Exploiting HF Ambient Noise to Synchronize Distributed Receivers

David Hong*[1] and Jeffrey L. Krolik[2]

[1] Duke University, Durham, NC, USA
[2] Duke University, Durham, NC, USA

Coherent processing of data from distributed HF receivers requires the receivers to be synchronized to an accuracy within fractions of a wavelength. The HF band extends from 3 MHz to 30 MHz and has wavelengths corresponding to time delays ranging from approximately 33 ns to 333 ns. Thus the receivers must be synchronized to within a few nanoseconds. This is typically beyond the capabilities of even GPS-disciplined oscillators. Traditional clock synchronization methods require distributing a common reference signal to all the receivers, either by cables or by using a local reference transmitter. Both these approaches introduce extra cost and complexity.

In this paper, we present an approach for clock synchronization which uses the coherent component of wideband ambient HF background noise to estimate time delays between receivers. The approach exploits the flexibility of inexpensive broadband direct-conversion digital receivers in the 3 – 30 MHz band. Two techniques are presented for measuring time delays between receivers: 1) Time-domain Green's Function estimator based on an approach recently used in underwater acoustics, and 2) an optimal Maximum Likelihood (ML) estimator. Both estimators are shown to choose the maximum of particular generalized cross correlations.

The Cramér-Rao Lower Bound (CRLB) for time delay estimation from ambient noise is also derived and simulation results are presented that demonstrate the performance of the estimators. For low signal to noise ratio (SNR) or low time-bandwidth product (TBP), the estimators do not achieve the CRLB due to peak ambiguities in the generalized cross correlations. However, for sufficiently large SNR and TBP, we demonstrate that the ML estimator is able to overcome the peak ambiguities and achieve the CRLB. In this case, the ML estimator is able to achieve sub-nanosecond RMS delay errors using a 2.5 s observation of 2 MHz bandwidth isotropic HF ambient noise. Thus the ML estimator is the preferred method for synchronizing the distributed receivers.