Dave's Story on how GPS helped NASA/JPL synchronize their Deep Space Network tracking stations

I just learned of the passing of a friend and colleague from Boulder, Dick Davis, the first of this year (2019). Dick was an amazing electrical engineer, and he was part of the team that developed TV captioning – earning them an Emmy Award. Later on, he was part of my time and frequency dissemination research team.

I had listened to a JPL talk at the Frequency Control Symposium in Atlantic City, NJ, on how they synchronized the Deep Space Network using quasar signals and hydrogen maser atomic clocks. The DSN locations were in Canberra, Australia, Goldstone, CA, and Madrid, Spain. They would point their 64-meter-wide dish antennas at the same quasar in the center of our galaxy, and then using the excellent time stability of the hydrogen maser atomic clocks, they would correlate the signals being received between these DSN sites.

It was a massive effort, taking about 125 hours of labor to process. After taking the quasar data and obtaining a synchronization solution, the antennas would be pointed toward the deep space probe – like voyager – to communicate with it and to guide it to fulfill its mission. Having to steer these enormous antennas in a different direction in the celestial sphere to synchronize their clocks was counterproductive to their mission of having them point toward a NASA/JPL spacecraft that needed communication and navigation information. I could see that the new GPS common-view receiver development we were working on in Boulder would help them tremendously with their synchronization problem.

When I shared this potential solution with them, they flew me out to Goldstone in their corporate jet to look at that facility, and they ended up funding the development of these unique GPS common-view time-transfer receivers. They were deployed at the DSN tracking stations and we synchronized them to the official time standard in Boulder, Colorado. It was a major metrology step forward for them, and Dick Davis was the principal electrical engineer in the receiver design and development. Marc Weiss helped me with theory and both the firmware and software needed, as well. Dick did the main microprocessor firmware as well as part of the engineering design and development. Dick had this clever self-calibrating 0.1 nanosecond (ns = a billionth of a second) counter built into the receiver and we designed a few nanoseconds of accuracy worldwide, which was an enormous step forward in international time transfer metrology for atomic clock data.

A humorous aside in the receiver development was first, we found the receivers made by others would not work because they were designed to determine position. Since we assumed in our design, we could put in the coordinates of a receiver's location and only solve for time that would simplify the software. But we had a smile come across our face when we tested the receivers between Boulder and Goldstone, because we saw these 200 ns timing errors as the GPS satellites would sweep across the sky. Oops, the receivers didn't know where they were located. So we made our receiver determine its position and then lock it in so we were only solving for time to minimize the timing error. That worked well.

This GPS common-view receiver design became so successful that it became the main means of accurate time transfer around the globe for the generation of international official time UTC, and for comparing primary cesium-beam standards amongst the major time standard laboratories and observatories for the nations participating in the generation of UTC. I also took a GPS common-view receiver to the Arecibo Observatory to help them improve the timing precision for their millisecond pulsar research, and for my research as well. Using ADEV, I discovered that the electron content on the path of the signal from PSR 1937+21 to the earth was a random-walk process and there was also evidence of it being a binary.