GPS timing: how it is transforming land acquisition

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Summary

The contributions of global navigation satellite systems, such as the GPS, for source & receiver positioning and timing are highlighted. While GPS positioning has been used for several decades, the impact of GPS timing on land acquisition is recent (2005). By enabling the time-stamping of all seismic samples in the recorder as well as in the autonomous receiver stations, it offers the possibility to synchronize all elements of a hybrid spread made of cable and cableless segments. The same flexibility is present on the source side as soon as vibrators are able to define by themselves the position and the start time of each shot (T0). By combining these possibilities different acquisition architectures are made available to improve productivity depending on terrain conditions.

Introduction: GPS positioning and GPS timing

In the field, sources and receivers require precise and accurate positioning. Since the early 90's, this has been achieved thanks to global navigation satellite systems (e.g. the Global Positioning System) providing the coordinates (x, y, z with respect to the Geoid) of any device placed under an open sky. Thus, Marine acquisition has been the first to benefit from GPS. To meet the requirements of seismic, positioning accuracy has improved (within 6 0.5m) by compensating clock and propagation errors with the help of a fixed reference station defining differential corrections (DGPS). By measuring the phase of the carriers in dual frequency mode (e.g. Real Time Kinematics) precision increased further (within 6 0.01m). Today, GPS positioning is not only delivered by specific surveying devices at each acquisition point. It also provides the vibrator position and guidance that made acquisition without stakes possible. Recently, GPS antennas were included within 3C Digital Sensor Units to automatically provide their own position (6 1m) & orientation (6 3°).

Another prerequisite during acquisition is that the relative time of the seismic samples must be defined with respect to a common reference. Before 2000, synchronization was performed via cable or radio links (VHF) with respect to the Central Unit clock. Now, synchronization to within 1µs can be established with respect to the very precise clock of the satellite (1ns/day). This assumes that the position of each element of the system has been defined, in order to know their distance to the satellites and compute the corresponding propagation time ($T = c.\Delta T$). In such mode, called GPS timing, only one satellite is required (vs. four for positioning) and the sensitivity is improved making it possible to work below the canopy. This GPS time is used by the Central Unit to synchronize seismic samples transmitted by cable. The same reference exists in each of the vibrators to start sweeping at a predefined GPS time (T0) or to define the exact time at which the sweep will start in case it is defined by the source itself. The recent inclusion (2005) of GPS chips within autonomous receiver stations has been the enabling technology for the rapid development of cableless systems.

Thanks to GPS timing we have now the option to keep field equipment centralized (e.g. cable systems) or to have it autonomous (e.g. cableless systems). The same occurs on the source side where vibrators can be under the control of the Central Unit for shooting or can do that independently.

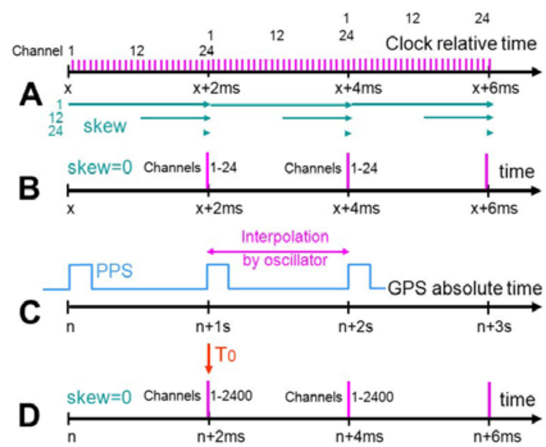

Figure 1: Evolution of the seismic sample synchronization by the Central Unit
A: first digital systems with a multiplexer
B: early telemetry systems
C: principle of GPS timing synchronization
D: latest cable and cableless systems with GPS timing

How digital recording systems are synchronized

In the early digital systems (since the late 60's) each group of geophones was individually connected to the recorder and the reference was the relative time as provided by the Central Unit clock (accuracy 1µs /s). For each of these channels, Analog-to-Digital (A/D) conversion was performed by a multiplexer within the interval between two samples as defined by the recorder clock. To synchronize all channels with the regular sampling intervals, a variable time shift called skew had to be applied (Figure 1A). With the advent of the first telemetry systems (since the late

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70’s) and the move of the A/D converter at each receiver point, it became possible to estimate the propagation delay (6µs accuracy) between each digitizer and the Central Unit in order to synchronize each sample with the sampling intervals. After correction, skew was zero (Figure 1B).

GPS has the advantage of providing an exact time-tag (Pulse-Per-Second with 6 15ns accuracy) every second. Between PPS’s, interpolation at the sampling interval is performed by an oscillator (1µs accuracy; Figure 1C). In the absence of GPS signal, this oscillator would be able to keep an accuracy of 10µs for at least 15mn (and even more depending on temperature variations). This time is absolute (number of micro-seconds since the origin of the scale at 00h on January 6th, 1980) which means that every sample or source start is not only synchronized but also chronologically dated. GPS time is slightly different (~34s) and more uniform than the Coordinated Universal Time (UTC) that has leap seconds due to irregular Earth rotation.

With the latest acquisition systems (since 2005), GPS time is made available both in the recorder, the autonomous receiver stations and the sources (e.g. Vibrator Electronics). By constraining T0 to be consistent with a PPS, we get an ideal situation where the start of the source and the first sample of the records are synchronized for all cable and cableless channels (Figure 1D).

Figure 2: Example of remote data harvesting of Acquisition Units using a mobile Wi-Fi antenna, while acquisition is not discontinued

Independent sources and receivers

It is only in the last six years that new technologies have made it possible to move from centralized cable systems to more autonomous cableless systems. A decisive breakthrough came with the availability of low-cost, low-power consumption, high-sensitivity miniaturized GPS chips. This GPS chip is not intended to be used as a positioning device since seismic requires at least the accuracy of the differential mode (DGPS), but as a synchronization clock to time-stamp seismic samples. This accurate timing (6 15ns) has been the key to eliminating the centralized synchronization systems and it has opened the way to autonomous receiver stations called Remote Acquisition Units (RAU). Other enabling technologies were compact Lithium-ion (LiO) batteries, high-capacity flash memories (4-16GB) required for continuous recording and low-power consumption and compact electronics. These have made the manufacturing of single receiver stations economically feasible although they are still more expensive than the equivalent cable stations.

The drawback with most of the cableless systems has been that data acquisition must be performed blind. However, with the newest high-technology systems this has been overcome. For real-time quality Control (QC), several cableless systems still rely on a centralized infrastructure based on long-range VHF radio to broadcast GPS timing and to collect QC status (battery, sensor, com-munication etc.) as well as some seismic attributes (first break, signal-to-noise, trace energy etc.). A more flexible approach based on Wi-Fi communication has been developed. This technology implemented in the unlicensed part (2-5GHz) of the microwave band enables larger amounts of data to be transmitted (up to 5Mbps). To overcome the reduced range of Wi-Fi (from 0.5 to 4km depending on terrain conditions, antennas & protocol used), the solution has been to use mobile antennas in vehicles (Figure 2) or in backpacks. By moving along receiver lines, quality controls are performed and seismic data are remotely harvested during acquisition. This makes it possible for a continuous flow of data to be available while recording is not discontinued.

On the source side, vibrators equipped with GPS for both positioning and timing may also be disconnected from the recorder. The Central Unit or the Remote Acquisition Units record a continuous stream of GPS time-stamped seismic samples. As the vibrators record the start time of each sweep (T0), a simple correlation by the pilot at that time is able to extract from this continuous record the cor-responding Vibrating Point (VP). Thus, without waiting for any command, vibrators can sweep as soon as they are ready (Independent Simultaneous Sweeping from BP). Shooting can also be done in accordance with a predefined GPS time table defining the time slots available for each fleet to avoid interferences (V1 from CGGVeritas). Both methodologies enable more than ten vibrator fleets to operate at the same time. They have increased significantly VibroSeis productivity in open terrain (more than 1000 VP’s per hour).

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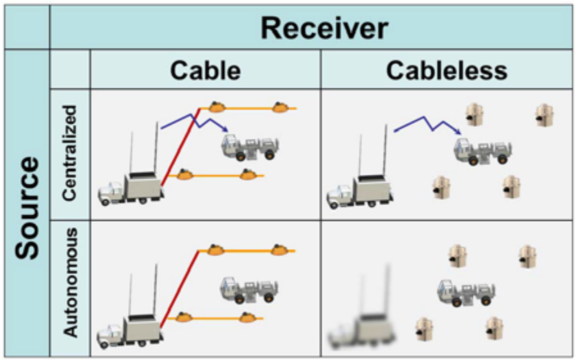

Figure 3: Different land acquisition architectures

Conclusion: towards new land acquisition architectures

Application of new technologies to land acquisition systems has opened the way to various survey architectures. In terms of both the sources and the receivers, we have the option to keep field equipment centralized (e.g. cable systems) or to have it autonomous thanks to GPS synchronization (e.g. cableless systems). With centralized architectures, receivers are connected via cables to the Central Unit and the sources are triggered by radio from the recorder (Figure 3). Synchronization as well as real-time QC's and data recovery are made easy. A totally autonomous architecture for both sources and receivers (e.g. ISS nodal from BP) offers great flexibility up to the point where a recorder is no longer required in the field, but acquisition is blind. Between these two opposite options, we may have either the source or the receiver connected to the Central Unit with the other component being autonomous.

In practice, these four options should not be considered as exclusive from each other. As survey size increases, terrain conditions diversify requiring the simultaneous use of different architectures, particularly on the receiver side. Today, more and more hybrid spreads including a mix of cable and cableless systems are used (Figure 4). They may be juxtaposed (infill mode, to be able to lay out continuous receiver lines even in obstructed areas) or superimposed (multi-spread mode to adapt receiver interval or sensor type to different target depths or reservoir studies). What matters in such a mix of architecture is integration of all the components in the spread. This is mandatory to gather in a uniform manner (same electronics, same processes, same QC's) a consistent dataset (e.g. with the right order in infill mode) to be output as a single Shot Point (Seg-D) at the end of the day.

Such flexibility in the acquisition architecture has improved crew productivity to such a level that high-density 3D surveys can now be performed in more difficult areas providing an imaging quality that was not available before.

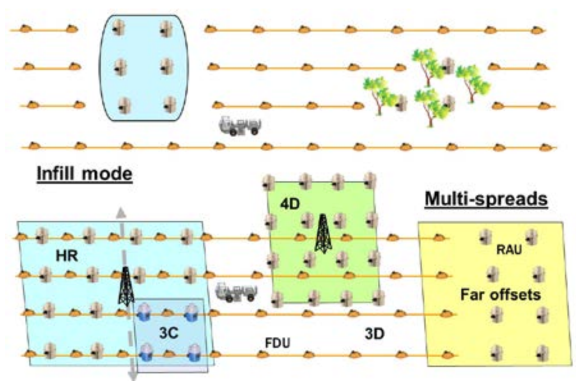

Figure 4: Examples of hybrid spreads with a mix of cable and cableless segments. In infill mode they are juxtaposed, while in multi-spread mode they are superimposed
FDU: Field Digitizing Unit; RAU: Remote Acquisition Unit
HR: High Resolution; 3C: 3 Components

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