

Spectrum Pre-compliance for Wireless LAN Regulatory Testing

Application Note

What is covered:

- The workflow of WLAN module integration.
- The basics about the spectrum regulatory compliance/pre-compliance testing for wireless devices, such as
 - FCC or ETSI
- How to use the Tektronix MDO4000B Series with SignalVu-PC software to perform regulatory testing.

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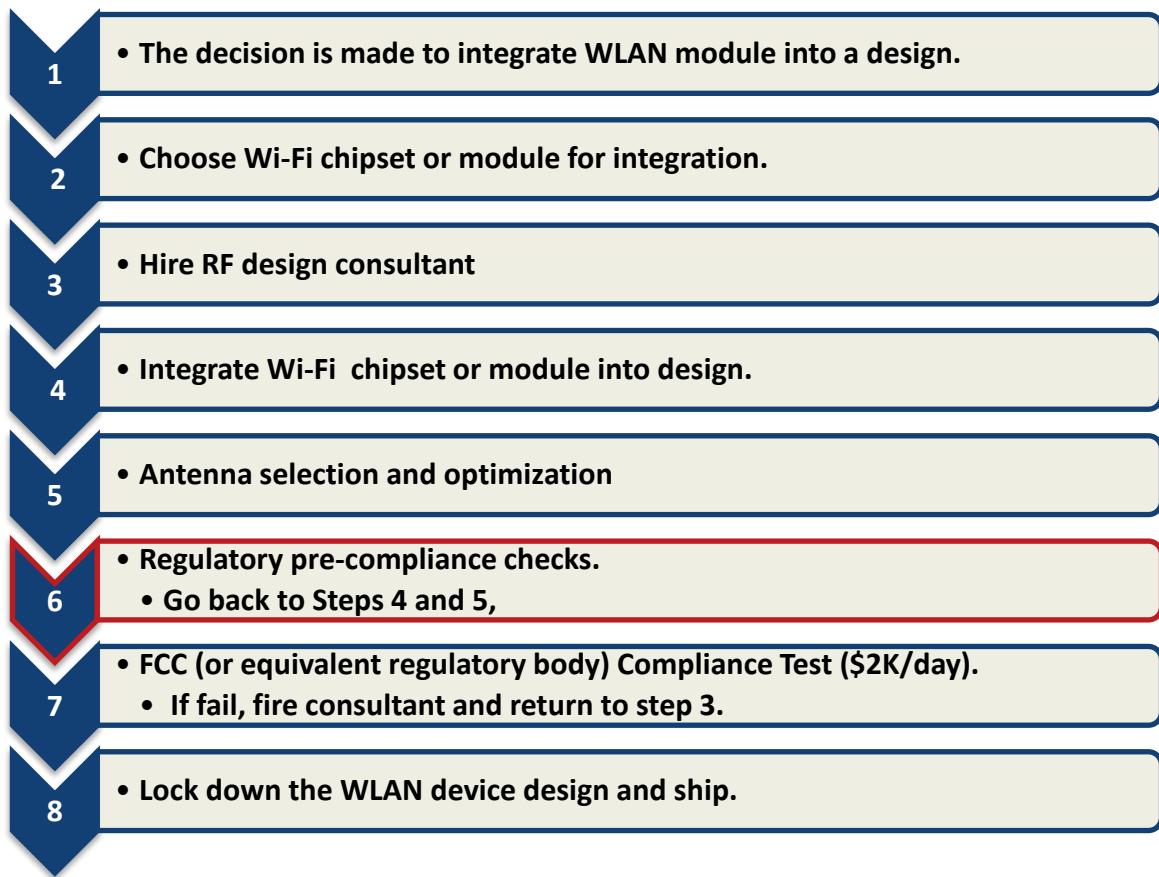
1. The Workflow of WLAN Module Integration

As we see the wireless revolution enter its next phase of deployment, we see a large shift to put wireless local area network (WLAN / IEEE802.11) capabilities on a wide variety of non-traditional products like thermostats, coffee makers, and even toothbrushes. Consumer items like these could be controlled through an application from a smart phone or other devices connected to the internet. One advantage of using connected devices like smart phones is the applications can be developed very quickly and the end customer is presented with an integrated experience with their wireless devices. Modern consumers are beginning to expect this integration as they see device after device become incorporated into this use model.

To date, smart phones and tablets have done this with music players, GPS devices, cameras, video cameras, televisions, video games, etc. Another application driving this is the Internet of Things (IOT), where even more industrial and consumer devices are connected wirelessly.

One challenging part of this revolution is that it demands that product manufacturers have to learn how to add this new wireless capability to their products. The most common way to add wireless capability is to use a prepackaged WLAN module. While this approach greatly simplifies the process, it still has many challenges. This application note will outline the typical design cycle and potential pitfalls that you may encounter.

1.1 If you want to add a Wi-Fi Module to your product, what's next?



We will take a closer look at Step 6. This includes the regulatory pre-compliance testing and the standards body testing (i.e. IEEE 802.11).

Compliance testing is exhaustive and time consuming, and a failure at this stage of product development can cause expensive re-design and product introduction delays.

Pre-compliance testing is not necessarily required to conform to international standards; the goal is to uncover potential problems and reduce risk of failure at the compliance test stage.

2. What Is the Full Compliance Test for Wireless Devices?

From the first wireless transmissions, spectrum emission has been a concern for design engineers. Regulatory agencies have placed limits on the emission levels, and have defined measurement methods for compliance testing. Compliance testing requires methods, equipment and measurement sites in compliance with international standards. Compliance tests are commonly done as part of the design qualification prior to production of a device.

This is different from general EMI Compliance testing, although much of the testing methodology is the same. For example, in EMI Compliance testing per CIPSR 16-1-1, there are no tests within the transmit frequency band of 2.4 GHz. In order to comply with the Regulatory Testing, the transmit frequency band needs to be tested as well. Those special compliance requirements are usually set separately to the general EMI limits.

2.1 What Are the Requirements for a WLAN Full Compliance?

If you want to integrate a WLAN transmitter into your design, the table below shows the basic compliance requirements for the 2.4 GHz band WLAN devices in US and Europe.

Table 1. IEEE 802.11g Spectrum Compliance Requirements (2400-2483.5 MHz)

	FCC 15.247	ETSI EN 300 328
Region	US	Europe
Frequency Range	2400-2483.5 MHz	2400-2483.5 MHz
Minimum Bandwidth or Minimum Data Rate	500kHz @ 6dB	250 kbps
Maximum Output Power	1 Watt	100 mWatt
Power Spectrum Density	The peak < 8 dBm in any 3 kHz band	The peak < 10 dBm in any 1 MHz band
Spurious Emissions	20 dB below Peak Power in the 100 kHz {measurement} bandwidth	-80 dBm/Hz Peak (EIRP ¹) -20 dBm Peak (EIRP) in 1MHz
General Intentional Radiated Emissions	Please check FCC 15.209	Please check EN 300 328
AC Conducted Emissions	Please check FCC 15.207	Please check EN 300 328

Table 1 above only shows the basic idea for the spectrum compliance; please check your local regulation for more details.

¹ EIRP: Equivalent Isotropically Radiated Power

2.2 Is the Standard Compliance the Same As the Regulatory Compliance?

Wireless networks implemented in accordance with standards like IEEE802.11 are subject to equipment certification and operation requirements established by regional and national regulatory administrations.

Standard Compliance

The standard specification, such as IEEE 802.11 family establishes some minimum technical requirements for the wireless devices, based upon established regulations at the time the standard was issued. These regulations are subject to revision, or may be superseded.

Regulatory Compliance

Some other requirements are not specified by the standards, and are only subject to local geographic regulations. Operation in countries within defined regulatory domains may be subject to additional regulations. Implementers are referred to the following regulatory sources for further information

Table 2. Regulatory Requirement List

The documents listed in the table below specify current regulatory requirements for various geographic areas. They are provided for information only and are subject to change or revision at any time.

Geographic Area	Approval Regulatory Standards
United States	Federal Communications Commission (FCC)
Canada	Industry Canada (IC)
Europe	European Telecommunications Standards Institute (ETSI)
Japan	Ministry of Internal Affairs and Communications (MIC)
China	Ministry of Industry and Information Technology (MIIT)
Korea	Korea Communications Commission (KCC)

2.3 What Equipment Do You Need For a Full Compliance Test?

- An EMI lab with large anechoic test chamber.
- An EMI receiver with Quasi-peak detector and preamplifier.
- Mast and Turn table.
- Antenna - Radiated measurements.
- EMI Software controlling the test equipment like masts, turntables, and EMI Receiver and generate reports.
- Line impedance stabilization network (LISN) for Conducted measurements.
- Transient Limiter for Conducted measurements.

2.4 What Is the Difference Between Radiated Emission and Conducted Emission?

The term radiated emissions refers to the unintentional release of electromagnetic energy from an electronic device. The electronic device generates the electromagnetic fields that unintentionally propagate away from the device's structure.

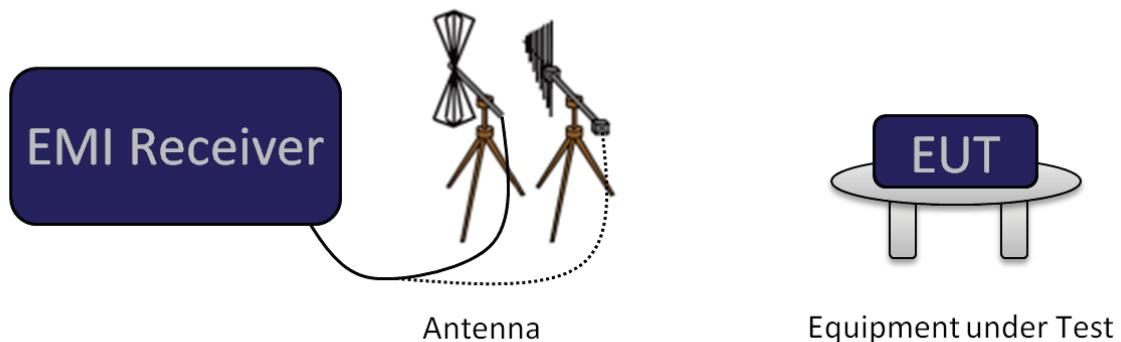


Figure 1. Radiated Emissions Test Setup

The term conducted emissions refers to the mechanism that enables electromagnetic energy to be created in an electronic device and coupled to its AC power cord. Similarly to radiated emissions, the allowable conducted emissions from electronic devices are controlled by different regulatory agencies. If the device under test passes all radiated emissions regulations but fails a conducted emissions test, the product cannot be legally sold for a particular region whose tests were failed.

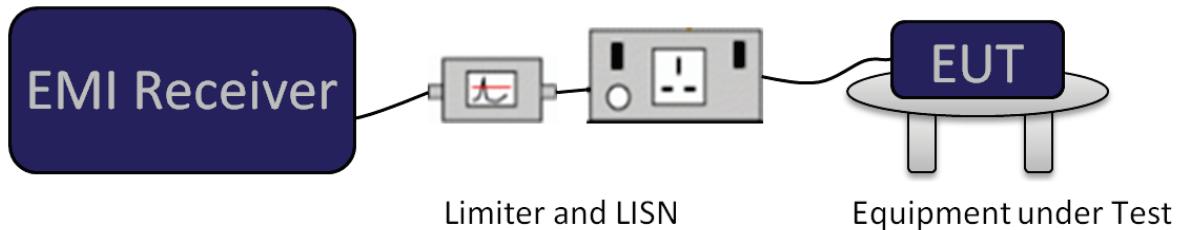


Figure 2. Conducted Emissions Test Setup

2.5 What Is the Difference Between Intentional Radiators and Unintentional Radiators?

The compliance regulations apply to electrical and electronic products that may produce radio frequency pollution. Two main types of products are:

- Intentional Radiators
- Unintentional Radiators

Intentional Radiator

This is a device that broadcasts radio energy (not infrared or ultrasonic energy) to perform its function.

Intentional radiators are things like:

- | | |
|---|---|
| <ul style="list-style-type: none">▪ Cell phones▪ CB radios▪ Walkie-talkies▪ Wireless connections | <ul style="list-style-type: none">▪ Bluetooth connections▪ Short-range broadcast equipment▪ Wireless key-access systems |
|---|---|

Clearly radio waves are needed for the thing to work. These devices intentionally use the radio spectrum and therefore always require FCC equipment authorization.

Intentional devices are also subjected to unintentional testing requirements. In general, radiated emissions are usually associated with unintentional radiators, but intentional radiators can also have unwanted emissions at frequencies outside their intended transmission frequency band.

Unintentional Radiator

This is a electronic digital or radio device that, because of the rapid oscillation of electric current in the device, produces radio signals that are broadcast through space, or conducted along power lines. Devices that receive radio waves (such as AM/FM radios and Televisions) electronically resonate and also unintentionally radiate radio waves.

Unintentional radiators are very common everyday electronic devices like:

- | | |
|--|---|
| <ul style="list-style-type: none">▪ Television sets▪ Computers▪ Electronic games▪ Radar detectors▪ Digital cameras | <ul style="list-style-type: none">▪ USB peripherals▪ Radios▪ Digital clocks▪ Musical equipment▪ MP3 devices |
|--|---|

Anything with a switching power supply, oscillator circuit, high speed digital circuitry, etc.

2.6 What Are Certification Labs?

Unless you are fortunate enough to have an accredited in-house full compliance laboratory in your company, the best choice is to involve a third-party compliance lab at the design stage and then follow through with testing of your product at the lab.

There are many EMC labs around the world. Take US for example, in accordance with 47 CFR 2.948, the FCC list labs that the FCC has on file for FCC Verification equipment authorization. For any FCC work, your lab should be on this list. The following website: <http://www.fcc.gov/oet/> can be used to find an FCC lab that is listed under 2.948 or Accredited for FCC work.

The full compliance test in a certificated lab is:

- Time consuming and expensive (usually \$1000 to \$3000 per day)
- The time to perform compliance test is long (even with an internal full compliance lab).
- A failure of these tests can mean some level of costly and time consuming design rework is required.

It is best to do as much as possible to reduce the risk of a failure during compliance test.

3. The Easier Way for WLAN Compliance Is the Pre-compliance Test

In the world of Electromagnetic Compatibility (EMC), different equipment and techniques are used at different stages of design and qualification. At the early stages of development, design-for-EMC techniques are combined with diagnostics to produce low EMI signatures and low susceptibility to both external and internal interference.

3.1 What Are the Benefits of the Pre-compliance Test?

- Catch EMI problems early - Greatly improve the probability of successful completion of full EMC compliance testing without additional redesign.
- Cost-effectively reduce your time-to-market.
- Use a less expensive, general purpose spectrum analyzer, such as Tektronix MDO4000B Mixed Domain Oscilloscope, rather than invest in a specialized EMI receiver.



Figure 3. Tektronix MDO4000B Paired with SignalVu-PC for Pre-compliance Test

3.2 Is the Pre-compliance the Same As the Full Compliance?

Compliance Testing	Pre-compliance Testing
<ul style="list-style-type: none">▪ Compliance testing requires methods, equipment and measurements in compliance with international standards.▪ Compliance tests are commonly done as part of the design qualification prior to production of a device.▪ Compliance testing is exhaustive and time consuming, and a failure in EMC at this stage of product development can cause expensive re-design and product introduction delays.	<ul style="list-style-type: none">▪ Pre-compliance testing is done after system integration to determine any problem areas in the design.▪ 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 does not have to include every feature and specification required by the standard, and can have lower accuracy and dynamic range than compliant receivers if sufficient margin is applied to the test results.▪ Pre-compliance testing may be done in a certified lab using fast measurement techniques intended to give a 'quick look' at problem areas, or done on the design bench by engineering personnel. General-purpose spectrum analyzers that contain general purpose filters and detectors are often employed in precertification, as they are fast measurement tools that often are already used in the design process and do not require additional capital expense.

3.3 Do you need a CISPR 16-1-1 Detector with a Low Pulse Repetition Rate and 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.

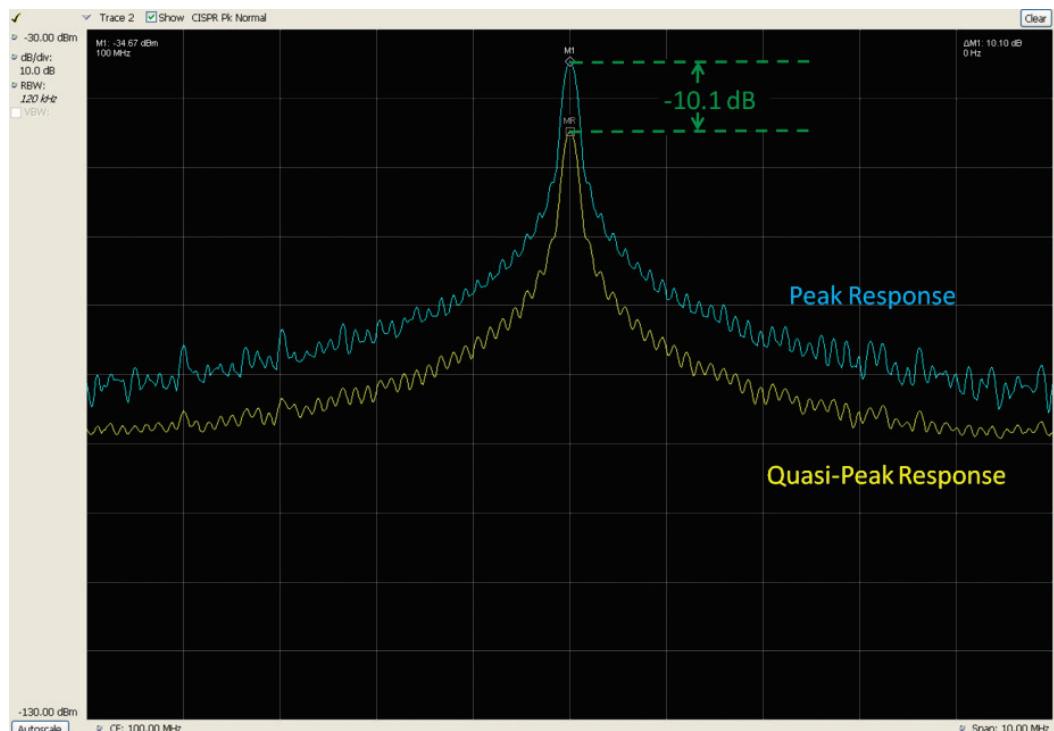


Figure 4. Peak Response vs Quasi-Peak Response

The effect of peak and quasi-peak detection on a signal with an 8 us pulse width and 10 ms repetition rate. The quasi-peak value is 10.1 dB lower than the peak value.

A Good Rule to Remember

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 used the QP detector 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.

For more detail, please check other Tektronix EMI application notes:

[Troubleshooting EMI Problems](#)

[Real-Time Spectrum Analysis for EMI Diagnostics](#)

3.4 What is the Probing Technology in the Pre-compliance Test?

In a full EMI compliance lab, EMI receivers and well-calibrated antennas are used to test the electronic devices over a distance of 3 or 10 meters. In other words, the measurements are done in the far field. In essence, the far field test can accurately tell whether the product passes or fails as a whole but cannot point the source of a problem. Using only the far-field test, one cannot isolate problems down to specific components or locations, like too much RF energy “leaking” from an opening in a metal enclosure or help identify a cable radiating too much RF energy. The near-field test is the only way to locate such emission sources and is typically performed using a spectrum analyzer and near-field probe.

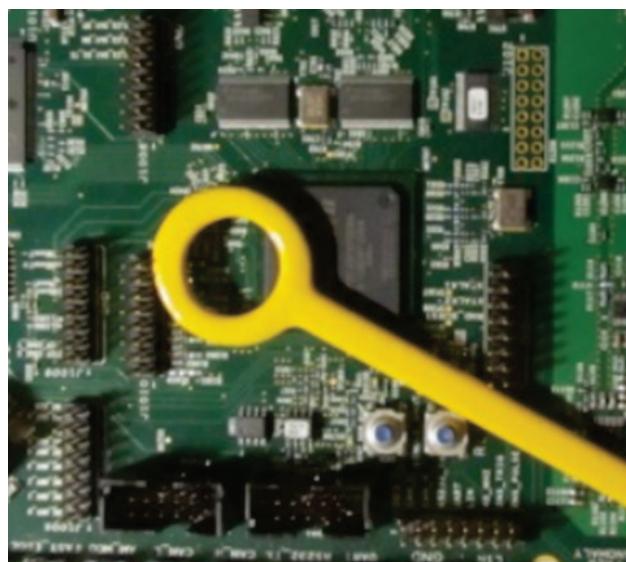


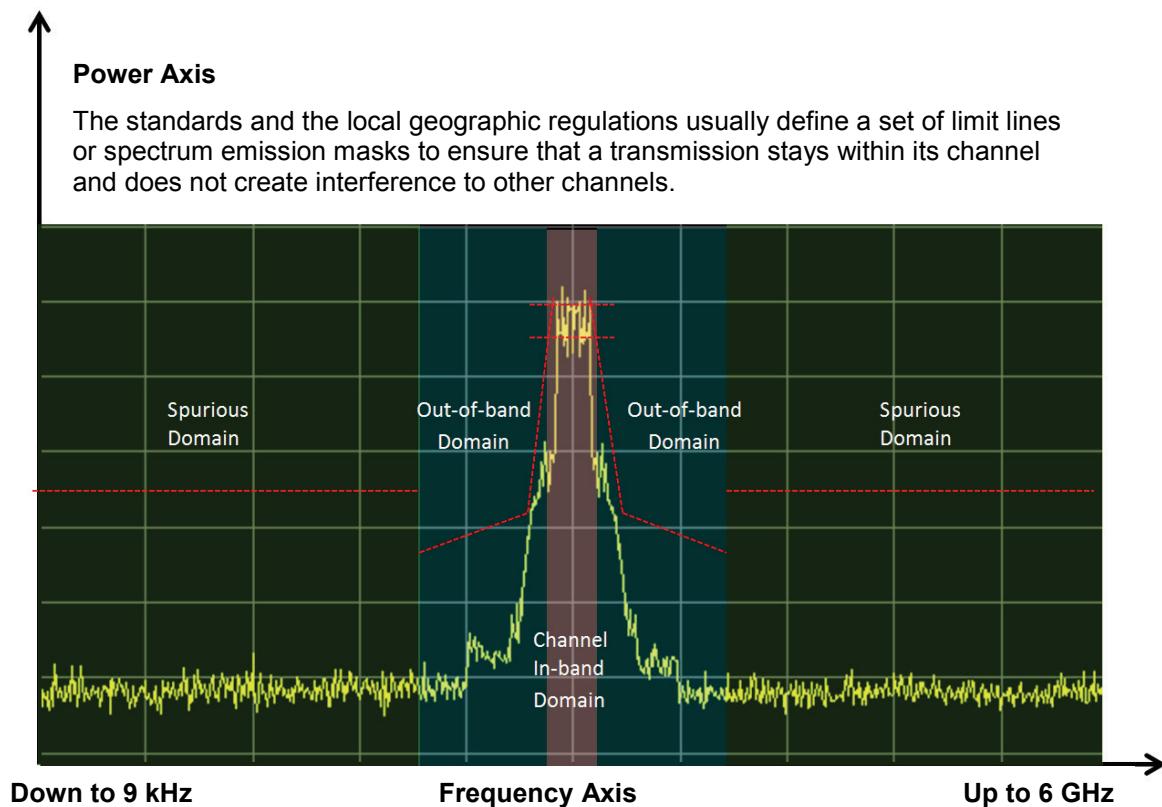
Figure 5. A Near-Field Probe Is Used to Discover the Location of Unintended RF

Near-field Probes	Voltage Probes
<p>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 provide kits 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 Efield probe may be driven by location of a signal in your design, or by the nature of its source (voltage or current).</p> <p>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.</p> <p>Near-field probes must be used to either pick up the signal near the device under test.</p>	<p>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.</p> <p>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.</p> <p>Furthermore, the noise floor and sensitivity of a spectrum analyzer is typically orders of magnitude better than an oscilloscope, so loss from a probe is rarely a limiting factor.</p> <p>Voltage probes must be attached directly to the circuit to pick up the signal.</p>

4. How to Perform the Pre-compliance Test with the Tektronix MDO4000B and SignalVu-PC Software

4.1 Three Basic Steps for Spectrum Pre-compliance Test

The goal of the Pre-compliance is to uncover potential problems and reduce risk of failure at the expensive compliance test stage. General-purpose spectrum analyzers that contain general purpose filters and detectors are often employed in precertification, as they are fast measurement tools that often are already used in the design process and do not require additional capital expense.



For pre-compliance test, the frequency domain is divided to 3 sub-domains (zones). Each has its individual regulation, and the wireless devices implementers need to be successful in “the 3 step spectrum pre-compliance test” before getting their products into market.

Step 1 In-band (Channel) Domain

Check the transmit power output, the transmit bandwidth, and power spectrum density, etc.

Step 2 Out-of-band Domain³

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.

³ Different regulations may have different definition of the emission sub-domains. Please check your local regulation for more details.

Table 3: An FCC example with the compliance requirements and how to use the Tektronix MDO4000B Series and SignalVu-PC software to make the pre-compliance test.

FCC Part 15 Section	Description/ Requirement	How to Measure with MDO4000B+SignalVu-PC
15.247(a)(2)	The minimum 6dB bandwidth shall be at least 500 kHz.	Occupied Bandwidth Measurement
15.247(b)(3)	The maximum peak output power of the intentional radiator shall not exceed 1 watt.	WLAN Summary
15.247(c)	In any 100 kHz bandwidth outside the frequency band in which the spread spectrum intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power.	Spurious Measurement
15.247(c)	Radiated emissions, which fall in the restricted bands, as defined in Sec. 15.205(a), must also comply with the radiated emission limits specified in Sec. 15.209(a). All others must be < -20dBc.	Spurious Measurement
15.247(d)	The peak power spectral density conducted from the intentional radiator to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.	Spectrum Measurement
15.207	AC Conducted Emissions	Spurious Measurement
15.209	Radiated Emissions	Spurious Measurement

4.2 Transmit Power Measurement

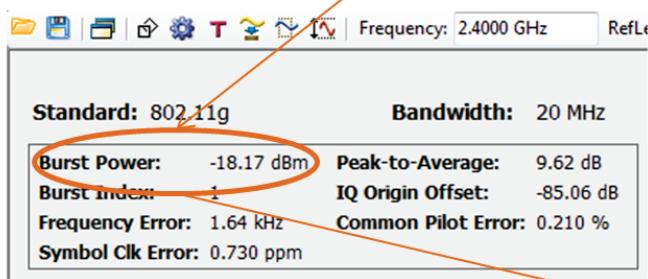
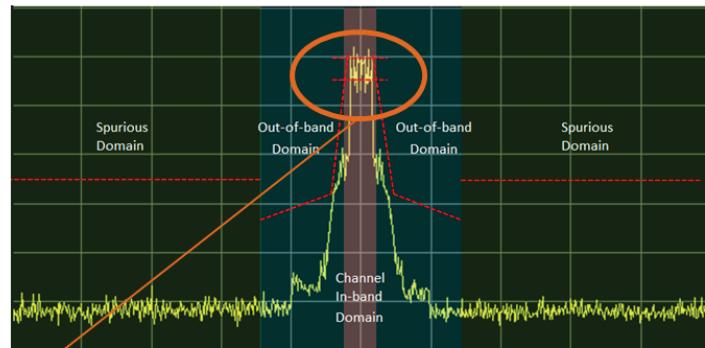
When planning or updating a wireless device installation, it's often necessary to determine if your wireless equipment can achieve a certain transmission distance. However, this information is not printed in the specs for wireless devices and antennas. Maximum allowable output power is measured in accordance with practices specified by the regional regulatory bodies. Therefore, you need to check the standards and regulations to ensure your device is able to pass the compliance test.

It is important to note that some WLAN signals exceed the bandwidth of an analyzer to perform the transmitted power measurement. For example, an 802.11ac signal would require a bandwidth of at least 160 MHz to perform the Burst Power.

Step 1:

Select the IEEE 802.11g as the Preset measurement standard in Tektronix SignalVu-PC.

Set the center frequency according to your interested channel.



Step 2:

In the WLAN Summary display, check the burst power.

Upper Limit: FCC indicated that the maximum Transmitter Power Output (TPO) is 1 watt (30 dBm).

Lower Limit: FCC does not set the requirement for the minimum transmitter power output.

Pass

Step 3:

Check if the transmit power is within the limitation of the regulatory standards.

Figure 7: IEEE 802.11g Transmit Power Measurement

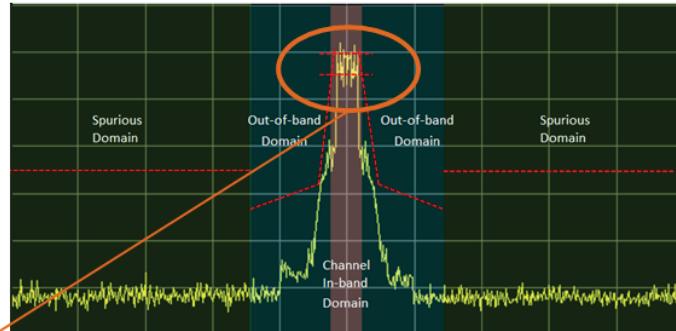
4.3 Occupied Bandwidth Measurement

Occupied bandwidth is a measurement of the frequency band bandwidth that contains a specified percentage of the total power of the signal. Occupied Bandwidth (OBW) is a measurement of how much bandwidth a signal consumes within an allocated channel. Typically, the OBW is specified as a percentage of the total power within the allocated channel bandwidth, such as 99% or the X dB down bandwidth. In this example, FCC requires that the minimum 6dB bandwidth shall be at least 500 kHz, so you need to make the 6 dB down occupied bandwidth measurement.

Step 1:

Select the Occupied Bandwidth display in SignalVu-PC.

Set the center frequency according to your interested channel.



Step 2: In the Occupied Bandwidth display, check the -6 dB bandwidth.

FCC Regulation: The minimum 6dB bandwidth shall be at least 500 kHz.

Pass

Figure 8: IEEE 802.11g Occupied Bandwidth Measurement

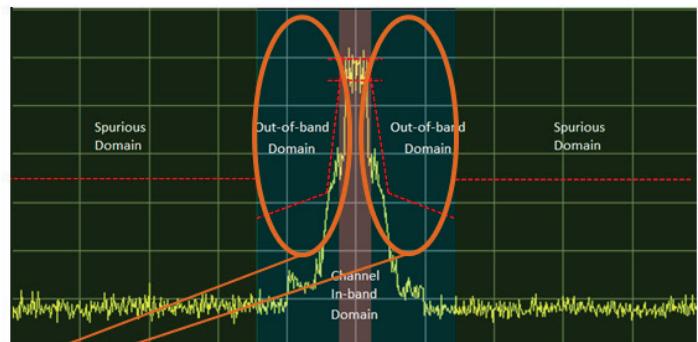
4.4 Spectrum Emission Mask Measurement

Once the transmit power output of your device meets the in-band compliance requirement, you can move on to test the out-of-band emissions. A spectral mask is a mathematically-defined set of lines applied to the levels of radio transmissions. This mask provides the limit under which the signal power is allowed to distribute over the channel. The Transmit Spectrum Mask is defined for each variant of the standard. Generally, the Spectrum Emission Mask (or out-of-band) domain starts at a frequency offset of 0.5 times the necessary bandwidth (allocated channel bandwidth) and extends up to 2.5 times the necessary bandwidth. For example, the IEEE emission mask domain of a 20 MHz bandwidth 802.11g signal is from ± 10 MHz to ± 50 MHz frequency offset from its center frequency.

Step 1:

Select the IEEE 802.11g as the Preset measurement standard in Tektronix SignalVu.

Set the center frequency according to your interested channel.



Step 2:

In the SEM display, the pre-compliance result will be shown automatically.

Figure 9: IEEE 802.11g SEM Measurement

4.5 Spurious Emission Measurement

A spurious emission is any radio frequency not deliberately created or transmitted, especially in a device which normally does create other frequencies. A harmonic or other signal outside a transmitter's assigned channel would be considered a spurious emission. The local regulatory standards such as FCC in US provides the limit (permissible value) of spurious emission power of a given unwanted emission domain.

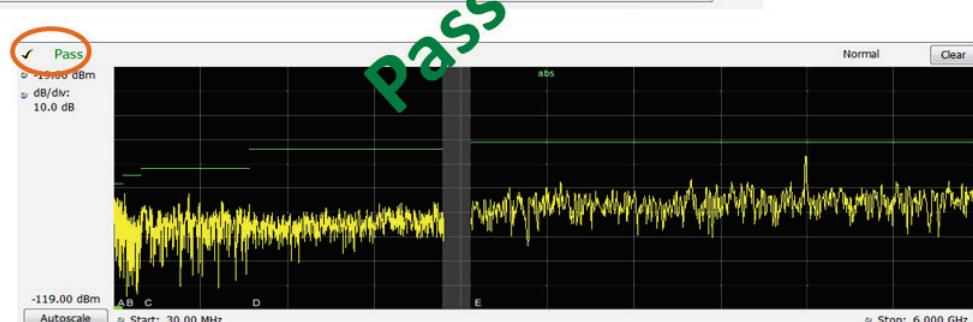
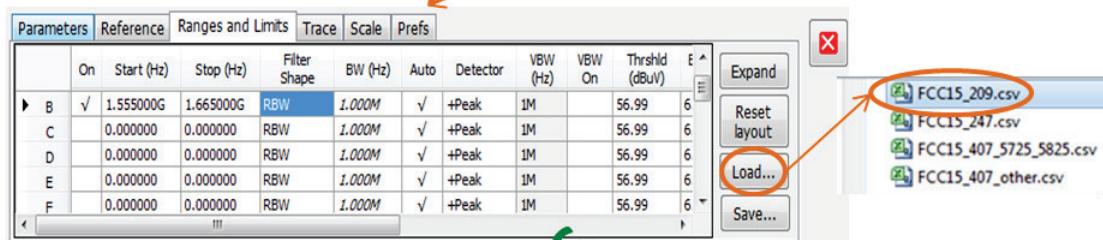
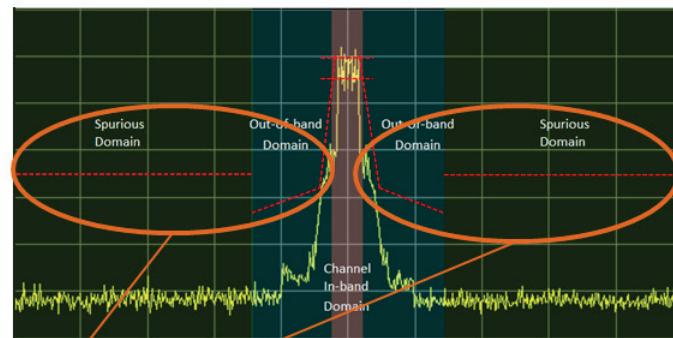
This measurement is done using a Spurious Measurement package on SignalVu-PC in this case. Here, the limit lines are loaded from this saved setup file with the appropriate RBW's for each of the frequency zones established in the standard.

Step 1:

Open the Spurious measurement display in SignalVu-PC.

Load your local limit line file from the limit line library.

The sample FCC pre-compliance limit lines can be found at:
<http://www.tek.com/fcc-mask>



Step 2:

In the Spurious display, the pre-compliance result will be shown automatically.

Figure 10: IEEE 802.11g Spurious Measurement

5. Recommended Configuration

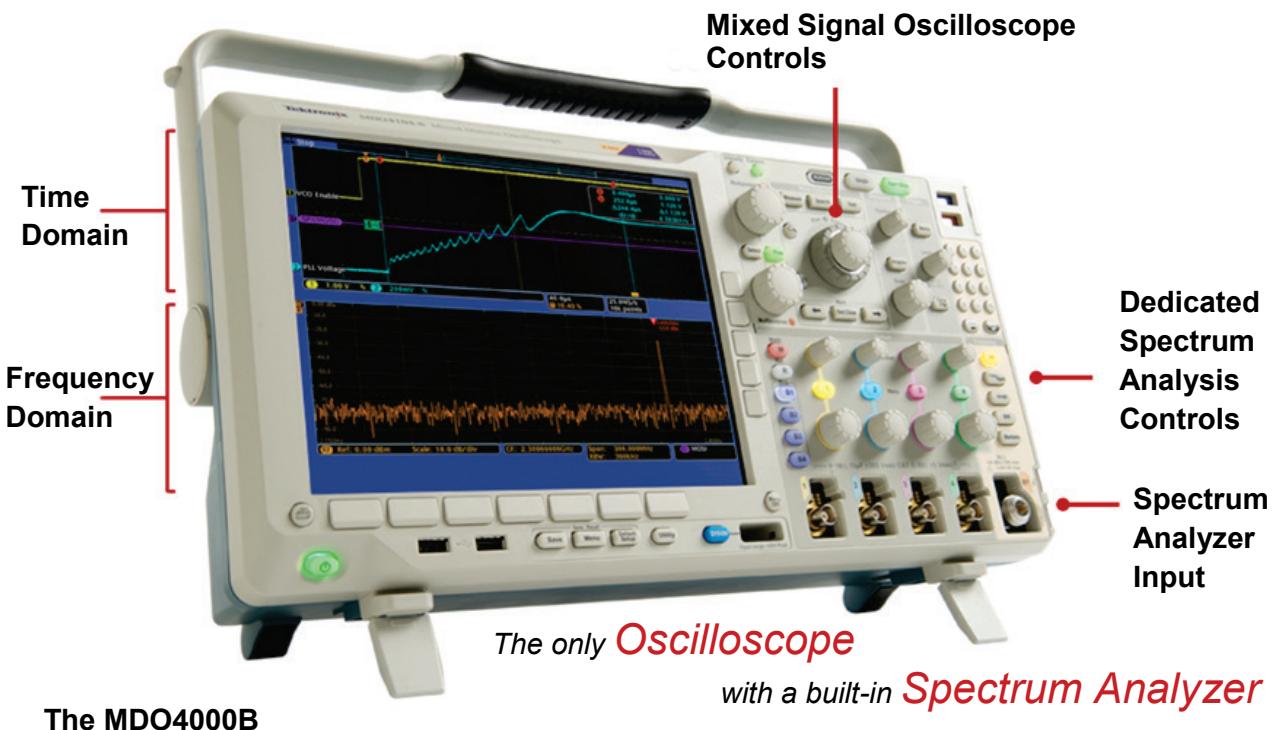
For the MDO4000B and SignalVu-PC software to perform the following required Spectrum Regulatory Pre-compliance Measurements:

Note: The Live Link to SignalVu-PC software is required to complete these measurements.

- WLAN Transmit Power
- Spectrum Emissions Mask
- Occupied Bandwidth
- Spurious Emissions

Recommended Options
Note: SignalVu-PC Opt SV2C Bundles the all of the above options into one package.
SignalVu-PC-SVE: SignalVu Essentials. This SW includes the spurious measurement, where mask limit lines can be added like the FCC regulatory masks
SignalVu-PC SVE Opt SV23: WLAN 802.11a/b/g/j/p measurements supported here. This package is recommended for the WLAN Transmit Power and Spectrum Emissions Mask when testing these WLAN standards ⁴ .
SignalVu-PC SVE Opt SV24: WLAN 802.11n (requires Opt SV23). This package is recommended for the WLAN Transmit Power and Spectrum Emissions Mask when testing these WLAN standards ⁴ .
SignalVu-PC SVE Opt SV25: WLAN 802.11ac (requires Opt SV23 and Opt SV24). This package is recommended for the WLAN Transmit Power and Spectrum Emissions Mask when testing these WLAN standards ⁴ .
SignalVu-PC Opt CON: Provides Connectivity between the MDO4000B and a PC running SignalVu-PC
SignalVu-PC Opt SV2C: Bundles all the above options into one package.

⁴ Note that all of the WLAN Physical Layer Measurements are also included in this package



6. Diagnostics Are Not Limited to the EMI Pre-compliance

Unfortunately, there can be failures to these tests as a result of integrating a WLAN module into a device. When there is a failure, further diagnosis is required. Of course, diagnostics are not limited to ensuring good EMC performance; system integration frequently requires extensive diagnosis and troubleshooting to ensure that all of the RF subsystems perform up to their required levels without being degraded by other parts of the integrated system.

With the MDO4000B Series, the world's first oscilloscope with a built in spectrum analyzer, and capture time-correlated analog, digital and RF signals for a complete system view of your device, you see both the time and frequency domain in a single glance and view the RF spectrum at any point in time to see how it changes with time or device state, to solve the most complicated design issues, quickly and efficiently. When both the spectrum analyzer and any analog or digital channels are on, the oscilloscope display is split into two views. The upper half of the display is a traditional oscilloscope view of the Time Domain. The lower half of the display is a Frequency Domain view of the spectrum analyzer input.

And now, with live link between MDO4000B and SignalVu-PC software, you can analyze the RF signal phase and amplitude in time and frequency as well as demodulate it. Plus, qualify the RF signal quality as well as extract the symbol information. There are also dedicated options to analyze Wi-Fi signals and in particular the wide bandwidth IEEE 802.11ac signals. And because the MDO4000B is able to acquire 1 GHz seamlessly, in one shot, all spectral, time-domain and modulation measurements can be done simultaneously. Other narrower bandwidth signal analyzers need to sweep to capture the Spectral Emission Mask for example, as more than 160 MHz of bandwidth is required for this measurement.

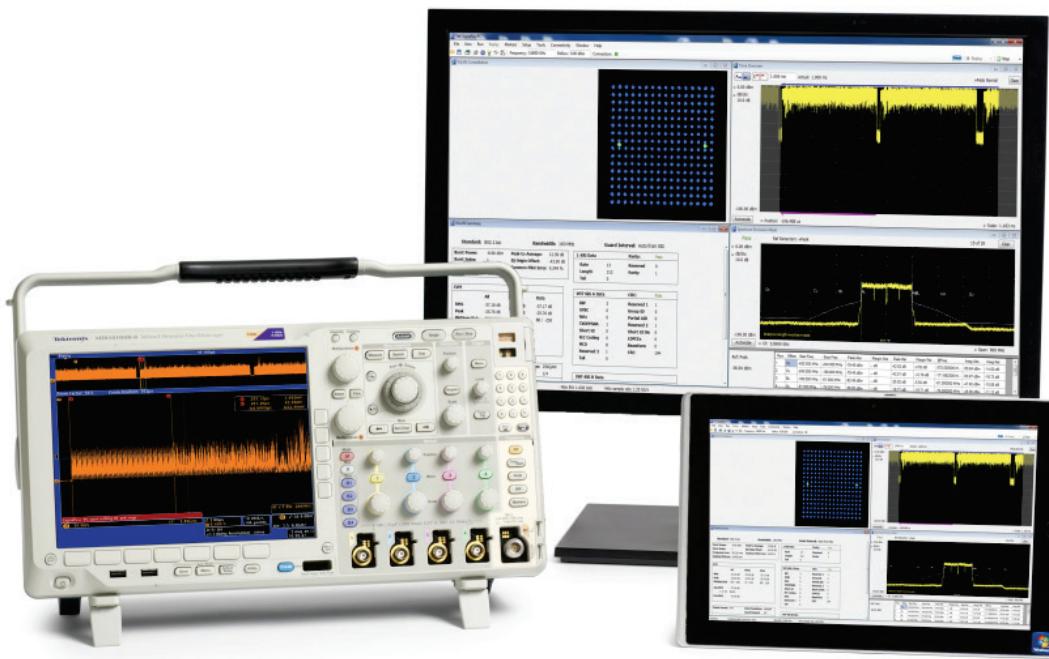


Figure 12. Tektronix MDO4000B Paired with SignalVu-PC to Analyze 802.11ac Signals.

ASEAN / Australia (65) 6356 3900
Austria* 00800 2255 4835
Balkans, Israel, South Africa and other ISE Countries +41 52 675 3777
Belgium* 00800 2255 4835
Brazil +55 (11) 3759 7627
Canada 1 (800) 833-9200
Central East Europe and the Baltics +41 52 675 3777
Central Europe & Greece +41 52 675 3777
Denmark +45 80 88 1401
Finland +41 52 675 3777
France* 00800 2255 4835
Germany* 00800 2255 4835
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Contact List Updated March 2013

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