EMI Measurements, Test Receiver vs. Spectrum Analyzer

Introduction

EMI measurements require a different approach than other types of general RF tests. In EMI, engineers never quite know what signals may be present. Since each new DUT (device under test) will be different, having the correct tools for characterization of the EMI signals is of key importance. Also, knowing the strengths and weaknesses of the tools being used is vital. Two instruments are used for EMI testing, spectrum analyzers and test receivers. Each requires a different approach to the test, and each has advantages and disadvantages. This paper will explore and compare both instruments.

Background

Spectrum Analyzers and Test Receivers are often lumped together as the same thing. Although both instruments measure the amplitude of signals in the frequency domain, the units are not the same, and require knowledge to extract correct measurements. Each can be abused, and each can return incorrect measurement results.

The differences between the two can be explored by examining a common test setup (i.e. the parameters necessary to configure each instrument).

Spectrum Analyzer tests set the following parameters:
- Start / Stop Frequency
- Resolution Bandwidth Filter and type (3 or 6 dB)
- Detector(s)
- Sweep Time
- Video Bandwidth

Most spectrum analyzers "couple" or lock the resolution bandwidth, video bandwidth and sweep time together so that critical timing requirements are not violated. These parameters can be manually controlled however, and even forced into modes where incorrect measurements are displayed.

Test Receivers follow a similar setup:
- Start / Stop Frequency
- Resolution Bandwidth Filter and type (3 or 6 dB)
- Detector(s)
- Measurement (dwell) Time
- Step size

These settings are often listed in the specification or standard being used to qualify the product. Using a "compliant" test receiver and calibrated test environment set according to the standard, should yield correct results.

Spectrum Analyzers Explored

If a compliant EMI test receiver, properly configured, will yield correct results, why use any other tool? There are several reasons to consider using a spectrum analyzer for EMI type measurements.

Versatility is the main advantage of a spectrum analyzer. The same unit can be used for general transmitter and receiver measurements such as adjacent channel power or noise figure. Most labs have one in house already, so it makes financial sense to use the same unit for EMI.

Familiarity is another advantage of spectrum analyzers. Most engineers have been exposed to them, even if they are not RF specialized.

There may have been a *Speed* advantage in the past if the operator knows EMI and the instrument limitations. Newer test receivers erase this advantage in most cases.

And finally, spectrum analyzers "tailored" for EMI are the *Comfortable* solution in the US because that is what most engineers are used to.

Spectrum Analyzer for EMI

Spectrum Analyzers are a versatile tool, but one that must be used with caution for EMI applications. Operators must be aware that for EMI, the spectrum analyzer is required to mimic a test receiver and

its testing methods. This is analogous to using a flat head screwdriver to drive a Philips type head. It can be done, but there are "issues" to keep in mind.

Issue #1: **Sub-ranging the span**
Most spectrum analyzers make 500 or 1000 measurements within the span (stop frequency – start frequency = span). If that span is set wide, say from 30 MHz to 1 GHz like the typical CISPR test, the measurement points will be made nearly 2 MHz apart. Obviously, these settings will skip over emissions since the resolution is too course for EMI applications. Sub-ranging the span into smaller chunks allows the measurement points to fall closer together, thus improving the resolution of the test. Sub-ranging the span is an attempt to make the spectrum analyzer mimic a test receiver's method. Since our goal is to improve the resolution, if sub-ranging the span, use the following rule of thumb:

 # measurement points = xxxx
½ RBW = max step size
step size X # points = subrange size

For instance, CISPR specifies a 120 KHz resolution bandwidth filter for the radiated emissions range (30 MHz – 1 GHz). A proper sub-range for testing this band will make the measurement points fall a maximum of 60 KHz apart (½ RBW). Using a spectrum analyzer with 500 measurement points, and running the calculation yields:

500 points
120 KHz / 2 = 60 KHz
60 kHz x 500 points = 30 MHz span

In this case, a proper test method is to test the first 30 MHz span (30 – 60 MHz), then the next (60-120 MHz), and so on until you arrive at 1 GHz. This process is highly time consuming. If your spectrum analyzer tests 1000 points, your subranges will be 60 MHz rather than 30 MHz wide. Also note that some devices may require a smaller resolution than ½ RBW (e.g. 1/3 RBW), requiring even more subranges.

Issue #2: **QP and AVE detectors**
Most EMI applications specify two types of detectors that may not be present on generic spectrum analyzer units. The first is called the Quasi-Peak or QP detector. This detector attempts to quantify the "annoyance factor" of a signal by weighing its repetition rate in addition to its frequency and amplitude. The QP detector must also conform to the CISPR requirements. Pre-compliant QP detectors are not acceptable for those who will "self-certify" compliance, or for test labs offering compliance services. The second detector to look for is called a CISPR-AVE detector. The differences between a typical AVE detector and a CISPR AVE detector have to do with the averaging time constants used, which is beyond the scope of this paper. Be watchful for both of these detectors when

purchasing instruments, since this is a key area.

Issue #3: **Resolution Bandwidths**
General purpose spectrum analyzers may not have the proper resolution bandwidth filters for EMI applications. Often "personalities" for the EMI bandwidths must be purchased as an option. EMI type RBW filters are narrower, rolling off at 6 dB per decade rather than 3 dB. Common CISPR RBW filters are 200 Hz, 9 KHz, 120 KHz and 1 MHz. MIL-STD 461 calls out 6 dB RBW filters between 10 Hz – 10 MHz. Using the incorrect filter can influence both amplitude and frequency values returned by the instrument. Very few spectrum analyzers have the 6dB filters for MIL-STD 461, so if you test to MIL-STD, check for the correct bandwidths.

Issue #4: **Power vs Fieldstrength**
General spectrum analyzers measure either power or voltage on the amplitude axis. Most EMI standards and limit lines are specified in fieldstrength at some distance from the DUT. In order to arrive at a measurement that is comparable to a limit line, and one that eliminates the differences between test environments, the spectrum analyzer must allow for "correction" of system transducers. When measuring radiated emissions, the effect of each particular antenna (antenna factor) and cable (cable loss) must be normalized through the use of files that give a correction

value at some frequency. When transducer correction is active, the Y axis of the EMI spectrum analyzer will read dBuV / meter (fieldstrength) rather than voltage or power. Since limit lines for radiated emissions are specified in fieldstrength, a limit line can now be displayed on the screen for direct pass / fail evaluations of the measurement results. Conducted emissions are specified in dBuV, or a pure voltage, but a correction value for cables and the tranducer (usually a line impedance stabilization network or LISN) is still used to eliminate the differences between various equipment and manufacturers. Insist on an instrument that has this capability.

Issue #5: **Measurement dwell time**
The QP, average and CISPR-AVE detectors have dwell time requirements in order to output correct results. For the QP, a one second dwell time is required in order to fully charge and discharge the filters in the detector. Both average detectors require 100 ms or more. Some spectrum analyzers now offer "zero-span". This capability is another "work around" to make the spectrum analyzer work like a test receiver and provide this dwell feature.

Issue #6: **Preselection & overloads**
Some of the signals encountered in EMI testing are high amplitude and can cover a wide frequency band. Spectrum analyzers measure everything that falls in the pass band of the RF front end. In other words,

even though you may not be looking at a signal on the screen, the RF front end is still measuring the total signal power over the entire frequency spectrum. Now, consider the scenario when a wide band signal is of sufficient amplitude to cause an RF overload condition - usually seen on the SA as spectral lines on the display. These "signals" will appear as though they come from the DUT, when in fact they are induced by the overload condition. An additional filter can be placed in the RF section to help prevent this condition. Called a preselector, this filter cuts out any signals not being displayed on the screen (with some limitations). This is critical for conducted EMI measurements when a very high amplitude signal may prevent measurements on the rest of the spectrum. What about using the RF attenuator? That may help, but in some cases it may attenuate wanted signals so much that they can no longer be displayed. Plus, setting the attenuation is a manual process on spectrum analyzers, one more thing to complicate the testing process. Preselector filters are seldom found on spectrum analyzers, but are a valuable option if available. Automatic attenuators can't work fast enough for a spectrum analyzer. Manual RF attenuators are available but they require constant adjustment during the test process and add room for inconsistency.

In summary, spectrum analyzers can be used for EMI, but various work-around methods must be used in order for the results to be accurate. Obviously, there are many opportunities for error. Incorrect sub-ranging, violation of dwell time requirements, use of incorrect RBW filters, overloads, and many other issues force us to conclude that the spectrum analyzer may not be the best tool for the job. Look at the tedious nature of sub-ranging alone. Even a high-end spectrum analyzer with 1000 points forces a 60 MHz sub-range. Seventeen ranges must be tested between 30 MHz and 1 GHz. The results of each range must be collated, corrected for transducer values, checked for overload conditions, and finally compared to a limit line for a pass / fail decision. Software helps, but it is one more complexity and one more cost. Also, software may be tied to only one spectrum analyzer or vendor. Fortunately, there is a better way.

Test Receivers Explored

CISPR, EN, FCC, MIL-STD and all the other standards bodies recommend using a test receiver for EMI applications for all of the above reasons. With a test receiver, what you set is what is measured, and these settings are listed right in the test standard. A typical test receiver setup illustrates the point. Using the same basic case used before, the keystokes are:

Frequency start: 30 MHz
Frequency stop = 1 GHz
RBW = 120 kHz (6 dB)
Step size = 60 KHz (1/2 RBW)
Activate transducer set
Overlay limit line

As you can see, these parameters are called out in the standard, entered directly as a test parameter, and now the operator needs only to press start. No sub-ranging, no zero-spanning, no mental conversions from voltage to fieldstrength. Furthermore, with automatic attenuators and preselection, it is possible for a compliant test to run without intervention. There are obviously reasons for an operator to interrupt the test, but the possibility does exist for a fully automatic test to yield accurate results.

In order to explore test receivers a bit more, some key features are called out in the next section that illustrate why a test receiver is a better tool for EMI testing.

Feature #1: **Measurement Points**
A scanning receiver will measure many tens of thousands of points if needed. For instance, in the previous test setup, the test receiver will measure:

1000 MHz - 30 MHz = 970 MHz
970 Mhz / 60 kHz = 16,170 pts

This level of accuracy is much improved over a spectrum analyzer's

500 or 1000 points. Tests with 100,000 measurement points are not uncommon in some MIL-STD applications.

Feature #2: **Tune & Dwell**
The second key feature is the tune and dwell capability native to a scanning receiver. Dwell time is set as a keystroke parameter, and violations to dwell time requirements of the various detectors are often "flagged" as incorrect.

Feature #3: **EMI Specificity**
This key feature rolls up all the "issues" discussed during the spectrum analyzer exploration, namely the availability of EMI specific features such as 6 dB RBW filters, transducer sets, limit lines and preselector filters.

Feature #4: **Automatic Control**
Scanning receivers can also take advantage of automatic control of certain parameters. Remember at the beginning when it was stated that certain modes could be forced on a spectrum analyzer that will yield incorrect results. This is also true for receivers, but much less likely since the receiver will "take care of itself" if left in auto-control mode. Automatic control of RF attenuation, preselection filtering, preamplification settings, RBW settings, and the step size is common. Auto-control of these settings can keep the user out of trouble in most cases. The auto-control of these parameters will follow what is called out in the standards. Since no one starts as

an expert, EMI novices may be saved from collecting incorrect data, and worse, making judgments on bad data.

Test Receiver disadvantages

Similar to spectrum analyzers, there are also disadvantages to test receivers. Scanning receivers are the right tool for the job mainly because they were built with EMI in mind. Specialized tools often cost more, and have limited use outside of the area of specialization.

Many proponents of spectrum analyzers will suggest that receivers are slower than analyzers. On the face, this is true, but if apples are compared to apples, there is no time penalty associated with using a receiver. The type of detector and its associated dwell time impose the true timing limitation. Also the number of measurements that must be made to ensure proper signal capture will be the same, regardless of which unit is being used. A true side-by-side comparison of a receiver scan and the sub-ranged spectrum analyzer sweep will show a time advantage to the receiver, not the spectrum analyzer.

Summary

In the end both tools may be used for EMI measurements. There may be overriding factors that guide your choice that were not discussed. One factor might be the requirements imposed by an accreditation body

like A2LA or NVLAPP. These bodies and military / government agencies may disallow generic spectrum analyzer measurements for EMI. The number of "work-arounds" is high, and the room for error is great. Before purchasing, check for these factors first.

Look also into the expertise level of the engineers and technicians that will be conducting these tests. What if the measurements are wrong? Will this force a board redesign, device recall, or rocket launch delay? The money value of incorrect measurement will almost always overcome any additional money spent acquiring the best tool for the job.

And if all else fails, look for an instrument that has both, spectrum analyzer and EMI test receiver. These units cost less than buying both units separately, will give flexibility to test in both modes, and can be used for many purposes other than EMI. There are some out there, and most of them can be found at www.rohde-schwarz.com.