

Institution: University of Cambridge
Unit of Assessment: UoA15
Title of case study: Zinwave
1. Summary of the impact (indicative maximum 100 words) Research at the University of Cambridge Department of Engineering (DoEng) created a novel wideband active Distributed Antenna System (DAS). The research was commercialised by Zinwave, a DoEng spin-off company [Text removed for publication]. Zinwave has developed a network of over 40 System Integrator partners to deliver DAS solutions to enterprises and building owners. It has also been selected by Verizon Wireless, one of the largest mobile operators in the world, to support its 4G network rollout in the USA. The first sales were recorded in 2009. Zinwave systems have been successfully deployed across the world. Zinwave's annual revenue has grown three-fold since first sales and was nearly GBP3M in the year ending December 2012.
2. Underpinning research (indicative maximum 500 words) Professors Richard Penty and Ian White moved from Bristol University to chairs in the University of Cambridge Department of Engineering (DoEng) in October 2001. Penty was the Principal Investigator for an EPSRC-LINK grant, Fibre Radio for In-building Distributed Antenna Systems (FRIDAY), which started in the DoEng in January 2002 and ran until July 2004. White was a Co-Investigator. They collaborated on FRIDAY with Professor Alywn Seeds at UCL. The collaborative project included several industrial partners, including Agilent and Airtech Ltd. Informed by earlier research on data communications, White and Penty knew that it was possible to obtain relatively low-loss transmission in a multi-mode fibre (MMF) system for signals on carrier frequencies greater than ten times the specified fibre bandwidth; the FRIDAY project research focussed on whether this could be used specifically for fibre radio systems. Their research combined theoretical studies, modelling, analysis and experiments to demonstrate this performance enhancement via utilisation of a previously unexplored "passband", and also focused on obtaining linear performance from <i>uncooled</i> laser diode optical sources which had recently been demonstrated by the Cambridge group for data communication applications. Seeds focused on better understanding of the radio frequency (RF) requirements for DAS, such as signal-noise ratio, dynamic range and distortion factors. Their work on FRIDAY led to three main research highlights from DoEng: <ul style="list-style-type: none"> • Penty and White proved that linear performance could be obtained from high-bandwidth semiconductor laser diodes that were used in existing high-bit-rate optical fibre communications systems using advanced laser modelling, backed up by experimental validation (Ref 1) • Penty and White advanced the theory and modelling of MMF passbands that showed good correlation with their experiments and used this to provide stable high performance by manipulating selective mode launches into the MMF (Ref 2) • Penty, White and Seeds showed that an MMF installation could support multiple wireless services having developed a better understanding of the RF requirements for a DAS (Ref 3). In November 2002, Zinwave Limited was founded to exploit the results from FRIDAY and Zinwave filed a patent application for the multimode fibre optical communication system in February 2003, prior to academic publications, listing inventors Penty, White, Seeds and Peter Hartmann (a DoEng Research Assistant who worked on FRIDAY). Penty and White secured an EPSRC Research Assistant Industry Secondment (RAIS) grant to enable knowledge transfer from the FRIDAY project to Zinwave. This funded Hartmann for a further year from June 2004. In addition to knowledge transfer, Penty and White led further research, in part under this grant, to use an RF mixer to demonstrate that successful transmission of wireless signals could be achieved over MMF links across the range 1-20GHz. The results were published (Ref 4 and 5) after a further patent application.

Penty and White's group continued its research from 2006 to 2007 with close collaboration with Zinwave, assisted by White's role as CTO and Chair of the Technical Advisory Board, and benefitting from in-kind support from Zinwave. The research used wireless propagation modelling and experimental coverage mapping techniques to demonstrate that the DAS provided better in-building coverage and data throughput than the standard single antenna solution, while using significantly lower (10dB) power. It also showed, as has proved crucial with the subsequent rise of the smartphone and explosion in mobile data, that capacity is also significantly improved (Ref 5).

White and Penty also won an EPSRC grant to research The Intelligent Airport (TINA), involving the University of Leeds, UCL and Cambridge along with Zinwave and other companies, which ran from 2006 to 2010. This project addressed the challenge of distributing wireless signals in airports to track several million items with radio tags and provide a network for rich media services. White and Penty showed how a distributed antenna network (DAN) can operate at lower power than a single antenna system and the conditions under which delay spread of the DAN does not degrade performance (Ref 6).

3. References to the research (indicative maximum of six references)

1. *Wide-frequency-range operation of a high-linearity uncooled DFB laser for next-generation radio-over-fiber. J D Ingham, M Webster, A Wonfor, R V Penty, I H White and J K White, Optical Fiber Communications Conference (OFC 2003), Atlanta, USA, 23-28 Mar 2003. DoI:10.1109/OFC.2003.1248548
2. *Low-cost multimode fibre-based wireless LAN distribution system using uncooled, directly modulated DFB laser diodes. P Hartmann, M Webster, A Wonfor, J. D. Ingham, R. V. Penty, I. H. White, D Wake and A. J. Seeds (UCL). ECOC 2003 (European Conference on Optical Communication), Rimini, Italy, 21-25 Sep 2003.
3. Dual-service wireless LAN antenna-remoting system using uncooled directly modulated DFB laser diodes. P Hartmann, R V Penty, I H White and A J Seeds. IEEE Conference on Lasers and Electro-Optics (CLEO) San Francisco, USA, 16-21 May 2004.
4. 1-20 GHz Directly Modulated Radio over MMF Link. P. Hartmann, X. Qian, A. Wonfor, R.V. Penty and I.H. White. MWP'05. in Proc. 2005 International Topical Meeting on Microwave Photonics, paper T3-1, Seoul, 12-14 October 2005. DoI: 10.1109/MWP.2005.203548
5. Wideband fibre-agnostic DAS using pluggable analogue optical modules. P. Hartmann, A. Bothwell, R. Cronin, K. Leeson, A. Loveridge, D.C. Parkinson, J.W. Ure, R.V. Penty, I.H. White and A.J. Seeds. MWP '06. International Topical Meeting on Microwave Photonics, Oct. 2006. DoI: 10.1109/MWP.2006.346503
6. *Uplink and downlink coverage improvements of 802.11g signals using a distributed antenna network. M J Crisp, S Li, A Watts, R V Penty and I H White. IEEE Journal of Lightwave Technology, Vol 25, pp 3388-3395, 2007 DoI:10.1109/JLT.2007.906819

* References which best represent the quality of the underpinning research.

4. Details of the impact (indicative maximum 750 words)

Penty, White and Seeds (together with Dr David Wake, UCL, and Dr David Parker, entrepreneur) founded Zinwave in November 2002 to commercialise the research results and associated patents, which were all assigned to the spin-off. Penty and White have supported all the investment rounds and helped with product development. They have also both served on the company's Technical Advisory Board (2002-2012).

System 3000 DAS is Zinwave's main product. Its unique selling point, namely broadband radio-over-fibre distribution of radio signals over a DAS network, is founded on research carried out in the FRIDAY and subsequent RAIS projects. It is a three-stage system, constituting a Primary Hub, Secondary Hubs, and Remote units configured in a tree network. It uses fibre cable for connectivity and offers true wideband capabilities that allow simultaneous support for any wireless standard including 2G, 3G, 4G, LTE, PMR/LMR, DVB-H, TETRA, Wi-Fi, WiMAX and RFID. Full management control over this spectrum allows new services to be added on-demand without deploying additional system components. The technology can be configured in a single, dual star or mixed architecture to meet exact service needs. Rival

solutions require the installation of dedicated narrowband equipment for each and every different wireless standard, which is less flexible, more expensive and more complex to maintain.

[Text removed for publication] Zinwave's headquarters are in Cambridge, but it has employees based in America and Malaysia. It employs approximately 25 people.

Zinwave made System 3000 generally available in 2008 and recorded its first revenue of approximately GBP1M in 2009. Annual revenue in the year ending December 2012 was GBP3M despite difficult market conditions.

Commentators have identified Zinwave as a company on a high-growth trajectory: ABI Research named Zinwave in 2012 as *"part of the next generation of DAS vendors and one of the companies to watch out for as the DAS market evolves"* (Ref 8); and the Red Herring Europe 100 Awards placed Zinwave among the finalists in April 2013 in its listing that *"analyses and selects the top private companies in the European region ... positioned to grow at an explosive rate"* (Ref 9).

Zinwave has sold its DAS product to three client types: Systems Integrators, Network Operators and Building Owners.

Systems Integrators, in this context design, are the companies that deliver, install and support bespoke communications solutions in a client's building or across a client's site, using expert knowledge of products and systems. Zinwave has established formal relationships with over 40 such Systems Integrators, which account for over 90% of its turnover.

Systems Integrator Obelisk delivered a DAS implementation at the Convention Centre Dublin (CCD) in 2010, working with ISM OpenOptics, and stated: *"When deploying cellular coverage across multiple operator networks and multiple services, including O2, Vodafone and Meteor, throughout the conference centre across the full service mix, being able to simply plug them in without worrying about service specific hardware is a major advantage. Zinwave's system has provided us with the most cost effective solution while the intelligence and flexibility of the architecture simplified deployment of cellular sectorisation. Thanks to Zinwave's innovative, future proof DAS, we can add any future service at any frequency that may become available, with the ability to easily expand to meet future needs"* (Ref 10).

ROOTS Communications (Singapore and Malaysia) stated: *"Flexibility, scalability and easy deployment are key to all our installations and Zinwave's DAS offers all of this. In addition, its ability to support all existing services as well as new ones on the same hardware layer makes it compelling to our customers because it eliminates the need for expensive rebuilds or upgrades"* (Ref 11).

Radio Access BV (Netherlands) stated: *"We have deployed Zinwave's DAS in numerous projects because it essentially allows us to provide our customers with a "wireless highway" from which they can run multiple services, irrespective of the frequency, over a single platform. It is unique in its ability to support all cellular frequencies, such as GSM and UMTS, as well as closed networks, over a single hardware layer making it completely future-proof"* (Ref 12).

Network Operator, Verizon Wireless, selected Zinwave in 2012 to support its 4G mobile network roll-out in the USA. This is a significant achievement for a company of Zinwave's size and maturity, because large operators, such as Verizon, which is the largest wireless operator in the USA and one of the largest in the world, tend to be conservative and choose to buy from well-established large equipment suppliers. The speed with which Zinwave has attained formal supplier status is also impressive. This is related to Zinwave having a unique product and meeting all the requirements for quality, service and support.

TriPower, a Systems Integrator working for Verizon, stated with regard to its project at the Pepsi Center Arena in Denver: *"The joint effort between TriPower as the deployment partner and Zinwave's 3000 DAS system allows us to deliver an optimum wireless solution for high-demand coverage...In addition to ensuring calls are successfully connected, the DAS will allow smart phones, tablets and other mobile devices to access the Internet, send text messages and quickly share photos and videos to social networking sites, enabling visitors of the arena to have a great network experience"* (Ref 13).

Building Owners benefit from Zinwave's DAS through improved in-building reception and

coverage of wireless systems, while reducing installation and operating costs. The Zinwave system also keeps their options open for choosing new wireless standards in the future. Dolya & Co highlights these benefits with reference to the UEFA Euro 2012 tournament co-hosted in Ukraine: *“The Zinwave system offered great flexibility and was easy to install. Its simple architecture and its multi-frequency support enabled us to integrate UEFA’s two-way radio system onto the overall DAS without affecting performance or signal output. During the opening ceremony it became apparent that our installation was the only one that provided reliable coverage underground. Zinwave’s DAS therefore played an important role during the tournament - acting as the “lifebuoy” for all critical radio and public safety communications”* (Ref 14).

Other buildings benefitting from deployment of Zinwave’s DAS include: the Erasmus MC and Martini Hospitals (Rotterdam and Groningen, Netherlands); a Garmin data centre in New Jersey; the 9/11 Memorial Museum in New York City; Jakarta international airport; the Perry nuclear power plant outside Cleveland, Ohio; and the Westfield retail complex in Melbourne.

5. Sources to corroborate the impact (indicative maximum of 10 references)

7. CTO of Zinwave
8. “Zinwave is recognised as a world leader in DAS innovation according to ABI Research”, <http://www.zinwave.com/news/release/zinwave-is-recognised-as-a-world-leader-in-das-innovation-according-to-abi-research/en>, Zinwave press release, 17 October 2012
9. 2013 Red Herring Europe Finalists, <http://www.redherring.com/events/red-herring-europe/2013-finalists/>, April 2013
10. “Zinwave addresses demanding multi-service requirements in prestigious International Conference Facility in Dublin”, <http://www.zinwave.com/news/release/zinwave-addresses-demanding-multi-service-requirements-in-prestigious-international-conference-facility-in-dublin/en>, Zinwave press release, 1 September 2011
11. “Zinwave’s in-building wireless coverage system chosen by Singapore’s Esplanade – Theatres on the Bay”, <http://www.zinwave.com/news/release/zinwaves-in-building-wireless-coverage-system-chosen-by-singapores-esplanade-theatres-on-the-bay/en>, Zinwave press release, 22 May 2013
12. “The largest hospital in the Netherlands selects Zinwave DAS technology for its indoor wireless coverage requirements”, <http://www.zinwave.com/news/release/the-largest-hospital-in-the-netherlands-selects-zinwave-das-technology-for-its-indoor-wireless-coverage-requirements/en>, Zinwave press release, 25 September 2012
13. “Tripower to participate at ACI’s 5th Annual DAS Congress”, <http://tripower.com/tripower-to-participate-at-acis-5th-annual-das-congress-3/>, Tripower press release, 27 November 2012
14. “Zinwave DAS technology guarantees TETRA coverage at Euro 2012”, <http://www.zinwave.com/news/release/zinwave-das-technology-guarantees-tetra-coverage-at-euro-2012/en>, Zinwave press release, 22 November 2012