Flexible active and passive seismic acquisition in difficult terrain

Lessons for the Asian environment

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Land geophysical contractors planning to work in the south and south east Asia regions face special challenges. These are not only some of the toughest and most varied environments in the world but there is also nowadays a growing need to be able to record both active and passive data.

CellSeis Geophysical, while being an established marine seismic operator, believed that by careful choice of equipment and operating procedures it could be successful onshore in this competitive area.

This article reviews the issues CellSeis considered in terms of cableless recording systems which could maintain communication in jungles of quickly changing elevation, through villages and major cities, and across difficult and deep water courses and shallow marine. Hardware considerations also covered the sources and source control which would bring extra versatility and effectiveness to operating in these difficult locations.

Less than a decade ago, the requirements placed upon most seismic contractors were quite unsophisticated, at least in comparison to those encountered today. Almost all work which the majority of companies could be asked to bid for entailed acquiring active data using fairly straightforward sources, in relatively simple geometries, with limited variety in terms of spatial sampling, offset and azimuth.

The notions of some form of less traditional data acquisition, such as passive recording (with all the many varieties this can take), complex active acquisition geometries or using multiple recording and/or source systems were not at all common. There has of course always been a need to work in environmentally awkward locations but such challenges were more often than not met by an easing of acquisition parameters to allow work to progress. In many such circumstances, data quality was compromised and sometimes so was safety.

Whether active of passive acquisition, from shallow marine to mountainous jungles. In Asia, one system must be able to do it all

Today the range of operations which a contractor can be asked to engage in is enormous and there is no sign that this rate of increase is slowing at all. Thus, while it may be a very exciting time for exploration geophysics, this growing variety of work means that the smaller contractor must tread very carefully

if it is to survive and prosper, including what equipment is chosen and how specifically it can be operated.

Large geophysical contractors can have a wide variety of hardware on their shelves to take on a range of operations but such luxuries are not available to newer or smaller operators. The established seismic contractor can also, and apparently sometimes do, afford to make mistakes in equipment choice and operational techniques employed when they approach something new. If they get things wrong, perhaps coming back with poor or no data, or losing significant sums on any operation by misjudging its complexities, they usually live to fight another day due to their financial backing. This is not the case with smaller companies.

Birth of new type of geophysical land operator

CellSeis Geophysical was a company already with a good reputation for specialist marine acquisition in the Middle East and south-east Asian regions, and it now wanted to move onshore by offering comprehensive land geophysical services too. By teaming up with Singapore based company Geophysical Services Ltd., and Singapore based processing house Quantum. it believed a full service operation could be provided, offering high quality, flexible and efficient land and TZ services. However, it knew it had to be wary of every possible pitfall, and be extremely discriminating in how it went about establishing itself on the land scene. It could not afford to make mistakes financially and was very conscious that only those who best understand the latest technology and techniques had any chance of successfully competing.

Not even CellSeis's most senior staff believed they could foresee every twist and turn that they may be faced with. However, as they started to consider the type of hardware which would be best suited to the challenges of this part of the world, they recognised that the industry was already undergoing significant technological changes regarding recording systems, sources and source controllers and they would need equipment which could keep up.

In terms of instrumentation, it needed technology able to work equally effectively in active and passive recording and in all the environments usually encountered in this geophysically difficult region. CellSeis rather quickly dismissed use of any seismic system which relied on digital telemetry cables. Cableless systems had been around for a few years and their advantage over cabled systems was already apparent. If CellSeis were planning to work in desert areas or some fairly flat geographical locations with few obstacles, then cabled systems may have been worthy of further consideration but this was not what was planned.


Preparing Sigma land system for transition zone and shallow water

Operating a crew with one thousand channels or one hundred thousand in desert locations seemed mostly to be only a matter of scaling up. Take a small cable system and keep adding to it, and as long as the environment is not too challenging and one does not exceed the data capacity of the cabling, then compared to the difficulties of work away from deserts, there was not much that could go wrong. It had been done many times before, over many decades and any reasonably experienced operator could make it work.

However, CellSeis's target environments were much tougher - typical terrains in SE Asia are far from flat and never without obstacle so some form of cableless kit was certainly necessary. Additionally, understanding the special needs placed on equipment when involved in exploring for unconventional resources meant that telemetry cabled systems were totally excluded. Operating a crew of just a few thousand channels in, for example, the jungles of Sumatra, or through major cities, busy villages or across difficult water courses, had far greater numbers of possible pitfalls than flat desert operations, and in such awkward areas any contractor large or small could get into trouble rather quickly.

Having ruled out cabled telemetry systems, the choice now was in regard to so-called cableless recorders. There were already about half a dozen such products on the market for CellSeis to seriously consider, broadly falling into two groups: those which offered no method of communication between central system and remote units, and those which claimed that they could provide some means of communication under certain circumstances.

Shoot blind or not Shoot blind

The former group is, for good

reason, known as "shoot blind" hardware because the observer literally may as well be completely without eye sight on the operation. Here, it would be impossible to remotely control ground units, which for Asian environments CellSeis believed essential as will later be described. Worse still, the user has no efficient or simple way to know if equipment, including connected batteries and sensors, is working properly, whether it has been disrupted, destroyed or stolen.

CellSeis had read material on such products explaining that the way around the issue of hardware security was to bury it on the basis that those likely to steal equipment would not be able to see it once buried. However, for the company's expected markets, burying equipment would be neither practical nor economic, or indeed, likely to be successful in thwarting the efforts of those determined to steal equipment.

Most importantly of all, given the type of active and passive work CellSeis realised that it would be bidding for, it understood that the ability at least to be able to check line or array noise (in the case of passive data acquisition) would be essential. Without being able to monitor either equipment security or data quality remotely, the company believed it could risk going out of business on its first operation, so CellSeis simply was not willing to take the chance.

This proved to be a very wise move for two reasons: Firstly, reports were soon to become public that in a few areas of the world where shootblind operations were common - primarily the Americas - some crews were coming back with rather poor data and, in some cases, very significant equipment losses. It was rumoured that at least one company may have gone out of business for choosing shootblind technology. Secondly, it was to turn out that on CellSeis's very first jungle operation, one of its active lines went through an area of undisclosed illegal mining which not only was a source of noise but very likely of theft. As it eventually turned out, thanks to the features of the hardware it had chosen, the operation was able to continue and work "around" mining noise, and no equipment was lost at all. CellSeis feel that neither good data nor lack of theft would have been the result had it not been able to use the seismic system to monitor closely what was happening on this line.

One extra advantage in deciding against shootblind technology was that it reduced the number of recording instruments the company needed to choose from. On reviewing the remaining systems, even though they all had to use the only licence free radio band available (the 2.4 GHz ISM band) it seemed they each made use of the technology in different ways. The downside of having to use this frequency is that it is very readily absorbed by water molecules, whether in the atmosphere or in vegetation. This problem is clearly a significant one for those wanting to work in equatorial rain forest and monsoonal areas. Thus, what CellSeis had to judge was which 2.4 GHz radio technique would meet its minimum operational requirements across the range of locations it expected to find itself in, most of which had humid climates and/or thick jungle, and in some places even significant radio interference.

The information available with all these systems spoke about a "real time" capability. However, on further investigation CellSeis discovered that "real time" for any cableless system had to be qualified by a discussion of just how much data would be available, after what sort of delay, and under what circumstances. The definition of "real time" for cable systems is not necessarily the same as when the term is used for cableless equipment.

Independent of the special problems of 2.4 GHz transmissions, the issue for all radio systems is the laws of physics. How these apply to seismic systems is that for the same amount of radio power, a system can transmit longer range with a small data rate, or a higher data rate with smaller range. The company had already read that it is more or less impossible using relatively easy to deploy equipment to send high bandwidth data, using legal low power 2.4 GHz-based transmission, through jungles over any reasonable range. So most importantly of all, CellSeis needed to know when the communication would fail and how the system would then behave - would it simply transmit less data, or would it revert to an autonomous shootblind mode? If the latter, would it then effectively stop working when communications with the central systems were not possible? It has astutely seen that most system

Sigma with mesh repeater. Maintains communications for all surveys

manufactures avoid discussing such critical issues in their brochures!

The Battery Problem

Batteries were another issue CellSeis thought needed some detailed consideration. A cable system of a few thousand channels may only need fifty batteries in total but autonomous cableless recorders need one battery per ground unit. Therefore, a two thousand channel cableless system with only one digitising channel per box ("single channel per box") needs at least the same number of batteries. And it turned out that some recorders even recommend the attachment of two batteries per box plus another large number to be on charge and waiting to be used. That could mean one hundred times as many batteries (cabled compared to cableless) in the extreme case.

Significantly, "the battery issue" and its knock-on effects has been mentioned in various publications covering cabled versus cableless operations, including most recently a paper authored by the Italian oil company ENI and given at the SEG Convention in Las Vegas in 2012. (This paper also happened to mention that the cableless system used which theoretically was capable of "real time communication", had apparently nevertheless not provided simple communication such as transmission of noise information during the test in terrain much simpler than that which CellSeis expected to encounter.)

CellSeis believed that the battery usage issue and lack of guaranteed communications were related problems and could be mitigated in at least two ways. The first was to avoid any system which only offered a single channel per box. Obviously, looking at recorders which, for example, included three recording channels per ground unit not only gave CellSeis the possibility to bid for 3C work but would also at a stroke reduce the number of batteries required by a factor of between three and six. Next, being able to remotely switch on and off ground units at any time would limit power consumption, so again the issue of guaranteed two-way communications in all environments came to the fore. CellSeis happened to notice, perhaps it was a coincidence, that most systems which claimed they were not shootblind but would also not guarantee communications, recommended the same expensive battery technology used by the systems which were designed to be shoot blind, namely lithium based batteries. CellSeis's technical personnel wondered why it would be necessary to rely on such costly batteries if one were able to switch on and off remote units to save energy.

CellSeis had a strong preference for not using this battery chemistry. Lithium offers more energy for unit of weight of battery (which may been essential if one cannot switch off the system remotely) than for example, sealed lead acid batteries, but is very considerably more expensive. Additionally, lithium based batteries generally had shorter lifetimes in terms of number of charging cycles, tended to be fussy about the temperature at which they could be charged, usually required special and expensive chargers, often had to be bought from a single source (not available locally) and counted as hazardous material when it came to shipping. As far as this part of the hardware was concerned, CellSeis saw significant advantage in being able to use locally supplied items, perhaps something like a motorcycle battery.

Taking all these issues in to consideration, in the end the decision about which system to choose was easy to make as only one system guaranteed that the company could maintain communications in all operational environments and would not insist on use of lithium-based batteries. By doing so, it relieved in one fell swoop CellSeis's fear about data quality, hardware theft, system power and being able to be sure that the company was acquiring data as per contractual requirements in terms of dead or noisy channels.

The communication technology employed by the basic system chosen is known as mess radio networking (MRN). It has worked every where CellSeis has operated, which includes thick jungles, across salt and fresh water, through villages and cities where there may be significant obstruction and interference. Areas of rapid elevation change can be used to advantage as MRN relays can be positioned such as to make the communication links even more foolproof. It works so well because it is not trying to break any laws of physics applied to 2.4 GHz transmission. In other words, it does not try to send too much data too far. In fact, the MRN system inside each ground unit just sends data to its nearest neighbour seismic ground units and leaves them to pass it along the mesh so formed to the central system which can therefore be located anywhere on the mesh. The data ending up on the observer's monitors comes from all deployed boxes includes everything one would expect to have available in a cable system with the exception of the seismic data file itself. If ground units tried to send something of this much higher bandwidth, then equipment would not be at all as easy to deploy and probably not work in jungle conditions due to range

limitation and absorption.

However, this still means that the MRN is able to test everything important to the health and security of the system and the data is is collecting, and return the test results more or less instantly to the observer. These tests include ground unit and battery condition, full sensor verification and GPS reception, box position and security information, noise and instrument tests if required. If one has tested all aspects of the deployed hardware and everything is found to be working, then what issues are left untested are mostly just those related to the geophysical problems of the survey, and those may need changes in survey design to fix, so these are not really then hardware issues.

Was able to make use of existing tracks in most cases for sources and receivers

When CellSeis want the full data set available, for example so the QC/ birddog can see how the data looks, the Sigma system even provides a few methods of very quick data harvesting which do not rely on any 2.4 GHz connection. They instead allow simple copying from internal box memory to an external memory device, via either the ground unit's built-in ruggedised USB or Ethernet connectivity. The company's original fear for the data harvesting phase was that if 2.4 GHz was a problem for sending real time data any distance, then it could be a similar problem if the technology was used for data harvesting. With memory-copying based harvesting, this issue was also taken care of.

Whereas the system manufacture has offered an option (simple plug-in add-on) to be able to transmit full data bandwidth real-time data cablelessly in all circumstances, using a technology known as Mesh WiFi Communications which is different to mesh radio networking, CellSeis so far has not seen the need. As long as the company can be sure the equipment is working according to specification and to contract, and the hardware is easy to deploy (this cannot be stressed enough, especially when working in challenging terrain) its aims are simply and adequately met using the built-in MRN.

Communications were possible throughout the survey even where terrain included thick jungle and obstacles

Working on Water

As stated earlier, it was important for the system chosen to be able to work across water bodies, such as rivers, lakes and shallow marine. One reason the company wanted this ability was that so much of S E Asia is crisscrossed by water courses of huge variety and the another is so it could tie in with CellSeis's existing marine services. However, it turns out that not all cableless systems can work very effectively on water. The Sigma recorder chosen by CellSeis was designed with this capability and the manufacture even offered a special floatation buoy for the purpose. However, CellSeis found it was possible to use simple floats made from life jackets instead.

With this capability, CellSeis's very first work for the Sigma recorder included hills, water courses, villages, jungles and shallow water, all using a single recording system, and with the observer in full communication with all equipment the whole time no matter where it was deployed .

Finally, before moving on to sources and source control, some mention should be made of GPS. CellSeis noticed that all these cableless systems rely on being able to receive GPS signals in order to time stamp the seismic data. Even though only a single GPS satellite is necessary for this function, there are times and places where even this is not guaranteed. In such circumstances, the data

collected could potentially all be useless. The system chosen, as part of the information it sends across the MRN, includes GPS reception status. This was very important knowing CellSeis would be working in thick jungle where GPS reception can be intermittent.

Sources and source control

Given the difficult nature of the environments the company planned to work in, and the flexibility needed, it is important to give some mention to sources and source control. When working in unchallenging locations it is often possible just to use a single source which is usually vibroseis, or dynamite if the terrain does not suit heavy vehicles. But such sources are mostly out of the question for the areas CellSeis's envisaged. Instead, the company knew it would have to make use of a variety of (mostly) impulsive sources for its active acquisition work in tight quarters.

CellSeis wanted a more lightweight, flexible and universal solution and believed that the latest weight drop systems could be used successfully in these areas, if they were coupled to the latest source control instrumentation. Most recorders under such conditions simply transfer time break from the source to the recorder location using radio or, in some cases, a pair of wires which obviously would not be convenient for how (with cableless equipment) and where (in tough environments) the company wished to operate.

Gunboat and Sigma system taken out to deep water

Weight drop taken to shore line

Running cableless crew: Source control benefits from extra levels of flexibility compared to that used for cabled system

Weight drop made use of existing tracks where possible

Instead, CellSeis offered weight drop systems where before dynamite had been used and demonstrated how powerful these can be, especially using multiple thumps per shot point. CellSeis also wanted to use a more flexible set up of source encoder/decoder pair, a remote radio trigger and source recorder combination from Seismic Source Company. This has many advantages for cableless operations in tough locations. One is that the timebreak is stored independently from the recording system nodes for quality control purposes and future processing, and another is that this combination utilises GPS, when available, to locate the shooter or source unit.

In this way, the nodes do not need immediate access to the timebreaks and the source can operate independently of the recording system. Using GPS where available, the equipment is able to provide its location to the observer to ensure that recording channels are working for each shot relevant to that source location - as is usually possible with a cable system but usually not possible with cableless, even those which claim not to be shootblind it seemed. Additionally, the process can then be automated which is especially useful when using weight drop systems in difficult areas. Finally, this combination would increase accuracy and help avoid the sort of

mistakes which have shown themselves easy to make in the past in such tough environments.

For additional backup, CellSeis also decided to use a Source Signature Recorder, which is an optional device using GPS to mark the location and time of every event, plus record and store any auxiliary data produced by each source device. This is, independent of the recording system and provides a backup record of the acquisition process. It is an important extra tool which can be invaluable to resolve timing and location issues on any field crew operating in tough environments.

Passive Operations

Until recently, "passive" geophysics meant more to those involved in pursuits such as earthquake monitoring than to anyone thinking of hydrocarbon or mineral exploration. However, in the last few years, the area of geophysics encompassed by the term passive is one that seems to be growing relentlessly.

Some of the areas of most rapid growth are in frac monitoring, direct hydrocarbon indication, seismic interferometry for imaging body waves, inversion of surface waves to obtain shear wave velocities, provision of extra physical values such as velocities which can be used to improve the active data, and land 4D which is not usually considered a pure passive technique.

Soon after starting its active land operations, the company was approached by a client potentially interested in using the company and its equipment to acquire passive data but in very difficult locations. This was something which CellSeis expected would happen but perhaps not quite so quickly. It had wanted to ready itself first by preparing in terms not just of equipment (since it understood that the cableless system now in its possession would work equally well for passive and active acquisition) but also wanted access to the necessary processing techniques. However, these first approaches for passive work were only in need of acquisition of data and the client would take care of the processing. However, more recently CellSeis has teamed up with passive processing companies and services providers to offer a much wider range of services.

It must be understood that taking on a range of passive work requires much more of the recording system than almost any active work can. As has been alluded to, operating in flat desert locations with tens of thousands of channels is relatively simple compared to a few thousand channels in the middle of a hilly rain forest where, for example, weather changes by the minute. But being able to offer services of passive data acquisition in these tough areas is an order of magnitude more difficult for hardware as there are simply so many types of passive work than can be undertaken.

Having equipment which could be configured to take on active and passive, virtually no matter how complex, was essential for CellSeis for obvious commercial reasons. It only wanted one core type of instrumentation in its inventory so it would have to be extremely flexible and configurable for different jobs if necessary, something which until then was unheard of in land seismic equipment.

No single contractor in the world can claim to know all passive techniques. CellSeis prefers to discuss with its customers what it is trying to achieve and work side by side the client to come up with the best techniques for that situation. This is why having configurable hardware and access to world experts on passive are so important.

Source and recorder system needs great levels of versatility to work well in tough environments

Ultra high resolution gas pipeline survey and small impulsive source. Using basic Sigma system in city environment

CitySeis

With a base established in Singapore, and word spreading of the company's unique success with cableless operations in Indonesia, CellSeis began to market its capabilities in Singapore and the modern cities of the Middle East. Here is a different sort of challenge for cableless technology. It is no longer the issue of absorption of 2.4 GHz signals but the

interference caused by a large modern city, and the huge number of obstacles, many of which like vehicles come and go.

However, the company was surprised about the first job it was awarded as it had not expected to entertain such work. CellSeis was asked if it could locate gas mains/ pipes laid in a reclaimed area of Singapore. The client already had tried ground penetrating radar but found it to be of little use given the level of the water table in that area.

Using a very low impact weight drop and extremely short group interval (33.3 cm) of single geophones connected into the Sigma ground units remotely controlled to be switched to very high sample rates, CellSeis was able to set up, acquire the data and move on in very short time. And the results were excellent, not only locating the desired pipes with extreme precision but also finding others which the client had not been aware of. By adjusting group interval, source energy, sample rates and so on (all made easy by the hardware configuration available) this technique is also about to be used for void location.

Such services are of course not considered main stream in terms of land/TZ seismic acquisition but CellSeis did not set out to be a traditional geophysical service company. It wanted to make use of its hardware for every type of operation, and with a range of work stretching from 2D and 3D (land 4D now also under consideration), jungles to offshore, active to passive, city centres to hills and mountains, the company is very pleased with the unheard of flexibility of the equipment now at its disposal.

Conclusion

CellSeis is, to its knowledge, the first company set up to employ cableless technology to acquire both active and passive data, in the most logistically difficult location of southern Asia. During the process of the company's birth and throughout it first operations it has come to understand certain issues are of great importance for such operations.

From our experience, we see almost no reason at all for any company, new or established, to rely any longer only on cabled system unless they are working in the most simple of locations and on the most unchallenging of active surveys. Such conditions seem to be almost the sole preserve of north America and the Middle East. It is our belief and our experience so far that south Asia has no simple environments, where cableless will not easily outperform cabled systems, as long as the hardware has the necessary functionality.

It is imperative to have available the right equipment and this can only be done by understanding all the problems one expects to encounter and know precisely how technology may help solve those problems. Most manufacturers make wild claims about what their hardware can do. This is only natural but no hardware can break the laws of physics, so our recommendation is to ask for proof that the recorder can do all it is claimed in the area you think you may work.

Working in dry climates or flat deserts is no challenge for any technology but this is not the case of southern Asia. The requirement to make sure the system really can perform as advertised was probably not necessary with cabled systems as their failure modes were well known. But cableless technology is very different, and unless a contractor can afford to make expensive mistakes by choice of the wrong equipment, then we believe that it is best to get guarantees (especially of communications capability) and, above all, understand how the equipment works.

Whereas the industry enjoys huge choice nowadays compared to just a few years ago when there were only a few cabled systems with little to differentiate them technically, it is the company's view that not much of this equipment variety is suited to the unique operating conditions of its target markets in south Asia, especially if any passive or joint active/passive work is to be considered. CellSeis believes that a new era is starting in land seismic, fuelled by instrumentation which can be bent to what the geophysicist requires, not the other way round. The trick is now to understand the instrumentation. dewjournal.com

about the author

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CSG in its first years carried out mainly marine Seismic in the MENA region. Three years ago. CSG decided there was a niche in the market for Smaller seismic surveys in more difficult areas and this is when CSG decided on Wireless systems and one in Particular, as this system had all the attributes that we required, such as online QC and easy to use systems with easy to use equipment and acquisition Software.