Letter to the Editor
Long baseline testing of a GPS based, autonomous event time-tagging system

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Testing of two prototype, event time time-tagging systems over a baseline of 11 km is described. The systems make use of commercial, low-cost Global Positioning Satellite (GPS) receiver modules. An L-band, bi-directional phase transfer system was used to generate test signals.

Design, implementation and testing of GPS based, prototype event time-tagging systems was described in a previous paper [1]; this should be referred to in conjunction with the present work. The intended application is time synchronization for a next generation extensive air shower (EAS) detector [2]. The footprint diameter of extremely-high energy, inclined EAS at ground level can be as great as ~ 10 km. Hence it was considered necessary to carry out a further test of the time-tagging systems over a baseline of this order. This was achieved by making use of an L-band radio phase transfer link which forms a small part of the Multi-Element Radio Linked Interferometry Network (MERLIN) centered at Jodrell Bank, UK.

Figure 1 gives a simplified picture of the experimental setup. The outgoing L-band link allows the remote station oscillator to be phase locked to the central hydrogen maser. The absolute phase offset remains unknown since the absolute link delay is not measured. However, the remote oscillator wave-train is re-broadcast back to the central site allowing any change of the link propagation delay to be monitored. Except during the most extreme weather conditions the delay is stable to $\ll 1$ ns over any 24 h period.

By synchronizing the frequency dividers using the GPS 1 pps, pairs of event pulses were generated 11 km apart, with a time interval between the two of ≈ 200 ms. (In the EAS array application measurement of time intervals

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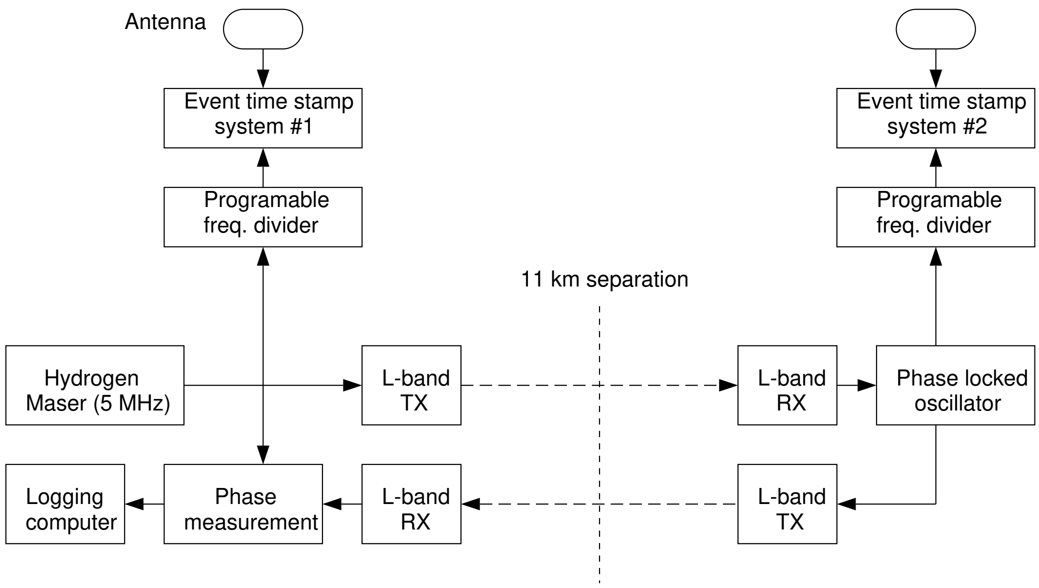

Fig. 1. Experimental set-up for 11 km separated event time-tagging system tests.

$\ll 100\ \mu$s is required.) The dividers were set such that the event pulse pairs stepped relative to the GPS 1 pps epoch at a rate of 3 ms s^{-1}, so that events fell in all parts of the second interval over time. Figure 2 shows the results from a typical 12 h test run. The increased wander of the short term mean, compared to the co-located and 500 m separated data shown in figures 4 and 5 of the previous paper, is due to one, or both, of the following effects:

- Incorrect antenna coordinates causing error modulation with satellite motion. Since the sky-view at the remote site was heavily obstructed by a large radio telescope dish the relative accuracy of the antenna coordinates derived via simultaneous position survey will have been reduced.
- Multipath reflection in the non-ideal antenna environments. This is the most probable cause since the wander appears to correlate with satellite elevation angle in a complex manner.

A series of 12 h runs gave time interval measurement error distributions with standard deviations of ≈ 7 ns. This is to be compared to ≈ 6 ns for co-located, and 500 m separated runs in the previous work. Since the MERLIN link is a phase, and not time, transfer system, it was not possible to measure directly the systematic error in this test. However, due to the variable geometry which occurs in the GPS system, it is very hard to envisage a fixed source of error scaling with distance. It can be concluded that the demonstrated performance of the timing systems is more than adequate for the intended application.

I would like to thank the staff of Jodrell Bank Laboratories, particularly Simon Garrington, for generously allowing me to use their facilities, and being highly cooperative while I was doing so.

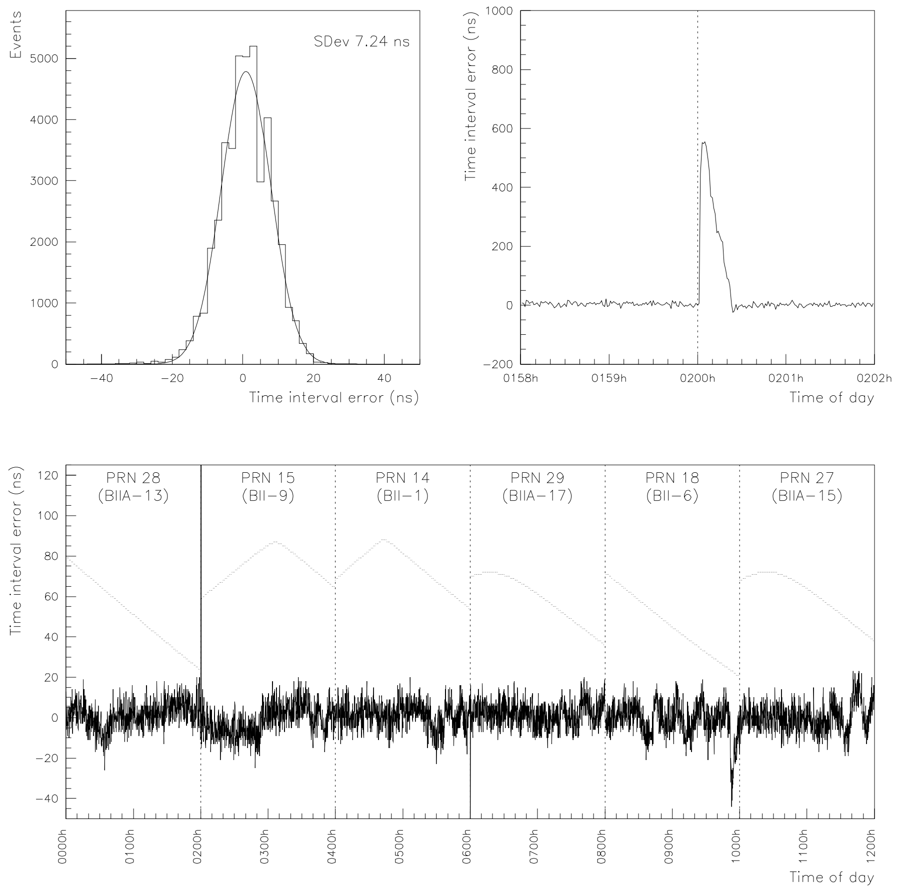

Fig. 2. Apparent event time difference with the time-tagging systems separated by 11.2 km during the morning of 26/1/95. The upper line of the lower plot shows the elevation angle of the satellite being used for time recovery, its PRN code being given at the top of the frame. The upper left plot shows the distribution of the data; at upper right an expanded view of the switch-over transient at 0200h is shown. Note that an arbitrary offset has been subtracted from the data (see text).

References

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[2] The Auger Collaboration, *Design Report - 2nd edition* (February 1997). Available from http://www-td-auger.fnal.gov:82/