FUNDAMENTALS OF EMI DEBUGGING & PRE-COMPLIANCE

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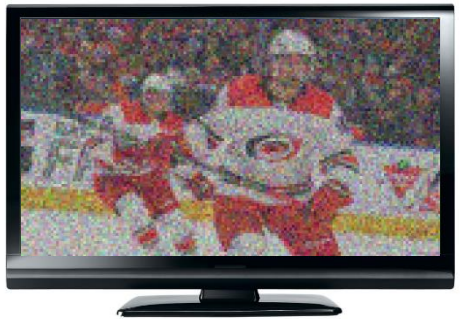
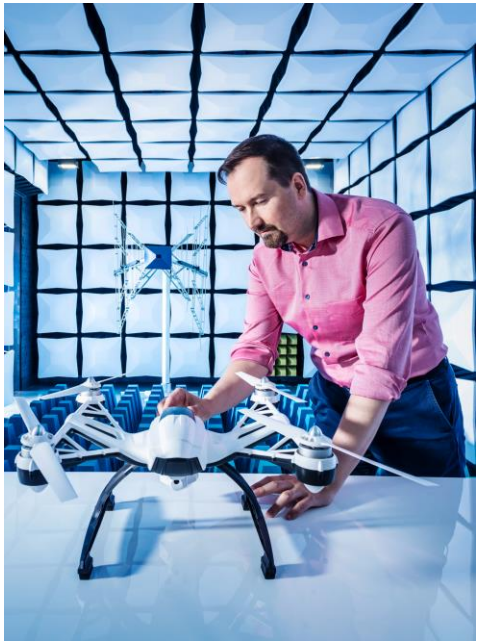
WHAT IS EMI?

- EMI (electromagnetic interference) is the unintended or undesired radio frequency emissions from a device



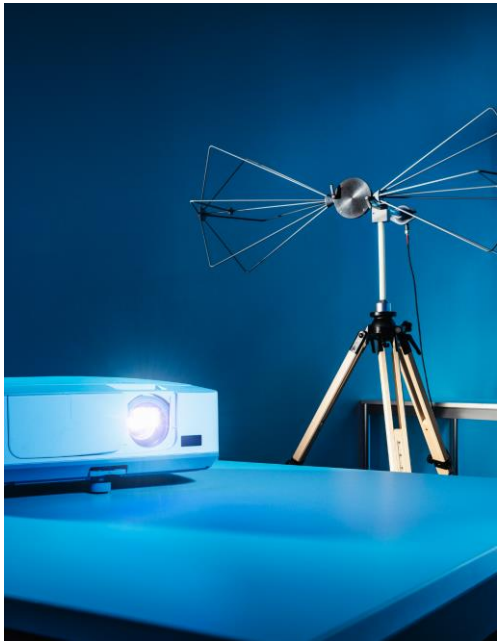
COMPLIANCE TESTING

- Done either in a certified test lab/house or by manufacturer
  - Follow strict and precise procedures
  - Requires specialized equipment, facilities, and personnel
  - Can be (very) expensive
- Failing compliance testing is not uncommon
  - **Failure rate is ~70-90%**
  - Must reschedule and retest (and pay

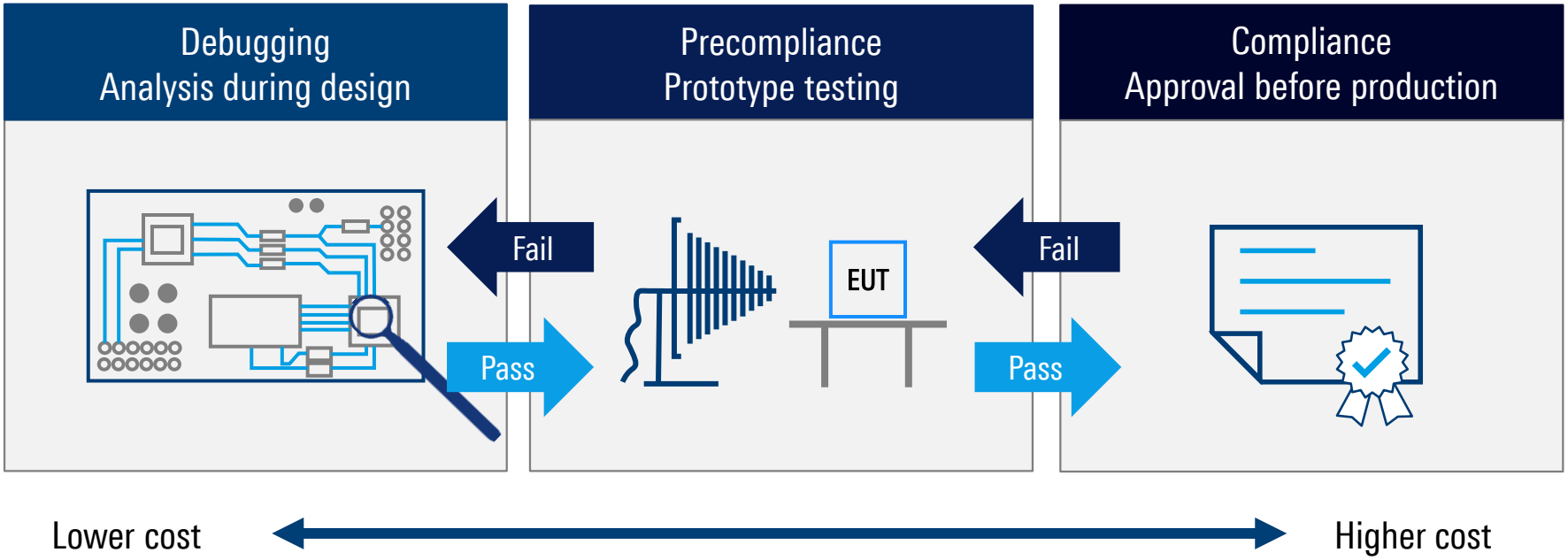


PRE-COMPLIANCE TESTING

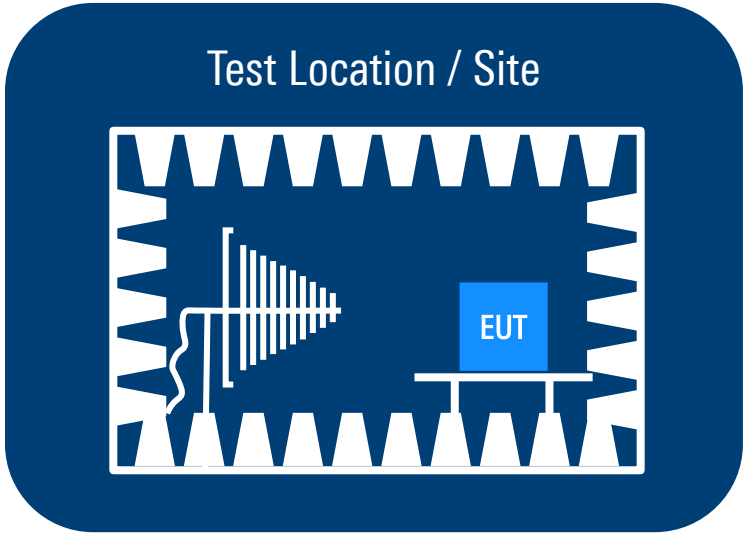
- Done by device manufacturers, in their labs, **before** compliance testing
  - Increases chances of passing
- Saves considerable time and money if problems are caught (and corrected) early in the design cycle
- EMI debugging is the process of detecting, analyzing, and correcting unwanted interference



FROM DESIGN TO COMPLIANCE

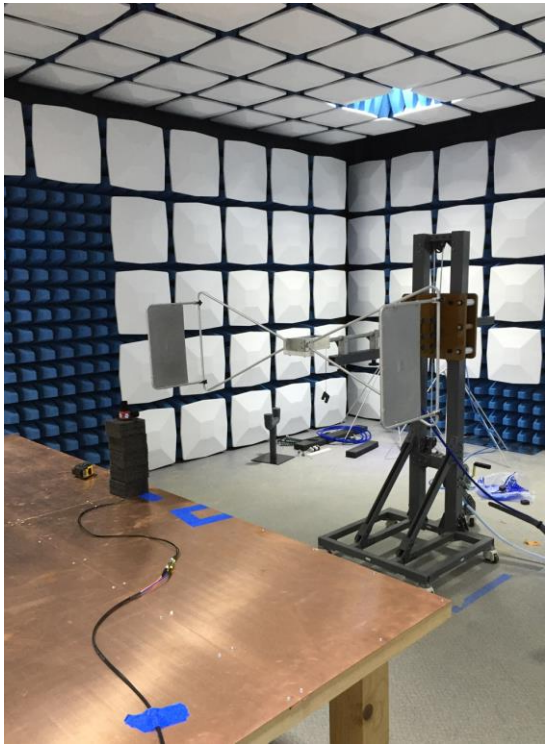


REQUIREMENTS FOR PRE-COMPLIANCE TESTING



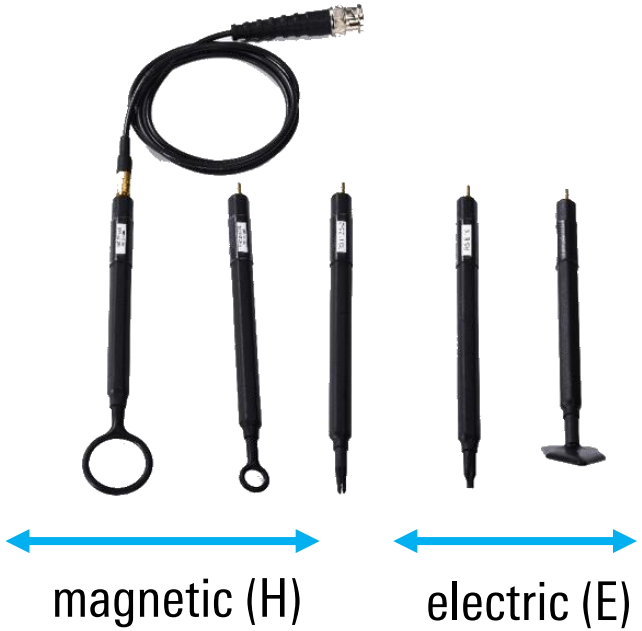
TEST LOCATION

- Specific test environments are needed for both conducted and radiated compliance testing
- Conducted testing is relatively easy to set up
- Radiated testing generally performed in a shielded chamber or an OATS (open air test site)
  - Radiated **pre**compliance testing usually does not precisely duplicate these environments
- For radiated precompliance, modifications must often be made and/or margins must be added to results
  - For example, if distance between antenna and EUT are shortened, limits will need to be raised

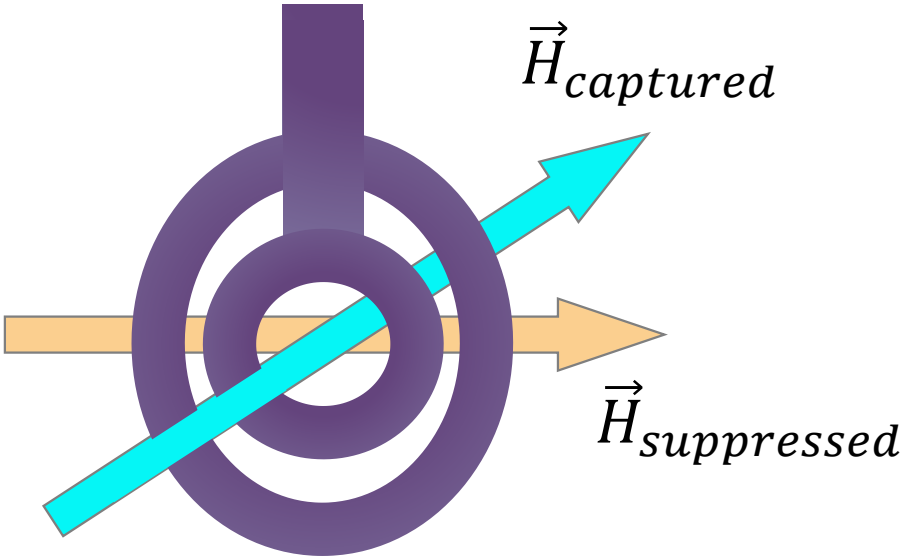


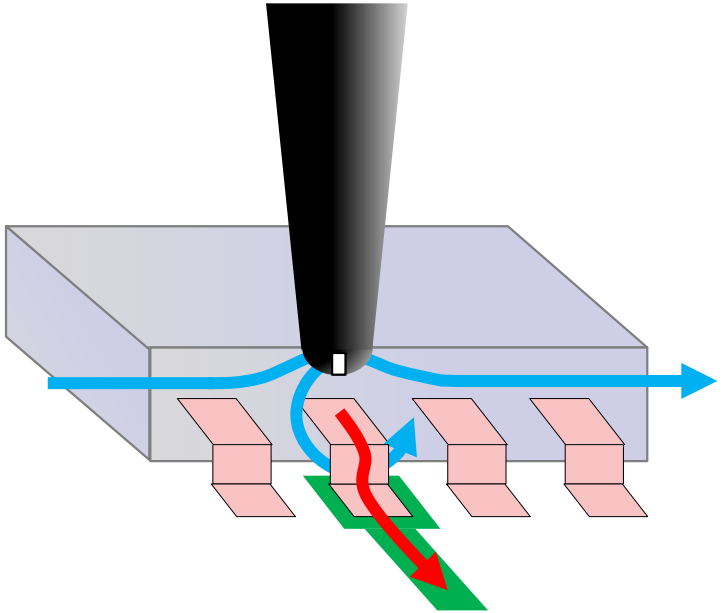
OSCILLOSCOPE DEBUGGING

Oscilloscope

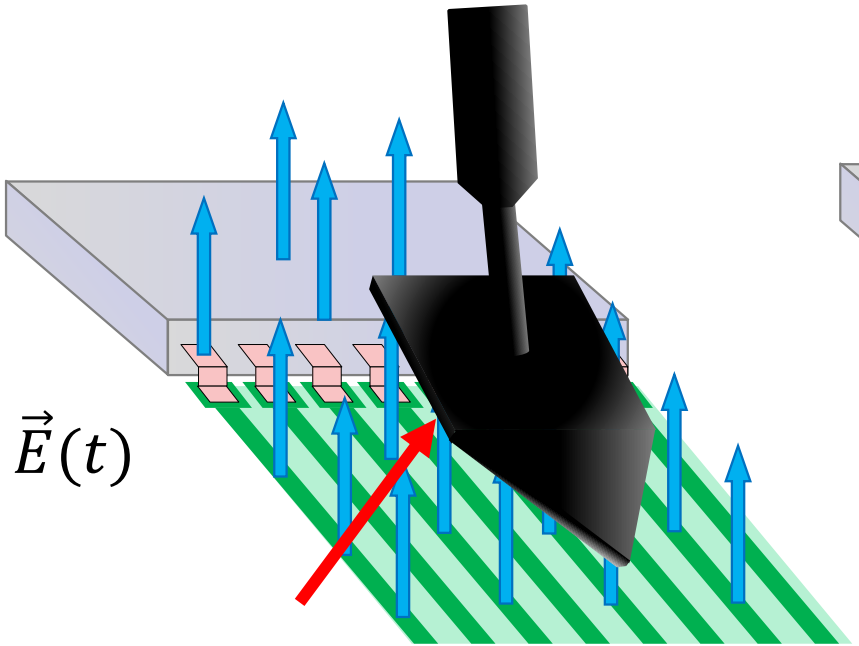


H FIELD PROBES

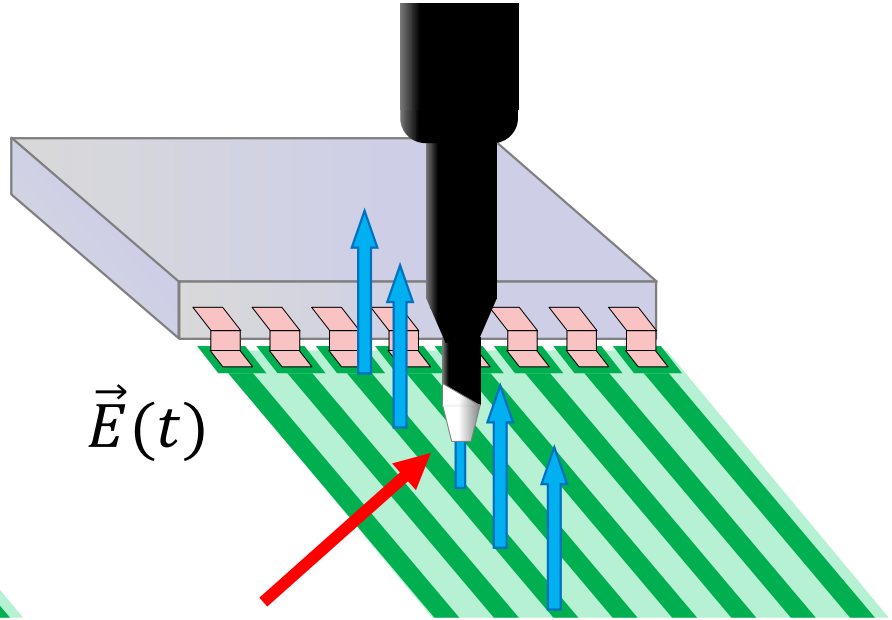




E FIELD PROBES



Field electrode

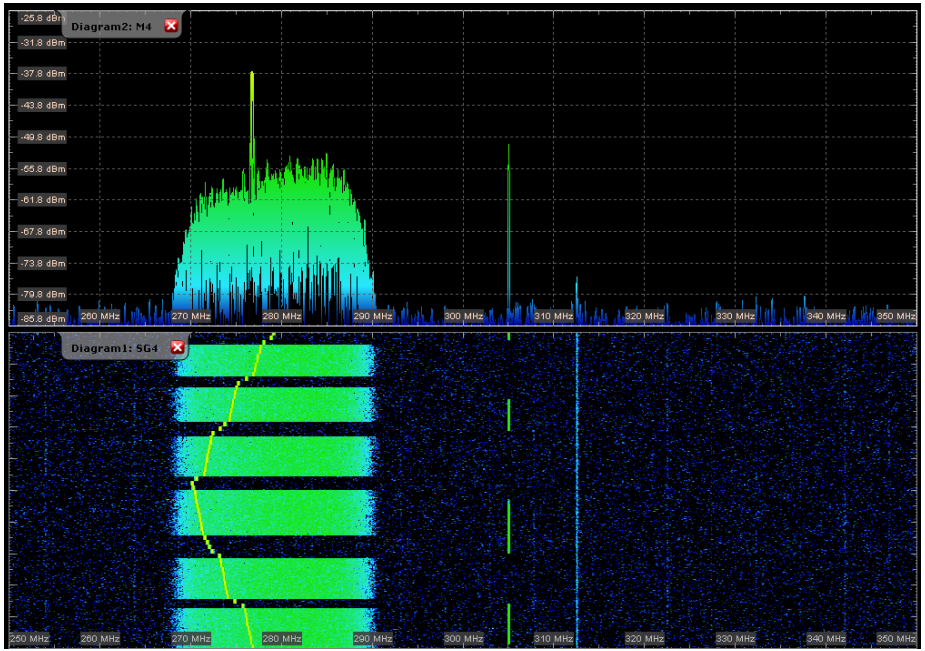


Field electrode

SPECTROGRAMS

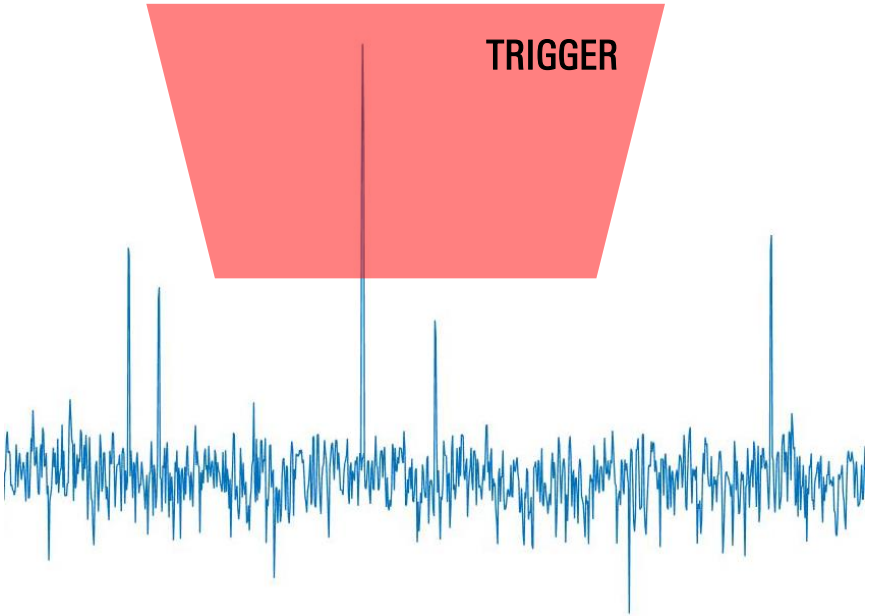
- Basic FFT shows power versus frequency
- Spectrogram shows power versus frequency as a function of time
- Color table maps power into colors

less power  more power



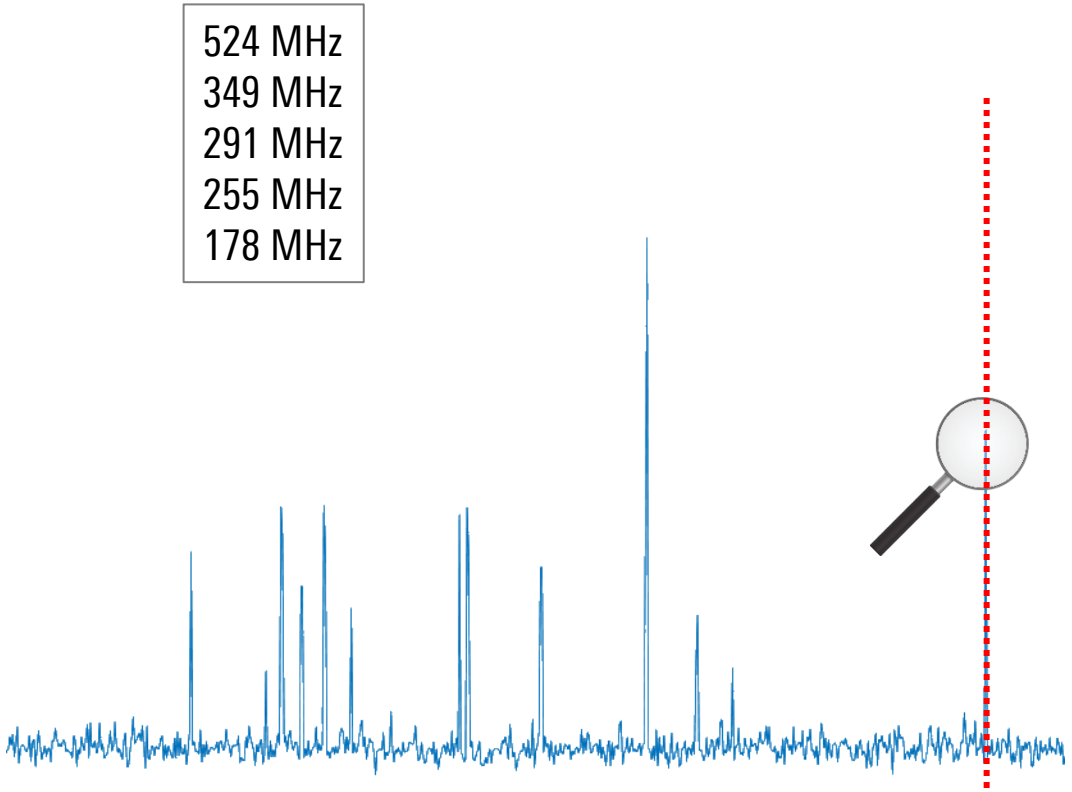
FREQUENCY MASK TRIGGER

- Difficult to detect and analyze short-duration (intermittent) events
  - Need to trigger on power exceeding a threshold at given frequencies
- This can be done using a frequency mask trigger
- When the mask is violated, the acquisition stops and captured data can be analyzed in detail



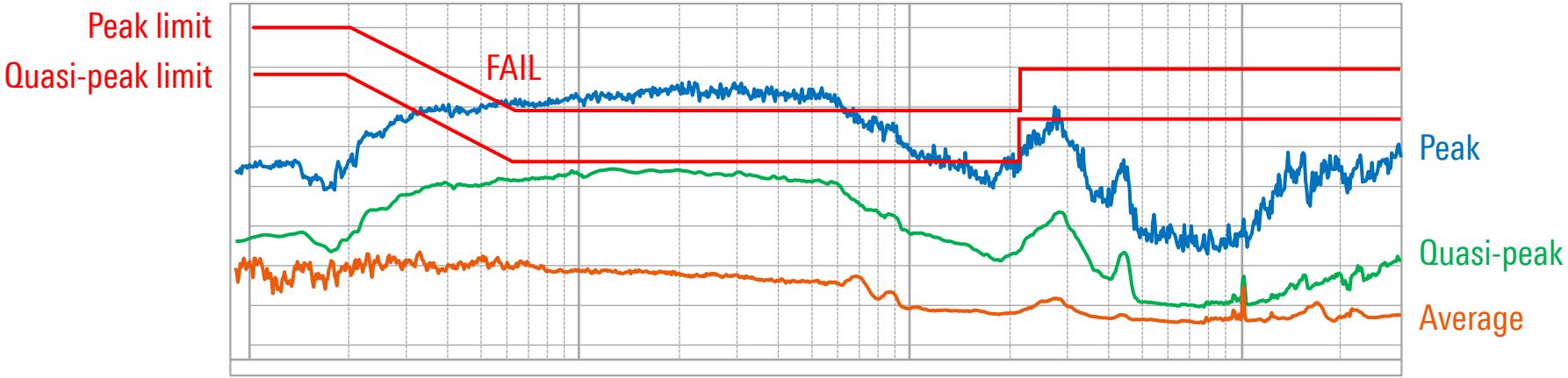
PEAK LIST

- In EMI debug, peak levels are often the most interesting / important
- Peaks can be found using:
  - Eyeballs
  - Cursors
  - Peak search / list
- Peak list gives the highest amplitude signals (or signals above a given threshold) and their frequencies



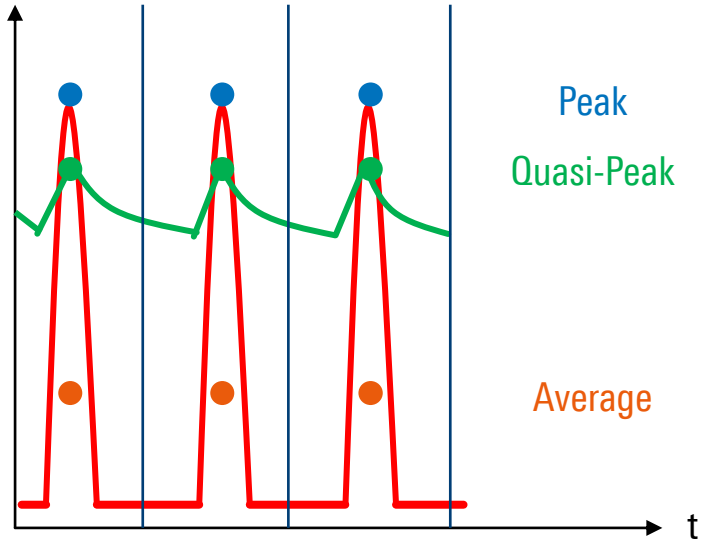
SPECTRUM ANALYZER

LIMIT LINES



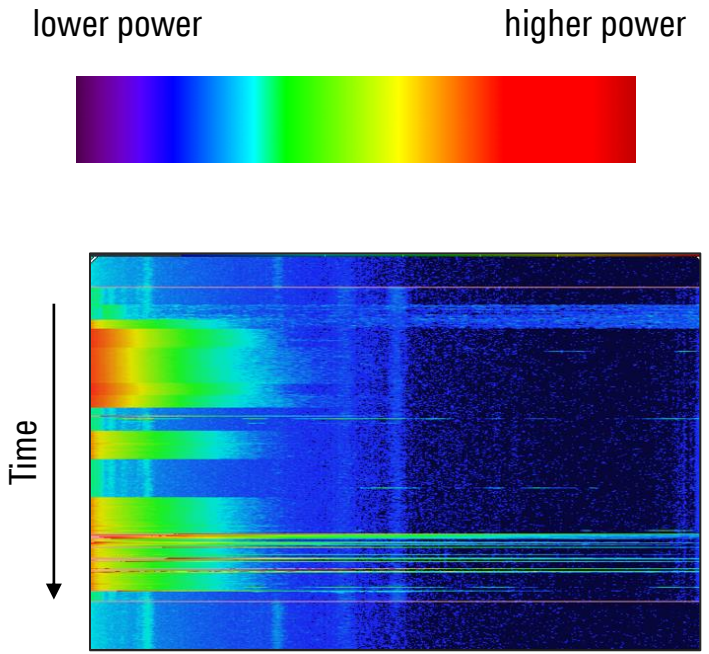
DETECTORS

- Detectors determine how values measured over an interval are combined into a single value
  - Peak: maximum value
  - Quasi-peak: measures the “annoyance” of a signal
  - Average: average value
- Compliance often uses quasi-peak
  - But precompliance tends to use peak detector
- Peak is much faster than quasi-peak
- Peak levels are always higher than quasi-peak
  - If signals are below limits with peak, they will always be below limit with quasi-peak



SPECTROGRAMS

- Power vs. frequency vs. time
  - Signal power (intensity) is mapped to color
- Appears as a “waterfall”
  - Most recent measurements at the top
- Visualize how the levels of signals change over time
- Enables easy identification of:
  - Time-varying behavior (drifting, hopping, etc.)
  - Small signals in the presence of larger signals
- Can be found on both EMI receivers and spec ans
  - Also common on oscilloscopes in FFT mode

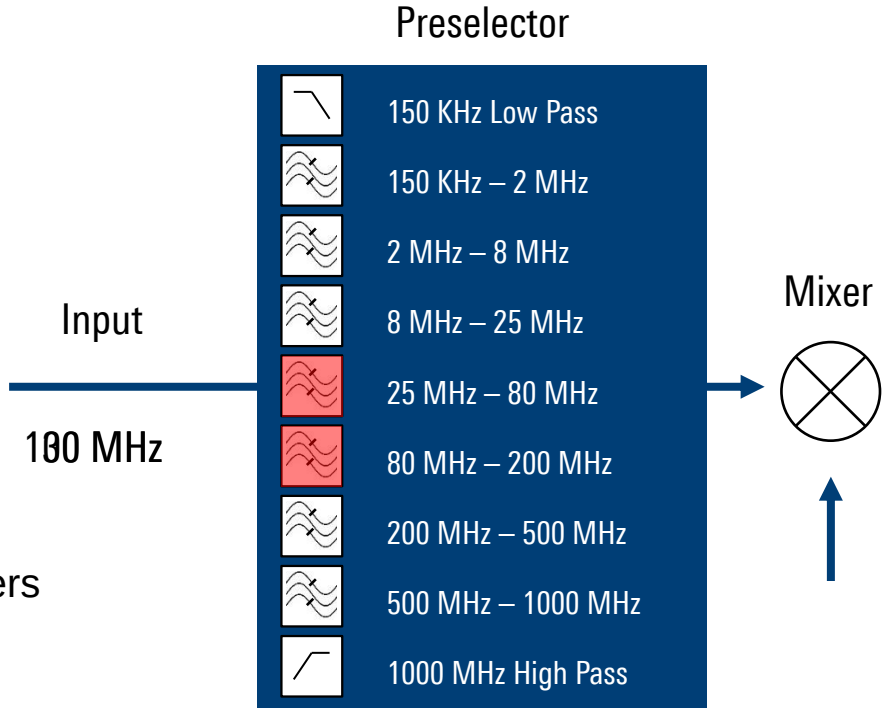


FPL1000

EMI RECEIVER

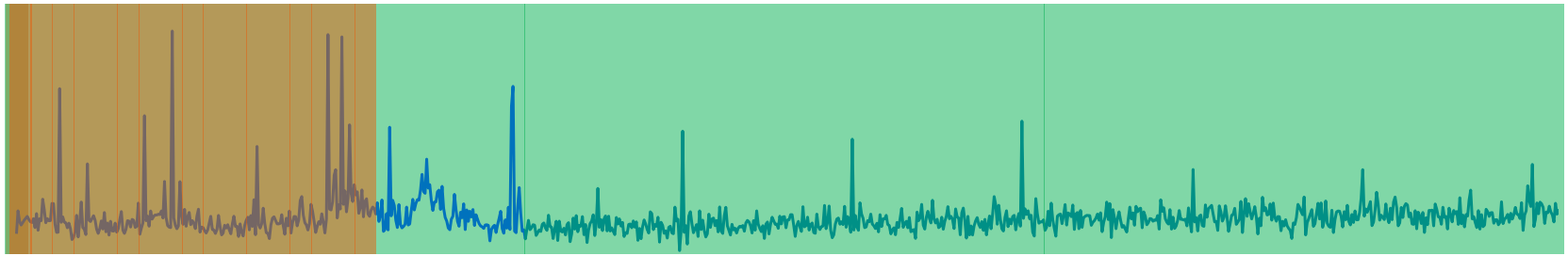
PRESELECTION

- Input signal is not known / controllable
- Out of band signals could overload the mixer
  - Causing compression or distortion and therefore invalid results
- Preselection protects the first mixer
  - Filters the inputs signal to select only the frequencies of interest
  - Automatically configured by receiver
- Many EMI standards require preselection
  - Compliance testing performed using receivers
  - Spectrum analyzer “preselection” is usually simply (YIG) high-pass filtering



TIME DOMAIN SCAN

- In a time-domain scan, measurement range is split into large blocks of spectrum
  - Digitized and processed using the FFT
- Used in both compliance and precompliance testing



EPL1000

SUMMARY

EMI Receivers

- Preselection
- Time domain scan
- Spectrograms
- Limit lines
- Spectrum Sweep
- More specialized
- Same instrument used in compliance testing

Spectrum Analyzers

- No preselection
- No time domain scan
- Spectrograms
- Limit lines
- Spectrum Sweep
- General purpose

Oscilloscopes

- No preselection
- No time domain scan
- Spectrograms
- No (native) limit lines
- Spectrum displayed by FFT
- General purpose
- Wide bandwidth
- Correlation of time and frequency domains
- Ability to measure multiple signals at once

FUNDAMENTALS OF PRE-COMPLIANCE

Rohde & Schwarz Korea

90 YEARS
OF ENSURING A SAFER AND CONNECTED WORLD

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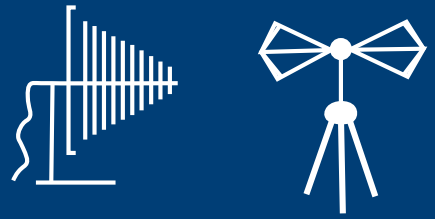
PRE-COMPLIANCE ACCESSORIES

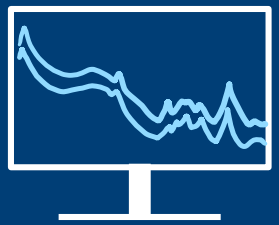
LISNs

Antennas



Near Field Probes

Software



LISN (LINE IMPEDANCE STABILIZATION NETWORK)

- Used in **conducted** emissions testing
  - Also known as an “Artificial Mains Network” (AMN) or a “V Network”
- Provides a stable impedance (50 Ω) on the AC mains end of the EUT power cord
- Blocks RF signals on the AC mains from entering the EUT via the EUT power cord
- Easy to use:
  - EUT mains cord is plugged into LISN
  - LISN measurement port is connected to measuring instrument (e.g. EMI receiver, spec an, etc.)

CONNECTING A LISN

VARIETIES OF LISNS

- Different standards and different device types may require different types of LISNs
- LISNs can differ in terms of :
  - Maximum current rating
  - Frequency range
  - Impedance presented to EUT
  - Number of supported phases
  - Support for DC input power
- LISNs may also have features such as built-in highpass filters, limiters, artificial hand connections, remote control capability, etc.

ADDITIONAL FUNCTIONS OF A LISN

- LISNs may also provide additional functions such as:
  - Artificial hand : simulates the capacitive effect of the human body on handheld devices (such as an electric drill)
  - Highpass filter : can be switched into the measurement path to suppress low-frequency signals (e.g. from switched mode power supplies)
  - Transient limiter : protects the measurement instrument from large voltage spikes
  - Remote control : allows remote or automated operation

ANTENNAS

- Radiated compliance requires antennas to measure emitted signals
  - Compliance testing is done in the far field
- Need to cover wide frequency ranges
  - Broadband antennas or combinations of antennas
  - Ex: log periodic, biconical, etc.
- Allow very precise measurements and frequency compensation (antenna factors)
- Antenna ↔ EUT distance is often shorter in precompliance
- Antennas not suitable for troubleshooting or debug
  - Too large / bulky (poor spatial resolution)

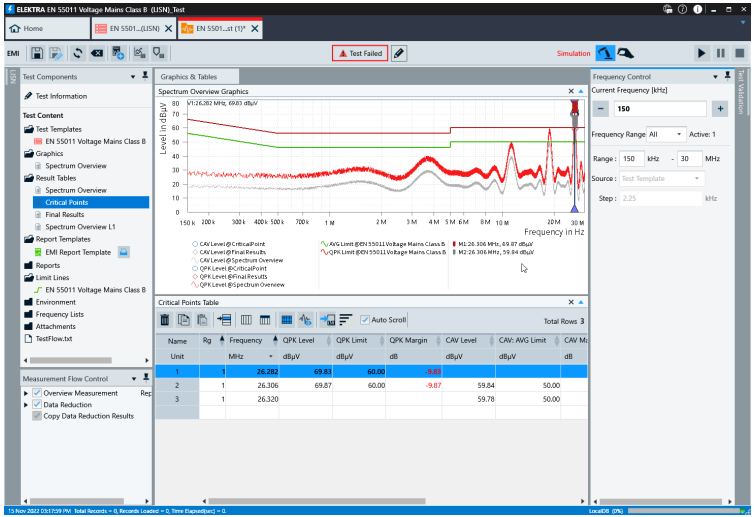
Biconical antenna

NEAR FIELD PROBES

- Work in the near field (close physical proximity)
- High spatial resolution: can be used to determine the precise source of an emission
  - Often down to a pin or trace on a PCB
- Only relative measurements
  - Good for finding sources, not for verifying limits
- Two different types: H-field and E-field
- Unless you are using a low noise oscilloscope, a preamplifier might be needed

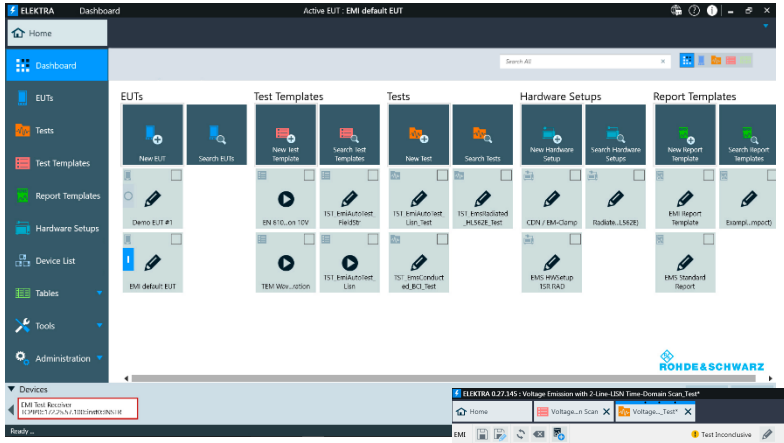
SOFTWARE(ELEKTRA)

- Software is often found in precompliance testing
- Used for scripting or automating tests
  - Can communicates with / control multiple instruments and accessories
- Collects and displays measured data
  - More sophisticated display and customization
  - Compensates for antennas, cables, etc.
  - Often can generate reports, etc.
- Higher speed and better repeatability than manual operation

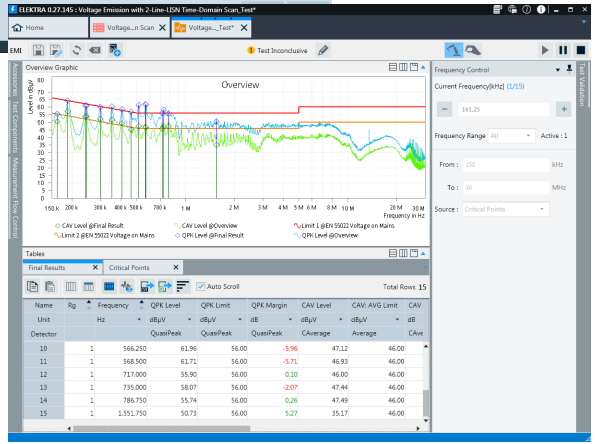


SOFTWARE(ELEKTRA)

- Intuitive, interactive and automatic EMC measurements
- Covers most common EMC standards with predefined settings/templates
- Efficient result analysis and customized reporting
- Creates test plans with multiple tests for easy management of EUTs



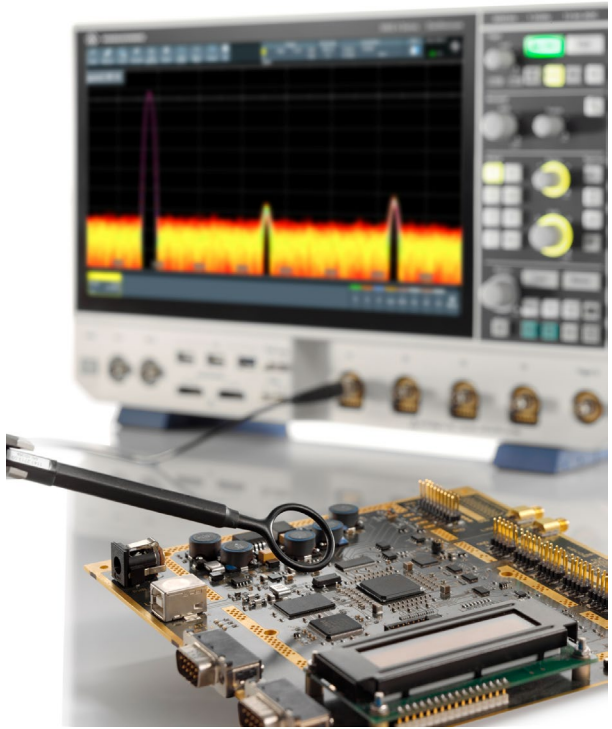
ELEKTRA Dashboard



Automated Test with Final Results

SUMMARY – PRE-COMPLIANCE

- Compliance testing is required for most electrical devices
  - Failure rate in full compliance testing is quite high
  - Redesign and retest require significant time and money
- Precompliance testing helps identify problems early
  - Faster and cheaper to correct issues
  - Increases probability of passing compliance tests
- EMI receivers, spectrum analyzers, and oscilloscopes are the primarily tools used in precompliance testing
  - Receivers / spectrum analyzers for measurements
  - Oscilloscopes for debugging
- Common accessories include LISNs, antennas, near field probes and software



SUMMARY – EMI DEBUGGING

- Undesired radio-frequency emissions can cause electromagnetic interference (EMI)
- EMI compliance is tested in the far field
  - Chambers, antennas, spectrum analyzers/ EMI receivers
- EMI debugging is performed in the near field
  - Oscilloscopes and near field probes
- Proper use of the two types of near field probes (E and H) is critical for effective EMI debugging
- FFT converts time domain to frequency domain
- Additional FFT-related functions are also helpful when debugging EMI with an oscilloscope