Agilent PN 4395/96-1

How to Measure Noise Accurately Using the Agilent Combination Analyzers

Product Note

Agilent Technologies 4395A/4396B Network/Spectrum/Impedance Analyzer

Introduction

One of the major concerns in C/N (carrier/noise) ratio measurement is understanding the factors that influence noise measurement accuracy. In noise measurements, different spectrum analyzers provide different measurement results caused by a difference of the signal processing algorithms or different RBWs (resolution bandwidths).

In this note, we will compare the combination analyzers (Agilent 4395A and 4396B) and conventional spectrum analyzers (Agilent 4195A, 3588A, 3589A, 3585A/B) with respect to noise measurement accuracy, and explain why the combination analyzers ensure higher accuracy in noise measurement.

Features of the Combination Analyzers

Each of the combination analyzers (4395A and 4396B) offers high performance, is economically designed, and contains vector network, spectrum, and impedance measurement functions available in one instrument. This design strategy allows measurement of gain, phase, group delay, noise, spurious, C/N ratio and more—all of which are indispensable for evaluating the performance of electronic components and circuitry in the important 500 and 1800 MHz frequency range. For spectrum analysis, in particular, these combination analyzers cover an extremely wide frequency range (4395A: 10 Hz to 500 MHz, 4396B: 2 Hz to 1.8 GHz) and feature the stepped FFT (fast Fourier) technique (4395A: all resolution bandwidth, 4396B: resolution bandwidth of 1 Hz to 3 kHz), providing a sweep time 20 to 100 times shorter than the conventional analyzers.

In addition, they use digital filters with a steep shape factor to provide substantially improved performance in analyzing closely-spaced signals. The analyzers are designed with utmost care to minimize internal generation of noise, thus allowing signals of extremely low levels to be measured without sacrificing its measurement speed. Furthermore, the time gated spectrum analysis function (Option 1D6) is optionally available for repetitive burst signal analysis.

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Differences between Analyzer Models

Measurement results vary from one analyzer model to another most frequently due to the following:

1. Difference in signal detection method between spectrum analyzers

2. Difference in RBW and its shape factor

Each difference is discussed in detail through comparison between the combination analyzers and other spectrum analyzers:

1. Difference in signal detection method between spectrum analyzers

Spectrum analyzers use one of the following detection methods:

A. Conventional detection method using a logarithmic amplifier and an envelope detector

B. True RMS level detection method based on the digitized incoming signal

When the conventional detection method is used, the noise level appears approximately 2.5 dB lower than the true RMS value, which is approximately 1.45 dB at the output of the logarithmic amplifier, and 1.05 dB at the output of the envelope detector. Therefore, a correction factor of 2.5 dB must be added to the measured noise level to provide the actual (RMS) level. Detection method B, however, leaves no room for error because the true RMS value of the incoming signal is obtained. The combination analyzers employ the true RMS level detection method, thus ensuring accuracy in noise measurement. Table 1 shows the detection method used by each model and the correction required to obtain the actual noise level.

2. Difference in RBW and shape factor

Noise is defined as spectral energy that is present over an entire frequency band. Consequently, measured noise level varies depending on the RBW (resolution bandwidth) of the filtering and the shape factor used by each analyzer.

The RBW filter (IF filter provided at the last filtering stage in an analyzer) can be broadly divided into two types: analog and digital filters. An analog RBW filter may cause up to 20% inaccuracy in its bandwidth. This means that the indicated noise level can be inaccurate by as much as 1.5 dB. A digital filter, however, causes no more than 1% inaccuracy in its bandwidth, which results in an inaccuracy of 1 dB or less.
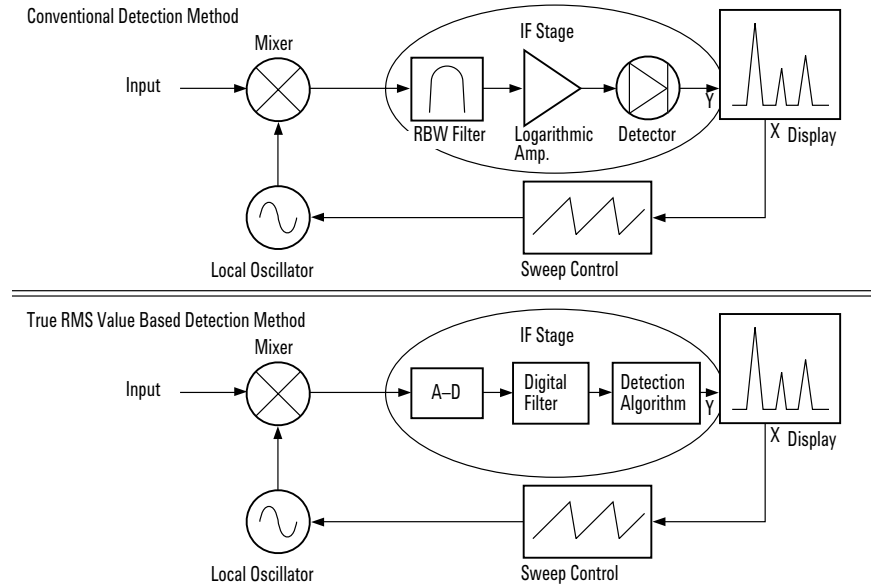

Figure 1. Difference in detection method

Table 1. Detection method of analyzers and correction required to obtain actual noise level

Model	Detection Method	Correction Required
3585A/B	(1) Logarithmic amplifier + envelope detection	Measurement results + 2.5 dB
4195A	(1) Logarithmic amplifier + envelope detection	Measurement results + 2.5 dB
3588A/89A	(2) True RMS level detection	Not required
4395A	(2) True RMS level detection	Not required
4396B	(2) True RMS level detection	Not required

The Agilent combination analyzers use digital RBW filters (4395A: all RBWs, 4396B: 1 to 3 kHz RBW), thus minimizing inaccuracy for precise measurement of noise levels. In addition, these filters offer a steep shape factor for substantially improved performance in analyzing signals whose frequencies are spaced close to one another.

The effective noise bandwidth (ENBW) is generally used for noise level measurement because the shape of the real RBW filter (IF filter provided at the last filtering stage in an analyzer) is not completely rectangular. Figure 2 shows the definition of effective noise bandwidth. Effective noise bandwidth (ENBW) is normally represented by k $\times$ RBW, where factor k is determined by the shape factor of RBW filter. Table 2 shows the correspondence between RBWs and ENBWs for each analyzer model.

In general, the normalized noise level (dBm/Hz) measured by noise marker function is equal in different RBWs measurements with the different spectrum analyzers. Also, a noise level measured in a specific bandwidth can be normalized to represent the corresponding level in the 1-Hz or any other bandwidth. In this case, we calculate the correction factor first, and then subtract this factor from the measured noise level as shown below.

Correction factor = 10 $\times$ log ((ENBW to be normalized)/(ENBW in which the noise level is measured))
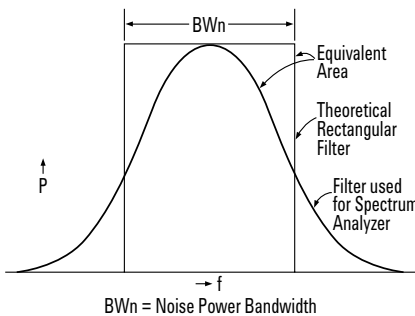

BWn = Noise Power Bandwidth

Figure 2. Effective noise bandwidth

When you wish to normalize the noise level measured at RBW = 30 kHz with the 4396B for the 1-Hz bandwidth,

Correction factor = 10 $\times$ log (1/32.1 k) = –45.1 dB

Thus, the noise power (power spectrum density) normalized for the true 1-Hz bandwidth can be obtained by subtracting 45.1 dB from the noise level measured at RBW = 30 kHz.

Ensuring Consistency between Noise Levels Obtained by Different Analyzer Models

When the noise marker function is not used, noise levels measured with different analyzer models are not always consistent with one another due to the difference in detection method or RBW (ENBW), as mentioned earlier. To ensure consistency, therefore, corrections are required to compensate for the difference in measured levels, which result from the difference in detection method and bandwidth.

The following shows how to normalize a noise level measured with one analyzer to obtain the corresponding level with other analyzer.

As an example, we consider noise level N measured at RBW = 30 kHz with the 4395A and normalize it to obtain the corresponding level at RBW = 30 kHz with the 4195A. First, make a correction to compensate for the difference in measured level—a result of the difference in the detection method. The 4395A employs the true RMS level detection method while the 4195A uses the logarithmic amplifier and envelope detection method. Consequently, the noise level measured with the 4195A is approximately 2.5 dB lower than that with the 4395A. We must also use the ENBW to calculate the correction factor for normalization.

Table 2. Correspondence between RBWs and ENBWs for analyzer models

3585A/B		3588A/89A		4195A		4395A		4396B	
RBW	ENBW	RBW	ENBW	RBW	ENBW	RBW	ENBW	RBW	ENBW
		17 k	18 k					3 M	3.21 M
		9.1 k	9.6 k			1 M	1.01 M	1 M	1.02 M
		4.6 k	4.9 k	300 k	284 k	300 k	303 k	300 k	315 k
		2.3 k	2.4 k	100 k	101 k	100 k	101 k	100 k	108 k
30 k	33.3 k	1.2 k	1.3 k	30 k	28.2 k	30 k	30.3 k	30 k	32.1 k
10 k	11.1 k	580	614.8	10 k	10.6 k	10 k	9.91 k	10 k	10.4 k
3 k	3.3 k	290	307.4	3 k	2.97 k	3 k	3.14 k	3 k	3.031 k
1 k	1.1 k	150	159	1 k	0.95 k	1 k	1.01 k	1 k	1.103 k
300	333	73	77.4	300	310	300	310	300	319
100	111	36	38.2	100	103	100	98.2	100	108
30	33.3	18	19.1	30	33.8	30	31.2	30	31.9
10	11.1	9.1	9.6	10	9.7	10	10.1	10	10.8
3	3.3	4.5	4.8	3	2.96	3	3.07	3	3.36
1	1.1	2.3	2.4			1	0.975	1	1.08
		1.1	1.2						

The ENBW for RBW = 30 kHz in the 4395A is 30.3 kHz while that for RBW = 30 kHz in the 4195A is 28.2 kHz.

Thus,

Correction factor = 10 log (28.2 kHz/30.3 kHz) = −0.3 dB

Adding the difference in measured noise level and the correction factor,

−2.5 dB − 0.3 dB = −2.8 dB

Therefore, noise level N (dBm) measured @RBW = 30 kHz in the 4395A would be measured as N−2.8 (dBm) @RBW = 30 kHz in the 4195A. For example, shown in Figure 3 is a noise signal that is measured as approximately −88 dBm @RBW = 30 kHz in the 4395A.

If we measure this noise at RBW = 30 kHz in the 4195A, it should be corrected as approximately −90.8 dBm (N−2.8 = −88−2.8 = −90.8 dBm). The noise level was measured as approximately −90.8 dBm, as shown in Figure 4. Thus, theoretical results are in good correlation with measurement data.

Measurement Format at Noise Measurements

The Agilent combination analyzer family (4395A and 4396B) has two methods for automatic normalization (spectrum power density automatic calculation (dBm/Hz)). One is to use the noise format function, and the other is to use marker noise function. The noise format function allows you to automatically set the detection model to the sample mode (which is equal to the peak-off mode), to normalize all measurement results to the value at 1 Hz ENBW, and to display the normalized value (dBm/Hz) on the screen.

The marker noise function allows you to normalize the value at the marker position to the value at 1 Hz ENBW. This is the same function as the marker noise function in the other conventional spectrum analyzers (Agilent 3585A/B, 3588A/89A) except for the detection mode setting. In the conventional spectrum analyzers, when the noise marker function is turned to ON, the detection mode is automatically set to the sample mode and several measurements are executed. After that, the average value (by calculating these results) is normalized to the value at 1 Hz ENBW (dBm/Hz). In contrast, when the combination analyzer's marker noise function is turned to ON, the detection mode is NOT set to the sample mode automatically, and the averaging is NOT performed. When the Combination Analyzer's marker noise function is used, the detection mode must be set to the sample mode, and the VBW must be set to the proper value for averaging the noise value.
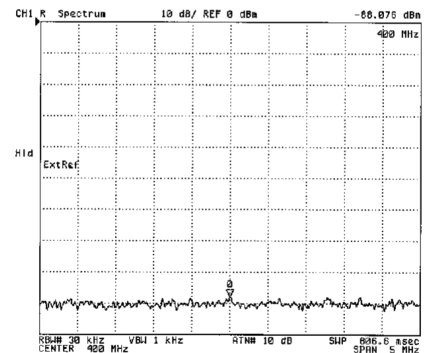

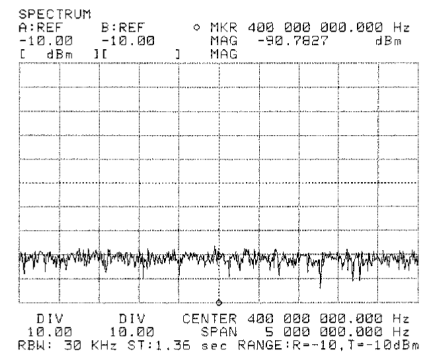**Figure 3. Noise measurement at RBW= 30 kHz in the 4395A**

Figure 4. Noise measurement at RBW= 30 kHz in the 4195A

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Convenient Noise Measurement Functions

The following section outlines the convenient noise measurement functions available with the combination analyzers.

Digital video filters

The combination analyzers use digital video filters. Unlike analog filters, digital filters allow you to specify the desired VBW without considering any time constant, thus ensuring trouble-free measurement with minimal noise level fluctuations.

Noise level conversion for consistency

As mentioned earlier, the combination analyzers employ the true-RMS level detection method. However, you can simply press a softkey to display the noise level that would be measured with an analyzer based on the logarithmic amplifier and envelope detection method (2.5 dB below the measured level). This function is extremely useful when you wish to make sure that measurement results are consistent with those obtained with your other spectrum analyzer.

IBASIC function available as standard feature

The IBASIC (instrument BASIC) is a programming language based on the HT BASIC for exclusive use with measuring instruments. This function allows an integral of noise level to be automatically calculated, thus ensuring flexible programming that best fits your application needs. Also, with the 4395A's unique feature, you can readily load the desired IBASIC program from the RAM or floppy disk and run it conveniently through key operations on the front panel. Therefore, with a variety of user-preferred programs stored on a disk, you can run them as desired for quick data collection and analysis, as if these programs were the built-in features of the analyzer.

Conclusion

The Agilent combination analyzers (4395A and 4396B) offer superior performance in terms of accuracy in noise measurement through the true RMS level detection method. In addition, you can obtain noise levels comparable to those with other analyzer models simply by correcting for the difference in detection method and using the ENBW. The computational power of the combination analyzers assists in making such corrections routinely.

Note: Detection Mode

The spectrum analyzer displays the value measured at the display point specified by NOP (number of points). However, the spectrum analyzer sweeps with the resolution specified by RBW. In the detection mode it is necessary to choose one level measured between display points for displaying trace. One of the detection modes (positive peak mode, negative peak mode, and sample mode) can be selected. Positive peak mode displays maximums between the display points. Negative peak mode displays minimums between the display points. Sample mode displays the signal value at the exact display point. In case of the noise measurement, the sample mode must be selected.

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