The Essential Signal Generator Guide

Building a Solid Foundation in RF – Part 1

Introduction

Eliminate uncertainties and doubts from your test results with a reliable signal source

The race to get to market faster is a fierce battle. To win the race, you need test results you can trust. That's why selecting the right instrument for the job is so important. You simply cannot afford to waste time second guessing your results.

In this first part of our two-part white paper on signal generators, we help you gain a sound understanding regarding the fundamental specifications of signal generators, enabling you to make the right choice when selecting a signal generator.

KEYSIGHT
TECHNOLOGIES

Contents

In Part 1 of our two-part white paper, we'll introduce you to signal generators as well as look at basic specification such as power, accuracy, and speed. We'll be talking about more advanced features such as modulation, spectral purity and distortion in Part 2.

Section 1. Key Attributes

Understand the components of a signal generator and what makes it unique from other sources. Explore the types of signal generators available and key specifications.

Section 2. Power

Learn the difference between *average power, envelope power and peak envelope power* as well as measurement applications for high/low output power.

Section 3. Accuracy

Have confidence in your measurements. Find out why accuracy matters and which type of accuracies to look out for.

Section 4. Speed

Speed is everything in manufacturing. Get to market faster and beat the competition. Learn to read the specs. Don't be left behind.

Section 1 - Key Attributes

Signal generators comes in many flavors, with a variety of form factors and capabilities available.

Figure 1-1. Keysight PXIe vector signal generator and analyzer.

Form factor: Do you need a benchtop or modular instrument?

Benchtop is the traditional form factor for many signal generators. This is the typical boxed instrument we usually find on benches and in our racks. The front panel display and controls on this instrument let you setup and debug failures quickly and easily. Benchtop signal generators have a comprehensive range of capabilities, from RF to microwave, and from analog to vector.

Figure 1-2. N5166B CXG X-Series RF vector signal generator.

Another form factor that is gaining rapid popularity is PXIe. Due to their compact form factor, PXIe signal generators are often used in applications that requires multiple channels. PCIe Gen 3 now allows for up to 24 GB/s system bandwidth, increasing the test throughput for high-performance applications such as FPGA streaming of I/Q data to a baseband generator or digital pre-distortion (DPD). A PXIe signal generator uses the same software applications as a benchtop signal generator, providing measurement consistency and compatibility from product development to manufacturing and support.

Analog, Vector and Agile Signal Generators

Signal generators are also classified based on their capabilities. The earliest signal generators, like the ones used to test sound equipment, were analog signal generators. The basic function of an analog signal generator is to supply a continuous wave (CW) sinusoidal signal. Modern analog signal generators are capable of amplitude, frequency, phase and pulse modulation as well. The maximum frequency for an analog signal generator today is nearly 70 GHz.

Vector signal generators are a newer generation of signal generators capable of complex Quadrature Amplitude Modulation (QAM) schemes. These vector signal generators have a built-in quadrature (also called IQ) modulator to generate complex modulation formats such as Quadrature Phase-Shift Keying (QPSK) and 1024 QAM.

The ability to quickly sweep through a list of frequencies and amplitudes is an important attribute, especially in manufacturing test. Agile signal generators are built for speed. These signal generators are able to quickly change frequency, amplitude and phase of the signal. This functionality is ideal for high-volume wireless device testing.

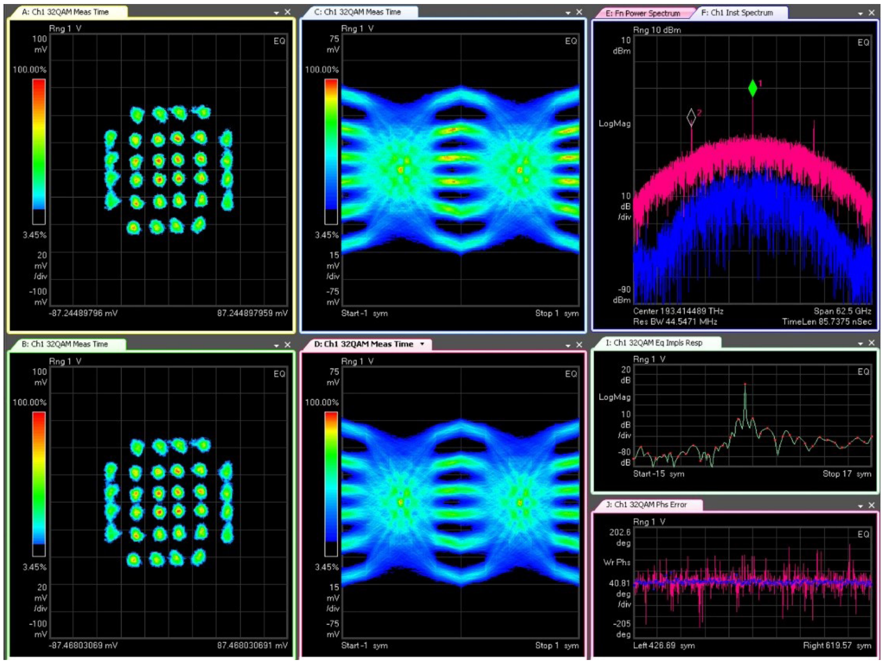


Figure 1-3. A 32-QAM modulation signal.

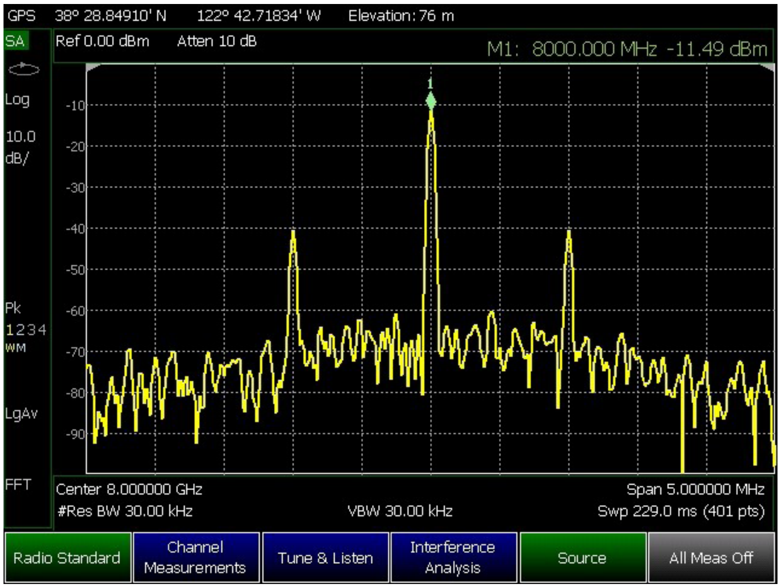
Overview of Key Specifications

To select the right signal generator for the job, you'll need to understand the performance specifications. Specifications tell you the capability of your signal generator with three key ones being frequency, amplitude and spectral purity performance. Let's look at each of these.

Frequency

The frequency specification defines the range, resolution, accuracy and switching speed of your signal generator.

- *Range* tells you the maximum and minimum output frequencies your signal generator can output.
- *Resolution* is the smallest frequency change.
- *Accuracy* is how close the source's output frequency is to the set frequency.
- *Switching speed* is how fast the output settles down to the desired frequency.



GPS 38° 28.84910' N 122° 42.71834' W Elevation: 76 m

Ref 0.00 dBm Atten 10 dB

M1: 8000.000 MHz -11.49 dBm

Log 10.0 dB/

Center 8.000000 GHz

Span 5.000000 MHz

#Res BW 30.00 kHz

VBW 30.00 kHz

Swp 229.0 ms (401 pts)

Figure 1-4. A spectrum analysis with frequency and amplitude readouts.

Power

Power specifications include range, resolution and switching speed.

- *Range* is the difference between the maximum and minimum output power capability of the signal generator. The signal generator's output attenuator design will determine its range. The output attenuator allows the signal generator to output extremely small signals used to test a receiver's sensitivity.
- The *resolution* of a source indicates the smallest possible power increment.
- *Switching speed* is a measure of how fast the source can change from one power level to the next.

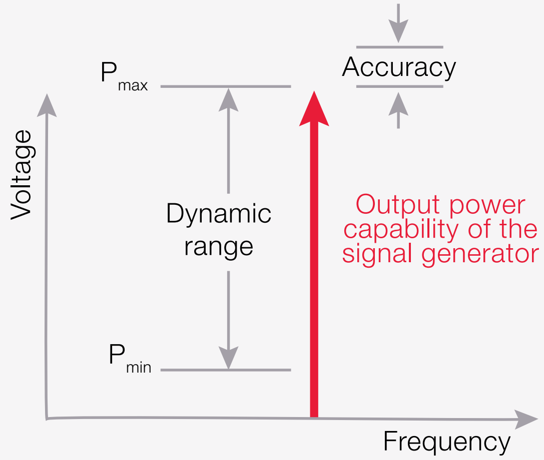


Figure 1-5. Figure showing power output range and accuracy.

Spectral Purity

Spectral purity specifications include phase noise, spurious and harmonic performance.

- *Spectral purity* tells you the idealness of your output signal. A perfect signal generator will generate a sinusoidal wave with at a single frequency without the presence of noise. However, signal generators are made with non-ideal components which introduce noise and distortion.
- *Phase noise* is a result of random frequency fluctuations in the sinusoidal wave and is usually caused by an imperfect oscillator in the system.
- *Spurs* are non-random or deterministic signals that are created from mixing and dividing signals to get the carrier frequency. These signals may be harmonically or non-harmonically related to the carrier.

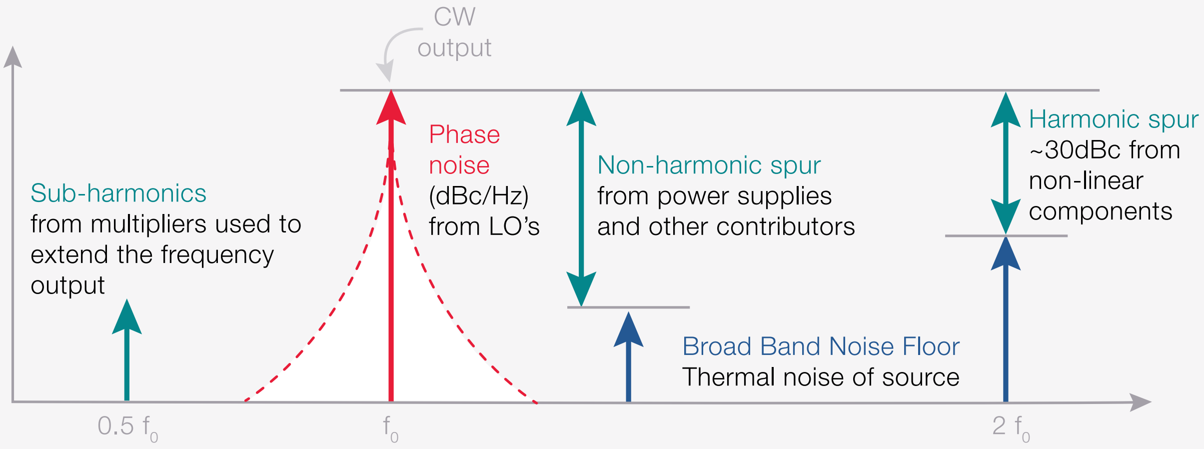
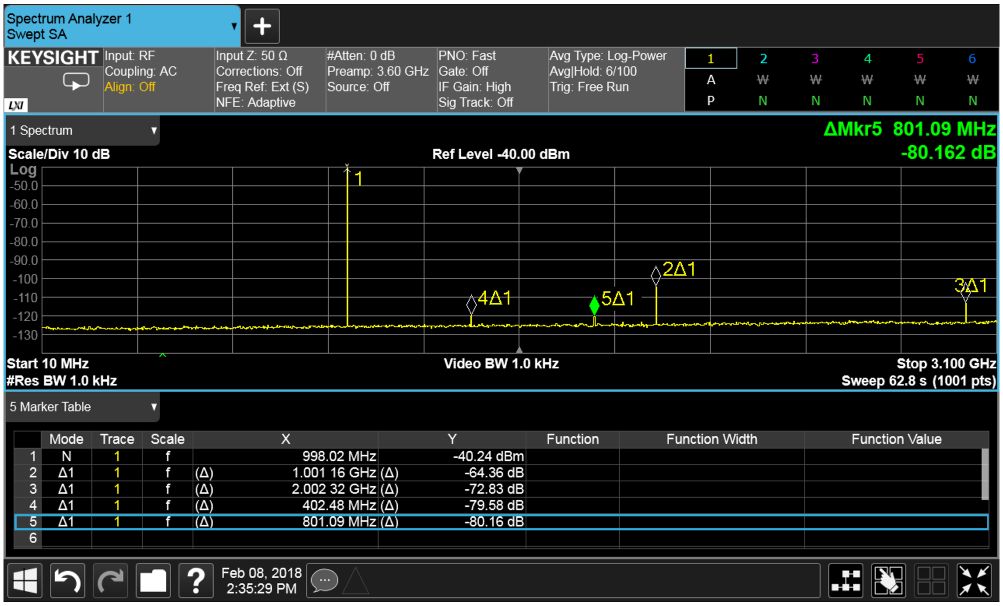


Figure 1-6. Signal purity measurements.

Harmonics are spurs occurring at integral multiples of the fundamental frequency. Harmonic spurs are caused by non-linear characteristics of components used in the signal generator. Multipliers are non-linear components needed to generate a broad range of frequencies and output powers.

Sub-harmonics are spurs with frequencies that are less than the fundamental frequency. Multipliers used in sources to extend the frequency output are the major source of sub-harmonics.

Learn more about our comprehensive list of Signal Generators for all your test needs with our Signal Generator Selection Guide here.



Input: RF
Coupling: AC
Align: Off
Input Z: 50 Ω
Corrections: Off
Freq Ref: Ext (S)
NFE: Adaptive
#Atten: 0 dB
Preamp: 3.60 GHz
Source: Off
PNO: Fast
Gate: Off
IF Gain: High
Sig Track: Off
Avg Type: Log-Power
Avg|Hold: 6/100
Trig: Free Run

ΔMkr5 801.09 MHz
-80.162 dB

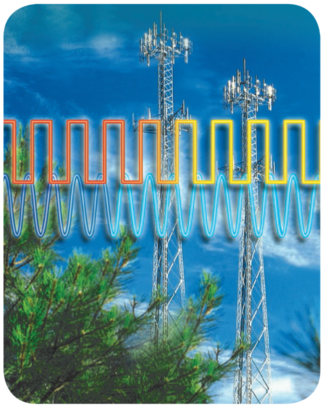
Scale/Div 10 dB
Ref Level -40.00 dBm

Start 10 MHz
#Res BW 1.0 kHz
Video BW 1.0 kHz
Stop 3.100 GHz
Sweep 62.8 s (1001 pts)

	Mode	Trace	Scale		X	Y	Function	Function Width	Function Value
1	N	1	f		998.02 MHz	-40.24 dBm			
2	Δ1	1	f	(Δ)	1.001 16 GHz (Δ)	-64.36 dB			
3	Δ1	1	f	(Δ)	2.002 32 GHz (Δ)	-72.83 dB			
4	Δ1	1	f	(Δ)	402.48 MHz (Δ)	-79.58 dB			
5	Δ1	1	f	(Δ)	801.09 MHz (Δ)	-80.16 dB			
6									

Figure 1-7. Spurious measurement.

Section 2 - Power



Signal generators provide precise and stable test signals for a variety of components and system test applications. An important specification of any signal generator is output power range. Often, signal generators need output signals as low as -120 dBm in receiver sensitivity testing and as high as +20 dBm in RF power amplifier testing. And they need to achieve this wide dynamic range while meeting key specifications such as accuracy, spectral purity and noise.

There are several types of power, ranging from average power to envelope power to peak envelop power. But before we look at each of these in detail, let’s first understand the basics of power.

What is “Power”?

Power is the rate at which energy is transferred and is measured in watts (W). One watt is equal to one joule of energy transferred in one second.

With direct current (DC), power is the product of voltage and current. It is the same for alternating current (AC), however with AC, changes in voltage and current cause instantaneous power to vary in time.

Output power in a signal generator is the average power being output. To get the average output power, we just need to integrate the area under the P curve as shown in Figure 2.1.

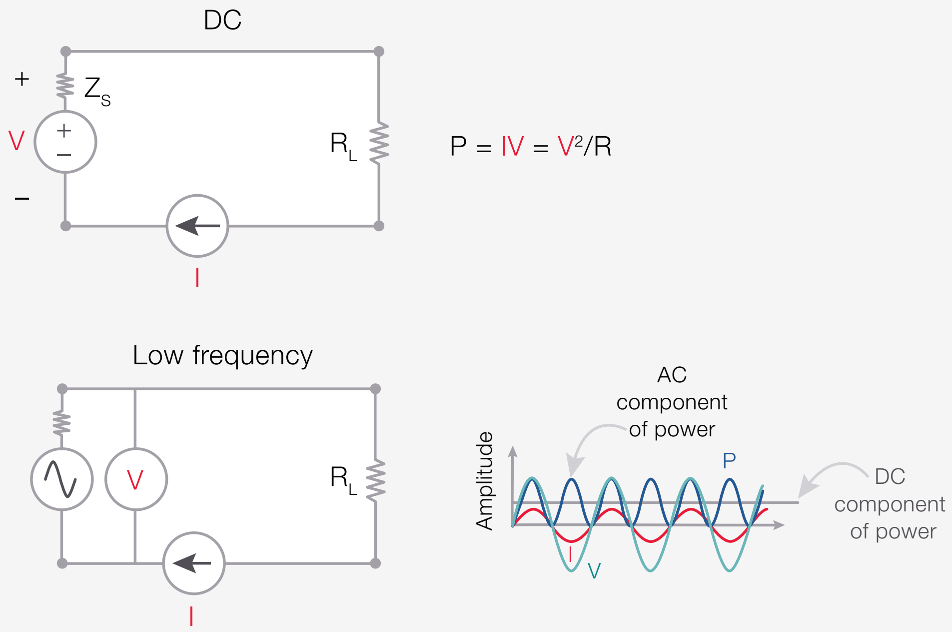


Figure 2-1. DC and low frequency power measurements.

Talking about dB and dBm

No discussion on power is complete without visiting the dB scale. dB stands for decibel and is used to express a ratio on a logarithmic scale. The formula to convert a ratio to dB is:

$$GdB = 10\log_{10}(P/P_o)$$

where P0 is the reference power level and P is the power level of interest. If P_0 is 1 mW, you’ll get dBm. In other words, dBm is referenced to 1 mW of power.

Why use dB and dBm? Well, dB and dBm are useful when expressing very large or very small values. For example, a ratio of 10,000,000,000 could be expressed as 100 dB and a ratio of 0.000 000 000 1 could be expressed as -100 dB.

Another advantage of using dB is it allows you to easily calculate total system gain or loss. You just need to add for gain and subtract for loss. This is a nice convenience, especially when you have multistage amplifiers and attenuators in RF systems.

Total gain = 5 x 13

= 65

= 10 log 65

= 18.13 dB

Total gain (in dB) = 6.99 dB + 11.14 dB

= 18.13 dB

Figure 2-2. Using dB scale, the total system gain is simply the addition of the two amplifiers' gain in dB.

What is Average Power?

The term "average power" is commonly used in RF and microwave systems, as opposed to instantaneous power. Instantaneous power varies too fast to be meaningful. Average power is the average energy transferred within the time period of the lowest frequency component. Power transferred is always a positive value, unlike voltage and current (which can fluctuate between positive and negative values).

Understanding Envelope Power and Peak Envelope Power

In RF power amplifier characterization, you need to understand power consumption under various operating conditions. Figure 2.3 shows a power measurement of a high-frequency modulated signal.

The envelope power is determined by averaging the power over a time period that is large compared to the period of the highest modulation frequency, but short compared to the period of the carrier. Envelope power allows you to examine the effects of modulation or transient conditions on power consumption. This is especially important as many RF power amplifiers go into battery powered mobile devices. Peak envelope power (PEP) is the maximum envelope power and is an important parameter for characterizing a transmitter.

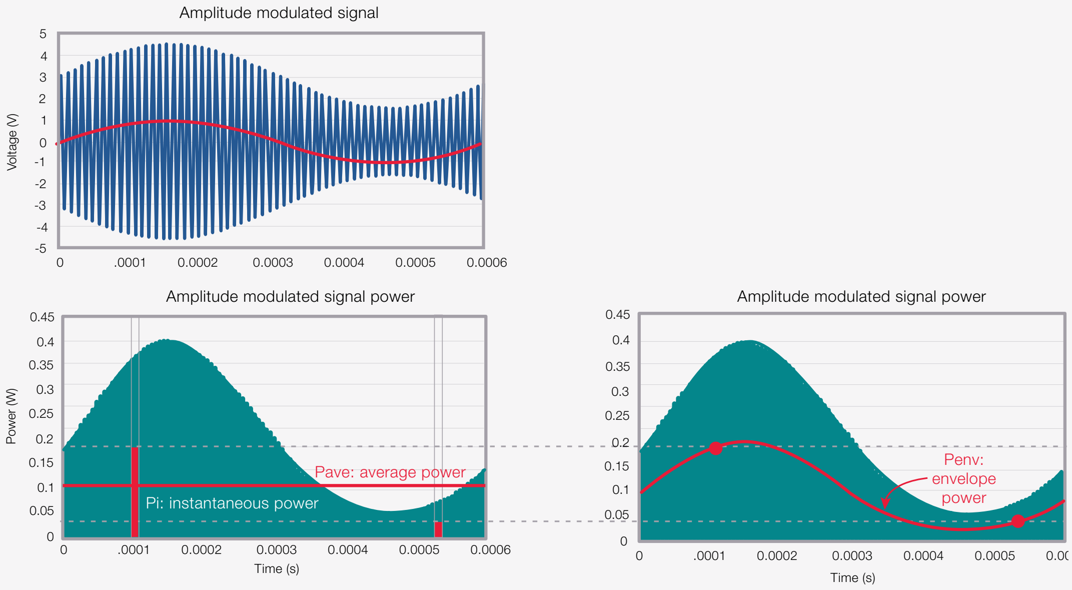


Figure 2-3. Voltage envelope and power envelope of a high-frequency modulated signal. The upper graph is the voltage envelope of the modulated signal. The lower left chart shows the instantaneous power of the signal in green, and the average power in red. The lower right chart shows the envelope power in red.

Understanding the Power Specifications

When it comes to power specifications, many signal generators' datasheets will list the power output range, resolution, and applicable frequency ranges. There are several points to be aware of:

- Output amplitude is affected by frequency ranges and operating temperatures.
- There are often options for higher output power needs.
- The step attenuator provides coarse power attenuation (in 5 dB steps) to achieve low power levels. Fine power level adjustment is provided by the ALC (automatic level control) within the attenuator hold range.
- The "Maximum output power" is for continuous wave (CW) mode. Some datasheets list maximum output power for I/Q modulation. For the Keysight CXG/EXG/MXG signal generators, power specification, it refers to PEP.

Tip: Source match is important because mismatch between source and the load impedance changes the effective signal input level to the DUT.

Output parameters	
Settable range	+30 to –144 dBm
Resolution	0.01 dB
Step attenuator	0 to 130 dB in 5 dB steps electronic type
Connector	Type N 50 Ω, nominal
Max output power [1] ( ) = typical	
Frequency	**Standard**
9 kHz to 10 MHz	+13 dBm
> 10 MHz to 3 GHz	+18 dBm
> 3 to 5 GHz	+16 dBm
> 5 to 6.0 GHz	+16 dBm

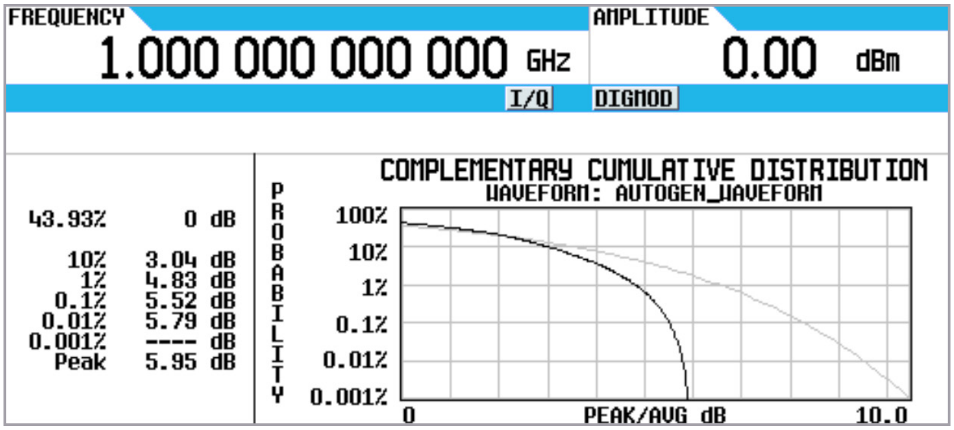
1. Quoted specifications between 20 °C and 30 °C. Maximum output power typically decreases by 0.01 dB/°C for temperatures outside this range.

Table 2-1. Amplitude specifications of Keysight CXG signal generators - Max output power.

Things get a little bit complicated with modulation

Many of the digitally modulated signals appear noise-like in the time and frequency domain, with peaks occurring seemingly random. How do you ensure you are not driving your signal generator to saturation during these peaks? The Power Complementary Cumulative Distribution Function (CCDF) curves tells us how high these peaks will go. As an example, Figure 2.4 tells us the highest peak to average ratio (PAR) is 5.95 dB.

If the maximum output power of the signal generator is 18 dBm, the maximum power output your signal generator can be set to is 12.05 dBm (18 dBm – 5.95 dB). Remember that the signal generator’s power output is average power output. Setting your signal generator’s output higher than 12.05 dBm will lead to clipped peaks.



FREQUENCY 1.000 000 000 000 GHz

AMPLITUDE 0.00 dBm

I/Q DIGMOD

43.93%	0 dB
10%	3.04 dB
1%	4.83 dB
0.1%	5.52 dB
0.01%	5.79 dB
0.001%	---- dB
Peak	5.95 dB

Figure 2-4. CCDF plot from waveform utility of Keysight's N5182B signal generator. The signal waveform shows here is a 64 QAM, symbol rates at 1 Msps and RRC (root-raised-cosine) baseband filter waveform.

Looking for some tips on high power applications? Get them here.

Measurement Applications

If you need to go beyond the specified range, you can use an amplifier to increase the output power or an attenuator to decrease the output power. However, you'll need to include the amplifier's gain uncertainty and the attenuator's flatness and accuracy into consideration. Here are some test applications for high and low output power.

High output power test applications:

1. Overcome switching losses within automated test equipment (ATE) systems
2. Address the attenuation of signals within long cable runs
3. High-power amplifiers
4. Receiver blocking tests

Low output power test applications:

5. Receiver sensitivity measurement
6. As interference signals

Section 3 – Accuracy

Avoiding a Speeding Ticket

After months of preparation, the summer vacation is finally here. Excitement is in the air and you can't wait to reach your destination. You hit the highway at dawn, hoping to beat the crowd to your destination. At the same time, you try your best not to exceed the 75 mph speed limit. Your speedometer is resting directly on top of the 75-mph mark. You don't want to go any slower, but you also don't want to risk a speeding ticket, which will ruin your vacation. As you speed down the highway, how confident are you that you are going exactly 75mph? Do you trust your speedometer? How accurate and precise is it?

Accuracy is often confused with precision. The accuracy of a signal generator is how close its output value is to the set value. Precision is the degree to switch the signal generator's output fluctuates. A high precision generator will have a stable output with little variations. However, a high precision generator may not necessarily have an accurate output. Figure 3.1 on the left shows the distinction between accuracy and precision.

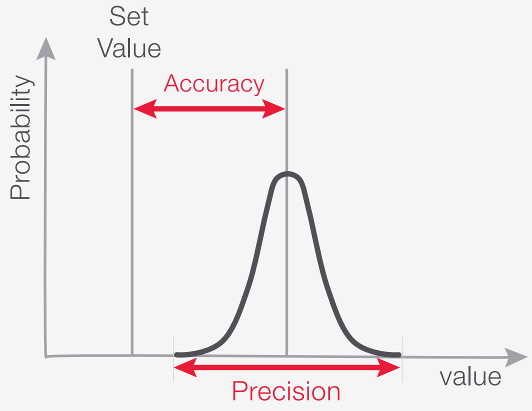


Figure 3-1. Accuracy vs precision

Key Accuracy Specifications

There are two key accuracy specifications, amplitude accuracy and frequency accuracy. How much accuracy you need depends on your application. If you are testing a wireless receiver's sensitivity with ± 4dB accuracy, you will need to use a source with ± 1dB amplitude accuracy to achieve a test accuracy ratio (TAR) of 4.

Amplitude Accuracy

Amplitude accuracy is how close your signal generator's output amplitude is to the set amplitude. Amplitude accuracy is often specified within a frequency and temperature range.

The temperature range is specified because the signal generator's output accuracy degrades with temperature. For example, the N5182B's absolute level accuracy degrades by 0.01 dB/°C when the ambient temperature is outside of the 20°C to 30°C range. Table 2.2 shows the amplitude accuracy specification of the N5182B MXG signal generator.

Absolute level accuracy in CW mode[1] (ALC on) ( ) = typical			
	Standard		
Range	Max power to -60 dBm	< -60 to -110 dBm	
9 to 100 kHz	(± 0.6 dB)	(± 0.9 dB)	
100 kHz to 5 MHz	± 0.8 dB (± 0.3)	± 0.9 dB (± 0.3)	
> 5 MHz to 3 GHz	± 0.6 dB (± 0.3)	± 0.8 dB (± 0.3)	
> 3 to 6 GHz	± 0.6 dB (± 0.3)	± 1.1 dB (± 0.3)	
Absolute level accuracy in CW mode (ALC off, power search run, relative to ALC on)			
9 kHz to 6GHz	(± 0.15 dB)		
Absolute level accuracy in digital I/Q mode (N5182B only)			
(ALC on, relative to CW, W-CDMA 1 DPCH configuration < +10 dBm)			
5 MHz to 6 GHz	± 0.25 dB (± 0.05)		

Table 3-1. Accuracy specification of N5166B CXG Signal Generator.

Amplitude Flatness

Amplitude accuracy affects the frequency sweeping capability of a signal generator. Frequency sweeps are often used in testing filters and power amplifiers. The less the amplitude changes from one frequency to another, the flatter the output is. The change in amplitude while moving from one frequency to another is called flatness. While closely related to amplitude accuracy, they are not the same. The flatness spec is tighter than the amplitude accuracy spec and is usually referenced to the amplitude of the starting frequency. Figure 3.2 illustrates this point.

Tip: To improve signal accuracy going into your DUT, we can perform a flatness correction at the point where your DUT is connected to the test system. Performing a flatness correction eliminates errors caused by cable and switching losses.

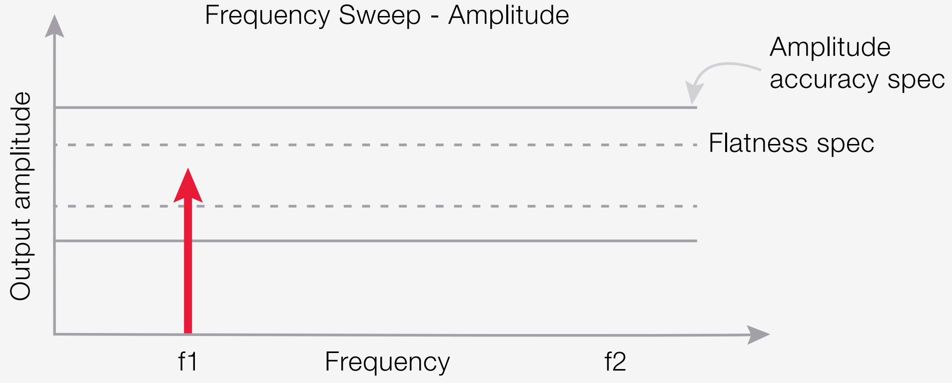


Figure 3-2. Comparison between amplitude accuracy and flatness.

Improve Accuracy to Improve Yield

Receiver sensitivity testing requires sources with accurate output power. Receiver sensitivity testing determines if a receiver is able to detect weak signals above a specified power level. For example, a 4G mobile phone receiver has a specified sensitivity level of -110 dBm. The receiver will be rejected if it fails to detect signals with a power level of -110 dBm or more.

To illustrate the effects of poor accuracy on test yield, let's use our 4G receiver example. Consider a signal generator with an amplitude accuracy of ±5 dB. To avoid over-accepts (or false positives), the signal generator is setup to output -115 dBm. At -115 dBm, the signal generator's output power will vary between -110 dBm to -120 dBm. As you can see in Figure 3.3, using this signal generator will cause you to inadvertently reject four perfectly good receivers with borderline performance.

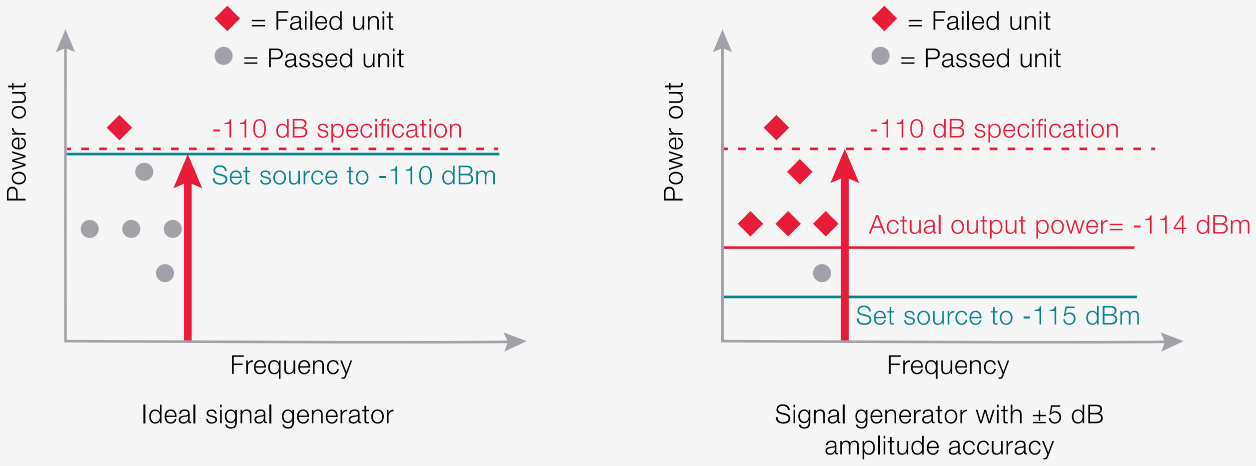
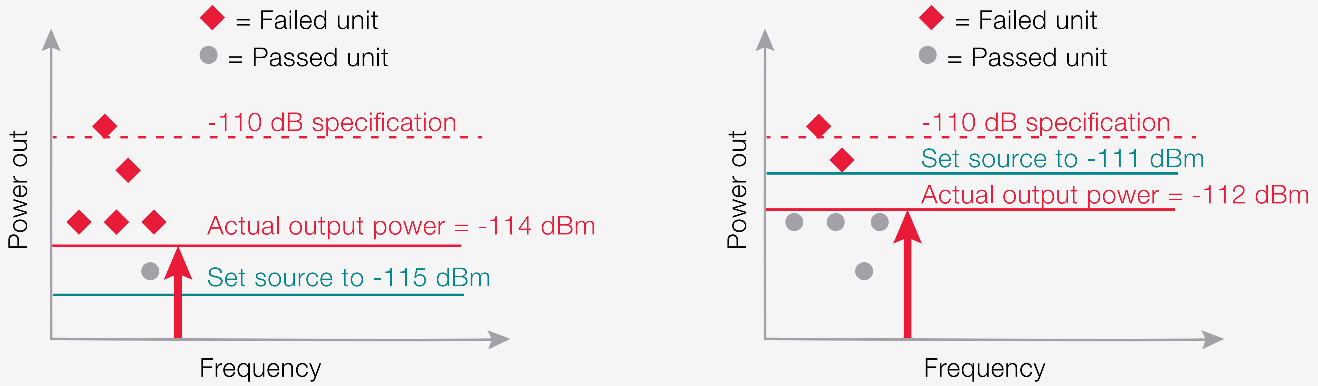


Figure 3-3. Effects of poor amplitude accuracy to test yield.

To improve the test yield, you just need to use a more accurate signal generator. Using a signal generator with an amplitude accuracy specification of ±1 dBm, our signal generator is setup to output -111 dBm. Figure 3.4 shows four of the same six receivers tested earlier now pass the sensitivity test. We have reduced false rejects by 75% just by using a more accurate source.

A more accurate source may cost more. However, in the long run, the improved yield will return the cost of investment many times over.



Signal generator with ±5 dB amplitude accuracy

Signal generator with ±1 dB amplitude accuracy

Figure 3-4. Effects of improved amplitude accuracy to test yield.

Frequency Accuracy

The frequency accuracy of a signal generator is affected by two main factors, the stability of the reference oscillator and the amount of time that has passed since the source was calibrated. Although temperature and line voltage also affect frequency stability, it’s effect is several orders of magnitude less than the aging effect. Therefore, the key specification to look out for is the reference oscillator aging rate.

A typical reference oscillator used in a signal generator has an aging rate of 0.152 ppm per year. A 10 GHz signal generator with this reference oscillator that has not been calibrated for one year will have a frequency accuracy of ±1.52 kHz. The calculation is shown below.

Frequency Accuracy (Hz) = Output Frequency (Hz) x Aging Rate (ppm/year) x Time since last calibration

= 10 GHz x 0.152 ppm/year x 1 (year)

= 1.52 kHz

Frequency reference	
Accuracy	± (time since last adjustment x aging rate)
	± temperature effects
	± line voltage effects
	± calibration accuracy
Internal time base reference oscillator aging rate[1]	≤ ± 5 ppm/10yrs, < ± 1 ppm/yr
Initial achievable calibration accuracy	$\pm 4 \times 10^{-8}$ or ± 40 ppb
Adjustment resolution	$< 1 \times 10^{-10}$
Temperature effects	± 1 ppm (0 to 55°C), nominal
Line voltage effects	± 0.1 ppm, nominal; 5% to 10%, nominal

Table 3.2. Accuracy specification of N5166B CXG signal generator.

Frequency Spectrum is a Limited Resource

Cellular 4G channel spacings are narrow to increase data bandwidth. Therefore, 4G receivers must be able to process weak signals while rejecting interference from adjacent channels. The adjacent channel selectivity (ACS) test measures a receiver's ability to receive a signal at its assigned channel while rejecting a strong signal in the adjacent channel.

This test uses two signal generators. One signal generator inputs a test signal at the in-channel frequency at a level above the sensitivity of the receiver. The second signal generator outputs an adjacent channel signal. The output of the out-of-channel signal is increased until the sensitivity of the receiver is degraded to a specified level.

In ACS, frequency accuracy of the test and interfering signals is important. Poor frequency accuracy will cause the signals to be either too close or too far from each other and from the filter skirts. For example, assume you are trying to set a 1-kHz separation between two signals centered at 200 MHz, and your sources have an aging rate of $\pm 1 \times 10^{-6}$/year. Your sources' frequency error in this case is $200 \text{ MHz} \times 1 \times 10^{-6}$, or ±200 Hz. The separation could be anywhere from 600 Hz to 1400 Hz as shown in Figure 3.5.

At best, this can cause over rejects, but at worst, this will lead to the false accept of an out-of-spec receiver.

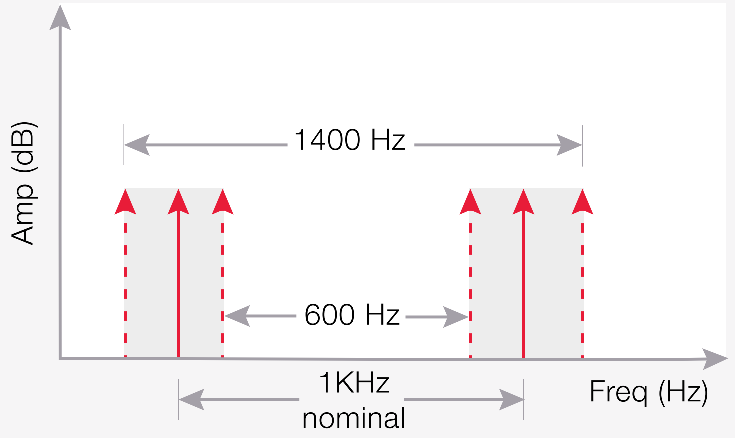


Figure 3-5. Impact of frequency accuracy on adjacent channel selectivity test. Instead of a 1 kHz separation between the two adjacent channels, we know have a separation of that varies from 600 Hz to 1400 Hz.

Section 4 – Speed

Your boss comes to you. He looks worried. He leans against your desk. He has just come out of a meeting with the VP of Manufacturing. The VP wants a 25% cost reduction on manufacturing expenses and your boss has until the end of the week to give him a proposal. Your boss need your help.

Test is a non-value-add activity, just like inspection in quality control. Ideally, products should work as designed when they finish manufacturing. However, things are never ideal. Therefore, we still need to test.

Testing costs money - lots of money. The shorter the test time, the less test costs. Therefore, the speed of your signal generator matters in manufacturing. So, what is a fast signal generator?

A fast signal generator allows you to quickly switch from one frequency to another, from one amplitude to another, or from one waveform to another. Speed is specified in milliseconds. Figure 4.1 shows the frequency switching speed specification for the N5182B MXG signal generator.

Frequency switching speed [1, 2]			
	Standard	Option UNZ [3]	Option UNZ, typical
CW mode			
SCPI mode	≤ 5 ms, typical	≤ 1.15 ms	≤ 950 µs
	≤ 5 ms, typical	≤ 900 µs	≤ 800 µs
Digital modulation on (N5182B only)			
SCPI mode	≤ 5 ms, typical	≤ 1.15 ms	≤ 1.15 ms
List/step sweep mode	≤ 5 ms, typical	≤ 900 µs	≤ 800 µs

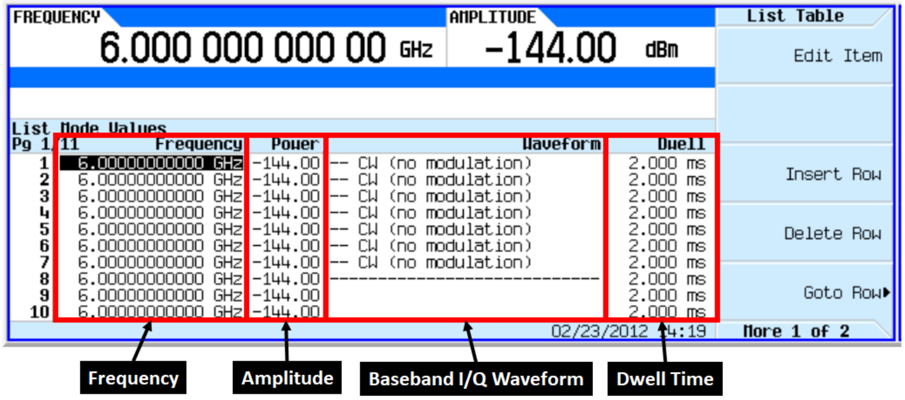
1. Time from receipt of SCPI command or trigger signal to within 0.1 ppm of final frequency or within 100 Hz, whichever is greater.
2. With internal channel corrections on, the frequency swithcing speed is < 1.3 ms, measured for list mode and SCPI mode cached frequnecy points. For the initial frequnecy point in SCPI mode the time is < 3.3 ms, measured. The instrument will automatically cache the most recently used 1024 frequencies. There is no speed degradation for amplitude-only changes.
3. Specifications apply when status register updates are off. For export control purposes CW switching speed to within 0.05% of final frequency is 190 µs (measured).

Table 4.1. Switching speed specification of the N5182B MXG signal generator.

Tip: Improve waveform switching speed by using the list/step sweep mode to pre-load the waveforms into the non-volatile memory.

Factors affecting speed

Switching speed is affected by the type of change and the source of commands. The time in the specifications refers to the amount of time needed for the output of the signal generator to stabilize once a command is sent. The speed specifications shown are worst case scenarios. Typical switching times are up to 40% faster.



```
FREQUENCY                          AMPLITUDE
      6.000 000 000 00 GHz           -144.00   dBm

List Mode Values
Pg 1/11         Frequency   Power                        Waveform        Dwell
   1  6.00000000000 GHz -144.00 -- CW (no modulation)            2.000 ms
   2  6.00000000000 GHz -144.00 -- CW (no modulation)            2.000 ms
   3  6.00000000000 GHz -144.00 -- CW (no modulation)            2.000 ms
   4  6.00000000000 GHz -144.00 -- CW (no modulation)            2.000 ms
   5  6.00000000000 GHz -144.00 -- CW (no modulation)            2.000 ms
   6  6.00000000000 GHz -144.00 -- CW (no modulation)            2.000 ms
   7  6.00000000000 GHz -144.00 -- CW (no modulation)            2.000 ms
   8  6.00000000000 GHz -144.00 ---------------------------      2.000 ms
   9  6.00000000000 GHz -144.00                                  2.000 ms
  10  6.00000000000 GHz -144.00                                  2.000 ms
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Figure 4-1. List sweep configuration table.

When the signal generator is set to a new frequency, the frequency synthesizer will change its output to the desired frequency. The output amplifier will then adjust the power level so that the output power stays the same at the new frequency. Essentially, frequency switching requires changes to both the frequency synthesizer and output amplifier, which is why frequency switching is often slower than amplitude switching.

During switching, command processing takes up the most time. Figure 4.2 shows the time components of processing a SCPI command request.

For faster switching speed, use the list/step sweep mode instead of sending individual SCPI commands. In sweep mode, the frequency, power, and waveform states are known in advance, and are downloaded to non-volatile memory in the signal generator. The signal generator is able to then sequence through the states in rapid succession. Typical switching time in sweep mode is 600 μs to 800 μs compared to 2 ms in SCPI mode.

Some signal generators offer high speed switching options. The N5182B, for example, has the UNZ option which offers sub-millisecond switching speeds, perfect for high volume production.

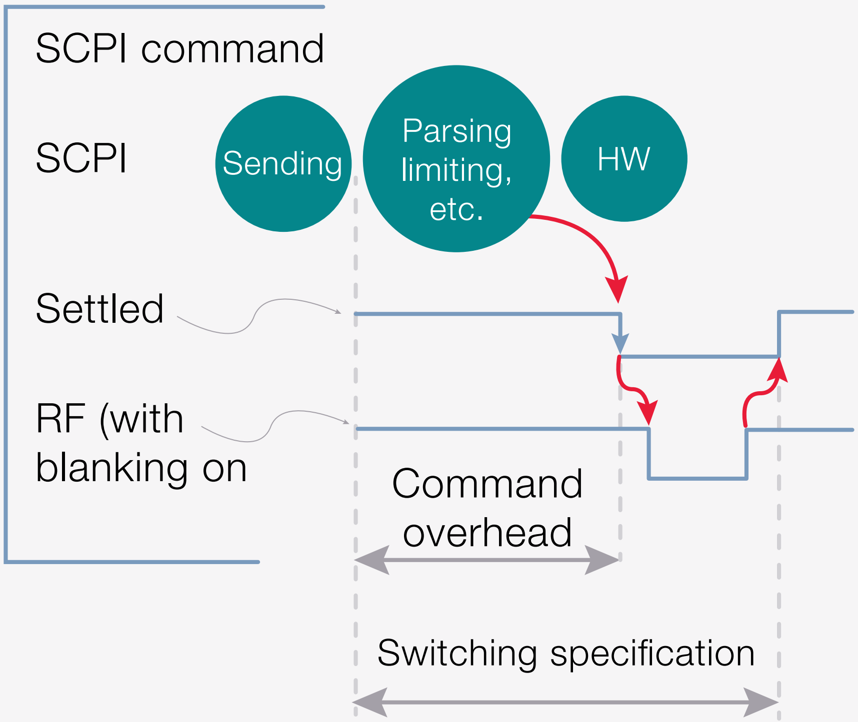

Figure 4.2. SCPI command processing time in a signal generator

When Speed Matters

Wireless Manufacturing

No so long ago, reducing test times required only a reduction in the number of test points. This strategy no longer works. Now, more tests are required as more features are built into modern wireless devices. Connectivity capabilities are expanding to include not just voice, but a variety of data connections such as RFID, *Bluetooth*®, LTE, UWB and 5G. These modes require testing and verification, over multiple channels, at different power levels, and with realistic waveforms. You are continuously searching for ways to increase test throughput to reduce cost. To achieve this, you need speed.

Here are some manufacturing scenarios where speed matters:

- Broadcast receiver measurements – wireless devices incorporating receivers for broadcast signals such as FM Stereo, GPS, or digital video require performance verification. In some cases, this may be a simple receiver sensitivity measurement, and in others bit-error-rate (BER) measurements may be required. In either case, rapid switching of frequency, amplitude, and waveform are required.
- Multiple waveform testing – many automated test procedures require multiple waveforms, for example, to measure distortion through an amplifier with different waveform types or to verify functionality of a variable adaptive data rate system, e.g. 8PSK and QPSK.
- Gain compression testing – amplifier gain compression can be measured by varying the power in. Exact gain compression points, such as 1 dB gain compression can be measured using iterative measurements to zoom in on the specific gain compression point.

Figure 4-3. A complex RF design verification test system.

Advance electronic warfare

Electronic warfare (EW) is the use of electromagnetic spectrum to impede radar sensing and radio communications, and to protect against these attacks. Productive and efficient engineering of EW systems requires test signals that accurately and repeatably represent actual EW environments. Simulation of multi-emitter environments is vital to ensure realistic and representative testing. These multi-emitter environments are typically simulated with large, complex, custom test systems that are employed in the system qualification and verification stage.

Validation and verification of EW systems is heavily dependent on testing with realistic signal environments. EW test realism increases as high-fidelity emitters are added to create density. In addition to emitter fidelity and density, platform motion, emitter scan patterns, receiver antenna models, direction of arrival, and multipath and atmospheric models enhance the ability to test EW systems under realistic conditions.

EW systems are now designed to identify emitters using precise direction finding and pulse parameterization in dense environments of 8 to 10 million pulses per second. Modern spectral environment contains thousands of emitters—radios, wireless devices, and tens to hundreds of radar threats—producing millions of radar pulses per second amidst background signals and noise. An overview of the threat frequency spectrum is shown in Figure 4.3.

For EW signal creation, download application note "*Creating Multi-Emitter Scenarios for Radar and Electronic Warfare (EW) Testing*".

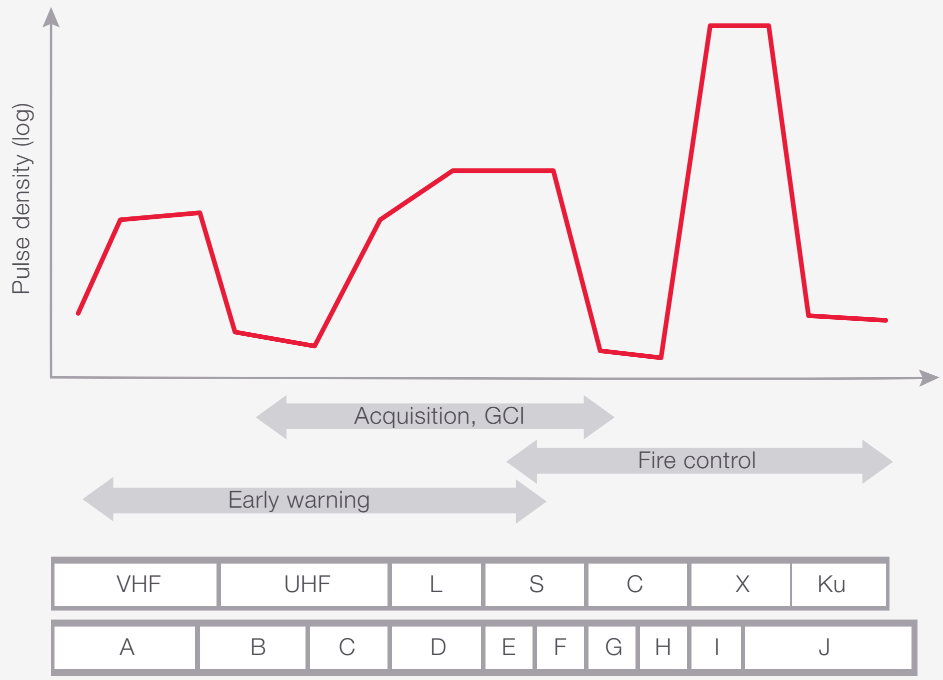

Figure 4-4. Example of a threat frequency spectrum used in EW simulation

Summary

More and more functionalities are integrated into wireless devices, requiring more tests with more setups under more conditions. A wireless device includes multiple wireless standards, multiple frequency bands, and multiple antennas. This increases significant test challenges in verification and production test. Test engineers are continuously looking for ways to improve test throughput and cost. When equipped with the fast switching capability, these signal generators can switch frequency, amplitude, or waveform in less than 1 millisecond in most cases.

End of Part 1

We have reached the end of Part 1 of our two-part white paper. We hoped you've gained valuable understanding on the fundamental specifications of signal generators. In Part 2, we will talk about more advance topics such as modulation, spectral purity, distortions and software. Learn about the various types of modulation schemes and gain a more in-depth understanding on harmonics and spurs. We'll share why distortions are not always evil and how you can improve your productivity with the latest software.

To stay up to date with the most recent tutorials, techniques, and best practices check out the Keysight Labs YouTube channel, follow the Keysight RF Test and Measurement Facebook Page, and subscribe to our blog.

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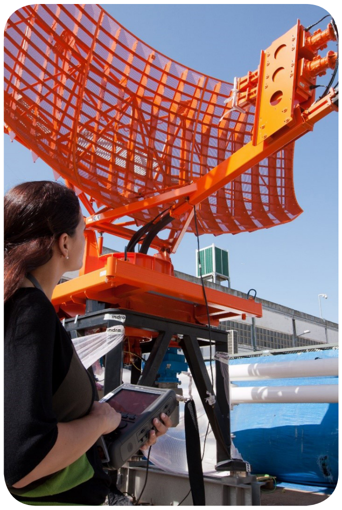

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