The Future of EMC Test Laboratory Capabilities

White Paper

The complexity of modern day electronics is increasing the EMI compliance failure rate. The result is a need for better EMI diagnostic capabilities at EMC test laboratories, as well as test speed improvements associated with iterative testing. Real-time mode enables a visualization of the spectrum that in turn provides valuable insight into identifying the sources of failing EMI emissions.

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White Paper

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1 Introduction

The growing complexity of electronic devices within both military and commercial products has lead to a significant increase in failure rate of EMC conformance testing. Product design cycle times continue to decrease due to competitive pressure in the market.

Product design companies are spending more money on multiple iterations of product EMI compliance testing at EMC test laboratories, and this comes at a significant financial cost. Product launch delays caused by EMI compliance failure further increases costs. Many companies calculate ROI (return on investment) based on the average number of times they must pay for a product to be repeatedly tested at an EMC test laboratory, but it often makes more financial sense for companies to invest in their own pre-compliance test solutions. Therefore there is a trend for companies to invest more in their own pre-compliance test equipment solutions.

What these companies need is an EMI test equipment suite/system that is better equipped to help them troubleshoot their failures. They can then quickly iterate the full-compliance testing and finish within the allocated time, even if failures occur.

More and more, the market will expect the EMC test laboratories to help them troubleshoot failures discovered during testing, and fast iterative testing maximizes the chances of products passing within the initial budgeted time. EMC test laboratories that are able to meet the changing needs of their customers will be well-positioned for future growth.

This white paper describes the cause of the shift in failure rate that many companies are experiencing, the need for increased speed in testing, and the revolutionary EMI diagnostic capability built into modern EMI receivers.

2 The Increase in Failure Rate of EMI Compliance Testing

The growing complexity of the electronics within both military and commercial products in causing a significant increase in failure rate of EMC conformance testing. The question is why?

There is on ongoing tendency to integrate predesigned "OEM" subassemblies into products that traditionally did not make use of this type of technology. From microelectronics in toilets to digital controls in motors to embedded wireless modules in almost every imaginable product, companies are integrating new types of circuits that fall outside of their traditional area of experience/expertise. This trend will only continue.

As the semiconductor industry continues to implement higher clock frequencies and shorter edge times, test failures caused by radiated emissions are recorded at ever-increasing rates. Switching power supplies are one example: in order to reduce the size of the power supply the clock rates of the switchers continues to increase

The most common radiated emissions test failures observed at EMI compliance testing at EMC test laboratories are caused by broadband periodic and broadband intermittent/pulsed sources. These types of failures are not typically found in the pre-compliance phase of testing, largely because of the limited ability of the measurement system to adequately visualize the resulting spectral signature. Most EMC test laboratories use some combination of a) swept-tuned spectrum analyzers, b) step-tuned test receivers, and/or c) a non real-time FFT based spectrum analyzer. The measurement challenge of visualizing and measuring broadband intermittent sources is finding the optimal balance between speed of testing (shorter dwell times) and high probability of intercept (longer dwell times). Shorter dwell times enable faster product EMI testing, but decrease the probability that each and every intermittent signal will be captured and properly measured. In contrast, longer dwell times greatly increase the probability of signal interception, but at the expense of longer overall test times.

3 Traditional Methods of EMC Spectrum Analysis

The spectrum analyzer has been the traditional instrument of choice of the EMC community. There has been a shift from spectrum analyzers to EMI receivers whose architectures are optimized for EMI measurements. Although the detailed architectural differences between spectrum analyzers and EMI receivers are beyond the scope of this white paper, one main difference is pre-selection, which is necessary to comply with CISPR 16-1-1 2010 for low pulse repetition rates.

It is becoming increasingly common for EMC test laboratories to support their customers in identifying failing emissions and performing short cycle iterative testing within the budgeted time constraints. Traditional test laboratory EMI debug capability is often limited to frequency and max-hold amplitude reports.

Max hold sweeping consists of setting the trace to max-hold and continuously sweeping the desired frequency range. Care must be taken to keep the sweep time long enough to not compromise the output of the resolution bandwidth filter. Sweeping too fast results in lower amplitude and slightly higher frequency measurements.

Zero-span time sweeping is commonly used after a problematic frequency has been identified as shown in Fig. 3-1. Here a pulse repetition rate can be measured for an emission at a constant frequency and pulse repetition rate.

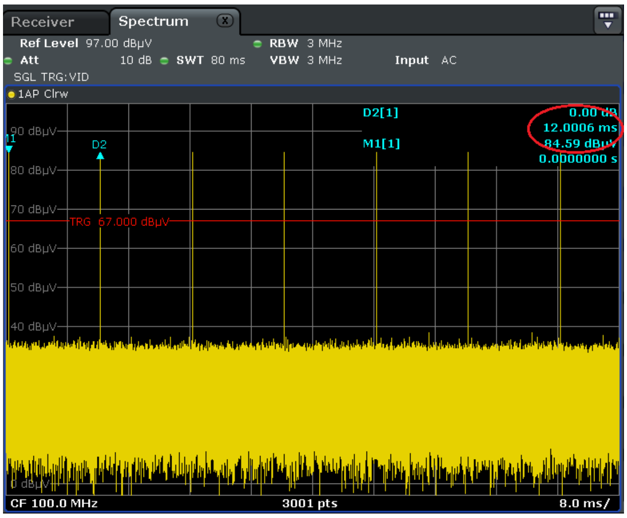

Fig. 3-1

However, zero-span time sweeping is of limited use when the source varies with frequency. This is because the energy may enter and leave a resolution bandwidth filter set to a single constant frequency. Furthermore, in zero span mode, broadband noise superimposed with narrowband interferers will produce a display that gives little insight to understanding what is actually happening in the spectrum. As discussed later in this paper, the spectrogram display in real-time mode solves this frequency dependence problem.

4 The Need For, and Evolution of, Speed: Time Domain Scan

Product design companies typically pay for a full day of testing in a full-compliance EMC test laboratory. If the product passes the first time, measurement speed is not an issue for either the customer or especially for the EMC test laboratory, since it now enjoys the revenue for a full day's work even though only a few hours were actually spent testing.

However, once a failure occurs, the need to troubleshoot the failure and iteratively test within the allocated day is of the utmost importance, both to the customer and increasingly so to the EMC test laboratory. Why to the EMC test laboratory? If one EMC test laboratory can provide a significantly better chance of quickly performing the EMI diagnostics and then provide an increased measurement speed more iterations of EMI troubleshooting can performed. Time domain scan can drastically reduce the measurement time and maximize the number of troubleshooting test iterations. The end result is maximizing the chance of customer success within the allocated time frame.

Time Domain Scan, which is relatively new to the EMC community, involves calculating the spectrum from a time series of ADC (analog-to-digital converter) samples using an FFT (Fast Fourier Transform). Integrity of the measured frequency amplitude is assured by the proper choice of windowing as described in CISPR 16-1-1. Although a thorough description of Time Domain Scan is beyond the scope of this white paper, more detailed information can be found in the Rohde & Schwarz Application Note "Comparison of Time Domain Scans and Stepped Frequency Scans in EMI Test Receivers".

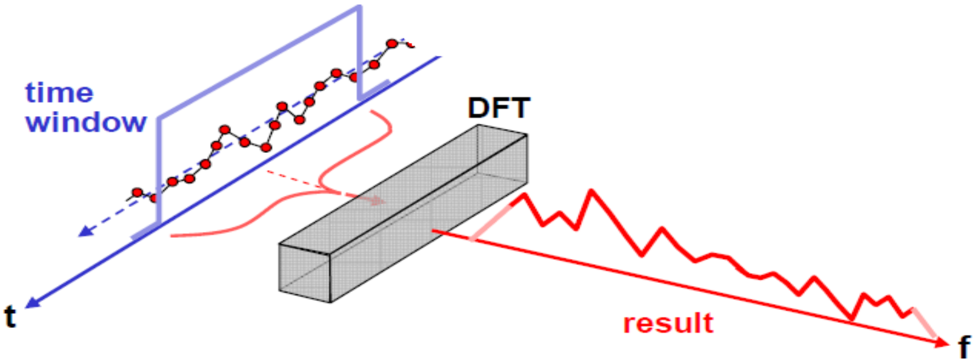

Fig. 4-1

Time Domain Scan provides a measurement speed significantly greater than the traditional frequency swept method typically used in the EMC community, particularly at lower frequencies where smaller resolution bandwidths are specified. This increase in speed is necessary when time is limited due to failures that may consume the limited time remaining within the budgeted day.

5 EMI Diagnostics: Real-time

Swept spectrum analyzers sweep through the spectrum continuously measuring the energy in the resolution bandwidth filter. However, this also means that one measurement point/frequency is taken at a single point in time and activity in other parts of the spectrum are not detected. In receiver mode, the receiver steps through the frequencies one at a time in discreet steps defined in the configuration. The benefit is increased accuracy since the exact frequency of the measurement is known and the receiver can dwell at that frequency for the configured dwell / measurement time. As discussed in the prior section, a significant advantage of time domain scan is the speed improvement over receiver mode due to many frequencies being measured simultaneously, in parallel. Another major advantage of time domain scan is the ability to monitor the entire FFT measurement bandwidth simultaneously such that all events within the real-time bandwidth are detected / captured, greatly increasing the probability of detecting an intermittent emission or emissions.

As per the CISPR standard, time domain scan must continuously sample the input signal for the entire duration of the dwell or measurement time such that no data is lost, resulting in gap-free acquisition and processing. This is necessary to avoid drop-outs which may result in missing intermittent or pulsed signals. "Real-time" refers to the ability of the measurement equipment to continuously acquire and process the data without loss by means of gap-free acquisition and processing.

The enhanced processing power in modern EMI receivers that enables real-time operation also enables the display of the real-time spectrum capture in new graphical formats. These new graphical formats provide a visualization of the spectrum yielding a revolutionary EMI diagnostic capability. The two main displays are the spectrogram and persistence mode.

5.1 The Spectrogram Display

Traditional measurements provide the peak spectrum measurements, but do not provide the time nature of the signal causing the failure. Spectrogram displays show the history of the spectrum, and this yields valuable insights into the nature of the emission. Fig. 5-1 shows the traditional instantaneous spectrum in the upper plot and a spectrogram in the lower plot.

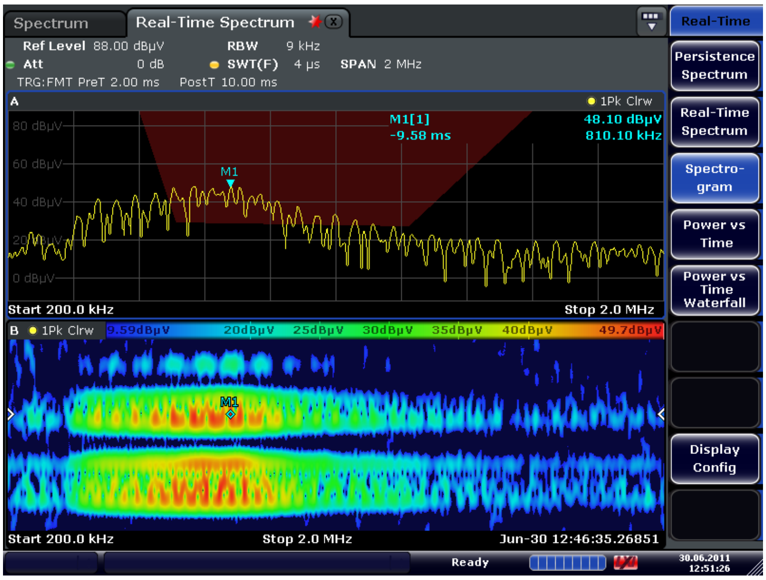

Fig. 5-1 Instantaneous Spectrum and Spectrogram Displays

The spectrogram display shows all three dimensions of frequency, signal level, and time. Frequency is displayed on the x axis and corresponds directly to the frequency axis in the traditional upper display. The color of the spectrogram indicates the signal level - red is higher signal level and deep blue to black is lower signal level. The color setting is user-configurable to optimize the visual display. Each row in the spectrogram represents the spectrum at a slice in time. The next row indicates the spectrum at the next slice in time*. The spectrum continues to move down and hence the spectrum has an appearance similar to a waterfall (another common term for spectrogram). The result is an intuitive graphical representation of the signal over time.

* This is true only in a real-time mode of operation, not traditional spectrum analyzer frequency swept mode or EMI receiver frequency stepped mode where there can be gaps in time between successive rows in the spectrogram.

Here Fig. 5-2, Fig. 5-3, and Fig. 5-4 show a sequence of three consecutive screen shots depicting the waterfall nature of the spectrogram display. The spectrogram display provides the ability to detect broadband intermittent emissions. Notice that the change in spectrum over time indicates an intermittent (possibly periodic) broadband emission. Traditional spectrum analyzers utilizing max-hold sweeping will only detect the maximum emission, with no ability to display the spectrum over time. Viewing the time history of the spectrum yields valuable clues in determining the source of the emission.

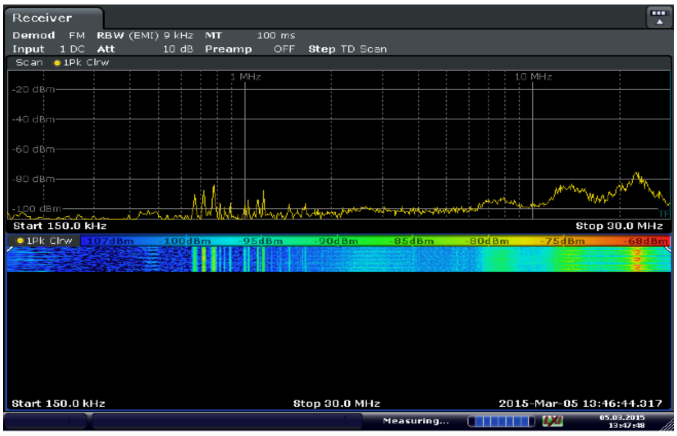

Fig. 5-2

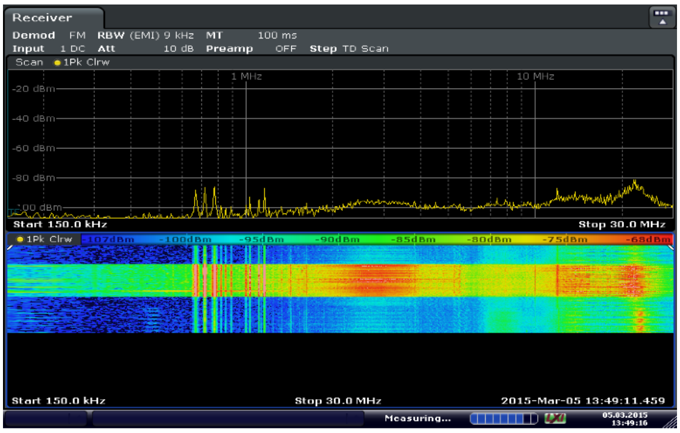

Fig. 5-4

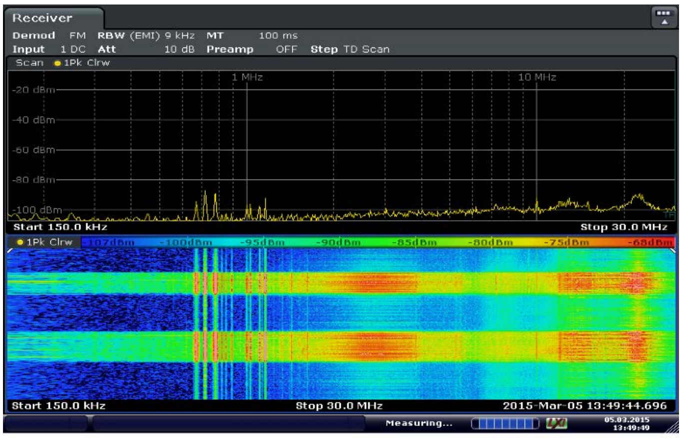

Fig. 5-3

Fig. 5-5, Fig. 5-6, and Fig. 5-7show a valuable capability of the spectrogram display, the ability to measure the pulse repetition rate, especially in the presence of multiple types of emissions.

Fig. 5-5 shows spectrum and spectrogram data in receiver mode, not real-time mode. It is clear that both intermittent broadband noise as well as an intermittent narrowband emission are present.

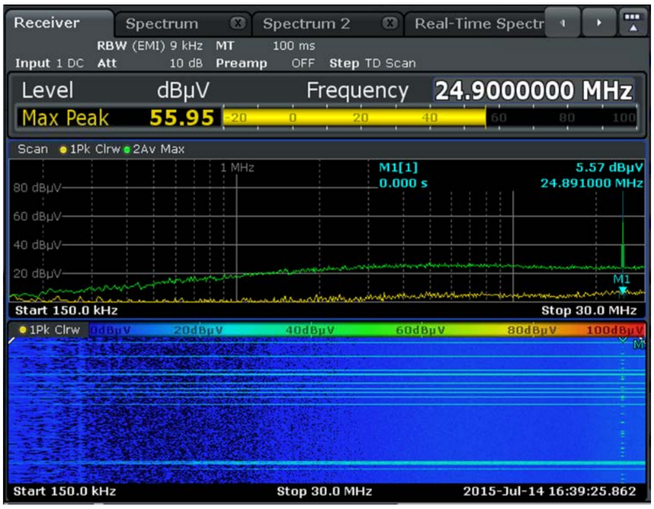

Fig. 5-5

Often EMC engineers will use the zero span mode of a spectrum analyzer at the frequency where an intermittent emission is detected. The resulting display is shown in Fig. 5-6. Notice there are multiple emissions with an inconsistent pulse repetition rate. This is because there are actually two signals present, a condition that cannot be properly characterized using a spectrum analyzer zero span mode.

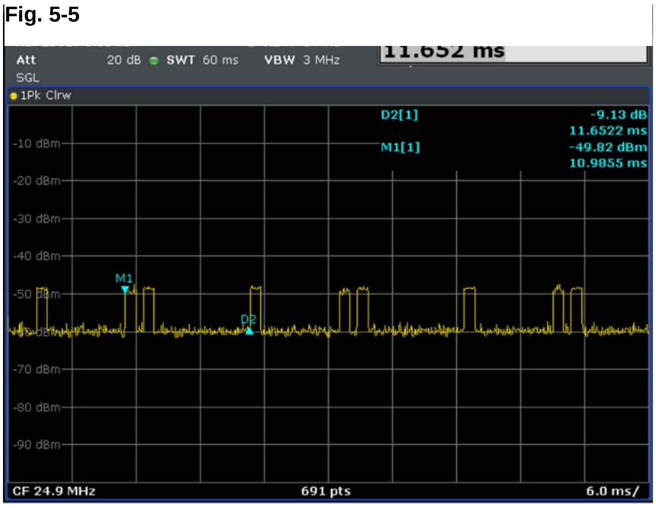

Fig. 5-6

The real-time mode spectrogram display solves this problem. The entire spectrum can be measured simultaneously with accurate data on the time axis due to gap-free acquisition and processing. The display in Fig. 5-7 clearly shows the two separate signals. Markers can be set on the display to measure pulse repetition rate of each signal. Also, the measurement is not dependent on the signal remaining within the resolution bandwidth filter at a single measurement frequency, as is the case when using spectrum analyzer zero span mode.

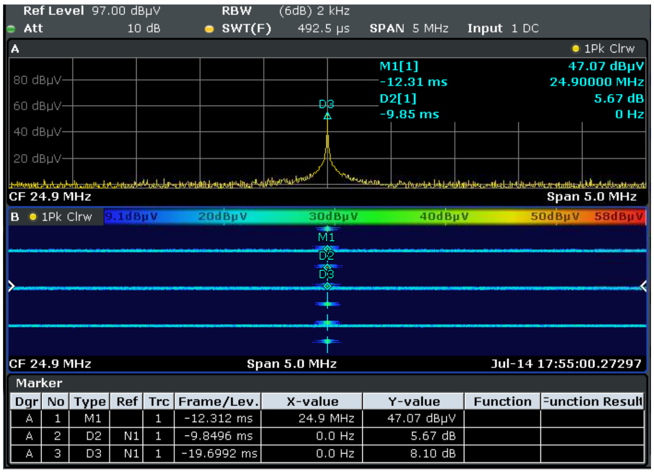

Fig. 5-7

The ability to store and post-process the real-time captured spectrogram data is of great importance. The ability to zoom in and out in time adds additional useful EMI diagnostic capability. Below Fig. 5-8, Fig. 5-9, and Fig. 5-10 show the same spectrogram recording with the time axis further zoomed in to provide better time resolution.

Note the importance of real-time capture to guarantee the validity of the data with respect to the time axis.

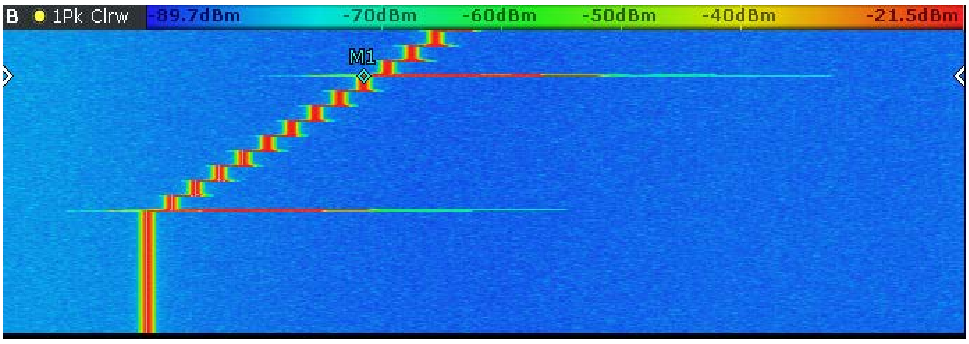

Fig. 5-8

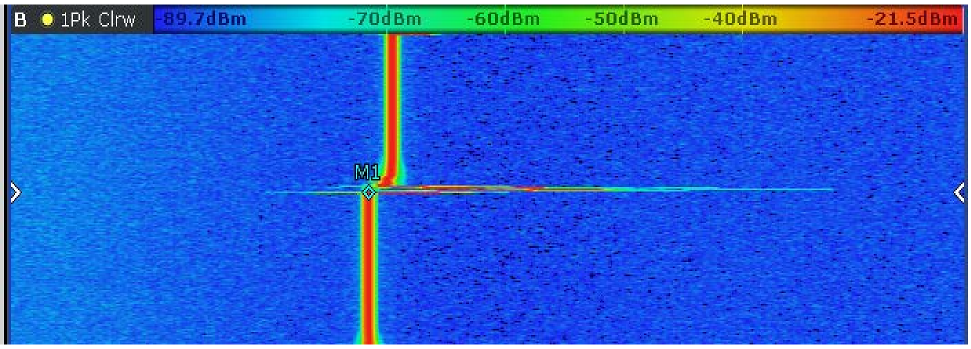

Fig. 5-9

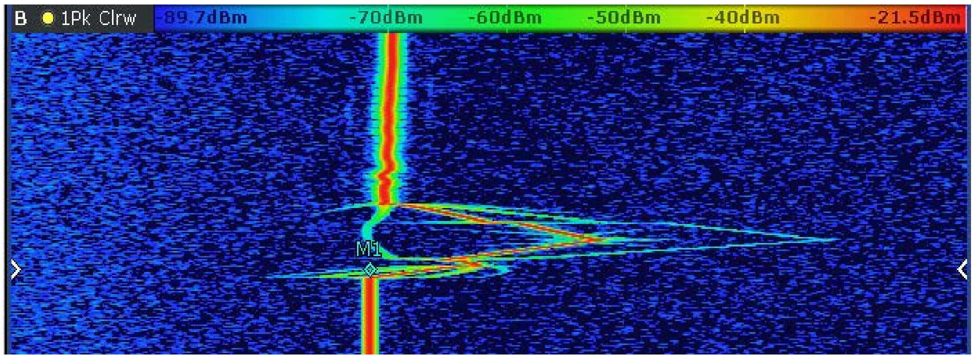

Fig. 5-10

5.2 The Persistence Display

Traditional spectrum measurements provide the peak spectrum levels, but do not provide the time nature of the signal causing the failure. The spectrogram display provides value insight on the time nature of the signal. However, it is of limited use when there are multiple signals causing failures on the same frequencies. What is needed is the ability to recognize signals on the same frequency that may appear both at different times as well as the same time. Real-time mode persistence display provides this capability.

Fig. 5-11 shows how the persistence display is calculated. As in traditional spectrum displays, the x axis represents frequency and the y axis represents amplitude. The added dimension of time is conveyed in the color coded display.

The user configures a measurement time which corresponds to the total display time. Each pixel represents the percentage of the total measurement time during which the signal was at that frequency and amplitude. The pixel on the far left indicates the amplitude was constantly at the same level as the noise floor throughout the entire measurement. The center column indicates that 80% of the time the signal was at the maximum amplitude, 10% of the time the signal was at a slightly lower amplitude, and 10% of the time the signal was off, or in the noise floor. This calculated data is used to create the grid/plot on the right where color now indicates the percentage of time the signal was at that amplitude. The coloring is user-configurable, but usually red indicates the highest time percentage.

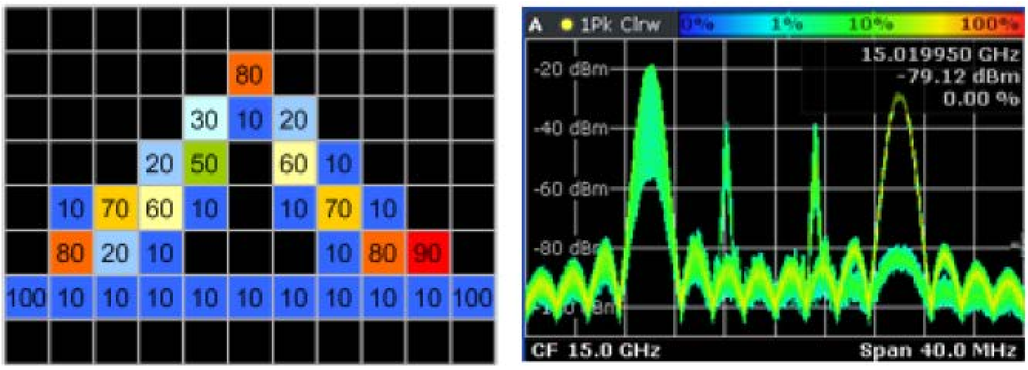

Fig. 5-11

Real-time mode persistence display is critical in identifying multiple simultaneous sources of failing emissions. Traditionally, EMC test laboratories provide the plot shown in Fig. 5-12, showing a broadband interference created using a max hold sweep. The blue trace shows a max hold and outlines the broadband signal. In the past, the EMC test laboratory provided the plot to the customer, the customer fixed the broadband source of information, and then returned to the EMC test laboratory for another round of expensive testing.

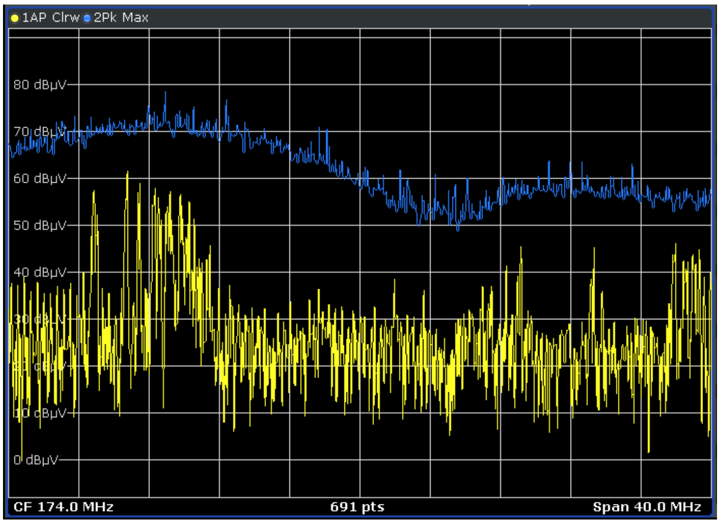

Fig. 5-12

As can be seen in Fig. 5-13, there is an additional narrowband signal that is hidden under the traditional spectrum peak plots and this signal may cause an EMI compliance failure. Real-time persistence display provides the capability to see multiple undesired emissions simultaneously. This allows designers to see multiple issues simultaneously, as opposed to sequentially finding and solving one problem at a time. Seeing all undesired signals at once greatly increases chances of passing EMI compliance testing.

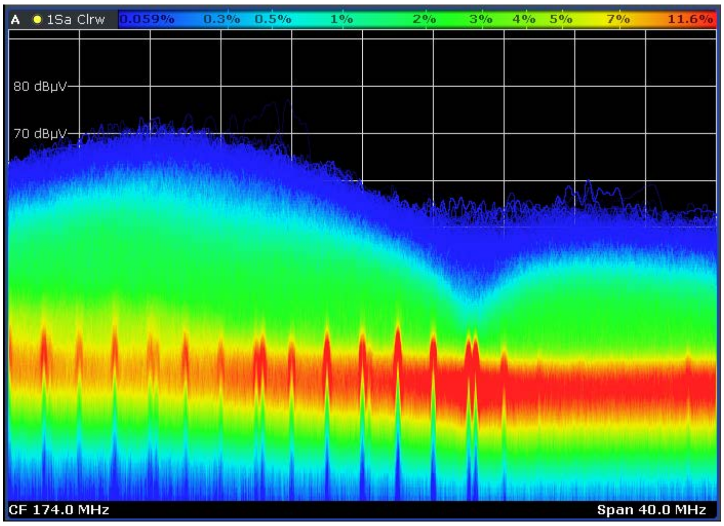

Fig. 5-13

Fig. 5-14 and Fig. 5-15 show another example of how real-time mode persistence display shows a hidden signal not visible with traditional spectrum measurement capability. Fig. 5-14 shows a narrowband signal hidden within a broadband signal.

Fig. 5-14:

Fig. 5-15:

Fig. 5-16: shows a WiFi (Wireless LAN) signal with a narrowband signal hidden underneath. This is extremely difficult to detect with traditional spectrum measurement techniques and demonstrates the powerful capability to see 'signals under signals' by coloring coding the signal to indicate the time nature of the spectrum.

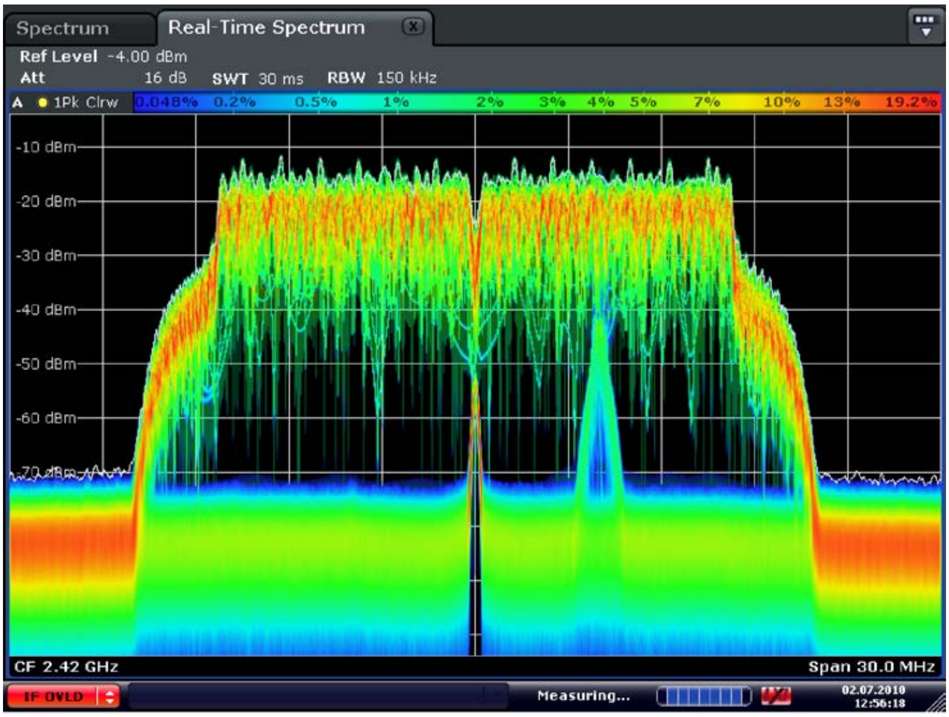

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Fig. 5-16: WiFi Signal with Bluetooth Signal

The use of a frequency mask trigger is very helpful in capturing an emission once a problem frequency is detected. The trigger mask can be set as a function of frequency and level. Masks are critical for triggering on an undesired emission in the presence of intentional radiators. The ability to capture the spectrum of a short duration emission provides valuable information in determining the source of the emission. The combination of a frequency mask trigger with persistence display yields a level of fast and powerful diagnostic capability.

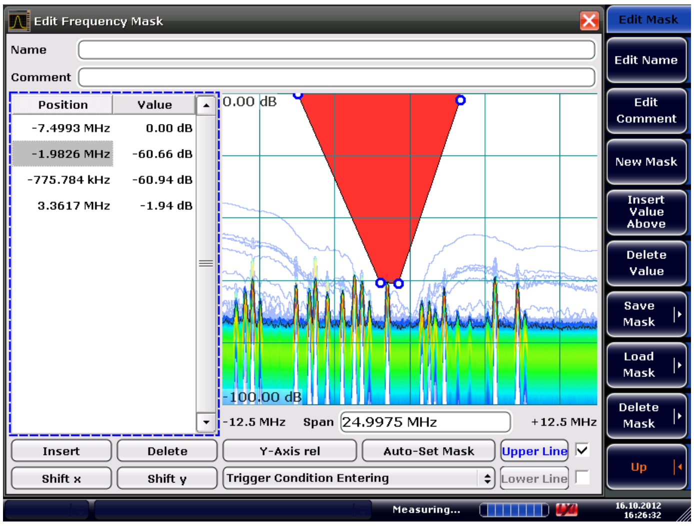

Fig. 5-17: Frequency Mask Trigger

An EMI receiver with the processing power to simultaneously calculate and display the both traditional spectrum with the real-time mode spectrogram as well as persistence displays represents the future of EMI receiver capability. This capability will grow in importance with the increased difficulty of passing EMI compliance tests and in turn will become an important capability for EMC test laboratories to provide for their customers.

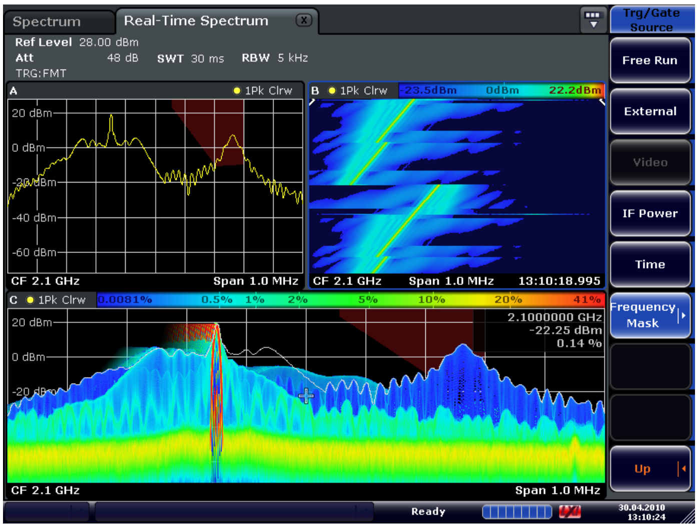

Fig. 5-18: Enhanced EMI Diagnostics

6 Summary

The increasing percentage of EMI compliance failures necessitates an improved capability not only in detecting emissions, but also characterizing the failing emissions. Iterative experimentation of EMC design fixes requires fast spectrum measurement. Analysis of the spectrum over time yields important information about the source of the failure and facilitates quick redesigns that suppress failing emissions below the defined limits.

Time Domain Scan can provide spectrum feedback thousands of times faster than traditional spectrum analyzer measurements.

Real-time mode spectrogram displays show a color coded representation of signal strength over time. This is extremely useful when examining the time nature of signals and when measuring pulse repetition rates without resorting to the zero span mode in a swept spectrum analyzer.

Real-time mode persistence displays amplitude as a function of the percentage of time the signal was at that amplitude. This gives the EMC designer the ability to visualize time-multiplexed signals, or ‘signals under signals’, eliminating costly multiple rounds of full EMC testing.

Combining the traditional spectrum plot with the real-time mode spectrogram and persistence displays provides the user with a variety of tools that can be used to identify the root cause failed EMC tests. As this technology continues to become more broadly used by EMC engineers, this capability will also be expected in EMC test laboratories.

About Rohde & Schwarz

The Rohde & Schwarz electronics group is a leading supplier of solutions in the fields of test and measurement, broadcasting, secure communications, and radiomonitoring and radiolocation. Founded more than 80 years ago, this independent global company has an extensive sales network and is present in more than 70 countries. The company is headquartered in Munich, Germany.

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