

# Fundamentals of Pulsed and Time-Gated Measurements

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Here is basic information on when and how time-related measurements are used in RF/microwave radar, communications, medical and industrial systems

Although many RF and microwave measurements can be made with continuous (CW) signals, there are many others that require sampling a signal at a certain point in time,

or applying non-CW excitation to a circuit under test. Pulses, on-off transitions, power control steps, and some digital modulation schemes are *not* CW signals, and their measurement requires more advanced techniques. This tutorial reviews several types of measurements that rely on timed “snapshots” of a signal to determine its parameters.

## Simple On-Off Pulses

The most straightforward time-gated measurements involve pulsed signals, such as those found in radar systems, magnetic resonance imaging (MRI) systems, on-off keying (OOK) modulation, and the on/off or transmit/receive transitions of signals with a constant RF envelope. The latter may include CW signals such as industrial RF apparatus, and frequency or phase modulated (FM or PM) signals.

### Example 1: OFDM Pilot Tone Power (1)

A wireless LAN pilot tone may operate at a low pulse repetition frequency (PRF) <100 Hz, with a very low duty cycle of <0.05%. Measuring the power level of these signals requires a power meter that can respond fast enough to accurately measure power in short time span. In addition to the timing of the measurements, the instrument must be controllable with regard to triggering, averaging

of multiple samples.

To assure that these fast power detectors are actually measuring the pulse and not the zero-power space between them, some computation must be done, which is typically included in the operating software. For example, an instrument may require averaging of 1000 or more samples to obtain a stable reading, which then must be corrected with information on the pulse shape and duty cycle. If the instrument is able to make sufficiently fast readings to follow the rise and fall of the pulse, this data can automatically be used to obtain a final measurement.

As with all high performance measurements, reliable results require an understanding of the signal behavior and the method by which the power is sampled, as well as knowledge of peak hold and averaging processes performed by the operating software. Most manufacturers provide extensive application data to assist with user setup for such measurements. Figure 1 is a screen shot from Ref. [1] showing the software setup parameters for the extended averaging function for data collected by a fast responding power sensor from Ladybug Technologies LLC.

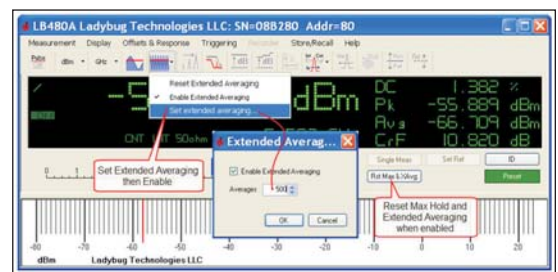


Figure 1 · Setup screen showing averaging options for the Ladybug Technologies LB480A power sensor.

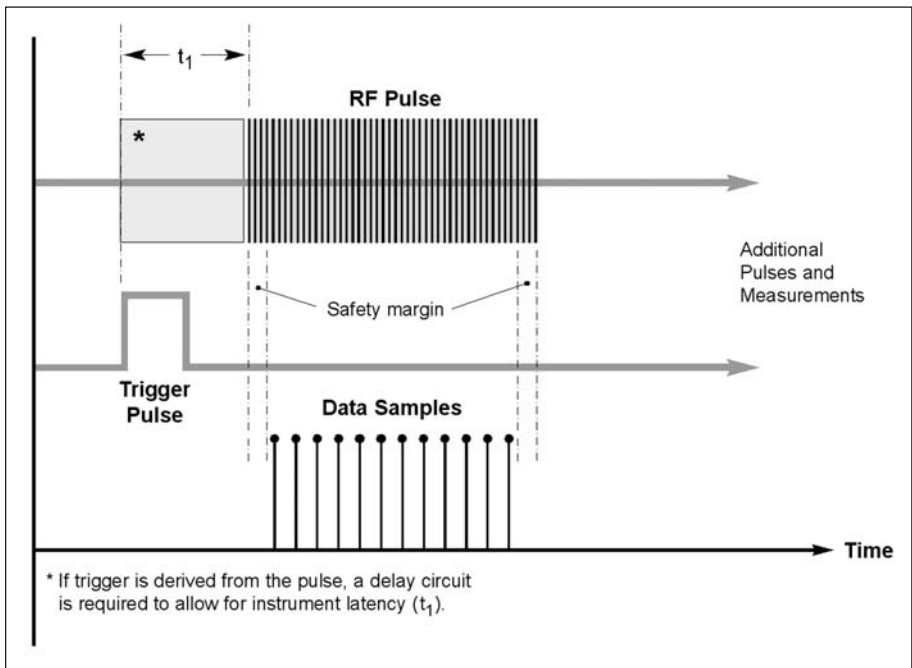


Figure 2 · Timing sequence for pulsed RF measurements.

There are also cases where the test excitation signal is pulsed, which is a different process than measuring a signal generated by the DUT. The

most common examples are power device testing, on-wafer testing and antenna system testing. In power devices and IC wafers, a pulsed test signal reduces the duty cycle and the resulting thermal effects. Pulsed antenna measurements can combine VSWR or impedance measurements with time-domain reflectometry (TDR), deembedding the antenna from the feedline, with the added benefit of providing distance-to-fault information if problems are identified.

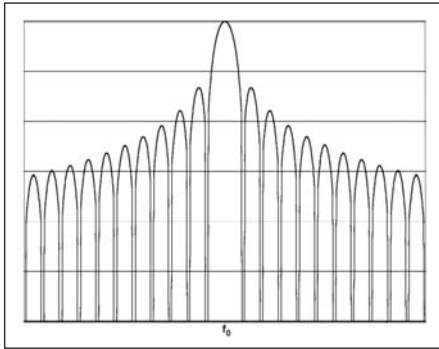
**Example 2: Pulsed S-Parameter Measurements (2, 3)**

Pulsed measurements for purposes such as probe testing of IC wafers requires knowledge of the device under test (DUT), operation of the test instrument under sampling conditions, as well as an understanding of pulsed signals (perhaps requiring a review of your undergraduate Linear Systems class textbook).

A simplified sequence of events for sampled measurements is diagrammed in Figure 2. The required trigger delays, pre- and post-sampling safety margins, the number of samples, and pulse repetition frequency (PRF) will be determined by the behavior of the specific measuring instrument.

Special attention is needed to allow for the spectral characteristics of a pulse sequence. The plot of Figure 3 shows this— $f_0$  is the RF frequency, and the sideband peaks are spaced at  $n \times PRF$ . The amplitude of  $f_0$  and the amplitude rolloff of the sidebands is determined by the pulse width. The information to be measured is at  $f_0$  and ideally the instrument IF bandwidth will reject the sidebands.

Readers should also note that Fig. 3 is also the general shape of a digital filter, as implemented in the DSP-based IF of modern network and spectrum analyzers. It is easy to imagine that an accidental alignment of pulse sidebands and filter side-



**Figure 3 · Spectrum of a pulsed RF signal, showing the sidebands generated by the process of pulse modulation.**

bands could result in measurement errors. In practice, the best option is to select a PRF that aligns the pulsed signal sidebands with the nulls in the instrument's digital filter response. (This is an example of the care that must be taken with pulsed measurements!)

The *S*-parameter measurements themselves are normal, as long as the instrument setup and test signal parameters are done as prescribed by the instrument manufacturer. Refs. [2, 3] are examples of two manufacturers' instructions.

### **Time-Gated, or Sampled Measurements**

Many modern wireless systems use complex modulation, often including power control and rapid transmit/receive cycles. Compliance with technical standards requires measurements to be made during the various modes of operation, e.g., peak or average power level during the transmitting period. Those standards may also require measurement of the characteristics during the transitions from one mode to another—settling time, overshoot, switching delay, etc.

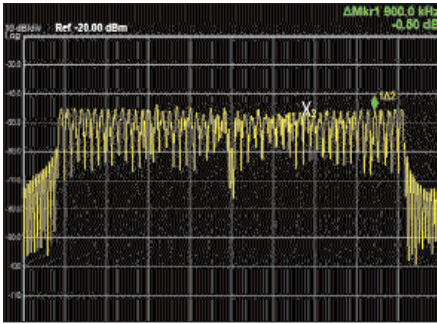
These measurements differ from simple on-off pulses in that the signals are neither constant, nor single frequency. Rather than measuring a single performance parameter, they are measurements of system behav-

ior during a specific time period when that behavior is active.

### **Example 3: Measurement of OFDM Subcarriers (4)**

One example of a time-selective measurement is a spectrum analyzer display of a WiMAX signal during the

preamble, when a sparse set of OFDM subcarriers are used to train the adaptive equalizer in the receiver. This measurement is needed to confirm proper spacing of subcarriers according to the WiMAX specification, taken during a period when the signal is in its simplest form. Figure



**Figure 4** · A gated LO measurement using the Agilent MXA Signal Analyzer to measure OFDM carrier spacing during the preamble of a fixed WiMAX signal.

4 shows a display of this measurement from Ref. [4].

There are various methods for gating the measurement timing in a spectrum analyzer.

*Gated LO* turns off the local oscillator outside the measurement period. The LO is a swept CW signal with constant amplitude, and is not in the signal path. Thus, control is readily accomplished with simple RF switching circuits.

*Gated Video* allows the spectrum analyzer to run continuously, but turns off the display outside the measurement period. With no gating of the frequency span, the full sweeps require more time, and many sweeps may be required to capture a complete spectrum measurement.

*Gated FFT* uses the digitized signal in the DSP-based IF processor of modern spectrum analyzers. Since digital information is already time-based, a sample during the desired time window will yield a full data set. Sufficient memory is required for the desired gate time, and multiple “sweeps” may require significant processing time.

Like pulsed measurements, the instrument performance must be known and accommodated. Filter transient response, settling time of the impulse response, switch settling times, and repeatability of performance during multiple sweeps are all

factors that must be understood in order to obtain accurate measurements.

### Other Timed Measurements

Some other measurements with time-related information involve the verification of sequences of both RF and control events. These might include the application of power amplifier gate bias prior to applying RF drive power, or assuring that a receiver gain control “hold” command is applied before switching to transmit mode.

Adaptive antenna arrays often use switches instead of analog phase shifters to change the radiation/reception directional patterns. Unless designed to handle “hot switching” with RF power applied, the sequence of switching control and RF power transmission will also need testing to verify proper operation.

### Instruments Used in Pulsed and Time-Gated Measurements

Time-controlled measurements often use an oscilloscope, since it is a time-domain based instrument. A current trend with high performance scopes is the option of extended digital waveform memory. This allows the user to analyze events that occurred prior to the measurement of the desired event. When measurements reveal incorrect operation, the ability to look back in time can be very helpful in identifying the cause.

Another common time-domain instrument is the dedicated I-V curve tracer, and its specialized adaptations. While not an RF/microwave instrument, these units are common in RF device manufacturing, since DC characteristics must be tested as well as RF performance.

The examples presented here have shown applications involving power meters, spectrum analyzers and network analyzers. As those examples point out, these frequency-domain instruments require careful attention to the interaction of fre-

quency and time domain behaviors of the IF filters, local oscillator and signal path switching, as well as digital IF and baseband signal processing. In these instruments, optional signal analysis post-processing software may be required to obtain the desired measurement capability.

Other instruments involved in this family of measurements include pulse modulators, both external and included within signal generators. Accessory RF switches, attenuators and couplers are typically part of the test setup as well.

Finally, always consult the manufacturers’ applications data for additional test setup information.

### References

1. This example is a summary of information contained in “Product Manual for the POWER METER APPLICATION,” for the Ladybug Technologies LBXXXXA Series USB Power Sensors, available for download at [www.ladybug-tech.com](http://www.ladybug-tech.com)
2. “Pulsed S-parameter Measurements,” Application Note, Anritsu, [www.us.anritsu.com](http://www.us.anritsu.com)
3. “Accurate Pulsed Measurements,” Application Note 1408-11, PNA Microwave Network Analyzers, Agilent Technologies, [www.agilent.com](http://www.agilent.com)
4. T. Wright, J. Gorin and B. Zarlingo, “Bringing New Power and Precision to gated Spectrum Measurements,” *High Frequency Electronics*, Aug. 2007. Available at [www.highfrequencyelectronics.com](http://www.highfrequencyelectronics.com)
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6. A. Parker, J. Rathmell, J. Scott, “Pulsed Measurements,” in *The RF and Microwave Handbook*, CRC Press, 2000.
7. “Pulsed Antenna Measurements Using PNA Network Analyzers,” Agilent Technologies White Paper, 2004, [www.agilent.com](http://www.agilent.com)