TDD Signal Analysis

with Spectrum Compact

APPLICATION NOTE

Broadband communications networks are quickly expanding around the world. In today's connected society we use our phones, tablets, and connected devices for everything from education, telemedicine, Zooming, and streaming Netflix. In this article we're discussing the fundamentals of TDD transmission along with guidelines for using a spectrum analyzer to study these signals.

Comparison between FDD and TDD Transmission

In today's mobile networks, either it's LTE or 5G, the amount of transferred data between the user device and the base station (the uplink) and vice versa (the downlink) is often asymmetrical, because typically the user downloads more than uploads. A focus on downlink capacity has worked out well so far. However, as traffic patterns are changing, more uplink heavy applications are anticipated – cloud storage, video calls, etc. and flexibility with uplink and downlink spectrum usage is desirable.

To increase flexibility as well as make spectrum usage more efficient, Time Division Duplex (TDD) is becoming increasingly common and important. It is possible to use Spectrum Compact for a list of TDD applications, such as:

- Interference and available channel detection
- Relative power observation between different TDD signals
- Channel bandwidth determination
- Traffic intensity survey for TDD signals (for instance with frequency hopping systems)
- Finding a TDD signal source by using Point-to-Point (PtP) narrow beam external antenna

Frequency Division Duplex (FDD)

FDD requires two separate communications channels (i.e., transmit frequencies) spaced with a guard band in-between to minimize co-channel interference (Fig. 1). Spacing between the central channel frequencies is referred as duplex offset or duplex shift. Good filtering, diplexers, and possibly shielding are a must to ensure the transmitter does

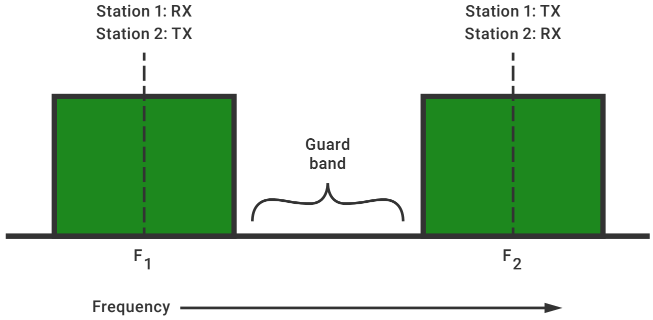


Fig. 1. FDD requires two symmetrical segments of spectrum for the uplink and downlink.

not desensitize the adjacent receiver. FDD radios are constantly transmitting in both directions to deliver full-duplex capacity through the radio link.

FDD application examples are – Microwave, Millimeter-wave point-to-point terrestrial links, most bands of LTE and 4G systems, some bands of 5G mobile.

Time Division Duplex (TDD)

TDD uses a single frequency band for both transmit and receive by assigning alternating time slots to transmit and receive operations (Fig. 2). The information to be transmitted — whether it is voice, video, or data — is in serial binary format. Each time slot may be 1 byte long or could be a frame of multiple bytes.

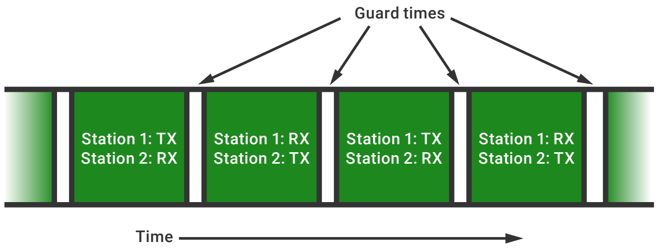


Fig. 2. TDD alternates the transmission and reception of station data over time. Time slots may be variable in length.

In some TDD systems, the alternating time slots are of the same duration or have equal download and upload time slots, however, TDD systems do not have to be 50/50 symmetrical. By changing the duration of these, network performance can be tailored to meet different needs and help provide the best possible experience. Systems can be designed for asymmetrical operation (typically 75/25 or 90/10 for instance) or for variable ratio based on traffic conditions.
TDD application examples are - Wi-Fi, WiGig, Bluetooth, some bands of LTE 4G and terrestrial radio links, and most bands of 5G mobile.

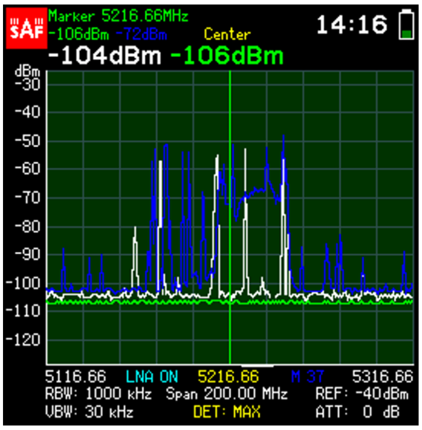
Setting up Spectrum Compact for TDD Spectrum Scans

Time Division Duplex radio systems transmit physical frequency carrier changes quickly in the time domain. To be able to display this type of signal on Spectrum Compact's screen it is necessary to configure your Spectrum Compact accordingly.

1. Disable "Signal ID" mode in *main menu* → TOOLS & SETTINGS → SETTINGS.
2. Select "AUTO" mode in *main menu* → RBW & VBW. This will automatically set optimal settings for selected SPAN.
3. To ensure the fastest scanning speed, use the narrowest SPAN setting that still allows seeing whole bandwidth of a signal. It is possible to set span in *main menu* → SPAN menu.
4. Because of the frequency carrier hopping nature of TDD signals (OFDM modulated carriers for instance), it is necessary to accumulate multiple spectrum scans over time. It is possible to use "MAX HOLD", "MIN/MAX HOLD" or "CUMULATIVE" traces in *main menu* → "TRACE" menu.

5. Optionally try various DETECTOR settings in *main menu* → "TRACE". Detector Max setting might allow to better notice TDD signal.
   a. For devices of frequency ranges 56-87 GHz DETECTOR settings are in *main menu* → TOOLS & SETTINGS → DETECTOR.

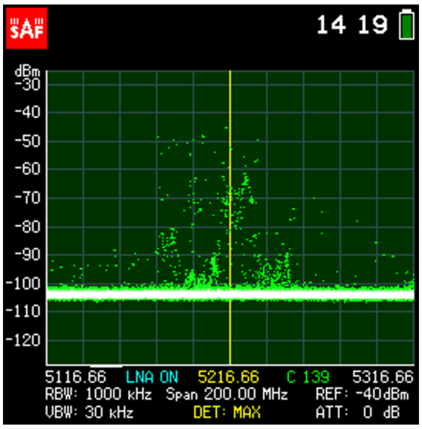
6. Optionally in *main menu* → "LEVEL" use LNA on/off (Low Noise Amplifier) and ATT (Attenuator) if a signal is just slightly above the noise level or overloads the device accordingly. Note that LNA and ATT features are not available for all Spectrum Compact models.



Max hold and min/max hold traces

A blue and green traces show the highest and lowest levels detected since sweeping commenced. During each sweep, only the frequency points with the highest or lowest power levels are updated. Tapping the MIN/MAX HOLD button repeatedly resets the MIN/MAX HOLD trace. A counter in blue below the grid shows the number of sweeps since the beginning of the latest MIN/MAX HOLD mode.

Fig. 3. Showing Wi-Fi signal readings in "MIN/MAX HOLD" trace mode

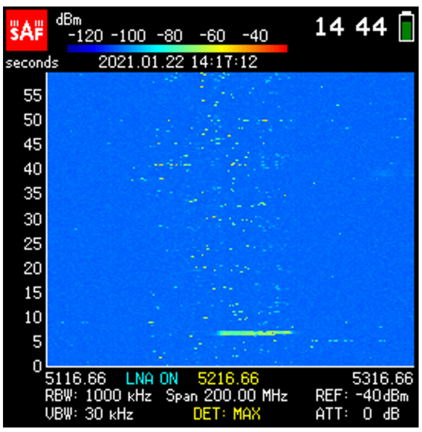


Cumulative trace

Shows in green the power levels of each frequency for all previous sweeps since sweeping commenced. During each sweep, only the frequency points with previously unsaved levels are updated.

Fig. 4. Showing Wi-Fi signal readings in "CUMULATIVE" trace mode

Record time plot mode*



This feature allows to observe the intensity of a signal over a period of time and it also records measurement data that can be used for later analysis. The RECORD TIME PLOT feature is located in *main menu* → "TOOLS" → "RECORD TIME PLOT". From here, select "NEW RECORD" and it will display received power levels according to color code. Note that before starting "NEW RECORD", "NORMAL" trace mode must be selected.

*** Record time plot mode is not available for devices of frequency range 56-87 GHz.**

Fig. 5. Showing Wi-Fi signal readings in "RECORD TIME PLOT" mode

Use example

In the next two figures are recorded spectrum scans for a 5 GHz Wi-Fi radio device that utilizes TDD transmission is displayed and explained in detail. A similar approach can be used for PtP radio, 5G mobile and other applications using TDD transmission technology. Please note, that in most cases it is not possible to observe accurate TDD signal by connecting spectrum analyzer directly to the radio unit as most TDD radios start transmitting in the full channel bandwidth and frequency range only when a link between the master and slave (PtP) or access point and client (Point to Multipoint (PtMP) is established.

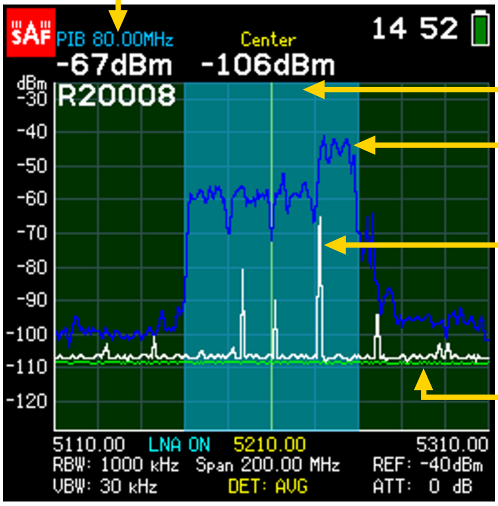


Fig. 6. Wi-Fi 5GHz TDD radio signal scan using "MAX HOLD" trace mode

Power-in-Band function allows estimating the width of the signal.

The turquoise area represents Bandwidth.

The blue line represents MAX HOLD trace. This allows seeing the highest detected signal levels.

The white line shows the latest spectrum scan. This allows seeing separate sub-carriers, which appear as spikes within the Wi-Fi band.

The green line represents MIN HOLD trace. This allows seeing lowest detected signal levels. As both MIN/MAX HOLD lines are apart from each other, it shows that the analyzer captured both – transmission and reception moments of the TDD transceiver.

When measured with Power-in-Band function, the channel bandwidth of the TDD signal is 80 MHz, however visually 4 separate 20 MHz channels can be noticed, meaning this transmitter is aggregating multiple Wi-Fi channels.

Fig. 7. shows the same situation as in Fig. 5., but in "RECORD TIME PLOT" mode for the recorded signal. The "RECORD TIME PLOT" mode allows seeing more precisely in the time domain – when the transmission was more active and when it is in receiving mode.

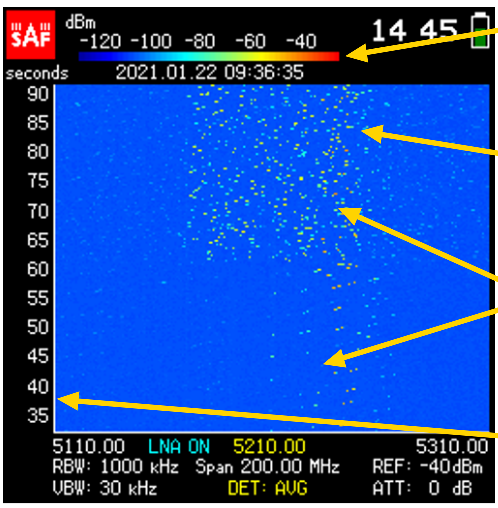


Fig. 7. Wi-Fi 5GHz TDD radio signal scan using "RECORD TIME PLOT" mode

Color code represents the signal's detected level. Blue is noise level, the closer it gets to red color, the stronger is the signal.

The separate "dots" are detected sub-carriers of the TDD signal. The number of those "dots" indicates how much data is being transmitted.

By looking at various "dot" density we can estimate at which moment data transition was more active and when it was less active.

The time scale indicates the time of transmission.

Summary

We learned about why TDD signals are commonly used in many 5G networks. We also covered the setup for looking at radio signals with a handheld spectrum analyzer. Spectrum Compact units are built for studying frequency ranges from 0.3-43 GHz and 56-87 GHz. The rugged and portable device performs physical layer testing for technologies using TDD, FDD, Wi-Fi, WiGig, Bluetooth, 4G LTE, 5G.

The Spectrum Compact handheld tool with the intuitive graphic user interface allows you to quickly evaluate radio spectrum to and come up with solutions while in the field.

Try our free interactive demo here:

spectrumcompact.com/emulator/

References:
5G TDD Synchronisation Q&A, GSMA, 2020
Lou Frenzel, What's The Difference Between FDD and TDD?, Electronic Design, 2012

spectrumcompact.com