Understanding WiMAX signal analysis

Adopting the best approach to making frequency and time measurements is crucial to successfully verifying and troubleshooting a WiMAX device.

By Ben Zarlingo

It is often more useful to have a clear understanding of the signal and a reliable analysis approach than to know all the technical details of a standard like WiMAX. A well-organized measurement approach to WiMAX signal analysis, for example, will reduce setup and measurement errors, find problems at the earliest stages in the analysis, and provide the quickest path to troubleshooting of the WiMAX component or system.

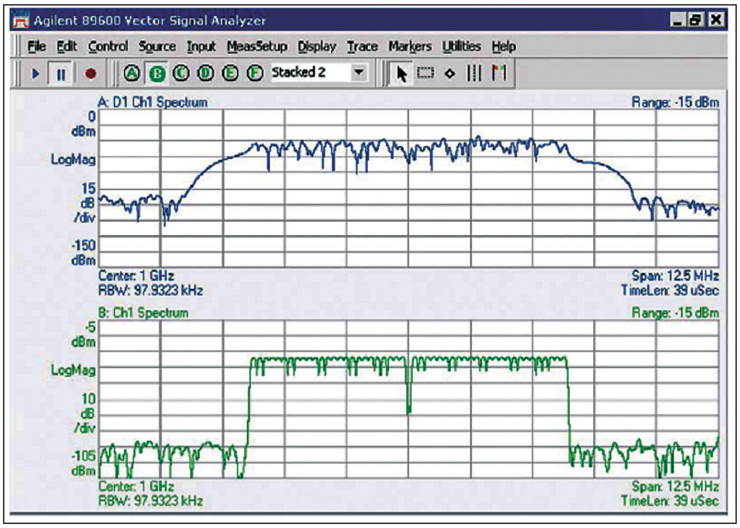


Figure 1. The importance of triggering for a time-variant waveform is illustrated. The difference between the spectrum of a WiMAX signal when the instrument is not triggered (upper display) and when it is triggered (lower display) is displayed. Both measurements were made using the Agilent 89600 series of VSAs with the averaging disabled.

Measurement of a WiMAX signal is best accomplished with a vector signal analyzer (VSA) capable of measuring the traditional RF parameters and the modulation quality of the digitally modulated signal. These DSP-based signal analyzers provide fast Fourier transform (FFT)-based spectrum analysis, wideband flexible vector demodulation and scope measurements on RF signals. The number of measurement types and analysis configurations available within the VSA is large. Properly selecting measurement configurations specific to WiMAX signal analysis will improve the process to successful and reliable testing.

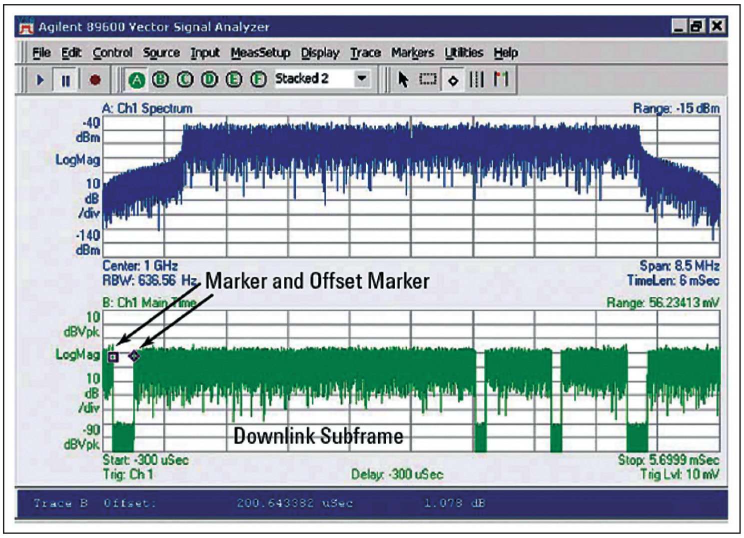
Consider basic spectrum and vector analysis using frequency and time domain measurements. These measurements will verify many WiMAX signal parameters such as center frequency, channel bandwidth, carrier spacing, amplitude levels, transient behavior, and frame and subframe lengths, as well as transmit/receive transition gap (TTG) and receive/transmit transition gap (RTG) durations. Successful spectrum and vector measurements using a VSA can allow the engineer to learn a great deal about digitally modulated signals before digital demodulation analysis is employed.

Measuring frequency spectrum

VSAs can perform spectrum analysis using a scalar measurement (stepped FFT measurement) or a vector measurement. Scalar measurements provide amplitude-only information over the full frequency range of the instrument. Vector measurements provide phase and amplitude information over the processing bandwidth of the instrument.

VSAs have two ways to process an RF signal for analysis and display. Measurements can be made on “live” signals or time-captured waveforms. All VSA measurements including vector (frequency and time) and digital demodulation can be made on both signal acquisition types.

Measurements from “live” signals can be made on the measurement hardware using signals delivered from a WiMAX radio system or component. In this case, the VSA processes the measurement from blocks of digitized time data. The length of the time block is related to the instrument settings such as span and resolution bandwidth (RBW). The instrument settings determine if the displayed spectrum is processed from contiguous blocks of time data. Real-time bandwidth (RTBW) is a specification used to characterize the performance of analyzers such as VSAs. RTBW is the maximum frequency span that can be continuously processed without missing any event on the input signal. The real-time bandwidth achieved varies with the amount of processing time required by the analyzer to calculate the FFT and to perform other selected operations such as averaging the results,



```
Trace B  Offset:          200.643382 uSec          1.078 dB
```

Figure 2. Measurement of RTG time using the marker functions of the Agilent 89600 series of VSAs. The upper trace shows the frequency response of the displayed time domain record (the lower trace).

updating marker calculations and displaying the data. Broadband signals such as WiMAX exceed sustained RTBW by a large margin, leading to the use of time capture in situations where analyzing contiguous blocks of data is desirable.

Time capture is a second approach to signal acquisition that involves recording a large block of continuous time data into the instrument's capture memory. The VSA application will allow the engineer to record time data from measurement hardware to memory and, if desired, to a PC's disk drive. Data can be played back or imported into another application. This technique allows "real-time" analysis of the WiMAX signal at the full-specified bandwidth without any gaps in the time record. Virtually any type of analysis can be chosen after the capture is performed.

Once the type of signal acquisition is decided, the VSA can be configured to measure the parameters of the WiMAX signal. The high-resolution digitized time domain measurement is the most basic type of signal analysis. It provides the foundation for all subsequent measurements including vector and modulation analysis and signal verification.

Measuring wideband spectrum

Analysis of a WiMAX signal starts with a wideband spectrum measurement. This measurement is used to verify the center frequency, nominal signal bandwidth, and amplitude and sidelobe level of the WiMAX signal. It is also an opportunity to verify the level of any spurs and other interference signals present in the frequency band that may cause errors during digital demodulation. Verifying the spectral content is often made using a maximum-hold detection scheme.

For broad coverage spurious measurements of the WiMAX signal, the VSA should be configured with a large frequency span (perhaps using the scalar measurement mode) and max-hold averaging. Continuous peak-hold averaging is a measurement function used by VSAs to measure and display the largest magnitude (determined over many measurements) for each frequency point in the span. Measurement of low-level spurious and interference signals should be performed using a Gaussian window, which provides the highest dynamic range in the measurement. The Gaussian window offers the lowest sidelobe level of any VSA window at slightly reduced amplitude accuracy. Combining peak-hold averaging and Gaussian windowing is ideal to ensure that no significant signals are missed either in the band or out.

When measuring wideband spectrum, the VSA's input range must be correctly set in order to obtain accurate measurements. If the input range testing is too low (too sensitive than necessary), the VSA's analog-to-digital converter (ADC) circuitry is overloaded and introduces distortion into the measurement. If the range is set too high (less sensitive than necessary), there may be a loss of dynamic range due to additional noise.

Measuring narrowband spectrum

For narrowband spectrum analysis of the WiMAX signal, the VSA's frequency span should be approximately set to 1.1 times the nominal bandwidth of the signal. Alternately, the span can be configured to match the bandwidth of a WiMAX front-end filter. Using a frequency span close to a receiver's RF bandwidth allows the VSA measurements to be performed with similar input noise and interference levels as would be seen in practice. Narrowband measurements provide improved frequency resolution and greater accuracy in setting the center frequency of the instrument or verifying the center frequency of the signal under test. The improved frequency resolution results from the inverse relationship between span and RBW.

Accurate amplitude measurements of the WiMAX signal are required for system verification, troubleshooting and compliance with local regulations. Amplitude measurements, as a function of frequency for these noise-like signals, should be performed using rms (video) averaging and rms detection. VSAs calculate the frequency spectrum using a FFT that results in the true rms power of the signal whether it is a single tone, noise or any complex signal. Rms averaging produces a statistical approximation of the true power level over the measured time record(s), which includes on/off times and the transient effects of the bursted WiMAX signal.

Time-variant signals such as WiMAX require spectral analysis over a smaller portion of the waveform, for example, during a subframe or even a portion of the subframe. In this case, the measurement needs to be stabilized using a VSA's trigger control function (Figure 1).

Linking time and frequency using vector analysis

Traditional spectrum analysis does not provide enough information when analyzing the complex, time-variant nature of the WiMAX signal. Because these signals contain magnitude and phase information, verification and troubleshooting of the waveform require vector signal analysis. In addition, the OFDM waveform is directly related to the time domain response through the inverse-FFT process. Consequently, measurements made in the frequency and time domains are necessary to cover the range of required measurements.

Vector analysis on the VSA begins with the process of digitizing the input RF signal and performing quadrature detection of the complex signal in the DSP. The in-phase (I) and quadrature phase (Q) time domain samples can be processed into a variety of formats and displayed as a time domain waveform.

This time-record of digitized data can be further processed using an FFT to display the associated frequency response. A time-record consists of all the time-domain samples that go into the FFT. The outputs from the FFT are the frequency-domain samples referred to as measurement points. For RF vector measurements, the output of the FFT yields as many measurement points as there are time-domain I/Q sample pairs. The time-record and its FFT are the building blocks for all subsequent measurements.

The power of vector analysis is evident when frequency and time domain measurements are linked. Many features can be combined in these measurements, such as linked frequency and time displays and measurements, triggering (live signals and recordings), variable block size and time resolution, band power markers, and time-gated spectrum and power (such as CCDF) measurements.

Finding frames and triggering measurements

Composite signals such as the WiMAX orthogonal frequency-division multiplexing (OFDM) waveform can be challenging to measure accurately in time and frequency. Due to time-varying characteristics such as unequal bursts, unequal off-times and changes in the statistics of amplitude variations due to different types of modulation, time-domain triggering and/or time-capture are often used to achieve a stable measurement for analysis. Time capturing a signal to memory does not require any instrument trigger and allows the engineer to progressively step through the measurement in time until an appropriate record is found for analysis. The flexibility of time domain triggering provides the capabilities required for verification and troubleshooting digitally modulated signals such as WiMAX.

When first examining the pulsed characteristics of the WiMAX signal, it is often necessary to adjust the time record length in order to see the entire frame or several frames within the waveform display. A large number of data points (sometimes expressed as time record length, frequency points or FFT points) are often necessary to obtain a sufficient time record length while maintaining adequate measurement bandwidth. For WiMAX, the number of points should be between 10,000 points and 50,000 points, though it can be set much higher if desired, to measure multiple frames.

A time-domain display using a large number of points and showing one to two frames can be used to measure the subframe lengths and transition gaps. These measurements can be used to verify the measured OFDM frame duration against the IEEE 802.16-2004 standard. As a measurement example, Figure 2 shows the frequency and time domain response of the WiMAX signal using 51,201 measurement points with a time record length of 6 ms. The upper trace shows the frequency response of the WiMAX signal calculated from the time-record shown on the lower time domain trace. The lower trace shows one complete OFDM frame consisting of one downlink (DL), base station to subscriber transmission, and two uplink (UL), subscriber to base station transmission, subframes. The offset marker function is used to measure the gap time at the beginning of the DL subframe. This gap represents the RTG, and is measured to be around 200 µs for this waveform. It also shows that the gap for the TTG is approximately half the duration of the RTG. Using the offset marker function centered on the TTG, this gap is measured to be 100 µs.

Triggering the VSA at specific time intervals within the WiMAX waveform requires the engineer to set the trigger type and magnitude level. Trigger hold off is frequently used on signals such as WiMAX/OFDM where the data modulation produces large amplitude variations that would otherwise cause false triggers. Once the VSA is properly triggered, analysis of different parts within the waveform can be made using the instrument's trigger delay function. When positive and negative (pre-trigger) delays are allowed the power of triggered measurements is considerably greater.

Vector measurements are valuable for verifying characteristics of the WiMAX signal that may not be obvious during digital demodulation measurements. For example, it is important to verify that the power levels within portions of the frame conform to the IEEE 802.16-2004 specifications. Also, it is necessary to confirm that the occupied frequency bandwidth falls within the local regulatory requirements. In many cases, these basic measurements may reveal problems in the WiMAX signal that digital demodulation may fail to uncover.

In order for the RF engineer to successfully test and troubleshoot a WiMAX device, a well-organized approach to the signal analysis is required. Its use yields the greatest level of understanding and reliability in the measurement and thus a faster path to a completed design. Performing vector measurements to provide verification of the quality within the WiMAX signal is one element of a well-organized approach. Beginning with vector measurements, it provides the groundwork for proper instrument configuration and successful signal analysis. These measurement techniques can also be used to uncover signal problems that may create difficulties when demodulating the WiMAX waveform. **EWT**

Ben Zarlingo is a product manager for Communications Test with Agilent Technologies' Wireless Business Unit in Everett, WA. For the past 15 years he has focused on emerging digital communications and vector signal analysis techniques.