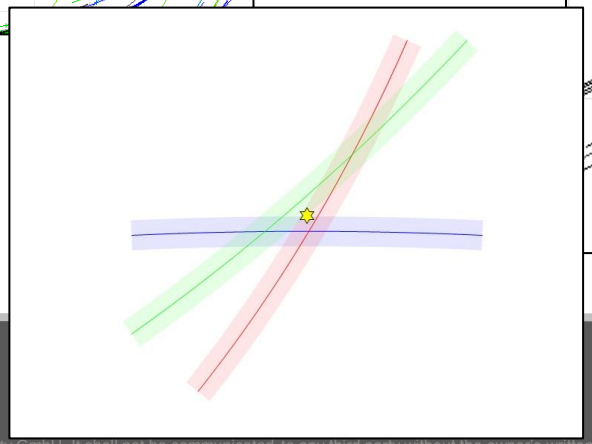
bistatic plot data



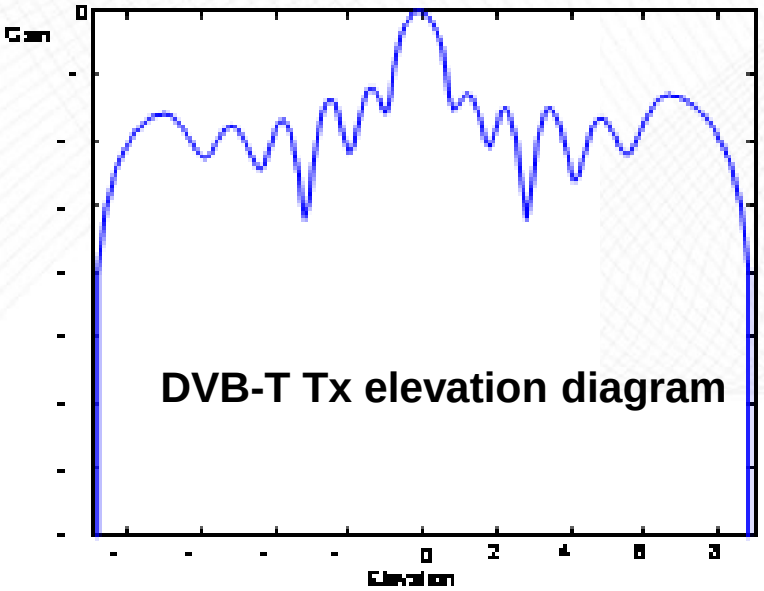
R-RR tracks & 3D-tracks:







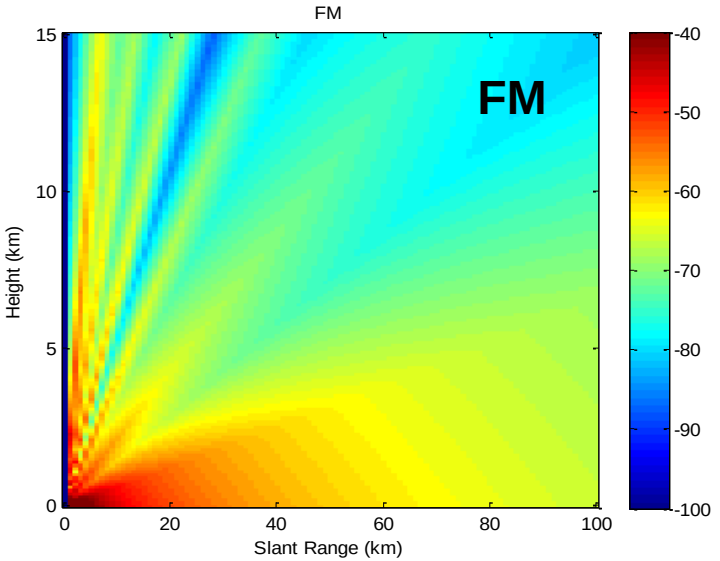
Analysis of Transmitter Networks in Germany: FM, DAB, DVB-T

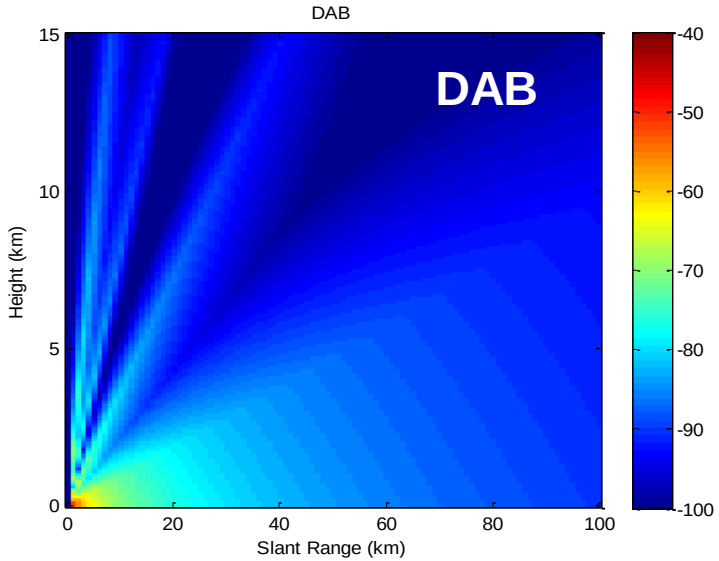


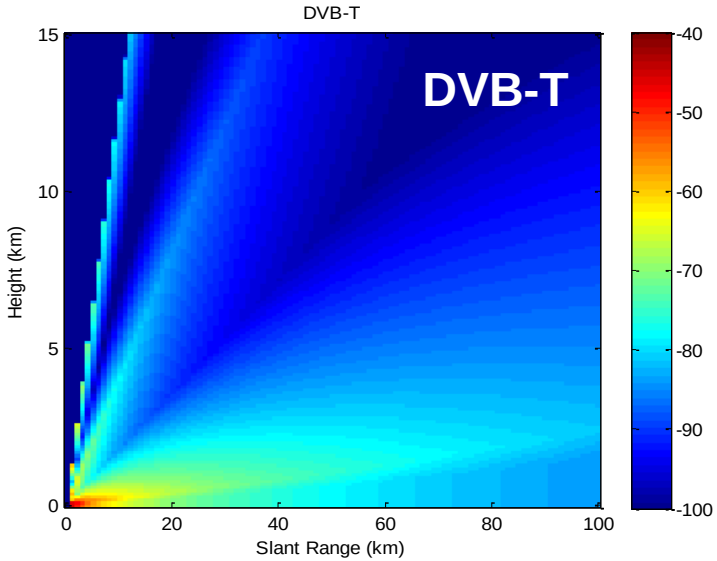
Broadcast Network	Frequency Band	Transmitter Bandwidth	Typical Transmitter Power (EIRP)
FM radio	88MHz - 108MHz	0 - 100kHz *)	10kW – 100kW
DAB radio	174MHz - 240MHz	1.5MHz	1kW – 10kW
DVB-T (television)	470MHz – 862MHz	7.6MHz	1kW – 100kW

Receive Powers:

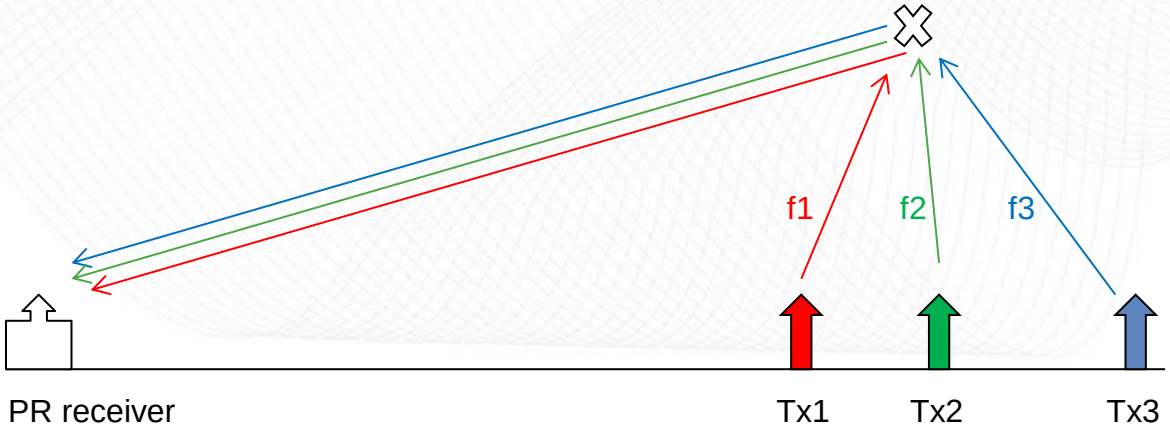
$$P_r = \frac{P_s \cdot G_s(El)}{4\pi \cdot R^2} \cdot \frac{\lambda^2}{4\pi}$$

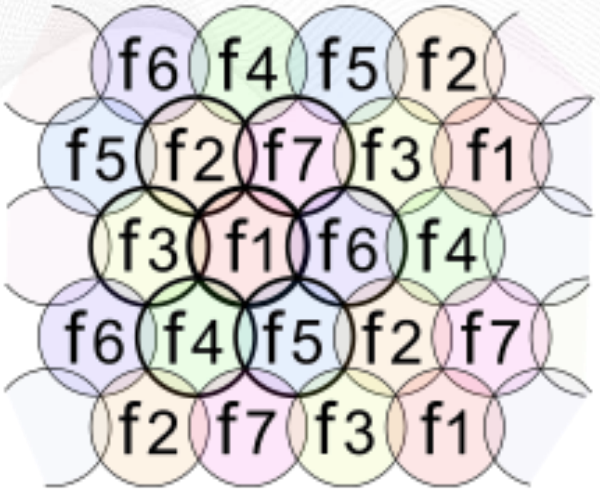




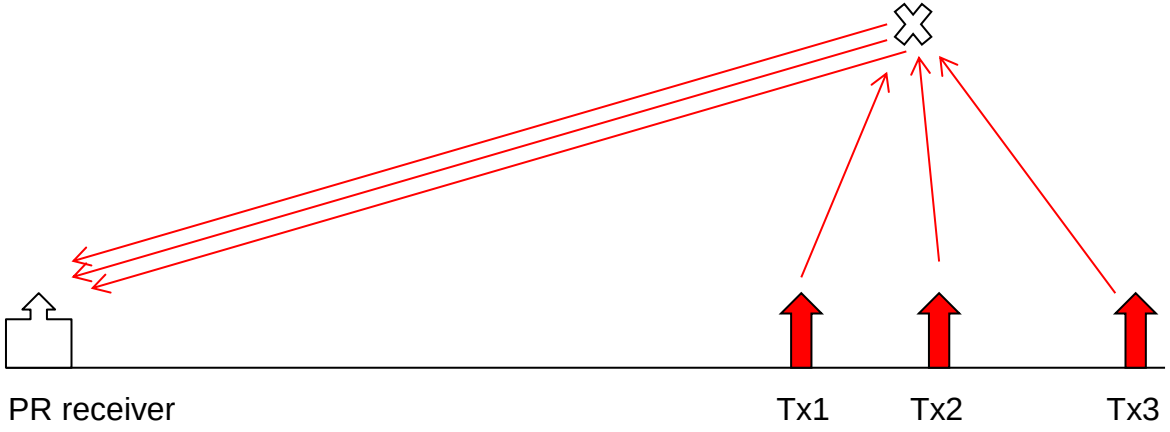


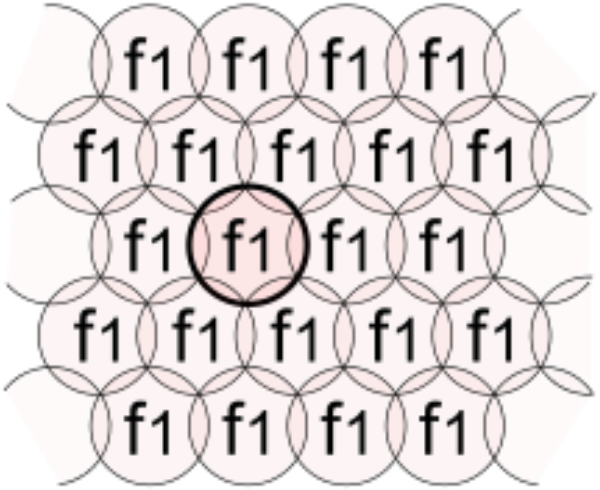
Multiple & Single Frequency Networks





MFN

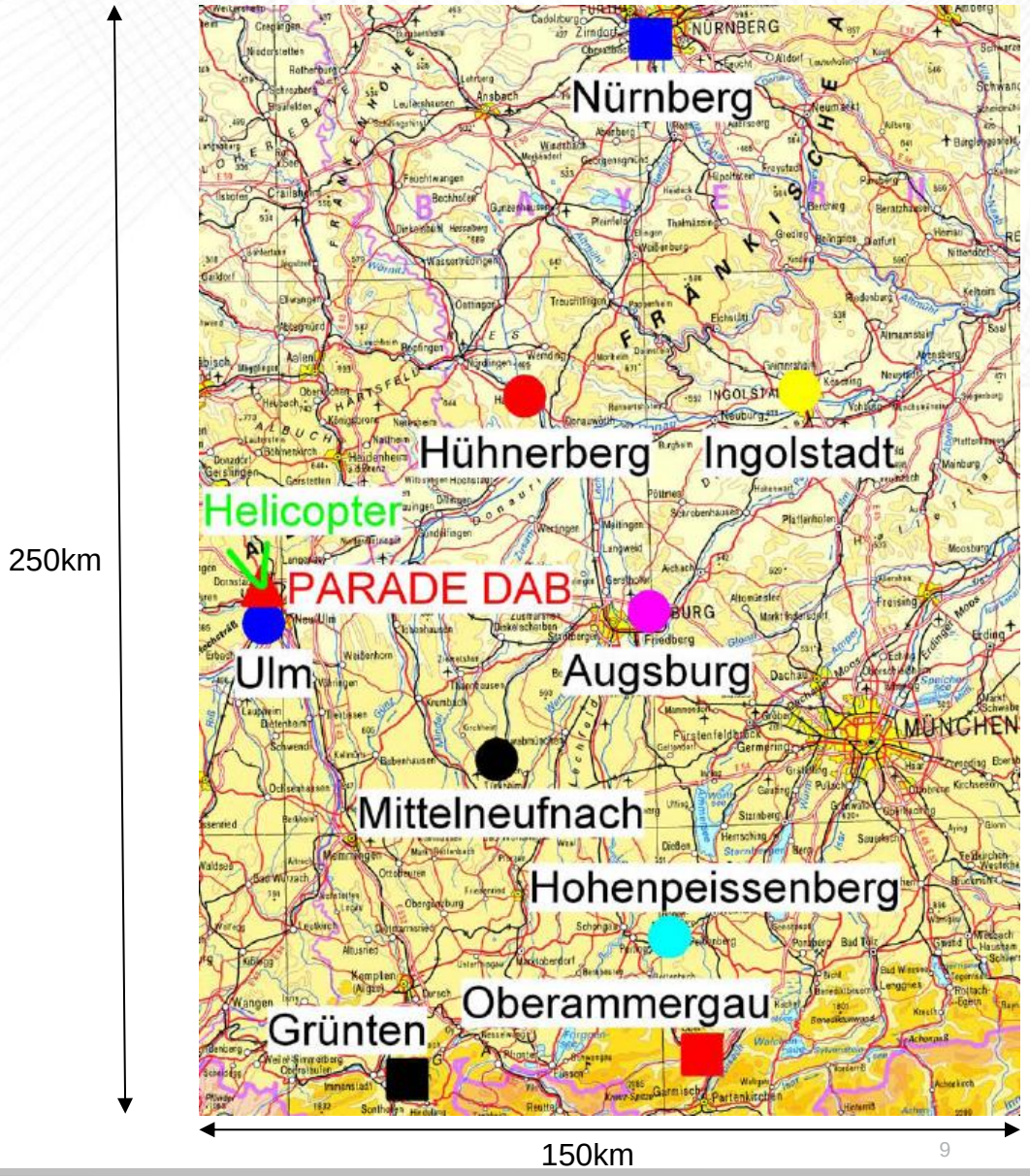


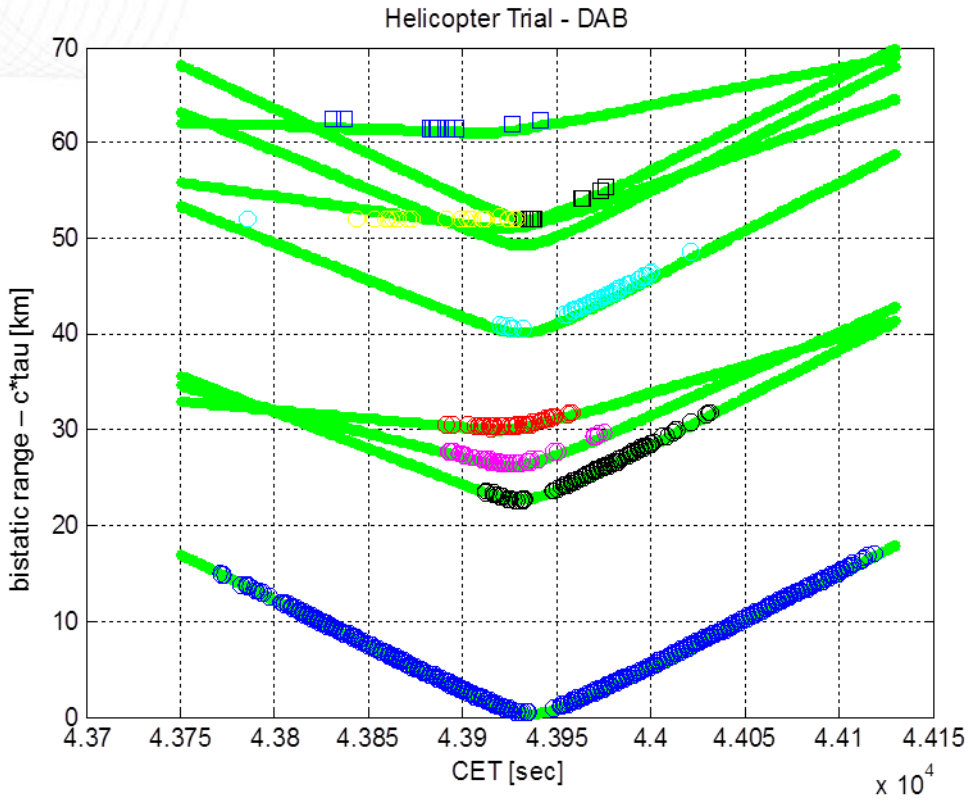


SFN

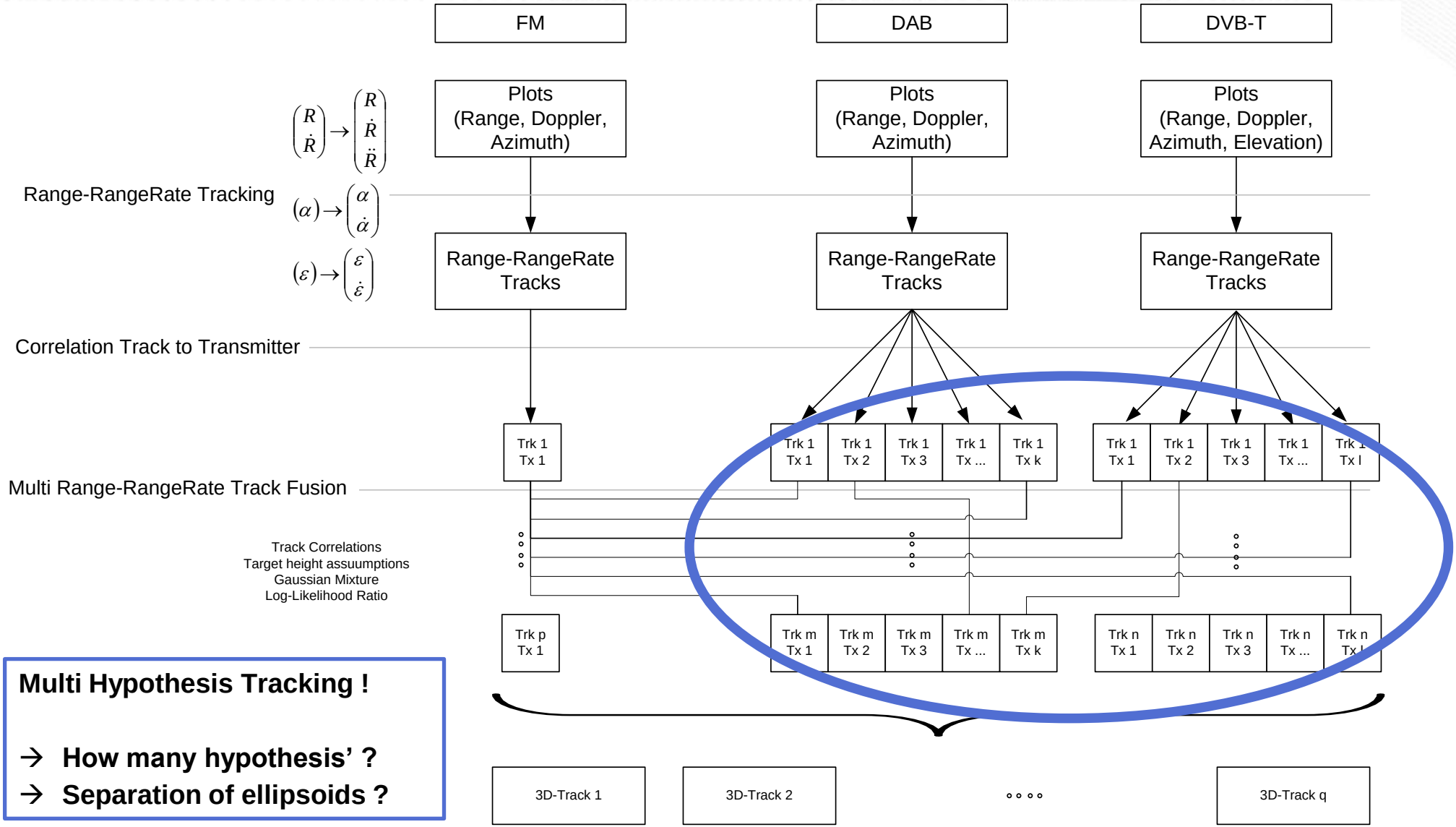
In SFNs an ambiguity w.r.t. the origin of each received reflexion exists → multiple hypothesis tracking → increases complexity !

DAB SFN Ambiguity: Measurements in Ulm, Germany





Data Fusion and Tracking in SFNs / MFNs



Multi Hypothesis Tracking !

→ **How many hypothesis' ?**
→ **Separation of ellipsoids ?**

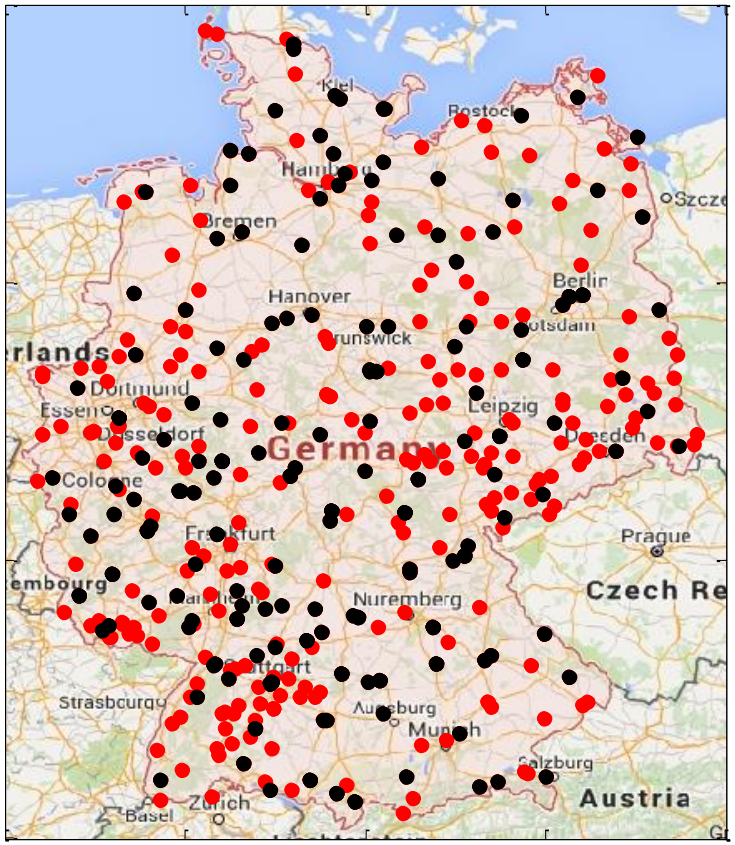
Analysis of Tx Networks in Germany (Area: 357.000km^2)

FM:
- 145 transmitters >40dBW
- Multiple Freq. (MFN)

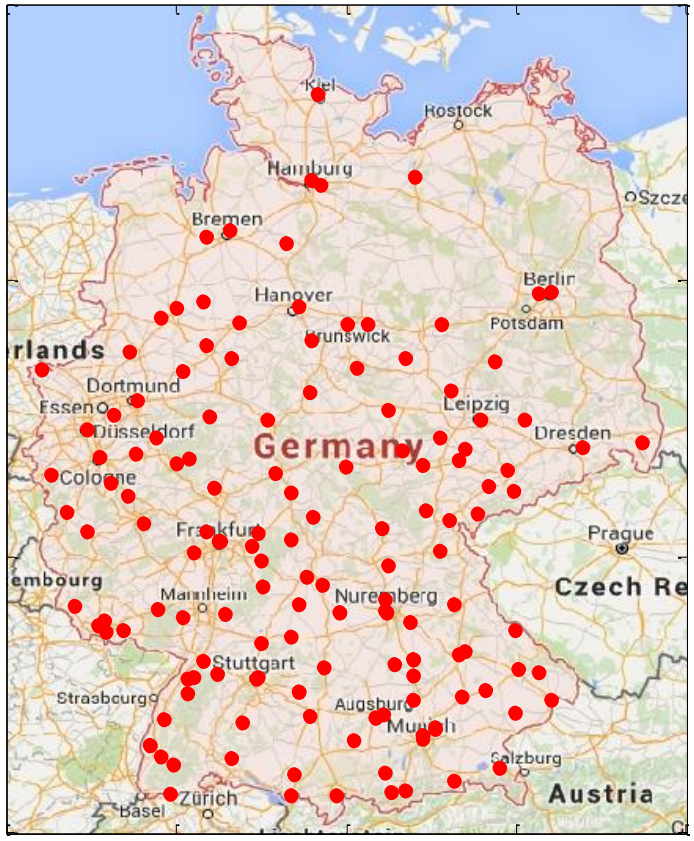
DAB:
- 176 transmitters >30dBW
- arranged in 33 SFNs

DVB-T:
- 434 transmitter >40 dBW
- arranged in 198 SFNs

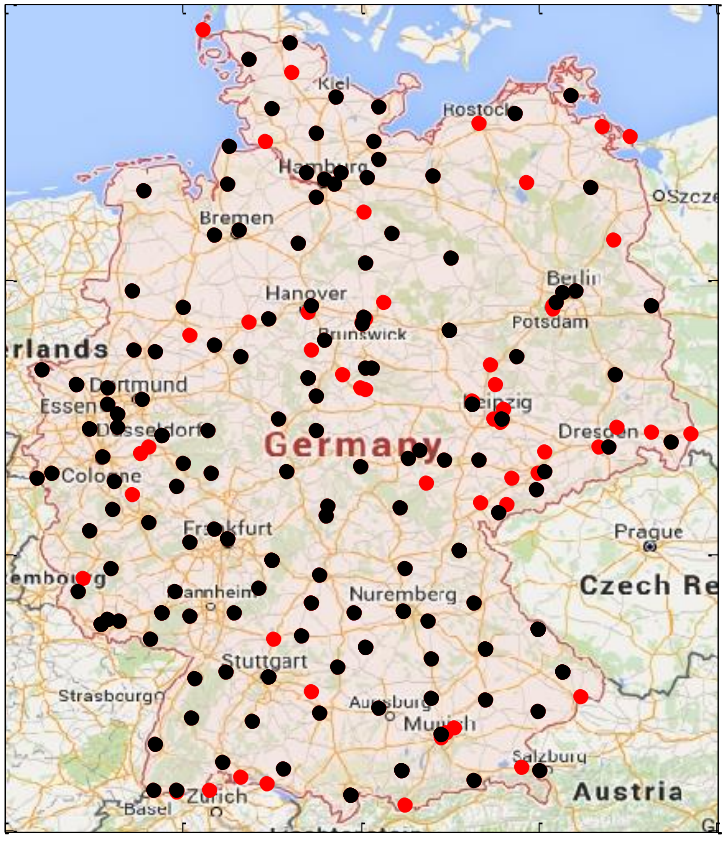
FM



DAB



DVB-T



transmitter sites with at least 1 frequency >= 30 dBW

transmitter sites with at least 1 frequency >= 40 dBW

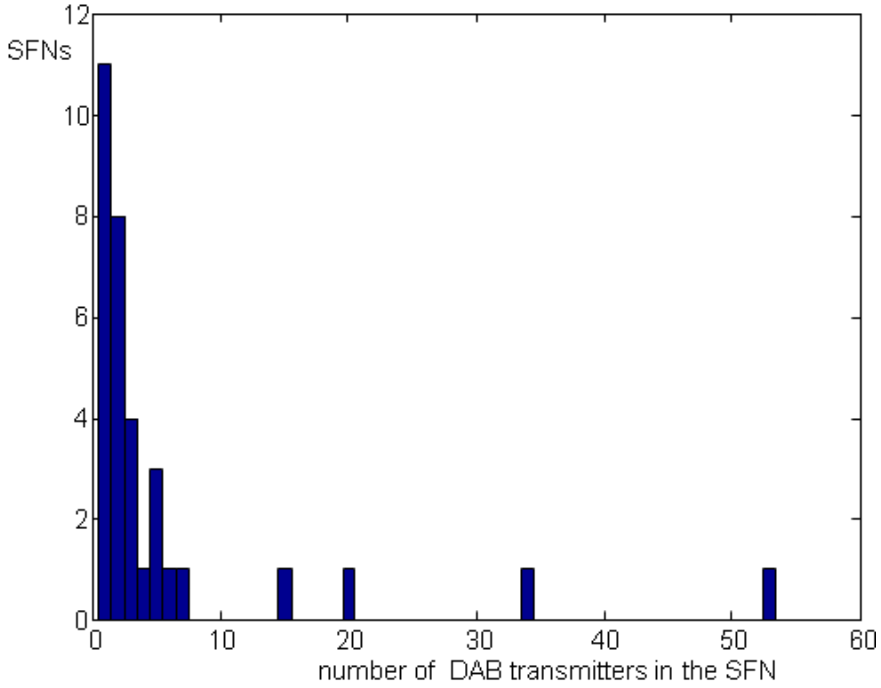
Analysis of MFN / SFN Networks in Germany

FM: MFN, Tx-Grid approx. 50km

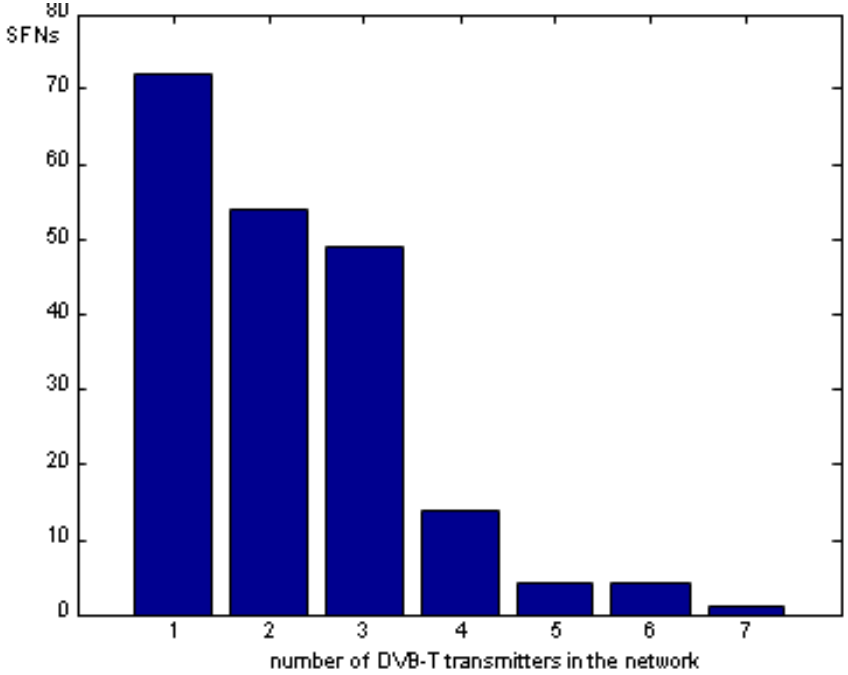
DAB: 33 SFNs of various size, typ. <10 Tx, max. 53 Tx per SFN

DVB-T: 198 SFNs of various size, <8 Tx per SFN

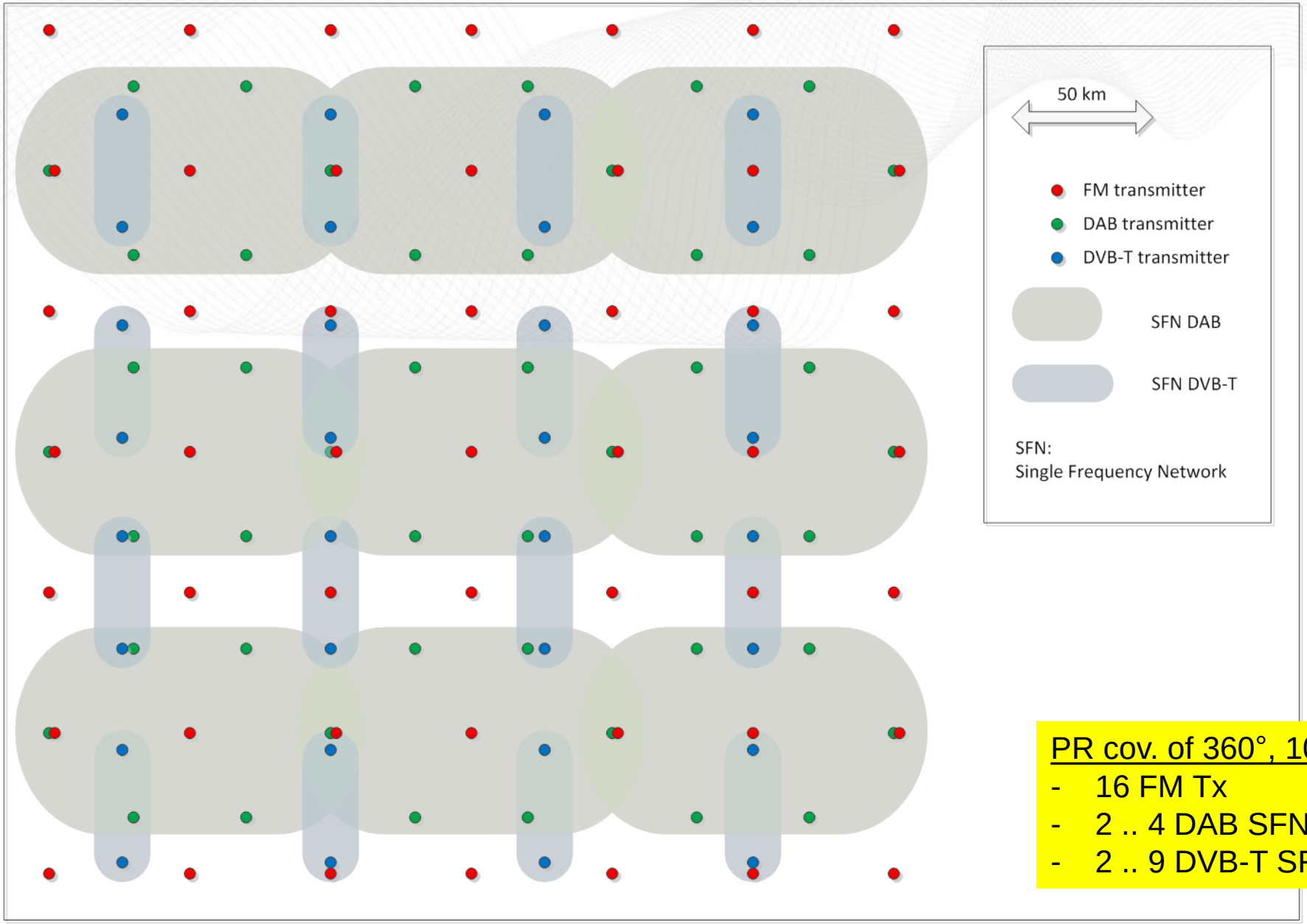
DAB



DVB-T



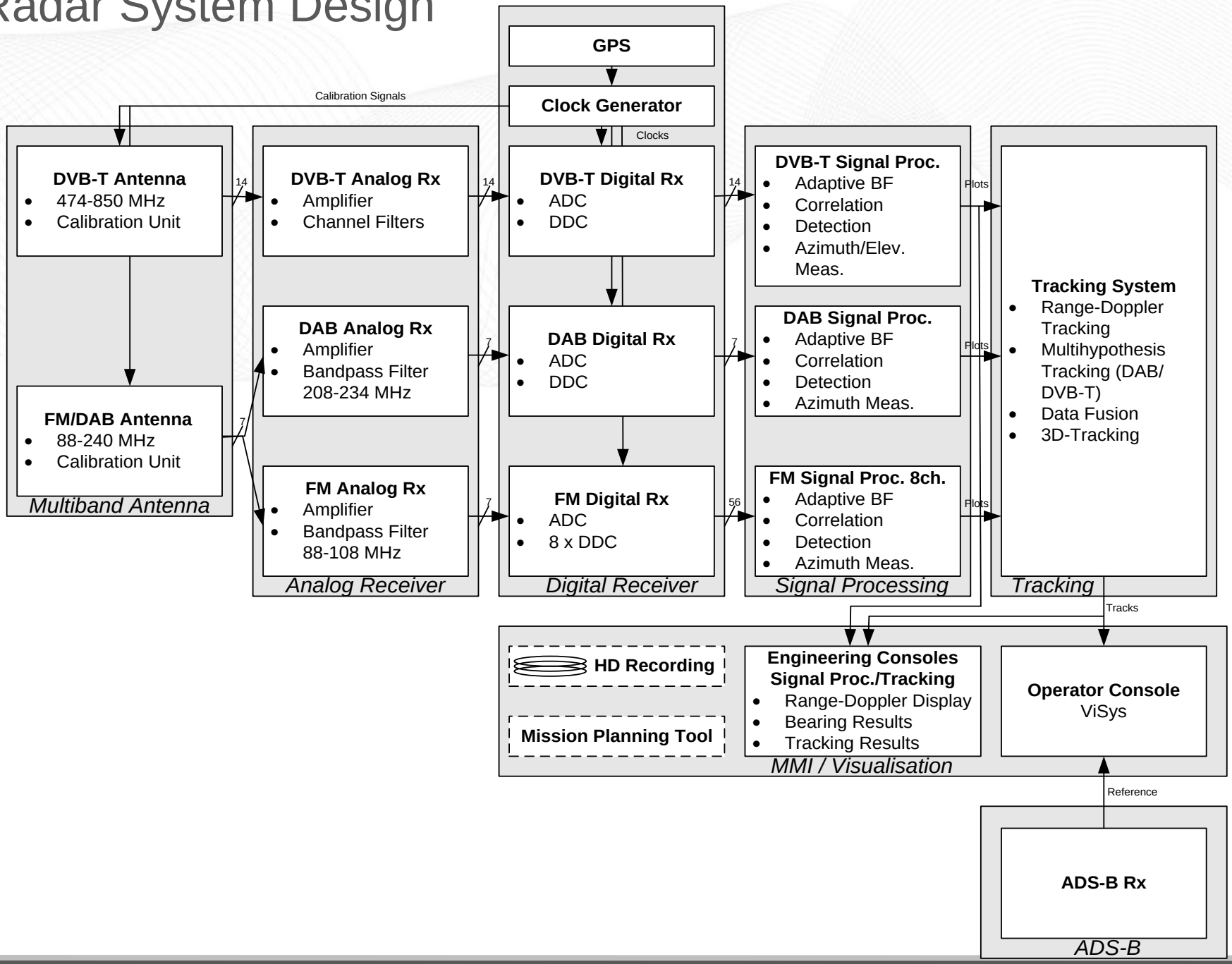
Tx Network Model for Germany



PR cov. of 360°, 100km range:

- 16 FM Tx
- 2 .. 4 DAB SFNs
- 2 .. 9 DVB-T SFNs

Passive Radar System Design



Passive Radar Multiband Demonstrator System

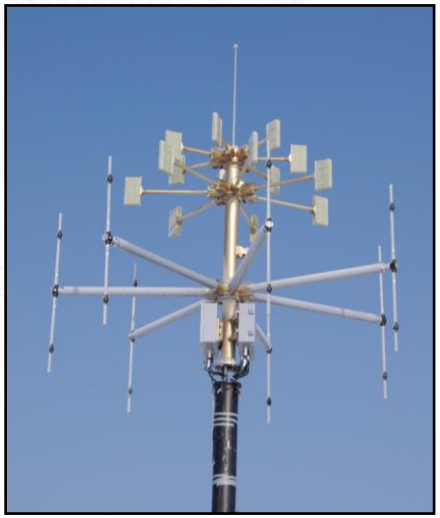
Multiband coverage →simultaneously processible transmitters:

- 8x/16x independent FM transmitters
  out of FM Band 88 – 108 MHz
- 1*x DAB Single Frequency Network (SFN)
  out of DAB Band 174 – 240 MHz
- 1*x DVB-T Single Frequency Network
  out of DVB-T Band 474 – 786 MHz

(3 SFN parallel)*

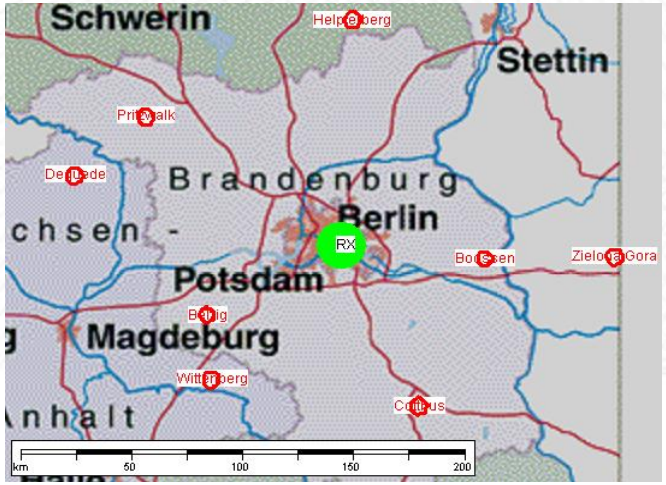
Processing:

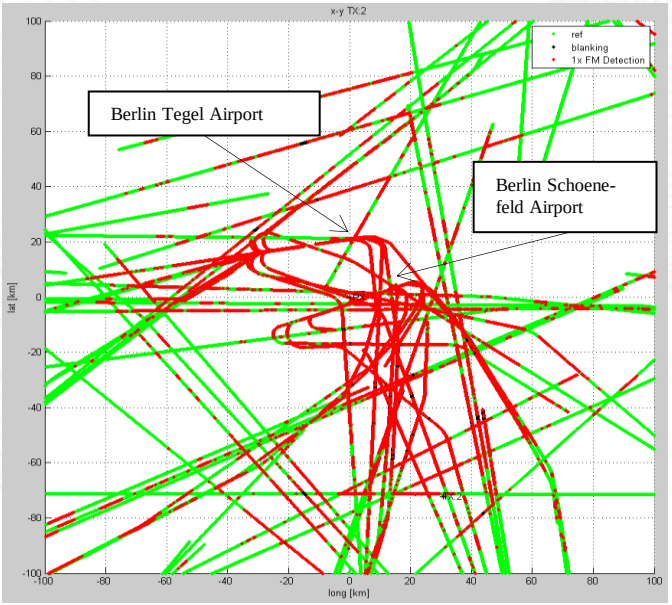
- Realtime signal processing
  (Bistatic Plotdata)
- Realtime 3D tracking system
  (including multihypothesis tracking for SFN &
  multi-sensor-tracking for sensor cluster operation)

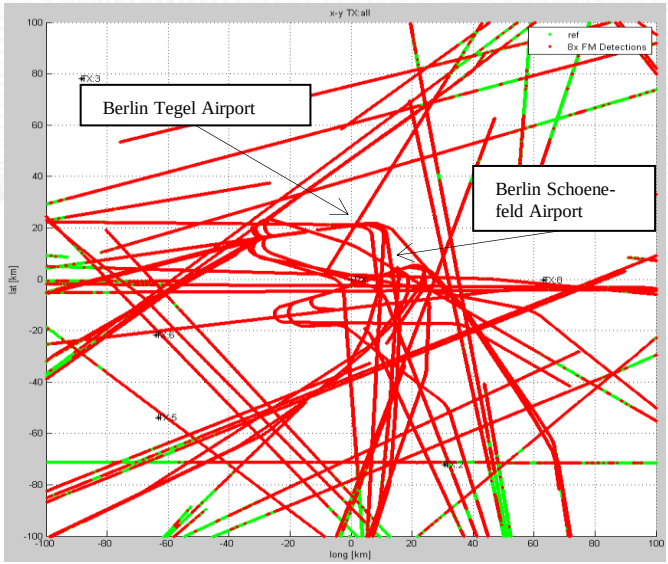


Single-Site Measurement Campaigns

Berlin Area, Germany, FM only





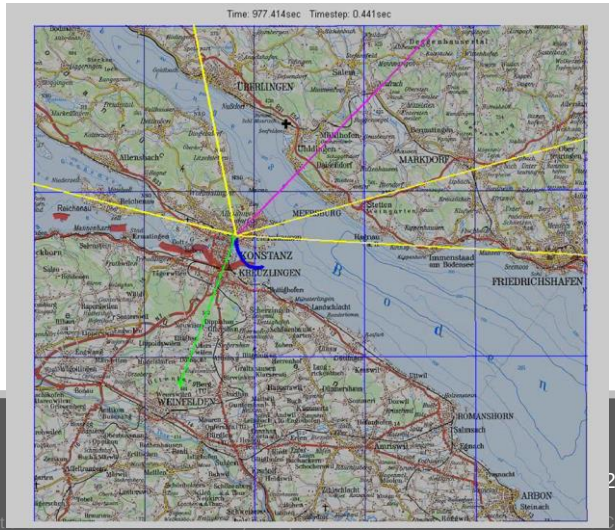


1 FM transmitter:
- range up to 100km
- covarage gaps
- accuracy >1km

8 FM transmitters:
- range up to 100km
- no covarage gaps
- accuracy <500m

Lake Constance Area, Germany

FM, DAB, DVB-T



Visualization of multistatic diversity:

Video: FM_DAB_DVB-T-Video

Dual-Site Operation

PCL1 (Master)

Signal-Processing
FM & DAB & DVB-T

LAN bistatic plot data

Multi-Sensor-Tracking
(data fusion of bistatic plot data and dislocated sensors)

Track data in ASTERIX

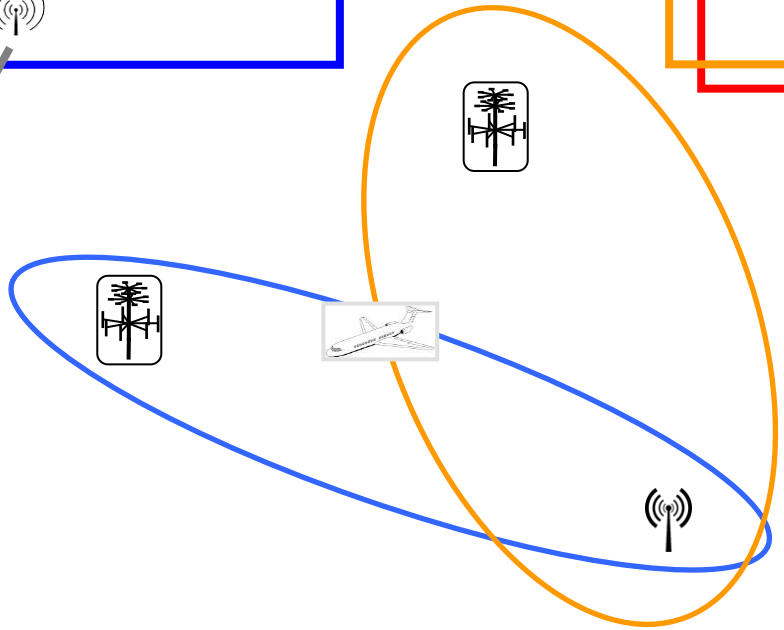
3G bistatic plot data

PCL2 (Slave(s))

Signal-Processing
FM only

LAN bistatic plot data

3D air picture using ASTERIX externally over 3G link online / real time



CRC / Network

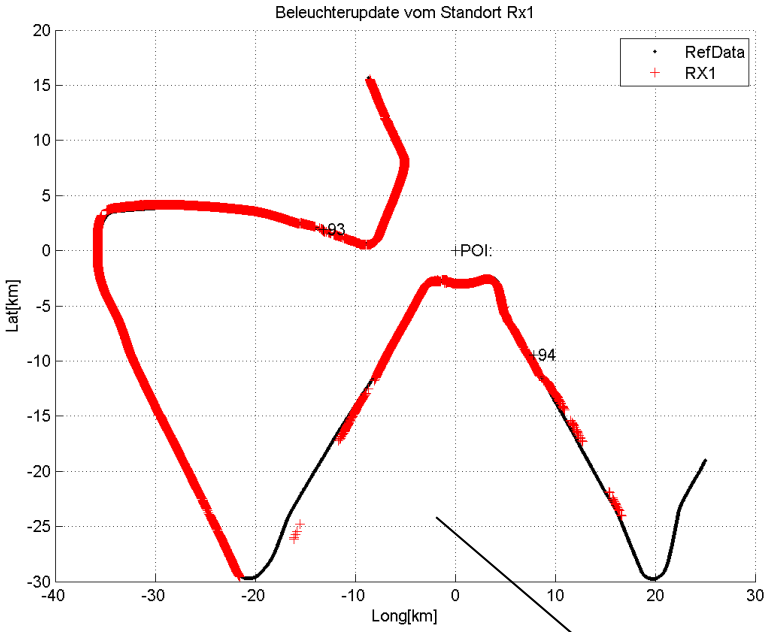
Track data in ASTERIX for distribution or display

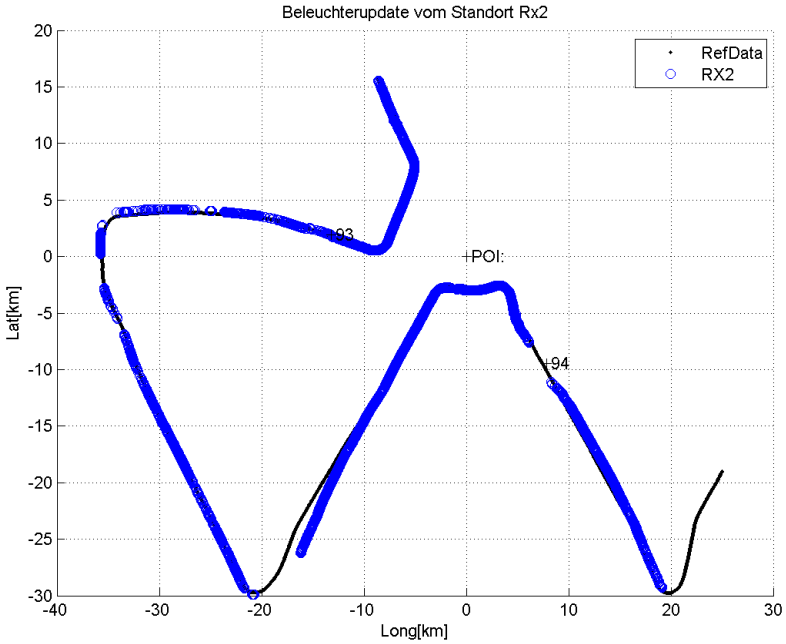
<u>Passive radar sensor cluster provides:</u>

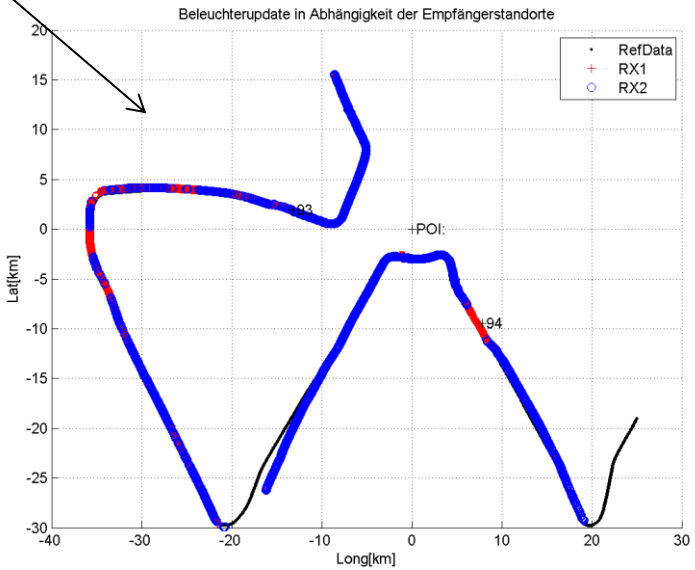
- increasing coverage
- increasing accuracies

Dual-Site Measurement Campaign

Passive Radar System Design







Evaluation of Combined Multistatic Plot Updates

Color Code:

number of plot updates to 3D-track per second

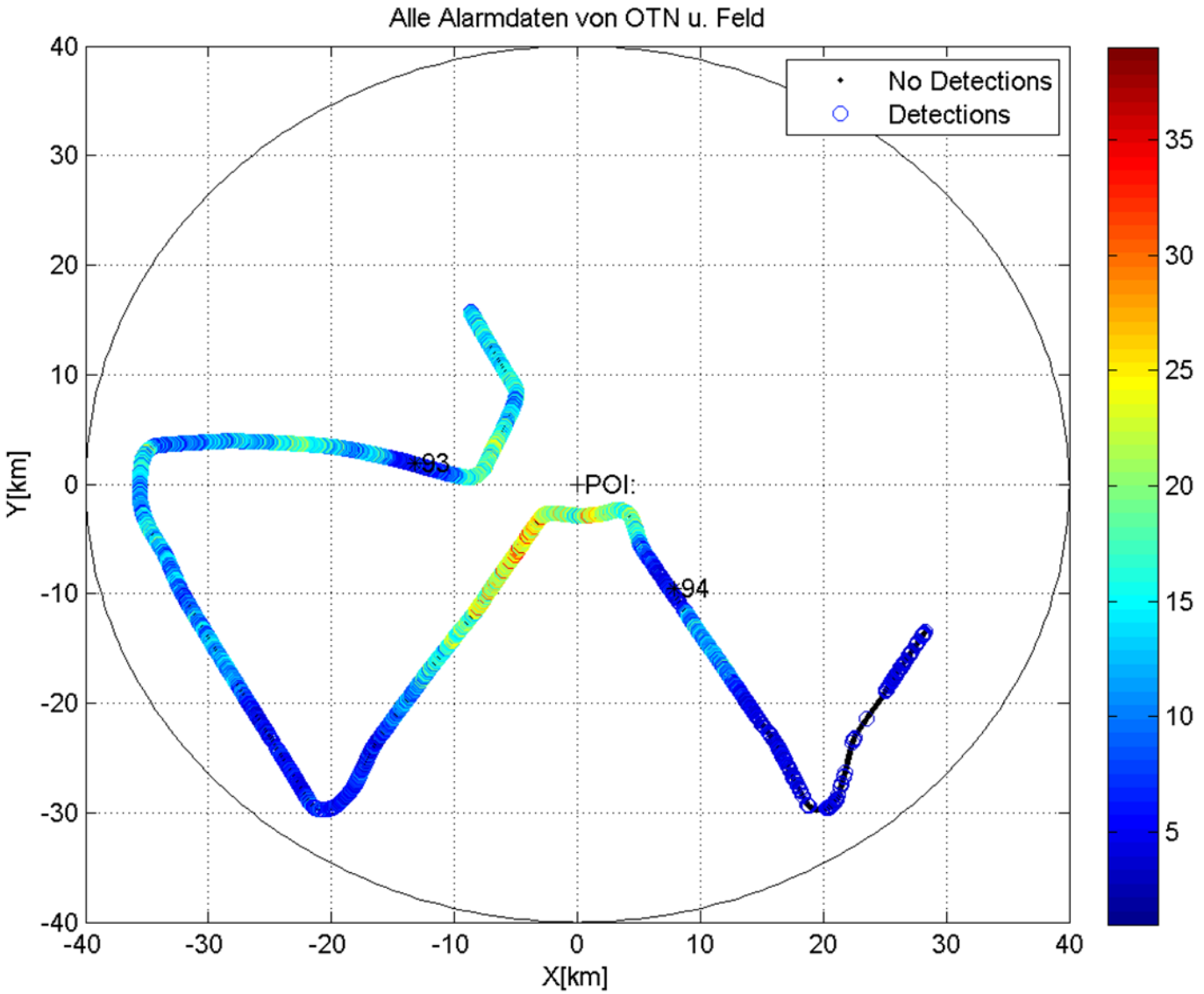
→ Min 3 updates / second
→ Max 30 updates / second

Provides by

- 2 x 8 FM Tx
- 1 DAB SFN
- 1 DVB-T SFN

Visualization of site-siversity:

Video_Site_and_Tx_Diversity



Lessons Learnt: Passive Radar Diversity Approach

Target detection by each one transmitter-receiver-constallation is limited by:

- terrain shadowing, esp. in low altitude targets

- multipath fading, both in the Tx-Target path and in the Target-Rx path

- angle-dependent target RCS fluctuation

- transmitter antenna elevation beamwidth, i.e. target illumination

- bistatic-range-dependent clutter characteristics

- PR blind zones (e.g. zero-doppler target trajectories)

→ Make use of diversity w.r.t. multiple Tx networks & frequency bands and multiple receiver sites

Summary

Transmitter network analysis (Germany):

- model for FM/DAB/DVB-T Tx grids, Tx power and elevation cov.

Passive radar system demonstrator built and optimised in several steps:

- FM
- DAB / DVB-T
- cross-band data fusion and tracking
- second PR receiver station (FM only) for receiver site diversity

Measurement results:

- FM: range 100km+, acc. ~ 500m
- DAB/DVB-T: range 50km+, acc. ~ 50m

Reliable wide area coverage:

- Tx diversity: 8...16 FM Tx, 1..4 DAB/DVB-T SFNs
- Rx diversity: multiple receiver sites