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Underwater mateable electro-optical connectors: the feedback from ANTARES

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Abstract

Underwater mateable electro-optical connectors operated by a submarine or a ROV are key components for present and future seabed detectors. After a test, ANTARES selected a type of connector from the Ocean Design (ODI) Company. The use of this device was not fully successful and it is considered today as the most critical part of the detector. Possible improvements in the use of this connector are suggested.

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Keywords: Cosmic neutrinos; neutrino detector; underwater mateable connector; electro-optical connector;

1. Introduction

ANTARES [1] is a cosmic neutrino detector located on the bottom of the Mediterranean Sea, under more than 2000 m of water, off the French Provence coast. The detector is connected to the shore by a 40 km long telecommunications type cable ending in a Junction Box (JB, [2], Fig.1).

The JB connected to 12 detection strings and has a total of 16 connection ports available. The link between the JB and each of the string anchors (Fig. 2) is made by a cable (2 electrical conductors + 4 single mode optical fibres) equipped at both ends with a pair of underwater mateable connectors (Fig. 3). The connection is performed by a Remote Operated submarine Vehicle (ROV). This paper will

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summarize the experience gained in ANTARES with this key equipment.

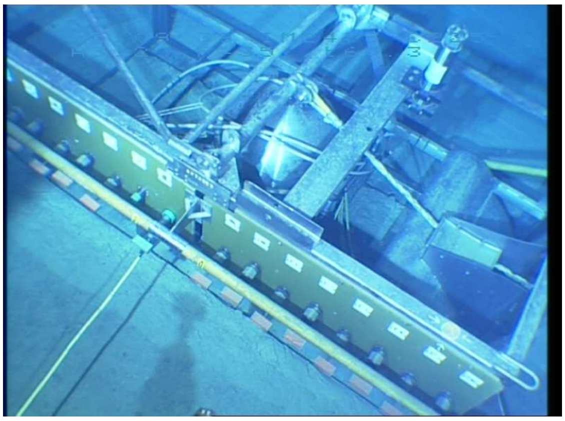

Fig.1. An interlink cable connected to the Junction Box

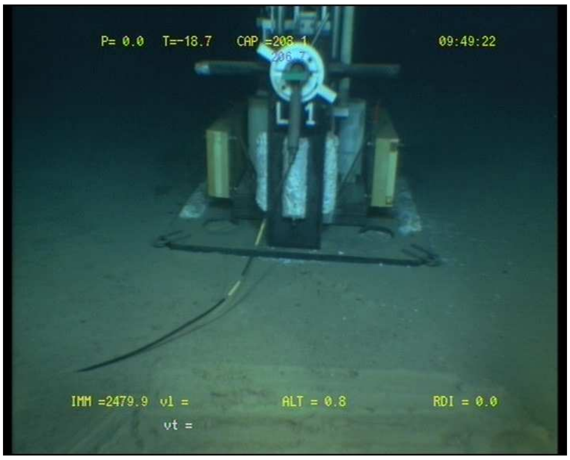

Fig. 2. An interconnected string anchor

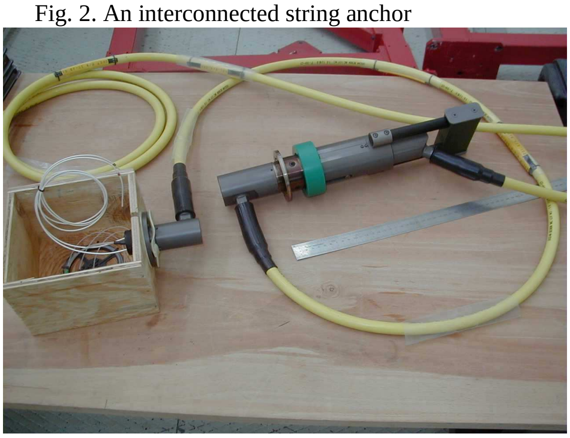

Fig. 3. A Jumper and with mated interlink cable

2. The ANTARES interconnection system

The complete configuration of the link is illustrated schematically in fig.4. It includes the cable (called the "jumper": Fig.3) between the Junction Box (JB, Fig. 1) and the first connector, a second between the string anchor socket (Fig.2) electronics container and its connector socket, together with the interlink cable terminated at each end by an underwater mateable 'plug'. The sockets are located in a position convenient for the ROV and for the automatic release system of the string.

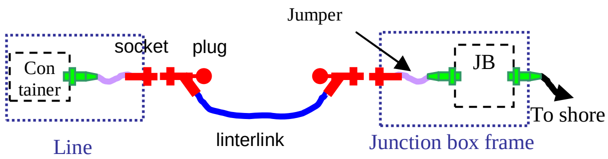

Fig. 4. Configuration of an underwater mated link

The 12 links needed in the detector have the following specifications:

- an operating depth of 2500 m;
- a length between 120 and 350 m;
- 2 power conductors for 500 VAC, 2.5 A and 3 mm^2 section each ;
- 2 single mode optical fibres for slow control and data transmission (8 x 1Gbit/s Ethernet DWDM[1], unidirectional);
- 2 redundant single mode optical fibres for clock distribution (bidirectional);
- optical losses less than 2dB on each channel.

Each of the 16 outputs of the JB is electrically protected by an thermo-magnetic breaker in the JB, re-armable remotely from the shore station via a triply-redundant control system.

[1] Dense Wavelength Division Multiplexing, central wavelength 1550nm, 400 GHz colour frequency spacing

3. Connector selection

Two underwater mateable connectors were tested:

- the *Hydrastar* from the SeaCon Company[2];
- the *MKII* from the ODI Company[3].

The tests included static pressure tests, connections under pressure, vibrations, temperature and thermal shocks. The SeaCon connectors exhibited oil leaks, so ANTARES chose the MKII from ODI.

4. Link connection

The interlink cable is initially stored on a drum equipped with an acoustic transponder-release. The connection procedure is the following:

- a surface boat launches the drum to the seabed, close to the site;
- using the acoustic transponder, the ROV recovers the drum and places it in front of the JB;
- the ROV performs the connection on the JB side;
- the optical and electrical connection from the shore station are checked: the optics tests use a time domain reflectometer and the electric test is sensitive to the extra capacitive AC current measured on the corresponding JB output;
- in the case of successful optical and electrical tests, the ROV unrolls the drum up to the string anchor;
- the ROV performs the connection on the string side;
- the string is fully tested from the shore station;
- Following the acoustic release of a deadweight, the empty drum autonomously rises to the surface and is recovered.

[2] Distributed by SeaCon Europe Ltd; Great Yarmouth, Norfolk, NR31 ORB, UK

[3] Ocean Design Inc, Daytona Beach, Florida 32114, USA,

5. The ODI Mk II connector

The ODI connector is composed of a mating socket and plug as shown in Fig.3. Both socket and plug are oil filled vessels in equipressure, closed by an aperture system called “the rollers”. During the first phase of the connection, the rollers rotate in such a way that both oil vessels communicate by a set of holes (one hole per fibre or contact). During the second phase, the fibre supports and the electrodes of the socket penetrate through these holes inside the plug and establish the optical or electrical contact. Then, a mechanical locking system keeps both parts in this position.

6. The ANTARES experience of connections

A total of 16 strings were connected by ANTARES, including prototypes. On the string anchor side, there was only one connection problem while, on the JB side, 5 of the 16 connections were problematic:

- In one case, both parts of the connector were mechanically damaged after several mate and de-mate operations. This was clearly observed via the video camera of the ROV. The link cable was recovered to the surface boat using the ROV and shipped to the manufacturer, who could not explain the damage observed;
- In two cases, (both after more than three years following JB deployment) the output breakers of two JB outputs tripped. All attempts of rearmament (to re-apply voltage to the JB output socket) were unsuccessful, meaning that the sockets are in short circuit. A possible explanation is that the oil was (at least partly) replaced over time by sea water.
- In one case the power was successfully connected but the attenuation of the fibre(s) was unacceptably large;

- In the final case, a mechanical part of a socket (a plastic ring used to centre the plug with respect to the socket) was torn off in an attempted connection. In principle this socket could be repaired by the ROV but several attempts have so far failed.

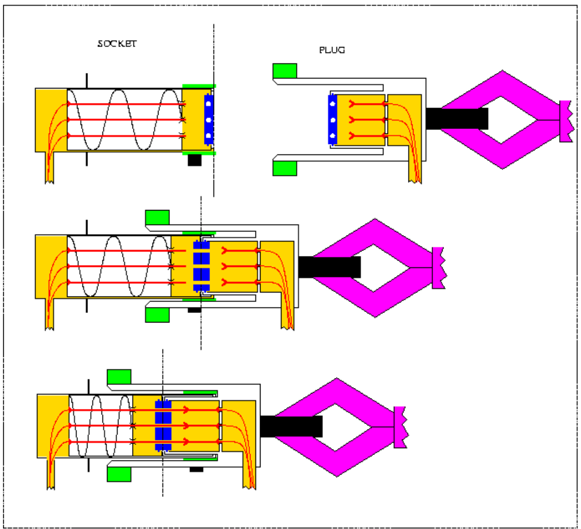

Fig. 5. Sequence in the connection of the Ocean Design MarkII underwater mateable hybrid electro-optic connector

7. Conclusion

We may ask why our connection problems are mainly on the JB side;

- A possible explanation could be that, on this side, there is no mechanical guide helping the connector insertion, while on the string anchor side, such a guide exists as part of the automatic disconnection system;
- Another explanation could be the difference in time spent in the water by the sockets before the connection: four to six years for the JB and only a few months for the string. Some absorption of water by plastic components could result in a mismatch of diameters, making the mating impossible. Or the deposit of sediments in the rear cavity of the JB socket (deposit which was observed when the ROV cleaned this part with a water jet) could disturb the mechanism.

It is clear that the JB connectors are the most critical part of the ANTARES detector. The recommendations for a future detector are:

- for a long term stay on the sea bed before connection, the socket must be protected against sediment by a convenient protection cap, closing also the rear cavity, not by the basic cap used by ANTARES nor with the (expensive) connector-like protection proposed by ODI;
- a modification of the concept of the link and the JB in such a way that there is only one connector per link (i.e. the mounting of link cables and their drums on the JB or on the string anchors), which would also reduce the cost;
- training the ROV pilots in the details and likely problems of these deep sea connections;
- making improvements in the reliability of the connector itself.

References

[1] M. Circella: these proceedings.
[2] M. Anghinolfi et al; Nucl.Instr.Meth A567 (2006) 527.