Agilent AN 1275

Automatic Frequency Settling Time Measurement Speeds Time-to-Market for RF Designs

Application Note

Fast, accurate synthesizer switching and settling are key performance requirements in modern wireless designs.

Considerations for the RF Designer

Complex modulation and multiplexing techniques in wireless communications systems continue to present many technical challenges to the RF designer. Additionally, fast time-to-market, high reliability, low cost, and low power consumption are critical factors in the design of any modern wireless communications system.

Because of cost, size, and battery life considerations, the frequency synthesizer found in virtually all wireless communications systems usually serves as both the transmit and receive local oscillator (LO). In addition to being required to change rapidly between transmit and receive frequencies within a cell, some systems hop frequencies continuously within the same cell to avoid multipath interference caused by structures and terrain. When the mobile unit moves or is handed off to an adjacent cell, it changes its carrier frequency and time slot to those assigned to it by the new base station.

The voltage controlled oscillator (VCO) within the local oscillator often must be sensitive enough to tune over a large frequency range. Any stray voltage on the tuning input will have a great effect on the synthesizer output frequency. Printed circuit board layout is critical to avoid signal paths that would allow unwanted coupling of any stray voltages to the tuning path.

Extra buffer stages between function blocks improve isolation but also increase cost. Added parts may also increase size. This reduces competitiveness in markets where small size and low power operation of a design are essential.

Timing of Frequency Changes is Crucial
Settling time is a critical parameter for synthesizer designers. Digital transmission techniques, such as TDMA, require transmission only during an assigned time slot, with each burst containing a frequency or phase-encoded bit pattern. Because the burst must occur at a precise time, designers need to know how much time to allow the synthesizer to settle to the correct frequency before keying the transmitter output stages (see Table 1). Between bursts the output RF amplifier is turned off, but the synthesizer hops to other frequencies for receiving and hand-off information. Correct timing of synthesizer switching and settling is crucial to maximize performance.

The Issue of Frequency Pulling
Many mechanisms can pull a synthesizer off frequency when the radio is taken from the receive mode to the transmit mode or vice versa. Turning the transmitter power supply on and off (as in a TDMA system) can cause frequency changes due to:

- Changes in impedance loading of the synthesizer and reference oscillator when the transmitter power amplifier turns on or off
- dc transients feeding back into the synthesizer or reference oscillator
- Radiated feedback from the output stage or antenna into the synthesizer or oscillator.

The performance of an entire system is often limited by the performance of the synthesizer. Optimizing system performance requires a complete characterization of the synthesizer, especially the settling time and frequency pulling characteristics. RF design engineers need a fast, accurate, and repeatable method for characterizing synthesizer settling performance.

Table 1. Typical Synthesizer Settling Time Requirements

System	Maximum Hop	Tolerance Band	Settling Time
DECT	130 MHz	50 kHz	30 to 400 μs
CT-2	4 MHz + IF	1 kHz	< 1 ms
CT-3	> 10 MHz	1 kHz	10 μs
GSM	75 MHz	100 Hz	500–850 μs
USDC	25 MHz	100 Hz	1 ms
PCN	170 MHz	100 Hz	500 to 580 μs
Private	2 MHz + IF	5 to 10 Hz	10 ms

Wireless system design requires tight synthesizer switching control.

Assessing Frequency Behavior—Alternative Test Methods

The Agilent Technologies 53310A Modulation Domain Analyzer with Option 031 was developed specifically for digital RF communications measurement needs. It allows RF designers to directly view synthesizer settling time and frequency pulling.

Traditional methods to make these measurements include the use of discriminators or spectrum analyzers. Both of these methods are indirect and subject to severe limitations.

Discriminator Method

This test method requires that the synthesizer output frequency be input to a discriminator which converts frequency to voltage. The output voltage of the discriminator can then be viewed on an oscilloscope (see Figure 1).

A major problem with using discriminators is that of repeatability and correlation of the results. The test system needs to be fully characterized to convert the voltage output of the discriminator into meaningful frequency values. Furthermore, the test system needs frequent calibration to be used with any confidence. The calibration process is time-consuming, tedious and difficult to automate.

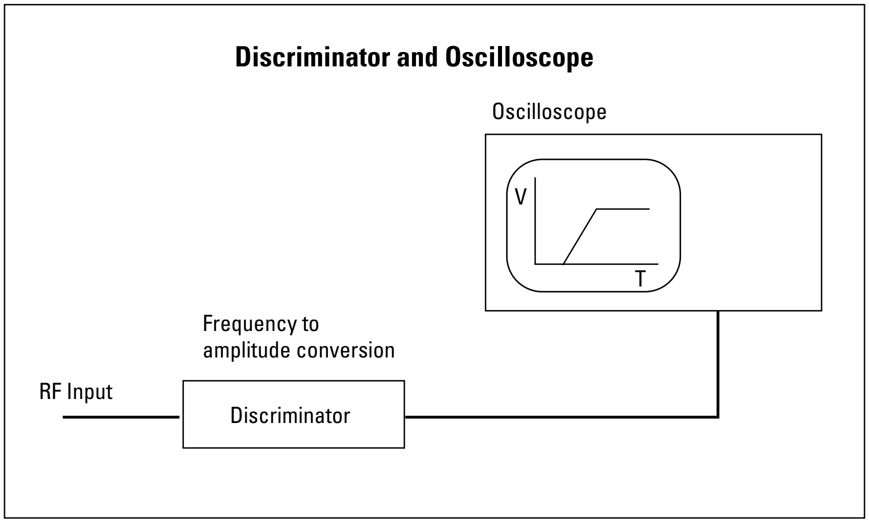


Figure 1. Using a discriminator for measuring synthesizer settling time does not provide calibrated, repeatable results.

Minor temperature changes due to changes in ambient temperature or device warm-up cause the output voltage to drift. The amplitude of the input signal is assumed to be constant. In reality, if fluctuations in the amplitude occur, the discriminator cannot distinguish between frequency and amplitude changes. A limiter circuit can be added to ensure that the discriminator does not see amplitude changes, but this adds one more burden on the designer.

Discriminators are narrowband and therefore inflexible. A single discriminator will only characterize a particular range of frequencies. If a frequency step is beyond a given range, the entire step cannot be measured. Often several discriminators must be used to characterize a single synthesizer, which is awkward and inconvenient. These limitations make it difficult to achieve repeatable, correlatable results.

Spectrum Analyzer Slope Detection
A spectrum analyzer can use slope detection in “zero span” to provide a view of frequency versus time. By placing a spectrum analyzer in zero span so that it does not sweep in frequency, you can use it to display a trace of signal power level versus time. Then, by tuning the spectrum analyzer so that the carrier frequency is centered on the filter “skirt,” small changes in frequency can be discriminated as the signal moves up and down the filter skirt (see Figure 2).

The spectrum analyzer must be tuned such that the carrier frequency is centered on the filter “skirt.” Limited FM demodulation is provided, but only by assuming that the carrier power is held constant. Again, fluctuations in the input amplitude will be indistinguishable from frequency changes. The range is limited, and the linearity of the filter slope is not guaranteed.

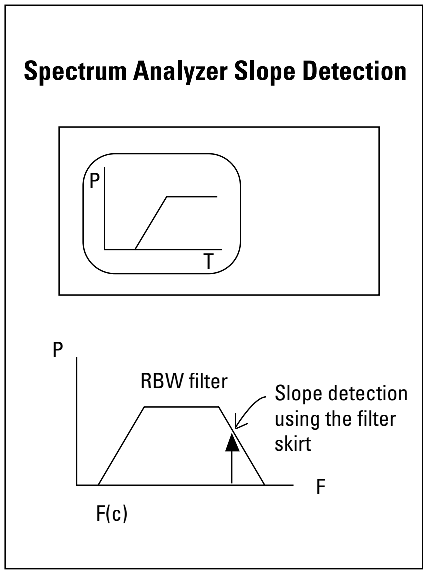


Figure 2. The slope detection method with a spectrum analyzer offers limited accuracy because of filter nonlinearity.

Modulation Domain Analysis
Modulation domain analyzers offer significant advantages over past techniques for measuring frequency settling time. By making individual frequency measurements in a continuous back-to-back fashion, the modulation domain analyzer provides a direct view of frequency versus time. You can simply enter the target frequency and tolerance band, and the analyzer automatically calculates settling time from the frequency versus time display. The results are accurate, fully calibrated, and easily correlated. Amplitude and temperature variations are ignored, making frequency changes singularly observable (see Figure 3).

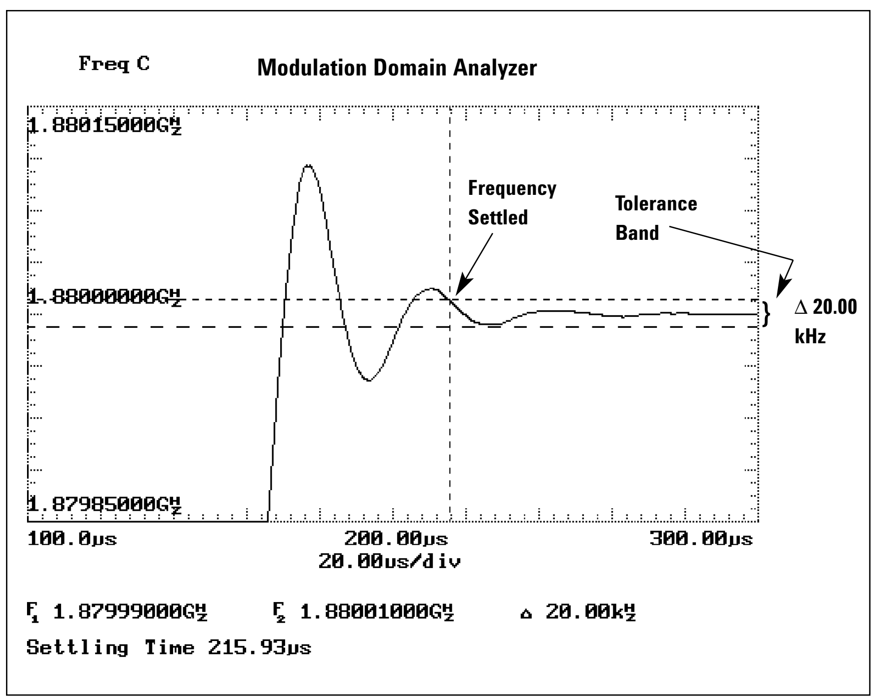


Figure 3. A modulation domain analyzer provides highly accurate automatic measurements of synthesizer settling time.

Frequency pulling effects are also easily seen on the frequency versus time display. You can quickly assess how far the synthesizer has been pulled off frequency and how long it takes to relock (see Figure 4).

The test setup shown in Figure 5 demonstrates just how simple it is to make this measurement with the Agilent 53310A Modulation Domain Analyzer with Option 031. Your synthesizer under test is connected directly to the 53310A's high-resolution RF input. Direct connection eliminates the need for external mixers, filters, discriminators, or detectors. A sync pulse, such as the "step-command edge" can be connected to the external trigger to accurately time reference settling time measurements.

The modulation domain analyzer is much easier to use than either the discriminator or spectrum analyzer methods. It is inherently more accurate, has better dynamic range, and is very affordable. The modulation domain analyzer's direct measurement technology provides results which are more repeatable and easier to correlate than those provided by previous measurement techniques.

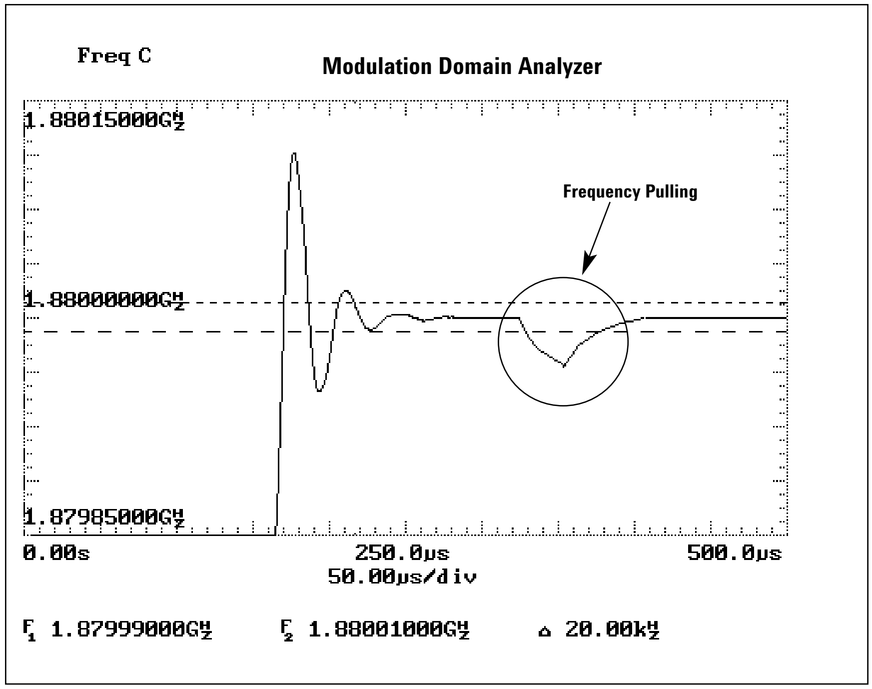


Figure 4. Frequency pulling effects can easily be seen using a modulation domain analyzer.

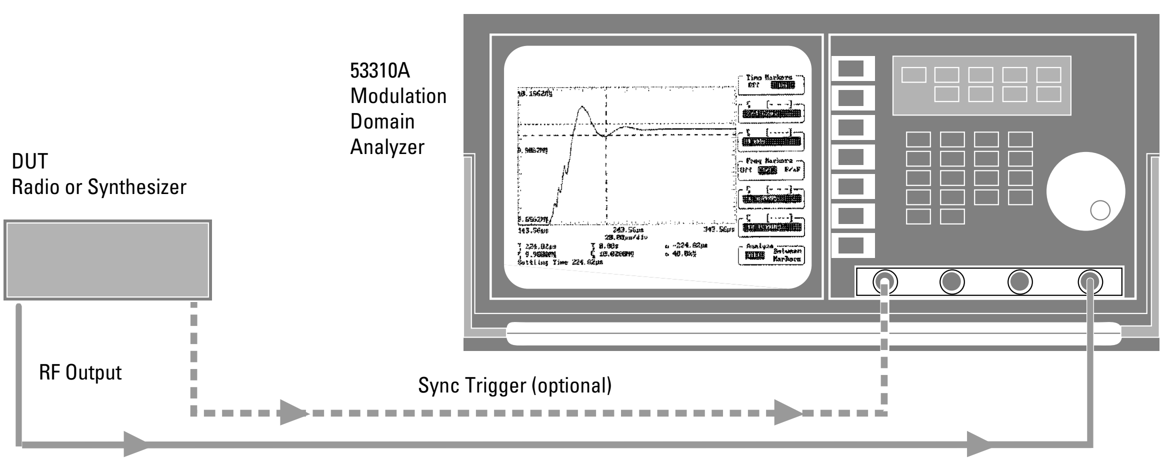


Figure 5. Direct connection makes measurement setup easy.

Additional Measurements for RF Communications Designers

In addition to synthesizer settling and pulling measurements, the Agilent 53310A Modulation Domain Analyzer with Options 031 and 305 provides several other important measurement capabilities for RF design engineers.

Easily Add Phase Analysis—Including Phase Noise

The 53310A's Option 305 Phase Analysis software adds the ability to measure phase settling time (see Figure 6), phase deviation, phase trajectory, and even phase noise. Noise floors as low as –140 dB at 100-kHz offset frequencies (–180 dB at 10 Hz) can be achieved. The software runs on an IBM-compatible PC.

Transmitter Turn-on and Turn-off Frequency Behavior

The modulation domain analyzer can also provide direct views of transmitter turn-on and turn-off frequency behavior. The transmitter frequency must be controlled tightly during burst turn-on and turn-off to minimize interference to adjacent channels. Innovative power-level triggering helps to meet complex regulatory test requirements for transmitter turn-on and turn-off behavior (see Figure 7).

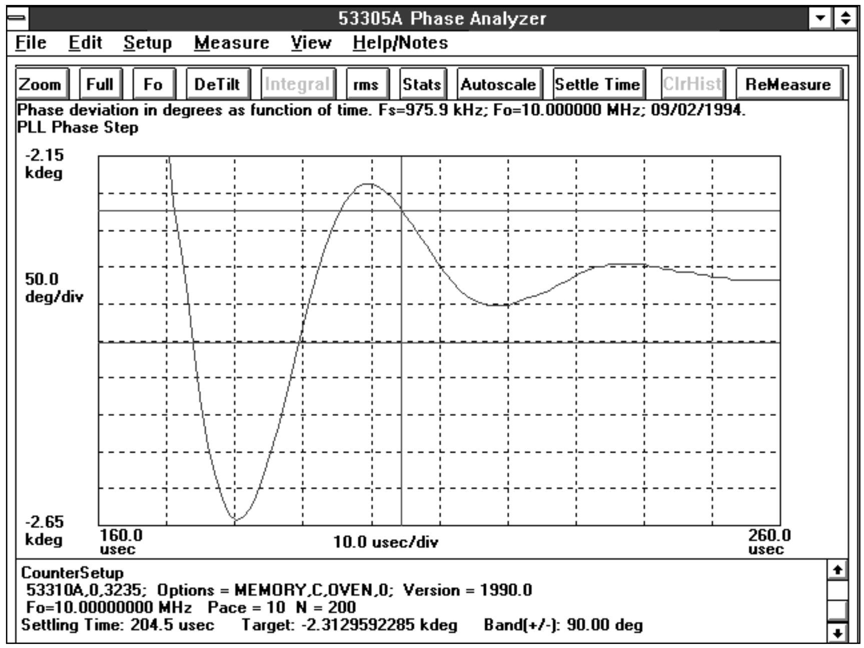


Figure 6. Phase analysis software offers the flexibility to view synthesizer settling in phase versus time.

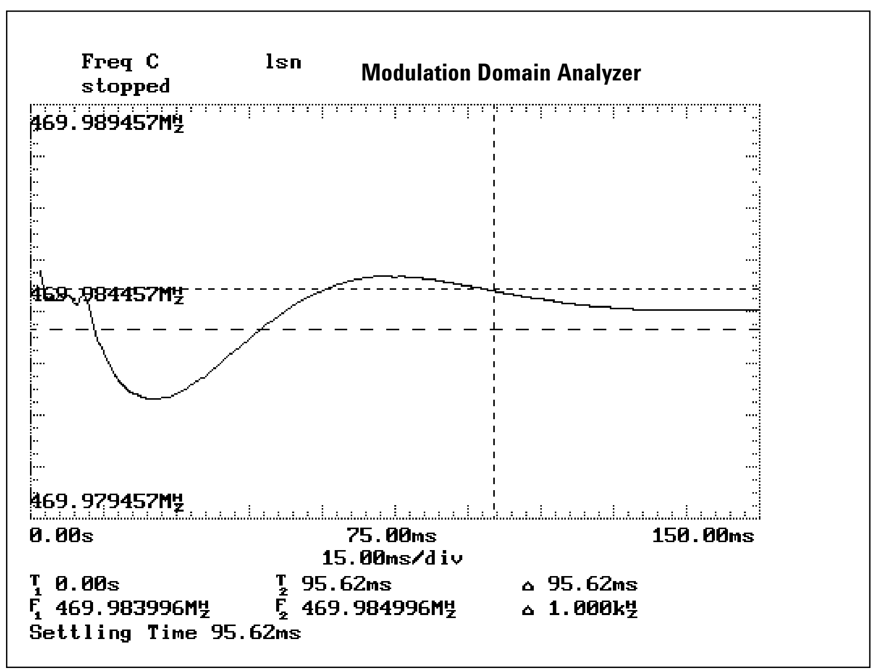


Figure 7. Frequency turn-on behavior of a mobile radio viewed directly on a modulation domain analyzer.

Fast, Direct Views of Complex Modulation
Complex frequency modulation such as Gaussian Frequency Shift Keying (GFSK) can be viewed directly in the modulation domain, offering valuable insights into modulator performance (see Figure 8). The Agilent 53310A demodulates complex frequency and phase modulation with high resolution without external downconversion. Automatic measurements of center frequency and peak deviation are provided for systems such as CT-2 and DECT.

Direct Frequency vs. Time Eye Diagrams
Frequency-versus-time eye diagrams allow you to view effects of bit jitter and inter-symbol interference directly on the RF carrier (see Figure 9). Comparing the 53310A's RF eye diagram and the baseband eye diagram viewed on an oscilloscope enables isolation of problems in the RF chain.

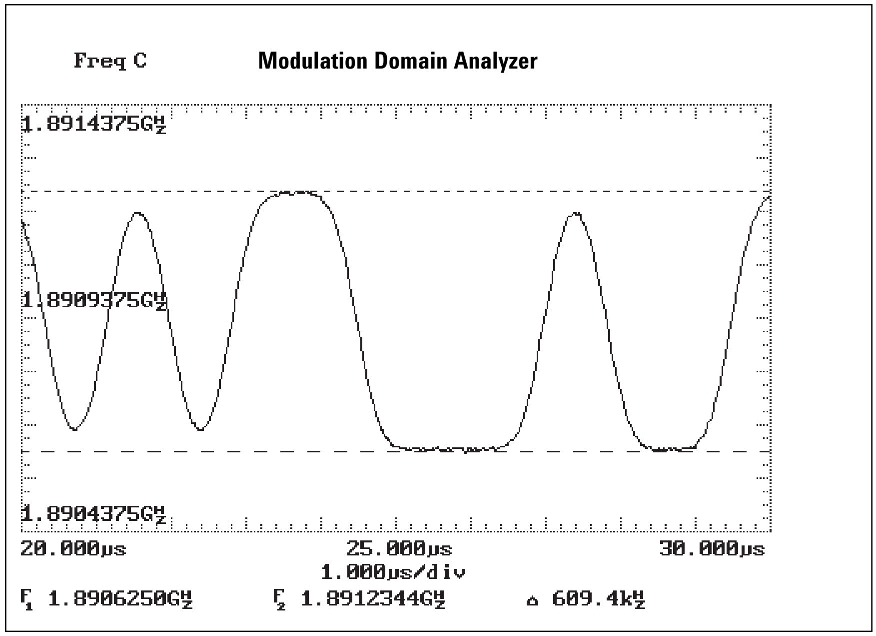


Figure 8. The high resolution RF input directly profiles the FSK modulation on a DECT signal.

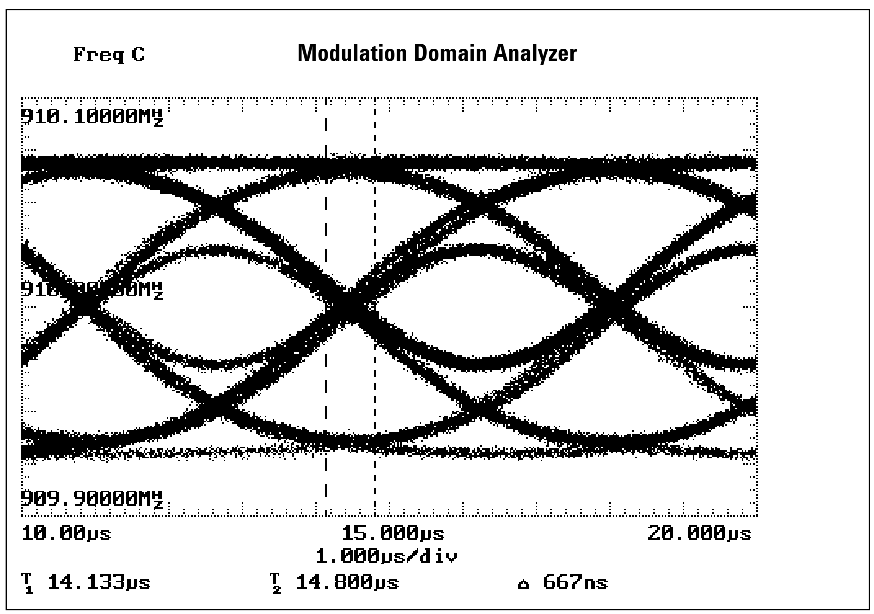
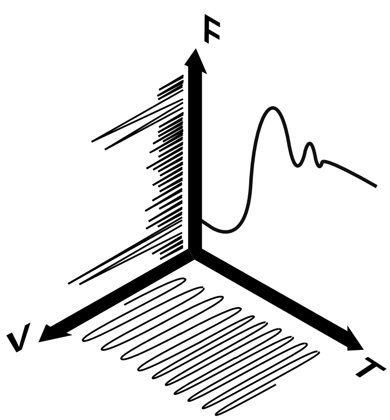


Figure 9. Frequency-versus-time eye diagrams make it easy to view jitter effects on the RF carrier.

The Modulation Domain Gives You a New Way to View Complex Modulation

Modulation domain analysis does for frequency what an oscilloscope does for voltage. The digitizing oscilloscope adds the time dimension to voltmeter readings, giving you a picture of the voltage variations over time. Changes in voltage are easily captured and analyzed. Measurements like V p-p, overshoot, and undershoot are simplified since voltage can be displayed as a function of time. With the modulation domain, this same simplicity is available for frequency measurements. The Agilent 53310A Modulation Domain Analyzer adds the time dimension to frequency counter results. You can view frequency variations on modulated carriers that were traditionally very difficult to view directly. More than simply plotting individual measurement results over time, the modulation domain analyzer makes frequency measurements continuously. Without the dead-time between measurements traditionally found in frequency counters, and with a maintained timing relationship between measurements, no information is lost. This gives you a better way to analyze your signals.



For more information

See also the Agilent 53310A Modulation Domain Analalyzer brochure and data sheet.

By internet, phone, or fax, get assistance with all your test and measurement needs.

Online Assistance
www.agilent.com/find/assist

Phone or Fax
United States:
(tel) 1 800 452 4844

Canada:
(tel) 1 877 894 4414
(fax) (905) 206 4120

Europe:
(tel) (31 20) 547 2323
(fax) (31 20) 547 2390

Japan:
(tel) (81) 426 56 7832
(fax) (81) 426 56 7840

Latin America:
(tel) (305) 269 7500
(fax) (305) 269 7599

Australia:
(tel) 1 800 629 485
(fax) (61 3) 9272 0749

New Zealand:
(tel) 0 800 738 378
(fax) (64 4) 495 8950

Asia Pacific:
(tel) (852) 3197 7777
(fax) (852) 2506 9284

Printed in U.S.A. 7/00
5964-4335E

Agilent Technologies
Innovating the HP Way