Troubleshooting EMI: To Peak or NOT to Peak

Learn about:

- The tools needed to perform EMI diagnostics and troubleshooting.
- Using a MDO4000 Series Mixed Domain Oscilloscope, which integrates a spectrum analyzer, oscilloscope and logic analyzer into a single tool, making EMI troubleshooting easier than ever before.

EMI Diagnostics- What is it?

EMI diagnostics is the process of identifying the source of an unwanted emission or interference source, and working to remediate the issue. EMI diagnostics are performed either when the designer suspects that EMI may be an issue with the design, or after failing a scan in the EMI laboratory. In either case, the application is the same. The physical area around where the problem is believed to be is scanned with a spectrum analyzer, often with a near field probe/antenna, to determine the location and extent of the current problem. The fix to an EMI problem may be in applying shielding to the design, redesigning existing shields, reducing the EMI at its source on the circuit board through changes in layout or component placement, or possibly changing how the firmware controls the source behavior. In every case, the design must be evaluated for emissions before, after and possibly while the design changes are applied to determine whether the fix was successful.

What is necessary to be able to do the job?

- **Spectrum analyzers** are almost always needed for EMI diagnostics work, to separate out the various frequencies in the RF spectrum and ensure that the sources of the offending frequencies are found and their amplitudes reduced.
- **Oscilloscopes** are frequently used to evaluate the source of EMI in both power supplies and digital circuits after they have been localized by the spectrum analyzer.
- **Logic analyzers** may also be used to determine if the EMI is caused by specific logic states or possible software errors in the device under test. The use of oscilloscopes and logic analyzers has become increasingly common as EMI becomes more transient due to the complex interactions of analog, digital and RF circuits in a design.
- **Probes** must be used to either pick up the signal near the device under test, or attached directly to the circuit.

Spectrum analyzers chosen for EMI diagnostics may be different from spectrum analyzers or EMI compliance receivers used in pre-compliance and compliance measurement applications. When performing pre-compliance testing, you may need to have the correct filters, detectors and averaging. Frequency accuracy, amplitude accuracy, limit line testing and dynamic range may be more important. Compliance and pre-compliance tools will often verify whether a problem exists, but may be unable to diagnose the root cause of the problem. For diagnostics work, the spectrum analyzer requirements are driven by the need to identify and troubleshoot the source of the emissions. Diagnostics requirements are shown below.

- Frequency Range: In most commercial designs, EMI diagnostics are performed below 1 GHz. You may need a higher frequency range depending upon your regulatory requirements or the performance of your design. For correlation of spectral events to digital and analog signals in your design, a spectrum analyzer that can capture a wide (>1GHz) instantaneous bandwidth is an advantage. This can help to show if emissions at various frequencies are all tied to a common fault or source.
- Frequency Accuracy: In order to find the signal of interest, a frequency accuracy of better than ±10 kHz at 1 GHz is sufficient in nearly all cases.
- Peak Detection and Max-Hold: This ensures that the peaks of the offending signal are found and kept on screen for later comparisons to the output of the modified product. Since only relative measurements are performed (pre and post-fix), it is not necessary for the analyzer to have standards-compliant quasi-peak detectors, filters or averaging. These EMI features only change absolute power measurements, not relative measurements, and thus have little value in the diagnostic and troubleshooting process.
- Sensitivity: Nearly all low and mid-range spectrum analyzers have sufficient sensitivity for diagnostics applications. Depending upon your probes and signal levels, a preamplifier may be needed.
- Dynamic range: Diagnostics is rarely an application with demanding dynamic range requirements. The signals being evaluated are generally the larger signals on screen, and 60 dB of dynamic range is generally more than enough.
- Amplitude accuracy: EMI diagnostics measurements are relative measurements made before and after a fix is applied. Absolute accuracy is not critical, but repeatability is. Nearly all spectrum analyzers have sufficient accuracy and repeatability for the job.

Oscilloscopes used for EMI diagnostics must have sufficient bandwidth and channels to examine the circuits of interest and make timing and level measurements before and after a fix is applied. In general, the oscilloscope used will be one that is already used in the design lab, and requirements of the design lab are the drivers in selection.

- Bandwidth: Must be able to measure level and timing of the signals present in the design. Most signals that cause EMI problems are below 1 GHz in clock frequency, and bandwidth selection can be guided by the needs of the specific frequency of the problem. However, since the oscilloscope will also find use as a general-purpose tool, other needs may drive the choice of instrument
- Number of channels: Four-channel oscilloscopes are most common in design applications and are sufficient for EMI diagnostics.

Logic Analyzer requirements are generally driven by the needs of the design lab, and the logic analyzer used is frequently what is available. For EMI diagnostic purposes, the function of the logic analyzer is largely to be able to examine what activity is occurring during a transient EMI event. The considerations for logic analyzers are;

- Bandwidth and channel count: This requirement is generally driven by other needs, not EMI diagnostics, and any logic analyzer that meets the design needs will be sufficient. The logic channel capabilities of an MSO or MDO are routinely capable of supporting EMI diagnostic needs.
- Bus and decoding support: The logic analyzer must be able to trigger on the signals in the design, and to decode the busses used in the design. Again, this need is driven by the design and function of the device under test.

Near-field Probes for EMI are electromagnetic pickups used to capture either the electric (E) or magnetic (H) field at the area of interest and are used with the spectrum analyzer.

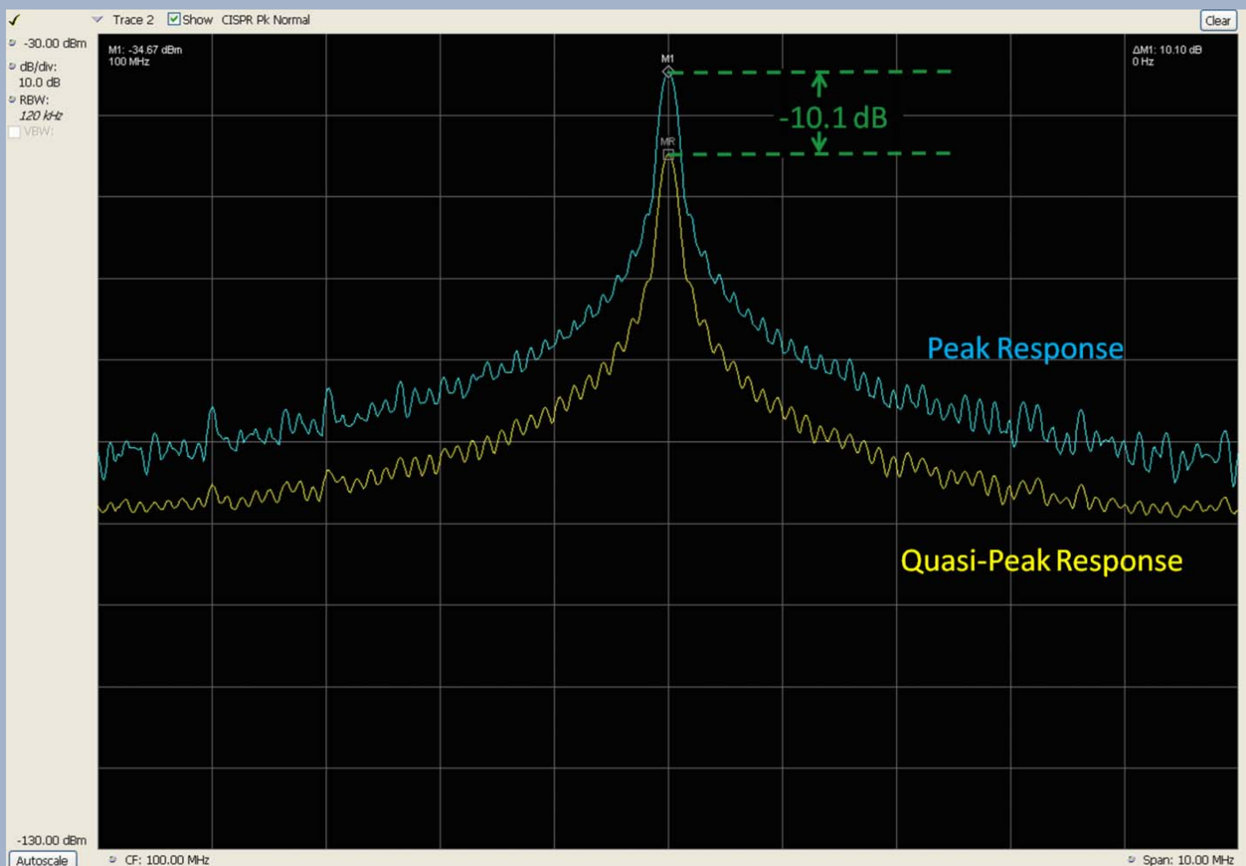
Manufacturers sell sets of probes that offer the best compromise between size, sensitivity and frequency range, and you may need all the sizes in your toolkit to solve your problem. Selection between an H-field or E-field probe may be driven by location of a signal in your design, or by the nature of its source (voltage or current). For example, the presence of a metal shield may suppress the E-field, making it necessary to use an H-field probe for the application.

Voltage probes are used with oscilloscopes and spectrum analyzers to attach directly to the circuit of interest. Conventional oscilloscope probes can be used with spectrum analyzers with a resultant loss in sensitivity depending upon the impedance of the probe. For example a 500 Ohm Z0 oscilloscope probe connected to a 50 Ohm spectrum analyzer will result in a 10:1 divider and a reduction in signal to the spectrum analyzer input of 20dB. However, when connecting directly to a circuit, the signals are generally large, and can be seen by the spectrum analyzer even with the reduced signal level. Furthermore, spectrum analyzers feature typical sensitivities that are orders of magnitude better than an oscilloscope, so loss from a probe is rarely a limiting factor.

Do you need quasi-peak detection?

EMI measurements can be made with simple peak detectors. But the EMI department or the external lab use quasi-peak (QP) detectors. So you wonder if you need a QP detector too.

The EMI department or the external labs typically begin their testing by performing a scan using simple peak detectors to find problem areas that exceed or are close to the specified limits. For signals that approach or exceed the limits, they perform QP measurement. The QP detector is a special detection method defined by EMI measurement standards. The QP detector serves to detect the weighted peak value (quasi-peak) of the envelope of a signal. It weights signals depending upon their duration and repetition rate. Signals that occur more frequently will result in a higher QP measurement than infrequent impulses.



An example of peak and QP detection is seen in fiigure above. Here, a signal with an 8 µs pulse width and 10 ms repetition rate is seen in both peak and QP detection. The resultant QP value is 10.1 dB lower than the peak value.

A good rule to remember is QP will always be less than or equal to peak detect, never larger. So you can use peak detection to do your EMI troubleshooting and diagnostics. You don't need to be accurate to an EMI department or lab scan, since it is all relative. If your lab report shows the design was 3 dB over and your peak detect is 6 dB over, then you need to implement fixes that reduce the signal by -3 dB or more.

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Application Example

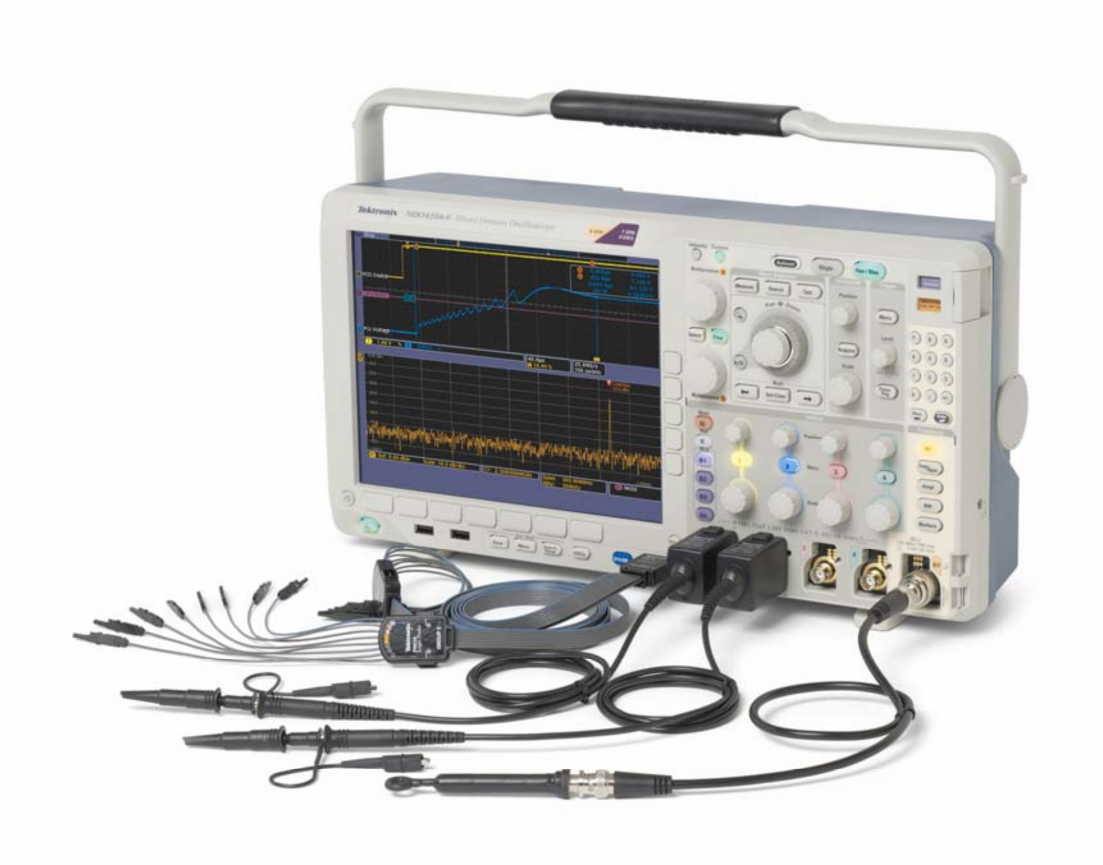

Figure 1: The Tektronix MDO4000 Series combines a spectrum analyzer, oscilloscope and logic analyzer in a single unit that produces time-correlated measurements from all three instruments.

The application example below uses the Tektronix MDO4000 Series with its integrated spectrum analyzer, oscilloscope and logic analyzer to zero in on the source of an EMI problem. Once the problem is understood, a fix can be implemented, and the offending signal level re-measured to determine the effectiveness of the change. The application is presented in three steps:

- Physically identify the location of the problem
- Electrically identify the source of the problem
- Measure the effect of the re-design

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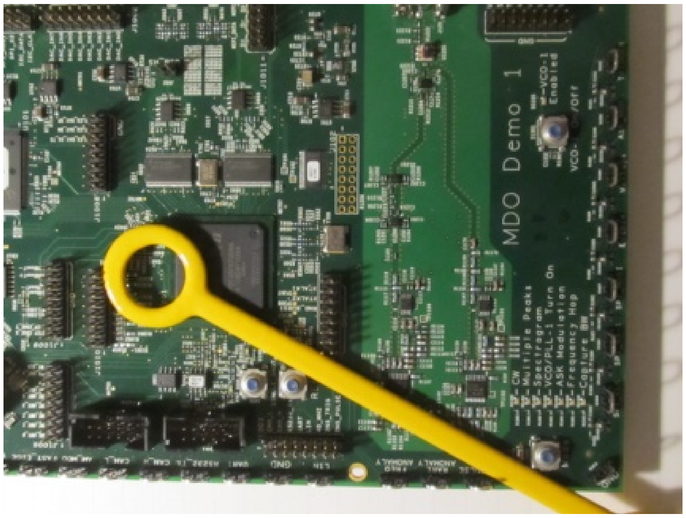

Figure 2: A near-field probe is used to discover the location of the peaks of the offending signal.

Zero in on the EMI problem with the spectrum analyzer. In this case, the highest peak in a broad scan was found to be a transient peak near 137 MHz. Using the MDO4000 spectrum analyzer and a near-field probe, the problem was found to be worst around one side of an FPGA in the circuit as shown in Figure 2.

Viewing the signal with both Max-Hold and Normal detectors on the spectrum analyzer quickly shows that this is an amplitude-varying signal that moves in amplitude by about 12 dB over time. Figure three shows the signal in both its peak and minimum conditions over a wide span.

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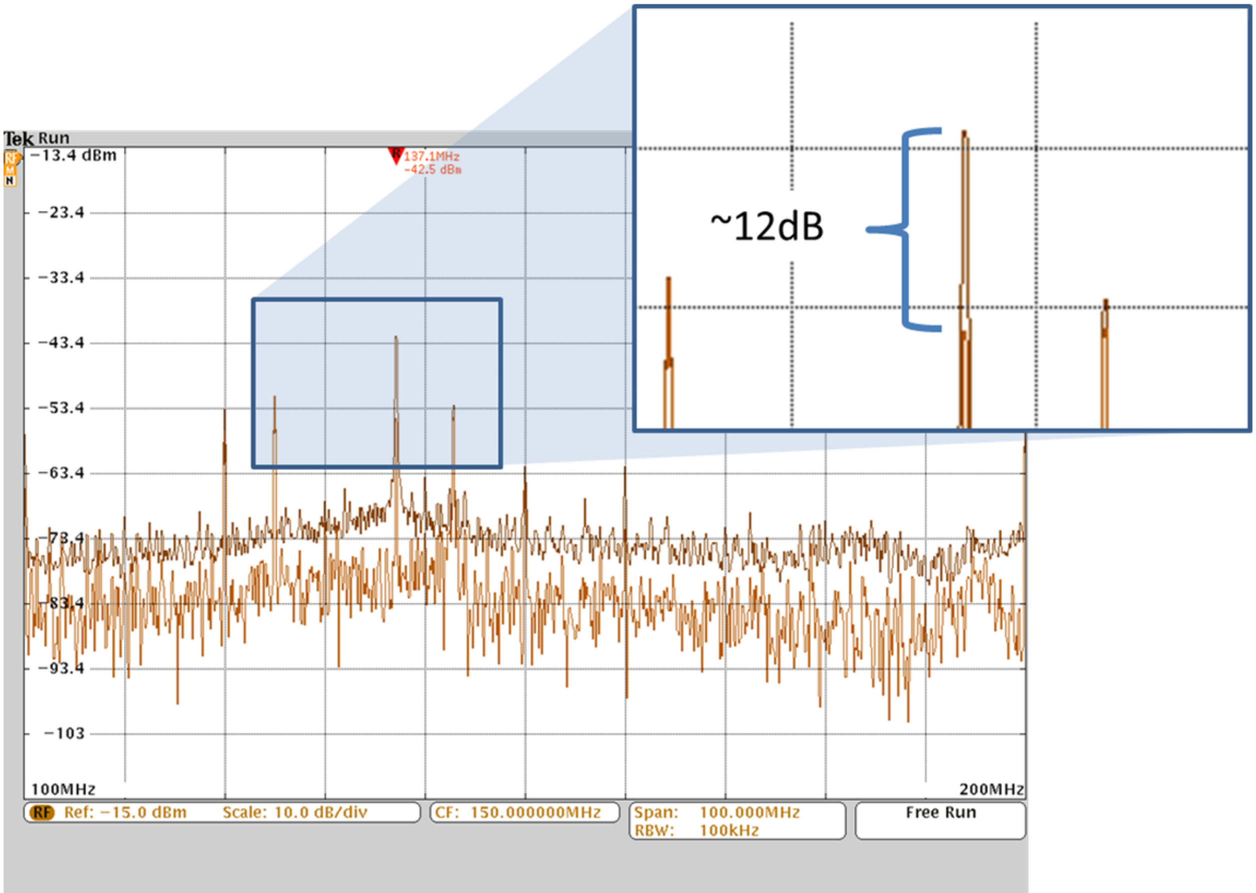

Figure 3: The signal is captured in Max-hold with peak detection at 137MHz. The detail shows that the signal increases by ~12dB at times.

Transient emissions such as these are some of the most troublesome to debug. With a conventional spectrum analyzer, there are few if any tools at your disposal to debug this problem and your troubleshooting is now at a dead end

With the MDO4000, you are one step from really finding the problem and proving it with measurements. The MDO4000's trigger system includes RF Power as one of the trigger sources. Given that this signal is large and is varying significantly (~12db) over time, it can likely be used to trigger the instrument. With the RF Power trigger properly setup, the time-domain nature of the signal can be observed.

The trigger system in the MDO4000 controls the acquisition on all of the inputs: the four analog scope inputs, the 16 digital inputs, and the spectrum analyzer input. Therefore, a single acquisition contains a seamless time capture of the signal activity on off of these inputs. This gives you the ability to observe the activity of all of these signals simultaneously on one time-correlated display. In our case, by triggering on the transient RF signal, we can now observe the time domain characteristics of the RF signal as well as surrounding signals on the board.

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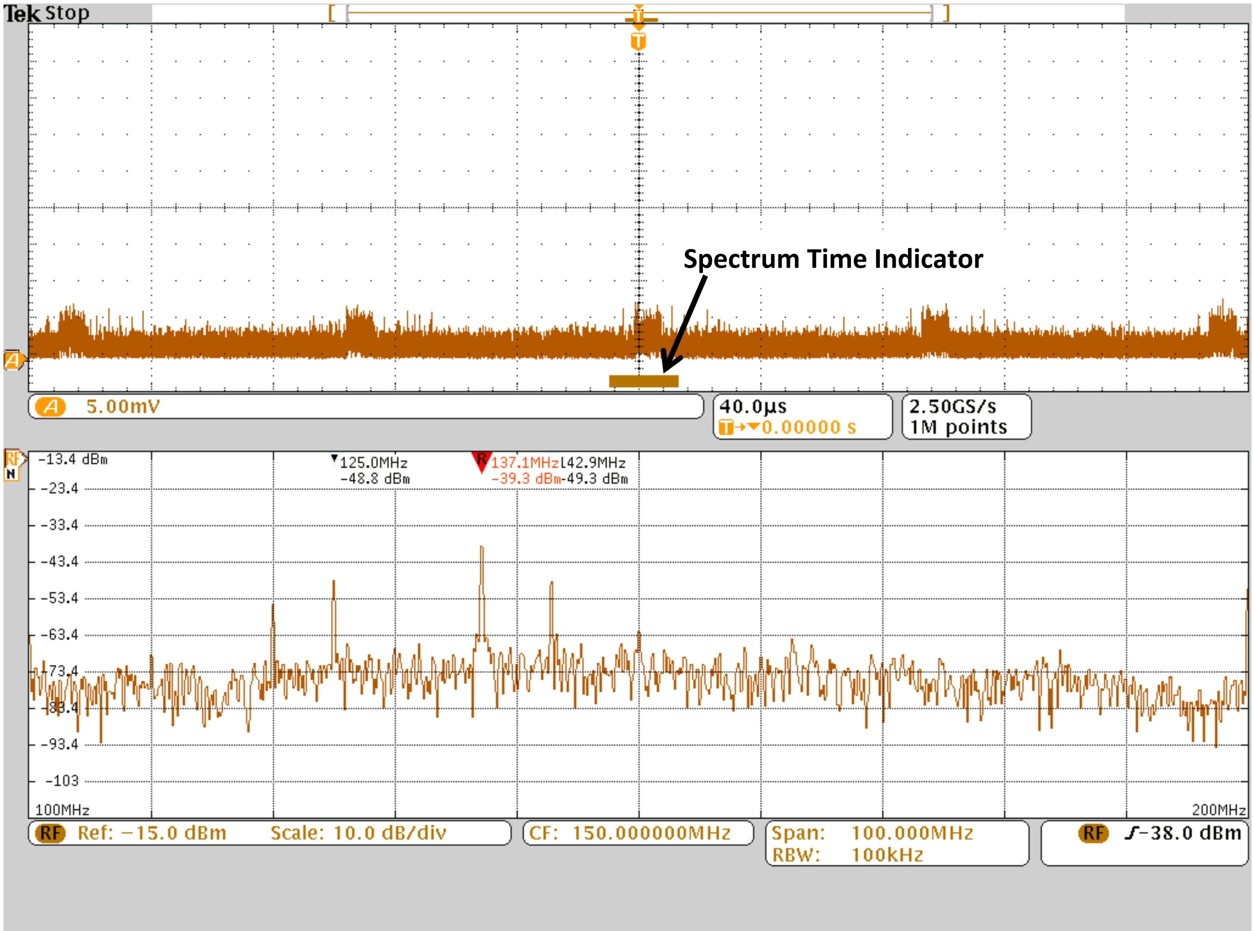

Figure 4: RF Amplitude vs. Time trace showing the periodic bursts of energy over time with the frequency span shown on the spectrum analyzer.

The signal at the spectrum analyzer input is recorded over time, which gives the ability to observe how the spectrum varies over time, as well as the RF Amplitude, Frequency and Phase variations over time. Figure 4 illustrates the addition of the RF Amplitude vs. Time trace to the MDO4000 display.

The short horizontal “bar” that is visible in the middle of the screen, just below the RF Amplitude vs. Time trace, is called the Spectrum Time Indicator. This bar indicates the specific period of time within the acquisition that the spectrum, shown in the lower pane, was measured. In this figure, the spectrum time indicator is positioned coincident with the burst of RF energy shown at the center of the screen. You might suspect that each of the bursts shown will correspond with the transient signal peak observed at ~137MHz. The spectrum time indicator can be panned back and forth within the acquisition to observe what the spectrum of the RF signal was at different points in time. Figure five shows the spectrum time moved to the right by about 50µs, so that it is in-between two of the bursts. It is clear from examining the spectrum traces in both cases that the level of the signal at 137MHz is about 12dB lower in this position. This confirms that the bursts observed in the RF Amplitude vs. Time trace correspond to the transient increase of the 137MHz signal.

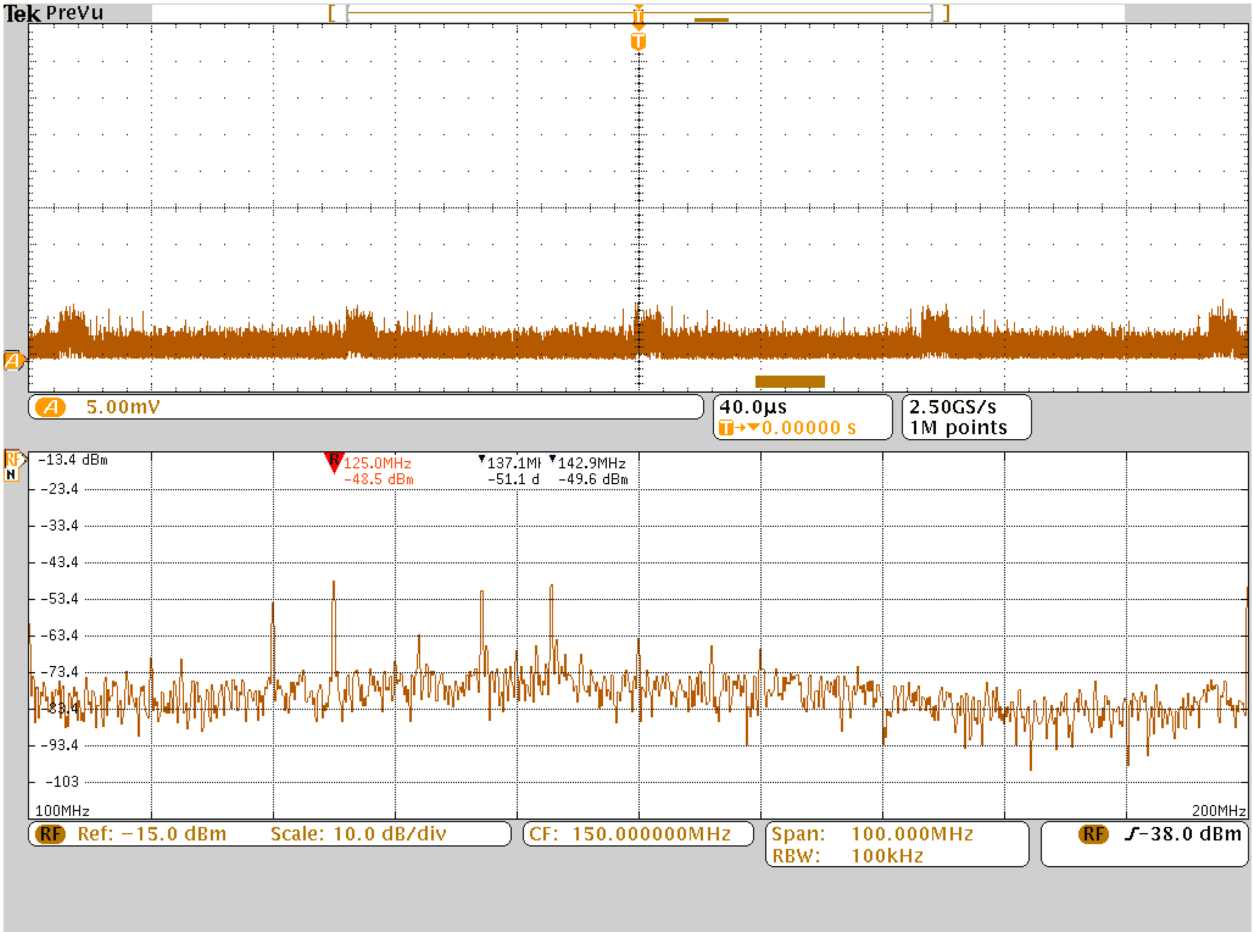

Figure 5: The spectrum time indicator is moved in-between the RF bursts. The level of the 137MHz signal at this location in time is ~12dB lower.

With the periodic nature of the 137MHz bursts confirmed, attention can be turned to identifying a potential root cause of this transient. A voltage probe is connected to CH1, and the CH1 trace is added to the display. While triggering on the RF signal, other voltages on the circuit board can be observed. Any signals that are unrelated to the troublesome RF burst will appear asynchronous or unstable with respect to the RF Amplitude vs. Time, while any signal that is coincident with the bursts will be stable and lined up with the bursts.

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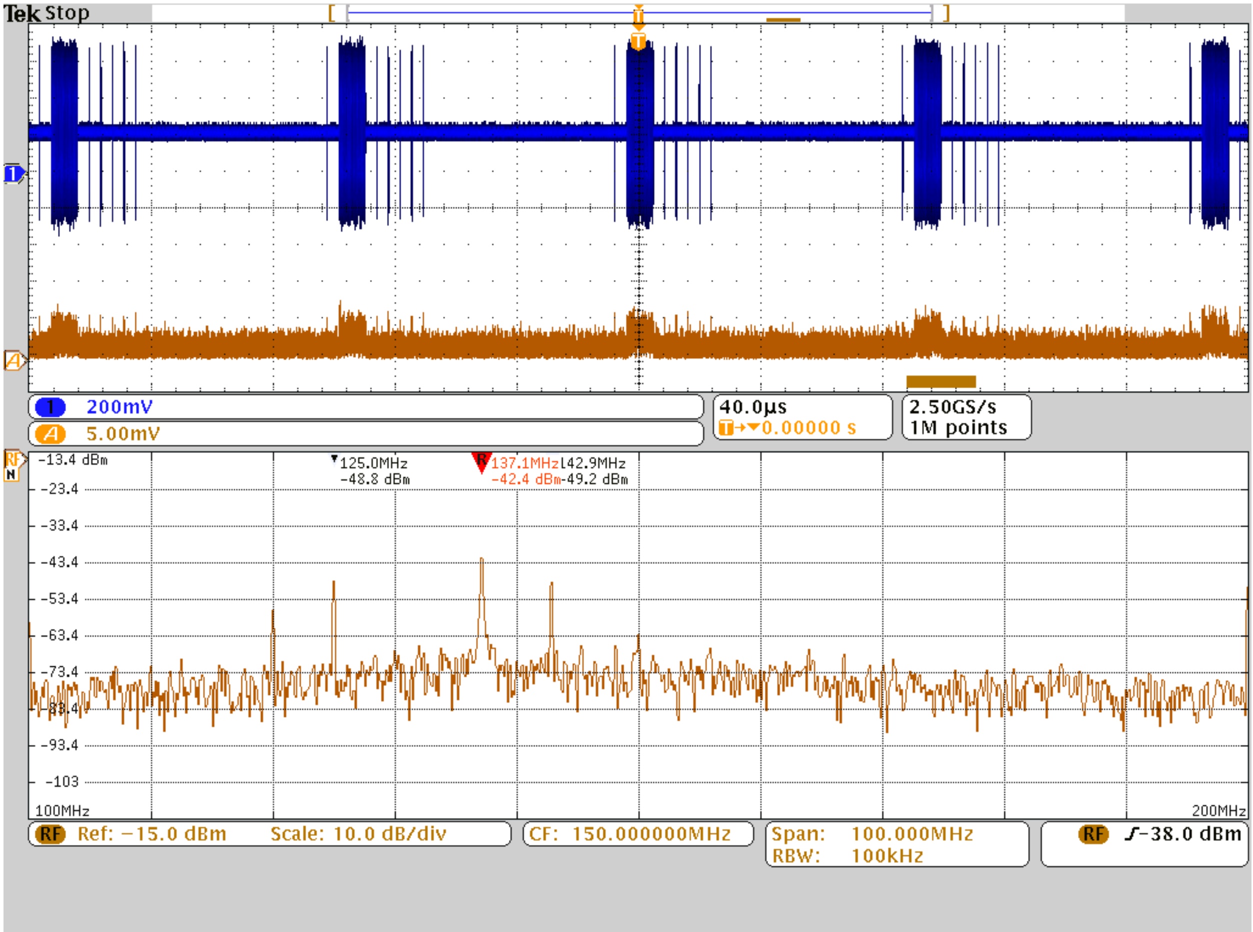

Figure 6: Channel one is showing the voltage on a USB_HS header. It is clear that the high speed data bursts on this header coincide with the bursts of energy at 137MHz.

Figure 6 illustrates shows the signal from a USB_HS header on the circuit board on CH1. It is clear that the high frequency burst of data on this signal exactly coincides with the bursts of RF energy. From this we can conclude that the generation and transmission of this high speed data burst on the USB_HS port is coincident with the transient emission at 137MHz.

It is important to note that the signals that are coincident to the RF emission might not be the actual source of the emission, but might simply be a clue to the help you find the actual source. In this case, the USB_HS signal that is being probed is about 3” away from the FPGA location where the RF signal is being picked up. Additionally, the USB_HS burst doesn’t contain energy at 137MHz. What is clear from this is that the activity that the FPGA is performing to create this USB_HS data is causing it to emit increased energy at 137MHz. This type of insight to the source of transient EMI sources is difficult or impossible to achieve without being able to time-correlate the RF signals to other signals on the circuit board as shown here.

Testing the Fix:

Now that the source of the problem is known, changes can be made to address it. This problem might be fixed by circuit board redesign, placement of RF suppression components on the board, a shield may be required for the design, or a change in the firmware. Whatever mitigation is chosen, the effectiveness of the change must be evaluated. This is done by repeating the initial measurement of the EMI problem with the near-field probe and measuring the difference your change makes in the signal level.

Conclusion

Performing EMI diagnostics is part of the job for many designers. Common tools are conventional spectrum analyzers and near-field probes. Oscilloscopes and logic analyzers may also be used as part of the diagnostic. By using an MDO4000 Series that provides time correlated spectrum analysis with analog and digital signals, problems can be more precisely isolated and faster than with conventional tools. The MDO4000 is a powerful and flexible instrument that will minimize the time required to find sources of interference.

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