Trouble-shooting Radio Links in Unlicensed Frequency Bands

TUTORIAL

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With the Internet of Things comes the Interference of Things

Over the past decade there has been a dramatic increase in the population of wireless transmitters found in the world. The "Internet of Things" has fueled demand for low cost, easy to implement chipsets to enable wireless connectivity. Engineers today have a variety of wireless solutions to choose from such as Bluetooth, ZigBee and all the flavors of WiFi (802.11). These chipsets are attractive because they utilize unlicensed radio spectrum and many solutions are available with reference designs which have already achieved regulatory approval.

Arguably the spectrum in the 2.4 GHz is the most popular operating area for low-cost, license free applications. There are literally thousands of radios operating in this frequency. To facilitate spectrum sharing radio standards must employ advanced hardware and software features such as:

- *Time domain multiple access (e.g. "time sharing a single channel")*
- *Clear channel assessment (e.g. "listen before you transmit")*
- *Adaptive frequency control (e.g. "frequency hopping")*

Engineers are finding that even when they use a "certified" solution, they are still having problems establishing a radio link and maintaining communications. So the real question becomes: ***"How do I troubleshoot my radio link?"***

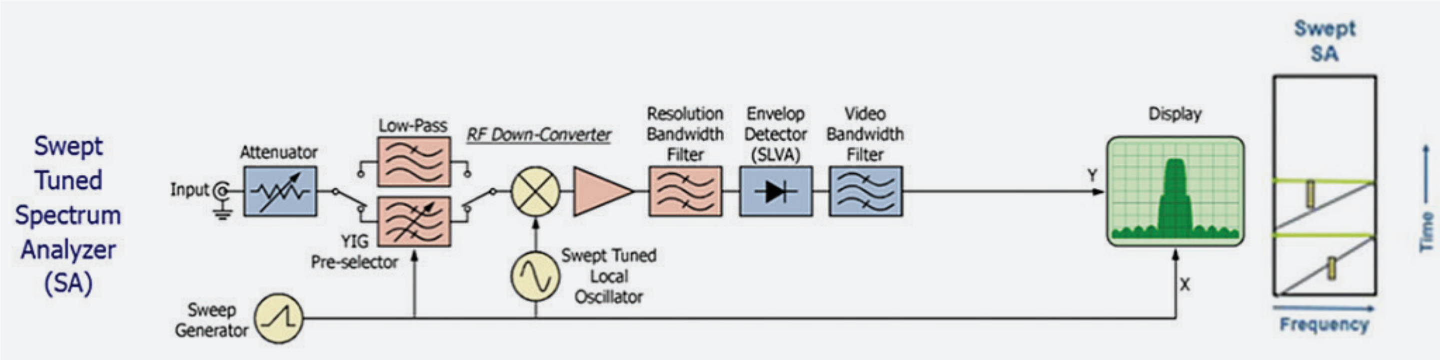

Figure 1. *This is a simplified block diagram of a traditional swept-tuned spectrum analyzer*

Characterizing The Radio Link

In order to trouble-shoot the radio connection we need some basic knowledge of the type of radio we are using;

Frequency or channel of operation	This tells us where we need to look in the spectrum
Type of radio (Bluetooth, WiFi, Zigbee, NFC)	This tells us what sort of spectrum signature to expect
	Also indicates special modes (e.g. TDMA, Hopping, FDMA operation)
Transmitted power level	This tells us how much power is coming out of our transmitter
Minimum receiver sensitivity	This tells us how sensitive our receiver will be to interfering signals

With this information we can use a spectrum analyzer to get some visibility on the radio link and to characterize the RF environment.

The spectrum analyzer is the go-to tool for making measurements in the radio spectrum. Figure 1 shows a simplified block diagram of a traditional swept-tuned spectrum analyzer for reference.

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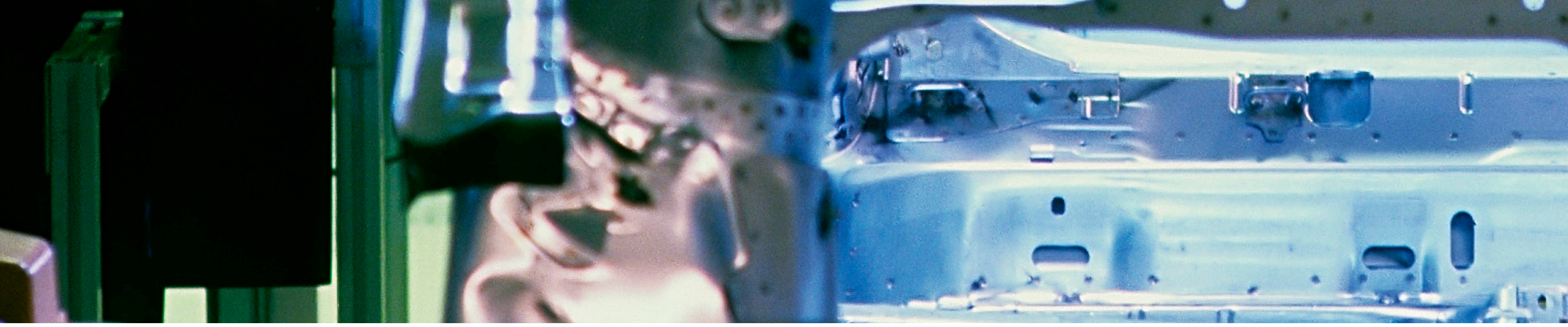


"Your IoT device will be connected using the same channels shared by over a billion different devices"

The super-heterodyne spectrum analyzer (SA) has been in use for many years. The challenge in using this type of instrument lies in the "sweeping" nature of its operation. What is measured on the spectrum display is disjointed in time and may not provide an accurate representation of the spectral information (especially for TDMA signals). Even the fastest swept-tuned SAs only provide a limited view of a transmitter that employs frequency hopping. In addition to the basic frequency vs. amplitude display, some manufacturers provide spectrogram information. In a sweeping SA this information is derived from multiple sweeps, so fundamentally the timing information can only approximate what may be happening with a pulsed or frequency agile transmitter.

A real-time spectrum analyzer (RTSA) provides the same basic functionality of a traditional SA with a number of added benefits. Figure 2 shows the block diagram of a basic real-time spectrum analyzer for reference.

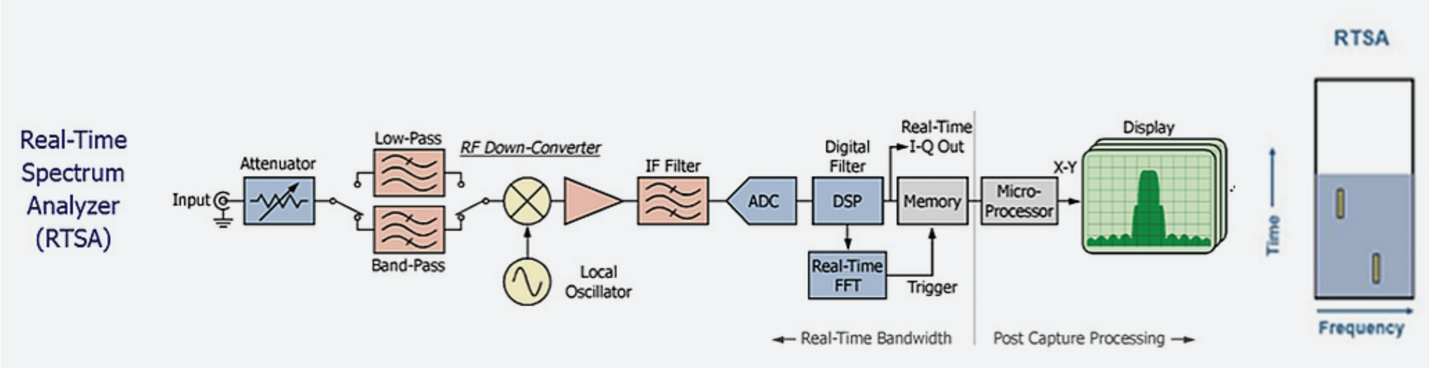
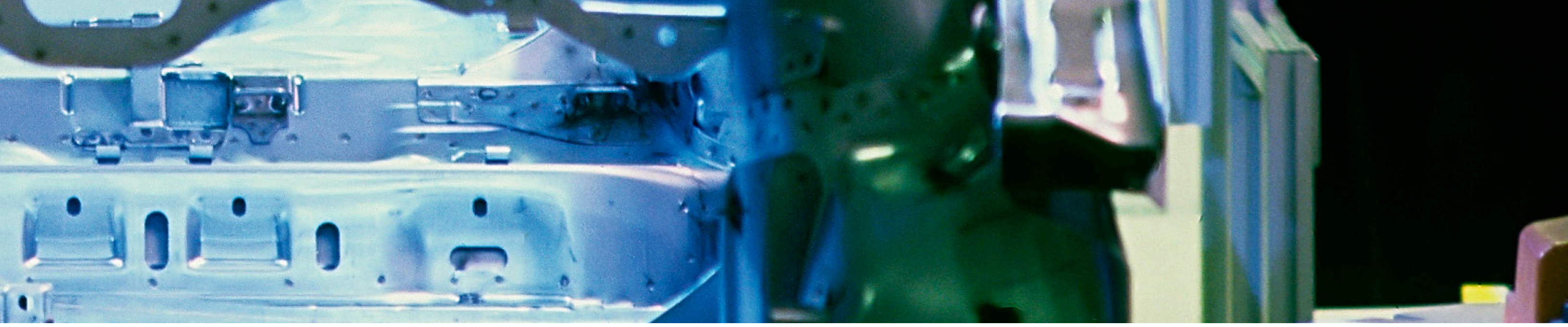


Figure 2. *This is the block diagram of a basic real-time spectrum analyzer.*



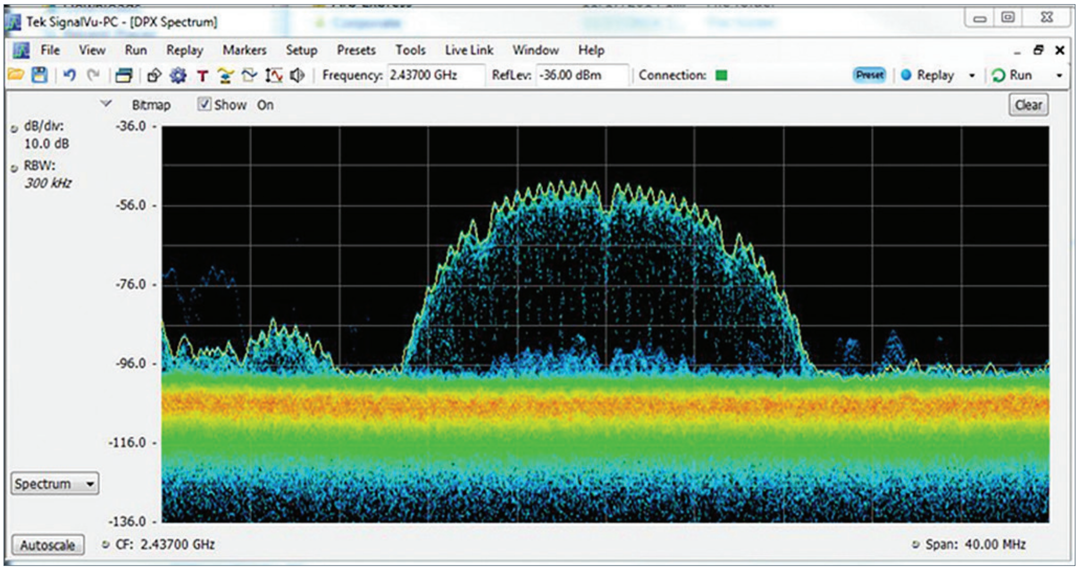


Figure 3. *A digital phosphor spectrum display lets the user "see" what the victim receiver "sees."*

One of the key differences between an RTSA and a basic signal analyzer is in the RTSA bandwidth specification. For any span up to the maximum real-time span, an RTSA does not have to sweep and is able to continuously capture spectrum information. An RTSA is also not limited to a single display at one time. Spectrum, spectrogram and modulation information can be simultaneously analyzed and because this data is from a continuous acquisition, the information is time-correlated.

An RTSA is particularly useful when analyzing systems that employ a TDMA protocol (i.e. Wi-Fi, Bluetooth, ASK/FSK). One of the biggest problems for devices that utilize the license-exempt frequency bands is managing the effects of multiple transceivers sharing the same spectrum. Regulatory requirements almost always require that devices operating in unlicensed frequency bands cause no interference, and must accept any interference that is present. A real-time spectrum analyzer is an ideal tool for quantifying the effects of interference as it is able to continuously capture spectrum information.

Figure 3 show shows a digital phosphor spectrum display from a real-time spectrum analyzer.

Important RTSA features include:

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- *Fast spectrum rates from 10,000 – > 3,000,000 acquisitions/sec*
- *Continuously record spectrum data*
- *Seamless recording of RF environment over time*
- *Time, frequency, and amplitude triggering*
- *Correlated time, frequency, and modulation measurements*

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Like a classic spectrum analyzer, the display shows frequency vs. amplitude information. In addition the pixels in the display have added color which tells you how often RF energy is being measured at that pixel (pixel occupancy). The digital phosphor spectrum measurement also allows you to specify a decay function, providing a phosphorescent effect which mimics the effects displays found in CRT based oscilloscopes. It adds the dimension of periodicity to the display, showing you how often a signal is actually being measured in the span of interest.

"A spectrum analyzer provides a window for you to see what is happening in the radio spectrum"

This form of real-time spectrum display lets you "see" what your receiver "sees," and provides greater insight into what exactly is happening over the span of interest. However, it doesn't provide enough information about the potential effects of interfering signals. By their nature spectrum displays are not able to show the time interleaving of signals. Employing a "zero-span" measurement would provide good detail about pulse amplitude and duration but lack frequency information.

The spectrogram measurement is designed to address this type of problem. Like the spectrum display it will show low frequency on the left-hand side, and higher frequencies on the right-hand side. Unlike a basic spectrum display, color is used to represent amplitude, and all of this information is plotted versus time on the y-axis. The spectrogram is effectively a strip chart recorder showing the spectrum activity over time.

In a swept tuned analyzer this spectrogram will be disjointed in time as the instrument is sweeping. The SA sweeps through frequency meaning that trace points on the left side of the span occur at earlier times than trace points on the right. As such, there can be no timing relationships within a spectrogram captured by a swept analyzer. A spectrogram created by a RTSA is comprised of continuously recorded spectrum data without sweeping. The RTSA has the added benefit of complete domain correlation, so information in the spectrogram can be directly correlated with other measurements (i.e. modulation, power, CCDF)

“Unlicensed spectrum means no protection…if you don’t think there will be interference it’s because you haven’t looked”

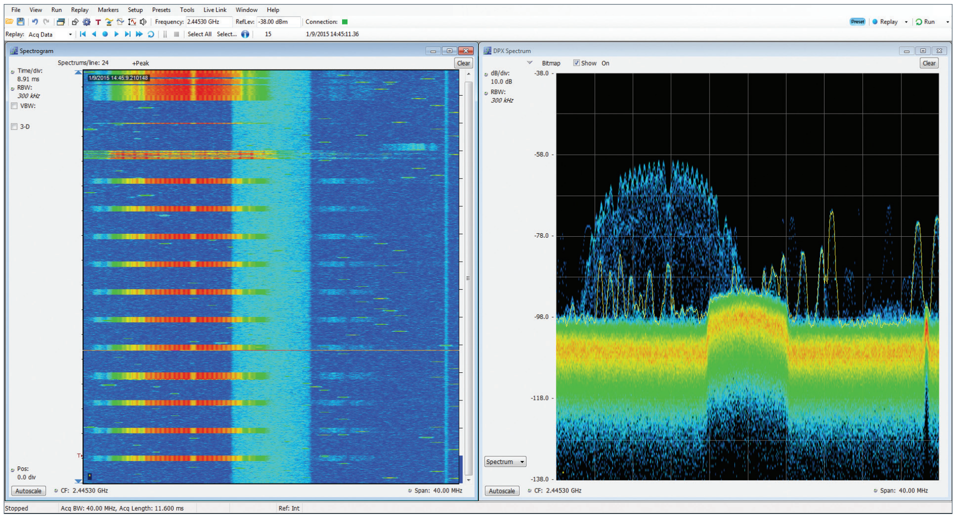
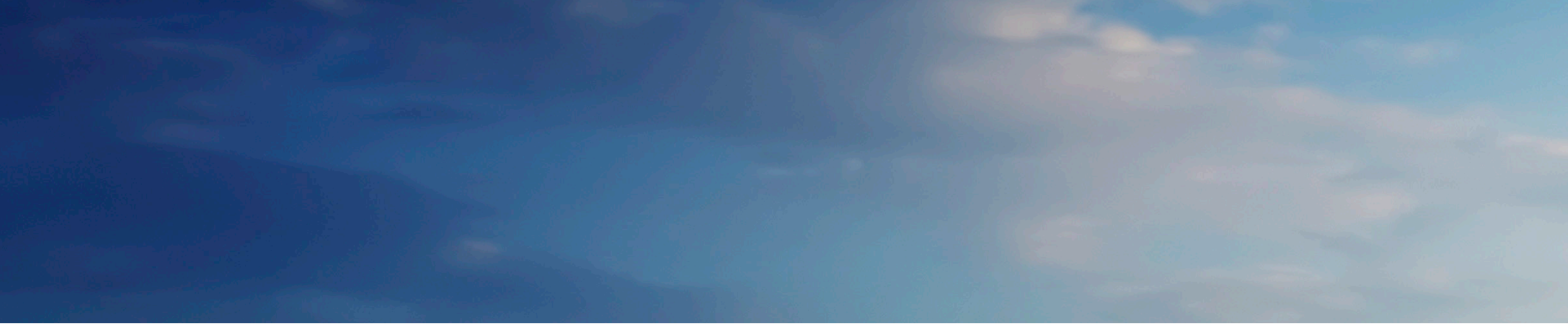


Figure 4. *An RTSA provides complete domain correlation allowing information in the spectrogram on the left to be directly correlated with other measurements.*

Figure 4 shows an example of a digital phosphor display in conjunction with a spectrogram. The digital phosphor display is showing a great deal of detail of the signals that are present. In the center of the display is a lower level wide-band signal which exhibits a large crest factor. Given the bright or “hot” coloring, this signal has a high level of channel occupancy (nearly continuous). A Wi-Fi signal can also been seen in the display, it appears to be operating on 2.437 GHz (Wi-Fi Channel 6). There are also more than 10 other signals in the display at varying frequencies and power levels. Given the spectrum shape and frequencies in use, these signals are probably from a Bluetooth device. **>>**



RTSA technology drives every day spectrum analysis

While there were many different services using the above measured spectrum, by utilizing active spectrum sharing techniques, these signals were time interleaved so there was little or no loss of link quality. Increasingly real-time spectrum analyzer technology is required for every day spectrum analysis.

While historically RTSA's were relegated to niche applications, modern radio designs clearly need the power and flexibility of real-time spectrum analysis to trouble-shoot system level issues and characterize modes of operation.

About the author

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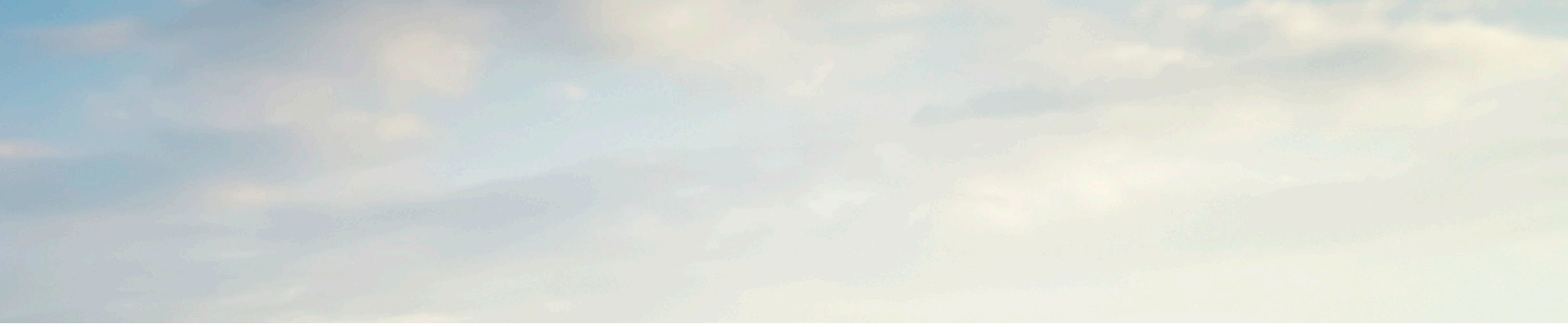
Robin Jackman is a senior member of the field application engineering team based in Toronto, Canada. He has been with Tektronix more than 15 years helping customers throughout North America. His work with Tektronix has covered both analog and digital design with a focus on RF applications. Prior to Tektronix Robin accumulated extensive experience in electromagnetic compatibility, radio regulations and interference as a Spectrum Management Officer with the Canadian government.



References

- ***eGuide to Signals***
  info.tek.com/AM-RSA306-e-guide-to-RF-Signals.html

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