NIST Utilizes AXIe Digitizer for 5G Channel Sounding

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Today's cellular systems are on their fourth generation of technology, labeled 4G LTE. While 4G continues to be enhanced, communication vendors, researchers, and regulators are busily defining, designing, and prototyping the next generation technology, simply called 5G. The goal is to bring an order of magnitude speed improvement, achieving in excess of 1Gb/s to the handheld.

To achieve these speeds, researchers are looking at much higher frequencies, where spectrum is plentiful, but propagation is unwieldy. Consider that today's LTE bands are constrained to 3.4GHz or lower, with some effort to extend that to unlicensed spectrum on the 5GHz Wi-Fi band. Now consider 5G. Trials are active at 28GHz, with research to nearly 100GHz. Spectrum allocations may be as wide as 2GHz, wider than the spectrum of all current cellular bands combined. This spectrum is often referred to as millimeter wave (abbreviation mmWave), since wavelengths are less than 1cm above 30GHz. What is there not to like?

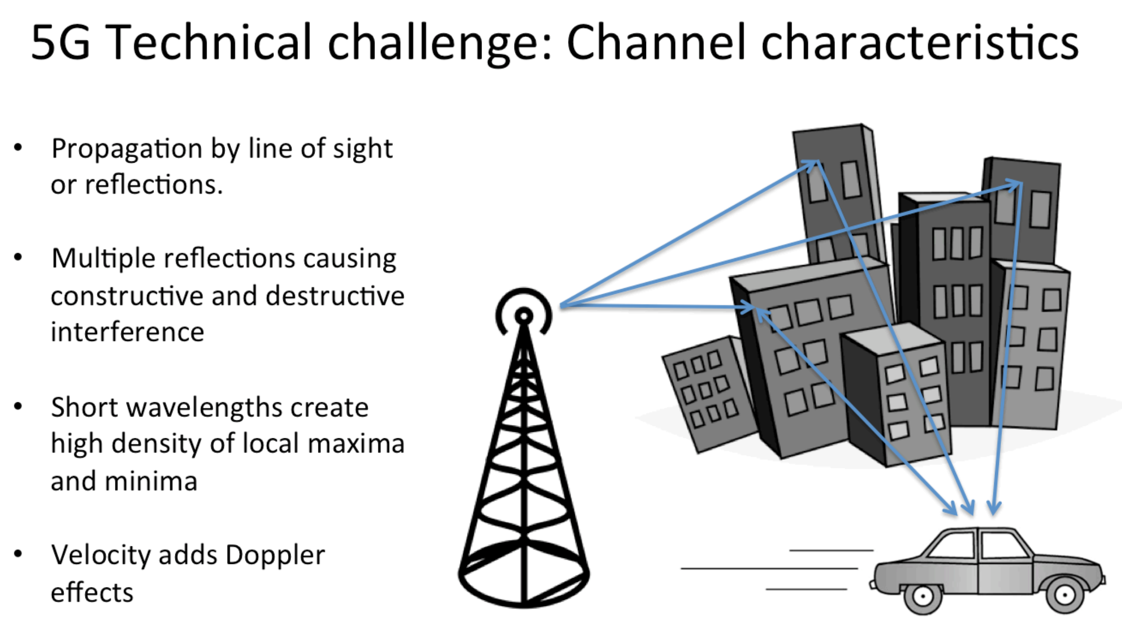

Figure 1 shows the role that multipath distortion may play at mmWave frequencies. Complicating the analysis is the fact that the receiver may be moving quickly.

And there lies the trade-off. Though spectrum is plentiful, propagation is ill-behaved. At lower frequencies, radio waves diffract around objects, reducing variabilities due to minor location and position changes. This is not the case with mmWaves. The short wavelengths cause numerous nulls and peaks within a very short distance due to multipath distortion. Objects, such as walls and people, present barriers to propagation, but also make effective reflectors. In many cases, the reflection may be the largest component of the received signal. In theory, the continuous advancement of Moore's Law allows sophisticated beam forming algorithms to overcome these limitations if channel propagation can be characterized. That's where NIST, the National Institute of Standards and Technology comes in.

The NIST Metrology for Wireless Systems Group supports the wireless industry by developing methods to test the functionality of wireless devices in the presence of various types of distortion. This includes tools to characterize propagation channels at mmWave frequencies. Chief among these is a channel sounding tool for mobile communications at 28, 60, and 83GHz.

5G Channel Sounder

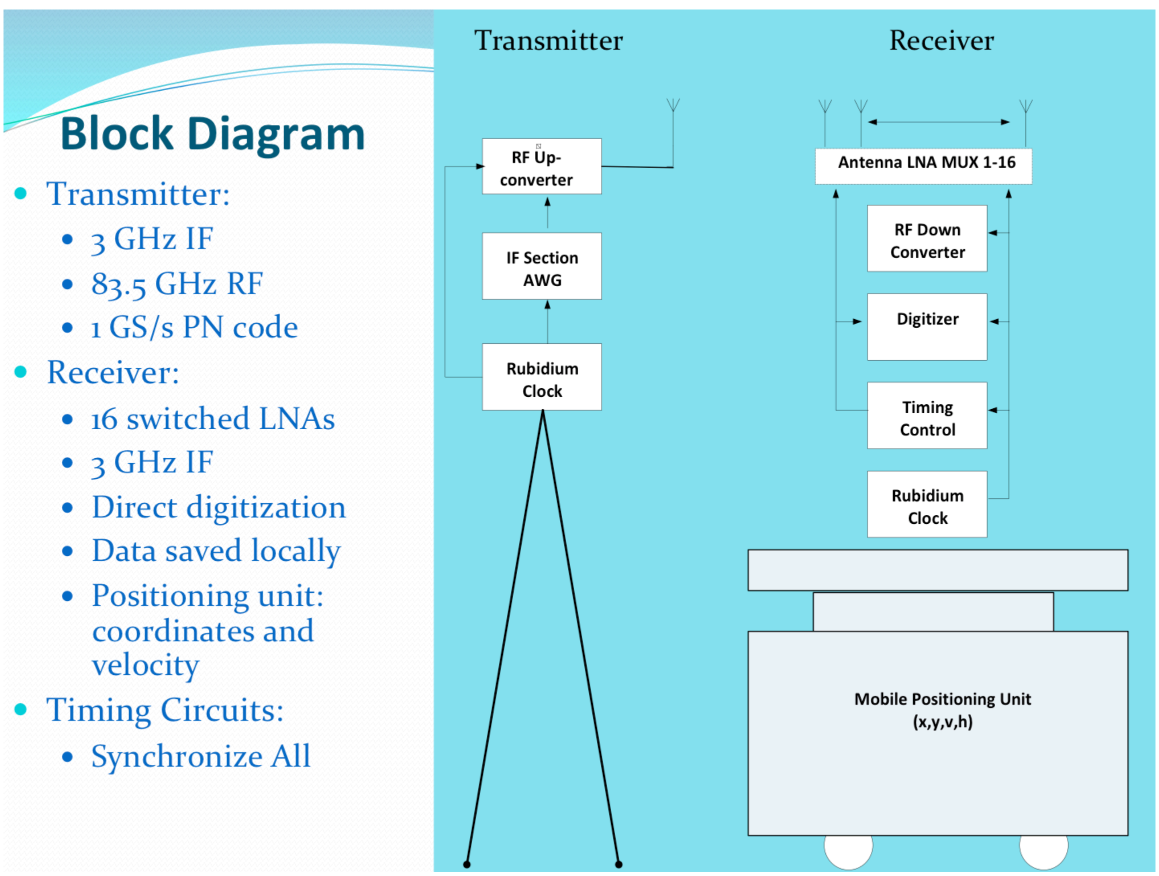

Figure 2 shows a block diagram of the NIST 5G channel sounder. The transmitter on the left is stationary, while the receiver on the right is mobile. Image courtesy of NIST.

Figure 2, above, shows a simplified block diagram of the channel sounder, along with key specifications. A wideband signal is generated and broadcast by the transmitter at 83GHz, modulated with a digital code. The receiver is placed on a battery-powered robot that can change location, orientation, and velocity programmatically. An array of 16 directional antennas allows analysis from different angles of arrival.

Key to the receiver design is the digitizer. After the received signal is down-converted, it is captured by the digitizer, and the data stream sent to the controlling computer. The demands on the digitizer are severe. A high dynamic range is needed, but at the same time the digitizer must acquire high fidelity samples at a fast sample speed and high bandwidth. The recordings are long, so deep real-time memory is a must. Once captured, the data must be quickly off-loaded to the controller. Finally, the digitizer must be compact, as it is situated on top of a battery-operated mobile robot.

NIST utilized the Guzik ADC6000 AXIe Digitizer. AXIe is a board-level modular standard that offers high performance in a compact form factor. In this case, a 2-slot AXIe chassis was chosen to house the digitizer, requiring just 3-1/2 inches of rack space. AXIe also includes a fast, low latency PCI Express bus, enabling a memory-mapped connection from the digitizer to the system controller. This link can off-load the digitizer's data at 1.6GByte/s.

The ADC6000 delivers 13GHz of analog bandwidth while digitizing at 40Gsa/s with eight bits of resolution. Why is such high-bandwidth required if the modulated symbol rate is just 1Gb/s? The answer lies in the system design of the channel sounder. The downconverter lowers the modulated signal to the 3GHz IF frequency, not baseband, which is a common practice with today's downconverters and mixers. Therefore, the digitizer must have the bandwidth to capture the IF signal, including the components on both sides of the IF center frequency. Essentially, the IF frequency is added to the bandwidth of the baseband signal to determine the overall bandwidth requirements. With 13GHz of analog bandwidth, the ADC6000 has plenty of bandwidth to spare.

The digitized samples are then stored in the 128 GBytes of onboard memory, allowing up to three seconds of non-interrupted acquisition if needed. The digitizer offers a programmable front end that allows the user to tune from -24dBm to +22dBm. This is an exceptional specification for a high-speed digitizer.

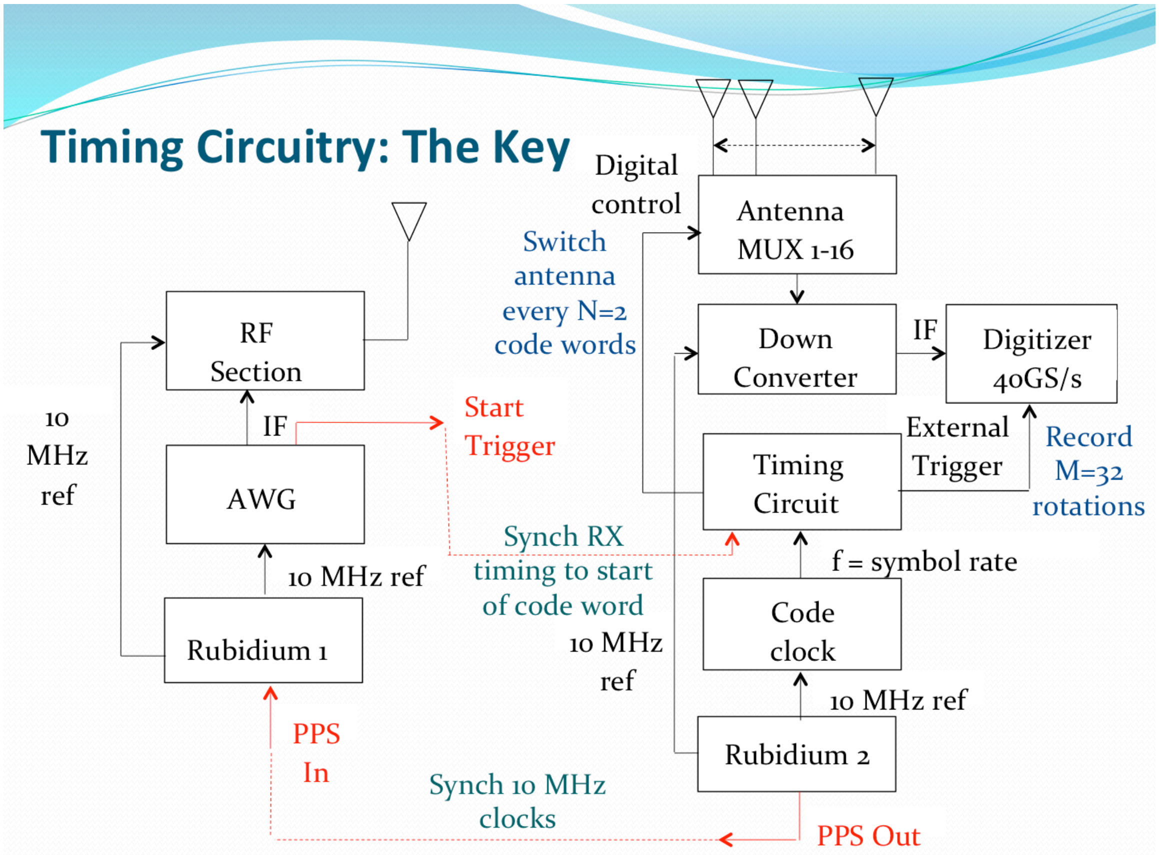

Figure 3 shows the timing diagram for the channel sounder. The key is to synchronize the transmitter, the antenna multiplexer, and the digitizer together. Image courtesy of NIST.

Timing is key for the operation of the channel sounder. A sync signal is generated by the transmitter at the start of each transmitted code word. This is connected to a timing circuit on the receiver that simultaneously coordinates the antenna multiplexer and the digitizer through an external trigger signal. After synchronization, the synch cable is disconnected and synchronization between the transmitter and receiver is maintained using rubidium clocks. This allows mobile measurements using the robot's guidance system, which reports the receiver location, heading and velocity relative to the transmitter. The timing circuit can be adjusted in software to collect multiple rotations of the antenna multiplexer. This allows the time between channel measurements to be adjusted to suit the mobile velocity and carrier frequency. By using this feature the Doppler power spectrum of multipath components can be measured. The digitized records contain the signals from all 16 antenna elements. By subsequently extracting the code words from the digitized record, the processed signal can reveal the power delay profile (PDP) and the angle of arrival for each antenna element. PDPs can be processed further to define the channel metrics versus angle of arrival. These statistics are at the heart of 5G channel modeling.

The results have been impressive, as presented in this paper describing the system in detail. The directional receive antenna array allows channel statistics for direct and reflected signals. Angle of arrival includes azimuth and elevation. Position, heading, and velocity of the robot can be programmed during acquisition, enabling Doppler effects to be characterized as well.

It should be noted that NIST has several 5G projects underway, primarily designed to deliver to industry the maximum metrological impact possible. AXIe, with its rich selection of digitizers and arbitrary waveform generators, is also being deployed increasingly in 5G test applications. Expect that both, NIST and AXIe digitizers such as the ADC6000, to play an increasing role in making 5G a reality.