Application Note

Anritsu envision : ensure

IQ Capture and Streaming for Monitoring Spectrum

Introduction

The RF spectrum is becoming increasingly crowded with new cellular, satellite, and radio links continually being rolled out. Society depends on radio communications for personal voice and data connections, businesses, security, and more. For anyone charged with managing wireless networks and spectrum, monitoring, tracking, and identifying known and unknown signals is critical to ensuring the performance of all transmissions. Spectrum monitoring can be done in many ways. In some cases, basic data throughput testing is enough for a network manager to gauge the health of the transmissions. In many cases, however, a much deeper analysis is required to better understand the intricate details of network traffic. This is where IQ data capture becomes important.

The Need for Spectum Monitoring

Spectrum is a finite resource that is carefully allocated and monitored to maximize its efficacy. Companies or organizations wishing to transmit over RF frequencies may pay millions – even billions – of dollars for the rights to do so. They then have a right to ensure their spectrum is free of unauthorized signals, as well as the responsibility to be a good neighbor to other spectrum owners that could be impacted by their signals.

In 2017, for example, T-Mobile spent over $2 billion dollars on a 600 MHz spectrum auction in the United States to acquire the rights to build out part of their 5G network. The bands up for auction had previously been used by local broadcast television stations for over-the-air (OTA) TV. With that kind of investment and a heated competition among US wireless carriers to “win” the 5G race, T-Mobile has a vested interest in ensuring their spectrum is clear of older or unwanted signals that could cause problems in their network, leading to unsatisfied customers and damage to their reputation.

For that same reason, national communications regulators, like the FCC in the US, KCA in South Korea, or ANFR in France, for example, have a critical responsibility to ensure that spectrum owners operate within the frequency limits allotted to them. Spectrum owners rely on them to police transmissions as well as find and eliminate unwanted signals.

Cellular communications are not the only ones with a need to regulate spectrum. For national defense and intelligence agencies, spectrum monitoring is a matter of national security. Nefarious signals can be used to transmit covert messages, interrupt mission critical communications, compromise confidential information, and create blind spots in security systems. Actively monitoring spectrum along with identifying and eliminating unwanted signals is essential to maintaining critical communications systems.

Importance of IQ Data

Spectrum monitoring can be done in several stages, beginning with simple trace monitoring on a receiver like a basic spectrum analyzer or power meter. Base power levels and frequency limit masks can be set and any signal that exceeds those levels can be identified. While useful as a starting point in identifying the presence of unwanted or illegal transmissions, these tools will not give a network manager detailed information on the characteristics of an unwanted signal. Power meters are broadband and only indicate power at some point in their detection range, while standard spectrum analyzers are swept-tuned which can result in gaps in analysis that can miss critical details. While a real-time spectrum analyzer removes these gaps to give the user a better view of intermittent or transient signals, it is still summarizing millions of points of data into a single spectral density display that can ultimately hide critical details and does not identify specific modulation schemes. In order to get to the required levels of detail about an unknown signal, it needs to be sampled at as fast a rate as possible and broken down into the basic building blocks of I and Q.

With the I and Q data captured, network managers have several options to play it back to analyze signal characteristics. To begin, the data can be played back in both the frequency and time domains, but at a much slower rate in order to find patterns or repetitions in the data. For example, a smart radar jamming device might use intelligence to lock into radar signals. By capturing the IQ data and watching the behavior of the jammer over time, signal operators may be able to implement countermeasures to adjust their radar behaviors to avoid the jammer.

With IQ data, signal hunters can also look at patterns in the I and Q itself to try to identify common modulation schemes to separate out nefarious and non-nefarious signals. For example, for someone like T-Mobile ensuring that broadcast television signals have been cleared, they could analyze IQ data against common TV modulation schemes to identify if the signal is, in fact, a station that has not yet been removed or if it is maybe just some old industrial equipment – like an arc welder – radiating noise into their bands. Another example might be a security agency preparing a room for a confidential meeting. Secure rooms are often swept for listening devices, but a typical spectrum analyzer or receiver would only show the presence of a signal, not what kind of signal it is. With IQ data, the agent might be able to tell if the signal is from a bug or just incidental radiation from the neon tube lights.

Tools for Capturing IQ Data

Traditional swept spectrum analyzers cannot be used for capturing IQ data because their method for capturing spectrum traces is based on sweeping local oscillators and analog detectors. Advanced spectrum analyzers – or vector signal analyzers (VSAs) – however, are common tools for capturing IQ data. These analyzers digitize RF signals with analog-to-digital converters (ADC) before running the data through fast Fourier transforms (FFTs) to produce frequency plots. The digitized data is what is used to analyze the IQ data of the signals. VSAs can vary in performance and form factor. Some key considerations when selecting an instrument are as follows.

RF Specifications

The fidelity of the IQ data will only be as good as the tool that captured it. Entry-level spectrum analyzers will typically sacrifice dynamic range, signal bandwidth, and amplitude resolution to keep costs of materials and manufacturing down. On the other side, premium benchtop instruments will generally offer superior RF specifications, but are bulky and very expensive. Which instrument you choose will depend on the information you want to get from the data. For deep analysis of modulation quality, I versus Q, eye diagrams, etc., higher RF specifications will provide much better data. However, if basic timing and relative power is all that is required, a lower end instrument may be a better choice. Among the specifications to consider are amplitude accuracy, frequency accuracy, measurement bandwidth, phase noise, dynamic range, and noise floor (DANL). To find the right balance of performance and cost, the following specifications need to be considered.

Capture Bandwidth

Capture bandwidth defines the size of the analyzer filters and essentially how much IQ data the analyzer can capture. Typically, the wider the bandwidth the faster the sample rate, so instruments with a wider analysis bandwidth specification will allow users to capture more in frequency and in overall data points. Wider capture bandwidths, however, require advanced hardware designs, more processing power, and more power consumption, so the widest captures are typically offered in big, expensive benchtop analyzers. The need for wider bandwidth will be determined by the use case. In general, wide captures are useful when monitoring for unknown signals. For example, a security agency that is monitoring wide bandwidths of frequency for any sort of nefarious communication will want as wide a capture bandwidth as possible to minimize the number of scans that must be done. On the other hand, in cases where the monitor knows the general frequency of the signal-of-interest (SOI), perhaps lower bandwidth captures may suffice.

Memory/Storage

As captures become wider in frequency or samples, the amount of data that needs to be stored and moved within the instrument will grow. Due to the speed of IQ sampling, most instruments will capture blocks of IQ data into RAM then move it out to a storage medium. This means the amount of time and bandwidth the analyzer can capture will be limited by the amount of available RAM. The more RAM dedicated to IQ capture, the greater the span and/or time that can be captured. For wider applications that require wide bandwidth captures, available analyzer memory allocated to the IQ capture process becomes especially important.

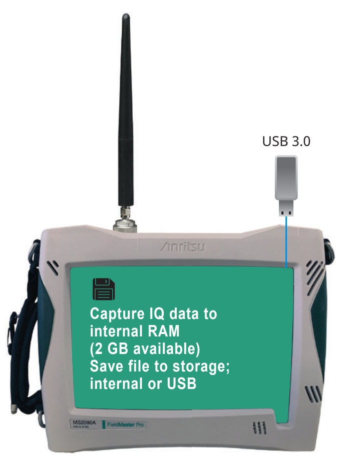

Figure 1. IQ Capture

More advanced instruments enable the streaming of IQ data directly to storage devices, like USB drives or PC storage. Data comes into a circular buffer in the instrument RAM and is continuously moved off to the external device. This type of capture will be limited to the transfer speeds between the RAM and the external storage device, but in general this will enable much larger amounts of data to be stored.

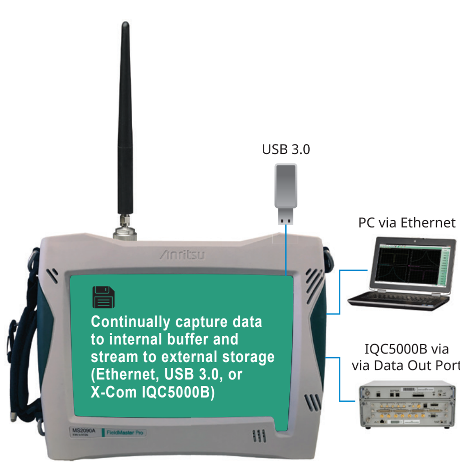

Figure 2. IQ Streaming

Advanced Triggering

IQ captures can be triggered in many ways. Most commonly, captures are started via a manual trigger, like a button press on the instrument. This is generally sufficient for applications where IQ data is being captured on a continuous or known signal where the timing of the capture is not critical. This can be problematic though for situations where IQ data is needed for an intermittent (sporadic) signal or when trying to monitor spectrum over a long period of time. If the user must start the capture manually and wait for an event, the available RAM or storage could be filled before the event occurs. Even if the event is captured, users may be left to sift through gigabytes of unwanted IQ data in order to find the event in question. Analyzers with video (level) triggers, external triggers, or interval triggers can help cut down the amount of data that must be analyzed. For example, if a regulator wanted to ensure that a swath of spectrum has been cleared over a 24 hour period, rather than collecting 24 hours worth of data, the engineer could set a level trigger just above the noise floor as a baseline. Any signals that rise out of the noise floor and cross the trigger line would be captured, yet during times where no interference is present no innocuous data would be captured.

Another valuable trigger function available on some analyzers is a negative trigger delay or pre-trigger. Once a trigger is armed to monitor for an event, IQ data fills a circular buffer in the instrument RAM. When the trigger event occurs, the pre-trigger tells the analyzer to go back in the buffer to start the capture at some defined time before the event. Seeing the spectrum activity just before the trigger event can provide additional insights in to the origins or characteristics of an unknown signal.

Form Factor (Portability)

The form factor of the instrument can play a big role in choosing the best analyzer for a particular application. As already discussed, benchtop instruments with a larger form factor will often offer the best performance, but will be heavy, large, and vastly more expensive than handheld analyzers. It is possible to rig benchtop analyzers in racks in vans for field tests, but these systems add cost, complexity, and maintenance issues that add up in a project. Furthermore, in some cases it is not practical at all to take a benchtop instrument, like on an aircraft with limited space or when trying to analyze signals in a more inconspicuous manner. Portable analyzers are specifically designed for this type of application.

Small form factor USB analyzers that utilize PC hardware as their processing engine have been developed for basic IQ capture applications. These can be an affordable, smaller solution, but require more software license management and can often reliability issues both with the PC operating system and with the USB connection. Handheld analyzers are more like the benchtop instruments with integrated screens and software, but are smaller and battery powered. The latest handheld spectrum analyzers have similar performance to traditional benchtop instruments.

Data Analysis Tools

While capturing the IQ data is the first step, it is also important to consider the software tools that will be used to analyze the data once it has been captured. There are a wide variety of software tools that range in features and focus. There are a multitude of different ways to view and analyze IQ data; some of the more common options that software tools will do with IQ data include:

- **Replaying the samples in the frequency and time domains –** This is valuable because the playback can be slowed down and analyzed for patterns or changes over time, like in the radar example above.

- **Auto detection of events –** By placing triggers or defining events, some software can automatically search through the sweeps to identify changes in power to make searching through the data faster. This is especially useful when large amounts of spectrum data have been captured, like in general spectrum clearing. Hours of wideband captures can be terabytes of data and could take days to playback. Smart searching tools can save magnitudes of analysis time.

- **View I and Q in a constellation diagram –** Plotting points in vectors of I and Q amplitude can show patterns of common modulation schemes, like 16, 64, or 256QAM. If no patterns exist, it may be a clue that the signal is something more random, like industrial equipment or tube lights.

- **Show I and Q in eye diagrams –** This is another way of viewing the modulation quality. A signal with a good gap or “eye” will show clean transitions in the 1s and 0s that are being transmitted and ultimately decoded by a receiver.

- **Modulation quality analysis –** IQ data can be used to measure things like error vector magnitude (EVM), frequency error, phase error, magnitude error, symbol rate, and more. Extracting this type of information, however, usually requires users to have some level of knowledge about the signal, like frame structures and modulation schemes.

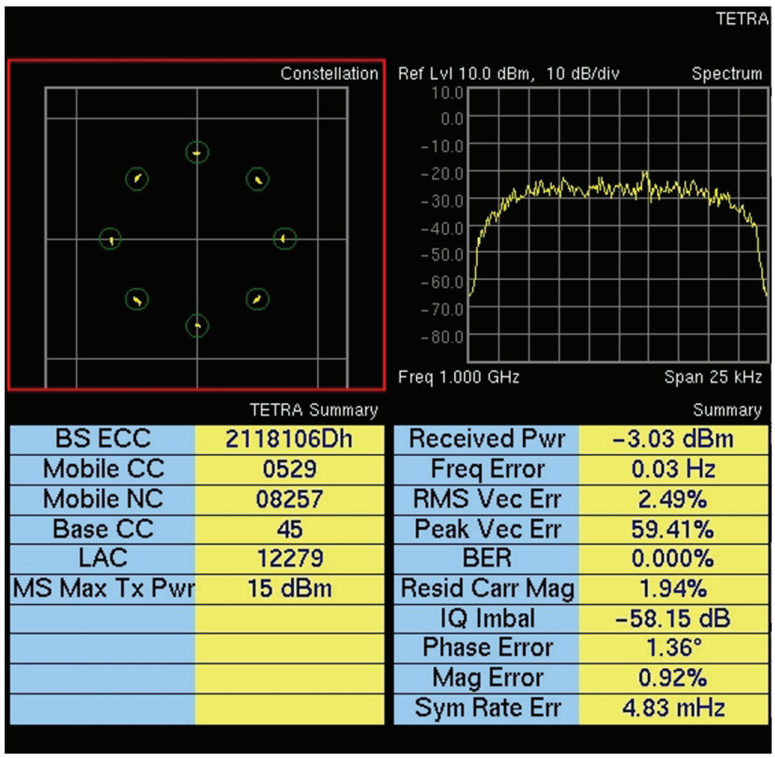

Figure 3 – IQ Analysis Tools Can be Used to Confirm Modulation Quality and Verify Signal Patterns

Instrument manufacturers offer analysis software directly or partner with third parties who have developed software for specific markets and use cases. In the case of government security agencies, they will typically develop their own post-processing analysis tools to maintain control over the intellectual property and confidentiality around their capability. Most analyzer manufacturers will provide information about the format of I and Q data in the captures and how it can be parsed for off line analysis.

IQ Capture and Streaming with the Field Master Pro™ MS2090A

The Field Master Pro MS2090A real-time spectrum analyzer (RTSA) from Anritsu offers a powerful combination of specifications, features, and portability for IQ capture and streaming applications in the field. Building on decades of leadership in the handheld analyzer market, the Field Master Pro MS2090A has benchtop-level RF specifications to go with up to 110 MHz of capture bandwidth.

The Field Master Pro MS2090A also dedicates a full 2 GB of RAM for IQ capture and streaming, which at 110 MHz capture bandwidth enables up to 5.37 seconds of capture. Users also have the flexibility to select different bit formats from 8 bits up to 32 bits. An 8 bit capture will save space and enable longer captures, while 32 bit captures will provide greater dynamic range for narrower band captures. The Field Master Pro MS2090A is the only handheld instrument that supports IQ streaming. Users can stream over USB, Ethernet, or to the IQC5000B from Bird Technologies.

Figure 4. The Field Master Pro is Compatible for Streaming Data to Bird Technologies IQC5000B

For users capturing data live in a field environment, the Field Master Pro MS2090A RTSA also supports simultaneous IQ capture/streaming and frequency domain display with density data and/or spectrogram. This enables visual analysis of the spectrum while IQ data is being stored for later evaluation.

For post processing, Anritsu has teamed up with Bird Technologies to offer IQ playback in the Spectro-X software suite. Spectro-X enables playback of traces along with smart search functions, data trimming, and more. Anritsu can also provide starter scripts for Matlab or Python for parsing IQ data for custom post processing tools.

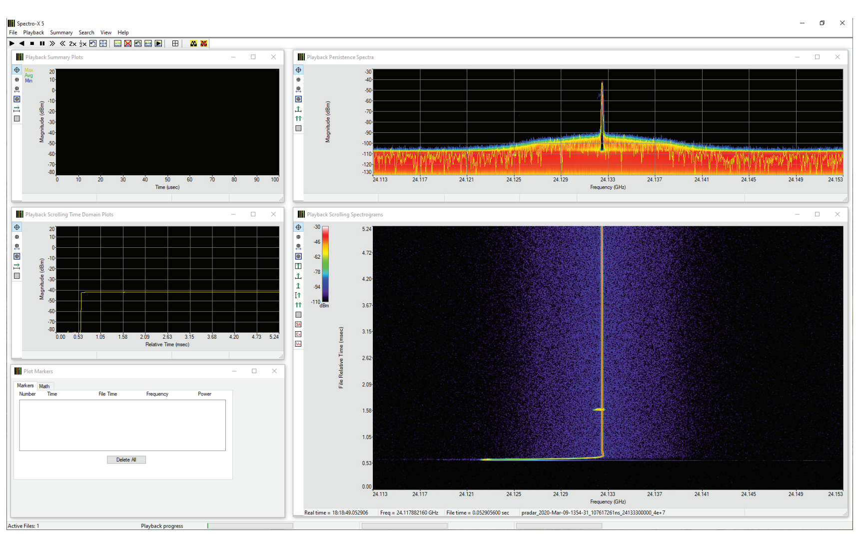

Figure 5. Spectro-X from Bird Technologies Allows Playback and Search of IQ Files from the Field Master Pro MS2090A

RF Specifications	• ±0.5 dB typical amplitude accuracy • > 106 dB dynamic range • As low as -164 dBm DANL
Capture Bandwidth	• Up to 110 MHz of IQ capture/streaming bandwidth (option dependent)
Memory/Storage	• 2 GB RAM dedicated for IQ capture • Streaming over USB, Ethernet, and PCIe • Compatible with Bird Technologies IQC5000B for up to 15 TB of storage • Settable IQ bit depths from 8 bits to save memory to 32 bits for greater dynamic range
Advanced Triggering	• Manual, interval, external, video (level) • Positive and negative trigger delay (pretrigger)
Form Factor	• Benchtop level performance in a portable form factor • Integrated screen, hardware, software • < 6 kg • > 2 hour battery life
Analysis Tools	• Compatible with Spectro-X analysis software from Bird Technologies • Raw IQ formats for custom tools – Matlab and Python starter scripts available

Summary

Identifying interfering or illegal signals in the RF spectrum is increasingly important. The spectrum used by communications networks is expensive, crowded, and needs to be monitored with actions taken to eliminate illicit signals. This can only be done if the SOI can be captured and analyzed to give the spectrum owners the information required to identify the source. Using a spectrum analyzer, such as the Anritsu Field Master Pro MS2090A, with the IQ capture and streaming functionality, and coupled with post processing software is the fastest way to resolve these situations.

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Specifications are subject to change without notice.

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11410-02835, Rev. A Printed in United States 2020-10