GPS BASED TIMING AND SYNCHRONIZATION SOLUTIONS FOR WIMAX

Ken Hartman, Chief Technologist Officer, The Connor-Winfield Corporation

With the recent surge in popularity of WiMax wireless broadband solutions for home and business, the best and brightest WiMax equipment providers are busy investigating and implementing the newest technologies available for their next generation products. To be able to compete in the steadily advancing and highly lucrative broadband marketplace, WiMax equipment designers require cost-effective and application-ready timing/frequency devices to meet their demanding market needs.

In the not-so-distant past, the dilemma presented to engineers, as well as those responsible for watching BOM costs, was somewhat complex as many different component solutions across the product were required for an adequate timing implementation. Stability, tolerance, holdover, and phase noise issues related to system timing corrupted the end product from many different points within the design. The diversity of components and an engineers' inability to create a fully integrated end product design made it nearly impossible to reduce the BOM count and save on expensive, high-end component costs.

How to Select an Appropriate Timing Solution

The days of complex timing solutions for fixed equipment and mobile base-stations have clearly come to an end. A diverse assortment of readily available and cost-effective GPS Timing and Synchronization solutions encapsulates the complexity of equipment timing and synchronization design into increasingly smaller packages.

While it is now possible to get UTC timing accuracy within nanoseconds at extremely reasonable prices, particular attention must be paid to total system specifications. An appropriate timing solution meets all equipment requirements and pricing expectations. If a timing solution is specified inappropriately, the result will either be an end product that doesn't operate as well as it should or is priced incorrectly. To understand the timing and synchronization choices that are available, system specifications must first be understood.

Information transport requires consistent sequencing of information bits in order to accomplish error free transmission and reception. The foundation for error free transport is a synchronized transport environment. The key to a well synchronized transport is found in the sync reference architecture and specification. Equally important is the proper application and understanding of the sync requirements. Time domain (phase) references provide this foundation. Additionally, wireless information transport networks are required to maintain proper channel spacing and a consistent operating frequency in order not to interfere with adjacent channel transmissions and in order to be heard. Frequency domain references provide the means to maintain precise channel separation and receiver selectivity.

Many COTS GPS devices provide both time and frequency reference outputs ideally suited for WiMax applications. Use of such devices allows for proper operation independent of any back-haul transport scheme or wired network complications. Simultaneous generation of coherent time-of-day, time and frequency references from a single, high quality, low cost source simplifies base station design and reduces cost.

Precision Navigation

Simultaneous generation of phase - 1PPS - and frequency - 10 MHz - ensures reference tracking to the GPS time scale and ultimately the UTC time scale to time accuracy of typically less than 15 nsec rms and a frequency accuracy of 1e-12 tau=24hr MVAR. It is useful to understand the origin of time and frequency references based in GPS time references. Time and position are intimately related.

Precision navigation is possible only with availability of precision time. To know where you are - you must know what time it is. The better you know time, the more precisely you can determine your position. GPS receivers use a direct application of the principle of triangulation to determine their position in space (X, Y, and Z directions) and time (t GPS timescale). To do this information from at least 3 satellites (solve for X, Y, and t) or 4 satellites, or more, (solve for X, Y, Z and t).

Time and Frequency Recovery/Generation

Time and frequency recovery/generation by a GPS receiver uses conventional clock recovery techniques in a somewhat un-conventional time and frequency reference implementation. A

WiMax requirements:			
Protocol	Multiplexing Method	Frequency Sync	Phase Sync
WiMax (mobile)	FDD	20 ppb	-
WiMax (mobile)	TDD	20 ppb	1 usec
WCDMA	TDD	50 ppb	2.5 usec
WCDMA	FDD	50 ppb	-
LTE	TDD	50 ppb	3 usec
LTE	FDD	50 ppb	4 usec (MBMS)

GPS receiver extracts or solves for GPS time from the ensemble of satellite signals that it qualifies e.g. carrier-to-noise ratio, satellite azimuth, constellation geometry, etc. To produce a precise one pulse per second consistent with the GPS time scale the receiver can either directly generate the pulse, at the "correct" time according to the most recent GPS solution; or gate a pulse from the local system clock at the correct point in time corresponding to the time of the most recent solution. In either case, the pulse and the 1PPS sequences are generally based on the accuracy and stability of the GPS time solution along with the accuracy and stability of the local clock.

Precise frequency generation is a bit more complicated. Since there is no intrinsic, recovered frequency from the GPS solution, a frequency must be synthesized by way of an FLL or more often a PLL. Using the 1PPS reference pulse ensemble and a *very* low bandwidth low-pass filter design (generally a few hertz to millihertz) with minimal peaking, an output reference frequency whose rate can vary from tens of hertz to 20 MHz (user command selectable) is generated as a square wave output from the receiver.

In some cases a disciplined NCO is the source of the reference frequency output. Because of inherent NCO frequency quantization limitations along with local clock drift and stability limitations, the reference frequency is likely to contain significant sideband artifacts and phase noise elements that must be filtered for RF carrier generation applications.

The output of the GPS time and frequency receiver is accurate and phase aligned with the GPS time scale. The GPS time scale is consistent with but different from the UTC time scale - GPS is a continuous time scale, with no leap seconds or time discontinuities. UTC is an astronomically tied time scale, with periodic adjustments of +/- one second to maintain synchronization with the earth's rotation.

Generation of UTC time-of-day time stamps for use with the 1PPS information is easy and straightforward using information supplied in the data from the GPS satellites. Phase locking the frequency reference to the 1PPS ensures close tracking of the periodic phase time and the continuous frequency phase information of the reference.

Understanding 1PPS and Frequency Reference Signals

It may be helpful to understand the characteristics of both the 1PPS and the frequency reference in order to more fully understand the appropriate use of each in system applications.

In the case of the 1PPS signal it is clear that information on this signal at rates above 1 Hz does not exist. Thus we look at the signal characteristics in the time domain using standard MVAR analysis. It is fairly apparent that the variance plot shows the ultimate convergence of the output to the absolute time reference as one would expect, with intermediate deviations from the straight line magnitudes at various observation times being caused by filter design and intrinsic noise processes of the satellite orbital dynamics, propagation path, receiver down-converter, Kalman filter and pulse generator errors.

In the case of the frequency reference signal - in this case a 10 MHz reference output - because we would prefer to use the frequency reference as the pilot reference for the base station RF carrier generation, we find it more useful to examine it from a PSD point of view. Clearly characteristics for the top end of the wander band (1 Hz to 10 Hz) and the low end of the jitter band can be set by the low-pass filter corner frequency.

Very low-jitter and low wander performance can be achieved using filters in the sub hertz range. Such performance dictates a very high-stability, disciplined oscillator however; generally an OCXO or very high quality TCXO. Opening the bandwidth of the low-pass filter relieves this requirement somewhat, but at the cost of introducing more of the intrinsic noise of the synthesized GPS reference.

Conclusion

Careful modeling and good understanding of system requirements will result in successful system implementations. The use of a high quality integrated receiver and reference with built-in holdover generally offers a direct, comprehensive solution to meeting all system requirements in the most cost effective manner.

Find more information on Connor-Winfield Timing and Synchronization products at our website: www.conwin.com or through our distributor, Digi-Key at www.digikey.com

Ken Hartman is Chief Technologist Officer for Connor-Winfield.

As seen in Wireless Design and Development