DEFINE AND TEST ELECTROMAGNETIC IMMUNITY OF UAS FOR FIRST RESPONDERS

Chr. Adami, S. Chmel, M. Jöster, Th. Pusch, M. Suhrke - Fraunhofer Institute for Technological Trend Analysis (INT), Euskirchen, Germany

Fraunhofer

INT

DEFINE AND TEST ELECTROMAGNETIC IMMUNITY OF UAS FOR FIRST RESPONDERS

- Introduction
- Common aspects of typical usage scenarios
- The test case environment in the example project ANCHORS
- Elaboration of parameters for laboratory testing
- Test setup and diagnostics
- Test results
- Summary and Outlook

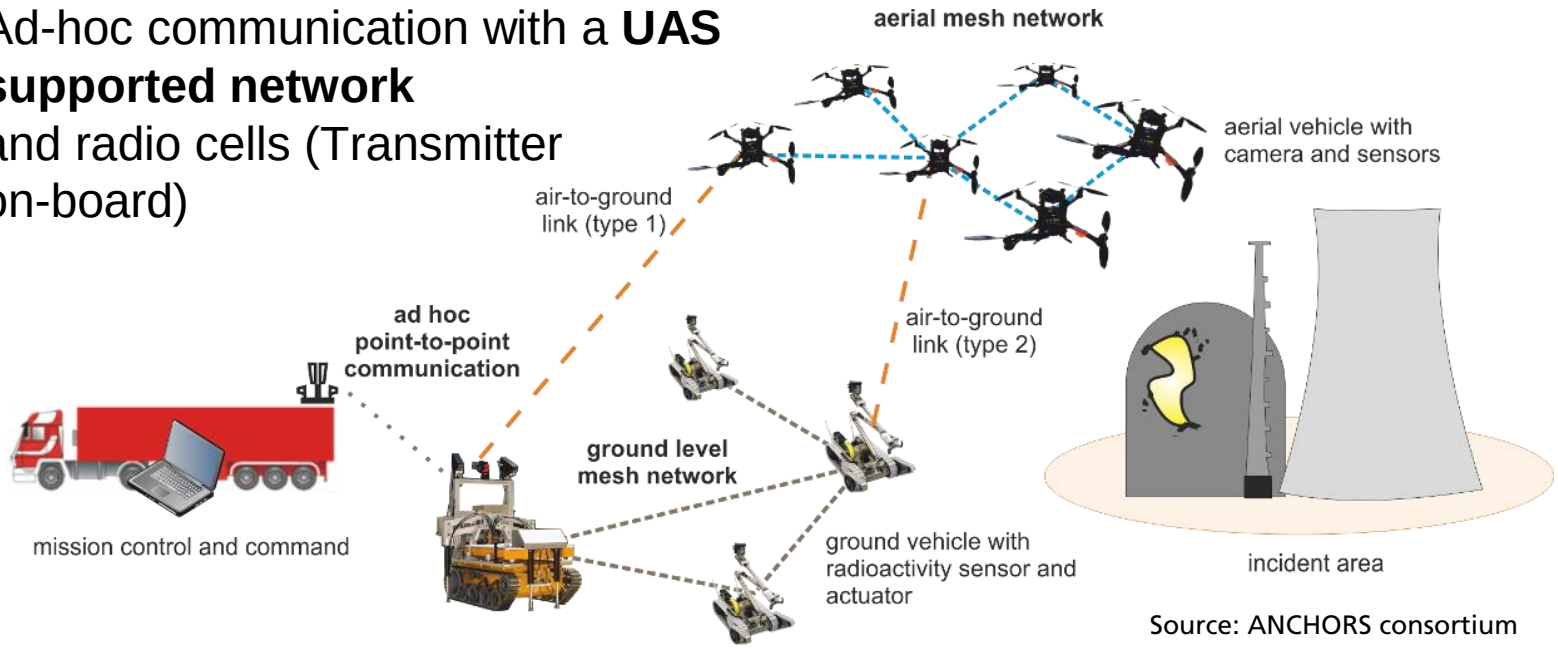
Introduction

- There are Unmanned Aerial Systems (UAS) **swarm concepts** tailored **for first responders in disaster situations** like the French-German project ANCHORS
- Depending on **the deployment scenario**, the UAS might have to withstand **electromagnetic interference (EMI) by RF sources**.
- The RF field strength might **exceed the classic electromagnetic compatibility (EMC)** balanced level approach **by fly over fences**.
- **Intentional Electromagnetic Interference (IEMI**) might be a threat **to be considered** for first responder scenarios using UAS.

- Therefore we discuss **generalities in UAS usage scenarios** regarding possible **susceptibility by RF**.

Introduction

- **Example project ANCHORS** = 'UAV-Assisted Ad Hoc Networks for Crisis Management and Hostile Environment Sensing' (2012-2015)
- **A swarm of UAS** and UGS **act autonomous** and flexible in a large scale incident
  - Independent **interaction of the swarm members**, roll management
  - **Wireless data communication links** air-to-air and air-to-ground
  - Ad-hoc communication with a **UAS supported network** and radio cells (Transmitter on-board)

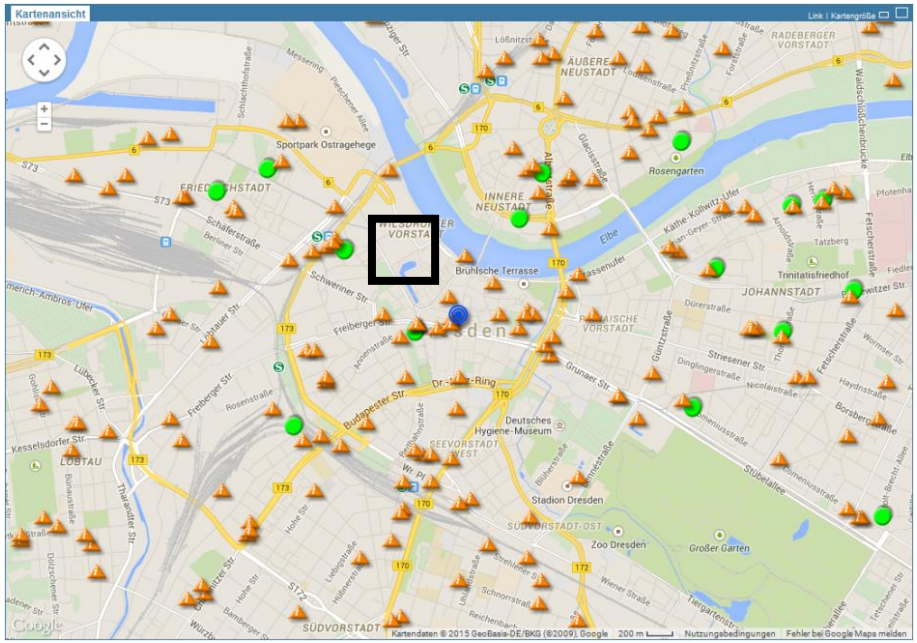


Source: ANCHORS consortium

Common aspects of typical usage scenarios

- UAS in **might be influenced by** the local **electromagnetic environment** of the operational area.

- **In general**: Because of the high coverage of mobile services in many countries, **stationary base stations** are part of this electromagnetic environment with a **high probability**.
  - Example right hand side: **Dresden map of stationary transmitters** queried in the *'electromagnetic fields' (EMF) monitoring data base* of German Federal Network Agency.
    □ = 500 m x 500 m



Source: http://emf3.bundesnetzagentur.de/karte/Default.aspx

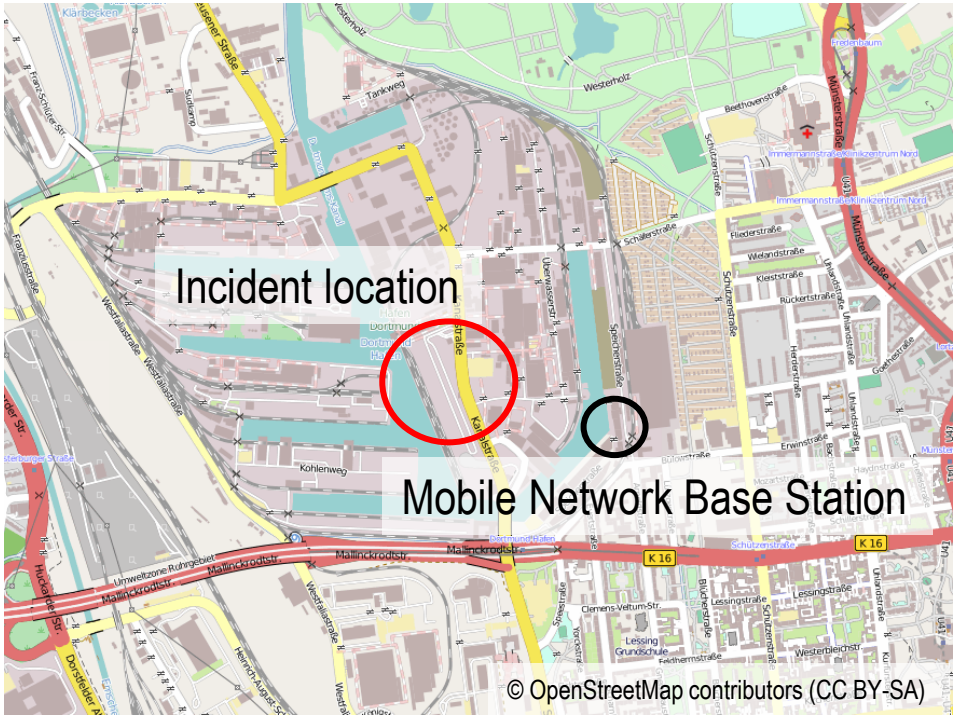
Common aspects of typical usage scenarios

- **In residential zones**: **Wireless** communication (e.g. DECT) and IT devices (e.g. WiFi, ZigBee, Bluetooth) with **low transmitter power** are common.
- **In industrial zones**: A variety of **business-specific transmitters**
  - local **wireless communication and IT** networks with **low transmitter power**
  - **directional radio links** with narrow antenna beam with **medium power**
  - ***broadcast stations*** with **medium and high power**
  - **radar facilities** in harbors, on ships, at airports and on aircrafts with **high and very high pulsed power**
- **Unintentional RF transmissions** are possible in industrial areas, as generated e. g. by power inverters.

- **Structural protection measures** for persons against high field values from stationary transmitters, like fences, **do not work for UAS automatically**.

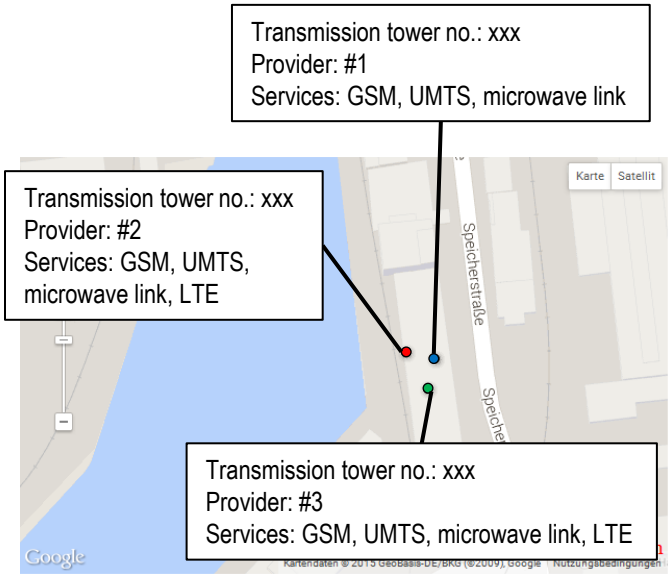
The test case environment in the example project ANCHORS

- In the ANCHORS project, a **large scale incident scenario** in the **Harbor of Dortmund** has been developed as the base of all further project work.
- With regard to the specified location, **a mobile network base station has been identified** in the direct incident area of the scenario.



The test case environment in the example project ANCHORS

- Link of **EU regulation test levels** for electronic equipment used **in industrial environments** EN 61000-6-2:2005 to **frequencies used with network services of the base station** located in the scenario area.



Source of base station details:
https://www.ruhrnachrichten.de/staedte/dortmund/Funkstationen-Finder-Wo-steht-der-naechste-Mobilfunkmast-von-Ihrem-Zuhause;art930,2116356

Table 1

*Service**	*Downlink*	*EMC test level***
LTE800 (FDD)	791 - 821 MHz	10 V/m
R-GSM900	921 - 960 MHz	10 V/m
LTE1800 (FDD)	1805 - 1880 MHz	3 V/m
GSM1800	1805 - 1880 MHz	3 V/m
UMTS	2110 - 2170 MHz	1 V/m
LTE2600 (FDD)	2620 - 2690 MHz	1 V/m

*in EU/Germany ** EN 61000-6-2

The test case environment in the example project ANCHORS

- **EMF monitoring data base of German Federal Network Agency** give **safety distances** related to **radiation angle** and height for each transmitter station. Safety distance is linked to **limits in 26. BImSchV***
- The data base **does not give service details** like communication standard and frequency **due to data protection requirements**

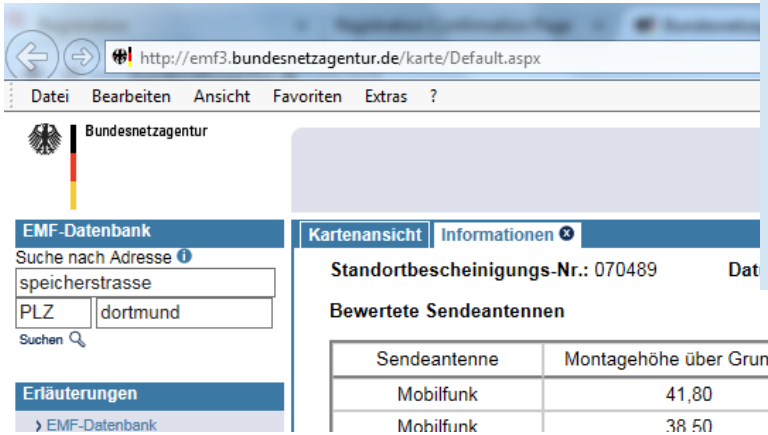


Table 2:

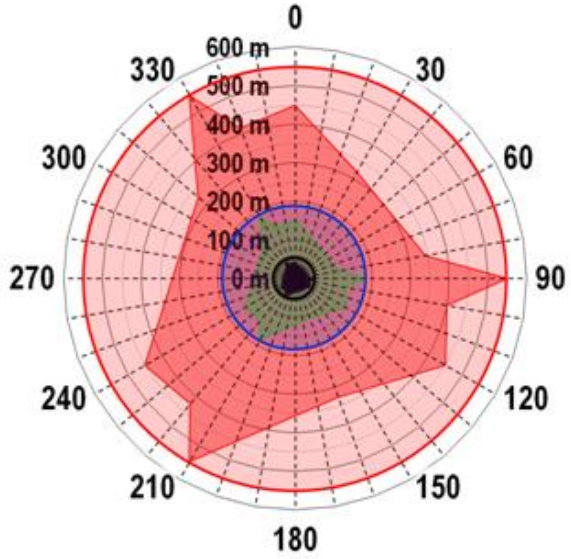
Frequency range	*El. field [V/m]***
10 – 400 MHz	28
400 – 2 000 MHz	$1{,}375 * f^{1/2}$
2 000 – 300 000 MHz	61

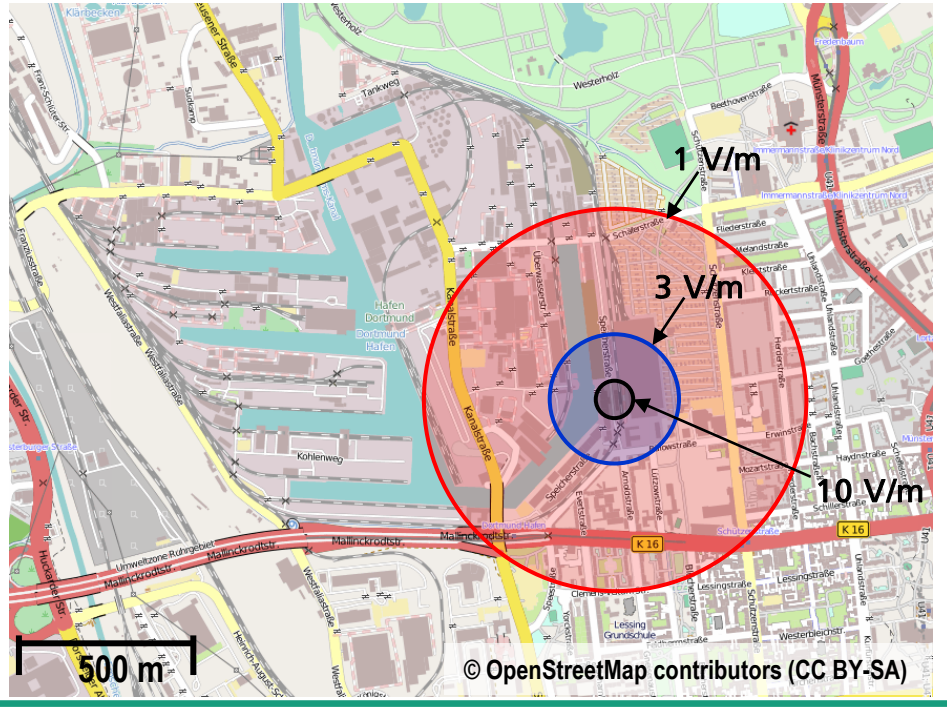
** Squared average 6 min

* Sechsundzwanzigste Verordnung zur Durchführung des Bundes-Immissionsschutzgesetzes (Verordnung über elektromagnetische Felder - 26. BImSchV)

The test case environment in the example project ANCHORS

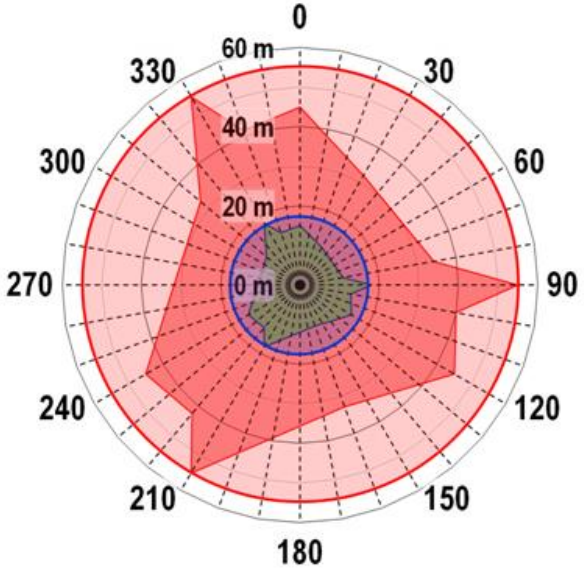
- In case the frequencies related to antenna systems would be known:
  - UMTS, LTE2600 - 1 V/m - **safety distance** up to **550 m**
    GSM1800, LTE1800 - 3 V/m - **safety distance** up to **190 m**
    GSM900, LTE800 - 10 V/m - **safety distance** up to **55 m**
- **Worst case** without frequency information is **550 m for safety distance**.
- **Radiation pattern** of base station (0° is N):

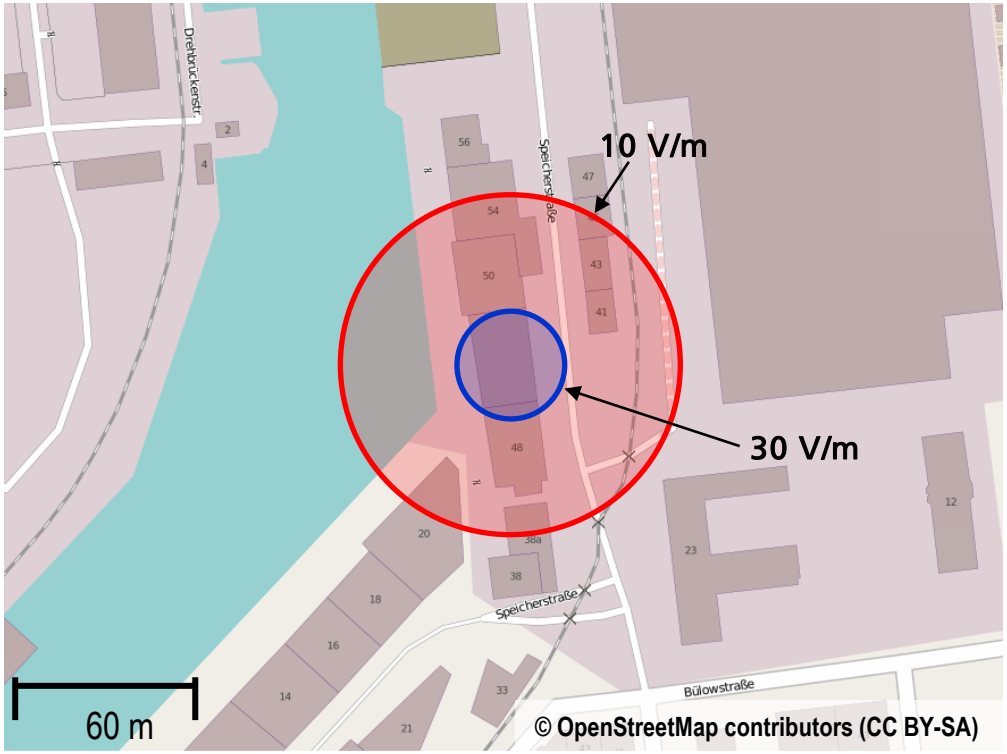




Elaboration of parameters for laboratory testing

- **Stick to test specification**, it allows to select severity levels up to **30 V/m**: IEC 61000-4-3, Table 1:“Test levels related to general purpose, digital radio telephones and other RF emitting devices”, Test Level 4
- 30 V/m: **18 m safety distance**
- A circle with a radius of **18 m can be handled** as is equivalent to the **size of a single building**
- Radiation pattern of base station:





Elaboration of parameters for laboratory testing

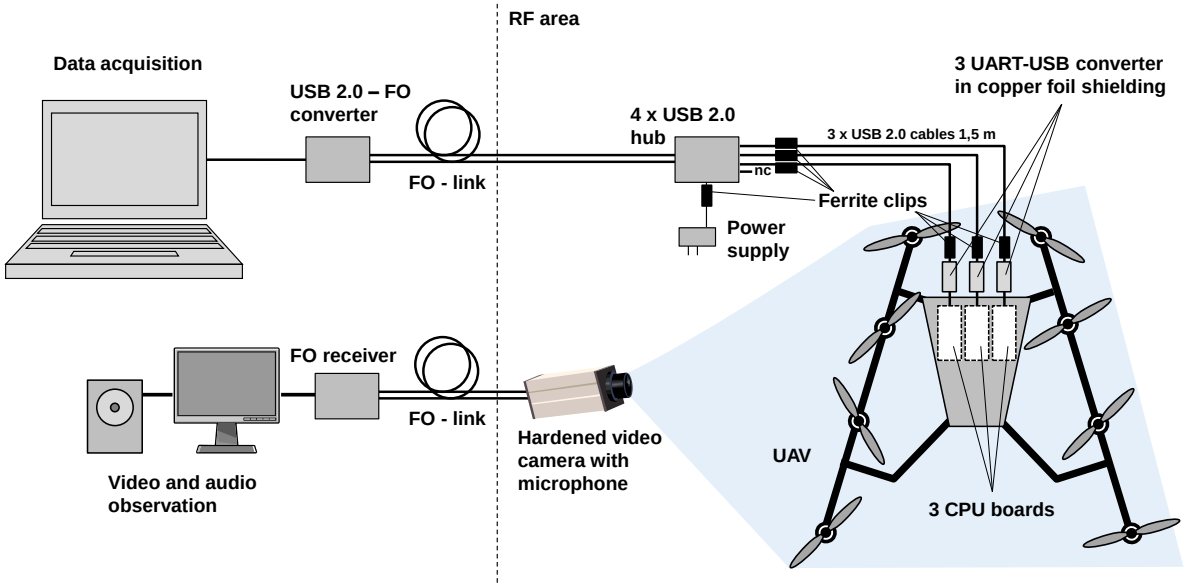
- Frequencies and severity levels **selected for ANCHORS** UAS immunity testing:

Table 3

Frequency	*Service*	*Immunity test value*
80 MHz - 1000 MHz	Basic EMC immunity requirement	10 V/m
1400 MHz - 2000 MHz	Basic EMC immunity requirement	3 V/m
2000 MHz - 2700 MHz	Basic EMC immunity requirement	1 V/m
400 MHz	LTE/PMR communication within ANCHORS, on-board transmitter	30 V/m
2400 MHz	Remote control, other services on 2.4 GHz ISM (Industrial, Scientific, and Medical) band	30 V/m
5200 MHz 5800 MHz	UAS remote control downlink channel, other services on 5 GHz ISM band	30 V/m
810 MHz 1840 MHz 2660 MHz	GSM/LTE stationary base stations, ANCHORS LTE/PMR communication with on-board transmitter	30 V/m
3020 MHz 9375 MHz	Stationary and mobile naval radar facilities in S- and X-band	30 V/m

Test setup and diagnostics

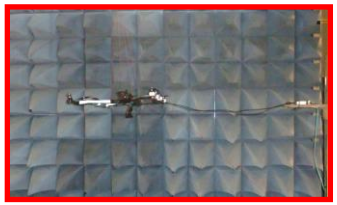
- Immunity tests performed in an **open TEM waveguide**
- **Observation of rotors** with an EMC hardened video camera and audio channel
- **Raw and control data** of all CPU boards are **streamed to a monitoring PC** via fiber optic USB link

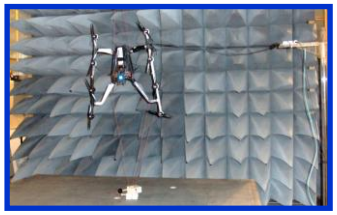


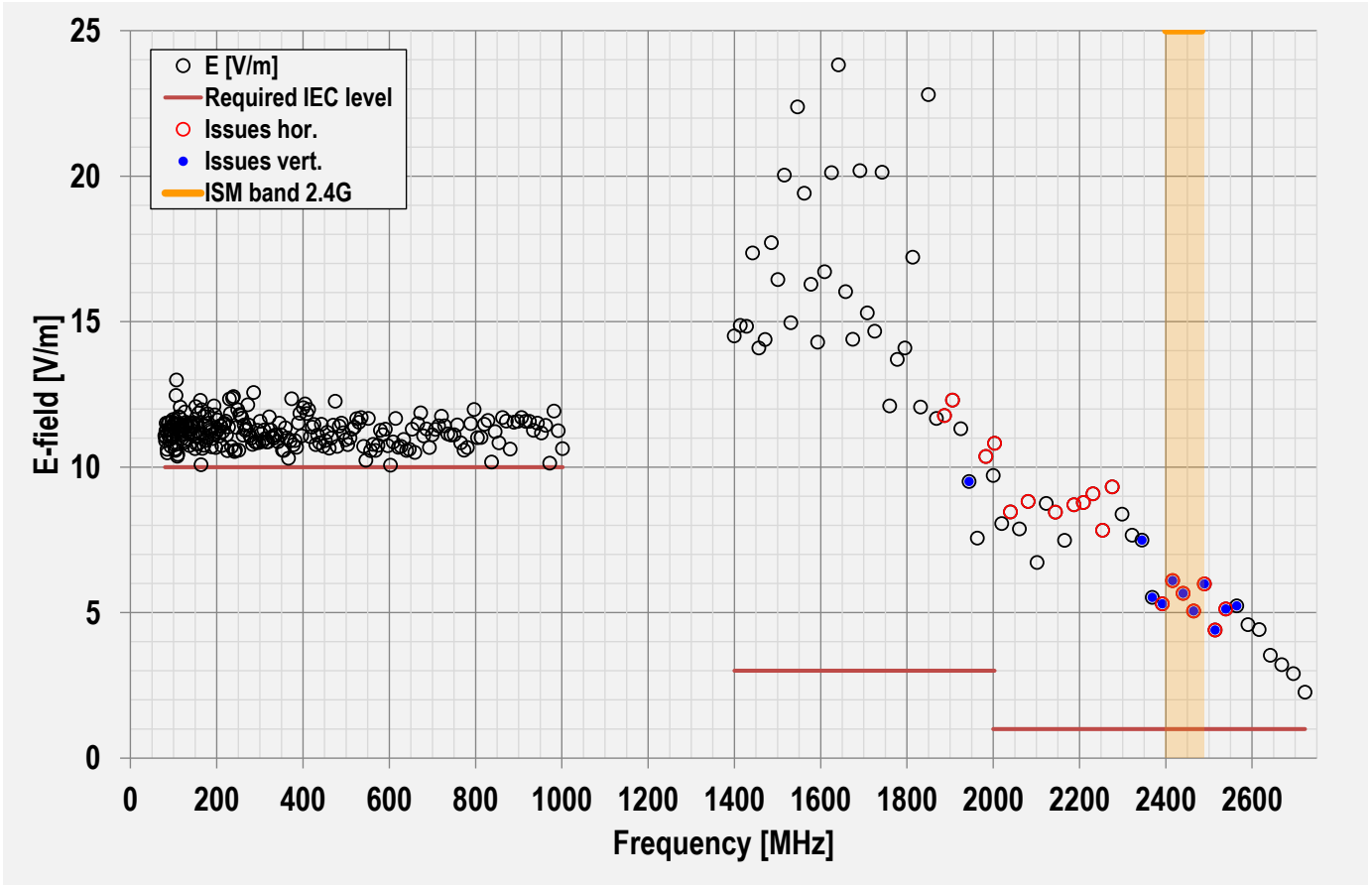
Source: ANCHORS consortium

IEC EMC immunity test 80 MHz – 2700 MHz

- **Only one failure picture** has been observed: one of the two established redundant remote control links on 2.4 GHz ISM band was interrupted during RF illumination

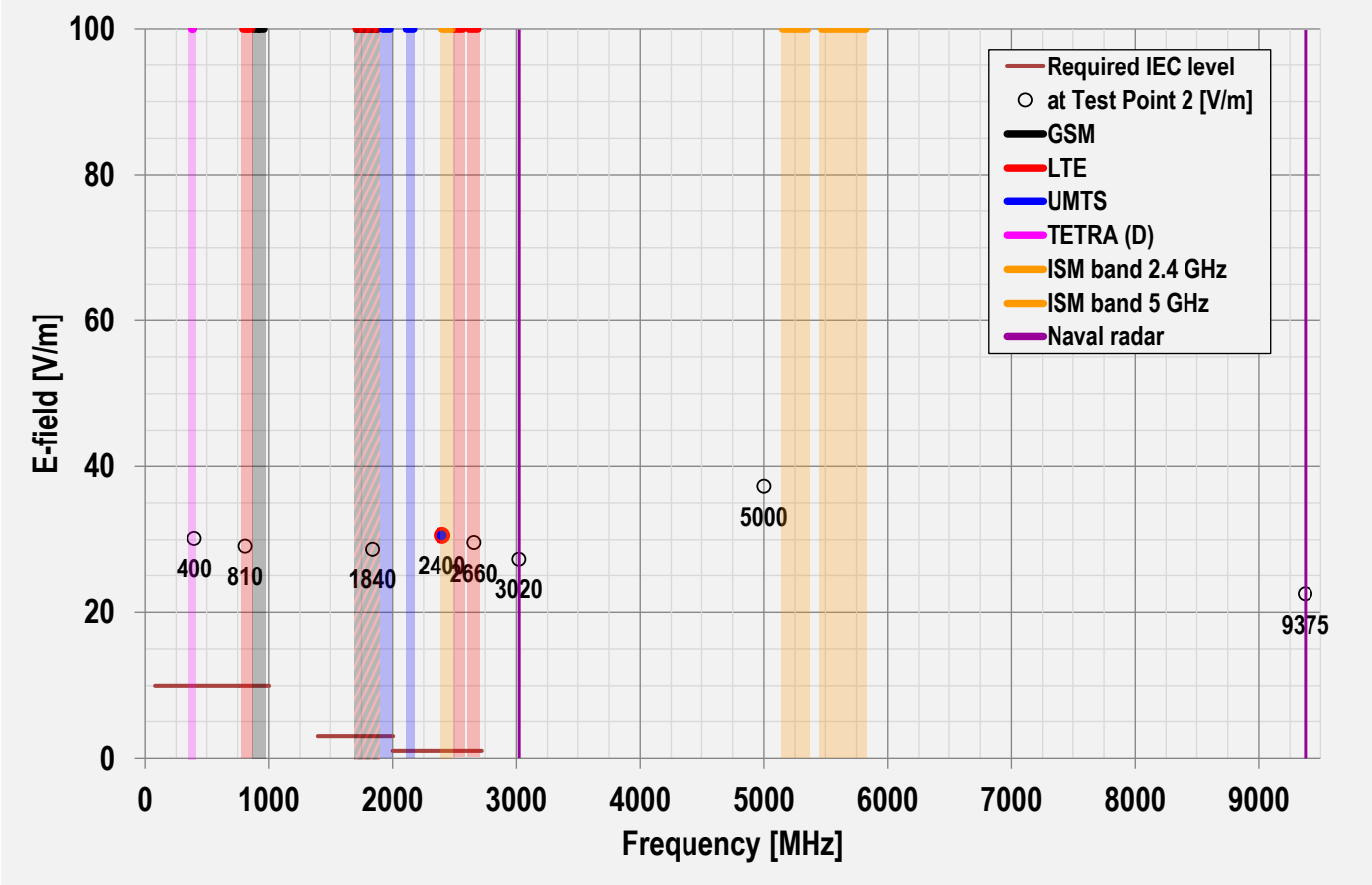






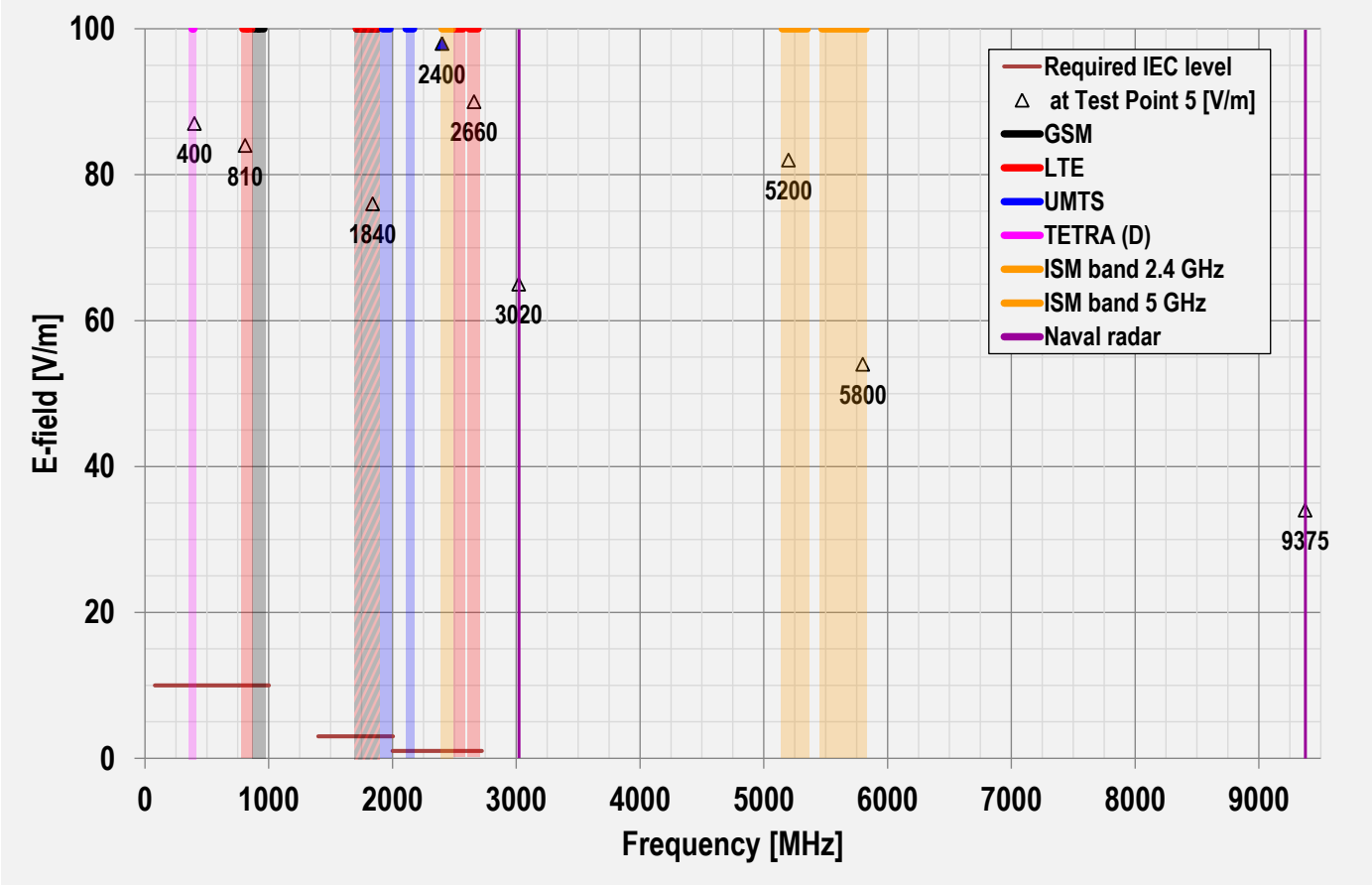
Additional frequencies with 30 V/m

- **Same failure picture** as previous test run



Additional frequencies with higher field strength

- **Test position changed** within TEM waveguide **to get higher field values**
- **Same failure picture** as previous test runs



Summary

- **One measure to control RF field strength** in an EMC environment is **keeping distance to RF sources**, e.g. with fences.
- UAS used **in crisis situations** cannot respect this measure.
- RF transmitter for **mobile network services** located within the operational area with a **high probability**.

- Therefore **standard EMC immunity** test **is not sufficient** for a certain set of frequencies.
- The **normative immunity target level 30 V/m is sufficient in combination with a reasonable safety distance** without UAS usage limitation in an incident area.
- The UAS designed within the ANCHORS project passed the new requirements defined with these considerations.

Outlook

- **Testing and hardening** with higher severity levels at wireless communication frequencies **in combination with keep-out area maps** could be a future solution.
- The discussed **safety distance** is based on worst case evaluation, **covering all mobile network service frequencies**, so **future changes** in base station configurations **do not affect** this safety distance
- **Intentional Electromagnetic Interference (IEMI)** should **be considered** as a possible threat to impede an operation of first responders. As a first step **the immunity margin** of UAS electronics should be evaluated **between 100 MHz and 5 GHz,** without the normative frequency gap.
- Handling **high field strengths** in specific environments, e.g. **radar**, is an issue, too.

Source: ANCHORS consortium

Define and Test Electromagnetic Immunity of UAS for First Responders

- Do you have any questions?
- What is your opinion to the presented EMC immunity issue of UAS?

The ANCHORS project at a glance

- **Objective:**
  Support for rescue operations and other measures at large scale hazardous incidents via an autonomous swarm of unmanned aerial and ground vehicles, including
  - Communication relay
  - Overview of the situation
  - Measurements of radioactivity

SPONSORED BY THE Federal Ministry of Education and Research

ANR

- **Consortium:**
  - Spokesperson: Technische Universität Dortmund, Lehrstuhl f. Kommunikationsnetze
  - German Partners: Stadt Dortmund, Feuerwehr (organisational management German part), Ascending Technologies (technical management German part), Mirion Health Physics, SGE GmbH, Kerntechnischer Hilfsdienst GmbH, Fraunhofer INT, RWTH Aachen – Institut für Flugsystemdynamik,
  - French Partners: Cassidian, LS telcom SAS, Commissariat à l'énergieatomique et aux énergies alternatives, ONERA, Groupe-Intra
  - Associated Partners: Feuerwehr Frankfurt a.M., LKA Berlin, Bundesamt für Strahlenschutz
- **Sponsored by** the Federal Ministry of Education and Research, Germany; and the French National Research Agency, France.

http://www.anchors-project.org/index.php/en/index.html