

USE OF THE GPS RECEIVERS FOR DATA SYNCHRONIZATION IN DISTRIBUTED SIGNAL ACQUISITION SYSTEMS

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Summary

The issues of synchronization of vibroacoustic measurements taken with the use of multiple mobile signal acquisition units were discussed in the paper. The problems existing with synchronization of DAQ measurement cards placed in different acquisition units were described and solutions allowing card synchronization using GPS signals were proposed. Described solutions were tested in the field measurements of the moving railway cars and simultaneously the stationary measurements taken next to the railway track.

Keywords: GPS, sound and vibration measurements, measurement synchronization, distributed signal acquisition systems.

WYKORZYSTANIE ODBIORNIKÓW GPS DO SYNCHRONIZACJI DANYCH W ROZPROSZONYCH SYSTEMACH REJESTRACJI SYGNAŁÓW

Streszczenie

W pracy omówiono zagadnienia związane z synchronizacją pomiarów wibroakustycznych wykonywanych za pomocą wielu mobilnych układów akwizycji sygnałów. Przedstawiono problemy występujące przy synchronizacji kart pomiarowych umieszczonych w różnych układach pomiarowych i zaproponowano rozwiązania pozwalające na synchronizację tych kart za pomocą odbiorników GPS. Zaproponowane rozwiązania zostały przetestowane w warunkach poligonowych podczas jednoczesnych pomiarów na poruszających się pociągach oraz pomiarów przytorowych.

Słowa kluczowe: GPS, pomiary hałasu i drgań, synchronizacja pomiarów, rozproszone systemy rejestracji sygnałów.

1. INTRODUCTION

In the measurement practise we are frequently forced to synchronize measurements taken simultaneously in separate distant places. Such systems are called distributed signal acquisition systems. An example of such measurements is the signal acquisition system built for the needs of acquiring signals needed for the development and testing of a pass-by railway monitoring station. For this purpose vibroacoustic signals from the moving railway car were recorded simultaneously on the stationary ground data acquisition station and on a mobile station carried on the moving railway car. The noise and vibrations signals from both stations were recorded and then analysed in laboratory for detection and removal of disturbances introduced in moving signal source by Doppler Effect [1, 2].

If we would like the time signals to be compared point by point we need the recorded data to be exactly timestamped. Speaking more precisely depending on the acceptable time difference

between the beginnings of the measurements, the need to synchronize measuring cards sample clocks as well as depending on the distance between the measuring computers and thus the possibility of exchanging information between them, various configurations of the measuring equipment and synchronization methods could be used. In this paper several possible methods of synchronization of the measuring gear will be discussed with special focus taken on the possibility of the use of the GPS signal for this purpose. The methods described were implemented and tested in practice during field measurements using National Instruments data acquisition hardware and programmed with LabVIEW. The tests took place on in Żmigród on a CNTK railway test track. The testing equipment consists of two independent NI/PXI-8186 controllers equipped with NI/PXI-4472B data acquisition cards and two Garmin 18LVC GPS receivers used for synchronisation purposes.

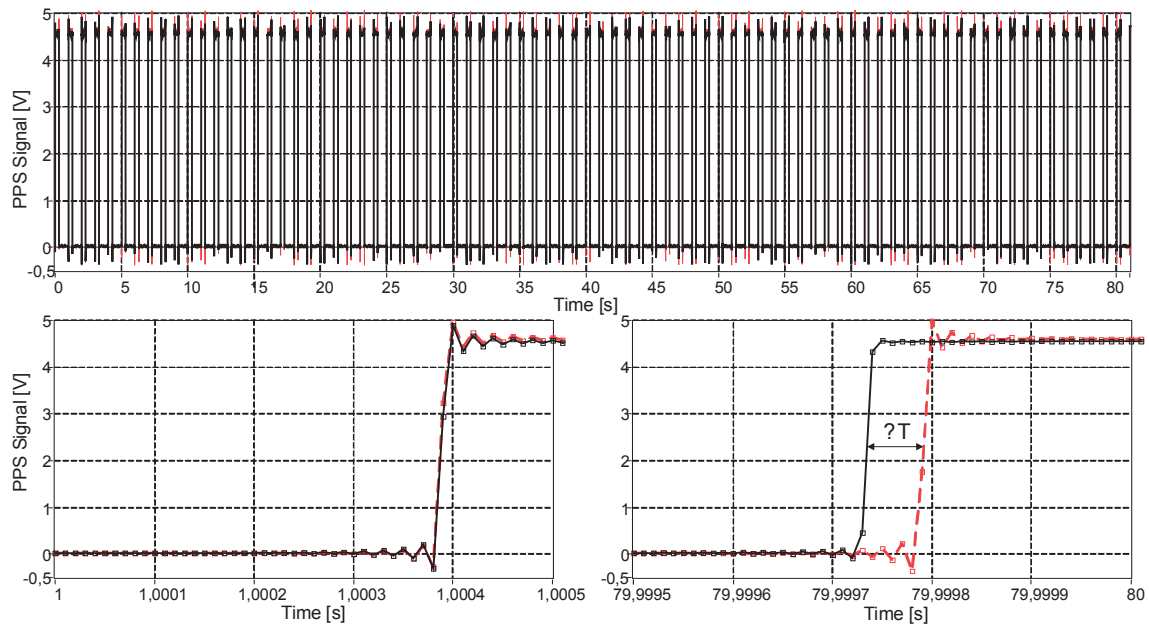


Fig. 1. Rectangular pulse acquired simultaneously with the use of two DAQ cards on separate units.

2. MEASUREMENTS SYNCHRONIZATION PROBLEMS IN DISTRIBUTED DATA ACQUISITION SYSTEMS

Proper synchronization of the signal recordings is very important if the correlation between time waveforms not their spectral representations should be analysed. For example if we would like to remove a Doppler Effect from the recorded signal of a moving source and would like to compare the results with data captured on a stationary system we need not only to align the beginnings of the recordings (starting points) but also align the sampling frequencies of the data acquisition (DAQ) cards.

In this paper we will not be dealing with inter channels synchronisation problems (i.e. multiplexed and non multiplexed cards) but rather focused on synchronisation problems of different, unconnected with themselves data acquisition units in a distributed signal acquisition system.

The first more common synchronization problem existing when synchronizing multiple units in distributed signal acquisition system is the simultaneous triggering of the DAQ cards i.e. selecting the moment of acquisition beginning. Usually it requires a physical (i.e. electric) connection of the cards and is possible only in case of relatively small distances between acquisitions units counted rather in meters. Other possibilities are to trigger the acquisition units using internet connection [3] or WI-FI signal or to start the measurements according to the specified time. Unfortunately, sending trigger signal over asynchronous lines except for small distances [3] introduces usually unknown delay hard to estimate and precision of the latter is very bad unless

a computer clocks are radio synchronized and the precise timing of data acquisition is known.

Another problem usually not taken into account while creating data acquisition systems is the synchronization of the card oscillators. Crystal oscillators are implemented in any of the data acquisition cards and are the frequency base for generating sampling frequency of data acquisition (sample frequency). Although this oscillators are very precisely made their frequencies differs slightly introducing small differences in sampling frequency even in the cards of the same type. If the acquisition cards are in the same DAQ unit usually there is a possibility to chose one oscillator (clock) as a basic for generation of sampling signals and exporting its signal programmatically or physically across the unit. For separate data acquisition units placed close to each other only hardware method of clock signal exporting is possible.

Usually the differences between clock frequencies are very small but even for the same type of cards if the signal is long enough the difference could disturb the synchronization between the signals recorded with use of different DAQ cards. An example of the rectangular pulses recorded on two independent NI/PXI-4472B DAQ cards placed in different, not connected with each other, chassis shows this problem (Fig. 1). On the upper diagram eighty seconds of 1Hz rectangular pulse sampled with 100kHz are visible. As was shown on bottom left diagram both signals were perfectly, to the single sample, aligned in the beginning (first acquired pulse). After next 78 seconds the rising edge of one of the signals is shifted $\Delta T = 6$ points from the other signal. Additionally it is visible that the recorded frequencies of both signals are looks a little bit faster than 1Hz what is caused by clocks slower than

documented. This frequency drift although very small could disrupt in some times, especially for very long recordings, the common analysis of recorded waveforms.

3. METHODS OF SOLVING MEASUREMENTS SYNCHRONIZATION PROBLEMS

As was mentioned above the two most common synchronization problems described could be easily resolved if the data acquisition units are in the same chassis or placed close to each other in such a distance that they could be connected with wires transmitted electric signals (clock). In other cases especially if the distance between units is too long for wiring or one or both DAQ units are placed on a moving platform we are limited to wireless communication between units or we could use GPS signal as a source of synchronization signals.

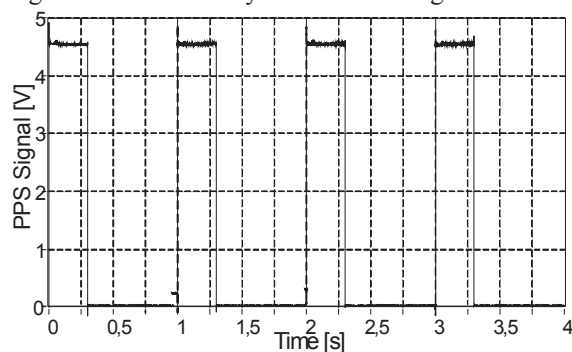


Fig. 2. PPS signal received from Garmin 18LVC GPS receiver.

3.1. GPS signal as a source of DAQ cards synchronization signals

GPS receivers could be used not only as a source of current position and precise time but also as a source of series of rectangular pulses that could be used for synchronising data acquisition cards. To do this the GPS receiver should be able to pass the Pulse Per Second (PPS) or Inter-Regional Instrumentation Group IRIG-B signal to its output. Both signals are of the TTL level. PPS signal is a rectangular pulse of duration of exactly 1 second (Fig. 2) with accuracy depending of the receiver electronics (for example for Garmin receiver 18LVC accuracy is $\pm 1\mu\text{s}$). On the other hand IRIG-B signal [4] contains BCD-coded information about the current time and date (Fig. 3). Usually IRIG-B signal is used for precise global timebase applications so the receivers are rather expensive and their usage is limited to standalone applications. On the other side the PPS signal does not contain timing information and as such should be accompanied with time data transmitted from the receiver over RS-232 interface.

PPS signal is usually available on OEM GPS receivers that supports serial RS-232 protocol and is not available on receivers with USB connections.

One example of such receiver is Garmin GPS 18LVC shown on Fig. 3. It's extremely low cost (~70USD) makes it available for applications where the cost is crucial. The unit requires 60mA @ 5V power source that is usually available in the DAQ card connectors and has unconnected wires that could be connected to the computer's RS-232 interface (Data wires) and the DAQ card trigger line (Measurement Pulse Output wire) in TTL standard. The accuracy of PPS signal is 1 μs [5] good enough for typical vibroacoustic signal recordings. Through the receiver's serial interface NMEA-183 text informations could be transmitted from the receiver to the recording computer with alphanumeric informations about current time, positions and signal quality. The transmitted NMEA sentences follows immediately rising edge of PPS signal, so the latter could be used for triggering RS-232 reading. An example of \$GPRMC (Recommended Minimum Specific GPS Data) sentence is shown below: \$GPRMC,091138,A,5128.1126,N,01651.5431,E,00 0.0,167.8,240707,003.0,E*73

This sentence contains current time (9:11:38), position (51°28'1126"N, 16°51'5431"E), speed in knots and course over ground (0, 0.0) and date (24-07-2007).



Fig. 3. Garmin 18LVC GPS receiver [5].

3.2. Triggering DAQ card with PPS signal

Practical realization of triggering the DAQ card acquisition with PPS signal at the specified time moment usually requires the use of additional digital counter card for triggering serial interface reading with this signal. The analogue acquisition is then started on the next rising edge of PPS signal (next second) after reading and checking specified time from the \$GPRMC NMEA-183 sentence. The flowchart of data acquisition triggered with pulse per second GPS signal for each of the computers is shown on Fig. 4.

As was shown above (Fig. 1) waveforms acquired simultaneously on different acquisition units differ slightly from each other because of different sampling frequencies of DAQ cards. Fortunately the drift of the clock frequencies is constant in time and easy to compensate assuming that the precise PPS signal will be recorded together with other signals. In that case the recorded signals could be resampled taking as a base time distance between first and last rising edges of the PPS signal. The resampling coefficients of clock waveforms would be (Fig. 5):

$$R_1 = \frac{T}{T - dT_1} \quad R_2 = \frac{T}{T + dT_2}$$

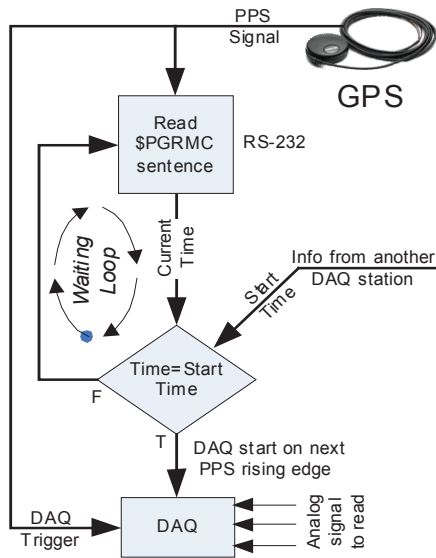


Fig. 4. Flowchart of data acquisition with PPS signal triggering.

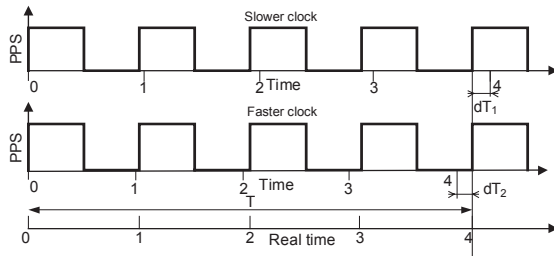


Fig. 5. Calculation of resampling coefficients using recorded PPS signal.

3.3. Online compensation of DAQ card clock frequency errors with PPS signal

The PPS signal could be directly used for online correction of clock oscillators in DAQ cards. There are at least two methods of doing this using National Instruments hardware on PXI platform.

First method [6] uses specially designed counter card NI/PXI-6608 as a source of clock for the DAQ card. This card has very stable clock oscillator capable of slightly changing its frequency according to the Pulse Per Second signal of the GPS receiver. The generated clock signal should then be exported to the DAQ card. During the measurement each rising edge of PPS signal introduces slight correction to the 6608 clock frequency so the timing of the DAQ card is very accurate (~300ns excluding GPS accuracy).

Another method requires use of FPGA (field-programmable gate array) acquisition card as a source of a sample clock for separate DAQ card. FPGA cards are extremely fast, capable of perform single loop in 25ns – 40Mhz. They could be used for generating sample clock of required frequency and in the same time for calculating time distance between consecutive PPS pulses. The frequency of the thus generated sample clock will be corrected in the last generated clock impulse but as this

correction is very small it will not introduce any disturbances in the recorded signal.

4. SUMMARY

GPS signal allows synchronization of measurements taken by independent, unconstrained data acquisition units distributed on unlimited area. The proposed method is very cheap but powerful. In the simplest form, if used in the field measurement, the starting time of measurements on different units could be defined with use of conventional voice media or automatically over WI-FI network. Results of the GPS synchronized measurements and their analysis were presented somewhere in this issue.

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