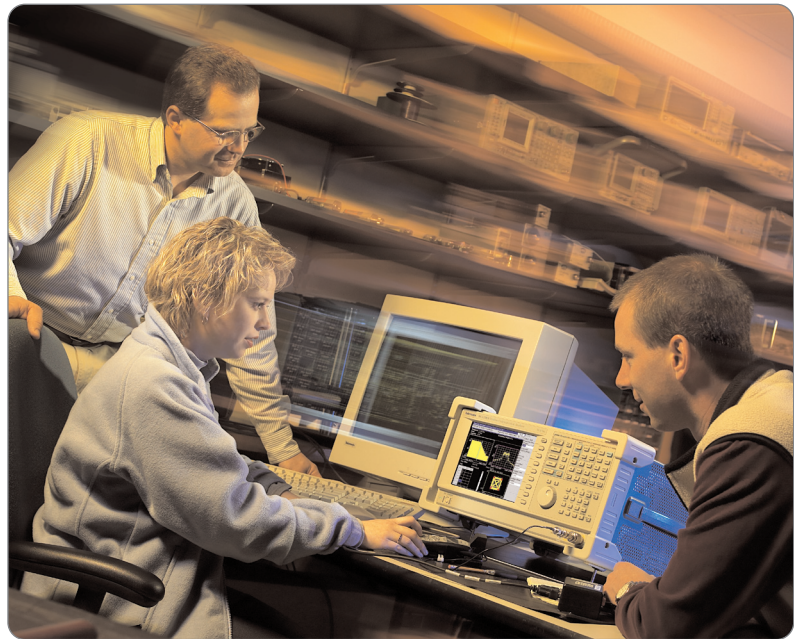


# Real-Time Spectrum Analysis for New Real-World Telecommunications Signals



## ► Conventional swept-frequency spectrum techniques can not fully characterize new generations of wireless standards

2.5G and 3G wireless telecommunication systems employ a wide variety of complex spread-spectrum RF signals to improve performance, optimize bandwidth utilization and expand services. The new signals present a measurement challenge for a conventional, swept, spectrum analyzer – the traditional measurement tool for characterization of wireless devices in the past.

High transmission rates, new sources of distortion and interference and the need to view subtle characteristics simultaneously in the time, frequency, modulation and code domains are beyond the capability of traditional test equipment. There is not always a solid, continuous carrier with a stable modulation envelope to acquire and analyze over a long period. Many signals now require the simultaneous acquisition of frequency and time information which is difficult to do with a swept analyzer, particularly if extensive time domain information is needed.

Conventional swept-frequency spectrum analyzers have a single path from the input to the display that is continuously tuned through the selected frequency range. Their displays represent

the composite result of tuned acquisitions taken serially over a relatively long period, a valid approach only for stationary, uninterrupted signals. Signal components at frequencies other than the current sweep value are not detected, so swept analyzers are more likely to miss intermittent events than capture them – events that are critical factors in new generation systems.

A fundamentally new real-time approach is needed to capture all of the new signal information faithfully and display it in formats that are easy to interpret and analyze. This application note describes revolutionary new Wireless Communication Analyzers that provide clear and comprehensive insight into the complex new systems. These advanced instruments use real-time spectrum analysis techniques to capture, record and display complex signals in multiple domains simultaneously – leading to optimum designs and shorter development cycles. Wireless Communication Analyzers are the instrument of choice in the challenging new world of wireless telecommunications.

# Real-Time Spectrum Analysis for New Real-World Telecommunications Signals

► Application Note

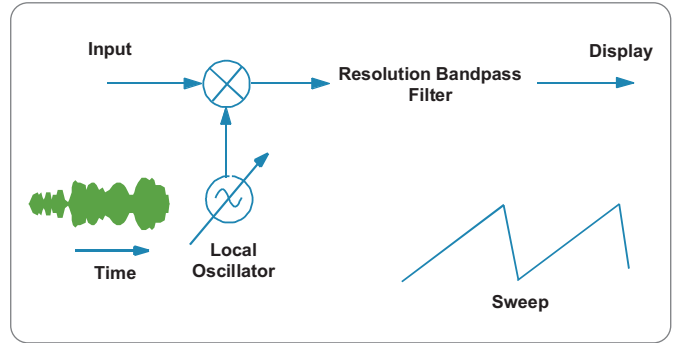
## Traditional swept-frequency spectrum analyzers

Swept-frequency spectrum analyzers have a single path from the input to the display. They accumulate a spectrum display by continuously tuning through consecutive frequencies and detecting the respective amplitudes. The display represents the compiled composite result of a stream of acquisitions performed sequentially as the analyzer sweeps through the range of frequencies. This technique requires a stationary, uninterrupted signal to produce valid measurements.

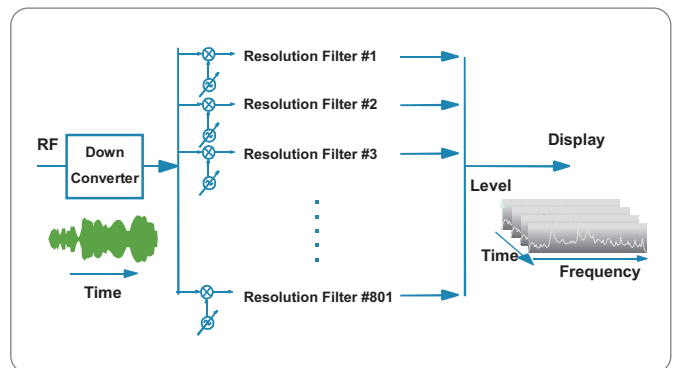
Figure 1 is a simplified illustration of the swept-frequency spectrum analyzer architecture. The local voltage-controlled oscillator continuously sweeps through a range of frequencies that are combined in a mixer stage with the input signal (a process known as heterodyning). The mixer is a nonlinear device that produces the sum and difference of the two signals, along with the originals and their harmonics. The resulting signal components are sent through a resolution filter that extracts the desired mixing product which is then detected and sent to the Y-axis of the display (amplitude). At the same time the voltage controlled oscillator signal is processed and sent to the display to create the X axis sweep (frequency).

The ability of a swept analyzer to resolve closely spaced frequency components is known as its “resolution bandwidth.” This function can be compared to a band-pass filter that is tuned over the frequency range of the instrument. At any given time, only one narrow band of frequencies is “seen” by the spectrum analyzer – all others are excluded. When tuned to frequency  $f_1$ , for example, signal components that are within the resolution bandwidth centered on  $f_1$  will be seen on the spectrum analyzer display. Later in the sweep, the filter will be tuned to another frequency,  $f_2$ , and all other signal components (including  $f_1$ ) will be excluded.

The response, or settling time, of the resolution filter limits the sweep rate of the analyzer, and sweep rate is proportional to the square of the bandwidth – the narrower the resolution bandwidth, the slower the sweep rate. If the analyzer sweeps too quickly the displayed amplitude will be lower than the actual amplitude and the



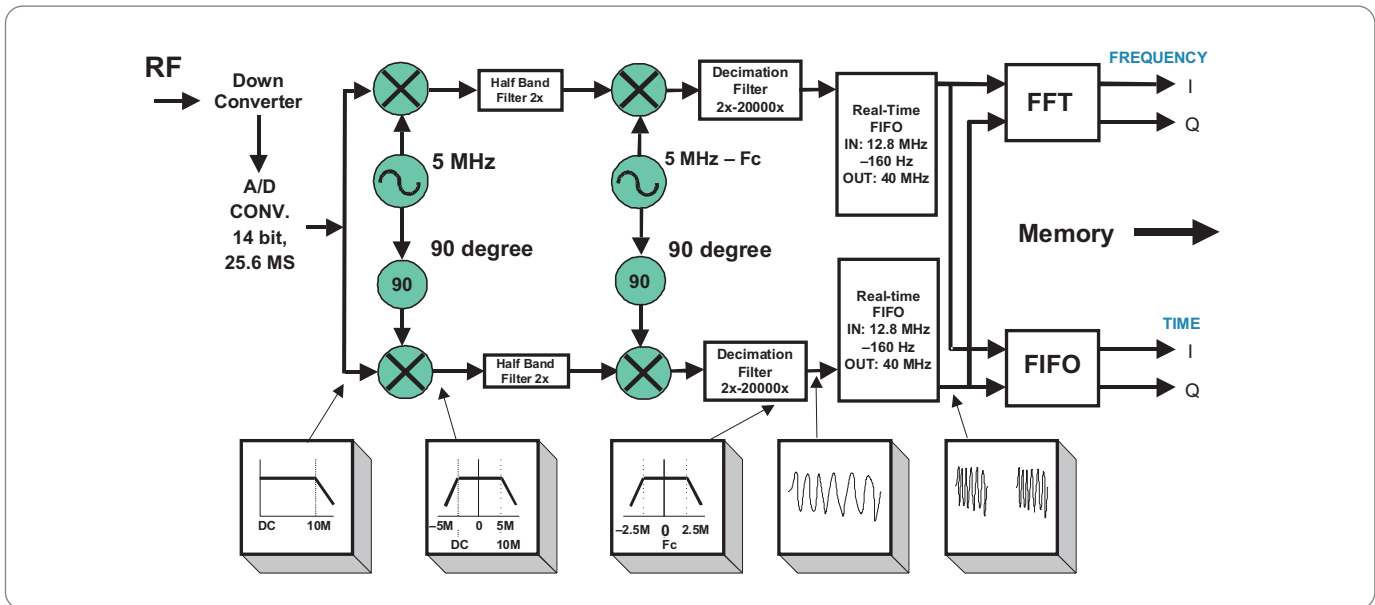
► **Figure 1.** Swept-frequency spectrum analyzer (simplified concept).



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

apparent frequency will be shifted to the right. Theoretically, the sweep rate should be infinitely slow, but that is not realistic – so, some amount of acceptable error must be specified.

Increased sweep times demand that the input signal remain stationary for even longer periods – usually disqualifying swept analyzers for the measurement of intermittent or periodic signals. When measuring over a range of frequencies, a transient event might occur at, say, the seventh frequency,  $f_7$ , in the range after the analyzer has moved on to  $f_8$  or  $f_{28}$ . The transient would be missed completely and it would be impossible to make an accurate power density measurement over the complete frequency range.



► **Figure 3.** Simplified Block Diagram of a Wireless Communication Analyzer.

Traditionally the major advantage of swept-frequency analyzers over real-time instruments has been their dynamic range. Recent advances in high-speed analog-to-digital (A/D) converter technology have narrowed that advantage, as new real-time analyzers feature up to 70dB dynamic range – more than adequate for wireless communication applications.

Some swept analyzers can be equipped with limited vector modulation analysis. They can produce various demodulation displays but do not have the simultaneous multi-domain capabilities of a Wireless Communication Analyzer, nor can they analyze vector modulation of anything but very short bursts of captured data.

## Real-time spectrum analyzers

Real-time spectrum analyzers take a totally different approach. Where the swept analyzer has one resolution filter, the real-time instrument has, in effect, hundreds of filters in parallel, each with its own “detector.” All of the hundreds of frequency components within the real-time bandwidth are “filtered” concurrently, and appear on-screen simultaneously. Figure 2 shows the real-time concept.

In practice, the Wireless Communication Analyzer uses Fast Fourier Transform (FFT) techniques rather than separate parallel hardware

filters to arrive at the spectrum data. The input signal is down converted, digitized, grouped into segments called frames, and then is transformed into its frequency components by FFT algorithms that operate in very fast hardware or software (see Figure 3).

Rather than waiting for a heterodyning process to sweep through the range of frequencies, the real-time instrument captures a block of data all at once during a user specified time window. Each window is transformed by the FFT algorithms into a set of data, called a frame, whose spectrum information corresponds to the full sweep of a conventional analyzer. The short frames can be repeated continuously over very long periods (up to many seconds or even minutes, in some models), with no gaps, or missed data, between frames. Time windows can be as short as 20 microseconds and still retain the ability to seamlessly capture a subsequent window without missing any data.

Because the instrument samples the full frames constantly and seamlessly (rather than waiting for the frequency range to be swept), the signal can come or go as it pleases and the real-time spectrum analyzer will capture the changes. The result is a continuously updated display that detects and accurately records real-world, real-time events such as are time varying signals.

# Real-Time Spectrum Analysis for New Real-World Telecommunications Signals

► Application Note

## Advanced solutions for complex challenges — the Wireless Communication Analyzer

A common characteristic of the new generation of communication signals is their non-stationary nature. In order to share time and bandwidth, information is transmitted in short bursts and carriers hop between different frequencies and/or are dynamically switched between system resources. Most of these signals are unpredictable; some occurring only once, others repeating, but at random. Time varying signals must be detected, accumulated and displayed in a manner that will reveal changes over the period of interest. Also, intermittent interference must be detected in the presence of the new variable signals.

Perhaps the single greatest measurement challenge is to identify specific problems or parameters from the vast amount of information that is needed to characterize the new signals. Signal quality is now evaluated in the frequency, time, modulation and code domains using methods such as codogram, spectrogram, EVM, constellation and vector diagrams, as well as code domain power and power versus time measurements. To provide these insights, instruments must be specifically designed to address wireless signals with appropriate trigger and acquisition options, display formats, and analysis functions.

The Wireless Communication Analyzer (WCA) specifically addresses the challenges of the evolving wireless technologies. Based on the real-time spectrum analyzer architecture that was pioneered by Tektronix, the WCA is capable of capturing continuous, intermittent, and random signals with equal ease. Because the instrument acquires full frames constantly, the signal can come or go as it pleases and the WCA will catch all of the information — even for single short events (the PRACH signal of a W-CDMA mobile station, for example).

In addition to conventional time/slope triggering, a frequency mask trigger allows capture of randomly occurring or infrequent signals based on their spectrum — even in the presence of other, nearby

signals. The WCA displays dynamic time, frequency, amplitude and code domain signal detail with powerful 3-D modes that reveal far more signal information than simple two-dimensional amplitude vs. frequency formats.

### Seamless Acquisition — capture all of the information

The WCA uses FFT techniques to produce, in effect, hundreds of filters in parallel. All of the frequency components within the real-time bandwidth are captured simultaneously. The resulting display is a continuously updated representation of everything that happened within the full spectrum of the capture band during a particular frame.

At any instant, a massive volume of signal information can be stored in memory for post-acquisition analysis.

The WCA200A Series features 15MHz real time bandwidth and a large memory that are well suited to the capture of random events during extended periods, such as handovers. With up to 256Mbytes of memory, the WCA200A is able to seamlessly capture and display up to 10 seconds of a 5MHz wide W-CDMA signal.

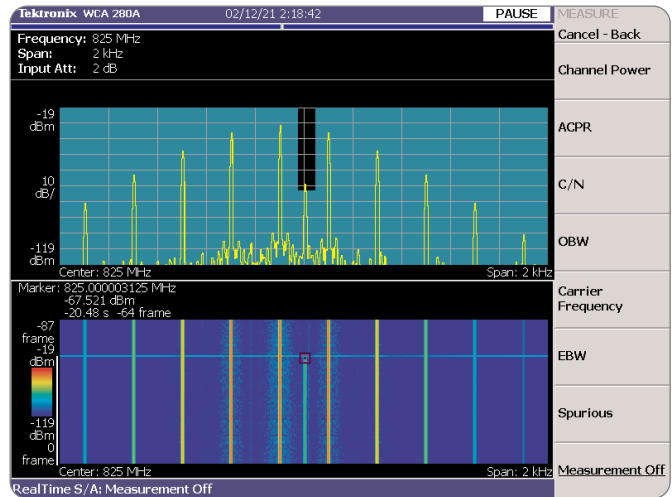
### Capturing elusive intermittent events — Frequency Mask Trigger

Triggering capabilities are vitally important for the analysis of today's real-world communication signals. The WCA includes both an amplitude time-domain trigger and a frequency mask trigger that enable precise acquisition even when signal events are erratic or infrequent. The frequency mask trigger can be used to capture signals arising from intermittent spurious or spectral re-growth events such as phase lock loop jitter and oscillator phase hits. Swept-frequency spectrum analyzers are limited to amplitude time-domain triggering — initiating a capture sequence when the signal crosses a predefined amplitude threshold.

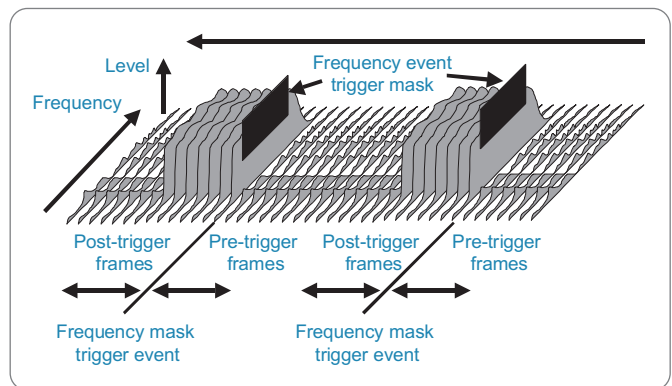
The frequency-mask trigger uses a frequency window as a condition of triggering. The user graphically defines the mask to trigger on a specific event in the frequency domain irrespective of other activity within the span (see Figure 4). The window can be set to watch for the disappearance or attenuation of a pre-existing signal, as well.

The main memory keeps a running record of the signal, discarding the oldest information as new data enters the memory (see Figure 5). When a trigger occurs, memory continues to acquire for a pre-scribed period (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 (pre-trigger), as well as the activity that followed it (post-trigger).

The frequency mask trigger has a second major benefit; it can be used to capture widely spaced events more efficiently. The instrument triggers only when the signal appears within the programmed window to allow the capture of “burst-on” periods and ignore the dead time intervals. The frequency mask trigger and the long memory work together to maximize the number of bursts that can be captured for subsequent spectral, time or modulation analysis, providing rich detail about the continuity of the signal.



► **Figure 4.** Frequency mask trigger event in spectrum display (upper) and spectrogram (lower). Spectrogram displays pre-trigger and post-trigger signals along vertical time axis, with amplitude represented by color.



► **Figure 5.** Pre- and post-trigger memory result of a frequency mask triggered acquisition.

# Real-Time Spectrum Analysis for New Real-World Telecommunications Signals

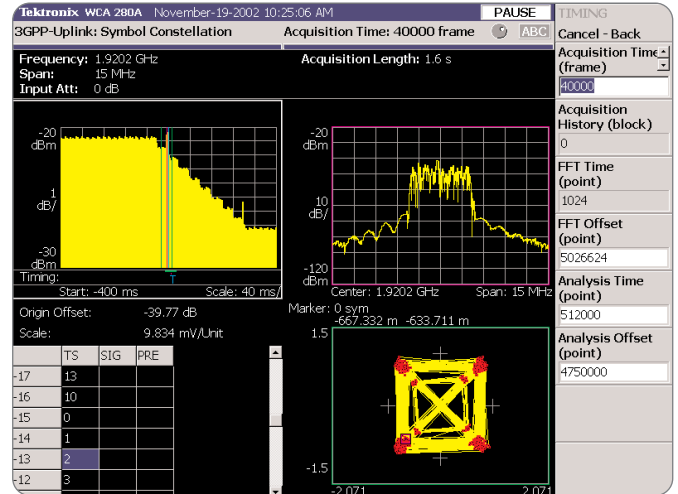
► Application Note

## Simultaneous Multi-Domain Analysis

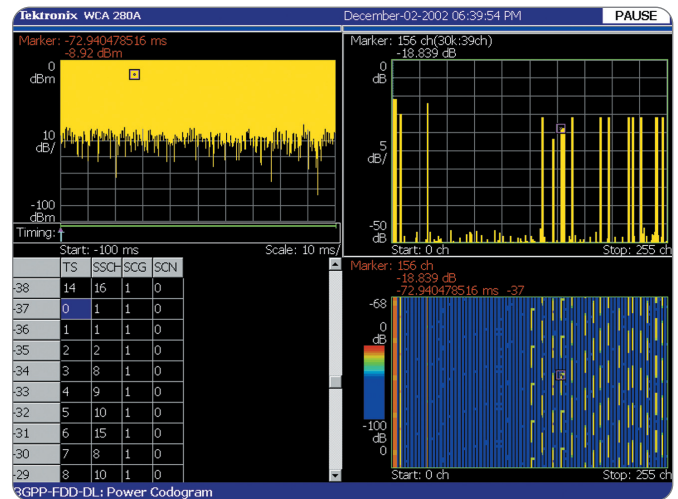
The ability to display correlated signal information in multiple domains at once provides a powerful insight into the performance of the device under test (see Figure 6). The ability to view any event in the time, frequency, modulation and code domains provides a unique insight in the characteristics of the device under test. For in-depth analysis of digitally modulated signals, constellation and vector diagrams are displayed, as are frequency, phase, magnitude, EVM, I and Q versus time. In the code domain, signals with high symbol rates such as W-CDMA, may be viewed during and after capture.

## Unique 3D Analysis Modes

Spectrogram and codogram displays add the third dimension of time to the spectrum and code versus power results. Figure 7 illustrates a composite analysis of a W-CDMA compressed mode downlink signal with Time versus Power, Code Domain and Codogram displays. The Codogram clearly shows the gap period and timing of the compressed mode signal and the increased thickness of the bars indicates that the data rate is higher than in the normal mode. All of the display windows are linked by common cursors – when the viewer scrolls or sets a marker to a certain point on the codogram, for example, the other windows follow to the same point in the signal. The spectrogram is another insightful 3D display that, in effect, raises the perspective to the point where the viewer is directly “above” the frequency-time plane, with frequency on the X axis, time on the Y axis and representing power density as color. In Figure 8, the behavior of a phase-locked loop (PLL) was analyzed as it was seeking frequency lock. The frequency mask trigger (left display) was set to detect changes on either side of the desired frequency so that any error would cause a trigger. The trigger position was set to 10 percent of the acquisition length to preserve both pre and post trigger results. The behavior of the PLL during settling can be clearly seen as the signal moves down the vertical (time) axis in the spectrogram (right display).



► **Figure 6.** Multiple domain analysis of a W-CDMA Uplink Signal. Power versus time display (upper left) shows decreasing power and transient events, spectrum display (upper right) shows adjacent channel leakage power caused by the transients and the constellation diagram (lower right) shows the effects in the modulation domain.



► **Figure 7.** Linked cursors in three displays: Time vs. Power (upper left), Code Domain Power (upper right) and Codogram (lower right). The time-slot information is also shown (lower left). Cursors are set to highlight a common time slot and code channel. Source is compressed mode downlink signal during a handover.

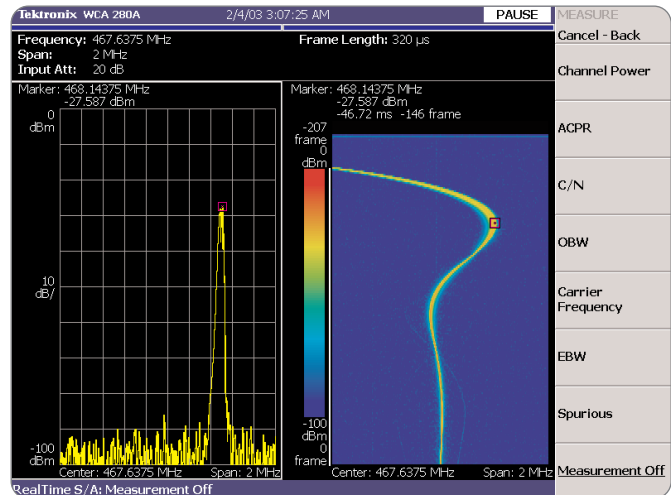
## Conclusion

As wireless telecommunications systems have grown to include broadband multi-domain characteristics, the traditional swept-frequency spectrum analyzer can no longer handle the new generation of signals. Tektronix has pioneered the development of a fundamentally new real-time approach to spectrum analysis to keep pace with the new system requirements. Wireless Communication Analyzers are able to capture all of the new signal information faithfully and display it in formats that are easy to interpret and analyze.

Wireless Communication Analyzers provide clear and comprehensive insight into the complex new systems. These advanced real-time spectrum analyzers reliably capture seamless records and characterize spread-spectrum signals in multiple domains simultaneously – leading to optimum designs and shorter development cycles. They are the system designer's instrument of choice in the challenging new world of wireless telecommunications.

The WCA200A Series specifically addresses the challenges of the evolving 2.5 and 3G wireless technologies. Based on the real-time spectrum analyzer architecture, the WCA200A Series is capable of capturing continuous, intermittent, and random signals with equal ease. Powerful codogram and spectrogram modes reveal the detailed behavior of intermittent non-stationary events such as compressed mode AICH signals and frequency-hopping Bluetooth transmissions. In addition to conventional time/slope triggering, a frequency mask trigger allows capture of randomly occurring or infrequent signals, in the presence of other, legitimate signals, based on their spectrum and yields highly accurate measurements of transmitted power in the spread spectrum signals.

The WCA200A Series offers a new and comprehensive set of measurement tools to the engineers and technicians who develop devices in today's rapidly evolving mobile telecommunications environment.



► **Figure 8.** Analysis of phase-locked loop. Spectrogram (right display) captures PLL response as it settles over time (top to bottom). Vertical axis is Time, horizontal axis is Frequency, and Power Density is represented by color.

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