Best Practices for Making Accurate WiMAX™ Channel-Power Measurements

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This article provides the fundamental information necessary for an engineer to make channel power measurements that are accurate and conform tothe WiMAX standard

Today's wireless designers are challenged to deliver state of the art devices. Rapid changes in technologies, along with the commercial promise of these modern gadgets, are forcing them to be more attentive to delivery schedules while at the same time ensuring that their designs conform to interoperability specifications. Although many wireless technology standards provide power specifications, the procedures for making these measurements are often unclear and therefore, the likelihood of making them incorrectly is high. This is especially the case with Mobile WiMAX™ signals due to the inherent complexity of the OFDM-based RF waveforms employed in the IEEE 802.16 standard. Consequently, spectrum analysis fundamentals must be properly understood and taken into account by the engineer. And, with the "burst" nature and high peak-to-average ratios encountered in WiMAX waveforms, the triggering techniques to be used and associated gating parameters have become critical to obtaining valid measurements of power and spectrum. As a result, a fundamental challenge that wireless designers now face with WiMAX is making accurate, repeatable and verifiable channel-power measurements.

This article provides critical information for making WiMAX channel-power measurements. The principles presented also apply to the three main WiMAX power measurements: transmit power, adjacent channel power and spectral emissions pass/fail testing.

Channel Power Measurement Basics

Some spectrum analyzers have a general-purpose measurement mode that is agnostic in terms of the many possible wireless standards they support. This gives designers complete flexibility and control over the measurement settings. The key to making an accurate channel-power measurement is to understand and address the effect of these various settings to ensure they reflect adherence to both the relevant interoperability specifications and optimal instrument usage.

Figure 1 shows the block diagram of a traditional analog spectrum analyzer. In modern spectrum analyzers, a majority of the signal

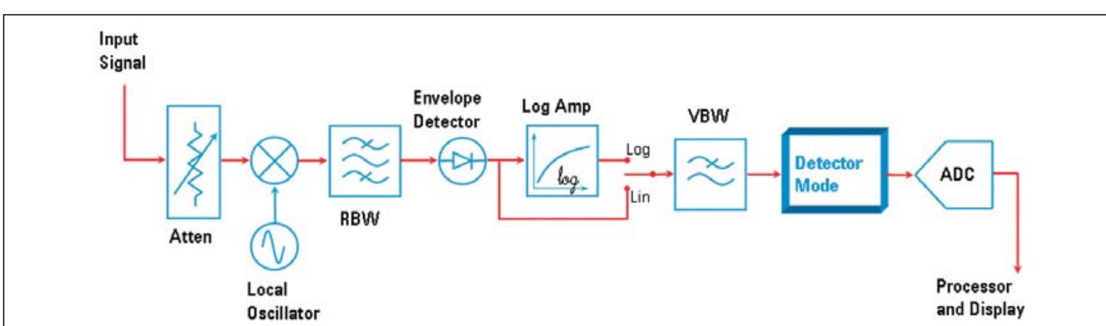

Figure 1 · Block diagram of a traditional analog spectrum analyzer.

conditioning and filtering functions that occur in the block diagram (after the local oscillator) are implemented using digital signal processing. However, their analog-equivalent properties and behaviors still apply. To make accurate measurements therefore, it is crucial that designers properly modify and set measurement parameters.

Display Detectors

Figure 1 shows both an envelope detector and display detector (Detector Mode). The characteristics of the envelope detectors are determined by the spectrum analyzer's design. Because they are not user controlled, they are not addressed in this article.

Different display detector types are implemented inside modern spectrum analyzers to accommodate a wide range of measurements and applications. In many cases, the bandwidth of the signal being sampled by the ADC exceeds the Nyquist rate, and therefore detectors are needed to make useful measurements. Detectors determine how a sampled signal is passed from one element of the spectrum analyzer's signal processing chain to the next before it is displayed as a trace point.

Certain detectors produce more optimal results for different types of signals. For example, peak detectors are designed to pass the maximum level detected from a set of sampled data points and thus make an appropriate choice for a continuous waveform (CW) measurement. This maximum level is then displayed as a trace point on the spectrum analyzer. In contrast, the average detector is designed to pass the average level of sampled data points to be displayed as a trace point.

The display trace points are often called buckets. The duration for which data points are sampled on a spectrum analyzer is referred to as a bucket interval. Figure 2 illustrates how the selection of the detector type affects the displayed trace point for a given bucket.

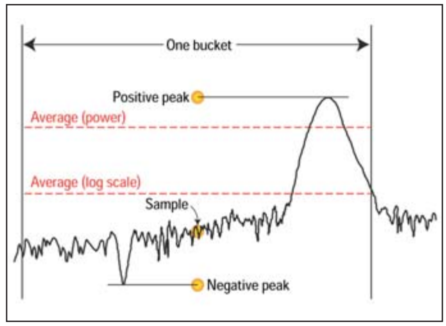

Figure 2 · For the bucket above, the displayed trace point is shown for a peak, average and negative peak detector.

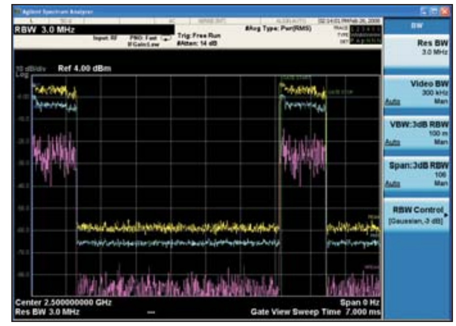

Figure 3 · Trace displays shown for a peak, average and negative peak detector from top to bottom, respectively, for a WiMAX burst.

For noisy signals, or those with noise-like characteristics (e.g., many digitally modulated signals), an average detector operating on the average power data yields optimal results. The displayed trace points are the result of averaging the sampled data. Figure 3 shows the different trace displays for a WiMAX signal based on the detector type chosen. Note that a 3-MHz resolution bandwidth setting was chosen to illustrate the distinctness of the traces.

Resolution Bandwidth

Power measurements are generally referenced to a certain bandwidth. Similarly, displayed points on the spectrum analyzer are resolved through a resolution bandwidth (RBW) filter. For CW signals, narrowing the RBW yields a smoother looking measurement due to better signal-to-noise ratio. For noise-like signals, wider RBWs allow more averaging in an average-detected bucket, or more smoothing with a narrow video bandwidth (VBW) filter. The penalty paid for using a narrower RBW is a longer measurement time.

When making channel-power measurements, spectrum analyzer users should set their RBW according to their wireless technology standard. As an example, documentation for the spectral emissions (SEM) tests that are specific to a given standard will usually include the required RBW settings for the measurement. The RBW setting required for SEM tests may also vary as a function of frequency over the entire span of the measurement, depending on the frequency region of the signal. When a RBW is not specified, users are advised to set the RBW optimally for their signal characteristics. For narrow bandwidth (CW) signals, use a narrow RBW filter. For noise-like signals such as WiMAX, a wider RBW (as wide as possible given the engineer's selectivity and sensitivity requirements) is usually best.

Averaging Techniques

Modern spectrum analyzers incorporate various methods for averaging and smoothing a signal. Like other parameters, certain techniques are more effective than others. The ways in which these samples are ultimately displayed as a trace point on the spectrum analyzer are heavily dependent on the averaging technique.

• *Sweep Time*

Modern spectrum analyzers typically take millions of samples per second. Assuming an averaging detector is selected, increasing the sweep time increases the number of data samples being averaged over the duration of a bucket, before a trace point is displayed. The resulting larger sample size reduces the variance of the displayed average point(s) and smooths out the displayed trace.

• *Video Bandwidth*

The VBW filter in a spectrum analyzer acts to smooth out the variation in measured levels, and thus serves the same purpose as increasing sweep. Older spectrum analyzers, as well as many modern ones, perform their VBW filtering on the same scale as the display scale which causes problems with power measurements.

Spectrum analyzers can either display their results on a log (decibel) or linear (linear in terms of voltage, not power) scale. Because VBW filtering is a form of averaging, any averaging on these scales is subject to errors (e.g., a –2.51 dB error for log averaging of noise or noise-like signals). When measuring average power, the designer wants the average of the power, expressed in a logarithmic form. But, averaging the log of the power is not equivalent to taking the log of the average of the power, because logging is not a linear operation and the order of processing matters. Therefore, the difference between the log of the average and the average of the log is 2.51 dB.

Ideally then, the VBW filter should be used on the power scale when making power measurements. Some modern analyzers (e.g., the Agilent PSA spectrum analyzers and X-Series (MXA and EXA) signal analyzers) can operate their VBW filter on the power scale and therefore avoid these substantial errors. Even so, the average detector is an excellent choice for smoothing results and works for all analyzers equipped with such a detector. The average detector, operating on the power scale, is often called an RMS detector.

WiMAX Channel-Power Measurement Settings

While the instrument settings and conditions described thus far are important for all power measurements, Orthogonal Frequency Division Multiplexed (OFDM) signals like WiMAX place additional requirements on proper measurement setups. For example, the time division duplexed (TDD) signals employed in WiMAX have a bursted nature in the time domain. Power can vary also, even during an RF burst or subframe. The non-continuous features of these signals make them hard to capture entirely on a spectrum analyzer. This is caused by the instrument's "frequency-swept" nature of operation when not using a trigger source.

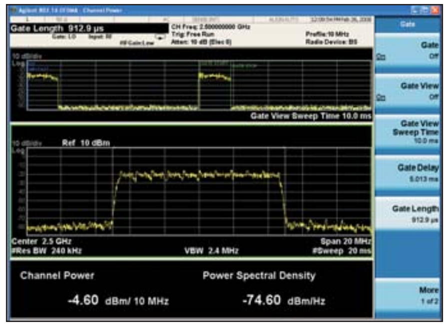

Figure 4 · The channel-power measurement above is gated over a WiMAX downlink burst consisting of one preamble and eight symbols.

Common trigger sources for allowing self triggering measurements in modern spectrum analyzers include an external trigger signal provided by the device under test, other synchronization sources, or the RF burst amplitude level of the signal. The external trigger source that is well-synchronized with the RF bursts is generally the best choice as the triggering mechanism. Because it provides the most robust form of triggering the data acquisition process within the instrument, it enables reliable and repeatable measurements.

For a WiMAX downlink signal generated by a base station under test, a suitable trigger signal may come from the base station itself. When performing component analysis, the signal generator used to provide the stimulus waveform offers a usable trigger signal for the spectrum analyzer. When an external trigger source is unavailable (e.g., an uplink WiMAX signal generated from a compact mobile DUT), triggering the analyzer on the rising edge of the actual RF burst amplitude level provides the best alternative. However, due to differing architectural implementations on various analyzer platforms, the procedure for triggering measurements in this manner can also vary.

Once a reliable trigger (as observed with a stable measurement) is achieved, the next consideration is from what temporal region of interest the channel-power measurement should be made. Clearly, the measurement should be taken when the signal is actually on. In some cases though, it is also important (and may even be a requirement) to measure during specific portions of the "on" portion of the RF burst or subframe. Therefore, proper gating of the area of the burst that the designer is interested in measuring is a requirement for accurate measurements.

Figure 4 shows a gated region of a WiMAX signal occurring over the second RF burst. Although the first burst initiates a trigger, gating over the second burst is recommended. This ensures that any swept LO settling transients generated by the analyzer are eliminated from the gated region, thereby reflecting a more accurate power measurement.

Stable triggering allows the spectrum analyzer to initiate its swept measurement process; however, for TDD wireless signals, gating the exact region of interest is critical to ensuring an accurate measurement. For example, variations in the downlink to uplink (DL/UL) ratio of a WiMAX signal, dependent on the test condition, may cause the length of the burst to vary. The gate length also varies accordingly to accommodate this change. Additionally, some designers may be only interested in the power level of the preamble or a particular zone of a WiMAX signal.

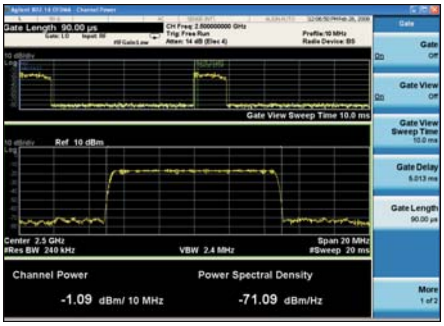

Figure 5 · The channel-power measurement above shows gating over the preamble only. This measurement is commonly referred to as the received signal strength indicator (RSSI) in WiMAX.

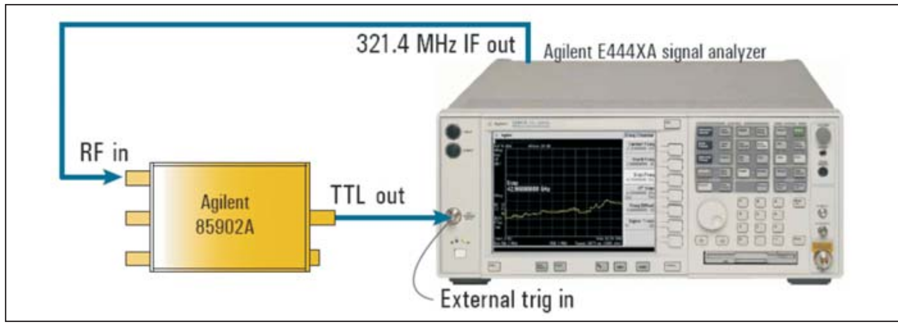

Figure 6 · The external configuration of the PSA integrated with the Agilent 85902A Burst Carrier Trigger (BCT) shows the 321.4 MHz IF output of the PSA connected to the RF input of the external BCT. This configuration ensures there will be a stable TTL signal provided by the 85902A for the wide range of WiMAX frequencies.

Figure 5 shows a gated preamble measurement of a WiMAX signal. Here, gating over the preamble only causes a change in the gating parameters required to ensure an accurate measurement.

Different Analyzer Platforms

Several different spectrum analyzers are now available to perform channel-power measurements on WiMAX signals. The Agilent PSA and X-Series analyzer platforms offer just one example. While modifying the various parameters on these instruments is crucial for obtaining accurate channel-power measurement results, it is just as important for the designer to adopt a number of best practices.

To better understand these practices, consider the PSA spectrum analyzer and X-Series signal analyzer platforms. It is equally simple to make an accurate channel-power measurement on either the spectrum or signal analyzer platform using an external trigger. However, to trigger the measurement using an RF burst, it is useful to adopt the following measurement techniques.

• *Spectrum Analyzer Platform*

For GSM waveforms, an analyzer's relative triggering feature (such as is available on the Agilent PSA analyzer) can be utilized to allow designers to change the input signal level to their device without having to reset the trigger level of the spectrum analyzer while making continual measurements. Eliminating this task saves time and frees the designer to focus more on work as opposed to test methodologies.

Another critical technique available is an RF burst trigger design implemented to trigger on an embedded –22 dB level relative to the peak envelope of the detected signal. This technique is invaluable for measuring GSM components, but is unsuitable for some modern modulation techniques such as OFDM. For OFDM technologies such as WLAN and WiMAX, the greater peak to average ratios in these signals can cause the relative trigger implementation on an analyzer to mis-trigger, and a different approach is required.

In cases where no external trigger source is available, an external burst carrier trigger accessory can be utilized to reliably trigger and achieve stable measurements of WiMAX signals. As an example, Figure 6 shows the PSA spectrum analyzer integrated with the Agilent 85092A Burst Carrier Trigger (BCT). The BCT samples the RF input signal to be analyzed and provides a TTL output signal synchronized to the burst when detecting a steady stream of RF bursts. It also provides an LED status indicator. This integration provides the stable trigger signal required to allow the designer to set up the gating parameters, as described earlier, to make accurate channel-power measurements.

• *Signal Analyzers*

Common trigger sources for signal analyzers can be externally supplied or derived from internal RF burst carrier triggering. Some instruments also feature stable self-triggering capabilities for use in cases where an external trigger is not available. This eliminates the need for an external burst trigger accessory for most common wireless communication signals, including WiMAX. RF burst carrier triggering on the X-Series analyzers is a prime example of one instrument with self-triggering functionality, including an absolute RF burst amplitude level, a periodic timer and a trigger holdoff function.

Triggering on an absolute RF burst amplitude level eliminates the mistriggering problems attributed to previous-generation spectrum analyzers when faced with the high Peak-to-Average Power Ratio (PAPR) nature of OFDM signals. Detection of the absolute RF burst level set above a fixed threshold level starts the "initial" triggering mechanism.

The periodic timer sets up an auto-

matic re-triggering process for a specified amount of time (user adjustable) and acts as a resynchronization feature once a trigger is established. This initial synchronization source may be selected by the user. It may be advantageous to set this parameter to equal that of the designer's frame duration, which ensures that at each frame boundary a re-triggering of the measurement is performed, regardless of drift or change in the external environment or instrument (Fig. 7).

Sync holdoff is a feature that enhances the accuracy of a trigger, which is critical since high PAPR can cause a trigger to start a measurement in an undesired portion of a burst. Setting the correct sync holdoff ensures that the actual triggering begins at a specified time period after the first trigger level has been encountered. Adherence to a stable and repeatable measurement point within the RF burst, based on a reliable trigger level, allows the designer to make accurate and repeatable measurements. Figure 8 illustrates what may occur without the application of sync holdoff. Note that the channel-power measurement is performed over the same uplink signal used in Figure 7. Limited or no power is evident in the spectrum view due to mis-triggering.

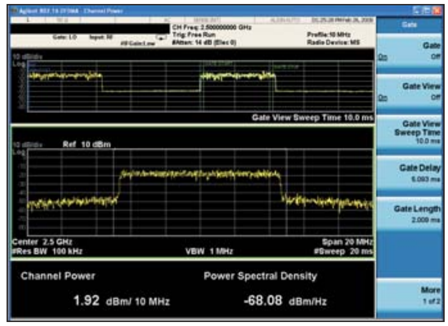

Figure 7 · The figure above shows both periodic timer and sync holdoff activated. With a stable trigger in place, the appropriate gating parameters for the uplink signal are shown to make the measurement.

Figure 8 · By turning sync holdoff off as shown, the trigger instability causes an inaccurate channel-power measurement, regardless of the gating parameters.

Conclusion

Accurate channel-power measurements are a critical aspect of wireless device testing. As wireless technologies become increasingly complex and time-to-market cycles decrease due to the demands of consumers and competitive pressures, adherence to defined measurement procedures and best practices will grow exceedingly important. Such procedures and practices offer designers a viable means of saving time, while ensuring the consistency and repeatability of channel-power and other associated measurements.

Achieving accurate channel-power measurements requires the designer to address both the most basic and advanced instrument setup parameters. Of critical importance to measuring OFDM-based signals like WiMAX, is stable triggering and accurate setting of gating parameters. Use of appropriate measurement solutions, such as the Agilent PSA or X-Series analyzers, can play a key role in allowing the designer to make fast, easy and accurate channel-power measurements.

Note: "WiMAX" and "WiMAX Forum" are trademarks of the WiMAX Forum organization.

Related Literature

1. Agilent Technologies, "8 Hints for Better Spectrum Analysis," Application Note 1286-1, Literature Number 5965-7009E.

2. Agilent Technologies, "N9075A 802.16 OFDMA Measurement Application Agilent X-Series Signal Analyzers (MXA/EXA) Technical Overview with Self-Guided Demonstration," Literature Number 5989-5353EN

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