

RADIATED EMISSIONS MEASUREMENTS IN AN OPEN AREA TEST SITE

Dennis Handlon
Agilent Technologies
1400 Fountaingrove Parkway, Santa Rosa CA 95403
Telephone 707 577 4206, dennis_handlon@non.agilent.com

Abstract: This paper explores some of the techniques used to identify radiated emissions signals (30 MHz to 1 GHz) from a device under test when it is not convenient to power the device off then on several times during the test process. Modern signal analyzers and EMI receivers have some of the processes available that is discussed in this paper.

1. INTRODUCTION

We have all made measurements in an open area test site (OATS), trying to determine whether the signal on our signal analyzer is an emission from our device under test (DUT) or part of the ambient environment. It is very labor intensive to go back and forth turning the DUT off, checking to see if the signal disappeared, then turning it back on again.

With this article, we hope to reduce the frustration of OATS testing by introducing some techniques for discriminating between DUT signals and the ambient environment. These techniques include using a turntable to identify DUT signals, using two antennas for signal discrimination, using shielding and using tune and listen for signal discrimination. We will also demonstrate the ability to remove ambient signals from the signal analyzer display leaving only the signals from the DUT using trace math functionality. Those EMI receivers and signal analyzers that have signal list capability, there is a process for removing ambient signals leaving only the DUT signals which will also be discussed.

The frequency range we are interested in is 3 MHz to 1 GHz

2. METHODS OF AMBIENT SIGNAL DISCRIMINATION

These methods are based on best practices at many of the major companies using OATS.

2.1 USING A TURNTABLE TO IDENTIFY DUT SIGNALS

For devices that are not easily powered on or off, identification of DUT signals can be facilitated by using a turntable. Signals radiating from a DUT are, in most cases, stronger in one plane than another. As the turntable is rotating, the DUT signals will vary

in amplitude. Observe the signals on your receiver as the turntable is rotating. Look for maximums and minimums of signals. For those signals above the regulatory agency limit or margin, record the signal's maximum value, frequency and the position of the turntable so you can return to the signal for further evaluation.

Identify ambient signals using the turntable rotation method. Ambient signals will not change in amplitude as the turntable is rotating. If measurements are made in the same area, it is advisable to maintain a list of ambient signals including their frequency and amplitude.

2.2 TWO-ANTENNA METHOD OF AMBIENT SIGNAL DISCRIMINATION

A very flexible method of ambient signal discrimination is the two-antenna method. An emissions measurement antenna is placed at the distance prescribed by the regulatory standard, usually 10 meters from the plane of the DUT. A second antenna is placed at twice the distance from the DUT. Both antennas are connected to a receiver using an RF switch. Measurements are normally made with the antenna that is placed at the required distance. When the operator encounters a signal that could be either an ambient or a DUT signal the amplitude is measured. The second antenna, set at twice the distance, is then switched in and the signal in question is re-measured. If the amplitude of the signal is approximately the same then the signal is an ambient. If the signal is 6 dB lower when measured at the second antenna then the signal originated from the DUT.

The two antennas are the same type and have similar transducer factors. Also, the antennas should be placed so that they are fairly close to lining up with each other and the DUT. This is to ensure that

both antennas are receiving emissions for the same plane on the DUT.

2.3 SHIELD METHOD OF AMBIENT SIGNAL DISCRIMINATION

A less used but effective method of ambient signal discrimination is to place a shield between the DUT and the measurement antenna when it is not convenient to switch DUT power on and off. The shield is usually a sheet of aluminum placed vertically in line with the antenna. It is important that the shield is connected to the OATS ground plane. Using this method on windy days can be a problem so the sheet of aluminum must be firmly attached to the site. The shield prevents DUT signals from getting to the antenna.

2.4 TUNE AND LISTEN TO IDENTIFY AMBIENT SIGNALS

Many signal analyzers and EMI receivers offer the ability to demodulate an AM or FM signal at a marker. Place a marker on a signal of interest and select whether you want to demodulate using AM, FM or Φ M. The sweep will pause at the marker for a specified duration while the signal is demodulated. This can be a very useful to quickly identify local radio stations versus DUT signals. This is not useful for identifying digital communications signals (cell phones, digital TV, etc).

2.5 REMOVING AMBIENT SIGNALS USING SIGNAL LISTS

One of the features available on signal analyzers and EMI receivers is the ability to place signal peaks into a list. These peaks could be either DUT radiated emissions or ambient environment signals. Figure 1 is a typical radiated emissions display that has ambient and DUT emissions signals.

With signal list entry manipulation such as mark signals and delete signals the list entries can be reduced to DUT emissions and any signal that was not present during the signal capture.



Figure 1. Radiated emissions display

The process is fairly straight forward. First a scan is taken without the DUT powered and the signals are placed in the signal list. The DUT is then powered on and a second scan is taken and again signals are placed in the signal list. Have the signal list search for duplicates. These duplicate signals are the ambient signals that are present during both scans. Figure 2 shows the signal list with the duplicates marked.

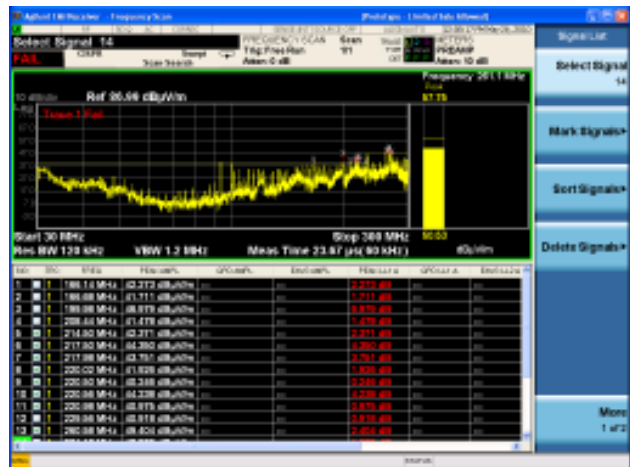


Figure 2 Duplicate signals marked

Delete the duplicate signals and the remaining signals are the DUT emissions and any signals that were not present during either of the scans. Figure 3 shows the remaining signals after the duplicates have been deleted.



Figure 3 Duplicates removed leaving DUT emissions

2.6 REMOVE AMBIENT SIGNALS FROM THE DISPLAYED SPECTRUM

The ultimate goal in making EMI emissions measurements is to identify DUT signals and remove all signals not associated with DUT emissions, because once all DUT signals are identified, we perform quasi-peak or average measurements to ensure that they pass the regulatory agency limit. For signal analyzers that do not have signal list feature shown above, here is a method for using advanced analysis features to remove displayed ambient signals. The method described here relies on the features of today's modern signal analyzers. The signal analyzer must have a high enough level of data points to give required frequency resolution in broad spans. The higher the number of data points, the less likely a signal will be missed or a lower than expected amplitude will be displayed.

The theory behind the removal of displayed ambient signals is fairly straightforward. Place both ambient and DUT signals in one trace and place ambient signals only in another trace, subtract the ambient trace from the "DUT plus ambient" trace and the result is DUT signals only.

Although the theory seems simple, the process of cancelling ambient signals is more complicated. The goal is to develop a list of suspect signals from the DUT which will be re-measured using the quasi-peak detector or average detector.

The key to being successful is to divide and conquer. The trace in Figure 4 shows a large number of DUT and ambient signals which are closely spaced. The frequency accuracy of the spectrum analyzer plays a part in how closely spaced a group of signals can be on the display. If the frequency accuracy is poor then the signals should be widely spaced and if the frequency accuracy of the signal analyzer is very good then the signals can be more closely spaced. The wider the span the closer together the signals appear to be. The following is a brief summary of the process we are going to use to remove ambient signals from the spectrum.

1. Set the device under test on a turntable and set up the antenna at the prescribed distance.
2. Connect the signal analyzer to the antenna and install the correction factors for the antenna and cables. Select the limit lines for regulatory requirement. Insure that there is enough sensitivity between the limit line and the noise floor, usually at least 6 dB. If not, you may need to add a low noise amplifier to improve sensitivity.
3. Switch on the DUT and view the spectrum. Span down using the stop frequency adjustment until the spectrum is reduced to about 25 or 30 signals. Remember, the spectrum includes both ambient and DUT signals. Add some trace averaging to reduce the noise. Store the trace.
4. Switch off the DUT and store this spectrum in a second trace.
5. Use trace math, in this case power difference, to subtract one trace from another. The result will be DUT signals and any signals that may have appeared between the storing of trace 1 and trace 2.
6. Store the amplitude/frequency pairs from the DUT in a spreadsheet for future analysis.
7. Since most DUTs do not radiate uniformly from all sides, it is helpful to rotate the DUT by 90 degrees and again perform the ambient cancellation and store the DUT signals. Perform this analysis for each of the DUT faces.
8. For each of the stored signals with amplitudes higher than the limit line, zoom in and perform a "measure at marker". Insure

that the quasi-peak value is less than the limit line.

2.6.1 DETAILED STEPS USED TO CANCEL AMBIENT SIGNALS

The ambient cancellation process is performed using a modern midrange signal analyzer. This process works equally well on the lower-priced mid range signal analyzers.

In the display below, the limit line for EN55022 class A Radiated 10 meter was entered along with correction factors for a biconical antenna. The stop frequency was reduced to display about 20 signals including the DUT signals.

2.6.1.1 SPECTRUM WITH BOTH AMBIENT AND DUT SIGNALS

Figure 4 shows ambient signals and the signals from a DUT. For smoothing, trace averaging is applied. In this case, 100 traces are averaged together to reduce the noise floor and stabilize the ambient signals. This is the trace that the ambient signals are subtracted from leaving the DUT signals.

Note that the ambient environment is constantly changing with signals fading in and out. The amplitude could be changing over time. If an ambient signal is reduced in amplitude or disappears completely after this trace is stored, then that ambient signal may appear as a DUT signal.

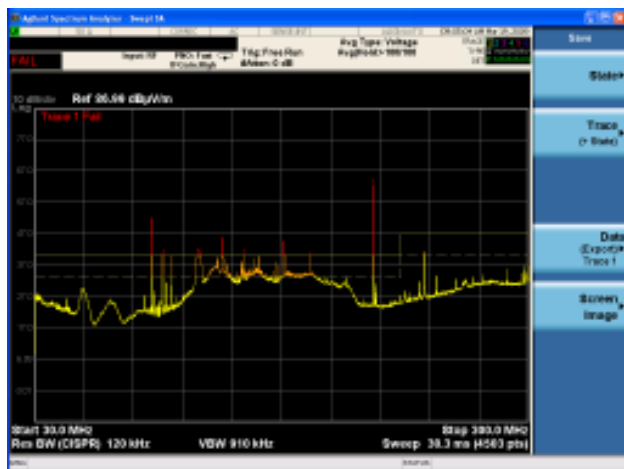


Figure 4 DUT plus ambient signals

Figure 5 (trace 2, blue) shows the ambient environment with the DUT switched off. Again 100 traces are averaged to reduce the noise and intermittent signals. We are going to subtract this

trace for the first trace. If an ambient signal appears in trace 2 that is not in the stored trace 1, the result is a negative spike. The negative spike is caused by the subtraction of a stored ambient signal from the point where the trace 1 did not have an ambient signal.

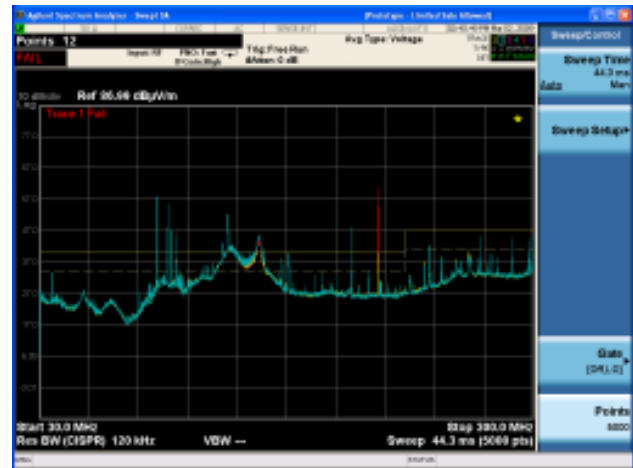


Figure 5 ambient signals

The next step is to subtract trace 2 from trace 1. This is accomplished using the “Power Difference” function available on some signal analyzers. The Power Difference function uses Operands. In this case Operand 1 is designated as trace 1 and Operand 2 is designated trace 2. Trace 3 is established as the destination trace for the difference result. So, at this point trace 1 is in the view mode, trace 2 is in the view mode and trace 3 is in the clear write mode. Subtract operand 2 from operand 1. Figure 6 shows the result of subtracting trace 2 from trace 1.

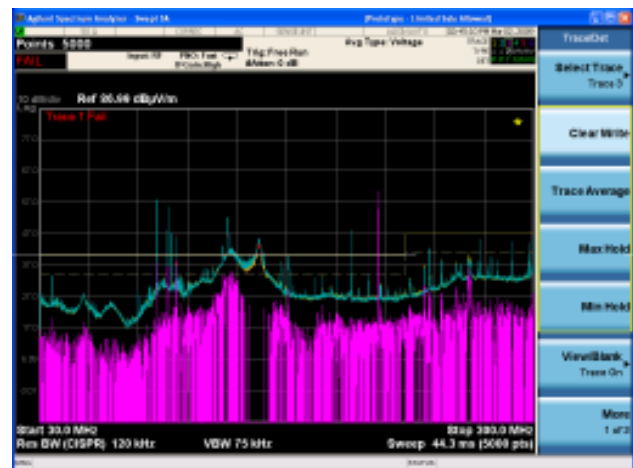


Figure 6 DUT and ambient signals minus ambient

Most of the ambient signals are removed. The remaining ambient signals are much lower in amplitude. These remaining signals are due to changes in frequency between the ambient/DUT observation in trace 1 and the “ambient signal only” observation in trace 2.

The trace is divided into 5000 points with each point representing a 54 kHz-wide band. The number of points is very important in removing ambient signals. If a low number of points are selected, DUT signals that are close to ambient signals may also be removed. If, on the other hand, a large number of points is selected, ambient signals that move slightly in frequency may not be removed. This is true of FM stations. If you look closely at trace 3 there are some signals that still appear but at a much lower amplitude. These are signals that had some changes in frequency between the two observations. The DUT signal from trace 1 observation is clearly seen as a signal with no or very little amplitude change.

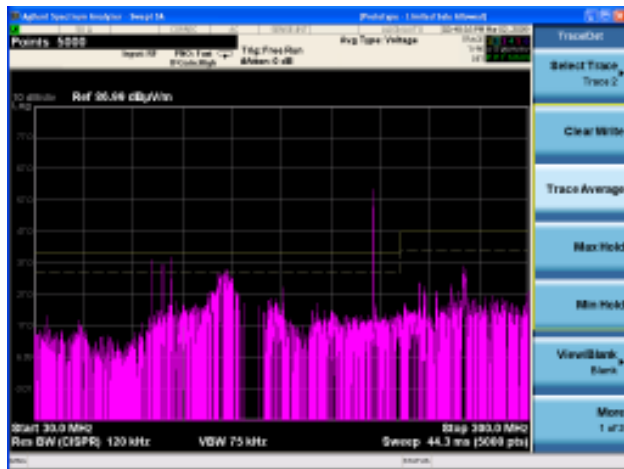


Figure 7 Trace 1 and Trace 2 blanked

With trace 1 and 2 blanked it is much easier to see the remaining signal. The DUT signal can easily be identified. All other signals are below the limit line or margin.

The trace in figure 7, in some cases, is below the bottom of the screen. This is due to the power difference result being out of the measurement range (negative power). The next step is to store the results for final tests using the quasi-peak detector or average detector.

The display line is used to capture device under test signals. Signals above the display line will be placed in a peaks list for future analysis. Usually the display line is placed on the margin or limit line. As a reminder, not all signals in the DUT trace are from

the DUT, they can be signals that were not present in one or the other previous scans.

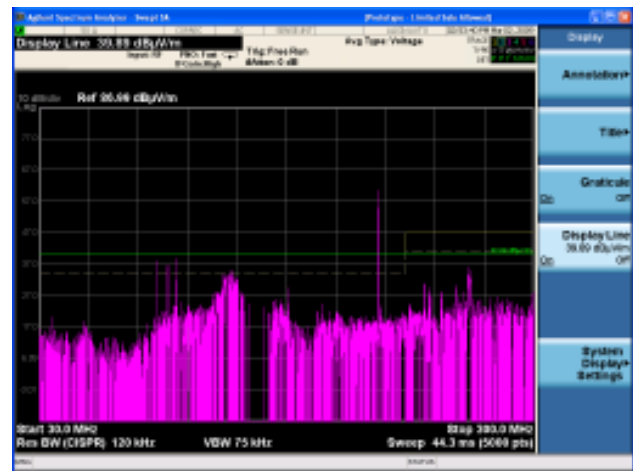


Figure 8 Display line and DUT trace

Signals identified for future investigation can be placed in a list and saved as a .csv file. Recall the file and measure the amplitude and frequency using the required detectors and placed the results in a spreadsheet for later re-measurement. Out of spec signals will require redesign and re-evaluation.



Figure 9 Peaks table for the DUT signals

3. AMBIENT VERSUS DUT SIGNAL DISCRIMINATION RESULTS

3.1. Turntable for discrimination

The turntable method is appropriate when the DUT cannot be powered down easily. Record and compare data from all four faces of the DUT to identify emissions.

3.2. Two antenna method of discrimination

This method is very fast for individual signal identification. Simply toggle between the two antennas to easily see if the signal is an ambient or DUT emissions. This method requires a very large test site.

3.3 Shielding to identify ambient signals

Setting up shield is at the low end of cost. However, it is a little cumbersome and needs to be installed and removed. Use the shield when you have several signals to evaluate.

3.4 Signal list method of ambient discrimination

The signal list method is fast and allows the user to make final measurements on the DUT signals directly from the list. The signal analyzer used must have signal list capabilities such as the Agilent N6141A EMC measurement application.

3.5 Remove ambient signals from the spectrum display

The advantage to this method is that the display only shows the DUT emissions and signals that did not

get captured in one or the other trace (ambient or ambient plus DUT emissions). DUT emissions can be viewed directly on the display. The signal analyzer used needs to have trace math capability.

4. CONCLUSIONS

The method chosen should be based on the DUT, the ambient environment and the site used. The more sophisticated the DUT (i.e. many internal clocks) the signal list or spectrum display may be used. If the ambient environment is at a low level (far below limit lines) then use the turn table method.

REFERENCES

- [1] Making compliance measurements with N9039A based EMI measurement receiver (5989-6899EN) www.agilent.com
- [2] Spectrum analyzer basics (5952-0292) www.agilent.com