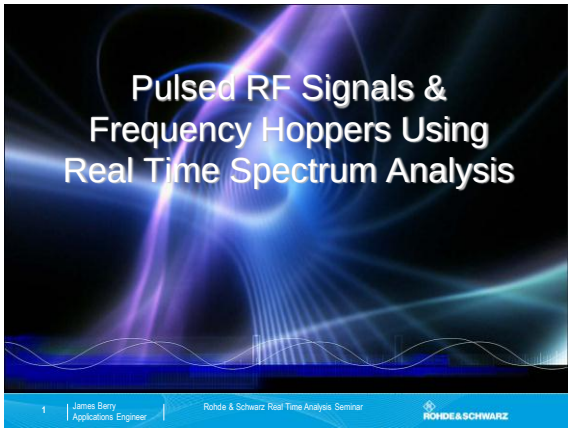


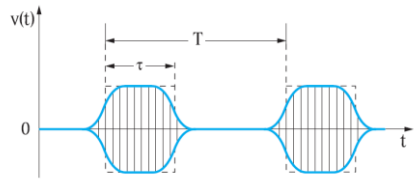
Agenda

- Pulsed Signals & Frequency Hoppers
  - Characteristics
  - Traditional Measurement Methods & Limitations
- Real Time Spectrum Analysis
  - Definition
  - Implementation in FSVR
  - Frequency Mask Triggering
- Live Demonstration
- Q & A

Pulsed Signals

- **What is a pulsed signal ?**
  - An RF signal which is switched on / off periodically
  - Within the pulse the carrier frequency might have additional amplitude/frequency or phase modulation.
  - Important parameters are the Pulse width t and the pulse repetition interval time T

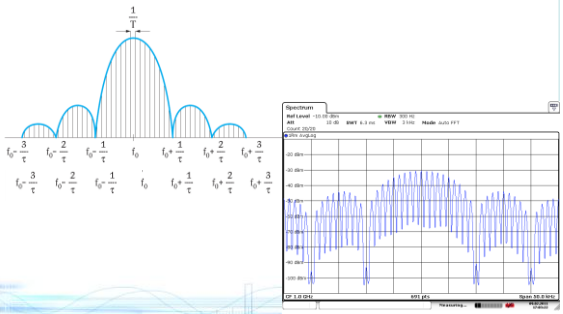
Pulsed Signals



Pulsed Signals

- **What does the Spectrum Analyzer display?**
  - Due to the periodic switching the typical pulse spectrum is a sin x / x function.
  - Remember: Important parameters are:
    - the **Pulse Width** (t)
    - the **Pulse Repetition Interval** time (T).
- Question: Where do we see them in the spectrum ?

Pulsed Signals



Measurement in Frequency domain

- **How much power does the SA show in frequency domain view ?**
  - Remember: Important parameters are the **Pulse Width** (t) and the **Pulse Repetition Interval** time (T).
  - Depending on the pulse parameters we can calculate the **Pulse desensitation factor.**
  - The line spectrum is displayed for RBW < Pulse Repetion Frequency
  - For the line spectrum the level is independant of the RBW
  - The pulse desensitation factor is only dependant on pulse parameters:

$$PDF_{line} = 20 \cdot \log(\tau/T)$$

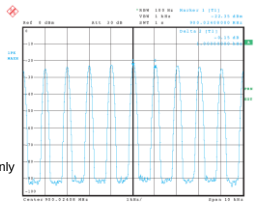


Fig. 6-13 Line spectrum of pulsed signal (measurement bandwidth B > 100 Hz < 1/T = 1 kHz)

Measurement in Frequency domain

- **How much power does the SA show in frequency domain view ?**
  - The desensitation factor is the reduction of the level measured within the pulse bandwidth of the spectrum analyzer
  - Marker reading + desensitation factor = Peak Power
  - Example:
    Pulse Repetition Interval (T): 1ms
  - Pulse Width (t): 100 us

$$PDF_{line} = 20 \cdot \log(\tau/T)$$

  - Desensitation factor = - 20 dB
  - Peak Power = -2.35 dBm

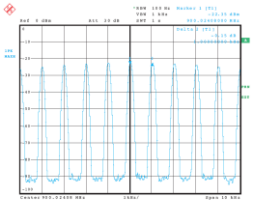


Fig. 6-13 Line spectrum of pulsed signal (measurement bandwidth B > 100 Hz < 1/T = 1 kHz)

Measurement in Frequency domain

- **Why is the RBW setting so important on pulsed measurements ?**
  - With a bandwidth wider than the spacing but still smaller than the spacing of the first null in the envelope (1 / pulse width), we get an envelope spectrum. Changing the RBW will lead to changes in the measured level.
  - The **Pulse desensitation factor** is now depending on the pulse parameters and the RBW**.**
  - Reason: The bandwidth is wider than the spacing of the spectral lines.
    The measured amplitude depends on the number of lines within the bandwidth and the total signal bandwidth.

$$PDF_{envelope} = 20 \cdot \log(\tau KB)$$

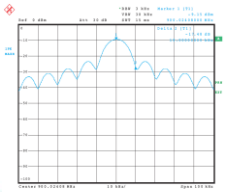
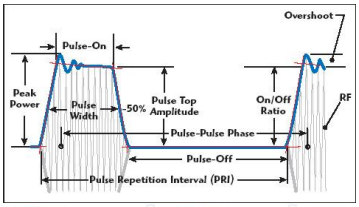


Fig. 6-14 Envelope spectrum of pulsed signals (1/τ < 10 kHz < B < 1 MHz < 1/T = 1 kHz)

Measurement in Time Domain

- **What information is available in time domain measurements ?**
  - With a wide bandwidth receiver we are able to characterize many important parameters about the pulse shape of our signal.
  - Time domain information is what todays radar designers are most interested in.



Measurement in Time Domain

- **Why is the RBW setting so important on pulsed measurements ?**
  - With the RBW too wide the line or envelope spectrum changes to a time domain spectrum, we start to see the impulse response of the RBW filter

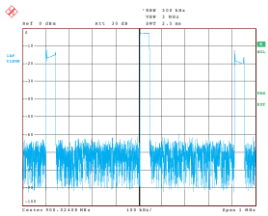
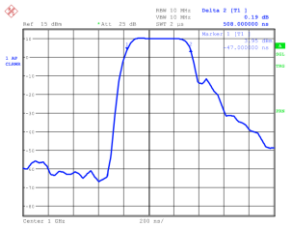


Fig. 6-15 Transition to display in time domain. Pulse duration of 100 µs and period of 1 ms can be clearly recognized.

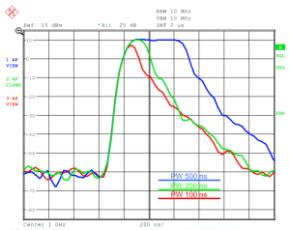
Measurement in Time Domain

- **Which measurements on pulsed signals are already available?**
  - With the SA in time domain, the **N dB down marker** gives a direct single button measurement for **Pulse Width**.
  - The normal **Peak Marker** allows to measurement of **Peak Power**
  - The delta markers allows to measure the parameters like rise time, fall time, pulse repetition interval, overshoot etc.



Measurement in Time Domain

- **What is the shortest pulse for a given RBW setting on pulsed signals ?**
  - With a wide RBW and VBW the spectrum analyzer is able to track the envelope of the RF pulse, we can see the impulse response of the pulse
  - The maximum RBW/VBW limits the SA capability to measure narrow pulses
  - Rule of Thumb for the shortest Pulse you can measure:
    Pulse width >= 2 / RBW
  - For SA 10 MHz RBW:
    FSV/FSU: ~ 200 ns



Frequency Hopping Signals

- **Similar to Pulsed Signal**
- **Frequency changes periodically**

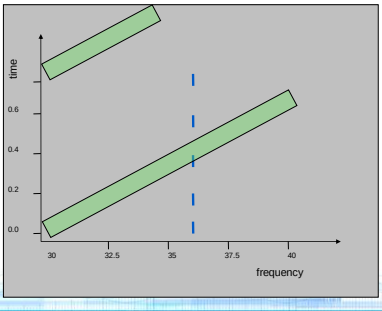
Agenda

- Pulsed Signals & Frequency Hoppers
- Real Time Spectrum Analysis
  - Limitations of conventional methods
  - Definition
  - Implementation in FSVR
  - Triggering

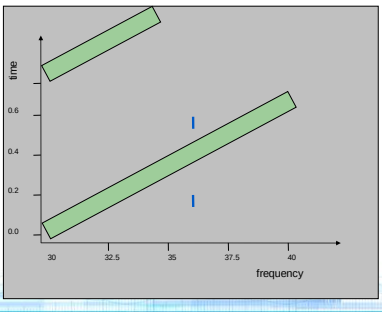
Swept Spectrum Analysis Limitations

- Sweep speed helps, but…
  - RBW filter must settle at every frequency point
  - LO settling from end 1st sweep to start of next
  - Processing time between points
- Great uncertainty with pulsed / hopping signals

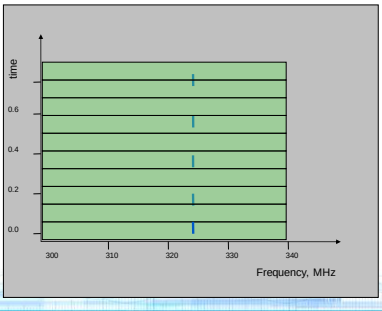
Swept Spectrum Analysis Limitations



Swept Spectrum Analysis Limitations



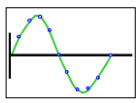
How Can I See Everything?



What is Real-Time

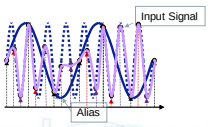
- Definition of Oscilloscope Users:

Real-Time
- Over-sampling following Nyquist rule



>10 samples

Non Real-Time: Nyquist Rule is violated:
- Sampling rate is smaller than 2x highest signal frequency.
- False reconstructed (alias) waveform is displayed !!!
- Non Real-Time scopes use varying offsets ....



What is Real-Time

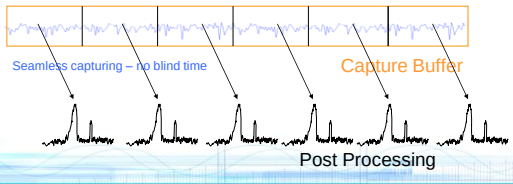
- **With *scope definition* R&S Spectrum Analyzers are Real-Time instruments already:**
  - FFT Filters in IQ (non-swept) mode
  - There is always oversampling in modern spectrum analyzers

BUT

- **In the world of spectrum analyzers and monitoring applications *Real-Time* means:**
- **Do not lose any information!**

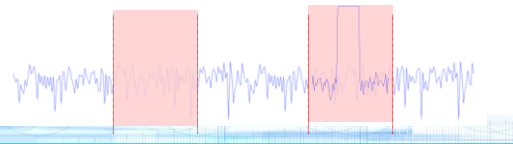
What is Real-Time

- **Real-Time scopes fulfill this requirement for a wide input bandwidth range, when**
  - Number of samples < Capture Memory: e.g. R&S®RTO : **8 ms** for **2 GHz**
- **Modern spectrum/signal analyzers fulfill this requirement for limited bandwidth (demodulation bandwidth), when**
  - Number of samples < Capture Memory: R&S®FSQ: **2 s** for **120 MHz**



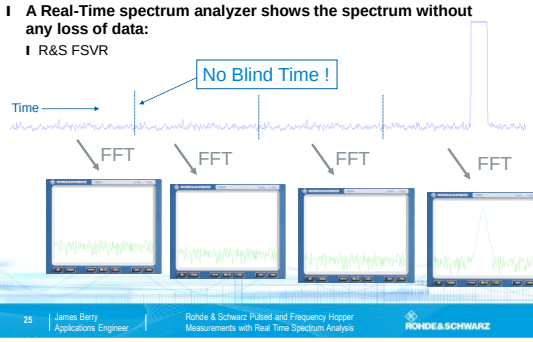
What is Real-Time

- **Spectrum analyzers and Real-Time scopes fulfill this requirement for:**
  - Number of samples < Capture Memory
    - R&S FSQ: 8 s Real-Time recording for 28 MHz
    - R&S RTO : 10 ms Real-Time recording for 2 GHz
- **After this data capturing and signal processing there is a blind time and information is lost before next data can be captured!**



What Really is Real-Time

- **A Real-Time spectrum analyzer shows the spectrum without any loss of data:**
  - R&S FSVR

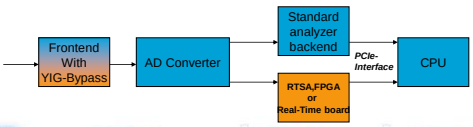


Concept of R&S FSVR
Based on R&S FSV

- **The Real-Time spectrum analyzer R&S FSVR**
  - Based on the successful signal and spectrum analyzer R&S FSV
- **Fully fledged spectrum analyzer**
- **Same RF front end as FSV => same RF performance as R&S FSV**
- **Same user interface**
- **All application firmware options, available for R&S FSV**
- **Nearly all hardware options of R&S FSV available for R&S FSVR**
- **Input frequency range up to 40 GHz**

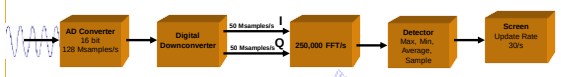
Concept of R&S FSVR
Additional Hardware

- **The R&S FSVR is equipped with additional Hardware:**
  - Real-Time board (extension unit)
  - YIG-filter-bypass (FSVR13/FSVR30)
- Necessary to transfer and processing of a huge amounts of data
  - **Very short time available**
  - **Mother board is PCI-express**

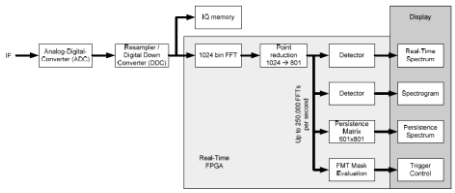


Real-Time Applications
Spectrum

- **Seamless Capturing and display of spectrum up to 40 MHz**
- **Digital Signal Processing:**

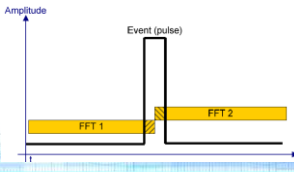


Concept of R&S FSVR
Additional Hardware



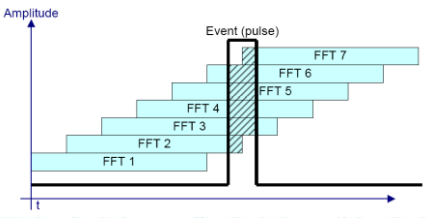
What About Short Events?

- **Sampling is a time domain process**
- **Occurs over a set period of time**
  - 1024 samples @ 128 MSPS
  - Many events shorter than full sampling time
  - How to capture accurately?

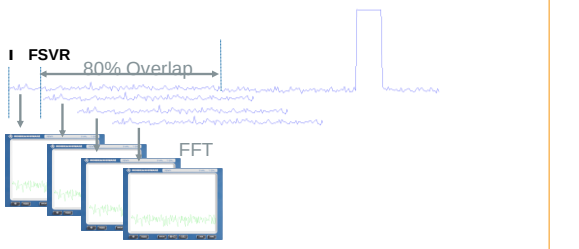


What About Short Events?

- Sampling is a time domain process
- **Overlap ensures capture**



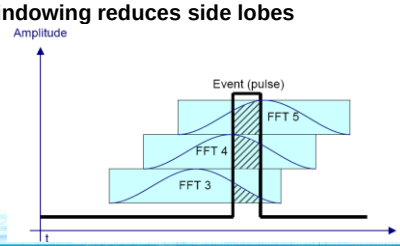
What is Real-Time – Overlap of FFTs



Effective exposure time = 20 µs

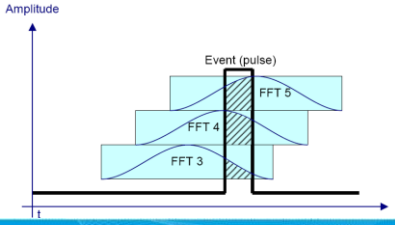
What About Short Events?

- Sampling occurs over a set period of time
- Overlap ensures capture
- **Windowing reduces side lobes**



What About Short Events?

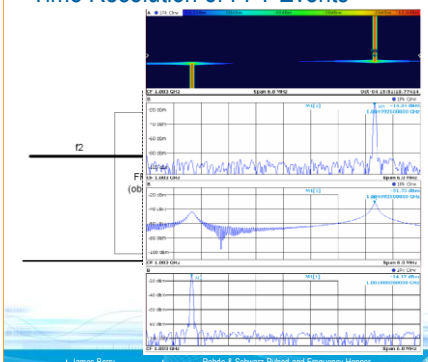
- Sampling occurs over a set period of time
- Overlap ensures capture
- **Windowing reduces side lobes**



Time Resolution of FFT Events

- **Example of Frequency Hop**
  - Freq F1 -> 10 μs gap -> Freq F2
  - Gap < 20 μs exposure time
- **Overlap => previous FFT results "held over"**
- **Components from F1 & F2 may appear briefly**

Time Resolution of FFT Events



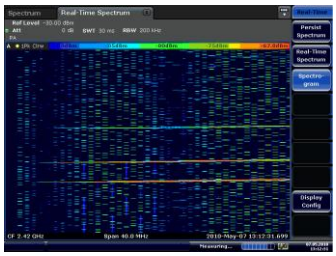
Real-Time Applications

Spectrogram

- Typical applications:
  - Observation of frequency hopping signals
    - R&D of communication applications
    - Service and Maintenance
  - Monitoring of frequency bands for
    - Regulation bodies
    - Military applications
      - (radio monitoring)
    - Aerospace applications
      - (satellite monitoring)

Frequency hopping of a Bluetooth signal
During frequency scan

Real-Time Applications
Spectrogram

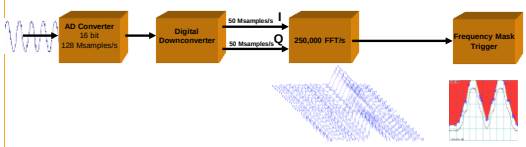


Triggering

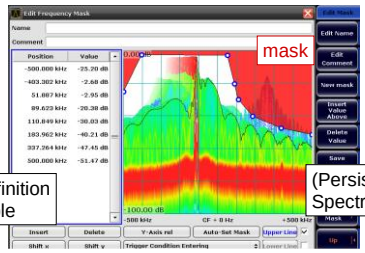
- **Same as available in swept spectrum**
  - Free Run
  - External
  - Power
  - Video
- **Frequency Mask**

Real-Time Applications
Frequency Mask Trigger, FMT

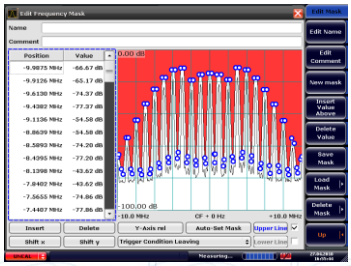
- **With the Frequency Mask Trigger (FMT) the instrument can trigger on a special event in the frequency domain**
- **If any FFT component violates the mask, a trigger event occurs**



Real-Time Applications
Frequency Mask Trigger, FMT

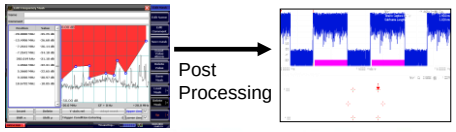


Real-Time Applications
Frequency Mask Trigger, FMT, Auto-Set mask



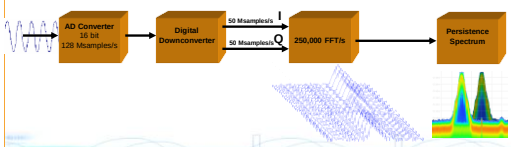
Real-Time Applications
Frequency Mask Trigger, FMT

- Typical applications:
  - Evaluation of the spectrum of of signals, which are available only once in a while:
    - Causing malfunction of base stations
    - Electromagnetic interference
    - Radio signals
  - Deeper Evaluation of signals (modulation analysis), which are difficult to capture by post processing of capture memory using internal measurement applications:



Real-Time Applications
Persistence Spectrum

- **Digital Persistence Spectrum (Persistence Spectrum) shows a spectral histogram or probability density function revealing effects, which cannot be seen in normal spectrum analyzer mode**
- **Digital Signal Processing:**



Real-Time Applications
Persistence Spectrum

- Typical applications:
  - Evaluation of combined signals, where one signal is hidden by another one
  - Settling effects
  - Monitoring

Real-Time Applications
Screen Shots