

Abstract for 40-minute invited talk at the URSI General Assembly in 2005
(URSI= International Union of Radio Science)

Near-term Time Transfer Technologies and International Atomic Time (TAI)

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While there are many forms of time-transfer, the most precise long-distance forms currently used for the generation of TAI and Coordinated Universal Time (UTC) involve either GPS or Two Way Satellite Time Transfer (TWSTT). This paper will give a brief description of their current and future capabilities, with emphasis on their uncertainties. Some of these uncertainties are due to inherent modeling or receiver instabilities, while others can be reduced through temperature and humidity stabilization, electronic impedance matching, and multipath minimization. The residual time-transfer uncertainties directly affect the uncertainties in each individual laboratory's realization of UTC.

GPS is the best-known means of precise time transfer, and the introduction of Common-View GPS contributed significantly to the great increase in the stability of TAI over the last 15 years. GPS pseudorange observations are currently adjusted by correcting the broadcast orbital and ionosphere delay information with post-processed values, and reduced in common-view mode, however "melting-pot" techniques have been shown to be more precise over long baselines. The continuous GPS observations are supplemented by periodic receiver calibrations, which have accuracies of several-ns. Greater precision (20 ps), but not significantly greater accuracy, would be attainable if carrier-phase GPS techniques were employed. Several institutions, and in particular the International GNSS Service (IGS), routinely provide publicly available carrier-phase based timing solutions in near-real time. Other institutions will reduce any laboratory's data for free via an automated procedure. A few institutions, such as JPL/NASA and NRCAN, provide real-time carrier-phase based time transfer as well.

Beginning in 2000, time-transfer links using Two Way Satellite Time Transfer (TWSTT) began to replace GPS links, and currently over half the clocks are linked to TAI via TWSTT. TWSTT links can be calibrated so to achieve slightly subnanosecond absolute time transfer, while the precision is in the range of a few hundred picoseconds. Carrier-phase TWSTT holds the promise of ps-level precision, but this promise has not yet been realized in any system. The theory relevant to carrier-phase TWSTT will be presented, as will some experimental data.

The generation of TAI involves merging information via dissimilar links, which greatly complicates the relevant statistical approach and strongly increases the dependence of TAI upon the stability of the time-transfer equipment at those "pivot sites", which are

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linked to some laboratories via TWSTT but linked to other laboratories via GPS. In order to correctly model the processes, the correlation and anti-correlation of time-transfer links that share common sites must be estimated and accounted for. The relevant mathematics will be developed and presented. Taking into consideration the dominant importance of robustness, it is possible to optimally combine all available information, and a method of achieving this will be presented.