Institution: University College London

Unit of Assessment: 13 – Electrical and Electronic Engineering, Metallurgy and Materials

Title of case study: New active target modulation scheme for marine navigation and port handling

1. Summary of the impact

A new product has been developed to aid marine navigation and berthing at ports, based on the use of a single-sideband (SSB) active target, offering the dual benefits of substantially enhanced performance, and reduced size and production costs. The research has achieved significant commercial impact via the incorporation of the technique, conceived by Brennan, into all such targets made by Guidance Microwave Ltd, a UK-based engineering company specialising in the development, manufacture and supply of short-range active target location systems. To date, the company has sold approximately 700 active targets (around 25 per month), generating more than £3 million in sales. The idea (subject to patent protection) was initially incorporated in the *mini-Radascan* product, which is now a valuable tool to the industry and has given Guidance Microwave Ltd. a competitive advantage, becoming their most successful product.

2. Underpinning research

Professor Paul Brennan (UCL 1989-present, Professor of Microwave Electronics since 2008) has a strong track record in microwave/radio frequency research and innovation, and he has undertaken extensive work on phase-locked loop frequency synthesis for mobile communications RFID tags, phased array antennas and oceanographic [1, 2] and geophysical imaging radar sponsored by and/or in collaboration with the EU, EPRSC, NERC, British Antarctic Survey, University of Cambridge, Philips, and Nokia. As a result of the reputation for expertise he developed through previous work in RF systems and radar, Brennan was approached by Guidance Microwave Ltd. in 2008 for advice on the development of their active target location systems operating at 9 GHz, and on a planned new system at 24 GHz. These systems are used to help ships navigate in, and berth at, ports, and at other structures such as oil rigs. A critical evaluation of Guidance Microwave Ltd.'s systems [3] was performed in 2008 by Brennan's team, including Kevin Chetty (then a Research Associate at UCL; now a Lecturer in its Department of Security & Crime Science). This research particularly analysed the system's existing demodulation configuration with a view to improving system functionality, efficiency and reliability, whilst retaining – and indeed enhancing – its commercial viability.

A number of new ideas emerged from this research [4-6] in particular a technique offering a substantial improvement to the active target modulation system, which was of clear value to Guidance Microwave Ltd. In the original Guidance system, the active targets used modulated backscatter based on on-off keying (OOK) modulation at 125 kb/s of a 1.75/2.5 MHz frequency-shift keyed (FSK) modulated subcarrier to indicate their identities. The challenge in demodulating these signals in order to recover the data is that the sub-carrier frequencies, at intermediate frequency (IF), are much greater than the carrier frequencies, leading to spectrum foldover and difficulty in recovering the data. This is conventionally managed by using IQ demodulation, requiring two signal channels in the subsequent digital signal processing. However, the UCL study revealed that if the active transponder were to single-sideband modulate the incident radar signal to produce a subcarrier at only the sum (or difference) frequency, then there would be no issue of spectrum foldover and data recovery could be readily performed without the need for IQ processing, halving the burden on the digital signal processing. An outline design of the hardware required to achieve this function was presented to the company in 2008, using digital quadrature generation of the modulated subcarrier (125 kb/s on a 2.5 MHz subcarrier) with a minimum of additional components. A signal-to-noise ratio (SNR) analysis demonstrated that the proposed approach also offered a significant improvement in performance that would lead to greater operating range.

Guidance Microwave Ltd. explored this idea when Brennan presented it to them in 2008 and were

very pleased with the results. Not only was a signal-to-noise-ratio improvement of some 9 dB obtained in all of their active target products, due to the avoidance of issues associated with spectrum foldover, but the new circuitry in the active targets was around 50% cheaper and less complex than the circuitry it replaced. Subsequent testing conducted in 2010 revealed that the operating range of these systems was increased by around 50% as a result of the new targets. This meant that the performance of a newer Guidance product, *mini-Radascan*, approached that of the larger *Radascan* system, making it particularly attractive to customers with smaller vessels and/or reduced budgets.

Since 2008, Brennan has continued to work with Guidance Microwave Ltd. on a range of areas of interest, including the development of a radically new approach to active target location, now the subject of a separate patent application. Work to demonstrate the feasibility of this new technique is nearing completion and a demonstrator was trialled in field tests in summer 2013.

3. References to the research

[1] G. Connan, H.D. Griffiths, P.V. Brennan, 'FMCW-SAR development for internal wave imaging', *Proc. OCEANS'97* Conference, Halifax, Nova Scotia, IEEE Publ. No. 97CH36105, Vol. I, 6-9 October 1997, pp. 73-78. http://dx.doi.org/10.1109/OCEANS.1997.634338

[2] R. Bullock, P.V. Brennan, H. Griffiths, 'Two-look roll compensation for aircraft-borne interferometric SAR without phase unwrapping', *IEE Elect. Lett.*, Vol. 41, No. 6, 17th March 2005. http://dx.doi.org/10.1049/el:20057589

[3] P.V. Brennan, K. Chetty, 'Portscan radar RF system study', confidential report to Guidance Microwave Ltd, Jan 2009. This report, though not in the public domain, gives a highly detailed technical account of the underpinning research – particularly Section 3.4, Fig. 3.4.2. Available on request.

[4] P.V. Brennan, D. Patrick, 'Active Target', UK patent application no. GB1004964.1, March 25 2010.
http://extwww.patent.gov.uk/p-find-publication-getPDF.pdf?PatentNo=GB2478954&DocType=B&JournalNumber=6403

[5] P.V. Brennan, D. Patrick 'Active Target', US patent application no. 2011/0234,447, March 23 2011. http://assignments.uspto.gov/assignments/q?db=pat&pub=20110234447

[6] Y. Huang, P.V, Brennan, D. Patrick, I. Weller, P. Roberts, K. Hughes, 'FMCW-based MIMO imaging radar for maritime navigation', *Progress in Electromagnetics Research*, Vol. 115, 327-342, June 2011. http://www.jpier.org/PIER/pier.php?paper=11021509

References [1], [2], and [6] best demonstrate the quality of the underpinning research.

Grant funding: The research was supported by funding of £177,000 from Guidance Microwave Ltd, between December 2008 and July 2013.

4. Details of the impact

Product improvements: The research outlined above led directly to improvements in the technology underpinning Guidance Microwave Ltd.'s seven active target products. The new technology means that **operating range performance is increased by 50%, from some 600m to 900m**; at the same time, **production costs have decreased by around 25%.** As a result shipping companies now benefit from **more reliable, short-range navigation** when berthing large ships, an improvement that is of particular importance to oil tankers berthing at oil rigs, often in severe weather conditions leading to poor visibility. In addition, port authorities have **greater assurance that ships will be able to berth quickly and safely**.

The new approach to active target design conceived by Brennan and based on SSB modulated backscatter, and demonstration of its effectiveness in both reducing the signal processing burden

and increasing the signal-to-noise ratio and operating range, led directly to the adoption of a new technique across the entire Guidance Microwave Ltd. product range, as indicated in the following extract of a letter (in April 2012) from the Managing Director of Guidance Microwave Ltd:

"In 2008 we were developing a 24GHz positioning system for use on land, based on our existing 9GHz positioning system used for local positioning of ships (RadaScan). We were developing an Active Target to replace the very large and bulky Van Atta targets for RadaScan and wished to do the same for the Portscan system. We contracted your services to help with the development of the system concept and this resulted in the outline design for the Active Target. This design has successfully been patented.

"The Active Target has since been developed for the RadaScan system and has been a very successful product for our company. All of the old Van Atta targets have been replaced with the new and much smaller Active Targets. To date, we have sold approximately 280 Active targets [700 as of July 2013] *with current sales of approximately 25 per month. Along with the RadaScan sensors, this is very good business for our company and we are grateful your support."*

Commercial benefits: The forerunner to this active target design used multiple antennas and amplifiers in a Van Atta array configuration in order to achieve satisfactory operation. The inherent 9-fold signal strength improvement of the new active target has convinced Guidance Microwave Ltd. to drop the Van Atta approach and use a simpler single-channel active target configuration, which actually confers improved performance: testing on *mini-Radascan* performed by Guidance Ltd in 2010 indicated a substantial improvement in operating range.

The impact of this adoption of new technology based on Brennan's research is two-fold: firstly, by reducing the signal processing burden it allows the **cheaper and easier production** of (smaller) active targets based on a single pair of antennas rather than multiple Van Atta pairs and, in particular, it reduces the signal processing and RF demands on the radar system that interrogates those targets; secondly, it provides **better performance via a substantially increased operating range**. The ability to develop better products at a lower cost has conferred a significant competitive advantage upon Guidance Microwave Ltd, whose products now outperform those of their competitors despite the lower cost of their production. Such products have been very successful for the company, and now **100% of their production has moved to the new design proposed by Brennan**. Guidance Microwave Ltd. began to deploy the new active target in 2009, switching over its entire product range before the end of 2010. The fact that Brennan's design allows for cheaper and easier production also means that Guidance Microwave Ltd. profits have been impacted positively: mini-Radascan is now the most successful Guidance product in terms of sales, according to the Managing Director of Guidance Microwave Ltd, generating **sales of more than £3 million**. In 2010 and 2011 UK and **US patent applications** were filed to protect the technique.

Wider benefits to the shipping industry: The unrivalled performance and efficient architecture afforded by this technique has helped Guidance Microwave Ltd to become the market leaders in this area. However, the technology has also benefitted the shipping industry (which contributed £12.5bn to UK GDP in 2011) much more broadly - including major oil companies - by providing a **short-range navigation solution with the best possible performance**. Guidance Microwave Ltd. estimate that around 300 ships and oil rigs currently have the technology installed.

5. Sources to corroborate the impact

The principal corroboration source regarding the impact of this research is Guidance Microwave Ltd, the managing director of which has provided a letter of support (April 2012) and email (July 2013), both available on request.

The patent applications listed in Section 3 confirm the technical basis of the invention and the report and paper listed in Section 3 provide more technical information on the work (particularly Section 3.4, Fig. 3.4.2. of the report 'Portscan radar system RF study'.