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ROHDE & SCHWARZ TECHNOLOGY SYMPOSIUM 2024 JAPAN

Weighting of interference through the ages of radio

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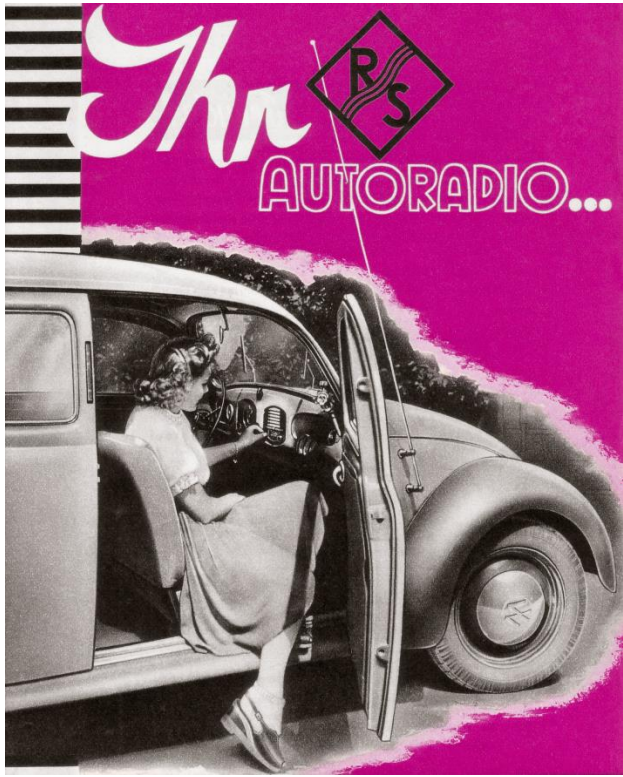
OVERVIEW

- Motivation
- CISPR
- Purpose of interference weighting
- Quasi-peak weighting function
- CISPR Average weighting function
- RMS-Average weighting function
- APD Measurement function

MOTIVATION – WEIGHTING OF INTERFERENCE

- **Introduction of AM broadcasting in the 1920s**
- **Numerous interference complaints from radio listeners made RFI suppression necessary for existing electrical devices and equipment**
- **But measurement procedures and instruments were not yet available**
- **First publications were RFI suppression guides**
- **Systematic research was needed for defining uniform measurement procedures**
- **Establishment of the International Special Committee on Radio Interference (CISPR) in 1933**



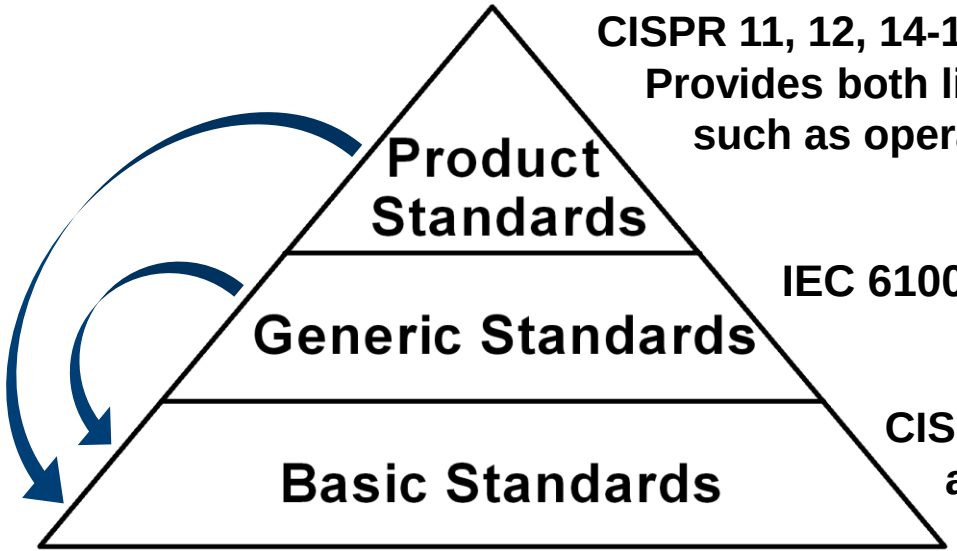
CISPR | International special committee on radio interference
| Comité international spécial des perturbations radioélectriques

- **Technical committee within the International Electrotechnical Commission (IEC)**
- **Long history - CISPR had its first meeting in June 1934 in Paris**
- **Members of CISPR are 41 National Committees (23 participate/ 18 observer), EBU, ETSI, CIGRE, IARU and both ITU-R and ITU-T**

WAS ESTABLISHED TO CONSIDER THE PROTECTION OF RADIO RECEPTION FROM INTERFERENCE

CISPR – PUBLICATION LEVELS

- **CISPR publications are structured into 3 levels**
- **Basic standards come into force with normative references in generic and product standards, today all standards have dated references, specific edition applies!**



CISPR 11, 12, 14-1, 15, 25, 32 and 36
Provides both limits and product-specific requirements such as operation and arrangement of the EUT

IEC 61000-6-3, -6-4 , -6-8

CISPR 16 series - Defines the measurement apparatus and methods, belonging uncertainties and test facilities

PURPOSE OF WEIGHTING

Goal: Keep RFI suppression costs low, while keeping an agreed level of radio protection

- It was soon recognized that the effect on radio reception depended on the type of interference (broadband or narrowband) and the radio service concerned
- Particular the dependence on the pulse repetition frequency (PRF) plays a roll
- WEIGHTING = PRF DEPENDENT CONVERSION (mostly reduction) of a peak-detected impulse voltage level to an indication which corresponds to the interference effect on radio reception
- Ideally the test equipment should only indicate a need for action at frequencies where such action was subjectively or objectively justified

1937 - FIELD METERS

- The HHF far-field meter, which marked the beginning of the measuring receiver history at Rohde & Schwarz
- Covering the frequency range from 100 kHz to 100 MHz
- There was no weighting detector implemented yet

PURPOSE OF WEIGHTING

- **1920-1930er: Introduction of AM radio services**
  Quasi-peak Detector = Simulation of radio receiver plus listener
- **Postwar period: Opening of the VHF band from 30 MHz to 300 MHz for FM radio and TV broadcasting**
  - 1949: FM radio, first European VHF (UKW) transmitter in Munich
  - 1952: Restart of AM based TV in Germany
- **The standards also had to be updated**
  - From disturbance voltage measurements up to 20 MHz
  - To disturbance field strength measurements up to 300 MHz
  - CISPR additionally demanded measurement of the disturbance Mains voltage up to 30 MHz

1949 – FM RADIO

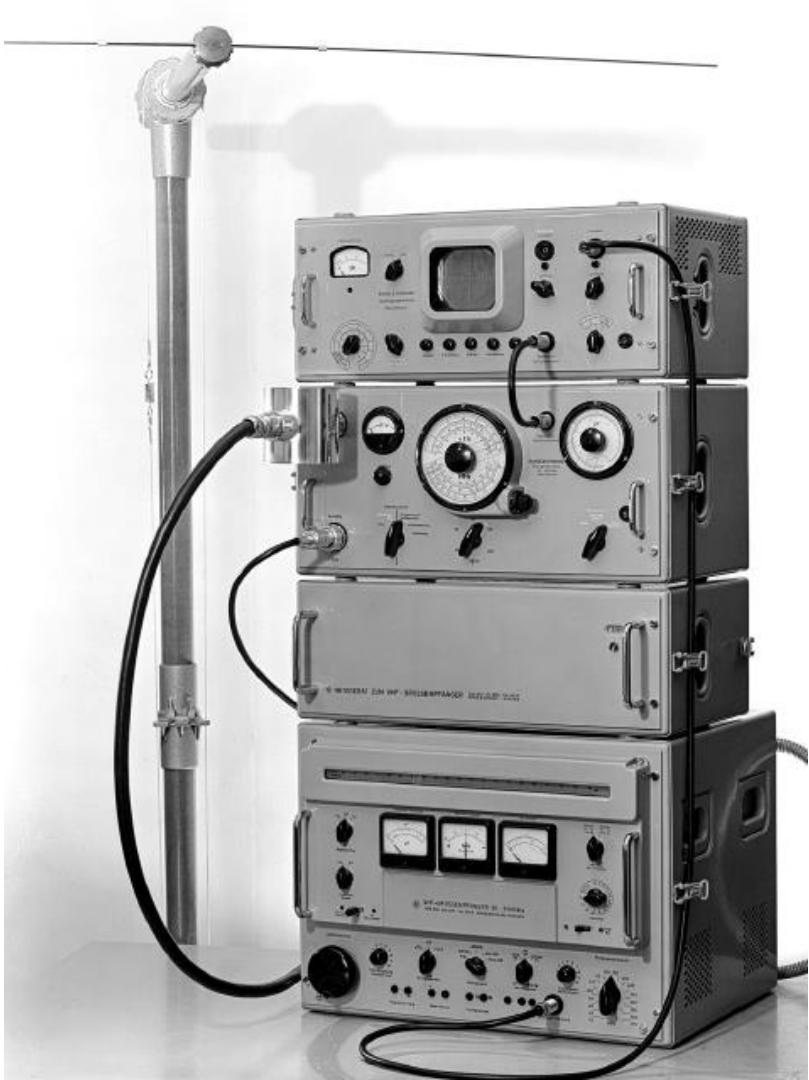
- The first European VHF (UKW) transmitter, built by Rohde & Schwarz and operating at 90.1 MHz, which was put into service by the Bavarian public broadcasting service on February 28, 1949, in Munich-Freimann

PURPOSE OF WEIGHTING

- The noise effect of electrical interference on AM radio broadcasting was known from earlier investigations
- But how about the effect of interference on TV and FM radio?
- It was found that the subjective perception of picture distortion was also dependent on the PRF of the interference pulses, but with a steeper drop compared to aural interference perception with radio reception
- Mapping the weighting all the way down to individual pulses would have required measuring receivers able to process amplitude differences greater than 50 dB without overloading – not possible at this time
- CISPR implemented a flattened weighting curve for quasi-peak indication in CISPR band C (30 MHz to 300 MHz), it specifies a 43.5 dB devaluation for single pulses relative to the peak value
- In addition the measurement bandwidth had to be adapted to the new broadcasting services → RBW = 120 kHz

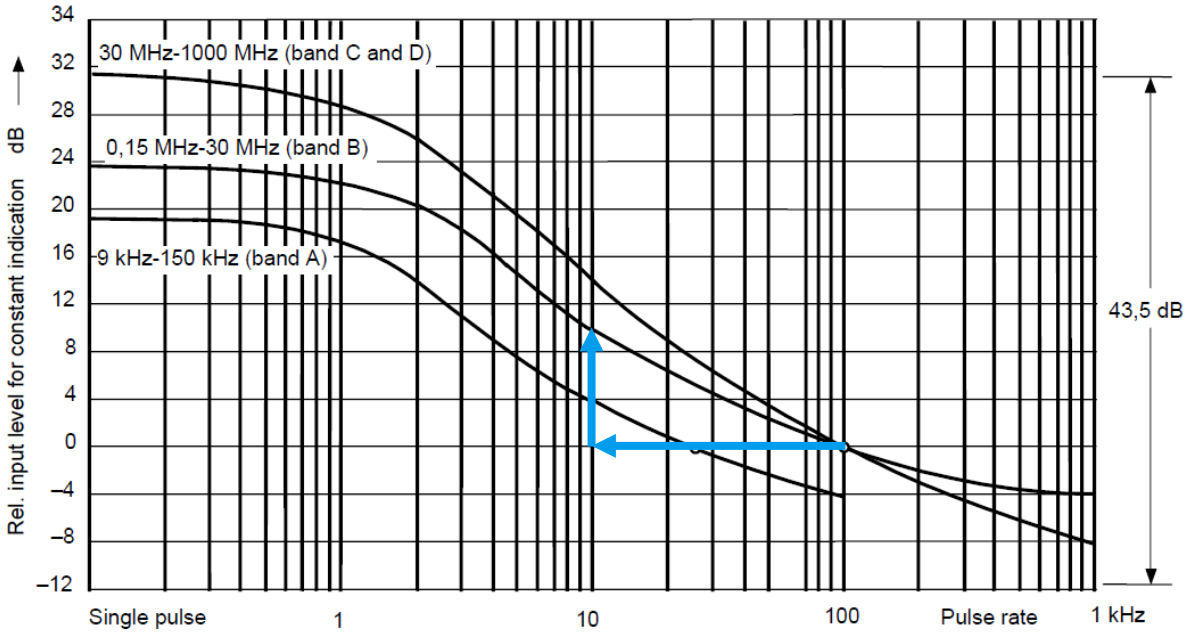
1953/1957 – TV DISTURBANCES

- VHF disturbance measuring system developed by Rohde & Schwarz, new model (from 1957) with ESG VHF test receiver (bottom) and **EZS interference measurement supplement (top)**
- Used by the German Telecommunication Engineering Center (FTZ) in Darmstadt and the interference measuring stations of Deutsche Bundespost to investigate the effect of interference on VHF broadcasting



CISPR 16 – QUASI-PEAK DETECTOR

- **The dependence on the pulse repetition frequency (PRF) led to the definition and introduction of the Quasi-peak detector**



Source: CISPR TR 16-3:2020

Low pulse frequencies are perceived as much less disturbing than higher ones, so they could be under-weighted in the measurement

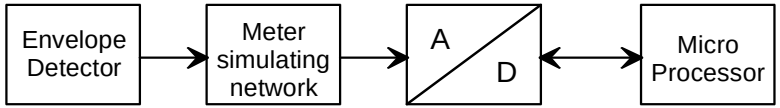
Example:
A 100 Hz impulsive disturbance has the same effect on a medium-wave receiver as a 10 dB stronger 10 Hz disturbance

1970 – AUTOMATIC QUASI-PEAK DISTURBANCE WEIGHTING

- HFV mobile VHF field strength meter with dipole antenna
- This model was not only the first fully solid-state Rohde & Schwarz test receiver, but also the **first able to perform automatic disturbance weighting according to VDE 0876 or CISPR Publ. 2**.

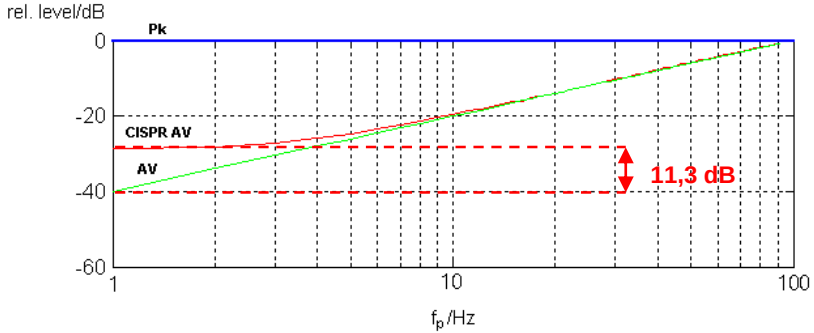
CISPR 16 – CISPR-AVERAGE DETECTOR

- **Weighting of intermittent, unsteady and drifting narrowband disturbances**
- **Linear CISPR-Average detector with meter time constant**
  - Band A/B = 160 ms, Band C/D/E = 100 ms



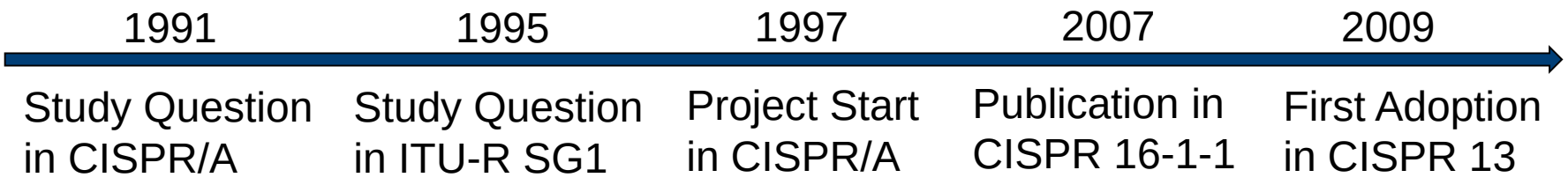
  - **For PRF < meter time constant the result is not the true average!**
    But the maximum of the output of the meter simulating network
  - Example

Band C/D/E:
T_{meter} = 100 ms



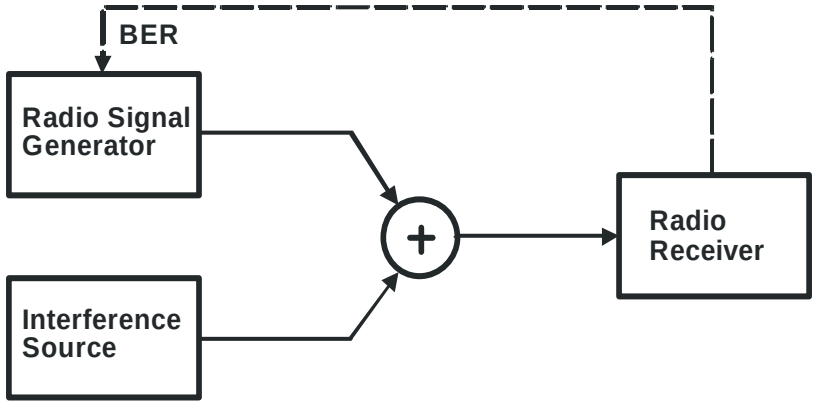
CISPR 16 – RMS-AVERAGE DETECTOR

- **Today: Digital radio services are widely used, Quasi-peak Detector ???**
- **CISPR/A has investigated that matter and came to the conclusion that a new weighting detector is necessary to better consider the impact of pulsed interferers on today's digital radio services**
- **References**
  - Amendment A2:2006 to CISPR 16-3:2003, "B*ackground material on the definition of* ***the r.m.s.-average weighting*** *detector for measuring receivers"*
  - Amendment A2:2007 to CISPR 16-1-1:2006, "*Weighting of interference according to its effect on digital communication services"*



CISPR 16 – RMS-AVERAGE DETECTOR

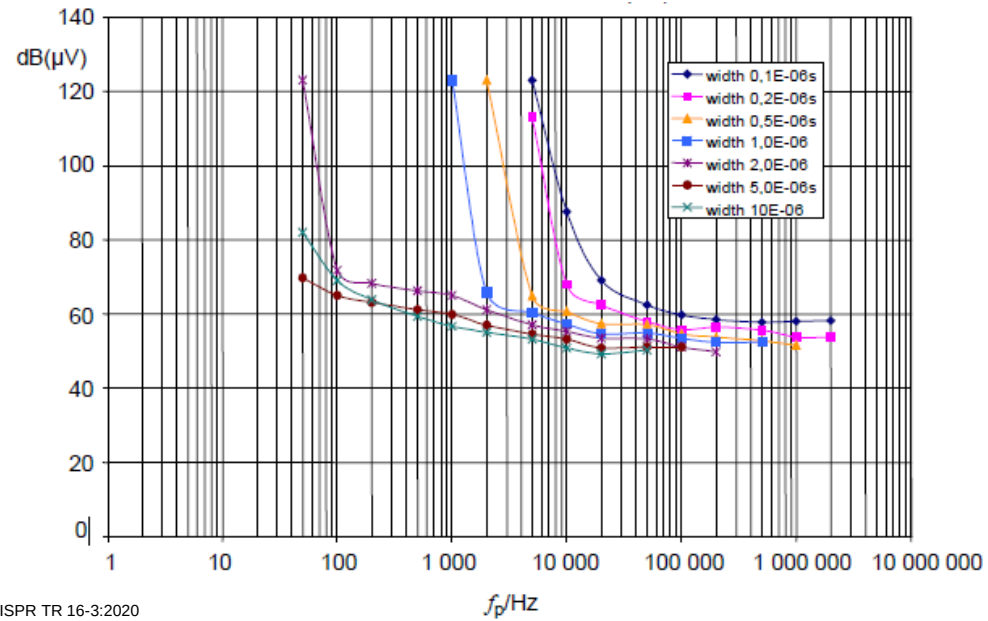
- **Determination of weighting function**
  - Principle investigation method by using a measurement instrument with BER meter (e.g. communication analyzer)



Simulation of weighting function

CISPR 16 – RMS-AVERAGE DETECTOR

- **Effect of impulsive disturbance on GSM radio communication system**
  - Weighting characteristic = peak voltage level as a function of PRF for a constant effect on a specific radio communication system



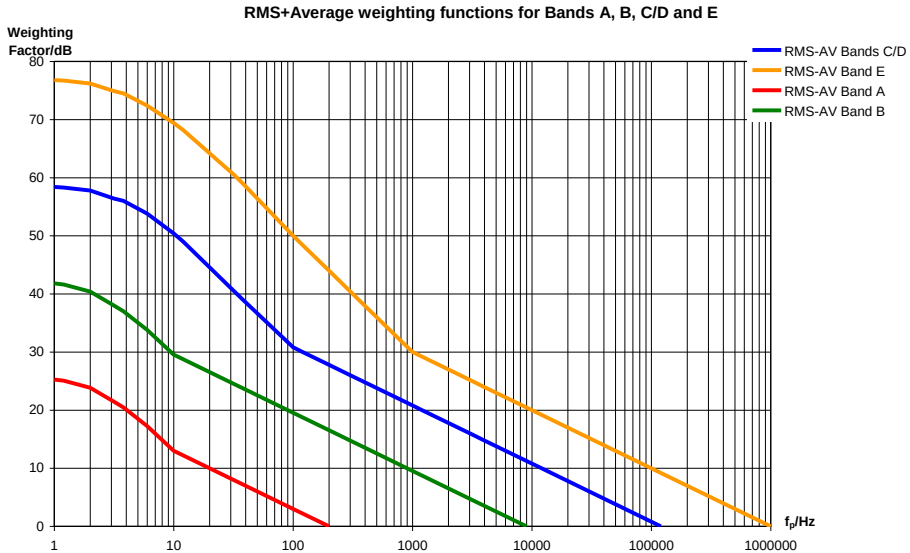
Source: CISPR TR 16-3:2020

Example:
Weighting characteristics for DVB-T with 16 QAM 8k as used in Germany:

- Convolution rate 2/3
- **BER = 2 × 10⁻⁴** (before Reed-Solomon error correction)
- -61,8 dBm
- 14,745 Mbit/s

CISPR 16 – RMS-AVERAGE DETECTOR

- **RMS-Average weighting function for all CISPR bands**
  - Weighting function = relationship between input peak voltage level and PRF for constant level indication of a measuring receiver with a weighting detector



Theoretical weighting curves if the shortest pulse widths are applied

i.e. pulse width < 1/10*RBW

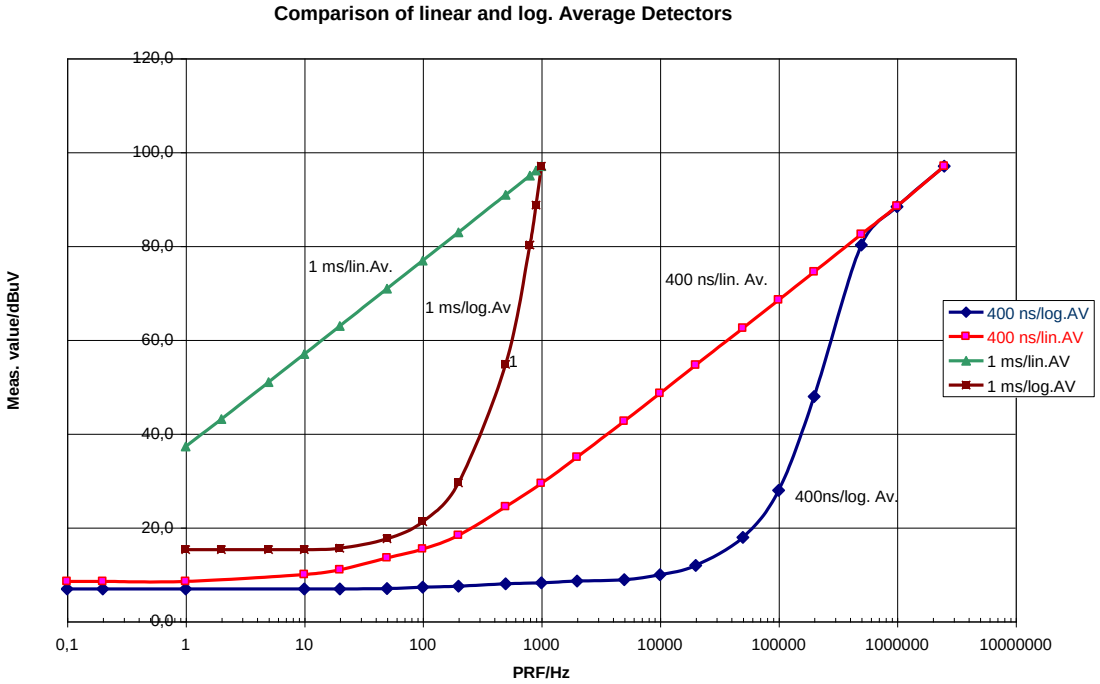
(<100 ns for RBW 1MHz)

CISPR 16 – APD MEASUREMENT FUNCTION

- **logAV is used for the weighting of fluctuating noise, e.g. in CISPR 11 for microwave oven testing**
  - The weighted (average) value is measured by reducing the VBW (10 Hz) in logarithmic mode = logAV
  - Therefore, the result does not give a true average value!
  - **The result does not represent the true impact on today's digital radio transmission quality**
- **Introduction of APD Measurement Function as an alternative method to present logAV measurements**
  - Can also be used to calculate the true average value
  - Shows high sensitivity, e.g. single impulse is measurable
  - Applicable for measuring unsteady levels
  - **Doing an adequate weighting of the impact of impulse noise on the radio spectrum above 1 GHz**

CISPR 16 – APD MEASUREMENT FUNCTION

► **Comparison of linear and logarithmic (video) average detector**



Green + Red Trace

→ **Linear AV**

Brown + Blue Trace

→ **logAV with VBW of 10 Hz**

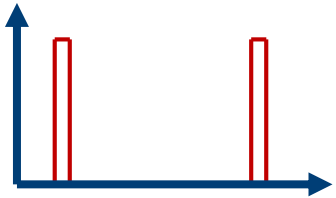
→ **High suppression of peak noise**

CISPR 16 – APD MEASUREMENT FUNCTION

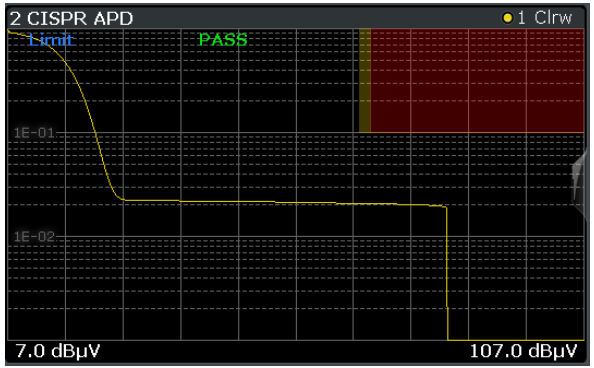
- **Amendment 1:2005 to CISPR 16-1-1:2003 (Ed.1)**
  - Amplitude Probability Distribution (APD) measuring function has been added
  - Frequency range 1 GHz to 18 GHz
  - Rationale for the specifications of the APD measuring function is given in Annex G
- **Amendment 1:2005 to TR CISPR 16-3:2003 (Ed.2)**
  - Background material to Amplitude Probability Distribution (APD)
  - Correlation between APD characteristics of disturbance and performance of digital communication systems

CISPR 16 – APD MEASUREMENT FUNCTION

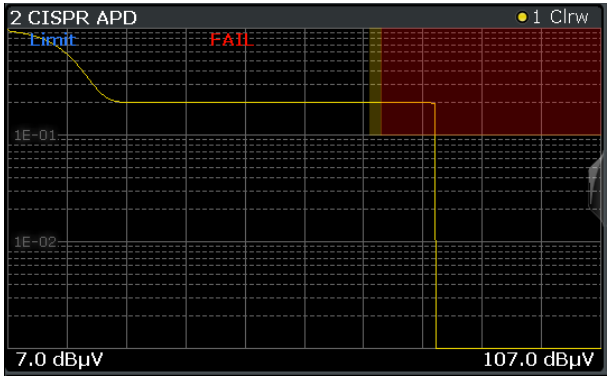
- **Weighting of interference signals by APD**

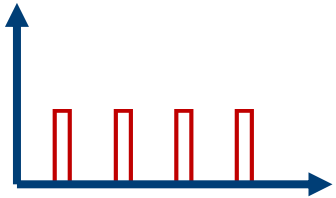


High amplitude
Low pulse frequency
Small pulse width

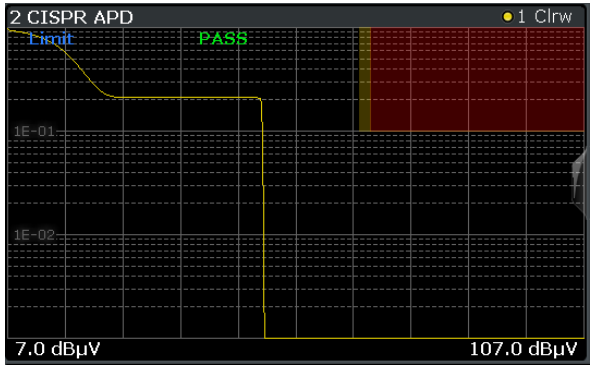


Pulse Frequency
Pulse Width





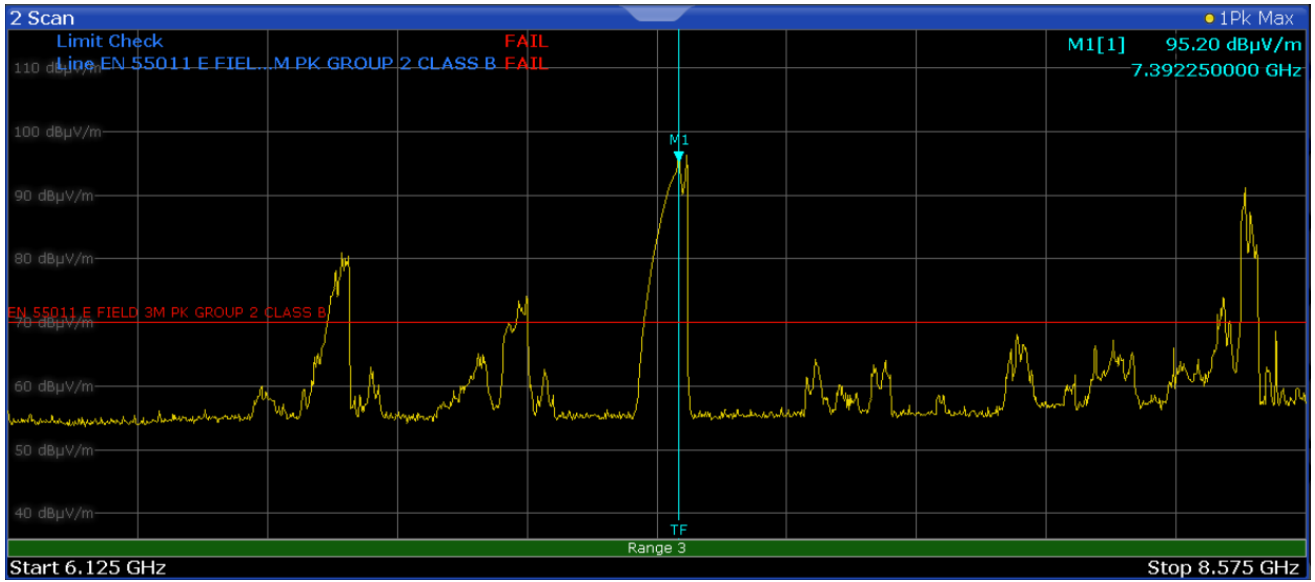
Low amplitude
High pulse frequency



Pulse Amplitude

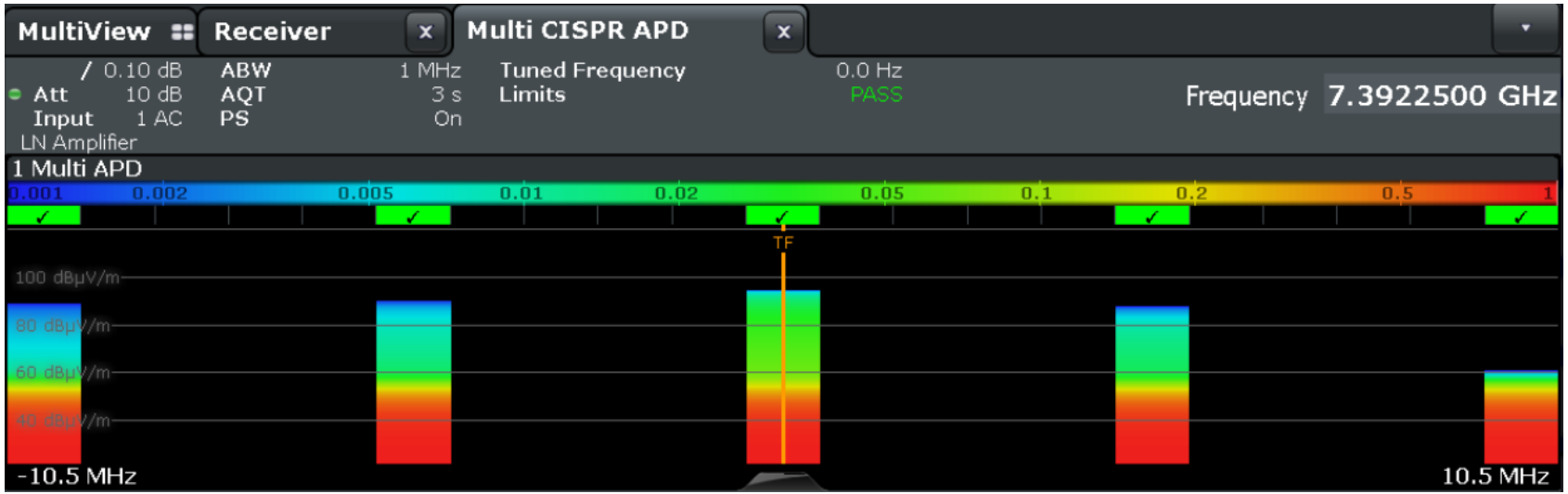
CISPR 16 – APD MEASUREMENT FUNCTION

- **Example APD Multi-Channel Measurement**
  - Preview measurement in subrange 3 (6.125 GHz to 8.575 GHz)
  - Peak level exceeds the CISPR 11 peak limit by far → Preview Result **FAIL**



CISPR 16 – APD MEASUREMENT FUNCTION

- **Example APD Multi-Channel Measurement**
  - Final APD measurement at the highest peak that exceeds the peak limit
  - 2D chart for visualization for all measurement channels, Tuned Frequency ±5 and ±10 MHz → Final Result **PASS**



2006 / 2012 / 2016 – AGE OF FFT-BASED EMI RECEIVERS

- FFT offers frequency scanning with quasi-peak detection fully compliant to the CISPR 16-1-1 standard
- R&S®ESU, R&S®ESR and the R&S®ESW naturally have RMS-Average detector and APD measurement function for proper interreference weighting in the age of digital radio services

THANK YOU FOR YOUR INTEREST!

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