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Real-Time Spectral Analysis for EMC Troubleshooting

Mr. Lee Hill

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Instructor Biography

Lee Hill is Founding Partner of SILENT Solutions LLC, an independent electromagnetic compatibility (EMC) and RF design firm he established in 1992. Besides providing EMC design review and troubleshooting services, Lee is also a member of adjunct faculty at Worcester Polytechnic Institute (WPI) where he teaches graduate courses in EMC. He is also an EMC class instructor at the University of Oxford (England), and for the IEEE EMC Society's annual Global University program and EMC Fundamentals workshop. In past years Lee was also an EMC course instructor for UC Berkeley Extension as well for Hewlett Packard and Agilent Technologies. Previously Lee was Principal EMC and Systems Engineer at Digital Equipment Corporation's Workstation Systems Engineering Group in Palo Alto, CA. In 2017 Lee founded SILENT Solutions GmbH in Munich, Germany.

Lee received the Master of Science Degree in Electrical Engineering & Electromagnetics with highest honors from the University of Missouri-Rolla, (now Missouri University of Science and Technology). He is an inventor of three US patents for EMI control in electronic systems, and provides expert witness services for patent litigation.

In the past fifteen years he has been a frequent featured speaker at IEEE EMC Society fundraising events in cities throughout the US including Santa Clara, Seattle, Portland, Chicago, Milwaukee, Dallas/Fort Worth and Detroit. He has also provided technical presentations to Society chapters in Los Angeles, San Diego, Santa Clara, Boston, Austin, Colorado Springs, Pittsburgh, and Orange County, CA. He served a term as an IEEE EMC Society Distinguished Lecturer from 1994-1996.

Lee has over twenty-five years of experience in the EMC design and retrofit of complex electronic systems. He has been teaching short courses on EMC design and troubleshooting for twenty years. Lee consults and teaches worldwide, and has presented classes in Taiwan, Singapore, Mexico, Norway, Canada, South Korea, France, Germany and United Kingdom. He has completed a three-year term on the Editorial Review Board of Printed Circuit Design Magazine.. He is an avid father, runner, motorcyclist, table tennis player and Amateur Radio operator, and has served as an officer on the board of directors of several non-profits.

Lee is past member of the IEEE EMC Society Board of Directors (2004-2007). From 1999-2006 he chaired the IEEE EMC Society's Distinguished Lecturer Program, and served as Co-Technical Chair of the 2003 IEEE Symposium on EMC in Boston, MA.
In 1999 Lee received a Certificate of Appreciation from the EMC Society for significant contributions to education through his annual participation in the Demonstrations and Experiments portion of annual IEEE EMC Symposia.

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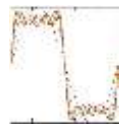
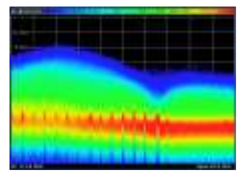
Outline

- Review of Old Measurement Technology

- Quick review of “EMI signals”



- Why I’m excited about
“Real-Time” spectral analysis &
“Persistence Display”



- Demonstration Videos

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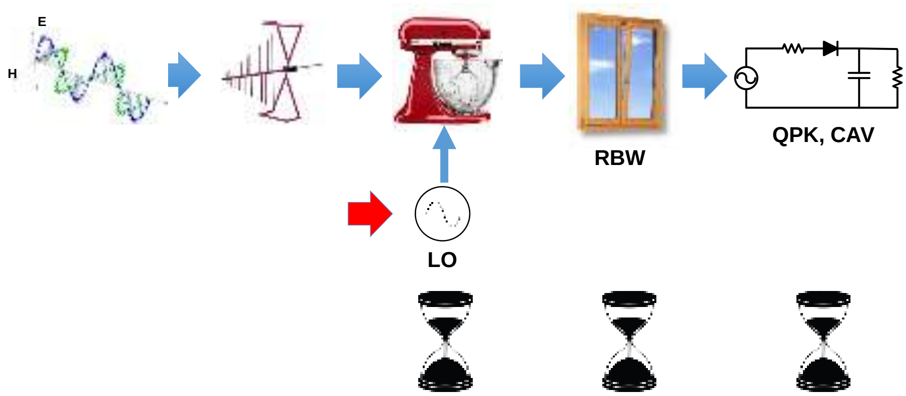
In the Old Days….
“Swept” Spectrum Analyzers
“Stepped-Tune” Receivers



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“Swept” Spectrum Analyzers
“Stepped-Tune” Receivers

- Sequentially step or sweep a narrow window across the frequency axis
- Good “intercept” with “continuous wave”, periodic signal ONLY
- Significant “blind time” when sweeping or stepping

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How “Slow” is “Slow”?
Swept-Tuned Spectrum Analyzer
vs. FFT Spectrum Analyzer

- For weak signal measurements, e.g. interference @ vehicle antenna terminals, narrow RBW is needed for low noise floor
- Where wide span is desirable to visualize wide spectral signatures, narrow RBW forces very slow sweep times
- Slow sweep times make it difficult for the EMC engineer to observe cause-and-effect changes in emissions during troubleshooting

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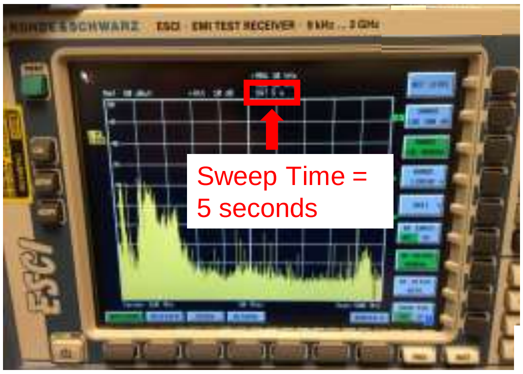
How “Slow” is “Slow”?
Swept-Tuned Spectrum Analyzer



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How “Fast” is “Fast”?
FFT Spectrum Analyzer

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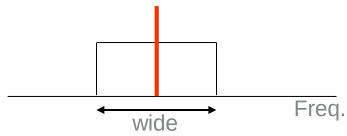
"FFT", "Fast Fourier Transform"
"Time Domain" Instruments



- Much FASTER
- Measure lots of signal frequencies simultaneously "in parallel", over a WIDE CHUNK of the frequency axis
- **Calculate** RBW instead of **waiting** for filter response
- Still some "blind time" to do processing (not "100% intercept")
- And only 1 measurement @ each frequency within a chunk

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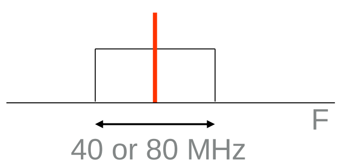
"Real-Time" FFT (Time Domain Scan)

- FASTEST – dedicated measurement hardware for FFT
- WIDE (up to 40 or 80 MHz) chunk of spectrum
- **Calculate** RBW instead of **waiting** for filter response
- Zero "blind time" "100% intercept" , within RT BW
- Multiple measurements @ each frequency in each chunk
- Allows for generation and display of signal statistics, i.e., how often and how strong a signal is present at a given frequency



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Review of Signals We're Going to See in the Demonstration

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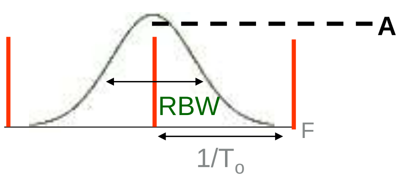
EMI Signal #1
Periodic, Continuous, "Power signal"



With proper choice of RBW, ("narrowband")

- can measure line spacing $1/T_o$
- measured amplitude "A" is NOT f(RBW)

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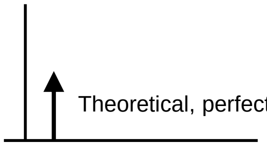
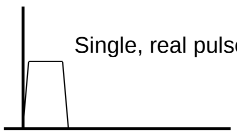
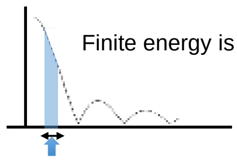
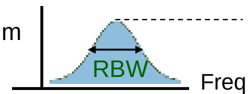
EMI Signal #2
Aperiodic, Transient, Discontinuous "Energy signal"







- With $T_o = \infty$, Fourier Transform → Energy Spectrum
- Measured amplitude "A" ▲ with ▲ (RBW)



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One Pulse

Let's (try to) watch a single pulse on a spectrum analyzer

1) Standard FFT, spectrum view. 40 MHz span. RBW = 100 kHz.
2) Real-Time FFT, spectrum view. 40 MHz span. RBW = 96 kHz

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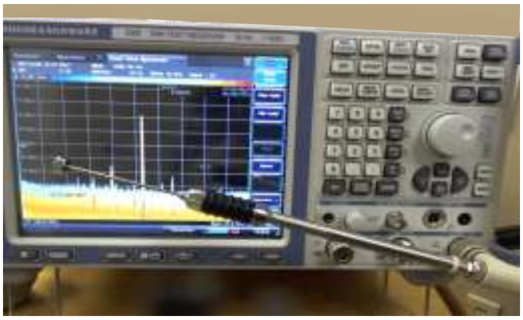
Standard FFT (NOT Real Time)

1) Standard FFT, 40 MHz span, 100 kHz RBW



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Let's Watch 100% Signal Intercept* That's Possible w/ "Real-Time" FFT

2) Real-Time FFT, 40 MHz span, 100 kHz RBW, 40 MHz RT BW*

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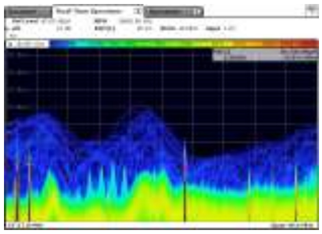
Persistence Display, a Feature of Real-Time Mode



A Totally Different Way to View, Measure, Identify EMI Sources

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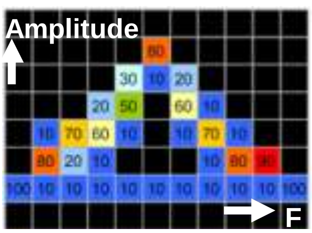
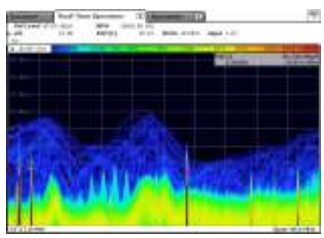
FFT, Real-Time Mode, Persistence Display





- With Real-Time, many measurements / frequency, can generate statistics
- The trace color shows how often a signal occurs at a specific frequency and amplitude
- Color = "Hit Rate" = how often signal occurs at particular frequency
  Height = amplitude of signal at particular frequency
- A signal histogram versus frequency
- Descriptive terms: % occupancy, amplitude, frequency

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Displaying “Signal under Signal” with Real-Time FFT

- At the same time (different % occupancy)
- At the same frequency (different amplitudes)

3 Different Noise Sources

Signal #1: DC motor + PWM controller	(broadband)
Signal #2: USB mouse	(broadband + narrowband)
Signal #3: 20 MHz digital clock on PCB	(narrowband)

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Real-Time FFT Displaying “Signal under Signal”

Center Freq. = 37.5 MHz Span = 40 MHz RBW = 100 kHz

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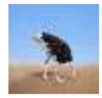

Summary – Old Technology

- **Previous generation spectrum analyzers and test receivers use "swept tuned" or "stepped tuned" architecture.**
- **OK for measuring continuous (i.e., not intermittent) periodic signals in narrow spans.**
  - When you ALWAYS know WHEN (time) and WHERE (frequency) the signal is (!)
- **Cannot**
  - reliably display pulse spectrums, or
  - visually distinguish between two or more broadband signals in a single piece of spectrum, or
  - display narrowband EMI signals "under" a larger broadband signal
- **"Blind" during large parts of sweep or step & dwell time**
- **Challenging to use for EMI debug expect for "trivial" signals like narrowband clocks that have 100% occupancy**

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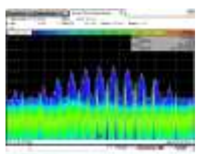
Summary: Real-Time FFT



- **100% signal intercept over a 40 or 80 MHz frequency span**.
  - FFT machines without real-time hardware will "miss" signals
- **A new intuitive way to VISUALIZE EMI signals**
  - Especially non-periodic, "blinky" and broadband signals
    (e.g., SMPS, motor control, & sparky signals - different from digital clocks)
- **The ability to clearly display "signal under signal" situations**:
  - Multiple broadband signals occupying the same frequency span
  - Weak narrowband signals "underneath" larger broadband signals
  - Multiple, co-located RF emitters that occupy the same frequency span such as Bluetooth, WiFi, Near Field Communication (NFC)

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Upcoming EMC Education from SILENT

For more EMC education with theory, applications, and live demos:

University of Oxford, England

Advanced Product Design & Troubleshooting for EMC	June 18-19
Advanced PCB Design for EMC.	June 18,20
Mechanical Design for EMC	June 18,21

Dresden, Germany

Advanced PCB Design for EMC	*April 17-18*
Mechanical Design for EMC	*April 17,19*

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