PARAMETRIC SUB-BOTTOM PROFILER, A NEW APPROACH FOR AN OLD PROBLEM

Geoff Holland, Alcatel-Lucent Submarine Networks
Geoff.holland@alcatel-lucent.com

Alcatel-Lucent Submarine Networks Ltd, Christchurch Way, Greenwich, London UK

Abstract: The largest external threat to cables within the shallow water buried sections of a cable system are from vessel anchors or fishing vessel trawl boards. This paper looks at an alternative type of sub-bottom profiler which could allow greater analysis of the uppermost 1-2m of sediments. This would aid the installation vessel to have greater awareness of seabed conditions and assist in achieving the greatest possible burial of the cable.

1. INTRODUCTION

Traditional cable route surveys within the shallow water sections of proposed cable routes comprise various technologies in order to identify all the elements to ensure not only a safe cable installation but long term survivability of the cable through its projected life span. Protection is required against both natural and man made risks and activities.

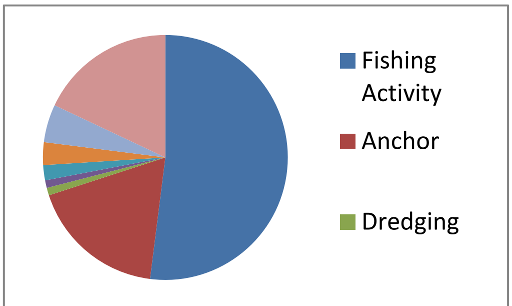

Figure 1 – Causes Of Cable Damage

The main components of a survey being, a) Multi-beam Echo-sounder, used to define water depth and seabed gradients to identify areas of risk to the plough b) Sidescan sonar, used to give images of the seabed to provide an initial assessment of seabed sediment composition and hazard areas such as rock outcrop or ship wrecks. c) Sub-bottom profile, used to identify the thickness and internal structure of all seabed sediments, particularly important for plough assessment studies d) Ground truthing of the seabed using gravity corer and grab sampler e) cone penetration equipment, to provide geotechnical information for burial assessment.

During the past 30 years there have been numerous developments in survey equipment. However the more traditional approach which is adopted for the sub-bottom profiler element of cable route surveys does not adequately identify the sediment layers within the top 1-2m of the seabed. The aim of this paper is to look at an alternate sub-bottom profiling technology. This alternative technology will not only give greater sediment resolution in the uppermost sediment layers, but can almost double the survey speed thus reducing survey time and associated costs.

2. IT WAS THIRTY YEARS AGO TODAY!

Well almost since the author conducted his first cable route survey for the Australia-Indonesia-Singapore co-axial cable system. What is very noticeable is how much the cable design, and more specifically transmission technology has changed in that period compared to the geophysical equipment used during the survey.

Back in the early 80's the survey was conducted using the same 3 survey elements of echo-sounder, sidescan sonar and sub-bottom profiler. One of the main developments in the intervening years has been the development of multibeam echo-sounder systems enabling a large swath of seabed to be covered in a single pass. Sidescan sonar systems have advanced particularly in terms of multiple ping systems allowing greater vessel speeds and target resolution. Sub-bottom profilers have developed chirp technology using a frequency spectrum to give greater penetration and enhanced resolution. Common to all these systems has been the development of digital technology to allow onscreen processing and interpretation negating the need for paper records.

Ground truthing of the sonar records was achieved by using a gravity corer or grab sampler whilst nowadays, with the development of portable cone pentrometer test rigs detailed geotechnical properties of the sediments to give shear strengths (for clay sediments) and relative density (for sand soils) is easily obtained.

Profile Equipment?

Sub-bottom profilers, or to give them the more common name of "*Pingers*" were derived from the echo-sounder principles.

Figure 2 – Typical Sub-Bottom Profiler complete with control units

The equipment typically consists of a series of transceivers which both transmit and receive the acoustic pulse to and from the seabed. Single frequency systems typically operate on a selectable frequency ranging from 3.5 to 5kHz with the higher frequency giving greater resolution but the amount of penetration into underlying sediments is reduced as the frequency is increased. Chirp systems operate with a Chirp sweep of typically 2 to 10kHz and in simple terms "*the frequency varies linearly in time between a starting value and an ending value over a defined duration*".

The advantage of using sub-bottom profilers over other seismic equipment is the ability to operate at higher frequencies giving greater resolution. A question that is often asked with profiling equipment is what sediment thickness can be resolved. This is defined by the *Rayleigh Criterion* and is ¼ of the signal wavelength;

Thus going back to basics,

W = V/F
Where W = Wavelength
V = Sediment velocity in m/sec
F = Signal frequency

In a typical soft clay/mud sediment which would have a typical acoustic velocity of 1600m/sec and using a frequency of 5kHz it is theoretically possible to resolve layers 8cm in thickness. In very soft material penetration can be in excess of 50m (Gulf of Thailand) but is more typically 10-20m.

The Problem

The problem that we are faced with when interpreting this type of data for cable route design is when you look at the sediment layers forming the upper 2-3m of the seabed. Whilst the resolution of the system will clearly identify thin sediment layers this is not always the case at the seabed. The initial part of the profiler record is often masked by signal reverberation, or "*ringing*". Ringing is a result of high intensity acoustic energy causing the sediment grains in the upper seabed to reverberate; this leads to a chaotic energy return to the transducer in the receive mode, thereby obscuring resolution in the upper seabed. It is particularly prevalent in sandy sediments in shallow water. Another phenomenon that can obscure data is that of record multiples or "ghost reflections", which are a result of the seismic wave reflecting off the air-water interface.

Due to sub-bottom profilers being towed only a few metres below the sea surface, or in shallow water areas this can be a significant problem. If the sub-bottom profiler is combined within the sidescan sonar and towed near to the seabed then the problem is significantly reduced.

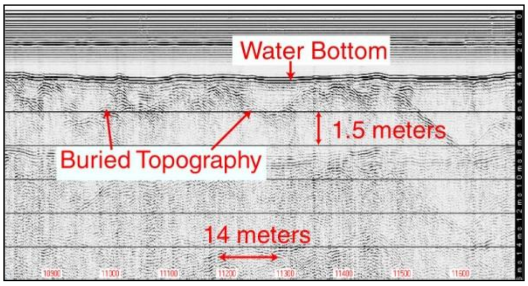

Figure 3 – Typical Chirp Profile Record

The waves propagates with low attenuation through the water column, with the seabed and sea surface representing two highly reflective horizons and in most instances the source generates residual oscillations of the initial pulse. The result of this combination is a general elongation of the transmitted signal resulting in a thickening of the reflectors and in particular those nearest to the seabed which is the most important area for predicting cable burial.

In addition to the reverberation the traditional single frequency sub-bottom profilers have quite a large acoustic beam. This can result in additional anomalies masking the true data from side echoes, particularly in deeper water as the beam spreads out more with increasing depth. This can be to such an extent that in deep water, with quite steep slopes the seabed can actually appear to be formed of thin sediment layers, when in reality no penetration is actually achieved.

The Solution

The problem of reverberation and side lobe images can be significantly reduced by the use of Parametric or non-linear technology.

The principle is to create a primary beam as narrow as possible and in addition have no significant side lobes. In a conventional system there is a main lobe with a certain half-power beam with side lobes. This results in the sound at the border having a longer travel time than the signal in the centre of the beam and makes the reflected signal longer than the transmitted signal. Particularly in deep water areas refraction due to changes of the sound velocity may additionally enlarge the insonified bottom area that again makes the signal longer and the longer the signal the poorer the resolution. In order to get good spatial resolution you require a narrow beam without side lobes.

By doing this you significantly improve the signal to noise ratio due to the reduction in the amount of bottom and volume reverberation and in addition it avoids the occurrence of ambiguous reflections which can lead to errors in data interpretation as mentioned previously.

In order to obtain this the transducer transmits two signals of slightly different high frequencies at high sound pressure simultaneously (primary frequencies). The result is that the primary frequencies interact during the sound propagation, thereby generating low frequency pulses, and producing the sound beam with the desired characteristics of narrow beam and lack of side lobes. In addition the high system bandwidth of the parametric system means that really short signals can be transmitted without ringing making it particularly useful in shallow water areas.

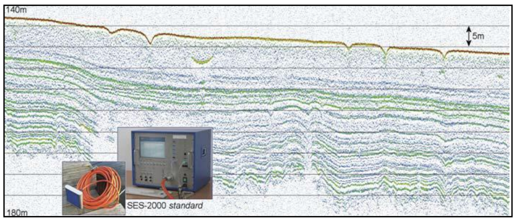

Figure 4 – Typical Parametric Record (Innomar Technologie GmbH)

A secondary advantage of the parametric system is that the transducers, unlike the conventional single frequency or chirp transducers are very lightweight and can be very easily manhandled. Especially useful when mobilising on a small inshore survey vessel and a relatively lightweight over the side pole mount can be utilised. Traditional system transducers weigh several kilograms and require much sturdier vessel mounts.

In addition to providing better quality of data and easier vessel mobilisation the parametric system can also add significant cost saving to projects. During a geophysical survey the sidescan sonar will be deployed at the same time as the sub-bottom profiler. Most modern sidescan sonar systems have multiple ping technology which allows data to be collected at speeds up to approximately 8 knots, survey vessel are usually limited to a speed of 4 knots due to the fact that above that speed the traditional sub-bottom profiler data becomes significantly degraded. Using the parametric sub-bottom profiler the survey speeds can be increased with the potential for reducing survey times by about 50%

3. CONCLUSION

From the research carried out there appears to be great potential for giving much clearer images of the seabed sediments to more clearly identify areas which could be difficult for ploughing. This would enable the installation vessels to be reacting in advance of the problems being encountered instead of reacting once encountered and giving areas of reduced burial which could potentially be avoided.

I would like to throw down the gauntlet to the survey industry to look in depth at this technology to see if it will give the cable industry the desired results. Whilst the physics of the sediments with which we are dealing with will never change I believe there could be advantages in looking at alternative variations of the current technology in order to produce more applicable survey results to obtain more consistent burial in sediments of varying nature.

Who knows what the next thirty years will bring !