

Re: I Owe Einstein an Apology. Sorry Albert!

Source: <http://sci.tech-archive.net/Archive/sci.physics.relativity/2004-12/4549.html>

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"Paul B. Andersen" <paul.b.andersen@deletethishia.no> wrote in message
news:cpk8u2\$915\$1@dolly.uninett.no...

> *Excuse me for butting in, but I find so much*
> *confusion about the GPS in this thread that I*
> *feel the need for clearing up a few misconceptions.*

>
>

> jahn wrote:

>> "The Ghost In The Machine" wrote:

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>>>>>>> *If the clocks are moving then SR predicts they will not remain*
>>>>>>> *synchronized.*

>

> *Clocks moving in a frame of reference will not*
> *generally stay synchronous in that frame,*
> *but they may do so in special cases.*
> *For example, clocks moving in a circle with*
> *the same speed will stay synchronous to each*
> *other in the "stationary frame". They will*
> *run slow compared to stationary clocks,*
> *but they will stay in sync.*
> *This is the case in the GPS.*
> *All the GPS satellite clocks stay in sync*
> *to each other in the ECI frame because*
> *they all move in circular orbits with the*
> *same speed and at the same gravitational potential.*

>

>>>>>> *SR predicts moving clocks can't keep good time?*

>>>>>>> *I have two garden hoses an egg timer and a bag*

>>>>>>>> *of marbles that says they must be broken.*

>>>>>>>>> <http://www.boulder.nist.gov/timefreq/time/commonviewgps.htm>

>>>>>

>>>>>> *The SR correction is $t' = (t - vx/c^2) * \gamma$.*

>>>>

- > >>>>The v/c^2 is merely a reflection that the two clocks are
- > >>>>communicating through speed-of-light (e.g., radio), but
- > >>>>the gamma is the killer; $\gamma = 1/\sqrt{1-v^2/c^2}$.
- >
- > The v/c^2 is a reflection of the simultaneity of relativity.
- > It has nothing to do with "communication through speed of light".
- >
- > >>>>It's a very slow killer, of course; the typical speed
- > >>>>of a spacecraft is on the order of $9 \text{ km/s} = 3 * 10^{-5} c$, which
- > >>>>results in a gamma of about $4.5 * 10^{-10}$. The GPS delta is
- > >>>>almost exactly this: $4.46 * 10^{-10}$. However, this is at
- > >>>>best a very very rough estimate, just to give one the feel.
- > >>>>It's also the wrong sign. :-)
- >
- > Which should tell you something. :-)
- >
- > It is actually quite simple to make a first order
- > calculation of the rate of the GPS satellites.
- >
- > The relative difference in the rate of a clock in circular orbit
- > compared to a clock on the surface of the Earth is according to GR
- > to a first order approximation:
- > (Approximation of the Schwarzschild solution)
- >
- > $(f_2 - f_1)/f_1 =$
- > $(G*M/(c^2*r_1) - G*M/(c^2*r_2)) - (0.5*v_2^2/c^2 - 0.5*v_1^2/c^2)$
- >
- > Where G = gravitational constant, M = mass of the Earth,
- > r_1 = radius of the Earth, r_2 = radius of the orbiting clock's orbit,
- > v_1 = speed of the Earth clock in ECI frame,
- > v_2 = speed of the orbiting clock in ECI frame
- >
- > Since we have $G*M/r_1^2 = g$, acceleration at Earth's surface, we have:
- > $(G*M/(c^2*r_1) - G*M/(c^2*r_2)) = (g/c^2)*r_1*(1-r_1/r_2)$
- >
- > Altitude of GPS satellites = 20200 km
- > Orbital period = half sidereal day
- > Radius of the Earth $r_1 = 6.37*10^6 \text{ m}$
- > Radius of GPS orbit $r_2 = 26.57*10^6 \text{ m}$
- > $g = 9.81 \text{ m/s}^2$
- >
- > Inserting these numbers, we find that the rate difference
- > due to gravitation is: $5.28*10^{-10}$ (+45.6 us/day)
- >
- > So to the speed part:
- > $v_1 = 40000\text{km}/(23\text{h } 56\text{m}) = 4*10^7/86160 = 464 \text{ m/s}$
- > $v_2 = 2*\pi*r_2/(11\text{h } 28\text{m}) = 3.87*10^3 \text{ m/s}$ (-7.1 us/day)
- >
- > $0.5*v_2^2/c^2 = 0.83*10^{-10}$
- > $0.5*v_1^2/c^2 = 1.2*10^{-12}$
- > Thus the rate difference due to the speed will be: $-0.82*10^{-10}$

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>
> *The combined rate difference: $(5.28-0.82)*10^{-10} = 4.46*10^{-10}$*
> *Note that the orbiting clock runs _fast_.*
>
> *During one day, the difference in proper times will amount to:*
> *$4.46*10^{-10}*86400\text{ s} = 38.5*10^{-6}\text{ s} = 38.5\text{ us}$*
>
> *According to:*
> *<http://vishnu.nirvana.phys.psu.edu/mog/mog9/node9.html>*

*****MORE BS *****

While trying to retrieve the URL: <http://vishnu.nirvana.phys.psu.edu/mog/mog9/node9.html>

The following error was encountered:

Unable to determine IP address from host name for vishnu.nirvana.phys.psu.edu
The dnsserver returned:

Name Error: The domain name does not exist.
This means that:

The cache was not able to resolve the hostname presented in the URL.
Check if the address is correct.

Your cache administrator is root.

> *the factor used in the GPS satellites is $4.4647*10^{-10}$.*
>
> >>>>*An accurate clock left running for a year in a GPS orbit*
> >>>>*will gain about a hundredth of a second.*
>
> *You mean a "normal clock" not slowed down*
> *by the factor $4.4647*10^{-10}$?*
> *Yes. It would gain ca. 14 ms a year.*
>
> [..]
> >>>>*(SR predicts loss*
> >>>>*of time, but then SR requires straight-line freespace*
> >>>>*travel. :-) . Therefore, GPS clocks are "broken" by*
> >>>>*design, coding in this adjustment factor -- and even*
> >>>>*then, they have to be steered from the ground using*
> >>>>*synchronization signals from the TAI.*
>
> *1. "GPS time" is a coordinated time where the coordinate*
> *system in question is stationary in the ECI-frame.*
> *The coordinate time is per definition such that*
> *clocks on the geoid will stay in sync (run at the same*
> *rate) with this coordinate time.*
> *"GPS time" is a theoretical time, derived from*
> *all the clocks in the system, that is all the satellite*
> *clocks and all the ground station clocks.*

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- >
- > 2. *This "GPS time" is steered so that it (but for a number*
- > *of whole seconds) is equal to UTC. The spec says it should*
- > *be within 1 us, but in actual practice, it differs but*
- > *few ns. This difference is known by the system, and each*
- > *satellite will transmit the difference GPS-time - UTC*
- > *so that a receiver can calculate the correct UTC.*
- > <ftp://tycho.usno.navy.mil/pub/gps/utcgps30.dat>
- >
- > 3. *The GPS satellite clock are built to run slow*
- > *(compared to a clock using the SI definition of a second)*
- > *by the factor $4.4647 \cdot 10^{-10}$ prior to launch.*
- > *In orbit, they will thus run synchronously to GPS-time.*
- >
- > 4. *The precision of the clocks is in the order of 10^{-13} .*
- > *That means that they during one day may drift off sync*
- > *by several ns - or even tens of ns. The most that can*
- > *be tolerated is a few tens of ns.*
- > *(Less than 100ns at the very most)*
- >
- > 5. *To correct for the latter, ground stations are monitoring*
- > *the satellite clocks, and are uploading correctional data*
- > *typically once a day. The "clock offset" is simply how*
- > *much the clock is off sync. For some satellites, this may*
- > *be up to milliseconds. The satellite clocks are not corrected,*
- > *but the "clock offset" is transmitted together with the*
- > *"clock time", and the receiver calculates the corrected time.*
- >
- > >>>Indeed:
- > >>><< *GPS TIME STEERING*
- > >>>=====
- > >>>GPS time is automatically steered to UTC(USNO) on a daily basis to keep
- > >>>system time within one microsecond of UTC(USNO), but during the last
- > >>>several years has been within 50 nanoseconds. The rate of steer being
- > >>>applied is $\pm 1.0E-19$ seconds per second squared.
- > >>><ftp://tycho.usno.navy.mil/pub/gps/gpstt.txt>
- >
- > Right.
- > But note that as stated above. this is steering of
- > the GPS-time, not of the individual satellites.
- > You have two different coordinated time systems,
- > each "living its own life" which should be made
- > to run equal. The $\pm 1.0E-19$ seconds per second squared
- > is the maximum "speed" with which the GPS time is changed.
- >
- >
- > >>>It must take a REAL good mathematician to get 7 microseconds
- > >>>per day out of that. ;-)
- >
- > .. and a real bad physicist to try. :-)
- >

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> >> *I get 38.53 microseconds per day out of the $4.46 \cdot 10^{-10}$ corrective factor.*
> >> *It's a simple enough multiplication:*
> >>
> >> $4.46 \cdot 10^{-10} \text{ sec/sec} * 86400 \text{ sec/day}$
>
> *Right.*
>
> > *The altitude effect isn't cumulative.*
>
> *Utter nonsense.*
>
> > *That is, you can move*
> > *from Honolulu to Tibet and make one adjustment to the*
> > *length of a pendulum. You don't have to do it every day.*
>
> *But the error is still cumulative, isn't it? :-)*
>
> > *The 7 ns per day is for transverse doppler effect (less*
> > *frequently called the SR correction)*
>
> *3 orders of magnitude wrong.*
> *(But we will call this a typo.)*
>
> > *It was included in*
> > *the preset because it does save the receiver some calculating*
> > *(there may have been some political reason to have all*
> > *the "relativistic" effects in one synthezer too [shrug])*
> > *Anyway the 7ns error would accumulate if it represented*
> > *a clock rather than a propagaion effect.*
>
> *Of course a rate error of 7 us/day would accumulate 7 us a day.*
>
> > *I think you can tell at a glance that $\pm 1.0E-19$ steering*
> > *and $\pm 50 \text{ ns}$ / daily won't on the worst day add up to*
> > *the 7ns necessary to atrribute to an SR clock anomaly.*
>
> *This confusion is too gigantic to try to remedy. :-)*
> *You really have no clue whatsoever, have you jahn Sue?*
>
> > *It's all public information.*
> > http://tycho.usno.navy.mil/gps_datafiles.html
> > <http://tycho.usno.navy.mil/systime.html>
>
> *But you have no idea of what they mean?*
>
> *Paul*