An Introduction to Subsea Electromagnetic Interference Strategies and Challenges

Scott Williams
OceanWorks International Corp.
Burnaby, BC, Canada
swilliams@oceanworks.com

Scott McLean
Ocean Networks Canada Innovation Centre
Victoria, BC, Canada
sdmclean@uvic.ca

As increasing numbers of systems are deployed to support power and information transfer between surface monitoring installations and subsea instrumentation, the need to support interoperability between devices becomes a major concern.

This article aims to provide an overview of the challenges associated with subsea electromagnetic interference mitigation and introduce strategies that can be used to overcome these challenges based on lessons learned during design and testing of systems for a wide range of subsea applications.

Keywords— Subsea Networks; Seafloor Networks; Seafloor Engineering; Instruments Management

I. SUMMARY OF EMI IN SUBSEA APPLICATIONS

In contrast to terrestrial applications, Electromagnetic Interference and Compatibility (EMI and EMC) standardization is limited for subsea applications, resulting in mitigation strategies often being reactive rather than preventative. The sources of EMI will remain the same however with DCDC converters or motors and their associated drivers being common sources in subsea applications.

The primary challenges in applying EMI mitigation strategies subsea stem from the lack of space typically available to the designer due to pressure vessel size constraints. Easy to implement strategies commonly used on terrestrial devices (e.g. increasing the separation between devices and re-routing cables away from areas of influence) often cannot be accomplished subsea so the designer must put increased focus on incremental changes to reduce the available paths for EMI to travel.

At the same time, subsea installations can provide opportunities for EMI mitigation by virtue of their immersion in seawater. Electromagnetic waves are attenuated at a higher rate when travelling through seawater than they are through air allowing for the majority of radiated emissions to be ignored when the conducting medium is seawater.

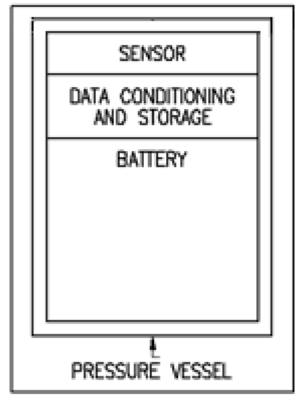

Fig. 1. Low Capacity Battery Contained Device

II. INTRODUCTION TO SEAFLOOR MONITORING

A. Traditional Instrumentation Methods

Traditional methods of seafloor monitoring have typically consisted of a battery powered sensor deployed on the seafloor and later recovered for data collection. By housing replaceable batteries inside the same pressure vessel as the sensor in question a small and simple to use device can be realized. See Fig. 1.

These devices are ideal for many applications where cost and simplicity are the driving factors as they may be deployed easily from smaller vessels. Battery size is the greatest limitation and capacity levels below 2kWhr are typical. Another common limitation to this approach is the inability to easily synchronize data from multiple sensors.

Though this method has worked well for low power applications it has proven insufficient for applications consisting of multiple sensors, higher power devices or long term deployments.

For higher power requirements, individually pressure balanced off the shelf batteries can be interfaced to the device in order to increase battery capacity without forcing an increased pressure vessel size. See Fig. 2.

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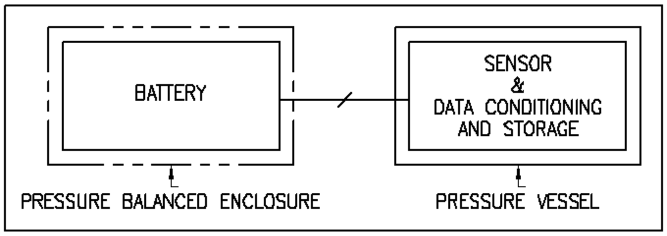

Fig. 2. Low Capacity Pressure Balanced Battery

Though the power capacity of a battery assembly can be improved by increasing the number of batteries, this will also increase the mechanical complexity and reduce the system efficiency due to losses in subsea cabling. These limitations make this an ineffective solution from a cost perspective for higher power systems.

By increasing the battery voltage to mitigate the efficiency losses along conductors a requirement is introduced to have DC to DC voltage conversion. Converters can further decrease the system efficiency and, in the case of switching power converters, a source of EMI is introduced in to the system.

This method of stand-alone devices with higher battery capacity will also face the limitation associated with synchronizing data from multiple sensing devices as each sensor or sensor site is supplied by its own battery pack.

B. *Seafloor Networks*

As an alternative method for long term deployments of multiple stand-alone sensors and instruments, seafloor networks have been implemented to provide a versatile platform for the continuous monitoring, observing and control of various underwater activities [1].

Nodes located on the seafloor, acting as branches or connection points, are incorporated into the network at intervals to provide connection from the surface station and corresponding backbone cabling to the junction box(es). Each node can be made capable of interfacing with a number of junction boxes which will in turn utilize 8-12 instrument ports to interface with a variety of subsea instruments. Typical seafloor network architecture can be seen in Fig. 3.

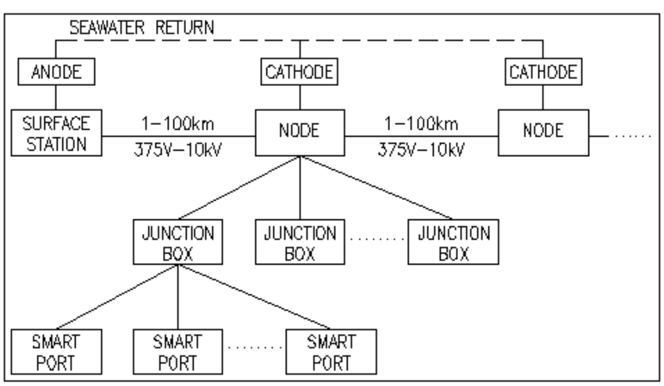

Fig. 3. Typical Seafloor Network Architecture

In order to reduce line losses across subsea umbilicals between nodes and from nodes to the shore station high voltage DC is used. DC to DC converters are then required to produce acceptable output voltages for instruments typically in the range of 12-48 volts. These switching converters introduce emissions not seen on traditional battery powered instruments.

C. *Interoperability Between Devices*

Many subsea instruments are designed to run from a battery providing a near ideal voltage source [2]. The lack of filtering associated with these designs allows for even low levels of EMI imposed on the supply voltage to be coupled to the sensor output.

Due to the limited standardization for subsea systems, EMI mitigation is usually a concern placed on the system integrator. System integration is often the first time these instruments are tested with the overall system creating the potential for issues to be discovered only after subsea deployment.

This increased risk can result in an associated increase in cost and development time or, in the worst case, a non-functional system. Whenever possible pre-deployment qualification testing should be completed on all instruments to ensure their susceptibility to electromagnetic interference does not affect the anticipated measurements.

III. Subsea EMI Propagation

A. *Radiated Emissions in Seawater*

As can be seen in [3], the attenuation of an electromagnetic signal through seawater increases exponentially per unit distance with respect to the log of the signal's frequency. This is in contrast to attenuation in free air which can be described using the Friss transmission equation to show a linear increase in attenuation based on the log of the frequency.

This increase in attenuation allows for radiated emissions to become non-critical for most applications where seawater is the conducting medium. Within a pressure vessel radiated emissions will remain a concern however. EMI mitigation at this level can be achieved using strategies similar to terrestrial devices.

B. *Conducted Emissions*

Due to the lack of standardization for subsea system to instrument interfaces and a potential lack of filtering at the instruments themselves, the largest source of EMI related failures during system integration will come from conducted emissions travelling through subsea cabling.

Fortunately the limitations on radiated emissions in seawater mean the majority of emissions will be conducted and an in-line filter can be placed close to the sensitive instrument in question using a simple pressure balanced oil filled discrete component solution (Fig. 4). This filter would attenuate the conducted emissions to an acceptable level based on the intended deployment configuration.

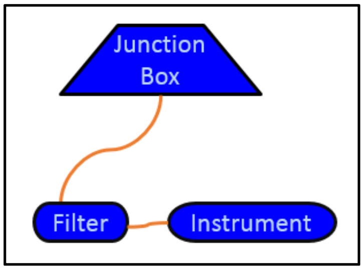

Fig. 4. In-Line Filter Placement

Although this solution is ideal for issues that arise during system integration and can provide a quick fix, it will cost more than a filter integrated in to either the Junction Box or Instrument due to the required additional enclosure, connectors and cabling. In order to reduce the system cost and complexity it is preferred to integrate the filter into either the Junction Box or instrument during initial development.

C. Internal to Assemblies

A common strategy when marinizing terrestrial power supplies, communications switches and other equipment is to contain them within a nitrogen purged pressure vessel. Though this approach allows a shorter design cycle by leveraging commercial off the shelf components it also limits the number of available options for EMI mitigation due to the general lack of separation available between emitters and other devices or cables (Fig. 5).

Because, the cost and required strength of the pressure vessel increases quickly with size, there are often space constraints preventing utilization of easier methods of EMI mitigation such as re-routing cabling away from noisy devices or increasing the separation between devices.

When the requirement for EMI mitigation presents itself during later stages of a project there can be insufficient room to implement the desired changes. Due to the increased cost associated with either changing the pressure vessel design or adding an additional vessel it is important to begin implementing EMI mitigation strategies or providing placeholders for future corrections as early in the project as possible.

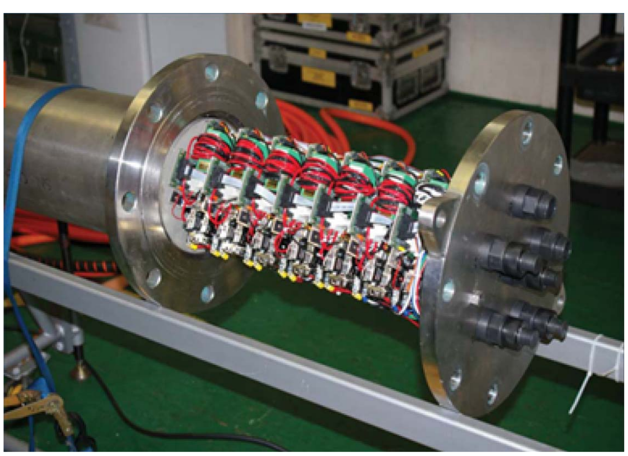

Fig. 5. Chassis Density Example

D. Land Acceptance Testing

The difference between land acceptance testing and subsea integration must be kept in mind when testing systems for EMC. Additional failures may occur during acceptance testing due to grounding loops or radiated emissions that are not present once the system is deployed in seawater.

IV. General Solutions

A. Guidelines

Because the limited space within subsea pressure vessels will often increase the difficulty of troubleshooting EMI issues late in the design cycle it is important that several guidelines are taken in to account early on.

Note that many solutions will be the same as for standard terrestrial systems and standard practices such as separating EMI sources from signal inputs and avoiding routing signal and power cables in the same cable run will be a good starting point.

1) Layout for Troubleshooting

For the purpose of troubleshooting it is important that all wiring and cabling runs be located in the same manner between systems of the same type. This allows any mitigation strategies found during testing and troubleshooting to be easily copied between systems. This will also help prevent cases where EMI radiated between conductors has a different response between systems requiring more than one solution to achieve acceptable results across all systems.

Note that layout for troubleshooting is especially important on systems where primary EMI sources remain undefined or on complex systems where there is a risk of EMI levels higher than anticipated. This includes systems where the envelope requires a motor driver, high power supply or other noisy device to be located within the same vessel as sensitive control and telemetry circuitry.

2) Early Cycle Testing

Whenever possible prototyping of the complete system should be completed early in the design cycle to help determine EMI sources and sensitive components or signal lines. Though full characterization and testing of the system cannot be completed until the final configuration is known, this early prototyping will allow for problem areas to be identified and dealt with as early as possible.

3) Solving Problems

Care must be taken when implementing any EMI mitigation that the appropriate frequencies are taken care of. An understanding of the system is vital in implementing the majority of EMI mitigation strategies. If implemented incorrectly many of these strategies can provide little benefit to the issue or potentially can make the problem worse.

It is also a requirement during this troubleshooting process that the system as a whole is considered. Changing the mitigation strategies in one section of the system has the potential to cause unanticipated issues elsewhere.

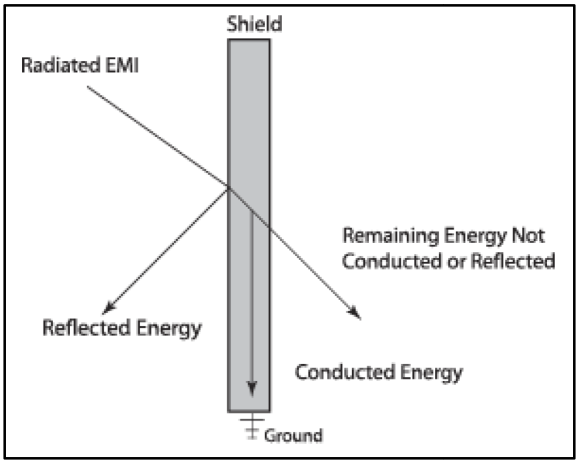

Fig. 6. Cable Shield Energy Paths from [4]

B. Cable Shielding

Cable shields can be used to reduce the effect of near-field radiated emissions within a subsea vessel. Cable shielding can act on EMI by reflecting the energy or by absorbing it and conducting it to ground (Fig. 6). Due to the confined nature of subsea vessels cable shielding will often be the easiest implemented EMI mitigation strategy.

Three common methods can be considered when applying shields to conductors internal to pressure vessels. Fig. 7 shows the relative effectiveness of these solutions. The bottom curve describes an aluminum foil shield, the middle curve shows a copper braided shield and the top curve describes a combination of the two shields. Note that shielding as a general rule is not required for subsea cables due to the attenuation of radiated signals in seawater.

In order to eliminate ground loops that have the potential to increase rather than attenuate system EMI levels it is important for most applications that the cable shield is terminated at one end only. In the case of a double shield such as a combination foil and braided shield it is recommended that the two shields be terminated at opposite ends of the cable if they can be isolated electrically from one another. This will provide the most complete shield while also reducing the potential for ground loops.

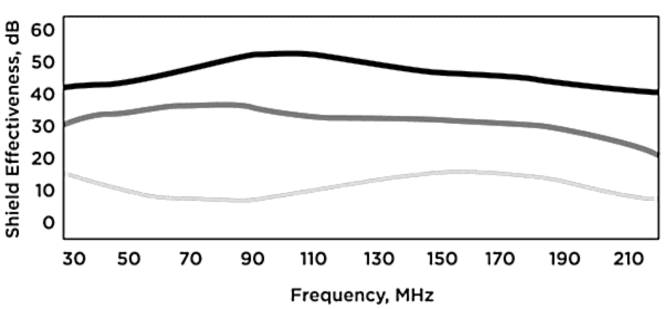

Fig. 7. Shield Effectiveness v. Frequency

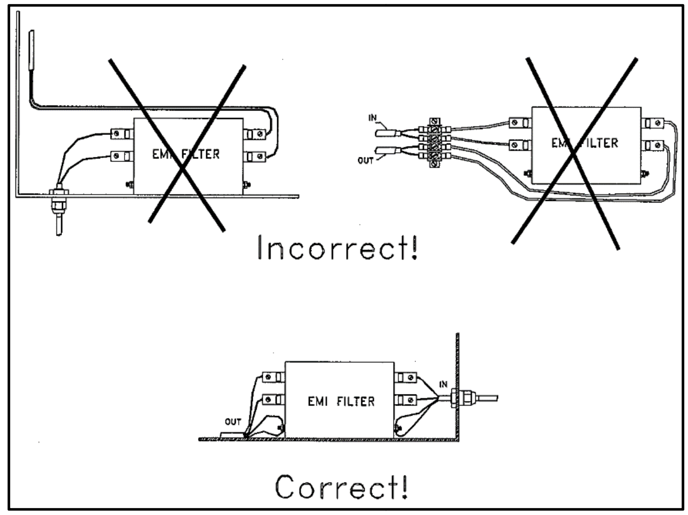

Fig. 8. Filter Cable Routing

C. Filter Location

Due to the near-field radiated emissions within enclosures and the limited space available for component placement and cable routing, filter location can quickly become a critical issue. As with terrestrial systems, filters should be placed as close to the EMI source as possible to reduce the amount of energy radiated from the conductor. Alternatively or additionally a filter can be placed close to the sensitive equipment to provide greater protection against an insufficiently protected cable picking up radiated emissions.

Special care must be taken to avoid breaking EMI isolation barriers with incorrect cable routing. Common terrestrial guidelines should be used for this routing including maximizing the distance between conductors on the input and output sides of the filter. Fig. 8 shows an example of this routing taken from [5].

Filter placement for connections going between vessels should follow the same guidelines listed above. When the filter is installed internally, it should be placed as close to the pressure vessel's connector as possible when the filter is placed internally to ensure that a minimum amount of unprotected conductor is available.

Due to the minimal effect of radiated emissions in seawater filters placed outside of the vessels can be placed nearly anywhere along the cable. For mounting purposes it is usually beneficial to have them placed near either the Junction Box or Instrument in question.

D. Standardization

For the purpose of EMI/EMC, acceptable levels within a system must be defined at the start of the project. This will allow for all sub-systems to be tested individually with a high confidence level but will need to be done on a project by project basis until industry wide standardization is realized.

V. SUMMARY AND CONCLUSIONS

Subsea systems can often see unforeseen EMI/EMC related issues only when integration is completed. Due to the high cost of implementing solutions late in the project cycle it is important to identify and define potential issues as early as possible.

This article gave a brief introduction and overview of the challenges associated with EMI/EMC when integrating subsea systems as well as several strategies for reducing project incompatibility risks.

REFERENCES

[1] D. Harvey, A. Woodroffe, S. W. Pridie, "The Next Generation of Subsea Instrument Interface Modules for Cabled Observatory Systems," Oceans'11 MTS/IEEE Kona, 110506-048, September 2011.

[2] S. Williams, R. Pomerleau, "Software Configurable Smart Ports in Subsea Networks," Oceans'14 MTS/IEEE St John's, 140417-033, September 2014.

[3] E. J. Hilliard, "Electromagnetic Radiation in Sea Water," USNUOS Consecutive No. 316, November 1977.

[4] AlphaWire, "Understanding Shielded Cable," Technical Note, 2009.

[5] Elmo Motion Control, "EMC User's Guide for ELMO Motor Drives," Technical Note, 1996.