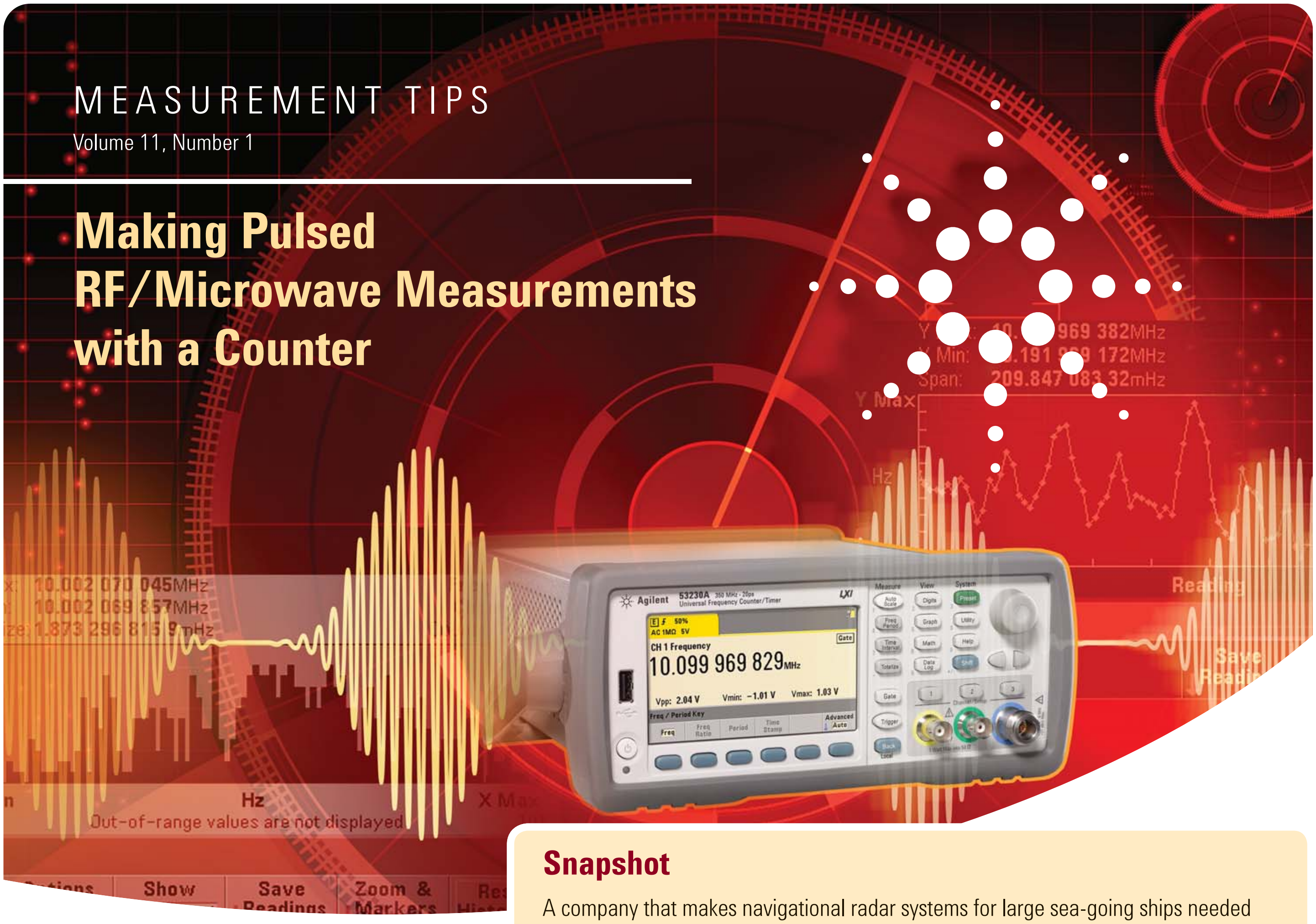


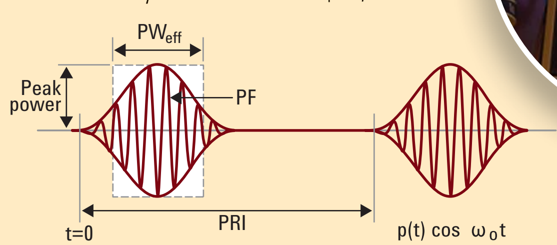
MEASUREMENT TIPS

Volume 11, Number 1

Making Pulsed RF/Microwave Measurements with a Counter

Snapshot

A company that makes navigational radar systems for large sea-going ships needed a pulsed microwave measurement system for its production test environment. Keeping equipment costs low is critical for staying competitive, especially when the company bids on large contracts. Company engineers used an Agilent 53230A universal counter because it provides high-accuracy measurement capability at a low cost. The 53230A can measure PW, PRF, PRI and PF. To measure the pulse power, they added a wideband peak power meter. This gave them a comprehensive pulsed microwave measurement system for less than $20,000.



$PRF = \frac{1}{PRI}$ Duty Cycle (%) $= \frac{PW}{PRI} \times 100$

PW_{eff} = Width of rectangular pulse of same height and area

Figure 1. Pulsed RF/microwave measurement parameters

Introduction

In radar and electronic warfare (EW) equipment design, accurate characterization of pulsed RF/microwave signals is critical for verifying the design is working correctly and that it meets specifications. Common measurements made on pulsed signals are shown in **Figure 1**. They include pulse width (PW), pulse repetition rate (PRF), pulse repetition interval (PRI), pulse frequency (PF), pulse rise/fall time, and signal power.

Recently, advanced counters with pulsed RF/microwave measurement capabilities have re-emerged in the test and measurement market. These advanced counters typically can make PF, PW, PRF, and PRI measurements on pulsed RF/microwave signals. In this measurement brief, we will explore:

1. Advantages and disadvantages of using a counter to make pulsed RF/microwave measurements
2. Creating a low-cost comprehensive pulsed RF/microwave measurement solution using a counter
3. Making pulsed frequency measurements using a counter on swept or chirped signals

Agilent Technologies

Measuring PW, PRF, PRI, and PF with a counter

The big advantage of using a counter for making PW, PRF, PRI, and PF measurements is the relatively low cost of the instrument. Typically, for about $10,000, you can get a counter that can measure these parameters with high accuracy. Compare this cost to other commonly used methods for making these measurements, such as using a spectrum analyzer or wideband scope with a signal analysis software package, or using a spectrum analyzer for PRF, PRI, and PF and using a scope with some type of detector on the input to measure PW. The price tag of these solutions can easily come to more than $80,000.

In some cases, the equipment cost savings example cited above may not be relevant because you already have a spectrum analyzer or scope in the test system for other measurements. But counters also offer cost savings a second way: they reduce test system configuration time. With just a few SCPI commands and a little bit of code, a counter can return PW, PRF (or PRI), and PF measurements to the test system software. **Figure 2** shows a short snippet of MATLAB® code for retrieving these measurements.

Code and SCPI commands to measure and store PW, PRF, and PF

```
% Connect to 53230A, obj1.
fopen(obj1);

% Measure and store PW, PRF, and PF with 53230A
fprintf(obj1, 'CONF:PWID:BURS');
PW = query(obj1, 'READ?')
fprintf(obj1, 'CONF:FREQ:PRF (@3)');
PRF = query(obj1, 'READ?')
fprintf(obj1, 'CONF:FREQ:BURS');
PF = query(obj1, 'READ?')

% Disconnect from 53230A, obj1.
fclose(obj1);
```

```
PW  = +1.99987851562500E-005
PRF = +1.00000021296738E+003
PF  = +4.00000039125104E+009
```

Measurement results

Figure 2. PW, PRF, and PF measurement code example

Other pulsed RF measurement solutions require much more complex code, larger instrument command sequences, and possibly custom hardware, all of which increase engineering and lifetime support costs.

The disadvantages to using a counter is it cannot measure pulse power, it does not provide much pulse shape information, and it's difficult to measure the PF of a chirped or swept signal. In the following sections we will discuss ways to overcome these disadvantages.

Low-cost, comprehensive pulsed RF measurement system

As we mentioned earlier, the most common measurements made on pulsed RF/microwave signals include PW, PRF or PRI, PF, pulse rise/fall time, and signal power. Testing pulsed RF/microwave signals can be challenging, because there is no simple off-the-shelf single-instrument solution that can perform all these measurements well. You can use a spectrum analyzer with a scope and a crystal detector or a spectrum analyzer with signal analysis software if your budget can accommodate $80,000 in equipment costs. But there is a much lower-cost approach that can give you the capabilities you need.

You can use a counter with pulsed RF/microwave measurement capabilities to measure PW, PRF, PRI, and PF in conjunction with a wideband peak power meter. A peak power meter provides the best accuracy for measuring signal power on pulsed RF/microwave signals. Besides signal power, wideband peak power meters typically can make PW, PRF, PRI, and pulse rise/fall time measurements. These instruments complement each other well because a counter cannot measure signal power, and that is the peak power meter's strong point; the peak power meter cannot measure PF, and that is the counter's strong point. These instruments together cost much less than the average spectrum analyzer. For instance, Agilent's 53230A counter with the channel 3 pulsed RF/microwave option and Agilent's N1911A power meter and N1921A wideband power sensor comes in at a combined price tag of about $20,000. Combining the counter and the wideband peak power meter gives you a comprehensive low-cost pulsed RF/microwave measurement solution.

MEASUREMENT TIP

On pulsed RF/microwave signals counters can provide some limited rise/fall time measurements and pulse shape information. You can make these measurements by adjusting the amplitude trigger point of the counter when you make PW measurements. For example, you can set Agilent's 53230A counter to trigger off two amplitude threshold points, the -6 dB point of the pulse (50% point of the pulse) or the -12 dB point of the pulse (25% point of the pulse). We can make a simple rise/fall time measurement between the two points by making PW measurements at both points, -6 dB and -12 dB, and then applying the following formula:

Let PW6 be PW measurement at -6 dB point and let PW12 be PW measurement at -12 dB point

Rise/fall time between points = (PW12 – PW6)/2

Of course, this method assumes that the pulse edges are symmetric.

MEASUREMENT TIP

When you combine a counter with a wideband peak power meter to build a comprehensive pulsed RF/microwave measurement system, there is typically some overlap in measurement capabilities. Both instruments can make PW, PRF, and PRI measurements, so which one do you use for these critical measurements? It makes sense to use the counter to make these measurements, since it provides higher resolution and accuracy then the power meter. For instance, on a pulse with a 10-us PW, the Agilent N1911A peak power meter combined with the N1921A power sensor provides approximately +/- 300 ns of measurement accuracy, while Agilent's 53230A counter provides approximately +/- 20 ns accuracy. But since the power meter digitizes over the entire pulse, it can provide a better picture of the entire pulse shape.

Making PF measurements on swept or chirped signals

Counters typically make PF measurements by triggering off the start edge of the pulse envelope and then they begin taking frequency measurements. They will take as many measurements as possible until reaching the other edge of the pulse. They then average all the frequency measurements together and return the result as the measured PF. This method provides maximum accuracy when you are working with a single carrier frequency, but not when you are working with a swept or chirped carrier. Fortunately, counters typically have capabilities that allow you to get a fairly good measurement picture of the swept or chirped frequencies. For instance, the 53230A counter's statistical capabilities allow you to capture the minimum frequency of the sweep, maximum frequency of the sweep, standard deviation, and peak-to-peak or Allen variance measurements of the sweep. As an example, **Figure 3** shows a screenshot of the 53230A making statistical measurements on a pulsed RF/microwave signal.

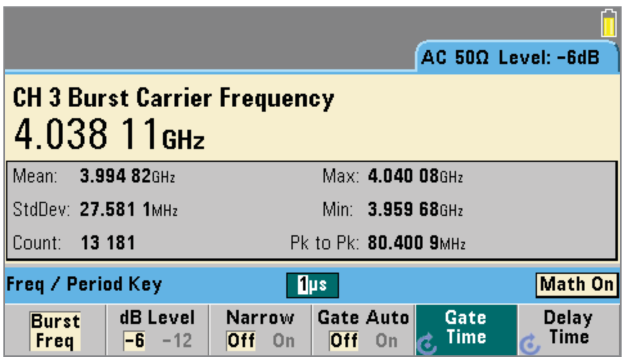


Figure 3. Screen shot showing 53230A counter statistical measurements of a swept carrier pulsed RF signal

The 53230A counter also allows you to adjust the gate time (frequency measurement window) and delay time from the edge of the pulse to the start of the PF measurement. On repeating swept pulsed RF/microwave signals, this means you can make multiple frequency measurements at different points in the sweep to get a more comprehensive picture of the frequency components in the pulse. **Figure 4** shows an example of this concept using two different sets of PF measurements. In the figure, both sets of measurements have the same gate time, but different delay times (first set of measurements has 0 delay).

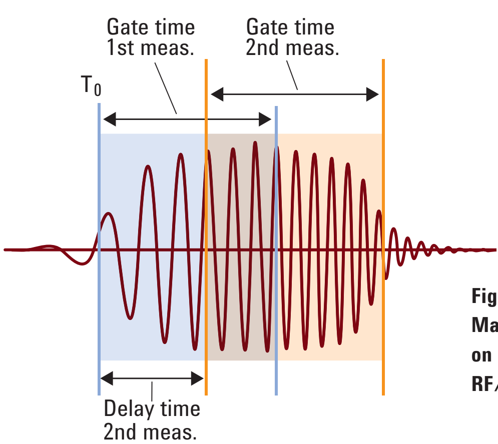


Figure 4. Making PF measurements on a swept pulsed RF/microwave signal

If we make multiple measurements at each delay time and apply statistics to each set of measurements, we can return multiple frequency measurements at different points in the sweep. For instance, in Figure 4 we could use the min, max, and average frequency measurements returned from the statistics function from both sets of measurements to make six different frequency measurements at six different points on the sweep. Since we know the gate and delay times we can determine with good accuracy where in the sweep these frequencies occurred. If we increase the number of measurement sets we take, vary the delay times, and use some math functions, we can make accurate frequency measurements throughout the sweep. In our example we assumed a simple linear sweep, which is not always the case when testing radar and EW equipment. You could use a similar method on other swept or chirped signals with just some added computation complexity.

Conclusion

Advanced counters on the market today provide the ability to make measurements on pulsed RF/microwave signals. These measurement capabilities typically include the ability to measure PW, PRF, PRI, and PF. The advantages over other existing solutions that counters provide in this measurement space include high-accuracy and -resolution measurements, low cost, and easy configuration. By using some of the advanced features found on counters like Agilent's 53230A, it is also possible to make limited rise/fall time measurements and swept or chirped PF measurements.

Author: Neil Forcier
Email: Neil_forcier@agilent.com
Blog: http://gpete-neil.blogspot.com/

www.agilent.com

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