Technologie moderner Messempfänger

und

deren Anwendung für EMV-Messungen in Echtzeit

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Outline

- Motivation
- Overview of Standard CISPR16-1-1 requirements
- Concept of the "FFT based Measuring Instrument" TDEMI
- Hardware Implementations
- Digital Implementations & Parallelization
- Applications and Measurements of typical DUTs:
  - » **Conducted Testing**
  - » **Disturbance Power Measurements**
  - » **Radiated Testing**
  - » **Dependency of dwell time**
  - » **Capturing single events/transients**
  - » **Highly fluctuating emissions**

Motivation

- More complex electronics => time-consuming emission measurements
- Investigation during development necessary
- Non-stationary emission
- Intermittent disturbances or single events, e.g. starter engine of a car
- Increasing number of operation modes of DUTs
- Additional measurement uncertainty by "pre-scan/final scan" procedure between the two measurements carried out at different times
- Updates in communication and EMC standards, e.g. CISPR 16-1-1, new detector types, wider frequency test ranges
- Longer observation times of signals (=> means higher accuracy)
- Easy investigation of intermittent disturbances and highly fluctuating emissions

→ **Reasons for new kind of instruments for various applications & easy to use**

FFT based Measuring Instrument

- Digitized signal contains all information about EMI
- Digitization of measurement equipment
- Speeding up by huge computational power and massively parallel implementation
- Weighting according to CISPR, MIL, DO and other standards, digitally implemented
- Parallel measurement at several thousands of frequencies

→ **TDEMI Measurement System**

CISPR 16-1-1

CISPR 16-1-1

IF - Filter
- Filter shape
- 6 dB Bandwidth

Distortion free Dynamic Range
- Sinusoidal signal > 40 dB
- Transient signal > 36 dB
- IF-Dynamic > 43.5 dB

Maximum Deviation
- 2 dB

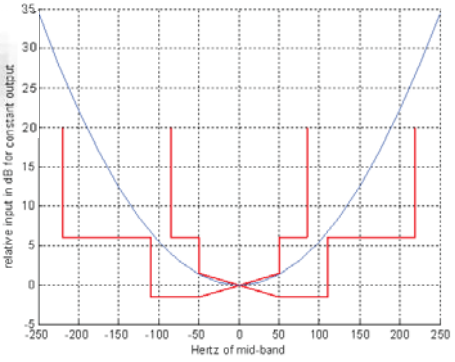
Input Port
- VSWR < 2.0

Detector implementation
- Peak, Quasi-Peak Average and RMS
- Level indication depending on pulse repetition frequency
- Level indication for stationary and transient signals

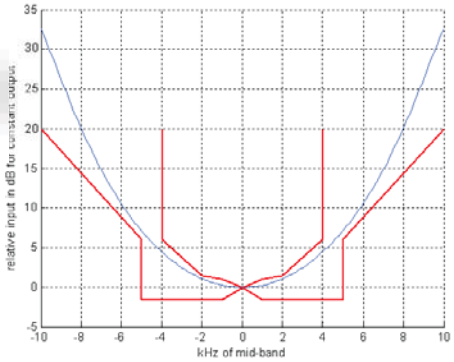
Analogue Output
- Quasi-Peak (optional)
- IF – Signal (optional)

CISPR Compliance - Example IF Filter (TDEMI)

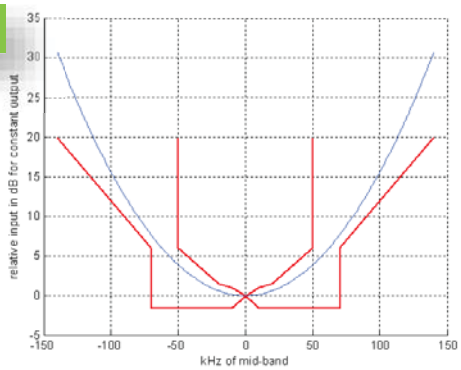
200 Hz



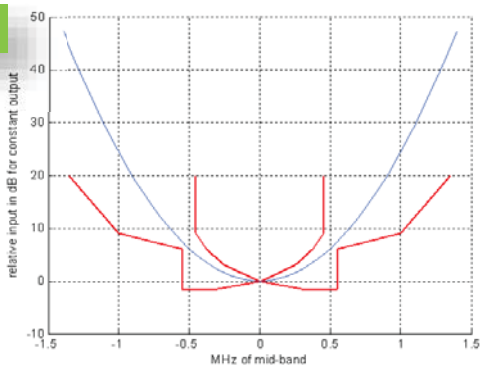
9 kHz



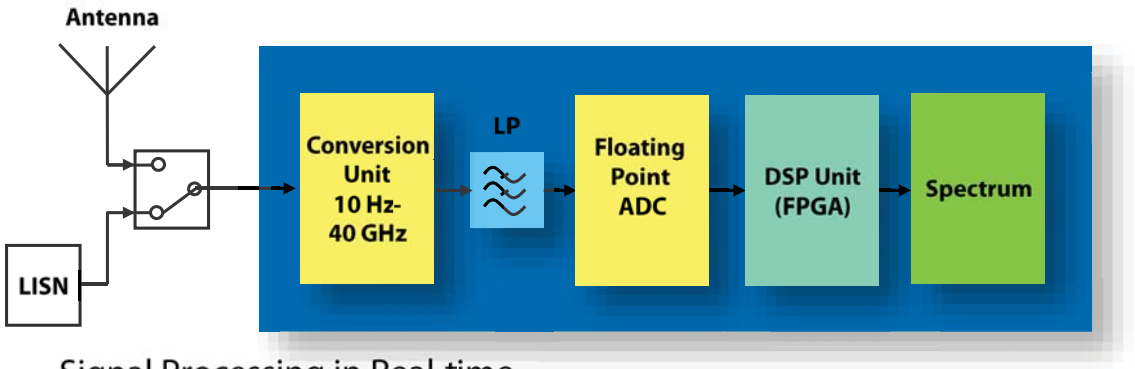
120 kHz



1 MHz

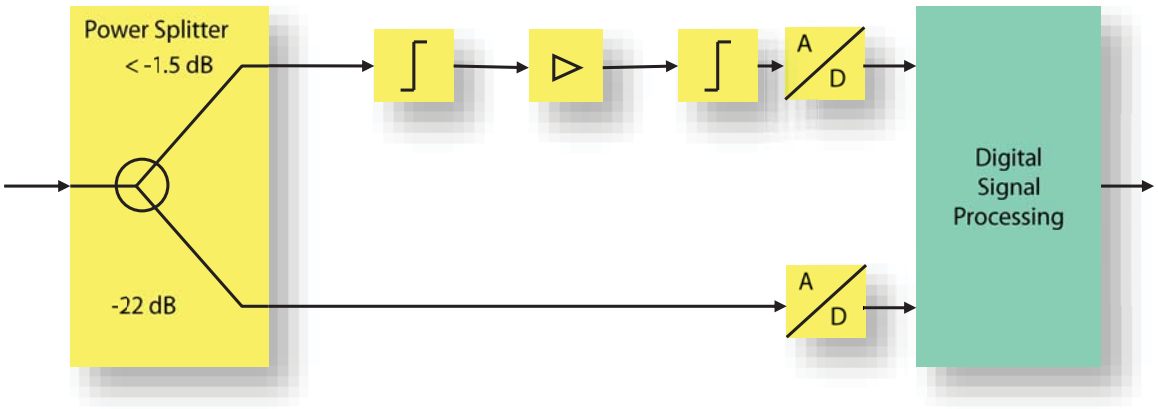


Concept & Architecture



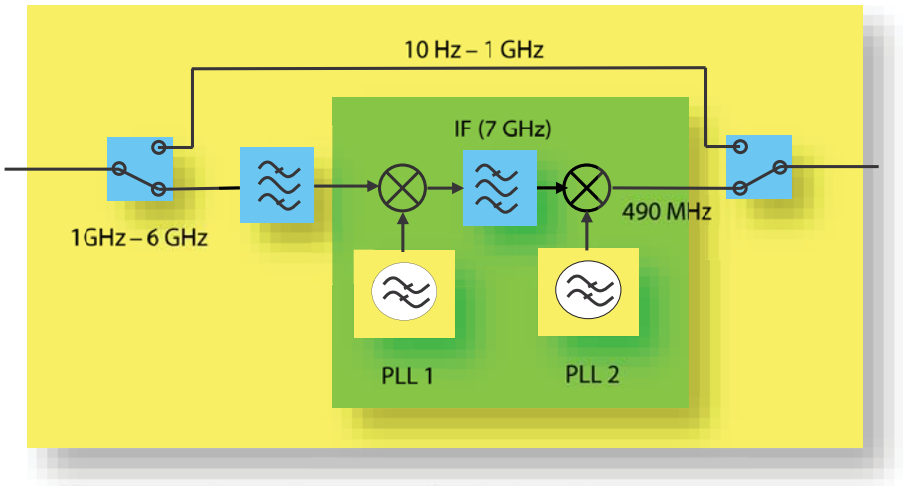
- Signal Processing in Real-time
- Full Real-time Analysis Bandwidth of 162.5 MHz, 325 MHz or even 645 MHz
- CISPR Bandwidth 200Hz, 9 kHz, 120 kHz, 1 MHz
- MIL/DO Bandwidth 10Hz,100 Hz, 1kHz, 10 kHz, 100 kHz, 1 MHz
- Peak, Average, CISPR-AVG, RMS, CRMS, and Quasi-Peak Detector, APD
- Weighted Spectrogram, i.e. Real-time EMI Receiver
- Time-domain Analysis Bandwidth 1 GHz
- 3 dB Spectrum Analyzer Bandwidths from 1 Hz – 30 MHz (145 Steps)
- Video Filter and Detectors (Maxpeak, Sample, Minpeak)

High Resolution 2.6 GS/s 12 Bit ADCs (2013)



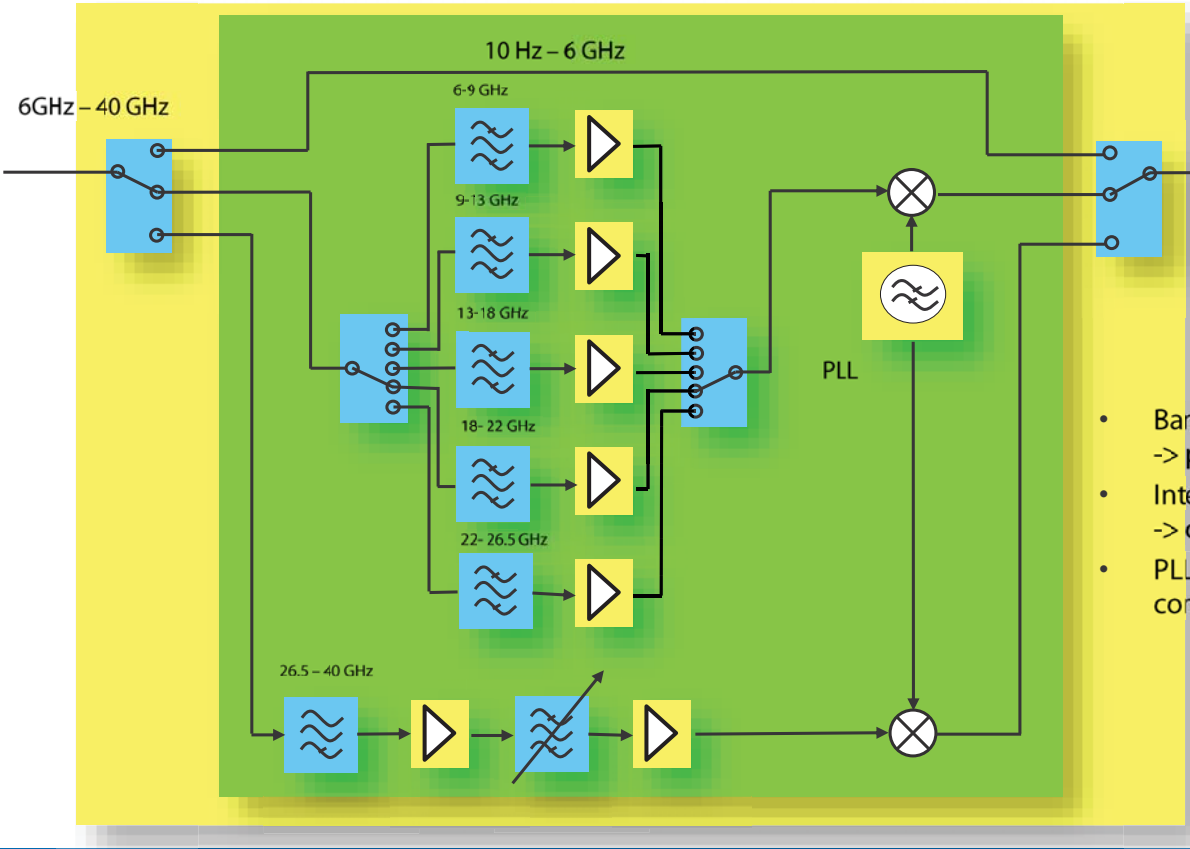
- 2 ADCs 12 Bit and 2.6 GS/s
- Limiter and amplifier
- ca. 25 dB improvement
- 100 dB dynamic (without preselection, without attenuator)

Broadband Conversion Unit 1 GHz to 6 GHz



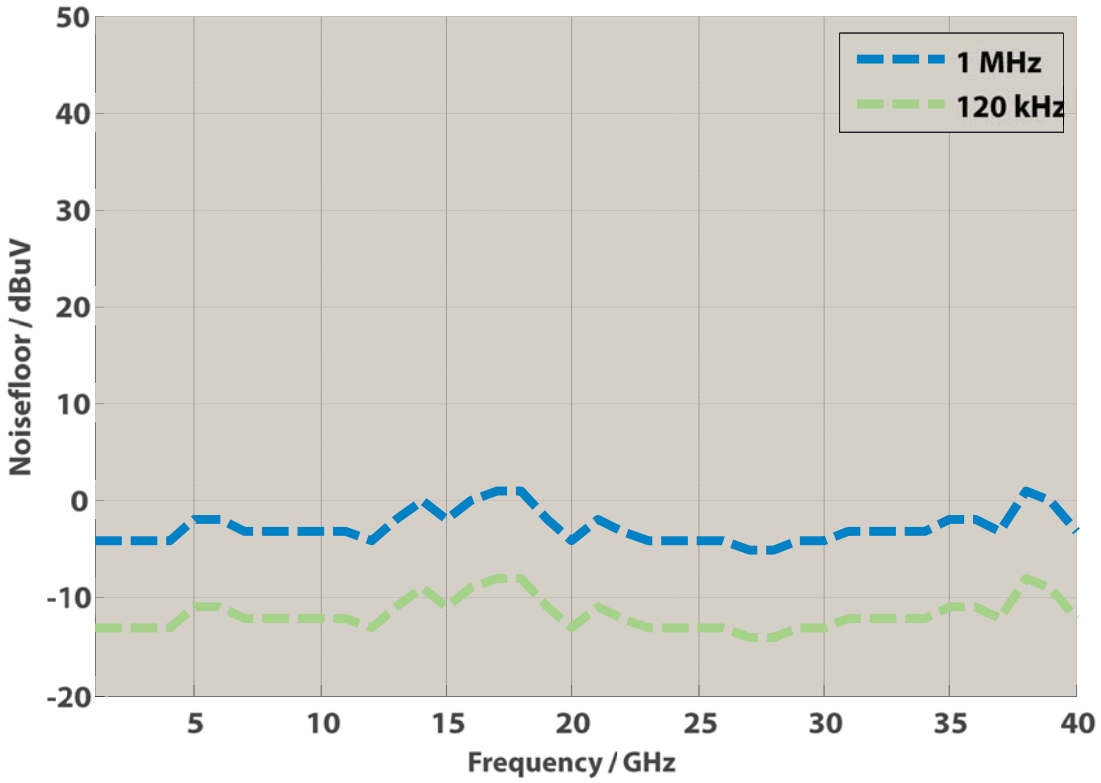
- Frequency band upconversion to IF > 7 GHz
- Broadband IF Filter with several 100 MHz
- Conversion to ADCs baseband
- Improved suppression of image frequencies and other mixing products (Rejection of image frequencys and unrequested frequency conversion product by optimum selection of PLL and filter)

Broadband Conversion Unit 6 GHz – 40 GHz



- Bandpass filter bank -> preselection
- Integrated LNA per band -> optimum noise figure
- PLL with low phase noise conversion unit

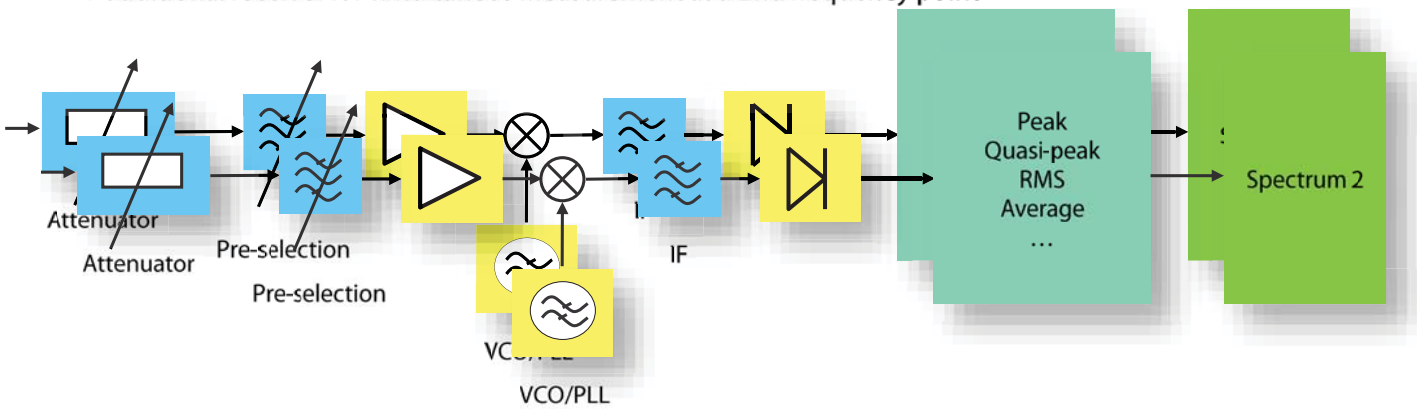
Typical Noise Floor 1 GHz – 40 GHz



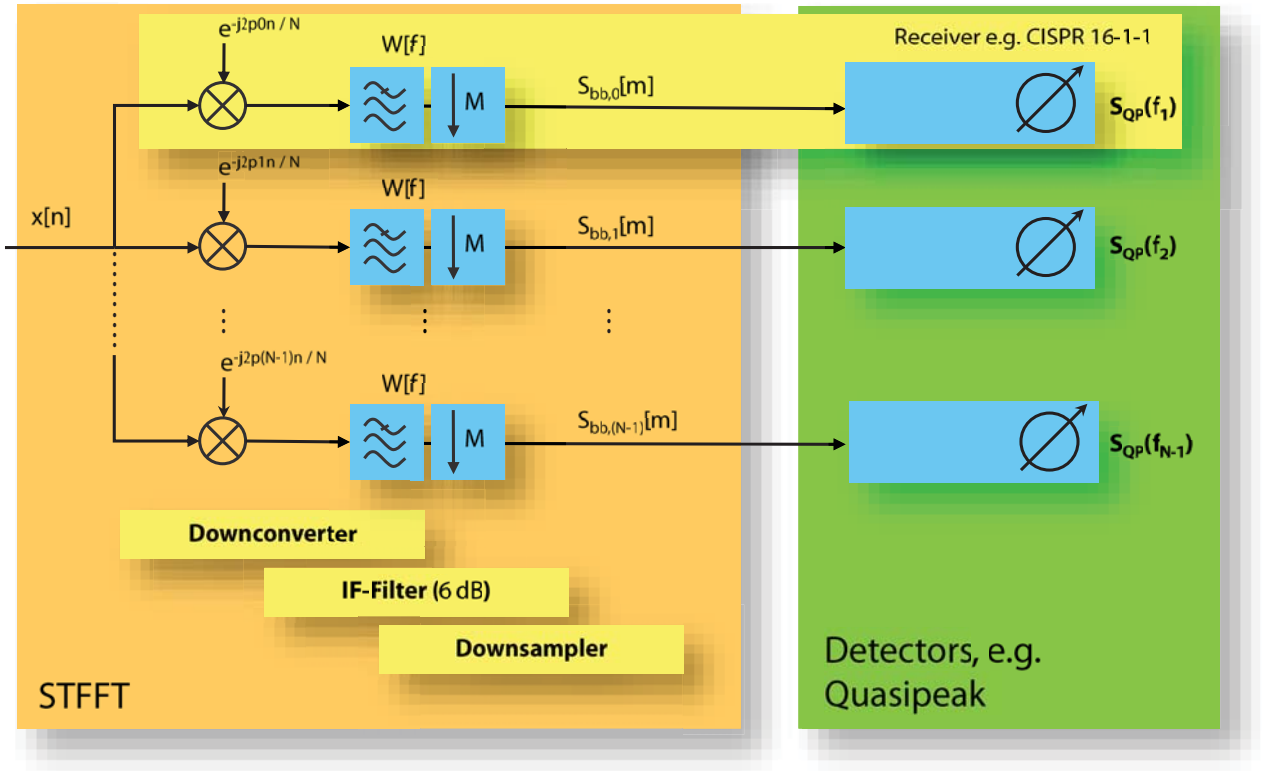
Conventional (analog) EMI Receiver

EMI receiver based on heterodyne receiver technique:

+ additional receiver for simultaneos measurement at a 2nd frequency point

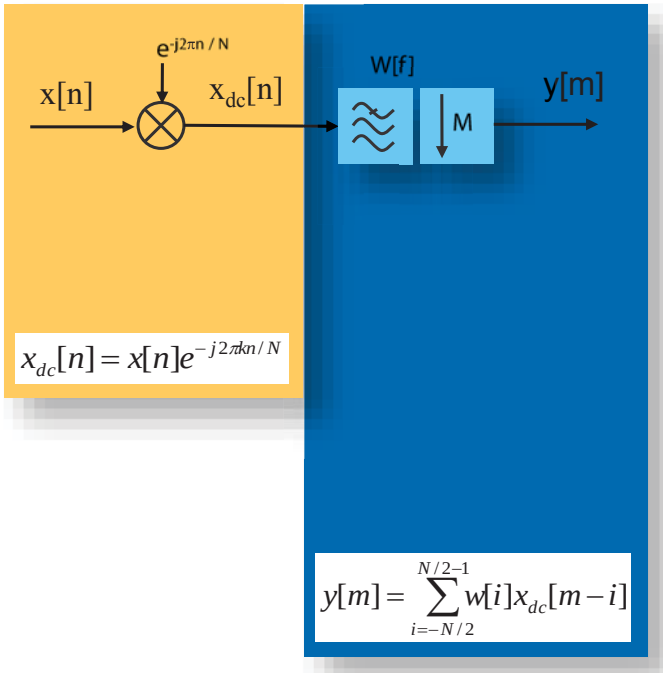


Short-term Fast Fourier Transform => Bank of several thousands parallel Receivers



Equivalence: STFFT - Digital Receiver/Spectrum Analyzer

Digital Receiver



STFFT

$$X[k,m] = \sum_{n=-\infty}^{\infty} x[n]w[n-m]e^{-j2\pi kn/N}$$

$$s_k[m] = \sum_{n=-\infty}^{\infty} x[n]w[n-m]e^{-j2\pi kn/N}$$

Mixer

$$s_k[m] = \sum_{n=-\infty}^{\infty} x[n]e^{-j2\pi kn/N}w[n-m]$$

$$s_k[m] = \sum_{n=-\infty}^{\infty} x_{dc}[n]w[n-m]$$

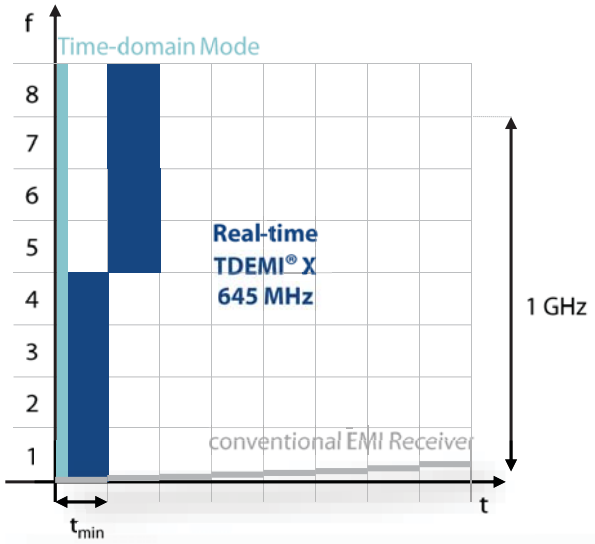
Substitution $i = n - m$

$$s_k[m] = \sum_{i=-N/2}^{N/2-1} x_{dc}[i+m]w[i]$$

$$s_k[m] = \sum_{i=-N/2}^{N/2-1} x_{dc}[m-i]w[-i] \qquad w[i] = w[-i]$$

$$\Rightarrow \quad s_k[m] = \sum_{i=-N/2}^{N/2-1} w[i]x_{dc}[m-i]$$

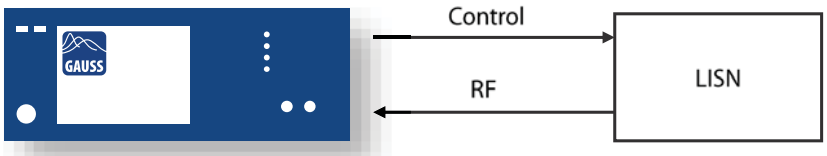
Short-time Fast Fourier Transform => Ultra high-speed Measurements



Traditional EMI Receiver / Spectrum Analyzer	Real-time TDEMI®
• Sequential Measurement • Preselection (Option)	• dwell time unlimited • Ultra-fast measurement • 2-7 frequency Bands (DC - 1 GHz) • Several ADCs • GS/s ADCs

IF bandwidth	Frequency points	Dwell time	Conv. EMI receiver	Real-time TDEMI® X
9 kHz	4096	200 ms	20 min	< 1 s
120 kHz	1024	100 ms	33 min	2 s
120 kHz	1024	3 s (QP)	9 h	< 9 s
1kHz DO160	4096	10ms	10 min	< 1 s

Test Setup: Conducted Emission Measurements – 4 Phases



Automatic Measurement of L1 ,L2 ,L3 and N

Extraction of Maxima

Report Generator

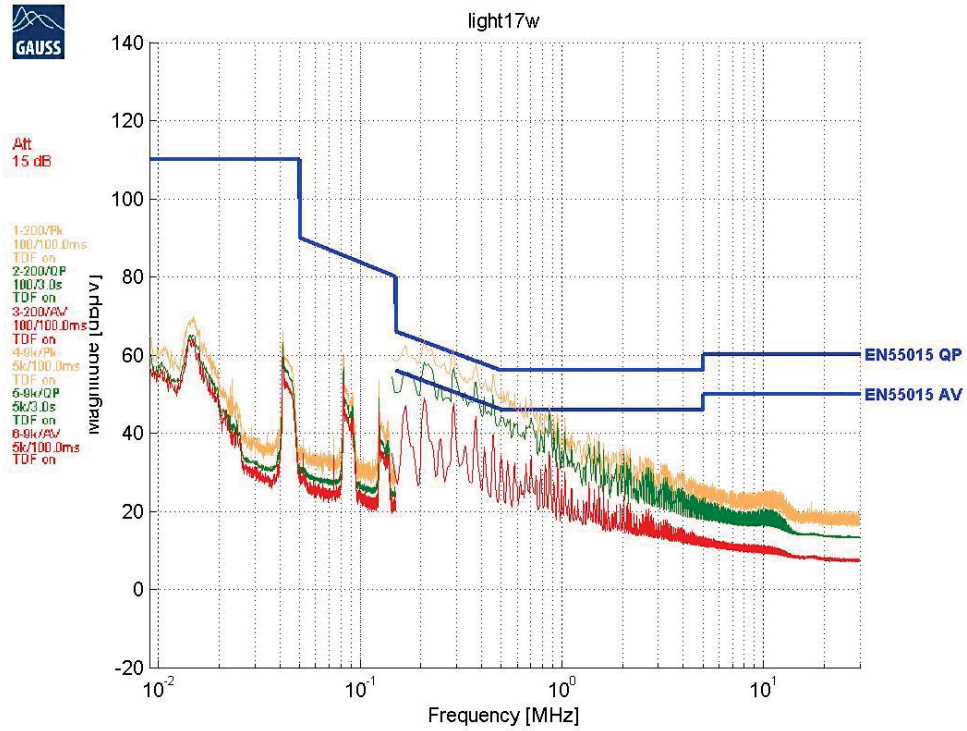
Approx. 2 sec. per Phase (Band A,B)
Approx. 1sec. per Phase (Band B)

Extraction of Maxima

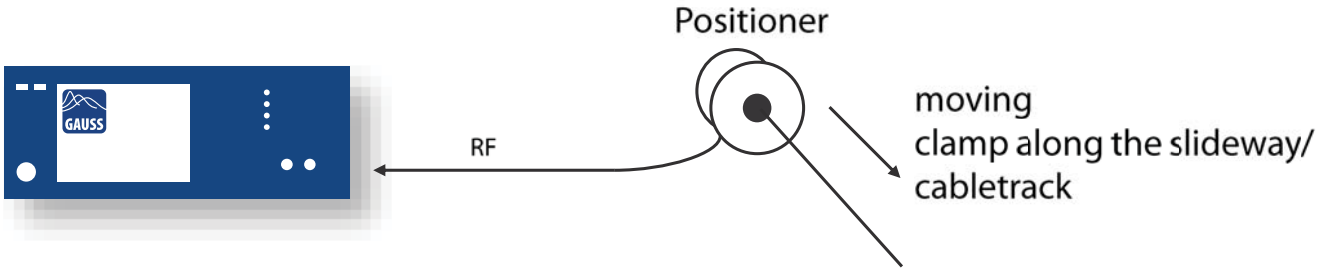
→ ~ 8 seconds for full measurement Band A+B

Application Field Electrical Lighting

Conducted (final QP!) Measurement up to 30 MHz



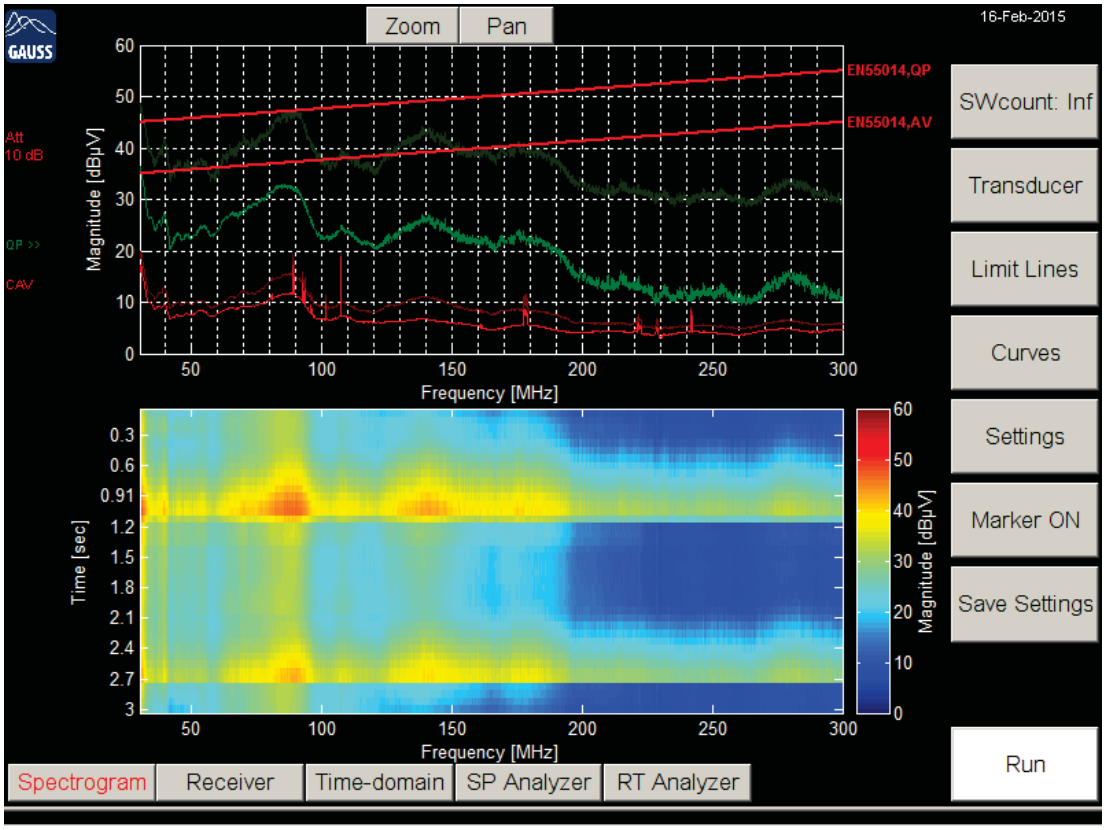
Test Setup: Measurement of Disturbance Power



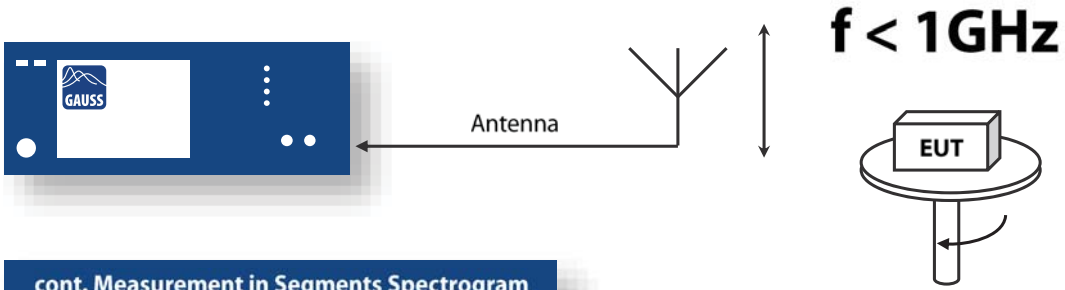
Fully Automated Report Generation

FULL QP characterization

Disturbance Power Measurement 30 MHz – 300 MHz in Real-time



Test Setup: Radiated Emissions up to 1 GHz



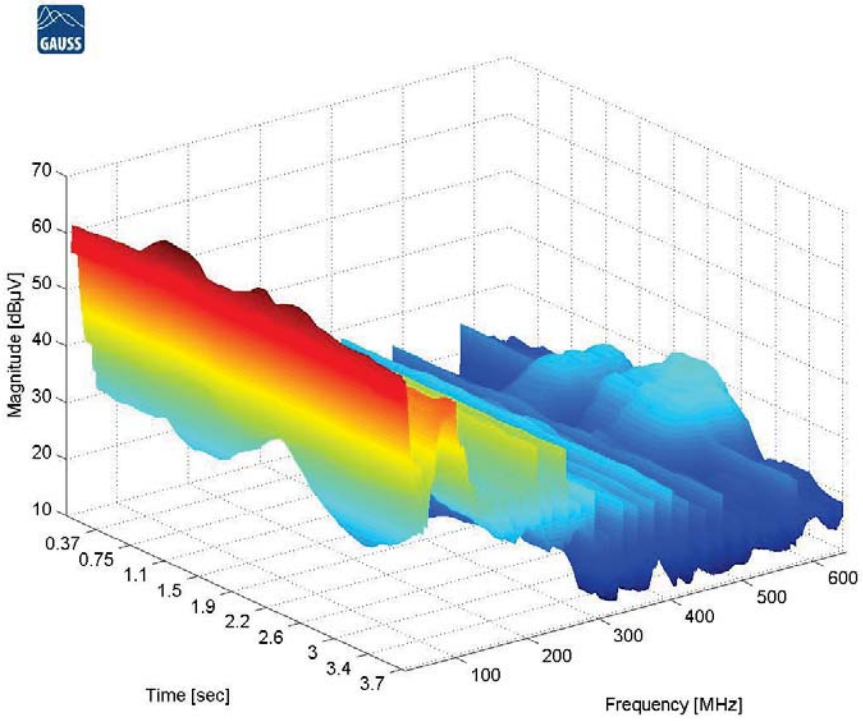
cont. Measurement in Segments Spectrogram

Maxima

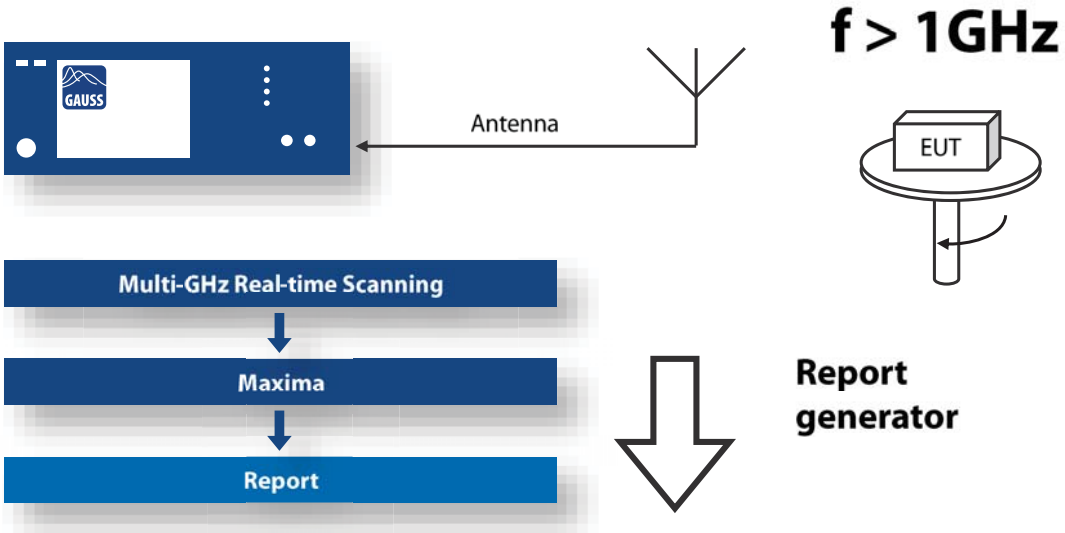
Final Report

Report generator

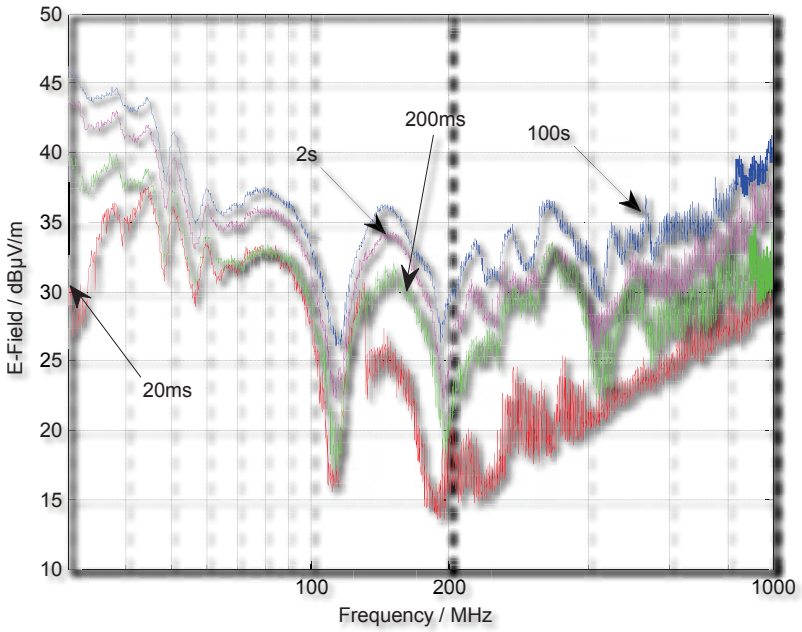
Continuous 3D Spectrogram of Measurement of E-Field Strength



Test Setup: Radiated Emissions above 1 GHz

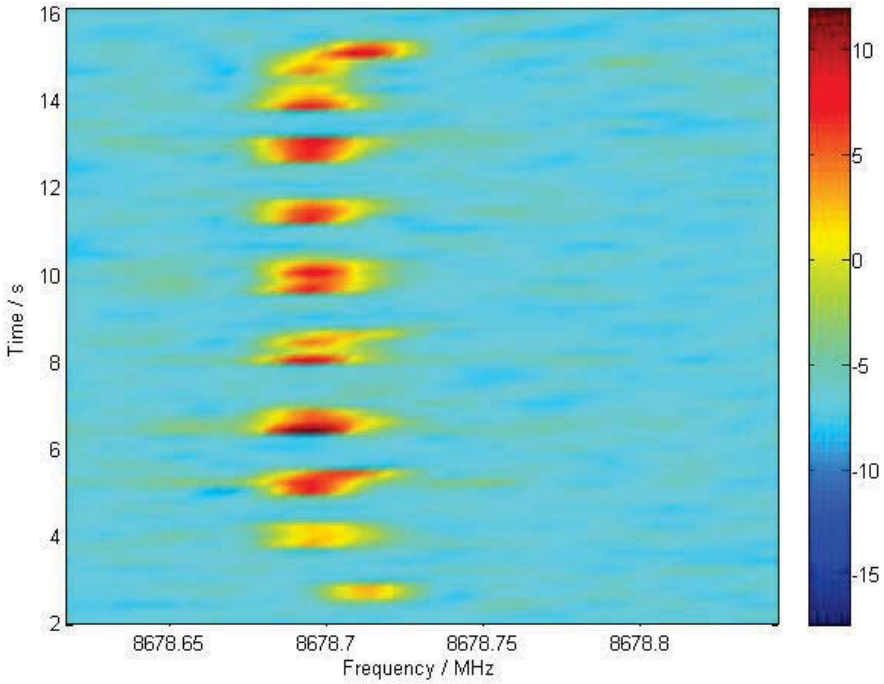


Radiated Emissions of a Brush Motor: Dependency of Dwell Time



Effects of the selection of the correct dwell time for EMC testing

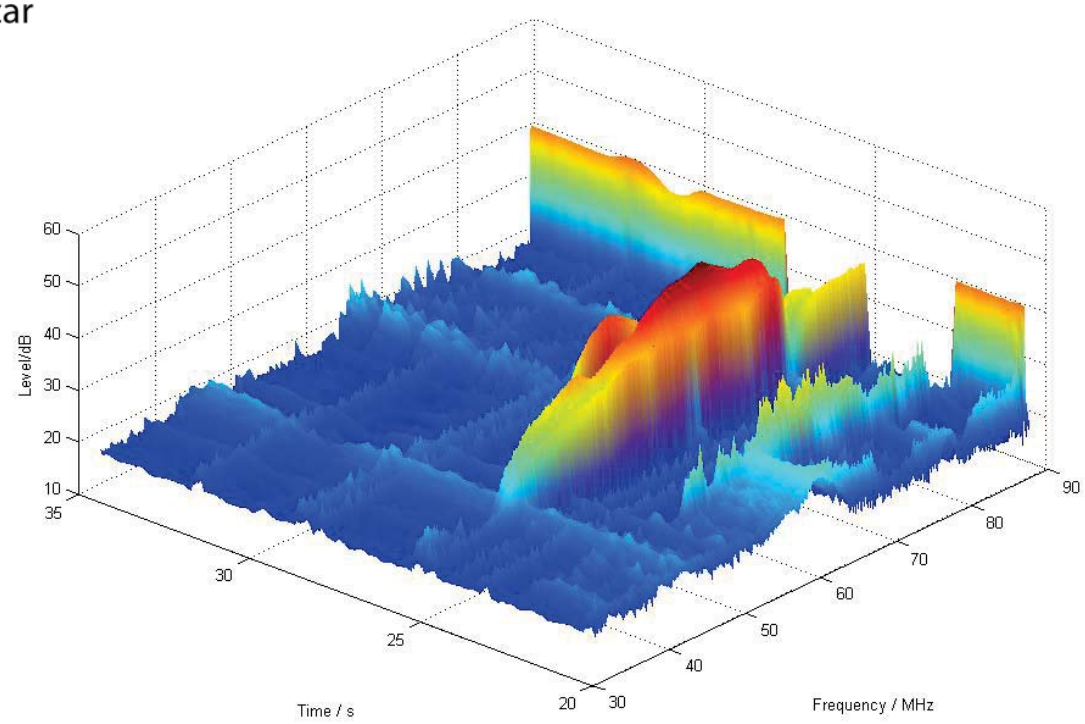
RFID Key



- Measurement of 10th Harmonic of Car Key (9 kHz IF bandwidth)

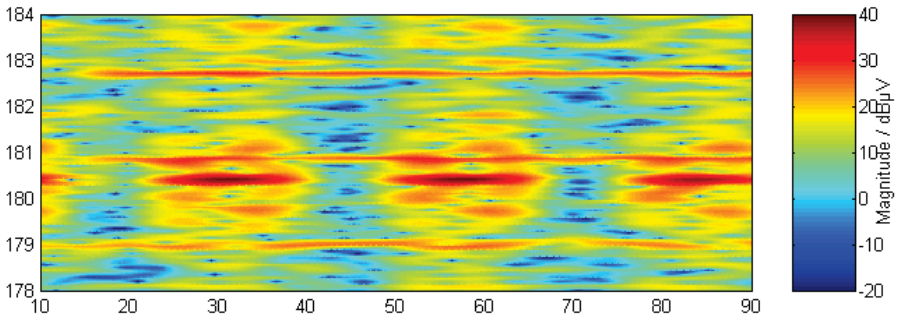
Ignition of an Engine

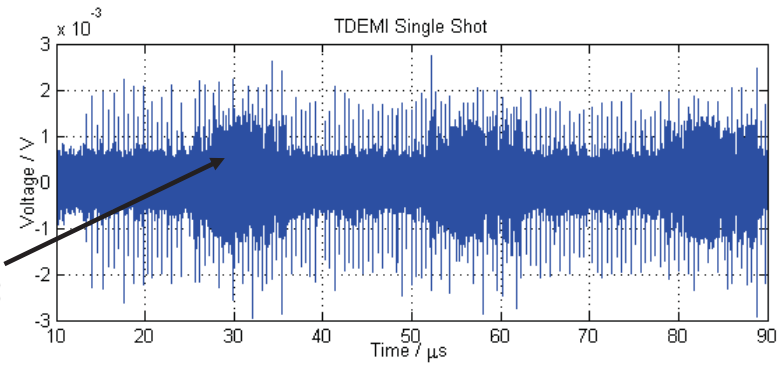
-3D-Plot of emission changing over time, ignition around 26 sec. starter engine of a car



Application Field IT Equipment: Radiated Emission of a Notebook

-Analyzing the Emissions in Spectrogram Mode (real-time)

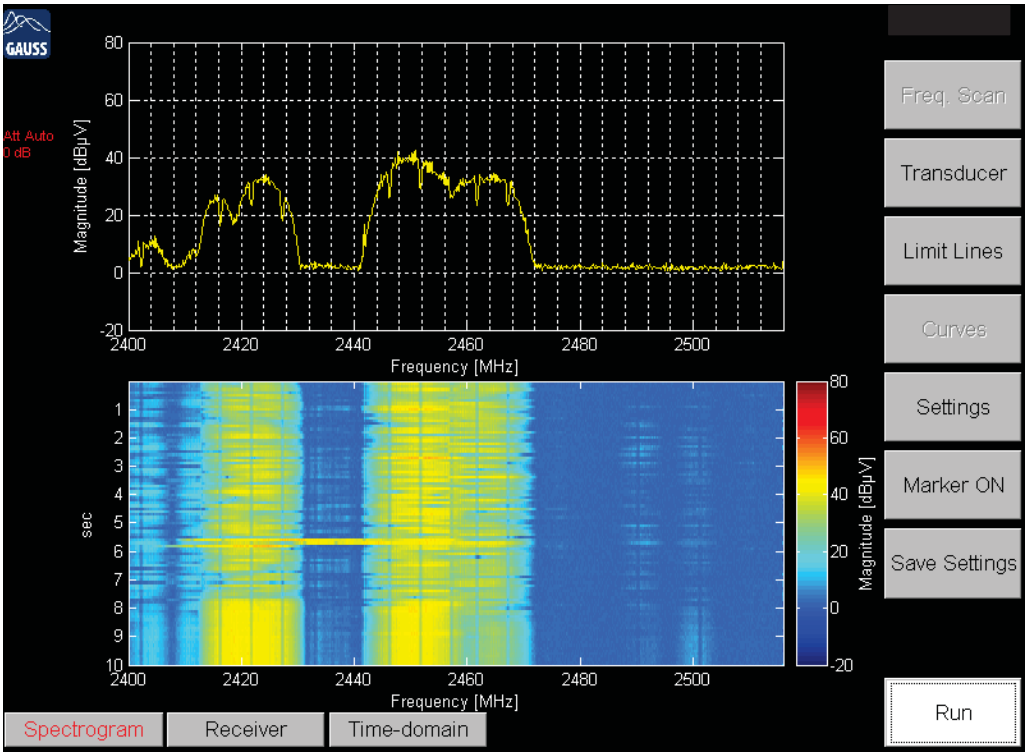




Data transfer-cycles Harddisc cable

Application Field IT Equipment: Radiated Emission of a Wifi Adapter

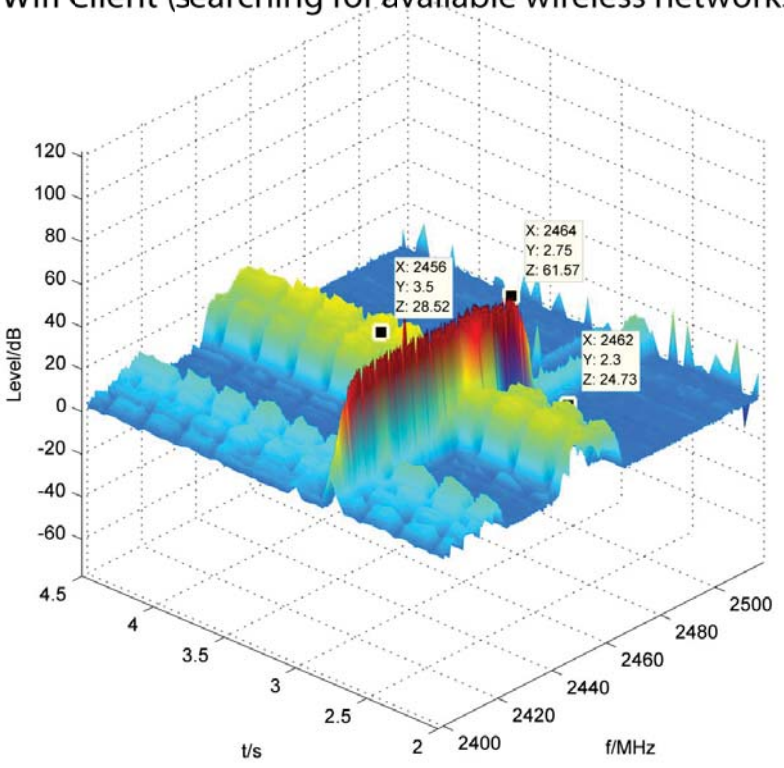
-Radiated emission of a Wifi Adapter above 2.4 GHz



Application Field IT Equipment: Radiated Emission of a Wifi Adapter

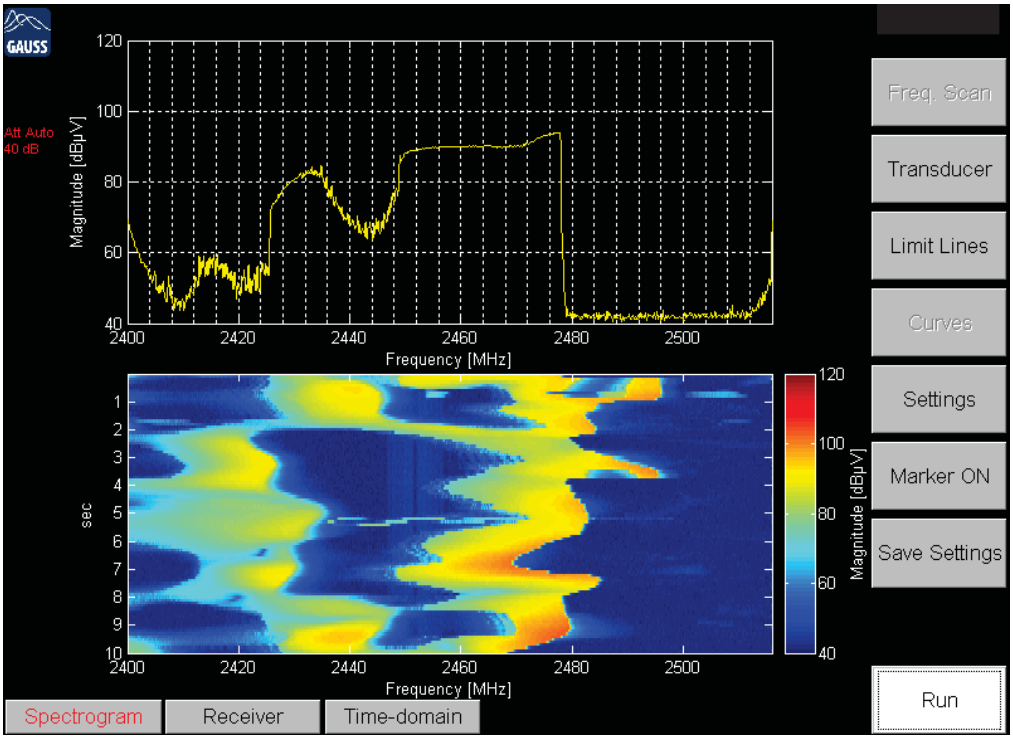
-Emissions of a Wifi Client (searching for available wireless networks at 3s)

-3D Plot

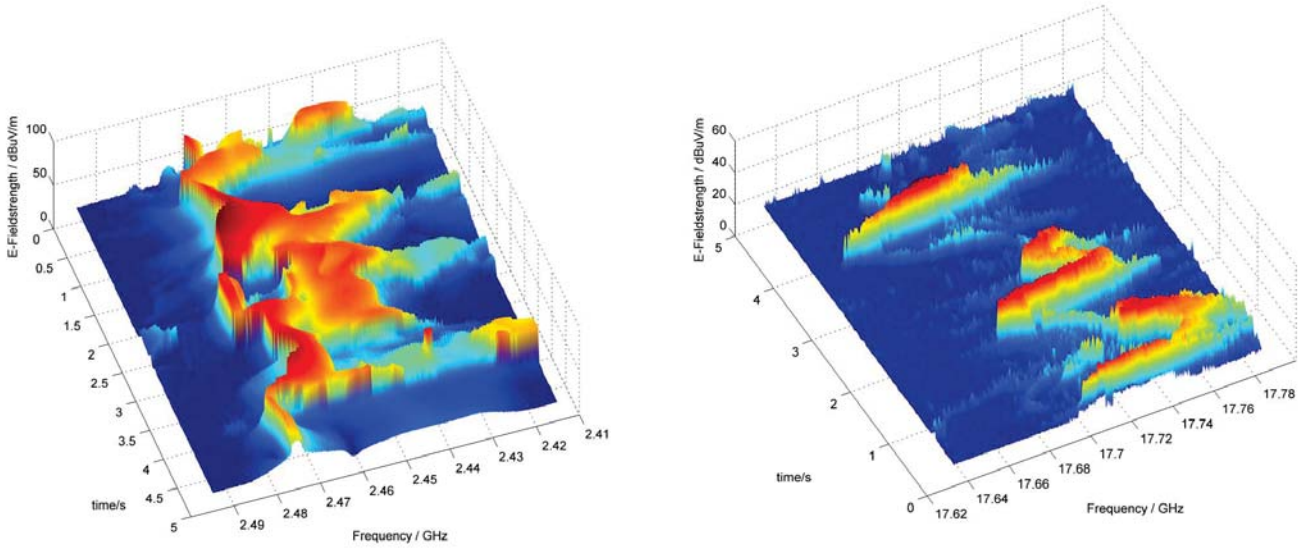


Radiated Emission: Microwave Oven

Radiated Emission Measurement of a Microwave Oven



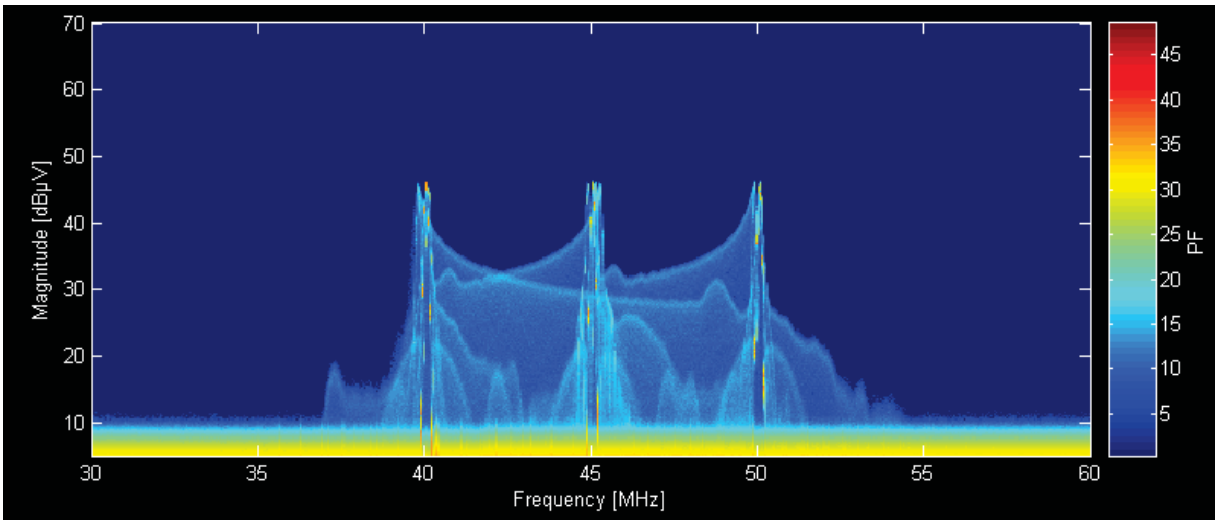
Radiated Emission of a Microwave oven



Fundamental frequency (ISM Band) Harmonics

Real-time spectrogram allows the characterization of the magnetron ‘s frequency drift at the fundamental and harmonics. E.g. the 4th harmonic

APD Measurement Function



- Probability function can give more detailed description of the emission behavior compared to single detectors
- Amplitude Probability Function (APD) describes the probability of a signal to have a certain amplitude.

→ **Observation and Analysis of intermittent or masked signals**

… and here is what we did:

- Receiver Mode (full CISPR 16-1-1 and MIL and DO compliant and more)
- Real-time Full Compliance Testing
- Real-time Diagnosing Tools for Pre-Investigation
- Real-time Spectrum Analyzer
- conventional EMI Receiver & Spectrum Analyzer (swept)
- Oscilloscope Mode for Pre-Investigations
- Disturbance Analysis according to CISPR 14
- APD function on high number of parallel channels (CISPR 16-1-1)
- increased dwell/observation time -> reduced uncertainty
- furthermore new measuring functions

Thank you for
your attention!

Questions & Contact:
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