

Keysight Technologies  
Signal Generator  
Spectral Purity

Application Note

## What is spectral purity?

Spectral purity is the inherent stability of a signal. Does it change in frequency? Stabilities can either be short or long term. Drift or long-term stability is usually defined over a period of time greater than a second. Does the signal drift off frequency in minutes, hours, days, or months? Current signal generator technology generally offers good long-term stability.

The greater concern is for short-term stability or changes in frequency in less than one second. These fluctuations come from non-deterministic signals like noise, shot noise and 1/f flicker noise that modulates the carrier. These affect both phase and amplitude.

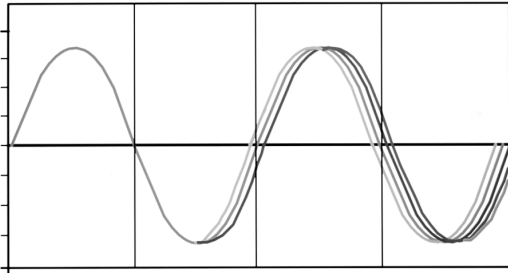


Figure 1. Oscilloscope display of short-term frequency fluctuations

## What are the components?

### Single-sideband phase noise

There are many ways to define spectral purity. The most common and meaningful method of specifying short-term stability is a plot of the signal generator's single-sideband (SSB) phase noise in a 1 Hz bandwidth versus the offset from the carrier. This is illustrated in figure 2. The SSB phase noise is expressed in dB relative to the carrier (dBc). A 1 Hz bandwidth is used since the noise in other bandwidths can then be easily calculated for comparison. This plot is a graphical representation of the phase noise distribution on one side of the carrier.

### Spurious

Non-random or deterministic signals are created from mixing and dividing signals to get the carrier frequency. These signals may be harmonically related to the carrier and are called subharmonics. The non-harmonic spectral line is called spurious. It is specified in amplitude in relation to the carrier (dBc).

### Residual FM

Residual FM is the undesired angular modulation or FM inherent in a signal generator with all the modulation turned off. It includes the effects of both spurious and phase noise. It is the integral or area under the SSB curve with limits set by the postdetection bandwidth. 300 Hz to 3 kHz and 20 Hz to 15 kHz are common bandwidths.

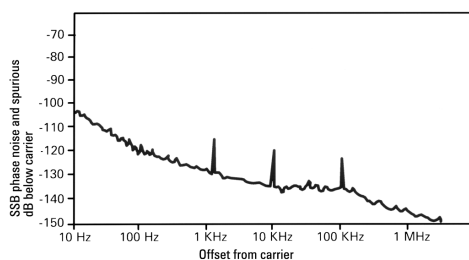


Figure 2. Signal generator SSB phase noise and spurious

## Why is spectral purity important for mobile radio?

### Narrower channel spacings

As available spectrum becomes more and more scarce, radio channel spacings will decrease. This puts a tighter constraint on receiver designers to design more selective receivers. To test receiver selectivity, a signal generator must have good spectral purity. If not, you will be testing your generator and not your receiver.

### The measurement: adjacent channel selectivity

One common measurement for testing receiver rejection of unwanted signals is adjacent channel selectivity. Figure 4 shows a receiver IF (intermediate frequency) pass-band with a signal in-channel at a set sensitivity level. A second signal generator is set one channel spacing away. Its amplitude is increased until the signal punches through the pass-band and distorts the in-channel signal by a set amount. The differences of the two signal levels is called adjacent channel selectivity.

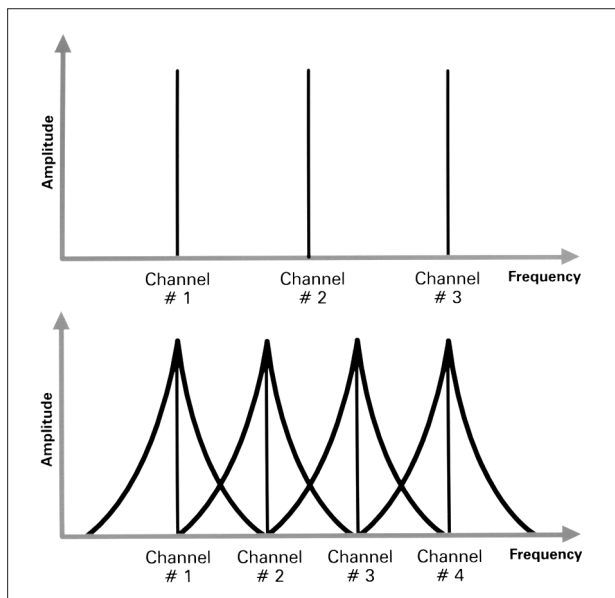


Figure 3. Smaller channel spacings mean greater need for spectral purity

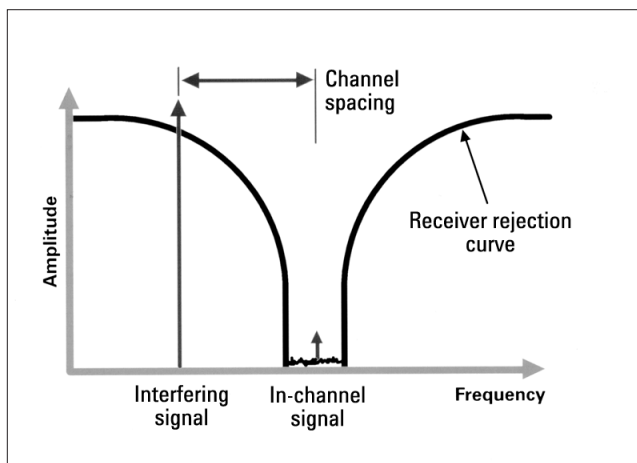


Figure 4. Receiver IF pass-band with in-channel signal present

## How signal generator spectral purity affects measurements

### Phase noise

Figure 5 shows what happens if the signal generator has high levels of phase noise. The phase noise spills into the pass-band, creating higher distortion on the desired signal. The receiver looks worse than it is.

### Spurious

Spurious causes much the same problem as phase noise. If a spurious signal shows up in the channel spacing of the radio, you will be measuring the difference in amplitudes of the spurious signal and the out-of-channel signal generator.

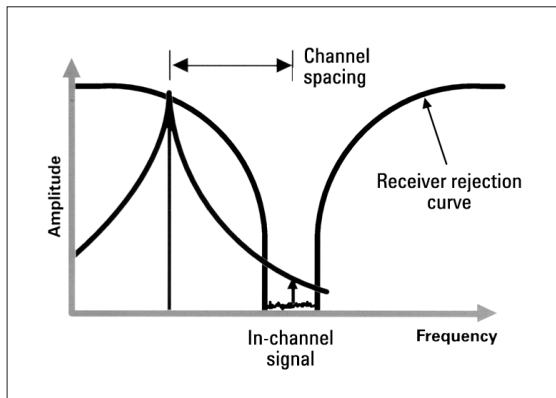


Figure 5. Out-of-channel phase noise causes in-channel distortion

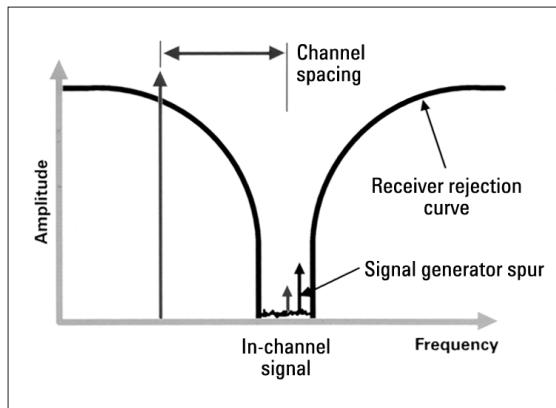


Figure 6. In-channel spurious signals makes a receiver look worse than it is

## Another measurement for receivers

### Hum and noise

Hum and noise measurement determines a receiver's signal-to-noise ratio. It is a ratio of a strong RF signal with audio present to the same signal with no audio present. It is measured in dB.

### Signal generator residual FM

High noise of a signal generator is directly added to the receiver noise. This gives a lower hum and noise ratio. Again it makes the receiver look worse than it is.

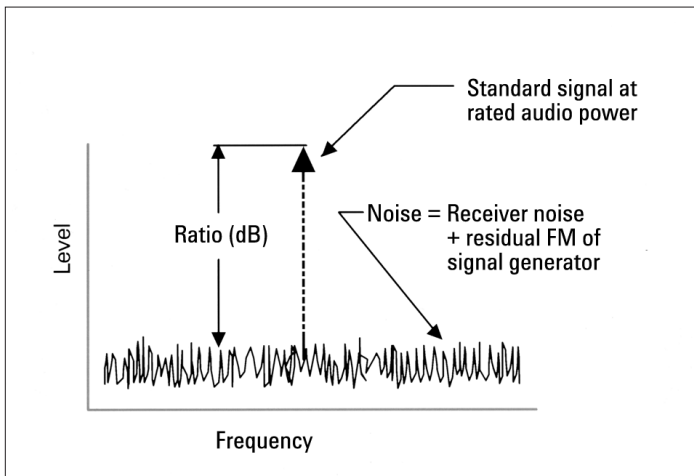


Figure 7. Signal generator residual FM adds to receiver noise levels

## Why is spectral purity important for local oscillator substitution?

### Signal generator as a local oscillator

Spectral purity is needed on signal generators used as local oscillators. Let's look at two signals,  $f_1$  and  $f_2$ , in figure 8. These signals will be mixed with a local oscillator signal (figure 9) down to an intermediate frequency (IF) where highly selective IF filters can separate one of the signals for amplification, detection, and baseband processing. If the desired signal is the larger signal, there should be no difficulty recovering it.

### How signal generator spectral purity affects the measurement

#### Phase noise

Any phase noise on the local oscillator signal is translated directly to the mixer products. If the desired signal is the smaller of the two mixed signals, the translated noise in the mixer output may completely mask the smaller signal.

Even though the receiver's IF filtering may be sufficient to remove the larger signal's mixing product, the smaller signal's mixing product is no longer recoverable. This effect worsens in receivers with high selectivity and wide dynamic range.

#### Spurious

Spurious signals on a local oscillator will cause the desired output to vary in phase at the IF frequency. This is a possible source of intermodulation products.

#### Residual FM

Residual FM or noise is directly added to the signals at the output of the mixer. This effect becomes more critical, the closer the signals are together.

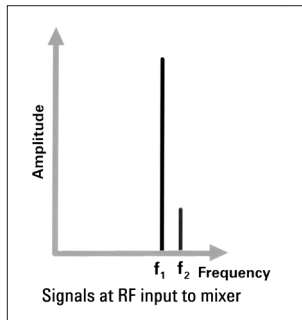


Figure 8. Two signals to be down-converted with a local oscillator

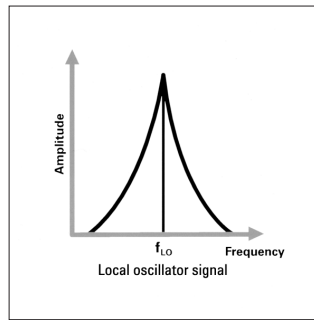


Figure 9. Local oscillator with phase noise

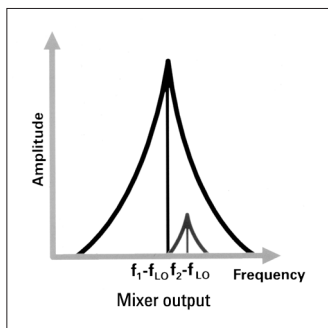


Figure 10. Phase noise masks the lower-amplitude signal

## Spectral purity in local oscillator applications

### Testing radar

Radar systems continue to demand greater resolution of targets. This puts higher requirements for spectral purity on local oscillators/signal generators.

For example, airborne and over-the-horizon radars want to detect slow moving surface vehicles. They must detect very low level return signals, which have very small doppler shifts.

Figure 11 shows signals from the ground return and the smaller doppler-shifted return from the moving vehicle. It also shows the effect of phase noise on the return signal. It will mask out the return or smaller signal.

### Making phase noise measurements of your devices

Another application where spectral purity is critical for a local oscillator (LO) is in phase noise measurements. One of the most sensitive measurement techniques is the two-source phase detector technique. A signal is down converted with an LO to 0 Hz and examined on a low-frequency spectrum analyzer. This proven technique requires a local oscillator with as good, or better, phase noise than the device under test. It is directly added into the measurement.

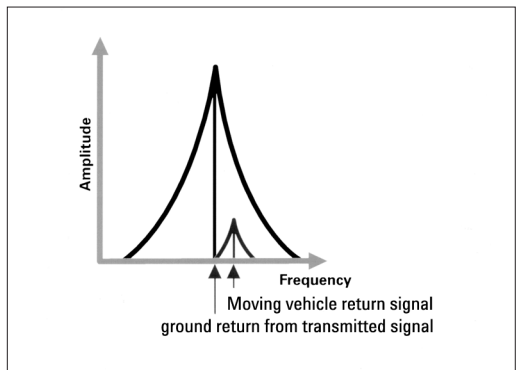


Figure 11. The effect of phase noise on radar

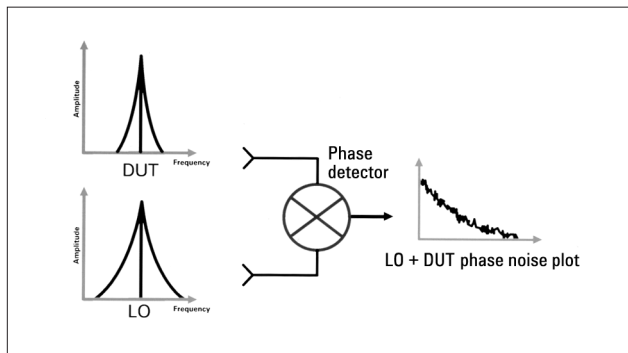


Figure 12. LO noise adds to the noise on the DUT

## Evolving Since 1939

Our unique combination of hardware, software, services, and people can help you reach your next breakthrough. We are unlocking the future of technology.

From Hewlett-Packard to Agilent to Keysight.



For more information on Keysight Technologies' products, applications or services, please contact your local Keysight office. The complete list is available at: [www.keysight.com/find/contactus](http://www.keysight.com/find/contactus)

### Americas

Canada	(877) 894 4414
Brazil	55 11 3351 7010
Mexico	001 800 254 2440
United States	(800) 829 4444

### Asia Pacific

Australia	1 800 629 485
China	800 810 0189
Hong Kong	800 938 693
India	1 800 11 2626
Japan	0120 (421) 345
Korea	080 769 0800
Malaysia	1 800 888 848
Singapore	1 800 375 8100
Taiwan	0800 047 866
Other AP Countries	(65) 6375 8100

### Europe & Middle East

Austria	0800 001122
Belgium	0800 58580
Finland	0800 523252
France	0805 980333
Germany	0800 6270999
Ireland	1800 832700
Israel	1 809 343051
Italy	800 599100
Luxembourg	+32 800 58580
Netherlands	0800 0233200
Russia	8800 5009286
Spain	800 000154
Sweden	0200 882255
Switzerland	0800 805353
	Opt. 1 (DE)
	Opt. 2 (FR)
	Opt. 3 (IT)
United Kingdom	0800 0260637

For other unlisted countries: [www.keysight.com/find/contactus](http://www.keysight.com/find/contactus) (BP-9-7-17)



[www.keysight.com/go/quality](http://www.keysight.com/go/quality)  
Keysight Technologies, Inc.  
DEKRA Certified ISO 9001:2015  
Quality Management System

### myKeysight

#### myKeysight

[www.keysight.com/find/mykeysight](http://www.keysight.com/find/mykeysight)

A personalized view into the information most relevant to you.

[http://www.keysight.com/find/emt\\_product\\_registration](http://www.keysight.com/find/emt_product_registration)

Register your products to get up-to-date product information and find warranty information.

### KEYSIGHT SERVICES

Accelerate Technology Adoption.  
Lower costs.

#### Keysight Services

[www.keysight.com/find/service](http://www.keysight.com/find/service)

Keysight Services can help from acquisition to renewal across your instrument's lifecycle. Our comprehensive service offerings—one-stop calibration, repair, asset management, technology refresh, consulting, training and more—helps you improve product quality and lower costs.



#### Keysight Assurance Plans

[www.keysight.com/find/AssurancePlans](http://www.keysight.com/find/AssurancePlans)

Up to ten years of protection and no budgetary surprises to ensure your instruments are operating to specification, so you can rely on accurate measurements.

#### Keysight Channel Partners

[www.keysight.com/find/channelpartners](http://www.keysight.com/find/channelpartners)

Get the best of both worlds: Keysight's measurement expertise and product breadth, combined with channel partner convenience.

This was formerly known as app note 388

