Weighing the role of cableless and cable-based systems in the future of land seismic acquisition

With the phasing in of cableless systems, Bob Heath,* veteran of the land seismic acquisition industry, provides a practical guide to the changing technology and its implications.

According to my reckoning it was a decade ago that a discussion first started in earnest about the possible benefits of land seismic exploration not dependent on digital telemetry cables. This is not to say that no one mentioned cableless equipment before, but most of those who did indulge in such wishful thinking were sidelined as heretics. Now, after a lengthy gestation period, the industry is debating topic and (some) cablefree technology is even recognized as universal rather than niche.

However, despite all the convention-floor talk and the tens of thousands of words published about cablefree equipment, including quite a few from me, some parts of the industry still seem a little unclear regarding its characteristics compared to the more established cable-based hardware. The confusion relates especially to relative weights per channel and how various bits of equipment have to go together to make a functioning whole. This is no surprise because the issues are far from straightforward. Some erroneously believe land seismic hardware is no more complex than hi-fi, and that you only need to look at one or two simple specifications from the manufacturer, and these will tell geophysicists all they need to know. If only it was that simple ...

There are also complications in the two important logistics-related areas of providing power to hardware and how each technology might be developed further to cope with new exploration challenges. Therefore, the aim of this article is to look at the claims and counter-claims of the various technologies so that better business decisions can be made in the future.

Definitions

I shall refer to equipment which relies on cables for passing of remote control signals from the central recorder to the spread and the return of complete digital seismic records, as cabled systems. For simplicity I will refer to hardware which does not rely on digital telemetry cables synonymously as cablefree, cableless, and wireless.

It makes sense to lay out in one place, possibly for the first time, information which enable readers to make their own comparisons but also indicate from an overall hardware architecture perspective how complex some equipment in both categories can be and where all those kilograms go. For those too impatient to use the tables provided and who want to know the conclusion in regard to weight: under almost all survey conditions common today a number of cablefree systems are lighter than any cabled version, some significantly so. This benefit extends right down to below the 15 m trace interval, even where cable systems have unusually little cable to account for on a per channel basis. This advantage alone may well explain why the number of cableless systems on the market is so high. In any case, once we get down to this level of spatial sampling, other issues affect conventional cable technology and weight is no longer the crucial deciding factor.

The comparisons here do not include central systems or sensors. The debate over the use of a point receiver or an arial array, or single versus multi-component, is not discussed. Neither is accelerometer versus velocity sensor. Even though it has been said that 3C accelerometers can sometimes provide data as good as 3C velocity phones, in an ideal world the choice of transducer should be independent of the recording instrument. So that readers can estimate weights of the various sensor approaches, Table 8 is provided. With regard to central control units, comparisons are impossible other than to say some cableless technologies can get away with little more than a PC in the field.

In order to assess fairly the two broad categories of recording technique, comparisons must take account of the fact that both types of equipment have a number of sub-

***Figure 1** Cabled and cableless systems under test. Relative weights and complexities are apparent.*

**rgheath@btconnect.com*

categories. Depending on how they are used, some wireless designs are quite a bit lighter than others, and the same applies to various cabled approaches. As far as possible we shall try to compare like with like. The figures and functionality given here are based on general specifications and first-hand field reports. Given the variety of technology available and the ways in which it can be used, readers are recommended to check with manufacturers for precise details.

Cable-based acquisition

Let's begin with hardware which relies on digital spread cables. A cable system is essentially made up of three elements of stuff. In rough order of contribution to weight on crews, the heaviest is the digital telemetry cable along with the digital telemetry connectors, then the method of powering the line electronics, and finally everything else, such as digitizing electronics, cross-line cables, essential auxiliary boxes, jumpers, etc. The field electronics, the business end of the whole shooting match, actually contribute the least to total weight. Like a high fat-content dressing on a lettuce salad, it is all the peripherals which put on the pounds.

The cable-connector combination can contribute 60-80% of all-in weight. This significantly affects the cost of exploration and is why it has always been a target for slimming down. However, digital transmission cables and their connectors are not just arbitrary lumps of plastic and copper, they are as high-tech as almost any other piece of equipment in the field. In order to support the huge data rates imposed on them by modern acquisition, i.e., cope with a wide variety of environments and yet still be fairly reliable, they have to be engineered to very close electrical and mechanical tolerances. Indeed they should be acknowledged as the leading edge of what is possible with wired data transmission: without them, 3D would never have been viable. Barring the invention of some miracle materials, modern connectors and cables are probably close to being as light as they are ever going to get (see Figure 2).

Almost all seismic cables use a few pairs of conductors twisted around each other to carry high speed digital data. Some cables also use extra wires to convey analogue signals from geophone take-outs to the digitizing line boxes. All these conductors are then covered in a protective jacket and sometimes some strength members are added. The weight of such cable varies between 47-100 kg per km. Taking 55 m as a common distance between take-outs means cabling alone accounts for 2.59-5.50 kg per channel. The range of weights for the connectors which join two pieces of line is usually 180-250 g. Each piece of cable needs two connectors, although a length of cable may service one channel or up to eight, so the contribution per channel due to line connectors ranges from 0.05-0.5 kg. The average is towards the lower end of this range, around 0.1 kg/ch.[i]

There is virtually no point in giving weight per channel in kilograms more accurately than two decimal places as there are so many variables which are practically impossible to calculate with any consistent accuracy. The spread of weights for various trace intervals using this connector average is presented in Table 1.

Power considerations

The weight imposed for providing power to the system totally depends on how each type of hardware is used.

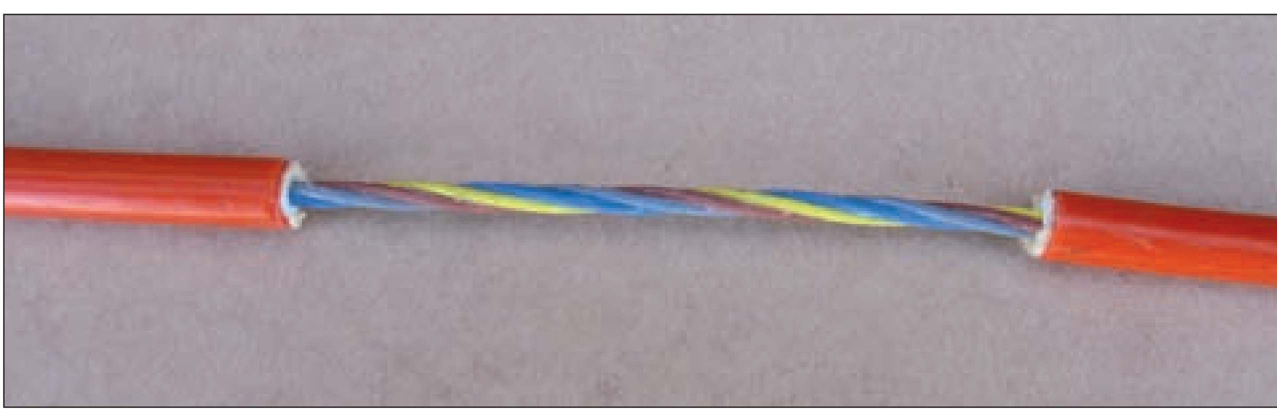

Figure 2 *Modern seismic spread cables are probably as light as they can be.*

i Having fewer take-outs per discrete length of cable has the advantage that when the cable needs to be replaced only a short piece must be handled. However, short cables also have disadvantages, one of which is that it leads to many more connectors and contact points on the spread. Good line connectors are very expensive and poor ones need frequent replacement. Some say that cable's non-weight related Achilles' heel is that high speed data must be made to work across connectors which may be covered in all sorts of field grime. Getting DC to go across a contact is not too tricky, getting high bandwidth digital data flowing is another matter. Therefore, the fewer connectors used, the fewer connectors points have to be negotiated by data as it speeds its way to the central system. Arguments about the best compromise have gone on for decades - indeed I have seen different articles from the same manufacture vigorously espousing the unique benefits of opposing alternatives. There are even apparent differences by region: in S. America three to four channels/cable seems to be a preference, the N. American choice is for fewer than this. In Russia four is a good number and Asia/Pacific often seems to range between two and four depending on working on land or marsh.

Cabling and Connectors	
Digital telemetry cable, range of weights.	47-100 kg/km.
Digital line connectors, range of weights.	180-250 gram, average 0.1 kg/ch.
75m cable including contribution for connector.	3.63-7.60 kg/ch.
55m cable including contribution for connector.	2.69-5.60 kg/ch.
30m cable including contribution for connector.	1.51-3.10 kg/ch.
15m cable including contribution for connector.	0.81-1.60 kg/ch.

Table 1 *Approximate contribution to all-in channel weight due to cables and line connectors.*

For a start, cabled hardware has more than one way to energize the line. The two main groups are simply differentiated by the way they employ batteries. I will arbitrarily refer to them as Group A and B systems:

- Group A: Those systems which rely on having one battery at each remote digitizing unit, which may typically house four, six, or eight seismic channels.
- Group B: Those systems which have one battery powering a much larger number of channels, i.e., they employ 'distributed power' sometimes called 'power down the cable' (PDC).

If we want to compare the total weight per channel of cabled versus cablefree, we must be clear about which type of cabled system. Despite claims to the contrary by advocates of both methods, there is no over-riding right way to power up hardware: each approach has advantages depending on operational considerations for the survey in question. For example, Group B requires perhaps five to 10 times fewer batteries on the line than Group A. However, if power consumption at the channel is the same for both groups, then Group A will require batteries to be changed five to 10 times less often, and that may be a very useful advantage in operations where the maximum load to be carried by any worker is restricted, or where regularly returning to the line is banned for environmental reasons.

Strictly speaking, we should not always talk in terms of powering digitizing units even though product specifications usually refer to how much power the field units consume on a per channel basis. Instead we should think in terms of energy consumption, i.e., providing power to the line for a fixed period. Energy is roughly the product of the average current being drawn from the battery and its nominal voltage, giving the number of watts, then multiplying this by the length of time for which it is used. One watt-second is the definition of a joule but almost no one in this industry talks about joules so we can stick with seconds and watts, or even hours and milliwatts in deference to the low current draw which all modern systems enjoy. Measuring in terms of energy like this is more like the way batteries are specified – their amp-hour (AH) capacity.

Another reason for thinking this way is that we end up with the important detail that a certain weight/type of battery will energize so many channels for such-and-such a time. Years ago some systems told you how long a specific battery would last. It's fairly recent practice to talk only about power/channel, and these figures can be very deceptive as they may bear little relation to what is actually being drawn from the battery.

Energy consumption in Group A hardware is not a set figure. The current drawn depends on how many active channels there are on a line, how many are acting as repeaters, and possibly a few other factors. Therefore, it is difficult to state anything else here other than what manufacturers claim: that the consumption seems to range between 170-320 mW/ch. Even though this is an almost 1:2 spread, they are at least figures we can use because there is almost no power loss with such equipment. However, we have to exercise caution when looking at Group B as there is a tendency to specify the consumption only of the digitizing electronics and not what is coming out of the battery. The two things can be very different, perhaps by a factor of two or more, and this is significant when calculating all-in weight per channel. Distributing power tends to be quite wasteful of wattage.

The problem for Group B equipment lies in the common exploration need for stretching cables over long distances, when conductors have finite resistance and lack the capability to use really high voltages for power distribution. For example, with take-out intervals of 50-60 m, hardware which supplies 40-50 channels from one battery would have to push its power down 2 km of fairly thin copper. Forcing electricity down cables, unless they are superconducting, takes power which equates to more weight. 'Not a big deal' I hear many say, 'power companies do it all the time'. Yes, they do, but they use huge great cables and hundreds of thousands of volts to reduce losses and they still waste about 10% in transmission. [ii]

However, to reduce weight and cost we want our cables as thin as they can be, even though the thinner conductor the higher its resistance, while for safety reasons we cannot go round using hundreds of kilovolts as a distribution voltage. In fact, the maximum commonly used in land seismic cables is about 50 V and it is this relatively low voltage (in power

ii Those familiar with Ohm's and Watt's laws will remember that the power lost moving electricity around a circuit is in direct proportion to the resistance and to the square of the current you want moved, which is why this type of waste is usually referred to as 'I-squared R loss'. It is also why energy companies want to put as little current through their transmission lines as possible. But to achieve the same amount of power delivery (more or less the product of the voltage and the current) means they must increase their voltage as much as possible, and that is why high tension cables are carrying hundreds of thousands of volts. But if the maximum you can inject into a seismic cable is only about 50 V, then to deliver wattage where it's needed to a large number of channels down a long length of cable, you need a lot of amps to balance the low number of volts. Thus I-squared-R losses are high. In Group B hardware, power is also lost in the conversion from battery voltage up to line transmission voltage and down again at each digitizer but good design can limit this to less than 10%.

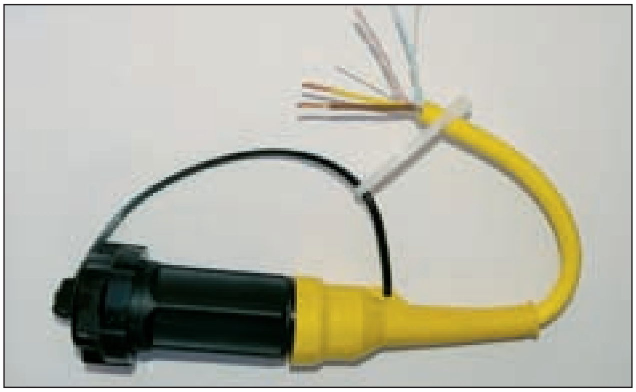

Figure 3 Spread cable with dedicated heavy duty power pair, two data pairs, and strength members.

Figure 4 Batteries for Group B systems.

distribution terms) that means more current must be used to provide the same power. Due to I-squared R losses, all we do by using thinner cables is waste more power and, at take-out intervals common today, about half of what comes out of the battery can be lost. Further, when adopting certain types of low cost batteries which should not be drained to less than half their fully charged capacity, only a quarter of the energy in the battery may be used for real data collection. This is clearly not the most effective use of batteries or the weight they impose, and this is why Group A, as well as cablefree systems, which also have one battery per box and no power distribution, can be more efficient in their use of energy.

Almost since cable-based digital telemetry was invented about three decades ago, there has been a struggle to make cables smaller, and energy distribution has been a very important consideration in those efforts. Even in the 1990s, to send voltage over long distances, most Group B systems had a dedicated 'power pair' of fairly heavy duty copper with very low resistance and, therefore, low power loss (Figure 3). The problem was that this contributed quite significantly to cost and weight. Some newer systems have done away with this pair, 'ghosting' power down much smaller wires which may also double up as part of the data transmission network. This slimming down exercise was a success from the point of view of getting cheaper cables. However, like any crash diet, it had side effects: in this case with regard to the increased conductor resistance and power loss.

Advocates of Group B like to claim that the Group A options, while not wasting power heating cables, are burdened with more weight in the form of battery packaging simply because they are carrying around five to 10 times as many. Ten batteries, each of X amp-hour capacity, will tend to weigh more than one battery of 10 X amp-hour capacity if they are of the same chemistry. However, this is a two edged sword. There are many surveys where Group A systems will not need to change battery during some period of operation while Group B batteries will have to be changed a number of times. In such cases Group B will be carrying around a lot of extra packaging too.

For Group B we need to consider the take-out interval and the toll it takes on providing distributed power.[iii] The rule of thumb is that at 55 m, if the manufacturer claims its digitizers consume about 100-150 mW, the actual power used from the battery is probably about twice this. So we will use the value of 250 mW/ch in round figures.[iv]

For digitizers spread along the cable at greater intervals, for example 75 m, the power lost may be 20% worse. True, not many people have such long inter-trace spacing nowadays, but it is not the trace interval on the ground that counts, it is the length of cable the power has to pass through. Some contractors may purchase cables with extra long take-out intervals so that they can bid for the odd job that requires them, it also gives them more flexibility for stretching cables around obstacles. The alternative is to buy different sets of cables for each survey type and/or extenders which can be very expensive. Where contractors are renting cables, longer than ideal cables may often be used as this is what is on offer. These are issues not generally experienced by cablefree owners.

When trace interval gets down to 30 m, total power used may be about two thirds more than what is coming out of the battery, so now drawing about 175 mW/ch. Even at 10 m intervals, cables will waste enough power that it adds a few

iii Note that power consumption is also affected by the data transmission rate used in the cable which varies between and within systems. The highest data rate can consume around 10-20% more than the lowest. If we were able to increase the reliable bit rate in twisted pair cable it would tend to increase the energy requirement.

iv We can test this figure to see if it is close to what manufacturers state in their specifications. A previous generation but still widely used recorder claims that a one 60 AH battery would supply about 48 digitizers spaced 55 m apart for about 27 hours and approximately 50% discharge the battery. (If some batteries are routinely more deeply discharged than this their life time can be severely affected). In other words, 30 AH is used up in 27 hours, or about 1.1 A current draw on average over this time. Assuming this to be a car/truck battery of nominal 12 V means the power draw is about 13 watts. This is shared amongst 48 channels (and the cable) which is about 270 mW per channel. Doubtless more modern systems use less power so the 250 mW seems not unreasonable.

grams/channel here and there, but we already decided it was not worth being that accurate. These results are summarized in Table 2. We can conclude that if the average power consumption of the Group A system is 250 mW/ch, then it is somewhere between 55-30 m trace interval that the Group B system can become lighter.

To calculate energy requirements we now need to choose a time period relevant to practical seismic operations. I am picking 100 hours as it is the duration a reasonable size 3D crew may have to leave equipment on the ground and powered up before it rolls through. This is of course little more than four days if working on 24 hr/day operation or about 8-10 days if working daylight operations. It also makes the maths easier.[v]

There are many different battery chemistries, all with varying energy densities or how many watt-hours are available per unit mass. The ones commonly found in land seismic go roughly in the following order though the list is not exhaustive and densities can vary between manufacturers: lead-acid, nickel hydride, lithium ion, and its varieties (See Table 3). Generally, the greater the energy density the greater its cost: those who have tried to get a spare battery for their mobile phone may have found it costs about the same as getting a battery for a Volvo! The choice of battery type also affects choice of battery chargers on a crew, as well as how easily shipping may be carried out. It then gets even more complex because some of these batteries don't mind being almost completely drained while others really cannot be more than halfway discharged without risk. In the case of the latter, it means that energy density is halved. It therefore appears to be rather difficult to figure out the weight contribution of providing energy to the line and the more important issue of how often the crew will be running around changing batteries.

The simple solution is to take the advice of the manufacturer. Table 4 gives some approximations of battery weight needed to supply a single channel of Group A and Group B hardware for 100 hours of operation at different group intervals.

Line electronics

Let us now consider the various types of line electronics including digitizers, peripherals, connectors, and cross-line cables which form part of a cable-based system.

Cable Systems Power Consumption	
Group A, (almost) any take-out interval.	170-320 mW/ch.
Group B, 15m take-out interval.	~125 mW/ch.
Group B, 30m take-out interval.	~175 mW/ch.
Group B, 55m take-out interval.	~250 mW/ch.
Group B, 75m take-out interval.	~300 mW/ch.

***Table 2** Typical power consumption figures for Group A and Group B systems.*

Battery Types and Typical Energy Densities	
Lead acid, 50% discharge.	75 kJ/kg = 21 WH/kg.
Lead acid, full discharge.	150 kJ/kg = 42 WH/kg.
Nickel hydride.	350 kJ/kg = 97 WH/kg.
Lithium ion.	450 kJ/kg = 125 WH/kg.

***Table 3** Typical energy densities for various battery chemistries.*

***Figure 5** Cable reels and auxillary boxes. Spot the digitizer.*

v Here we see an important difference between systems which need distributed power and those which do not, either Group A cable or cablefree. One large battery may be used to supply a larger number of channels with 'distributed power' but it will require regular return to the line if the battery does not last for a period longer than it takes to roll through/pick up the equipment. In this case, personnel and effort must be extended to change batteries much more often. For example, a reasonable sized 3D survey of 4,800 channels (20 lines of 240 ch, 50 m trace interval = 12 km lines) may require equipment to stay deployed on the ground for 100 hours. A battery which has to be changed after only 30 hours will require a return to the line three times during this period compared to no returns at all for Group A or cablefree. If we assume all batteries are changed in one go, then a journey approximately equal to the entire length of line of 240 km is required three times – more than 720 km compared to none for the alternative. Such trips could certainly present a problem on a portable crew and not even necessarily be without consequences where vehicular access is limited. Batteries must be changed before they reach the recommended depth of discharge, cutting it too fine not only results in line breaks but also a reduction in long-term battery life.
When the debates about new-era cablefree systems started in the mid 1990s, one champion of 'de-escalating crew logistics' suggested that some fraction of the weight of the vehicle and person required to carry out this task, (plus fuel for the vehicle, food for the person, etc) should be added to the weight of the cable system. I will make no attempt to do this calculation here.

Weight of Energizing Cabled Systems				
100 HOURS OF OPERATION	Lead acid, 50% discharge.	Lead acid, full discharge.	Nickel hydride.	Lithium Ion.
Group A	0.81 - 1.52 kg/ch	0.40 - 0.76 kg/ch	0.18 - 0.33 kg/ch	0.14 - 0.26 kg/ch
Group B, 15m take-out interval.	0.60 kg/ch	0.30 kg/ch	0.13 kg/ch	0.10 kg/ch
Group B, 30m take-out interval.	0.83 kg/ch	0.42 kg/ch	0.18 kg/ch	0.14 kg/ch
Group B, 55m take-out interval.	1.19 kg/ch	0.60 kg/ch	0.26 kg/ch	0.20 kg/ch
Group B, 75m take-out interval.	1.43 kg/ch	0.71 kg/ch	0.31 kg/ch	0.24 kg/ch

***Table 4** Weight to provide energy for 100 hours to different types of cabled system and varying trace interval, using different battery types.*

Other Hardware in Cable Systems	
Digitizing electronics.	~0.35 - 0.45 kg/ch
Junction boxes, data collectors, and similar.	~0.05 kg/ch
Cross-line cabling, repeaters, and other batteries.	~0.10 kg/ch
Total:	**~0.50 - 0.60 kg/ch**

***Table 5** Approximate weight contributions from other constituent parts of cabled equipment.*

For digitizing electronics, whether in one channel per package or as many as eight, whether Group A or B, a weight range from about 350-450 g per channel covers most hardware, with the multi-channel boxes tending to be the lighter on a per channel basis. Some systems need some form of 'extra box' on the line at various intervals depending on system architecture, maybe as a data collector or repeater. The weight of these may be shared amongst perhaps dozens of channels, so allowing 50 g/channel probably covers most eventualities. There are cable junction boxes, which sometimes have other functions but their weight is shared amongst hundreds of channels. Crews also usually require cross-line cables which vary little from the range 50-100 kg/km, and possibly repeaters and batteries supplied on the cross-line too. Here the weight may also be distributed amongst hundreds or even thousands of channels rather than just dozens, so adding in about 100 g/channel is good enough for most situations. Thus, this final element of a cable system ranges from 0.5-0.6 kg/ch.

Cablefree

Now let us look at land acquisition without spread cables. Even though this option may be called wire/cableless or cablefree, with one or two exceptions, these systems still require bits of cabling, perhaps to external batteries and/or to geophones. To some, this explains the difference between cablefree units: those totally free of all external cables while a cableless product is one with less (or fewer) cables.

The number of manufacturers who claim some sort of market presence is in double figures. However, there is a huge variety in how these products work and the functionality they offer, far more so than with cable. This makes comparisons with cabled equipment inherently tricky. Nevertheless, this modern technology broadly falls into three categories as opposed to cable's two: these are systems which make no attempt to send anything at all back to the central system (so called shoot-blind hardware), those which can send something such as system QC and/or status, and finally those which have the ability to send back some or all of the seismic record. These categories are not mutually exclusive but because the ability to return the full seismic record tends to be a non-essential add-on sometimes with quite complex equipment required, its additional burden is not considered here.

The term 'shoot-blind' is misleading in that such ground boxes not only have no way to transmit anything back to the observer, they also cannot receive any radio signals for remote control – what some describe as 'shoot-deaf'. This has some knock-on effects, not so much in that you cannot change field settings or do much testing from the comfort of the dogbox, more that you cannot switch on/off the field unit at will without going up to it. This can be a major concern as often the heaviest part of cablefree is the energy supply and if this cannot be flexibly controlled then it adds unnecessarily to weight and reduces operational flexibility. That may explain why second

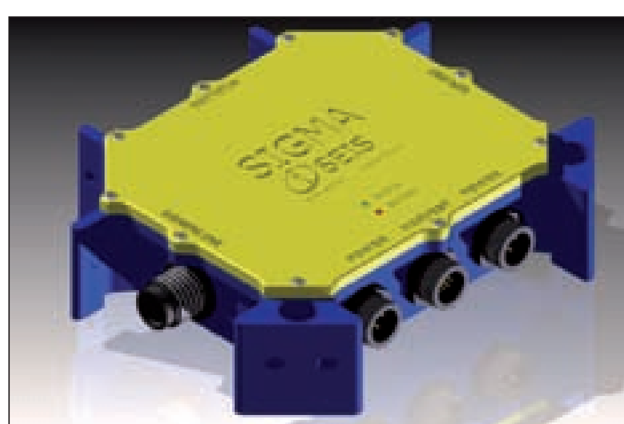

***Figure 6** Individual connectors for each seismic input used on a cableless system.*

generation cableless systems are now becoming available which do provide two-way communication via a licence-free mesh radio network. Mesh radio of course may take some energy which shoot-blind/deaf does not, but it is inherently low power technology meaning that efficiency is improved overall as power is only used when it's needed.

Different cablefree systems offer varying numbers of channels per ground unit and most products fall into the range of one to four. The advantage of single channel is that you end up with less external geophone or jumper cabling but the disadvantage is that the per channel weight is likely to be greater as is the price, and the number of batteries is much larger. Systems with fewer than three channels per ground unit also make life impractical for some in that it takes away the easy option to be able to acquire 3C data.

Even though cablefree components can be put into three categories, the groupings are different from those used on cabled systems. The main reason is that some cablefree ground units include internal batteries so it can be awkward to separate out the electronics and the energy supply weight. The following figures are based on what is available from manufacturer's websites or other communication.

The first category is cabling. Referring to cables sounds contradictory when discussing cablefree equipment. However, the cable being referred to is the jumper, adaptor cable, or geophone extension sometimes needed. Theoretically, no additional cable has to be used for ground units with two channels or fewer as long as the box has separate input connectors for each seismic channel. But with boxes which have a single multi-purpose connector or with three or more channels being used for P-wave recording, then adaptors such as pig tails and/or geophone extenders have to be used. The former weigh around 500 g to be shared over some low number of channels. The latter, the geophone jumper cable, while light compared even to the smallest grade of digital telemetry cable, cannot be ignored as it add to the system total for long trace intervals. Weights for such cable are in the 16-23 kg/km range while a typical geophone connector which would be needed on both ends starts at around 75 g and can be double this. Therefore, a single 50 m geophone jumper could add between 0.95-1.45 kg. Depending on how the ground equipment is employed, and assuming the geophone string itself does not have enough spare lead-in, one such jumper for every seismic input would be needed where the ground unit has more than two channels. For example, a three channel box needs at least one jumper and a four channel box would need at least two. You also need the adaptor in some cases. Once the weight of all these is totalled, it must be divided by the number of channels per box.

The second grouping of equipment is the ground electronics plus system power for 100 hours. Here, the weight of any length of cable and connector which joins an external battery to the box should not be ignored. Not all manufacturers quote actual power consumption, preferring just to say how long a battery lasts for a certain number of channels. There are further hidden complications in that various systems' internal batteries last different lengths of time, so some need extra batteries to cope with 100 hours. Additionally, some justifiably claim that cableless systems could handle much of this duration by using a small capacity battery with a solar panel which would give a lower total weight. This is true and is one of the advantages of having one battery per box whether with cable or cablefree. However, to avoid quoting a few dozen sets of numbers, figures for the battery chemistries suggested by the makers is quoted and solar power is ignored.

For 100 hours of non-stop acquisition, the range of weights across both shoot-blind/deaf systems and those with

Figure 7 *Cableless is increasingly a preferred method of acquistion.*

Cabling	
Adaptors/pigtails.	0 - 0.50 kg.
Geophone jumper cable.	16 - 23 kg/km.
Geophone connectors.	0.08 - 0.15 kg.
15m take-out interval.	0 - 0.37 kg/ch, average = 0.19 kg/ch
30m take-out interval.	0 - 0.62 kg/ch, average = 0.31 kg/ch
55m take-out interval.	0 - 0.91 kg/ch, average = 0.46 kg/ch
75m take-out interval.	0 - 1.14 kg/ch, average = 0.57 kg/ch

Table 6 *Approximate contribution to weight due to cable used in some cableless systems.*

Cableless System Weights	
Ground unit and battery for 100 hours of operation.	0.7 - 1.7 kg/ch
Line peripherals.	0.0 - 1.0 kg/ch

Table 7 *Range of weight contributions for electronics, power and possible peripheral subsystems.*

Weight of Sensor/String Components	
Geophone on spike.	~0.08 - 0.13 kg
Geophone cable.	16 - 33 kg/km
Geophone connector.	75 - 150 grams
3C geophone (nail/tripod).	~0.39 - 0.85 kg
3C MEMS device.	~0.43 - 0.63 kg

Table 8 *Range of weights for parts required in various types of sensors excluding power requirements necessary for MEMS devices.*

some form of communications ranges between 0.7-1.7 kg/ch. There are a handful of systems which offer the ability to add on equipment for sending the whole seismic record over some form of wireless system to the observer. However, calculating the extra weight of doing is difficult given the complexity of techniques to achieve this. This does not imply that the weight is always excessive or compares unfavourably with that of a cable system, but this feature tends to be an option (where it is available at all) which is why its weight is not included here. Note that transmitting data is an energy intensive business, whether along cables where it can use up to a third of all the power being used by electronics or via radio. As using power adds weight, you can ask whether it is really important to expend energy of any sort just to received all data virtually instantaneously?

Figure 8 *Solar power-assisted cableless acquisition equipment on passive monitoring.*

Peripherals

The final group of parts in cablefree is the line of peripherals. In some cases, this is optional equipment, and sometimes essential for system layout or function. This group may include ruggedized PCs, GPS receivers, portable data harvesters, and various other bespoke items. Where they are essential, their weight might be divided between dozens or even hundreds of channels so their per channel contribution goes from zero to perhaps 1 kg. This last figure is a guess and may be on the high side. It is included in Table 7.

Using information in all the tables provided and elsewhere, it is now possible to compare weights, system complexities, and viability for different operations. If operations will benefit from avoiding excess weight or system complexity, then cableless is clearly the answer.

Finally, those interested in comparing the differences between active and passive sensors, arrays and point receivers, and so on, can refer to Table 8 but remember to add on the requirement for energy that active devices have. It is not always clear what the figures are in this respect and one should refer to manufacturers' websites.

Conclusion

We can safely conclude that (a) cabled systems are under almost all conceivable circumstances the heavier way to go, (b) they

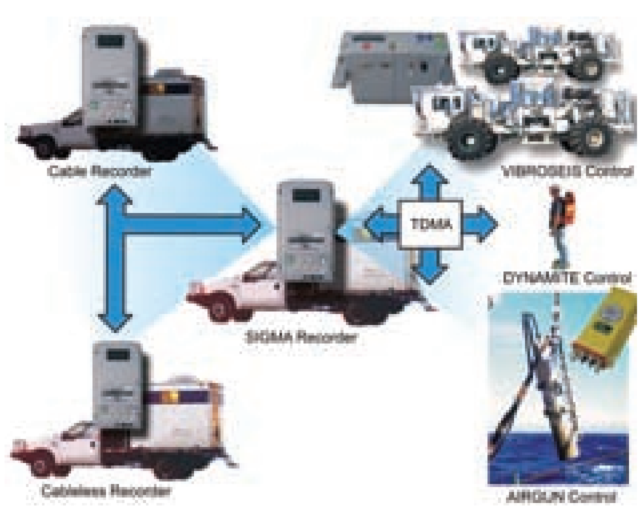

Figure 9 *The future is for multiple source, multiple recorder, and multiple receiver types on the same operation. Source control equipment must also be able to cope.*

are significantly more complex than most of the alternatives, but (c) currently they are the only field-proven way to retrieve data in real time in the seismic environment. (This full data return capability is something being addressed by second generation cablefree hardware.) However, cable technology may be close to the practical limit of how many channels it can support for this purpose, and more operations each year no longer consider instantaneously accessible data important to their success.

All this makes for a very exciting period for our industry. The era of cable-only acquisition is coming to an end and land seismic is entering a new phase. Cableless recording is just beginning to evolve and we can expect new technologies to be integrated into existing cablefree systems: this should help to lower the cost of owning and operating the equipment. We have already witnessed oil companies buying their own cablefree hardware. Meanwhile some acquisition contracts on offer cannot be fulfilled using conventional cables, and one oil company is doing something which has not happened for almost 40 years, namely building its own major recorder, and the design apparently will not be making much use of digital cables.

Right now cabled and cableless systems are used side-by-side to get the best of both worlds, not just mixing recording technologies but also sensor types. The number of ways that different sources can be used on the same operation is also challenging some control systems, which is why the instrumentation industry is now starting to turn its development skills in this direction.

All this is not only good for hydrocarbon exploration, for the seismic business as well. We cannot go on using the techniques that have served us for 30 years expecting them to be equally appropriate for another 30, not if we want to discover the evermore difficult-to-find fields, and not if we want to reduce our costs and HSE exposure. At the current rate of progress, it may be less than a decade before most acquisition is done without cables.

Further reading

Heath, R. and Jack, I. [2009] System 2000 revisited. *The Leading Edge*, **28**(11), 1304-1313.

Jack, I. [2003] Land Seismic Technology: Where do we go from here? *First Break*, **21**(2), 33-36.

Mougenot, D. (2010) Land cableless systems: use and misuse. *First Break*, **28**(2), 55-58.

Savazzi, S. And Spagnolini, U. [2008] Wireless geophone networks for high density land acquisition. *The Leading Edge,* **27**(7) 882-886.