Improving Clock Performance

The basic theory behind BESTIME® technology is the use of multiple sources of time and frequency to compare the others and adjust to what is determined as known error. BESTIME adaptively ensembles commonly available frequency sources including T1 or E1 signals, GPS signals, remote oscillator signals, and a local oscillator to provide unparalleled time and frequency output performance. Local oscillators provide the most stable reference during short periods of time. However, without long term stable reference, the oscillator by itself will drift over time. The higher quality the oscillator the less the drift, but this improved performance comes with an associated cost. Typically, the local oscillator is the single largest cost component of GPS PRS systems. BESTIME provides improved performance with lower quality quartz local oscillators, thereby reducing the cost disadvantage.

GPS serves as a very stable time reference to discipline local oscillators once the negative impact of Selective Availability (SA) is filtered out by the GPS receiver. SA is the degradation imposed on the GPS system by the Department of Defense for national security reasons. BESTIME algorithms use the local oscillator and GPS signals to characterize the T1/E1 network clock and filter out the jitter and wander. Jitter and wander are naturally occurring phenomena in all telecom networks which tend to impair synchronization signals, and therefore, need to be minimized in order to ensure the quality of the network. The BESTIME algorithm enhances performance even when the synchronization recovered from the T1/E1 network is marginal. As an example, a T1 signal carried within a SONET payload, which is subjected to wander due to SONET pointer adjustment activity, can be successfully used by BESTIME to enhance clock performance.

An example of the type of performance which can be achieved by using BESTIME technology is illustrated in Figure 1 below. The BESTIME algorithm uses the "best" synchronization characteristics of each of its inputs to create the best possible timing output. As shown, the oscillator is used for its superior short term performance while the system is integrating the data received from GPS and T1 network inputs. The T1 network input performs best in the medium term, while GPS provides superior long term performance. The resulting BESTIME output is the best combination, or ensemble, of the three timing inputs. Results would be improved by using a remote oscillator input instead of, or in conjunction with, the T1 span.

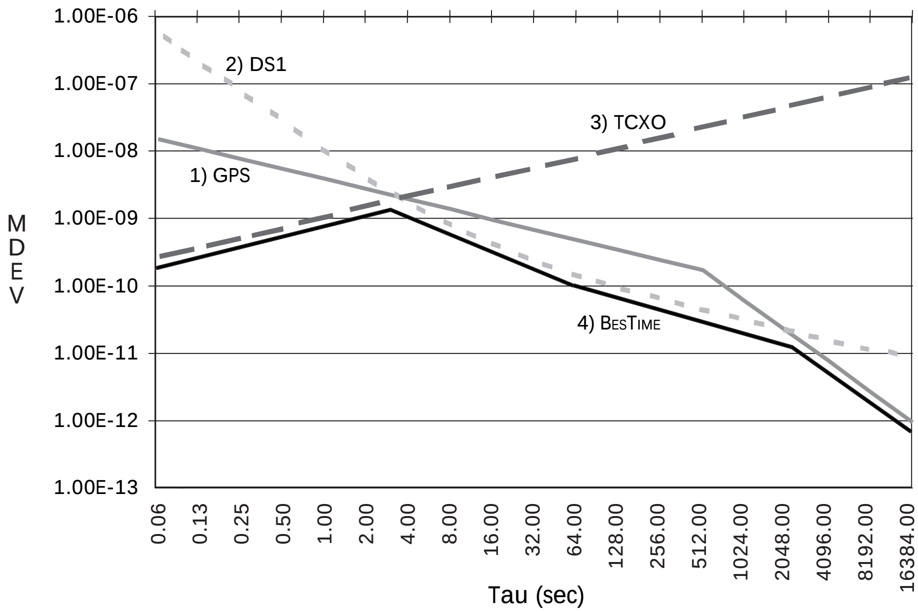

Figure 1. Stability comparison of timing inputs and BesTime output

BesTime places a the weighting value on each input as it learns the timing and frequency characteristics of the input. After initialization, BesTime continues to monitor all inputs in the event that an input degrades or is lost, and will dynamically adjust weighting values to the remaining inputs according to their timing performance. The most stable, least noisy inputs will always receive the greatest weighting value, thus ensuring optimal performance at all times.

It is important to note that the BesTime engine will work like a traditional GPS PRS. That is, BesTime will provide a PRS quality output with a GPS reference and local oscillator. The use of additional T1/E1 or remote oscillator inputs to boost overall system performance is strictly at the option of the user.

Extending Holdover

BesTime continuously performs a holdover prediction process on all inputs. In holdover, BesTime calibrates the local oscillator with input values calculated via the prediction process. The prediction process provides the long term correction frequency required to minimize frequency error and maintain stability of the outputs.

The result is that the output performance during holdover is significantly better, and can be maintained significantly longer, than what can be obtained when only the local oscillator is used to provide holdover. For simplicity sake, the holdover prediction process is illustrated for a single input, GPS, in figure 2 and described below.

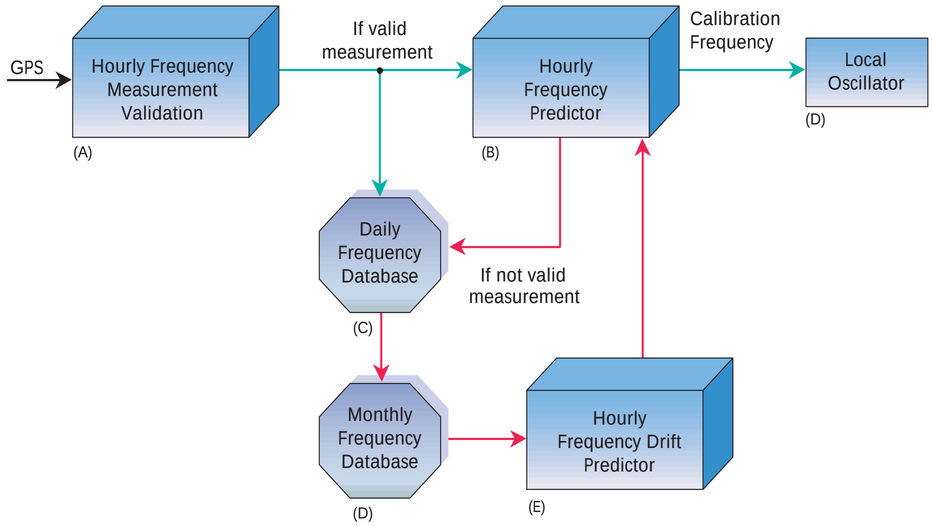

Figure 2. Holdover Prediction Estimation (for one input channel)

Hourly data (A) is validated based on sufficient good minutes of transient free GPS input. If the measurement is valid, it is sent directly into the hourly frequency predictor (B) and logged into the daily frequency database (C). If the hourly data is invalid, then a predicted value calculated by the hourly frequency predictor (B) is logged into the daily frequency database (C).

The hourly frequency predictor (B) determines a calibration frequency, which is the best estimate or prediction of the frequency correction, to apply to the local oscillator (D). The predicted calibration frequency is used only if the GPS input is invalid or unavailable. The predicted calibration frequency is based on the hourly frequency drift predictor (E). Hourly drift prediction is calculated using valid and predictor frequency history stored in the daily and monthly frequency databases (C) and (D).

BESTIME continually calculates a predicated calibration frequency and compares this value against valid measurement data for each input used in the ensemble. In holdover, the weight assignments for each input are based on the predicted calibration frequency over the most recent 24 hours. Output performance during holdover using the BESTIME prediction system is superior to systems which rely on a local oscillator alone or a local oscillator combined with intelligent "learning" software.

Summary

BESTIME is an innovative clock algorithm designed to improve performance while reducing the cost of the GPS clock subsystem. The advantages of using BESTIME include the following:

- Optimized clock performance by using the best frequency and time attributes of all available synchronization sources which typically include GPS signals, T1 or E1 span lines, and remote oscillator references.
- Extended holdover performance via prediction models built on the long term stability of the GPS reference and short term stability of the local oscillator.
- Maximized redundancy and reliability by using multiple timing references which boost performance and provide back-up when GPS signals are lost.
- Reduced cost with high performance by using single oven quartz oscillators as compared to varactor pulled approaches that require double oven quartz oscillators.

Products which use the BESTIME clock engine are available today from Symmetricom. The TimeSource 3000 is a BESTIME-based system which is a stand alone PRS in an inexpensive, compact package designed for central office and remote office application. TimeSource 3000 also meets Bellcore GR-2830 and ANSI T1.101 standards, is NEBS compliant, and TL1 compatible. For more information on the TimeSource 3000 and other BESTIME products available from Symmetricom, see our web page at www.symmetricom.com.