SUBNANOSEC – LASER-PULSE TIME TRANSFER TO AN AIRCRAFT TO MEASURE THE GEN. RELATIV. ALTITUDE EFFECTS ON ATOMIC CLOCK RATES

C. Alley
University of Maryland

ABSTRACT

"Paper Not Received"

QUESTION AND ANSWER PERIOD

McDADE:

McDade, General Electric.

Why do you double your light beams?

PROFFESOR ALLEY:

The photo multipliers we use have phot cathodes that are sensitive to the green, and not sensitive to the infra-red, so we get better quality efficiency that way. There is some slight improvement in the pulse width from the doubling but it is mainly a quantum efficiency reason.

MR. BABITCH:

Dan Babitch, Hewlett-Packard.

Did you happen to make any fractional frequency stability analysis of the data on that last viewgraph of the airborne standards? It looked like about 1.5 nanoseconds peak to peak for two days.

PROF. ALLEY:

Yes, we have done calculations of the Allan variance as a function of the averaging time, and unfortunately I don't have any viewgraphs prepared with that, but, on the cesium standards, we see them getting down to below 10^{-13} level in something like three hours.

The stability, I think, would be down in a few parts to 10^{14} over that period of time. We have not ever been able to run our clocks for very long periods, so that we could have a large number of several-day intervals contiguous to one another. There is always something required to be changed or moved, so we just don't have a full calculation of that performance yet, but after the experiments are concluded, we hope to have some uninterrupted time in which to log that kind of data.

MR. BABITCH:

I was wondering if the data shown on the airborne system met or exceeded or was worse than similar data for laboratory ground-based systems of the same type. In other words, how good was your environmental isolation? Did it really do a lot for you?

PROF. ALLEY:

Yes, it did a great deal for us, but it didn't do all we would like it to do. It is somewhat worse on the planes than it is on the ground. We suffer there from sort of a primary difficulty, in that the plane's own environmental control system never has worked properly.

We can get temperature excursions up to 18 to 20 degrees Fahrenheit in the plane, whereas in the trailer we can keep our temperature within a degree or better, over a long period. Our shielding is not perfect. And the gradients, of course, change. They are particularly bad in the airplane.

DR. REPASS:

Dr. Don Repass, Naval Avionics.

I was wondering what kind of changes you made to the HP-5061.

PROF. ALLEY:

Well, I mentioned two of the changes; namely, the increased oven temperature to get a larger beam flux, which of course is at the expense of the lifetime of the standards, but Dr. Winkler kindly consented to that change, and the other I mentioned was the introduction of a second order control loop. The third change is one that HP wishes to remain proprietary at the present time.

HARRY PETERS:

I wondered if you could tell us what the resolution on relativity effects of potential and velocity should have been theoretically in your experiment and from your data how close you might approach this value.

PROF. ALLEY:

Well, we are still analyzing the data, Harry. Harry and I discussed this type of measurement several years ago at one of these PTTI conferences. I am hopeful that we can get down to the approximately 1 percent accuracy on the measurement. The comparisons so far -- and we haven't fully assessed the uncertainties that the range introduces in its measurements. They have an elevation altitude uncertainly of about 100 feet, but it is their angles that are a little bit more uncertain, and that enters into the velocity.

We have tried to keep those uncertainties down to on the order of .3 of a percent, but I am not sure that has been achieved yet. Right now, roughly the measurement accuracy on each flight is about a nanosecond, which is about 2 or 3 percent in a 40 to 50 nanosecond difference, and by combining these several flights -- we have had four long flights, and we have a fifth long flight scheduled for hopefully next week -- it may be possible to get down to around 1 percent, but don't mistake what I am saying. We haven't really done that yet.

DR. WINKLER:

At any rate, your resolution seems to be good enough to discover errors in the range tracking.

PROF. ALLEY:

Perhaps.

DR. WINKLER:

Very good. But, there is one comment I would like to make, and that is that I have two sincere hopes connected with the execution of that experiment; No. 1, it undoubtedly demonstrates the ultimate which can be achieved with today's technology; this technology which is available right now, if you use every one of our assets. This includes unprecedented time transfer precision in the order of 10 to the minus 10 seconds resolution. It includes stabilities of these clocks in hostile environment, which is a few parts in 10^{14}, but I have also a second hope and that is that such an experiment executed, again as the previous one by Hafele and Keating with real clocks which have been calibrated and sent out into a distance and returned to the laboratory -- that these experiments will hopefully finally

put to rest an endless scientific dispute carried out by sometimes not very qualified people in all kinds of journals, and establish as a fact the reality of these effects which we have to take into account when we talk about nanoseconds timekeeping and time measurements in an actual environment.

I think -- I am convinced that these experiments will accomplish these goals.

PROF. ALLEY:

May I respond briefly to that? One of the justifications for the Navy supporting these measurements has been that in the planned global positioning system, if the positioning accuracies that they talk about publicly of 10 to 20 feet are to be achieved, one has to make these relativistic corrections due to the ellipticity of the orbit.

DR. WINKLER:

But, even in other time transfers, for instance, in experiments which have been carried out between here and Japan recently, that was a correction which had to be applied to the portable clock measurements in order to make them agree with the results through the ATS satellite.