White Paper

Embedded Design Compliance & Certification - Wireless & EMI/EMC

Wireless Standards Compliance Testing and Certification – is it worth my time?

You have been tasked with adding wireless to the latest generation of products your company manufactures. There are a number of technologies to choose from, including standards such as Wi-Fi®, Bluetooth®, ZigBee®. Wireless technologies are adopted as standards in order to ensure products can interoperate within the ecosystem where they will be deployed. And in order to release the product to the marketplace, the product will not only need to meet regulatory certification as defined per the country where it will be sold but also qualification as defined per the standard selected. The aim of the standard qualification (such as Bluetooth) is to deliver a seamless user experience throughout the vast number of Bluetooth devices that are available in the market. Failing either certification or qualification can mean design turns that will delay the final product release and draw additional significant development cost.

Now assuming the volume of your product is small enough, you may have opted to buy and integrate a wireless module, rather than create your own custom wireless design. However there is a flurry of different modules and the module providers are not always very clear at communicating to what level these modules have been pre- qualified and pre-certified. So what do you need to put in your test plan? This White Paper is designed to help you decide what to include in your test plan so that you ensure the product will pass regulatory certification and standard qualification. It will explain why pre-compliance testing for the wireless standard selected is needed.

…but this is not your only consideration >>

Tektronix

Vicom
Leading the way in test and measurement

Uncover EMI Problems Early with Pre-compliance Testing

EMI regulations are in place throughout the world to provide improved reliability and safety for users of electrical and electronic equipment. Compliance testing is exhaustive and time consuming, and a failure in EMI at this stage of product development can cause expensive re-design and product introduction delays. In addition, the full compliance test in a certificated lab can be expensive.

Pre-compliance testing is commonly used to catch compliance problems early and improve the probability of a successful first pass of full EMI compliance testing. Today, cost effective test solutions can easily be setup to quickly reduce your time-to-market. This white paper discusses what you will need to setup your own pre- compliance testing capability and useful tools for troubleshooting problems that you may uncover.

> "Failing either certification or qualification can mean design turns that will delay the final product release"

What does Standard Qualification / Certification mean?

Qualification *in this white paper is the term used to describe what tests a product is required to pass so it meets a wireless standard.*

Qualification *provides insurance the product will interoperate with other devices using the same wireless standard. Bluetooth products have to be qualified before getting the Bluetooth Logo. Wi-Fi products need to be certified before getting the Wi-Fi logo. Not all test houses have been selected to dispense the standard qualification tests. The Bluetooth Special Interest Group (SIG) and the Wi-Fi Alliance publishes the approved test houses.*

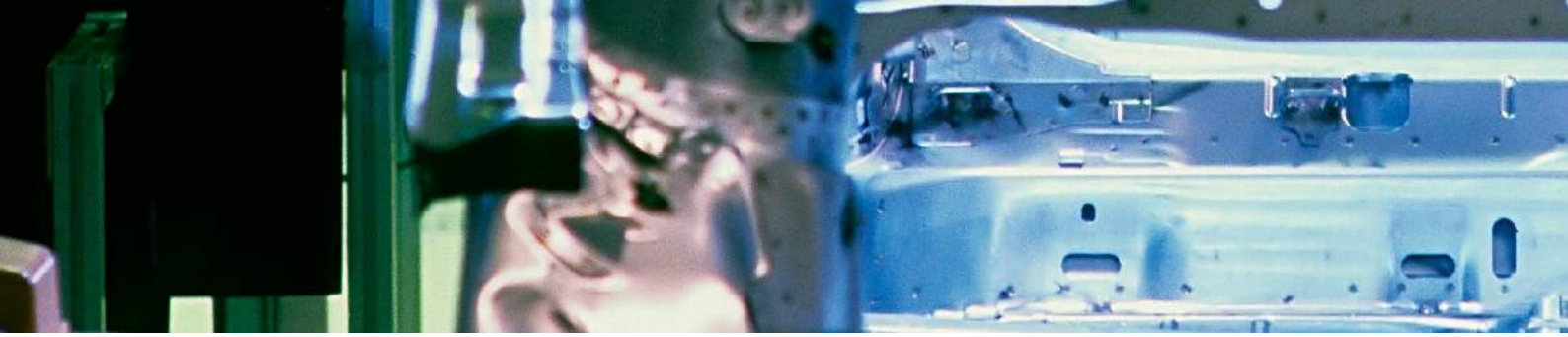
What does Regulatory Certification/ Compliance mean?

Certification *is the term used in this tutorial to describe this critical step to bring a wireless enabled product to market. Certification allows the product to be sold in a particular country, because it meets the country regulatory rules.*

Certification is to be obtained in a test house that has been selected by the local authorities. The certification rules are twofold. Firstly, general emissions testing rules that nearly every electronic product must comply with; secondly, intentional radiation testing rules that only products design to transmit data wirelessly must comply with. The rules may vary within a country depending on the frequency range and the type of intentional emission e.g. hopping or not).

What Are Typical Testing Costs?

Going through standard qualification or regulatory emission tests can range in $10,000 - 15,000 in a test house per standard or per country (assuming you pass the first time). This test house may not be so close to your location, so travel costs and time may also be incurred.



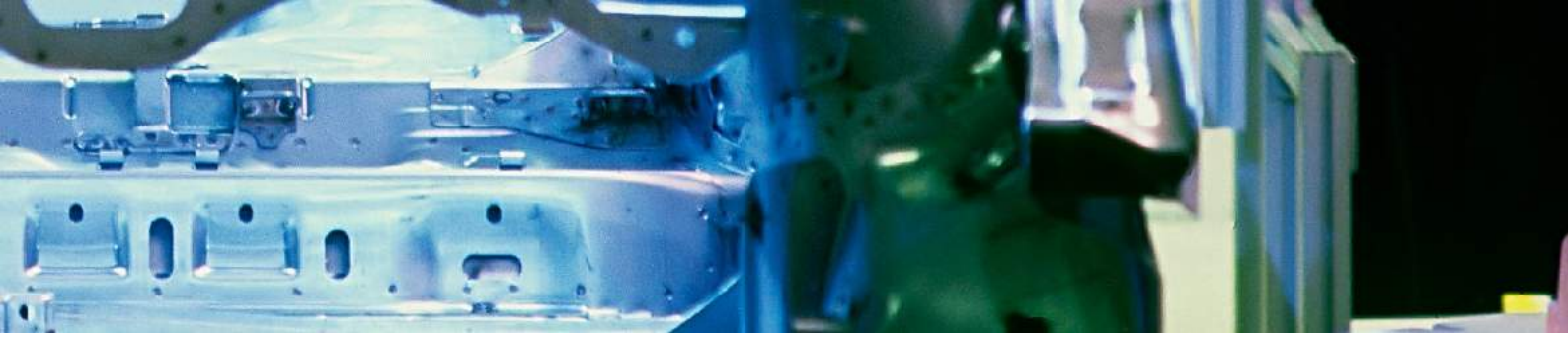
Wireless Standards Compliance / Certification

Do you know the different kinds of antennas used for low power wireless field?

The "whip" antenna is the basic one. It can be inserted on a PCB as a trace, a stub or a coil. The newest types of antennas are called Chip antenna that are surface mounted. It is also possible to use a loop although they tend to have poor gain. What is key to remember is that, regardless of the choice of antenna, any changes in nearby materials or dimensions can affect the antenna performance and make your end-product wirelessly unusable. Also fast digital switching circuitry close to the antenna may create noise that will cause interferences and reduce the receiving performance of your end-product

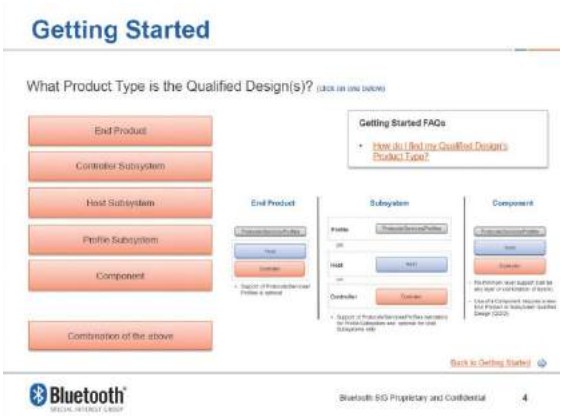
Pre-certified modules come with a lot of constraints, if you want to leverage the value of the pre-certification; especially you cannot make any changes to the antenna, or any changes to the RF path at the physical layer, as presented by the reference design. This is true for all modules including Wi-Fi, Bluetooth or Zigbee modules.

You will also need to ensure that your device is not failing intentional radiation testing rules for the countries where the end-product will be marketed. More on this testing can be found later in this white paper. You will need to perform pre-certification with some test equipment that can also be reused for your wireless pre-qualification testing.

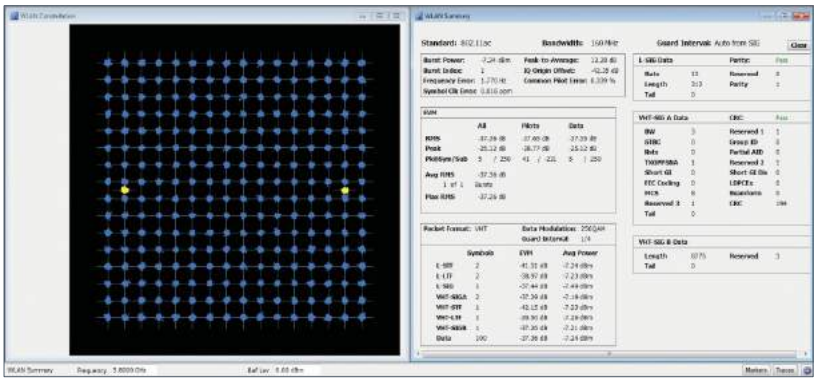


Qualification with the standard is also something you need to worry about, even if the module has been qualified. Let's take a closer look at what Bluetooth Qualification is about:

Products need to go through Bluetooth qualification to be granted the Bluetooth Logo before being released. Bluetooth Special Interest Group (SIG) has defined its qualification process exhaustively. ***The aim of the Bluetooth SIG qualification is to deliver a seamless user experience Throughout all Bluetooth devices that are likely to interoperate***, e.g. making sure you can readily connect your smart phone with the Bluetooth hands-free feature available in your car. Qualified Bluetooth products can be modules too. Module vendors get the module reference designs qualified. You may have used these qualified reference designs to prototype your end-product. However, this is not sufficient to automatically qualify your product per Bluetooth SIG definition. For example, if the reference design was not strictly followed or the Bluetooth profiles were changed, the product will need to go through the complete qualification process. Also, if the RF circuitry on the product's PCB is not "similar enough" to the reference design, and required a new controller subsystem to be created, then the RF-PHY tests of the qualification will be needed. Test procedures and requirements can be found on the Bluetooth SIG website (www.bluetooth.org/en-us/test-qualification), once you become a member of the Bluetooth SIG. **>>**



Bluetooth SIG presentation shows what Product Type is the Qualified Design.



Picture of a constellation diagram for WLAN 802.11ac and EVM measurement results

Let’s now consider Wi-Fi certification per the Wi-Fi Alliance. In order to use the "Wi-Fi Certified" logo on the product, your company will need to become a member of the Wi-Fi Alliance; “Certification” consists of the technical process in which members submit their product for certification testing at Wi-Fi Alliance’s designated certification testing facility. These tests include verifying whether the radio in the product meets the specifications defined by the IEEE 802.11 standard committee. To perform the tests, the radio is put in direct transmit mode and run the different WLAN 802.11 modes and emitting channels. At the physical layer, the radio output power is measured, and other measurements such as specific emission shape and error vector measurements are performed.

Type of Measurement	Measurement	DSSS	"b"	"a"	"g"	"n"	"ac"	IEEE Standard Limit
Transmit Power Measurements	Transmit power	YES	YES	YES	YES	YES		country dependent
	Transmit Power On/Off Ramp	YES	YES					(10%-90%) 2 usec
Transmit Spectral Measurements	Transmit Spectrum mask	YES	YES	YES	YES	YES	YES	Std mask
	RF Carrier suppression	YES	YES					-15dB
	Center frequency leakage			YES		20MHz		-15 dBc or +2 dB w.r.t. average subcarrier power
						40MHz		-20 dBc or 0 dB w.r.t. average subcarrier power
	Transmit Spectral flatness			YES		YES	YES	+/- 4 dB, +4/-6 dB (various BWs, 20-160 MHz)
	Transmission spurious			YES				country dependent
	Out-of-band spurious emission	YES	YES	YES	YES			country dependent
Transmit Frequency Measurements	Transmit Center frequency tolerance	YES	YES		YES			+/-25 ppm (DSSS,b,g)
				YES				+/-20 ppm (20 MHz and 10 MHz), +/-10 ppm (5 MHz)
						YES	YES	+/-20 ppm (5 GHz band), +/-25 ppm (2.4 GHz band)
	Symbol clock frequency tolerance	YES	YES	YES	YES	YES	YES	+/-20 ppm (5 GHz band), +/-25 ppm (2.4 GHz band)
Transmit Modulation Measurements	Transmit Modulation accuracy	YES						Peak EVM < 0.35%
			YES					Peak EVM < 0.36%
	Transmitter Constellation Error							
	Modulation Type / **Coding rate**	Limits in dB						
	BPSK / 1/2			-5		-5	-5	
	BPSK / 3/4			-8				
	QPSK / 1/2			-10		-10	-10	
	QPSK / 3/4			-13		-13	-13	
	16-QAM / 1/2			-16		-16	-16	
	16-QAM / 3/4			-19		-19	-19	
	64-QAM / 2/3			-22		-22	-22	
	64-QAM / 3/4			-25		-25	-25	
	64-QAM / 5/6					-27	-27	
	256-QAM / 3/4						-30	
	256-QAM / 5/6						-32	

List of WLAN 802.11 compliance measurements

Pre-testing for standard qualification is a cost-effective way to catch problems early, while there is time to correct issues without costly redesigns, delays, and retesting at the test house.

Pre-certification or pre-qualification are also called pre-compliance because it encompasses measurements required for both certification and qualification.

Pre-compliance doesn't have to be an expensive nor a long process. It is important though that it is exhaustive to ensure the end-product doesn't fail certification or qualification, and also that it communicates to its ecosystem as planned. Pre-compliance testing is also needed to confirm that as the end-product ages and is used in rough conditions, its wireless communication is still fully operational.

Bluetooth Low Energy measurements to pass before going to the test house

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- *In-band Emission*
- *Modulation Characteristics*
  - $\Delta f1$ *frequency deviation average for a test pattern "1111000"*
  - $\Delta f2$ *frequency deviation average for a test pattern "10101010"*
  - $\Delta f2$ *avg /* $\Delta f1$ *avg*

“Pre-compliance testing doesn’t have to be expensive.”

The Tektronix RSA306B and SignalVu-PC Bluetooth application software include Bluetooth test set ups that make standards testing much easier.

The required tests can be easy to perform when the pre-compliance analysis software that is usually an add-on to the basic feature of the test equipment, actually helps with configuring the instrument. That way you don’t have to remember how to do it again, if your device failed at the test house or later when you will test your next wireless product. In order to test wireless standards, you will need a spectrum analyzer that has vector signal analysis capability. The latest generation of such spectrum analyzer is USB–based, very affordable, easy to operate and portable. The pre- compliance analysis software typically uses the data acquired by the Spectrum Analyzer and run on a PC or tablet. **>>**

Test specification provided by Bluetooth SIG.

The Wi-Fi or WLAN, Bluetooth or ZigBee pre-compliance software that runs on a spectrum analyzer will get you ready for certification and for qualification at the physical layer in no time. Note that qualification may also involve upper layer testing such as MAC, Link, and Transport layers if you design new wireless functionality. Tests to be performed are usually defined by the standards.

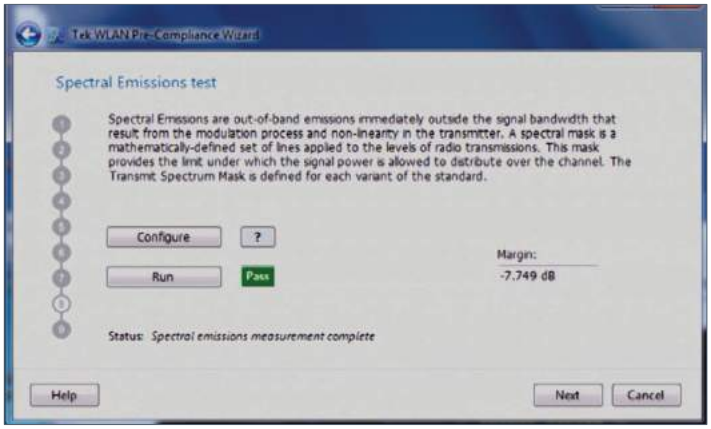
"A portable USB spectrum analyzer that captures signals in real-time is also very handy in the field."

“Standard pre-compliance measurements that are easy to set-up, and graphically report pass/fail results will be a huge time saver.”

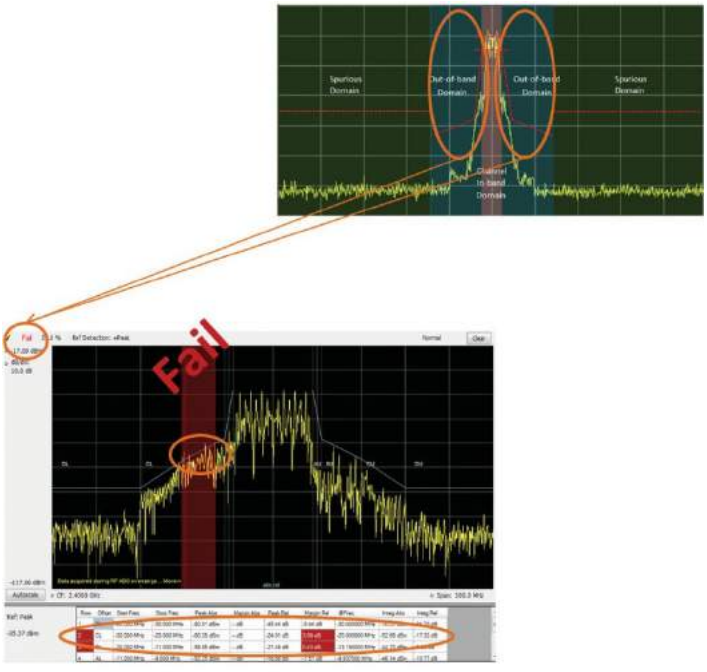
As most wireless standards are using digital modulation techniques to encode the transmitted data, modulation fidelity such as Error Vector Magnitude or Frequency Deviation have become required measurement in addition to typical power and spectrum emission tests with pre-defined masks. Measurements that are easy to set-up and graphically report pass/fail results will be a huge time saver. Tektronix has developed a Wizard to ease the whole process of WLAN pre-compliance with a true push-button approach. And the Tektronix RSA306B Real Time Spectrum Analyzer can also be set up through Signal Vu-PC software to run push-buttoned tests and graphically report pass/fail results.

Later, once the device you worked on has been released and deployed, you may still need to debug it, probably in the field. By comparing the lab testing results to what you measure in the field, you can accelerate the whole debug process later.

A strong pre-compliance testing plan can save you time, money, and your own frustration. The test equipment doesn’t have to be expensive, and a lot can be accomplished with the right spectrum analyzer and supporting software. Later, when you need to support the deployment of the product you designed, then a portable USB spectrum analyzer that captures signals in real-time is also very handy in the field. You will be able to compare the results you see in the field to what you actually measured in the lab. The real-time capability of Tektronix RSA306B will also help when you look at capturing the RF noise around the product as you try to understand what is going on. For learning more about capturing interference and noise, please read the “Interference of Things” tutorial.



WLAN Wizard and SignalVu-PC makes WLAN testing possible with the click of a few buttons.



Easy to read graphical outputs make the problems obvious so that you can spend more time building your device and less time searching.

EMI / EMC Compliance

Setting Up for Pre-compliance Testing

Pre-compliance testing is not required to conform to international standards; the goal is to uncover potential problems and reduce risk of failure at the expensive compliance test stage. The equipment used can be noncompliant and have lower accuracy and dynamic range than compliant receivers if sufficient margin is applied to the test results.

With the introduction of the Tektronix RSA306B USB based Real Time Spectrum Analyzer, pre- compliance testing has never been easier or more cost effective. Test setups using the RSA306B and similar low cost products are used to perform both radiated and conducted emission measurements that can help you minimize both your expense and schedule for getting your products EMI certified.[1]

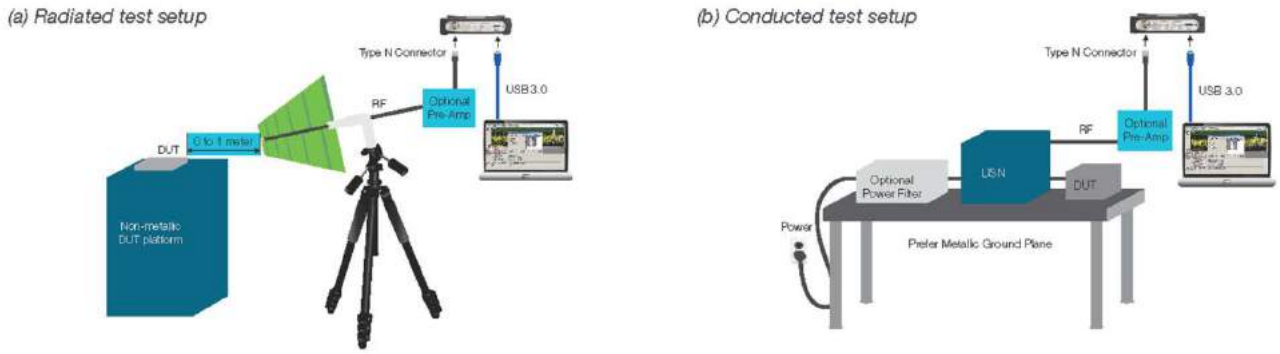
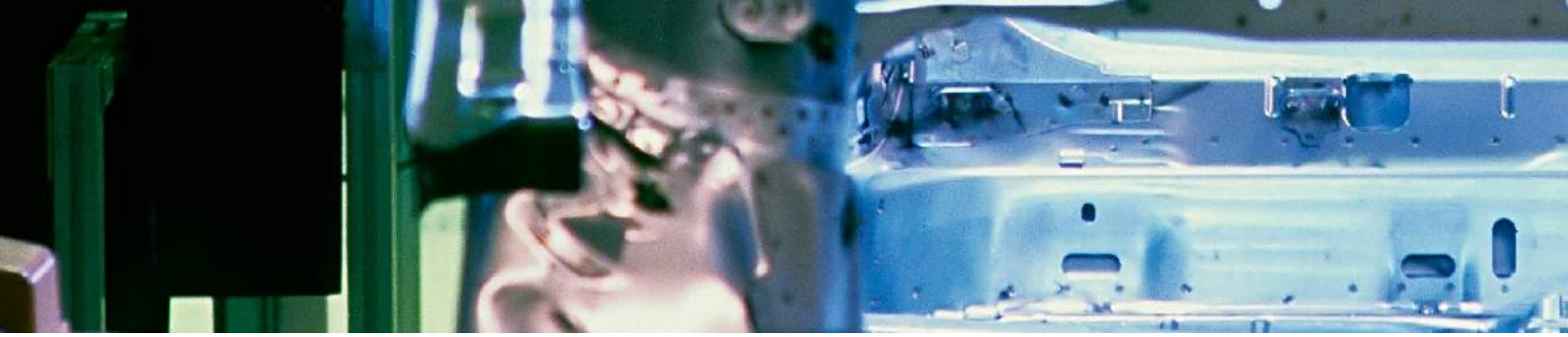


Figure 1. *With the Tektronix RSA306B USB based Real Time Spectrum Analyzer pre-compliance testing has never been easier or more cost effective.*

Near Field Probes – a Cost-effective Alternative

Of course, not everyone can justify the expense of setting up a radiated and conducted test lab as shown above. For many new design pre-compliance testing tasks, a set of “Beehive” 100A near field test probes used with the Real Time Spectrum Analyzer provides a highly effective alternative.



"Use the same test setup but focus only on the frequencies defined by the WiFi, Bluetooth, etc. specs."

Becoming an Intentional Radiator

The race to add products to the Internet of Things brings a degree of complexity to EMI testing. Not only do product manufacturers need to learn how to properly add a wireless

An intentional radiator is a device that broadcasts radio energy (not infrared or ultrasonic energy) to perform its function. These devices intentionally use the radio spectrum and therefore always require FCC or other equivalent equipment authorization. Devices that are intentional radiators are also subject to unintentional testing requirements. Emissions at frequencies other than those the device is designed to use can occur because of internal circuitry.

The test setup for an intentional radiator is the same as the radiated emissions setup shown in Figure 1a. However, in this case, the frequencies of interest are limited to the radiated frequencies and frequency masks defined by the specifications, such as WiFi, Bluetooth, etc.

For pre-compliance testing, the frequency domain is divided to 3 sub-domains (zones). Each has its individual regulation, and the wireless device integrators should be successful in "the 3 step spectrum pre-compliance test" before taking your products to a compliance lab. [2]

Step 1 In-band (Channel) Domain
Check the transmit power output, the transmit bandwidth, and power spectrum density, etc.

Step 2 Out-of-Band Domain
Check the spectrum emission or the adjacent channel power ratio (ACPR). The mask is usually defined by communication standards like IEEE.

Step 3 Spurious Domain
Check the spurious emission.

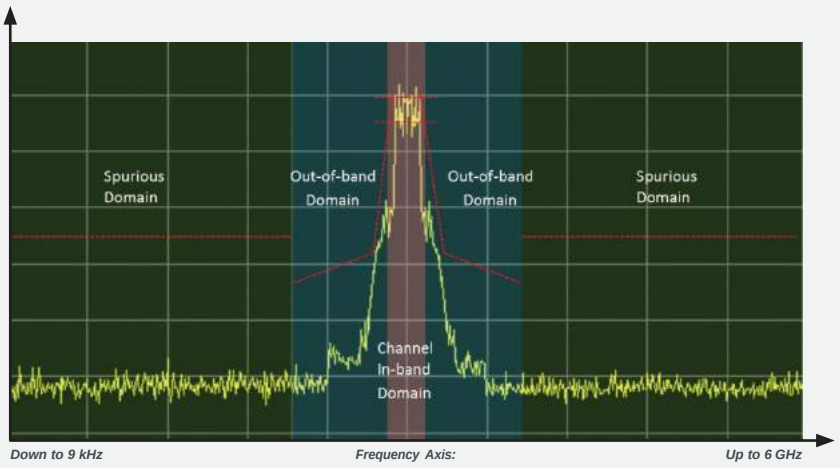
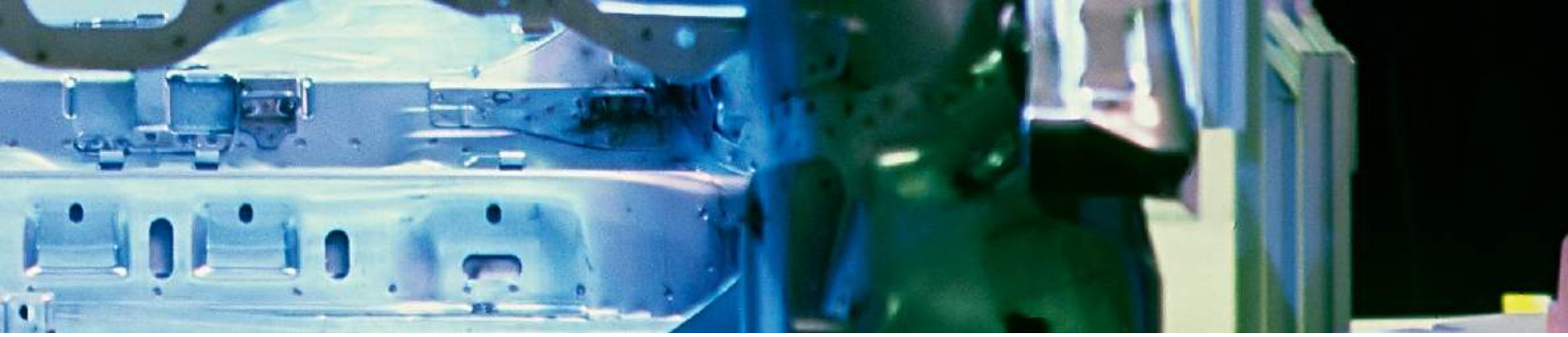


Figure 2. *The compliance of intentional radiators is divided into three sub-domains or zones.*



Troubleshooting Your Design

When looking at any product from an EMI perspective the whole design can be considered a collection of energy sources and antennas. To identify the source of an EMI problem we have to first determine the source of energy and second find out how this energy is being radiated. Common sources of EMI problems include:

- Power Supply Filters
- Ground Impedance
- Inadequate Signal Returns
- LCD Emissions
- Component Parasitics
- Poor Cable Shielding
- Switching Power Supplies (DC/DC Converters)
- Internal Coupling Issues
- ESD In Metalized Enclosures
- Discontinuous Return Paths

"When evaluating your design, just think of it as a collection of energy sources and antennas."

—

While this list outlines some common sources of EMI it is by no means a definitive list. To identify the particular source and antenna at the heart of a particular EMI problem, we can examine the periodicity and coincidence of observed signals.

Periodicity:

- *What is the RF frequency of the signal?*
- *Is it pulsed or continuous?*
- *These signal characteristics can be monitored with a basic spectrum analyzer.*

Coincidence:

- *Are there signals generated by the DUT design that are unexpectedly showing up in your EMI results?*
- *What signal on the DUT coincides with the EMI event?*

>>

"Quickly discover intermittent problems with Digital Phosphor Processing (DPX)."

Finding Elusive Time Varying Signals

While the EMI standards-based methods of measurement are necessary for regulatory compliance, they frequently do not address, or even detect, the problems faced in designing for EMI in today's systems. The circa-1930's Quasi Peak (QP) detector was not intended to determine the effects of today's complex multiprocessor consumer electronics on the transient, hopping, digitally modulated and ultra-wideband signals used in modern communication and computing systems. Fortunately, measurement techniques have evolved to match these needs.

Examining the EMI signature of the DUT with Digital Phosphor Processing (DPX) is useful when trying to quickly discover intermittent problems. The DPX™ spectrum display, unique to Tektronix RTSAs, processes up to 590,000 spectrum measurements per second, and ensures that any signal lasting longer than a few 10s of microseconds is instantaneously captured and displayed. When the required span exceeds the maximum real time bandwidth, DPX can also be used in a stepped fashion.[3]

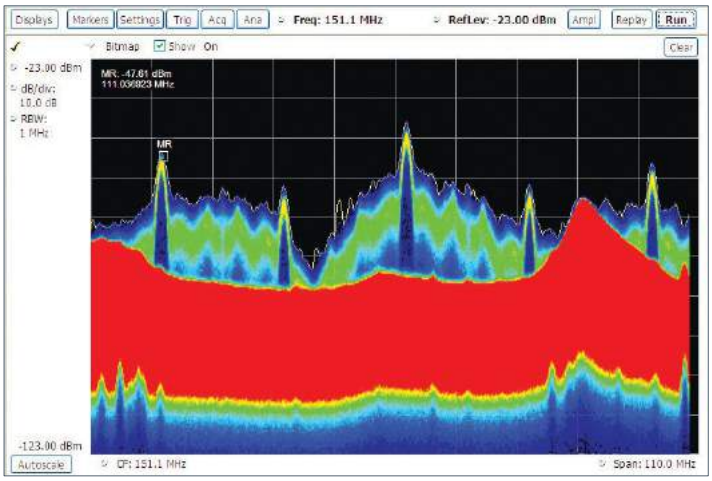


Figure 3. *Digital Phosphor Processing (DPX) may be used to quickly discover intermittent problems.*

Correlating Problem Signals Across Domains

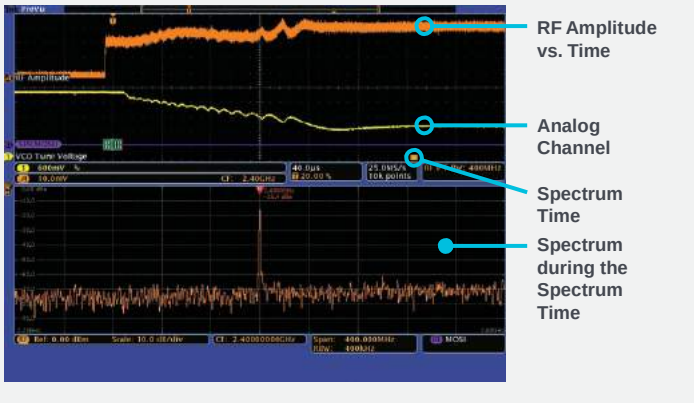


Figure 4. *Textronix's MDO4000C Series offers a unique ability to view analog signal characteristics, digital timing, bus transactions, and frequency spectra synchronized together.*

Examining the coincidence of EMI problems with electrical events is arguably the most time consuming process in EMI diagnostics. In the past it has been very difficult to correlate information from spectrum analyzers, logic analyzers and oscilloscopes in a meaningful way. The introduction of the MDO4000C Mixed Domain Oscilloscope has eliminated the difficulty of synchronizing multiple instruments for EMI troubleshooting. The MDO4000C Series offers a unique ability to view analog signal characteristics, digital timing, bus transactions, and frequency spectra synchronized together.[4] **>>**

Conclusion

Failing either certification or qualification of wireless technologies embedded in a new product design can mean design turns that will delay the final product release and draw significant developments costs. However, pre-compliance testing to wireless standards doesn't have to be an expensive or long process. It is a cost-effective way to catch problems early and avoid costly redesign, delay and retesting at the Test House.

Similarly, failing an EMI compliance test is expensive and can put a product development schedule at risk. However, setting up your own pre-compliance testing can help you isolate any problem areas and fix them before you go to a compliance Test House. Tektronix offers the tools you need to develop a low cost pre-compliance capability that will help you minimize both your expense and schedule in getting your products EMI certified.

"Tektronix offers the tools you need to develop a low cost pre-compliance capability."

References

1. ***"Low-cost EMI Pre-compliance Testing Using a Spectrum Analyzer"***
   Application Note 37A-60141-0
2. ***"Regulatory Pre-compliance Testing for Wireless LAN Transmitter"***
   Application Note 55W-30065-2
3. ***"Real-Time Spectrum Analysis for EMI Diagnostics"***
   Application Note 37W-22084-1
4. ***"Practical EMI Troubleshooting"***
   Application Note 3GW-30828-0

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