Application Note

Real-Time Spectrum Analysis

Overview

The proliferation of wireless applications and services has increased the demand for radio frequency (RF) spectrum. As more and more radio transmitters are added into the RF system, the potential for RF interference grows exponentially. RF interference (RFI) can be defined as the effect of unwanted energy due to one or a combination of emissions, radiations, conductions, or inductions upon reception in a radio communication system, manifested by any performance degradation, misinterpretation, or loss of information which could be extracted in the absence of such unwanted energy.

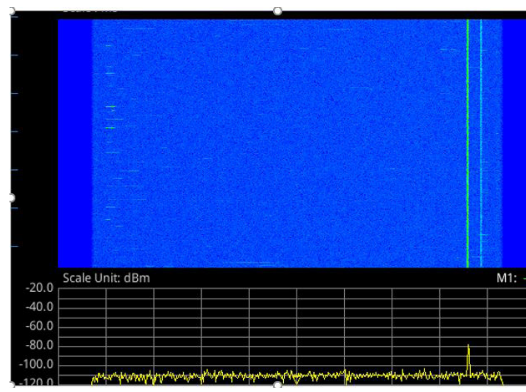

Fig. 1-a Persistent interference

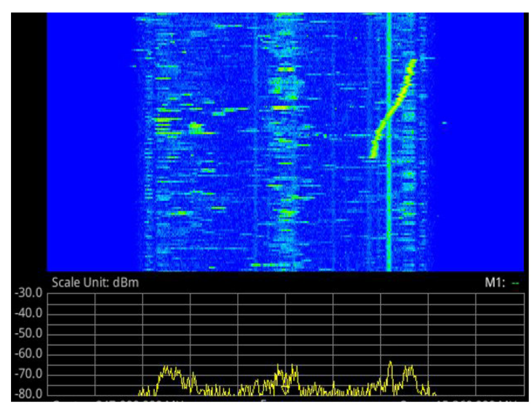

Fig. 1-b Transient interference

RFI in cellular networks is one of the most common problems in the radio access network (RAN). Mobile users near the interference source will experience degraded call success rates, increased dropped calls, decreased battery life, poor voice quality, and reduced data throughput. Interfering signals can be persistent, such as intermodulation products generated by active or passive components, or can be transient in both time and frequency domain. Identifying such interfering transient signals in the uplink, where other varying control and data channels exist, makes the task of interference hunting more painful. The first step under those circumstances is to effectively distinguish and track the interference signal from the superimposed traffic signals. Typically, the spectrogram (AKA waterfall diagram) supported by most spectrum analyzers is a very useful tool in identifying intermittent interference signatures as shown in figure 1-b.

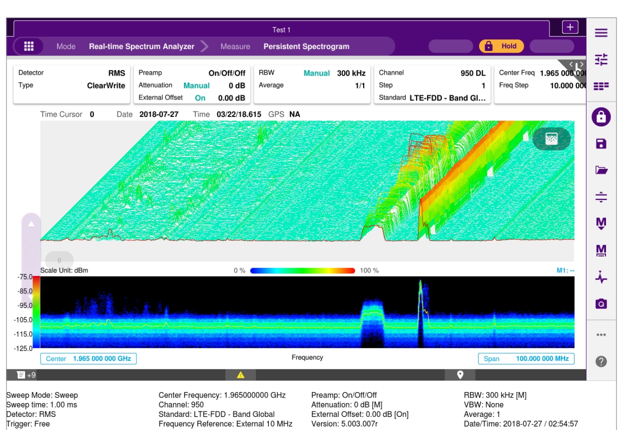

Fig. 2 3D waterfall diagram

Interference Hunting Challenges in 5G

The physical layer of 5G New Radio (NR) continues to use orthogonal frequency division multiplexing (OFDM); however, the duplexing options supported in NR include frequency division duplex (FDD), time division duplex (TDD) with semi-statically configured UL/DL configuration, and dynamic TDD. In the TDD scheme, both DL and UL use the same frequency but are allocated different time slots for transmission and reception. In that scenario, identifying an interference signal is extremely difficult when the base station is transmitting the signal in the DL. To overcome this challenge, a gated sweep functionality that only measures the signals during the UL transmission period is used. Gated sweep is essential to isolate interfering signals in the UL. However, as 5G NR introduces dynamic TDD where UL and DL transmissions can be changed dynamically, the gated sweep function will no longer be effective.

Addressing the Challenges with Real-Time Spectrum Analysis

A real-time spectrum analyzer (RTSA) addresses this challenge by detecting signal level and frequency of occurrence of rapidly changing interfering signals overlapped with the 5G NR signal. A real-time spectrum analyzer can capture transient and fast signals more quickly as well. Traditional spectrum analyzers perform data sampling and Fast Fourier Transform (FFT) processing in a serial manner, sweeping across the spectrum by capturing small parts of the spectrum at a time and building a complete picture over time. As a result of this serial process, a traditional spectrum analyzer is blind to other spectral regions during the sweep time. If an event (interfering signal) occurs in one part of the spectrum while a different part of the spectrum is being examined, the event will be missed. On the other hand, a real-time spectrum analyzer can perform the data sampling and FFT processing in parallel, and theoretically can capture every intermittent signal without missing any signals for the entire range of spectrum.

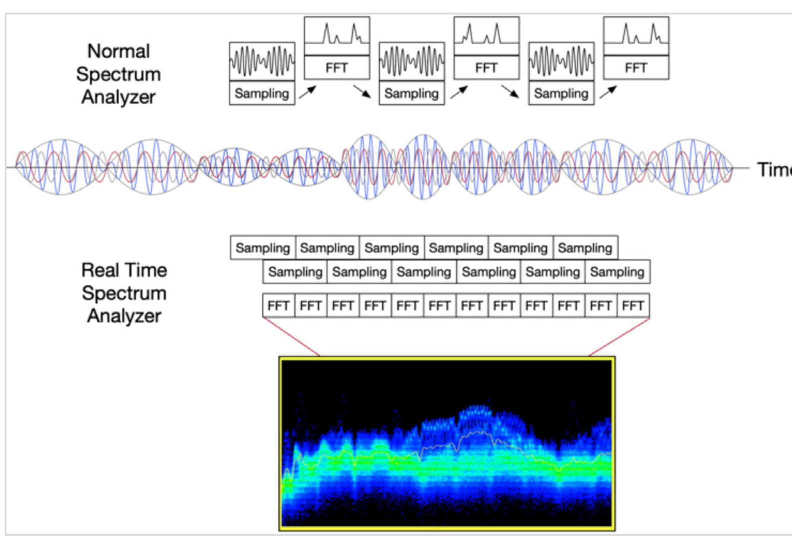

Fig. 3 Overlapped signal processing scheme of RTSA

A real-time spectrum analyzer can process thousands to hundreds of thousands of spectrums per second, but the visually perceptible screen update rate is about 30 frames per second. To overcome this, an RTSA uses a viewing method called persistent spectrum display, which shows hundreds or thousands of spectrum data on a screen, but with a different color or brightness per frequency of occurrence to determine the probability of signals appearing rather than just the amplitude of a signal.

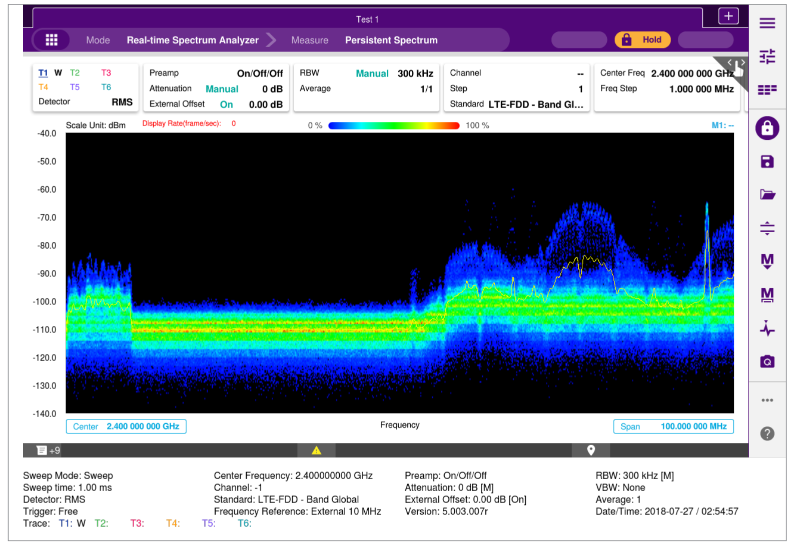

Fig. 4 Persistent display showing interference signals in 2.4GHz band

One key performance indicator for an RF signal analyzer is the probability of intercept (POI). POI represents the amount of time that a signal needs to be present above the noise floor, such that there is a probability that the signal will be intercepted and adequately captured for the purposes of analysis. POI of the RTSA is mainly determined by the sampling frequency, signal bandwidth, and FFT size.

Now let's understand POI in the context of 5G NR. As we all know, 5G NR offers scalable subcarrier spacing to accommodate different applications from eMBB to URLLC. Just like LTE, a subframe is divided into slots consisting of 14 OFDM symbols. However, the duration of a slot depends on the subcarrier numerology. For example, for a 15 kHz subcarrier spacing, an NR slot has the same structure as an LTE subframe with 1ms slot duration, which is beneficial from a coexistence perspective. Since a slot is defined as a fixed number of OFDM symbols, a higher subcarrier spacing leads to a shorter slot duration as shown in figure 5.

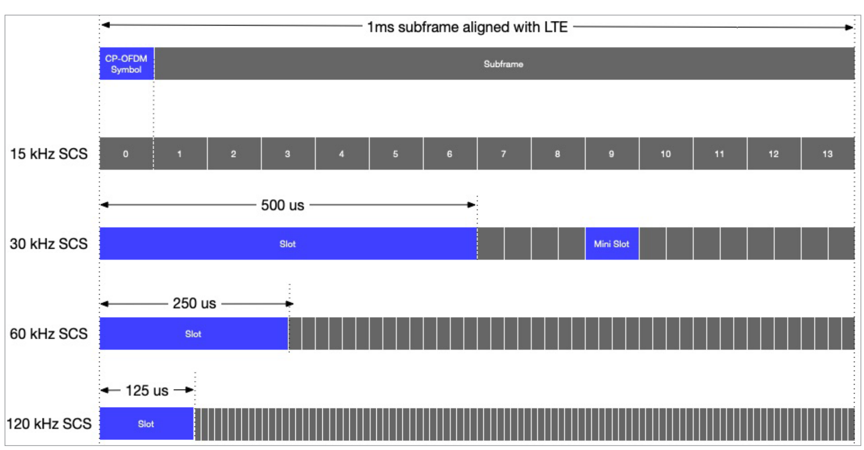

Fig. 5 Slot duration vs. subcarrier spacing

The table below shows the relationship of subcarrier to slot duration.

Subcarrier spacing	Cyclic Prefix	Operating band	Slot Duration	Slots per subframe	Number of subframes
15 kHz	Normal	FR 1	1 ms	1	10
30 kHz	Normal	FR 1	500 µs	2	20
60k Hz	Normal Extended	FR 1	250 µs	4	70
120 kHz	Normal	FR 2	125 µs	8	80
240 kHz	Normal	FR 2	62.5 µs	16	160
480 kHz	Normal	FR 2	31.25 µs	32	320

From a RTSA perspective, signal events larger than the POI limit can be captured and analyzed; otherwise, events with durations smaller than the POI of the RTSA will be missed. Therefore, a much more granular POI performance is required for different subcarrier spacing and DU-UL slot scheduling to avoid the possibility of missing any interference signals due to insufficient filter charging time.

Fig. 6 clearly shows an interference signal on 5G NR FR1 band. A fixed spur is shown with a high probability of interference.

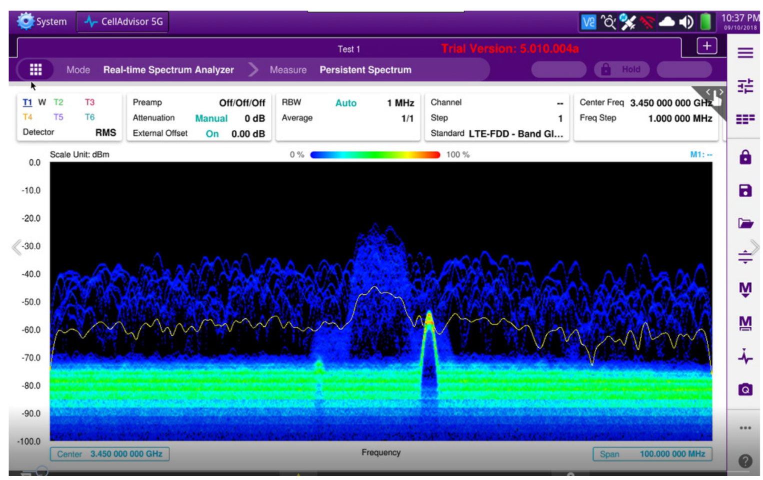

Fig. 6 5G NR spectrum with two persistent interferences

VIAVI CellAdvisor™ 5G

CellAdvisor 5G is the ideal field portable solution for identifying and troubleshooting interference issues in both FR1 and FR2 bands. CellAdvisor 5G performs real-time spectrum and interference analysis with persistence for an entire 100MHz signal. By accumulating more than 15,000 traces on a screen with a color index representing the time duration and repletion rate of every signal, CellAdvisor 5G provides the optimal condition for identifying the signatures of intermittent interference sources. CellAdvisor 5G is the industry's most efficient real-time field spectrum analyzer available today for identifying the most challenging interference sources.

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