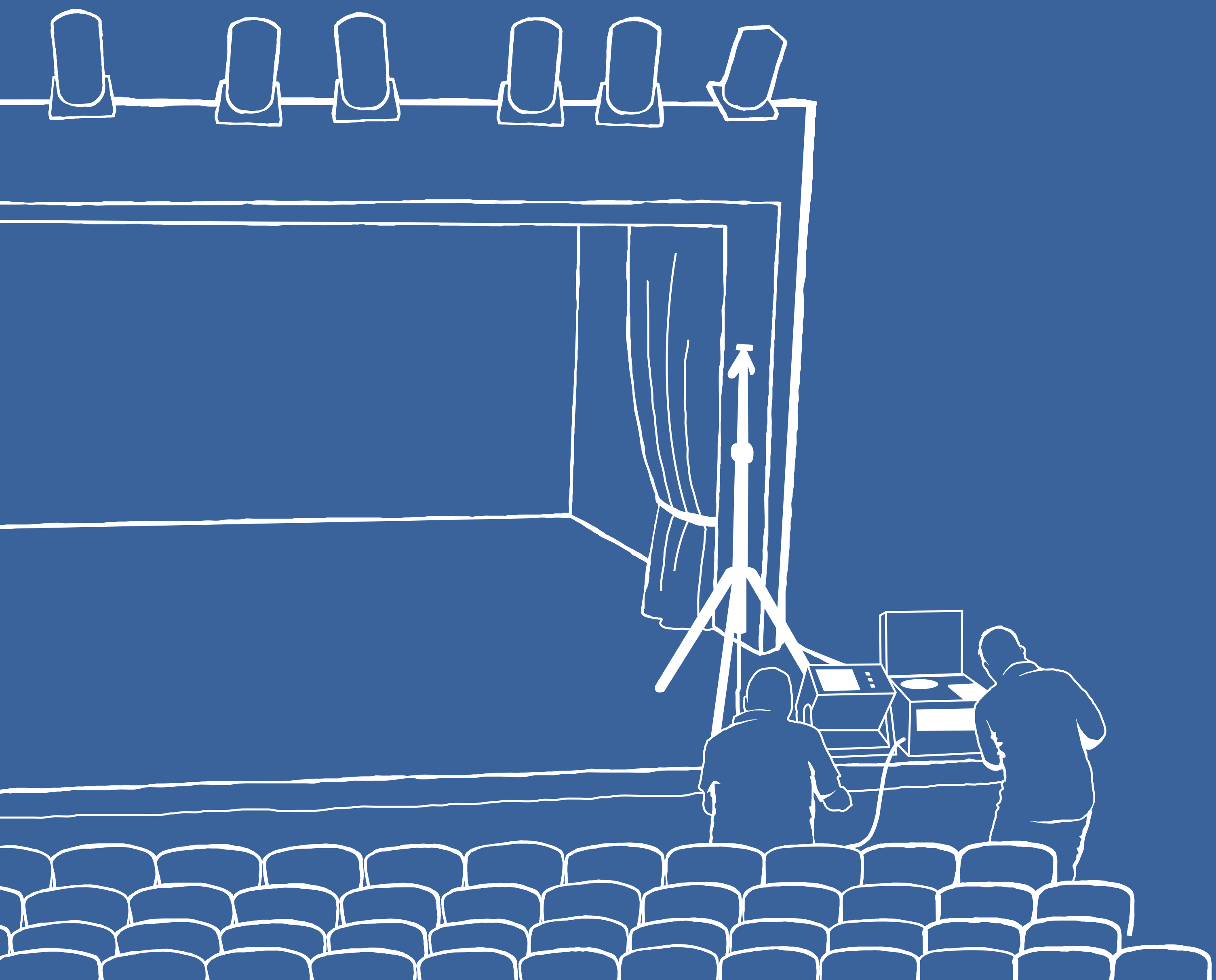
Cambridge White Spaces Consortium

Recommendations for Implementing the Use of White Spaces: Conclusions from the Cambridge TV White Spaces Trial

Contents



Executive Summary: Key Findings and Recommendations

There is a growing view that the traditional method of allocating spectrum can create scarcity. Emerging techniques potentially allow a more flexible use of spectrum than the traditional approach where spectrum is allocated across a region for a particular use, but not necessarily used intensively throughout that region. Traditional spectrum allocations pre-date the recent growth in demand for wireless broadband connectivity and a more flexible approach could help address this demand. The fixed nature of radio spectrum as a physical asset, coupled with the increasing demand for it, suggests that it is now appropriate to consider smart technology to facilitate sharing of the radio spectrum between different users and applications.

In June 2011, 11 leading companies and organisations[1] in the telecommunications, media and technology sectors worldwide came together in a consortium to test the technical feasibility of using television (TV) white spaces for a number of applications, including:

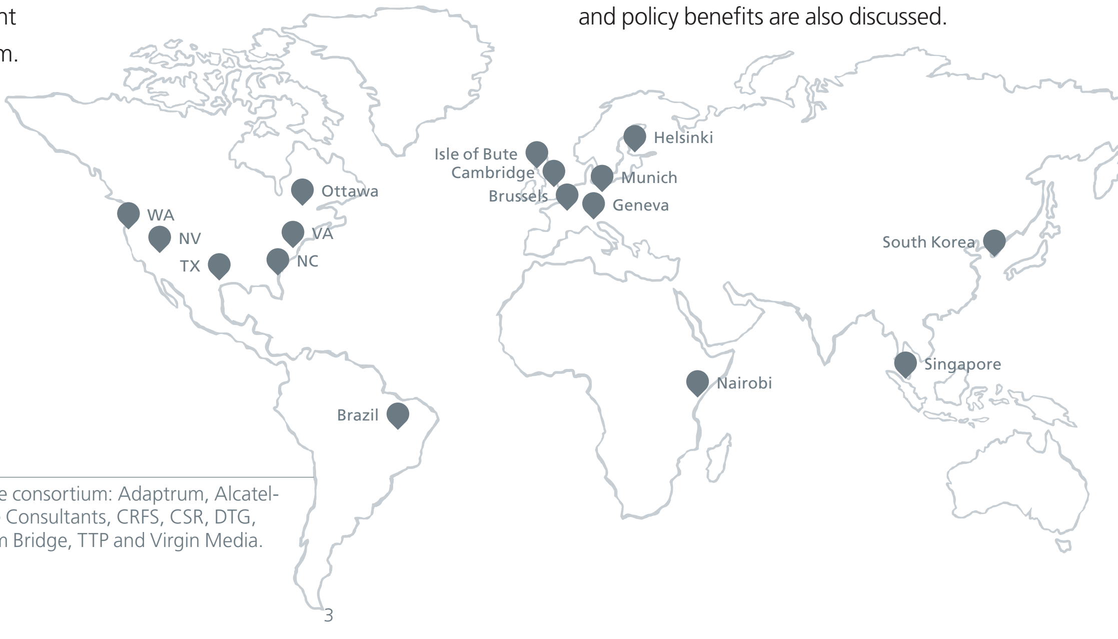
- Broadband access in rural areas
- Urban broadband coverage with the potential to offload data from congested mobile broadband networks
- 'Smart city' applications
- Location-based services and local content distribution

Within this consortium (which has risen to 17 members), the Trial was carried out in and around Cambridge, England, UK. The location was chosen because of the presence of key consortium members and the innovation-friendly record of the City. Cambridge also benefits from a flat terrain that gives rise to a relatively abundant amount of TV white spaces spectrum.

A primary purpose of the Trial was to assist Ofcom, the UK regulator for media and telecommunications, in developing the regulatory framework which will facilitate the use of TV white spaces and help to achieve certain policy objectives, i.e., improving spectrum efficiency and providing universal broadband access. These policy goals are shared in the European Union (EU) and also globally and in many regions, the increasing demand for wireless applications and devices is fuelling a spectrum shortage. Accordingly, although regulatory regimes differ throughout the world, the findings and recommendations arising from the Cambridge Trial are considered suitable for more widespread application.

Similar trials are also under way in Germany, Finland, the USA and Singapore: thus, governments and regulatory authorities both internationally and throughout the EU are now considering the appropriate regulations to allow businesses and consumers to benefit from the innovation, investment and services which flexible spectrum access could offer. The use of TV white spaces is considered an important first step in developing a more flexible approach to accessing radio spectrum and the findings of this Trial should inform the process.

The key findings of the Cambridge Trial and the policy recommendations are set out in the next chapters. Additional information about TV white spaces, the associated use of geolocation databases to allocate and manage spectrum and the Cambridge Trial itself appears in later sections. The economic and policy benefits are also discussed.



[1] Currently 17 companies are members of the consortium: Adaptrum, Alcatel-Lucent, Arqiva, BBC, BSkyB, BT, Cambridge Consultants, CRFS, CSR, DTG, Microsoft, Neul, Nokia, Samsung, Spectrum Bridge, TTP and Virgin Media.

Key Findings of the Trial

- TV white spaces spectrum can be used for a range of applications, from improving rural broadband connections to machine-to-machine applications.
- There is significant TV white space capacity, depending on the power requirements and regional variations, which could be shared with new broadband devices. The amount varies with location; in Cambridge, where the terrain is favourable, there are typically between 15 and 20 TV white space frequency channels for applications requiring transmit powers of 1W or less, corresponding to a bandwidth of between 120 and 160 MHz in total.
- Geolocation databases potentially provide a reliable and responsive way to control frequency use by the TV white spaces radio devices. Since the TV white spaces spectrum varies from location to location, the geolocation databases can provide a practical way to enable sharing and prevent interference to TV and programme making and special events application (PMSE)[2], which are both incumbent services and must be protected. For the trial a full set of test and development frequency channels was loaded into two prototype databases. A simple web interface was provided by each database to enable temporary TV white space channel reservations to be made for wireless microphones and similar PMSE applications. The web interface was used by JFMG[3], Ofcom's dedicated band manager, to allow white space devices (WSD) to share the TV white spaces spectrum with PMSE users.
- The use of geolocation databases allows spectrum access to be adapted to accommodate changes in the television service during digital switchover and temporary requirements for wireless microphone applications at events in and around the city.
- The use of carefully designed online databases accessed by white spaces devices (WSD) utilising accurate geolocation capability can provide the necessary protection to licensed services[4].
- Test and measurement work by the BBC revealed significant weaknesses in the performance of TV receivers which need to be taken into account in calculating geolocation database content. These findings have been submitted to CEPT and Ofcom for further consideration. The DTG[5] has started to look at performance requirements for future TV receivers and white space devices that could allow more efficient spectrum use and improved co-existence.
- Spectrum monitoring has a role to play in establishing the efficient use of spectrum by increasing the transparency of its use – both authorised and unauthorised. Real-time networks of low-cost monitoring nodes could help white space applications to optimise the selection and use of channels indicated as available by a geolocation database.
- The basestations were carefully commissioned by Arqiva to prevent interference and no complaints arose from activities in the Trial. Houses in the areas around the basestations were provided with contact details in case they encountered any reception problems and none were reported. This, together with measurements made by Arqiva during the commissioning process, proved the validity of Ofcom's conservative assumptions on the protection requirements for television and PMSE users in assigning the non-operational (test and development) licences used for this trial.

[2] Which includes radio microphones

[3] JFMG is the dedicated band manager for programme-making, entertainment, special events and other related broadcasting activities in the UK.

[4] For this trial, the practicality and performance of location services such as GPS (or WiFI) has not been assessed

[5] The Digital TV Group (DTG) is the industry association for digital television in the UK

Recommendations

Administrations should:

- Recognise the potential contribution which TV white spaces and database-enabled spectrum access can make to improving spectrum efficiency[6] and to mitigating the spectrum shortage.
- Within the EU, implement the recommendations of the Radio Spectrum Policy Program (RSPP)[7], especially those regarding white spaces, without undue delay. The Trial has demonstrated that TV white space devices can co-exist with established services. Given the use of a correctly designed geolocation database (or databases) to enable TV white space spectrum access, any changes arising from the evolution of market requirements and technology advances can also be accommodated.
- Enable a harmonised approach to authorisation of geolocation databases. It should be open to any organisation to create and operate a geolocation database, provided it meets the technical requirements laid down by the regulator.
- Consider multiple TV white spaces device profiles for use by the database, including support for roof-top, mobile, and indoor fixed deployments. Power control, to facilitate spectrum re-use, is considered desirable and the regulations should encourage only the minimum necessary power to be used by the device.
- Promote a harmonised approach to TV white space spectrum access. So far as possible, the same methodology (e.g., for calculating permitted power levels) should be adopted by administrations. They should also ensure that spectrum emission requirements are appropriately specified; enable devices to report frequency usage back to the database; and enable database providers to exchange information on spectrum usage in order to help predict channel quality in a given location and to coordinate device deployment.
- Promote the interoperability of databases through the use of a harmonised interface between the devices and the databases. This would enable national differences (e.g., in power levels) to be confined to the database and still permit the benefits of a larger European (or even global) market for devices. Interoperability of databases would facilitate mobility of devices, innovation, and choice for end users. It would also help to make white spaces technology more affordable.
- Consider a harmonised approach to licence-exemption and conformance regimes for the equipment.
- Promote the development of TV white spaces equipment standards through ETSI and other standardisation bodies and to establish database systems to reflect national requirements. Multiple solutions and technologies could be used and a technology-neutral, flexible, generic framework is desirable. This will require careful evaluation of the interference characteristics of the candidate technologies to the incumbents.
- Recognise the value of spectrum monitoring and promote its use as part of a progressive approach to managing spectrum more efficiently.

In moving toward implementation, we need a timely definition of an appropriate regulatory framework and industry standards to ensure we enable innovative new access to our spectrum in a way that safeguards other uses.

Ed Richards, CEO, Ofcom
Speech at the Dynamic Spectrum Access Conference, Brussels, 7 March 2012

[6] See discussions at WRC 12, RSPP, Digital Agenda, etc
[7] http://ec.europa.eu/information_society/policy/ecomm/radio_spectrum/eu_policy/rspp/index_en.htm

What are TV White Spaces?

TV white spaces are pockets of UHF spectrum which are not being used for the delivery of television services. They result from the way television networks have been traditionally planned and vary in number and frequency from one location to another. Traditionally, they have been only been used by PMSE applications, but others could also share this spectrum.

How TV white spaces arise

In the UK and the rest of Europe, terrestrial television services are distributed mainly on a national or regional basis. In the UK, television services are distributed using a multi-frequency network (MFN), meaning that the services are transmitted using different frequencies in different parts of the country[8]. Because the TV broadcast network uses a high power network of transmitters, it is necessary to leave gaps to prevent TV coverage areas from overlapping which would cause interference and disrupt TV reception. Topography also affects the number of transmitters and the associated number of RF channels required to achieve coverage. In more hilly areas, for example, many more channels may be needed for television service distribution. These features of terrestrial network planning maximise coverage, minimise interference and allow terrestrial broadcasters to insert regional content. This also leads to spectrum being partially unused, giving rise to the pockets of capacity which are referred to as TV white spaces.

At each television transmitter site, only a fraction of the available UHF channels will be used to deliver the TV services. The remainder are reserved to protect the delivery of services in adjacent regions from adjacent transmitters. For example, around Cambridge most of the population is served by a single main transmitter (Sandy Heath) which uses just six UHF channels to deliver the full digital terrestrial television service. In principle, the other 26 frequency channels allocated for broadcasting in the UK are potential white spaces within part of Sandy Heath's coverage area. Towards the coverage edge, channels from adjacent DTT transmitters will spill over, potentially carrying alternative regional content. Regulators would need to consider what power constraints on white space devices might be needed in these areas to protect the adjacent TV services. Appropriately constructed geolocation databases allow these requirements to be accommodated in a practical way, whilst delivering a more comprehensive use of the available spectrum.

With today's technology it is possible to apply more precision in calculating coverage area than in the past. Thus, capacity for new TV white spaces applications can be accurately calculated, and the resulting spectrum, previously opened only for PMSE, can be shared.

Factors constraining the use of available TV white spaces capacity

At any given location the number of available white space channels is a function of the transmission power required by the white space devices and the number of TV channels that must be protected in the area. Low-power indoor white space devices such as home networking access points, for example, could be expected to find many more usable channels than higher power applications using a roof-top external antenna. This was confirmed by BBC calculations.

There are many theatres, studios and other venues where wireless microphones are licensed to use TV white spaces and which must be protected from interference. This limits available white space spectrum at those locations. To assist Ofcom's determination of restrictions that need to be applied to TV white space devices in the vicinity of these venues, the Cambridge Trial included analysis and measurements of what the protection requirements should be for PMSE applications.

[8] Digital television transmission technology also supports what is known as a single frequency network (SFN), however this places constraints on the physical configuration of the network and requires content to be identical across all transmitters in the network – this is typically not the case in the UK.

Coverage and data throughput potential

TV white space networks can benefit from the excellent propagation characteristics available in the UHF bands, albeit they are subject to interference from adjacent DTT transmitters. For a given transmission power level, the lower the UHF frequency used, the greater the range that can be achieved (although the final value also depends on the terrain losses). The actual coverage/throughput combination for white spaces is a function of the following variables:

- The transmission power that a given type of TV white space device will be allowed by the regulator to use for a given location and channel combination;
- The height and gain (directionality) of the basestation and client antennae;
- Applications using white space channels in the lower part of the UHF bands enjoy improved propagation compared with those in the upper zone;
- The nature of the 'clutter' between basestation and its client or clients, which can lead to varying levels of absorption of the signals; and
- The level of interference and noise that is present in the protected terrestrial TV channel. The higher the level of interference and noise, the more limited the throughput and/or range available for the TV white space devices.

Within these constraints white space networks can trade off coverage for increased throughput. For example, in remote rural areas where user density is low, it might be desirable to enhance coverage at the expense of throughput.

The technology for more dynamic spectrum access has come of age without being exploited fully. At the same time, consumer demand for services has exposed the limitations of the current arrangements. It is time to progress on these issues. It is now up to the regulators and policy makers to provide the means to unleash the innovative potential of dynamic spectrum access and, in doing so, play an important part in tackling the spectrum crunch.

Ed Richards, OFCOM Chief Executive

Speech for dynamic spectrum access forum, Brussels, March 7 2012

PHY Rate versus Range

Geolocation Database: the key to securing flexible, dynamic and cost-effective spectrum access

Protection of existing licensed services is a prerequisite for the use of the white spaces. Essentially, TV white space devices need to know which frequencies are available for them to use and at what power levels. This information is provided through a geolocation database. The database provides a list of white space channels with corresponding transmission power limits for a device at a given antenna location, height and configuration. It may also indicate the duration for which the frequencies can be used and, hence, when the database would need to be consulted again.

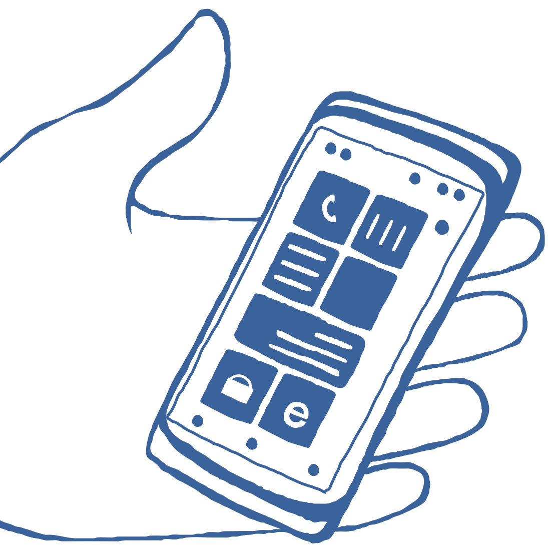
This dynamic approach to spectrum access allows it to be shared effectively and enables the framework to evolve with changing technologies and market requirements. By preventing disruption to the licensed services, the database facilitates use of the spectrum on a licence-exempt basis, lowering the barriers to the introduction of new technologies and applications. This complements the licensed use of the UHF bands and is likely to bring significant additional benefits to businesses and consumers alike.

If there is more than one geolocation database there may be advantages in the database providers communicating with each other in relation to spectrum usage. The regulatory regime has to be designed with this in mind. In Cambridge, the 10 frequency channels allowed by Ofcom[9] under the Trial's non-operational test and development licence were pre-loaded into two geolocation databases provided by:

1. Spectrum Bridge Inc., the company which has gained the first approval by the Federal Communications Commission (FCC) to operate commercially as a white spaces database service provider in the USA and
2. Microsoft Research, which was adapted from a service which has also been submitted for approval in the USA.

In the Trial, the geolocation databases were shown to be capable of adapting readily to PMSE requirements for local short-term reservations and to variations in frequency channel availability demanded by the on-going UK digital television switch-over programme. Reservations made using these interfaces caused the TV white space radio devices to shift frequency, promptly, when required.

As databases and devices get smarter, greater spectral efficiencies can be achieved and this lays the foundation for enhanced consumer services.



The old and new approaches can be compared in terms of a car park. The old approach – where network operators are given continuous allocations of channels for wireless broadband – is to pre-assign all the parking spaces, whether there are any cars there or not. The new approach – where network operators apply cognitive radio […] – is to look around the car park to see where the spaces are and take them up as needed.

David Wood, EBU, and Christoph Dosch, IRT
Paper presented at WRC12

[9] A *non-operational or test and development* licence was obtained from Ofcom by Arqiva and held on behalf of the consortium, to cover 19 sites around the city of Cambridge. A thorough site commissioning process was agreed with Ofcom, whereby each TV white spaces basestation was checked as it was commissioned. The licence enabled access to ten UHF channels (8 MHz each).

Economic and policy benefits from the use of white spaces

A range of studies have looked at the potential value of licence-exempt use of spectrum. These include studies commissioned by:

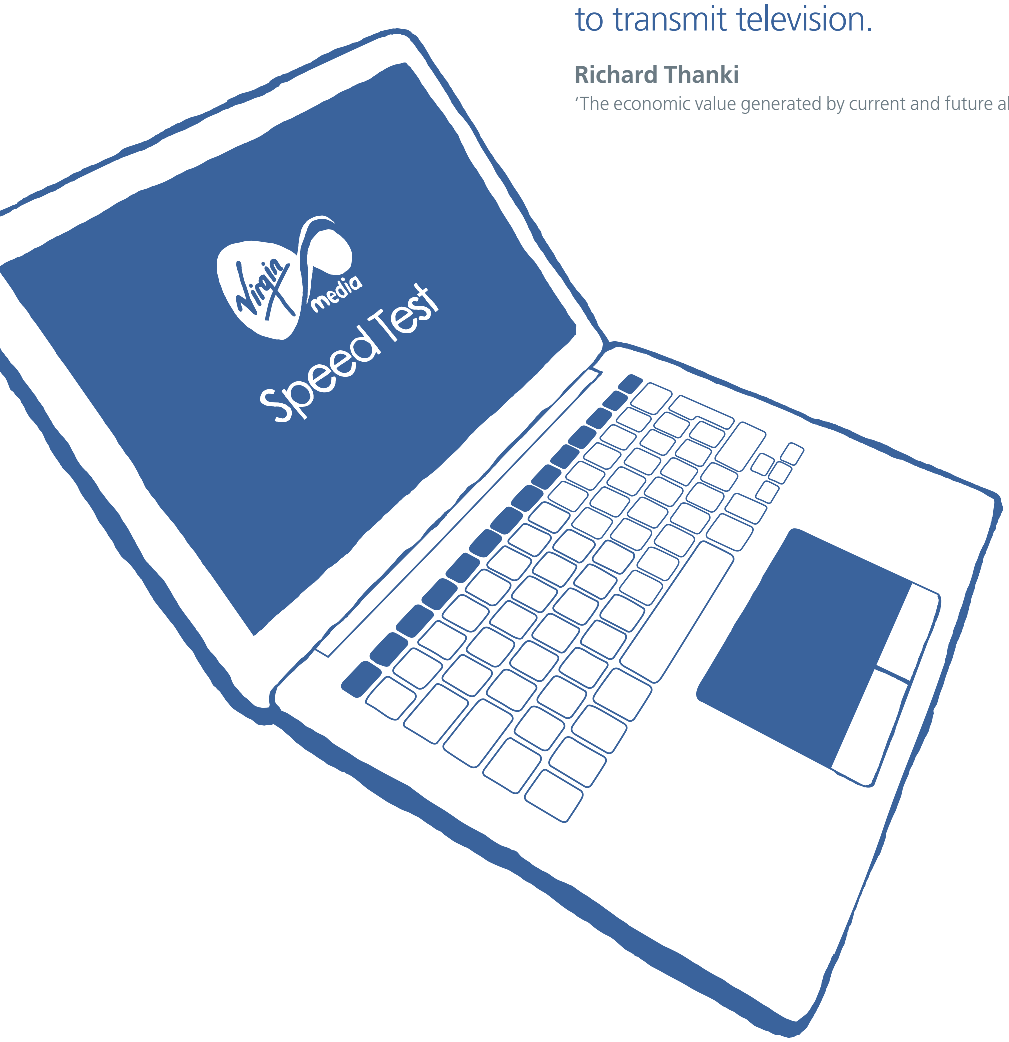
- Ofcom, in 2006, from Indepen, Aegis and Ovum[10];
- Microsoft, in 2009, from Richard Thanki (then at Ingenious Media)[11];
- Google, in 2011, from respected US economists[12]; and
- The Consumer Federation of America, published in November 2011[13].

The last three have included estimates of the economic potential from the TV white spaces. Although they were focused on the US, with FCC proceedings in mind, the applications they identify are just as relevant in the UK and the rest of Europe, as they are in other parts of the world.

The studies lay out the theoretical potential value from TV white spaces if they were applied to the given applications. The actual value that can be delivered is dependent on the enabling regulatory framework. Higher levels of protection for existing services would come at the price of reducing the economic and social value that white space technology can provide.

> Our contention is that regulators and legislators have the option now to reinforce the level of innovation and advancement in communications by recognising and supporting the use of unlicensed applications in areas of spectrum that are being liberated by technological advance – most notably, the 'white spaces' that exist in the valuable frequency bands currently used to transmit television.

Richard Thanki
'The economic value generated by current and future allocations of unlicensed spectrum', 8 September 2009



[10] J. Mitola II, G. Q. Maguire, Cognitive Radio: Making Software Defined Radio More Personal, IEEE Personal Communications, Vol. 6, No 4, August 1999 Ofcom, The economic value of licence exempt spectrum, December 2006: http://stakeholders.ofcom.org.uk/binaries/research/technology-research/value.pdf

[11] R. Thanki, The economic value generated by current and future allocations of unlicensed spectrum, 8 September 2009, http://fjallfoss.fcc.gov/ecfs/document/view?id=7020039036

[12] Stanford Report: Milgrom, Paul R., Levin, Jonathan D. and Eilat, Assaf, The Case for Unlicensed Spectrum (October, 23 2011). Available at SSRN: http://ssrn.com/abstract=1948257

[13] Consumer Federation of America, The Consumer Benefits Of Expanding Shared Used Of Unlicensed Radio Spectrum, Mark Cooper, 29th November, 2011. http://www.consumerfed.org/pdfs/Consumer-Benefits-of-Shared-Use-Spectrum.pdf

The EU Digital Agenda

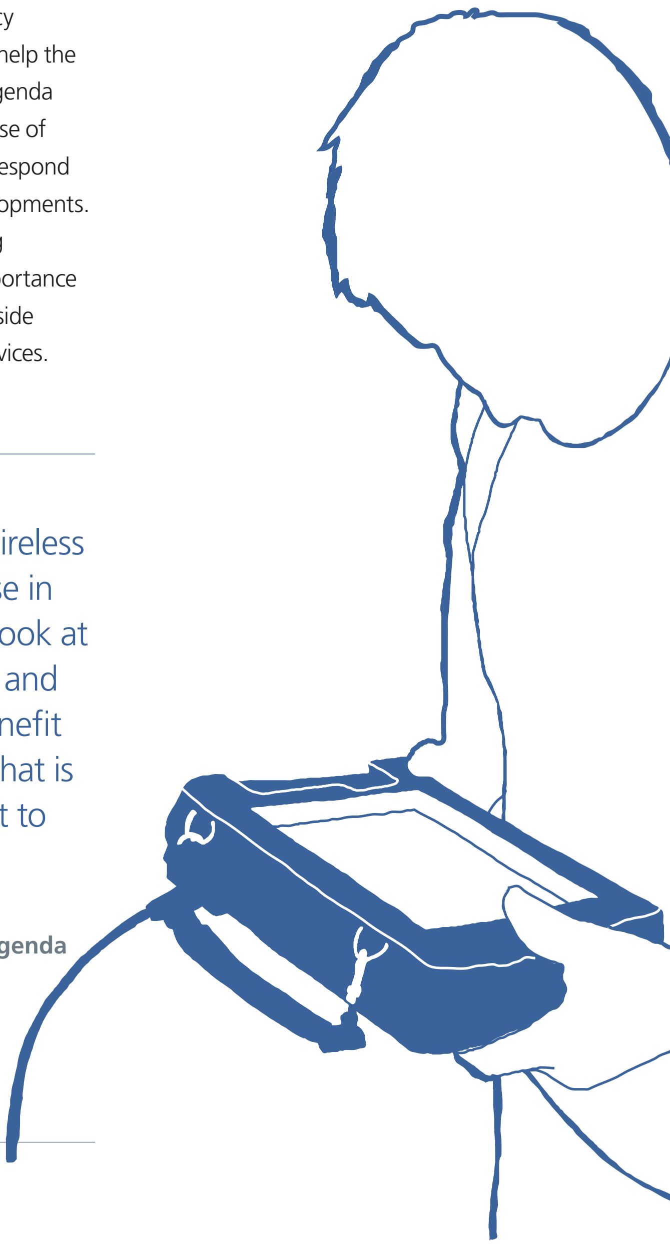
The European Digital Agenda[14] is a portfolio of policy objectives aimed at creating the conditions and infrastructure which Europe needs in order to stimulate economic recovery, remain competitive and ensure that the benefits of ICT can be enjoyed by all of its citizens.

Central to the Digital Agenda is the availability of broadband access for all (as well as high speed broadband).

Use of TV white spaces offers the potential to support at least two of the Digital Agenda's key policy objectives:

- Digital Inclusion: ensuring that all Europe's citizens enjoy at least the minimum level of broadband performance needed to access the full range of public services; and
- Innovation: supporting the development of emerging technologies, applications and services – such as the *Internet of Things* (enabled by what sometimes is referred to as *machine-to-machine* communications).

Together with other initiatives, the European Commission's Radio Spectrum Policy Programme (RSPP)[15] is designed to help the European Union reach its Digital Agenda objectives through more efficient use of spectrum and greater flexibility to respond to market and broader policy developments. The RSPP recognises the competing demands for spectrum and the importance of developing shared access, alongside exclusive allocations for specific services.



The Digital Agenda has set out some very clear targets on broadband access: wireless helps deliver them. Already, wireless solutions are essential for getting basic broadband to those in rural areas where wired is not an option… We must also look at novel ways to share spectrum: so that for example, public and commercial users, or different commercial sectors, can benefit from shared access to the same spectrum bands. I know that is a bold step, and indeed it may not be straightforward. But to such exponential challenges, we need creative answers.

Neelie Kroes
Vice-President of the European Commission responsible for the Digital Agenda
Giving Europe a Mobile Broadband Boost, 2012 Mobile World Congress Barcelona, 27 February 2012

[14] http://ec.europa.eu/information_society/digital-agenda/index_en.htm

[15] Decision No 243/2012/EU Of The European Parliament and of the Council of 14 March 20 establishing a multiannual radio spectrum policy programme, OJ, 21.03.2012, L81/7

About the Cambridge Trial

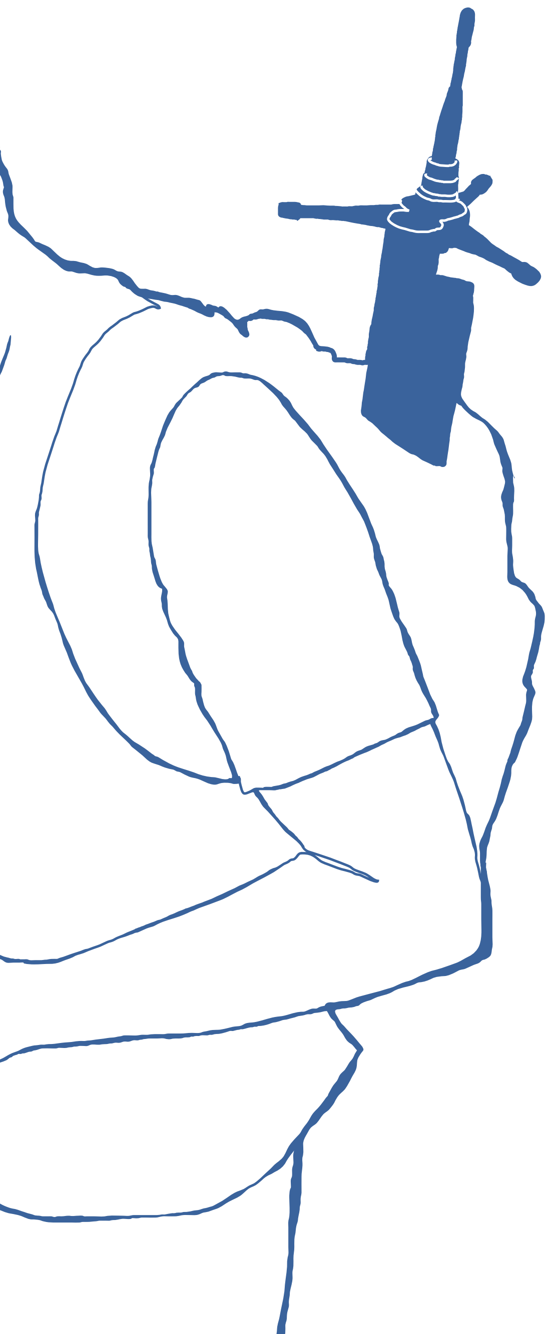
Objectives

The Cambridge Trial was established to help the UK regulator, Ofcom, to finalise the regulatory framework for making TV white spaces spectrum available, through work to confirm the protection requirements for digital terrestrial television (DTT) and other licensed services (mainly PMSE). It was also intended to help industry understand the capability of TV white spaces to serve a wide range of applications, through key factors such as the coverage and performance that can be achieved.

The Consortium Members

In the Consortium, 17 leading companies and organisations from the telecommunications, media and technology sectors, ranging from large multinationals to local high-tech start-ups, brought a diversity of perspectives and a powerful array of experience and resources. The consortium included:

- Companies experienced with the operating requirements of the existing television broadcast services in the UHF band (Arqiva, BBC, BSkyB, DTG Testing Ltd and Virgin Media);
- Companies bringing extensive knowledge of new applications, such as broadband access (Alcatel-Lucent, BSkyB, BT, Cambridge Consultants, Microsoft, TTP and Virgin Media);
- Global device manufacturers (Nokia and Samsung);
- A world-leading silicon device manufacturer (CSR);
- Companies developing TV white spaces radio devices technology (Adaptrum, KTS, and Neul);
- A leading developer of spectrum monitoring technology and solutions (CRFS); and
- Geolocation database service providers (Microsoft Research and Spectrum Bridge).



The Trial Network

The network sites were provided by the consortium members and driven by end-users and their local connectivity requirements in homes and businesses.

The Trial made use of five basestation devices located at the north side of the city centre, with the aim of providing widespread coverage. The basestation radio devices were located inside local public houses and connected to dual omni-directional antennae mounted at roof-top level. Dual-antennae provided a latent opportunity to counter strong interference sources such as distant powerful TV transmitters. Noise reduction has not been explored in the Cambridge Trial because none of the available white space radio prototypes were ready to support it.

TV White Space Radio Devices

White space standards and radio implementation were at an early stage of development when the Trial launched so it was not possible to obtain mobile devices which had native white space interfaces. Instead, it was necessary to convert the signals from TV white spaces to WiFi.

At different stages and locations radio devices from four different manufacturers, 6Harmonics, Adaptrum, KTS, and Neul, were tested and used in demonstrations of white space network links in the Trial. These devices use an intelligent basestation which interfaces with the geolocation database. Within the Trial most radios were under the control of a central monitoring facility operated by Arqiva.

About the Cambridge Trial (continued)

Trial use cases

Urban broadband

TV white spaces can be used to fill broadband access gaps and provide a way of offloading data traffic from congested mobile broadband networks. This is essentially like WiFi but with larger cell sizes ('Super WiFi')[16] and greater penetration into the interior of buildings. The Cambridge Trial examined how TV white spaces basestation radio devices could complement the coverage obtained with conventional WiFi hotspots.

Rural broadband

A number of rural communities around Cambridge have complained about the poor broadband performance they receive from currently available commercial services. Their experience is not unusual in other rural areas around the UK and elsewhere in Europe. The key attraction of TV white spaces in this application is the enhanced range[17] which lower frequencies enable (compared to the higher frequency bands traditionally used for wireless broadband access). This extended range translates into fewer basestations being required to cover a given area and, hence, lower coverage costs. An additional advantage of licence-exempt access, which can be enabled through the use of geolocation databases, is that rural communities would be free to provide their own wireless networks.

Machine to Machine

The *Internet of Things* (also known as machine-to-machine communications) embraces a wide range of emerging applications with the potential to enhance the quality of daily life and increase sustainability. A vast number of possible applications have been suggested, for example, from environmental sensors to traffic management and healthcare applications, to smart grid and metering.

The Trial's use case took advantage of the widespread coverage provided by five basestations located close to Cambridge city centre (the same as those used in the urban broadband use case). Implementing machine to machine applications in the Cambridge Trial demonstrated how the Internet of Things can be enabled with relatively sparse infrastructure operating at low power levels, using the TV white spaces.

[16] The term 'Super WiFi', originated from the United States Federal Communications Commission (FCC), has become associated with broadband access using TV white spaces – because of the additional range it offers, compared to WiFi networks in the 2.4GHz band. Capacity in a single UHF channel is generally lower than for WiFi, as the channel bandwidth is smaller (8MHz cf 20MHz). However white spaces device manufacturers may aggregate channels to produce larger effective bandwidth. In other regions channel bandwidths vary, e.g., 6 or 7MHz.

[17] Another trial on the Isle of Bute, Scotland, has also been looking at TV white spaces potential to serve rural communities. Recently, BT, the leading partner in the Bute trial, noted that: 'The Bute trial has generated some encouraging results and so it is time to extend it to a larger audience and to test the technology further.'

Location based services

The range offered by white space networks enables more reliable and flexible delivery of services intended to be relevant to device users at their current location. For example, a local business may want potential customers to be aware of an offer – perhaps only a short walk or cycle ride away. The potential of location-based services in a retail environment is clear, but there are also benefits in other industry sectors, including heritage and leisure attractions. In the Cambridge Trial a sample service was developed for deployment in the internationally renowned aircraft museum at Duxford. By leveraging location-awareness in white space devices and databases, visitors can choose to enhance their enjoyment by receiving prompts with information and relevant audio-video content from the museum's collection as they approach featured exhibits.

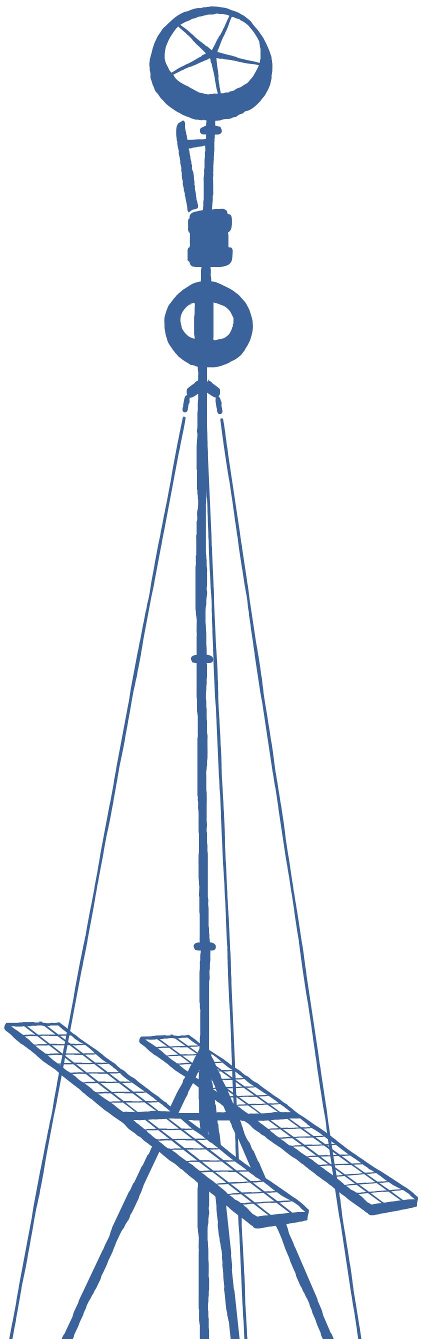
Local content distribution

The potential of UHF spectrum to enable cost-effective, wide-area distribution is already well established in terrestrial broadcasting. However, traditional transmission technology is relatively costly and, therefore, has limited scalability in a local area network solution. Now the combination of lower cost technology and flexible access to spectrum enables this type of application to be revisited. TV white spaces provide the potential to offer content across a community or a venue.

Examples of local content distribution that might be facilitated or enhanced through white spaces include:

- Local television, radio and a variety of interactive services;
- Distribution of advertising content to public displays, e.g. around a sporting or entertainment venue.

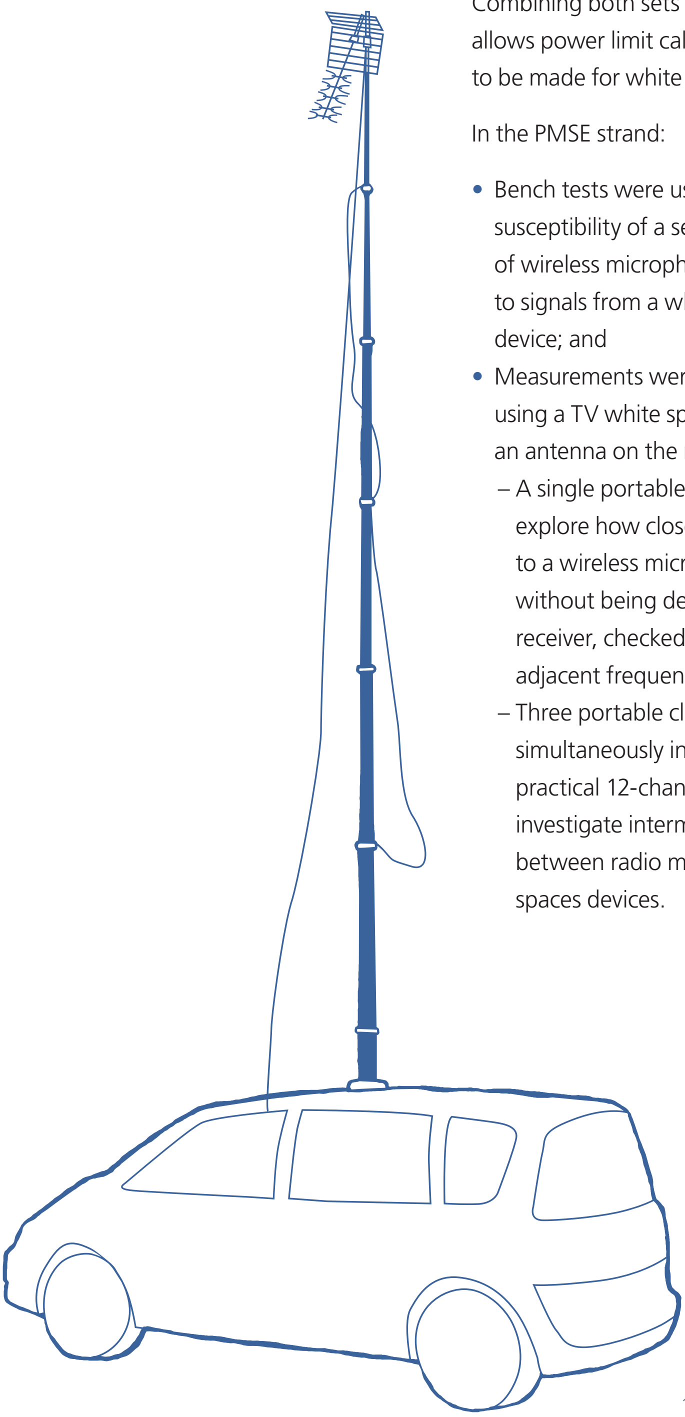
The Trial simulated a small scale service area (tens of metres in radius) within which users were able to browse a location-dependent electronic content guide and sample a selection of rich video content on suitably adapted smart phones and tablets.



Trial Test and Measurement Programme

An intensive programme of testing was designed to confirm the protection requirements needed for the licensed services, with the benefit of having access to real TV white space devices, in "lab" and "field" based configurations.

The testing was organised into the following strands: Digital Terrestrial Television (DTT) protection requirements, PMSE protection requirements and performance and coverage from both urban and rural TV white spaces basestations.



In the DTT strand:

- Bench tests were used to evaluate the potential impact from each of the sample white space devices on each of a selection of television receivers (set top boxes and integrated TVs); and
- Field tests were used to determine the potential impact of the rooftop basestation deployment scenario around one of the basestations that had been installed in the city.

Combining both sets of results allows power limit calculations to be made for white spaces devices.

In the PMSE strand:

- Bench tests were used to evaluate the susceptibility of a selection of wireless microphone receivers to signals from a white space device; and
- Measurements were made in a theatre, using a TV white spaces basestation with an antenna on the roof with:
  - A single portable client device, to explore how close it could be brought to a wireless microphone receiver without being detectable by that PMSE receiver, checked across a range of adjacent frequencies; and
  - Three portable client devices simultaneously in conjunction with a practical 12-channel PMSE system to investigate intermodulation effects between radio microphones and white spaces devices.

Surveying the white spaces

To evaluate the quality of the spectrum a network of fixed and mobile monitoring stations was installed at a number of locations across the city across the UHF bands. By establishing a reference for the background noise and interference conditions, this in-depth monitoring capability allowed the quality of the spectrum to be evaluated, thereby significantly enhancing the value of the other in-field measurements.

Coverage and Performance

Urban

Measurements were made to establish the coverage and performance that could be achieved around one of the city basestations. Measurements were taken with a roving antenna at street level (1.5m) and at 10m heights, with checks on both signal level and data throughput (uplink and downlink). The coverage achieved matched reasonably well with predictions made using propagation modelling tools.

Rural

Two links were established from member company locations to villages on the outskirts of Cambridge. In excess of 5km in length, these links used directional antennae to maximise the performance achieved.

More details

The results from all of these strands are summarised in an associated technical report, and more detailed descriptions of the results, methodologies and analysis are available in separate technical reports being produced by the Cambridge Trial Consortium members.

Design: Park Corner Design, parkcorner.com
Illustrations: Peagreen, peagreen.co.uk

The Cambridge TV White Spaces Consortium gratefully acknowledges the expertise and support of the Test and Measurement activities: Adaptrum, Arqiva, BBC, CRFS, CSR, DTG Testing Ltd, Microsoft, Neul, BSkyB, TTP and wireless microphone suppliers in conducting these tests.

The Cambridge TV White Spaces Consortium comprises the following companies: