Covert communication using free space optical modems

I. Tena, Sonardyne International, United Kingdom (ioseba.tena@sonardyne.com)

Abstract — Covert communications are an enabler for the coordination of force multipliers, such as unmanned underwater vehicles. Traditionally, subsea communications use acoustic signals as sound travels further through water than electromagnetic waves. However, these signals can be detected over the same ranges in which the signals are effective, which is often over many kilometres. A new commercial innovation in free space optics is being used to enable communications over significant distances of up to 150m and with significant bandwidth up to 10Mbps. This system is much more difficult to observe; you would need to be within the range of the sensor to detect its transmissions. It is therefore a much more practical communication tool that, under the right concept of operations (CONOPS), can be used to maintain covert operations.

1 Communications subsea

Acoustic waveforms have traditionally been used to enable communications subsea. Low and medium frequency systems can be used to communicate over vast ranges and data rates can sustain up to 3000bps, even over 11km. Acoustics systems can be used to support a wide range of missions, including dynamic positioning (DP) for vessels in GPS-denied environments, tsunami monitoring, command and control of unmanned underwater vehicle (UUV) swarm operations and data harvesting. In the military domain, they are extensively used by hydrographic teams and in support of mine countermeasure operations. These operations are typically conducted overtly. Acoustic communication broadcasts can be easily detected beyond their effective range. Passive acoustic listening stations can be readily configured to detect, range and calculate bearing and elevation to acoustic modem pairs. They are of limited use for operations which require covert communications

2 Emerging concepts of operations

Emerging CONOPS for submarine operations are generating a demand for additional levels of covertness when communicating subsea. Future capabilities envisage submarine to UUV communications. In these CONOPS, the UUV acts as a force multiplier, supporting the submarine in carrying out anti-submarine warfare (ASW) and other missions. Acoustic modems quickly compromise the mission and are of little effective use. However, without the ability to communicate with the UUV the envelope of missions which can be attempted is severely limited. Even as UUV systems improve and become more autonomous they are required to, at some point, share their information as well as receive new mission objectives. The UUV, without people on board, may take higher risks and even use acoustics to communicate and engage in ASW using bistatic techniques. The submarine, on the other hand, should attempt to remain covert at all times. It is therefore imperative to develop alternative communication techniques.

3 Free space optical modems

Free space optical modems have emerged as an alternative to acoustic modems. These systems use rapidly modulated light to transfer significantly larger volumes of data than acoustic modems can. The bandwidth ranges between 5-500Mbps. Light attenuates rapidly in water meaning that the effective range of these modems is between 7-150m. This range is significantly lower than that of acoustic modems. In the military domain, this limitation provides a clear advantage over acoustic modems, namely covertness. To identify a free space optical modem, the listener needs to be within the operating range of the modems. Since the range is so limited, and providing the user of the modems is careful in their use, the listener would need to be acting on intelligence to be within that range.

4 Options for communications

Free space optical modems, such as BlueComm 200 from Sonardyne, use the visible light spectrum to provide high-bandwidth communications over ranges in deep-water applications. Blue light can travel further than other electromagnetic waves and is therefore preferred to maximise the range of communications. In fact, the blue light contained within sunlight can travel deep into the ocean. Most blue light travels down to 150m and it is not uncommon for small amounts of sun light to travel as deep as 300m to even 1000m depth.

BlueComm 200 uses arrays of high power light emitting diodes (LEDs) that are rapidly modulated to transmit data. To maximise their effective range, highly sensitive receivers are used to detect and decode extremely small light signals. The modems use time division multiple access (TDMA) methods to provide a bi-directional high-speed low-latency link that supports TCP/IP based network protocols. Allocation of bandwidth ratios in each direction is user selectable and fully flexible. The allocation of bandwidths is ideal for applications where high-speed data transfer is mostly required in only one direction. This system is ideal for deep-water operations where it can't be interfered with by sunlight. Since it operates within the visible light spectrum it is also sensitive to artificial lights. These lights are not uncommon subsea, particularly on unmanned systems that are operating or conducting surveys close to the seabed.

An alternative system, which is also available, is the BlueComm 200 UV. This system works outside the visible light spectrum (and thus outside the artificial light range) in the ultra violet light range. Ultra violet light does not penetrate as far as visible light, so it becomes an effective modem in shallower waters. The disadvantage over the standard BlueComm 200 system is that its range is limited to 75m. The advantages are that it is more covert as the users will be able to work within 75m of the water's surface while unseen and without interference from artificial light sources. This makes it the ideal platform to support new CONOPS where unmanned platforms are used as force multipliers by traditional submarine fleets.

These systems will enable for UUV systems to be piloted, covertly, in real-time by operators through the delicate docking and undocking phase from submarine bays. The systems will also enable submarine-to-submarine, submarine-to-UUV and UUV-to-UUV communications.

Data harvesting will be possible with BlueComm 5000, an additional system in the BlueComm family which uses lasers over a much-reduced range of 7m to transfer up to 500Mbps. This enables submarines and UUVs alike to upload data from instruments used to monitor vital choke points.

4 Practical examples

In 2016, Sonardyne conducted a series of trials and demonstrations at the NASA Neutral Buoyancy Laboratory (NBL) using SAAB's Sabertooth UUV and BlueComm optical modems. The Sabertooth was remotely piloted via the optical link without a physical tether. The Sabertooth came out of its docking station, carried out an inspection of its surroundings, harvested data and then went back to its dock, while being piloted through the optical link.

Fig. 1. Sabertooth at the NASA NBL uses BlueComm free space optical modem to enable real-time tether-less piloting.

More recently, the optical space modem was used to enable large volume data transfer between an L3 ASV C-Worker autonomous surface vessel and the United Kingdom's National Oceanography Centre's (NOC) Autosub Long Range (ALR) UUV. The ALR demonstrated data transfers to the surface via an optical link.

Fig. 2. C-Worker and ALR seen from above. Picture captured during trials used to demonstrated the optical link between both platforms.

4 Future work

In the commercial sector, free space optical modems are being used to enable long-term deployment UUV concepts. These UUVs are intended to monitor subsea infrastructure for prolonged periods of time. The optical modems will be connected in vital locations to enable tether-less control around the operations area. In the military domain, naval laboratories and academia are evaluating the effective range of these modems over varying conditions and considering their use for future concepts of underwater maritime capability. From data harvesting to UUV-to-submarine communications. The covertness these systems can provide offer a significant advantage.

Author/Speaker Biographies

Ioseba (Joe) Tena is Global Business Manager - Marine Robotics Systems at underwater positioning, navigation and communications technology company Sonardyne. Joe has more than 20 years' experience working with marine robotic systems. Prior to joining Sonardyne, he was one of the founders of advanced software for underwater vehicles company SeeByte. Joe has a PhD in Electrical and Electronic Engineering from Heriot-Watt University in Edinburgh, where he was also a Research Associate at the university's Ocean Systems Laboratory, focusing on the use of sensors to improve situational awareness for underwater robots.