8 Errors Common to Spectrum Analysis

Improving the accuracy of Spectrum Analysis
Overview

Spectrum analysis is essential for understanding the frequency domain characteristics of components, circuits, and systems, but these instruments and their measurements are not foolproof. In fact, eight common mistakes plague the accuracy and effectiveness of spectrum analyzer measurements. These errors can lead to improperly adjusting a device under test (DUT) or shipping a device to a customer that has not met its required specifications. Luckily, some simple guidelines can be followed to ensure that the spectrum analyzer (also called a signal analyzer) is used properly and is performing to expectations.

Many of the mistakes made when using a spectrum analyzer have to do with using the wrong equipment, or else using the analyzer’s controls incorrectly. The eight common errors are as follows:

1. Using the wrong detector
2. Using the wrong averaging type
3. Measuring the analyzer’s own internally generated distortion products
4. Incorrect mixer level for error vector magnitude (EVM) measurements
5. Not using single sweep when remotely controlling the analyzer
6. Not synchronizing measurements with operation complete (OPC) flag
7. Not turning the display off and using binary data types when transferring data for speed
8. Feeding too much power to the input of the spectrum analyzer
1. Using the Wrong Detector

Picking a Detector

There are different types of detectors used in spectrum analysis. Selecting the proper detector for a spectrum analyzer is a simple enough task when some general rules are followed. Using the wrong detector type can produce incorrect results, potentially leading to incorrectly adjusting a device under test (DUT) or missing a present-but-undetected signal. For example, the peak detector can be used for measuring continuous-wave (CW) signals and the average detector can be used for noise-like signals.

![Image of spectrum analyzer](image)

**Figure 1.** The yellow trace uses sample detection in a wide span and a narrow RBW, causing signals to be missed that are detected with the blue trace using peak detection.

Sample Detector

A sample detector provides a single sample for each trace point on the analyzer display. Each trace point will represent a single sample evenly spaced across the span of the instrument in the frequency domain. A sample detector is effective for measuring noise-like signals. The sample detector predates the introduction of the more powerful average detector that is favored for measuring noise-like signals. When using the sample detector, the analyzer’s resolution bandwidth (RBW) must be set wider than the trace point interval. If too narrow, CW signal amplitude measured with a detector may appear too low or be missed, which under response error is sometimes referred to as scalloping. Spectrum analyzers will automatically select the sample detector when trace averaging is applied, so it is important to check that the correct detector is being used for the measurement.
Peak Detector

A peak detector maintains the highest amplitude value in the measurement interval and displays this value in the trace point. A peak detector is effective for measuring CW signals. However, a peak detector can provide incorrect levels when measuring noise-like signals unless it is a “max hold” type measurement where the analyzer is being used to read worst-case maximum power.

Average Detector

An average detector averages power between two trace points and displays the mean power that has been averaged on a linear scale, such as in milliwatts (mW). Average detectors are well suited for noise-like signals and effective for showing the amplitude of CW signals. The RBW needs to be at least as wide as the trace point interval, because if it is too narrow then it can show too low of a reading for the amplitude of a CW signal. The average detector was introduced in the year 2000 with the launch of the first all-digital IF spectrum analyzer, The PSA Series Spectrum Analyzer. The average detector performs an RMS power average over all sample points within a trace point interval. This is more efficient than using a sample detector which only uses one of the sample points within a trace point interval and discards all of the remaining trace points. When using the sample detector, it takes many trace averages to achieve the equivalent amount of averaging achieved with one trace acquisition using the average detector. Therefore, there is an incredible time savings when using the Average detector compared to using the sample detector.

Normal Detector

A normal detector is the default detector for X-Series signal analyzers. A normal detector always shows the correct amplitude for CW signals regardless of the RBW selected relative to the trace interval. Good for measuring noise-like signals, a normal detector displays peak value of a signal that rises and falls in level during the odd trace point and shows the minimum value of the signal during the even trace point. This causes the peak-to-peak value of a noise-like signal to be accurately represented on the analyzer’s display. Normal detectors should not be used when integrating noise power, since the alternating peaks and minimums will improperly represent the distribution of the power in a noise-like signal.

Summary

In general, unless there is certainty about the type of detector to use for a particular measurement, it is best to use the default detector selected by the spectrum analyzer. And if there is some uncertainty, the peak detector can be used for measuring CW signals and the average detector selected for noise-like signals.
2. Using the Wrong Averaging Type

Averaging

Averaging helps to reduce variations due to noise in a signal, which enables the user to differentiate important spectral components from noise. Most spectrum analyzers offer a choice of log-video or power (RMS) display averaging types.

Log-video Averaging

Log-video averaging will be performed on a logarithmic scale. Log-video averaging causes noise-like signals, such as the noise floor of the analyzer or a WCDMA signal, to be measured as much as 2.51 dB below the actual level. Log-video averaging doesn’t affect the measurement and display of a CW signal which makes it useful for measuring a CW signal that is close to the noise floor of the spectrum analyzer. It reduces the noise floor and improves the instrument’s signal-to-noise-ratio (SNR) performance.

Power Averaging

In most cases power averaging should be used when measuring noise-like signals if averaging is applied. Averaging could be trace averaging or averaging caused by reducing the analyzer’s video bandwidth (VBW) to less than the RBW. When power averaging and reducing the VBW to be less than the RBW, the modern analyzers such as the PSA Series Spectrum Analyzer and X-Series Signal Analyzers will automatically correct for any under-response that would otherwise be present in older analog spectrum analyzers. The net effect of reducing VBW below the chosen RBW bandwidth is that the sweep time will be increased.

Summary

In general, log-video averaging is best suited for CW signals and power (RMS) averaging for noise-like signals.
Figure 2. The WCDMA signal is averaged in the yellow trace using log-video averaging, resulting in a -2.5 dB error compared to the same signal correctly averaged using power (RMS) averaging in the blue trace.

3. Measuring the Analyzer’s Own Internally Generated Distortion Products

It is important for spectrum analyzer users to measure the distortion products of the DUT rather than the distortion products of the analyzer.

Distortion products of interest for a DUT are due to third-order intercept (TOI), adjacent channel power (ACP), or harmonic signals. The relative amplitude of these distortion products is related to the level of the input signal fed to the DUT. Unfortunately, a spectrum analyzer may also be capable of generating distortion products when handling an input signal with sufficient power. Internal distortion products are a function of the mixer level of a spectrum analyzer. It is possible for the analyzer’s internal distortion products to sum with the distortion products constructively or destructively from the DUT, causing incorrect results.

Summary

The level of test signals to the mixer can be reduced by increasing internal or external attenuation. Attenuation should be increased to the point where the relative level of the distortion product no longer changes. This attenuator setting will ensure that distortion measurements are being performed on the DUT alone, and not the combination of the DUT and analyzer. As the attenuation is increased, the RBW can be decreased to gain back sensitivity that is lost. The sweep time will increase as RBW is decreased.
4. Incorrect Mixer Level for EVM measurements

EVM measurements are achieved by using the vector signal analysis (VSA) mode of the spectrum analyzer. In this mode, a signal is downconverted directly with an analog-to-digital converter (ADC). Most of the time, the appropriate bandwidth is automatically selected. However, sometimes the measurement may not be optimized in the signal analyzer. A mixer level that is too low or too high can degrade the performance of the measurement.

To optimize the EVM measurement, the input attenuation should be reduced until an ADC overload condition is displayed, the attenuation should then be increased just until the overload condition is resolved. At this level of attenuation, the full range of the ADC is being effectively used. Reaching the optimum level may require turning on preamplifiers or adding additional gain to the system for low-level signals. Sometimes this is achieved by selecting the Full Bypass Path (FBP) in the signal analyzer. FBP almost always improves EVM results at lower power levels. X-Series Analyzer embedded applications such as for 5G NR and Wireless LAN have a built-in function called “Optimize EVM” that will automatically choose the best signal path, RF attenuation, and IF gain to achieve the most optimal EVM results.

Summary

It is important to select the correct mixer level to optimize EVM measurements. Specifically, the steps above can help optimize the power level seen by the mixer.
5. Not Using Single Sweep when Remotely Controlling the Analyzer

Under remote control a spectrum analyzer will run slower in continuous-sweep rather than in single-sweep mode. When an INITIATE command is sent, the instrument must abort the current sweep mode and then reinitiate the current request measurement. In many cases, it might be desirable to have the instrument in single sweep and initiate any measurements to maintain speed and synchronization.

Summary

While it may seem controlling a spectrum analyzer in continuous-sweep mode would be faster when controlling the analyzer remotely, it is better to keep it at single-sweep. To avoid resynchronizing the analyzer and observing slower measurements, use single-sweep mode.

6. Not Synchronizing Measurements with Operation Complete (OPC) Flag

The sixth common analyzer mistake is not synchronizing measurements with the “operation complete” flag (*OPC). Automating signal analysis measurements can be confusing and, at times, incorrect results can occur. Some operators may add a “sleep” statement to delay their programming code to reduce the frequency of the error or resolve it altogether. But the error may be the result of a synchronization error, and synchronization can be maintained by using the operation complete flag that indicates when a measurement or sweep is complete.

Programmatically, the code should be:

- INIT: CONT OFF (sets the measurement to single sweep)
- INITIATE (initiates the measurement)
- *OPC? Requests a 1 returned after the measurement completes
- Read the 1 that is returned when the sweep or measurement is complete
- FETCH (Fetch the measurement results or place a marker on the trace)

Summary

Synchronization can cause errors but using the OPC flag can prevent the synchronization errors and can also indicate when a sweep or measurement is complete.
7. Not Turning the Display Off and using Binary Data Types when Transferring Data for Speed

Binary data is a combination of ones and zeros, so it requires minimal storage, which means it reduces data when transferred in this form compared to ASCII form. Binary data does not increase the measurement speed; it just reduces the data that is being transferred. By reducing the amount of data transferred, the overall time to make a measurement and fetch the results back is reduced. Displaying results on the instrument’s screen takes computational power by the instrument’s CPU. Turning off the display allows for the faster return of remote data. There is more of time savings when not having to display results such as for EVM constellations and other complex plots as would be displayed in measurement applications such as 5G NR and Wireless LAN.

Programmatically, the code should be:

- INIT: CONT OFF (sets the measurement to single sweep)
- FORMAT: DATA REAL32 (sets the data results to binary block real 32 data)
- DISPLAY: ENABLE OFF (turns off the display)

Summary

To maximize the throughput of a test, the display will be turned off and binary data will be used to reduce the amount of data that is transferred. The program above can improve throughput significantly.

8. Feeding Too Much Power to the Input of the Spectrum Analyzer

Feeding too much power or DC voltage higher than what the analyzer is rated into the input of the spectrum analyzer can be a very expensive error. The damage level of most spectrum analyzers is about one watt or 30 dBm. When a signal that exceeds the damage level is supplied to the input port of the spectrum analyzer it overloads the front-end electronics. Typically, the screen will not display a signal, and the analyzer will require repair.

Summary

To avoid damage to the spectrum analyzer, limiters should be used at the input port. This can save time and money by preventing damage to front-end electronics.
Conclusion

Spectrum analysis is a complex science, and it is important for transmitters and receivers such as those used for 5G NR and Wireless LAN work appropriately. Spectrum analyzers are used to identify noise and potential spurious responses in these systems. To make sure all the errors are identified correctly we need to remove errors from the spectrum analyzers, themselves. The eight errors mentioned above affect troubleshooting and identification of problems within systems. Following the practices mentioned above to reduce the eight errors will greatly improve spectrum analysis capabilities and ensure that spectrum analyzers produced the desired results.