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Frequency Changes in GPS Satellite Signals

(short version of the article *Gravitational frequency shift and the transverse Doppler effect in the GPS system*)

If the source of electromagnetic radiation moves in a direction perpendicular to the "source-receiver" line, the radiation comes to the receiver at a reduced frequency. When a stationary source is located higher the receiver, the receiver sees an increased frequency. These two effects are well known and confirmed experimentally with high accuracy [1, 2]. Advocates of special relativity argue that these effects are relativistic, and that frequency changes occur due to time dilation in moving systems and changes in gravity [3-6]. In our previous works [7-10] it was shown that no time dilation exists, and the transverse Doppler effect and the gravitational frequency shift have a purely classical explanation

An increased frequency signal arrives from the GPS satellite orbit to the control center on Earth. This increase in frequency is partially offset by a decrease in frequency due to the speed of the satellite. A slight decrease in frequency occurs when the satellites moving at the same speed in the same orbit send signals to each other. Why and how do these effects arise and are they relativistic? It is shown below that these are not relativistic effects and they are explained from a purely classical point of view.

Signals between satellites moving with the same speed in the same orbit

The atomic clocks at the control punkts are tuned to a frequency ν_o = **10.23** GHz. Lets imagine that no relativistic corrections are introduced into the atomic clock of the satellites, and each satellite sends a signal to another satellite at a frequency of **10.23** GHz.

If the satellites were moving in an ideal v o i d , the photons would travel the distance between the satellites at a speed C and the signal frequency would not change. But since the satellites move not in a void, but in a rarefied atmosphere, due to the re-emission of photons by atoms of the atmosphere, their speed changes, the Doppler effect occurs twice and the signal frequency decreases

At the first moment after emission, the photons emitted by the first satellite towards the second satellite have a frequency of **10.23** GHz and move relative to the satellite at a speed C and relative to the rarefied atmosphere at a speed C + V.

As soon as the photons meet the atoms of the atmosphere, they are re-emitted, their speed changes, and relative to the atmosphere they travel with the speed C / n (where the refractive index n is practically equal to unity).

In accordance with the Doppler effect, the frequency of photons decreases from νo = **10 230 000 000** Hz to $\nu_1 = \nu_0\left(1 - \frac{V}{C}\right)$ and at a speed of movement V = **3.874** km / s becomes equal to **10 229 867 805** Hz.

10 230 000 000 (1 – 3 874 / 299 792 458) =
= 10 229 867 805.146719201321602293277

With a frequency of **10 229 867 805** Hz, photons travel in the atmosphere to the second satellite and meet with it at a speed of C + V. In accordance with the Doppler effect, their frequency changes in

(1+V / C) and becomes equal to **10 229 999 998** Hz.

10229867805.146719201321602293277 (1 + 3 874 / 299 792 458) =
= 10 229 999 998.291742010368339285864

Thus, after a two-fold Doppler frequency change, the second satellite, instead of a signal with a frequency of νo = **10.23** GHz, receives a frequency $\nu = \nu_0\left(1 - \frac{V^2}{C^2}\right)$ = **10 229 999 998** Hz, which is **1.7** Hz lower than νo.

10 230 000 000 - 10229999998.291742010368339285864 =
= 1.7082579896316607141356676158811

The signal frequency changes in the same way when the second satellite sends a signal to the first satellite going ahead: the frequency of the received signal turns out to be **1.7** Hz lower than **10.23** GHz.

Signals from the satellite to the Earth without taking into account the influence of the speed (the gravitational change only)

The frequency change occurs due to the fact that the satellite transmitter and the control center receiver are at different heights (similar to what happens in the Pound-Rebka experiment).

If relativistic corrections are not introduced into the satellite's atomic clock and the satellite sends a signal at a frequency of **10.23** GHz, the sishgal arrives at the control center with a frequency of **10.230,000.004.574 856** GHz, which is **4.574856** GHz higher than **10.23** GHz.

It is customary to explain this change in frequency by two relativistic effects:
- at an altitude of 20 184 km, time flows faster and therefore the frequency increases by 5.5189 Gz
- since the satellite is moving at a speed of 3.874 km / s, time on the satellite flows slower and the signal frequency decreases by 0.854 Hz.

In our work [10], it is shown that there is no “acceleration” or “deceleration” of time on the satellite, and the frequency changes are explained by purely classical effects.

During the time 20 184 / 299 792, 458 = 0.067 326 576 9 sec, while the signal from the satellite goes to the Earth's surface, the speed of photons under the influence of gravity increases by 0.161 734 m / sec or in relative units by 5.3948 e-10.

0.161 734 / 299 792 458 = **5.3948**862990861707269507308789386e-10

Due to the increase in the speed of photons by **5.394**8 e-10, the signal frequency changes by the same amount **5.394**8 e-10 and turns out to be equal to **5.5189** Hz.

10 230 000 000 x **5.3948**e-10 = **5.5189**686839651526536705976891542 Hz,

Thus, the receiver on Earth sees an increase in the signal frequency by **5.518**9 Hz and this increase in frequency is explained only by the gravitational increase in the speed of the photons and therefore does not need any "relativistic" explanations.

Signals from satellite to Earth excluding gravity (frequency change because speed only)

If we do not take into account the influence of gravity and if the satellite emits a signal at a frequency of **10.23** GHz, the frequency of the signal received on Earth turns out to be **0.854** Hz less than the frequency of **10.23** GHz.The decrease in frequency is explained not by any time dilation, but by the transverse Doppler effect - a change in the speed of photons in the direction perpendicular to the speed of the satellite. As shown in our works [7, 10], the transverse effect is explained by the fact that only photons emitted at some angle back travel in the direction perpendicular to the source's velocity, and therefore the initial (before re-emission by the atoms of the medium) velocity of the photons is determined by the vector addition speeds C and V.

The vector addition of the speed 299 792 458 km / s and the satellite speed V = 3.874 km / s gives the value of the speed with which the photons move towards the Earth before the first re-emission by the atoms of the medium: 299 792 457. 974 969 55710502476504676 m / s.

This speed is by **0.02 503** 044289497523495324 m / s less than C (the relative change in speed is **8.34**9 257 036671427856013642611382**8e-11**) and therefore at the time of re-emission the photon frequency changes by **0.854** 12899485148706967019563914446 Hz from **10 230 000 000** Hz to **10 229 999 999.145** 87100514851293033 Hz.

Thus, due to the movement of the satellite at a speed of **3.874** km / s, the frequency of the signal received on Earth decreases by **0.854** Hz.

Since both effects

\- **the gravitational frequency change and the speed frequency change** act simultaneously, the resulting change is equal to 5.5189 - 0.854 = 4.6649 Hz, which is quite close to the known value of 4.574856 Hz.

Conclusion

The need to introduce adjustments to the atomic clock of GPS satellites is explained not by the so-called SRT effects - slowing down or acceleration of time in satellites, but by changes in the speed of the photons and resulting Doppler effect.

The classicall explanation of the frequency changes in the GPS system allows us to assert that the SRT fantasies about slowing down or speeding up time are erroneous and should be excluded from scientific research

References

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