ETH zürich

P&S: Our Daily Exposure to Electromagnetic Radiation

Measuring Personal RF Exposure

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Content

- Personal RF-EMF Exposure Assessment
- Methods, requirements and challenges
- ExpoM-RF: Personal RF-EMF Exposure meter developed at IEF
- Organization group projects

Personal RF-EMF Exposure

800 MHz

900 MHz

1800 MHz

2100 MHz

2600 MHz

3600 MHz

100 MHz

550 MHz

0.8 – 5.8 GHz

2.4 GHz

1900 MHz

5.8 GHz

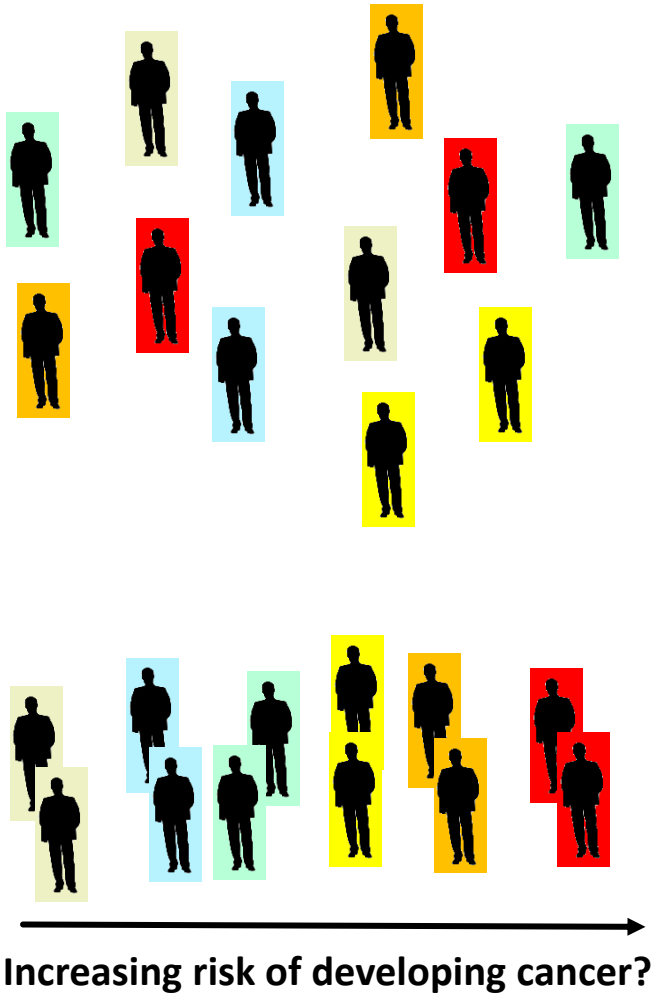
433 MHz

Why is it important to know the individual exposure?

Epidemiological studies

- Goals
  - Determine the risks associated with EMF exposure
  - Determine dose responses and/or damage thresholds

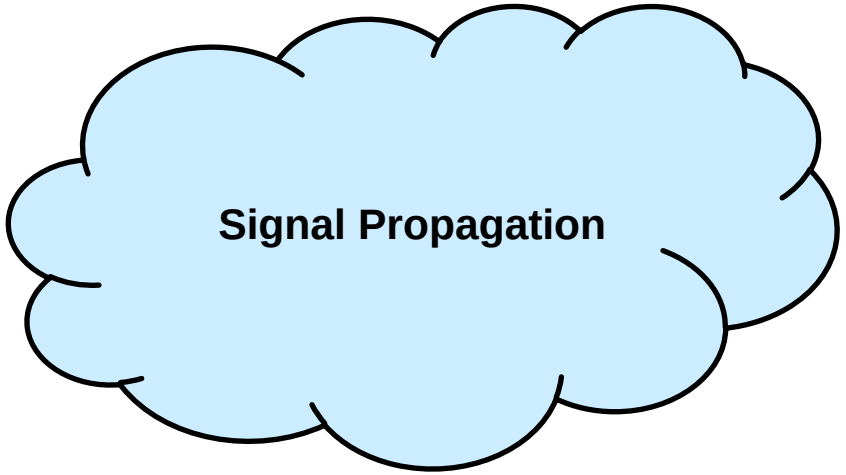
- Challenge:
  - Exposure level op single person is hard to predict
  - Individual measurement values are therefore needed
  - Population must be sorted by exposure level to perform systematic assessments



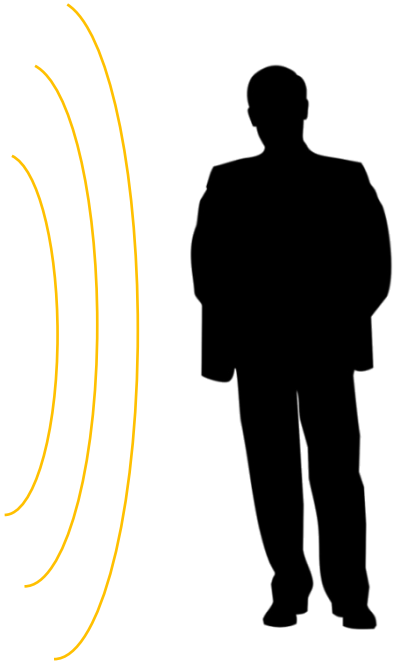
Personal RF-EMF Exposure measurements

Goal: Measuring the **Immission** at the location of the person

Emission: 50W, 2.1 GHz



Immission: 0.2 V/m RMS



Emission: 1W, 800 MHz

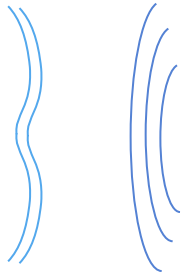
Personal EMF exposure: Influences & Variations

NF - sources

- Power
- Frequency
- Modulation
- Device type
- Antenna type
- Operation mode

FF - sources

- Power
- Frequency
- Modulation
- Device type
- Antenna
- Operation mode



Propagation

- Distance
- Scattering/ Reflection
- Re-radiators
- Environmental conditions
- Coupling

Person

- Anatomy
- Tissue parameters

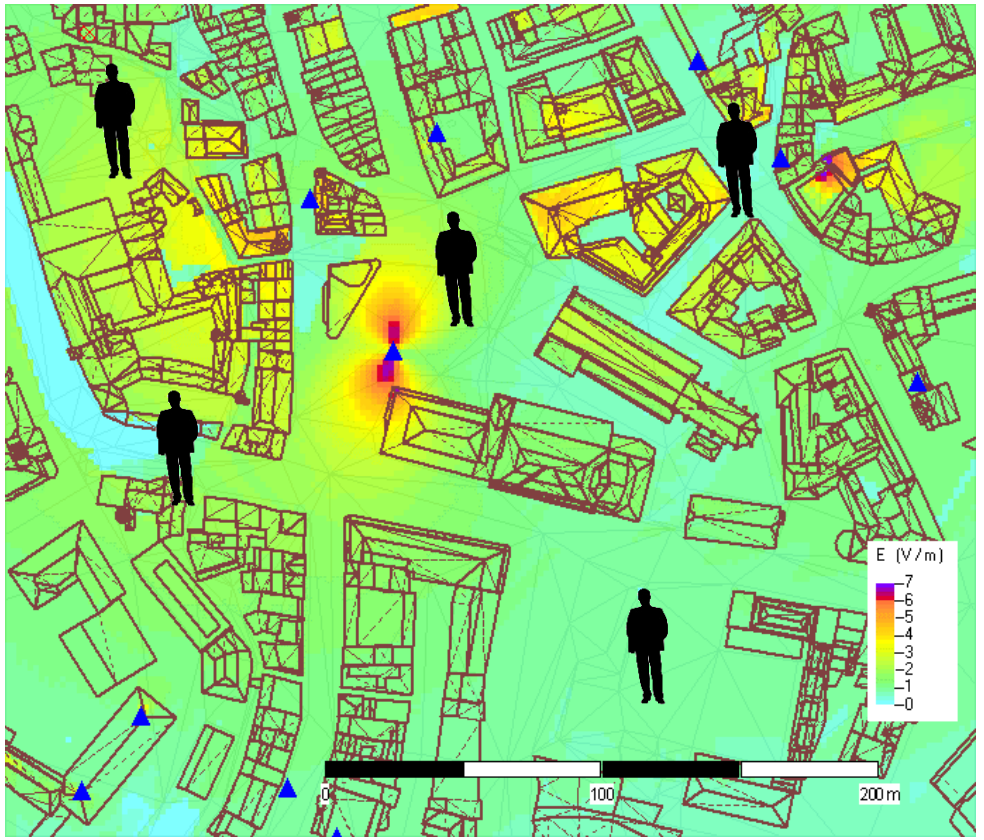
Behavior

- Lifestyle
- Posture
- Usage pattern

Methods to assess Personal EMF exposure (1)

Field maps using computer simulations

- Average exposure of population
- Very large samples
- Low cost per test subject
- Values in V/m



Limitations and challenges:

- Need for accurate propagation models and base station parameters
- Individual usage patterns are ignored
- Does not consider uplink contributions

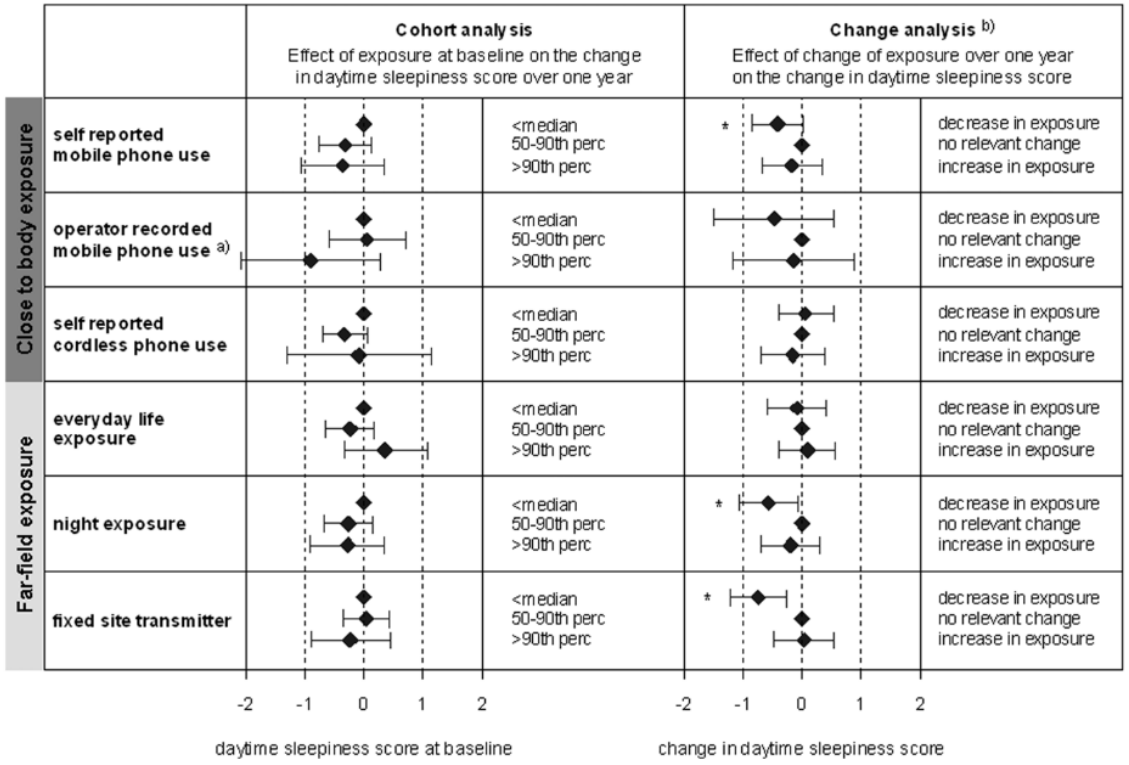
Methods to assess Personal EMF exposure (2)

Questionnaires

- Subjects are asked to fill out forms
- Correlation with other personal data
- Moderate cost & effort per test subject

Limitations and challenges:

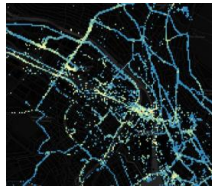
- Self-reporting is prone to biases (recall bias)
- Subjective and approximate answers
- No specific values in V/m



Methods to assess Personal EMF exposure (3)

Smartphone Apps

- Principle: Using available cellular signal strength indicators (RSSI, RSRP, …) to estimate the field strength
- Very low cost per test subject; highly scalable



Limitations and challenges:

- Incomplete data: only selected cells of own provider are considered
- Values need to be calibrated
- No useful information about uplink exposure
- Data of users using all active service providers must be combined
- Software challenges: sample interval limited by power saving features

Sunrise Salt. swisscom

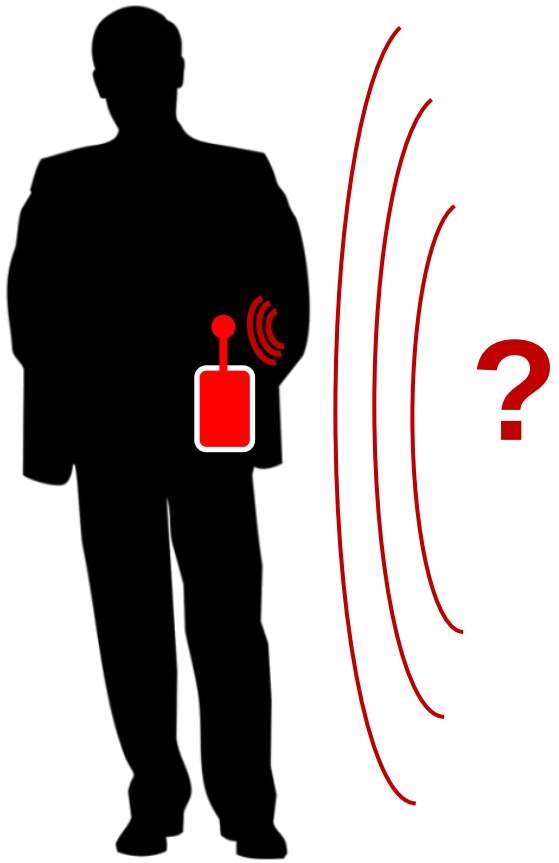
Methods to assess Personal EMF exposure (4)

Personal Exposimeters:

- Take samples of the total exposure
- High specificity (location and time)
- Representative for real-life situation
- Values in V/m

Limitations:

- Proximity and shadowing effects
- High cost and effort per test subject



Personal RF-EMF Exposimeter: Requirements

Technical requirements

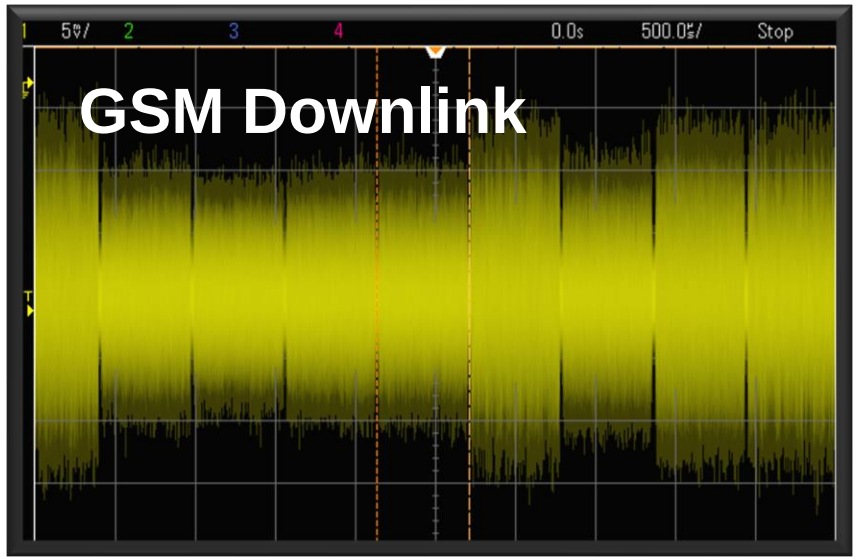
- Measurement shall allow comparison across **modulation and wireless standards**
- Measurement shall be insensitive to **direction of incidence**
- Measurement shall be insensitive to **polarization of EMF**
- Measurements shall be **frequency selective** (identification of probable sources)
- Large dynamic range and high sensitivity

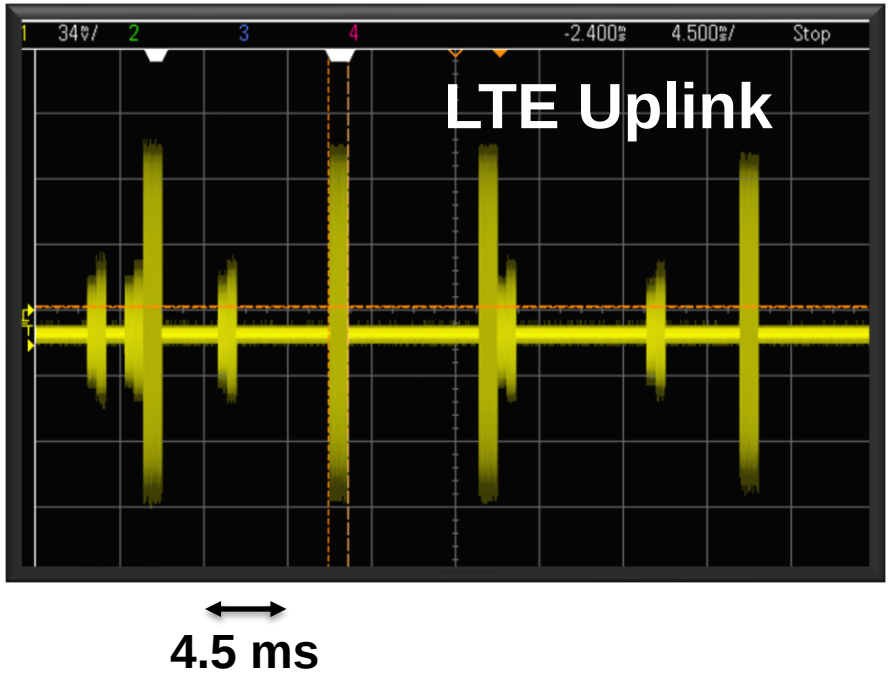
Practical Aspects

- Portable, lightweight (minimal influence on behavior of test subjects)
- Long battery life time
- Robust and easy to use

Personal RF-EMF Exposimeter: Requirements

Modulated RF signals can have very different shapes





How can we compare the field strength of these signals?

→ **True-RMS value** is used in guidelines and limits (thermal hypothesis)

True-RMS value of electromagnetic fields

Properties and Definition

- RMS = root mean square
  - Average value in terms of **power density / power**
  - Fields -> power density -> averaging/sum -> convert back to E-Field
  - Equivalent field strength required to achieve the same **thermal** effect (heating)
  - Drawback: information about signal shape is lost

- Formulas for summing and time-averaging field strength values
  - RMS sum: $E_{RMS} = \sqrt{E_1^2 + E_2^2 + \cdots + E_N^2}$ (e.g. sum of several bands)
  - RMS average: $E_{RMS} = \sqrt{\frac{1}{N}(E_1^2 + E_2^2 + \cdots + E_N^2)}$ (e.g. averaging over time)

ExpoM-RF – A Personal RF-EMF Exposimeter developed at ETH

Size: 16 x 8 x 5cm
Weight: 320g

- Measurement Range from 50 MHz to 6 GHz
- True-RMS detection
- Localization (GPS)
- Live visualization with Smartphone App
- PC Software

ExpoM-RF – Frequency bands

	Band name	Frequency	Wireless services (selection)
1	FM Radio	87.5 – 108 MHz	FM radio
2	DVB-T	470 – 790 MHz	TV bands IV and V, wireless microphones / speakers
3	Mobile 800 MHz downlink	791 – 821 MHz	mobile communications (4G)
4	Mobile 800 MHz uplink	832 – 862 MHz	mobile communications (4G)
5	Mobile 900 MHz uplink	880 – 915 MHz	mobile communications (GSM/3G/4G)
6	Mobile 900 MHz downlink	925 – 960 MHz	mobile communications (GSM/3G/4G)
7	Mobile 1800 MHz uplink	1710 – 1785 MHz	mobile communications (GSM/4G)
8	Mobile 1800 MHz downlink	1805 – 1880 MHz	mobile communications (GSM/4G)
9	DECT	1880 – 1900 MHz	cordless phones
10	Mobile 2.1 GHz uplink	1920 – 1980 MHz	mobile communications (3G/4G)
11	Mobile 2.1 GHz downlink	2110 – 2170 MHz	mobile communications (3G/4G)
12	ISM 2.4 GHz	2400 – 2485 MHz	Wi-Fi, Bluetooth, microwave ovens…
13	Mobile 2.6 GHz uplink	2500 – 2570 MHz	mobile communications (4G)
14	Mobile 2.6 GHz downlink	2620 – 2690 MHz	mobile communications (4G)
15	Mobile 3.5 GHz	3400 – 3600 MHz	Point-to-point links, WiMax
16	ISM 5.8 GHz / U-NII 1-2e	5150 – 5875 MHz	Wi-Fi, RADAR, wireless video

Basic Concept

Measurement Device

Simple

- No display
- Low-power CPU
- Long battery life

Specialized

- Optimized for the requirements of RF-EMF exposure assessment

Bluetooth

- Wireless interface to smartphone

GPS

- Localization of measurements

Smartphone

Connectivity

- Bluetooth
- Wi-Fi, internet access etc.

Familiar user interface

- Large touch screen
- Real-time interaction and visualization

Computing Resources

- Large memory and CPU
- Increases with each generation
- Low cost

Extendable

- Custom Apps extending functionality

ExpoM-RF Software and Tools

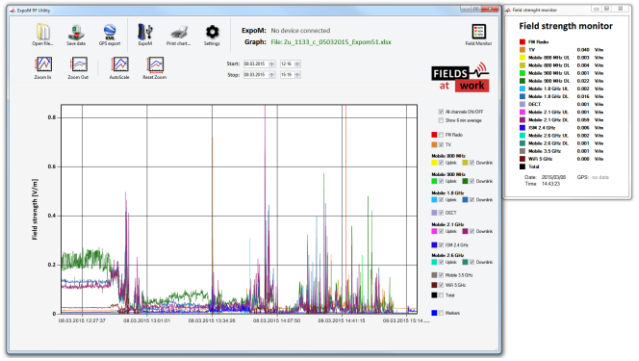
1. Measurement device (Sensor)

- EMF Measurements
- Automatic data logger

2. ExpoM-RF Android App

- Live visualization

3. ExpoM-RF Utility PC Application



- Data download
- Visualization and analysis
- Save/Load XLSX/CSV files
- Export GPS tracks
- Manage device settings

ExpoM-RF Software and Tools

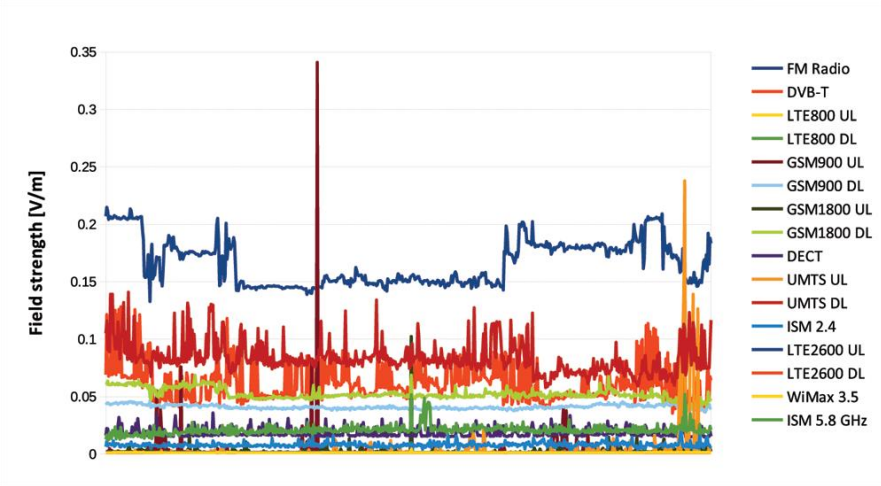
1. Measurement device (Sensor)

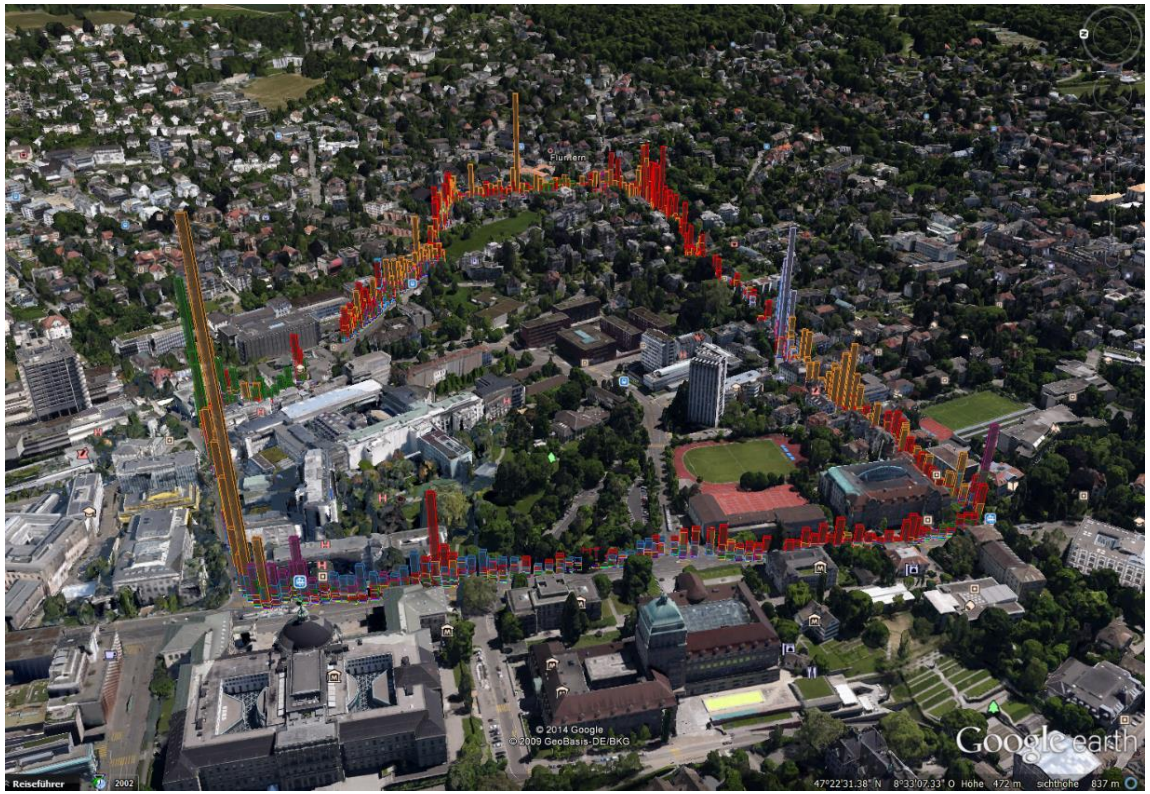
2. ExpoM-RF Android App

3. ExpoM-RF Utility PC Application

All software, device datasheet, manual etc.)
Can be downloaded from P&S homepage

Visualization of measurement values



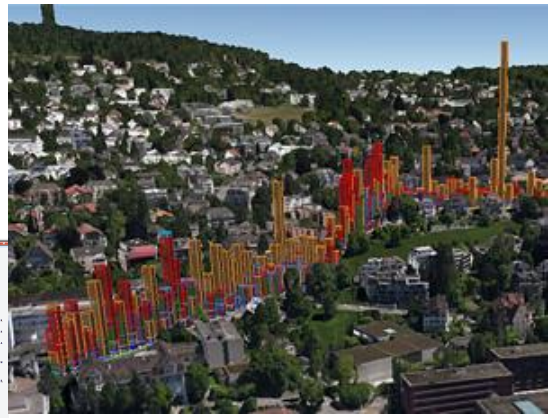


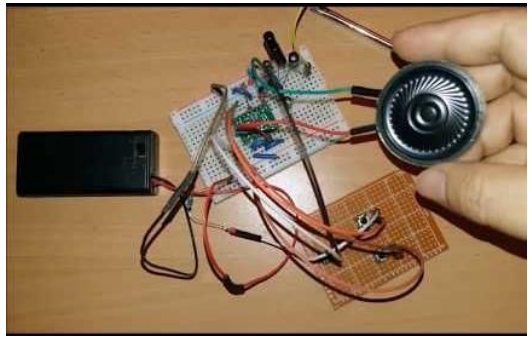
Now it’s your turn!

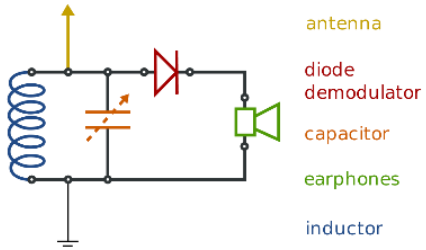
Group project

Laboratory Experiments

Environmental Exposure Measurements

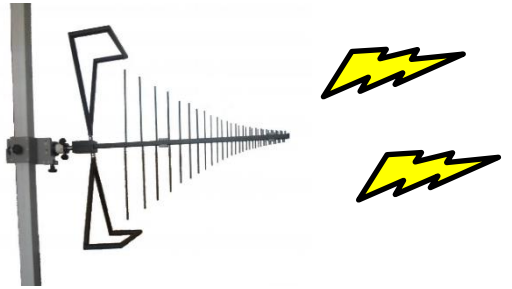






Build your own radio receiver / detector

Provocation studies



Project

Steps:

1) Form 3-4 groups (3-4 people each)
2) Set up an idea / hypothesis and a corresponding measurement plan to verify it
3) Follow and adapt measurement plan, analyze data. Weekly discussion of results and progress
4) Present findings in presentation and written report at end of semester

Examples

- EMF at ETH (indoor/outdoor), on Swiss lakes, in trains with different levels of occupation…
- Comparison of RF-EMF exposure between parts of the city
- Compare ETAIN app measurements with exposimeter values
- Measurement of specific EMF emitting devices in various modes of operation
- Investigate effectiveness of measures to reduce EMF exposure
- Build and test your own EMF sensor
- Adaptive antennas: Can you visualize beamforming of 5G antennas?

Organisatory info

- Several ExpoM-RF devices are available for the P&S
  - You can keep the devices for the duration of the P&S
  - ExpoM-RF devices must be returned at end of semester
  - Additional or new generation (Model 4) devices can be organized if needed for specific measurements

- Regular group meetings and discussions
  - Usual time slot
  - Groups meet separately (35 min each)

- Experiments involving ETH lab instruments, anechoic chamber etc. can be scheduled separately as needed.

Forschungsplan

- Festlegung von gemeinsamen Zielen
  - Was soll untersucht werden?
  - Welche Objekte? Welches Verhalten?

- Festlegung des gemeinsamen Vorgehens
  - Wie sollen die Ziele erreicht werden?
  - Wie werden die Objekte untersucht?
  - Welche Parameter werden verändert?
  - Wie soll die Arbeit aufgeteilt werden?

Titel	
Gruppe	
Messobjekte	
Ziele	
Vorgehen	

Messtagebuch

- Schreibt immer auf, wann ihr welche Messung gemacht habt
- Genaue Uhrzeit ist sehr wichtig um die Messdaten zuzuordnen
- Kopiert Messdaten regelmässig auf PC / Notebook / Cloud
- Benennt Dateien um und vergebt sinnvolle Dateinamen

Gruppeneinteilung FS 2025

Name	Vorname	e-mail
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Stoychev	Maximilian	mstoychev@student.ethz.ch
Xu	Linqi	linqixu@student.ethz.ch

Gruppe 1 (Bluetooth Kopfhörer)	
1 Ishita	3 Nicolas
2 Vien Kheo	4 Linqi

Gruppe 2 (EMF Stadt / ETH etc)	
1 Laura	3 Remi
2 Maximilian	4 Anahi

Gruppe 3 (EMF Vergleiche zuhause)	
1 Tin	3 Ludwig
2 Hugo	4 Bennet