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Application Note

MS2660 Series Spectrum Analyzers

Time Domain Displays for Pulse Measurements

Background

Every sine wave has a frequency, amplitude, and phase component. Equation 1 shows how these are related to each other.

A spectrum analyzer is a frequency-selective measurement system that can display the magnitude and phase value of sine waves in the frequency domain.

In contrast, an oscilloscope typically displays the instantaneous voltage of a sine wave over a given time period. Hence, an oscilloscope displays the waveform in the time domain.

Complex waves are composed of combinations of sine waves – with various amplitudes, frequencies, and phases – over a given period of time.

$$V(t) = A\sin(\omega t +/- \Phi)$$

V(t): Time-varying voltage of the sine wave
A: Amplitude
ω: Frequency component in radians
Φ: Phase

Equation 1. Components of a sine wave.

Fourier Analysis Techniques

Fourier Analysis can be used to analyze waveforms mathematically. Confirming the description above, Fourier theory states that a complex waveform is composed of individual sine waves of various frequency, phase, and amplitude.

Using Fourier theory, a sine wave or complex waveform can be transformed into the frequency domain. Measurements in the frequency domain can display how much voltage or power is present at a particular frequency. If proper filtering or preselection is used, as with a modern spectrum analyzer, a waveform can be decomposed into its corresponding individual sine waves or spectral components. Very importantly, the same Fourier theory can also be used to transform a waveform from the frequency domain into its corresponding time domain components.

A modern spectrum analyzer can therefore use Fourier Analysis to convert a frequency domain display to a time domain display. This is accomplished using the Fast Fourier Transform, or FFT. The FFT application nomenclature for frequency-to-time conversion is the iFFT, or inverse Fast Fourier Transform. When looking at the frequency spectrum (e.g. looking at spectral components such as harmonics and intermod products), phase is generally not critical. But for frequency to time domain conversion, phase can sometimes be very critical. This will be explained further below in the discussion of pulse measurements.

Many modern spectrum analyzers use DSP-based techniques to process the frequency information of an RF wave and display its time domain (iFFT) representation with the touch of a button on the front panel. This DSP-based technique can be used in place of, or in conjunction with, a traditional tuned receiver-based superheterodyne architecture.

Burst and Radar Pulse Measurements

Why does anyone want to display time domain on a spectrum analyzer? The time domain can easily and accurately indicate rise, fall, overshoot, and ringing of an RF signal.

One of the most popular applications for using time domain measurements on spectrum analyzers is in connection with burst and radar pulse measurements. Today's complex radar systems using a chirp signal to determine very accurate distance and positioning of targets need to be tested using an accurate system. Many of these radar systems send out pulses with nanosecond pulse widths and rise times. A microwave spectrum analyzer, such as Anritsu's MS2667C or MS2668C with the High Speed Time Domain option, can resolve these pulses with an alias-free resolution of 250 ns.

A Burst Average Power measurement can be made on a radar transmitter microwave frequency pulse or burst, when properly triggered, using the MS2667C/68C and a power template or gate. This measurement can also give the peak power based on the average of all power measurements within the pulse, as illustrated in Figures 1 and 2.

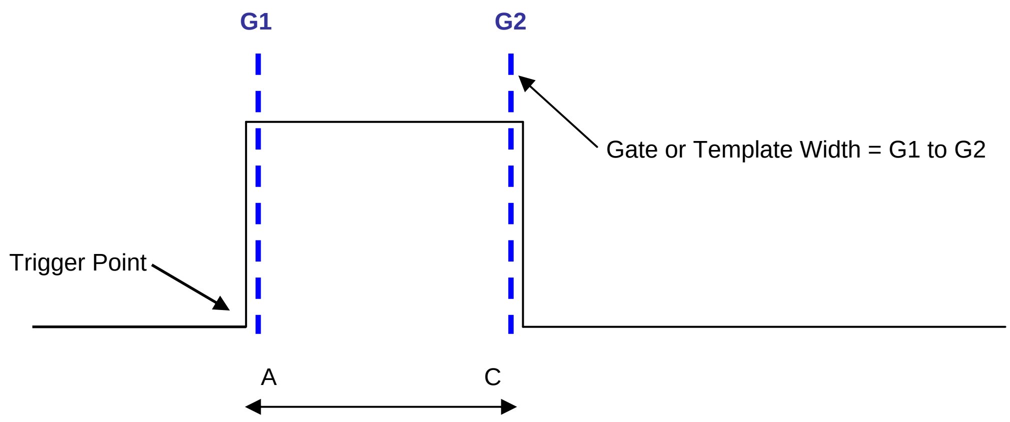

Figure 1. Peak power in the pulse is the average of all power readings from A to C.

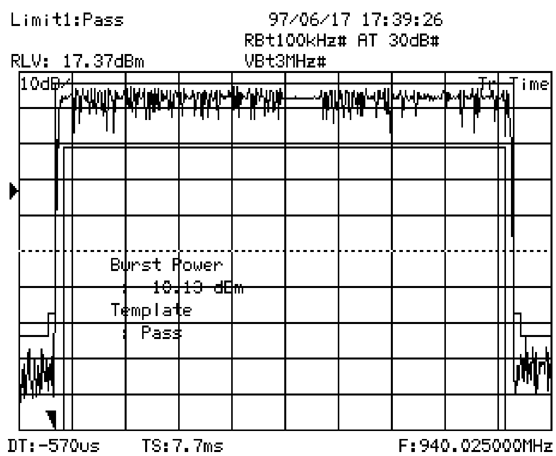

Figure 2. Burst Power in a MS2667C/68C time domain display.

An engineer or technician might also need to measure the ramp-up characteristic of a radar pulse to study the turn-on time of the transmitter's amplifier and characterize the pulse shape. Radar systems have tight pulse generation specifications and a poorly shaped pulse with too much rise/fall time can lead to position and distance inaccuracies, which ultimately lead to false target readings.

MS2667C/68C spectrum analyzers with the High Speed Time Domain option can accurately measure the pulse characteristics illustrated in Figure 3. The major parameters of such pulses are:

- Power in the pulse
- Overshoot and undershoot
- Droop
- Rise time
- Pulse repetition interval (PRI)

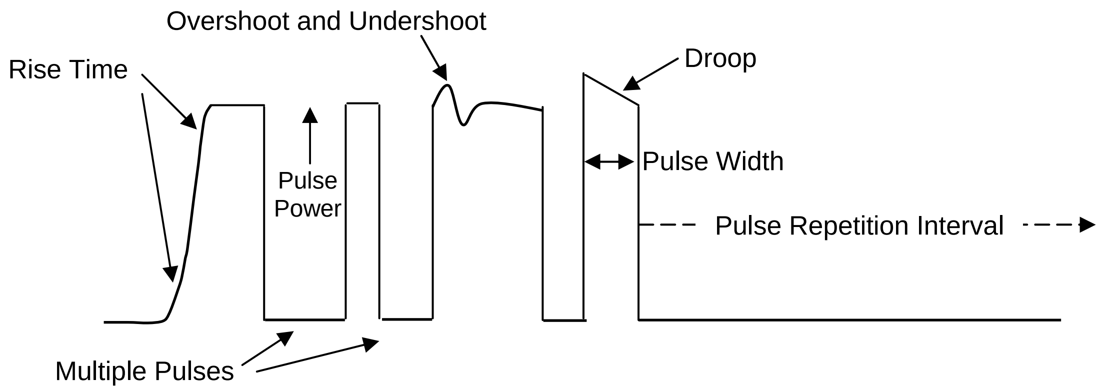

Figure 3. Important time domain characteristics of radar signals.

Synthesizer Switching Speed Measurements

Synthesizer switching speed measurement is another powerful application for time domain displays on a spectrum analyzer. Many of today's synthesizers, such as Anritsu's MG3690A Series Synthesized Signal Generators, can generate internal pulse modulation. The highly accurate pulses from such synthesizers can drive a wide variety of systems for applications that include radar transmitter simulation and receiver testing. Using time domain analysis, one can accurately measure and characterize the pulse period and delay, as well as the Pulse Repetition Interval (PRI).

Many radar and electronic countermeasure systems use more than one pulse for their applications, and the MG3690A Series can output a quad pulse train to test such systems. Using the wide IF bandwidth of the spectrum analyzer (typically 20 MHz) and external triggering from the signal generator as depicted in Figure 4, it is possible to make a highly accurate triggered measurement of the pulse train. As with radar measurements, a gating function can be used to capture and measure the pulse power between the rising and falling edges of a pulse.

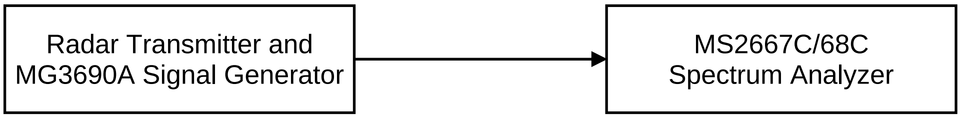

Figure 4. Test setup for multiple pulse train applications.

Figure 5 shows a quad pulse with pulse sync output that is used to provide the external triggering input to the spectrum analyzer. This type of signal combination can be generated by the MG3690A Series Synthesized Signal Generators.

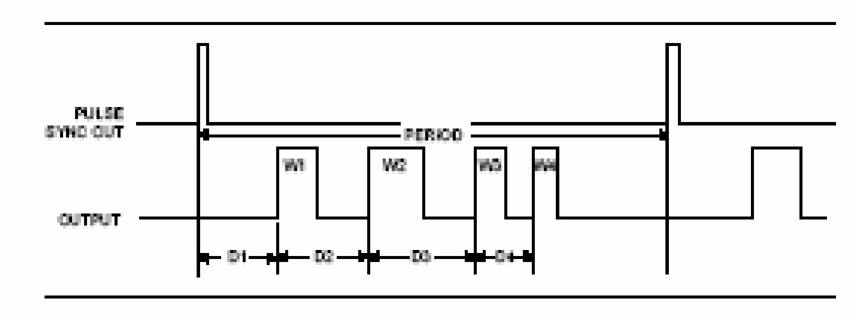

Figure 5. Quad pulse with spectrum analyzer trigger signal.

Using time domain to accurately characterize the pulse train of a synthesizer makes it easy to determine pulse width, delay, and even PRF (Pulse Repetition Frequency).

Simultaneous Frequency/Time Domain Displays

The MS2667/68C spectrum analyzer split screen function makes it possible to display a signal in both the frequency and the time domain simultaneously. In Figure 6, the top half of a typical MS2667/68C display shows the input signal in the frequency domain, while the bottom half shows the same signal in the time domain. This is another powerful demonstration of the FFT function implemented in the firmware of these modern spectrum analyzers.

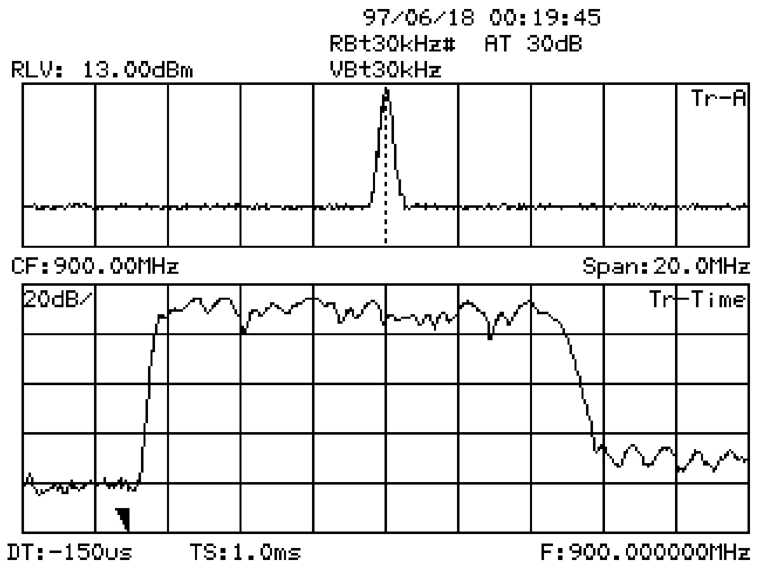

Figure 6. Split-screen frequency domain and time domain displays.

Summary

Anritsu's spectrum analyzers, with their unique time domain options based on fast inverse FFT computation, are powerful test systems for measuring and characterizing the critical aspects of individual pulses as well as multiple pulses. They provide a critical tool for the engineer or technician who needs to analyze pulses for radar or ECM, or study the pulse modulation of a synthesizer.

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