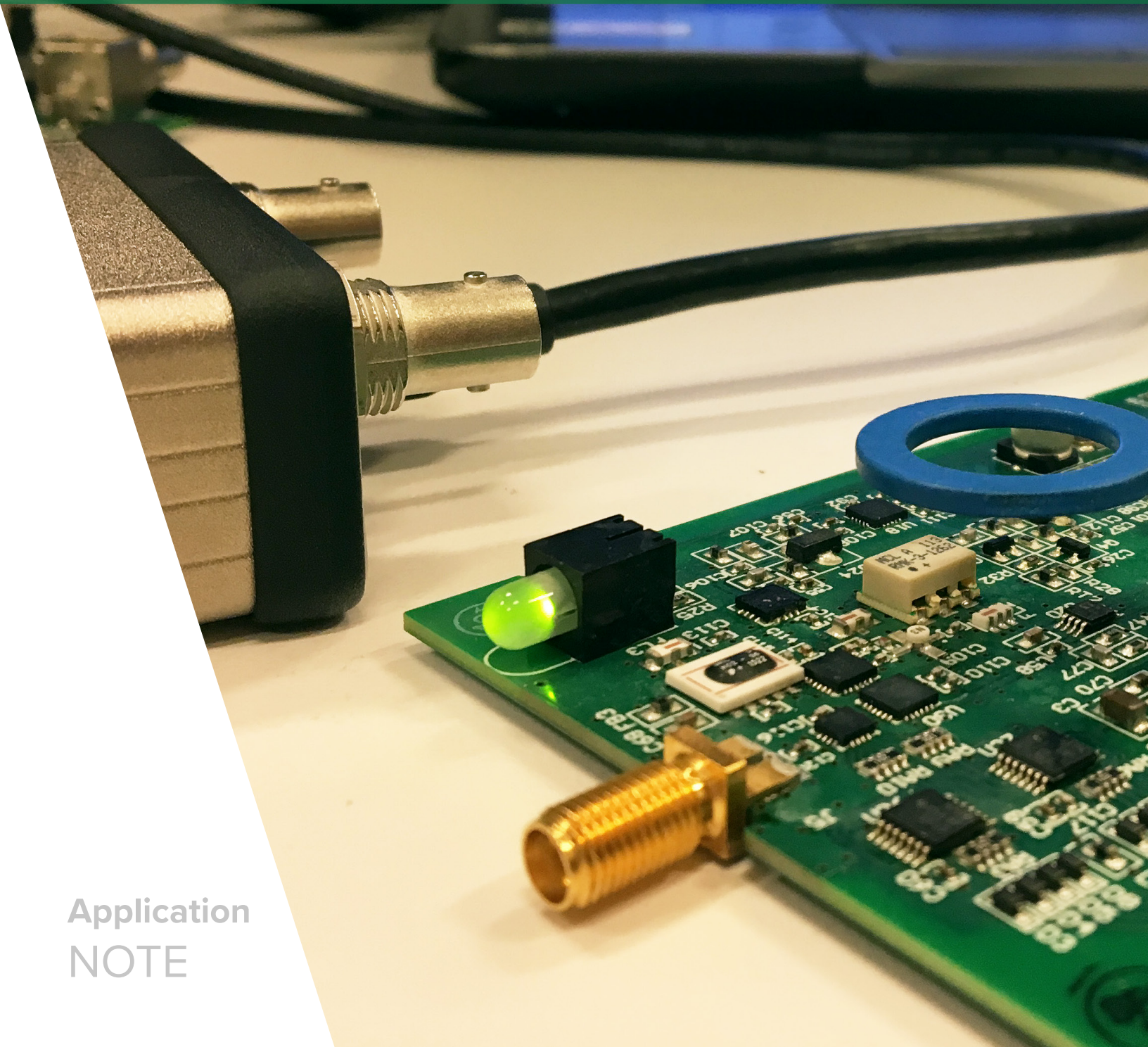




Setting Up an EMC Precompliance Radiated Emissions Test Using Signal Hound's Spike™ Software

Signal Hound — October 14, 2016



Application
NOTE

Introduction

By leveraging the Signal Hound BB60C USB-powered Spectrum/Signal Analyzer and Spike Software, users have a powerful tool to make several highly flexible EMC Precompliance measurements. One such measurement is a standards-based EMC precompliance sweep with pass/fail limits and multi-sweep capability. Each of the 10 log scaled sweep ranges that can be programmed allow for custom limits and sweep parameters to be applied. In the same display, a Spur Table and Quasi-peak, Peak, and Average Detector Meter are also available.

In order to perform a legitimate EMC test, there are many very detailed and specific tools, environments, processes, and procedures that need to be put in place with exacting detail. However, this is too costly and time consuming for many organizations working with production deadlines. So, many organizations opt for cost-effective EMC Precompliance measurements before taking their prototypes or early products to an EMC laboratory for official testing. Another thing to remember is that even with full EMC laboratory testing, any failing measurements means that further product engineering is still required before the new product becomes EMC compliant and ready for manufacturing.

There is hope, though, as tools such as the BB60C Real-Time Spectrum Analyzer (RTSA) and a set of simple antennas and probes can provide real-time EMC Precompliance measurements that can be performed while testing variations rapidly and cost-effectively. Measurements that the BB60C can help with could range from full-blown EMC mockup tests to quick troubleshooting and probing of PCBs with excessive emissions.

This tutorial will take a user through the dynamics of setting up the EMC Precompliance Sweep for conducted and radiated emissions measurements. As Path Loss Tables and Antenna Factor Tables are an important part in calibrating an EMC Precompliance Sweep test setup, these tools will also be briefly discussed.

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Step 1: Deciding what standards and measurements to make

There are a diverse range of conducted and radiated emissions tests that can be performed along with several standards that can be applied. The standards to apply, ultimately, are decided by the geographic regions in which the device will operate, the application, and the frequency range of operation of the device. There are European (EN), International (ISO, IEC, CISPR), US FCC, and US Military standards for conducted and radiated emissions, as well as many others. The Signal Hound BB60C RTSA and Spike software can be very effective tools for performing EMC Precompliance measurements during product development, and as quality control sampling during the manufacturing of electronic products.

The tables below contain some common measurement examples:

CISPR 16-1-1 BANDWIDTH, RBW, & FREQUENCY RANGE			
Band	Frequency Range	Bandwidth (6dB)	RBW
A	9 – 150 kHz	100 – 300 Hz	200 Hz
B	0.15 – 30 MHz	8 – 10 kHz	9 kHz
C + D	30 – 1000 MHz	100 – 500 kHz	120 kHz
E	1 – 18 GHz	300 – 2000 kHz	1 MHz

ANSI C63.2 BWS & FREQUENCIES FOR PEAK, AVERAGE, & RMS DETECTORS	
Frequency	Bandwidth
10 Hz – 20 kHz	10, 100, and 1000 Hz
10 – 150 kHz	1 and 10 kHz
150 kHz – 30 MHz	1 and 10 kHz
30 MHz – 1 GHz	10 and 100 kHz
1 – 40 GHz	0.1, 1.0 and 10 MHz

MIL-STD-461E FREQUENCY RANGE & BANDWIDTHS	
Frequency	Bandwidth
30 Hz – 1 kHz	10 Hz
1 kHz – 10 kHz	100 Hz
10 kHz – 100 kHz	1 kHz
150 kHz – 30 MHz	10 kHz
30 MHz – 1 GHz	100 kHz
1 GHz +	1 MHz

It is important to understand exactly what tests and measurements need to be conducted. The closer a precompliance test resembles an EMC test, the greater potential that test has to reflect what could be the results in an EMC test. The less accurate the test, the more time and over-engineering may be spent on correcting an emissions problem that has been exaggerated. Or, an emissions problem could be under-emphasized by several dB, which could lead to a failure in a real EMC test. The following steps in the tutorial will focus on setting up an EMC precompliance radiated emissions test using a Signal Hound BB60 and Spike Software version. This tutorial will not cover a rigorous review of how to set up a fully compliant EMC test, but will discuss some of the components in doing so.

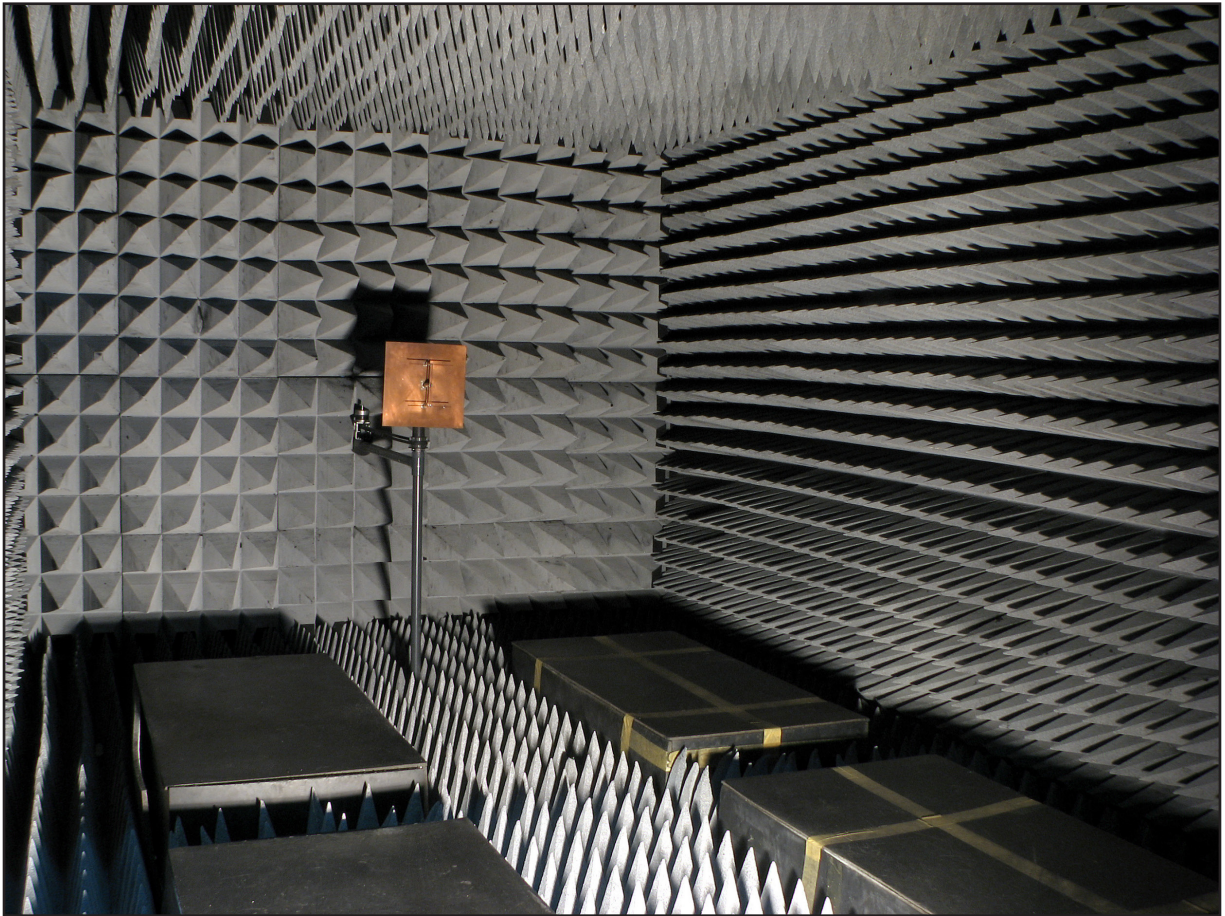


Figure 1—An Anechoic Chamber is an expensive, but often necessary, method of EMC testing. This chamber absorbs electromagnetic energy internal to the chamber, preventing reflections while preventing intrusion of external electromagnetic interference from adding error to measurements.

Step 2: Develop Path Loss Tables

Path Loss Tables are power level correction tables that enable Spike to adjust for loss or gain in system components not under test. This typically applies to interconnect components, attenuators, preamplifiers, and any components with a significant amount of loss (see Figure 2). These tables are important in EMC Precompliance and testing, as the interconnect and signal conditioning components necessary to connect the antenna to the test equipment can impact the measurement readings.

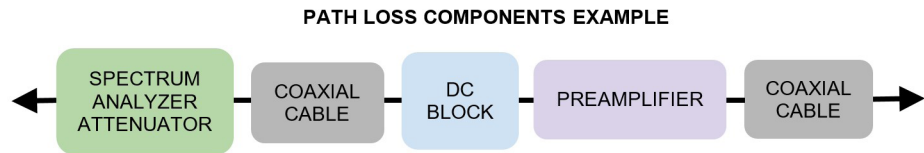


Figure 2—There are several interconnect, attenuation, and amplification components typical to a radiated emissions EMC Precompliance test.

Path Loss Tables in Spike are implemented as frequency and dB correction pairs [frequency, dB]. The Path Loss Tables editor can be accessed through the “Utilities” menu at the top of the Spike Control Panel. This panel gives access to three editable path loss tables and one antenna factor correction table. The editor can be used to create, load, and save Path Loss Tables. Aside from the EMC Precompliance mode in Spike, path loss tables are also applied to standard swept analysis, real-time spectrum analysis, and scalar network analyzer sweep modes (see Figure 3).

The correction factors in the Path Loss Tables are applied to the measured data before being displayed or processed. Spike will normally extend the first and last entry in the Path Loss Table to the start and end of the frequency sweep. If this is not desirable, the Path Loss Table first and last entry can be padded with a zero to limit the corrections to the Path Loss Table entries.

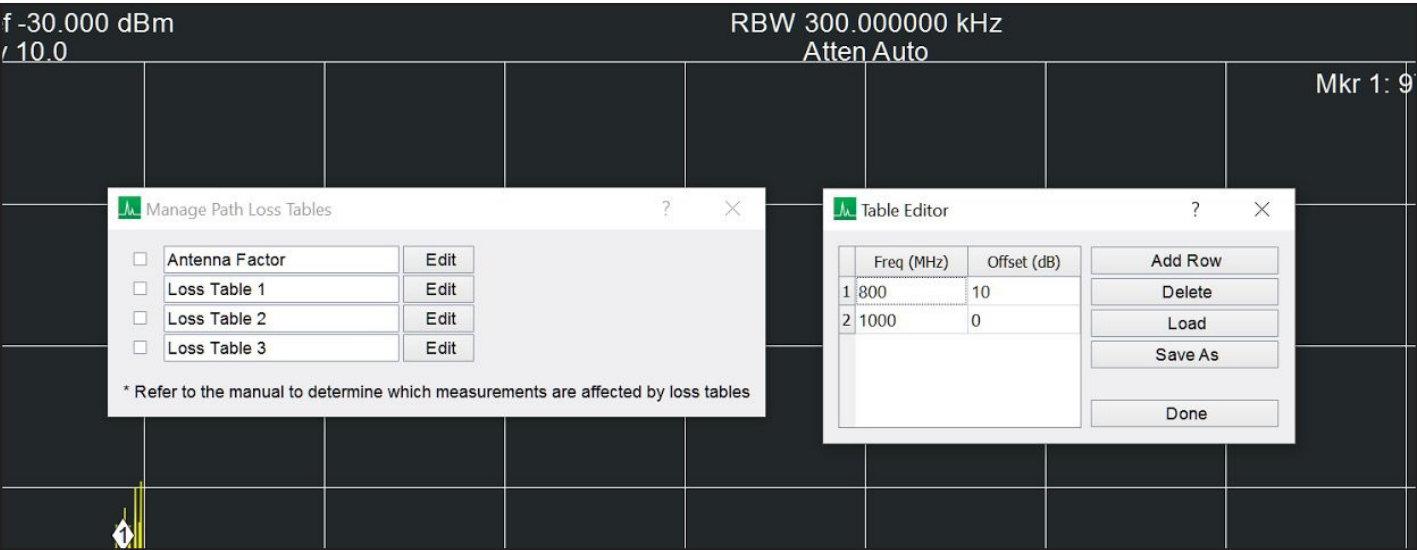


Figure 3—Up to 3 Path Loss Tables and 1 Antenna Factor Correction Table are accessible through the Path Loss Table Manager in Spike, where the tables can be manipulated by **Add Row**, **Delete Row**, **Load**, and **Save As** features.

Step 3: Develop Antenna Factor Correction Tables

Similar to Path Loss Tables, Antenna Factor Correction Tables are used to calibrate the performance of an antenna to provide more accurate representations of emissions test power levels. Antenna Factor Correction Tables are often contained as frequency and dB/m pairs, as the standard EMC method calibrates antennas based on electric field strength measurements. Spike uses this method, and one Antenna Factor Correction Table can be created, edited, loaded, and saved in the Path Loss Table Manager. As with the Path Loss Tables, the first and last entry of the table may need zero padding to avoid correcting to either extreme of the frequency sweep.

As many antennas will only provide the antenna gain information in an antenna datasheet, equations that can convert the antenna gain to an antenna factor can be used. This equation is used for far-field antenna response. For antennas, such as magnetic-field and electric-field probes, the appropriate antenna factor response will need to be calculated from the datasheets.

Converting from antenna gain:

$$AF(dB/m) = 20 \log \left(\frac{2\pi}{\lambda} \sqrt{\frac{2.4}{10^{\frac{G}{10}}}} \right), \quad \begin{array}{l} \lambda = \text{wavelength in meters} \\ G(dBi) = \text{Antenna Gain} \end{array}$$

Magnetic field probes:

$$AF(dB[\frac{A}{Vm}]) = 20 \log \left(\frac{H_{inc}}{V_{out}} \right), \quad \begin{array}{l} H_{inc} = \text{Incident Magnetic Field} \\ V_{out} = \text{Voltage Out} \end{array}$$

Electric Field Probes:

$$AF(dB[\frac{V}{m}]) = 20 \log \left(\frac{E_{inc}}{V_{out}} \right), \quad \begin{array}{l} E_{inc} = \text{Incident Electric Field} \\ V_{out} = \text{Voltage Out} \end{array}$$

Step 4: Setup Range Table/Limit Line Table

Range Tables and Limit Lines are used in precompliance measurements to gauge the behavior of emissions by providing pass/fail regions of the frequency sweep. The Limit Lines of a Range Table are dictated by the various standards, which also dictate the settings of the resolution bandwidth filter (RBW) and other EMC standard specific settings. Fortunately, the engineers at Signal Hound have developed a Range Table utility that can easily be adapted or customized to various standards with the following settings. Spike comes equipped with flat-top 3dB RBW filtering and 6dB CISPR RBW Gaussian filtering:

RANGE TABLE CONFIGURATION PARAMETERS (SPECIFICALLY FOR SPIKE SOFTWARE)	
Load Default	Load the default range table inputs.
Save Table	Save the current table setup to a CSV file.
Load Table	Load a previously save table setup. This overrides the current setup.
Enabled	Enable or disable the selected range. Enabling ranges are swept and shown on the sweep display.
Start Freq.	Select the start frequency of the selected range.
Stop Freq.	Select the stop frequency of the selected range.
RBW Shape	Select between the 6dB CISPR RBW (Gaussian) or Flattop 3dB RBW filter.
RBW	Resolution Bandwidth.
VBW	Video Bandwidth.
Auto VBW	When enabled, tracks RBW. When disabled, VBW must be equal to or lower than RBW.
Video Units	Video processing unit type.
Detector	Select between Peak and Average detectors.
Dwell Time	Select the duration the spectrum analyzer dwells at any given frequency. This is helpful for capturing a periodic event. It is recommended to have the peak detector enabled when increasing dwell time.
Threshold	Minimum signal level for a signal to be considered a spur. This value must be lower than the limit setting.
Limit	Set the level at which a signal is considered to fail the test setup.
Selectivity	Determines how sensitive the spur detector is. Higher values increase the necessary separation needed for a signal to be considered a spur. Caution: low selectivity values may greatly increase the number of reported spurs.

The EMC Precompliance module in Spike displays the Range Table Manager with the Load Default, Save Table, and Load Table options, below the Frequency Scan Display (see Figure 4). Each of the elements of the Range Table can be manipulated with the above feature options, and even disabled/enabled easily.

Range Table														
Load Default	Enabled	Start Freq.	Stop Freq.	RBW Shape	RBW	VBW	Auto VBW	Video Units	Detector	Dwell Time (ms)	Threshold (dBuV)	Limit Start (dBuV)	Limit Stop (dBuV)	Selectivity (dB)
Save Table	1 Enabled	9.000000 kHz	150.000000 MHz	CISPR	200.000000 Hz	200.000000 Hz	Auto	Power	Peak	1.000	40.000	60.000	60.000	6.000
Load Table	2 Enabled	150.000000 kHz	30.000000 MHz	CISPR	9.000000 kHz	9.000000 kHz	Auto	Power	Peak	1.000	40.000	50.000	50.000	6.000
	3 Enabled	30.000000 MHz	1.000000 GHz	CISPR	120.000000 kHz	120.000000 kHz	Auto	Power	Peak	1.000	40.000	65.000	65.000	6.000
	4 Disabled	1.000000 GHz	1.800000 GHz	CISPR	1.000000 MHz	1.000000 MHz	Auto	Power	Peak	1.000	40.000	60.000	60.000	6.000
	5 Disabled	150.000000 kHz	30.000000 MHz	CISPR	9.000000 kHz	9.000000 kHz	Auto	Power	Peak	1.000	40.000	60.000	60.000	6.000
	6 Disabled	150.000000 kHz	30.000000 MHz	CISPR	9.000000 kHz	9.000000 kHz	Auto	Power	Peak	1.000	40.000	60.000	60.000	6.000
	7 Disabled	150.000000 kHz	30.000000 MHz	CISPR	9.000000 kHz	9.000000 kHz	Auto	Power	Peak	1.000	40.000	60.000	60.000	6.000

Figure 4—The Range Table Manager in Spike enables complete control of the Range Table properties, and can be adjusted to comply with a wide range of US, European, International and Military standards.

Not to be confused with the Limit Lines available in the EMC Precompliance mode, Limit Lines Tables in regular spectrum analysis modes can be loaded or cleared in Spike by selecting the “File” menu option, then the “Import” selection option, and lastly selecting either “Import Limit Lines” or “Clear Limit Lines”. This is not the same as the Range Table information, but it may aid in EMC Precompliance troubleshooting or Interference Hunting applications.

Step 5: Assemble and Calibrate Test System (TEM Cell Example)

Depending on the test being performed, there are a large variety of test assembly and calibration procedures that can be followed. Additionally, there are a variety of methods that can be used to enhance the accuracy of an EMC Precompliance test, however, these are beyond the scope of this work. An example assembly (see Figure 5) and the calibration procedure is roughly detailed below. This procedure uses a transverse electromagnetic (TEM) cell and a spectrum analyzer to measure the radiated emissions from a flat semi-rectangular DUT, such as a microprocessor PCB.

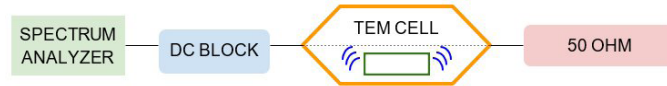


Figure 5—An example low-cost EMC Precompliance test setup using a TEM cell and a Spectrum Analyzer.

EMC Precompliance TEM Cell with Spectrum Analyzer Setup Procedure:

1. Connect the Spectrum Analyzer to the DC Block with 50 Ohm Coaxial Cable
2. Connect the DC Block to the TEM Cell with 50 Ohm Coaxial Cable or Via Direct Connection
3. Connect the Free Terminal of the TEM Cell to a 50 Ohm Termination
4. Place DUT under TEM Cell Septum
5. If The Spectrum Analyzer is a BB60C:
 - a. Connect The Signal Hound Real-Time Spectrum Analyzer to a USB 3.0 Enabled PC with Spike Software Installed
6. Initiate Spectrum Analyzer EMC Precompliance Test Mode
 - a. Initiate EMC Precompliance Test Mode
 - b. Load Path Loss Tables
 - c. Load Antenna Factor Correction Table
 - d. Load Range Table or EMC Compliance Standard Program
7. Turn On DUT and Begin Testing

Additionally, there are some methods that adapt magnetic and electric near-field probes (see Figure 6) to far-field response. Though the accuracy of this method may not be up to EMC standards, if performed carefully, this test could be used to isolate, troubleshoot, and enhance a failing area of a complex DUT. The setup procedures for this process is as follows:

Magnetic & Electric Field Probe Setup Procedure:

8. Connect the Probe Antenna to the Preamplifier (If Applicable)
9. Connect the Spectrum Analyzer to the EMC Precompliance Probe
10. If the Spectrum Analyzer is a BB60C
 - a. Connect the Signal Hound Real-Time Spectrum Analyzer to a USB 3.0 Enabled PC with Spike Software Installed
11. Initiate Spectrum Analyzer EMC Precompliance Test Mode
 - a. Initiate EMC Precompliance Test Mode
 - b. Load Path Loss Tables
 - c. Load Antenna Factor Correction Table
 - d. Load Range Table or EMC Compliance Standard Program
12. Turn On DUT and Begin Probe Testing



Figure 6—A set of near-field probes for performing radiated emissions EMC pre-compliance measurements.

Step 6: Run Test

Once the initial EMC Precompliance set up is performed, the EMC Precompliance Frequency Scan and spur selection are conveniently automated in Spike Software. The Frequency Scan Display will respond to the configuration of the Range Table and a default scan setting. The pass/fail indicator is located at the top middle of the Frequency Scan Display. Failing spurs will be tagged in the “Peak Table”, which can be selected at the bottom of the Spike window, and the spurs can be further analyzed.

Step 7: Analyze Frequency Scan Display for Pass/Fail

There are several tools available to analyze the signal characteristics and dynamics within the EMC Precompliance window (see Figure 7). Markers and trace display options can be used to further analyze and detect transient effects, which can then be documented and analyzed further in real-time measurement modes.

Marker Controls are also provided, which can be used to perform a Peak Search and send the results to the reference or to the peak, quasi-peak, and average (RMS) meter when it is being run. The Marker Data will appear in the upper right side of the Frequency Scan Display (see Figure 8), and can be sent to the Bar Meter Plot for deeper evaluation and documentation of the frequency behavior at the marker location.

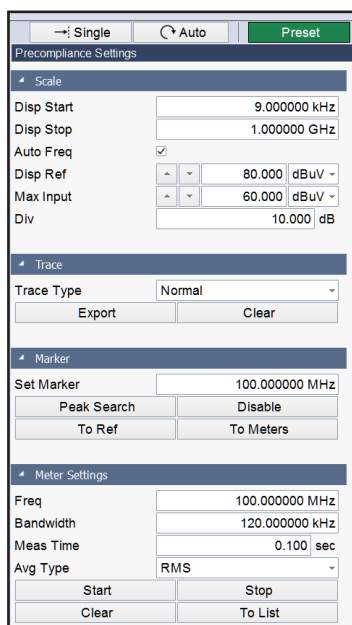


Figure 7—The Precompliance Settings Manager can be used to customize and control the EMC Precompliance Module within Spike Software.

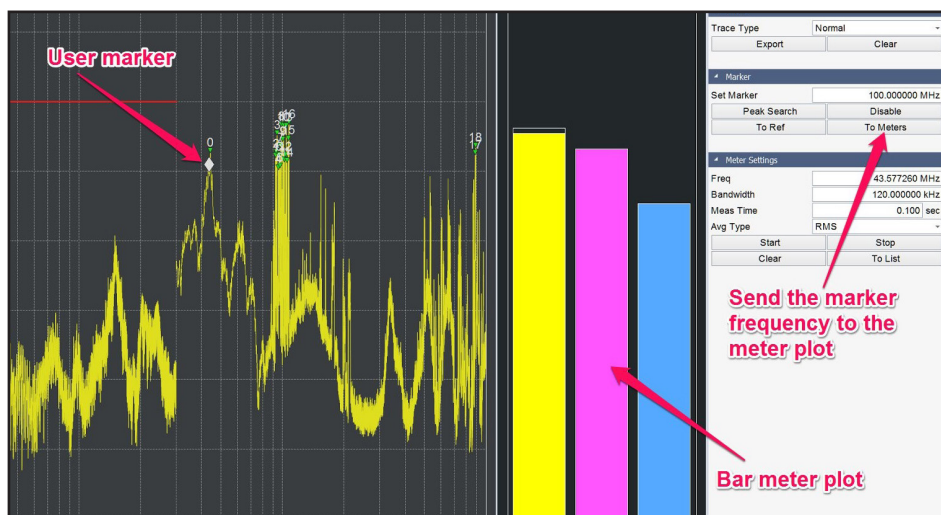


Figure 8—Any frequency of interest can be explored with the Marker feature, including sending the marker frequency to the meter plot for further investigation and documentation.

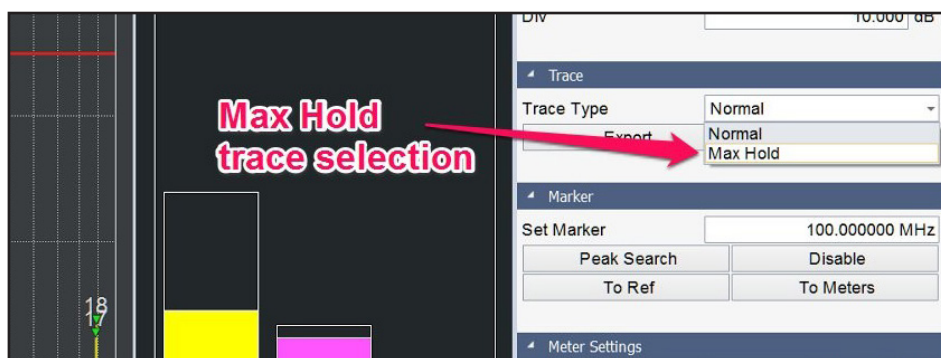


Figure 9—The Max Hold feature in the Trace control options in Spike Software's EMC Precompliance Module can easily be accessed in order to reveal transient emissions behavior.

If needed, the Trace Type of the Frequency Scan Display can be adjusted to Max Hold (see Figure 9), which will only update as the frequency response of the DUT exceeds the last greatest setting. This feature can be used to illuminate the worst case transient behavior and can be used to isolate transient spurs.

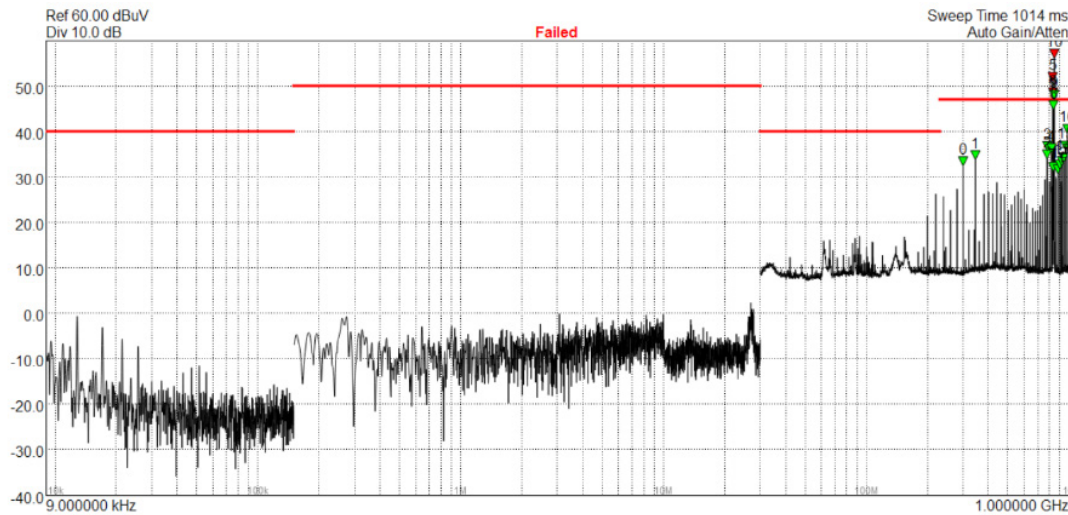


Figure 10—Any spur violating a Limit Line will lead to a failed condition, which can be further investigated with the Bar Meter Plot, Markers, Peak/Spur Table, and data recording features of Spike Software's EMC Precompliance Module.

Step 8: Analyze Spur Table for Pass/Fail Details or Spurs of Interest

A failed condition can be further investigated with the Peak Table (see Figure 11), as each emissions spur that exceeds the spur limit will be numbered in an ascending frequency sequence. The Peak Table can be accessed from the bottom tab selection, along with the Range Table and Meter Readings.

Peak Table					
Export Spur Table		Spur	Range	Freq	Amp (dBuV)
Selected Spur To Meter					Limit (dBuV)
		0	3	101.91408...	40.63
		1	3	103.57424...	42.20
		2	3	104.23830...	45.87
		3	3	105.17580...	47.59
		4	3	106.77736...	50.83
		5	3	107.46095...	52.52
		6	3	174.31644...	40.50
Range Table Peak Table Meter Readings					

Figure 11—Each spur that exceeds a certain dictated limit will be marked in the Frequency Scan Display and assigned an identifier number. This corresponds to the information contained in the Peak Table in Spike Software.

Step 9: Deeper Analysis of Individual Spurs with The Bar Meter Plot

Spike Software leverages a unique digital quasi-peak detector algorithm which performs the quasi-peak detection function otherwise only performed with expensive EMC receiver test sets. The quasi-peak detector is important, as some EMC standards specifically require quasi-peak detection readings for spur analysis, as displayed in the following table.

QUASI-PEAK DETECTOR DEFINED BY CISPR 16.1 & ANSI C63.2 STANDARDS		
Frequency	Charge Time Constant	Discharge Time Constant
10 – 150 kHz	45 ms	500 ms
150 kHz – 30 MHz	1 ms	160 ms
30 MHz – 1 GHz	1 ms	550 ms

The Bar Meter Plot (see Figure 12) can be used to analyze any spur selected, either from the Peak Table using the Selected Spur To Meter option, or the Marker selection being sent to the Bar Meter Plot with the To Meter option. Firstly, the Bar Meter Plot must be initiated from the Meter Setup portion of the Precompliance Settings menu. The Bar Meter Plot can be controlled with the Start, Stop, Clear, and To List functions. To List will send the current Bar Meter Plot readings to the “Meter Readings” selection tab at the bottom of the Spike Software Window.

The Bar Meter Plot’s frequency, bandwidth, measurement time, and average type can also be adjusted manually by the user. These features can be useful for investigation and documentation purposes. The Max Hold function also applies to the results displayed in the Bar Meter Plot.

The Bar Meter Plot Meter Readings can be exported for recording purposes. A variety of EMC standards dictate the use of a quasi-peak detector in analyzing and reporting functions. Typically, a max-hold trace setting is applied to identify the worst-case response of the spurs, or troubled areas, then the bar meter plot with quasi-peak detector is applied to the spur of interest. These results are then analyzed to ensure a particular spur or signal area of interest is within the limit line threshold.

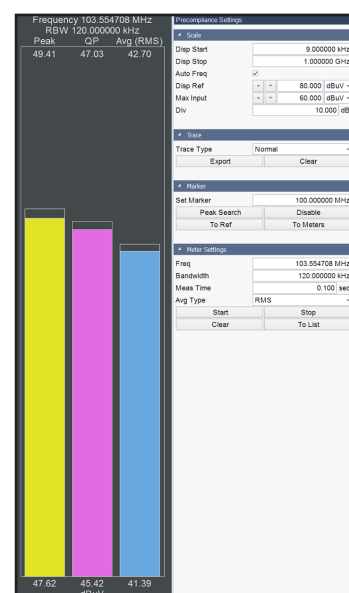


Figure 12—The Bar Meter Plot presents the peak, digital generated quasi-peak, and RMS average readings of any spur or marker selected location in the EMC Precompliance Module of Spike Software.



Further Reading

For more EMC analysis information download the Spike software manual from signalhound.com/spike.

About Signal Hound

Signal Hound designs and builds powerful, affordable spectrum analyzers and signal generators for engineers and RF professionals around the globe. Whether you're needing EMC precompliance capabilities in a small two-person shop or spectrum monitoring on a national scale, our test equipment is designed with you in mind. Accurate and powerful enough for mission-critical RF analysis, priced at a point accessible to most, and supported by a talented group of engineers committed to what they do – we truly believe that our devices offer unrivaled value in the test equipment industry.

In business since 1996 and selling our own line of Signal Hound test equipment since 2010, we've built the foundation of our company on years of test equipment repair, service, hardware and software development, and manufacturing experience. Signal Hound is a small company with big goals – and an even bigger commitment to providing our customers with an outstanding experience when purchasing and using our products.

