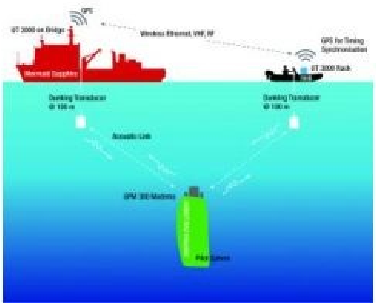
UNDERWATER COMMUNICATION SOLUTION FOR JAMES CAMERONÂ€™S DEEPSEA CHALLENGE

Communications to the Deepest Point on Earth



In March 2012, filmmaker and explorer James Cameron successfully completed his one-man dive to the bottom of the Mariana Trench. The dive was the centrepiece of the Deepsea Challenge expedition, a joint scientific project by Cameron, the National Geographic Society and Rolex to conduct deep ocean research and exploration. A range of technological innovations were required for the venture, one of which was a reliable method for sending voice and data between the 'Deepsea Challenger' submarine and its support vessels on the surface. At a depth of almost 11km, the Mariana Trench is the most remote and isolated place on Earth.

In 2011, only six months before the expedition, the Australian company L-3 Oceania (formerly L-3 Nautronix) was tasked with providing a technical solution that would enable James Cameron to remain in contact with the surface at all times. In addition to underwater communications conveying voice and text for status updates, mission support and co-ordination, it was also very important to monitor vital signs like the submarine’s oxygen and battery levels, depth, speed and range position from the surface.

Facing the Challenge

Two significant challenges were quickly identified. Firstly, a technical solution had to be found to ensure reliable underwater communication over such an immense distance. Secondly, the expedition schedule was extremely tight and offered a very limited period for building, installing and integrating the system into the submarine and the support vessels *Mermaid Sapphire* and *Prime RHIB* (Rigid Hulled Inflatable Boat).

Long-range hydroacoustic communication is a very challenging task due to limited bandwidth, slow propagation time, multi-path and inter-symbol interference, ray bending and frequency dependent attenuation. The low carrier frequencies required by underwater acoustic signals are influenced by Doppler shift arising from movements of the sender or receiver. Noise levels in particular, influenced by sea conditions, weather and noise from the supporting surface vessels with their equipment generating acoustic and structure-borne noise, have a significant impact on the quality of communications. Very faint signals received from a long distance will be masked by this noise. Acoustic system designers must take all these factors into account as well as assure the quality of the installation and eliminate interference from nearby equipment to provide good communication performance.

Engineering the Solution

The underwater communication solution that was engineered for the expedition was based on well-proven components: L-3 Oceania’s GPM 300 modem with electronics, transducer assembly and a full ocean depth housing along with the German sister company L-3 ELAC

Nautik's UT 3000 underwater communication system. Analogue communications for voice and digital communications for data were supported. Analogue communications used normal underwater telephone (STANAG 1074) modulation, and digital communications used the latest L-3 underwater spread spectrum signalling known as MASQ. Each MASQ digital data packet is time-referenced so that time of flight and thus range can be computed – a capability that was used to assist in locating the submarine.

The GPM 300 modem with its full ocean depth housing was installed on the exterior of the submarine, outside of the small (43-inch diameter) pressure sphere housing the pilot, saving precious space inside the highly restricted living space. For analogue voice communication, the modem was attached to an audio interface and speaker box allowing it to be operated by the pilot using only a small, lightweight ear-mounted microphone. Digital text messages were received and sent by a tablet PC with a touch screen, whereas vital status information (such as CO_2 level, temperature and battery levels) was automatically retrieved and sent out from the sphere control system. A second modem was installed as an autonomous backup with its own power supply and the ability to independently monitor depth. The second modem could also be controlled from the surface to trigger devices such as lights and an emergency weight release.

Communication with the Underwater Telephone UT 3000

The underwater telephone UT 3000 that was installed on the two surface vessels combines analogue communication modes such as telephony, telegraphy or pinger mode with digital communication capabilities based on Multiple Frequency Shift Keying (MFSK) techniques. Similar to a mobile phone, the UT 3000 allows SMS messages to be sent using a small built-in keyboard or, for convenience, using an external USB keyboard. On the receiver side, SMS reception automatically opens an SMS viewer. A binary file transfer mode allows the selection of a file from a USB memory stick or an Ethernet Network File System (NFS) server connected to the UT 3000. On the receiving side, files are automatically stored on an attached USB memory stick or an NFS server.

The baud rate for digital underwater communication is not comparable to Ethernet-based LAN or WLAN networking. The underlying mechanism is similar to old-fashioned acoustic couplers where digital data is converted to acoustic signals. Travelling through water, sound waves are compromised by the aforementioned factors, calling for data recovery and forward error correction information to be included in the data stream. This guarding information is used by the receiver for data reconstruction. Besides the slow signal propagation speed in water, the amount of forward error correction information included reduces effective baud rates to less than 4,000bps. A typical trade-off between data reliability and transmission time results in a baud rate of approximately 1,000bps. Most data transfers include readable ASCII-based messages and can be interpreted even when they include corrupted characters. In any case, low transmission speed practically restricts underwater file transfers to files of a couple of kilobytes, which despite their small size are still suitable for underwater tasks.

The UT 3000 system was designed in a modular manner, allowing the unit to be tailored to customer-specific needs. Benefits include the capability to expand processing power for signal processing algorithms, and also the support of different transducer configurations. L-3 ELAC Nautik supplies a range of transducers for various underwater tasks, including transducers especially designed for underwater communication. These transducers cover different frequency bands and installation aspects for installation on surface vessels or submarines.

The standard UT 3000 system includes two Digital Signal Processor (DSP) boards each equipped with five multi-core DSPs. These boards are dedicated to analogue and digital communication modes.

Digital Communication via MASQ

The UT 3000 allows the addition of extra DSP boards for signal processing enhancements. This capability was exploited with the development of the sophisticated MASQ spread spectrum digital signal processing in an inter-company development between L-3 ELAC and L-3 Oceania. MASQ is supported on the UT 3000 by adding an extra DSP board to run the spread spectrum communication algorithms.

Underwater spread spectrum technology was first introduced to the world by L-3 Oceania in the 1990s to provide reliable and discreet communications where other systems failed. The spread spectrum techniques used in MASQ include multi-channel direct sequence spread spectrum and forward error correction which make it highly resistant to the problems posed by the underwater channel. Signals can still be decoded in highly reverberant environments with low signal-to-noise ratios and reception levels well below the background noise.

For the Deepsea Challenge project, the transfer of data to and from external systems such as the submarine control system was vital and so the MASQ Graphical User Interface (GUI), resembling a kind of email client, was run on a PC at each end. In addition, both vessels were connected via a TCP/IP network that ran over wireless Ethernet, which meant that all data could be collated in the communications centre on the primary dive support vessel, the *Mermaid Sapphire*.

Dealing with the Environment

The transducer initially selected for the Deepsea Challenge was the WB 54, a small omni-directional transducer. The WB 54 is a circular, barrel-shaped array, primarily designed for installation under the hull of surface vessels (typically covered by a sonar dome for acoustical improvement and mechanical protection) or onto a hoisting gear for retraction into the ship's envelope in case of transit.

The WB 54 was chosen for the expedition as a trade-off between size, performance and lead time. The small size allowed it to be lowered below the hull of the *Mermaid Sapphire* using a moon pool. A second WB 54 was installed on the *Prime RHIB*.

The test dives performed during the Deepsea Challenge expedition showed that intelligible and reliable underwater communication could be established between both the *Deepsea Challenger* and *Prime RHIB* equipped with the WB 54 down to a depth of approximately 8,200 metres. Unfortunately the noise from the *Mermaid Sapphire*'s own dynamic positioning system inhibited the use of the WB 54 from that platform, with the *Prime RHIB* proving a more suitable platform for receiving the quiet underwater sound signals.

To counter the impact of ship noise, an external, mobile transducer was used, equipped with a long cable which allowed it to be dropped overboard. The configuration mechanically decoupled the transducer from the ship, reducing direct acoustic interference and increasing penetration of the acoustic layers below the surface. An external dunking transducer with 125m of cable and a matching transformer was connected, and lowered approximately 100m below the surface. This allowed communications from the *Mermaid Sapphire* to be carried out by the dunking transducer, whereas the *Prime RHIB* system used both the WB 54 and a dunking transducer.

At maximum depth, the noise of the *Mermaid Sapphire* still prevented the reliable use of the dunking transducer for reception, masking the low level receive signals. Primary reception was therefore carried out by the *Prime RHIB*, drifting with disengaged engines. The voice signals received by the *Prime RHIB* system were relayed to the *Mermaid Sapphire* by RF transmission and the data relayed by wireless Ethernet. In effect, most communications at full ocean depth were carried out downwards from the *Mermaid Sapphire* to the *Deepsea Challenger* and then upwards from *Deepsea Challenger* to the *Prime RHIB* and onto the *Mermaid Sapphire* via RF link.

Historic Dive

At 7:52 a.m. on 26 March 2012, James Cameron touched down at a depth of 10,911 metres and was able to answer to a voice message sent down by his wife who was on the *Mermaid Sapphire* as well as relay the world's first tweet from the deepest part of the ocean. The use of standard voice communications also made it possible for Paul Allen, who was present at the dive location on board the *Octopus* yacht, to follow the whole communication with another underwater telephone, the L-3 ELAC Nautik UT 2000, and to share updates about the dive on Twitter.

Throughout his three-hour stay on the bottom of the Mariana Trench and while taking 3D film footage and scientific samples, James Cameron remained in constant contact with the surface. Cameron later commended the L-3 communications solution, saying "We were pleased to have solid voice comms to full-ocean-depth using the L-3 system. It was amazing to talk to my wife Suzy from the deepest point in the world's oceans."

Conclusion

Thanks to the close co-operation of the engineers working on the submarine and the flexibility of the UT 3000, a sophisticated communications solution was developed in a comparatively short amount of time. This solution has successfully proved that reliable two-way voice and data communication to the deepest part of the ocean is possible.

Acknowledgements

The L-3 team wishes to thank James Cameron, Ron Allum, Tim Bulman and the other members of the Deepsea Challenge team as well the expedition sponsors, National Geographic and Rolex, for the opportunity to have participated in this historic event.