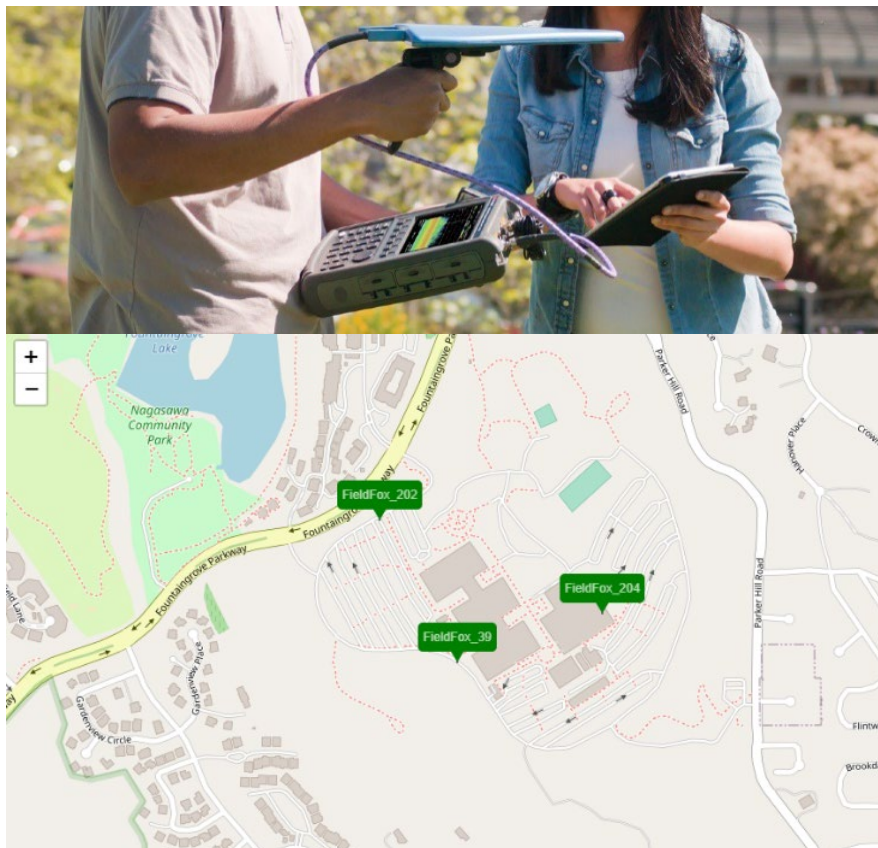


Keysight Spectrum Management Software

Executive Summary

Keysight Spectrum Management Software (KSMS) is a comprehensive software tool kit to modernize how frequency regulators, public and private network operators manage its frequency resource, detect, locate and mitigate interference issues, provide full stack spectrum optimization from RF to over the air analog and digital demodulation.

KSMS works with Keysight FieldFox RF and MW analyzers with an operating frequency from DC up to 54 GHz. FieldFox can be networked and mobile in a vehicle. Users can quickly setup ad hoc or mobile signal monitoring network to monitor RF spectrum activities, report frequency allocation and usage, detect any interference and locate its whereabouts using Time of Difference of Arrival (TDOA) and Received Signal Strength (RSS) techniques. FieldFox RTSA with a handheld directional antenna can find source of interference at last mile.



Signal Management and its Challenges

Signal Monitoring



Telecommunications industry has been cutting wires for the past decades, 5G and broadband communication catapults spectrum usage in a whole new level. The biggest challenges are higher frequency usage, base station density, and heterogeneous network deployment (5G, 4G, Wi-Fi, IoT and Satellite communication).

Higher frequency like mid-band and mmWave (FR2) deployment rendered existing signal monitoring infrastructure, which is hard to provide any useful information, because current signal monitoring sites are fixed and built for < 1 GHz, signal at higher frequency will not reach monitoring antenna.

Multi-layer dense base stations sharing same or adjacent spectrum, exacerbates interference issues, coordination between Macro, Micro, Pico, repeater and indoor DAS proves to be difficult, some operators don't even know what kind of assets are available in the given area, it complicates spectrum planning, clearing, and control.

Heterogeneous network deployment makes 5G, 4G, WiFi, IoT, Satellite communication and public safety all intrinsically dependent on each other, and they can also interfere with each other to impact coverage and network quality, testing and verifying radio coverage becomes interesting. More radio in any given area, more RF exposure generated, EMF becomes imminent tasks instead of nice to know.

In the meantime, broadcasting and critical communication LMR/Air traffic ground communication still needs to work perfectly and reliably.

Spectrum management including spectrum monitoring is facing a tremendous challenge to keep the wireless world in order, it requires fast and easy to use tools to increase spectrum management efficiency.

Keysight Spectrum Management Software with FieldFox provides a forward-looking platform to the industry to address these challenges.

Signal Analysis

One of the key trends in signal management is to have a better understanding of the signal formats and their impact on spectrum usage and noise generated due to channel allocation and guard bands. 5G like signals tend to have wideband and high peak to average ratio, these types of signals can easily over drive amplifiers and create spectrum regrowth impacting adjacent channels.

Massive MIMO and beamforming technologies make wireless networks more efficient at providing coverage, but it also proves to be challenging to verify transmitter's total transmit power, makes the spectrum control challenging. This is particularly problematic with spectrum sharing networks like CBRS.

All the trends point to a need to understand signals deeper under management, in addition to conventional regulation on frequency and power, frequency regulators and operators also need to proactively understand signal formats and their impact on network performance and spillover effects.

KSMS provides both standard power spectrum management measurements and signal demodulation / decode capability to provide full stack insight of signals under management.

Spectrum Occupancy / Usage Stats

With explosive growth of wireless connectivity from 5G to satellite communications, regardless how advanced technologies are, one limiting factor can hinder its adoption is frequency resources. And spectrum policy also heavily relies on available frequency resources.

To have better understanding of the effectiveness and fairness of frequency allocation, and utilization of existing spectrum to assess current air interface capacity, frequency/spectrum occupancy measurements are essential measurements/statistics to provide insight for network planning and operation.

Interference Detection

Interference impacts the network capacity and utilization rate the most, there are many types of interference, from network vantage point, there are internal and external interference, from frequency operation angle, there are co-channel, adjacent channel, and intermodulation interference.

In order to achieve better network efficiency, wireless networks move to wide bandwidth, variable data burst, and higher modulation schemes. These techniques make interference detection particularly challenging. Traditional swept tune spectrum analyzer is no longer enough, real time spectrum analyzer plays dominant roles to detect and locate interference. However, in order to sweep wide bandwidth and not miss any interferers, both sweep FFT and RTSA are needed. Keysight FieldFox RF/MW analyzers provide wide frequency coverage (54 GHz) and the widest real time bandwidth (120 MHz) in a handheld analyzer, it can quickly and reliably detect interference issues.

Interference Finding

Interference signals can be static, moving, or bursty, it also could occur during a specific time. This makes locating interference particularly difficult and time consuming.

There are typically 3 types of methods to locate a source of interference, Angle of Arrival (AoA), Time Difference of Arrival (TDOA) and Received Signal Strength (RSS).

Angle of arrival DF method typically uses a yagi or log periodic handheld antenna to manually track down interference based on its signal strength. It is the most common and cost-effective way to locate the source of interference, but it requires a well-trained engineering staff and is time consuming. Typically, this is for last mile interference direction finding.

Time Difference of Arrival (TDOA) is a DF method to determine emitter location using the relative arrival times of a signal at multiple receivers (≥ 3), it requires all receivers be networked and time synchronized with GPS. It is particularly effective to measure wideband signals. It is not as effective as AoA when measuring narrowband, and not suitable for CW signals.

If signal under investigation is present at an urban area with a lot of high-rise buildings and indoor setup, Received Signal Strength (RSS) proves to be very effective as well. It can average out some multipath effect and suitable for any type of signals, but this method is less accurate and takes more time to do averaging.

KSMS with FieldFox supports, TDOA and RSS, it can also combine both methods to provide hybrid DF to improve DF reliability and speed.

Key Features

Keysight spectrum management software is a comprehensive software platform (S9910A) to support spectrum management tasks, signal monitoring, spectrum occupancy statistics, interference detection, direction finding (S9911A/TDOA, RSS and Hybrid), and signal analysis like analog and digital demodulation (requires FieldFox relevant options or VSA 89600).

Spectrum Monitoring

In signal monitoring mode, KSMS can monitor a spectrum from multiple receivers (FieldFox) at the same time. It measures spectrum trace and spectrogram with markers.

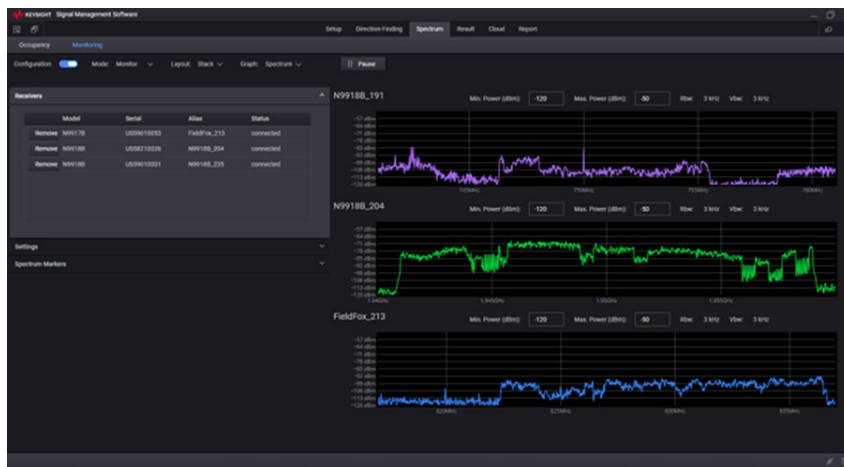


Figure 1. Spectrum trace from three receivers



Figure 2. Spectrogram display from three receivers

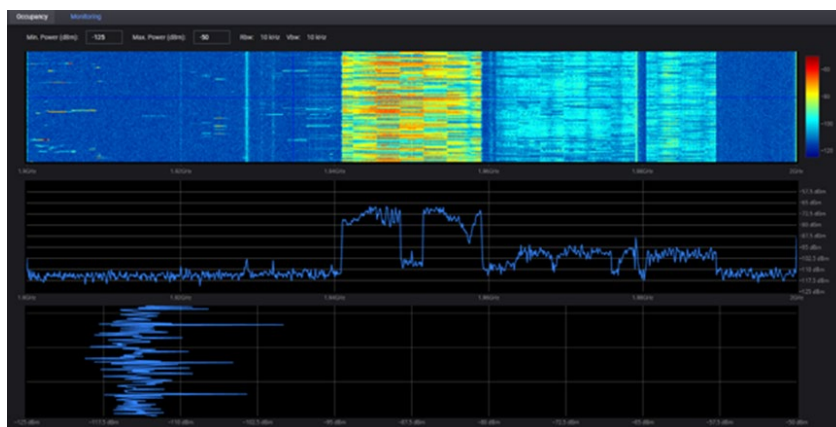


Figure 3. Cross domain display: spectrogram, spectrum domain, and time domain

Spectrum Recording

KSMS can record multiple receiver spectrum at same time, in the case of interference, user can define threshold for interference detection, measure interference frequency profiles, power levels, duration of interference/event, with precise GPS time stamp.

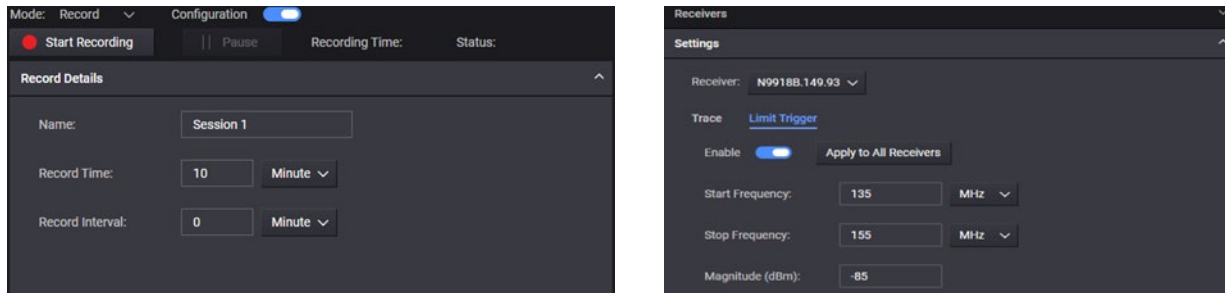


Figure 4. Recording and frequency mask trigger

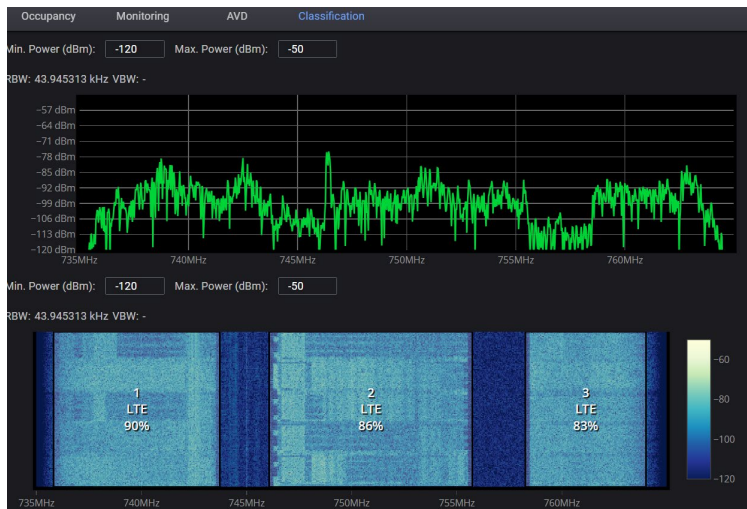
IQ Capturing and Streaming

KSMS can perform IQ capturing and IQ streaming. RF IQ data can provide deep insight information of the signal under test, it can be further analyzed in KSMS to find signal under signal, identify signal types, and even demodulate and decode them. In addition, IQ streaming is gapless capture, which is critical to contested spectrum operation with fast time variant signals.

- IQ capture / Segmented IQ: up to 120MHz with FieldFox (Option B10)
- IQ streaming: 1MHz with FieldFox B and C model, 120 MHz with FieldFox D model
- Playback recorded IQ data
- Analyze data in Keysight VSA software

AI/ML Waveform Classification (S9916A)

Wideband IQ capture enables the FieldFox and Keysight Spectrum Management Software (KSMS S9910A) to perform waveform classification using AI/Machine Learning (ML). The latest ML model (S9916A) now supports major cellular and enterprise wireless signals, including LTE, 5G NR, WiFi, and *Bluetooth*®. This integration significantly reduces the customer's time-to-resolution. Moreover, the AI model provides deep insight into congested and sometimes contested spectrum operations.



Spectrum Occupancy Measurement

KSMS allows user to define a set of channels – frequency, bandwidth, and threshold, and measure their usage over a defined period of time. This helps to provide insight of channel utilization. Channel can be defined manually or import as a csv file. The tabular results can be exported as csv file.

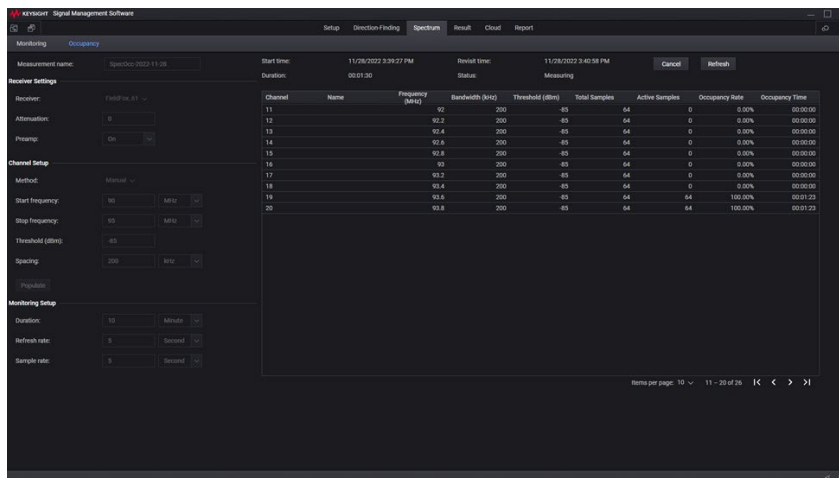


Figure 5. Frequency occupancy measurements

KSMS allows users to take long duration of spectrum recording and calculate spectrum activities by compressing entire duration into a manageable spectrogram display, user can set the analysis based on peak, average or percentage of signal above settable threshold.

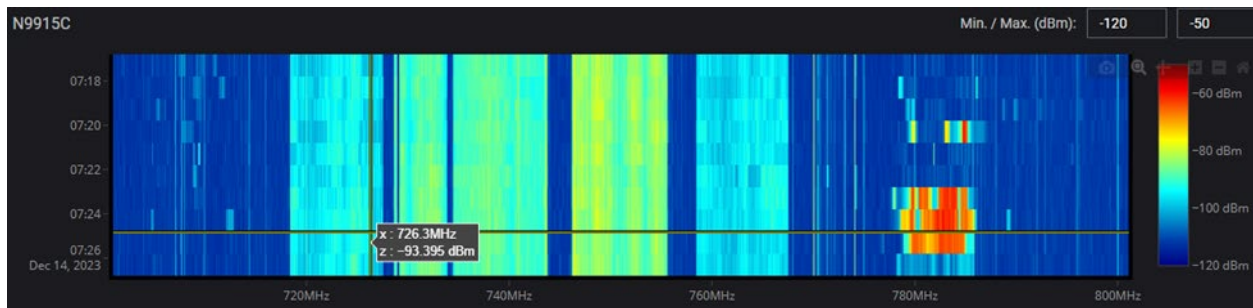


Figure 6. Compressed spectrogram

Direction Finding (DF) – Time Difference of Arrival (TDOA) with Look Back Buffer

Modern wireless systems are based on wideband and digitally modulated signals, to track down this type of signal, TDOA DF is more effective, accurate, and reliable. To run TDOA DF, it requires at least three networked receivers (FieldFox with option 390) with GPS synch and precision time stamped signal capture.

FieldFox/Receiver can be installed on a roof top, in a vehicle or in a backpack, given 4G/5G signals are allocated at higher frequency bands like > 2 GHz to 7 GHz, more deployment will be in vehicles, so FieldFox can be close to premises and produce reliable measurements.

Modern signals are wideband and dynamic, **TDoA look back / pre trigger** takes advantage of FieldFox circular buffer to trigger and search fast changing signals and send synchronized IQ captures from 3 units of FieldFox to KSMS TDoA engine to perform geolocation, it significantly reduces misses.

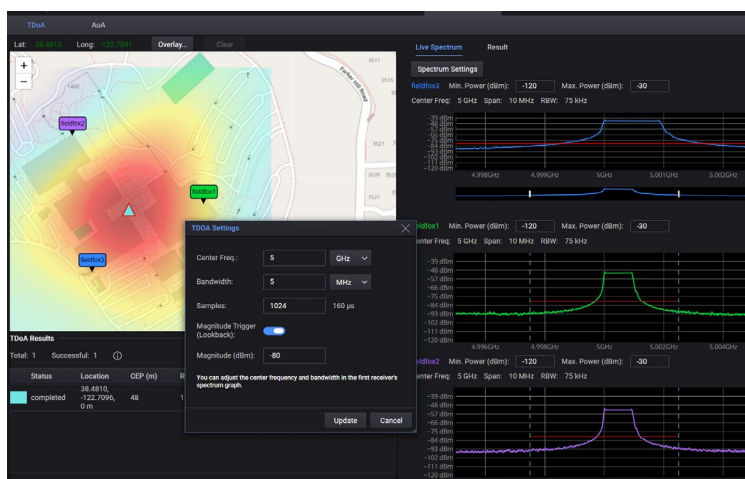


Figure 7. Direction Finding – TDOA

Spectrum Management Software Configurations

KSMS is a software platform to support signal spectrum management, interference analysis, and direction finding.

- S9910A Keysight Spectrum Management Software: This is a base platform module. It includes spectrum monitoring, Segmented IQ, IQ streaming, spectrum occupancy, record and playback, and database support. All optional software packages require S9910A to run.
- S9911A Direction Finding TDOA: It requires each FieldFox B and C model with Option 390 DF TDOA support. S9911A requires S9910A to run.
- S9916A Automatic signal classification – civil and commercial
- Supported Receivers: FieldFox N991xB, N993xB, N991xC, N993xC, N991xD, N993xD, N995xB, N996xB, N995xD and N996xD with spectrum analyzer option or spectrum analyzer. The following FieldFox options are required for full functionality
 - Option 307 GPS Receiver
 - Option 351 IQ Analyzer
 - Option 353 IQ Streaming
 - Option 390 Direction Finding TDOA
 - Option 391 Direction Finding AOA
 - Option 235 Pre-Amplifier
- Note: The following receivers support only basic spectrum monitoring functions; N991xA, N993xA, N995xA and N996xA
- Note: The following receiver is not supported by KSMS: N9912C

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