

**Institution: Newcastle University**

**Unit of Assessment: 13 Electrical and Electronic Engineering Metallurgy & Materials**

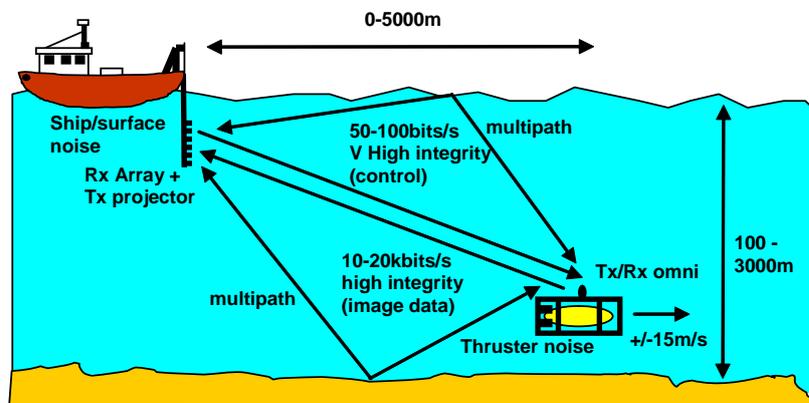
**Title of case study: Commercialisation of underwater acoustic communication and positioning technology**

### 1. Summary of the impact

The commercialisation of Newcastle University's pioneering research in underwater acoustic communication has created market leading products, achieving economic impact, enhanced subsea operations, an award for improved diver safety and reduced impact of subsea acoustic emissions on marine mammals. Our research outputs have been incorporated in a range of products manufactured under licence by Tritech International Ltd. Since 2008 the MicronNav product has become the preferred solution for tracking underwater remotely operated vehicles from manufacturers including Seabotix Inc and Videoray Inc, with over £2M of licensed products sold to date. Bespoke high performance data telemetry systems have also enabled previously impossible subsea operations to be completed.

### 2. Underpinning research

Due to the absorption of radio waves in water, the subsea industry relies on acoustic signalling for wireless communication and navigation. Underwater acoustic modems transfer digital data between underwater equipment and surface vessels/platforms. Early modem designs employed simple analog technology which was



unable to meet industry demands for data rate, range and reliability. Such systems failed to address the extreme multipath/reverberation, noise and Doppler effects encountered in the underwater channel, typically 100-10,000x greater in magnitude than in radio communications. The research underpinning these improved products was performed from 1994-2005 by Prof Oliver Hinton, Prof Bayan Sharif and RA Jeffrey Neasham.

During work funded by G1, the team introduced bandwidth efficient, phase shift keying modulation where less efficient schemes such as frequency shift keying had previously dominated, increasing data throughput by an order of magnitude. This was enabled by the development of sophisticated adaptive receivers [P1][P5], employing arrays of receiving transducers, to overcome the multipath/reverberation problem. These innovations led to reliable transmission at data rates of the order of 20kbits/s through severe multipath channels spanning hundreds of symbols and with rapid fluctuations in path amplitude and phase. Understanding of underwater adaptive array receivers was further enhanced during G2 and G5-7, leading to the demonstration of very long range, multi-user networks [P2].

During G3 and G4, the group then developed novel algorithms to estimate and remove the extreme Doppler effects occurring with moving platforms and which previously led to loss of synchronisation. A journal article on this subject remains one of the most cited references in the field of underwater communication with 187 citations [P3]. The later development of closed-loop tracking techniques allowed synchronisation to be maintained between highly dynamic platforms such as small robotic underwater vehicles and naval submarines [P4] with Doppler shifts of 1-2%.

The robust signals designed for synchronisation were then adapted to form an extremely reliable, spread spectrum communication system for low bit rate command/control applications. This is able

## Impact case study (REF3b)

to operate with SNR as low as -10dB (noise power is 10 times higher than the received signal power). Furthermore, by virtue of its broadband signal correlation, the same hardware was able to deliver range and direction information accurate to 10cm and 1 degree respectively.

From 2003 onwards the group collaborated with Tritech to develop a number of high performance demonstrator systems based on the above technologies, including modems for:

- The ALIVE autonomous intervention vehicle, achieving a world first by carrying out maintenance on a 500m deep installation entirely by acoustic communication of commands, video and sonar data.
- The Halliburton Geosub Autonomous Underwater Vehicle for subsea geological surveying.
- The continuous reception of current meter data in a shallow estuary channel, with busy shipping traffic, where acoustic emissions had to be limited due to concern over harbour porpoise populations [P5].

### 3. References to the research

#### **Peer reviewed publications: (Key publications are P1, P3 and P4)**

- P1. Neasham JA, Thompson D, Tweedy AD, Lawlor MA, Hinton OR, Adams AE, Sharif BS, *Combined Equalisation and Beamforming to Achieve 20kbts/s Acoustic Telemetry for ROVs*, Proceedings of MTS/IEEE OCEANS, 1996, Volume 2, pp 988 - 993. **(21 citations)** – This paper showed how high data rate underwater transmission in severe multipath was possible.
- P2. Thompson, D.; Neasham, J.; Sharif, B.S.; Hinton, O.R.; Adams, A.E.; Tweedy, A.D.; Lawlor, M.A.; *Performance of coherent PSK receivers using adaptive combining, beamforming and equalisation in 50 km underwater acoustic channels*, Proceedings of MTS/IEEE OCEANS '96, Volume: 2, 1996, pp 845 – 850. **(21 citations)**
- P3. Hinton OR, Neasham J, Sharif BS, Adams AE, *A Computationally Efficient Doppler Compensation System for Underwater Acoustic Communications*, IEEE Journal of Oceanic Engineering, 25, No 1, 52-61, 2000. **(187 citations)** – This publication showed how synchronisation could be maintained under severe Doppler effects with moving platforms.
- P4. Sharif BS, Neasham JA, Hinton OR, Adams AE, Davies J, *Adaptive Doppler Compensation for Coherent Acoustic Communications*, IEE Proceedings on Radar, Sonar and Navigation 2000, 147(5) **(26 citations)**. – This paper showed how receivers could tolerate high acceleration platforms and defined a technique used today in Tritech modems and UK MoD systems.
- P5. Paul A Van Walree, Jeffrey A Neasham, Marco C Schriver, *Coherent Acoustic Communications in a Tidal estuary with Busy Shipping Traffic*, Journal of the Acoustical Society of America 2007, 122(6), 3495-3506.

#### **Funding**

- G1. High Data Rate Sub-Sea Acoustic Communications for UUVs (TUUV1), EPSRC GR/H85281/01, November 1992 – October 1994, £123,856.
- G2. Long Range Acoustic Communication (LORACOM), EC, 1994 – 1996, £160,000
- G3. Robust Bidirectional Communications for UUVs (TUUV2), EPSRC GR/L11670/01, May 1997 - Sept 1999, £187,703.
- G4. Doppler Tolerant Receiver, DERA funded project, July 1998 – Dec 2000, £120,000
- G5. Long Range Telemetry in Ultra-Shallow Channels (LOTUS), EC, Oct 97 - Jan 01, £1.2M.
- G6. Shallow Water Acoustic Networks (SWAN), EC, Dec 1997 – Nov 2000, £300,000
- G7. Acoustic Communication network for Monitoring of underwater Environments in coastal areas (ACME), EC FP5, Dec 2000 – Nov 2003, £250,000

## Impact case study (REF3b)

### 4. Details of the impact

*“Newcastle’s research on underwater acoustic technology has had a strong and lasting impact on Trittech’s business and the subsea industry as a whole, reaching the offshore oil & gas industry, oceanographic data collection, renewable energy, search & rescue and professional & recreational diving.”* – Technical Director 1990 – 2009, Trittech International [E5].

#### **Impact on business**

A licence agreement and Knowledge Transfer Partnership with Trittech has directly resulted in 3 innovative products being marketed by the company since 2008. The first two of these were the micron data modem [E2, E5] and MicronNav USBL tracking system [E3,E5] which incorporate Newcastle’s Doppler tolerant spread spectrum signalling and range/angle estimation algorithms. These products now provide tracking for the majority of miniature underwater vehicles being sold worldwide. Over 300 licences have been issued by the University to date with a sales value of £2M.



**The market for these devices is growing rapidly, currently accounting for around 10% of company turnover in a business employing ~100 people.** The most recent product introduced is the high performance AM400 acoustic modem [E4, E5] which incorporates all of the underpinning research outputs and has demonstrated unparalleled performance in terms of data rate (up to 32kbits/s) and range (up to 10km). This has enabled the company to win contracts for high value bespoke systems, to operate in very severe channel conditions where competing products are completely unable to operate, and the university has issued 6 licences corresponding to around £300k of sales since 2010. These products represent major steps forward in performance, miniaturisation and cost, which wouldn’t have been possible without Newcastle’s innovative signal processing [E5].

#### **Impact on the subsea industry**

The MicronNav USBL and micron modem products have provided a reliable, cost effective and miniaturised solution for the tracking of small underwater robotic vehicles. **This is now the preferred solution adopted by vehicle manufacturers such as Seabotix Inc [E6] and Videoray Inc who account for the majority of the world market.** Many end users, including the US and Canadian Navy [E7], have found the ability to accurately track these vehicles invaluable in rapidly locating and/or tagging seabed targets. The combination of accurate tracking and data communication in one miniature unit has also led to its deployment on several autonomous underwater vehicles under development around the world [E8]. Likewise high performance AM400 modems delivered by Trittech have enabled very challenging operations to be carried out. A good example of this is the remote collection of large data files from subsea tidal turbine near Orkney, overcoming severe noise and wake effects and a hostile 5km shallow water channel.

#### **Impact on diver safety**

Inspired by the death of a well known diver, the IET and the British Sub Aqua Club (BSAC) launched an international competition to challenge engineers to develop an affordable system to track and monitor the world’s estimated 3 million divers. The Newcastle group and Trittech teamed up to develop low cost prototypes for a diver personal transponder and surface interrogator based on the successful spread spectrum concepts. 4 teams from around the world entered devices but, after successful trials by BSAC divers in Scotland, the Newcastle-Trittech design was declared the winner [E9] and the team were presented with an award and prize money by the IET. **BSAC described this as one of the most significant contributions to diver safety in the last 50 years and could help to reduce the estimated 100 deaths each year in diving accidents.** Since 2008 Trittech have delivered several systems for diving applications, enabling multiple divers to be tracked from the surface, to receive commands and to signal if they get into difficulty. Working with another commercial partner, a mass market product accessible to all recreational divers is undergoing final testing at the time of writing ahead of a product release.



**Impact on the environment**

Another positive impact brought about by the research is the reduced impact on marine life, since some environmental groups estimate that up to 10 million whales/dolphins are affected by high power acoustic systems per year. Both the spread spectrum technology and the adaptive array receivers dramatically reduce the required acoustic source power for a given range. **The AM400 product emits a total acoustic power of approximately 10W which is up to 10 times lower than competing systems intended for the same range.** Similarly the Micron modem and USBL products may operate over 1km radius without exceeding the safe limit on acoustic intensity suggested by marine biologists of approximately 100mW/m<sup>2</sup>.

**5. Sources to corroborate the impact**

- E1. 2007 Licence agreement between Newcastle University and Trittech International Ltd.
- E2. <http://www.tritech.co.uk/product/micron-data-modem> - specification sheet for micron data modem product.
- E3. <http://www.tritech.co.uk/product/usbl-tracking-system-micronnav> - specification sheet for MicronNav tracking system.
- E4. AM400 acoustic modem data sheet, Trittech International, 2010.
- E5. Corroborating statement from Technical Director, Trittech International Ltd.
- E6. Corroborating statement from Senior Vice President of Seabotix Inc.
- E7. [http://www.seabotix.com/about\\_seabotix/news/news12/rimpac.htm?story\\_link=email\\_msg](http://www.seabotix.com/about_seabotix/news/news12/rimpac.htm?story_link=email_msg) – documentation of the MicronNav USBL system being applied in underwater vehicle trials by the Canadian Navy
- E8. <http://www.fer.unizg.hr/zari/labust/equipment/auv> - description of micron modem product deployed on autonomous underwater vehicle (htm supplied).
- E9. <http://www.bsac.org/news.112.htm> - article on the final of the IET/BSAC Divetrack competition.