SPECTRUM ANALYSIS USING OSCILLOSCOPES

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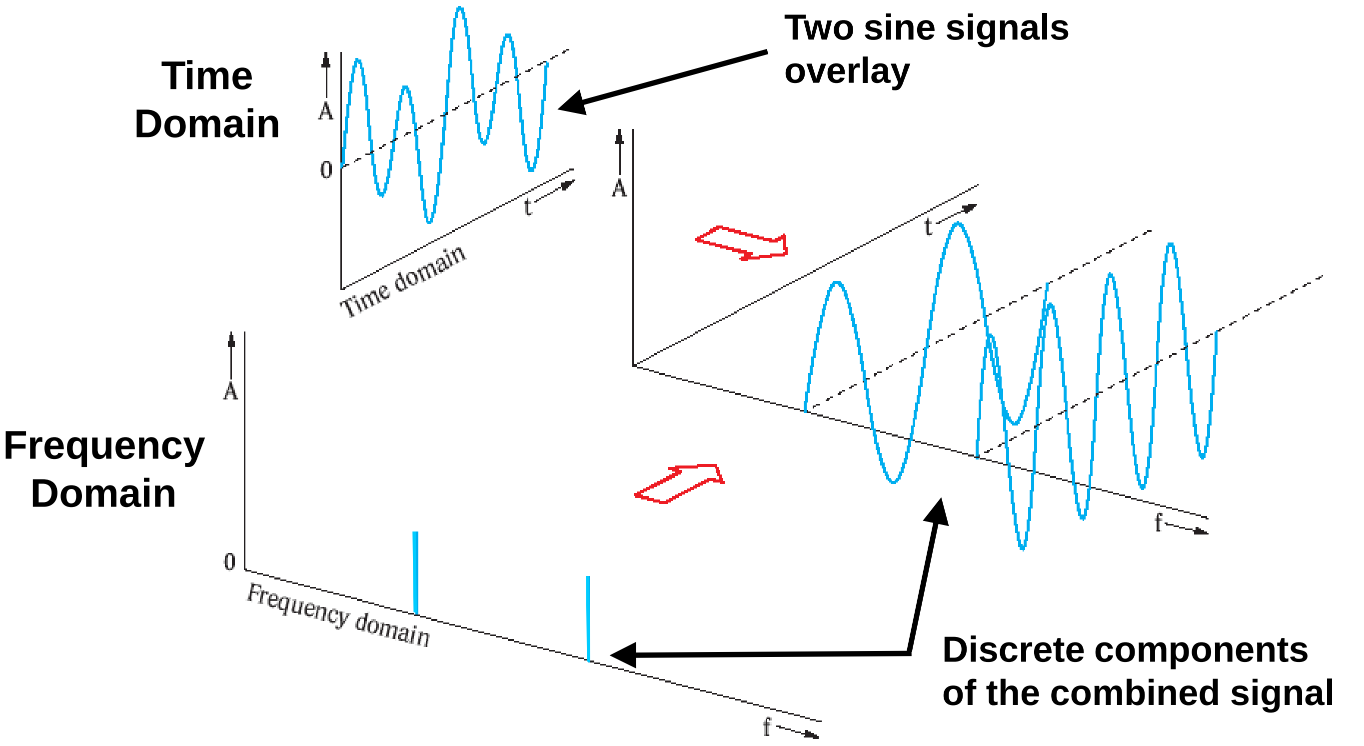
ROHDE&SCHWARZ

Make ideas real

OSCILLOSCOPE RF BASICS

WHY TALK ABOUT TIME AND FREQUENCY DOMAIN?



HOW TO ESTIMATE THE NEEDED BANDWIDTH?

- Required scope bandwidth depends on test signals frequency components
- Bandwidth relates to rise time $\mathbf{t_r}$
- If only a max. slew rate is given the rise time is calculated accordingly: $t_r = \frac{\Delta Voltage}{Slew\ Rate}$

- Estimating the Bandwidth needed

  Investigating the units:

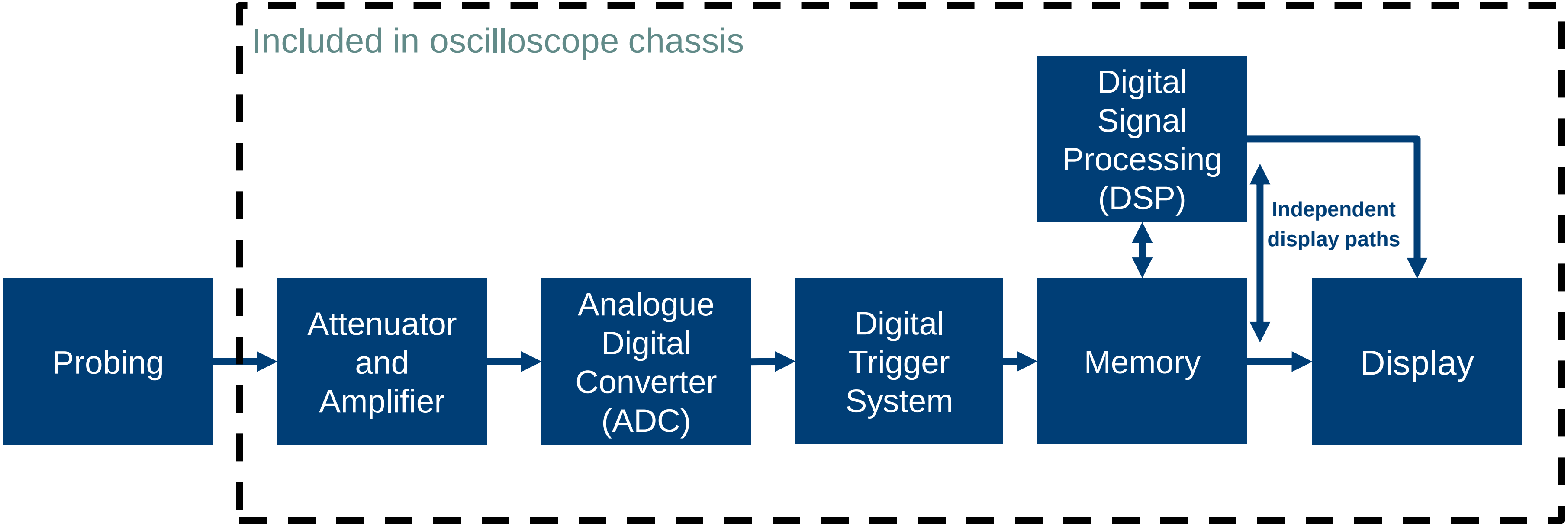
  Rise time t_r is expressed in [s]

  Frequency is expressed in [Hz]

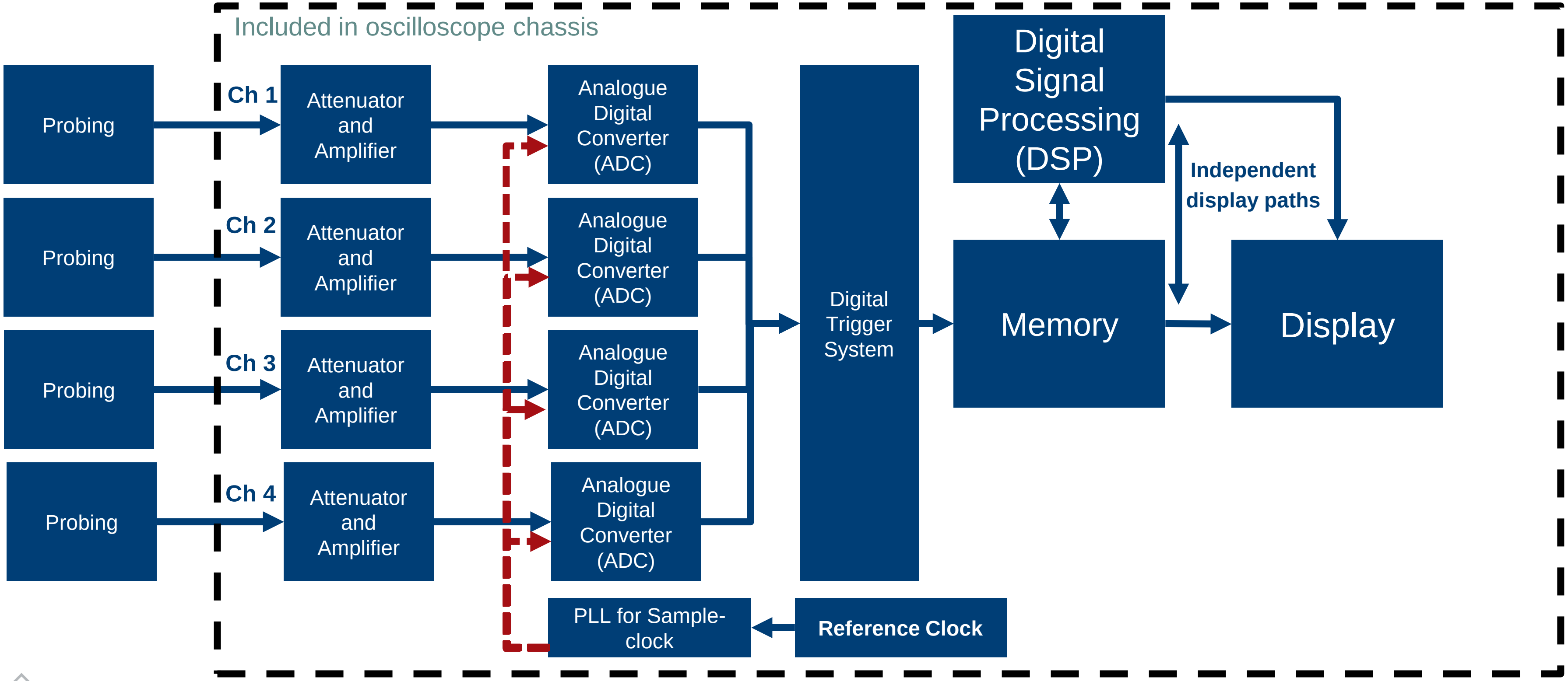
  $$f_{max} = 1/t_r$$

  - **As a rule of thumb $\boldsymbol{f_{max}}$ can be estimated by using the equation $\boldsymbol{f_{max} = 0.5/t_r}$**

DIGITAL OSCILLOSCOPE DIGITAL TRIGGER UNIT

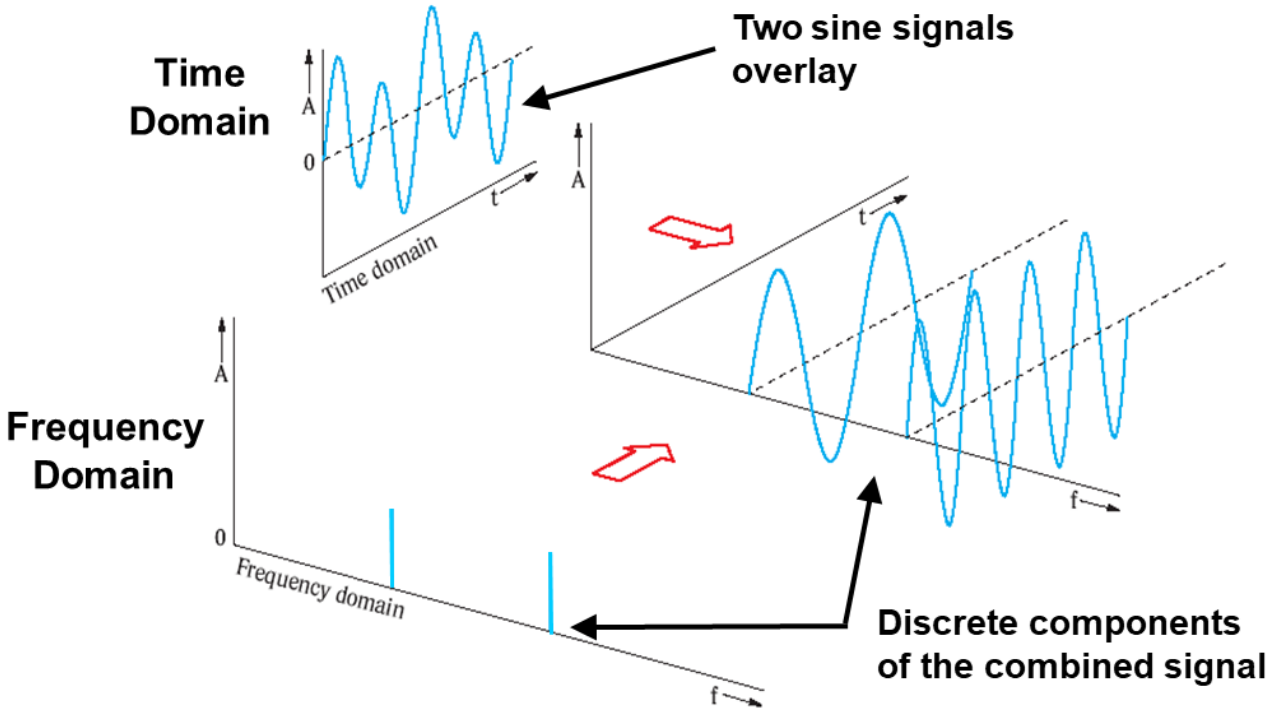


WHY IS AN OSCILLOSCOPE A COHERENT RECEIVER?



PROPERTIES OF SPECTRUM ANALYSIS IN OSCILLOSCOPES

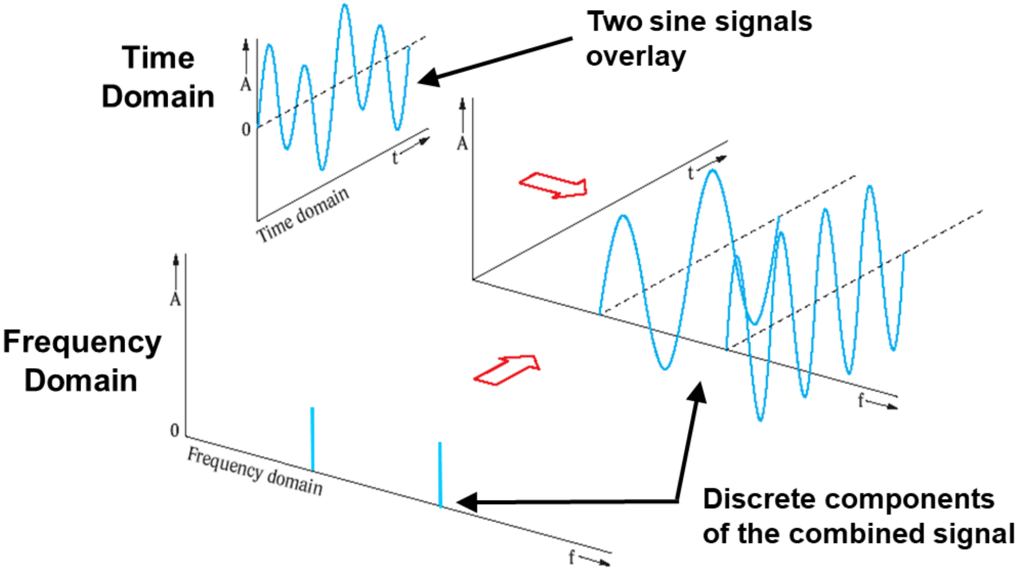
WHY TALK ABOUT TIME AND FREQUENCY DOMAIN?



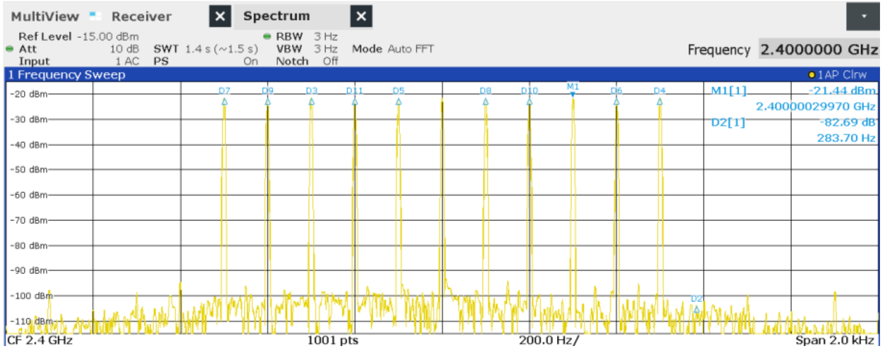
WHY TALK ABOUT TIME AND FREQUENCY DOMAIN?

► **Typical objections using an oscilloscope for spectrum analysis:**

1) Sensitivity and Selectivity of an oscilloscope are insufficient.
2)
3)



MULTITONE SIGNAL @ 2.4 GHZ
11 CARRIERS WITH 100 HZ SPACING



Type	Ref	Trc	X-Value	Y-Value
M1		1	2.4000003 GHz	-21.44 dBm
D2	M1	1	283.7 Hz	-82.69 dB
D3	M1	1	-599.4 Hz	-0.00 dB
D4	M1	1	199.8 Hz	-0.00 dB
D5	M1	1	-399.6 Hz	-0.00 dB
D6	M1	1	99.9 Hz	-0.00 dB
D7	M1	1	-799.2 Hz	-0.01 dB
D8	M1	1	-199.8 Hz	-0.00 dB
D9	M1	1	-699.3 Hz	-0.00 dB
D10	M1	1	-99.9 Hz	-0.01 dB
D11	M1	1	-499.5 Hz	-0.01 dB

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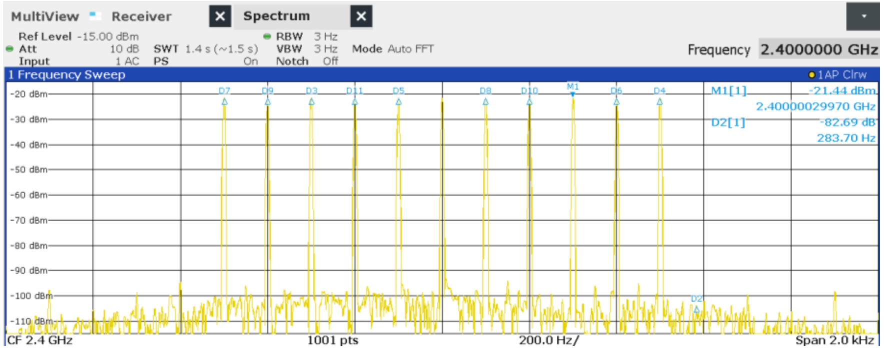

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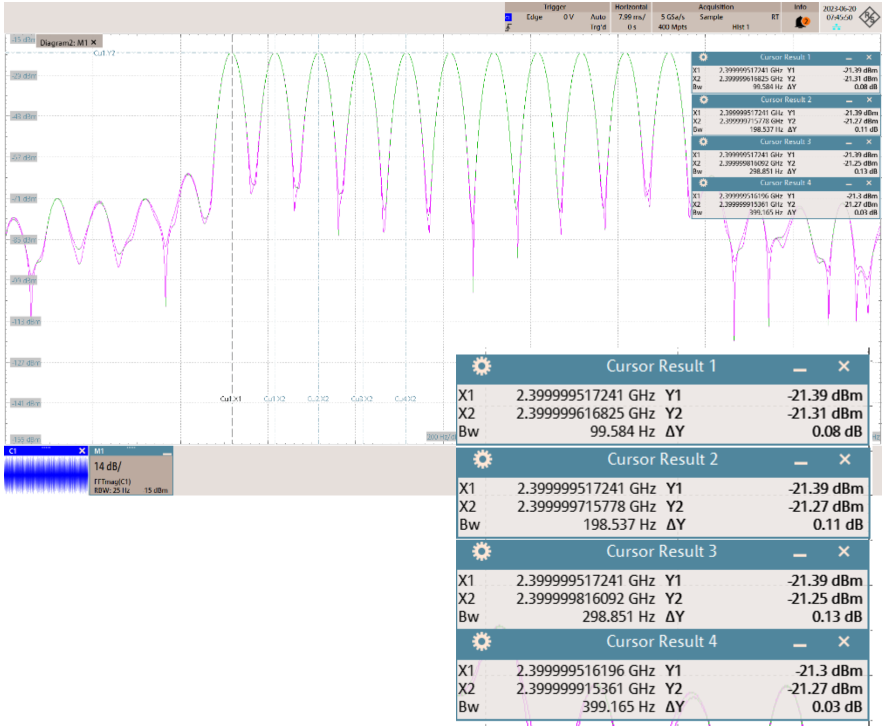
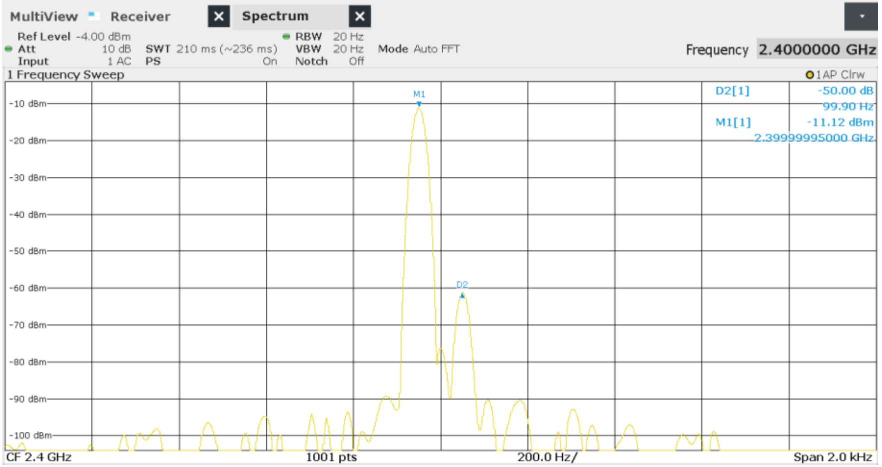
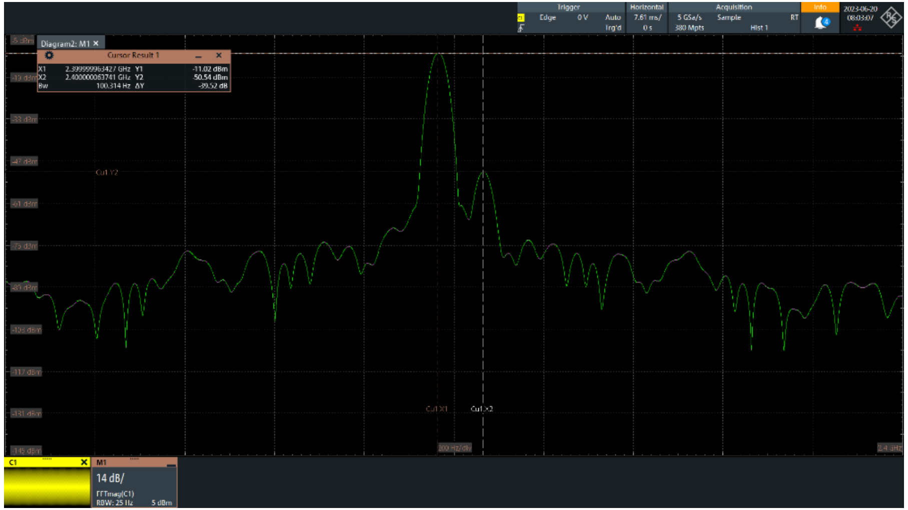


MULTITONE SIGNAL @ 2.4 GHZ
2 TONES WITH 50 DB ATTENUATION



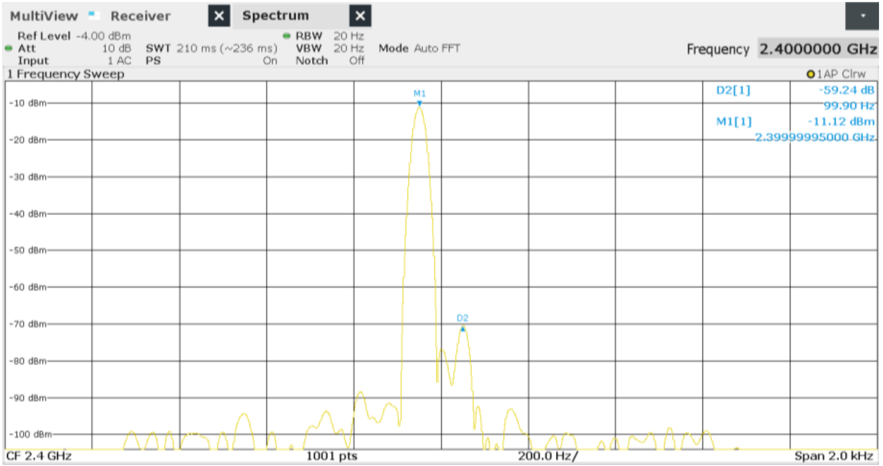


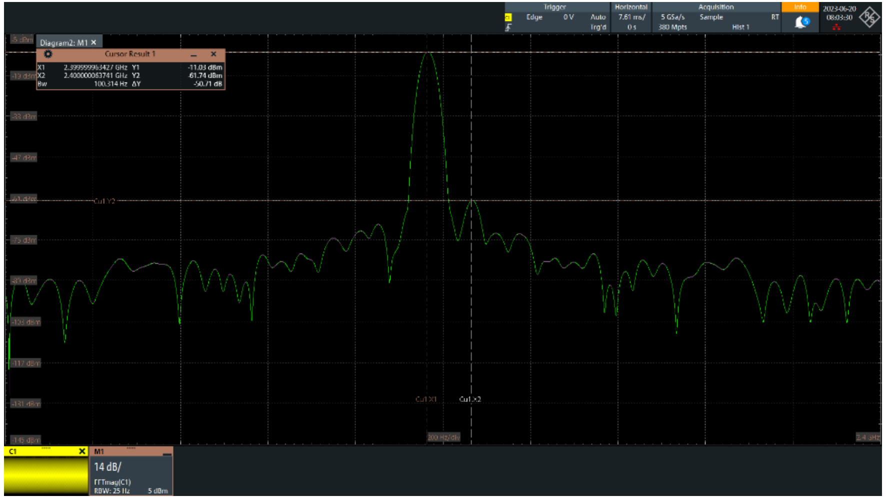
Type	Ref	Trc	X-Value	Y-Value
M1		1	**2.39999995 GHz**	**-11.12 dBm**
D2	M1	1	**99.9 Hz**	**-50.00 dB**

Cursor Result 1

X1	2.399999963427 GHz	Y1	-11.02 dBm
X2	2.400000063741 GHz	Y2	-50.54 dBm
Bw	100.314 Hz	ΔY	-39.52 dB

MULTITONE SIGNAL @ 2.4 GHZ
2 TONES WITH 60 DB ATTENUATION



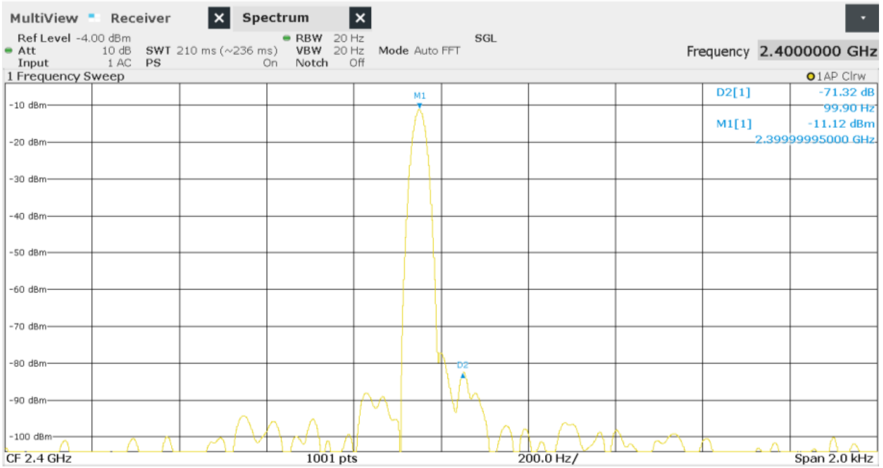


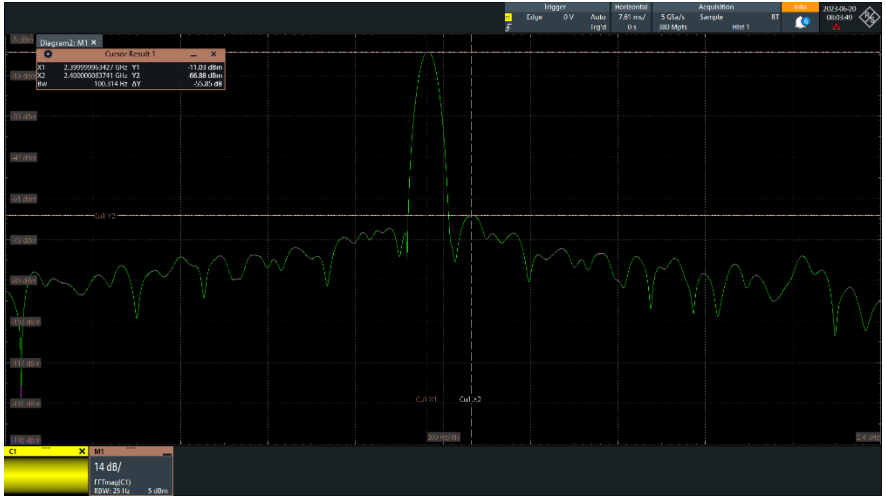
Type	Ref	Trc	X-Value	Y-Value
M1		1	2.39999995 GHz	-11.12 dBm
D2	M1	1	99.9 Hz	-59.24 dB

Cursor Result 1

X1	2.399999963427 GHz	Y1	-11.03 dBm
X2	2.400000063741 GHz	Y2	-61.74 dBm
Bw	100.314 Hz	ΔY	-50.71 dB

MULTITONE SIGNAL @ 2.4 GHZ
2 TONES WITH 70 DB ATTENUATION





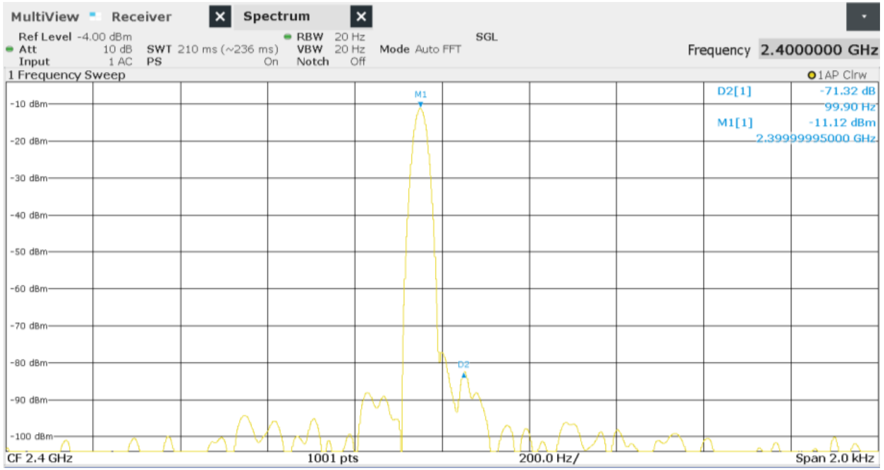
Type	Ref	Trc	X-Value	Y-Value
M1		1	**2.39999995 GHz**	**-11.12 dBm**
D2	M1	1	**99.9 Hz**	**-71.32 dB**

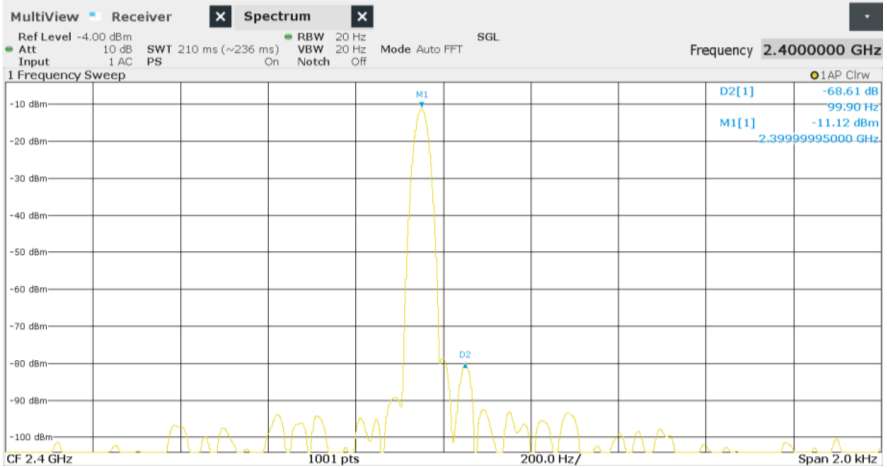
Caption: 2 Marker Table

Cursor Result 1

X1	2.399999963427 GHz	Y1	-11.03 dBm
X2	2.400000063741 GHz	Y2	-66.88 dBm
Bw	100.314 Hz	ΔY	-55.85 dB

MULTITONE SIGNAL @ 2.4 GHZ
2 TONES, 70 DB ATTENUATION, COMPARISON NOISE FLOOR





Type	Ref	Trc	X-Value	Y-Value
M1		1	2.39999995 GHz	-11.12 dBm
D2	M1	1	99.9 Hz	-71.32 dB

Type	Ref	Trc	X-Value	Y-Value
M1		1	2.39999995 GHz	-11.12 dBm
D2	M1	1	99.9 Hz	-68.61 dB

WHY TALK ABOUT TIME AND FREQUENCY DOMAIN?

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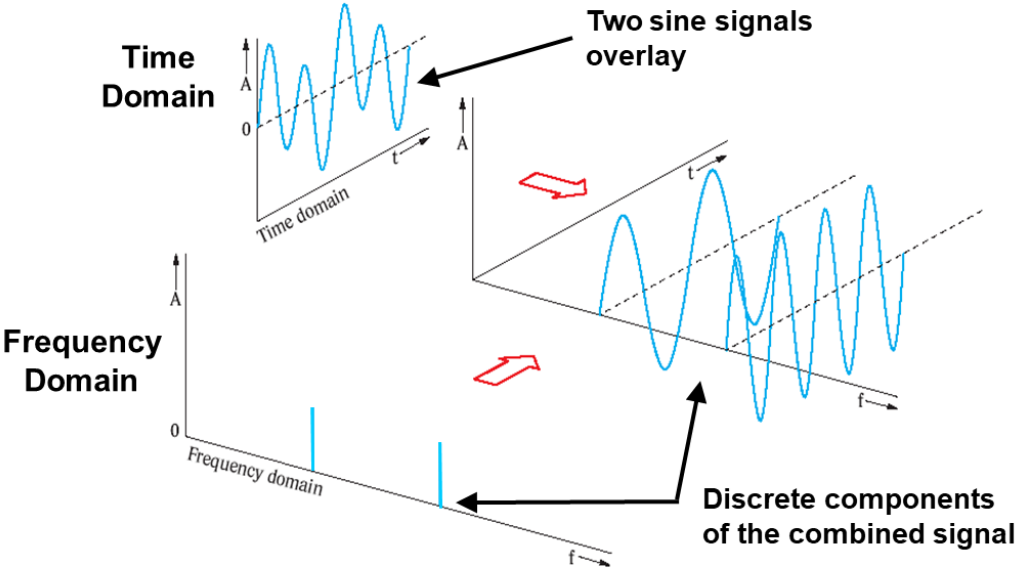
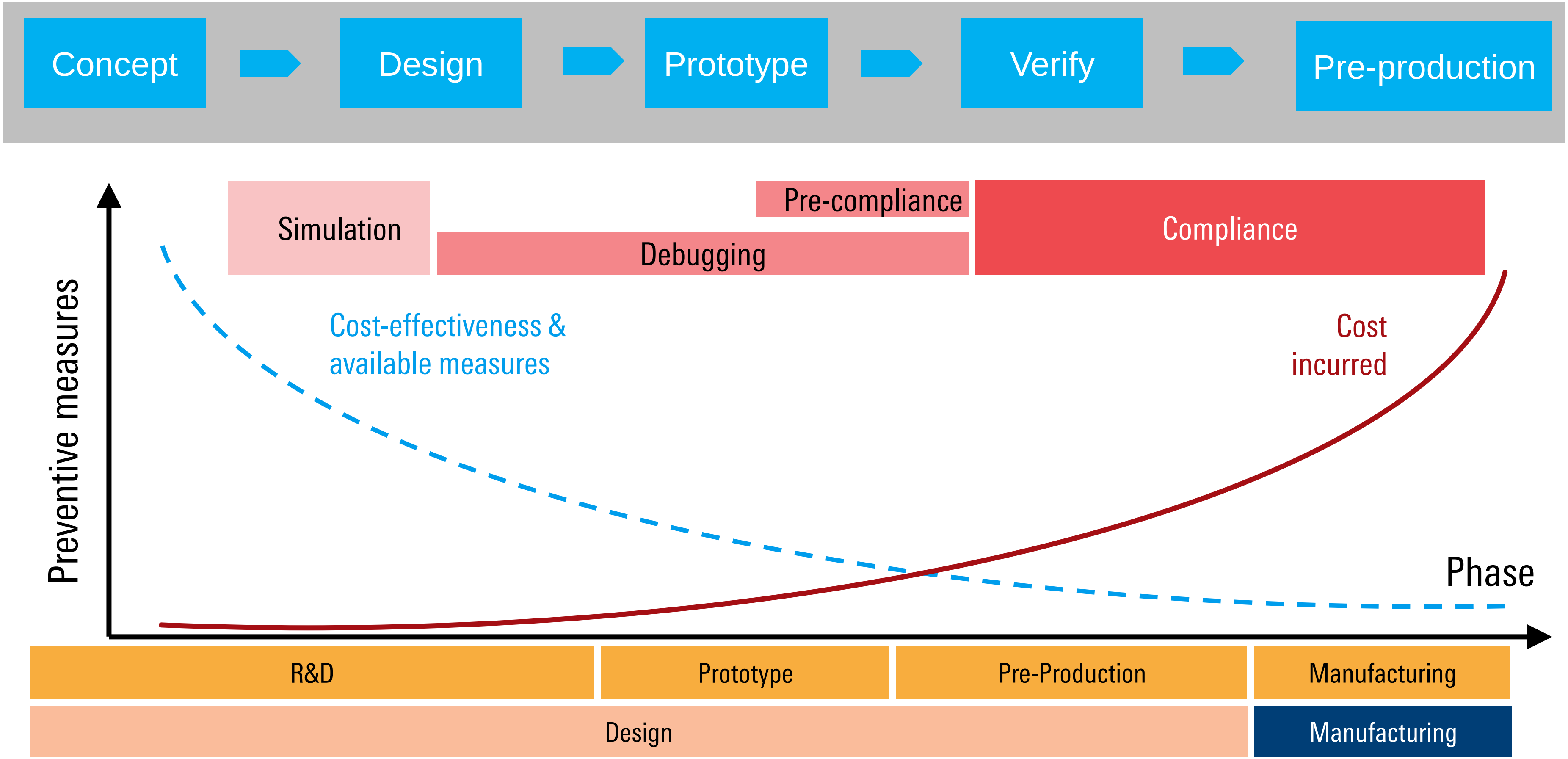
Dismissed

2) No gapless recording possible.

3)




Concept
Design
Prototype
Verify
Pre-production
Simulation
Pre-compliance
Debugging
Compliance
Preventive measures
Cost-effectiveness & available measures
Cost incurred
Phase
R&D
Prototype
Pre-Production
Manufacturing
Design
Manufacturing

WHEN TO USE WHICH INSTRUMENT?
FROM COMPLIANCE TO EMI DEBUGGING

EMI Receiver
- 6 dB Filters
- Preselector available
- Highest selectivity
- CISPR compliant detectors
- Demodulation of signals possible
- Time domain scan reduces sweep time to a minimum

Spectrum-/ Signal analyzer
- 3 dB (6 dB) Filters
- High selectivity
- High sensitivity
- Analysis on wide frequency range possible (today up to 8 GHz internal analysis BW available)
- Demodulation of signals possible

Oscilloscope
- 3 dB Filter
- One shot analysis of whole frequency range
- Measures down to DC
- Trigger capabilities for signal separation
- Mask testing in frequency and time domain
- Gated FFT possible
- Multichannel coherent receiver

WHEN TO USE WHICH INSTRUMENT?
FROM COMPLIANCE TO EMI DEBUGGING

EMI Receiver

- 6 dB Filters
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Full Compliance

Spectrum-/ Signal analyzer

- 3 dB (6 dB) Filters
- High selectivity
- High sensitivity
- Analysis on quency range pc day up to 8 GHz i nalysis BW av
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Pre-Compliance

Oscilloscope

- 3 dB Filter
- One shot analysis frequency ranc
- Measures C
- Trigger es for signal sep
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- ated FFT possible
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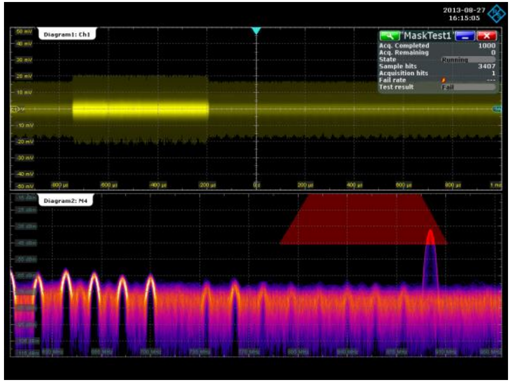
EMI Debugging

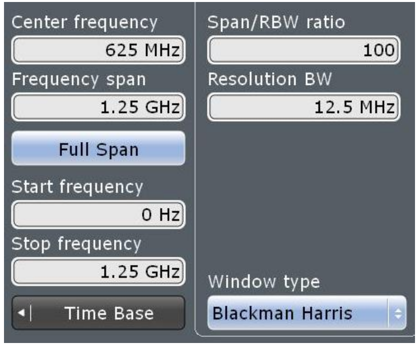
EMI DEBUGGING WITH OSCILLOSCOPES?
YES, WE CAN! (AND IT'S VERY HELPFUL)

- ► Available on every R&D engineer desk
  - – Easy debugging of EMI problems in R&D
  - – Improvements can easily be tested

- ► Oscilloscopes show both time and frequency domain
  - – Correlation between unwanted spectral emission and time-domain signal parameters easily possible
  - – Time-domain trigger has advantages for capturing intermittent signals

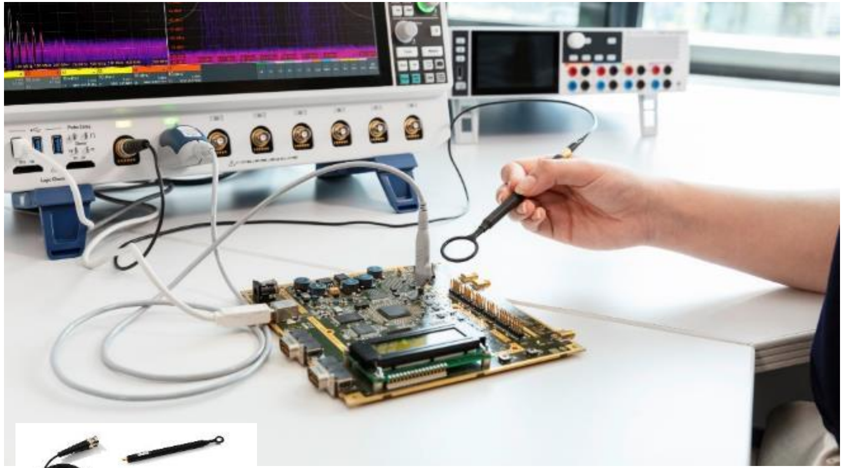
- ► Today's oscilloscopes provide excellent sensitivity and usability
  - – 1 mV/Div corresponds to DANL ~0dBuV (R&S®RTO at 500 MHz, 120 kHz RBW, 50 Ω)
  - – Direct input of frequencies and resolution bandwidth



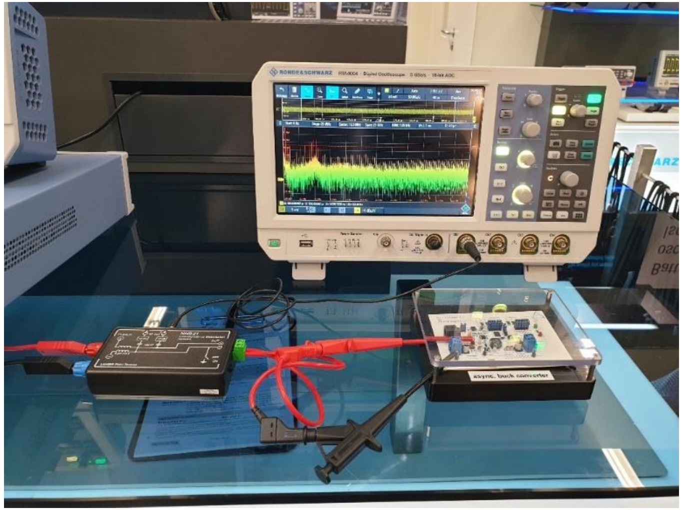


EMI DEBUGGING WITH OSCILLOSCOPES

Radiated Emission
Debugging after failed Pre-Compliance or Compliance



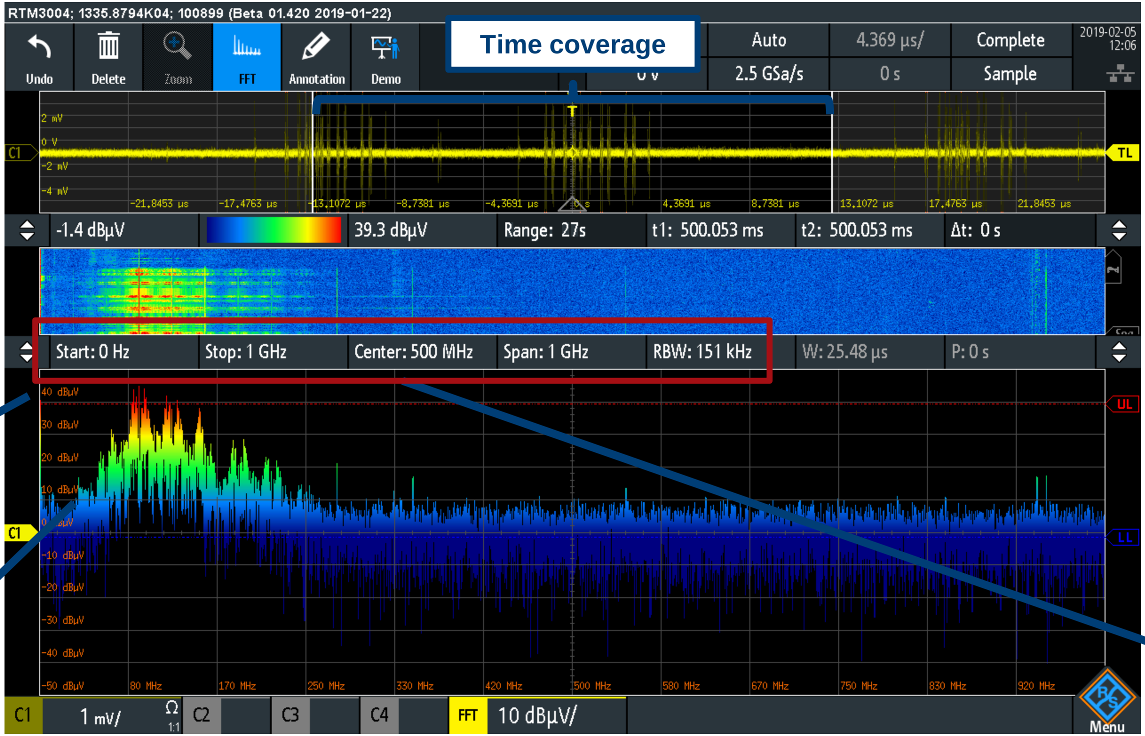
Conducted Emission
Pre-test and debugging in the R&D lab



BASIC EMI DEBUGGING WITH OSCILLOSCOPES

RTM3000 / RTA4000

MXO4



Waterfall diagram helps to show short emissions

dBuV scaling like in EMI measurements

Color coding display for better visibility

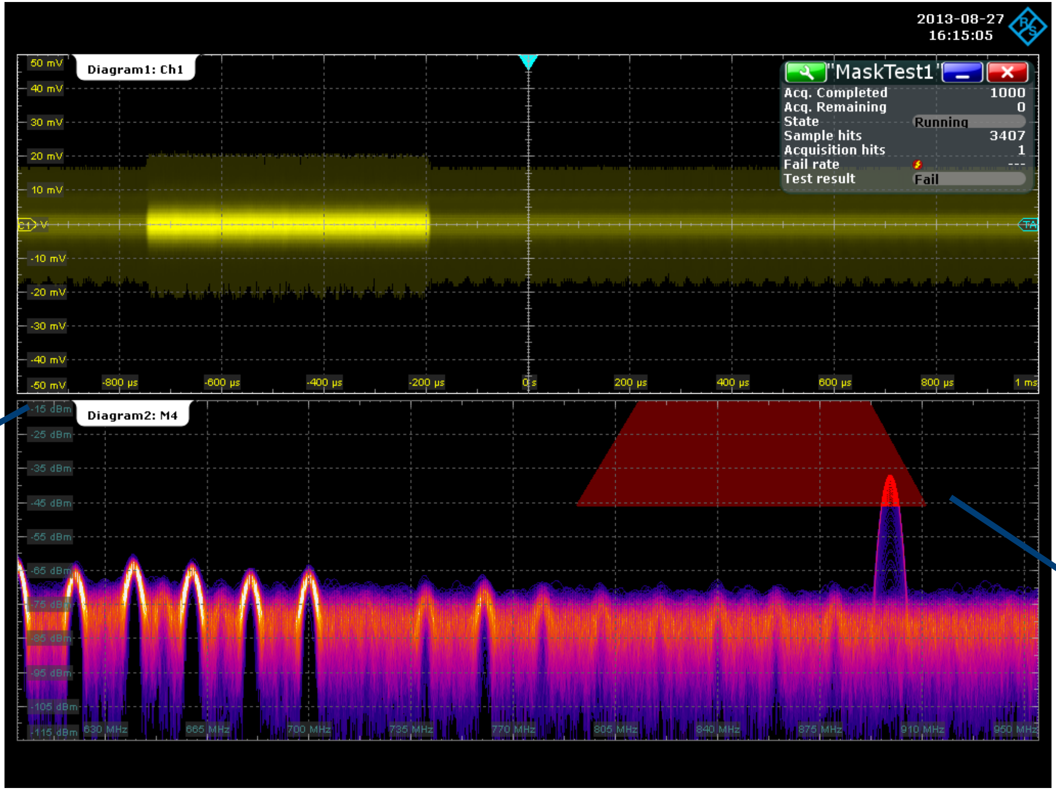
Time-frequency correlation of emissions

Directly set start, stop and resolution bandwidth

ADVANCED EMI DEBUGGING WITH OSCILLOSCOPES

RTO6

MXO5



Waterfall diagram (not shown here)

Flexible scaling, dBuV, dBm

Color coding display shows how often disturbance happens

Time-frequency correlation of emissions

Spectral mask allows „stop-on-violation“

EMC DEMO

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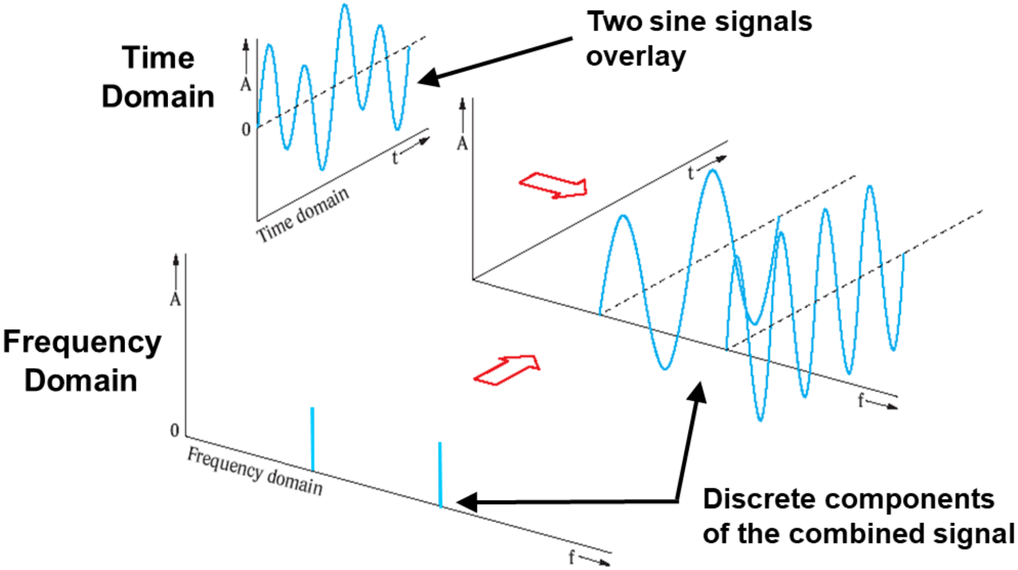

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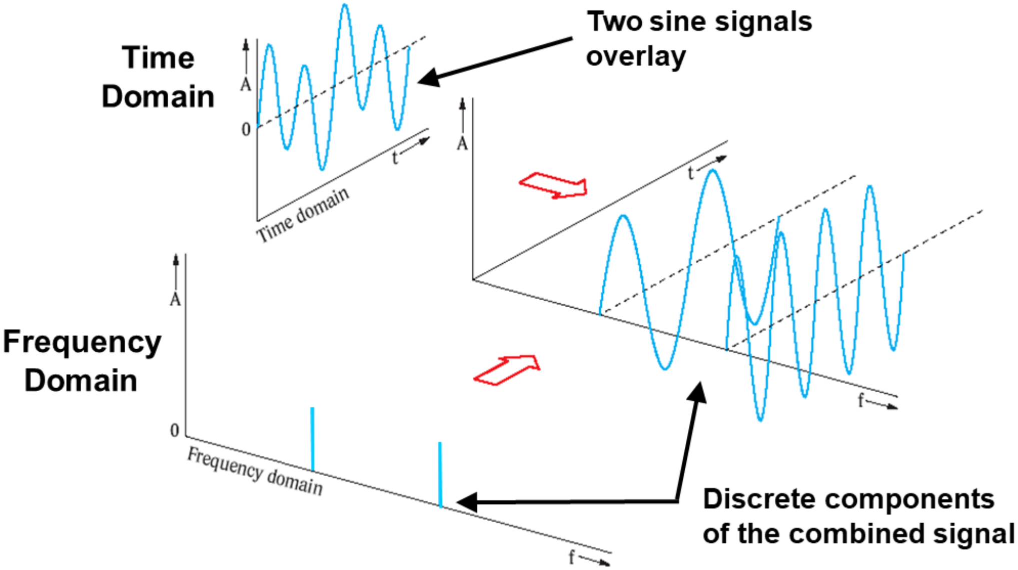

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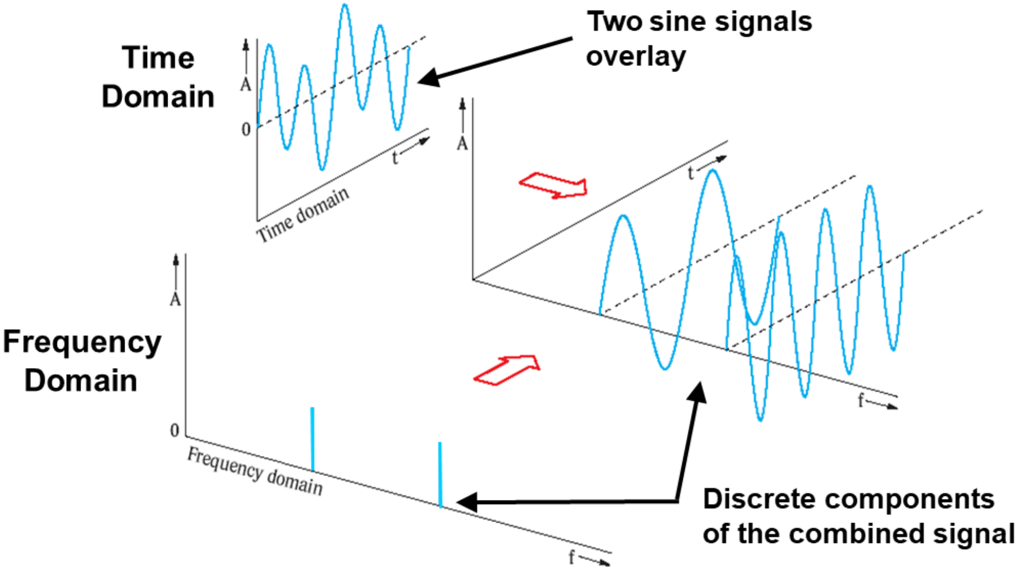
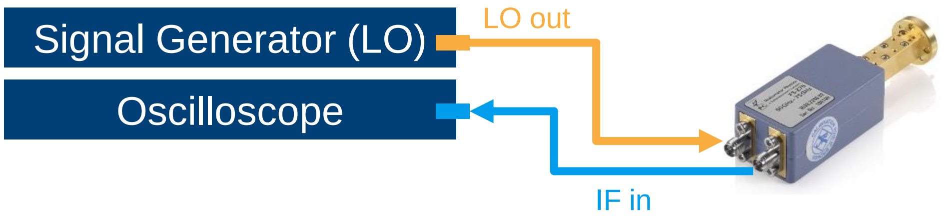
3) Frequency range is limited to analogue bandwidth



HARMONIC MIXERS

- FS-Zxxx **Harmonic** mixers
- Extend frequency range of R&S instruments up to 325 GHz
- Up to 4.4 GHz analysis BW
- Conversion loss characterized <u>for each and every mixer</u> in production line
- Calibration files included
  - *.acl files for spectrum analysis and narrowband IQ signal analysis
  - *.b2g and *.b5g files for wideband IQ signal analysis



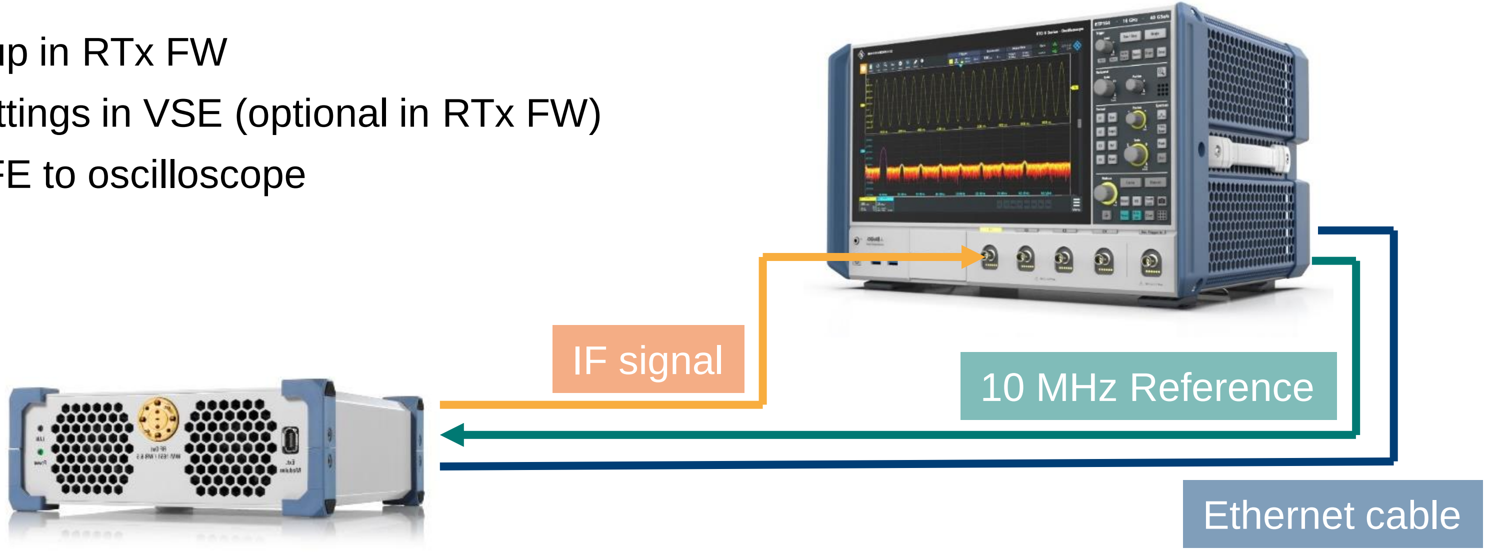
Type	Frequency Range [GHz]
FS-Z60	40-60
FS-Z75	50-75
FS-Z90	60-90
FS-Z110	75-110
FS-Z140	90-140
FS-Z170	110-170
FS-Z220	140-220
FS-Z325	220-325

EXTERNAL FRONTENDS

- **High-End external frontends for wideband IQ-signal analysis**
  - Integrated high-end LO synthesizer with very low phase noise
  - Spectrum analyzer class dynamic range through power level control (RF and IF attenuators)
  - Large IF bandwidth
  - Integrated/optional band-pass filters for image rejection and spur suppression
  - Automated calibration
  - For frequency bands with high potential/interest
    - 5G FR2 → FE44S and FE50DTR
    - 6G → FE170ST/R

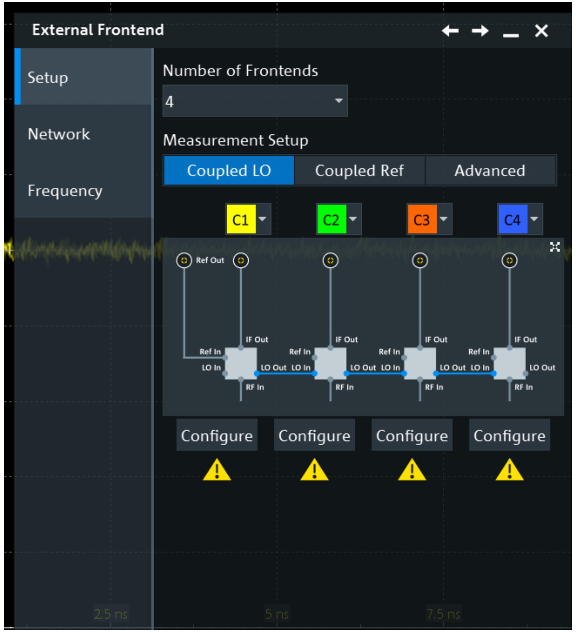
FRONTENDS AND OSCILLOSCOPE FW

- In general:
  - Detailed setup in RTx FW
  - Use-case settings in VSE (optional in RTx FW)
- First, connect FE to oscilloscope

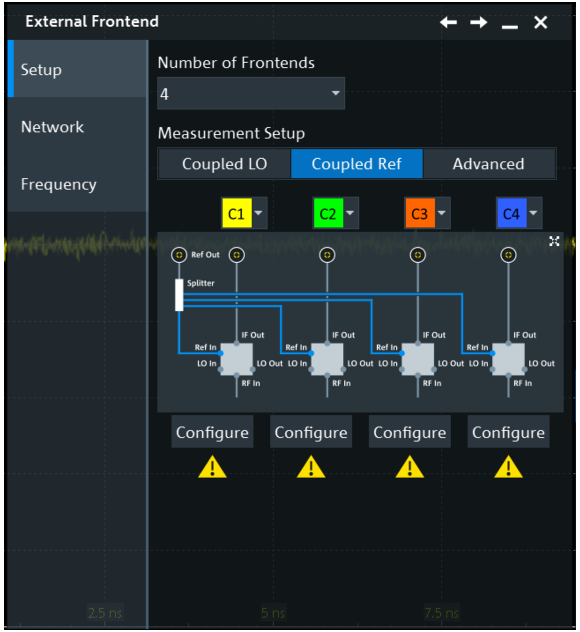


SETUP WITH GUI INSTRUCTIONS

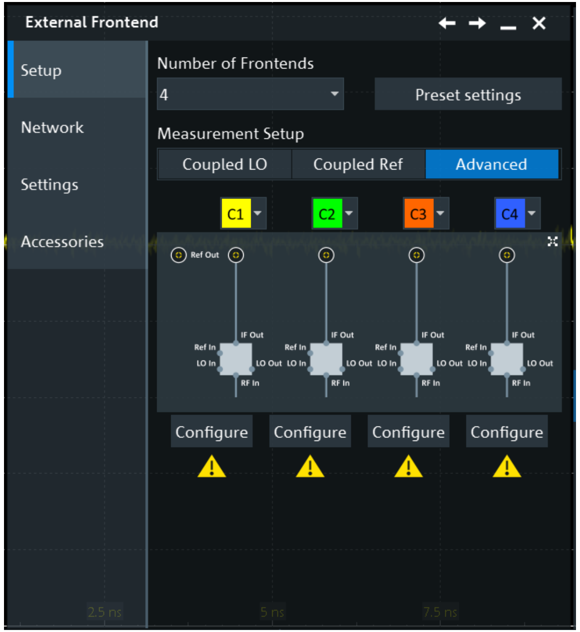
Coupled LO – minimum phase noise



Coupled Ref – Easy setup



Advanced - configure each FE to your liking



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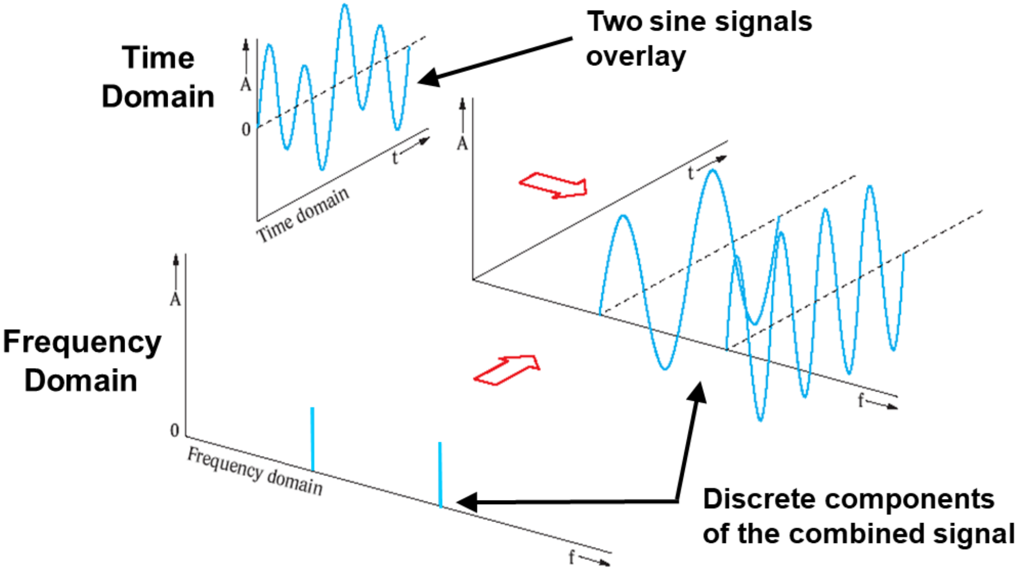

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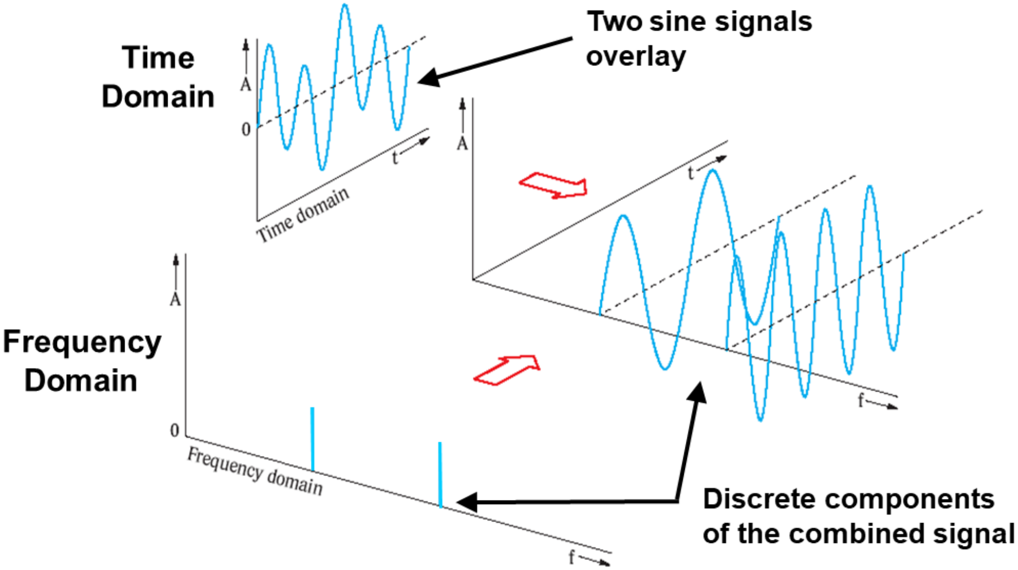
3) Frequency range can be extended using external mixers or frontends.



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www.rohde-schwarz.com/oscilloscopes

Questions?

ROHDE&SCHWARZ

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