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Determination of CALLISTO radio-spectrometer timing uncertainty

Chr. Monstein

IFA Scheuchzerstrasse 7, ETH-Zentrum, CH-8092 Zürich, Switzerland

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Abstract. Natural lightning strokes near Bleien observatory were used to analyze Callisto timing uncertainty compared to Phoenix-2 timing which was used as a reference. Two different methods were applied to analyze the data. Both lead to the same result of about $-0.06 sec$ which Callisto is 'slower' than Phoenix-2.

Key words. Lightning stroke, time source, GPS, Phoenix-2, Callisto.

1. Theory

Lightning strokes during $May\ 12th$ 2004 near Bleien observatory were used to determine the overall timing error compared to Phoenix-2 (Messmer, 1999) timing which is frequency- and phase locked to the GPS system. Callisto was also frequency locked to the same GPS system, but the phase was locked to a standard internet network time system (windows XP © allows direct time synchronization with any nettime-server on the web). With this analysis we want to find an answer to the question whether Callisto measures with the same phase as Phoenix-2 does, or not. All relevant data containing the most impulsive lightnings stroke spectra were saved in raw-format (see table 1) covering time range from $15.00UT$ to $15.30UT$. Unfortunately not all lightning strokes can be recognized in both spectrometers due to the fact that both are frequency agile. Very often a lightning stroke is much shorter in time than the sweep time of the measuring spectrometer. During the observation period of 30 minutes 40 lightning strokes could be visually identified and analyzed in both instruments. One 15 minute file of Phoenix-2 and Callisto are presented in Fig. 1 respective Fig. 2. In both plots the x-axis t_p respective t_c was re-calculated into real time - which means - that for each pixel the true time was calculated using linear transformations Eq. 1 and Eq. 2.

$$t_p(ch_p, sn_p) = T0_p + sn_p * \Delta T_p + ch_p * \delta t_p \quad (1)$$

where $T0_p$ refers to the still unknown absolute phase error of Phoenix-2 against UTC. ch_p corresponds to the channel number in the frequency file $frq05031.cfg$, our standard frequency file for Phoenix-2. sn_p stands for the sweep number within the raw data file. $\Delta T_p = 100msec$ is the spectrum resolution in time domain or sweep time

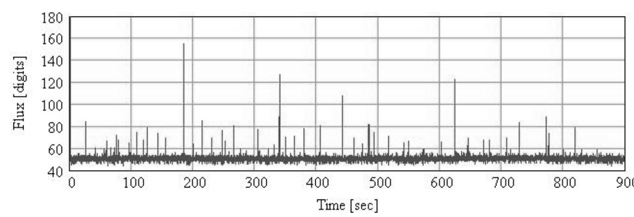

Fig. 1. Phoenix-2 lightcurve of 30th channel at frequency $372MHz$

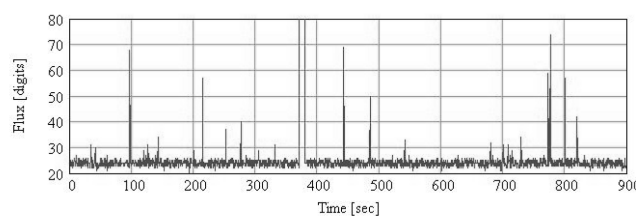

Fig. 2. Callisto lightcurve of 300th channel at frequency $397.490MHz$.

while $\delta t_p = 0.0005sec$ is the step time between 2 consecutive pixels or frequency channels. It is also identical to the integration time in the backend circuits. Similarly to Phoenix-2 we may get for Callisto:

$$t_c(ch_c, sn_c) = T0_c + sn_c * \Delta T_c + ch_c * \delta t_c \quad (2)$$

where $T0_c$ refers to the result (timing or phase error) we want to get with this paper. ch_c corresponds to the channel number in the frequency file $frq01501.cfg$, our standard frequency file for *Callisto*. sn_c stands for the sweep number within the raw data file. $\Delta T_c = 500msec$ is the actual spectral resolution in time domain or sweep time while $\delta t_c = 0.00125sec$ is the step time between 2 consec-

Phoenix-2 files	Callisto files
$DAT02196.RAW$	$C20040512\_150001\_5958.raw$
$DAT02196.RAW$	$C20040512\_151501\_5958.raw$
$DAT02196.RAW$	$C20040512\_153001\_5958.raw$
$frq05031.cfg$	$frq01501.cfg$

Table 1. Data files and frequency programs involved in present analysis. Phoenix-2 filenames are consecutive numbers without any meaning, while Callisto filenames denotes to their starting time in UTC.

utive pixels or frequency channels which also corresponds to hardware integration time.

2. Results

2.1. Manual method

As a first estimation, all 40 lightning stroke spectra were analyzed manually using trace function of *MathCad* 2000 ©. Statistical evaluation lead to an average value (median value) of $< T0_p - T0_c >= -0.06sec$, which means that *Callisto* is $0.06sec$ later in capturing the data onto the internal hard disc than our reference spectrometer Phoenix-2. Unfortunately the standard deviation of these 40 results is in the order of $\sigma = 0.136sec$. Two aspects lead to this rather high level of σ. One cause is the low time resolution $\Delta T_c = 500msec$ of Callisto, the other point is caused by the little number of available lightning flashes. Manual analysis of timing data is also rather time consuming, thus another method is necessary which will be presented in the following subchapter.

2.2. Cross correlation method

The same lightcurves as shown above where used in the cross correlation analysis. But now a certain trigger level was set to get rid of the noise floor. The trigger level was set in such a way (120% of the mean value) that only the lightning flashes were copied into the temporary arrays while the noise (radio noise of quiet sun) was set to zero. The cross correlation function of Phoenix-2 and Callisto is indicated in Fig. 3. The time lag of the cross correlation function ccf is given by Phoenix-2 sweep time, which is $\Delta t_p = 0.1sec$. With this information, setting $T0_p = 0$ (we still don't know the absolute phase difference of Phoenix-2 against UTC) and combining Eq. 1 and Eq. 2, the timing error can be estimated to:

$$T0_c - T0_p = (ch_p \delta t_p - ch_c \delta t_c) + ccf \Delta t_p \quad (3)$$

The result for all lightning flashes between $15.00UT$ and $15.15UT$ lead to $T0_c = -0.065sec$ while the flashes between $15.15UT$ and $15.30UT$ lead to $T0_c = -0.060sec$.

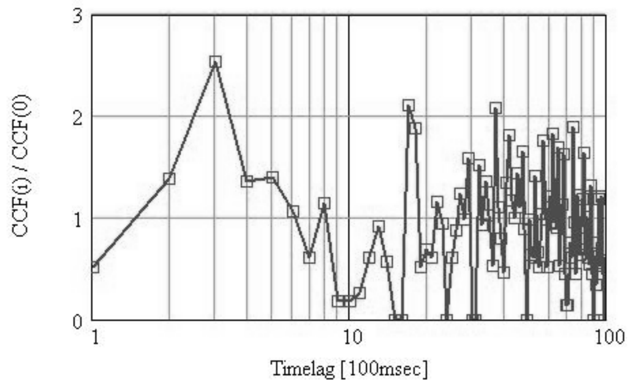

Fig. 3. Cross correlation function of local lightning flashes seen by Callisto- and Phoenix-2 frequency agile spectrometers. While Callisto data (lightcurve) were kept constant, Phoenix-2 data (lightcurve) were moved step by step to right (increasing time lag, $100msec$ each).

2.3. Conclusion

Both results correspond very nicely with the result given by the manual method. But the results using cross correlation on a PC are much easier to get. Now the final result is given by the average value of all three above partial results (1 manual and 2 cross correlated) $T0_c = -0.062sec$.

Earlier experimental analysis of Phoenix-2 timing by P. Messmer have shown that it is about $35msec$ 'later' than the longwave UTC-atomic clock distribution transmitter DCF77 near Braunschweig Germany. Thus, in total Callisto is about $100msec$ behind UTC, which for most applications seems to be acceptable. As soon as possible, we will also try to phase lock Callisto to our GPS timing system. But this upgrade demands an additional COM-port (RS232) on the spectrometer PC and appropriate software. At the moment the GPS system is also not yet prepared to supply more than one consuming PC.

References

Messmer Peter, *Phoenix-2: A New Broadband Spectrometer for Decimetric and Microwave Radio Bursts., Peter Messmer, Arnold O. Benz and Christian Monstein.)*