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Bringing New Power and Precision to Gated Spectrum Measurements

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Today's pulsed and time-multiplexed signals may require spectrum analyzer measurements that occur only during the active periods, a process that requires an instrument with precise timing accuracy

Making accurate spectrum and power measurements—including adjacent channel power (ACP), CCDF, etc.—on the desired portion of time-varying and complex-modulated signals is now a common measurement challenge. Many modern communications signals such as WiMAX are RF "bursted" and have spectral content which varies during each burst. These signals are often measured using a spectrum analyzer and one of several types of time-selective spectrum analysis. The most powerful approach for swept analysis is called "gated LO" or simply "gated sweep." For this type of measurement, the sweeping local oscillator of the analyzer is directed to sweep and measure only during the desired portion of the signal.

The goal is a measurement that has the same amplitude and frequency accuracy, and the same resolution as a non-gated measurement, and which can be made quickly and simply. The task is complicated by the need for accurate triggering and gate timing, potential errors created by the interaction of the changing signal and the dynamic characteristics of the analyzer's LO and IF filters.

To achieve this goal, signal analyzers are evolving with new analysis techniques to identify sources of measurement error and eliminate them. In particular, the Agilent MXA signal analyzer uses new algorithms to optimize gated-sweep measurements and allow for full performance specifications on gated measurements.

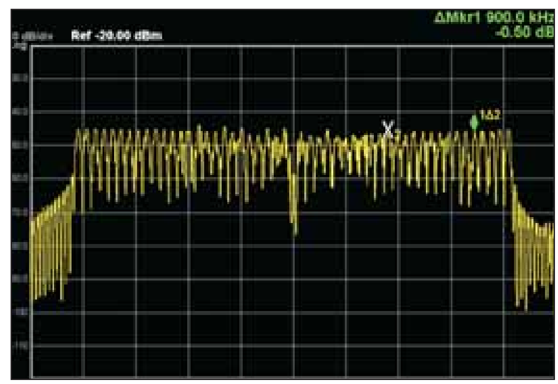

Figure 1 · This gated LO measurement of the preamble of a fixed WiMAX signal shows the sparse set of OFDM subcarriers used to train the adaptive equalizer in the receiver. The relative marker is used to measure the frequency spacing of ten of the transmitted subcarriers, yielding an accurate measurement of subcarrier spacing from the preamble alone.

In applications such as communications and radar, time-varying signals have become the rule rather than the exception. Thus, time-selective analysis is essential for both spectrum analysis and more specific measurements such as ACP, occupied bandwidth and CCDF. An example showing the spectrum of the preamble of a WiMAX subframe is shown in Figure 1.

Time-Selective Measurement Techniques

Three different techniques are generally used for time-selective spectrum and power measurements. As for general terminology, the terms "gated sweep" and "time gating" are used most commonly, though there is no universal agreement as to which one of the three techniques they refer. Below is a summary of the techniques. More complete information, including block diagrams and the benefits and drawbacks of each technique is available in Agilent application note AN-150 [1].

Gated LO

The spectrum analyzer's local oscillator is controlled so that it is sweeping (and spectrum is measured) only during the desired portion of the input signal. Otherwise the measurement is halted, or paused, when the signal is outside of the gate interval. Sweeping then resumes at the beginning of the next gate interval. Multiple sweep segments are required to generate a complete spectrum, with the number of segments required depending primarily on the analyzer's sweep time and the duration of the gate.

Gated Video

The analyzer sweeps continuously with the gate signal used to select which measurement points are retained and displayed. The analyzer's sweep time must be set so that the gate signal is valid during at least some portion of the duration of each display point. If not, gaps in the measured spectrum will result. Gate time must therefore be carefully chosen and hundreds of sweeps may be required for a complete spectrum measurement; frequently resulting in slow total measurement times.

Gated Fast Fourier Transform (FFT)

The signal in the analyzer's IF is digitally sampled and a time record is constructed from the samples that are within the gate window. A Fourier transform is performed on the time record, yielding a spectrum measurement of the signal from the valid gate interval only. No sweeping local oscillator is involved, and in many cases the spectrum can be measured from a single gate interval. Where necessary, signal analyzers such as the Agilent MXA can concatenate FFT results from multiple gate intervals to produce arbitrarily wide frequency spans. Note though that measurements requiring these multiple FFTs will be considerably slower than those that do not.

For swept spectrum analyzers, the gated LO technique is generally the best one to choose—assuming it is available on the analyzer being used. Gated LO provides good flexibility in frequency span and gate timing, and measurements are completed faster than with gated video. Gated LO measurements are also easier to set up than gated video, as there is no need to carefully choose a sweep time.

In gated FFT measurements the gate width (e.g., time record length) is determined automatically, based on the RBW setting. In many measurements the gate width will be much narrower than the valid portion of the signal. This narrowness provides a measurement benefit. If the spectrum measurements vary with the location of the gate within the allowable region, no gating technique can be accurate, and the gated FFT mode will allow the engineer to learn of, and understand the nature of the dependence.

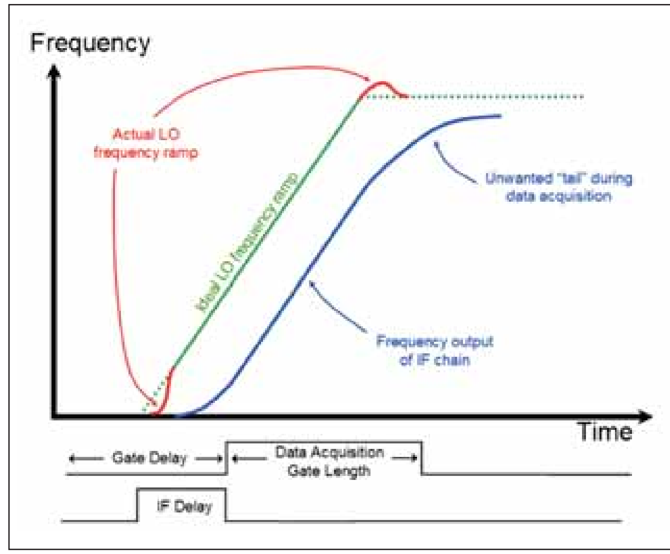

Figure 2 · This timing diagram shows typical LO settling phenomena and their effects on the frequency output of the IF chain. These settling effects can cause measurement errors in some gated LO spectrum measurements.

Challenges for Accurate Gated LO Measurements

While the gated LO technique has significant advantages for the spectrum analyzer user, it places considerable demands on the analyzer and its designers. Specifically, there are two significant problems and analyzer phenomena which can compromise accuracy, complicate measurement setup and make it difficult to know how much accuracy to expect. These include:

Transient response of the RBW and VBW (IF) filters: The filters in the IF chain must have adequate settling time before their output can be accurately sampled. This settling time reduces the available measuring time for each gate event and increases the minimum allowable gate time. To minimize this undesirable settling time, the precise settling behavior of the IF filters must be predictable and well understood.

LO settling (transient response): The LO cannot be instantly started and stopped, and its linearity (e.g., frequency vs. time) is imperfect near both the start and stop events. Because the usual practice is to synchronize the LO sweep start/stop exactly with the acquisition of data, delays and settling errors accumulate with each sweep segment.

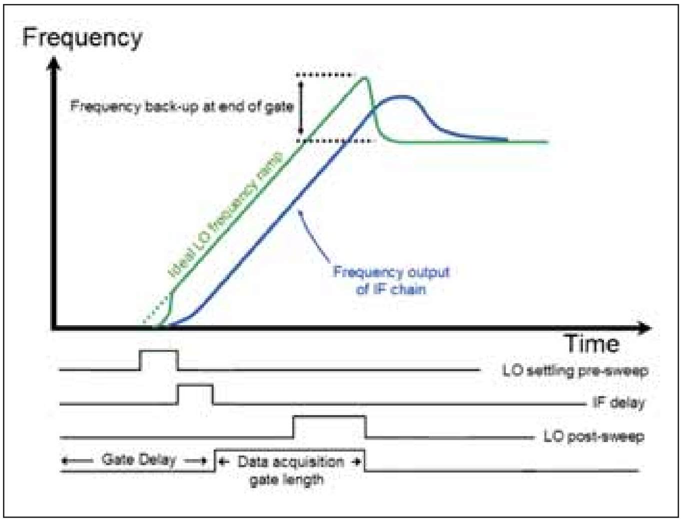

Figure 3 · This timing diagram shows the intelligent pre-sweep, post-sweep and LO "back-up" functions implemented to ensure that the LO and IF chain are at the correct frequencies during the data acquisition time gate.

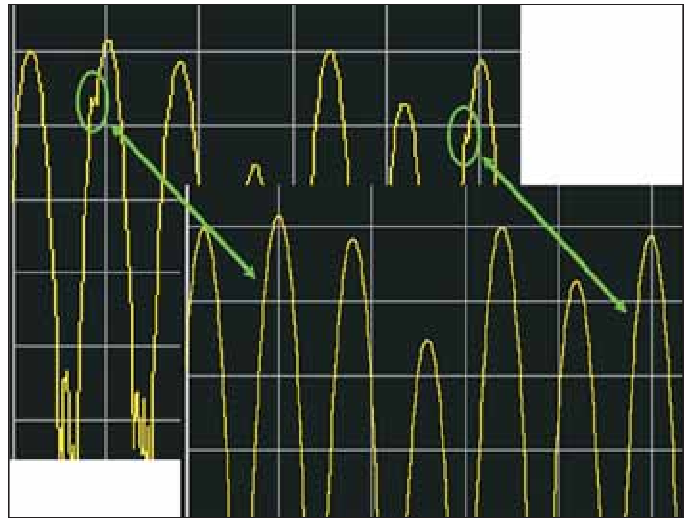

Figure 4 · This comparison (enlarged) of two spectrum measurements shows LO and IF transient effects in gated measurements, and how they are eliminated with the full correction features in the Agilent MXA signal analyzer.

The LO settling phenomena and their effects are shown in Figure 2.

When implementing gated LO solutions in swept analyzers, the general practice has been to minimize error sources and, where possible, to provide appropriate supplemental specifications for gated measurements, along with operational cautions and exceptions. Whether time-gated measurements are specified or not, in some cases spectrum analyzer users are unaware of the potential accuracy and repeatability problems of time-gated measurements.

Existing Solutions—IF Filter Response

The most straightforward way to account for the settling time required by the IF filters and preselectors is to add a delay, from when the gate opens and/or the signal is valid, to the measurement process. To improve measurement speed and allow for the shortest gate times, this delay should be minimized. However, the use of the delay alone cannot fully compensate for two sources of error:

Data acquired at the end of a sweep segment when the LO is settling to a stop: The frequency of some measured data will be distorted by the frequency settling of the LO as it is stopped at the end of the gate.

Sweep linearity errors (frequency and span errors) accumulating due to small LO frequency errors in each sweep segment: The usual practice of sweeping for precisely the duration of the gate does not allow for any correction of imperfect frequency start/stop values associated with non-ideal behavior of the LO at the beginning and end of gate segments.

Existing Solutions—LO Settling

For a first order solution the starting and stopping of the analyzer's LO must be accurately controlled, and the sweeping must remain as linear as possible despite the start/stop operations. Since the spectrum result is assembled from multiple sweep segments, each one must accurately match those before and after it. Also, timing/frequency errors must not be allowed to stack up, especially in situations where a spectrum measurement is made from a large number of segments.

Previous solutions can produce significant transient errors at the "seams" between the sweep segments due to the settling of the LO. These errors can only be minimized by sweeping the LO much more slowly than normal. These transient errors are glitch-like, and will thus effectively cause both frequency and amplitude errors when using a peak search method of measurement.

Innovative Gating Solutions

The increasing importance of gated measurements has driven solutions to several of these accuracy problems, particularly in the case of the Agilent MXA series signal analyzers. Several innovative techniques provide measurements that are more accurate and repeatable, and ease measurement setup. In most measurement situations the MXA can meet the goal of making time-gated measurements with no loss of amplitude or frequency accuracy.

Collectively, the improvements involve more powerful and flexible LO sweep capabilities and a user interface to improve measurement configuration. Dedicated circuitry and algorithms manage the LO's advanced sweeping operations without involving the host processor.

The primary innovation is an LO with intelligent "pre-sweep" and "post-sweep" functions, and the ability to perform a precise "back-up" operation to return a post-swept LO to the correct frequency for the start of the next gate. The pre-sweeping of the LO occurs during the gate delay, allowing both the LO and the IF filter settling transients to stabilize before measurement data is taken. The intelligent LO sweep operations are shown in the form of a timing diagram in Figure 3.

At the beginning of the gate a measurement delay is implemented to allow LO transients to die out. This is shown in Figure 3 by the LO pre-sweep signal. At the end of the gate the LO continues to sweep (post-sweep) for a short time so that its sweeping is entirely linear for the full duration of the sweep segment.

A key feature of this invention follows the post-sweeping of the LO—a calibrated "back-up" or partial retrace of the LO frequency sweep. The back-up of the LO is essential to allow for the post-sweeping of the LO and to reset the LO frequency accurately for the beginning of the next sweep segment. In practice the LO backs up by the sum (in frequency) of the pre-sweep and the post-sweep. The result of this advanced LO control capability is an improvement in both the accuracy and consistency of gated spectrum measurements.

A comparison of time-gated measurements both with and without this technology is shown in Figure 4. Note that full correction of the LO and IF transient effects change both the measured frequency of the signal and the shape of its spectrum.

Summary

Innovations in hardware and measurement algorithms now allow a swept spectrum analyzer to make time-gated measurements with no compromise in accuracy, and with minimal impact on measurement speed. These innovations, when combined with enhancements in the user interface, make gated measurements easier and less prone to errors that are hard to detect.

References

1. Agilent application note AN-150 Spectrum Analysis Basics, pages 38-43, literature number 5952-0292. A printed copy can be requested or the note can be downloaded at www.agilent.com.

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