EMC Receiver Concepts

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EMI Receiver Product Management

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Questions for Audience

- **What Standards work with?**
  - Aerospace & Defense
    - MIL-STD461? DO-160? AIAA? Others?
  - Commercial
    - CISPR? FCC? Others?
- **EMC SW automation vs front panel operation?**
  - What SW automation? Tile! ? EMC32? Others?
- **What types of Signals are in products tested?**
  - High power?
  - Continuous vs time varying spectrum?
  - Repetitive pulsed vs Intermittent?
  - Minimum duration pulse to characterize? Measurements Accurate?

Questions for Audience

- **Use spectrum analyzers or EMI receivers?**
  - Know the difference?
  - Need for pre-selection? Familiarity of pre-selection?
- **Use Time Domain Scan (now in MIL-STD461G)?**
  - Familiar with benefits of Time Domain Scan?
- **Familiar with Real-time Spectrum Analysis?**
  - Persistency Display?
  - Spectrogram displays?
    - Real-time spectrogram vs non real-time?

Agenda

- **What does Compliance Mean?**
  - CISPR 16-1-1
- **Spectrum Analyzers vs EMC Receivers**
  - Purpose / Application
  - Architecture
- **The Value of Pre-Selection**
- **Time Domain Scan**
  - Ability to Capture Intermittent Signals
  - Speed
  - Measurement Time (Dwell Time) / PRI (Pulse Repetition Rate)
- **AGC: Automatic Gain (of Level) Control**
- **User Interface**
- **Real-time Spectrum Analysis**

What is Compliance?

- CISPR 16-1-1 is the standard which puts specifications on the ‘measuring apparatus’
  - Be it spectrum analyzer, EMI test receiver, FFT analyzer
  - ‘Black box’ approach
- MIL-STD461 indirectly references CISPR 16-1-1 requirements via ANSI C63.2
  - Therefore, even the MIL-STD community is governed by requirements in CISPR16-1-1
- CISPR 16-1-1 has requirements on the ability of the ‘measuring apparatus’ to properly measure pulses
- The pulse handling requirements translate into dynamic range and pre-selection architectural requirements of the ‘measuring apparatus’

What is Compliance?
MIL-STD461 references ANSI C63.2

MIL-STD-461G

IEEE/ASTM INTERNATIONAL

IEEE/ASTM SI 10	American National Standard for Metric Practice

(IEEE and ASTM International publish this standard jointly. Copies are available from http://www.ieee.org/ or http://www.astm.org/.)

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)/IEEE

ANSI C63.2	American National Standard for Electromagnetic Noise and Field Strength Instrumentation, 10 Hz to 40 GHz Specifications
ANSI C63.14	American National Standard Dictionary of Electromagnetic Compatibility (EMC) including Electromagnetic Environmental Effects (E3)

What is Compliance?

ANSI C63.2 references CISPR16-1-1

American National Standard for Electromagnetic Noise and Field Strength Instrumentation, 10 Hz to 40 GHz Specifications

1. Normative references

The following referenced documents are indispensable for the application of this standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

CISPR 16-1-1, Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods—Part 1-1: Radio Disturbance and Immunity Measuring Apparatus—Measuring Apparatus.[1]

What is Compliance?
CISPR 16-1-1

INTRODUCTION

The CISPR 16 series, published under the general title *Specification for radio disturbance and immunity measuring apparatus and methods*, is comprised of the following sets of standards and reports:

- CISPR 16-1 – five parts covering measurement instrumentation specifications;
- CISPR 16-2 – five parts covering methods of measurement;
- CISPR 16-3 – a single publication containing various technical reports (TRs) with further information and background on CISPR and radio disturbances in general;
- CISPR 16-4 – five parts covering uncertainties, statistics and limit modelling.

What is Compliance?
CISPR 16-1-1

CISPR 16-1 consists of the following parts, under the general title *Specification for radio disturbance and immunity measuring apparatus and methods – Radio disturbance and immunity measuring apparatus:*

- Part 1-1: Measuring apparatus
- Part 1-2: Ancillary equipment – Conducted disturbances
- Part 1-3: Ancillary equipment – Disturbance power
- Part 1-4: Ancillary equipment – Radiated disturbances
- Part 1-5: Antenna calibration test sites for 30 MHz to 1 000 MHz

- **Family of CISPR product standards all reference CISPR 16-1-1**
- **MIL-STD461 indirectly references CISPR 16-1-1**

What is Compliance?

CISPR 16-1-1

Section 6 → Average Detector
Section 7 → rms-average detector

– 2 –   CISPR 16-1-1:2010
+AMD1:2010+AMD2:2014 © IEC 2014

CONTENTS

What is Compliance?

CISPR 16-1-1

5.5 Response to pulses

Up to 1 000 MHz, the response of the measuring receiver to pulses with impulse area 1,4/B_{imp} mVs (where B_{imp} is in Hz) e.m.f. at 50 Ω source impedance shall be equal to the response to an unmodulated sine-wave signal at the tuned frequency having an e.m.f. with rms value of 2 mV [66 dB(μV)]. The source impedances of both the pulse generator and the signal generator shall be the same. The pulses shall have a uniform spectrum according to Table 2. A tolerance of ±1,5 dB is permitted in the sine-wave voltage level, and this is a requirement for all pulse repetition frequencies for which no overlapping pulses occur at the output of the IF amplifier.

NOTE 1 Annexes B and C describe methods for determining the output characteristics of pulse generators for use in testing for the requirements of this subclause.

NOTE 2 At a repetition rate of 25 Hz for Band A and 100 Hz for the other bands, the relationship between the indications of a peak measuring receiver and a quasi-peak measuring receiver with the preferred bandwidth are given in Table 7.

Table 7 – Relative pulse response of peak and quasi-peak measuring receivers for the same bandwidth (frequency range 9 kHz to 1 000 MHz)

Frequency	A_{imp} mVs	B_{imp} Hz	Ratio peak/quasi-peak (dB) for pulse repetition rate 25 Hz	Ratio peak/quasi-peak (dB) for pulse repetition rate 100 Hz
Band A	6,67 × 10^{-3}	0,21 × 10^3	6,1	–
Band B	0,148 × 10^{-3}	9,45 × 10^3	–	6,6
Bands C and D	0,011 × 10^{-3}	126,0 × 10^3	–	12,0

NOTE The pulse response is based on the use of the reference bandwidth only (see Table 6).

Above 1 GHz, the required impulse area is defined using a pulse-modulated carrier at the frequency of test, since pulse generators with a uniform spectrum up to 18 GHz are not feasible. See E.6.

Table 2 – Pulse response of quasi-peak measuring receivers

Repetition frequency Hz	Relative equivalent level in dB of pulse for stated band: Band A 9 kHz to 150 kHz	Band B 0,15 MHz to 30 MHz	Band C 30 MHz to 300 MHz	Band D 300 MHz to 1 000 MHz
1 000	Note 4	–4,5 ± 1,0	–8,0 ± 1,0	–8,0 ± 1,0
100	–4,0 ± 1,0	0 (ref.)	0 (ref.)	0 (ref.)
60	–3,0 ± 1,0	–	–	–
25	0 (ref.)	–	–	–
20	–	+6,5 ± 1,0	+9,0 ± 1,0	+9,0 ± 1,0
10	+4,0 ± 1,0	+10,0 ± 1,5	+14,0 ± 1,5	+14,0 ± 1,5
5	+7,5 ± 1,5	–	–	–
2	+13,0 ± 2,0	+20,5 ± 2,0	+26,0 ± 2,0	+26,0 ± 2,0*
1	+17,0 ± 2,0	+22,5 ± 2,0	+28,5 ± 2,0	+28,5 ± 2,0*
Isolated pulse	+19,0 ± 2,0	+23,5 ± 2,0	+31,5 ± 2,0	+31,5 ± 2,0*

* These values are optional and not essential.

NOTE 1 The influence of the receiver characteristics upon its pulse response is considered in Annex D.

NOTE 2 The relationships between the pulse responses of a quasi-peak receiver and receivers with other detector types are given in 5.5, 6.5 and 7.5.

NOTE 3 The theoretical pulse response curves of quasi-peak and average detector receivers combined on an absolute scale are shown in Figure 1d. The ordinate of Figure 1d shows the open-circuit impulse areas in dB(μVs) corresponding to the open-circuit sine-wave voltage of 66 dB(μV) rms. The indication on a measuring receiver with an input matched to the calibrating generators will then be 60 dB(μV). Where the measuring bandwidth is less than the pulse repetition frequency, the curves of Figure 1d are valid when the receiver is tuned to a discrete line of the spectrum.

NOTE 4 It is not possible to specify a response above 100 Hz in the frequency range 9 kHz to 150 kHz because of the overlapping of pulses in the IF amplifier.

NOTE 5 Annex A deals with the determination of the curve of response to repeated pulses.

What is Compliance?

CISPR 16-1-1

The response curve for a particular measuring receiver shall lie between the limits defined in the appropriate figure and quantified in Table 2. For spectrum analyzers without preselection, the requirements in Table 2 for pulse repetition frequencies less than 20 Hz are not applicable. The use of such instruments for compliance testing is conditional. If such spectrum analyzers are used for measurements, the user shall verify and document that the equipment under test does not emit broadband signals of pulse repetition frequencies of 20 Hz or lower. A determination of the suitability of a spectrum analyzer for testing shall be made by performing the procedure documented in Annex B of CISPR 16-2-1, Annex B of CISPR 16-2-2, or Annex B of CISPR 16-2-3.

The pulse response is restricted due to overload at the input to the receiver at frequencies above 300 MHz. The values marked with an asterisk (*) in Table 2 are optional and are not essential.

What is Compliance?

CISPR 16-2-1

Annex B
(informative)

Use of spectrum analyzers and scanning receivers
(see Clause 6)

B.1 Introduction

When using spectrum analyzers and scanning measuring sets, the following characteristics should be taken into account.

B.2 Overload

Most spectrum analyzers have no RF preselection in the frequency range up to 2 000 MHz; that is, the input signal is directly fed to a broadband mixer. To avoid overload, to prevent damage and to operate a spectrum analyzer linearly, the signal amplitude at the mixer should typically be less than 150 mV peak. RF attenuation or additional RF preselection may be required to reduce the input signal to this level.

What is Compliance?
CISPR 16-2-1 / 16-2-2 / 16-2-3

CISPR 16-2-1/3 all have sections on measurement times and method for automated measurements

Table 1 – Minimum measurement times for the four CISPR bands

Frequency band		Minimum measurement time T_m
A	9 kHz to 150 kHz	10,00 ms
B	0,15 MHz to 30 MHz	0,50 ms
C and D	30 MHz to 1 000 MHz	0,06 ms
E	1 GHz to 18 GHz	0,01 ms

Table 2 – Minimum scan times for the three CISPR bands with peak and quasi-peak detectors

Frequency band		Scan time T_s for peak detection	Scan time T_s for quasi-peak detection
A	9 kHz to 150 kHz	14,1 s	2 820 s = 47 min
B	0,15 MHz to 30 MHz	2,985 s	5 970 s = 99,5 min = 1 h 39 min
C and D	30 MHz to 1 000 MHz	0,97 s	19 400 s = 323,3 min = 5 h 23 min

Depending on the type of disturbance, the scan time may have to be increased, even for quasi-peak measurements. In extreme cases, the measurement time T_m at a certain frequency may have to be increased to 15 s, if the level of the observed emission is not steady (see 6.5.1). However isolated clicks are excluded.

Scan rates and measurement times for use with the average detector are provided in Annex C.

Most product standards call out quasi-peak detection for compliance measurements that is very time consuming if no time-saving procedures are applied (see Clause 8). Before time-saving procedures can be applied, the emission has to be detected in a prescan. In order to ensure that e.g. intermittent signals are not overlooked during an automatic scan, the considerations in 6.6.3 to 6.6.5 shall be taken into account.

What is Compliance?

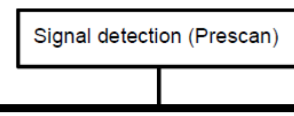
CISPR 16-2-1 / 16-2-2 / 16-2-3

CISPR 16-2-1/3 all have sections on measurement times and method for automated measurements

8.2 Generic measurement procedure

Signals need to be intercepted by the EMI receiver before they can be maximized and measured. The use of the quasi-peak detector during the emission maximization process for all frequencies in the spectrum of interest leads to excessive test times (see 6.6.2). Time-consuming processes like absorbing clamp position scans are not required for each emission frequency. They should be limited to frequencies at which the measured peak amplitude of the emission is above or near the emission limit. Therefore, only the emissions at critical frequencies whose amplitudes are close to or exceed the limit will be maximized and measured.

The generic process shown in Figure 10 will yield a reduction in measurement time:



8.7 Emission measurement strategies with FFT-based measuring instruments

Depending on the implementation, FFT-based measuring instruments may perform weighted measurements significantly faster than the tuneable selective voltmeters. A weighted measurement over the frequency range of interest may then be faster than a measurement consisting of a prescan and final scan performed with a superheterodyne receiver, as described in 8.3.

IEC 1839/10

Figure 10 – Process for reduction in measurement time

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  - Purpose / Application
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- **The Value of Pre-Selection**
- **Time Domain Scan**
  - Ability to Capture Intermittent Signals
  - Speed
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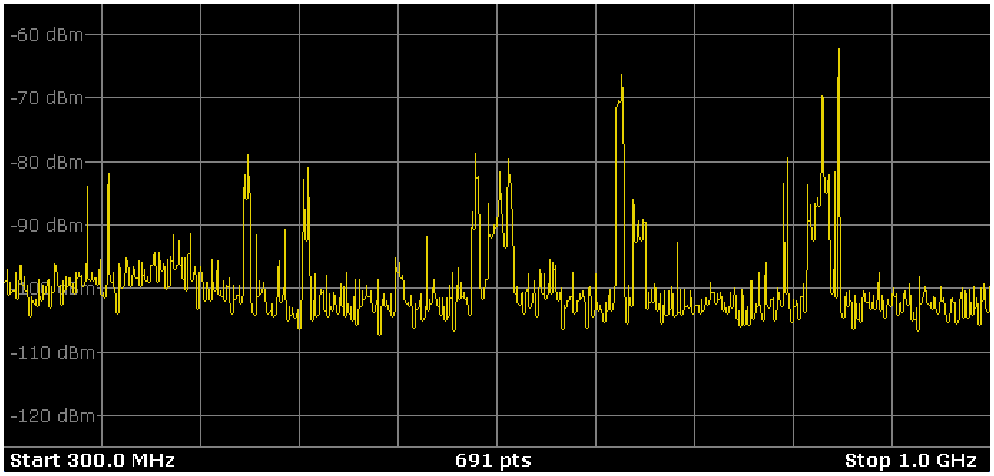
- **AGC: Automatic Gain (of Level) Control**
- **User Interface**
- **Real-time Spectrum Analysis**

Spectrum/Signal Analyzer Architecture

Typical Measurement

- Frequency measurement
  - Absolute and relative
- Power Level
- Channel Power
  - Total power in a given bandwidth
- Adjacent channel power
- Spectral purity of RF signals
  - Spurious, harmonics, Intermodulation products, etc.
- Modulation analysis
  - Analog signals (AM, FM, and PM)
  - Digital signals (QPSK, BPSK, QAM, etc.)
- Phase noise and noise figure



Spectrum/Signal Analyzer Architecture

Typical EMC Related Measurement

- Frequency measurement
  - Absolute and relative
- Power Level
- Channel Power
  - Total power in a given bandwidth
- Adjacent channel power
- Spectral purity of RF signals
  - Spurious, harmonics, Intermodulation products, etc.
- Modulation analysis
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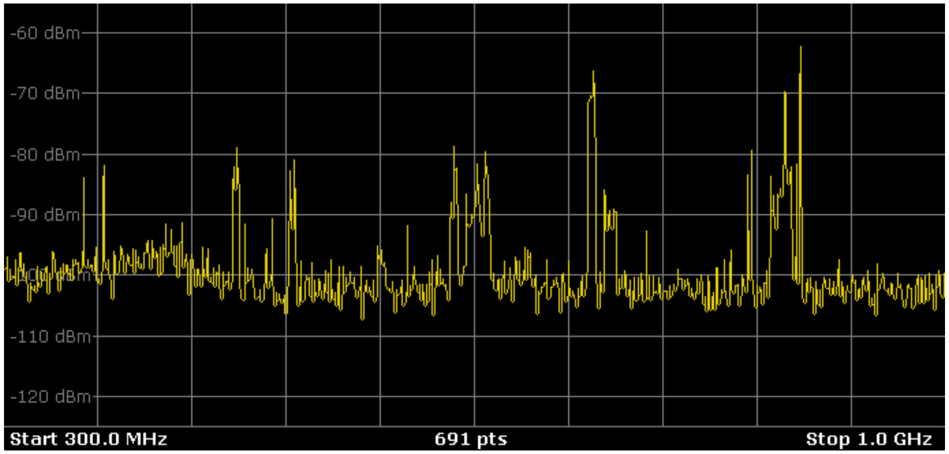
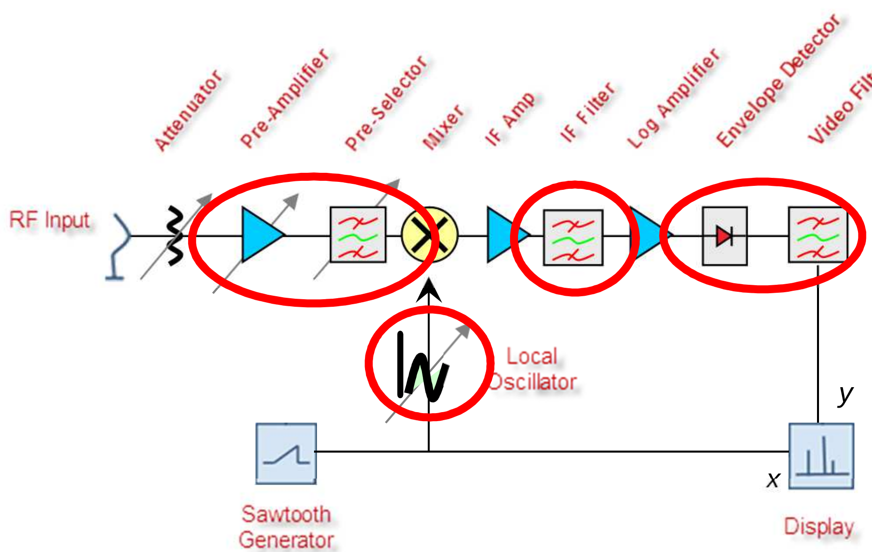
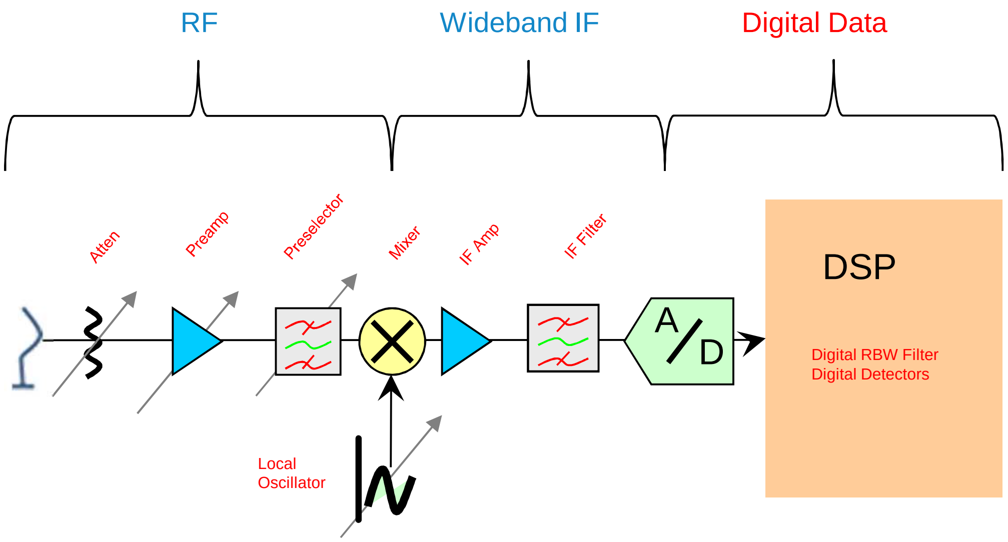


Spectrum Analyzer vs. EMI Receiver



- Pre-amp & Pre-selection
- AGC: automatic gain control
- Local Oscillator
  - Swept vs Stepped
- Detector
- IF Filter

Typically Modern EMI Receiver Design



Wideband IF into ADC and digital signal processing provide for a entire new level of feature / functionality including:

- Time Domain Scan
- Real-Time Processing
- Revolutionary New Displays

Agenda

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- **Time Domain Scan**
  - Ability to Capture Intermittent Signals
  - Speed
  - Measurement Time (Dwell Time) / PRI (Pulse Repetition Rate)
- **AGC: Automatic Gain (of Level) Control**
- **User Interface**
- **Real-time Spectrum Analysis**

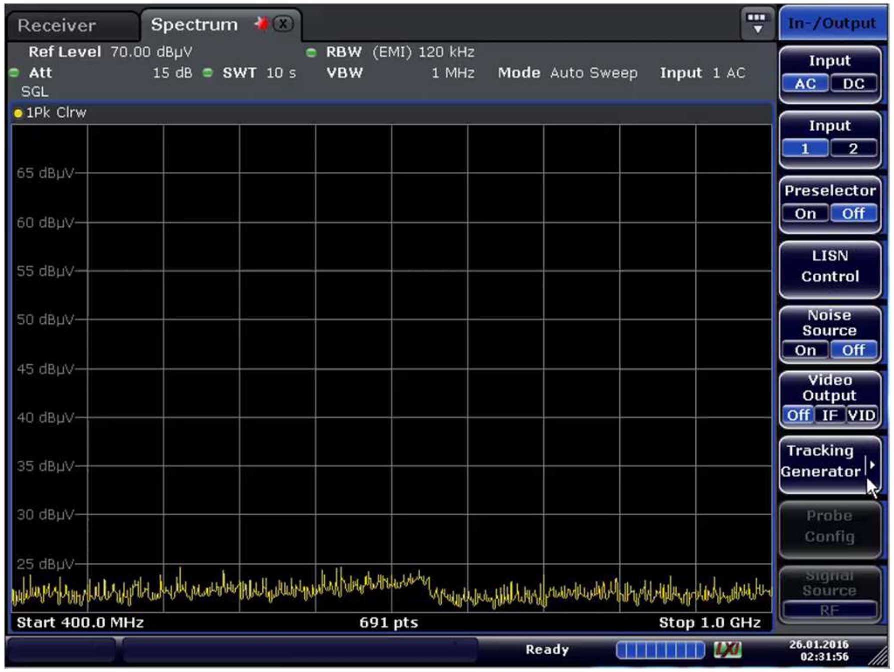
Outline

- **Video demonstrating effects of pre-selection**
- **Spectrum Analyzer vs EMI Test Receiver**
- **Pre-selection in the standards**
  - MIL-STD461 & CISPR 16-1-1
  - Time & Frequency Characteristics of Pulses
  - Pulse Requirements in CISPR 16-1-1
- **Pre-selection in a Spectrum Analyzer**
  - Image Rejection
- **Pre-selection in an EMI Receiver**
  - Overload protection
  - Ability to properly measure pulses
- **Video demonstrating the effects of pre-selection**

Longer Presentation

Video Demonstrating Effects of Pre-selection

400MHz -1GHz Sweep with RBW = 120kHz

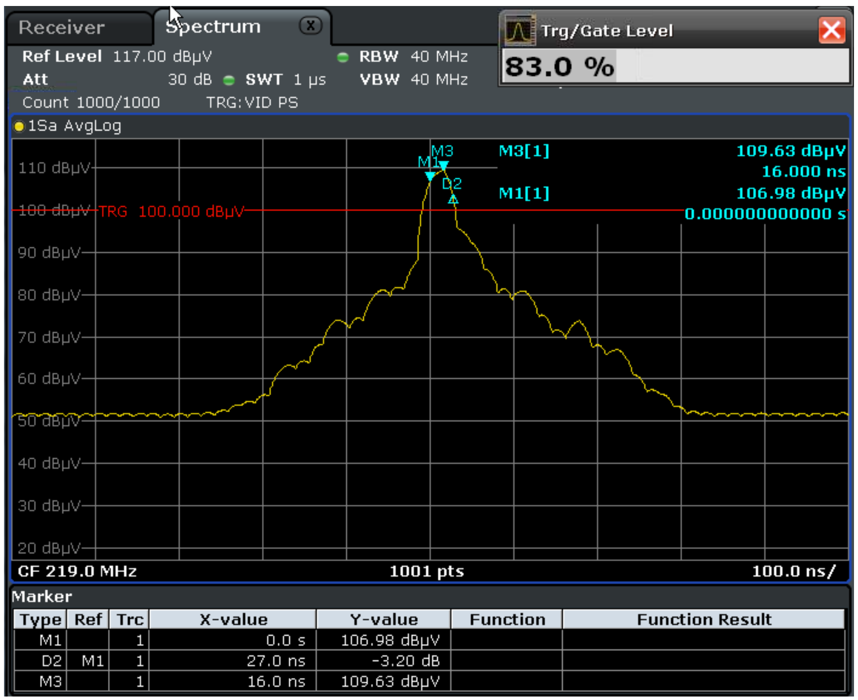


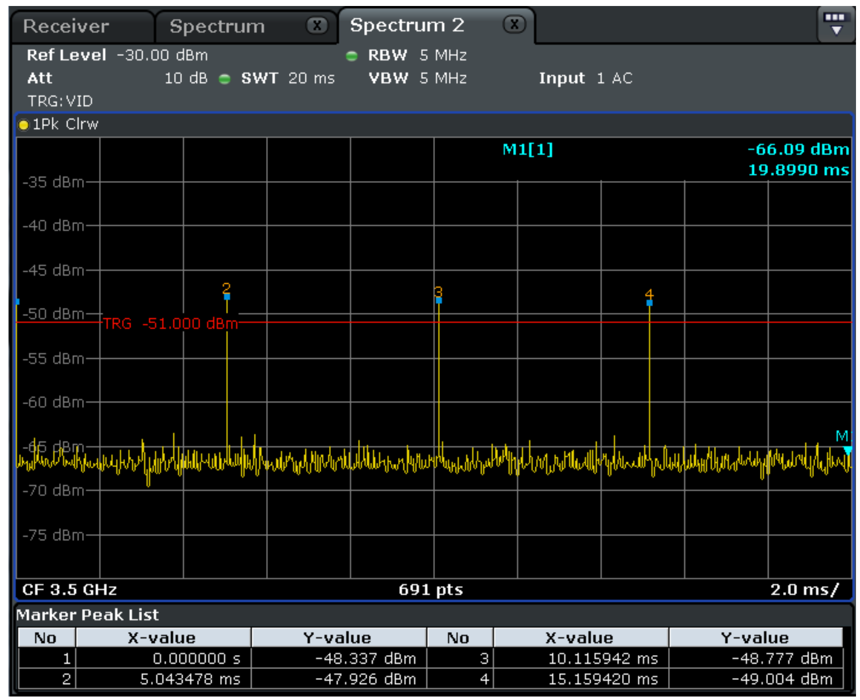
CISPR- Standard Calibration Pulse Generator

IGLK 2914 Schwarzbeck MESS-ELETRONIK

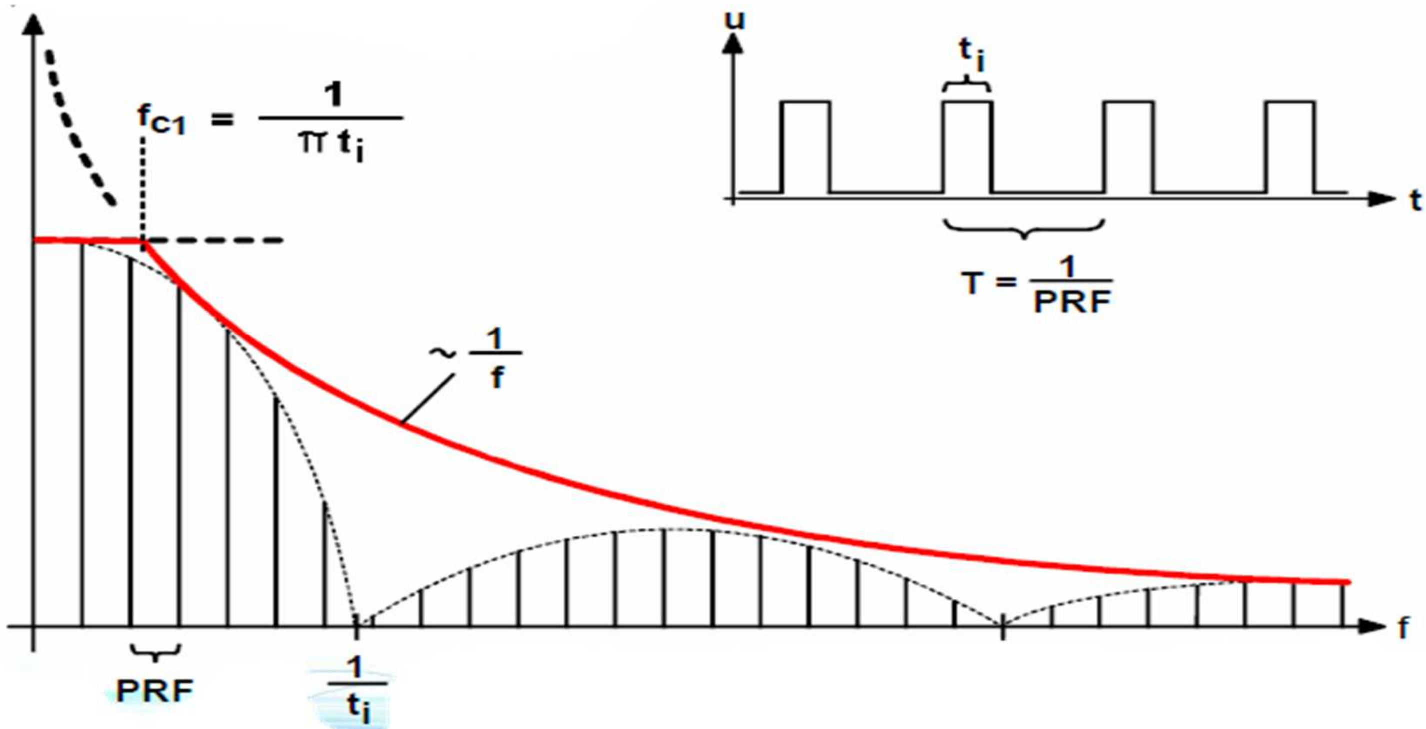
Parametrics

- Pulse type = CISPR 1 (9 kHz)
- Pulse Width ~ 41 ns
- PRF= 200 Hz
- Power = 56 dBuV





Time & Frequency Domain Characteristics of a Pulse

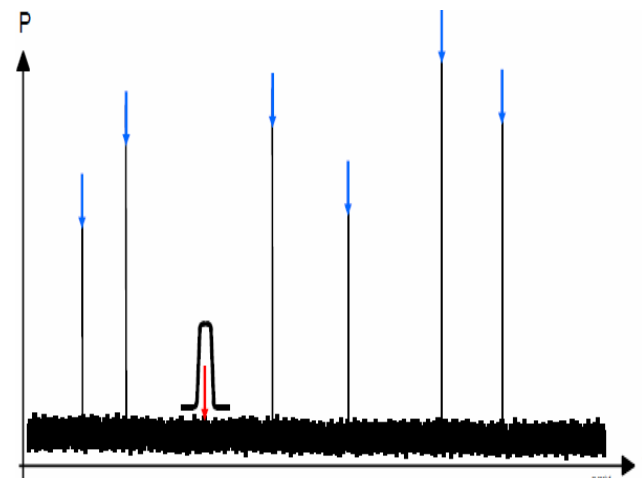


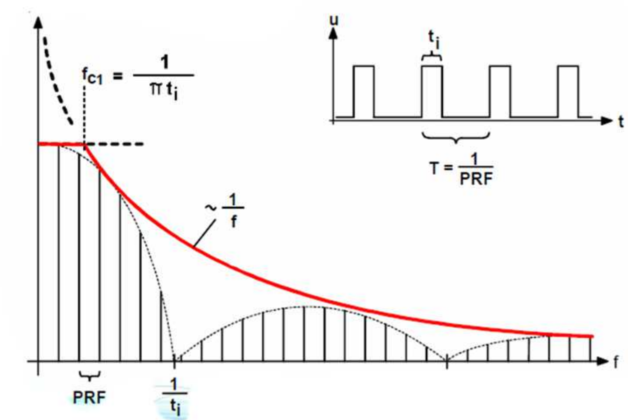
Pre-selection in an EMI Receiver

- **Purpose of pre-selection**
  - NOT image rejection or improved harmonic performance
  - Pre-selection protects the front end mixer
  - Helps eliminate mixer compression and overload

- **Two main situations where pre-selection is required**

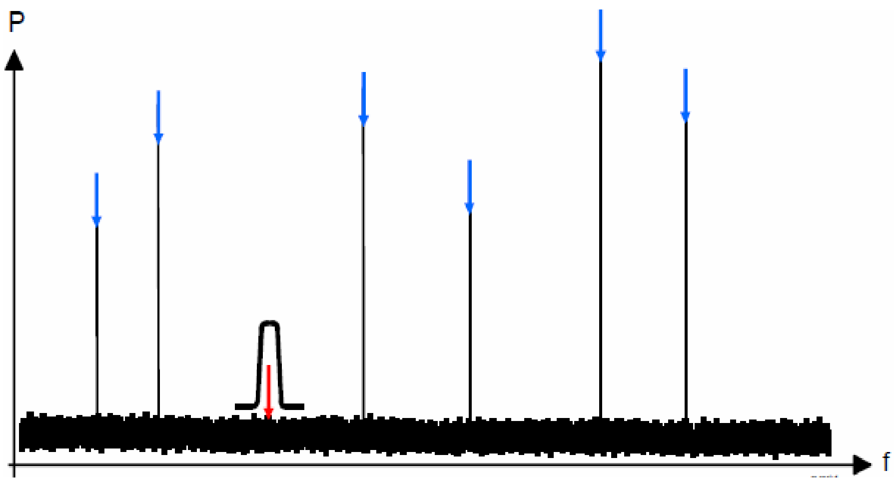
1) Spectral content at frequencies other than the desired measurement frequency is overloading the mixer resulting in reduced dynamic range
2) Single short duration pulse input resulting in very wide bandwidth spectral content at the mixer



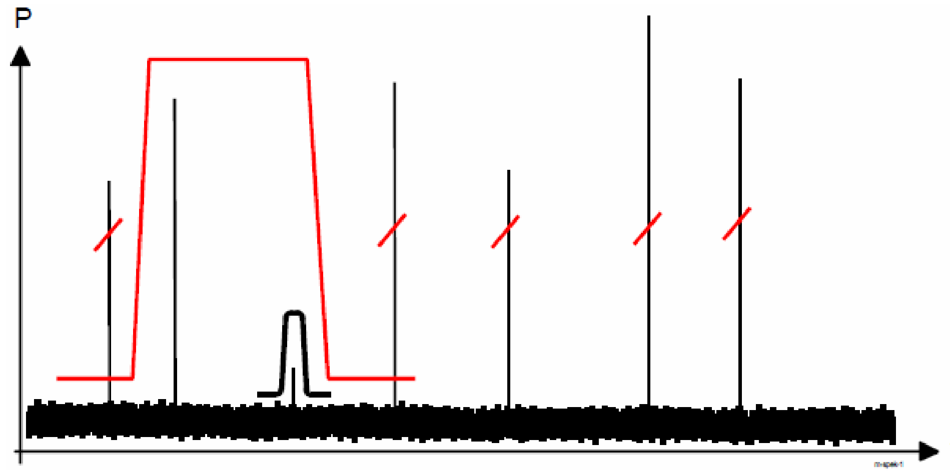


Pre-selection in an EMI Receiver

- Every signal hits the mixer
- If compressed → wrong results



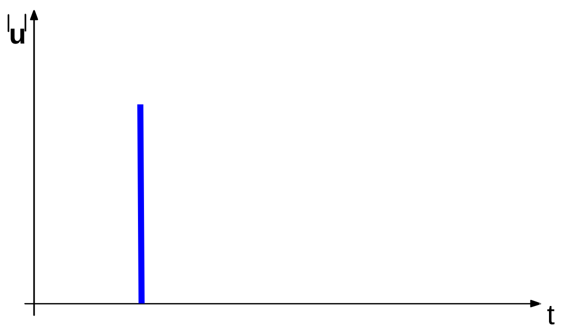
- Pre-selection protects the front end mixer
- Helps eliminate compression



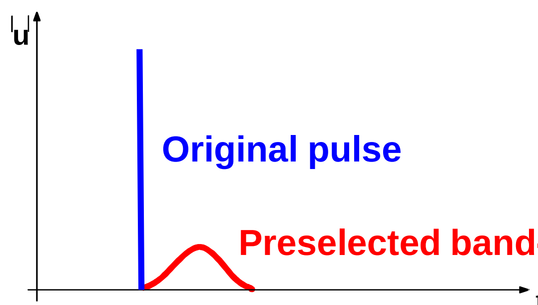
Pre-selection in an EMI Receiver

Filtering Effects in Time and Frequency

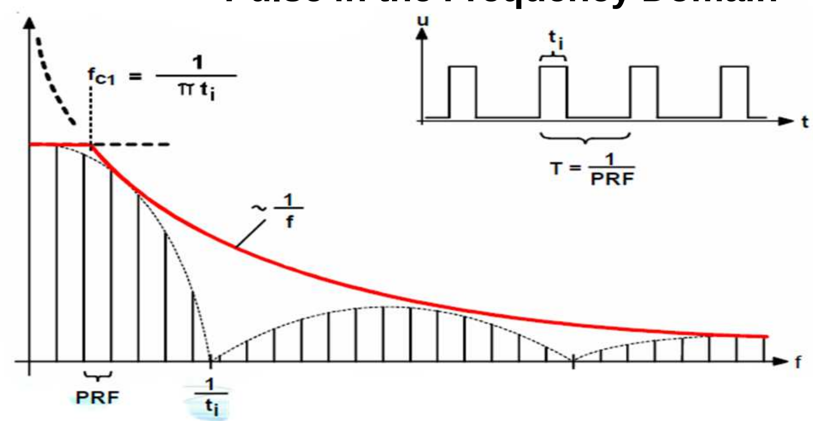
Pulse in Time Domain



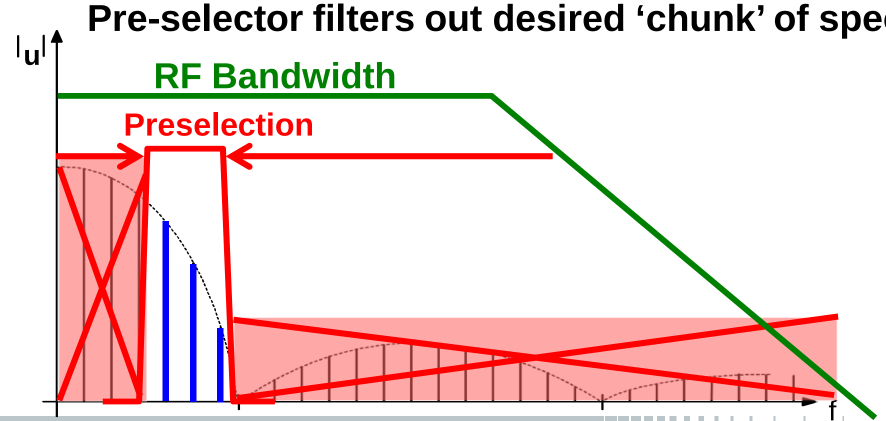
Resultant Pulse in Time Domain



Pulse in the Frequency Domain

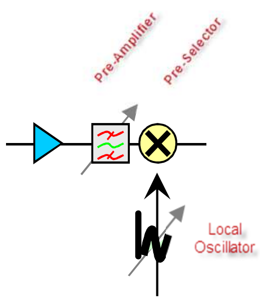


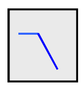
Pre-selector filters out desired 'chunk' of spectrum



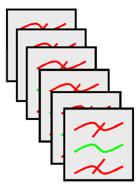
Pre-selection in an EMI Receiver

Bank of filers switched in automatically

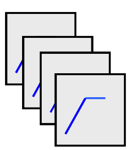




150 KHz LPF

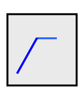


Fixed bandpass filters covering range 150kHz to 1005MHz



Fixed highpass filters covering range

1005MHz to 7000MHz



> 7 GHz YIG filter

Preselection and preamplifier

Preselection		
State	receiver mode	always on
	analyzer mode	on/off (selectable)
Number of preselection filters		16
Bandwidths (–6 dB), nominal	10 Hz to 150 kHz	fixed lowpass filter
	150 kHz to 30 MHz	35 MHz, fixed bandpass filter
	30 MHz to 80 MHz	94 MHz, fixed bandpass filter
	80 MHz to 130 MHz	94 MHz, fixed bandpass filter
	130 MHz to 180 MHz	91 MHz, fixed bandpass filter
	180 MHz to 230 MHz	105 MHz, fixed bandpass filter
	230 MHz to 300 MHz	110 MHz, fixed bandpass filter
	300 MHz to 425 MHz	195 MHz, fixed bandpass filter
	425 MHz to 570 MHz	200 MHz, fixed bandpass filter
	570 MHz to 715 MHz	210 MHz, fixed bandpass filter
	715 MHz to 860 MHz	200 MHz, fixed bandpass filter
	860 MHz to 1005 MHz	200 MHz, fixed bandpass filter
	1005 MHz to 1750 MHz	fixed highpass filter
	1750 MHz to 2850 MHz	fixed highpass filter
	2850 MHz to 4850 MHz	fixed highpass filter
	4850 MHz to 7000 MHz	fixed highpass filter
	7 GHz to 26.5 GHz	YIG filter
Preamplifier	switchable	
Location	1 kHz to 7 GHz	in the signal path between preselection and 1st mixer
	7 GHz to 26.5 GHz	in the signal path between diplexer and preselection
Range		1 kHz to 26.5 GHz
Gain	1 kHz to 7 GHz	20 dB (nom.)
	7 GHz to 26.5 GHz	30 dB (nom.)

Pre-Selection
Demo

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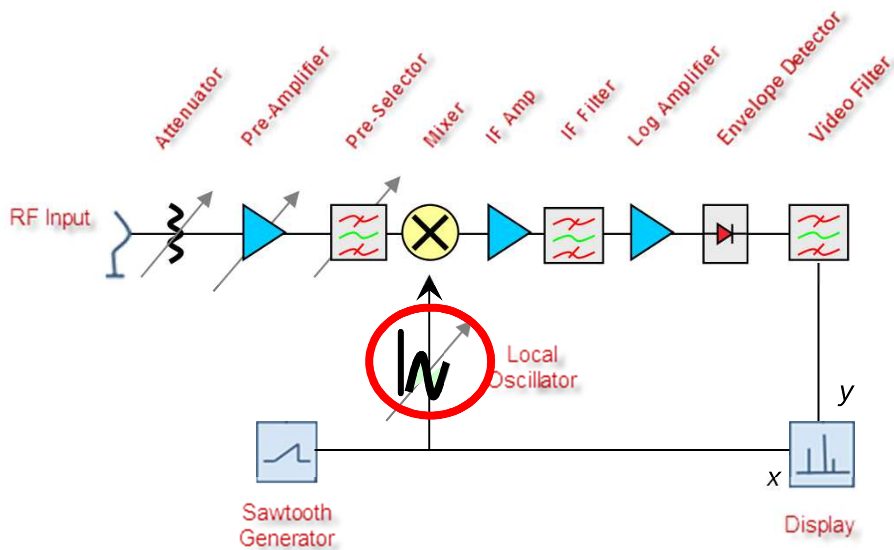
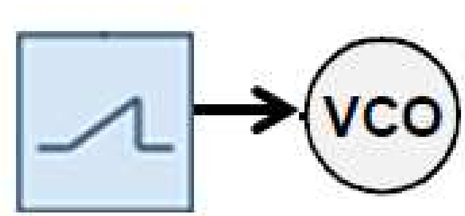
LO - Sweeping vs. Scanning

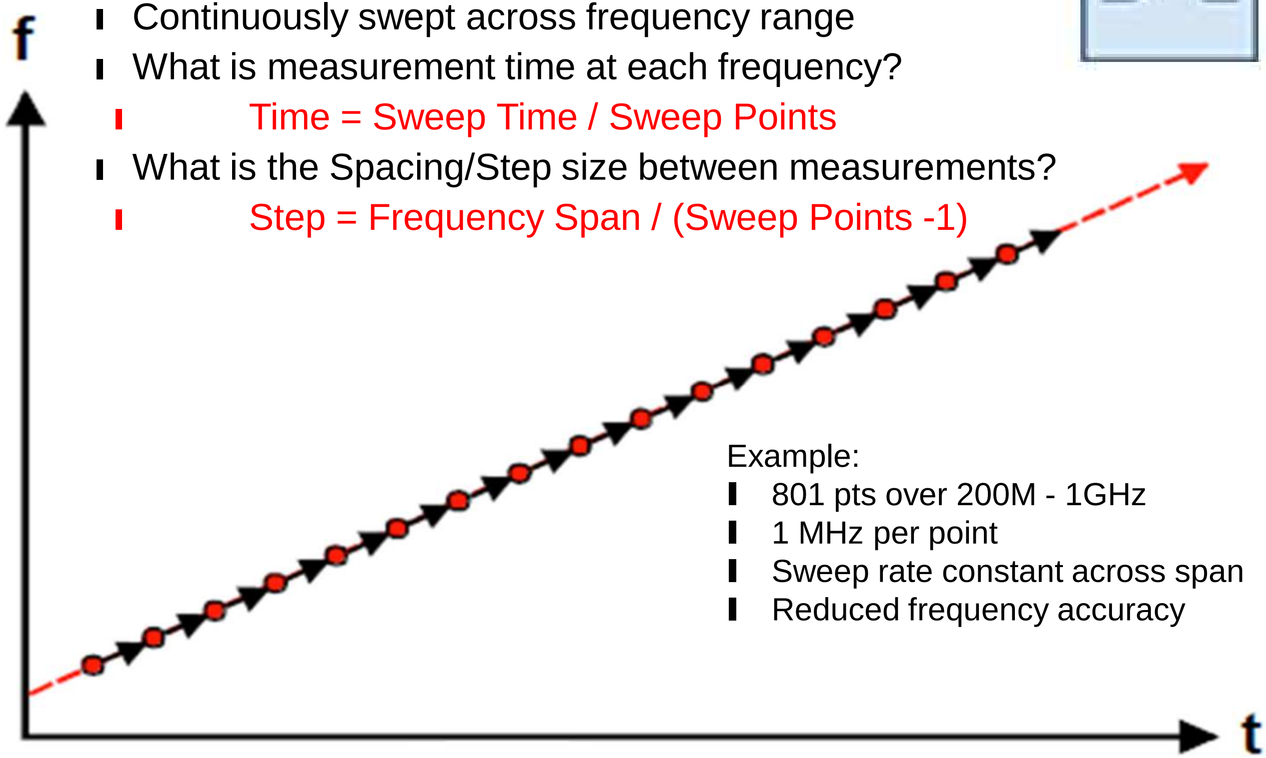
- Controls the measurement frequency
- Spend enough time at each frequency to detect pulsed emissions



Sweeping Spectrum Analyzer

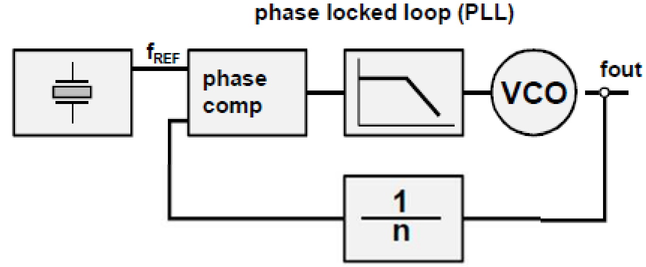


- Continuously swept across frequency range
- What is measurement time at each frequency?
  - Time = Sweep Time / Sweep Points
- What is the Spacing/Step size between measurements?
  - Step = Frequency Span / (Sweep Points -1)



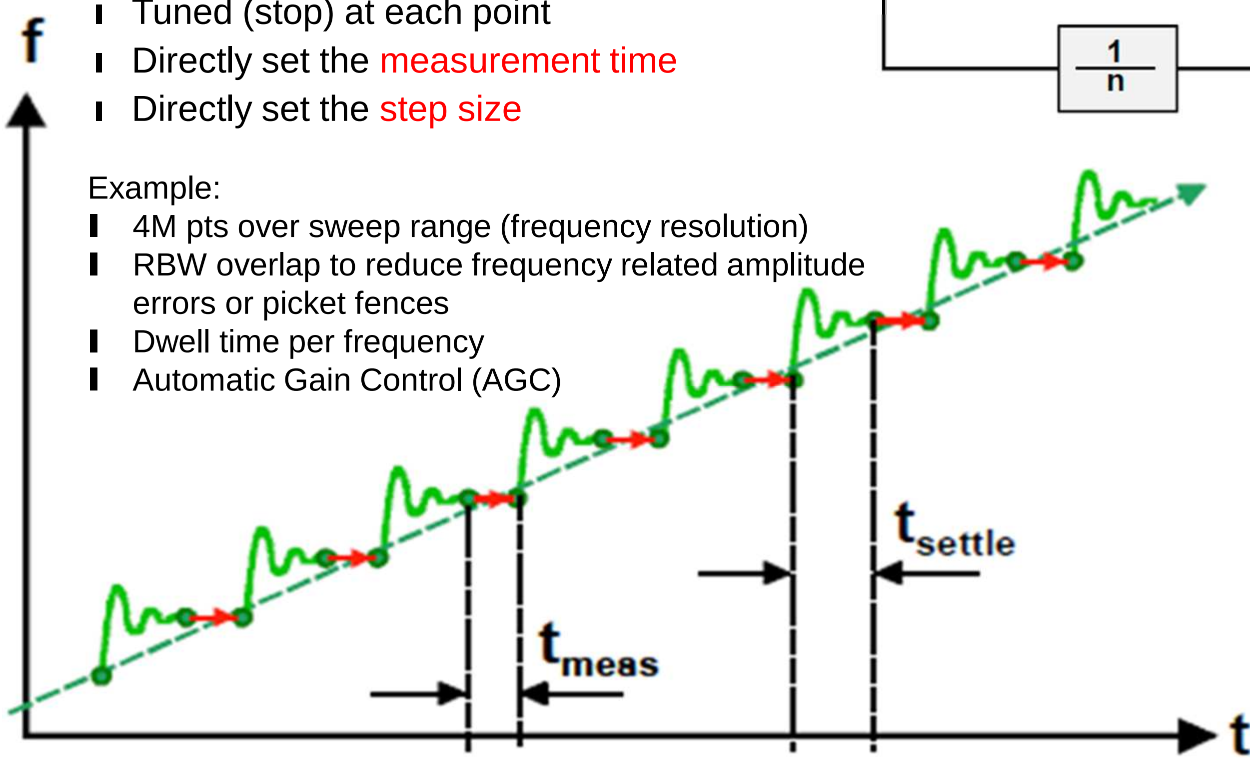
Example:
- 801 pts over 200M - 1GHz
- 1 MHz per point
- Sweep rate constant across span
- Reduced frequency accuracy

Scanning Receiver



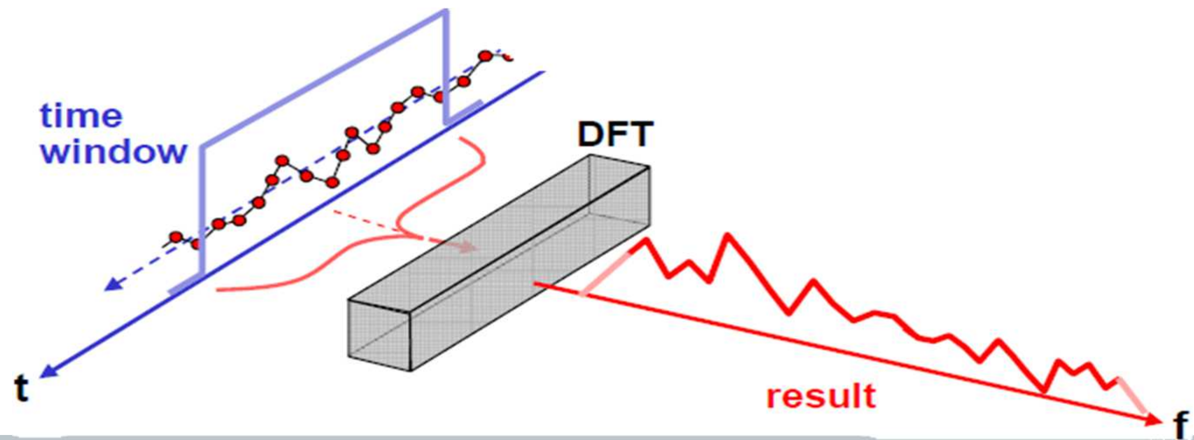
- Tuned (stop) at each point
- Directly set the measurement time
- Directly set the step size

Example:
- 4M pts over sweep range (frequency resolution)
- RBW overlap to reduce frequency related amplitude errors or picket fences
- Dwell time per frequency
- Automatic Gain Control (AGC)



Time Domain Scan

- The Discrete Fourier Transform (DFT) is a numerical mathematical method that calculates the spectrum for a periodic signal
- Use DFT to simultaneously measure many frequencies in parallel
- The Fast Fourier Transform (FFT) is an efficient algorithm to compute the DFT using symmetry and repetition properties
- FFT is much faster than DFT due to reduced number of multiplications

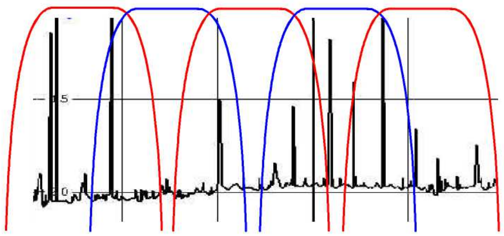


Speed Improvement of FFT Scan

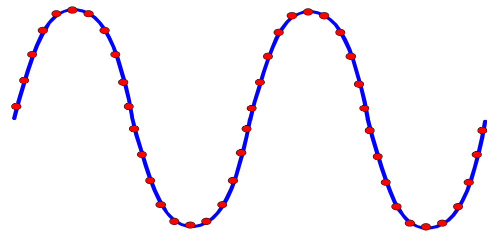
Freq Range	Weighting Detector	Meas/Dwell Time	Meas BW	# Points Freq Stepped	# Points Time Domain	Time (sec) Freq Stepped	Time (sec) Time Domain	Speed Factor Increase	Time Savings (minutes)
CISPR Band B 150K - 30MHz	Pk	100ms	9kHz	9950	13267	995	0.11	9045	17
CISPR Band B 150K - 30MHz	QP	1sec	9kHz	7463	9950	7463	2	3731	124
CISPR Band C/D 30M - 1000MHz	Pk	10ms	120kHz	24250	32333	243	0.52	466	4
CISPR Band C/D 30M - 1000MHz	Pk	10ms	9kHz	323333	431111	3233	0.82	3943	54
CISPR Band C/D 30M - 1000MHz	QP	1sec	120kHz	24250	32333	24250	80	303	403

- # Points Frequency Stepped → Freq Step of Meas BW / 3
  - Step 3.0kHz for 9KHz Meas BW
- # Points Time Domain → Freq Bin of Meas BW / 4
  - Freq Bin of 2.25kHz for 9kHz Meas BW
- Time (sec) of Time Domain is taken from R&S ESR

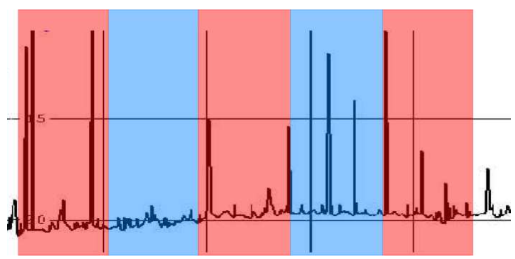
Time Domain Scan



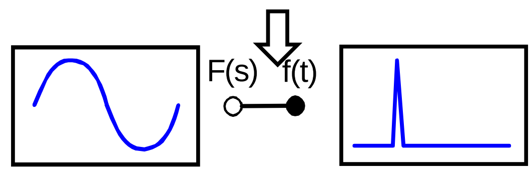
Frequency domain
Split the measured frequency range into consecutive frequency intervals



Time-domain
Sample the frequency interval with high sampling rate



Frequency domain
Merge the spectra of all frequency blocks



Fast-Fourier transformation
Transform the signals from time domain to frequency domain

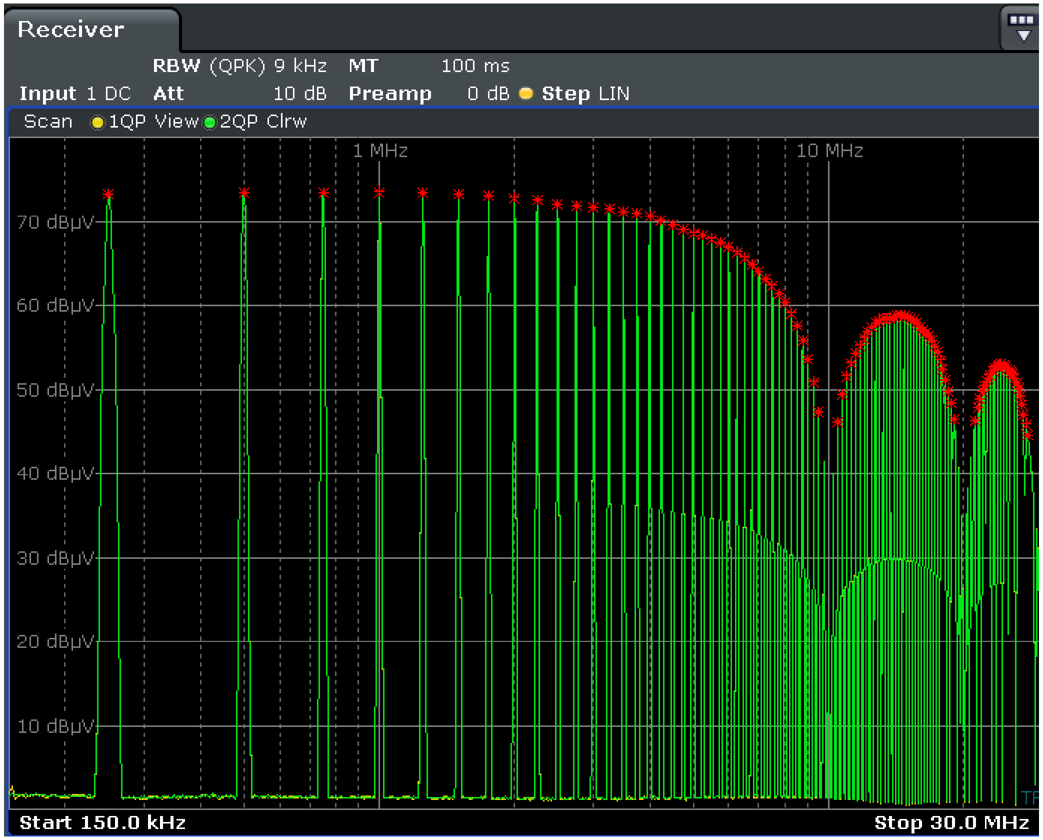
Level Accuracy

Time Domain Scan versus Stepped Scan

Pulse Input

- 4.00 µs Pulse Period
- 0.10 µs Pulse Width
- Detector Quasi Peak

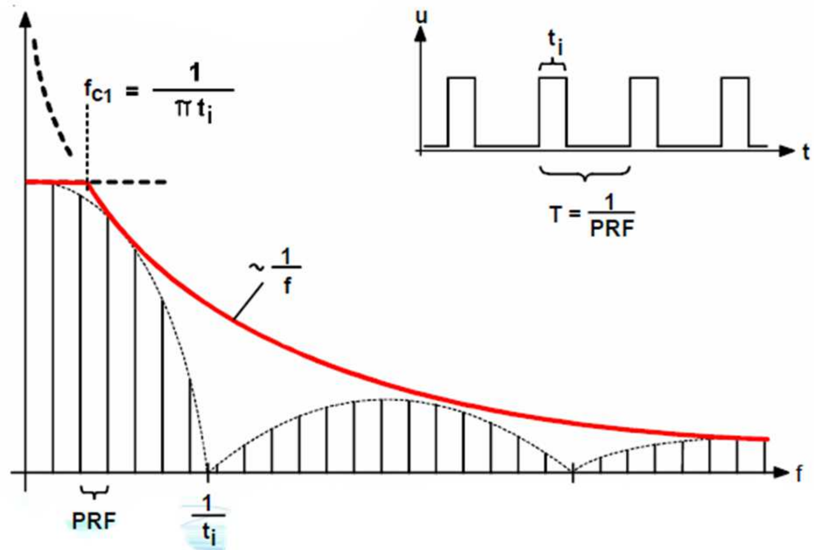
- **Yellow Trace**
  - Time-Domain
- **Green Trace**
  - Freq Stepped



Anatomy of a Pulse
Pulsed Emissions

- Minimum dwell time at each frequency in order to catch a pulse
  - Related to pulse repetition rate
  - If pulse occurs once every 10 ms…

  - Then
    - We must dwell for
    - 10 ms at each
    - frequency ….

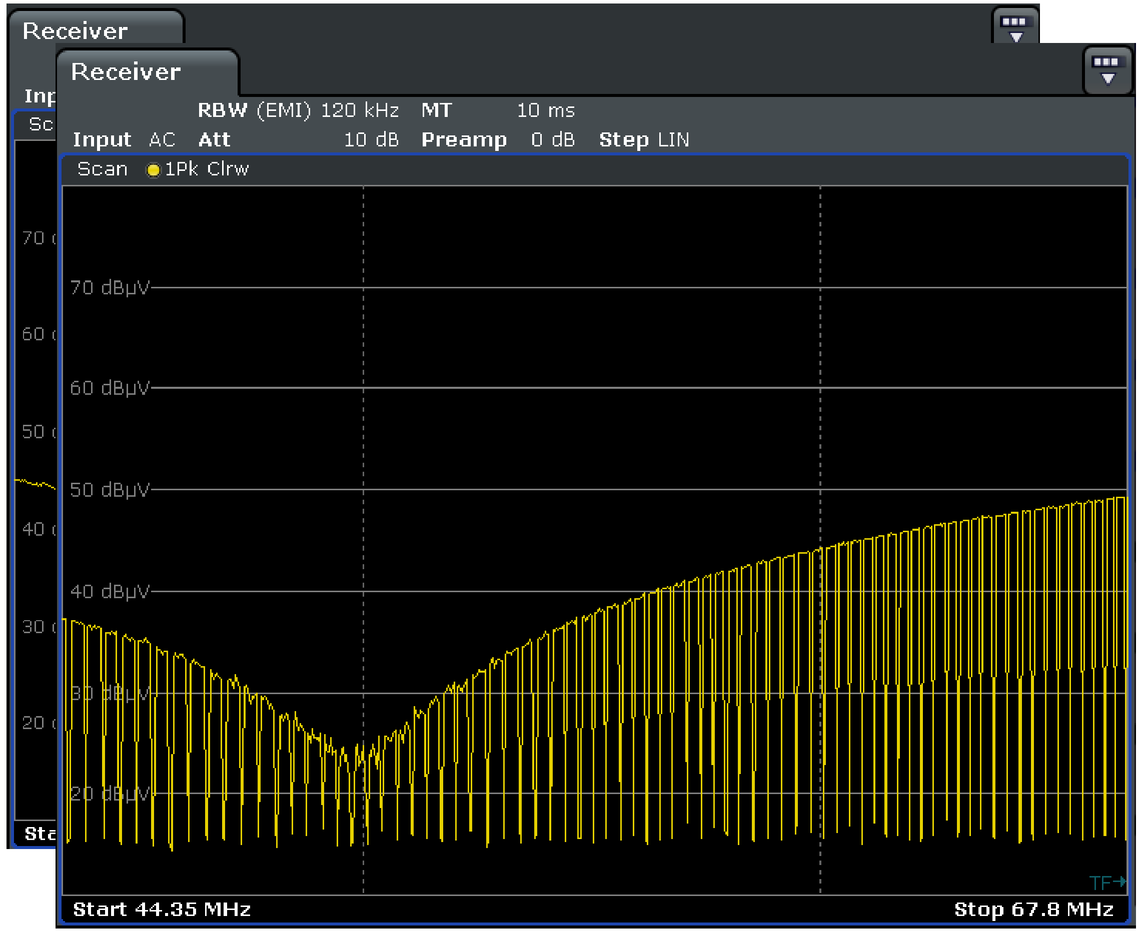


Measurement Time
Frequency Stepped

Input Signal
- Pulse Modulated
- 12 ms pulse period

Even 10 ms measurement time yields a closed trace

Zooming in reveals gaps in the trace



Measurement Time

Time Domain

Input Signal

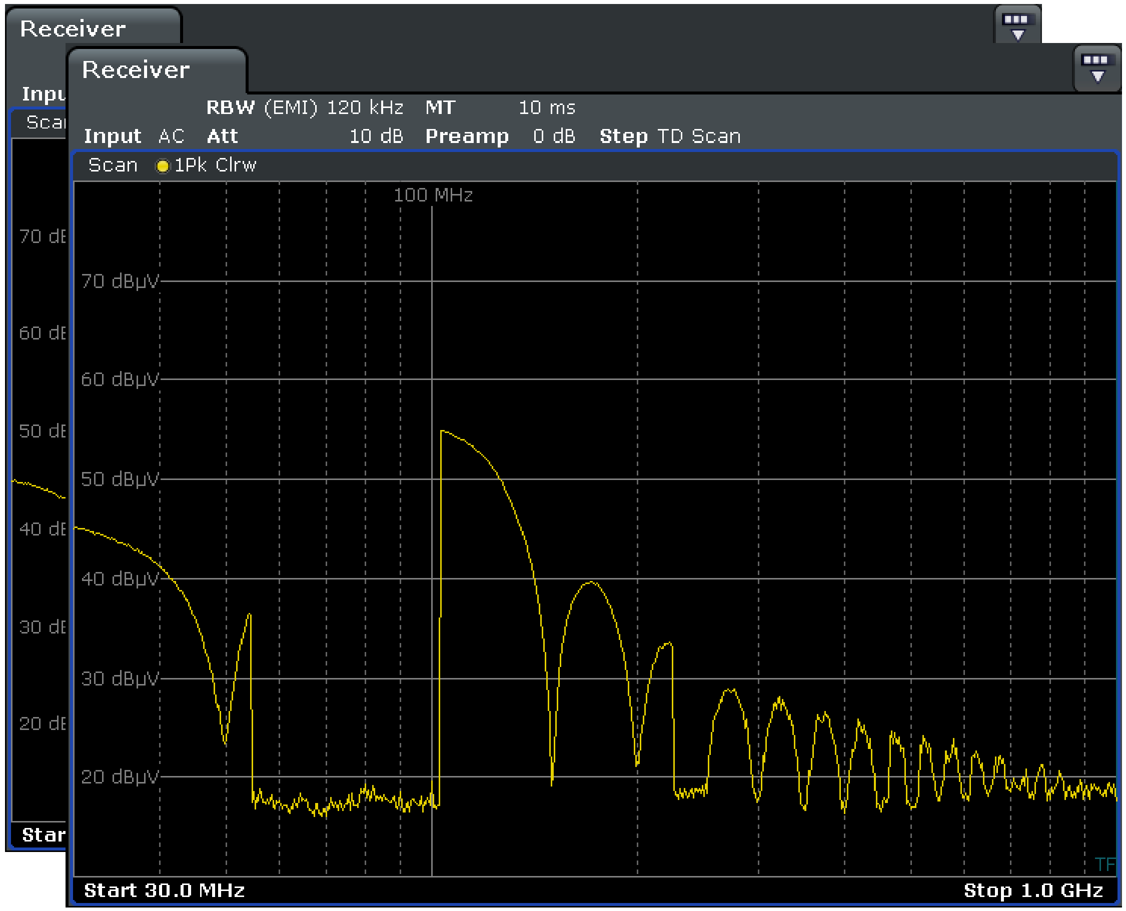
- Pulse Modulated
- 12 ms pulse period

Closed trace with 12 ms measurement time

Gaps in trace with 10 ms measurement time

Important:

Measurement time ≥ signal period



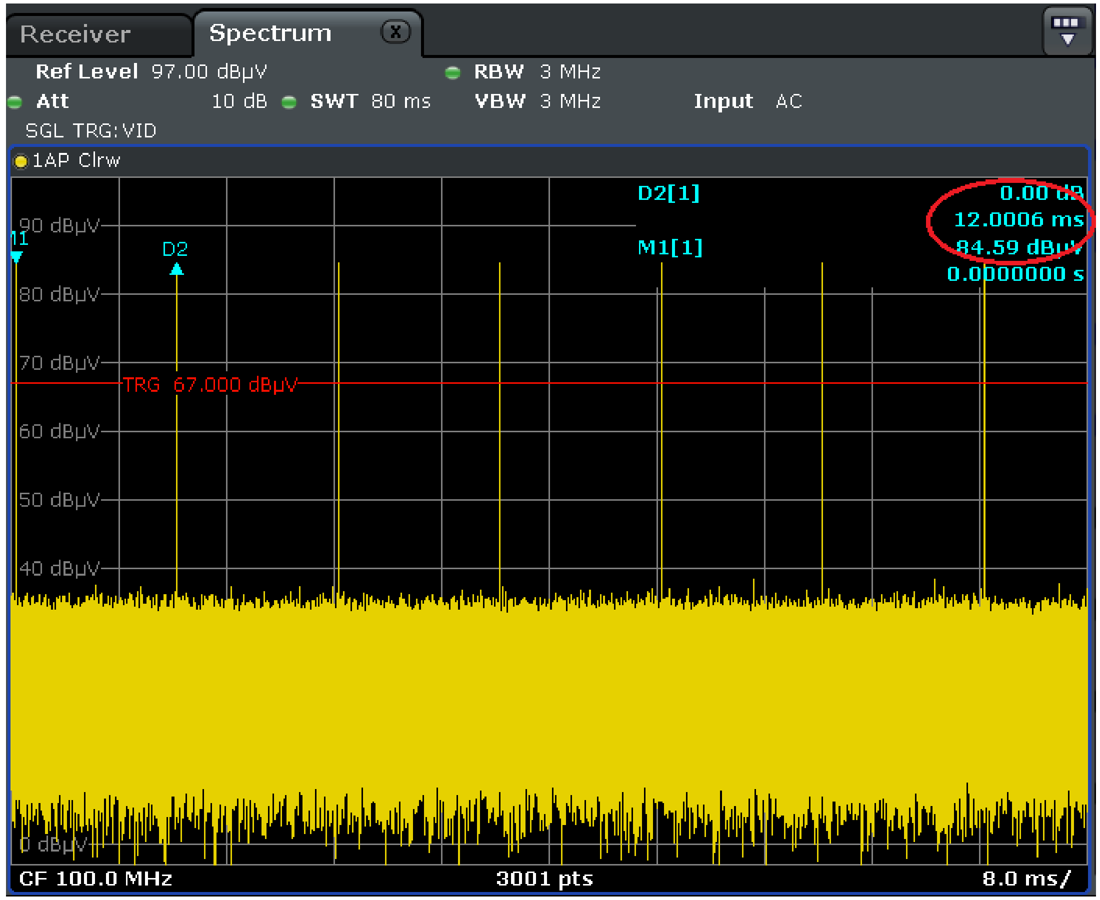
Measurement Time

Spectrum Analyzer Zero Span Mode

Input Signal

- Pulse Modulated
- 12 ms pulse period

Zero span display in spectrum analyzer measures signal period

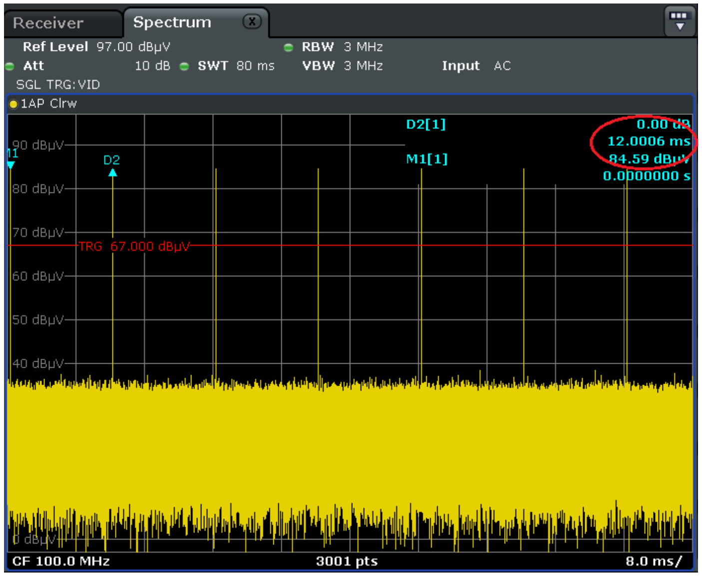


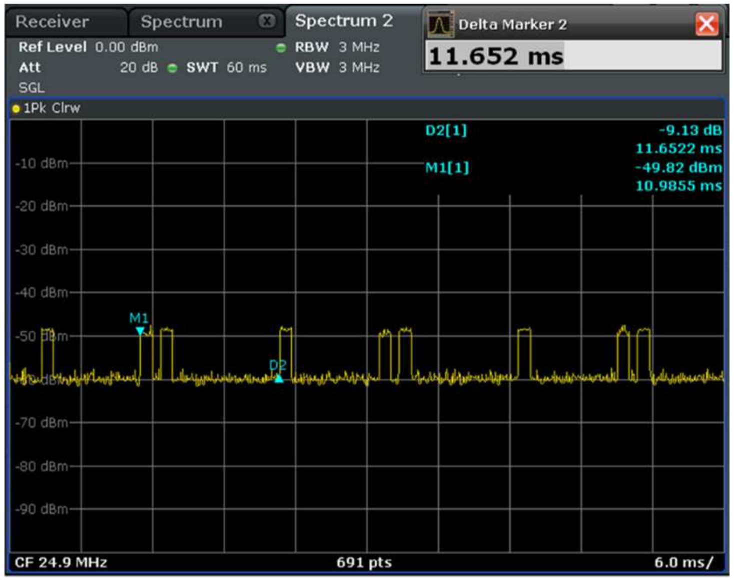
Analyzing Intermittent Signals
Real-time Spectrogram Display

Wouldn't it be great if you had the ability to see multiple sources of emissions on the same frequency at the same time?

Zero span display in spectrum analyzer measures signal period / pulse repetition rate

Zero span works when there is a single frequency emission, but what about cases with multiple frequency emissions? Or multiple repetition rates on same frequency?





Comparison Videos

- Videos 1-5:
- Input signal:
  - 10ms pulse period (repetition rate)
  - 10us pulse duration @ 700MHz
- RBW = 100kHz

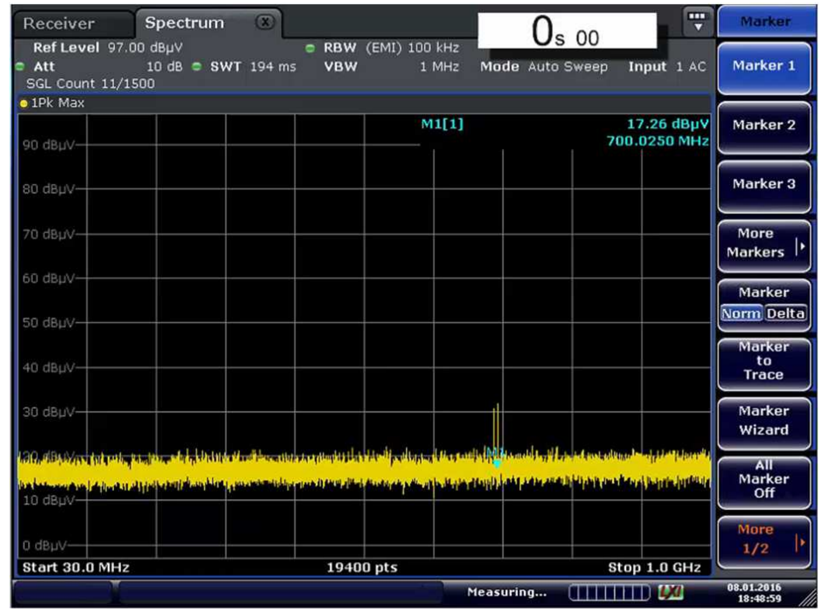
Video #	Time Duration	Freq Range	Method	Sweep/Dwell Time	Notes
1	1:34	30M – 1G	Swept	Auto: 194ms	
2	2:31	30M – 1G	Swept	Per MIL-STD461: 146sec	Freq Resolution: Need to Zoom in
3	0:08	30M – 1G	Time Domain	Per MIL-STD461: 15ms	

Time Domain Scan
Demo

Frequency Swept - Capture Pulsed Event (1:34)

Fast Sweep with Max Hold

- **Conditions**
  - 10ms PRI with 10us pulse duration @ 700MHz
  - Sweep from 30MHz to 1GHz
  - RBW = 100kHz (6dB MIL-STD 461 filters)
  - Default Sweep Time = 194ms
    - MIL-STD461 sweep time spec is 145.5sec
      - (1GHz – 30MHz) * 0.15sec/MHz = 145.5sec



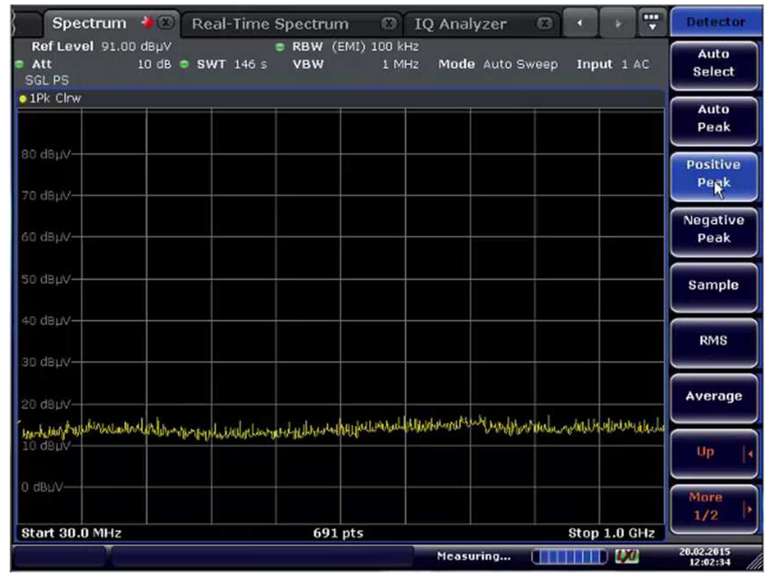
- **Observations**
  - Takes almost 4 minutes to capture
  - Almost have to know it's there, can be misleading

Frequency Swept - Capture Pulsed Event (2:31)

MIL-STD 461 Spec Sweep Time with Max Hold

- **Conditions**
  - 10ms PRI with 10us pulse duration @ 700MHz
  - Sweep from 30MHz to 1GHz
  - RBW = 100kHz (6dB MIL-STD 461 filters)
  - Spec'd Sweep Time = 146sec
    - MIL-STD 461 sweep time spec is 145.5sec
      - (1GHz – 30MHz) * 0.15sec/MHz = 145.5sec

- **Observations**
  - High probability to capture 10ms PRI pulsed signal
  - Takes 146sec, 2:26

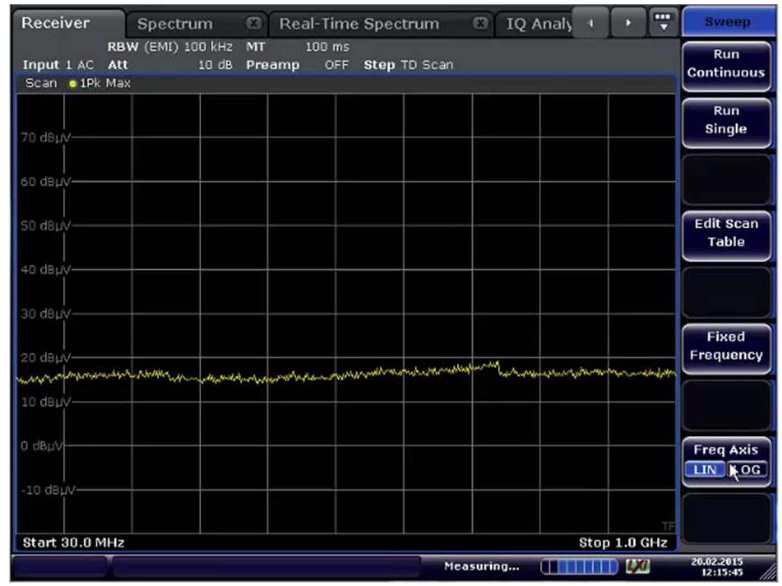


Time Domain- Capture Pulsed Event (0:08)

MIL-STD 461 Spec'd Dwell Time

- **Conditions**
  - 10ms PRI with 10us pulse duration @ 700MHz
  - Sweep from 30MHz to 1GHz
  - RBW = 100kHz (6dB MIL-STD 461 filters)
  - Spec'd Dwell Time = 0.015sec = 15ms

- **Observations**
  - Event detected and captured in just a few seconds
  - Time Domain is much faster and less likely to miss intermittent event



Agenda

- **What does Compliance Mean?**
  - CISPR 16-1-1
- **Spectrum Analyzers vs EMC Receivers**
  - Purpose / Application
  - Architecture
- **The Value of Pre-Selection**
- **Time Domain Scan**
  - Ability to Capture Intermittent Signals
  - Speed
  - Measurement Time (Dwell Time) / PRI (Pulse Repetition Rate)
- **AGC: Automatic Gain (of Level) Control**
- **User Interface**
- **Real-time Spectrum Analysis**

Auto-Ranging AGC

- **Automatic Gain Control**
  - Protect the receiver from overload conditions for in-band signals
  - Applies attenuation to keep receiver operating in linear conditions
  - Can be implemented in RF stage or IF stage or both
  - Examine conditions of signal in 600 MHz TV bands with an over-the-air interference signal

Auto-Ranging AGC

500 – 700 MHz – Spectrum Analyzer vs EMI Receiver (with and without AGC)

- **Signal Conditions**
  - Using an antenna over-the-air, demonstrating front-end saturation and IF overload of a strong signal at 600 MHz
  - Other signals are TV bands and other broadcast signals

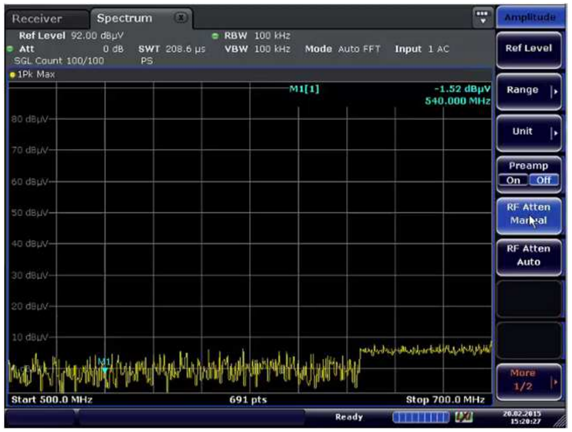
- **Observations**
  - IF overload occurs in sweep mode (spectrum)
  - Receiver mode is selected and auto-ranging scan is turned on …..reducing the level of the signals measured in the IF
  - Notice the RED overload indicator

Auto-Ranging AGC

Attenuation vs. AGC impact to noise floor

- **Signal Conditions**
  - Using an antenna over-the-air, demonstrating front-end saturation and IF overload of a strong signal at 600 MHz
  - Other signals are TV bands and other broadcast signals

- **Observations**
  - Attenuation is manually applied to 30 dB in Swept mode to reduce the IF Overload signal (it actually flickers at 25 dB, but the video did not capture this)
  - Notice the increase in noise floor
  - Notice the signal at 620 MHz actual reduce at the last step of 30 dB (compression)
  - Receiver mode is selected and the first run with AGC off, then on to show the improvement in noise floor



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Spectrum Analyzers vs EMI Receivers: User Interface

Measure from 30MHz – 200MHz

Spectrum Analyzer: user calculates…

- Sweep Time
  - (200M-30M) x 0.15sec/MHz
    - = 25.5 secs*
    - * unless look at Appendix A to match frequency stepped, in that case double it to 51sec
  - Or…(25.5sec / auto sweep time) = # sweeps

- Frequency Resolution
  - # points = at least…
  - ((200M-30M)/RBW) * 2 + 1
  - = 3401

TABLE II. Bandwidth and measurement time.

Frequency Range	6 dB Resolution Bandwidth	Minimum Dwell Time		Minimum Measurement Time Analog-Tuned Measurement Receiver 1/
		Stepped-Tuned Receiver 1/ (Seconds)	FFT Receiver 2/ (Seconds/ Measurement Bandwidth)	
30 Hz - 1 kHz	10 Hz	0.15	1	0.015 sec/Hz
1 kHz - 10 kHz	100 Hz	0.015	1	0.15 sec/kHz
10 kHz - 150 kHz	1 kHz	0.015	1	0.015 sec/kHz
150 kHz - 10 MHz	10 kHz	0.015	1	1.5 sec/MHz
10 MHz - 30 MHz	10 kHz	0.015	0.15	1.5 sec/MHz
30 MHz - 1 GHz	100 kHz	0.015	0.15	0.15 sec/MHz
Above 1 GHz	1 MHz	0.015	0.015	15 sec/GHz

1/ **Alternative scanning technique.** Multiple faster sweeps with the use of a maximum hold function may be used if the total scanning time is equal to or greater than the Minimum Measurement Time defined above.

2/ **FFT Receivers.** FFT measurement techniques may be used provided that FFT operation is in accordance with ANSI C63.2. The user interface of the measurement receiver must allow for the direct input of the parameters in Table II for both FFT Time Domain and Frequency Stepped modes of measurement in the same manner, without the necessity or opportunity to control FFT functions directly.

Spec Ans vs EMI Receivers: User Interface

Measure from 30MHz – 200MHz

EMI Receiver: user calculates…

NOTHING, just enter in table…

TABLE II. Bandwidth and measurement time.

Frequency Range	6 dB Resolution Bandwidth	Minimum Dwell Time		Minimum Measurement Time Analog-Tuned Measurement Receiver [1/]
		Stepped-Tuned Receiver [1/] (Seconds)	FFT Receiver [2/] (Seconds/ Measurement Bandwidth)	
30 Hz - 1 kHz	10 Hz	0.15	1	0.015 sec/Hz
1 kHz - 10 kHz	100 Hz	0.015	1	0.15 sec/kHz
10 kHz - 150 kHz	1 kHz	0.015	1	0.015 sec/kHz
150 kHz - 10 MHz	10 kHz	0.015	1	1.5 sec/MHz
10 MHz - 30 MHz	10 kHz	0.015	0.15	1.5 sec/MHz
30 MHz - 1 GHz	100 kHz	0.015	0.15	0.15 sec/MHz
Above 1 GHz	1 MHz	0.015	0.015	15 sec/GHz

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  - Measurement Time (Dwell Time) / PRI (Pulse Repetition Rate)
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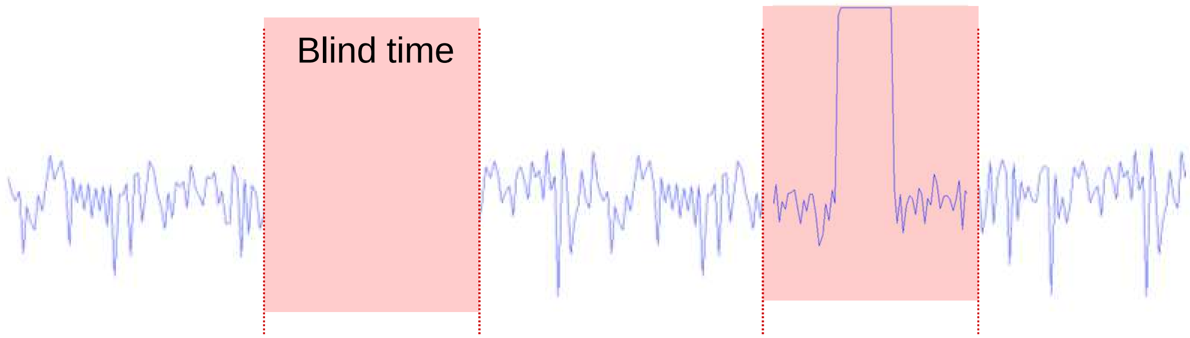
- **User Interface**
- **Real-time Spectrum Analysis**

Analyzing Intermittent Signals
Real-time Introduction

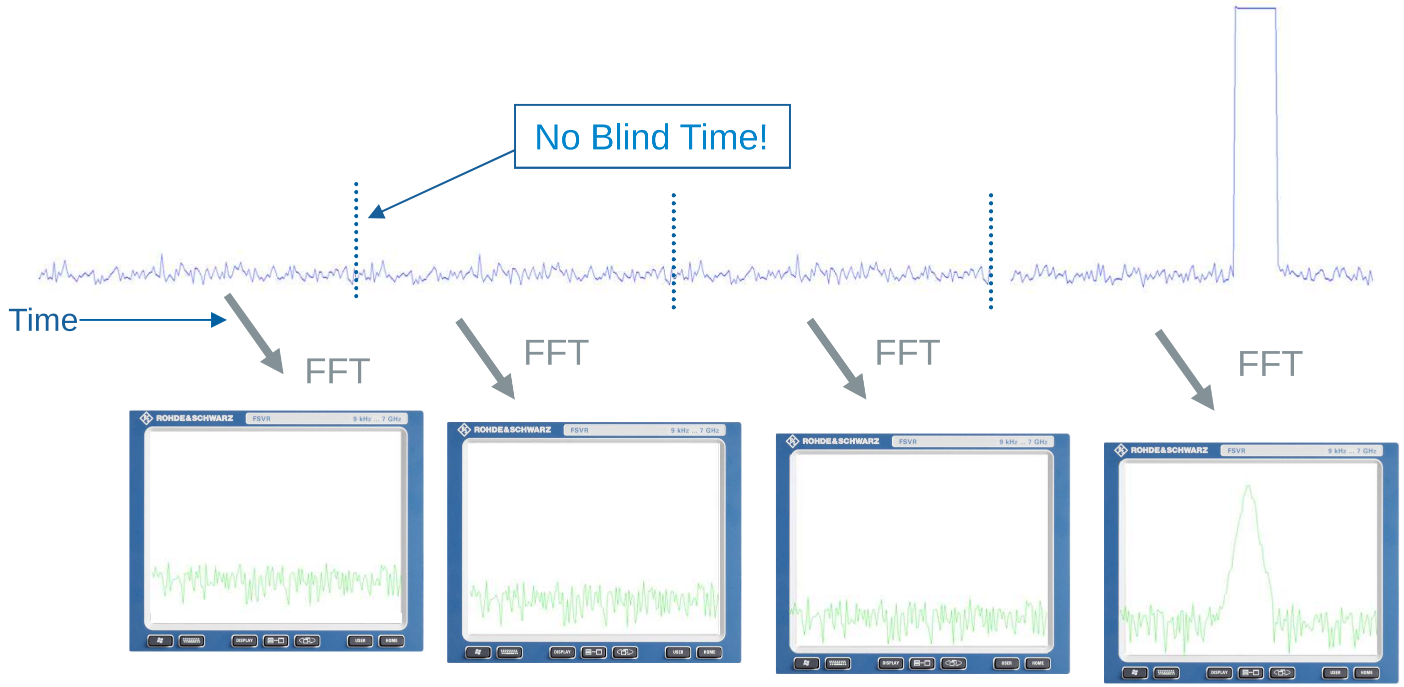
- With traditional instruments there are blind times between signal acquisition



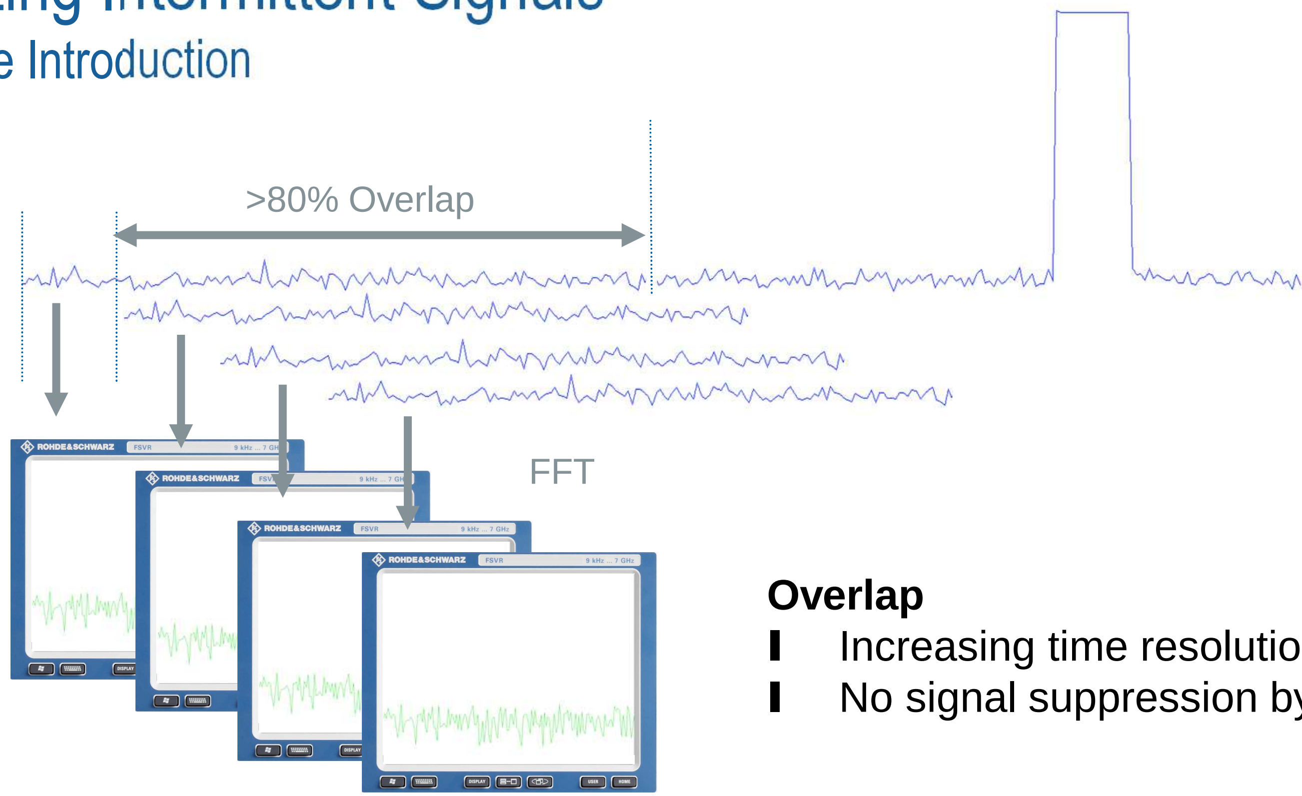
- Information might be and will be overlooked

Analyzing Intermittent Signals
Real-time Introduction

- A Real-time spectrum analyzer shows the spectrum without any loss of data



Analyzing Intermittent Signals
Real-time Introduction

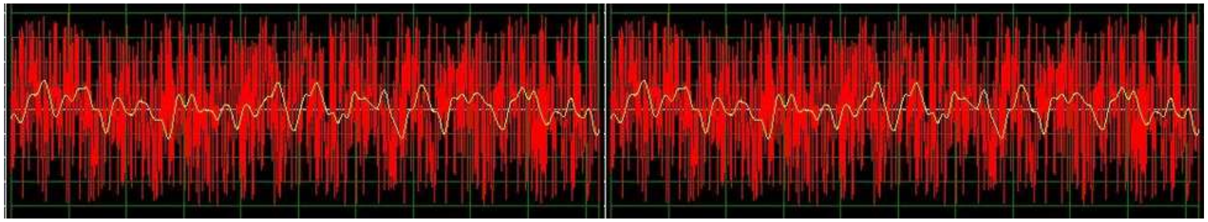


Overlap
- Increasing time resolution
- No signal suppression by windowing

Analyzing Intermittent Signals

Real-time Introduction

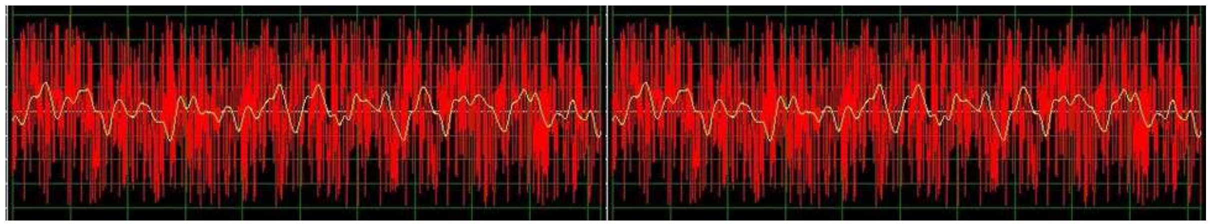
Live
Spectrum



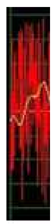
Analyzing Intermittent Signals

Real-time Introduction

Live Spectrum



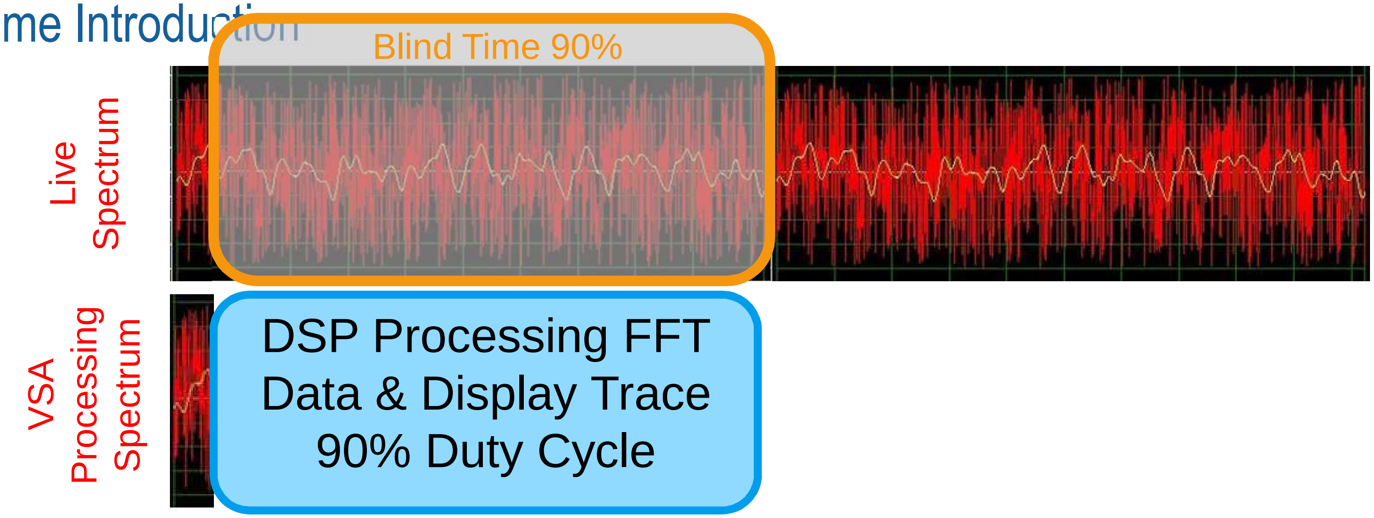
VSA Processing Spectrum



1. Acquire

Analyzing Intermittent Signals

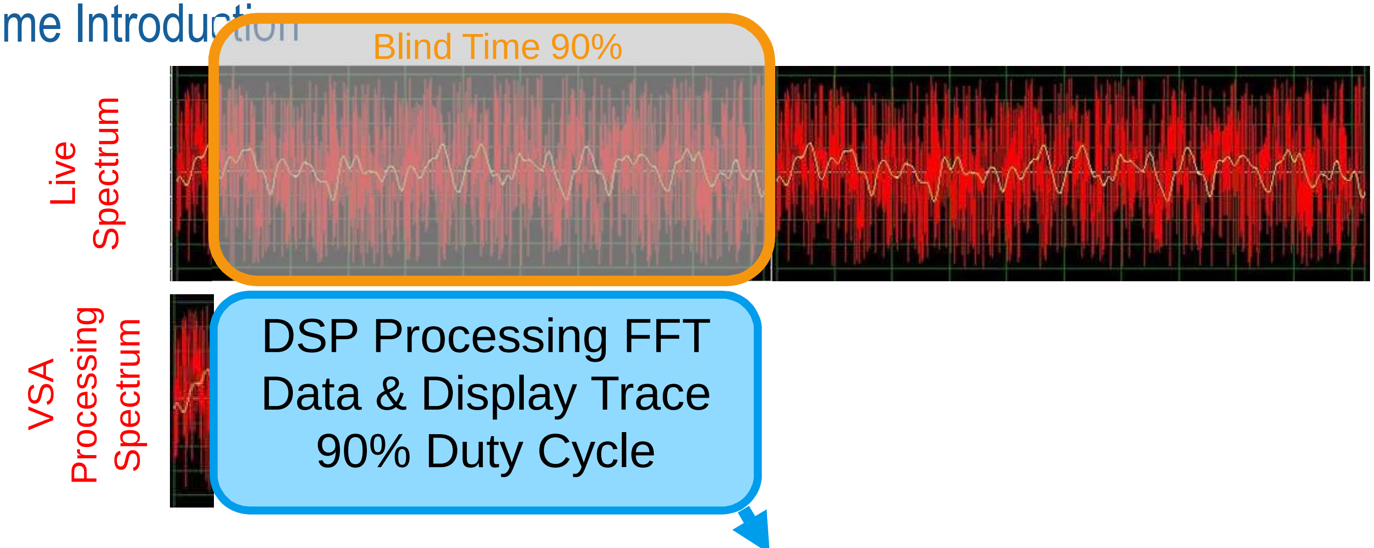
Real-time Introduction



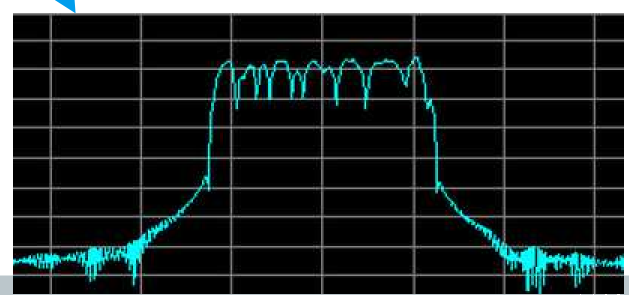
1. Acquire
2. Process

Analyzing Intermittent Signals

Real-time Introduction

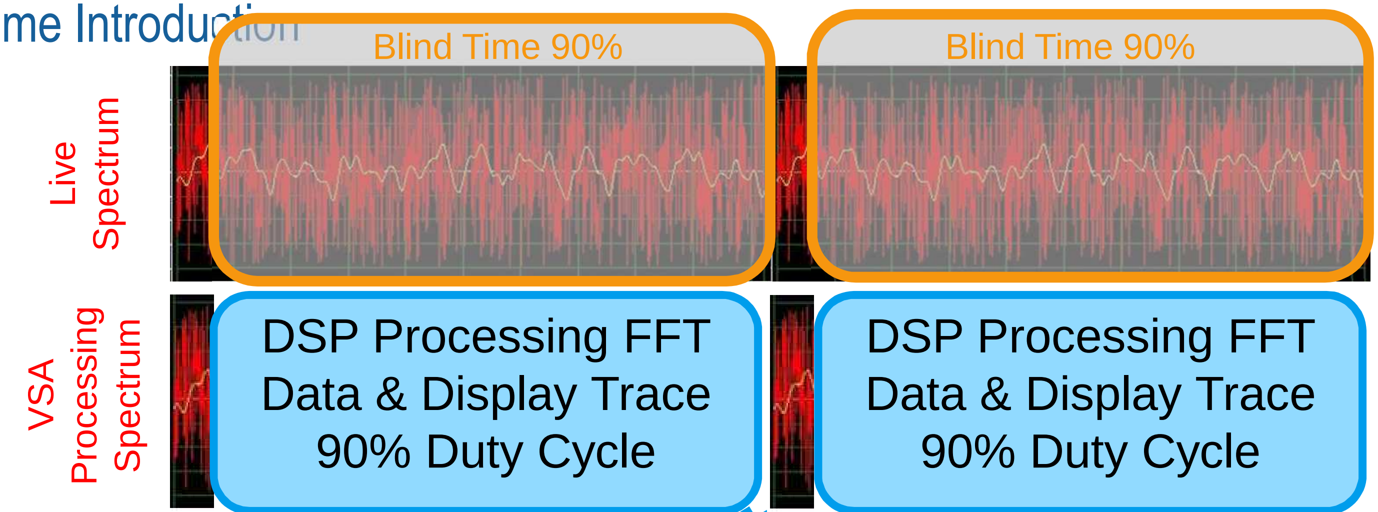


1. Acquire
2. Process
3. Display

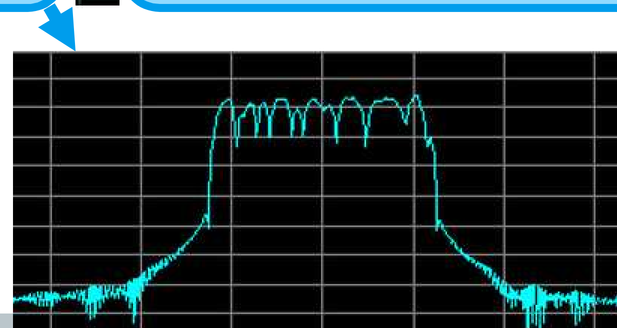


Analyzing Intermittent Signals

Real-time Introduction



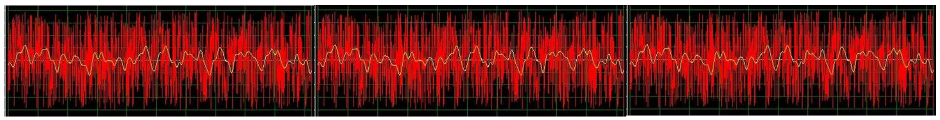
1. Acquire
2. Process
3. Display



Analyzing Intermittent Signals

Real-time Introduction

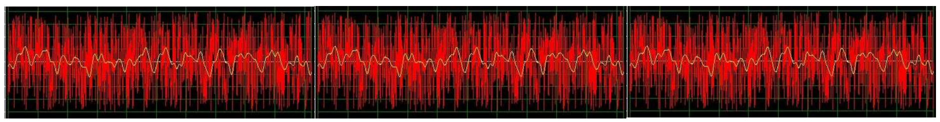
Live Spectrum



Analyzing Intermittent Signals

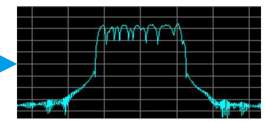
Real-time Introduction

Live Spectrum



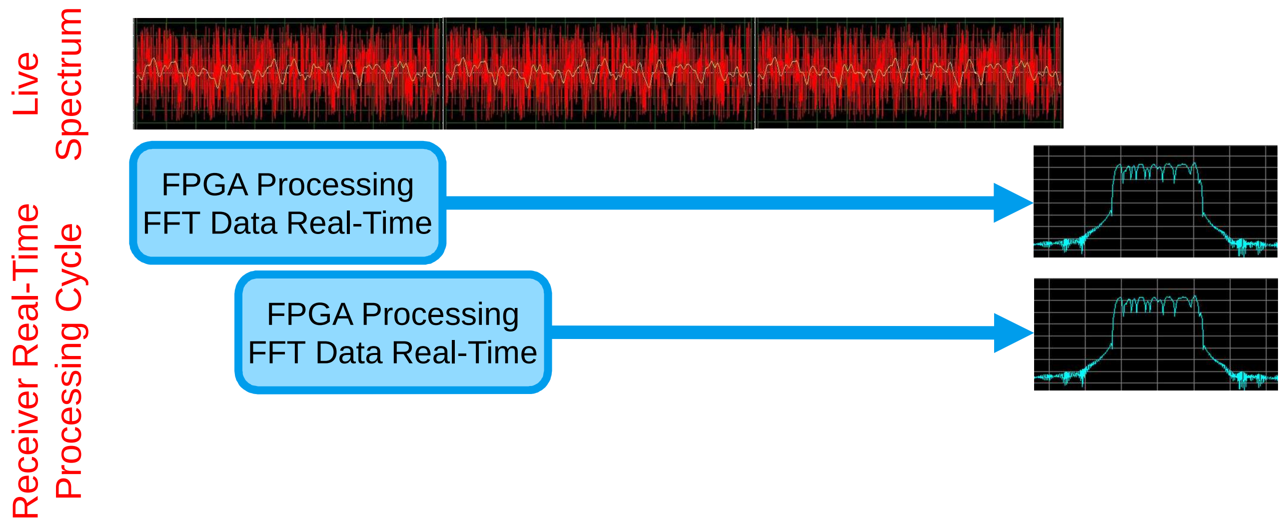
Receiver Real-Time Processing Cycle

FPGA Processing
FFT Data Real-Time

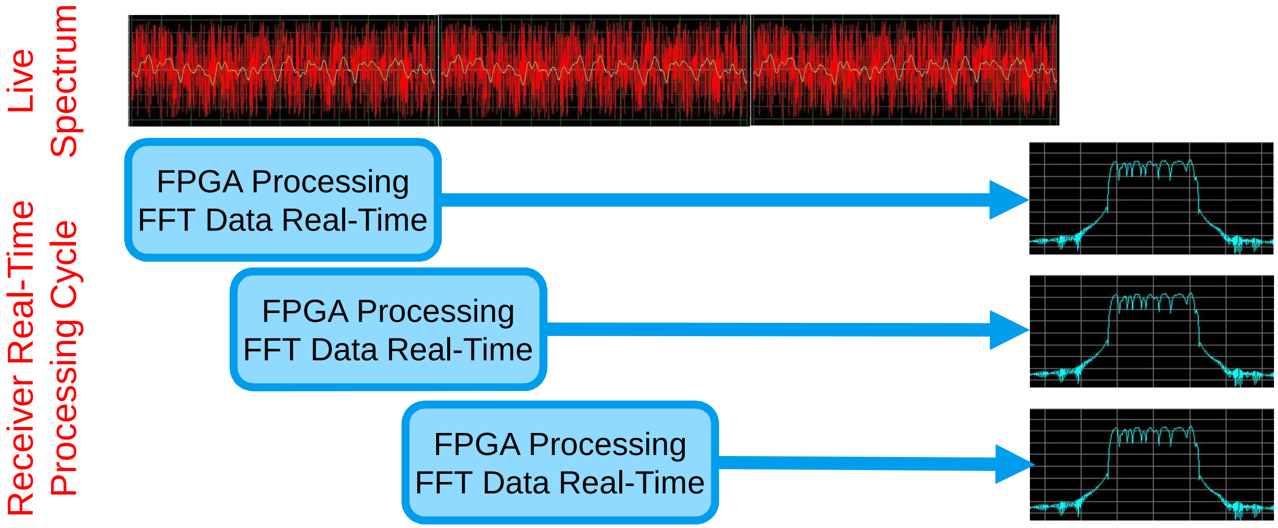


Analyzing Intermittent Signals

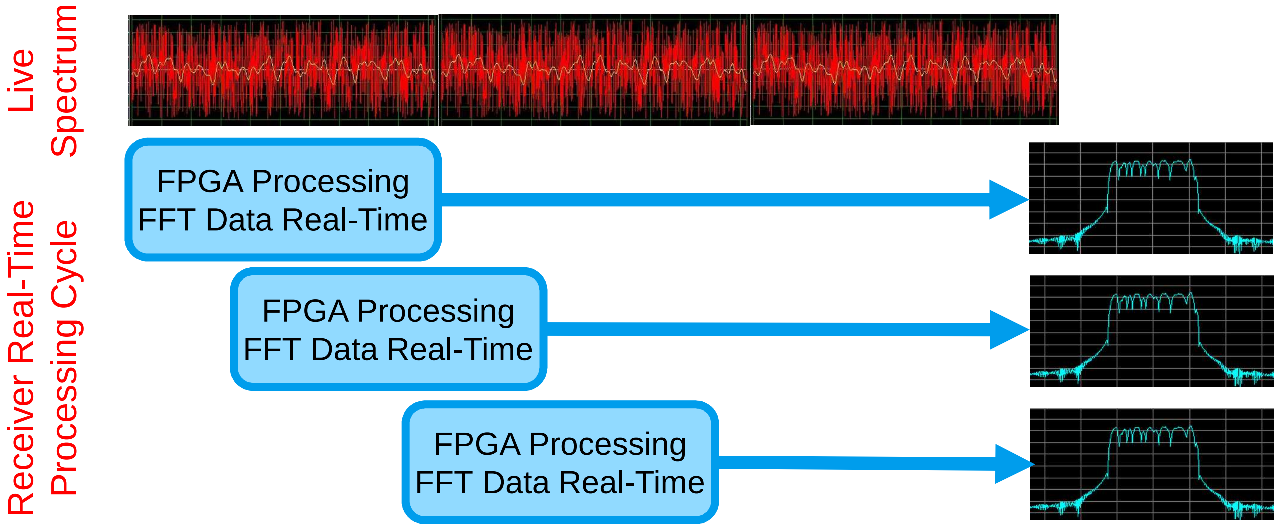
Real-time Introduction



Analyzing Intermittent Signals
Real-time Introduction



Analyzing Intermittent Signals
Real-time Introduction

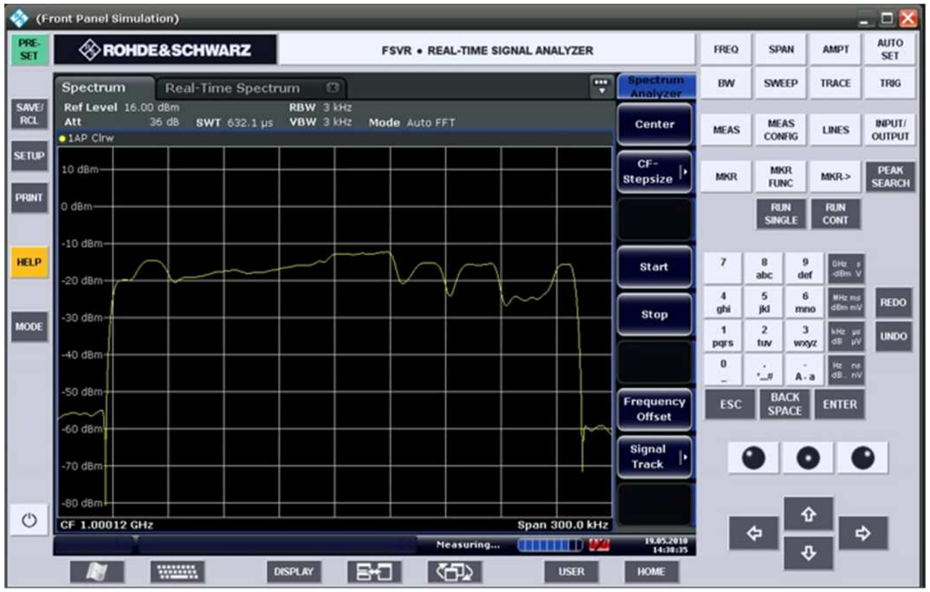


- Processing in FPGA allows data to be processed as fast as it can stream in
- 100% Acquisition Cycle – NO Blind Time
- Overlapping catches any events lost or attenuated by Windowing
- 1000's of spectrums processed

Analyzing Intermittent Signals

Real-time Spectrogram Display

- The Spectrogram Display provides information on the time nature of the signal
- Information on the time varying nature of the signal provides a wealth of information in understanding what the signal is and what is generating the signal

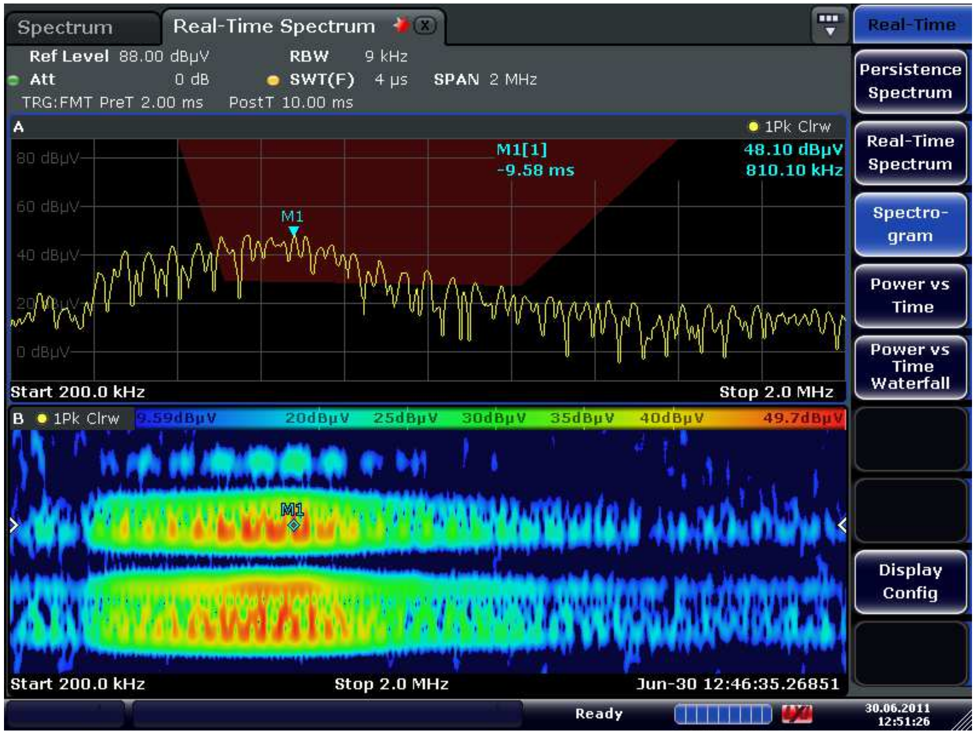


Analyzing Intermittent Signals
Real-time Spectrogram Display

Spectrogram

3 dimensional display

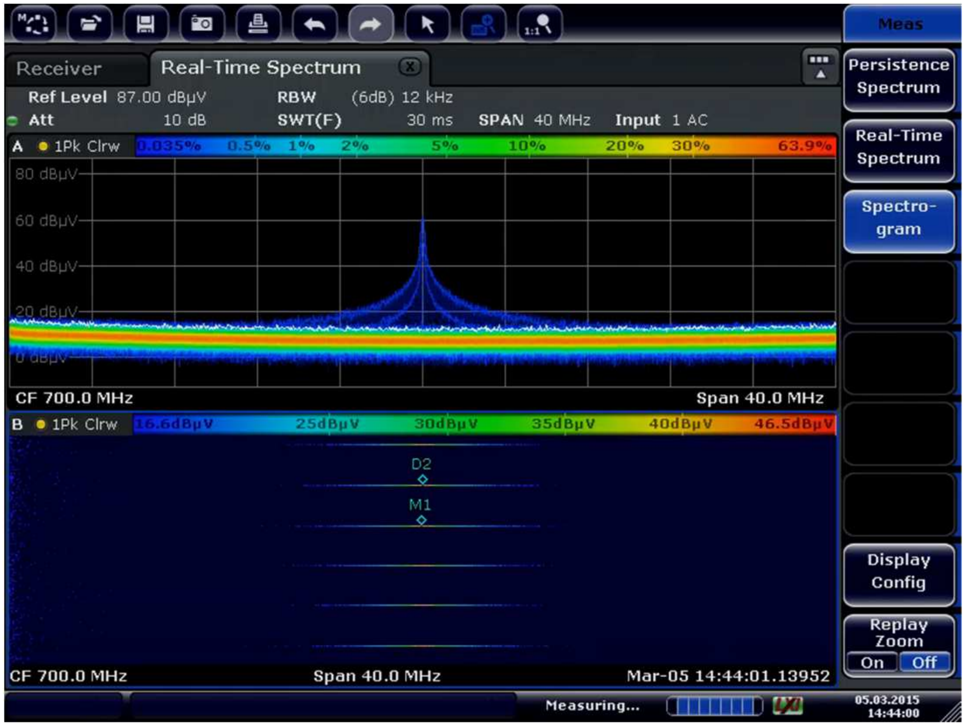
- X axis: frequency
- Y axis: time
- Color: signal level



- EUT is a laptop power supply
- Different load conditions change the spectrum over time

Analyzing Intermittent Signals
Real-time Spectrogram Display

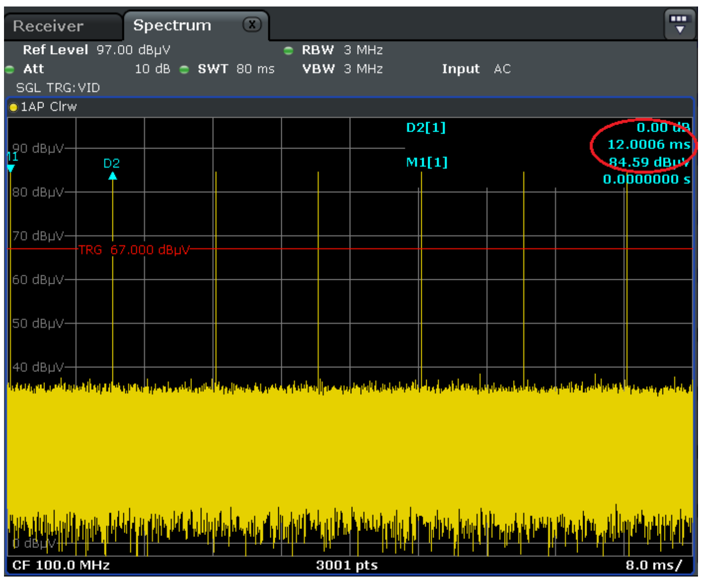
- Ability to measure PRI



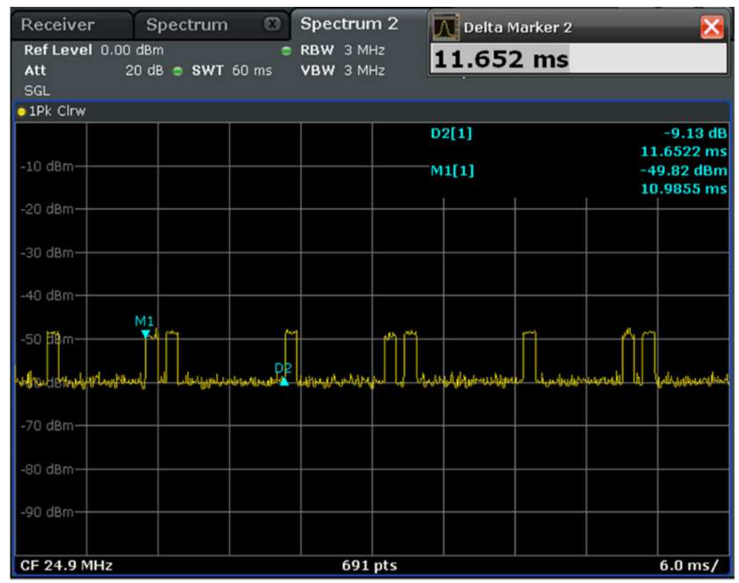
Analyzing Intermittent Signals

Real-time Spectrogram Display

Zero span display in spectrum analyzer measures signal period / pulse repetition rate

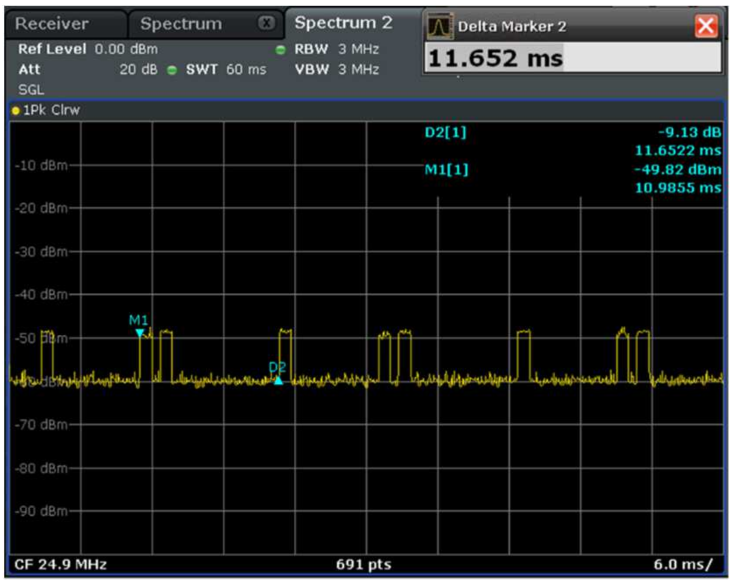


Zero span works when there is a single frequency emission, but what about cases with multiple frequency emissions? Or multiple repetition rates on same frequency?

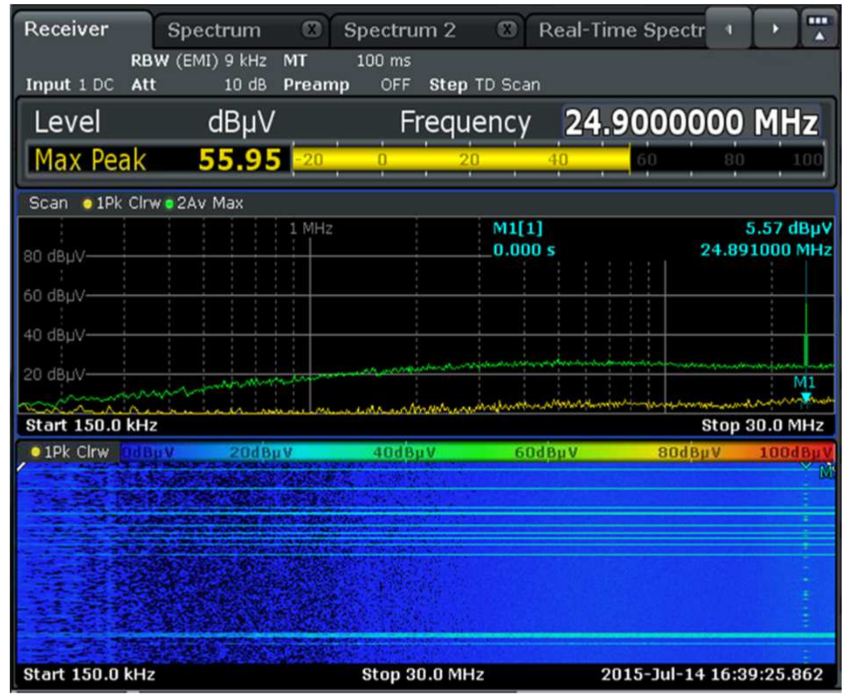


Analyzing Intermittent Signals
Real-time Spectrogram Display

- What about cases with multiple frequency emissions?
- Or multiple repetition rates on same frequency?



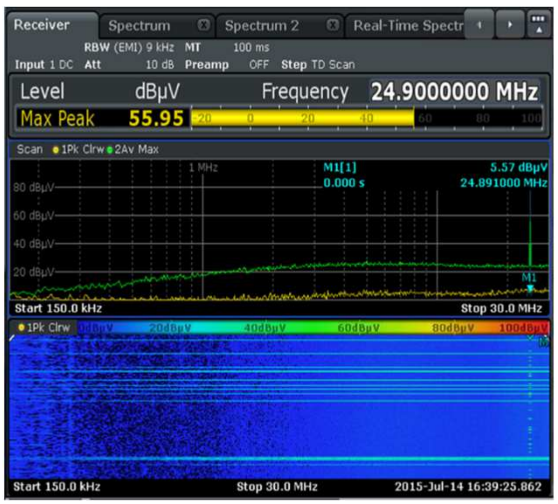
- Spectrogram reveals simultaneous narrowband and broadband emissions
- BUT NO Periodicity – NOT Real-time

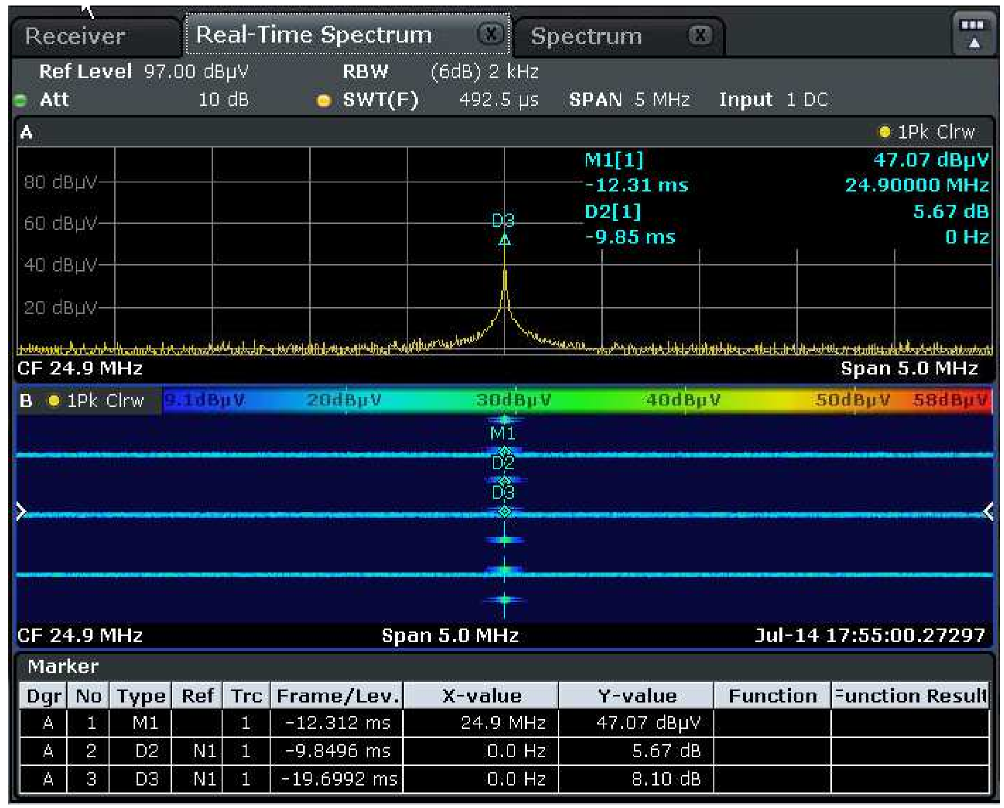


Analyzing Intermittent Signals

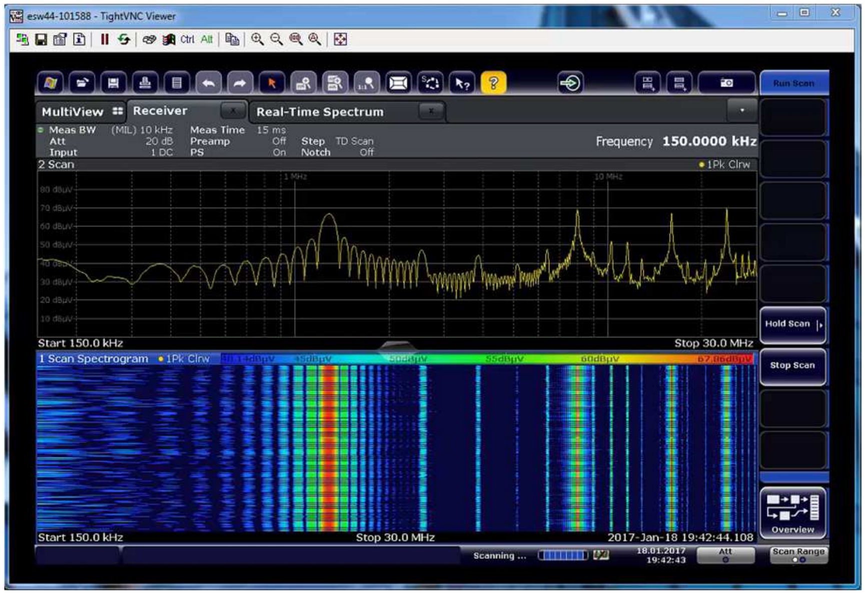
Real-time Spectrogram Display

Real-time Spectrogram is useful to identify and characterize multiple simultanous emissions in cases where emissions are on the same frequency, and different frequencies





Analyzing Intermittent Signals
Real-time Spectrogram Display



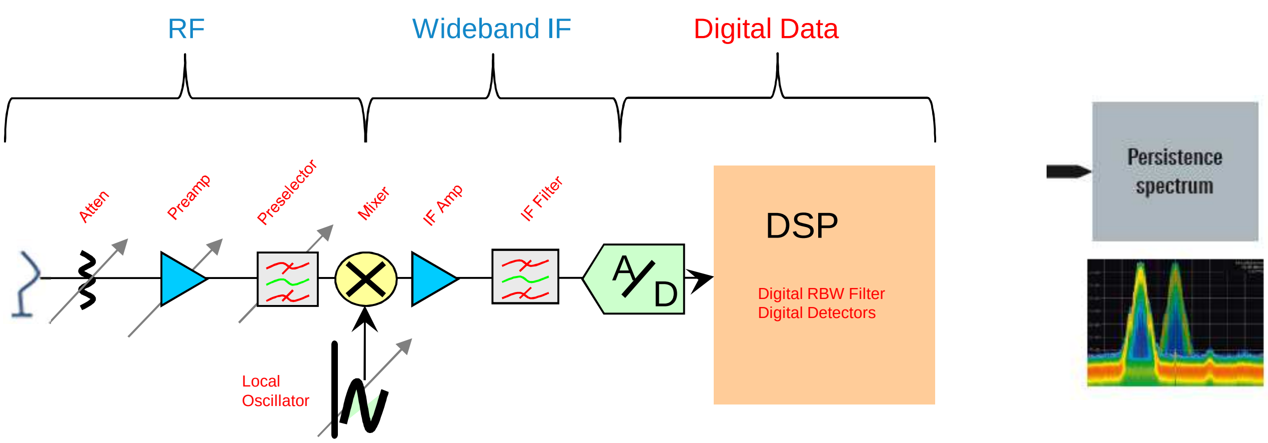
Summary Video

Analyzing Intermittent Signals

Persistence Display

Benefits for EMI Diagnostics

- Valuable aid for examining signals that change over time
- Impulsive interferers are clearly contrasted with continuous interferers
- Different impulsive interferers can be easily distinguished
- Shows signals that are not detectable with conventional analyzers



Analyzing Intermittent Signals
Persistence Display

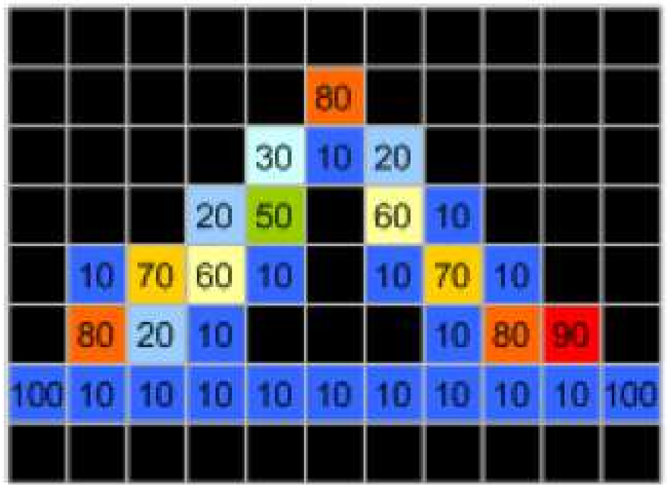
Seamless superimposition of all spectra in one diagram

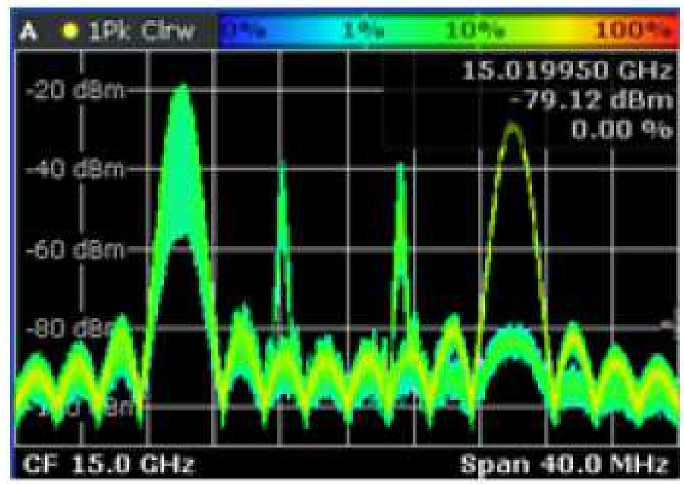
Virtual table and diagram containing the results after one FFT

					1					
		1	1	1		1	1			
	1							1		
1									1	1

Analyzing Intermittent Signals
Persistence Display

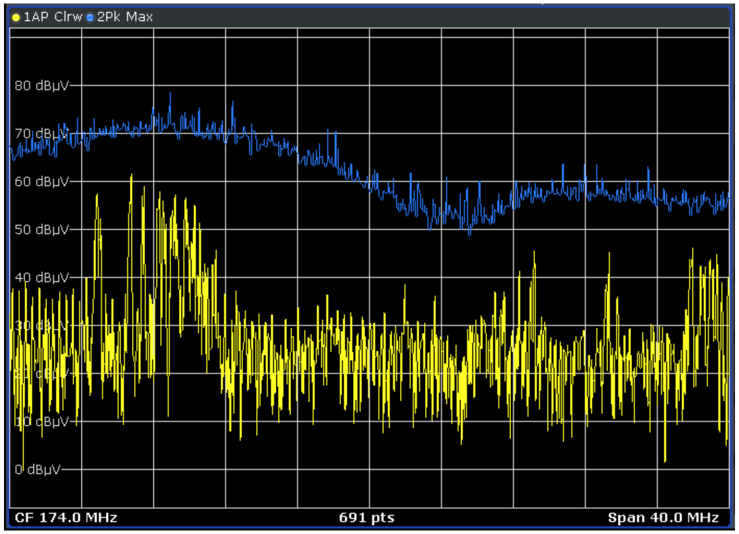
- The trace color shows how often a signal occurs at a specific frequency and level
- ⇒ Spectral histogram
- Virtual table and result display





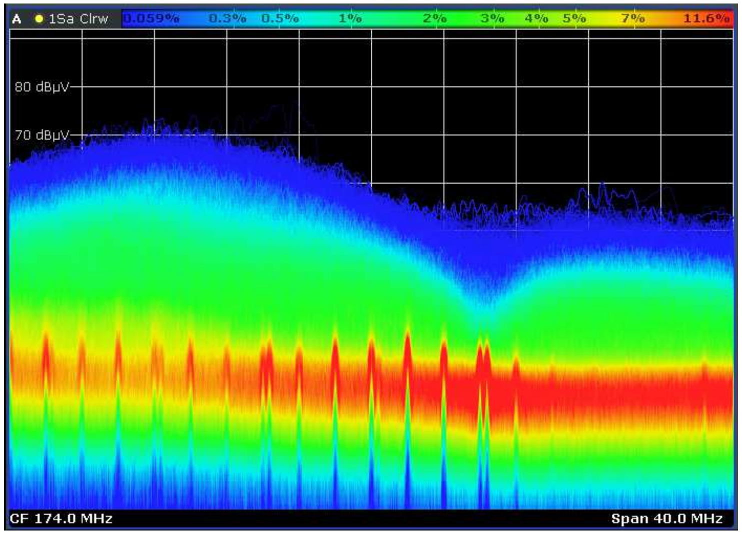
Analyzing Intermittent Signals
Persistence Display of Windshield Wiper Motor

Conventional Spectrum Analysis



Yellow Trace: Clear write display
Blue Trace: Max hold display

Real-time Persistence Display

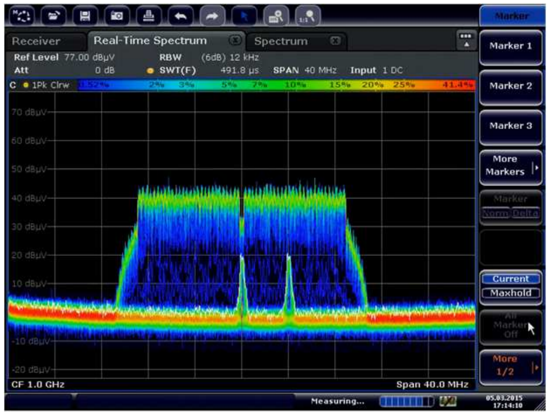


2nd pulsed disturbance signal hidden by the broadband noise, not detectable by conventional spectrum analysis

Analyzing Intermittent Signals
Persistence Display

Conventional Spectrum Analysis

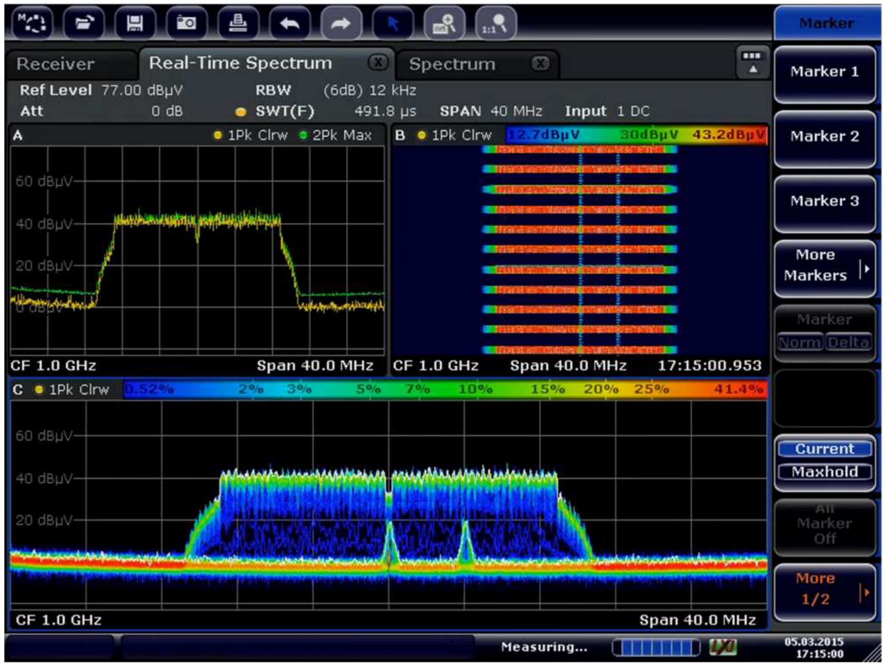
Persistence Display



Spectrogram Display

Analyzing Intermittent Signals

Simultaneous Displays: Powerful Analysis



Summary

- **What does Compliance Mean?**
  - CISPR 16-1-1
- **Spectrum Analyzers vs EMC Receivers**
  - Purpose / Application
  - Architecture
- **The Value of Pre-Selection**
- **Time Domain Scan**
  - Ability to Capture Intermittent Signals
  - Speed
  - Measurement Time (Dwell Time) / PRI (Pulse Repetition Rate)
- **AGC: Automatic Gain (of Level) Control**
- **User Interface**
- **Real-time Spectrum Analysis**