

Choosing the Right Spectrum Analyzer

What type of spectrum analyzer should one buy—swept, FFT, real-time spectrum? The type of analyzer that will work best for a particular application depends on a number of factors. This application note explains how these three spectrum analysis methods work and compares what they measure to your potential applications.

Swept Spectrum Analyzers

Originally designed to display broadcast spectral content, the swept spectrum analyzer was a relatively huge, bulky, heavy, power-hungry instrument used to measure transmitter quality such as harmonics and spurs. The cable TV industry soon adapted it to help maintain the cable plant.

Dominating the market for almost 50 years, swept spectrum analyzers have a simple principle: measure each frequency sequentially and plot the results on an x-y axis.

In Figure 1, each point on the X-axis represents a point in time. Sequential points in time correspond to sequential points in frequency. In early analyzers, this was achieved by using a voltage controlled oscillator (VCO) driven by a ramp.

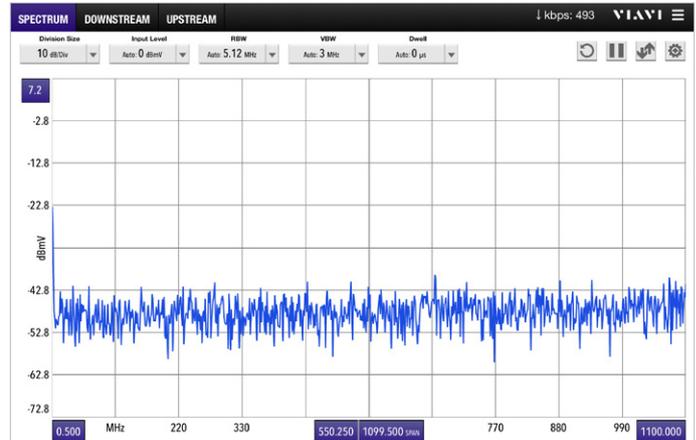


Figure 1. Spectrum analyzer display

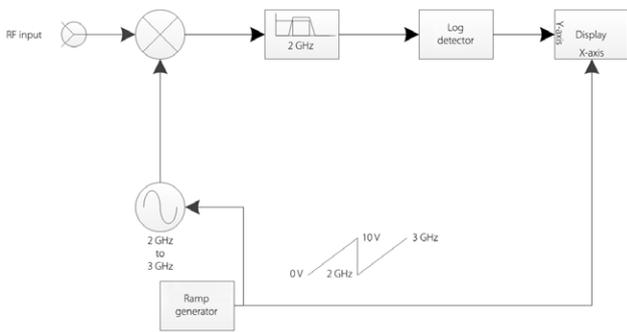


Figure 2. Swept spectrum analyzer block diagram

In Figure 2, when the ramp generator is generating zero volts, the VCO is set to 2 GHz. Any signal at DC is up-converted to 2 GHz. The 2 GHz bandpass filter (BPF) removes signals outside of its bandwidth and the log detector produces a voltage proportional to input power. Additionally, when the ramp generator produces 1 V, the VCO is set to 2.1 GHz and any signal at 100 MHz is up-converted to 2 GHz. The 2 GHz BPF allows only the signal proportional to the 100 MHz signal to the log amp and produces another point on the graph. This continues until the ramp reaches 10 V and the signal at 1 GHz is up-converted to produce its point on the graph corresponding to 1 GHz.

Originally, the ramp and log amp output were applied to the cathode ray tube (CRT) X-axis and Y-axis drivers respectively to create the display. Calculating and adding up tolerance factors shows that the ramp generator had to be very well controlled: a 1 mV change would cause a 1 MHz frequency change in the local oscillator (LO). This led to using phase-locked loops to control frequency. With the advent of microprocessors and phase-lock loops, the X-axis ramp and output frequency could be indirectly tied to each other and precise frequency control was achieved.

Spectrum design still measures one subset of frequency at a time. If a spectrum analyzer plots 801 points across the X-axis, there are 801 discrete measurements made in discrete time steps. If the analyzer takes 20 mSec to scan the full bandwidth, each frequency point takes 20 mSec/800 or 25 uSec per point. The results on the screen show only what occurred during the 25 uSec at that frequency.

A swept spectrum analyzer has many tools that are optimized for continuous signal measurements. One can adjust resolution bandwidth (RBW), video bandwidth (VBW), and scan or dwell time on each point. One can average results, and one can hold the maximum value at each frequency.

The drawback of a swept spectrum analyzer is that one misses a lot of information. If the swept spectrum is measuring at 100 MHz, and an event occurs that has only spectral power at 200 MHz, then one doesn't see the event. Generally, a swept spectrum analyzer uses a RBW of 2% or less of the full span. This means that on transient signals, there is a 98% chance of missing the event, even with an optimum setup.

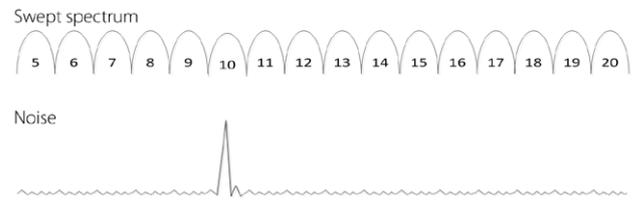


Figure 3. Swept spectrum analyzer example with pulse noise

In Figure 3, the analyzer is starting at 5 MHz and continuing sequentially to 20 MHz. A noise event occurs only while 10 MHz is being measured. In this case, the display will only show elevated noise at 10 MHz. If this event is infrequent, a user could mistake this single point as a signal that only had energy at 10 MHz.

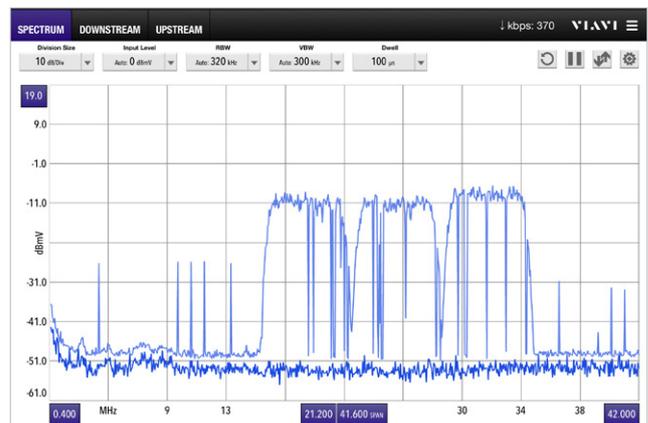


Figure 4. Swept spectrum analyzer with impulse noise and DOCSIS carrier

Figure 4 shows an upstream capture. After a minute, the max hold trace shows peaks at 4, 10, 11, 12 and 13 MHz. It is difficult to discern whether these are parts of another carrier that is infrequent or if it is noise. It is actually impulse noise recurring on a 1 sec interval.

Fast Fourier Transform Analyzers

Spectrum analysis tried to overcome the sampled nature of swept spectrum with the fast Fourier transform (FFT) analyzer. Instead of using a tuner that is time sequenced, an analog to digital convertor (ADC) is attached to the input and all the spectral information is gathered simultaneously.



Figure 5. FFT analyzer

An FFT analyzer must meet Nyquist requirements. Nyquist found that to get an accurate mathematic model of a signal, one must sample at least twice the rate of the bandwidth. For an 85 MHz signal, one would have to sample at least 170 MHz. However, sampling also has a side effect called aliasing. If one samples at 170 MHz, the signal at 86 MHz shows up mathematically at 84 MHz.

A filter is therefore needed to remove the alias components. For a 70 dB dynamic range, the filter has to reject the alias components from the usable range. So far, no one has manufactured a filter that can perfectly pass 84.99999 MHz and reduce 85.000001 MHz by 70 dB, so headroom must be built in to simplify the anti-alias filter. If sampling is at 200 MHz, the filter has to pass 85 MHz, and stop 115 MHz (200-85). This is a very achievable filter structure.

If one is sampling at 200 MHz and the signal is resolved to 70 dB, 12 bits of resolution are required. The bit rate will be 12 x 200 MHz or 2.4 G. Up until a few years ago, the only way to capture and calculate that data was by using a FIFO.

Once a FIFO has the data, a digital signal processor (DSP) can turn that data into a spectral plot. For a 300 kHz RBW (traditional spectrum RBW), data must be captured for a longer period of time than 1/300 kHz or 3.333uSec. For the FFT algorithm to work, a power of 2 sample sizes is needed. If the ADC is sampling at 200 MHz, a power of 2 sample sizes must be captured. Each sample lasts 5 nSec. A sample block of 1024 samples lasts 5.12 uSec. This satisfies the requirement for the samples needed for 300 kHz RBW.

Another drawback of the Fourier transform is that if the beginning and ending samples are not both 0 energy, energy smearing occurs. This is usually handled by applying a window function to the data. In many cases, a Hann window is used to remove the energy smearing.

These calculations and samplings take a lot of processing. Until recently, DSP devices could not keep up with the sampling rate of 200 MHz. In many cases, it took much longer to process the data than to collect it, and the FFT analyzer would be idled for 99% percent of the time. If an event occurred while the ADC was collecting data, the result would be very informative, but if it occurred outside the sampling time, there was nothing captured and it would be missed. Usually, the event occurred outside the sampling time.

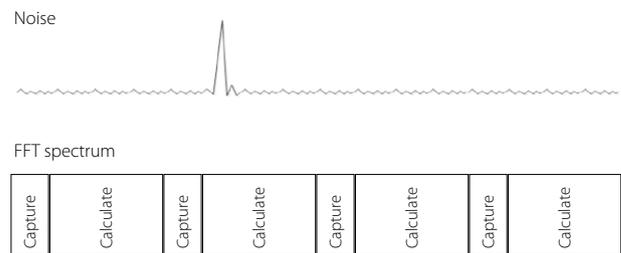


Figure 6. FFT example spectrum

The noise in Figure 6 is the same noise that is in Figure 3. In the FFT case, the event occurs while the DSP is processing the previously captured signal so the resultant display shows no noise events at all.



Figure 6. FFT example spectrum

Figure 7 shows an FFT upstream spectrum capture. After several minutes, even though it is updating 10 times per second, it only occasionally shows DOCSIS bursts and never captures the impulse burst.

Real Time Spectrum Analysis (RTSA)

Sonar applications have used RTSA for years. Sonar runs in the audio frequency range of 10 kHz, while cable TV runs in delaying MHz ranges, and it has taken a few years to catch up to that standard. RTSA uses the same concept as the FFT analyzer except that the calculation time is reduced and capture and calculation occur simultaneously.

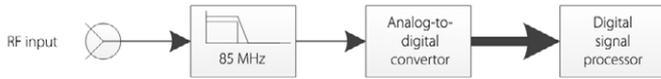


Figure 8. RTSA

In this case, the FIFO is removed. The DSP is performed in hardware, since speed is of the essence. A field programmable gate array (FPGA) performs the Hann window and FFT functions. Instead of using a waterfall display, data appears on a standard spectrum graph.

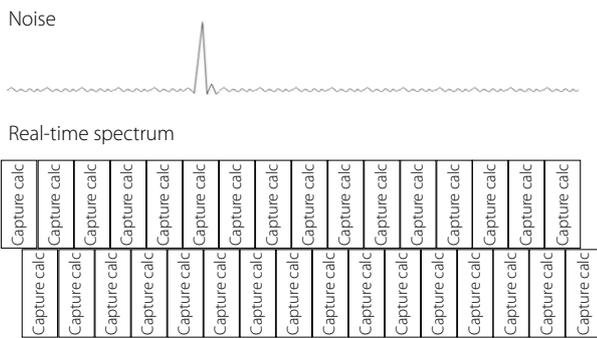


Figure 9. Real-time or hyperspectrum capture

Figure 9 shows two live FFT systems running in the background. They overlap each other by 50%. Each FFT runs at 200,000 per second. Further processing calculates a max hold for the last 1 sec. This trace is called a LIVE MAX. This insures that no impulse signal will be missed in a capture time.



Figure 10. VSE-1100 HyperSpectrum display with live and max trace with DOCSIS and impulse noise

Figure 10 shows the first displayed live max trace from a VIAVI Solutions VSE-1100 spectrum analyzer in HyperSpectrum mode. The instrument captures all the DOCSIS channels clearly and the impulse noise in less than 1 sec.

The Importance of a Real-Time, Hyperspectrum Display

When looking for ingress and noise, a real-time, hyperspectrum display shows the entire upstream spectrum, and no noise is missed regardless of where it appears in the plant. The deeper into the plant one troubleshoots, the less modem traffic is encountered. If one is at a node, the same traffic appears that would be seen at the headend—with 100 active modems on a node, they all appear. If one is 2 or 3 amps deep into a node, one may be down to one or two modems with perhaps no active modems generating traffic. Using the VSE-1100 Packet Dashboard and HyperSpectrum features, one can identify a noise spectral signature associated with a single modem burst and follow the spectral signature out though the plant.

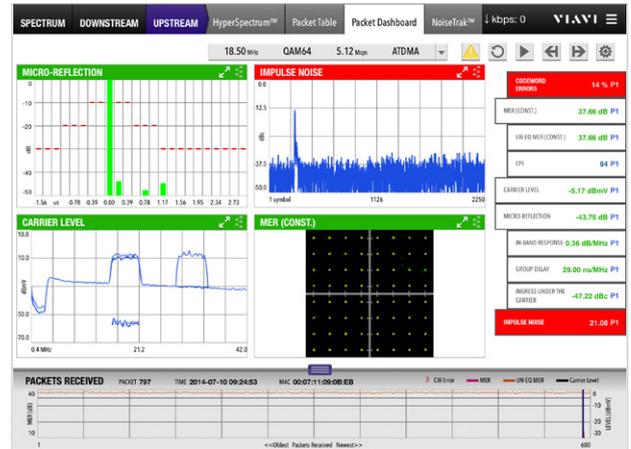


Figure 11. VSE-1100 Packet Dashboard display with impulse noise causing code Word errors

Figure 11 shows the Packet Dashboard feature identifying a packet with code word errors (CWE). Not every packet is affected, but about one out of 800 packets show CWE. When inspected using the Carrier Level graphical display feature, we see the spectral signature of the packet when CWE occur. Using HyperSpectrum, the technician can then follow this spectral pattern to find the source.



Figure 12. VSE-1100 dual-channel HyperSpectrum

Figure 12 shows the dual input feature of the VSE-1100 upstream analyzer. Using both port 1 and port 2, a technician can clearly see that the noise is on port 2 (violet input) while port 1 (blue input) has most of the modem traffic.

Additionally, with the intermittent nature of upstream noise, it is important to identify and move on. If you can identify the noise path in seconds versus minutes, you will be more likely to track the noise to its source.

Conclusion

Troubleshooting upstream problems requires less guesswork and more facts. Using real-time spectrum analysis such as that available with the VIAMI VSE-1100 can help quickly get those facts. The HyperSpectrum feature captures every bit of noise and displays it to the user when other spectrum-analysis techniques only provide hints of noise. Combined with the upstream demodulation feature of Packet Dashboard to identify noise signatures, HyperSpectrum will help the user track down the noise that causes CWE. Coupled with the dual channel feature, the technician can follow the noise to the source even when there is little or no modem traffic.