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5G TDD Network Solutions – Precision Timing

Due to its flexibility and improvements to spectrum utilization, time division duplex (TDD) is vital to the successful operation of 5G cellular communications networks. TDD implementation requires superior synchronization and precise timing at the transmitter and receiver to avoid latency and timing overlap. Occurring within mobile devices as well as base stations, the location of components responsible for transmit/receive switching is dependent on the application and network infrastructure, and each operates at a rapid pace, typically down to the microsecond or nanosecond time range.

Capturing the Performance of High-speed Switches

Developers must provide components that function at acceptable switching speeds to meet precise TDD parameters. Switching speed is defined by the elapsed time interval between a switch's ON/OFF state or OFF/ON state, and key parameters for defining switching speed are rise time and fall time. As defined by IEEE, rise time is the time it takes a signal to change from about 10% to 90% of the signal magnitude (time interval from the first crossing of the proximal line to the first crossing of the distal line). Similarly, fall time is the time it takes a signal to change from about 90% to 10% of the signal magnitude (time interval from the last crossing of the distal line to the last crossing of the proximal line). Among the leading performance metrics of the Berkeley Nucleonics 12200 Series USB Peak Power Sensor is its 3 nanosecond (ns) rise time capability, which can accurately capture the rise time of today's fast-moving TDD switches.

However, in communications systems the interval between 90% to the signal's maximum performance, known as the settling time, is just as important in developing a proper understanding of a component's switching speed to minimize error corrections. The signal's peak performance can be 100% of the signal's magnitude, but some even consider a certain threshold, such as < 0.1 dB from a signal's maximum, as a sufficient indication that it has settled (Figure 1). This critical time frame still denotes a region of unusable data and can add valuable microseconds on top of rise time figures, which edges even closer to the precise TDD switching time specifications that these components must deliver.

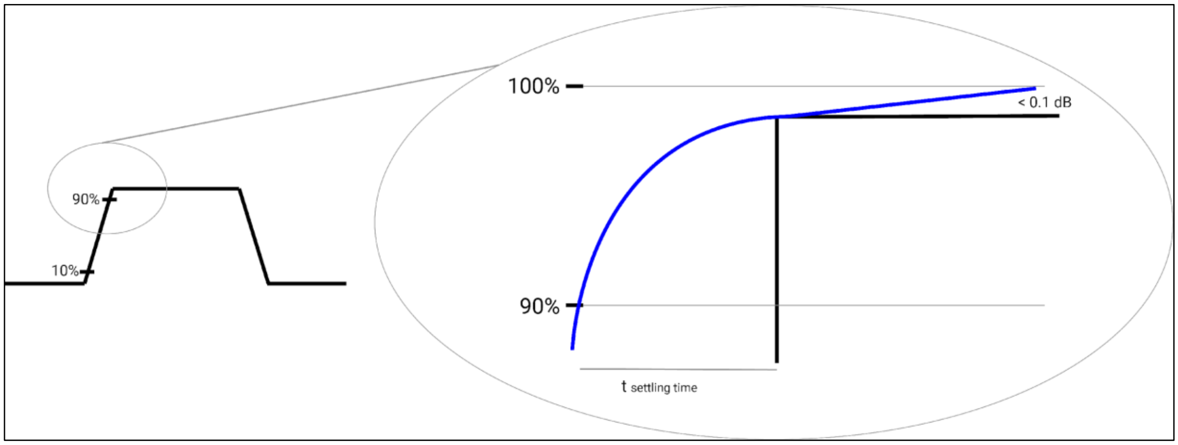

Figure 1: Magnified view of pulse vertical settling time. Settling time of a signal (90% to < 0.1 dB of its maximum value). Response Time = Rise Time + Settling Time.

Without taking note of a signal's settling time, interference can occur with the leading portion of data. Used as a merit for quality control, block error rate (BLER) is the ratio between erroneous data blocks to the total blocks transmitted. Invalid data caused by settling time can lead to a high BLER, which often necessitates retransmissions and ultimately reduces network performance. The 12200 Series and the complementary Berkeley Nucleonics Power Profile software enables developers to easily place vertical and horizontal markers for pinpointing the exact settling time period, ensuring this important window is taken into consideration to maximize data transfer.

Propagation Delay and Sensor Synchronization

Some switches, especially those alternating from a power amplifier (PA) to a low-noise amplifier (LNA), may experience propagation delay due to several factors such as excessive cable length, board runs, improper time adjustments, or software commands. Propagation delay is the round-trip time interval as a signal travels from the sender, through all the necessary circuitry and networking infrastructure, to the receiving device. This delay can create a bleed through from the PA to the LNA, leading to unwanted signal phenomena such as overshoot, which occurs when a signal exceeds its top amplitude and is often followed by ringing artifacts until the signal reaches its steady, final value. While overshoot exceeds a signal's target, a similar effect known as undershoot occurs when a value dips below the set minimum. To maintain efficiency of network operation, designers must have the capability to capture and quantify the occurrence of any delay or unwanted signal phenomena in TDD circuitry (Figure 2).

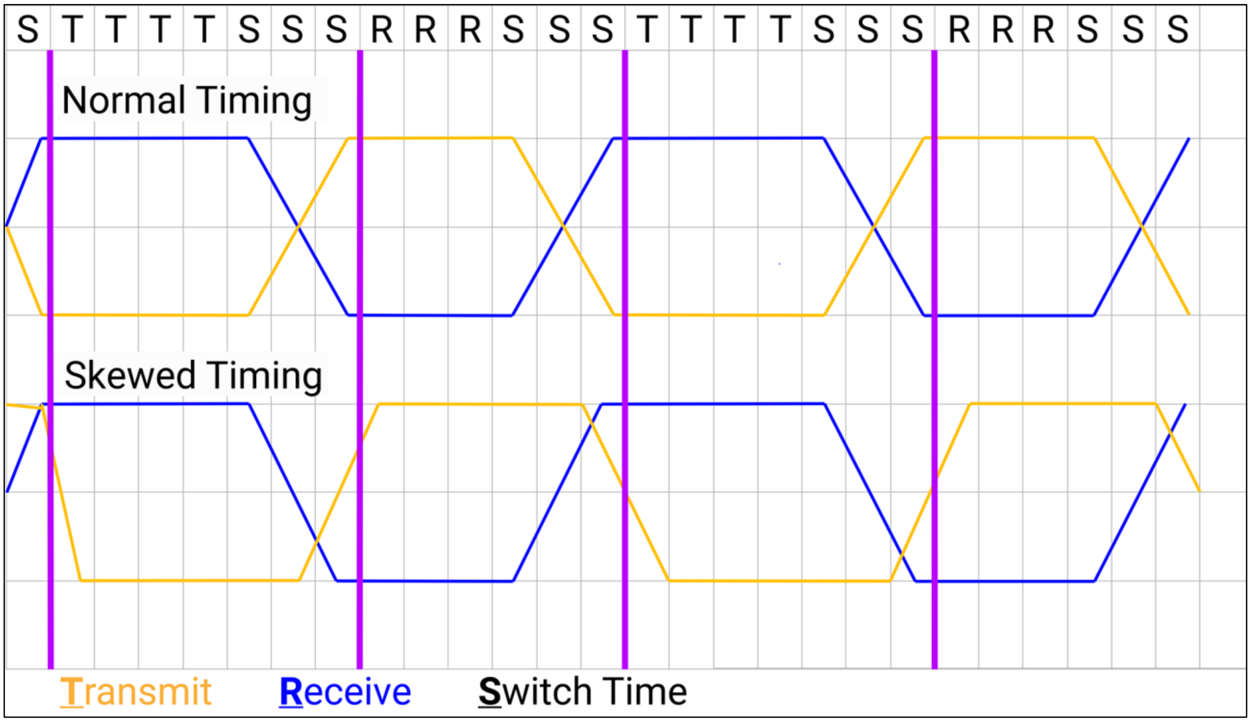

Figure 2: Ideal timing of TDD switches exhibit extreme precision, with handoffs occurring uniformly within the delay frames between transmit (yellow) and receive (blue) operations. Skewed timing caused by propagation delay, for example, can lead to switching overlap and leading data errors, among other challenges, which decreases the integrity of TDD transmissions.

Berkeley Nucleonics 12200 Series USB Peak Power Sensors provide an effective means for measuring propagation delay, switch handoff, and crucial waveform events in TDD communications systems. The sensors can capture the incident pulse as well as the pulse coming out of a test setup after traveling through the communications pathway. Measurement markers can then precisely pinpoint the delay window between input and output signals. In addition to the 3-ns rise time and rapid measurement speed of the 12200 Series, quantifying propagation delay is further aided by superior trigger stability and a unique digital signal processing approach. The software keeps pace with signal acquisition by performing vital processing steps in parallel, beginning immediately after the trigger. For comparison, conventional processing methods stop acquisition for sequential processing, which creates long gaps between triggered sweeps that may miss intermittent waveform events. This eliminates computational overhead, buffer size constraints, and the need to stop acquisition for trace processing, delivering gap-free signal acquisition.

A situation with a single transmitter and receiver provides a simplistic TDD overview, but in more complex, practical situations there are various signals traveling at once emanating from multiple antennas, such as multiple-input and multiple-output (MIMO) applications that increase radio link capacity. In this scenario, key questions arise: Are antennas switching at the same time? What is the time discrepancy between transmissions? One method to monitor more sophisticated systems is to utilize a vector network analyzer (VNA) such as Berkeley Nucleonics' VNA-04xx series. While these VNAs are competitively proceed, they will add to the cost of a project. Providing a more economical approach, multiple 12200 Series sensors have the capability to synchronize in a test setup, meaning they can monitor the timing, integrity, and accrued delay of numerous TDD signals. Additionally, Berkeley Nucleonics sensors provide a 100-picosecond time resolution that can easily resolve a 1 to 2 nanosecond difference in timing between switches.

A further advantage using 12200 Series sensors over a VNA for TDD transmission testing is the ability to use a client's actual signals. Providing a simple methodology for signal optimization, clients can pinpoint delay and necessary corrections as signals travel through TDD switches, many of which are embedded in the hardware of the RF cards. Software adjustments can then be used to fine-tune and optimize performance.

The high-speed performance of switching devices is enabled by advanced test solutions like the Berkeley Nucleonics 12200 Series, which can meticulously measure any delay experienced at various points along the communications path, catch signal phenomena like undershoot/overshoot, capture time between switch actuation, and aid with multi-signal timing through synchronization and superior time resolution capabilities. Therefore, Berkeley Nucleonics test solutions strengthen the performance of switching devices in TDD systems as well as aids in the process of selecting the best high-speed switch for each TDD network application.