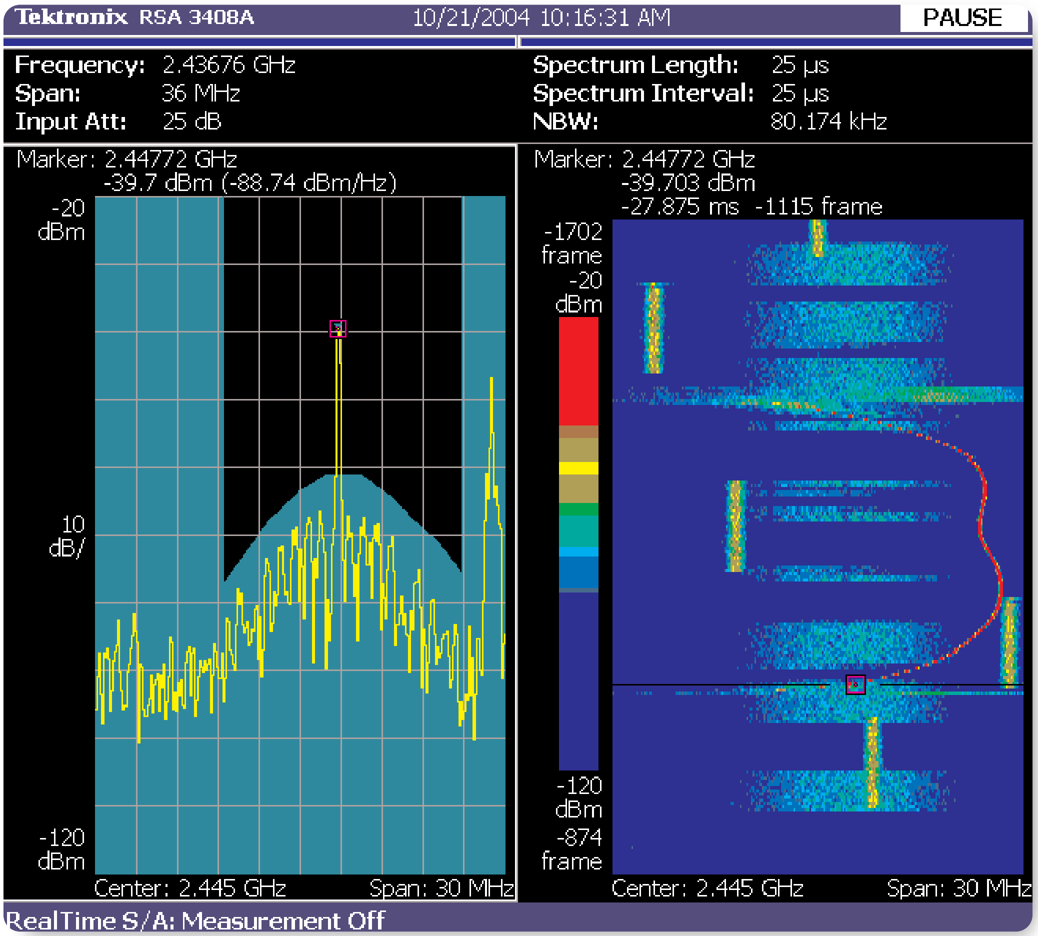
Real-Time Spectrum Analysis for WLAN and Combo Devices



Introduction

Wireless combo devices that incorporate multiple RF communications protocols such as Wireless Local Area Network (WLAN), Bluetooth and 3G cellular standards are becoming increasingly popular, enhancing connectivity and performance in the wireless marketplace. Combo devices present a challenging set of signal measurement issues for the wireless engineer, whether validating a reference design or working on the next generation modulation format. Packet signal transients, asynchronous packet collisions and a variety of self-interference modes can be difficult or impossible to diagnose with traditional signal analyzers. The Tektronix Real-Time Spectrum Analyzer (RTSA) offers a unique and practical solution to many of these difficult signal measurement problems.

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This application note focuses on key measurement issues for WLAN and combo devices, how the RTSA addresses those issues, and why traditional signal analyzers are not adequate. We begin with a brief overview of the key concepts of real-time spectrum analysis, including the ability to flexibly trigger on RF signals, seamlessly capture them in memory, and perform time-correlated multi-domain analysis based on a variety of wireless standards. Next, the WLAN measurement analysis software available for the RSA3408A Real-Time Spectrum Analyzer is reviewed. Finally, we explore some of the real-world problems encountered with wireless combo devices that can be solved using the RSA3408A. Issues like packet collisions between Bluetooth and WLAN devices, internal interference caused by poor filtering and poor shielding in a GSM/WLAN device, and the unwanted interactions between RF packets and high-speed digital logic circuits are explored.

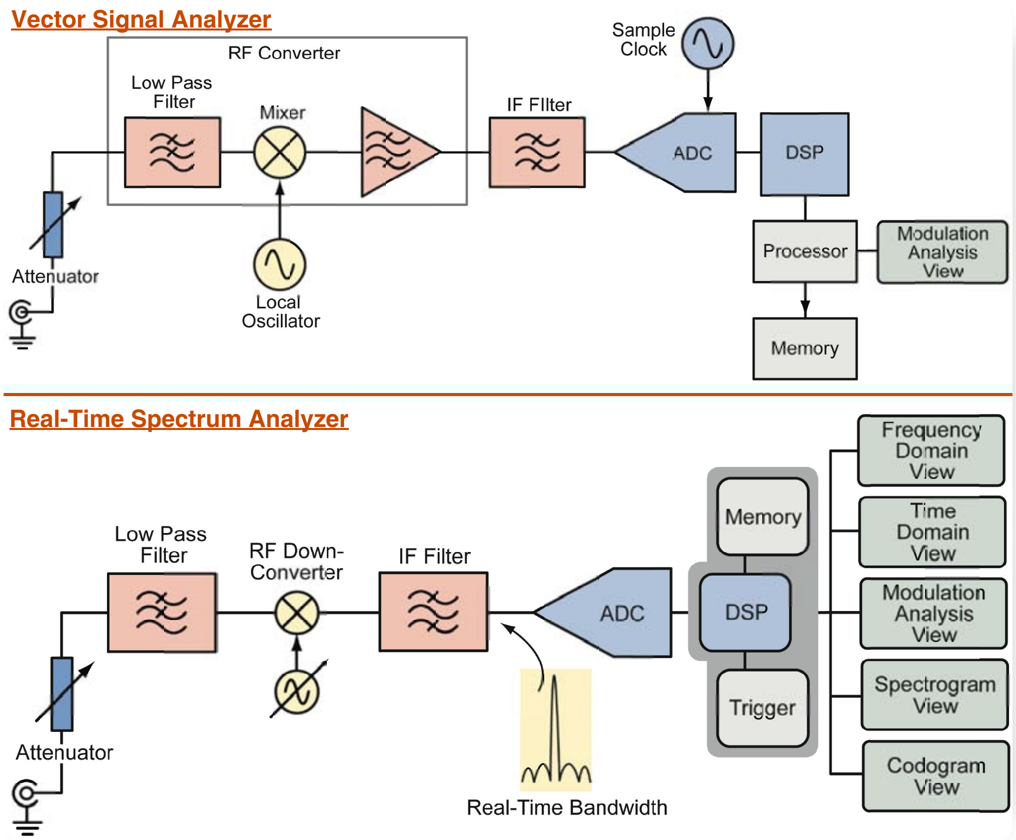
The Real-Time Spectrum Analyzer

The RTSA is designed to address the measurement challenges associated with dynamic RF signals such as the bursted packet transmissions like WLAN and Bluetooth. The fundamental concept of real-time spectrum analysis is the ability to trigger on an RF signal, seamlessly capture time synchronized data into memory, and analyze it in multiple domains. This makes it possible to reliably detect and characterize RF signals that change over time.

Figure 1 shows a simplified block diagram of RSA3408A. The RF front-end can be tuned from DC to 8 GHz, and the input signal is down-converted to a fixed IF related to the maximum real-time bandwidth of the RSA. The signal is then filtered, digitized by the ADC, and passed to the DSP engine that manages the instrument's triggering, memory, and analysis functions. While many elements of this block diagram and acquisition process are similar to those of the traditional vector signal analyzer (VSA) architecture also shown in Figure 1, the RTSA is optimized to deliver real-time triggering, seamless signal capture, and time-correlated multi-domain analysis. In addition, advancements in ADC technology enable a conversion with high dynamic range and low noise, allowing the RSA to make traditional frequency domain measurements that equal or surpass the basic RF performance of many swept spectrum analyzers.

The traditional VSA can trace its lineage primarily back to the development of digital Continuous Wave (CW) modulations. Early digital modulation developers sought tools that could do a better job of analyzing vector signals in the modulation domain than the oscilloscopes or scalar analyzers of the day. This led to the development of the constellation analyzer. Initially, constellation analyzers were little more than specialized oscilloscopes. More recently, the functions of the constellation analyzer have been combined with a spectrum analyzer to facilitate the down-conversion of RF signals, leading to what has become the present day VSA.

Unlike the vector signal analyzer, the real-time spectrum analyzer can trace its origins back to the demands of the signal intelligence community based on the limitations of the swept spectrum analyzer. Swept spectrum analyzers only capture small time samples of the RF spectrum, leaving large periods in between sweeps unaccounted for. To the intelligence community this unaccounted for period of time represented a significant problem. A signal could be quickly bursted on and off to intentionally avoid interception. To the intelligence analyst, missing an important communications intercept could have grave consequences and was unacceptable. This led to the demand for a real-time spectrum analyzer that would capture everything with no time gaps. Tektronix began pioneering this family of instruments over 20 years ago.



▶ **Figure 1.** *VSA and RTSA Block Diagram comparison showing DSP differences.*

The RTSA offered a reliable solution for intercepting the intermittent signal. As signals grew in complexity, the need for precise event triggering became a critical requirement. Recording and analyzing long periods of inactivity quickly became impractical. This led to the development of the sophisticated real-time triggers now available in the modern RTSA.

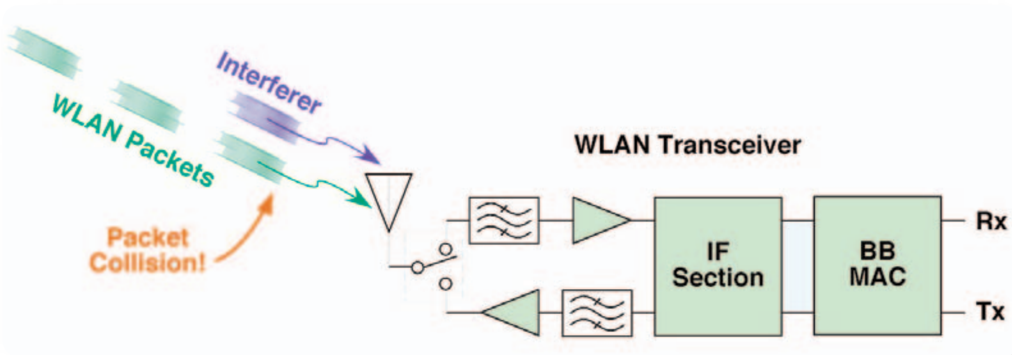
The RTSA's frequency mask trigger allows the engineer to view elusive transient signals that are impossible to see in free run mode. Real-time triggering makes it possible to reliably detect and capture intermittent RF signals, even when they occur in the presence of much more powerful adjacent signals.

Unlike many vector signal analyzers that operate by taking snapshots of a modulated signal, the RTSA has no holes or gaps in the time domain record that it uses to make time, frequency, and modulation domain measurements. The true time correlated multi-domain analysis provided by the RTSA allows users to precisely correlate diagnostic data across multiple domains to rapidly understand the nature of the signal.

RTSA and WLAN Combo Devices

We have discussed how the RTSA differs from the traditional VSA. Why, then, are these differences so important to the WLAN combo device engineer?

WLAN combo devices share a unique set of measurement problems, which seem to be central to the future direction of communications.



▶ **Figure 2.** *Interfering signal bursts arriving at the antenna at same time as the desired signals, causing collisions with the WLAN packets.*

The advent of low cost, high-speed logic devices and block error detection-correction schemes has propelled the communications industry in the direction of packetized information transmitted via intermittent RF signal bursts. The Internet is an excellent example of this powerful trend toward packetized communications. WLAN, an extension of the Internet, is also a packet based communications system.

What are the unique problems associated with packet communications systems like WLAN?

Unlike older CW communication systems, packet communication systems use asynchronous data transmissions. Analysis of WLAN signals requires the ability to capture specific asynchronous RF signal events and efficiently find them in the captured record for analysis. WLAN packet communications thus present precisely the same problem the surveillance industry has had for many years, and has been central to the evolution of the RTSA.

Though many vector signal analyzers have some ability to characterize WLAN signals, it is often in highly controlled environments that lack the real-world asynchronous interference issues associated with the more complex WLAN combo device.

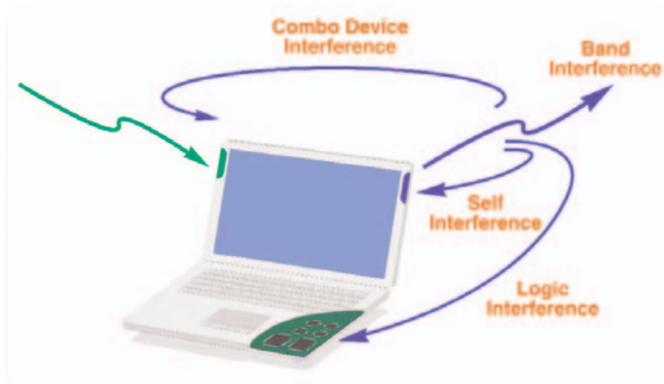
Packet collisions, intermittent signals, and startup/shutdown transients are asynchronous events that demand an analyzer with triggering abilities suitable to capture these events and a truly time correlated multi-domain analysis ability to diagnose them.

Take, for example, a WLAN combo device dropping 5% of the WLAN packets under ideal signal conditions. How would an engineer determine if it was an uncontrolled packet collision or a logic problem in the setup of the Media Access Controller (MAC)?

Using the MAC for a VSA trigger source not only necessitates a time-consuming connection, but also may be a questionable practice if the MAC is part of the problem to be diagnosed. Searching 100 signal bursts in the VSA's capture record to find the 5 that have a problem is an inefficient, time-consuming approach to diagnosis. Using the RTSA frequency mask trigger will capture this problem for analysis without complicated external triggers or time-consuming data searches.

Combo devices have more modes of interference than the typical transceiver. Not only does the engineer have to cope with the in and out of band emissions regulations, but also with the effects of the RF emissions on co-located receivers, transceivers and high-speed microprocessors.

The intermittent nature of WLAN packets can make interference related issues very time consuming to identify without the triggering capability of the RTSA. Asynchronous RF intermittent interference problems frequently cause project delays, as engineers struggle to gain insight into these unintentional sporadic interactions.



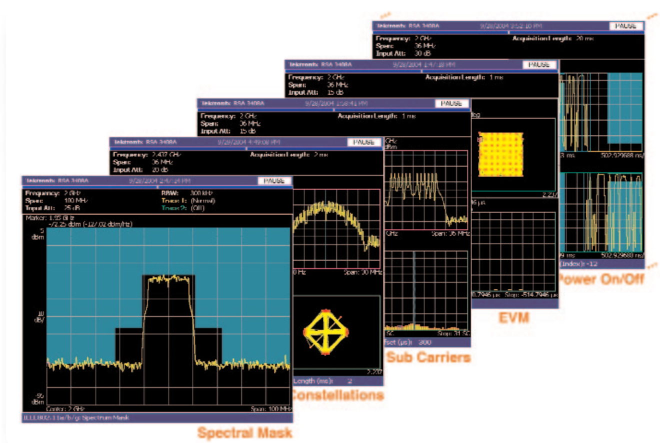
▸ **Figure 3.** *Modes of combo device interference.*

WLAN Specific Measurements

The RSA3408A has the technical ability to trigger and reliably capture intermittent signals. To be an effective diagnostic tool for combo devices it must also have a complete set of WLAN measurements.

The RSA3408A is available with an optional, full-featured, WLAN analysis package. Included in the analysis package are all the popular 802.11a/b/g measurement standards, preset for rapid signal characterization. Measurements such as Spectral Mask, EVM, On/Off Power Transient, CCK Constellations, OFDM Constellations, Sub-carrier Constellations, and many others are part of this comprehensive analysis software.

This application note, however, will focus primarily on the RSA3408A's unique measurement and analysis abilities. More information on the industry standard measurements can be obtained by contacting your Tektronix representative.



▸ **Figure 4.** *Common 802.11a/b/g measurements.*

The RSA3408A offers several unique WLAN analysis abilities designed to provide the engineer with fast insights and reliable data. Let's look at some of these WLAN analysis features.

Time-Correlated Multi-Domain Analysis

As mentioned earlier, the DSP capabilities of the RTSA provide true time-correlated multi-domain analysis for the entire signal stored in memory.

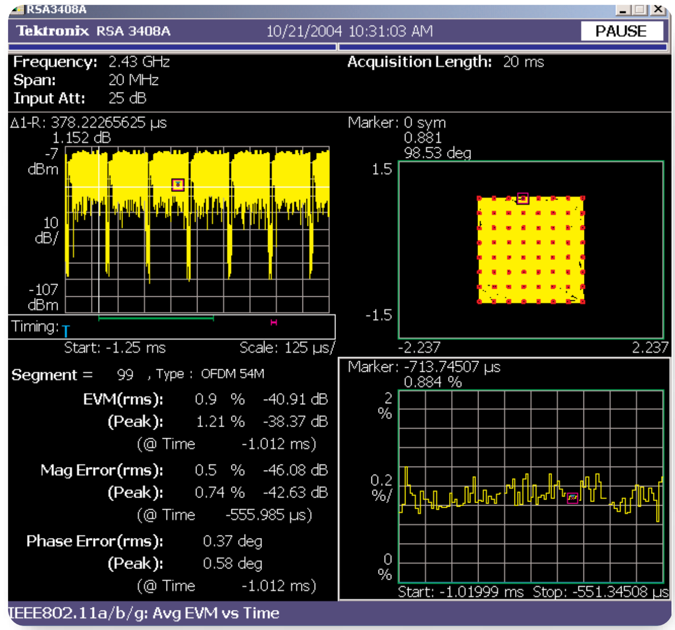
Switching between time domain, frequency domain, modulation domain, spectrogram and code domain displays to view signal characteristics in the most logical way is possible without loss of timing information on the RSA3408A.

The seamless signal capture of the RSA3408A enables markers set in the spectrogram to be precisely time correlated with markers in other domains.

Completely time correlated displays allow seamless analysis from the most understandable point of view. An event captured in the spectrogram or frequency mask trigger display can be viewed in the modulation domain to evaluate its impact on error performance. Simply place the marker on the event in a spectrogram and view the corresponding symbol on the constellation diagram.

This ability to identify anomalies in one domain and instantly evaluate their impact at that exact time in another domain is an essential part of rapid diagnostic insight.

A key example of the benefits of multi-domain analysis is seen when analyzing 802.11b packet bursts with three different display domains.



▸ **Figure 5.** *802.11 Multi-Domain Analysis.*

Power vs. Time, Spectrum and EVM can be seen all at once. Moving the marker in the Power vs. Time display will automatically show the spectrum and EVM as the marker moves. Time correlated marker movements can also be done with the Spectrogram, Symbol Constellation and Voltage vs. time displays.

Using the different points of view available from time correlated multi-domain analysis can be particularly advantageous for analyzing WLAN devices: power on transients spectral impact PA linearity, spectral output at corner symbol points, and signal collisions in the spectrogram are helpful diagnostic displays.

802.11 Auto-Detection

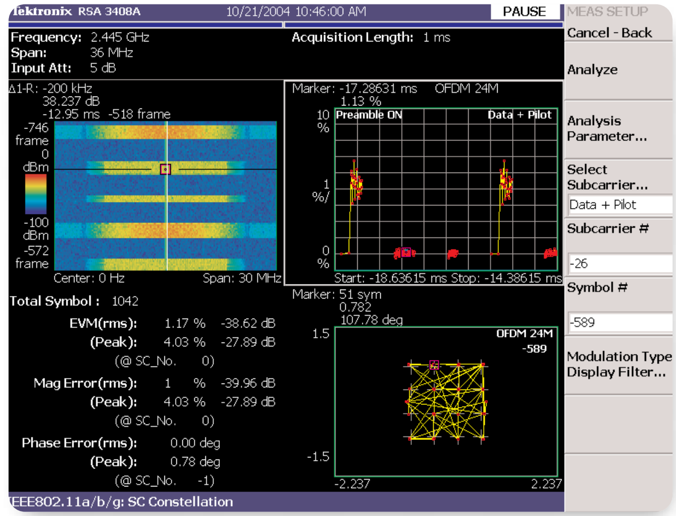
802.11g, 54 MBPS OFDM capable WLAN devices require backwards compatibility with the earlier 802.11b's 11 MBPS CCK format. Many devices produce both signals, presenting a test problem.

Vector signal analyzers often must switch between analysis modes to acquire the signal burst and demodulate it for modulation measurements. This can be complicated since different bursts may be captured as part of the same time record. Switching modulation formats and rates can be a time-consuming process on most signal analyzers, requiring format and rate information entry.

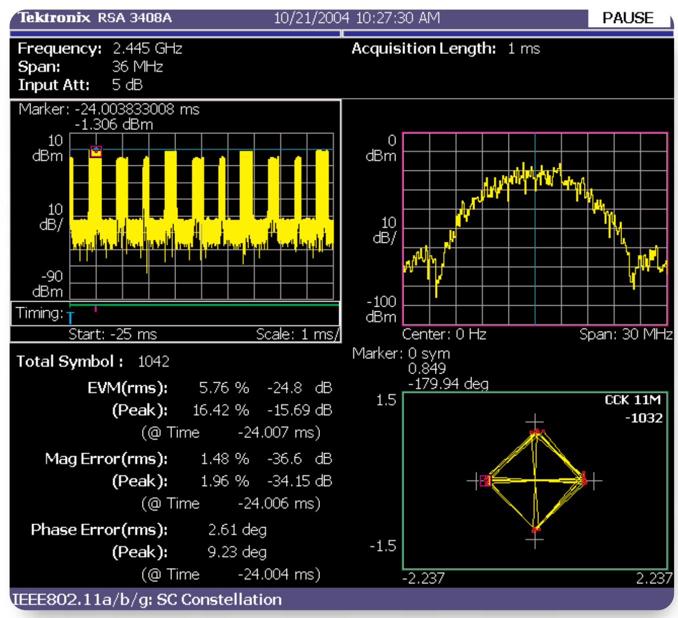
The RTSA features Auto-detection of CCK or OFDM modulation formats and rates. This is convenient for WLAN devices, and essential for many combo devices where complex interference scenarios can necessitate mixed mode operation for diagnosis.

The auto-detection feature allows the engineer to zoom in and analyze each burst automatically, with the instrument selecting the appropriate format and data rate. With the analyzer set to automatic detection, just place the marker on the burst of interest and the instrument does the rest.

This key Tektronix feature enables rapid time to diagnostic insight when evaluating many different transmission packets. Auto-detection allows the engineer to concentrate on the design instead of the test equipment setup.



▶ **Figure 6.** *Auto-detection 24MBPS OFDM.*



▶ **Figure 7.** *Auto-detection of 11 MBPS CCK.*

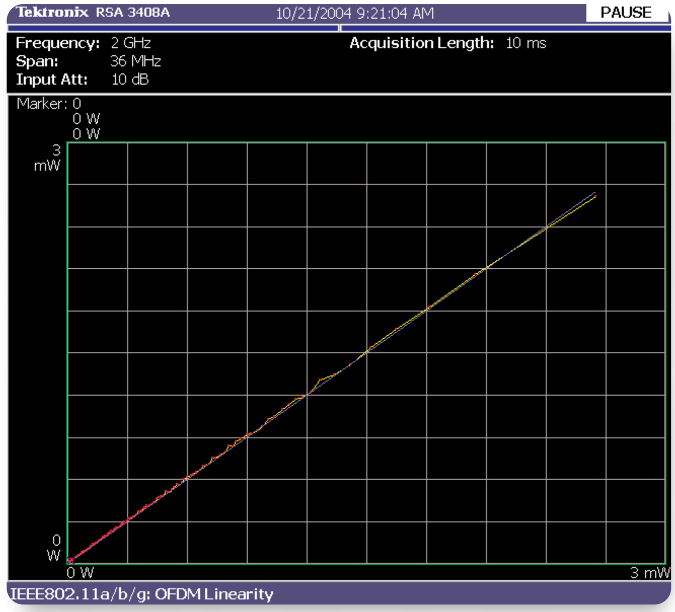
OFDM Linearity Measurement

OFDM signals are well known for their high peak-to-average power ratios, and can significantly stress the transmitter Power Amplifier's (PA) linear amplification range if not properly set up.

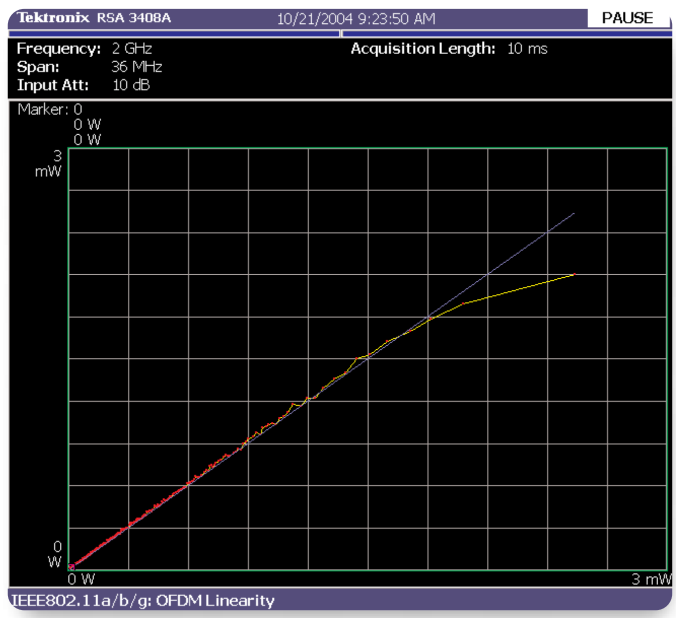
Measuring the PA's linearity quickly and accurately can be a difficult task. Vector Network Analyzers (VNA) can easily measure PA linearity with AM/AM compression measurements. To do this, however, the PA's input must be uncoupled from the device for characterization, making the VNA approach ill suited for quick linearity measurements. EVM can be helpful for judging where the maximum PA power output can be set, but since EVM is a composite of a variety of probabilistic and deterministic sources of error, interpreting EVM to determine the maximum PA output level can be difficult.

The RSA3408A's WLAN analysis software offers an exceptional OFDM linearity measurement display designed to quickly show amplifier signal compression without the need to connect to the input of the PA. Similar to the power in versus power out curve of the VNA, the OFDM linearity measurement plots actual power out versus expected power out. Expected power output is derived from the received symbol data.

It is significant to note that this measurement is both wide bandwidth and applied for each of the OFDM carriers. A VNA would only be able to analyze a narrow band AM/AM compression measurement. The OFDM linearity measurement can be applied to a real signal, addressing the actual bandwidth and dynamic range demands of the PA.



▶ **Figure 8.** *OFDM linearity measurements with properly setup linear (backed-off) PA.*



▶ **Figure 9.** *OFDM linearity measurement with compressed PA.*

With a perfectly linear PA, the expected power is equal to the actual power and a straight line at 45º results. As PA output power increases toward amplifier saturation, the straight line begins to bend. Actual output power falls short of the expected signal power, bending the line.

The OFDM linearity measurement is ideal for quickly spotting linearity problems, sorting through PA candidates or establishing operating levels for 802.11a/g transmitters. The curve can be easily obtained by simply entering the display mode, with the analysis software automatically predicting the expected power and displaying the difference. OFDM linearity is another measurement to quickly get WLAN devices up and running correctly.

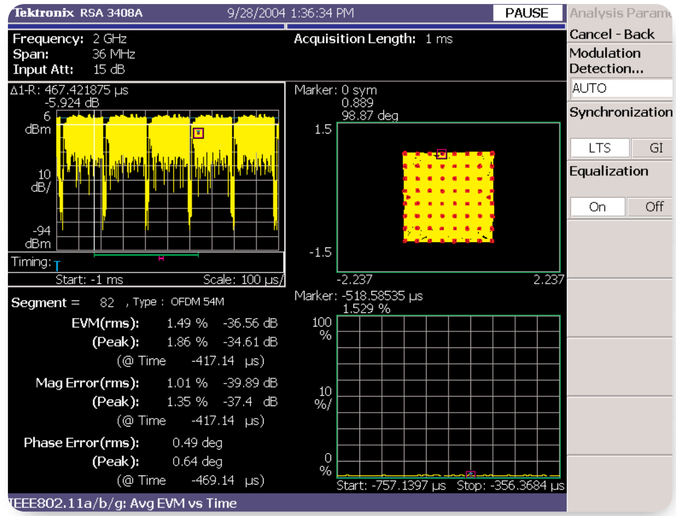
LTS/GI Synchronization

OFDM carrier synchronization is a complex subject and has been a popular topic at conferences. Accurately establishing phase and frequency for many carriers as well as symbol clock timing in a dispersive channel can be difficult.

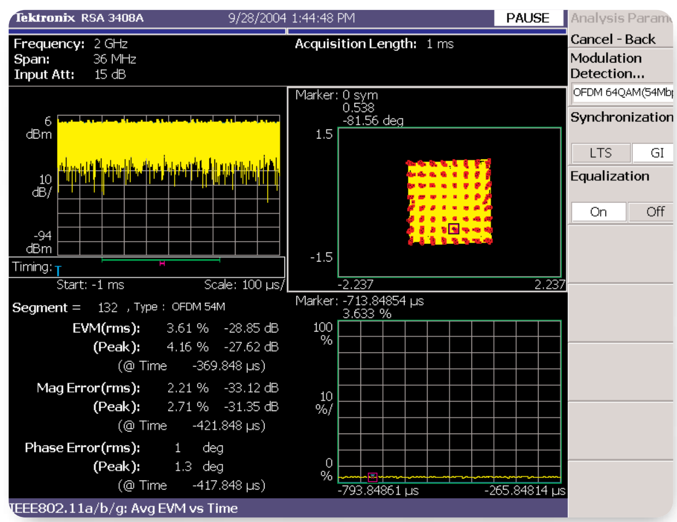
Another unique Tektronix feature designed to aid the engineer in rapid analysis of WLAN signals is the choice of OFDM synchronization methods.

The Long Training Sequence (LTS), contained in the packet burst preamble, is typically used for synchronization of WLAN receivers. The initial symbols of the packet provide a known data pattern useful for estimating carrier frequency error and channel dispersion.

Using the LTS for synchronization is not always possible in the development environment. Unavailable or corrupted preambles by a number of circuit problems, such as a malfunctioning equalizer, PA startup transients, etc. can prevent or degrade synchronization with the LTS.



▶ **Figure 10.** *LTS synchronization option showing no constellation phase rotation.*



▶ **Figure 11.** *GI synchronization option showing some constellation phase errors.*

To get around these problems, Tektronix offers synchronization based not only on the LTS, but also on the Guard Interval (GI) symbols. Guard Interval symbols placed between data segments in the packet burst to improve multi-path tolerance can be used for synchronization. Presented as a simple menu choice, the operator can select the desired synchronization method, LTS or GI.

The longer length of the LTS can provide more accurate synchronization and is generally preferred, if the preamble is functioning properly.

The GI synchronization option can be useful in checking the LTS synchronization performance. If the GI synchronization appears better than the LTS, a problem with the LTS synchronization is likely.

The choice of synchronization methods is an important tool in diagnosing OFDM synchronization problems, as well as enabling continued development progress when properly functioning preambles do not exist.

These unique WLAN analysis tools help the combo device designer and production manager get fast WLAN diagnostic insights with reliable, revealing measurements.

Real-World Combo Device Problems

Test equipment must have a "combo" of analysis measurements available for each standard in the combo device to be tested. The RSA3408A is capable of supporting most modern wireless modulations including 802.11a/b/g, GSM/EDGE, W-CDMA, HSDPA, cdma2000, 1xEV-DO, TD-SCDMA, and more. With 36 MHz of real-time RF capture bandwidth and greater than 78 dB dynamic range (TOI), the real-time spectrum analyzer is ideally suited for combo device work and supports many popular WLAN companion transceivers.

Like the WLAN analysis option, all the supported wireless standards are powerful, multi-domain analysis packages. In addition to the time correlated multi-domain ability, these other analysis packages also benefit from the patented frequency domain triggering ability. Thus, the RSA3408A offers the same unique fast time to diagnostic insight for all the supported modulations.

We have seen the powerful RSA3408A DSP advantages, unique WLAN analysis measurement software and the wide range of available wireless standard options. Next, we shall look at some real-world examples and see how to apply this technology to solving some common combo device problems.

WLAN/Bluetooth Packet Collisions

Combo devices that use both Bluetooth Personal Area Network's (PAN) and 802.11b/g WLAN networks have a unique set of RF interference problems because they share the same 2.4 GHz Industrial/Scientific/Medical (ISM) frequency band.

Often advertised as compatible and complementary, Bluetooth and WLAN modulation formats can interfere with each other when the transceivers are located less than a few meters apart. This is clearly the case when they must coexist in a combo device.

The proximity problem arises from the lack of sufficient Anti-Jam (AJ) capabilities in their respective modulation formats. Both modulations use spread spectrum technology. Bluetooth uses Frequency Hop Spread Spectrum (FHSS) and 802.11b/g uses Direct Sequence Spread Spectrum (DSSS) or OFDM. Unfortunately, the coding gain is small in both cases, providing little interference or AJ protection.

Initially, the interference issues were not viewed as substantial problems, because products were viewed as standalone applications. As the need for Bluetooth products to interface with the computer grew and high speed WLAN connectivity became essential for many computers, the WLAN/Bluetooth Combo device interference issue emerged quickly.

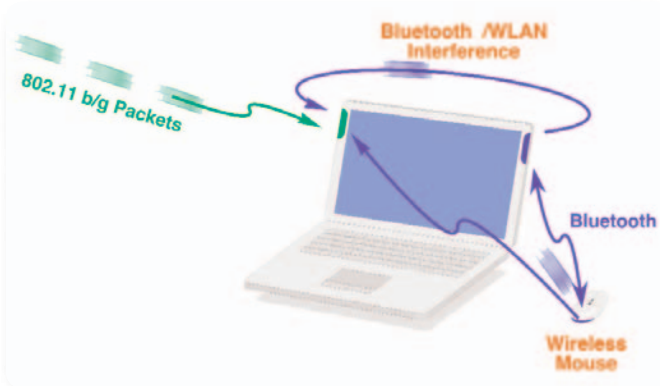
Signals Collide

The loss of the packets due to simultaneous signal arrival and subsequent jamming interferes with proper device function. In the case of our Personal Computer (PC) combo device example, a Bluetooth mouse can interfere with WLAN Internet downloads. Mouse movements effectively slow down Internet connection speeds.

These problems were envisioned early in the development of both the Bluetooth and WLAN standards and devices. Devices would first listen in on the channel before transmitting to assure the channel was not already in use. These Carrier Sense Multiple Access/Collision Detection (CSMA/CD) protocols were added to avoid interrupting either Bluetooth or WLAN transmissions.

The listen before talk method used by the WLAN CSMA protocol dictates that the receiver must listen for other signals in the channel for a time interval, usually 10 µS, before allowing the transmitter to turn-on. When a signal is detected, the transmission is delayed for a random number of time intervals, which is also usually 10 µS. This 10 µS granularity leaves a period of uncertainty when another device could choose to access the channel.

Unfortunately, WLAN/Bluetooth combo devices still have asynchronous transmission packets. A clear channel now does not guarantee a clear channel a moment from now. As such signal packets will still occasionally collide.



▶ **Figure 12.** *802.11b/g signal packets colliding with Bluetooth signal packet.*

A Measurement Problem

Evaluating the packet interference performance of a WLAN/Bluetooth combo device can be difficult. The need to capture the collision of signals requires a trigger capable of catching the event. Triggering on either the Bluetooth or WLAN packets could leave a time record with hundreds of packets to manually search and only a few collisions. Triggering on power versus time would only work reliably if the signals were of equal amplitude, which is rarely the case. External triggers are possible, but in this case a complicated logical AND process would be required in addition to the sometimes-difficult circuit connection.

A free-running acquisition could be used, but might be very misleading. Asynchronous signals go through periods of high activity and low activity. Free-running acquisitions also require extensive analysis time to eliminate the non-collision data.

Without adequate diagnostic tools, one might be tempted to use packet loss data alone. Analysis of packet loss data does not provide reliable insight into the nature of the packet loss. Was it a signal collision or just an improperly set up PA? Such incomplete analysis can lead to project and production disasters.

What may be viewed as a minor PA setup issue can incorrectly lead engineers to commit to schedule dates that do not reflect the complexity of the unknown underlying problems. Worse yet, if the product is released to production, it may be a matter of time before an embarrassing, costly production stoppage occurs from component tolerances. By the time the underlying problem is recognized, if ever, projects can be far behind schedule with costs mounting. In real-world devices, it is essential to have the tools necessary to gain clear diagnostic insight in order to keep projects on schedule.

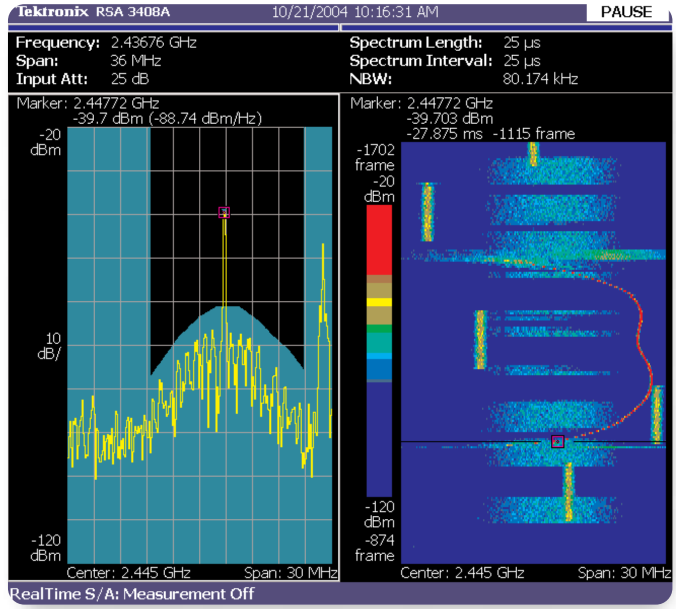
As you can see, all these approaches to capturing WLAN and Bluetooth packet collisions are flawed, time-consuming or difficult to set up.

The Real-Time Trigger Solution

RTSA's can detect signals colliding in a band using the frequency mask trigger. This patented trigger allows for rapid measurement setup and capture of the asynchronous WLAN/Bluetooth packet collisions.

To set up the frequency mask trigger for capturing packet collisions, begin by capturing an 802.11b/g signal packet. The captured WLAN packet should be free of Bluetooth interference. Using either the spectrogram or power versus time display, place a marker on the payload portion of the 802.11b/g packet burst. Avoid using the preamble portion of the packet as it does not contain the widest spectral envelope.

Next, using the time correlated multi-domain analysis capability of the RSA3408A; view the corresponding spectrum plot of the data payload section of the 802.11b/g burst using the 36 MHz real-time bandwidth of the analyzer to capture approaching signals.

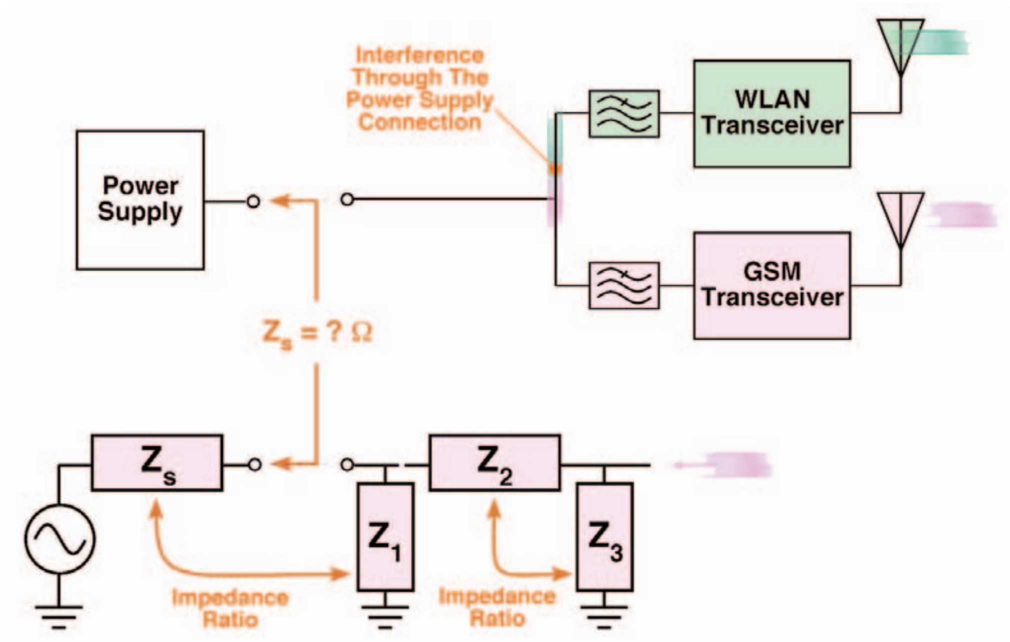


▶ **Figure 13.** *Frequency Mask Trigger Capturing, 802.11b/g CCK signal packets colliding with a Bluetooth FHSS signal and a microwave oven.*

A frequency trigger mask is then set up just outside of the 802.11b/g spectrum. The mask should be set up far enough away so the WLAN packet bursts by themselves will not trigger the analyzer. The analyzer is then armed for triggering and the Bluetooth transceiver is then activated.

As the Bluetooth FSK FHSS signal hops across the 802.11b/g packet it will break the frequency mask and trigger the analyzer on the packet collision. Likewise, as in Figure 13, transient interference from a microwave oven can break the spectral mask and trigger an acquisition of signal data.

Unlike the VSA approach of long captures followed by detailed examination to find the signal collisions, the engineer will find a very short capture length is usually adequate on the RSA3408A. Frequency mask triggering can efficiently identify the collision information and store only the packets of interest into memory. This eliminates the time consuming process of searching through a long record for occasional errors and reduces the capture memory requirements. Pre and post trigger delays can be used to assure complete capture of the WLAN/Bluetooth burst, if desired.



▶ **Figure 14.** *GSM interference coupling to the WLAN transceiver via power supply connections illustrates the difficulty of filtering in low impedance systems.*

It is worth noting that the unlicensed ISM band has many possibilities for interference scenarios. Hospitals, stock exchanges, and manufacturing plants often have immensely complicated ISM band RF environments. In the field it has traditionally been difficult to precisely determine the interference sources. Using the same procedure outlined above for the development laboratory, it is now possible to quickly identify interference sources in the field.

Validating Synchronized Signals

Recently many combo 802.11b/g and Bluetooth designs are beginning to synchronize transmissions at the MAC level. This avoids combo device interference at the RF level.

Synchronized combo devices require validation to assure correct operation. This can present a significant problem in the volume production environment where physically probing the circuit is not desirable. Using the frequency mask trigger, the combo device can be exercised while the RSA3408A checks regulatory mask violations and packet collisions. This is a fast, easy way to identify problems with failing synchronization circuits.

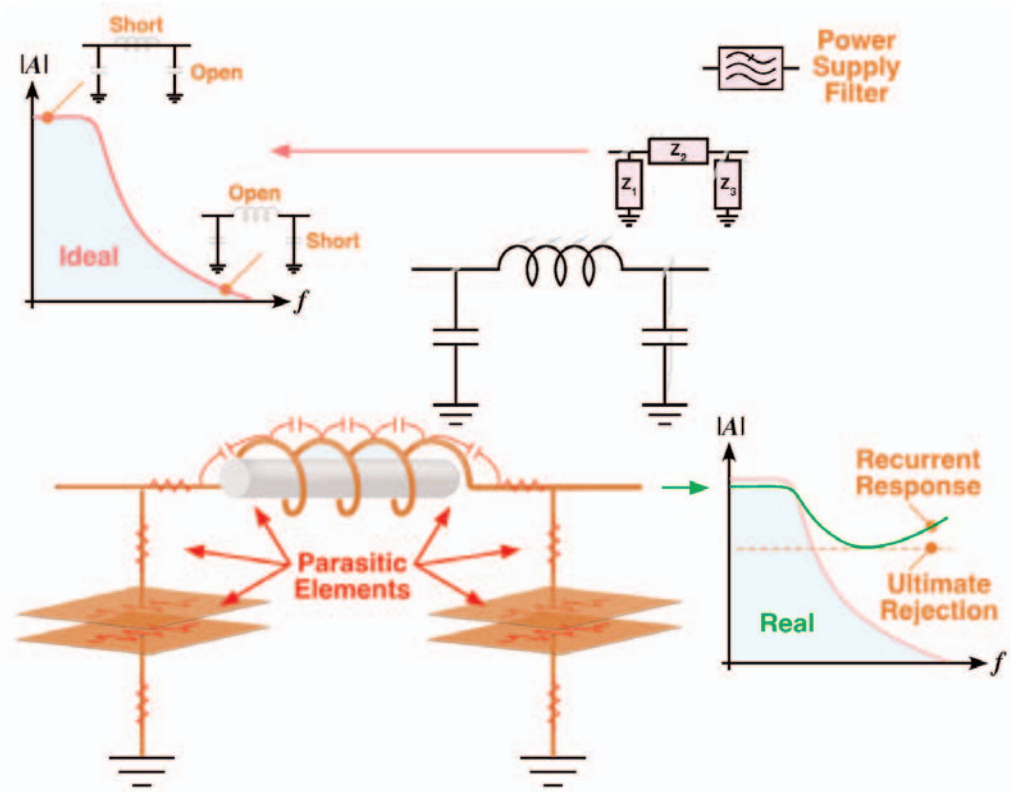
The RSA3408A is ideally suited for WLAN/Bluetooth communications analysis. It goes beyond the traditional VSA, enabling the engineer to gain insight into the difficult, real-world interference problems of the combo device.

GSM/WLAN Combo Devices

In the last example we looked at two RF signals interfering with each other in the same frequency band through the antenna. Next we will look at preventing two RF devices from interfering with each other through internal connections within the same combo device.

WLAN Effects on a Co-located GSM Device

WLAN and GSM transceivers do not use the same radio frequency band. Separate bands eliminate direct interference between the two communications systems. There are, however, many internal interference mechanisms that can impair the performance of two RF transceivers operating in the same PC board, package or product.



▶ **Figure 15.** *Effects of filter parasitic elements on ultimate rejection and recurrent responses.*

Transients from a co-located device can find their way across circuit boards and wiring harnesses via electric or magnetic field coupling. They can also travel along power supply or control lines creating unintended interference.

Unlike other sources of interference that are continually present or occur at predictable times, interference caused by packet communications devices is sporadic and asynchronous, making it very difficult to pinpoint the root causes and to engineer solutions.

Separating the signals in time, only allowing one device to communicate at a time, can eliminate co-located interference altogether. It however reduces the usefulness and throughput of the combo system. Spectral control, using filters and shielding, is the usual avenue to taken to allow both devices to operate independently.

The addition of shield walls between transceivers can offer many dB of isolation. The effectiveness of a shield, however, is only as good as the filtering used in the power supply and control lines entering each of the shielded spaces. Feed-thru filters are often used to prevent RF leakage between modules. The effectiveness of feed-thru filters is often compromised by parasitic effects as well as cavity and trace resonances that can couple energy in the WLAN and GSM bands.

The rejection of a low-pass filter is related to the ratio of impedances between the series and shunt elements. Figure 15 illustrates how the parasitic resistance and inductance of capacitor leads can raise their high frequency impedance. It also shows how turn-to turn capacitance in inductors can lower its impedance when used as a shunt element in a low-pass filter. Another effect is that shielded enclosures often behave like waveguide resonators in the vicinity of WLAN frequencies (2.40 to 2.43 GHz and 2.50 to 2.60 GHz). Resonant effects can couple energy into power supply and control lines even when good filters are used.

Another common effect comes from the limitations of the active devices used in power supply circuits and systems. An imperfect regulator can have output voltage variations that result from current pulses drawn in other circuits. This provides a mechanism where the high current drawn by the power amplifier in one transceiver can cause an error in the other RF device.

The lack of ultimate rejection on power supply and control lines can make it very difficult to achieve sufficient internal isolation in combo devices. This leads many combo device designers to use temporal separation in order to minimize internal interference.

Time Domain Duplexed (TDD) systems are popular with low cost wireless appliances for several reasons. TDD systems work well where asymmetrical data payloads between the uplink and downlink exist, such as WLAN. TDD systems also use a Transmit/Receive (T/R) switch that is easily integrated onto a chip. Thus the TDD approach is particularly attractive to the System on a Chip (SoC) designer. Another key benefit of the TDD system is the elimination of expensive transmit/receive duplexing filters. Using TDD time slots instead of frequency bands removes the need for high Q, high performance duplexers.

The less expensive filtering used in typical TDD systems such as WLAN leaves the receiver and transmitter more susceptible to interference. Interference transmitted through power supply traces can easily jam receivers or add excessive spurious to transmitted signals. These problems can be difficult to economically resolve.

The RSA3408A easily captures this interference and can greatly aid the engineer in determining the level of spectral control necessary to prevent interference. Understanding the level of spectral control needed is an essential step in economically preventing interference. Though it is usually preferable to use spectral control, cost constraints may prohibit this method for many applications.

Using temporal separation, WLAN and GSM signals can be kept free of internal interference. The penalty for using temporal separation in WLAN/GSM combo devices is that simultaneous signal operation is not possible. This reduces data throughput, even though the two standards work in different RF frequency bands. It does save the expense of much more complicated shielding, RF filtering and power supply filtering.

To maximize throughput of a temporal or TDD system with multiple transmitters and receivers, accurate timing information is needed. The time necessary to turn on and off the packet burst is an important part of minimizing dead-time, when no data is being transported, in a TDD system. Accurate measurements of the delays between commanding a packet sent until the RF packet begins to emerge from the transmitter are important in setting up digital timing of the combo device. We shall use WLAN power on and power down transients to illustrate.

WLAN Power On and Power Down Transients

When a WLAN packet is to be transmitted, startup and shut down transients exist. WLAN standards require these transients to be kept within a minimum range to assure adequate RF power during the preamble and to avoid excessive periods while the system waits for the PA to turn off.

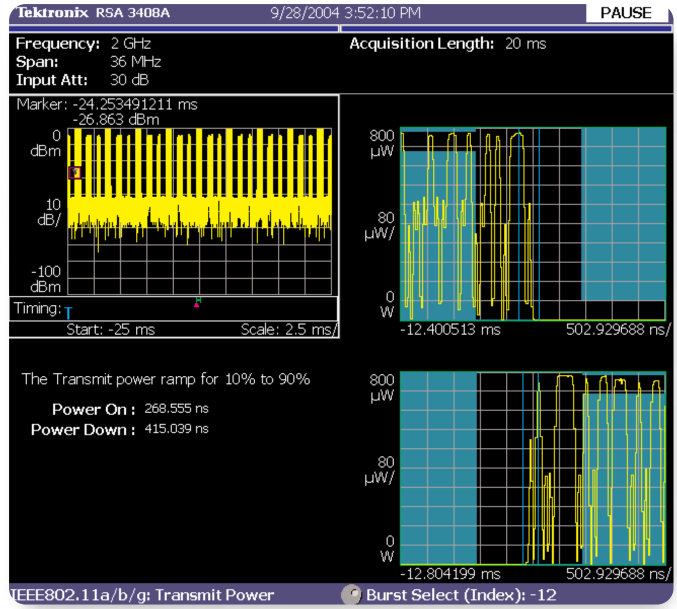
The RSA3408A can automatically measure the power on and power down transients for WLAN and GSM packets. In the power versus time display or spectrogram, simply place the marker on the desired packet and enter the power on/off measurement mode. Auto-detection selects the desired WLAN format and rate. The RSA3408A analysis software will then draw the appropriate wireless standard mask and display the measurement results.

The RSA3408A conveniently provides the power on time and power down time transients. With the use of an external trigger connected to the send packet command line, the timing between the command and the actual RF pulse can be measured. Again, simply place the marker on the first packet burst after the trigger. Adding the power on time to the record time in the lower left of the display will give the total time between the send command and RF packet.

Validating the delays through the transmitter allows the engineer to compensate circuit timing so data transport is continuous with minimal dead-time.

Power transient measurements are important for many designs because the response frequently depends on the power amplifier, usually a separate semiconductor from the WLAN part. Insufficient source current to the PA or excessive capacitance on control lines can slow system performance and destroy compatibility.

Engineers must validate the PA is turned on and ready for the transmission before the modulated signal actually reaches the PA. This timing advance is usually setup in the control software. Optimizing this timing can be a critical balance between assuring the PA is settled for transmission and minimizing PA on time to extend battery life. Changes in the PA, such as a die change or die shrink can require timing to be reset. The most reliable way to assure optimal timing is to measure the on/off signal transient.



▶ **Figure 16.** *WLAN Power On and Power Down measurement on the RSA3408A.*

Visualizing Problems

Using the RSA3408A it is possible to trigger on, capture and rapidly analyze these transient events. It is useful to point out that many of the RSA3408A analysis measurements provide a great deal of information about the underlying circuit performance.

The deep memory and unique triggering abilities of the RSA3408A allow it to capture large amounts of information in a single acquisition. With over one second of capture buffer at 36 MHz bandwidth, 10 seconds at 5 MHz bandwidth, and a trigger that fills the buffer at just the right time, the real-time spectrum analyzer provides a great deal of insight during the evaluation of complex circuit problems.

Engineers are finding RF analysis on the RSA3408A is often the fastest means of diagnosing many problems. The rich information content of multi-domain analysis allows detailed circuit problems to be identified from a top-level measurement.

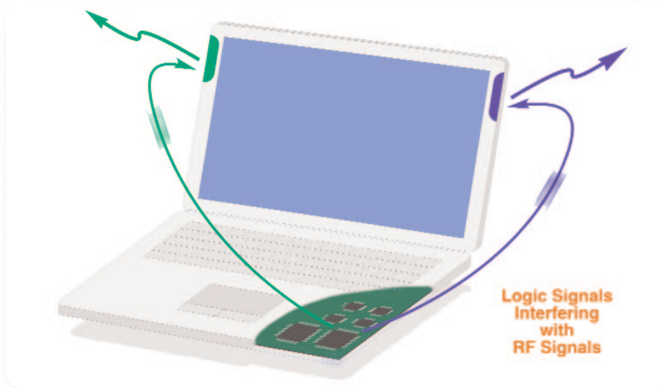
In the preceding examples, not only does the RSA3408A provide information about RF interference issues, it can also provide information on digital timing. Test assets such as this, that can provide the greatest breadth of diagnostic insight with the least setup difficulty, deliver the best engineering value.

RF Bursts and Logic Signals

A real-world problem that is commonly encountered for the combo device engineer is the interaction of very high-speed microprocessor logic and clock signals with RF signals.

In recent years, microprocessor speeds have been approaching those of microwave devices. It is now not uncommon to find microprocessors with clock speeds of 2.4 GHz, which is effectively the same frequency at which 802.11b/g WLAN and Bluetooth devices operate.

In the past, digital logic frequencies were usually substantially lower than the wireless operating frequency. This greatly simplified the filtering of unwanted interference. The engineer would simply use a low pass power supply filter and shielding to keep digital logic interference out of sensitive RF receivers. Conversely, RF signals rarely interfered with digital logic, because logic circuits were not fast enough to respond to RF energy.



▶ **Figure 17.** *High-speed digital logic interference.*

With RF data links now being integrated on to circuit boards that have GHz clocks, the challenge of preventing logic from interfering with RF signals and RF interference from corrupting digital logic has never been greater. Compounding these challenges, modern packet communications and logic control functions present interference that is typically intermittent in nature.

Logic Interfering with RF Signals

RF engineers have for many years been concerned with microprocessor clock harmonics falling in RF bands and desensitizing receivers. This problem still exists and is growing more challenging, as the interference is now more likely to come from the fundamental frequency in addition to the harmonics.

Among the most common mechanism of digital logic signals interfering with WLAN links is logic signals entering the very sensitive receiver. The large amount of gain in the receiver makes it the most susceptible to interference. Now that logic clocks are at RF frequencies, the ability for these signals to enter in through the antenna, preamplifier or IF section is a concern for the combo device designer.

When a logic signal enters the receive chain it competes with the desired signal and can cause EVM to go up and eventual create symbol errors.

Identifying the means of coupling logic noise or clock signals into the RF is usually done through a process of trial and error. Suspect paths are removed or filtered until the EVM is minimized.

Types of Clock Interferences

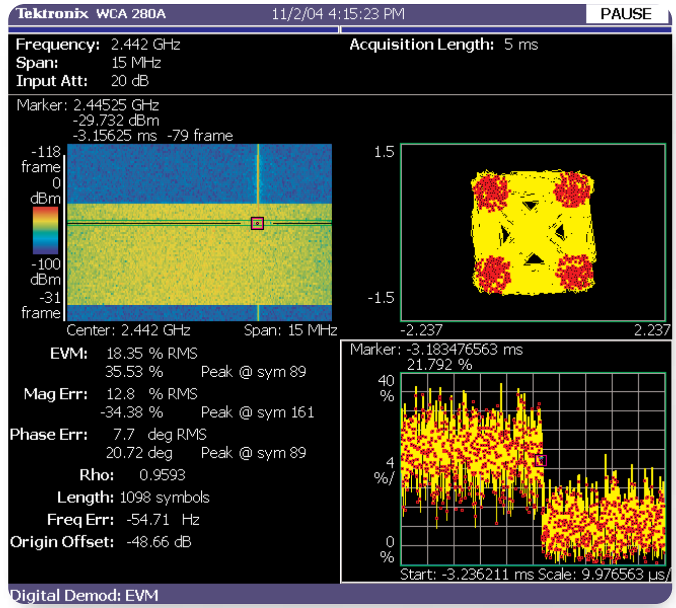
Unlike the opposite problem of digital interference desensitizing the receiver, which is more easily identified, RF packet interference with logic devices can be particularly difficult to isolate.

Troubleshooting RF packets getting onto high-speed digital logic and causing problems was once a rarity. High-speed clocks, precision timing and low voltage logic is making logic interference more common for many designs. The combo device designer has a particularly difficult job, for often the small, portable nature of their products severely restricts the shielding and filtering options.

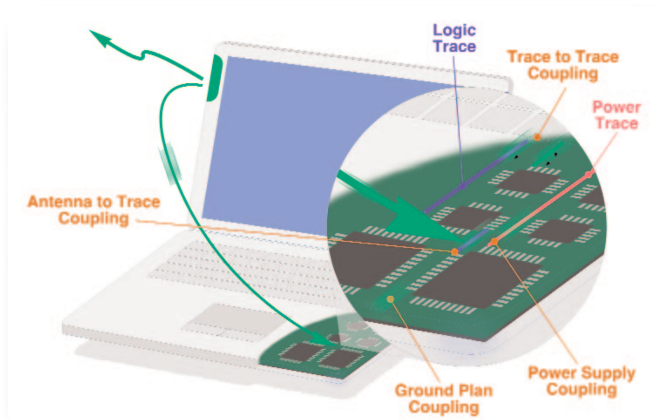
In this section our focus will be the growing problem for the combo device designer of having transmitter signals interfering with digital logic.

Co-located combo device RF transmitters can add jitter to high-speed microprocessors' clock and logic lines. This in turn can interfere with digital timing, causing data errors and system problems.

Several different coupling mechanisms are possible for the RF packet to get onto digital logic signals. RF radiated from the antenna can couple to the logic traces. RF transmission lines can couple to logic lines. RF packets can be transmitted through power supply connections and ground planes. Diagnosing which mode of unintentional coupling is responsible for logic problems can be difficult with intermittent packet bursts.



▶ **Figure 18.** *An intermittent clock signal causes higher EVM during the first part of the burst.*



▶ **Figure 19.** *WLAN RF bursts and digital logic signals.*

Conventional Test Solution Limitations

Oscilloscopes are often the first choice for diagnosing high-speed logic problems. Unfortunately, the high-speed oscilloscope usually lacks sufficient dynamic range to display or trigger on the RF packet burst. Typically with only 8 bits of digitizer dynamic range, the high-speed oscilloscope has less than 48 dB of dynamic range.

Swept spectrum analyzers have considerably more dynamic range than the high-speed oscilloscope. However, the swept spectrum analyzer lacks the real-time, seamless capture necessary to view the intermittent interference as it changes over time.

RSA3408A's Dynamic Range

The dynamic range of the RSA3408A is far better than the typical high-speed oscilloscope. With 14 bit Analog-to-Digital Converters (ADCs) the RSA3408A delivers greater than 78 dB of dynamic range (TOI). This allows the user to see signals far below what can typically be viewed on the fast oscilloscope.

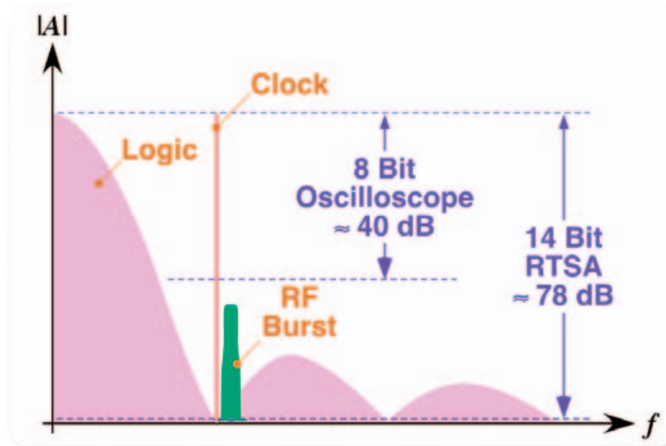
Viewing signals this far down in amplitude is helpful when trying to determine the cause of unwanted system phase transients. Often, the RF bursts will appear on digital clock and logic lines as phase jitter.

Excessive phase jitter can lead to timing problems that cause data or control errors. Signal analyzers need to be able to characterize this jitter to provide insight into its cause. Dynamic range is key to being able to fully view and understand the spectral signature of the interference.

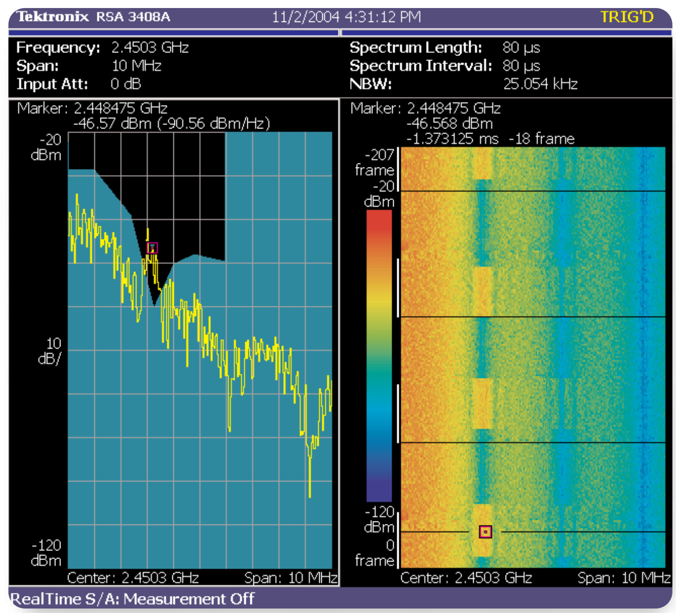
RSA3408A Captures Transients on Clock Lines

The RSA3408A's unique frequency mask trigger and high dynamic range makes it easy to find corrupted logic and clock traces. With the wireless devices off, a frequency mask trigger can be set just beyond the capture of a normal logic or clock spectrum plot. The wireless device can be turned on, and if packet bursts are coupling on to the trace, the frequency mask trigger will capture the events. Spurious signals invisible to a normal oscilloscope will clearly stand out on the RSA3408A.

Furthermore, the wide dynamic range of the RSA3408A will enable complete viewing of the spurious so its cause will be clearer. This is important because packet interference with logic devices requires isolation of the coupling modes to identify the unintentional design error to be fixed.



▶ **Figure 20.** *High-speed oscilloscope versus real-time spectrum analyzer dynamic range.*



▶ **Figure 21.** *RF bursts on digital logic signal.*

No other stand-alone analyzer can reliably capture RF intermittent signals on digital logic with the clarity of the RSA3408A.

Summary & Conclusion

WLAN combo devices offer a unique set of measurement challenges. Asynchronous RF signal packets and a variety of interference modes between the co-located communication systems create many scenarios where it is difficult to trigger on and capture critical events.

Beyond having adequate bandwidth and sufficient dynamic range for WLAN, signal analysis tools must have standards-based measurements available to support the combo device. Instruments must also be able to practically handle these complex bursted RF signals. Many analyzers, such as a traditional vector signal analyzer, require long, time-consuming capture searches that are not practical in today's time pressured world.

The RSA3408A offers a unique solution to the WLAN combo device engineer. With its frequency mask trigger and seamless signal capture, and time-correlated multi-domain analysis, the analyzer provides many unique tools for designing and troubleshooting packet-based RF communications systems.

This application note has pointed out some of today's WLAN combo device challenges. There are many more combo device measurement challenges that are beyond the scope of this application note. Your Tektronix representative has the tools and information to assist you.

Tektronix is dedicated to bringing the wireless industry products that rapidly provide diagnostic insights and would like to help you succeed.

Contact Tektronix:

ASEAN / Australasia / Pakistan (65) 6356 3900
Austria +41 52 675 3777
Balkan, Israel, South Africa and other ISE Countries +41 52 675 3777
Belgium 07 81 60166
Brazil & South America 55 (11) 3741-8360
Canada 1 (800) 661-5625
Central Europe & Greece +41 52 675 3777
Central East Europe, Ukraine and Baltics +41 52 675 3777
Denmark 80 88 1401
Finland +41 52 675 3777
France & North Africa +33 (0) 1 69 81 81
Germany +49 (221) 94 77 400
Hong Kong (852) 2585-6688
India (91) 80-22275577
Italy +39 (02) 25086 1
Japan 81 (3) 6714-3010
Luxembourg +44 (0) 1344 392400
Mexico, Central America & Caribbean 52 (55) 56666-333
Middle East, Asia and North Africa +41 52 675 3777
The Netherlands 090 02 021797
Norway 800 16098
People's Republic of China 86 (10) 6235 1230
Poland +41 52 675 3777
Portugal 80 08 12370
Republic of Korea 82 (2) 528-5299
Russia, CIS & The Baltics 7 095 775 1064
South Africa +27 11 254 8360
Spain (+34) 901 988 054
Sweden 020 08 80371
Switzerland +41 52 675 3777
Taiwan 886 (2) 2722-9622
United Kingdom & Eire +44 (0) 1344 392400
USA 1 (800) 426-2200
USA (Export Sales) 1 (503) 627-1916
For other areas contact Tektronix, Inc. at: 1 (503) 627-7111
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AFC INGENIEROS, S.A.

AFC Ingenieros S.A.
Paseo Imperial, 6, 2ºD
28005 Madrid

Contacto: Juan Ojeda
Directo: 91 7104883
Móvil: 629160579
Oficina: 91 3654405
Email: jojeda@afc-ingenieros.com