SMART CABLES: A SPECIFICATION TO ENABLE INFORMED INVESTMENT

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Abstract: The concept of SMART (Sensor Enabled Scientific Monitoring and Reliable Telecommunications) Cable Systems has been the subject of study for several years, notably within the ITU/WMO/UNESCO IOC Joint Task Force to investigate the use of submarine telecommunications cables for ocean and climate monitoring and disaster warning, which was established in late 2012.
Much discussion to date has been focused on how to design and engineer SMART cables to address the practical challenges of building a hybrid telecom/science cable, such as the resolution required of various environmental sensors to obtain meaningful data.
This paper takes a complementary approach, by proposing a draft specification which will allow potential investors in a new telecom cable to evaluate the business case trade-offs of including SMART capability. It is intended to be a stand-alone Annex to any telecom cable ITT. The responses of cable system suppliers to this specification will allow investors to fully understand the business implications of commissioning a SMART cable in comparison to a 'standard' telecom cable, and to weigh up these considerations against: (a) the societal benefits that SMART cables promise, and (b) the level of any additional funding available to realise SMART capability.
The proposed specification includes aspects such as system availability, maintenance, powering, backhaul requirements and security, and includes a summary table to facilitate side-by-side comparison of a SMART cable versus a telecom-only cable system.

1. INTRODUCTION

In 2010, an opinion article in Nature titled 'Harnessing telecoms cables for science' proposed the routine addition of sensors to telecom cables in order to monitor the oceans [1]. In response to this article and the industry debate which it sparked, an ITU/WMO/UNESCO IOC Joint Task Force was created in 2012 to investigate the use of submarine telecommunications cables for ocean and climate monitoring and disaster warning. The term 'SMART' has been applied to such hybrid cable systems, meaning 'Sensor Enabled Scientific Monitoring and Reliable Telecommunications' [2].

Since that time, many ideas to realise the vision of SMART cables have been put forward and discussed. Some of the debate initially focused on the ocean science itself, such as the environmental parameters which may be practically measured, and the resolution and sampling rate required of sensors to obtain meaningful data. Subsequent thoughts turned to the engineering challenges involved, such as the isolation of sensors from potential temperature perturbations caused by nearby telecom repeaters, means to separate electrical powering schemes for the telecom system and the scientific sensor package, and options to transmit the real-time science data back to shore via optical fibre.

While various options are being explored to find sources of funding to build SMART functionality into a telecom system, the availability of funds is only part of the business case for a SMART cable. The Purchasers of a new submarine telecom cable potentially incorporating additional SMART functionality are entitled to ask questions such as: 'What are the additional risks to my cable?', 'How much commercial traffic I am sacrificing?', and 'Will the cable take longer to build?'

This paper takes a new approach, by proposing a draft specification which will allow potential investors in a new telecom cable to evaluate the business case trade-offs of including SMART capability in a cable. The specification is intended to be a stand-alone Annex to any telecom cable ITT. The Purchasers of the telecom cable can specify an option for SMART capability in their cable's ITT requirements, and the responses of cable system suppliers to this specification will allow investors to make a side-by-side comparison between a 'standard' telecom cable and a SMART-enabled version of the same.

In doing so, the Purchasers can fully understand the business implications of commissioning a SMART cable, and weigh up these considerations against: (a) the societal benefits that SMART cables promise, and (b) the level of any additional funding available to realise SMART capability. In this way, the authors hope to lower the barriers to building SMART cables.

The full specification itself is freely available: this paper summarises the key elements of it.

2. PRINCIPLES

The proposed specification on Ocean Observation Functionality has been developed based on the following principles:

- It tries to anticipate questions asked by investors when seeking board-level approval for a SMART-capable telecom cable, and to give those investors sufficient information to make a well-informed decision on the viability of the SMART option
- It requires the tenderer of the cable system to make a direct comparison of multiple system parameters, with and without SMART functionality
- The specification elicits responses from the tenderer with the same degree of rigor as a telecom system. It uses the same format and conventions as the General Technical Requirements issued for telecom cable ITTs by Vodafone
- The specification is offered as a straw man: it is self-contained, but fully editable if required

The authors recognise that while the parameters covered in the specification can be typically be converted to a monetary value (CapEx, OpEx, etc.), many of the societal and corporate benefits of SMART cables are hard to evaluate in this way. Separate 'softer' arguments for realising a SMART cable are therefore required in parallel.

3. DEFINITIONS

In developing the specification, it quickly became clear that new definitions would be required to ensure that a clear, fair and accurate comparison could be made between a standard telecom cable system and a hybrid system incorporating ocean sensors. Some of these definitions are paraphrased below.

Ocean Observation Functionality: The optional capability of the System to perform real-time measurements of parameters associated with the ocean environment, and to transmit the resultant data to shore.

Ocean Observation System: The sum total of all additional equipment specifically to equip the System with Ocean Observation Functionality.

Telecom System: all equipment, *except* that equipment exclusively required to implement Ocean Observation Functionality.

Note that the specification itself does not use the term 'SMART', as this may change in meaning over time.

These definitions are illustrated in Figure 1. Figure 1(a) shows an example Telecom System, comprising Cable Landing Stations (CLSs) and a submarine cable system with optical fibre pairs, repeaters, branching units and Cable Landing Station Equipment (CLSE). The additional components required to implement the Ocean Observation System are shown in grey and with dotted lines in Figure 1(b). These include additional functionality in the cable stations, and of course ocean sensors. These sensors are shown implemented in three possible locations: (a) internally to the telecom repeaters; (b) externally but in proximity to the repeaters (in 'Sensor Pods'), and (c) in a 'Sensor Node' on a dedicated branch cable.

Figure 1(c) shows an intermediate solution, wherein the Telecom System is pre-equipped with one or more stubbed branching units for future inclusion of Ocean Observation Functionality. Some interface equipment in the landing stations may also be provided.

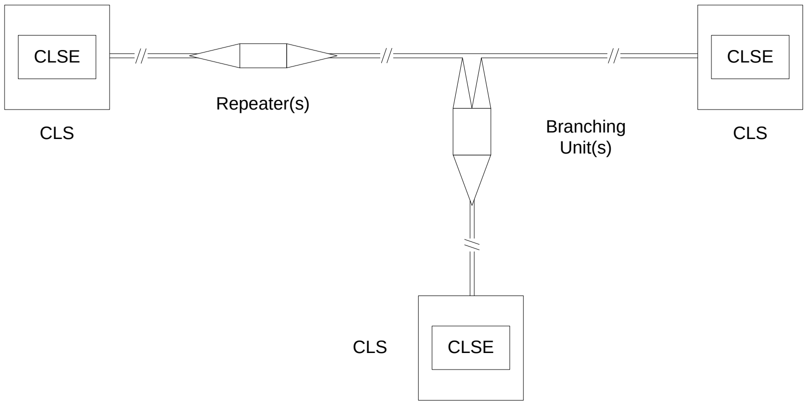

Figure 1(a): Telecom System components

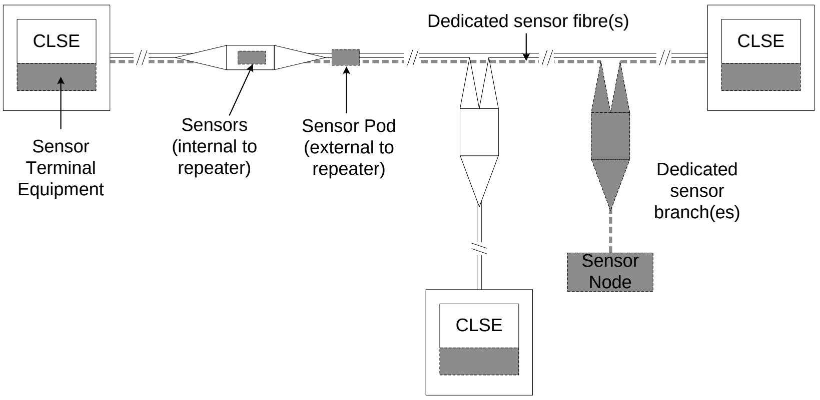

Figure 1(b): Ocean Observation System components, shown in grey/dotted lines

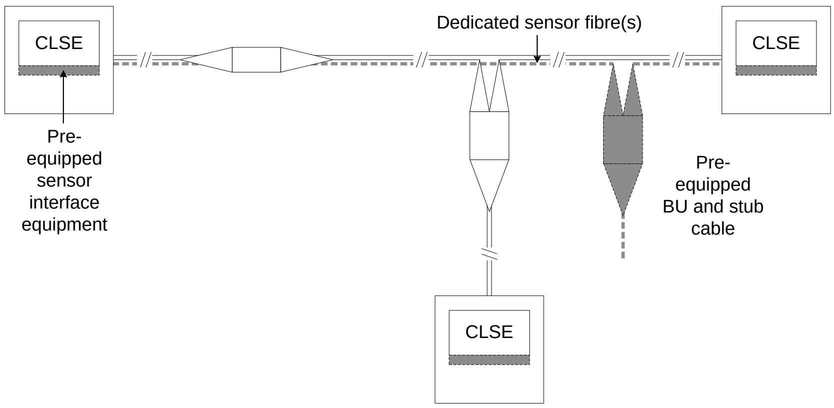

Figure 1(c): Pre-Equipped Ocean Observation System components, shown in grey/dotted lines

While some optical bandwidth in the system is required to transmit the sensor data back to shore, no *a priori* assumption is made about how this is achieved. A dedicated fibre may be provided (at a higher CapEx cost but achieving greater functional separation from the Telecom System), or the Ocean Observation System may use a small part of the bandwidth which would otherwise be available for commercial telecom traffic. This latter option may require additional measures to segregate the traffic generated by the Ocean Observation System to alleviate any concerns about data security.

4. SPECIFICATION FORMAT

Consistent with the format of Vodafone's General Technical Requirements for submarine telecom cables, the specification consists of three main sections:

- **Functional Requirements**, which mandate design principles and system behaviours. For example, in the section on Security, one functional requirement is that "*It shall not be possible for the Ocean Observation System to determine the commercial status of the Telecom System, such as the commercial occupancy of fibre pairs…*"
- **Tenderer Information Requirements**, in which the Tenderer is required to provide both qualitative information (such as the design philosophy of the Ocean Observation System), and quantitative information. This section is arguably the most important; the responses allow for the direct side-by-side evaluation of the system, implemented with and without Ocean Observation Functionality. Some of the information sought in this section is described further below
- **Contractor Information Requirements**, listing the additional deliverables to be provided with the system, such as an operations handbook for the Ocean Observation System

5. MAIN TENDERER INFORMATION REQUIREMENTS

Lack of space prevents a more detailed description of the specification's contents, so some of the main sub-clauses are summarised here.

The **General** section requests information about how the system is designed to minimise the interdependence of the Ocean Observation System and the Telecom System, and on the qualification status of the Ocean Observation System.

The **Mechanical** section concerns the additional space requirements in each cable station. Where Sensor Pods are proposed, details of the design of the feedthroughs required to connect these pods to a nearby repeater are requested.

The Tenderer is asked to quantify the additional **Electrical** needs of the system, including maximum power consumption and heat dissipation per CLS contributed by the Ocean Observation System. These parameters are relatively easy to convert into CapEx costs (HVAC plant) and OpEx costs (electricity bills).

The Tenderer is also asked to describe any required changes to the **Marine** operational procedures, such as wet plant handling, on-board storage and monitoring and load/lay techniques.

Other topics covered include: data acquisition and transmission; optical requirements; system integration and testing; training, and permitting.

6. RELIABILITY CALCULATIONS

In the section we focus on a subject of critical importance to potential investors: the reliability impact on the Telecom System which is directly attributable to the integration of the Ocean Observation System. We expect that the ability to demonstrate that any reliability impairment is minimal will greatly enhance the chances of implementing a SMART cable system.

Figure 2 shows the three main potential contributions to reduced availability of the Telecom System. The first contribution comes from a failure in the sensor package or its associated auxiliary functions such as power circuitry (including DC/DC converter), and data transmission functions. This contribution includes any change in the FIT rate of repeaters as a result of adding feedthroughs (penetrators) to repeater housings to accommodate Sensor Pods.

Secondly, there may be some additional common components required to support Ocean Observation Functionality, such as WDM devices and optical couplers.

Finally, the electrical load of the Ocean Observation System may require the common Power Feeding Equipment (PFE) to be upgraded to a higher voltage rating, with a higher FIT rate.

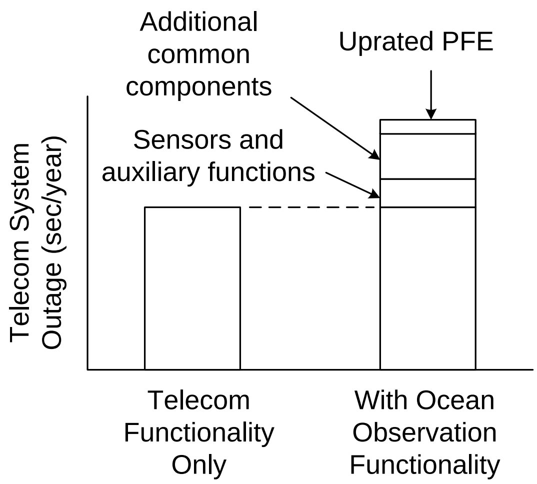

Figure 2: Comparison of reliability parameters (example)

Taking a simple example, the probable number of wet plant failures requiring ship repair in the system design life of 25 years is calculated by multiplying the total probability of failure for submarine repeaters by the number of hours in 25 years:

$$P = \lambda_{REP} \times R_{QTY} \times 10^{-9} \times 24 \times 365 \times 25$$

Where λ_{REP} is the FIT rate of an individual repeater, and R_{QTY} the number of repeaters in the system.

Industry norms require that the probability of ship repair over the cable design life does not exceed unity. In a cable system of 100 repeaters, according to the above equation, the repeater failure rate must therefore not exceed 45 FIT. Care is required to demonstrate that the reliability of SMART repeaters in a specific application does not cause the ship repair rate to exceed – or indeed approach – the maximum specified value.

7. KEY PARAMETER TABLE

Finally, an Appendix to the specification provides a table of the key quantifiable parameters which allows side-by-side comparison of the base Telecom System with that incorporating the Ocean Observation System. A version of this Key Parameter Table is shown in Table 1.

Key Parameter		Telecom System Only	With Pre-equipped Ocean Observation System	With Ocean Observation System
Date of full System qualification				
Number and type of racks in each CLS				
Maximum total power consumption per CLS				
Maximum total heat dissipation per CLS				
End-to-end trunk System voltage				
Trunk line current				
Backhaul requirements for ocean observation data				
Optical bandwidth required to support Ocean Observation Functionality				
FIT rate	Repeater			
	BU			
	Trunk PFE			
Outage time of Telecom System				
Availability of Telecom System				
Ship repair rate of Telecom System				
Changes to permitting requirements foreseen? (Yes/No)				
Total impact on Plan of Work (days)				

Table 1: Key Parameter Table

8. CONCLUSIONS

This paper summarises the essential content of a technical specification developed to allow potential investors in a new telecom submarine cable to evaluate the business case trade-offs of including 'SMART' ocean observation capabilities in that cable. It is intended to be appended as a stand-alone Annex to any telecom cable ITT.

By soliciting the information requested in the specification, the Purchasers can fully understand the business implications of commissioning a SMART cable, and weigh up these considerations against: (a) the societal benefits that SMART cables promise, and (b) the level of any additional funding available to realise SMART capability. In this way, the authors hope to lower the barriers to building SMART cables. The specification is both freely available and editable. Anyone wishing to obtain the full specification should send an e-mail to submarine@emea.nec.com with the phrase 'smart cable specification' in the subject line.

9. REFERENCES

[1] J. You, 'Harnessing telecoms cables for science', Nature **466**, pp. 690–691 (2010)
[2] S. Lentz and B. Howe, 'Scientific Monitoring and Reliable Telecommunications (SMART) Cable Systems: Integration of Sensors into Telecommunications Repeaters', OCEANS'18/MTS/IEEE Kobe/Techno-Ocean 2018, Kobe (2018)

