Institution: University of Sheffield

Unit of Assessment: 13B - Electrical and Electronic Engineering, Metallurgy and Materials: **Electronic and Electrical Engineering**

Title of case study: Commercial and environmental impacts arising from the creation of a spin-out company: Antenova Ltd.

1. Summary of the impact

Antenova Ltd, a spin out company created to exploit University of Sheffield research, is a leading developer and supplier of high performance antennas and radio frequency (RF) antenna modules for wireless communication and consumer electronic devices such as smartphones, laptop computers and tablets. Significant commercial impact has been generated: Antenova has 6% of the global mobile antenna market (2 Billion units) and is a leader in the global antenna design market with a 15% share, employing 40 staff worldwide and with an annual turnover of about $8 million. To gain commercial advantage Microsoft Corporation bought out Antenova in 2013.

Small high dielectric constant chip antennas resulting from the underpinning research allow multiple wireless services to be provided on small devices such as smart phones and as these antennas are very efficient, save energy, extend battery life and so bring environmental benefit.

2. Underpinning research

The Department of Electronic and Electrical Engineering at the University of Sheffield has a Communications group with a long history of research in electromagnetics and antenna systems. Antennas play a significant role in modern wireless communications where the challenge is to provide small antenna systems operating at multiple frequency bands. The underpinning research which led to this spin out company was an equal and joint effort by Dr Simon Kingsley (Reader, Sheffield University, 1980-2001) and Dr Steven O'Keefe (Senior Lecturer, Griffith University) into dielectric resonator antennas from 1998-2002. Such antennas had originally been based on low permittivity dielectrics but research by Kingsley and O'Keefe extended this to much higher permittivity materials allowing much smaller antennas to be made. This in turn led them to develop small low profile antennas. In [R1] they changed the radiated beam direction of a dielectric resonator antenna (DRA) by exciting different probes within the dielectric. In some combinations, a pair of probes had a much greater bandwidth than a single probe which overcomes a significant and fundamental limitation. They also examined cylindrical and rectangular dielectric resonator shapes [R2] to study the fundamental antenna properties that were achieved when the DRAs were bisected through an image plane by a conducting sheet. The resultant half DRAs were smaller in volume and had a more directional radiation pattern than conventional DRA geometries. A number of patents were filed (some key patents [R3-R5]) were the direct outcome of the research [R1] and [R2].

The fundamental output of the underpinning research has resulted in very small, high dielectric constant antennas that are able to function at many different frequency bands and are highly resistant to detuning. The current range of Antenova chip antennas would not have been developed without the early work at Sheffield showing that practical antennas can be made from high dielectric materials. The advanced antenna technology developed from the academic partners has resulted in smart phones and other mobile devices being able to perform a very wide range of functions in a small miniaturized unit. This research on high dielectric constant antennas was instrumental in making practical mobile phone antennas from the invention.

Kingsley and O'Keefe had an equal intellectual input to Antenova researching the High Dielectric Antenna technology [R1, R2] that resulted in the significant patents [R3-R5]. Kingsley made further contributions to the impact taking place by extending the research into Antenova.

Kingsley recognised the potential impact of this research and left Sheffield in June 2001 to set up and work at Antenova as Chief Scientist. Sheffield continued to collaborate with Antenova in the following period with advice on setting up and calibrating anechoic chambers, and also in training some of the Antenova staff.

Simon Kingsley became a Visiting Professor at Sheffield in 2007 and Antenova funded a PhD studentship (Luyi Liu) at Sheffield developing reconfigurable antenna technologies [R6]. These new technologies have led to significant new antenna products for Antenova from 2012.

3. References to the research

The underpinning work that led to the setting up of Antenova includes two international Journal publications, which best indicate the quality of the underpinning research:

R1. "Beam steering and monopulse processing of probe-fed dielectric resonator antennas", S P Kingsley and S G O'Keefe, IEE proceedings Radar Sonar and Navigation, 146, 3, 121 - 125, 1999. doi: 10.1049/ip-rsn:19990307

R2. "FDTD simulation of radiation characteristics of half volume HEM and TE mode dielectric resonator antennas", S. G. O'Keefe, S. P. Kingsley and S. Saario, IEEE trans. Antennas Propagat., volume AP-50, pp. 175-179, February 2002. doi: 10.1109/8.997991

Some key patents resulting from the research in [R1,R2] are:

R3. S.P. Kingsley and S.G. O'Keefe: "Multi-segmented dielectric resonator antenna", Mar 2001, EP1264365 B1, EP1264365A1, US Patent No 6,452,565

R4. S.P. Kingsley and S.G. O'Keefe: "Steerable-beam multiple-feed dielectric resonator antenna of various cross-sections", Oct 2000, EP1232538 B1

R5. S.P. Kingsley and S.G. O'Keefe: "Dielectric resonator antenna with special polarisation properties", 2002 UK Patent No 2377319.

Later research funded by the studentship:

R6. L. Liu and R.J. Langley: "Tunable Multiband Handset Antenna Operating at VHF and UHF Bands" IEEE Trans. On Antennas and Propagation, 61(7):3790-3796 Jul 2013 DOI: 10.1109/TAP.2013.2254447

4. Details of the impact

Joint research by Kingsley and O'Keefe into dielectric resonator antennas has had significant commercial impact through the spin out company Antenova. The company was registered by the University of Sheffield in 1999 and fully funded in 2001. Sheffield University owned 18% of Antenova.

From the **basic research** Kingsley, as Chief Scientist and co-inventor, further developed small dielectric antennas which eventually led to the current range of RADIONOVA products in 2008 that can be seen on the Antenova website (www.antenova.com) [S1] and the more recent chip antennas (2010) produced in considerable numbers that appear in mobile phones and tablets.

The PhD student (Dr Liu) became an Antenova employee on completing his studies in 2011 taking the research into the company for commercial development. Dr Liu has designed two standard antennas, that are selling in high volumes, as well as several custom antennas which arose from research at Sheffield. For example a project in production with LG for their 7 – 10 inch portable multi-media devices uses the low frequency band technology for FM/TV bands reported in [R6]. The ideas on capacitive coupling structures in [R6] resulted in two products: (i) a pentaband antenna for a portable payment machine using MEMS switches has been implemented in a Glintt

payment machine; and (ii) a Miniaturized pentaband chip antenna which has been used in several of Silverspring's M2M products, mainly for their smart metering systems. Both go into mass production in 2013. This work has contributed significantly to Antenova's recent commercial success.

The worldwide antenna business is dominated by high volume manufacturing of low-cost, low performing products that also have low margins, typically around 10-11%. Antenova was set up to work at the high end of the market using advanced antenna technology to make products for high-end feature phones and smart phones. The requirements on the antenna are much more severe in these products. The antennas are correspondingly more expensive, but attract a much higher margin, typically 60%.

The IP and Engineering assets of Antenova were bought out by Microsoft Corporation, USA in 2013 to gain commercial advantage for their future products.

Company Performance

Antenova was a UK-registered, UK-based company with its headquarters in Cambridge. There are other company offices in Chicago and Taiwan and several staff (~6) in other Asian countries. The company employed 40 people of whom 75% have advanced degrees (Masters or PhDs).

Economic Impact

Antenova turnover totalled £16m between 2009 and 2012 reflecting increased year-on-year sales for the same period:

Turnover:

- 2009: £3.1M or $4.96M
- 2010: £4M or $6.4M
- 2011: £3.9M or $6.24M
- 2012: £5M or $8M

Units sold

- 2009: 7.75M direct units shipped
- 2010: 10M direct units shipped
- 2011: 11.7M direct units shipped
- 2012: 15M direct units shipped

Units sold under licence:

- Antenova has also generated considerable downstream revenue over its lifespan. Antenova made about $17.5M in revenues from licensing and royalties. This is made up from: Murata=$3M; Galtronics=$4M; Sony Ericsson=$2M; Flextronics=$2.5M; others (includes LG, Inpaq, etc.)=$2M; and Microsoft=$4M.[S1]

Antenova is one of the most innovative and advanced antenna companies in the industry and is the only company to produce antennas for the full range of mobile devices and protocols (phones, tablets, laptops, M2M, etc.). Many products are customer specific.

Microsoft's new Surface Tablet only uses Antenova antenna technology (1M sales 4th Quarter 2012) due to their multiband capabilities combined with a small physical volume.

Market share: According to a major report on the mobile antenna industry in 2012 by *Mobile Experts* [S2, S3] the overall antenna market consists of "more than 2.3 billion structures shipped

annually (2012)". The report contains a pie chart showing that Antenova has 6% of the market. The most valuable part of the company is its high dielectric antenna technology according to the same report by *Mobile Experts* [S2] with Antenova having the largest share of the global Antenna Design Market at 15%.

Main customers: Antenova's main customers over recent years have been Microsoft, Dell, Nokia, LG, Samsung, Foxconn, TomTom, Philips, Motorola, Sony Ericsson (now Sony), HP and Murata.

Further Impact to beneficiaries: Antenova's high dielectric technology has contributed to mobile devices becoming smaller, more robust and more efficient (15%), thereby contributing to increased battery life (5%) and enabling energy savings which has benefits for both the consumer and the environment [S4]. Since the technology enables design flexibility and rapid design cycles, it has helped to reduce the cost of mobile products too. Users also benefit from improved signal reception and the ability to receive multiple protocols such as Bluetooth, WiFi, telephone, Internet, Radio and TV, Navigation, etc. making their mobile device so multi-functional. Overall these economic, consumer and environmental advantages also give a competitive benefit the suppliers of mobile devices. [S5]

Professor Kingsley can be contacted for a general overview of the research and company product development [S6].

5. Sources to corroborate the impact

S1. To corroborate product range and range of customers (on file)

http://www.antenova.com/Documents/Antenova_CorpOverview_04Sept09.pdf

S2. Mobile Experts www.mobile-experts.net/ report (on file) corroborates market share of Antenova.

S3. Company Report (on file) confidential – corroborates market share

S4. For the technical perspective, a member of Antenova staff (and Visiting Professor at QMUL).

S5. For corroboration of the commercial advantages of the high dielectric technology, Marketing Director at Antenova.

S6. Prof Simon Kingsley can corroborate the technical and product development details.