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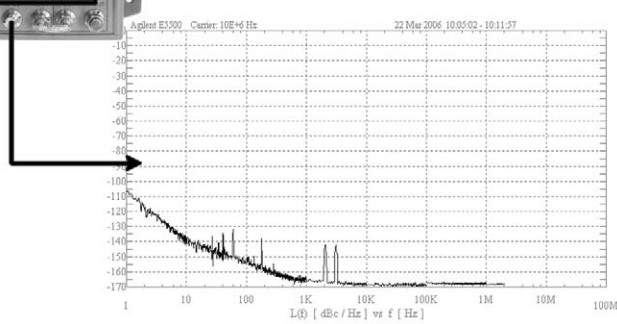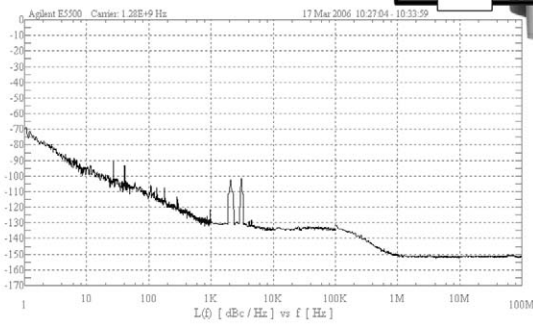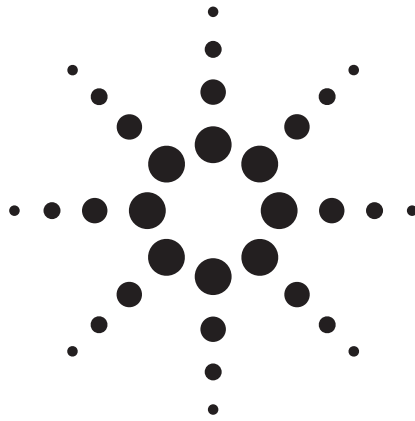
Using external, low-noise frequency dividers to improve the E8663B phase noise performance below 250 MHz

Product Note

Introduction

The E8663B analog signal generator, along with the E8257D (with appropriate options), provides excellent signal power, resolution, stability, and analog modulation performance for coaxial applications to 3 GHz and is a high performance replacement for the RF signal generator performance standards - the Agilent 8662A/63A signal generators that have been discontinued and are no longer available.

The purpose of this note is to demonstrate how to use low-noise frequency dividers with the E8663B signal generator to improve phase noise performance for frequencies less than 250 MHz (the output frequencies of the heterodyne band), to discuss other performance limitations resulting from using external frequency dividers, and to discuss applications that benefit from significantly improved phase noise performance. This note applies equally to the E8257D when configured with options 1EA, UNX, and UNT.
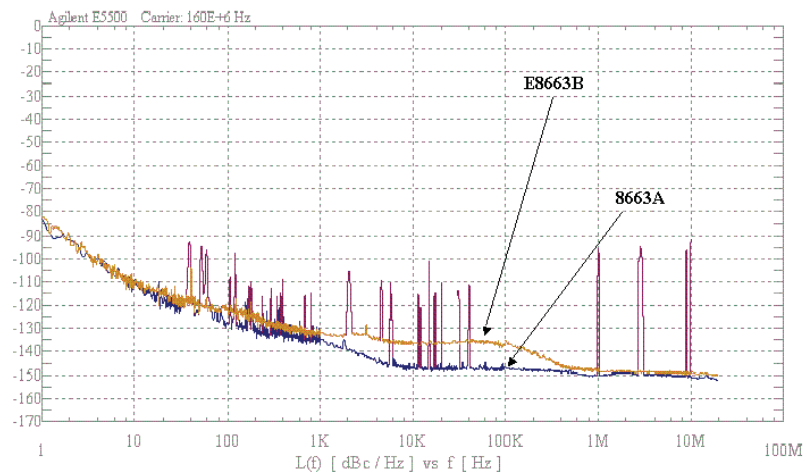
Performance Summary of the E8663B

The E8663B meets or exceeds the performance of the 8662A/63A signal generators for frequencies greater than 250 MHz. As shown in Figure 1, the typical phase noise performance of the E8663B is lower than the 8662A/63A at 1280 MHz except for offsets far from the carrier where the E8663B internal dividers
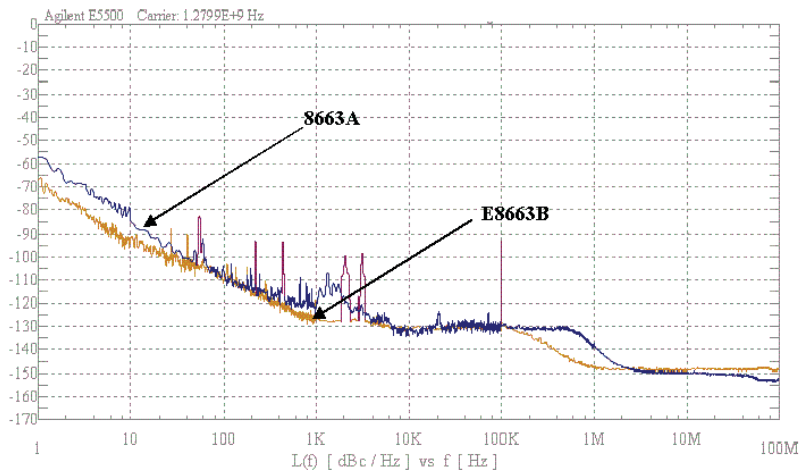
additive noise limits the performance.

Figure 1. Phase noise of the 8662A/63A versus the E8663B at 1280 MHz

Below 250 MHz, the E8663B uses an internal heterodyne structure to provide exceptional frequency (FM) and phase (PM) modulation characteristics. This heterodyne structure, similar to the structure in the 8662A/63A for frequencies below 120 MHz, results in E8663B phase noise performance that is slightly higher than the phase noise performance of the 8662A/63A signal generators in

frequencies between 120 and 250 MHz.

Improving the E8663B Phase Noise Performance for Frequencies Less Than 250 MHz

E8663B operation

The E8663B uses internal frequency dividers with its internal, base frequency band to provide output frequencies in bands: 2 to 3.2 GHz, 1 to 2 GHz, 500 MHz to 1 GHz, and 250 to 500 MHz. These internal dividers not only divide frequency, but also divide the base frequency band's FM and PM capability. As shown in Figure 3, the phase noise reduces 6 dB each time the frequency is divided. The compression of data beyond 500 MHz shows the additive noise floor of the
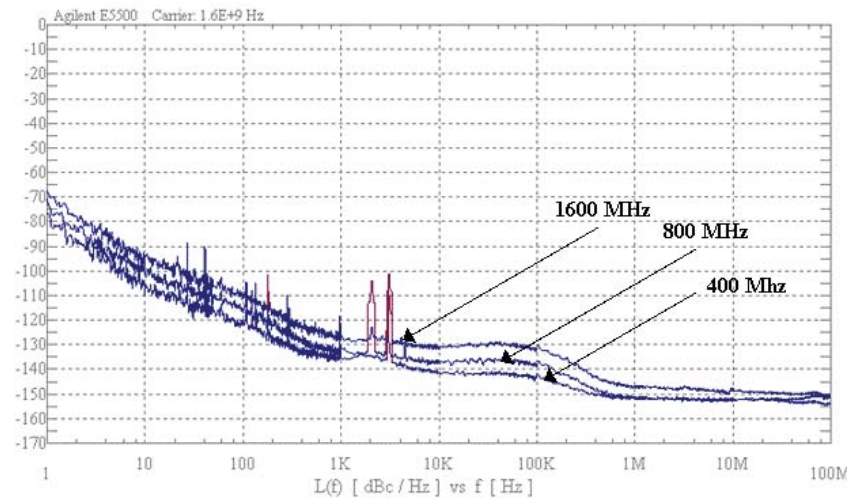
internal dividers.

Figure 3. Typical phase noise performance of frequency bands > 250 MHz

The 100 kHz to 250 MHz frequency band uses the 500 MHz to 1 GHz frequency range capabilities as the synthesized frequencies for the heterodyne operation and hence has similar FM, PM, and phase noise performance of the 500 MHz to 1 GHz band. As shown in Figure 4, when frequencies are reduced by a factor of
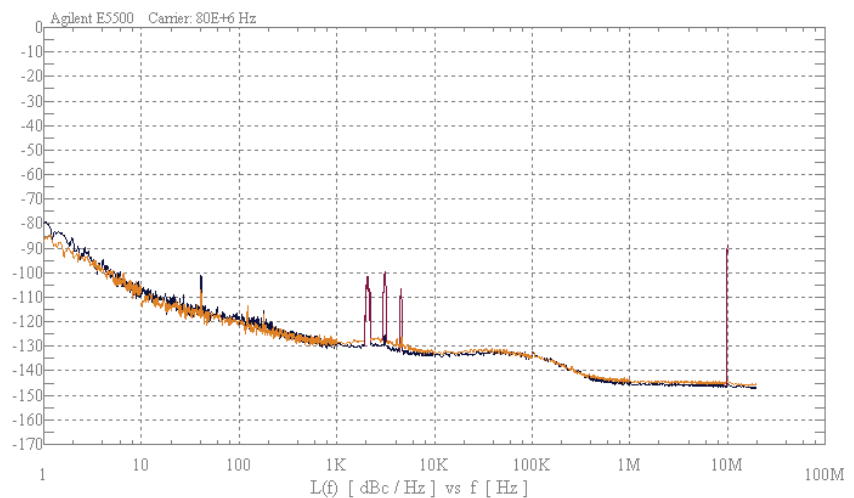
2 the resulting phase noise performance changes little.

Figure 4. Typical phase noise performances of frequencies < 250 MHz

Dividing Frequencies Also Reduces the Phase Noise Characteristics

When a carrier signal is routed through a frequency divider, the carrier frequency is reduced directly by the divide number – n:

$$F_{out} = F_{in} * 1/n \text{ where } F_{in} \text{ is the input frequency and n is the divide number}$$

In the case of a divide-by-2 divider, the output frequency is $1/2$ of the input frequency.

In addition to the reduction in the carrier frequency, the carrier phase noise is reduced by a 20 log (n) factor:

$$L(f)_{out} (dB) = L(f)_{in} (dB) - 20*log(n)$$

For the example of a divide-by-2 divider, the output frequency's phase noise will be 6 dB lower (20*log2) than the phase noise of the input frequency. Figure 2 demonstrates this clearly, as the phase noise characteristics of each divide-by-2 frequency band is 6 dB lower than the previous, higher frequency band. This reduction in noise is ultimately limited by the additive (residual) phase noise of the dividers and frequency dividing will not reduce the associated phase noise characteristic. The far-from-carrier phase noise characteristics in Figure 3 demonstrate this (offsets greater than 500 kHz from carrier).

When using FM or PM in a signal generator, dividing a carrier frequency will reduce the FM deviation and the PM deviation by a factor of 1/n. For a divide-by-2 scenario, this results in modulation deviation capability that is reduced by a factor of 2 for each divide-by-2 stage.

4

External Low Noise Frequency Dividers

External low noise dividers need to have certain capabilities to be useful:

- flexible divide ratios – typically divide by 2^n where n= 0,1,2,3,...
  (n is large enough to meet the application needs)

- low additive (residual) phase noise - the lower the additive noise, the better

- a wide input frequency range

- sufficient RF output power (without using an additional, external RF power amplifier)
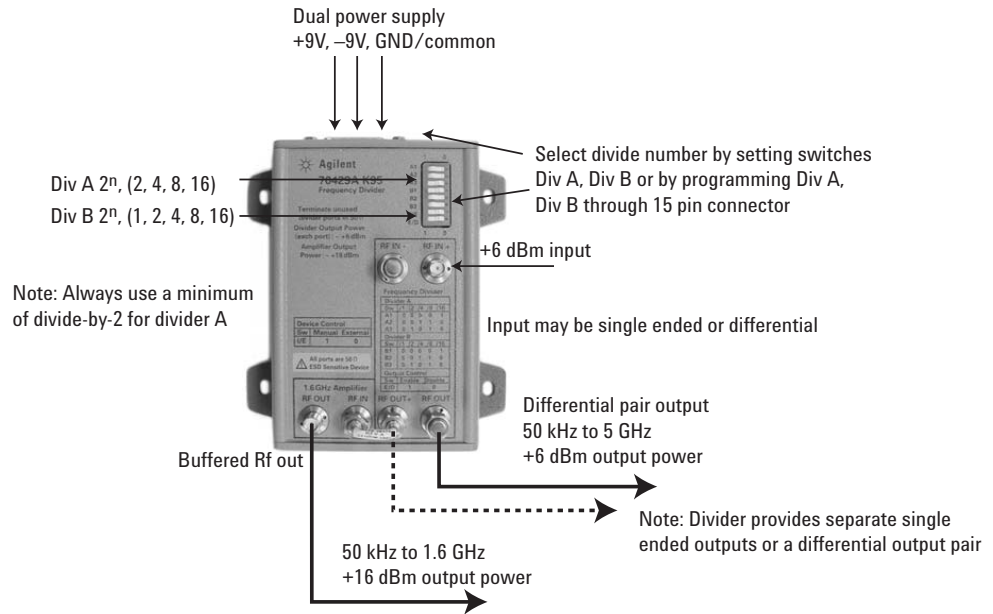

Dual power supply
+9V, –9V, GND/common

Div A 2^n, (2, 4, 8, 16)
Div B 2^n, (1, 2, 4, 8, 16)

Select divide number by setting switches
Div A, Div B or by programming Div A,
Div B through 15 pin connector

+6 dBm input

Note: Always use a minimum
of divide-by-2 for divider A

Input may be single ended or differential

Differential pair output
50 kHz to 5 GHz
+6 dBm output power

Buffered Rf out

Note: Divider provides separate single
ended outputs or a differential output pair

50 kHz to 1.6 GHz
+16 dBm output power

Figure 5. 70429A Option K95 low noise frequency divider

The Agilent 70429A Option K95 is a low-noise, flexible divide-ratio divider with a wide input frequency range and high output power. It provides:

- divide numbers from 2 to 256 in powers of 2 (divide by 2^n, n=1 to 8)

- an input frequency range of 50 kHz to 10 GHz

- high output power; single ended 50 ohm output of +16 dBm from 50 kHz to 1.6 GHz or differential 50 ohm output of +6 dBm from 50 kHz to 5 GHz

- very low additive noise characteristics

The 70429A Option K95 output limiting amplifiers do not allow power control of the output signal. Any desired power control at the output of the divider can only be accomplished through an external step attenuator (not shown in Figure 5). In addition, the shape of the output signal is a square wave. Applications that require low harmonics will also require a low pass filter to reduce the presence of odd harmonics. This unique divider requires a dual voltage supply of + 9V (100 mA nominal) and –9V (700 ma nominal).
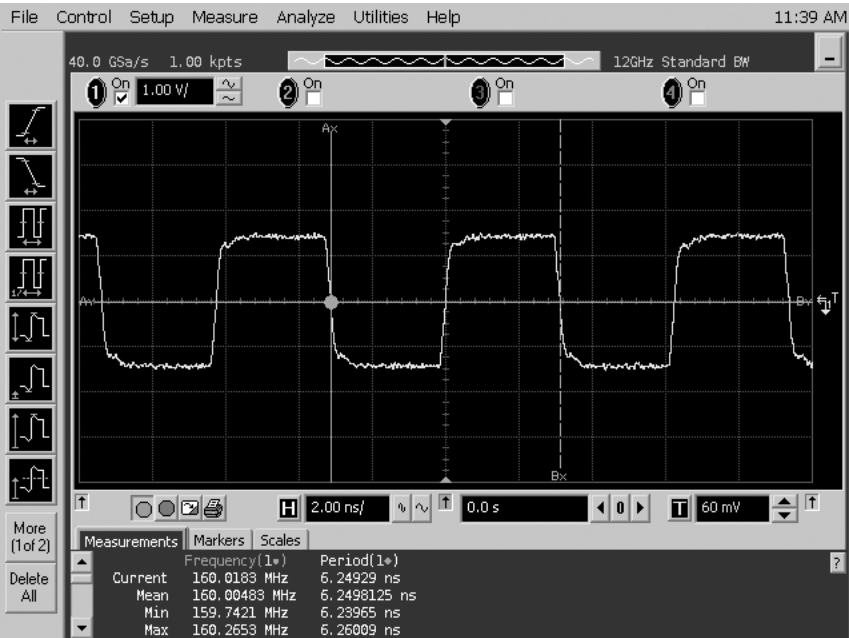

Figure 6. Typical 70429A Option K95 high power output waveshape

The 70429A Option K95 divider has a two-stage divide network: divider A (divide by 2^n, n = 1 to 4) and divider B (divide by 2^n, n = 1 to 4). The total divide number will be divider A x divider B, providing a total divide-by range from 2 to 256. The divide number is set by using the DIP switches or programmatically via the control lines (refer to the 70429A operating manual). It is highly recommend that divider A is set to a minimum of a divide-by-2 setting.

As with using internal frequency dividers, any reduction in carrier frequency with the external divider will also reduce the FM and PM deviation maximums. In addition, amplitude modulation (AM) and pulse modulation are not possible through an external divider.
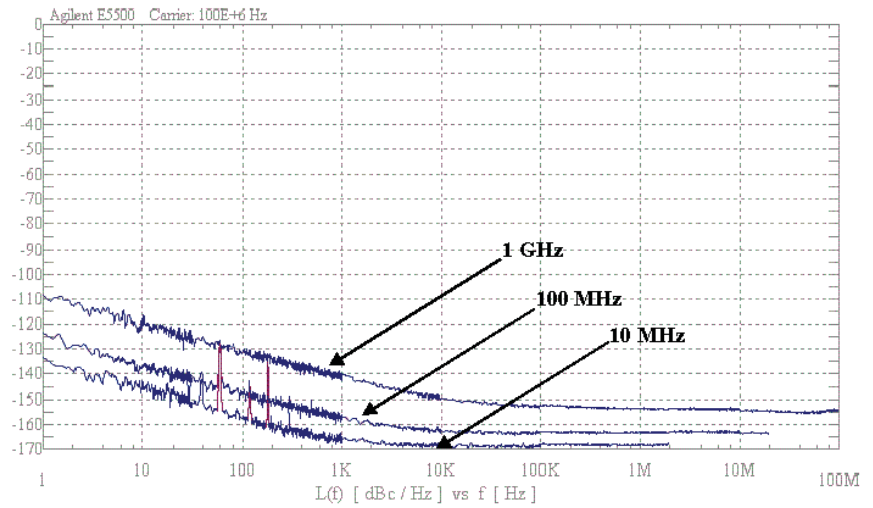

Figure 7. Typical additive noise characteristics of 70429A Option K95 at different output frequencies

Notice that the additive noise floor is a function of the divide number. 10 MHz out uses a divide number of 256, 100 MHz uses a divide number of 64, and 1 GHz uses a divide number of 8. The higher the divide number that can be used, the lower the divider additive noise will be.

Using the Agilent 70429A Option K95 Divider With the E8663B

Figure 8 shows the basic connection diagram between the E8663B and the 70429A Option K95 divider to improve phase noise performance for frequencies < 250 MHz. The recommended input power to the K95 is +6 dBm and is achieved by setting the E8663B RF output power to +16 dBm followed by a 10 dB attenuator. This approach provides the best possible signal-to-noise ratio at the output of the signal generator.
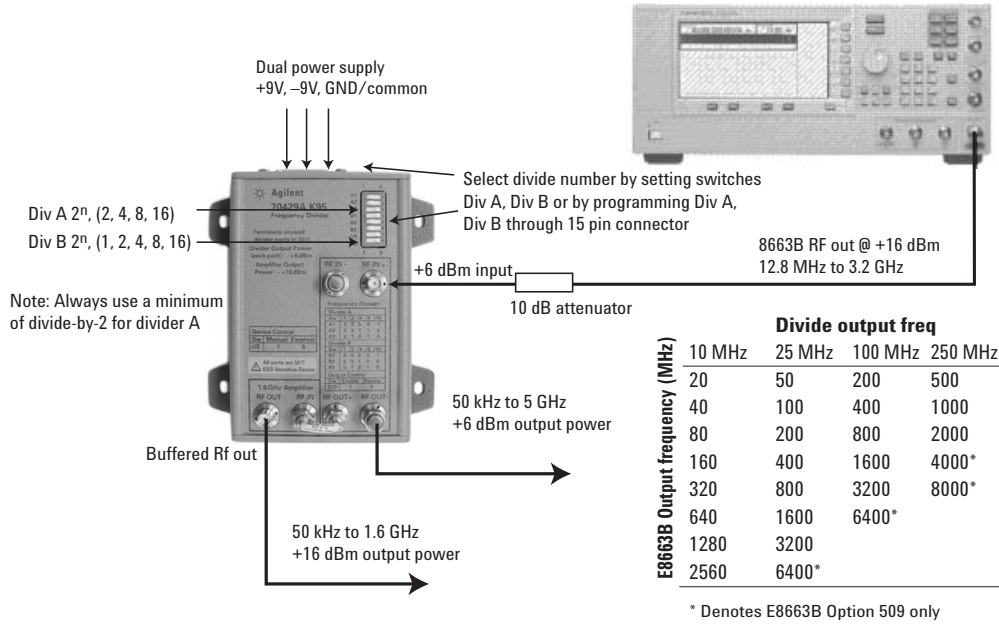

Dual power supply
+9V, −9V, GND/common

Select divide number by setting switches Div A, Div B or by programming Div A, Div B through 15 pin connector

Div A 2^n, (2, 4, 8, 16)
Div B 2^n, (1, 2, 4, 8, 16)

8663B RF out @ +16 dBm
12.8 MHz to 3.2 GHz

+6 dBm input

Note: Always use a minimum of divide-by-2 for divider A

10 dB attenuator

50 kHz to 5 GHz
+6 dBm output power

Buffered Rf out

50 kHz to 1.6 GHz
+16 dBm output power

E8663B Output frequency (MHz)	Divide output freq			
	10 MHz	25 MHz	100 MHz	250 MHz
	20	50	200	500
	40	100	400	1000
	80	200	800	2000
	160	400	1600	4000*
	320	800	3200	8000*
	640	1600	6400*	
	1280	3200		
	2560	6400*		

* Denotes E8663B Option 509 only

Figure 8. Connecting the 70429A Option K95 to the E8663B

The divider output signal will be from the single-ended, buffered, output connector that provides high power signals from 50 kHz to 1.6 GHz.

The E8663B Option 503 has a maximum output frequency of 3.2 GHz, thereby limiting the combinations of input frequency and divide ratio to achieve the desire output frequency < 250 MHz. For example, if the desired output frequency is 250 MHz, then the possible input frequencies (and divide numbers) are limited to 500 MHz (div 2), 1 GHz (div 4), and 2 GHz (div 8). The E8663B Option 509 has a maximum output frequency of 9 GHz and provides additional combinations.

The lower the output frequency desired, the greater the numbers of possible combinations of input frequency and divide number are available. For example, if a 10 MHz output frequency is desired, then there are 8 possible input frequencies and divide numbers possible to achieve it with the highest being 2.56 GHz and a divide ratio of 256. The highest possible divide number will yield the lowest divider additive noise.

Typical Examples of Comparisons to the Agilent 8662A/63A Signal Generators

Example 1. 250 MHz improvement

The 70429A Option K95 divider can improve phase noise performance for a 250 MHz output frequency, but only for frequencies greater than 10 Hz offset from the carrier. Figure 9 shows three noise curves for the E8663B. The upper trace shows the phase noise for a 2 GHz output frequency which will be the input frequency for the 70429A Option K95 divider set to a divide-by-8 factor.
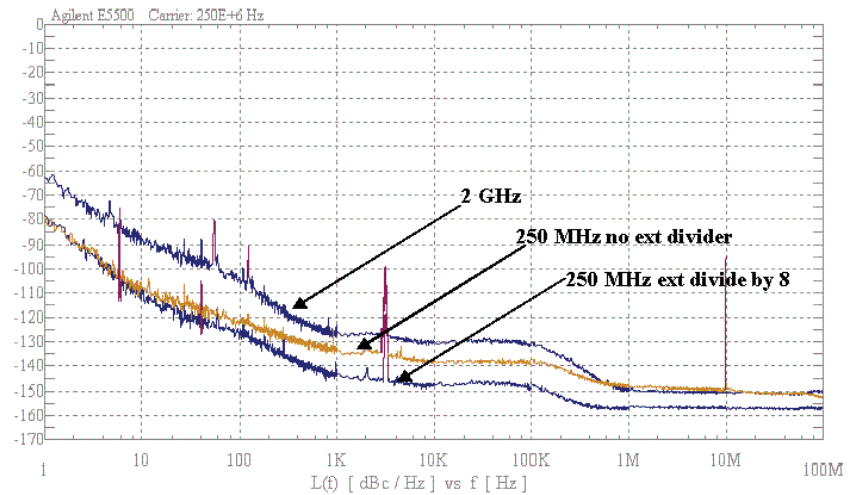

Agilent E5500 Carrier: 250E+6 Hz

2 GHz

250 MHz no ext divider

250 MHz ext divide by 8

L(f) [dBc / Hz] vs f [Hz]

Figure 9. Typical E8663B 250 MHz phase noise improvement

The lowest trace is the phase noise of the 250 MHz output frequency of the 70429A Option K95 (the divider set for divide-by-8). The difference between these two traces is 18 dB (n=3, n x 6 dB improvement) except for offsets far from the carrier where the additive noise floor of the 70429A Option K95 limits any improvement. The middle trace is the phase noise performance of the E8663B with a 250 MHz output frequency and no external divider. The E8663B is still in the internal divider mode. Notice that the higher noise floor of the internal divider causes the noise trace between 1 kHz offset and 100 kHz offset to be ~ 3 dB greater than it actually is.

Example 2. 160 MHz improvement

Figure 10 shows three traces. The upper trace is the typical phase noise performance of the E8663B at 2560 MHz. The lowest trace is the typical phase noise performance of 160 MHz output from the 70429A Option K95 (using a divide by 16 factor, 24 dB improvement) with 2560 MHz as the input frequency. The middle trace is the typical phase noise of the E8663B with a 160 MHz output using no external divider (when the E8663B is in its heterodyne band). Overall improvement using the 70429A Option K95 external divider is mostly for offsets > 10 Hz from the carrier.
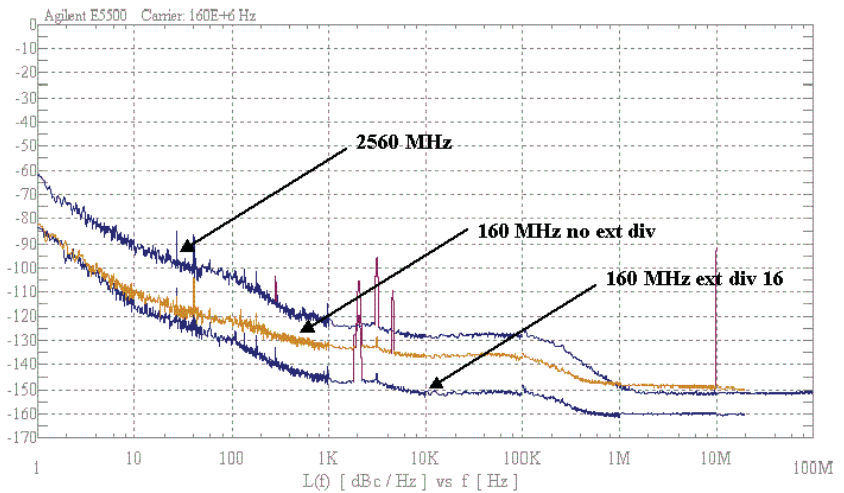

Figure 10. E8663B improvement at 160 MHz

Example 3. 10 MHz improvement

Figure 11 shows three traces. The upper trace is the typical phase noise performance of the E8663B at 1280 MHz. The lowest trace is the typical phase noise performance of 10 MHz output from the 70429A Option K95 (using a divide by 128 factor, 42 dB improvement) with 2560 MHz as the input frequency. The middle trace is the typical phase noise of the E8663B with a 10 MHz output using no external divider (when the E8663B is in its heterodyne band). Only the external dividers additive noise floor limits the overall improvement for offset frequencies greater than 1 kHz.
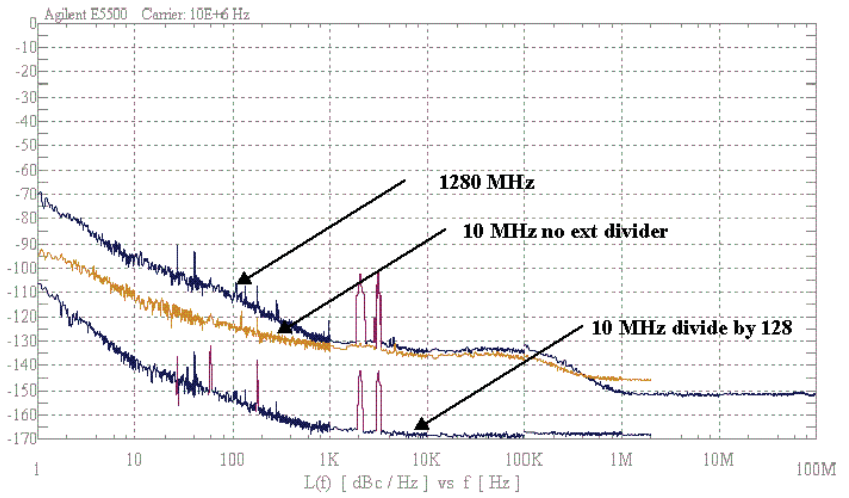

Figure 11. Typical E8663B 10 MHz improvement

Example 4. E8663B comparisons to the 8662A/63A signal generators

At greater than 250 MHz, when the E8663B is not in its heterodyne band and when not using any external frequency divider, the performance of the E8663B is generally better than the 8663A, as shown in Figure 12. When the 70429A Option K95 external divider is used (with a divide-by-8 factor), the E8663B is always better for offset frequencies greater than 10 Hz, and comparable for offset frequencies less than 10 Hz.
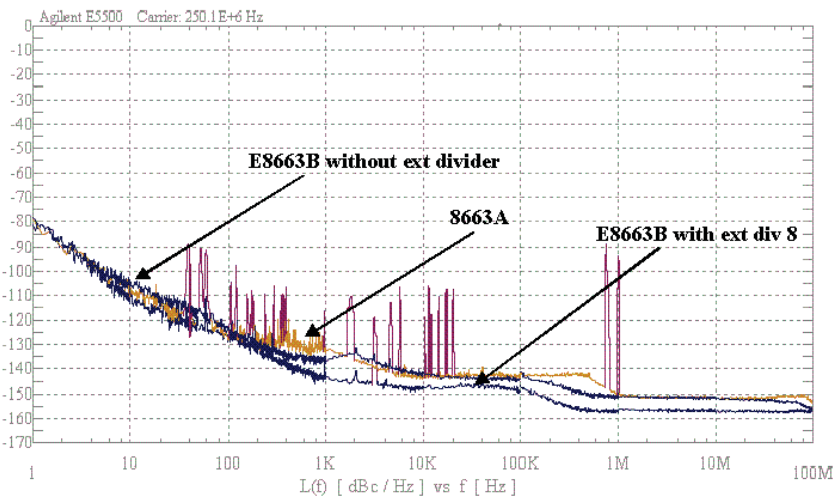

Figure 12. Typical 250 MHz comparison to 8663A

As shown in Figure 13, at 160 MHz, the E8663B is in its heterodyne band and its performance is sometimes better than the 8663A. When the 70429A Option K95 external divider is used (with a divide-by-16 factor), the E8663B is always better for all offset frequencies.
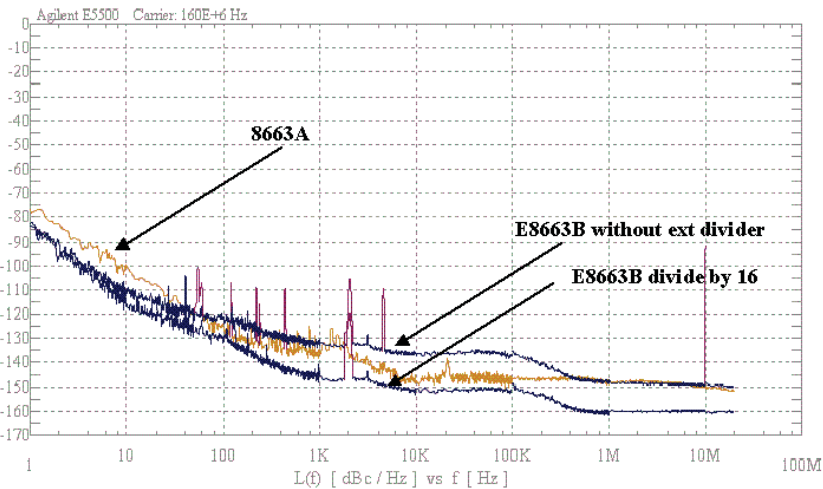

Figure 13. Typical 160 MHz comparison to 8663A

At 100 MHz, the E8663B is in its heterodyne band and its performance is sometimes better than the 8663A as shown in Figure 14. When the 70429A Option K95 external divider is used (with a divide-by-32 factor), the E8663B is always better for all offset frequencies.
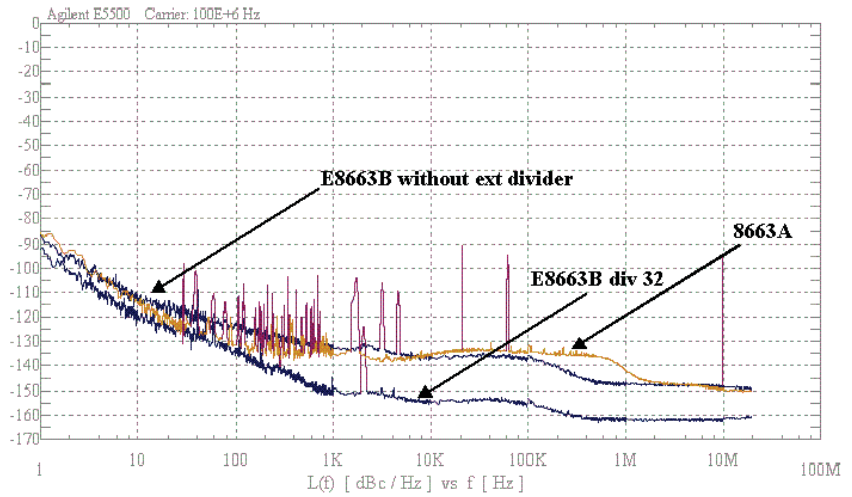

Figure 14. Typical 100 MHz comparison to 8663A

Figure 15 clearly shows the value of adding the external divider. The highest trace is the E8663B at 10 MHz and no divider, the middle trace is the 8663A and the lowest trace is the E8663B with an external divider (divide-by-128).
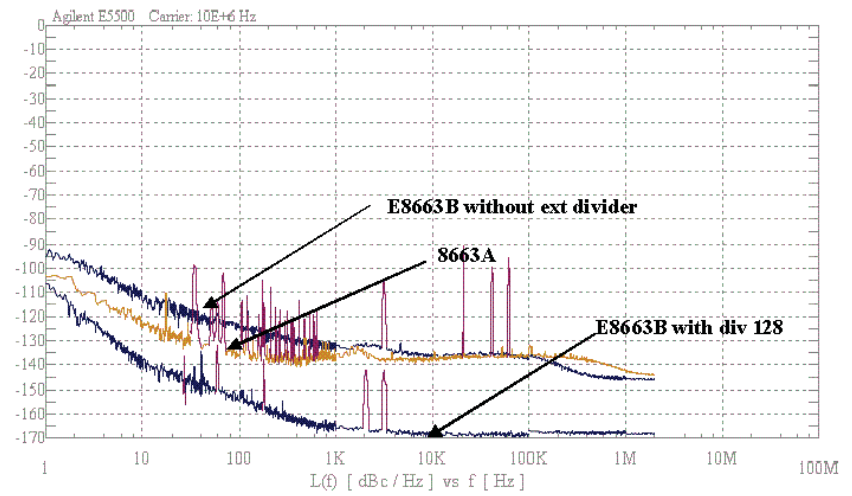

Figure 15. Typical 10 MHz comparison to 8663A

Applications for Very Low Phase Noise RF and IF Signals

Low noise radars and low jitter clocks

The E8663B may be used for LO substitution in low noise radars and low jitter clocks in wideband optical communications systems and IF substitution in low noise communications systems

LO substitution, low noise or low jitter receivers

LO substitution, when testing low noise or low jitter receivers, requires sources that have very low phase noise. Depending on the receiver IF filtering, low harmonics may or may not be critical.
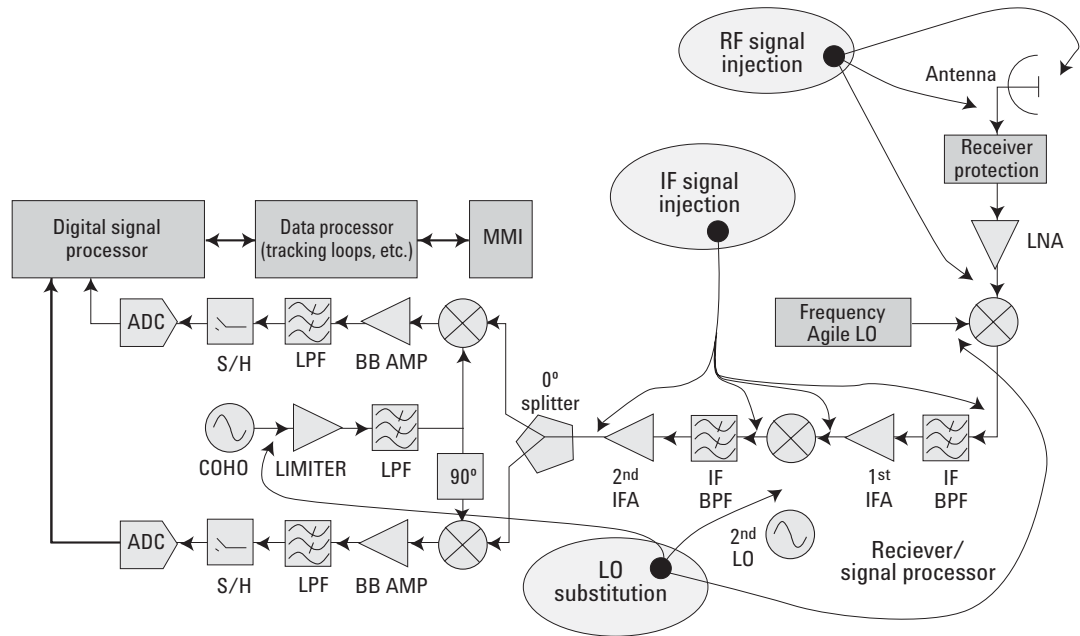

Figure 16. Typical low noise receiver diagram

IF substitution, low noise or low jitter receivers

IF substitution, while requiring low phase noise, also requires power control and low harmonics. When using the 70429A Option K95 external divider with the E8663B for receiver testing, external filtering and power control on the output of the frequency divider will be necessary and will depend specifically on the receiver being tested.

Crystal oscillators and other low noise oscillators and synthesizers

The E8663B can be used as a low noise reference source for measuring the phase noise performance of crystal oscillators and other low noise oscillators and synthesizers. To ensure that the E8663B provides the lowest possible phase noise performance when in DCFM, use less then 0.1 ppm/Hz tune sensitivity. Simply multiply the output frequency of the DUT (Hz) by 0.1×10^{-6} to obtain the maximum Hz/Volt DCFM sensitivity value to use.
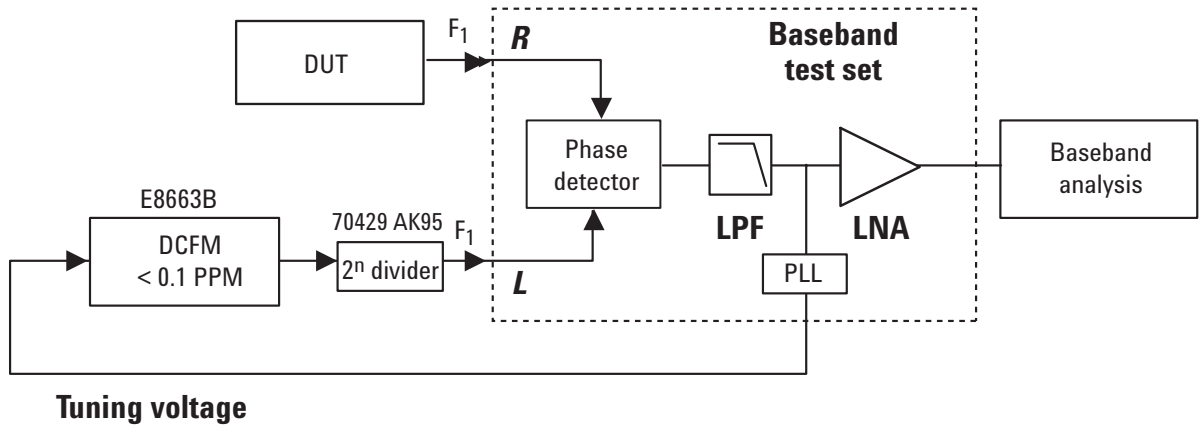

Figure 17. Typical low noise oscillator phase noise measurement diagram

When used as a low noise reference source for testing low noise oscillators such as XO's and VCXO's, the E8663B with the 70429A Option K95 divider provide a very low noise, frequency flexible solution that works seamlessly with the Agilent E5500 series phase noise measurement solution.

Web Resources

For more information about the Agilent E8663B, go to:
www.agilent.com/find/e8663b

Related Agilent Literature

Agilent E8663B Analog Signal Generator, Data Sheet, Literature number 5989-4866EN

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