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3D Oil

The latest technology in seismic imaging

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Sudhir Vasudeva, CMD,ONGC Speaks

"ONGC is focused on opening new growth avenues"

Cableless seismic recording and a new problem for geophysicists

Robert G Heath, Technical Marketing Manager, Seismic Source Co. & iSeis Company, UK

In some countries when medical doctors graduate, they swear the Hypocratic oath, promising to do no harm to patients and their best to heel all under their care. Scientists and engineers pledge no such oath. However, our profession is as vital to humanity's well being as any doctor. Hydrocarbons account for about eighty percent of the world's total energy and almost all of its low cost fuel. This is important as cheap power is an absolutely vital ingredient to lift people out of poverty, to improve their health and life expectancy. And much to the annoyance of those who believe in manmade climate change, an interesting fact is that the higher the CO2 output per person in any country (an indication of how much affordable energy it has at its disposal), generally the lower its child mortality rate, the greater this contribution to mankind's well-being and (for those who think growing world population is a problem) the lower its birth rate. So the substance we look for is vital to mankind's future in many ways.

It is our task and duty to keep finding hydrocarbons and it is obvious that we must use everything at our disposal to do our job as well as any oath would have us pledge. Radically new tools and techniques are now available for this task, what I believe come under the umbrella term of "future-seismic". And just as good medical professionals stay up to date with the latest surgical procedures and medical hardware, so all those with positions of responsibility should make themselves aware of the latest geophysical tools and "experimental techniques". Universal seismic equipment represents the best on offer and I hope our industry continues as it has already started, moving ever more quickly to its wider adoption.

Like many other branches of science, geophysics is a practical field and what we call seismic acquisition is often just another form of data gathering experiment. And, as with almost all physics, the way we can conduct this process is strongly influenced by our understanding of the theory, the hardware at our disposal and especially the way we are forced to operate equipment for whatever reason.

Unfortunately, it has been my experience, in the west anyway, that understanding limitations forced on our experiments by the design of instrument and peripherals sometimes seem to be more widely acknowledged in other areas of scientific endeavour, such as astrophysics, than our own. For example, even those who are uninterested in stars tend to be aware that equipment limits what can be observed: the characteristics of a refracting optical telescope are not those of a reflecting one, and a radio telescope is different again. Placing any optical telescope near light sources causes images to be noisy (from light pollution) and distorted (from atmospheric disturbance of light rays) and this is why the best devices are located in earth orbit. If Galileo had the Hubble telescope at his disposal in 1610 and, even more importantly known how to use it properly, he would not have thought there were four satellites of Jupiter but 63.

First use of Sigma universal seismic recorder in India

We recognise noise and distortion in geophysical data acquisition but not everyone appreciates how the use of particular types of equipment sets strict limits on image quality. This is not just referring to possible data degradation caused by inappropriate or substandard digitising electronics although, as we will see, these surely can be issues. It is the process through which results are compromised by the way systems have to be deployed. This lack of knowledge is especially relevant when it comes to employing hardware now becoming available because some of it is so capable, in the right hands, of giving us so much more. The fact is that today, more than at any time in our history, equipment design and an understanding of how to use available features are the primary issues affecting how we can progress our science to find more hydrocarbons.

I have spent my entire professional life, not far short of four decades, focussed on land seismic equipment. Recently, I have devoted time to trying to explain to those who do not have a strong instrumentation background how new options in hardware strongly affect their "experiments" too. I am not sure the message always gets through. This article is an attempt to ameliorate the situation. (A short course is also under consideration).

Background

Along with seismic source controllers and sensors, recording instruments are the main items in our tool box. But until recently there was little choice in the type of recorder available. There were just a few cable systems working in much the same unsophisticated way they had done for decades, and with little difference between them. It is as though the only tools were hammers, and when only hammers are available every problem must resemble a nail.

We did not notice this restriction so much before, possibly because we concentrated on the easier exploration tasks where limited equipment capability was not so apparent. When the surveys are basic 2Ds or 3Ds, or when we think in terms only of CDP recording, then cable hardware can be made to suit in the way that hammers can also always be made to do something. But when we consider wavefield recording and the variety of survey types that this offers to the imaginative explorationist, we can see instantly that the geophysical equivalent of a mallet is not much use.

Nowadays, it is not enough just to think of simple symmetrical sampling, or operating only where obstructions do not exist. It is not acceptable to have a high environmental and health/safety impact. It is not reasonable to have field geometry in any sense restricted by equipment, similar to how cables force receivers to be deployed in lines with limited leeway in trace spacing, offset and azimuth range. It is not commercially viable to have serially dependency where a fault with one small piece of equipment may bring the whole survey to come to a halt. And it is strange that seismic hardware should still be so expensive to buy and use when in almost every other field of electronics, the opposite is true. It is as though we have not only have been limiting ourselves to hammers, we have also kept their price and cost of use artificially high. For these restrictions, for the limitations on the "seismic experiments" we can undertake, and for poor data quality they output, we can blame hardware based on cables.

What is wrong with cables?

To record routinely on all types of land operation without telemetry cables has been a desire of exploration industry for a third of a century. There are several advantages to this, many of which relate directly

Digital cable telemetry, little choice and little future

to cable's problems: its weight, its cost, its servicing burden, the low number of environments it can be used in, its HSE overhead, its relative unreliability to handle huge data rates and so on. Cables also force the use of spread connectors which are expensive and can be the cause of much downtime. Even a medium sized operation needs thousands of digital connector contact points all working perfectly. Instruments which suffer none of these drawbacks offer significant advantages even to simple surveys, and would make practical whole new types of exploration currently impossible with the straightjacket of cabling.

The total weight of equipment affects the number of people and vehicles needed, and thus cost and environmental impact. The weight of the cable itself can account for up to

Universal seismic recorders offer far wider range of affordable "seismic experiments"

80% of the total entire of system-specific ground equipment but such products add even more weight in how they waste energy. They are more power hungry than is often assumed since, with the relatively large trace parameters more or less forced on us by cable, the power lost in the DC transmission may be greater than that used by the electronics. Doing away with cables, therefore, can save power and weight. (Author's note: I have seen some claim that cabled systems are lighter by referring to specific sets of circumstances which favour particular types of cable operation and comparing against what are some of the heaviest cableless recorders used in the least efficient way. As this caused some confusion, I was asked to write an article for First Break in 2010 which enables anyone to calculate exactly how much lighter their cableless system will for almost any operation. This is referenced at end of this article).

Cables are also usually the most common cause of lost production when "bringing up the line" if equipment is left out. They are especially susceptible to harm and, being serially dependent, even a small amount of damage can bring the entire operation to a halt. Thus, cables limit the types of experiment we dare to do or can afford to undertake. None of this is news to this industry.

However, in my opinion the worst thing about such instruments, and something which is not generally perceived, is that they represent a simplified and out-of-date view of acquisition exemplified by the idea of common midpoint recording. Furthermore, suppose we want to use equipment purchased for 3D regional surveys in a high resolution 2D mode. That system could definitely not be used as cheaply and effectively as one unrestricted by cable. Alternatively, imagine we want to record three components or acquire very large offset and/or azimuth surveys. This variety of operations, which is not that wide, is impractical with a single cable system. So this inherent lack of flexibility tends to make us employ hardware in ways which are far from optimal, compromising data quality, safety, productivity and, in some cases, the geophysical model has to be revised just to allow use of what equipment contractors happen to have available. What we need is universal hardware which does not limit the parts of the wavefield we can record economically, which does not force changes on the experiments we want to run.

Additionally, wavefield recording should not be limited to active surveys; we may also want to acquire passive data, for example micro seismic monitoring, frac monitoring or some form of (semi) permanent arrays. Should modern instruments not let us take on everything?

Cable was already perceived as having many restrictions but as we start to appreciate newer exploration methods, we see it in an even worse light. Fortunately, cableless recorders are available and for those with the right features, the versatility to undertake a much wider variety of "seismic experiments" is now open to us. One system - iSeis's "Sigma" can trace its development back ten years when its parent company was the first to use Wi-fi to control and gather data remotely from a seismic line. So are all these recorders equally suited to this new frontier?

Cableless flexibility - risking the wrong choice

Something to celebrate is that this industry's demands were heard, there are more than ten cableless recorders on the market so there is great choice. But despite all the time manufacturers had to undertake market research, it seems that not all these instruments offer the flexibility we wanted. Indeed, it now turns out imperative to be very careful when choosing a cableless recorder because despite not being tied by cable, some may nevertheless incline the operator to work under worse restrictions than were enforced by older technology. It seems just because something does not need telemetry cables, it does not mean it works better.

This is because there are new things to go wrong with cableless kit which did not affect cabled systems, and users must understand these risks or seismic experiments will be compromised in novel ways. In the west, which has been using these instruments for a while, very expensive mistakes have already happened, with some contractors (who did not realise the risks) finishing with unacceptable data or no data at all in some cases. Choice is usually good but unless we understand what perils each comes with, then variety can also be very dangerous.

And there are commercial risks too. The industry is not large enough to support many manufacturers and some have already disappeared. Others might stay in business but not make enough profit to invest in new software or hardware options. Some better systems will probably disappear simply because of something as mundane as bad marketing whereas conversely, some poor ones will survive because they are marketed by richer companies. But how do seismic contractors select the right one and how do geophysicists learn what each system is capable of? These questions can only be answered by first understanding more about the differences between the technologies.

Beginning with the basics,

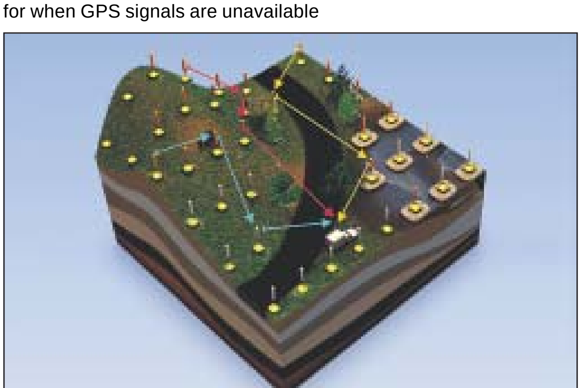
digital telemetry cables are there for a reason - in fact at least three major reasons. Firstly, out from the central system to the ground units cables carry timing information. Next they transport remote control commands. Thirdly, they bring back QC and status information along with a great deal of seismic data. If we build a cableless recorder, then we have to know how to incorporate those capabilities or cope without functions which were until now considered vital. In making such decisions, each manufacturer has had to come to terms with what they as a company can develop. However, that apparently did not always mean that they tried to understand all the experiments the industry wanted to do. Let us start with system timing.

Many, though not all, cableless instruments manage to do away with cables for distributing timing because inside each ground unit is a GPS receiver which of course primarily is a way to pick up very accurate time information. Most products actually use the same GPS receiver chips, so in this sense there is not much to choose between them - as long as there is GPS signal reception, seismic data can be timed stamped. But therein lies the problem. GPS signals are not always available. It some locations it is at best intermittent and in others is non-existent. What happens then?

It is not just jungle where GPS is not guaranteed; I have been on crews with wide open skies where GPS suddenly became unavailable. After all, the operators of GPS satellites do not guarantee service everywhere 24 hours per day. There are also times when GPS cannot be properly received even when signals are available - some boxes may not receive if they are accidentally knocked upside down. This is why a few recorders were designed not to rely solely on GPS but have options to use alternatives when GPS is unavailable. After all, a ground unit, which for whatever reason, cannot accurately time stamp each seismic sample is virtually useless.


Cableless line boxes must be tough to protect data and prevent tipping


Choices in time stamping. More accurate clocks and VHF timing option for when GPS signals are unavailable


Mesh Radio Networking. Two way communication for cableless systems

Further, some systems, in trying to reduce the problems experienced with theft, suggest that ground units should be buried, apparently so as not to attract thieves. GPS receivers are more sensitive nowadays and work under some centimetres of dry earth or snow but when that cover becomes wet, then reception may not be so reliable. No wonder that not all manufacturers rely on GPS exclusively for timing! All this makes you realise that building in important functionality is not easy. At least with old technology, if the cable broke the observer knew about it - no data lost. Some cableless kit cannot even alert the observer when it is not receiving GPS - the worst of all worlds.

Fortunately, there is hardware which has given due consideration to this most serious of potential problems. It has a higher quality on board clock so that when GPS is intermittent, timing remains accurate for some hours. And in an area of zero reception, it can be enhanced with VHF-based synchronisation. VHF signals, being about tens times the wavelength of GPS signals, penetrate heavy foliage and other difficult areas much better. Further, its design is that it is almost impossible to tip over.

Since seismic instruments essentially record voltage (e.g. the output of a geophone) against time, ideally both with an accuracy approaching 1 ppm, equipment which is not able

Sigma with optional MRN repeater to increase range

to perform reliably cannot really describe itself as viable. So my advice is to not consider anything which does not always guarantee accurate timing and also let you know instantly it is no longer working. This is because, if it can only guarantee to work 95% of the time, and you do not know when the other 5% is, it seems there's a one in twenty chance of going out of business.

Cable's next function is to carry commands to remote units. If no wireless alternative is offered, is this an issue? Providing wireless control to an entire receiver spread requires significant development effort, and to avoid this some manufacturers pretend it is irrelevant and do not offer it. They claim most surveys are done without changing acquisition settings, that since cableless recorders are generally continuous record systems and there is no need to repeatedly start-stop recording, what would one need to control? If you hear this, turn away immediately as it ignores one of the major potential drawbacks of "going cableless": cableless equipment uses much smaller batteries but higher numbers of them - as many as two per channel (though some need very much less). Large numbers of small cheap batteries can either be an advantage if you can control them, or a serious headache if you cannot.

This does not mean more power necessarily is being used in cableless recording because, as already intimated, cable is wasteful in distributing power (it can double quoted consumption) and transmitting data can take as much as some nano joules per bit per transfer. In fact, there are times when having a small low cost battery run a few channels rather than a large one running tens of channels is a definite advantage - it means one battery can last weeks instead of just days. But if you have hardware which inherently needs very high numbers of batteries, or does not let you monitor remaining battery power, or requires bespoke batteries and chargers, then you have problems you never had with cable. This is why remote control is so important - it is nothing to do with changing sample rates or preamp gains. It is to solve the battery problem.

Another response from some manufacturers who do not provide control is that their systems can be preprogrammed to switch on/off or left on continuously instead. The first of these suggestions may end up with thousands of channels all programmed to switch off at, say, 6 p.m. Perhaps your shooting is running a bit late, you are left with a handful of shots but suddenly the whole spread goes dead. Now you are almost a day behind just because you have no easy control over the equipment. Or you accept the idea you never switch off boxes but this makes them high energy users as they need power 24 hours per day when perhaps they only should have been switched on for eight. In either case, this requires use of more expensive or heavier batteries, or a need to change them much more often as well as using up memory capacity. My advice is always consider how much energy your are forced to use as this is what indicates whether having lots of small batteries is an advantage you can profit from or the exact opposite.

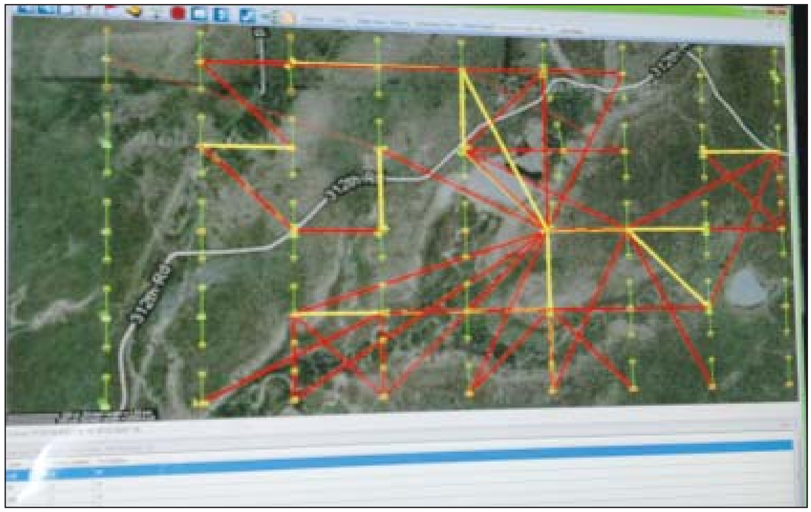
The last purpose of cables is to return QC, line equipment status and the seismic record itself. But in the cableless world it is a mistake to think of this all as one set of information. What most cabled systems display to the observer - or perhaps what most bother to look at - is not the data itself but QC, status and noise levels. They feel that if there is acceptable spread noise, if boxes, sensors and batteries are all working well then probably the data is fine too.

This is an important consideration when discussing cableless technology because the quantity of data per channel contained in QC, status and noise is less than ten percent of that in real-time data files. And it is this difference which smarter products make use of because high bandwidth wireless transmission is expensive and power hungry but low bandwidth is far simpler to deal with. Thus cableless systems cannot just be segregated into those which send back nothing (so-called shoot blind systems) and those which send everything (so-called real-time systems). There is a third choice: those that send back just QC/status and noise. Cabled equipment did not have this valuable distinction.

Furthermore, instruments with bandwidth capable of returning QC/status also have capability to send out remote control commands, i.e. the essential energy saving feature discussed earlier. So avoiding recorders which force you to shoot-blind reduces risk of equipment theft and data loss, and guarantees control over line power too. This explains why, in my view, the only recorders to consider are those which provide this minimal functionality.

So what technologies provide the bandwidth to control boxes individually or in groups and also send back enough information to let the observers know everything is working well? There are only a few choices but of prime importance is how simple deployment is in the field. The ideal solution is that of mesh radio networking (MRN). This is not new but making it work reliably in the seismic environment has taken considerable development effort.

An MRN does not attempt to transmit from each separate ground unit all the way to the central system. It only tries to reach nearby boxes which in turn talk to their neighbours and so on until a complete web of communication routes is available, effectively allowing every unit to be in touch with the observer. Networks are self-generating and self-healing making them ideal for our application. Also, because they only communicate over short distances and at low bandwidth (though external repeaters can increase range by a factor of ten) they take little power and are less fussy about how they are deployed than high bandwidth hardware.



MRN builds it own network of communication routes automatically. This can be monitored by the observer. (Courtesy Sigma Observer software)

So appropriate mesh technology has proven the best solution today for cableless applications if it is not vital to get all data in real-time due to its advantages ease of deployment and cost reduction. But note this implies that data harvesting must be easy as well, and this is an issue we must return to. In fact, remote monitoring and flexible harvesting are a pair that should always be available in any "universal" system because operating as an duo they are very powerful tools whereas one without the other is not so game-changing at all.

Having seen how new instruments either offer the same functionality as cabled systems or force you to take new risks, we now look more closely at other features which cableless kit must provide which cabled technology did not need to. We continue with systems which do not send back all the seismic data wirelessly and consider what consequences this has.

Data harvesting issues

Whether the recorder is shoot-blind or offers some form of QC/status return, the fact remains that our data sits in memory inside ground units till we harvest it so let us first look at storage capacity. Even in something so basic, not all cableless systems are created equal. It is simple to calculate necessary storage size: multiple sample frequency by no. of bytes per sample, by number of seconds in operation (if there is no remote control the number of seconds may be the those in a whole day), by no. of days between harvests, by number of channels per ground unit. Add 10-25% for overhead. Now check the capacity each unit offers as this differs wildly - some are limited to only 2 or 4 GB of addressable memory space. This is OK for simple types of regularly harvested active surveys but we see that other operations can rapidly deplete available storage.

So the amount of memory may be the determining factor when it comes to how and when you must harvest - but you do not want to have to pick up boxes simply because of limited storage capacity. And here is another reason not to choose a shoot-blind system: how do you know the memory is filling up? Fortunately, some products not only have far bigger built-in memory capacities but also larger addressable memory space and generally these also do not force you to shoot-blind.

Having to collect up ground units

to retrieve data and the problems this causes are not new. It was a limitation of the SGR developed by Amoco about thirty years ago where data was written to tape with only some tens of megabytes capacity. One would have thought that three decades would not only have seen advancement in terms of data storage- which most assuredly in the case given the easy availability of large memory chips with tens of gigabytes capacity. But also that there might be quicker ways of harvesting valuable data than actually having to pick up boxes, bring them to a staging area, connect to a download rack and wait for files to be created.

Yet, surprisingly, this is how some modern cableless crews still are forced to operate. The disadvantages should be clear. If ground units are not busy acquiring data, then they are costing money rather than making it as extra channels must be bought to compensate for when units are not on the line. And having to use expensive harvesting racks also adds to the cost of most shoot-blind systems.

This unhappy state of affairs is made still worse if units have internal batteries, especially those based on lithium, which can only be charged when they are within a limited temperature range. This may take some hours to achieve once the boxes are taken off the line. So add this wait time to the charging and harvesting periods and ground units may be unavailable for recording during an important fraction of survey time.

Conversely, some systems operating even in modes where they are not transferring the complete seismic file in real-time do not need to be picked up for data to be harvested. They can be left in position, without interrupting their essential task of recording while an operator copies data from each unit into some mobile device which is then taken to a central location for SEG file generation. There are various ways to do this copying but in my experience no single one is always best so users should demand multiple choices as each survey may benefit from a different approach. But we must also consider what must actually be copied because here is something else we did not need to worry about with a cabled system.

As cableless recorders also tend to be continuous record systems, once they start digitising, they do not stop until told to. Any device with no communication capability must be preprogrammed to stop digitising, or an operator will have to go to every channel on the spread and make them halt somehow. So this continuous record characteristic comes with important issues to consider. A single seismic channel with a 1 mS sample interval will require almost 1 GB of storage after two days operations. However, if we consider impulsive shooting, then perhaps only 1-2% of the memory used up contains actual seismic reflection data. So some recorders - generally only those few which have well integrated source control can instruct their harvesting devices just to download the relevant portions of the memory which hold useful data, accelerating downloading by a large degree. Data is recovered far more quickly and require fewer people for the task. This sort of data retrieval is called "SMART harvesting".

Armed with hardware benefiting from some download-during-recording SMART feature, what methods exist to transfer data from box to mobile harvesting device? The most basic is simply connecting a laptop or tablet PC using a short cable, such as an Ethernet link, to the line unit during acquisition. Such a connection is very low cost, works well and enables data download rates only limited by memory read speed. This may appear very low-tech but, as we will see, the value of this simplicity should not be underestimated. To demonstrate this we investigate how some cableless units also offer different forms of Wi-fi connectivity allowing various forms of "pass- by" data retrieval and discover this does not always live up to claims made for it.

"Pass-by" is a generic term

SMART harvesting using Ethernet cable link between PC and line unit, while not interrupting acquisition

Internal Wi-fi for pass-by harvesting. Special projects, Quito, Ecuador covering walking, floating, driving or even flying by ground units, as long as connectivity is achieved long enough between box and Wi-fi-enabled harvesting device for all relevant data to be collected. But experience shows that this period needed to allow data transfer is almost certainly longer than many expect, sometimes hugely so and to the extent that it greatly slows down operations, especially in memory-limited systems.

The reason is that Wi-fi connection speeds are not just determined by the protocol, but many variables in the external seismic environment can have surprisingly deleterious (and very disappointing) effects. Connection stability is a major issue which can become suddenly apparent if there is a lot of data to transfer, especially when communicating with multiple units. I have seen transfer rates expected in megabits quickly descend into not much better than 100 kpbs. In other words, to achieve outdoors in terms of connectivity what is achieved indoors with Wi-fi is no simple matter so do not be seduced by Wi-fi's hi-tech nature.

Thus, even in something as simple as Wi-fi, there are important choices which must be made, especially: where is it best to have the ground unit's Wi-fi? It is possible to install internally and, whereas this is sometimes convenient, it reduces the connection range and likely maximum transfer rate. Similarly, use

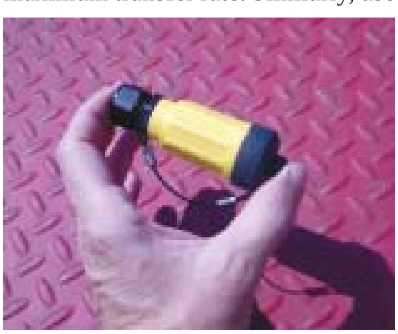
External Wi-fi for long range pass-by harvesting. Passive acquisition operation

of high gain antenna on the harvester also affects the efficiency of operations (but to a lesser extent). Therefore, Sigma provides choices in external or internal Wi-fi, can switch Wi-fi off remotely to save power when not needed, and also offers various harvesting antenna. Experience shows that to overcome the already-listed potential drawbacks of Wi-fi harvesting, by far the best pass-by combination is external Wi-fi plus hi-gain harvester antenna - but also give yourself the option of being able to go back to other data transfer approaches when Wi-fi does not live up to expectations. With more than ten years' experience at the forefront of Wi-fi in seismic, the iSeis company warns of potential disappointment if this is all you rely on. Such ground unit Wi-fi choices also have knock-on effects in any real-time mode i.e. when seismic data is sent back wirelessly to the observer.

In fact, do we really need Wi-fi at all to copy data from what is essentially one memory to another? Wi-fi relies on 2.4 GHz radio communications which also can have numerous other drawbacks. So Sigma also allows the connection of ruggedised types of USB memory to which data is copied. This has the highest transfer rates and overcomes all the limitations of Wi-fi. And if the memory is left connected, then data is written to internal memory and simultaneously to external memory, so harvesting happens as quickly as it is possible to unplug the USB device. This option is extremely useful where there is no risk of theft and it has many other advantages: PCs and Wi-fi do not need to be taken to the line and it lets the crew retrieve data instantly as and when required, perhaps for quality verification during start-up. This is all part of the philosophy of a universal approach.

So it seems multiple methods of harvesting during recording are vital. Sigma lets operators use all of them on the same survey and for crews which have tried all the above mentioned methods it seems that the USB memory is the preferred. But the important issue is to offer choices to maintain efficiency.

Now let us consider cableless


External USB memory for Sigma system. Potentially the fastest way to harvest data

USB memory harvesting Sigma data


Real-time cableless data transfer using 2.4 GHz semidirectional Wi-fi in daisy chain mode

systems with options to send back data in real-time. Here the choice is rather limited and in all cases rely in some way on the 2.4 GHz licence-free ISM band. Be careful about being tempted to use anything which offers other connection frequencies, they are not all legal in many countries. Also be aware that the 2.4 GHz band has limitations in terms of effective radiated power with 100 mW ERP being the maximum accepted in most jurisdictions. Some new seismic hardware may only work well when it exceeds this.

Because this band is made such great use of in exploration, it is worth extra note of caution when thinking about real-time recording. For those who are not aware, 2.4 GHz is the frequency of microwave ovens. This frequency is chosen because it is the one which is most absorbed by the sort of molecules found in the food we want to warm up, the most common being water. So in our environment, signal is attenuated by continually varying levels of water vapour in the air and in vegetation which may surround equipment. Therefore, a real-time wireless link based on technology designed for use inside and which can provide high transfer rates only over short ranges, cannot automatically be thought of as ideal for seismic, whether used for pass-by harvesting or real-time cableless acquisition.

Therefore, we need to know the various failure modes of 2.4 GHz and make sure equipment suffers from them as little as possible. For example, it is possible to set up some cableless systems such that they work perfectly during the day but if left out at night, you may find they do not work so well the next day. The reason may be as simple as that dew has attached itself to foliage which then additionally attenuates transmission and this can be enough to halt real-time operations and even slow things

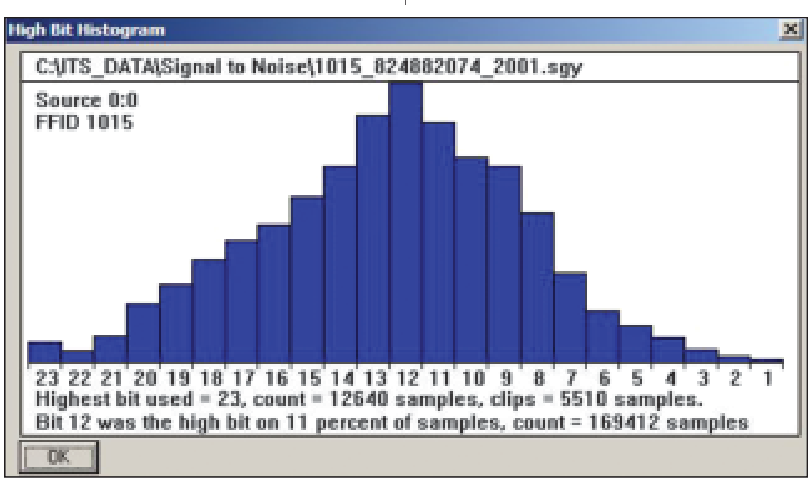
Permanent array (> 2 years, 24/7) using Sigma for real-time data transfer over 750 sq.km area and local storage, USA

down considerably in some types of Wi-Fi-based harvesting.

So it is the way manufacturers “make do with” 2.4 GHz which differentiates real-time recorders. If line boxes only offer some form of omni-directional or internal antenna then you can sure that they probably also provide the least flexibility. If you are operating with no vegetation, then use omni-directional antenna only if you can be sure that receiving antennae density is high enough. Otherwise, use more directional antenna which will also permit a lower density. It is important that the recorder offers this choice or you may find yourself with something claiming to offer real-time but which does so only occasionally. It is also very convenient when the ground unit Wi-fi subsystem which provides pass-by harvesting can be used for real-time recording as needed, and it much more user-friendly when such Wi-fi is external to the ground unit.

On Wi-fi’s positive side, even low power 2.4 GHz, with a semi-directional antenna can successfully connect over large distances to other directional antenna. The best example of this of is the Sigma deployed over an area of 750 sq.km in one of the hilliest states of the USA, with significant temperature and humidity swings, sending data back in real-time from around a thousand stations, and all powered by solar arrays. Not only would this be impossible with a cable system, it is impossible with every other cableless technology. The array, used to gather micro-seismic monitoring data, has been operating for over two years, day and night. Cables left deployed for so long in such a rugged area would quickly have been destroyed.

We should also look at whether electronic specifications acceptable for cable are sufficient for cableless. Many think that one set of specs is much the same as the next, and in



Average bit utilisation with 24 bit crew. Bit 10 was highest for largest no. of samples active cable-based hardware there is truth in this. There is virtually no difference at all between such systems' specifications, and where there is, it is nothing compared to improvements which would come from such basics such as planting geophones well. But are we getting the best out of new recorders or, to use our astrophysics analogy, are we taking the Hubble telescope and deploying it in the middle a well lit city?

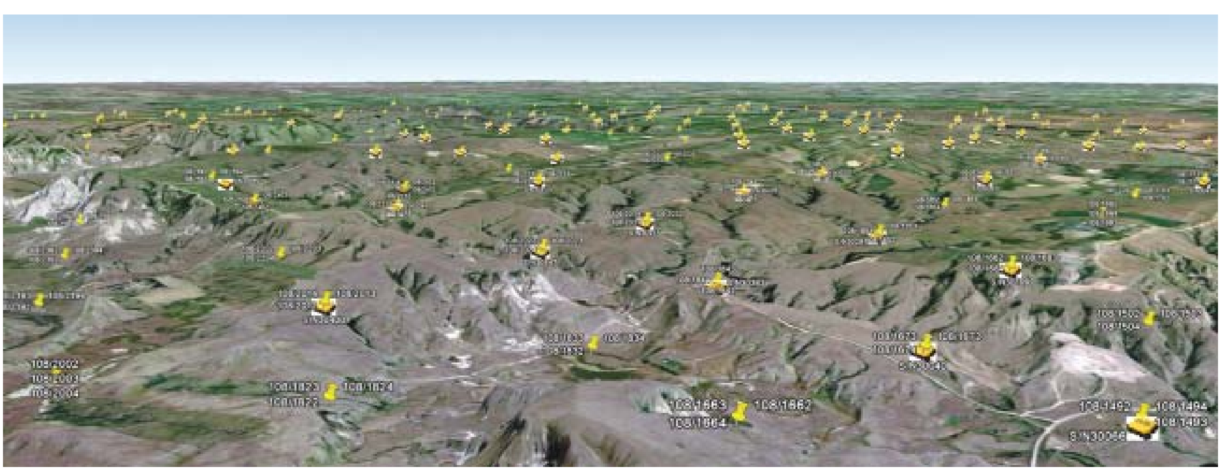
Some geophysicists are under the impression that 24 bit systems, almost no matter how used, give the best results that modern technology can manage. For example, they believe that their data is coming with the highest dynamic range data and frequency content. But this was rarely true even with simple surveys using cabled systems. Let us start by looking at dynamic range.

Since the introduction of over-sampling convertors in land about 15 years ago, we may be losing instantaneous dynamic range compared to older technology, with large parts of the active spread on most 24 bit surveys only triggering 10 -12 bits. This is due to the way that delta sigma convertors work compared to floating point amplifiers and successive approximation convertors. Whereas this may not

Long range/high throughput Wi-fi data retrieval (Courtesy iSeis company)

always have been noticeable given the small range of surveys which geophysicists tend to carry out with 24 bit cabled systems, the same cannot be said with cableless recorders called on to carry out a far wider variety of experiments. For example, cableless can be connected to single sensors in a very quiet downhole environments or to large surface arrays with potentially high voltage output from series coupled geophones. This is a much greater range of input signals than we have been used to and is why it makes sense to choose instruments with 32 bit conversion, not just 24. They offer better bit utilisation and come with some more obscure electronics benefits important to cableless such as the way the modulator is designed to prevent overscaling. So 32 bit and cableless can thus be considered natural bedfellows.

The same issues apply to any survey where we are interested in low frequencies. Most 24 bit systems have built-in 3 Hz low cut or DC offset removal filters. This may not have been an issue before but in more and more active recording, and almost all passive recording, we want to record below 3 Hz. For example, using sensors capable of <1 Hz lets us tap into passive surface and body waves to image the subsurface geology in new ways. Also, the presence of partially saturated hydrocarbon reservoirs is associated with spectral anomalies in the range of 1-6 Hz in microtremors. When measured at the surface, the spectral energy is elevated above a hydrocarbon reservoir compared with spectral energy measured at positions away from a reservoir (1-3.5 or 1-6 Hz) and the spectral ratio between vertical and horizontal components can show an anomaly in the presence of hydrocarbons. The polarization of the waves might also provide information about the time variability of the microtremor phenomena related to hydrocarbon reservoirs. So functionality to cope with all this needs to be catered for in anything which wants to describe itself as good for passive applications, so check if your



GoogleEarth support for sources and receivers recorder allows recording below 3 Hz.

Currently, there is much work underway in regard to new sensor technology, both single and multi-component and it seems that analog sensors still offer significant benefits. These include superior performance in terms of noise, the ability to use in arrays and with different recording systems, better cost and robustness. Also, as passive generally requires use of cableless recorders where power is precious, any transducer, such as MEMS accelerometers which require power, should be seen as a drawback. However, there are other active technologies now under development to out-perform MEMS and I believe we shall be seeing other recorders follow Sigma's lead in being able to offer internally mounted as well as external sensors of up to 3 components before long.

New and better seismic experiments

Active acquisition is no longer just about simple surveys as the easy-to-find hydrocarbons have already been located. Exploration today is about going to new areas with complex geology and tougher operational environments or returning to existing fields to capture some new aspects of the wavefield. However, these are not the only experiments we want to perform. As well as research, multi-recorder and multi-source acquisition, the fastest growing market is non-active surveys, covering what may be termed passive acquisition, permanent and microseismic recording, everything from frac monitoring to 4D.

Having said all this, this author at least believes there is still a place for cabled telemetry. My estimate is that realistically it offers some benefits over cableless equipment for as much as ten percent of the market. Therefore, contradictory though it may seem, a universal cableless system should also have (flexible) cabled telemetry option, for example letting that part of the spread be a separate cabled local area network which then communicates over appropriate Wi-fi to the central system, which avoids the difficulty where older technology inconveniently forces users to make sure cables always end up connected to the recording truck.

However, it is not just handy to have all the above-mentioned functionality, it is even better to be able to use all the capabilities at the same time. This is because most survey sites are not homogenous so it is useful in one part of the spread to shoot-blind and harvest in a few different ways while in another use a MRN monitoring system, and in another (perhaps where geophysicists want to keep a close eye on data quality) operate in real-time with cable-LAN or Wi-fi. All of this can be loaded into detailed GoogleEarth imagery, which the observer uses as his display backdrop, which can track moving sources and other important crew assets in real time. This is true flexibility and to date, only one system has been developed which is capable of all this.

And such universal equipment also allows whole new methods of operating. There are already "recorderless" crews where the traditional recording truck no longer exists. With the more modern and

Very low frequency seismic data acquisition

open architecture source control systems coupled to cableless hardware with the right communication facilities, there is no need.

Cabled and cableless together - harmony or trouble?

The desire to use cableless systems to augment older recorders is growing rapidly but most hardware does not handle this well. Many new instruments can only harvest data in common receiver domain which is OK for SEGY but SEGD does not support this. This is of course can be a problem for all the processing companies who demand SEGD (even though this format sometimes seems not to have been designed with the flexibility of cableless in mind). Therefore, to be universal, the essential issue is that an instrument can quickly generate files in both SEGY and SEGD with correctly populated headers, as well as any associated support files and only Sigma is capable of this. Effectively it is clever enough to blend the all input "raw ingredients" together, handling timing and phase differences along with correlation and stacking etc., producing any/all output required by the processing centre. In other words, universal systems have to be much more flexible even in the area of data output than any cabled system needed to be and this seems to be an area where some manufacturers of new systems were not entirely aware of the requirements.

However, even this is not all there is to it; to make side-by-side operations work efficiently also requires flexibility in source control which most instruments cannot manage because of their closed architecture. Closed architecture was designed into systems primarily to make sure that a contractor had to use

Multiple source and multiple (cable and cableless) recorder testing, only made possible using Sigma-based instruments and source controller

as much hardware as possible from the same company. This was possibly acceptable as a philosophy previously but now we want multiple systems (sources and reorders) to work together, it is clear that it is not the flexible way to go when crews want to make full use of their inventory. Therefore, it is clear, one contractor with one cableless system may be called on to do all of this today and something new tomorrow, so spending several hundred thousand dollars or some millions on a product which cannot cope is potential commercial suicide.

Conclusion

In some countries when medical doctors graduate, they swear the Hypocratic oath, promising to do no harm to patients and their best to heel all under their care. Scientists and engineers pledge no such oath. However, our profession is as vital to humanity's well being as any doctor. Hydrocarbons account for about eighty percent of the world's total energy and almost all of its low cost fuel. This is important as cheap power is an absolutely vital ingredient to lift people out of poverty, to improve their health and life expectancy. And much to the annoyance of those who believe in manmade climate change, an interesting fact is that the higher the CO2 output per person in any country (an indication of how much affordable energy it has at its disposal), generally the lower its child mortality rate, the greater this contribution to mankind's well-being and (for those who think growing world population is a problem) the lower its birth rate. So the substance we look for is vital to mankind's future in many ways.

It is our task and duty to keep finding hydrocarbons and it is obvious that we must use everything at our disposal to do our job as well as any oath would have us pledge. Radically new tools and techniques are now available for this task, what I believe come under the umbrella term of "future-seismic". As just as good medical professionals stay up to date with the latest surgical procedures and medical hardware, so all those with positions of responsibility should make themselves aware of the latest geophysical tools and "experimental techniques". Universal seismic equipment represents the best on offer and I hope our industry continues as it has already started, moving ever more quickly to its wider adoption.

For those who would like more specific advice or explanation in regard to such equipment, I welcome any feedback and communication.

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