A NEW TECHNOLOGY FOR DETECTING AND TRACKING BURIED CABLES

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Abstract: This paper describes a novel electro-magnetic induction and sensing technology for detecting and tracking buried submarine cables. The technology uses a combination of local antenna and local sensors on the host platform to detect cables to a far greater burial depth than conventional technology whether the cable is powered, unpowered or broken.

1. INTRODUCTION

Conventional methods of detecting cables and tracking their X-Y-Z position in real time are well understood [1], [2]. In cases where an applied tone is not available or poor quality, the existing technologies require the target to be magnetized prior or use pulse induction where the target shall have a high metallic content to be detectable in the seabed. This paper describes a different technology where a tone is generated in the target using an antenna on the host platform (ROV, AUV or Trencher). A local set of sensors on the host platform can then detect this "lit" cable. The paper will describe the technology in more detail, its demonstration offshore including use cases and the performance of the sensors with a range of typical submarine cables construction types.

2. TECHNOLOGY OVERVIEW

The technology has two forms. The first is a conventional passive mode where the cable is live (see Figure 1) or has a strong and detectable AC tone (see Figure 2). Figure 1 shows the sensor array tracking and surveying either AC cables or unipolar DC cables transmitting at 50Hz or 60Hz or any harmonic from the live power transmission.

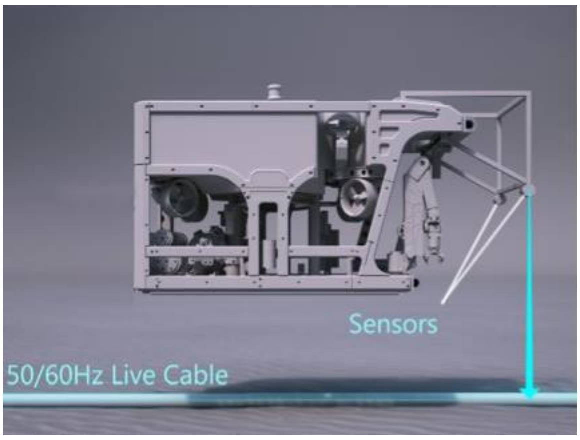

Figure 1 - Tracking a Live 50/50Hz Cable

Figure 2 shows the sensor array tracking and surveying cables with little or no power or bipolar DC cables.

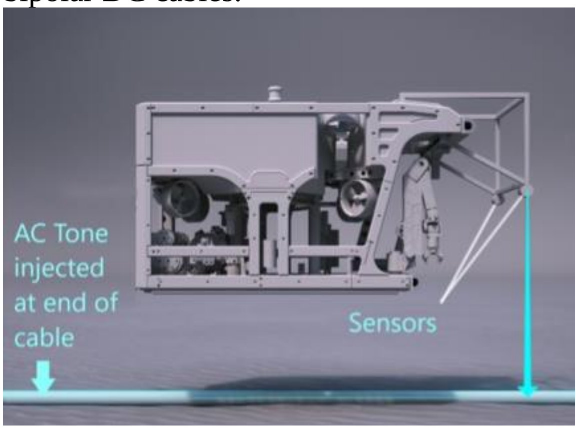

Figure 2 - Tracking via A/C Tone

A tone is applied at the end of the cable either at the beach or an offshore substation. This passive sensor technology form has been demonstrated and in the commercial sector under the trade name Orion [3].

The second mode is the focus of the technology development and consists of active tracking or survey of cables that are Live (AC or DC), Un-powered, Damaged or Cut.

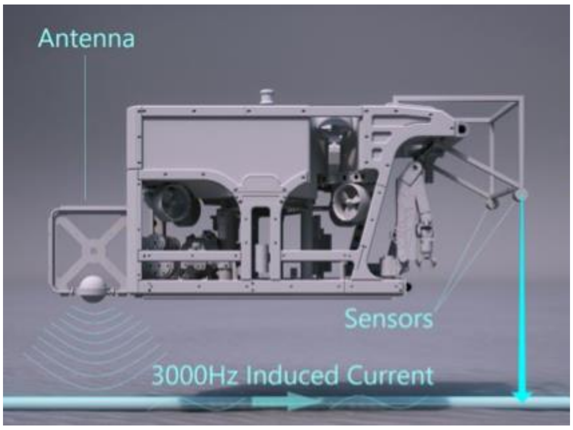

Figure 3 - Tracking of any cable target using an induced current

Figure 3 shows the new technology hardware consisting of the antenna on the host generating a 3kHz AC magnetic field inducing a very small current in the cable and the sensors are set to look for a specific target frequency.

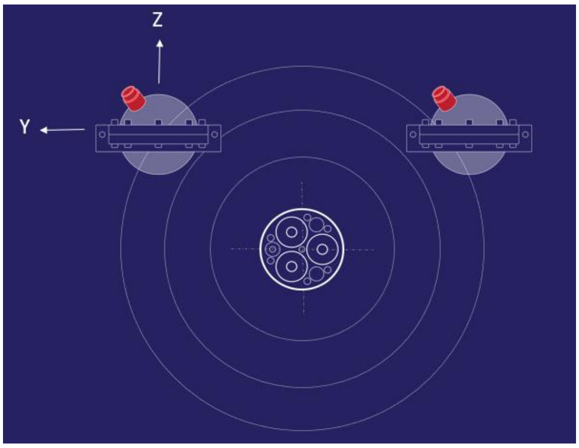

Figure 4 - Idealised magnetic field pattern and 2-sensor array configuration

Figure 4 shows a front sectional view of a 2-sensor array and a target power cable. The magnetic field from a cable can be assumed to be circular and by identifying the centre of the magnetic field the technology can predict the centre of the cable.

The aim of the offshore testing phase was to demonstrate the sensor and antenna technology in an offshore environment with different cable constructions, seabed types and host platforms. And most importantly to be able to characterise the magnetic field accurately in order to perform X-Y tracking and X-Y-Z depth of burial data in real time without any post processing of data.

3. PRE-OFFSHORE TESTING

Prior to full scale offshore testing, the sensor / antenna combination was tested in a flooded dry dock in Blyth, UK with a buried power cable to a depth of 3m. This provided two valuable insights,

- adjusting the theoretical model for field distortion and
- the best technique to calibrate the antenna and sensors

Figure 5 illustrates how the induced magnetic field can be distorted with refraction at the water / seabed interface.

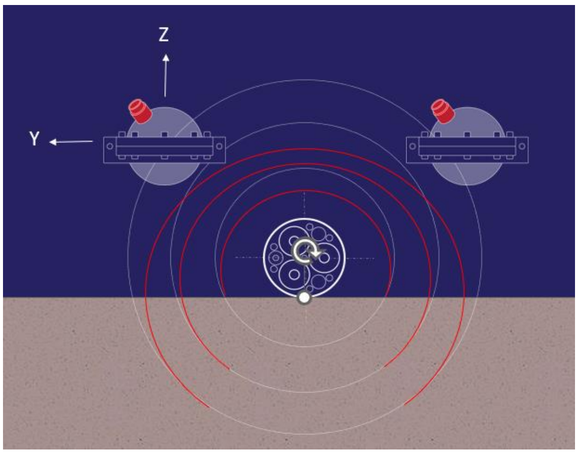

Figure 5 - Distortion of the magnetic field due to refraction at the water / seabed interface

The technology uses a semi-empirical model to firstly predict where the centre line of the target should be and then correct that with the live information fed back from the sensors. The dry-dock trials demonstrated an improvement of the model was required to accommodate how much the field was distorted based on the sensor to seabed height.

Figure 6 shows how noise is generated by a direct path route from antenna to sensor, H_{direct} in combination with the transmitted noise along the cable H_{cable}. The dry dock trials characterised the noise and we were able to demonstrate how this can be cancelled and cleaned from the model by a simple series of fly over tests.

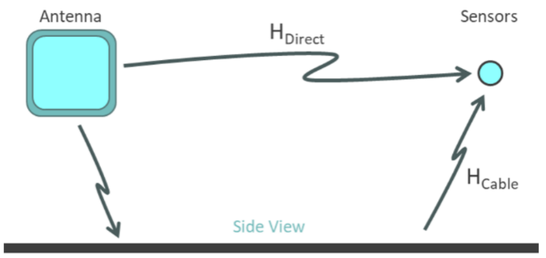

Figure 6 - Direct Path Noise

Operating instructions for set-up were improved and we established quality indicators or confidence levels in the sensor data.

4. OFFSHORE TESTING

Table 1 shows an early 2019 offshore trial summary.

Year	Client	Product / Project	Development
2019	N-Sea	Dan Tysk Offshore Wind Farm	+/3 m offset plus 2m burial of un-powered HVDC bundle

Table 1 – Project Summary (N-Sea)

This development trial was performed to prove the technology against the established market leading cable tracker when a tone was applied (benchmark) and when it was removed. Figure 7 (upper image) shows the ROV flying offset (+/- 3m) to the cable route to prove its sensing range. Figure 7 (lower image) shows the estimated Depth of Burial in the forward pass direction and reverse direction. Figure 7 (middle image) shows the variation of altitude over the cable route in first pass forward and second pass reverse.

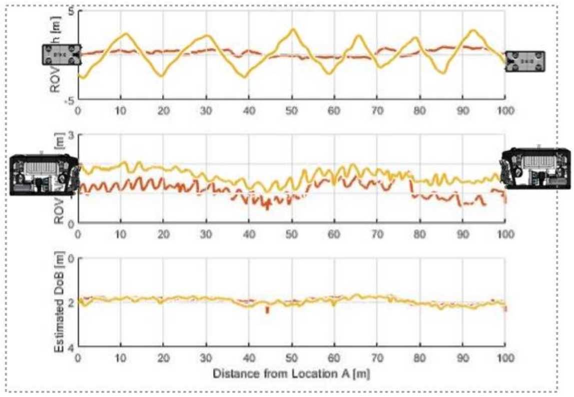

Figure 7 - N-Sea ROV DoB Survey Data

The conclusion from Figure 7 is how robust the sensor array is to running the ROV offset because of poor survey data, presence of high currents or simply operator drift. Further the robust nature of the sensor range in Z direction when the ROV is flying at different and variable heights over the cable.

This early trial did not have access to live sensor height over seabed data and therefore the results had to be processed later.

Table 2 shows a later 2022 offshore trial summary

Year	Client	Product / Project	Development
2022	Global Marine	Arcadis Ost 1 Offshore Wind Farm,	Live DoB of 300m trials power cable benchmarked against toned results

Table 2 - Project Summary (Global Marine)

This 2022 trial was a further demonstration of the technology against an AC tone benchmark with the opportunity to have live mean seabed level data to present live Depth of Burial data.

The antenna and sensor array were fitted to a standard work class ROV (FCV3000) performing post trenching survey runs, see Figure 7 below.

Figure 7 – Antenna and 3-Sensor Array on FCV3000 Survey ROV

The antenna is mounted aft (left image) and the 3-sensor array is mounted fore (right image).

Figure 8 shows the final processed results from a multi-pass trenching operation. Mean Sea Bed Level (MSBL) is shown at (-43.4m nominal). "Reference" is the cable position obtained by applying a tone to the cable with TSS350 and "Run 1" and "Run 2" are the cable position based on the Artemis data log files following removal of data from sensor 3.

The trials demonstrated two further insights as the technology is tested offshore. First, the theoretical definition of Mean Sea Bed Level is difficult to define in post survey jet trenching operations. Any open trench will have an ill-defined profile and variable spoil heaps on the seabed. Any height sensors on a survey ROV such as an altimeter of multi-beam sonars will provide variable data that must be analysed and post processed to the satisfaction of on-board survey engineers. Therefore, the DoB data needs to wait for the processed MSBL data. Secondly, each sensor has a live confidence level available to the surveyor or ROV operator. The trials suggested Sensor 3 was outside the acceptable confidence levels and indicated a fault. During the post processing of the MSBL, the DoB data was presented without Sensor 3 information as shown in Figure 8.

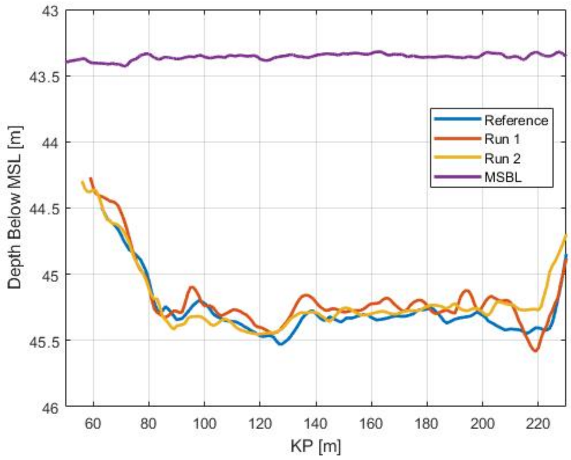

Figure 8 – Global Marine Arcadis Ost 1 Test Power Cable Depth Below MSBL

During this Offshore Trial it was also possible to test the technology to detect and measure the depth of burial of the Baltica telecoms cable. The time was extremely limited, nonetheless the cable was positively tracked and depth of burial confirmed between 2m and 3m. This trial has been the first evidence that the technology can detect power and submarine telecoms cables and do that without interrupting their service.

Table 3 shows a further offshore trial on an in-service power cable to an offshore wind substation

Year	Client	Product / Project	Development
2022	Guangzhou Salvage Bureau	XUWEN II Offshore Wind Farm	Remedial burial of 4 x 35kW 3-core XLPE armoured cables

Table 3 - Project Summary (Guangzhou Salvage Bureau)

The test demonstrated the combination of two sensor locations as shown in Figure 9 in live trenching mode. The forward sensor array enabled the operator to track the cable on the seabed or partially buried ahead of the trencher. The rear sensor array enabled the operator to confirm the position of the cable between the jetting swords and its instantaneous burial position as it enters the trench.

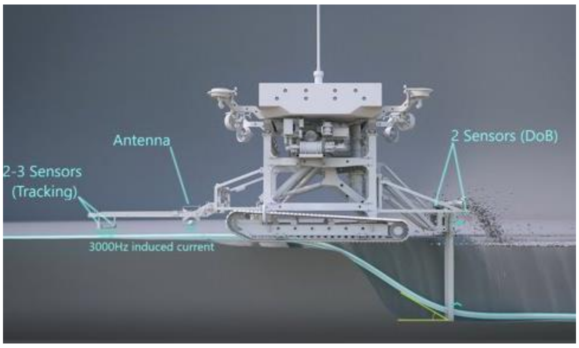

Figure 9 - Tracking and Real-Time DoB data on a trencher

The antenna is available in this arrangement in Figure 9 if the Live power transmission or the AC tone is interrupted, temporarily unavailable or not effective. Figure 10 shows the mounting arrangement on the host trencher. The forward sensor array is shown clearly ahead of the trencher, the rear sensor arrays are mounted on the stainless steel bars projecting aft to the far right of the picture. They remain above the jet tool as it is deployed into the trench.

Figure 10 - Trencher with forward sensor array and (obscured) rear array

Cable	Operating Condition	Trenching Distance /Times	Burial Depth (m)
1	Wind Speed Level 5m 2m Wave Height	378m / 5hr	2.4 – 2.7
2		656m / 4hr	2.5 – 2.6
3		3096m / 6hr	2.0 – 2.7
4		2895m / 6hr	2.0 – 2.7
5		378 / 1hr	2.0 – 2.2

Table 4 - Shallow Water Trencher Remedial Burial Performance

The objective was to safely bury or re-bury cables to the minimum 2.0m below the mean seabed level. The trencher provided a stable and fixed platform and the forward sensor array height above the seabed is fixed and therefore real time depth of burial using the rear sensor has a high confidence level. Also, second pass burial campaigns to increase the depth of lowering are not popular in the offshore wind market given the lack of confidence in the position of the cable and therefore the risk of lowering trenching tools in the vicinity of the cable. The rear sensors provide that confidence level to lower the port / starboard swords

Figure 11 - Operator display showing plan view (X-Y) and front view (Z) position of cable

Figure 11the image to the left shows the tracking position of the cable forward and aft of the vehicle. The image to the right is the Depth of Burial with a circular confidence bound.

5. PERFORMANCE DATA

Table 4 shows the performance range of the technology benchmarked against [1] and [2].

	SMD	TSS 440 / 350	Innovatum
Live	10m	1.8m	Magnetized Only
Toned	10m	10m	5m
Un-Powered	4-5m+	1.8	Magnetized Only

Table 5 - Sensing Range for Wet Armour Power Cables

Assuming the sensors are 1.0m above the seabed, the depth of burial range is reduced by 1.0m. Table 4 is based on proven performance with power cables. The patented core technology requires the target cable to have wet armour (an electrical path to earth from metallic armour to seawater) and be able to conduct 25 – 300mA of an induced current in an unpowered cable. The current range of SWA submarine telecom cables have these features.

6. SUMMARY

This paper describes the testing and development of novel technology to detect and track surface and buried submarine cables. The technology has been shown to detect cables to a far greater burial depth than conventional technology whether the cable is powered, unpowered or broken. The testing has shown that real time depth of burial data can be prepared but the height of the sensors above the Mean Sea Bed Level must be available and its accuracy qualified to build confidence in the data. Trials have shown the technology is independent of seabed composition and is not affected by metallic content through the mix. Most of the tests and offshore trials through to 2022 have focused on larger power cables. We intend to look for sponsors to demonstrate the technology for submarine telecom cables and their maintenance and survey to prove its capability in 2023 and beyond.

7. REFERENCES

[1] HydroPACT 660E, Teledyne Marine www.teledynemarine.com

[2] SMARTRAK, Innovatum, www.innovatum.co.uk

[3] Orion — Optimal Ranging