Radar Pulse Measurements with a Spectrum Analyzer

A spectrum analyzer enables you to measure pulse power and view pulse shape.

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Radar has a multitude of uses from commercial aviation to weather mapping; it is no longer just for locating enemy aircraft. Many diverse radar types have emerged to meet the unique needs of each application, leading to an even wider range of measurement requirements. Within the next ten years, automobiles may commonly use radar technology for collision avoidance, which may require evaluating the impact of pedestrian and guardrail clutter on a radar's operation.

The characteristics of a radar signal determine how well it will perform its intended function. For example, many police radars use CW signals to assess Doppler shift, but range information is unnecessary. Therefore overall performance and accuracy take a back seat to low cost and small size. At the other extreme, a sophisticated phased-array radar may have thousands of T/R modules operating in tandem. Multimode operation may require adaptive side-lobe nulling, staggered PRI, frequency agility, real-time waveform optimization, wideband chirps, and target-recognition capability.

With this diversity of applications and radar types, the applicable measurements cover the entire range of test techniques. While research continues into the 200- to 300-GHz range, most radars operate between 400 MHz and 18 GHz. As interest in target imaging continues, more and more systems are resorting to higher bandwidths. Furthermore, frequency agility will be increasingly common as an effective measure against many types of jamming. This implies tests such as frequency-switching speed measurement and hop-sequence verification.

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Even with the added complexity of modern radar systems, pulse power and pulse shape remain important characteristics of a radar signal.

Measuring Pulse Power

There are many different terms used when talking about signal power. Average power is typically implied when talking about "power", and is the average of the power delivered over several cycles including when the pulse is off. Peak power is the maximum instantaneous power, and is required on many of today's complex wireless modulation systems.

One of the reasons for making measurements on a transmitter's power spectrum is the high cost of peak power. The high peak power generated within a radar often determines the expense and reliability of the system; the output stage in a pulse-doppler radar is one of the most expensive components in the radar.

Peak power is an important specification to manufacturers because of their desire to specify the device as high as possible and still be able to produce it with an acceptable yield. Peak power is also a critical specification to end users, because for a given receiver noise figure, higher peak power means greater range, or better probability of target detection for a given range.

Making accurate power measurements on pulsed microwave signals presents challenges both in terms of understanding the fundamental measurement techniques and interpreting the results. Either a power meter or a spectrum analyzer can be used to measure pulsed power. A power meter makes very accurate measurements, but lacks sensitivity. A spectrum analyzer provides wide dynamic range, but cannot match a power meter for accuracy. Viewing a pulsed signal on a spectrum analyzer and computing band power also provides insight into how the various types of radar signals use bandwidth.

Using a Spectrum Analyzer

A spectrum analyzer is useful for analyzing radar signals as it can characterize them in both the time and frequency domains. One of the reasons for making measurements on a transmitter's power spectrum is the high cost of peak power. The more power out of the receiver's passband, the less range the radar will be able to cover. Also, excessive out-of-band power can interfere with other electronic equipment.

Although peak pulse power cannot be measured directly with a spectrum analyzer, it can be determined once the duty cycle of the pulse is known. This is because a pulse, by definition, is not on all of the time, while a spectrum analyzer is averaging over time.

A spectrum analyzer allows pulse measurements to be taken on a wide frequency range. If the frequency of the signal can be determined with sufficient accuracy, the frequency span can be reduced, thereby lowering the resolution bandwidth, to produce a very large dynamic range. If the frequency span cannot be

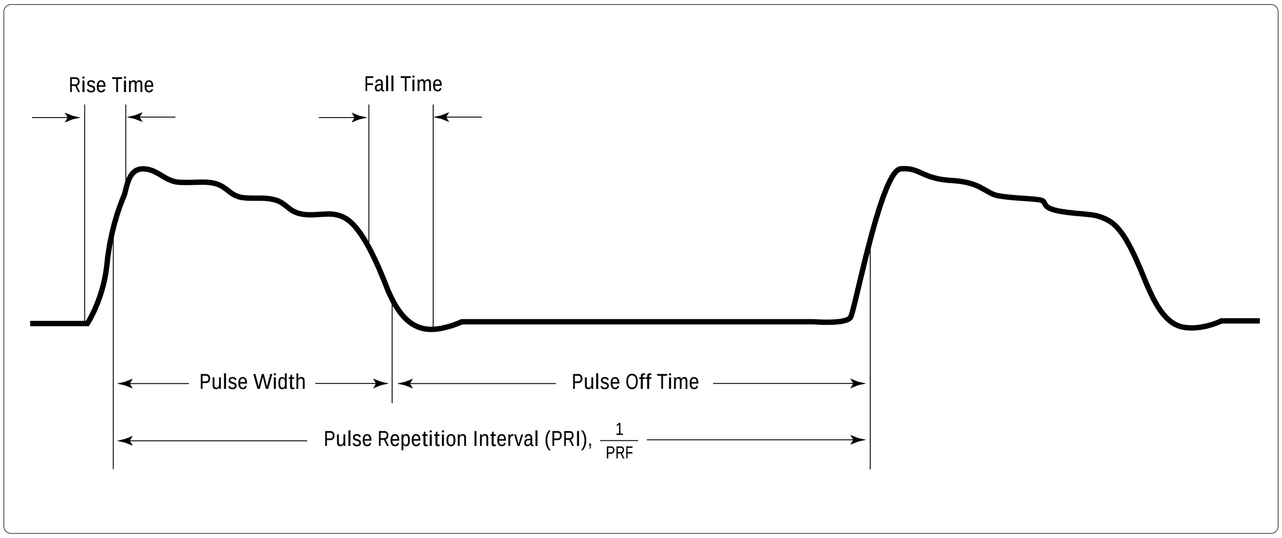

Figure 1. Anatomy of a radar signal

reduced, then the resolution bandwidth can be reduced separately to help reduce the noise from other frequencies not related to the pulse, which may affect the measurement. Because of its frequency filtering, a spectrum analyzer can measure the power in a particular band, excluding noise and other interference outside of the selected level.

Pulsed power measurements are only appropriate at points in a radar system's signal path where a pulse is present. In the transmit path, that is after the pulse is modulated onto the signal. On the return path, the pulse is present until the sample and hold circuits. It is even present after the I/Q portions of the signal have been separated.

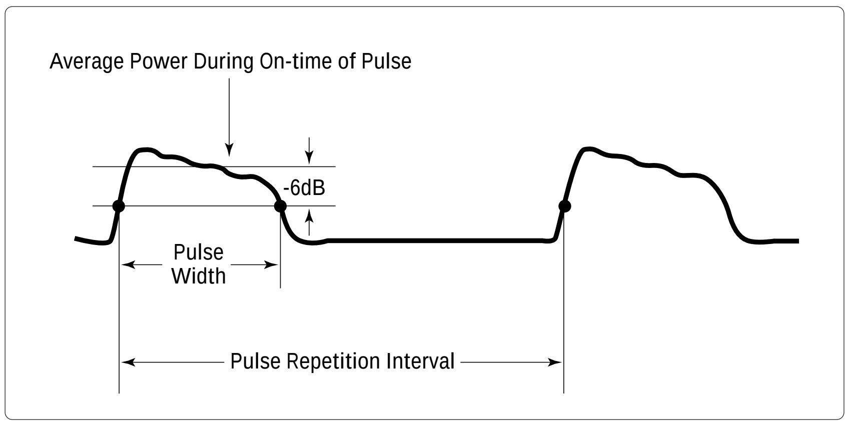

Figure 2. Measuring pulse width

Radar Signal Terminology

Figure 1 illustrates many of the terms associated with a radar signal. The pulse repetition interval (PRI) is the interval between the leading edges of two consecutive pulses. Pulse repetition frequency (PRF) is the inverse of the PRI.

Figure 2 shows how pulse width is measured. First, the average power during the on time of a pulse must be computed. Then the point 6 dB below this average power must be determined. This is called the 6-dB point. Where the pulse waveform crosses that power level with

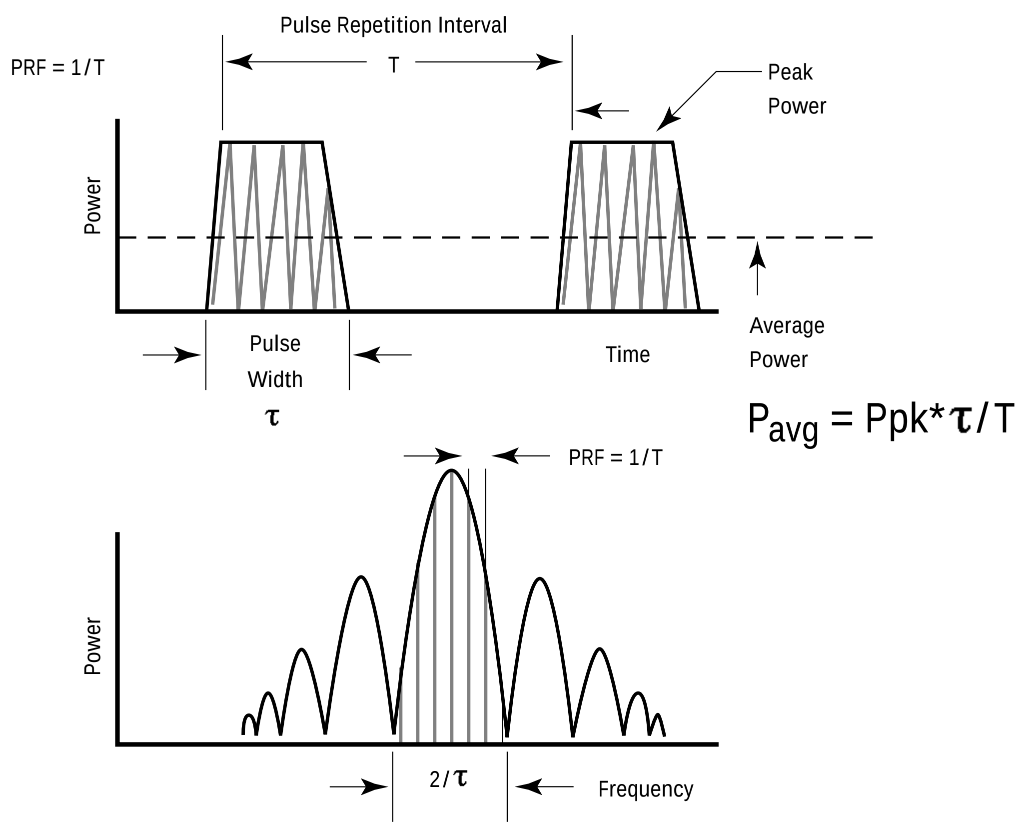

Figure 3. The time- and frequency-domain representations of a radar signal

increasing power is the start of the pulse-width measurement. Where the pulse waveform crosses that power level with decreasing power is the end of the pulse-width measurement. Other common pulse-width measuring points are the 3-dB point and the 1/2-power point. They all use the average power during the on time as their starting reference, but use a different delta from that value to determine the power level to start and stop measuring the pulse width.

Figure 3 shows a radar-signal representation in the time domain and the frequency domain. The frequency domain is what the spectrum analyzer produces unless it is in time-domain mode. PRI is indicated with **T**, so PRF is 1/**T**. Pulse width τ is generally measured from the 6-dB point. The frequency representation of the pulse shows that there are spectral lines offset from the center frequency by the PRF. Also, the frequency range between the first two nulls is equal to the inverse of one half of the pulse width. The wider the pulse, the narrower the frequency-domain peak will be on the spectrum analyzer.

As peak pulse power cannot be measured directly with a spectrum analyzer, a method of extrapolation must be used. The spectrum analyzer is averaging the signal over time, which reduces the displayed magnitude of a pulsed signal.

Therefore, to determine the actual peak power it is necessary to use the duty cycle of the pulse to determine how much the displayed magnitude has been reduced. This is accomplished by calculating a pulse desensitization value that can then be added to the displayed magnitude to derive the actual peak pulse power **(figure 4)**. Pulse desensitization is calculated by taking the duty cycle (PW/PRI) and converting it to dB (taking the log and multiplying by 20). Simply adding this value to the displayed magnitude results in the peak pulse power.

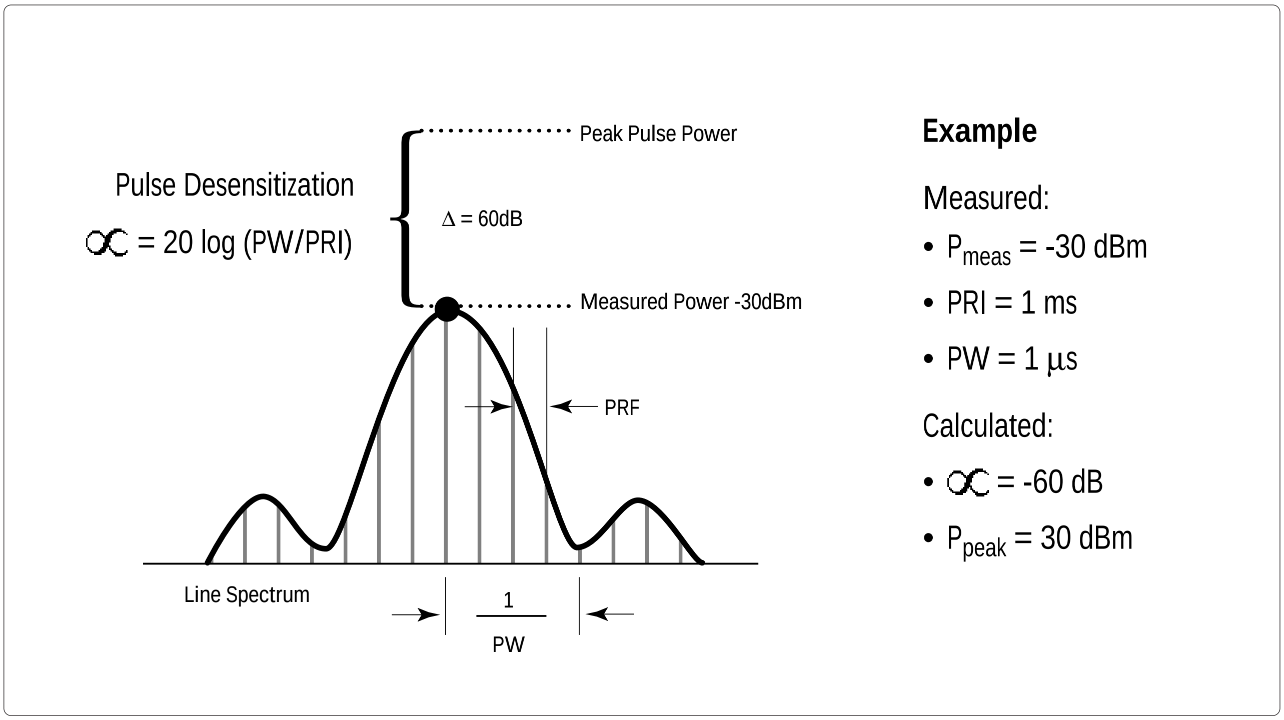

Figure 4. Measuring pulsed power with a spectrum analyzer

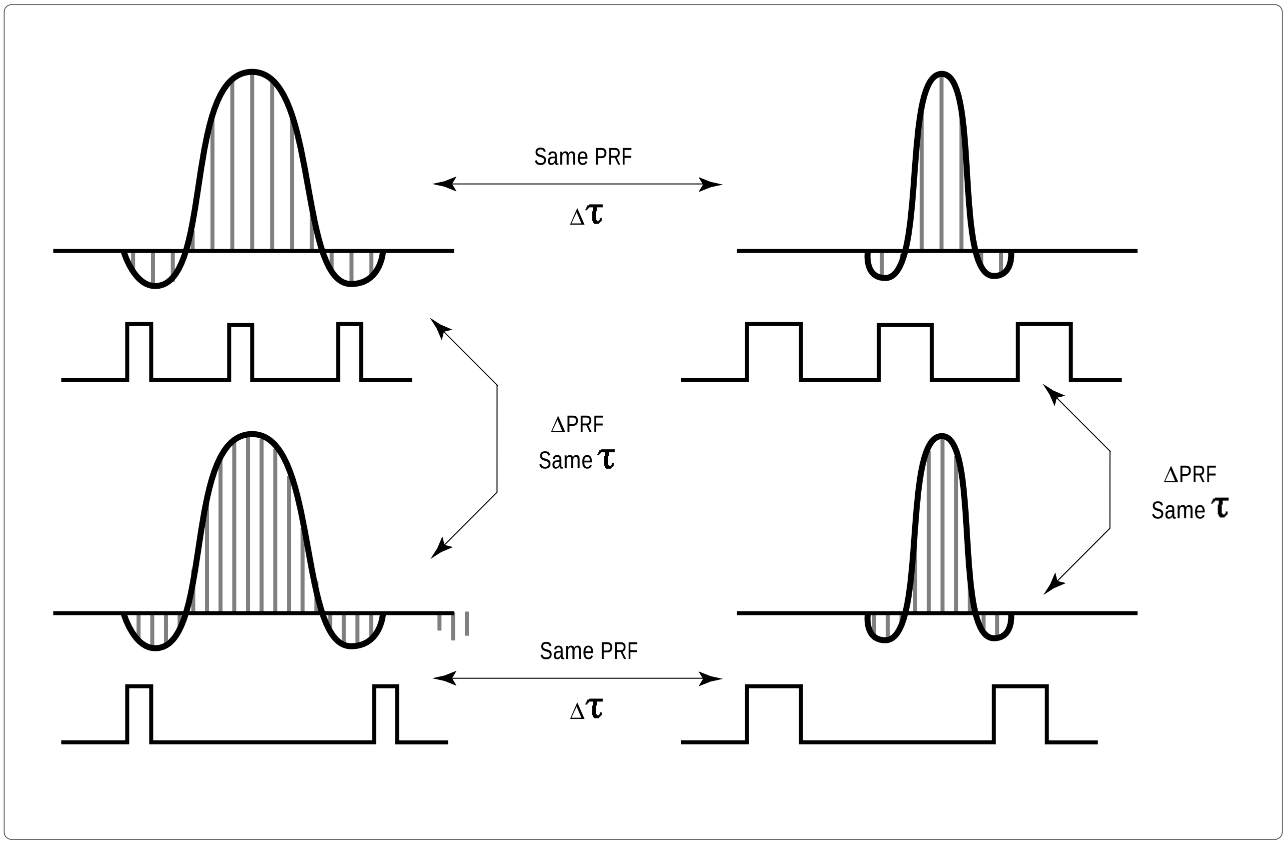

Figure 5. Changing a signal's pulse repetition frequency or pulse width changes its frequency spectrum

Pulse Characteristics Affect Performance

It is necessary to measure pulse parameters because these determine radar system performance. For example, the smaller the pulse width, the better the resolution of the radar. However, the bandwidth of the signal is inversely related to the pulse width. Therefore, the smaller the pulse width, the larger the bandwidth. Pulse width also affects the average power. The smaller the pulse, the smaller the average power. This means that the range is also increased with a smaller pulse width.

Figure 5 shows the results of changing the PRF (or PRI) and pulse width. The top left figure shows a frequency-domain and time-domain representation of a signal. If that signal's pulse width is increased, the frequency spectrum shrinks as shown on the top right. If the PRF is decreased, the number of spectral lines increases, as shown on the bottom left. Increasing the pulse width while decreasing the PRF produces a smaller spectrum with more spectral lines, as shown on the bottom right.

A spectrum analyzer is a valuable tool for making radar-pulse measurements. Its ability to create time- and frequency-domain representations of the signal provides a wide variety of information about a radar signal, and its large dynamic range and frequency-filtering abilities enhance its information-gathering capabilities.

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