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GRUPPO FERROVIE DELLO STATO

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Accreditamento di Procedure di Prova per la Misura delle Emissioni Radiate del Sistema Ferroviario

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Agenda

- Introduction (radiated emissions, normative EN 50121 & IEC 62236)
- Motivation for accreditation (according EN ISO/IEC 17025)
- Measurement equipment
- Instruments calibration & software validation
- System uncertainty
- Test procedure & results
- Conclusions

Radiated emissions

- Electromagnetic field radiated by
  - ✓ rolling stock
  - ✓ infrastructure

- Magnetic field (lower frequency band)
  - ✓ power drive system
- Electric field (higher frequency band)
  - ✓ pantograph sliding contact, on board communication systems

- EMC assessment of railway system, internal and towards outside world

EN 50121 / IEC 62236 standards

- Estimation of radiated emissions in the 9 kHz – 1 GHz frequency range
- Railway applications, urban vehicles
  - ✓ 750 V & 3 kV dc, 15 kV & 25 kV ac power supply systems

Part 2

- Emission of the whole railway system to the outside world
  - ✓ moving trains & railway substations

Part 3-1

- Rolling stock – Train & complete vehicle
  - ✓ stationary & slow moving trains

Motivation for accreditation

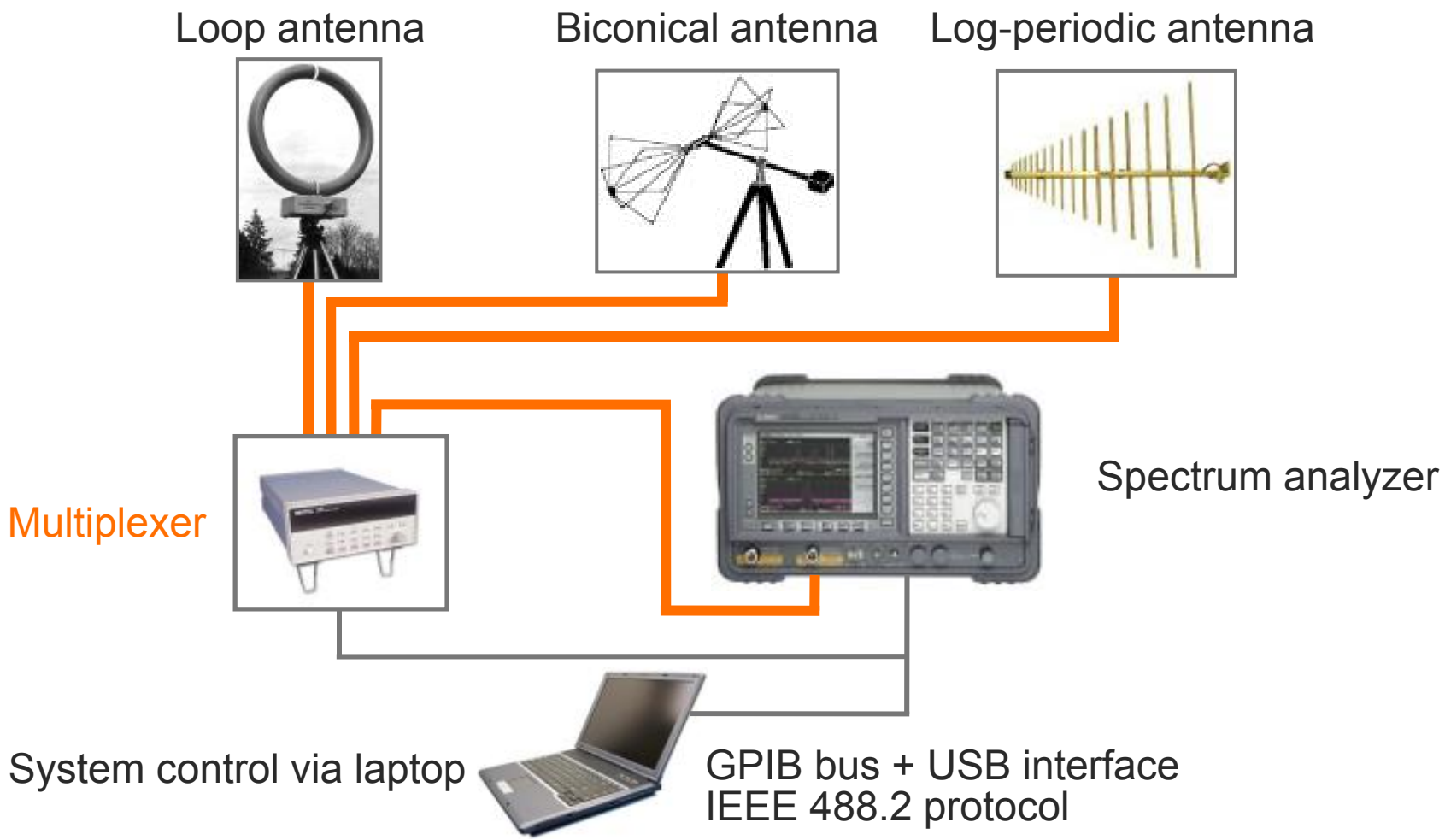
ISO/IEC 17025

- General requirements for the competence of testing and calibration laboratories

- Labs advantages
  - ✓ *'… operate a management system, are technically competent, and are able to generate technically valid results.'*
  - ✓ impartiality, independence, uprightness, clearness, privacy
  - ✓ mutual recognition among countries
  - ✓ EU rolling stock cross-acceptance assessments

- The Italian accreditation body

Measurement system



Instruments calibration

- According to recommendation issued by
  - ✓ SINAL
  - ✓ National Metrology Institute (Istituto Elettrotecnico Galileo Ferraris)
- Antennas
  - ✓ external calibration, two years calibration interval
  - ✓ calibration interval extension through VSWR check before employment
- Receiver
  - ✓ external calibration, one year calibration interval
  - ✓ CISPR 16-1-1
- Cables
  - ✓ internal calibration by means of the receiver just after its calibration
  - ✓ one year calibration interval
- Metrological confirmation before & after every test campaign

Software validation

- Injection of synthetic signals at multiplexer input
  - ✓ spanning the entire frequency range 9 kHz – 1 GHz
  - ✓ in all operating modes (zero span & frequency sweep)
  - ✓ detection & measurement verification
  - ✓ comparison with theoretical response
- Enhanced signal processing functions
  - ✓ 2D & 3D visualization of the entire measurement
  - ✓ transients identification & removal
  - ✓ single frequencies & bands exclusion
- Data management
  - ✓ entry
  - ✓ integrity & storage
  - ✓ protection & confidentiality

System uncertainty

- Estimated in compliance with CISPR 16-4-2, it is constituted by the following components

$$u(F) = [u(V_r)^2 + u(\delta V_{sw})^2 + u(\delta V_{pa})^2 + u(\delta V_{pr})^2 + u(\delta V_{nf})^2 +$$ Receiver

$$+ u(AF)^2 + u(\delta AF_h)^2 + u(\delta AF_f)^2 +$$
$$+ u(\delta A_{dir})^2 + u(\delta A_{ph})^2 + u(\delta A_{cp})^2 +$$ Antennas

$$+ u(\delta M)^2 +$$ Mismatching

$$+ u(L_c)^2 +$$ Connections

$$+ u(\delta d)^2 +$$ Distance

$$+ u(\delta R)^2]^{1/2}$$ Repeatability

Reproducibility & repeatability

Reproducibility

- Feature of the test, depends on
  - ✓ test site (geometric, electromagnetic, …)
  - ✓ test conditions (environmental, meteorological, …)
  - ✓ train state (speed, power, configuration, driver behavior, …)
- System under test does not suitable for multiple measurements nor they are required by normative
  - ✓ Project main goals are test optimization & cost abatement

Repeatability

- Feature of the measurement system, it can be
  - ✓ included in the uncertainty budged *a priori*
  - ✓ estimated through repetitive measurements of a reference source

Measurement repeatability

- A reference source as system under test
- Selection of a frequencies set in the 9 kHz – 1 GHz range f_i, $i=1,\ldots,8$
  - ✓ 2 frequencies in every sub-band: 9 – 150 kHz, 150 kHz – 30 MHz, …
- 10 measurements for each frequency f_i
  - ✓ assembling & disassembling measurement systems
- Experimental standard deviation of measurements @ f_i

$$u(\delta R)_{f_i} = s_i = \sqrt{\sum_{q=1}^{10} \left(x_{iq} - \bar{x}_i\right)^2 / 9}$$

- Repeatability uncertainty is chosen as

$$u(\delta R) = \max\left\{u(\delta R)_{f_i}\right\}_{i=1,\ldots,8}$$

Test procedure for moving trains

- Minimum requirements: three monitored frequencies per decade
  - ✓ five decades bandwidth ⇨ 15 frequencies

Standard mode

- Zero span
  - ✓ one monitored frequency per train run
  - ✓ 15 frequencies require 15 train runs!

Optimized mode

- Zero span + frequency sweep
  - ✓ more than one monitored frequency per train run
  - ✓ sequence of multiple sweeps
  - ✓ time interval between two readings at the same frequency less than 1 s

Optimized mode

- BW_1 9 kHz – 150 kHz, RBW 200 Hz
  - ✓ zero span, 2 or 3 monitored frequencies per train run
  - ✓ two train runs required
  - ✓ frequency sweep does not match time interval condition
- BW_2 150 kHz – 30 MHz, RBW 9 kHz
  - ✓ frequency sweep, entire band processed in one train run
- BW_3 30 MHz – 300 MHz + 300 MHz – 1 GHz, RBW 120 kHz
  - ✓ switch changes over between biconical & log-periodic antennas
  - ✓ frequency sweep, entire band processed in one train run

Test on the whole band (BW_1 + BW_2 + BW_3) requires only 4 train runs!

Comparison with standard mode ⇨ -70% of testing time & resources

Accreditation test

- Train under test – ETR600.002 high speed trainset

ETR 600 main features

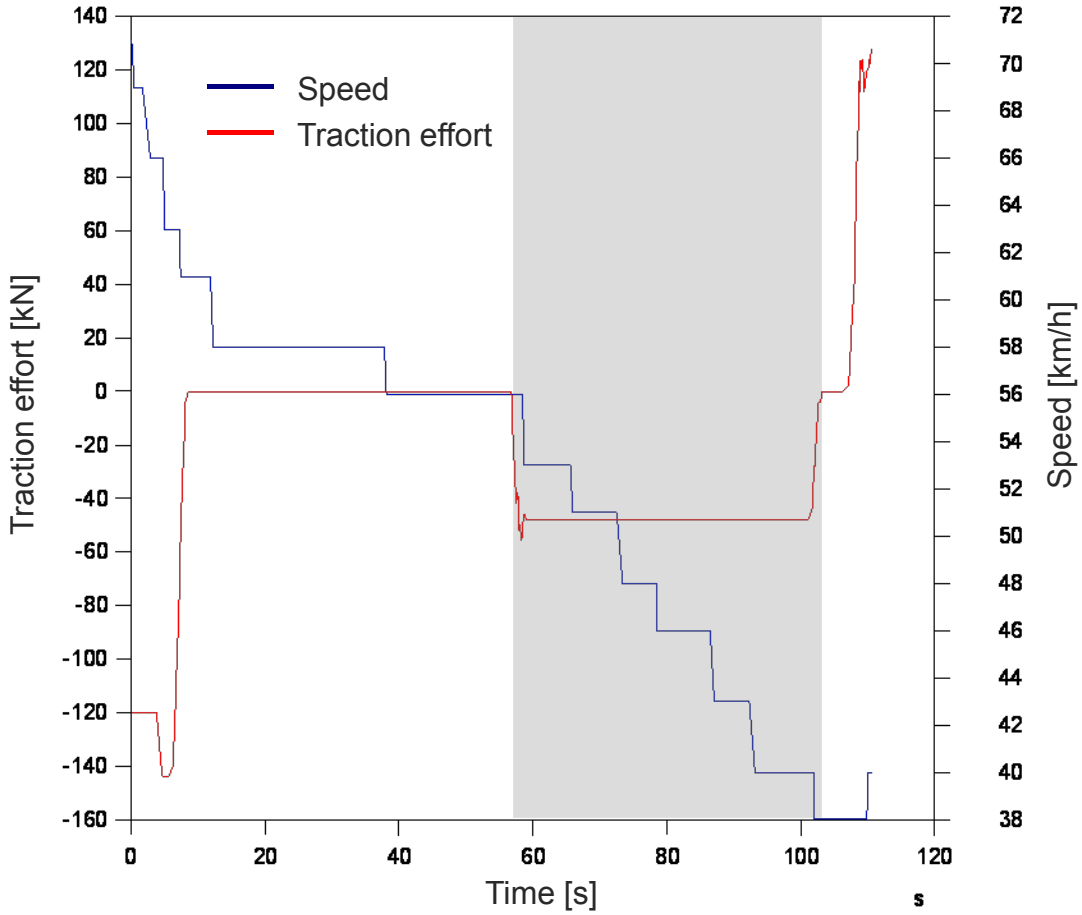
- 3 kV dc & 25 kV ac
- 5.5 MW traction pwr
- 250 km/h
- Ultimate tilting tech
- Distribute traction
- Multiple unit

- Florence-Rome line @ km 189+100
- September 24th, 2007

Measurement results

Software report printout

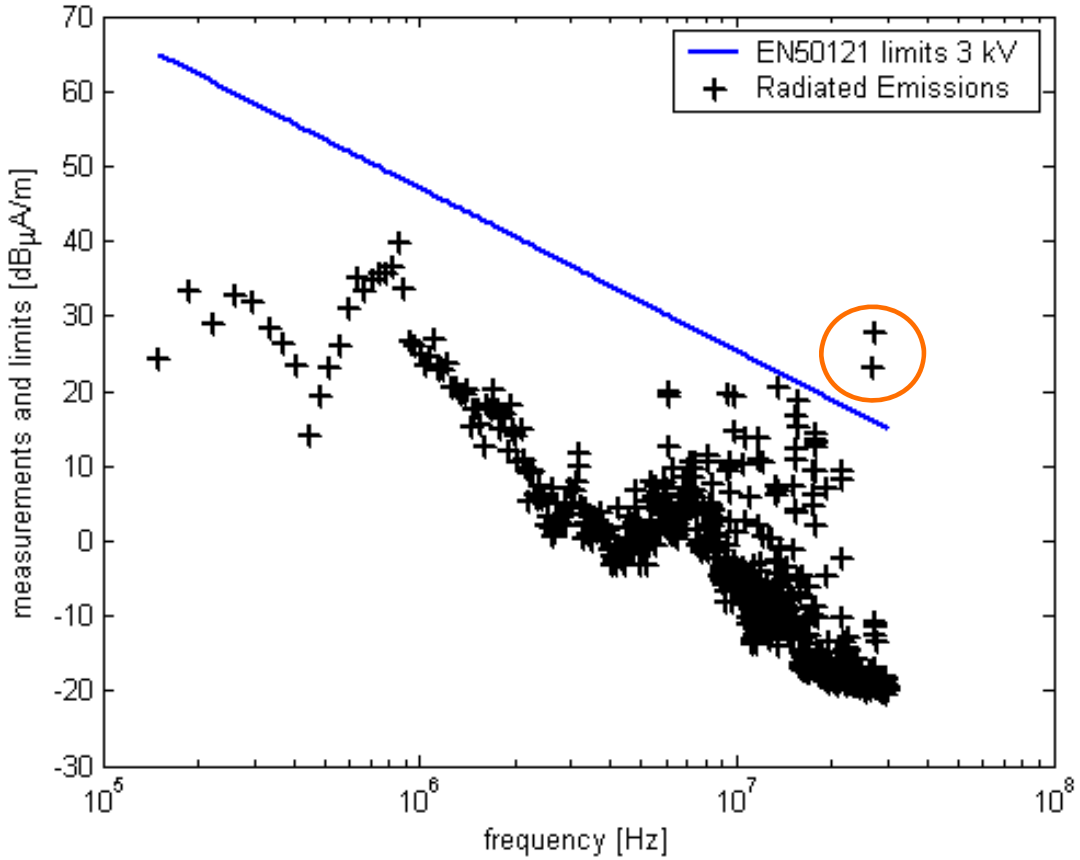
Site: Rome-Florence line @ km 189+100
Description: Slow motion – Deceleration ETR600.002
Railway system: 3 kV
Distance: 10 m
Polarization: NA
Date: 24-Sep-2007
Operating Mode: Frequency Sweep
Initial Frequency: 0.1500 MHz
Final Frequency: 29.9900 MHz
Trace Points: 800
S.A. Ref.Lev.& Scal.: 80 dBuV - 10 dBuV/div
Sweep Time: 0.839759 s
Measurement started at: 14:57:25.999
Measurements done: 376
Total time: 348.5 s
Mean time between two measurements 0.929333 s
Max time between two measurements: 0.985001 s
Time Compliance Index: 100 %



Test condition – Train state

Results – Low frequency magnetic field

- Maximum emission vs. frequency
- Comparison with emission limits: compliance analysis
- Train emission “signature”

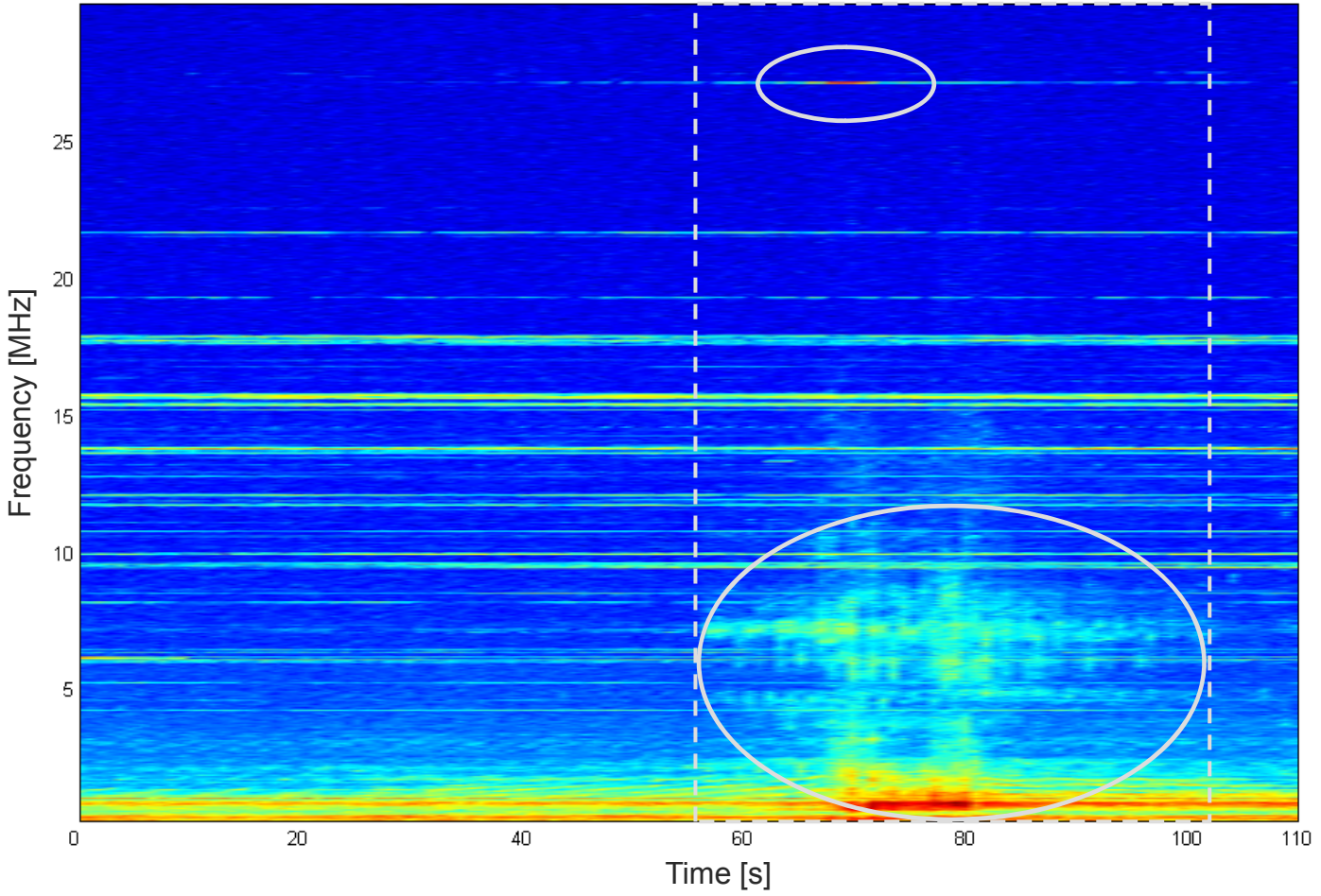


ETCS/ERTMS antenna

- **27.096 MHz**
- **30.06 dBμA/m**
- **Power signal to energize on track Eurobalise transponder**
- **Railway system transmission**
- **Allowed by normative**

Results – Low frequency magnetic field

- Time-frequency color map ⇨ allows detailed investigation



- ✓ Train brakes electrically in front of measurement station
- ✓ Electrical power converters & traction system noise
- ✓ ETCS/ERTMS 27.06 MHz power radio signal

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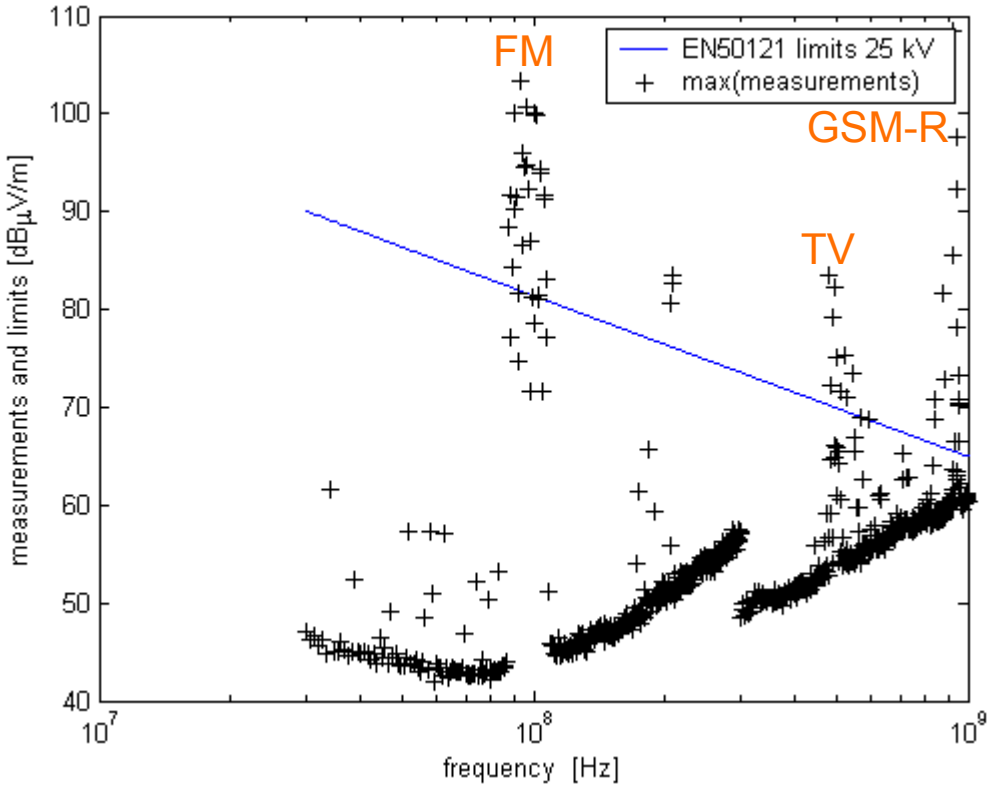
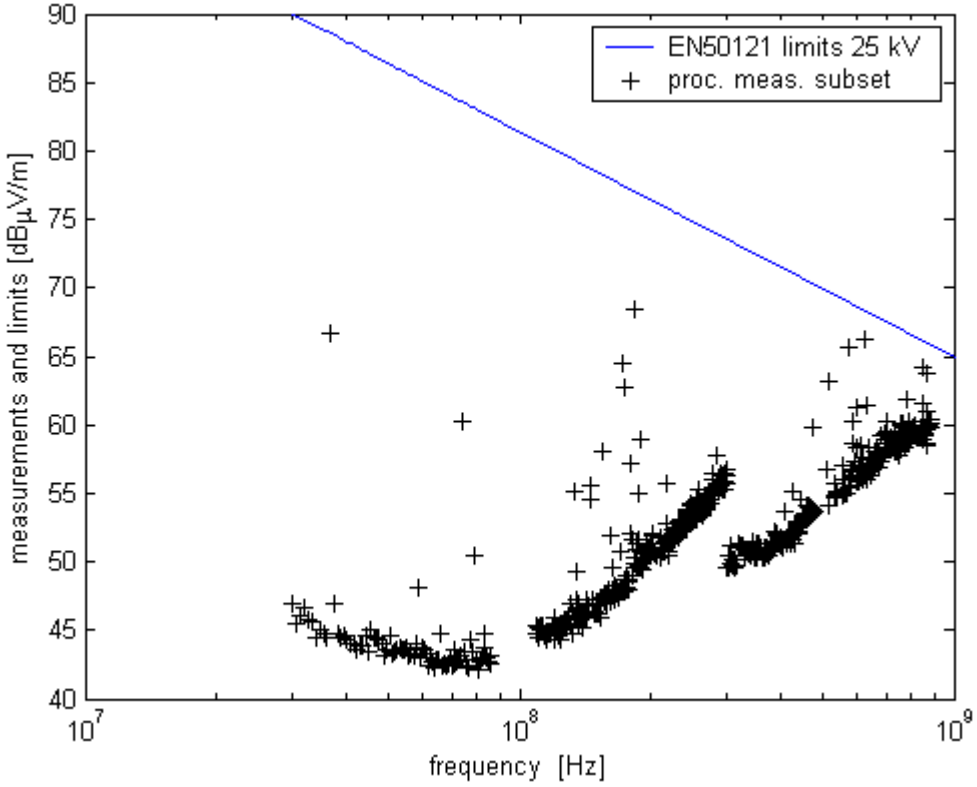
Results – High frequency electric field

- Biconical & log-periodic bands spanned in sequence
  - ✓ [30, 300] MHz + [300, 1000] MHz in less than 1 second & just 1 train run!



Test-site noise



Train emission

Conclusion

- Importance of accreditation according ISO/IEC 17025
- One of the main task is the measurement uncertainty estimation
  - ✓ CISPR 16-4-2 as guideline, it is not a straightforward application
  - ✓ uncertainty budget has to be tailored
- Optimized measurement system for compliance testing according to EN50121 & IEC62236
  - ✓ Part 2 Emission of the whole railway system to the outside world
  - ✓ Part 3-1 Rolling stock – Train & complete vehicle
- Improvement on test performance
  - ✓ detailed emissions characterization
  - ✓ test cost abatement (70% saving of testing time & resources)