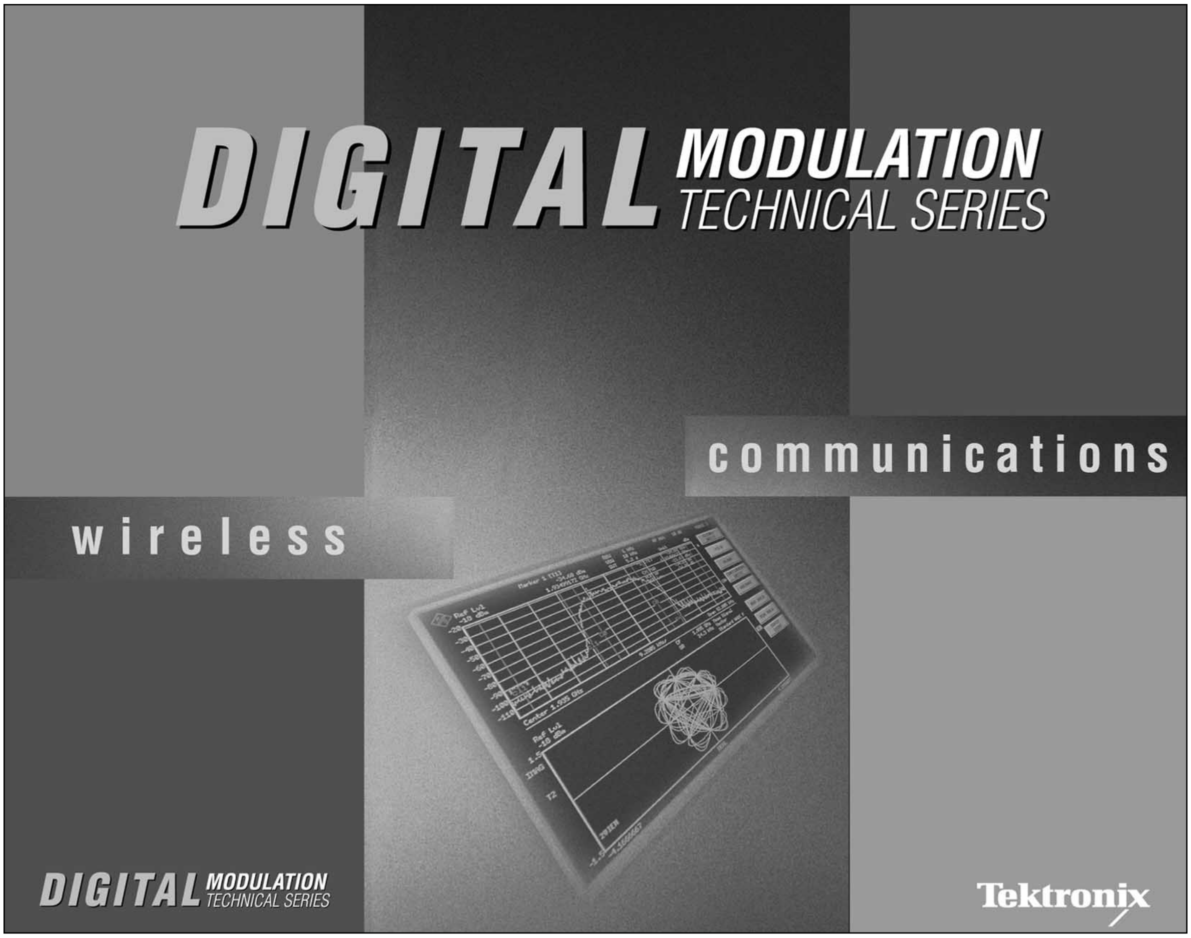
Tektronix

Digital Modulation Technical Series

Real Time Measurements of Digital Mobile Signals



Modern digital mobile communication methods impose ever-increasing demands on test equipment. In particular, the burst nature of IS-136, GSM, or variable rate CDMA reverse link transmissions can make modulation measurement within a burst difficult to achieve.

This application note introduces the concept of real-time spectrum analysis and how its ability to seamlessly capture a signal leads to enhanced measurements in the time, frequency, and modulation domains. Examples from second and third generation digital mobile systems are used as illustrations. In particular, the examples focus on new measurement capabilities that real-time spectrum analyzers can provide to the wireless designer.

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Introduction

Spectrum analyzers have long been an essential piece of equipment in the toolbox of the RF design engineer. They are invaluable for analyzing the spectrum of analog or digitally modulated signals. And with modern additions such as RMS detection, they also provide a valuable tool for the measurement of power and adjacent channel power of such signals (see References 1 and 2). However, the swept nature of the conventional spectrum analyzer may pose acquisition problems and lead to missing parts of the signal.

This application note reviews the operation of traditional swept spectrum analyzers and then explains the operation of a real-time spectrum analyzer. The real-time spectrum analyzer has the advantage that it can seamlessly acquire the signal. Finally, some examples of the types of signals that can be acquired by a real-time spectrum analyzer are given.

Conventional Spectrum Analyzers

Figure 1 shows a simplified block diagram of a conventional swept spectrum analyzer. In this example, there are two signals present at the input of the analyzer. The RF signals are down-converted by a swept local oscillator. The IF output of the down-converter is fed to a bandpass filter. This filter defines the resolution of the spectrum analyzer. As the local oscillator is swept in frequency, a different input frequency is down-converted such that its IF passes through the bandpass filter.

Another way of looking at this is to imagine that a filter is being tuned over the frequency band between F_{start} and F_{stop}. At any one time, only one narrow band of frequencies is "seen" by the spectrum analyzer.

In Figure 2, signal A is within the pass band of the filter and hence will be seen on the spectrum analyzer display screen. At some time later in the sweep, the filter will be tuned to the frequency of signal B. If that signal is still switched on, it will appear on the display. However, if it is now switched off, it will not appear. It may have disappeared because it is intermittent or it is a burst signal.

Real-Time Spectrum Analyzer

A real-time spectrum analyzer may be conceptually viewed as having a bank of contiguous filters as shown in Figure 3. In this way all signals within the range of the bank of filters may be viewed simultaneously and a continuous time-record of all the signals can be captured.

Figure 4 shows this concept of contiguous filters and both signals A and B will be acquired and displayed simultaneously.

Nowadays, other techniques are available that allow the simultaneous capture of signals which are spread over a range of frequencies. For example, Fast Fourier Transform chips can be used to convert time domain data to frequency domain spectra.

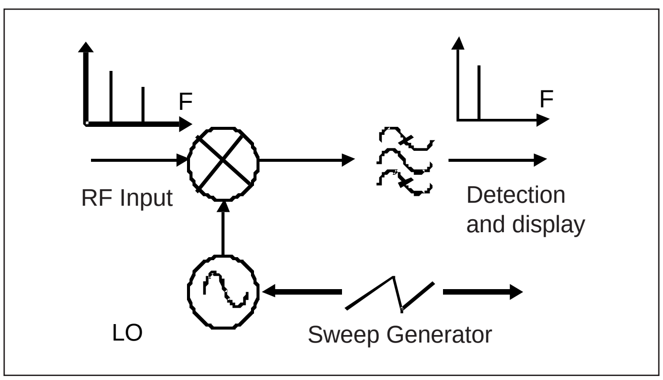

Figure 1. Block diagram of conventional spectrum analyzer.

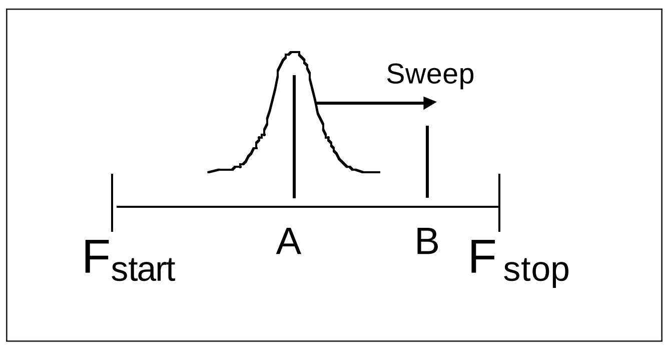

Figure 2. Sweep of conventional spectrum analyzer.

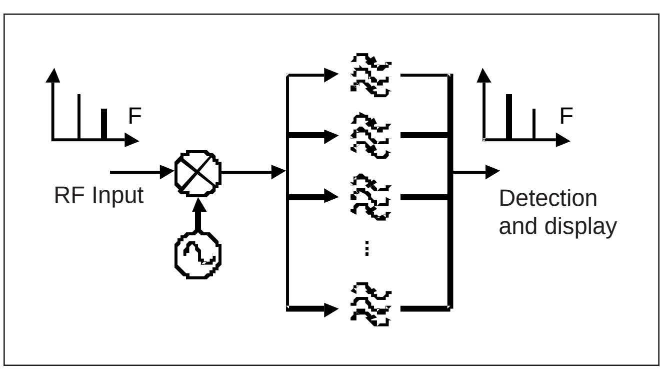

Figure 3. Conceptual block diagram of a real-time spectrum analyzer.

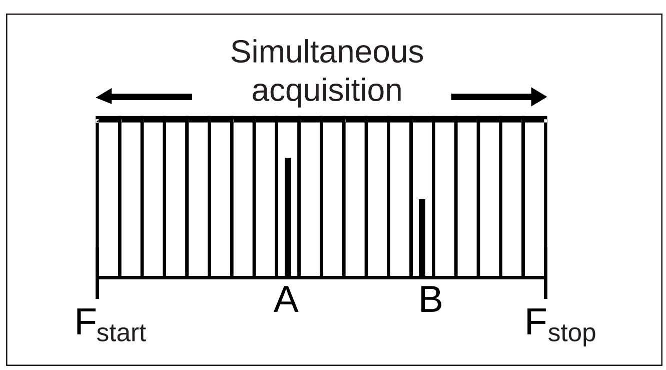

Figure 4. Simultaneous acquisition.

Figure 5 shows the acquisition of a series of frames of sampled time-domain data. This data represents a time-domain record of the signal over the entire real-time bandwidth of the analyzer. Each of these frames of data is then processed by an FFT chip to yield a spectrum for that frame time. In this way, the spectrum is acquired for the entire real-time span in one shot. The process is repeated for successive frames.

A practical representation of this technique is shown in Figure 6. This shows the block diagram of the Sony-Tektronix 3066 DC to 3 GHz Real-Time Spectrum Analyzer. The RF input is down-converted by use of a mixer and stepped local oscillator. For RF spans of 5 MHz or less, the local oscillator does not sweep. The resultant IF is digitized using a 25.6 MHz A/D converter and the resultant bit stream passed through a digital down-converter. The signal path now splits; time-domain data is fed into memory and also to an FFT chip. The output of the FFT chip is also fed into memory. As a result, both time and frequency domain data are available for display simultaneously.

Practical Results

Figure 7 shows a display from the 3066 Real-Time Spectrum Analyzer. The lower left quadrant shows a spectrogram. The horizontal axis is frequency, the vertical axis is time, and the color represents signal amplitude; blue is low and red is high. Here we are looking at a CDMA signal that was captured off-air from a mobile phone in variable speech rate mode. The red "bursts" are when the phone transmitter is on and the green color is the background noise. The circled box shows the position of a marker, which determines the frame to be used for analysis in the other display windows.

The upper left quadrant represents the spectrum of the marked frame. The black area at the top of the CDMA "bart head" represents a user-defined frequency mask trigger. This was set to enable the acquisition of each of the pseudo-randomly timed bursts of the CDMA mobile. The user sets a value for the number of frames to be captured and the percentage split between pre- and post-trigger frame acquisitions.

Frequency Event Trigger

Figure 8 shows the principle of operation of the frequency event trigger. When the frequency event trigger is enabled, the 3066 is continuously acquiring frames until a signal occurs which enters the region of the user-set frequency mask. When this occurs, a pre-set number of pre-trigger and post-trigger frames are retained in memory. The trigger is re-armed and the process repeats when another burst occurs. In this way, it's possible to capture signals, even when they do not occur in a periodic way. Memory efficiency is also max-

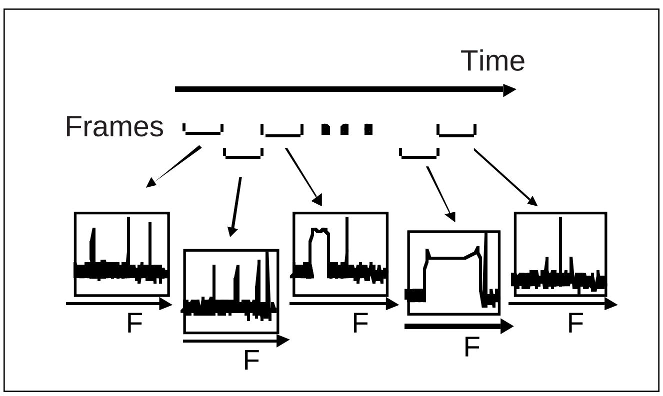

Figure 5. Frame acquisition.

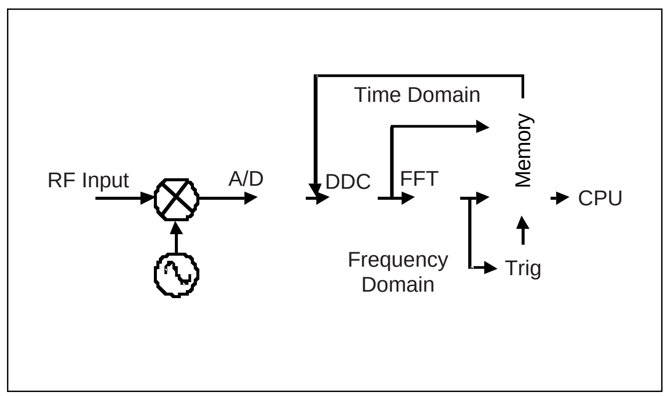

Figure 6. 3066 block diagram.

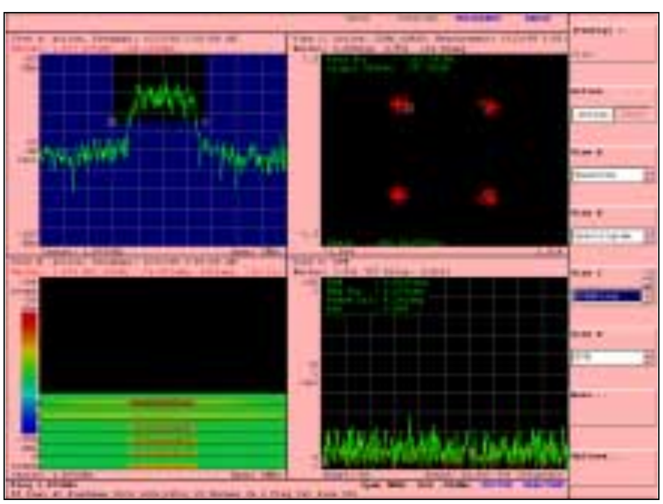

Figure 7. CDMA mobile phone RF output.

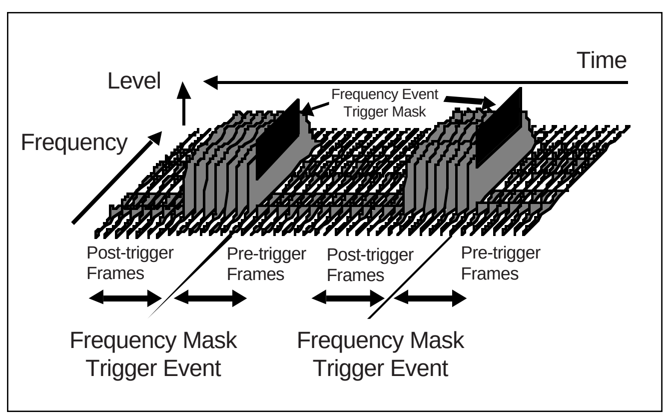

Figure 8. Frequency event trigger.

imized as only the required number of frames are stored.

Having captured the signal, it is then possible to analyze in the modulation and time domain as well as in the frequency domain. The upper right quadrant of Figure 7 shows the constellation diagram of the CDMA mobile O-QPSK modulation. The lower left quadrant shows the plot of error vector magnitude versus time and numerical results for phase and magnitude error as well as rho.

Post Capture Zoom

The stored signal can be further manipulated. The user can acquire a frequency-time record from over the full real-time bandwidth of the analyzer and then subsequently zoom on a particular frequency of interest. This can be done with a magnification factor up to 1000X. Figure 9 shows an example of this for an IS-136 base station transmission captured off-air. The desired signal is shown in the middle of the upper left quadrant. This is zoomed and the spectrum of the frequency of interest displayed in the upper right quadrant along with the constellation diagram in the lower right.

Third Generation Cellular

As we move towards third generation standards, the chip rates of systems are increasing. Figure 10 shows the spectrogram, spectrum, constellation diagram, and EVM plot for a 4.096 MHz W-CDMA signal that was generated using a signal generator.

Summary

Real-time spectrum analyzers offer the R&D engineer the possibility of easy capture and analysis of burst signals and signals of an intermittent nature. Although this application note has concentrated on the application for developers of second and third generation mobile cellular equipment, there are also many applications associated with the development of components. One such application would be the capture and analysis of phase hits occurring in local oscillators.

As time-to-market pressures increase for the developers of second and third generation mobile phone and base stations, the real-time analyzer with its ability to seamlessly capture signals will become an ever increasingly important tool in the R&D engineers toolkit.

References

(1) Josef Wolf and Bob Buxton. ***Measure Adjacent Channel Power With a Spectrum Analyzer***, Microwaves & RF, January 1997, pp. 55-60.

(2) Bob Buxton, Steve Stanton, and Josef Wolf, ***ACP Measurements on Amplifiers Designed for Digital Cellular and PCS Systems***, Proceedings of the Sixth Annual Wireless Symposium, February 1998, pp. 122-127.

Written by Bob Buxton, Tektronix Inc.

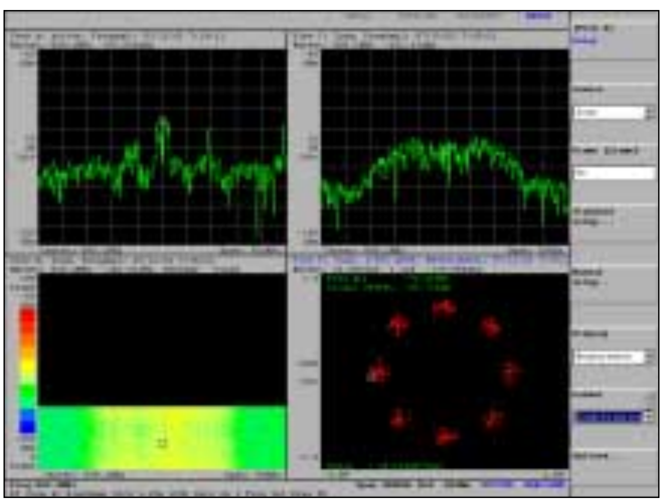

Figure 9. Digital zoom on off-air IS-136 signal.

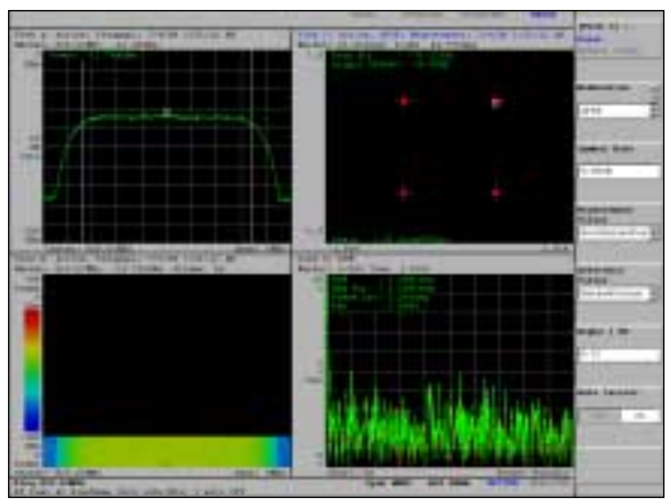

Figure 10. 4.096 MHz W-CDMA signal.

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