Bridge Method for Measuring Amplitude Intermodulation Distortion

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This article describes a distortion measurement method that greatly reduces contributions from the signal source and the spectrum analyzer. This method utilizes a bridge technique to cancel the test signals, leaving the distortion products of the device under test (DUT).

For designing and manufacturing multi-channel communication networks, the distortion products of the components must be measured. Distortion in an RF amplifier can be measured with no more than a signal source and a spectrum analyzer. One or more signals are fed into an amplifier and the amplifier output is displayed on the spectrum analyzer. Those signals not present at the input of the amplifier, but which are a result of the signals, are distortions.

There are two critical limitations that make these measurements difficult. The signal sources may not be completely distortion-free. It is often necessary to design separate combining networks with amplifiers and pads to minimize these products. Second, it is often necessary to amplify the signal source before applying it to the DUT, and amplifying a signal inevitably raises the noise level and degrades the signal-to-noise ratio.

The spectrum analyzer may generate its own distortion. In many applications the distortion from the spectrum analyzer may be overcome by the use of a bandpass filter that passes only the distortion product of interest. This causes some problems in calibration and is impractical in the case of closely-spaced multiple signals.

The bridge method for making distortion measurements solves these problems. This method is similar to that used in the first part of a feedforward amplifier. The circuitry of both the bridge method and feedforward amplifiers extract only the distortion products. The feedforward amplifier design uses these products to effect distortion cancellation at the output, while the bridge method cancels the test signals at the amplifier output, allowing measurements of only the distortion products.

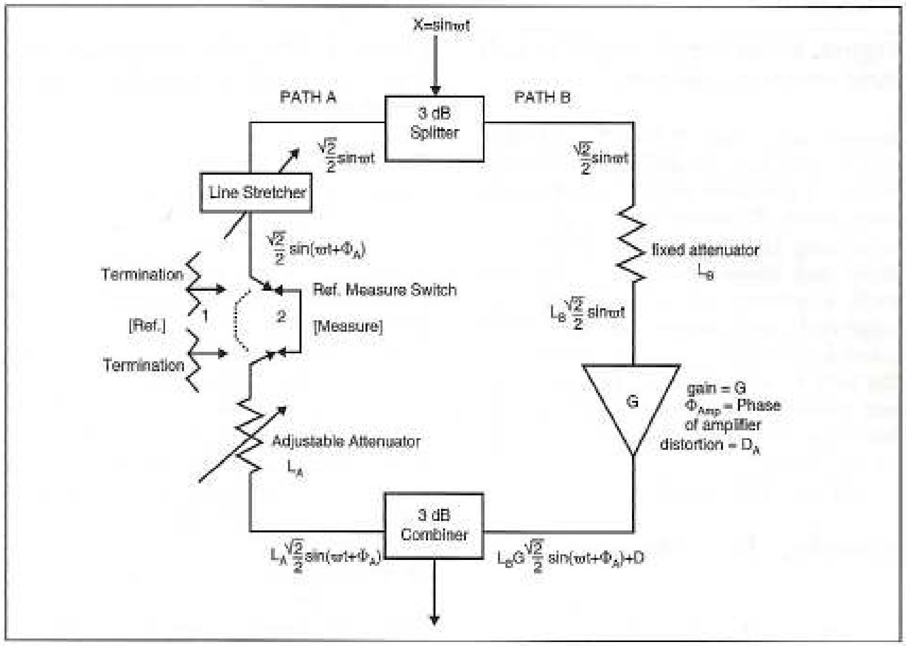

Figure 1. Block diagram of bridge setup to cancel source noise.

Implementation

Referring to Figure 1, the input signal (X) is divided by using a 3 dB power splitter. One half of the signal is fed through path A that contains a continuously variable attenuator (L_B) and a line stretcher (Φ_A). The line stretcher is used as a phase shifter. The second half of the signal is fed through path B, which contains a fixed attenuator (L_B) and the amplifier under test (G). The value of the attenuation should be such that the gain in path B is nominally –5 dB, that is 5 dB loss. Although it may not be immediately apparent, the signal-to-noise ratio of the measurement is better when the attenuation is on the input side of the amplifier rather than the output. When measuring high power amplifiers it may be necessary to add attenuation at the amplifier output. The variable attenuator and phase shifter are now adjusted until the input signals from the source are nulled at the output.

In order to null the signals, a 180° phase shift is required in one path. When testing a non-inverting amplifier, a 180° combiner must be used. Typical nulls of –40 dB can be achieved over 20 percent bandwidth in spite of the fact that the splitters and combiners are not specified to this performance. This is because the variable phase shifter and attenuator compensate for the inherent inaccuracies of the two paths. Actually, a –25 dB null can be attained over decade bandwidths with comparative ease. This suppression not only suppresses the signal, but any other extraneous signals and distortions along with any noise produced by the source.

Although nulls exist whenever the signals are out of phase at the output, the broadest null occurs when the time delays in both paths are equal to each other. It may be necessary to add lengths of cable to one of the paths

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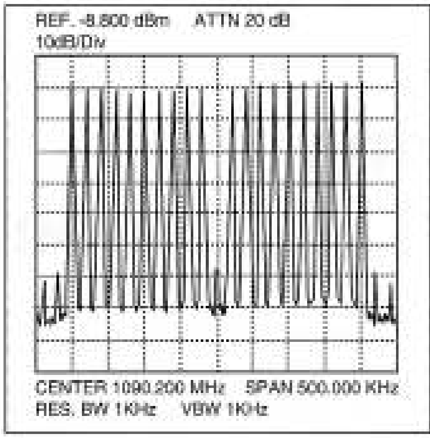

Figure 2. 20 input signals with their inherent distortion.

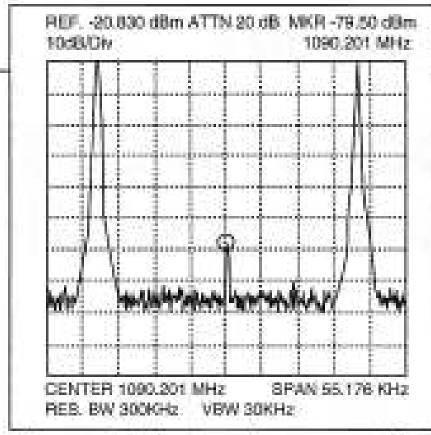

Figure 3. The two innermost signals, with the distortion signal between them.

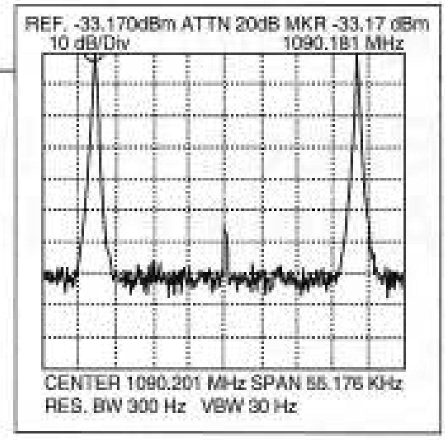

Figure 4. Spectrum of signal through path B.

because the phase shifter range is limited. It may also be difficult to find the null that produces equal time delay in both paths. To simplify the process of adjusting the circuit for equal time delay and hence produce a broadband null, a sweep signal generator or amplified noise source may be substituted for the signal source. This allows the user to adjust the L_A to equal $L_B G$ and therefore, the resulting equation from Figure 1 will be the difference of the two paths:

output = path A – path B

$$\text{output } D_A = L_A\left[\frac{\sqrt{2}}{2}\sin(\omega t+\Phi)\right] - \left[L_B G\left[\frac{\sqrt{2}}{2}\sin(\omega t+\Phi_{Amp})\right]+D_A\right] \quad (1)$$

where:
X = input signal = $\sin(\omega t)$
L_A = loss of variable attenuator
Φ_A = variable phase shift
L_B = fixed attenuator
G = amplifier gain
Φ_{Amp} = amplifier phase shift; and
D_A = amplifier distortion

Example

Figure 2 shows the 20 input signals from the signal generator along with its residual distortion. Figure 3 is expanded around the center to show only the two innermost signals and the distortion present in the input signal. This distortion is about 60 dB below the signal level.

Figure 4 is a representation of the signals when the transfer switch position is at 1 (referring to Figure 1). The reference level reading of the signal is taken at this point, and is –33.2 dBm. The insertion loss from the amplifier output to the input of the spectrum analyzer is 3.2 dB. This makes the amplifier output level –30 dBm.

Figure 5 is a representation of the signals after a 40 dB suppression with the transfer switch at position 2 (referring to Figure 1). The input signals and their distortions, along with any noise present in the input, have been nulled at this point. This has allowed a 20 dB decrease in the RF attenuation of the spectrum analyzer, therefore improving the noise floor. The amplifier distortion is now visible and is 74 dB below the reference signal level.

The distortion products of the signal generator and the spectrum analyzer are no longer a factor in our measurements because the 40 dB suppression of the input signals and the input distortion level of –60 dB is the equivalent of –100 dB distortion levels at the input. At this particular signal level, the spectrum analyzer is not contributing any significant distortion. This is verified by adding attenuation to the input of the spectrum analyzer and observing that no change occurs in the carrier to distortion ratio.

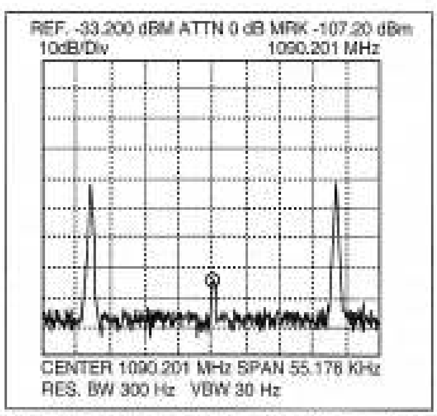

Figure 5. Spectrum of signal after passage through paths A and B and combination.

Conclusion

By using this technique, we have alleviated many of the problems encountered while using other distortion measurement methods, such as signal source distortion and noise from the spectrum analyzer. Although the example chosen was for a low level amplifier, the technique is also useful for high level amplifiers and other active devices. Our experience indicates that the bridge method of distortion measurement eliminates the need for bandpass filters. *RF*

References

1. *RF/IF Designer's Handbook*, Mini-Circuits, 1992.
2. *Multiple Frequency Comb Generator Handbook*, Matrix Test Equipment Inc.
3. *HP 8560 E Spectrum Analyzer Operating and Programming Manual*, Hewlett Packard, 1992.
4. C. Rice, "Techniques to Achieve Linear Amplification at HF", *RF Design*, December 1993, pp. 46-49.

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