Institution: University College London		
Unit of Assessment: 12 - Engineering		
Title of case study: Zinwave Ltd: Global distribution of wideband radio-over-fibre connections, improving communications networks in real estate, enterprise and healthcare settings		
Period when the underpinning research was undertaken: 2000 - 2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Alwyn Seeds	Professor of Opto-electronics	1986 - date
Period when the claimed impact occurred: 2013- 2020		
Is this case study continued from a case study submitted in 2014? Y		

1. Summary of the impact

Zinwave Ltd has introduced wideband Distributed Antenna Systems (DAS) to the global marketplace, with systems deployed in Europe, the USA, Australia, China and the Middle East to provide cost-effective wireless coverage for hospitals, office campuses, public buildings and more. DAS systems are implemented for distributing Cellular and Wi-Fi signals throughout a building or area. Zinwave, a company founded to exploit the underpinning research, has grown strongly with its annual turnover increasing from GBP3,572,000 in 2013 to over GBP10,000,000 in December 2019. Following Professor Seeds work, the Zinwave 3000 System, the Zinwave DAS system and the Zinwave 5000 UNItivity system provide communication solutions for facilities spanning a total area exceeding 24,697,223sqm.

2. Underpinning research

Within buildings, coverage from outside cellular wireless base stations is poor due to the absorption of wireless signals by typical building materials. Since the 1980s, wireless signals have been distributed within buildings by coaxial cable, which is heavy, has high losses (> 245dB/km, LMR-400, 3GHz) and is becoming increasingly costly, making installations in many buildings uneconomical. The transmission of wireless signals over optical fibre based on the work from UCL and other groups (**R1**), led to commercial systems using either single-mode optical fibre (such as Andrew Inc.), requiring the use of expensive packaged single-mode optoelectronic devices; or multimode fibre (such as LGC Wireless), where the limited bandwidth makes it possible to carry only a single wireless service on each fibre. This approach makes it expensive to provide widespread multi-service wireless coverage in buildings.

The UCL group carried out extensive research on wireless-over-fibre links and the underpinning microwave photonics technologies (**R1**). At Bristol University, Dr Penty had shown that it was possible to increase the data transmission capacity of multimode fibre through the use of sub-carrier multiplexing (SCM). Professor Seeds at UCL, realised that this research could be adapted to transmit wireless signals over multimode fibre without down-conversion/up-conversion as used in commercial systems. In addition, this could enable multiple wireless signals to be distributed over a single multimode using cheaper multimode fibre components to reduce costs dramatically.

Professor Seeds proposed a collaboration with Dr Penty and his colleague Professor White; to explore this possibility and together they wrote a proposal for the collaborative project "Fibre-Radio for In-Building Distributed Antenna Systems (FRIDAY)". This was funded under

the EPSRC-DTI LINK scheme, with project partners Agilent Technologies (UK) Ltd and Airtech Ltd, and undertaken between 2001 and 2004 between UCL and the University of Cambridge (Dr, later Professor, Penty and Professor White having moved to Cambridge). UCL researchers Professor Seeds and Dr Wake showed for the first time that it was possible to transmit wireless signals over multimode fibre without down-conversion (**R2**). The FRIDAY research showed that it was possible to carry multiple wireless services (such as cellular and Wi-Fi) over a single optical fibre, and that multimode optical fibre could be used to carry wireless services with carrier frequencies beyond its -3dB (electrical) frequency cut-off reliably (<4dB/km, 3GHz).

This led to a joint UCL/Cambridge patent (**R3**) with Professor Seeds and Dr Wake (UCL), and Professors Penty and White, together with Dr Webster and Dr Hartmann (Cambridge) listed as inventors and with equal revenue sharing and intellectual property (**R3**).The patented technology has enabled multiple wireless services to be carried on a single multimode or single mode fibre using low cost directly modulated laser technology, offering a major cost reduction (**R4, R5, R6**). Professor Seeds and Dr Wake, with Professors Penty and White and Dr Parker (CEO of SPI Lasers), founded Zinwave Ltd in November 2002 to exploit the research commercially. Professor Seeds was a Zinwave Director from November 2002 to December 2006 and negotiated the Pre-Seed, Seed and GBP5,870,000 Series A funding rounds and was a member of the Technical Advisory Board until 2012.

On behalf of the patent owners (UCL and Cambridge), UCL licensed patent WO2004056019 and associated know-how to the company in 2003. To enable knowledge transfer from the FRIDAY project to Zinwave, Professor Seeds obtained an EPSRC Research Associate Industrial Secondment (RAIS) grant of GBP36,500 enabling radio-over-fibre researcher Dr Chin-Pang Liu to work at Zinwave 0.5FTE for two years, commencing May 2004. Since 2005, Professor Seeds has obtained further support for UCL wireless-over-fibre and related research totalling some GBP20,000,000.

3. References to the research

R1. **Seeds, AJ**.: "Microwave photonics", IEEE Trans., 2002, MTT-50, pp. 877-887, (Invited Paper) http://dx.doi.org/10.1109/22.989971

R2. Wake D, Dupont S, Vilcot J-P. **Seeds AJ** (2001): "32-QAM radio transmission over multimode fibre beyond the fibre bandwidth", International Topical Meeting on Microwave Photonics. Post Deadline Papers. MWP'01 (Cat. No.01EX476), pt. suppl., 4 pp. http://dx.doi.org/10.1109/MWP.2002.982299

R3. WO2004056019: **Seeds AJ**, Wake D, Penty RV, Webster M, Hartmann P, White IH, priority 13 December 2002 http://patentscope.wipo.int/search/en/WO2004056019; Revenue Sharing Agreement concerning the patent between UCL and Cambridge University available on request.

R4. **Seeds AJ**. (2002): Wireless access over optical fibre: from cellular radio to broadband; from UHF to millimetre-waves, 15th Annual Meeting of the IEEE Lasers and Electro-Optics Society, Glasgow, Scotland (Cat. No.02CH37369), 2002, pt. 2, pp. 471-472. (Invited Paper).http://dx.doi.org/10.1109/LEOS.2002.1159385

R5. **Seeds AJ**, Ismail T (2010): Broadband Access Using Wireless Over Multimode Fiber Systems. IEEE/OSA J. Lightwave Technol., , 28 (16), pp. 2430-2435 (Invited Paper). http://dx.doi.org/10.1109/JLT.2010.2053347

R6. Hartmann P, Bothwell A, Cronin R, Leeson K, Loveridge A, Parkinson DC, Ure JW, Penty JW, White, IH., **Seeds AJ** (2006): "Wideband fibre-agnostic DAS using pluggable analogue optical modules", International Topical Meeting on Microwave Photonics. MWP'06, pp. 1-4, http://dx.doi.org/10.1109/MWP.2006.346503

4. Details of the impact

Since 2013, Zinwave Ltd has developed global activities. Through the UCL patent and subsequent development (**R4, R5, R6**), Zinwave wireless over fibre systems continue to be

deployed. Its unique selling point, namely wideband radio-over-fibre distribution of radio signals over a DAS network, uses research carried out in the FRIDAY (**R2**) and subsequent RAIS projects. The Zinwave DAS is a three-stage system for in-building cellular and wireless services, constituting a primary hub, secondary hubs, and remote units. It uses multimode or single-mode fibre cable for connectivity.

The technology features true wideband capabilities allowing 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. The advantage to the customer is that a single distribution system can distribute multiple wireless services operating with different protocols and at different frequencies. A single system can carry private VHF radio, public safety radio, such as TETRA, 2G cellular services at 900MHz and 1,800MHz and 3G/4G services at 800MHz, 900MHz, 1,400MHz, 1,800MHz, 2,100MHz, 2,300MHz and 2,600MHz from multiple operators.

Zinwave's global reach

Zinwave has introduced wideband distributed antenna systems to the global marketplace, with systems deployed in Europe, the USA, the Middle East, Australia and China. Since mid-2018, the company has been registered in England and Wales, with its corporate headquarters in Dallas, Texas, technology development in Cambridge, England and offices on the East and West Coasts of the US, in Macau and in Australia. This has created a need to open additional facilities to support the company's world-wide customer base and "*anticipate strong market demand*" for the company's solutions, states Zinwave President and CEO (**S1**). Its systems provide wideband wireless coverage in shopping malls, auditoria, office buildings, casinos, convention centres, hospitals and airports, in the US, European countries (such as Iceland and the Netherlands), the Middle East and the Asia-Pacific region (such as Jordan and Australia respectively).Through Zinwave Ltd, Professor Seeds' research underpins the Zinwave 3000 System, the Zinwave DAS solution and the Zinwave 5000 UNItivity solution. These products have provided communications solutions for diverse applications.

Zinwave's technology deployed in healthcare facilities

Using the technologies developed by Professor Seeds and his team (**R1-R6**), Zinwave's existing partnerships with over 40 specialist in-building system integrators continues and since 2013 has extended its reach into both commercial and public safety markets. Testimonies from these partners attest to the cost-effectiveness, ease of use and flexibility of the Zinwave DAS for its customers. For example, following patient and visitor concerns over mobile phone connection problems, the Broomfield Hospital Trust, with a space reaching 43,000sqm (**S2**), identified Zinwave DAS as the most suitable and cost-effective solution to signalling problem (**S2, S3**).

The IT Operations Manager at Mid Essex Hospital NHS Trust stated: "*The key decision in us moving forward with Zinwave as a solution was the vendor agnostic operator approach...we have high praise for the smoothness of the installation*" (**S3**), which was completed within 8 weeks of approval. The conventional approach would 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 (**S2**). In addition, Erasmus Medical Centre and Martini Hospitals (Rotterdam and Groningen, Netherlands, with total areas of 365,000sqm and 134,000sqm respectively) have also deployed Zinwave technology (**S2**).

Zinwave solutions deployed among public venues

Using the technologies developed by Professor Seeds and his team (**R1-R6**), Zinwave has provided solutions for the 9-11 Memorial Museum, New York City (10219sqm), with a reach of 3,000,000 visitors annually, Queen Alia international airport in Jordan, serving over 6,000,000 passengers annually and with building facilities spanning a total area of 19,000,000sqm (**S2**). Zinwave performance enabled Queen Alia Airport to overcome several

safety and performance concerns and secured the competitive commercial TETRA licence for the 350-360 MHz band. Zinwave solutions continue to be adopted at the Jakarta International Airport (2,458,000sqm); and the Westfield retail complex in Sydney, Australia (88,000sqm).

Zinwave's products deployed in commercial real estate and enterprise

In 2017 the Zinwave DAS solution, based upon Professor Seeds' research (**R1-R6**) was deployed to eliminate wireless coverage and capacity issues at Sky's new headquarters in Osterley West London, UK (with a combined total area of approximately 46,000sqm) (**S4**). The Sky campus in West London had recently undergone an extensive redevelopment, consolidating the company's operations. With multiple floors and the use of dense materials, mobile signal coverage was heavily affected, which led Sky to turn to experienced Systems Integrator Herbert, who recommended the globally proven Zinwave UNItivity solution, which ensures that wireless communications (mobile signal, public safety and IP access services) are always available. The Planning & Delivery Manager (for Network Implementation) at Sky said; "*Sky is very forward thinking and technically capable, and had the foresight to install single operator DAS in our existing buildings on campus, but when it came to our new Sky Central building, we wanted multi-operator coverage to cope with user volumes and multiple Mobile Network Operators throughout this much larger building… Zinwave UNItivity met the desired criteria, with Herbert pulling out all the stops with the project scoping, implementation and in-building integration in the timescales required*" (**S4**).

As such, the Marketing Director at Herbert states that *"the implementation of innovative turn-key solutions such as the Zinwave UNItivity product … ultimately keeps their business at the forefront"* [**S4**]. Zinwave's UNItivity system was also selected to provide a sustainable and in-building future-proof wireless user experience at Imperial Pacific Resort Hotel in Saipan, a 14-storey building with a total area of 140,000sqm. According to the CEO of DC Systems, not only were they "*impressed with the UNItivity system's ease of installation*" at the resort (**S5**), but it now delivers "*the kind of seamless user experience the Imperial Pacific Resort Hotel had hoped for* " (**S2**) for their employees, guests and visitors.

Zinwave DAS solutions, again based on Professor Seeds' research [R1-R6], have also been adopted for applications as diverse as a Garmin data centre in New Jersey, Convention Centre Dublin (4,500sqm exhibition space), The Pepsi Center, Denver CO (roughly 62,700sqm), Norwegian Cruise Line Terminal, PortMiami, FL and the Harpa Concert Hall and Conference Centre, Reykjavik (28,000sqm) (**S2**).

Finally, as a result of Professor Seeds' sustained research and stakeholder collaborations, Zinwave was acquired by McWane Inc. in 2014 and annual revenues have risen from GBP3,572,000 in 2013 to over GBP10,000,000 in 2019 (**S6**).

5. Sources to corroborate the impact

S1. Testimonial from Zinwave president and CEO
S2. Zinwave Case Studies:
Pepsi Center Arena, Denver
Martini Hospital, Netherlands
Erasmus Medical Centre, Rotterdam
Harpa Concert Hall, Reykjavik
Imperial Pacific Resort Hotel, Saipan
9-11 Memorial Museum, New York
Westfield Australia
Jakarta Airport, Indonesia
S3. Broomfield Hospital, Chelmsford, selects Zinwave DAS for its in-building mobile coverage
S4. Zinwave eliminates mobile phone 'not-spots' at Sky new HQ
S5. Zinwave provides in building wireless tech for hotel in Northern Mariana Islands
S6. Global database: Zinwave Limited Annual Report and Financial Statements 2019