Tektronix

Real-Time Spectrum Analysis Tools Aid Transition to Third-Generation Wireless Technology

Constellation & Vector

Time Domain (Amplitude, Phase)

Spectrogram

Spectrum (Frequency vs. Amplitude)

Modulation Quality (EVM, etc.)
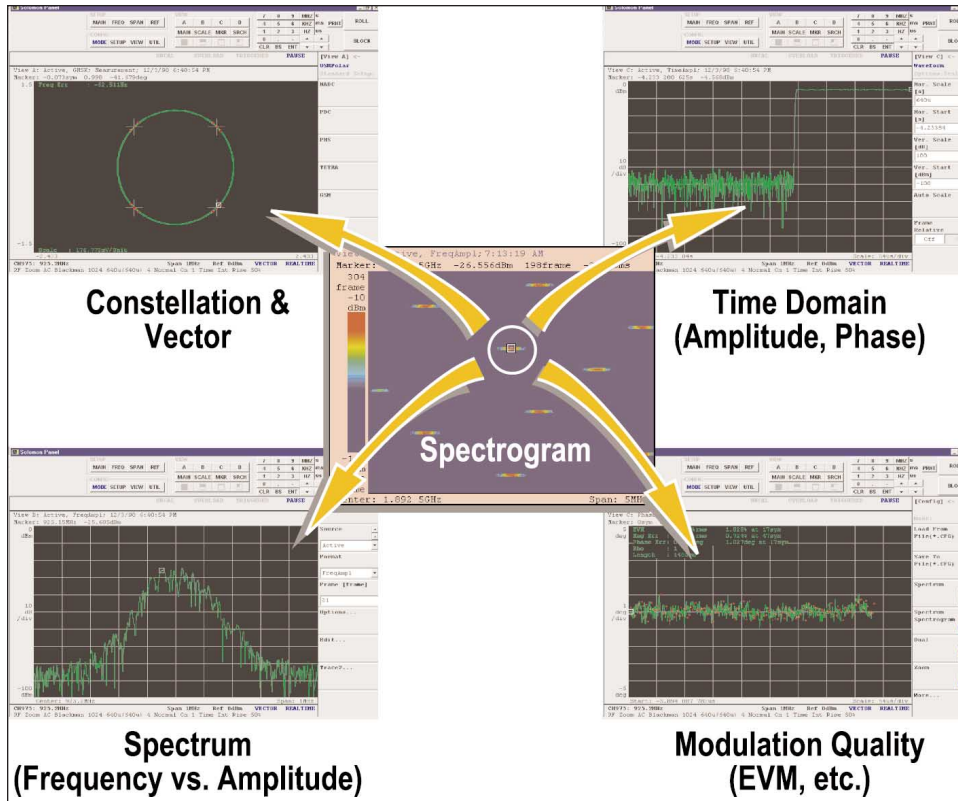
As we enter the transition toward third-generation (3G) wireless technologies, there are many modulation formats contending to be the eventual "world-wide standard." Whether or not any single format ever prevails, almost all share a common transmission characteristic: they create spread-spectrum signals with an intermittent, "bursty" nature. They're anything but consistent. No longer is there a solid, continuous carrier and

stable modulation envelopes to observe. That's a challenge for test instruments, especially the spectrum analyzers that are the cornerstone of so many wireless measurements. When viewing bursty wireless signals, the conventional swept spectrum analyzer is as likely to miss an event as capture it.

There is a solution to this problem. It resides in an innovative class of instruments known as Real-Time Spectrum

Analyzers (RTSA). The RTSA has a vastly different architecture from traditional tools, and is uniquely capable of capturing continuous, intermittent, or random signals with equal ease. Tektronix has delivered RTSA solutions to the aerospace and research communities for almost a decade, and is currently introducing the world's first RTSA instruments designed for wireless test applications.

Real-Time Acquisition Captures More Signal, Faster

Swept spectrum analyzers have one path from the input to the display, and that path is tuned to only one frequency[1] at any given time. They accumulate a spectrum display by "scanning" – tuning the path to successive frequency steps and capturing the respective amplitudes at each step. The display represents the compiled result of many single-frequency acquisitions performed sequentially. This requires a steady, uninterrupted signal to produce a meaningful measurement.

Figure 1 is a simplified illustration of the swept spectrum analyzer architecture. The local oscillator does the frequency stepping. This feeds a mixer stage that combines it with the input signal (a process known as heterodyning). Then the resulting signal components go through the resolution filter and into the display processing circuitry.

Real-time spectrum analyzers take a whole different approach. Rather than acquiring one frequency step at a time, the real-time instrument captures a block of frequencies all at once during a user-specified time frame of, say, 20 microseconds. These 20-microsecond frames repeat continuously, with a full acquisition every frame. Because the instrument samples these full frames constantly (rather than waiting for each discrete frequency step to be measured), the signal can come or go as it pleases and the real-time spectrum analyzer will detect the change instantly.

Consider a simplified example that contrasts the two architectures:

When measuring a block of frequencies, a swept analyzer steps through a series of frequency increments and displays the result. But a transient event might occur in, say, the seventh increment after the analyzer has moved on to the eighth – or the twenty-eighth. This transient is lost.

The real-time spectrum analyzer captures the whole block at once, then proceeds to capture that block again, and so on. The result is a continuously updated display that brings out real-time events such as W-CDMA bursts.

Figure 2 shows the real-time spectrum analyzer concept.

Where the swept analyzer has one resolution filter, the real-time instrument has, in effect, hundreds of filters in parallel. All of the hundreds of frequency components within the real-time bandwidth are filtered concurrently, and appear on-screen simultaneously. In practice, the real-time analyzer uses FFT techniques rather than parallel hardware filters to arrive at the spectrum. This is the enabling technology for real-time spectrum analysis, and it depends on very fast, accurate FFT hardware. Tektronix' decade-long involvement with RTSA systems is a solid foundation for the company's new series of RTSAs for wireless measurements.

Spectrogram Display Brings Out Wireless Signal Details at a Glance

The real-time spectrum analyzer, thanks to its continuous frame acquisition, provides powerful display modes that reveal far more signal information than the normal two-dimensional (2D) frequency vs amplitude display.

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[1] **Actually a very narrow frequency band determined by the instrument's resolution bandwidth.**
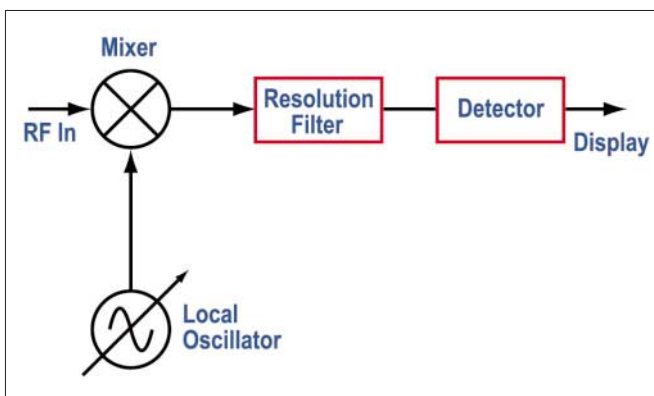

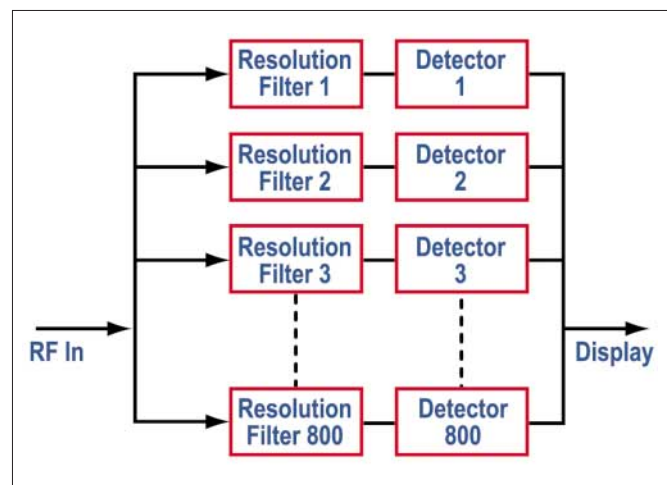Figure 1. Swept spectrum analyzer (simplified concept).

Figure 2. Real-time spectrum analyzer (simplified concept).

The most versatile of these is the spectrogram display. This format reveals telling details about spread-spectrum signals at a glance. Equally important, it provides ways to "drill down" into the signal for even more information,

Figure 3 depicts an actual spectrogram display of a CDMA mobile signal captured "off-air" with a Tektronix 3066 RTSA. The image contains three dimensions of information: frequency (the X axis), time (the Y axis), and amplitude. The latter, known as the Z axis, is expressed by color. Here, the highest peaks would appear in red. In Figure 3, ten bursts are visible. There is no signal present between the bursts. A steady carrier, if present, would appear as a narrow line connecting the bursts. Note how easy it is to comprehend the "big picture." Signal aberrations, if any, show up as telltale gaps, transients, and color (amplitude) variations. The spectrogram, more than any other display format, reveals the nature of CDMA, W-CDMA, and other spread spectrum signals.

Looking "Beneath" the Spectrogram

Like the tip of an iceberg, the spectrogram sits atop a huge volume of additional data about the signal. There's enough information about time- and frequency-domain characteristics to generate constellation, zero-span, frequency vs amplitude, phase domain, and modulation quality displays for any time-slice on the spectrogram.

The RTSA actually keeps two concurrent acquisition records – one for frequency domain data, the other expressly for time domain measurements. The basic architecture is shown in Figure 4. The frequency and time memories are time-correlated, as are the displays that can be generated from the stored data. That means any selected point on the spectrogram is a window on the same moment in time displayed in any of the other available formats.
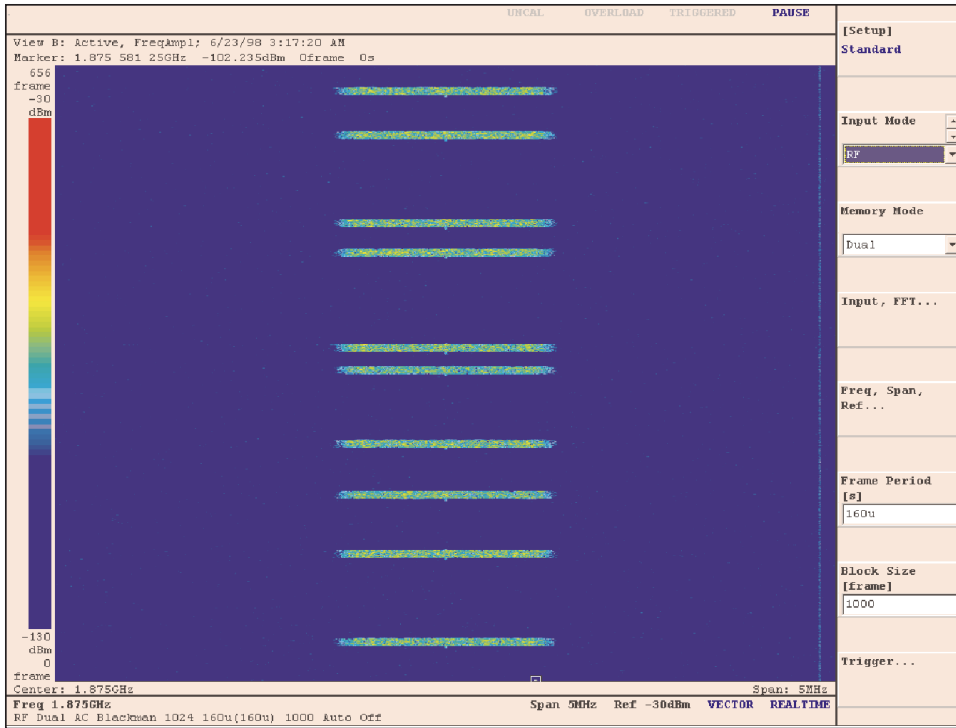

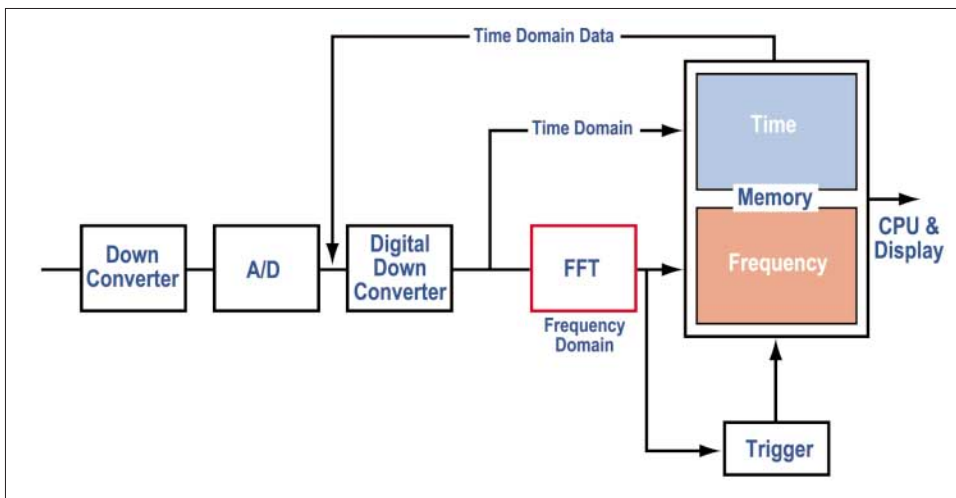Figure 3. Spectrogram screen.

Figure 4. RTSA architecture, showing frequency and time memories.

Figure 5 illustrates the concept. By placing a cursor on the spectrogram, it's possible to look at the modulation quality or the vector diagram that pertains to a specific point. If, for example, there was a brief 20 dB drop in amplitude during one of the signal peaks (remember, peaks are red in this case), the spectrogram would show it as a yellow band in the midst of the red peak region. With the cursor positioned on this yellow area, the frequency vs amplitude display gives the exact power reading at that point.

Instruments in the Tektronix 30x6 family can produce a multi-windowed display on their color LCD screen. Figure 6 depicts such a screen image. Here the 3086 RTSA has captured a W-CDMA spectrogram, with its associated vector, EVM, and frequency vs amplitude displays.

The RTSA can also produce dynamic "Waterfall" displays which are an accumulation of many frequency vs amplitude traces overlaid in front-to-back fashion. By elevating the perspective slightly, it's possible to see the changes that occurred as these traces build up over time. This makes it easy to detect transients and amplitude variations, especially since the RTSA updates the waterfall continuously in real-time. While some swept spectrum analyzers can produce waterfall displays, they are limited by their "single-stepped" acquisition. Their displays are static graphs produced after the fact.

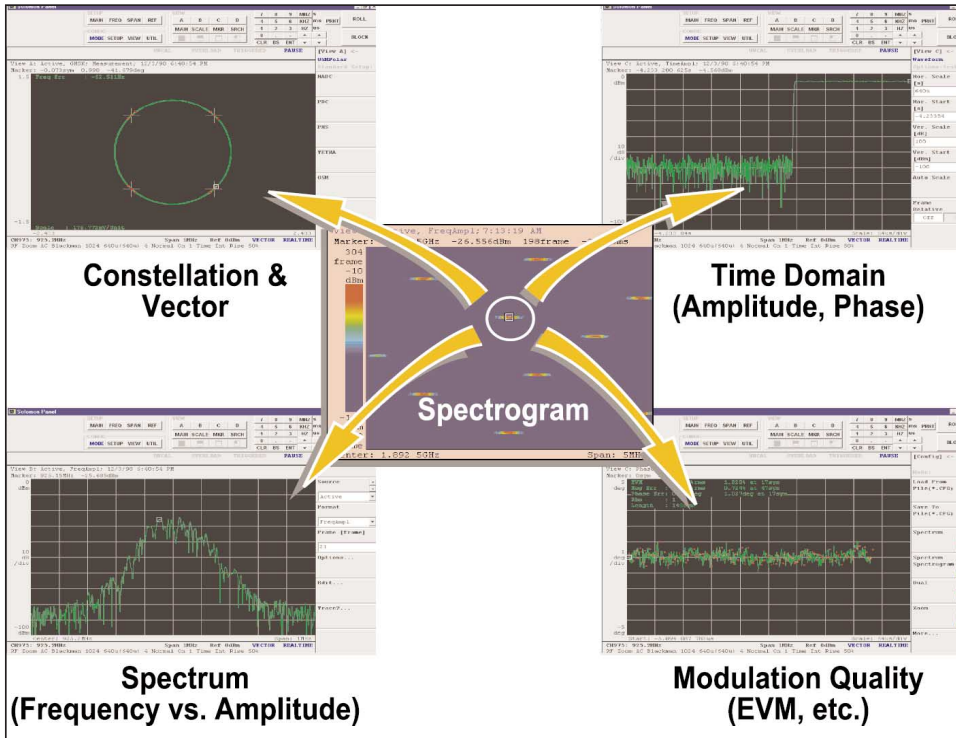Table 1 summarizes a few of the major differences between the swept spectrum analyzer and the RTSA.

Looking at the Results

Up to this point, the discussion has focused on real-time acquisition. But the real-time spectrum analyzer offers powerful post-capture analysis features as well. With its continuously updated acquisition frames, the instrument has a massive volume of signal information available. At any instant, this information can be frozen in memory.

The Zoom mode takes full advantage of the frequency memory content. It provides a microscopic view of events that occurred within an acquisition frame. The analyzer captures a full frame (that is, a block of frequencies), and Zoom permits the user to expand any portion of the frame by a ratio of up to 1000:1. Because the frames

Figure 5. Spectrogram and associated displays.
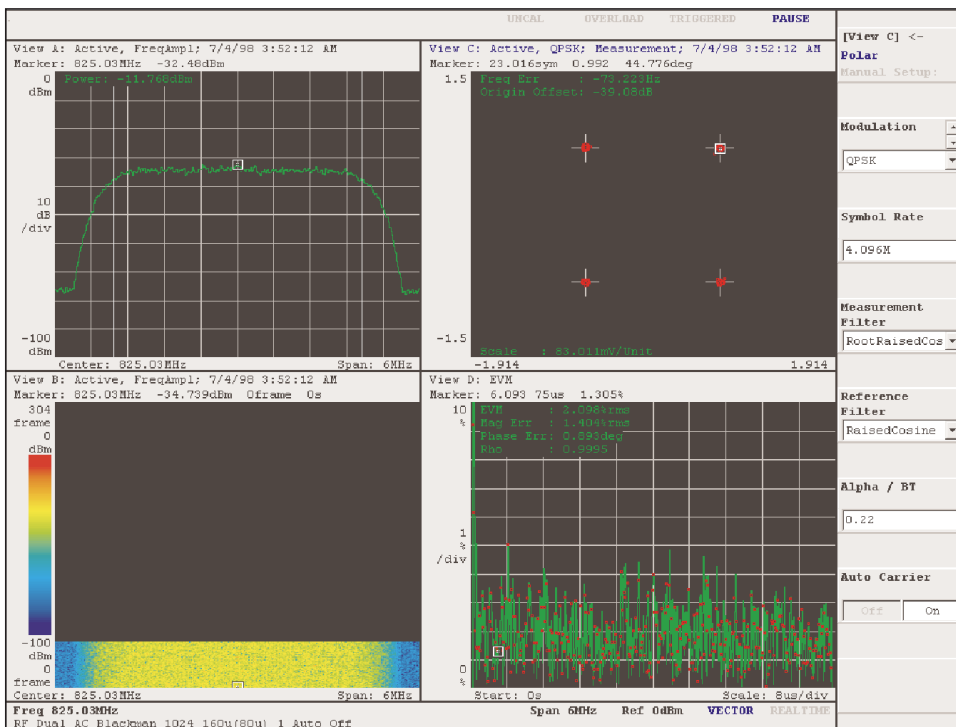
Figure 6. 3086 multi-window display, W-CDMA signal.

Table 1.

Real-time Spectrum Analyzer	Conventional Swept Spectrum Analyzer
Uses real-time FFT to parse a block of frequencies into a spectrum display	Uses heterodyning to build up a spectrum display
Captures a full spread-spectrum channel width at once	Acquires one narrow band of frequencies at a time
Acquires and stores frequency and time data simultaneously	Acquires frequency data for a single sweep only
Displays spectrograms, frequency vs amplitude, error vector, constellation, and zero span, singly or simultaneously	Displays frequency vs. amplitude; constellation when equipped for modulation analysis
3G-ready	Limited to 2G measurements

are in memory, no re-acquisition is necessary.

Triggering in Time and Frequency Domains

Whatever the display mode, whatever the bandwidth or resolution, an acquisition instrument's triggering functions are key to every measurement. Conventional spectrum analyzers rely on time-domain triggering, just like an oscilloscope. When the signal crosses a certain amplitude threshold, the instrument begins its capture sequence. This trigger mode is most useful for acquiring steady-state signals.

The latest RTSA instruments also offer a Frequency Mask trigger function that aids acquisition when signal events are erratic or infrequent. Examples include phase lock loop jitter and oscillator phase hits (in which an oscillator's spectrum shifts intermittently). This trigger allows users to specify a frequency window to be used as a condition of triggering. Again using its real-time continuous acquisition, the instrument waits to trigger until the signal appears within the programmed window. Similarly, the window can be set to watch for the disappearance or attenuation of a pre-existing signal. Inherently the frequency-domain memory (see Figure 4) keeps a running record of the acquisition frames (time) as they accumulate. It constantly discards the oldest information as new data enters the memory. When a trigger occurs, the memory waits a prescribed number of frames (set by the user), then stops recording. At that instant the content of the memory reflects all the activity that led up to the triggering event, as well as the activity that followed it. The spectrum analyzer display provides a user-selected viewing range, such as 20 frames before the event and 50 frames afterward. Thus the Frequency Mask trigger and the frequency domain memory working together provide rich detail about the continuity of the signal.

The Frequency Mask trigger makes use of a feature that truly distinguishes real-time spectrum analyzer architecture. Capturing an entire span of frequencies simultaneously and analyzing them with an FFT does not in itself define real-time. Rather, it's the ability to capture frames of spectral data in a contiguous manner, or even with overlap. In this way, no event is missed whenever the instrument is in its armed mode, and the Frequency Mask trigger receives continuous updates of the real-time frequency range (see Figure 7).

The Frequency Mask trigger has a second major benefit. It can be used to capture widely-spaced events, while discarding the time in between. The 12.5% duty cycle of a GSM burst is a perfect example of such a signal. It consists of narrow (577 µs) data-bearing events spaced 4.615 ms apart. The events carry 114 bits of data each. By setting the Frequency Mask trigger to reject everything but the data, it's possible to accumulate a spectrogram made up almost entirely of the events of interest. This conserves memory and display space, and allows the user to analyze many consecutive GSM bursts at once.
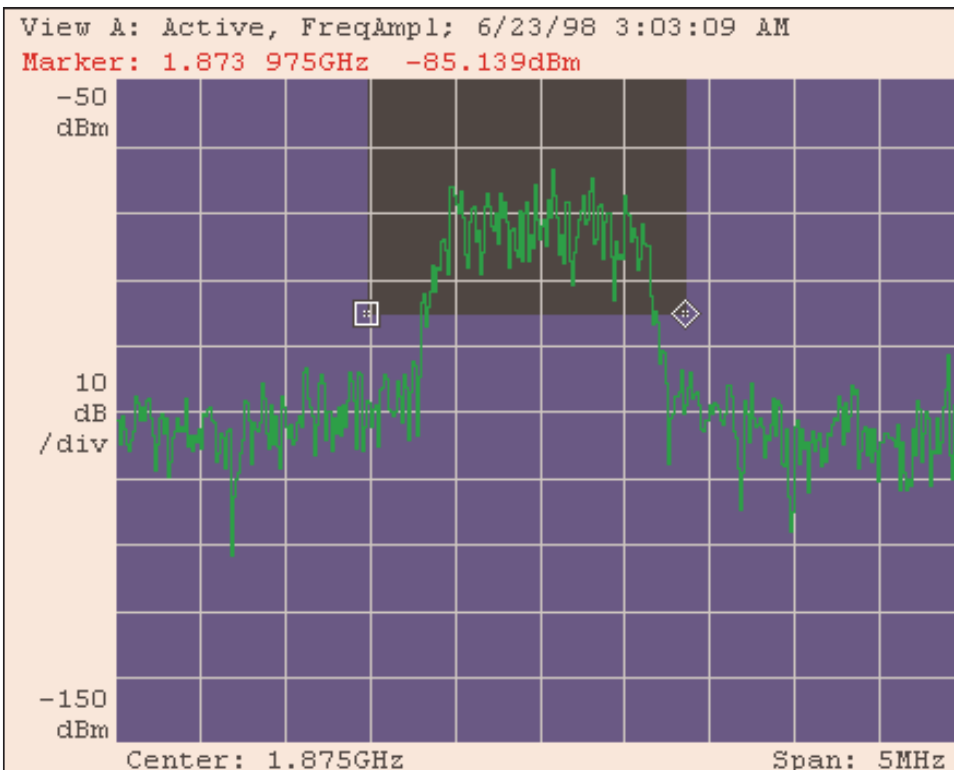
Figure 7. Trigger mask screen.

Bandwidth Today and Tomorrow

Real-time acquisition isn't the only attribute a modern wireless measurement tool needs – especially if it's expected to make the transition from 2G to 3G technologies.

As explained earlier, spread-spectrum technology is the engine of advancement toward 3G. CDMA (IS-95) is the leading spread-spectrum standard in the market today, while Wideband-CDMA (W-CDMA) and cdma2000 are expected to influence the direction of future 3G standards. Any measurement tool in the 3G arena must anticipate the demanding "speeds and feeds" that 3G will bring.

Present-day CDMA has a chip, or symbol, rate of 1.2288 Mchips/sec, with a channel width of 1.25 MHz. W-CDMA plans call for rates as high as 16.384 Mchips/sec and a channel width of 20 MHz. During the transitional period, a chip rate of 4.096 Mchip/sec (again, with 20 MHz channel width) addresses the needs of near-term W-CDMA developments.

Today only one RF instrument, the Tektronix 3086 RTSA, addresses all foreseen W-CDMA data rates. This instrument has a wideband input mode that delivers a 20.48 MChip/sec symbol rate, eliminating the need for an external wideband receiver. This reduces the cost and complexity of setting up for W-CDMA product development. An IQ input mode provides 30 MHz vector bandwidth. Clearly the 3086 RTSA has room to grow with evolving 3G measurement needs.

Conclusion

The real-time spectrum analyzer's ability to capture the full frequency breadth of spread-spectrum digital wireless channels is a unique advantage when designing, debugging, and installing the latest wireless equipment. As the communications industry makes the transition from second-generation to third-generation technologies, the RTSA will be there to capture challenging modulated signal events, and reveal details that elude today's tools.

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