# Using Handheld Devices to Survey the 2.4 GHz Band

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## Abstract

Conventional spectrum monitoring typically uses a measurement receiver and an antenna, which are calibrated and deployed according to a particular measurement procedure. This arrangement is hard to deploy in dense, urban environments.

A research programme is currently being conducted, on behalf of Ofcom, to see whether small, handheld devices could be used to obtain useful statistics on the utilisation of the licence-exempt 2.4 GHz ISM band. Initial results are encouraging, with survey work having revealed interesting results in town and city centres.

## Introduction

Following several years of carrying out spectrum measurements using fully-calibrated test equipment, MASS, on behalf of Ofcom, is now looking at using small, handheld receivers to monitor the usage of the licence-exempt 2.4 GHz ISM band.

It is recognised that conventional spectrum monitoring equipment is bulky and obtrusive. When the predominant radio transmitters in a band are Short Range Devices it can be hard to get good measurements in the places where usage is likely to be at its highest. A good solution to this problem would therefore be to use portable monitoring receivers that can be easily carried into shopping arcades, factories, offices, homes, etc.

MASS has carried out monitoring in dense urban areas using handheld receivers and is currently examining the data collected. The results of this programme have already shown that the geographic coverage is excellent and much better than other methods when looking at Short Range Devices in such locations.

## Background

The management of the UK's radio spectrum is the responsibility of Ofcom, the government body that is also responsible for overseeing broadcast and journalistic media. MASS, as part of Ofcom's research programme, has carried out a number of specialist surveys concentrating on licence-exempt band utilisation [1], man-made noise levels [2, 3] and the development of new techniques to measure interference levels in the VHF and UHF bands [4, 5, 6].

In 2003 MASS carried out a survey of the licence-exempt 2.4 GHz ISM band using a spectrum analyser and antenna [1]. Band utilisation statistics were logged on a laptop computer and the system was operated at various sites using a car (Figure 1) to transport the equipment.

**Figure 1 Surveying the 2.4 GHz band in 2003**

Between 2005 and 2007 the Autonomous Interference Monitoring System (AIMS) (Figure 2) was developed for Ofcom by MASS [4, 5, 6]. This system can be configured to perform different kinds of measurements and includes novel algorithms for measuring interference and noise in occupied channels. AIMS can be left at a site for several days to log the statistics of band utilisation and can perform man-made noise measurements for submission to the ITU-R P.372 databank. AIMS was used in 2006 to survey all the VHF and UHF licence-exempt bands, as part of a wider survey of the UK.

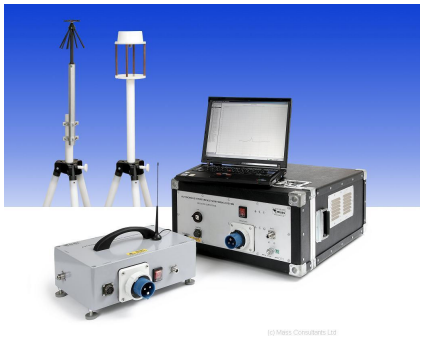

**Figure 2 Autonomous Interference Monitoring System (AIMS)**

## 2.4 GHz Licence-Exempt Band Utilisation

The 2006 survey results are summarised in Figure 3 which shows the utilisation levels across all the Licence-Exempt bands [5]. The busiest band was the 458.5 - 459.5 MHz band and the least busy was 5150 – 5815 MHz. Clearly this graph does not show the whole picture, but it does give a useful indication of the variation in usage across the bands.

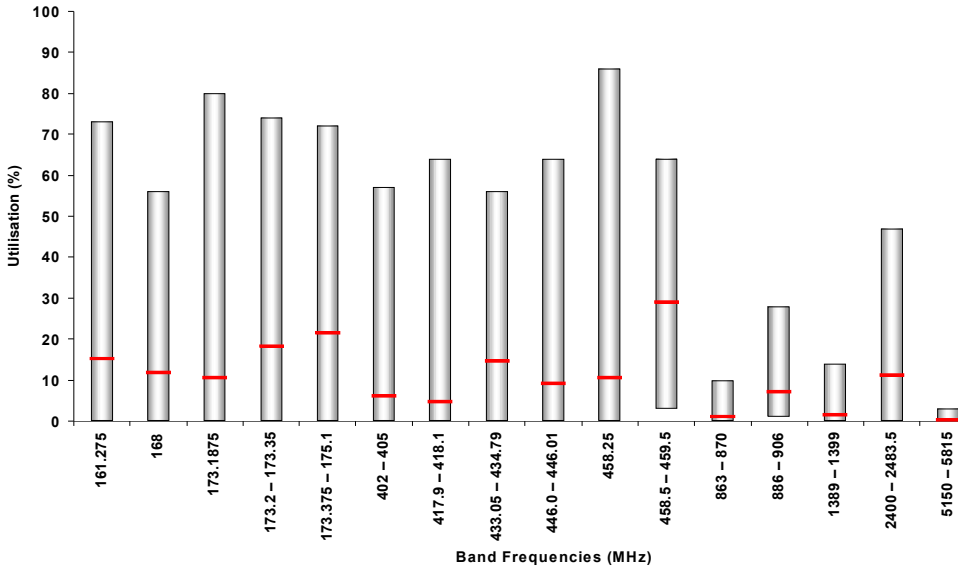


**Figure 3 Licence-exempt band utilisation 2006**

Comparing just the 2.4 GHz band usage between the 2003 and 2006 surveys is complex, but there were three sites that were visited in both cases, all of which were indoor sites. These were a school in Birmingham, the IET headquarters in London and Addenbrookes Hospital in Cambridge. Considering the mean utilisations at the three sites (Figure 4) we see that activity increased in each case. In fact the average utilisation increased from 6% in 2003 to 14% in 2006 [5].

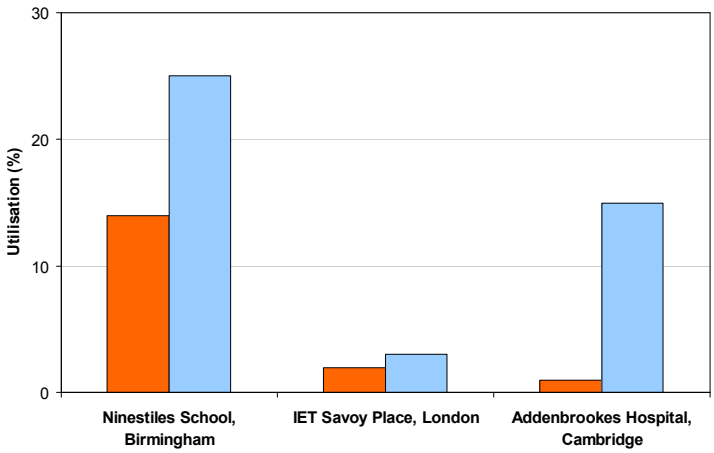


**Figure 4 Comparison of 2.4 GHz utilisation, 2003 and 2006**

Such findings support the common knowledge that the 2.4 GHz band is being used more and more and supports an increasingly complex set of radio systems. These include 'WiFi' and 'Bluetooth' as well as analogue video senders, 'Zigbee' and a plethora of proprietary radio types.

## WiFi Congestion

There has been a suggestion that, in some urban locations, the use of WiFi networks in the 2.4 GHz band is now difficult, because this band is becoming too busy [7]. The degree to which this is true is not, however, well supported by field measurements.

There are a great many problems with using WiFi devices in urban locations, not all of which can be attributed to wireless congestion. Other factors include:

- Inadequate signal strength because of range to transmitter, obscuration or other effects;
- Internet Service Provider (ISP), backhaul network or web server problems;
- Configuration problems with users' laptops or smart phones;

In addition to these real-world effects, there is a tendency for users to report connectivity issues as congestion. This is driven by the rapid increase in the numbers of Access Points (AP) visible at any one time.

As part of the current research programme MASS has carried out a survey of user and stakeholder opinions in this area and the results were interesting. In particular a number of widely-held beliefs are in circulation:

- It is believed that most urban areas are suffering from WiFi congestion, even though there is only limited, anecdotal evidence for this;
- Most commercial WiFi networks are correctly set up. It is the residential users that cause the problems, partly because they use the networks excessively and partly because they leave their networks on the default channel;
- More licence-spectrum should be made available in order to facilitate increased usage of WiFi technology. It is clear that many businesses are now relying on the 2.4 GHz band, even though it is licence-exempt and so has little protection.

It must be stressed that there is little evidence for these beliefs. Part of the motivation for the current project is, therefore, to start to clarify some of these issues.

## Monitoring Using Handheld Devices

In order to provide Ofcom with a clearer view of WiFi usage, MASS is currently working on a research programme which is due to end in February 2009. This project is aiming to define one or more measures of congestion that can be obtained by passive radio monitoring using handheld receivers.

The device being used for this exercise is the Nokia N810 Internet Tablet (Figure 5) which is easily carried around in urban areas, indoors as well as outdoors and can easily be taken to places inaccessible to vehicles.

These devices run a form of Linux operating system called Maemo, which is reasonably well supported by the open software community. The same operating system was used for the models 770 and N800 and is starting to become mature enough for extended monitoring programmes.

The Internet Tablet has an integrated GPS receiver and an IEEE 802.11b/g receiver. It can record WiFi frames continuously at rates in excess of 500 frames/second and can be used in 'RF monitoring' mode, which allows all the frames to be processed, not just the data frames.


**Figure 5 Nokia N810 Internet Tablet**

It is very easy to carry devices like this around and a spectrum survey can be carried out at a wide variety of sites. Once configured it therefore makes for a relatively inexpensive way of gathering data over a large geographical area. Fitted with 4 GB memory cards these devices can record for several days, meaning that the battery life becomes the limiting factor. An external battery pack has been built to enable longer recordings to be carried out.

Figure 6 shows a map overlaid with a typical walking route, this case in central London. Our results to date suggest that the GPS receiver accuracy of these small, handheld devices is adequate for carrying out such surveys. The grid squares shown are 1 km resolution and the highest resolution needed for such works is in the order of 500 m. Producing statistics at 500 m resolution is therefore practical and will give Ofcom a clear picture of where utilisation levels are perhaps excessive.

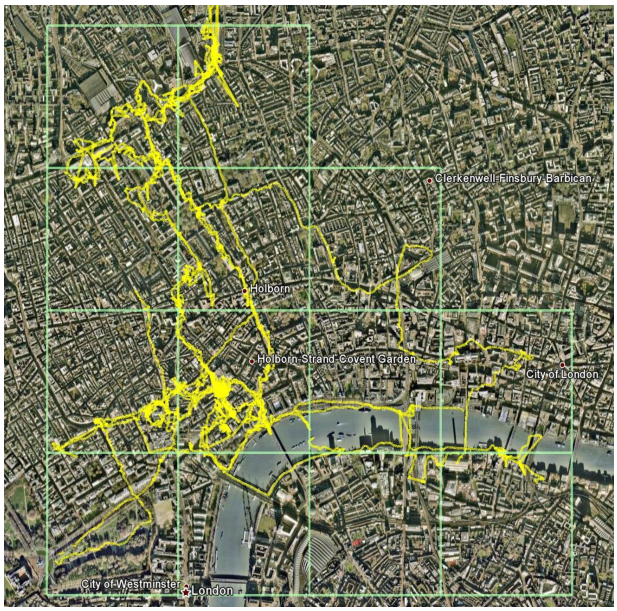


**Figure 6 Typical walking route, central London**

Using the Internet Tablet, or a similar device, as a measurement receiver is clearly good for achieving geographical coverage. It does, however, raise issues when compared to using fully-calibrated test equipment, such as the AIMS (Figure 2):

- Being portable, the antenna gain pattern will be affected by the person carrying the device. This would seem to be a downside of the approach as results are unlikely to be repeatable and field strength calibration is not possible;
- It is unlikely that the results of such a survey would be accepted by the ITU-R. To do so would need a lot of work on test methods and receiver build standards.

Given that such questions are not insurmountable, MASS is currently investigating the ways in which the information gained from these devices can be interpreted. The emphasis is on answering the research question of how congestion should be measured using a passive monitoring approach.

Figure 7 is just one of the many ways of looking at the data gathered. It shows the average rate at which retry frames are detected plotted against the total frame rate. The results shown are just those from Cambridge, London and a set of laboratory tests. Clearly, in this particular case, the London data shows higher usage and higher error rates than the Cambridge data. MASS is now looking at using these statistics to infer the user experience that might be expected in an area.

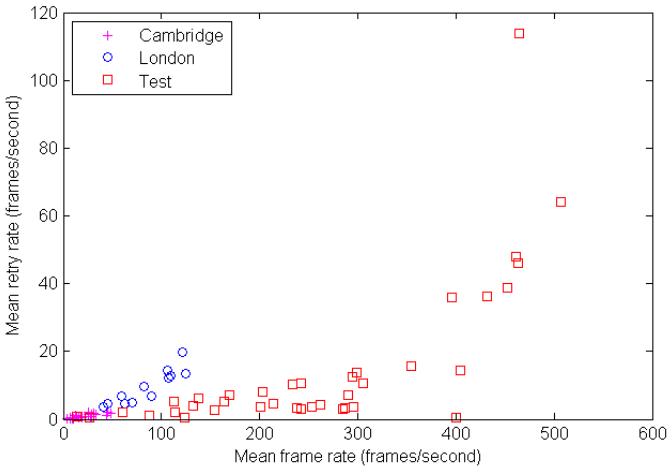


**Figure 7 Retry rate versus frame rate**

## Conclusions

MASS has deployed a number of Internet Tablets to see whether handheld devices can produce useful statistics on the level of usage and congestion of the licence-exempt 2.4 GHz band. The results so far have been extremely encouraging, but further work is needed to examine the data in detail and produce recommendations on the way forward.

The GPS performance of these devices is adequate for such surveys, even in dense urban locations. Also, the storage capacity is ample, placing the emphasis on battery life as a limiting factor.

The WiFi density in the centre of London is clearly substantially higher than in the smaller towns covered by the monitoring to date. This higher level of usage is accompanied by an increased frame error rate, which explains some of the reports of poor connectivity in London.

A final report from this research project will be published in February 2009 and will be made available on both the Ofcom website and MASS website.

## References


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