

# FAULT LOCATION ON SUBSEA CABLE SYSTEMS

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**Abstract:** Cable system fault location techniques for coaxial cables were well established and accurate with several tools available. Fibre Optic systems are not constructed in the same manner and therefore require different fault location tools, practices and procedures.

The accuracy of fault locations on the current generation of optical Subsea cable systems needs review. Inaccurate fault locations can result in extended repair times and increased cost to the owners. To avoid this it is essential that the tools and techniques that are currently available are understood and used to their best advantage.

As new systems are being installed it is important that the requirement to be able to locate faults on these systems is understood and that the appropriate equipment procurement takes place to facilitate this. There is a serious risk associated with the ongoing manufacture and supply of this specialised test equipment (i.e. cessation of the Advantest COTDR and of some dc test equipment manufacture).

It is hoped that the paper will act as a catalyst to stimulate industry debate on fault location equipment, techniques and accuracy.

## 1 INTRODUCTION

The accuracy of fault locations on the current generation of subsea cable systems needs to be reviewed. Ship's time is being utilised trying to localise faults using electroding when it may be possible to be more precise with shore based locations. The tools and techniques that are available at present need to be understood and a recommendation provided as to how improvements may be achievable. This document aims to provide that review and suggest a way forward.

## 2 HISTORY

Fault location techniques on coaxial systems were well established. There were several techniques usable, for example Impedance Frequency (Dutch Bridge, Hatfield Bridge, PS19/SPM19 + Software, etc), Pulse-echo using TO3 and TO8 test sets. These gave good accurate fault locations when used by experienced personnel. These techniques were possible due to the coaxial construction of the cables and the techniques used throughout the system to maintain a constant 54 ohm impedance.

## 3 CURRENT TECHNIQUES

The primary fault location technique for faults on repeatered optical systems is the use of Coherent Optical Time Domain Reflectometer (COTDR). COTDR can provide a location to within 1 Km but can only be used where the damage to the cable has caused a significant optical fault. If an electrical "shunt fault" occurs and there is no serious optical damage only electrical techniques can be used.

## 4 OPTICAL FAULTS

### *Limitations of the COTDR*

To date there has been only one supplier of the COTDR. This has been Advantest but this supplier has

withdrawn the device from their current product list and stated that they will no longer manufacture or supply this unit. This may be an important issue in the future. However, Anritsu have developed a prototype COTDR but further progress and manufacture of this unit will only occur if and when sufficient orders are received. It is also understood that TYCO are incorporating some COTDR capability into their Terminal Equipment.

It should be noted that COTDR can only locate faults on the Transmit Fibre. If the fault is on the Receive path the fault can be identified only to the appropriate cable section. A location must be made from the distant end and therefore a COTDR must be available at both ends.

The accuracy of the COTDR depends on some unknown parameters. The COTDR measures the **optical** distance to the fault. This is different to the physical distance because in each joint and repeater there is an unknown amount of fibre. There are known joints within the cable (repairs) and there are manufacturing joints that were present when the cable was laid. There is also "fibre slack" that is present in some types of cable construction.

An estimate can be made as to how much should be allowed for these unknown lengths and it is usually calculated as a percentage of the length and is referred to as "fibre slack".

The distance to any fault location is measured (calculated) using the "refractive Index" of the fibre. This may vary along the length of the system. Fibre refractive index varies by a small amount when the fibre is manufactured. This variation is quite small but over a long distance this can become significant.

Different types of fibre (with different refractive index) are used in the construction of the system. The systems are constructed to compensate for Chromatic Dispersion along the system length. This is done by

using different types of fibre (ie LEAF, SMF, SMR, etc). To achieve an accurate distance, to any fault, these changes need to be accurately calculated and the correct value used in the COTDR. In practice a compromise value is used and this allows a sufficiently accurate position to be provided especially if the distance is taken from a known point, for example the nearest repeater.

Inaccuracies occur when a location is made without “zooming in” to the damaged section. Time also needs to be allowed for the trace to fully build and stabilise. This can take a considerable amount of time if the signal levels are poor or if a lot of “noise” is being generated by the fault.

It should be noted that no real development in the COTDR has been made since it was first introduced. The Advantest machine could benefit from updating especially in its usability.

### 5 ELECTRICAL FAULTS

If the cable is electrically damaged but there is no optical damage (i.e. a shunt fault) then COTDR cannot be used and the only techniques available are dc fault location techniques. However the systems are not provided with any automated dc fault location capability. All location calculations must be performed manually. The construction of the cable does not provide constant impedance and coaxial cable techniques (referred to previously) cannot be used.

The primary technique, in general use, is to utilise the Power Feed Voltages and Current to calculate the location of the fault. This requires very detailed and accurate calculations to be made in order to achieve an acceptable location.

#### Limitations when using PFE Voltages

There are many issues that can cause inaccuracies:-

- There are many different sections of cable used to provide a cable system.
- Each section may contain several cable types which may have different electrical resistance characteristics.
- The voltages and current values used are values taken from the digital meters within the PFE. The values displayed may not be the actual values of the voltage and current that are being fed into the cable (i.e. the cable head voltage).
- Voltage is lost into the earth return system and some PFE’s have a built-in variable resistance (slope resistance) to prevent instability between the two PFE’s that are working in “constant current” mode. This “slope resistance” needs to be understood and taken into account when calculating the distance to the fault.

- The calculations required are involved and it is very easy to make an error, especially if these calculations are being performed without the aid of a comprehensive spreadsheet.
- The results of the calculations can only be as good as the data that is available to feed into the process. It is clear that the supplier’s data may not be as precise as we require to enable us to achieve good accuracy for our fault locations.
- A bespoke spreadsheet is required for every cable System and, in the case of a branched system, this may involve several individual spreadsheets for calculating the position of a fault using data from different landing points and power configurations.
- Any resistance at the fault location will cause inaccuracies in the calculated location.
- Any inaccuracies with the calibration of the PFE volt / ammeters will also introduce further errors.
- Interactions between the PFE’s can also give misleading results.

#### Proprietary Fault Location Instruments

One of the major problems associated with proprietary DC fault location tools are the limitations of their power supplies. The dc characteristics of an optical repeater (Figures 1 -4 below) are such that the resistance is very high at low test currents.

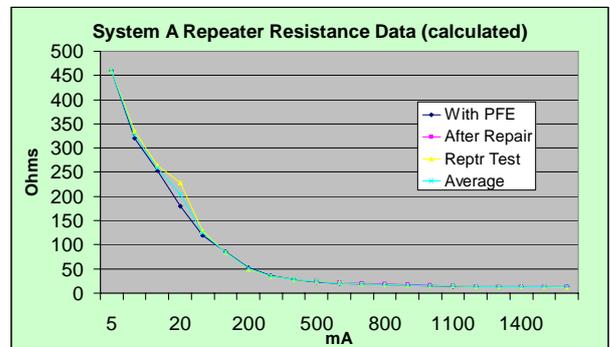


Figure 1

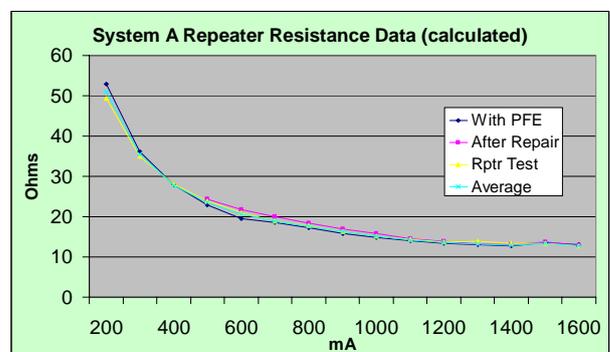


Figure 2

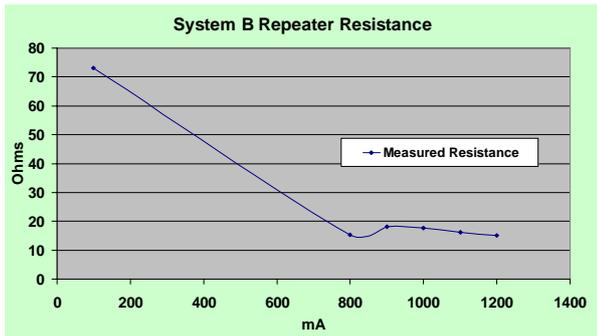


Figure 3

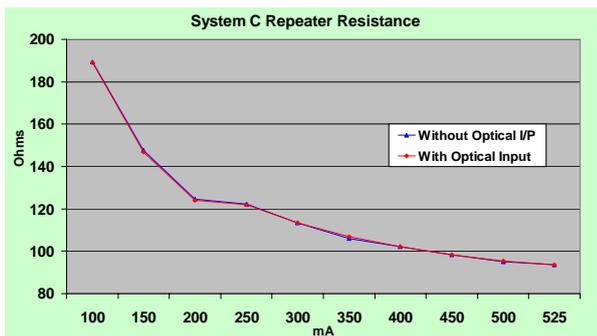


Figure 4

It can be seen from the data above that test currents below 300 mA are of little use.

## 6 TINSLEY FAULT LOCATION EQUIPMENT

Tinsley currently manufacture three instruments:-

The 5901C – Maximum testing current is 10 mA and, as seen from the graphs above, this is insufficient.

The 5902 – The maximum testing current with this instrument is 200 mA. This is approaching a useable testing current but is still too low to give predictable results.

The 5910 – Maximum testing current is 100 mA so again is also insufficient.

All these instruments give a result of x Ohms to the fault. This has to be converted into a distance to fault and requires complex spreadsheets to be built in order that this can be achieved. Any small inaccuracy in resistance measurement can make a very significant error in the fault location as 1 Km of cable has a resistance of less than 1 Ohm.

## 7 EXCEM L2G

Several years ago an automated dc fault location tool was manufactured by a French company called EXCEM. The development of this machine, known as the L2G, was initially funded by France Telecom. Unfortunately the prime instigators of this work moved on and progress within FT ceased. However BT also purchased a unit and has continued to try to understand the issues associated with using this device. Progress

has been made within BT and we have had success using this machine to locate electrical faults on optical systems.

The device itself is a power supply capable of delivering either 3125 Volts at 1.6 amps into the system or a second model can supply up to 6250 Volts at 800 mA.

It develops these supplies from a three phase mains input. It is connected directly to the cable head in place of the Power Feeding Equipment and so alleviates some of the unknowns of using PFE's.

The unit is controlled by a Personal Computer via an optical interface and this ensures safe operation.

Unfortunately the software that controls this device was created to run on a Windows 95/98 platform and further development has not occurred.

## 8 CONCLUSION - THE WAY FORWARD

Consideration needs to be made as to how the industry should move forward.

- Additional development in COTDR needs to be looked at and, if Advantest will no longer progress development, an alternative supplier needs to be considered and possibly supported. Anritsu do have a prototype COTDR available if sufficient orders are placed.
- Suppliers should be encouraged to provide COTDR capabilities within the terminal equipment if this can be shown to provide accurate results and be done cost effectively.
- DC fault location techniques and equipment need to be reviewed and support provided for the development of existing or new products. The Excem L2G warrants further development primarily by updating the software.
- Suppliers could incorporate the L2G techniques within the Power Feeding Equipment but the standalone option is probably a better way forward. Suppliers should be encouraged to provide a direct access connection point within the PFE at the cable-head.
- Maybe we must accept that the only viable way forward is to spend additional ship time to locate faults using existing or improved electroding techniques. However it is my opinion that investment in shore-based location equipment would be a more cost effective solution.

It is clear that the industry needs to consider the options and make some decisions and possibly investment to overcome these difficulties.