WSA TDD 4G/5G Analysis & Uplink Interference Hunting Guide

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Introduction

Since the arrival of TDD-4G-LTE signals, RF signal analysis has become more complicated. Such signals have not only rendered the conventional sweeping spectrum analyzer obsolete, even for broad-band FFT analyzer (or so-called RTSAs), their usefulness and efficacy in practical application scenarios are often limited and even questionable. Yet broadband OFDM TDD-type of signals are increasingly becoming the trend. All practical 5G-NR implementations are TDD types as the same frequency band for both up and down links make the MIMO channel equalization process more efficient. All Wi-Fi signals from version 5 are TDD-OFDM types. We have no doubt to believe that the future NTN (Non-Terrestrial-Networks) signals for the upcoming 6G will also be dominantly TDD types for the ease of spectrum management and coordination among the ground and satellite base stations.

To make RTSA useful for TDD type of signals, precise time gating is needed in order to discriminate between the powerful downlink signals from the minute uplink ones. For all TDD type of signals, the following three applications come up naturally and frequently:

1. How to locate the minute interference signals that only seem to affect the uplink period?
2. How to ensure the downlink to uplink transition (or switch over) from a signal source (base station) is correct?
3. How to ensure time synchronization among adjacent cell sites and sectors to make sure one sector's powerful downlink won't affect another sector's fragile uplink?

In response, the WSA-408/308 instruments from Sage Instruments provide the following 3 killer applications:

1. Time gated RTSA;
2. Time and frequency co-domain synchronized analyses;
3. Detailed 4G/5G signal analysis with automatic timeslot synchronization and arbitrary time-domain power profile mask creation and application.

Time Gated Spectrum Analysis

A broad-band FFT analyzer (or RTSA) has the ability to turn a short segment of time domain signal into a snapshot of spectral display within its analysis bandwidth. Which segment of time domain signal to use gives rise to two different working modes:

1. Free running “continuous” mode: the RTSA indiscriminately takes any segment of time domain signal, performs FFT, and displays the spectrum as fast as the display can keep up;
2. Time gated mode: the RTSA performs analysis on a segment of time domain signal only periodically with its period precisely synchronized to the innate rhythm (or cadence) of the TDD signal to be analyzed. For example, all 4G/5G signals have the 10 ms frame rate, and within each 10 ms period, the uplink and downlink signal structure stays the same. If the gating period is set 10 ms, then the spectrum analysis can be guaranteed to perform only in the uplink or downlink period.

Let’s look at a specific example. Figure 1 shows a 100 MHz wide spectral display of true signals over the air. The 20 MHz wide signal at the center (Fc=1895 MHz) is a TDD-4G-LTE signal while all other signals are FDD-LTE signals. With spectrum analysis in free running mode, you can not tell the differences between them. Neither can we see any problems hidden underneath the TDD-LTE signal.

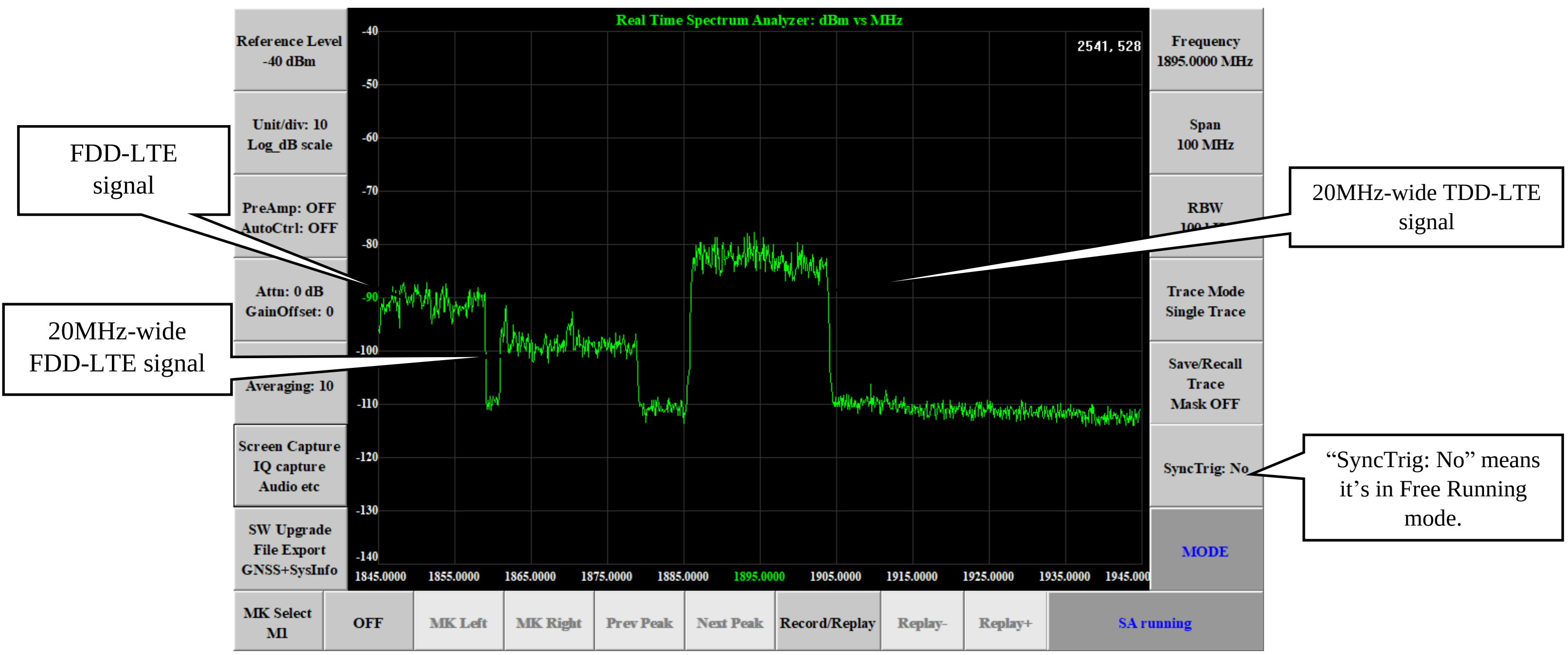

Figure 1 - Spectral Display in free running mode. Although the center is TDD-LTE and the two signals at the left are FDD, the spectral display in free running mode does not reveal any differences among them.

But once we enter the “Gated mode”, as shown in Figure 2, we not only see differences between the FD and TD signals, we also see obvious differences between the uplink and downlink periods of the TDD signals.

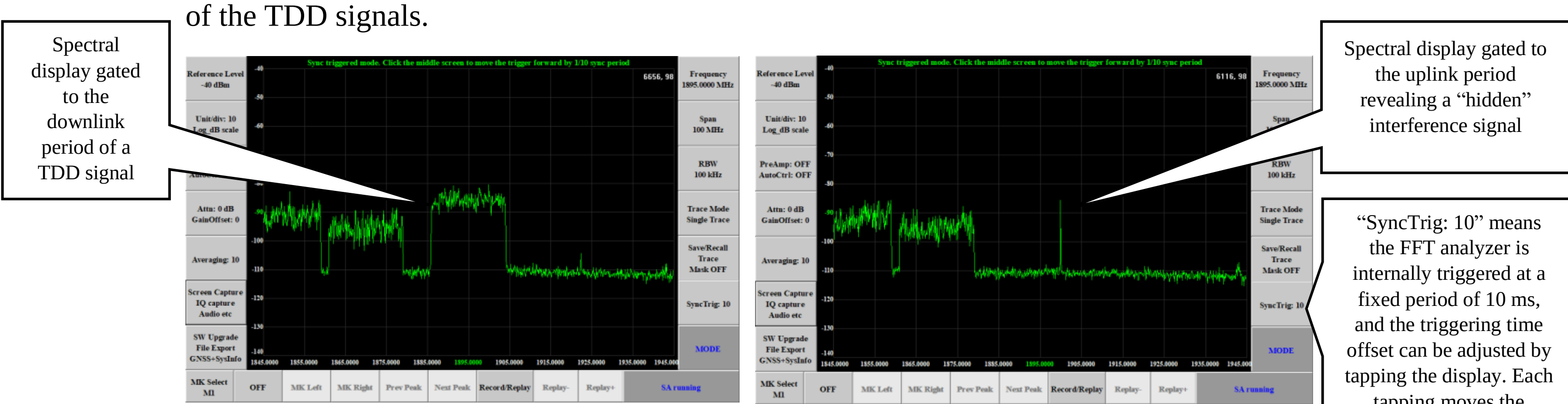

Figure 2 - Spectral display when it’s set to “Gated” mode. The left display is gated to the Downlink stage whereas the right display is gated to the uplink stage, revealing an Intentional interference signal added at 1.9 GHz.

For both Figures 1 and 2, an intentional interference signal (a persistent tone at 1.9 GHz) was added by connecting an antenna to a signal generator transmitting at -30 dBm. Figure 1 in free running mode shows no sign of interference signal. In gated mode of Figure 2, when gated to the downlink, no interference signal is shown, but once gated to the uplink stage (Figure 2 right), the interference signal is revealed beyond any reasonable doubt.

For such uplink interference hunting scenario, the common tactics in the market is to use RTSA’s DPX display. Figure 3 shows an example of DPX display by WSA-408/308. Yes, we can “clearly” see the persistent presence of a “hidden” interference signal, but to pin-point the exact nature of the interference (amplitude and frequency precisely), the spectrum analysis in gated mode shown in Figure 2 is no doubt far more superior and much more effective.

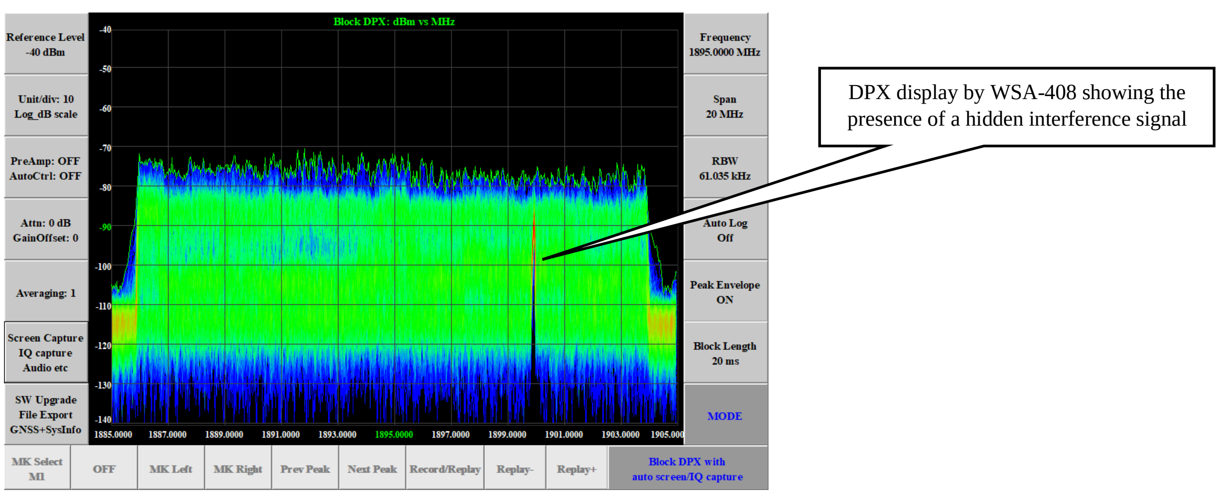

Figure 3 - DPX display revealing the hidden interference signal

TD-power plus spectral display

WSA-408/308 has another way to precisely dissect the TDD-type signal as shown in Figure 4.

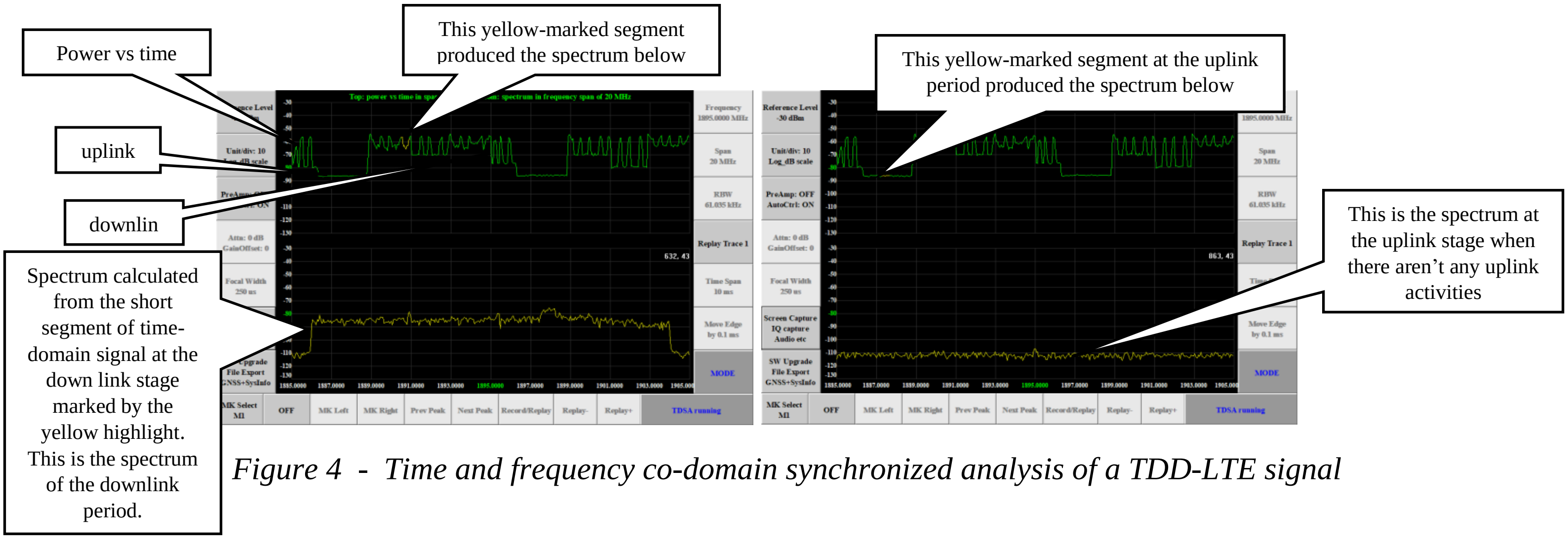

Figure 4 - Time and frequency co-domain synchronized analysis of a TDD-LTE signal

After introducing intentional interfering signals, we observed the test results shown below in Figure 5. Pulsed interfering signals were introduced for the case shown at the left, and steady state tone signal was introduced for the case shown at the right.

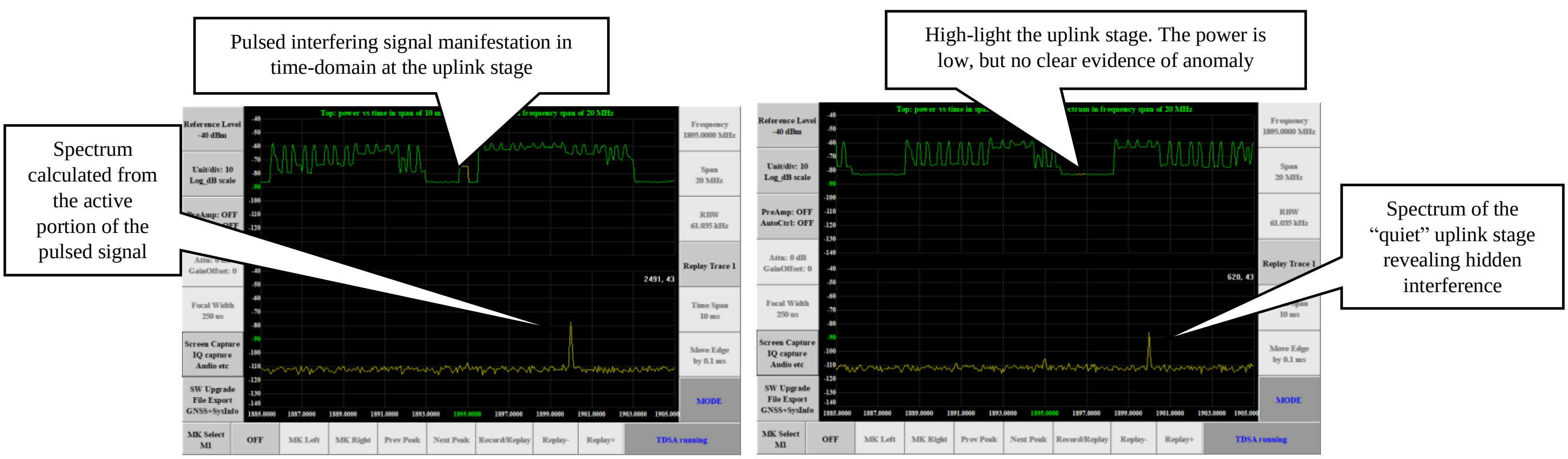

Figure 5 - Time and frequency co-domain synchronized analysis of TDD-LTE signal with intentional interfering signals added. For the case at left, pulsed interfering signals were added. For the case at right, steady state tone interfering signal was added.

As shown in Figure 5, no matter what type of interfering signals were added, pulsed or continuous, the TD-power+SA display (time and frequency co-domain analysis) test offers the most precise analysis of such complex signal situation.

TD-power profile under 4G/5G analysis test

Under the 4G (or 5G) analysis test function on a WSA-408, there is a TD-power display mode. In this mode, one can define and then import a power-profile mask, as shown in Figure 6. The designed purpose of this test is to verify the downlink to uplink transition timing and power accuracy. The user definable mask helps one verify such accuracy.

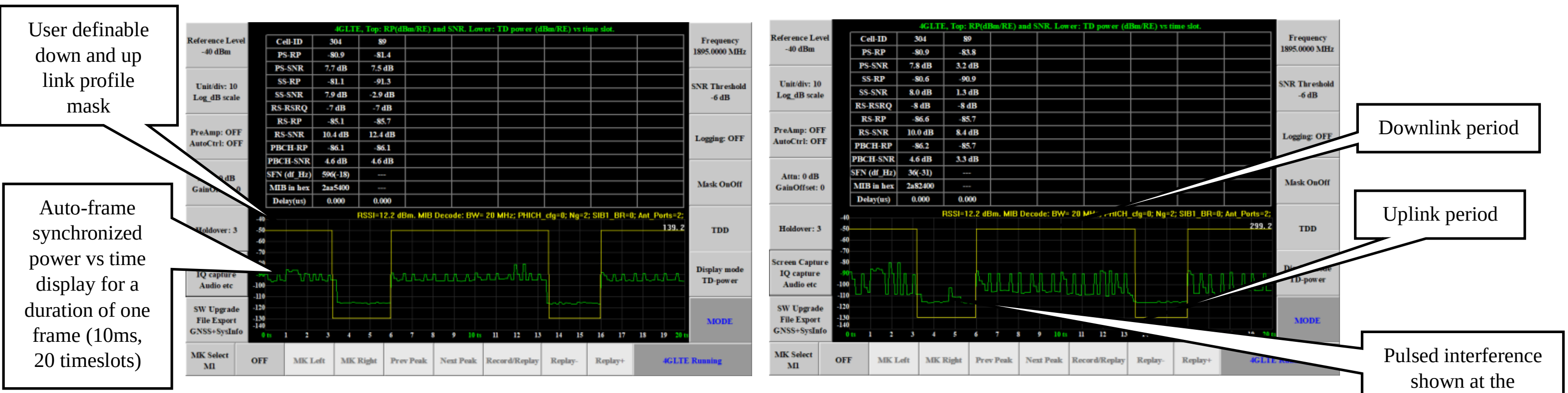

Figure 6 - Frame-synchronized time-domain power display of all 20 timeslots within a frame under the 4G-LTE analysis test (also applies to 5G test)

As shown in Figure 6, the bottom green-colored power vs time (20 time slots within 10 ms frame) is frame synchronized, meaning the left most point corresponds to the starting point of a 10ms frame. The design purpose of this test is to verify the accuracy of downlink to uplink transition, or to verify the time alignment among adjacent cell sites or sectors. As shown here in Figure 6, we can clearly see the pulsed uplink interference at the right display.

The yellow-colored mask shown in Figure 6 is simply defined by users. The mask shown here is defined by a simple text file (but with file extension named "*.tdm*"). This file's content is displayed below in Figure 7.

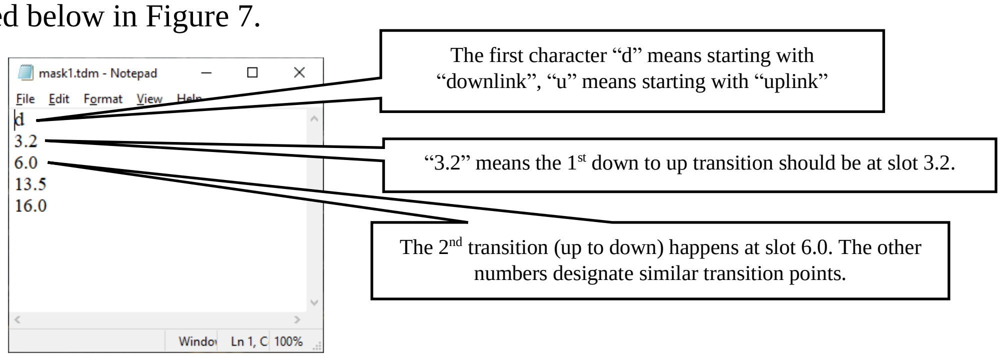

Figure 7 - A simple text file that defines the time-domain power profile shown in Figure 6

Save this text as something like "*mymask.tdm*" onto a USB drive, then plug this drive to the USB port of a WSA-408 (or the PC's USB port controlling a WSA-308), press the right 4 button "Mask onoff" button in Figure 6. Follow the steps to import the file and the mask will be shown as in Figure 6.