The findings in this report are those of the authors and do not necessarily represent those of the Department for Communities and Local Government.
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Chapter 1

Introduction

1.1 Background

This project is one of a series undertaken as part of the Building Disaster Assessment Group (BDAG) established to consider the issues, for fire and rescue services in the UK, that have been highlighted by the World Trade Centre incident of 11 September 2001 (9/11).

The projects’ aim is to provide advice and guidance on the possible types of communications infrastructure that may be needed in the built environment to support fire and rescue service intervention.

This scoping study forms the first part of that project and the study’s aim is ‘to review the current level of knowledge and understanding of the forms of communications infrastructure available in the built environment and the requirements for effective communications on the incident ground within the UK’ [Ref. 1-1].

Mott MacDonald has been appointed to complete this study.

1.2 Purpose and scope

This Technology Review Report is an interim deliverable within Stage 1 of the Study, Information Gathering, and is the output of Work-streams 1.2a and 1.2b as described in our proposal [Ref. 1-2]. As such it provides information on the:

- Built Environment found in reviewing current practices and trends in the construction industry (Work-stream 1.2a); and
- Communications Technologies found in considering the current and emerging possibilities (Work-stream 1.2a); followed by a
- Risk Review to identify risks presented by the built environment and the technology (Work-stream 1.2b).

The following sections summarise these findings and provide some commentary on their significance. These findings will be used as input to Stage 2 of the Study, Analysis, along with the other interim deliverable from Stage 1, the Current Situation Report.
1.3 Key drivers

The key drivers are highlighted in the brief provided [Ref. 1-1] as follows:

‘The radios presently used for incident ground communications in the UK operate in the Ultra-High Frequency (UHF) range. As such, signal transmission between handsets can be adversely affected by the interruption of the signal by a number of factors, including the materials used in building construction. Signal problems may be encountered in any environment but are a particular issue in the built environment (especially large or complex buildings, and tunnels and other sub-surface structures) due to the nature of the construction methods used.

Problems in fire and rescue service communications may also occur where in-built systems, such as dedicated fire control points within buildings, are adversely affected by extreme events such as terrorist activities.

The McKinsey report into the response of New York Fire Department (FDNY) to the World Trade Centre incident [Ref. 2-6] identified that any interruptions to incident ground communications, particularly in large or complex buildings, can have a severe effect upon the effective command and control of incidents and thus the safety of firefighters and occupants. The U.S National Institute of Science and Technology (NIST) NCSTAR 1-8 report (Federal Building and Fire Safety Investigation of the World Trade Center Disaster) [Ref. 2-7] also identified radio communication problems.

In the UK access and facilities for the fire and rescue service are identified through the Building Regulations, however, there are presently no general requirements for communications infrastructures to be provided to overcome communications problems as part of such facilities. The most recent consultation document on the Approved Document ‘B’ of the Building Regulations [Ref. 2-8] does contain some recommendations on the provision of communication systems in some circumstances.

1.4 Issues to address

Issues to be addressed by this study are also highlighted in the brief provided [Ref. 1-1] as follows:

‘The scoping study will take the form of an international literature review and survey of current practice, nationally and internationally, to identify and quantify where appropriate:

1. The forms of communications infrastructures currently used on the incident ground by the fire and rescue service in the built environment

2. The present advice and guidance provided on communications infrastructures designed to support fire and rescue service intervention in the built environment
3. The forms of communications infrastructures and systems which are, or in the foreseeable future will be, available for use in the built environment

4. The effect that the nature, configuration and construction of the built environment has upon fire and rescue service communications infrastructures

5. The use of telemetry equipment by fire and rescue services to monitor personnel and the incident environment and the interaction of this type of equipment with the built environment

6. The need for emergency service inter-service communication on the incident ground

7. The efforts of the communications industry, and others where identified, in devising means of suppressing or restricting radio communications within the built environment and the potential impact of these activities on fire and rescue service incident ground communication

8. The communication needs of the fire and rescue service currently and the likely needs in the next five years

9. A ‘gap analysis’ between the needs and the provisions currently, and in the next five years.

This Technology Review Report is one part of that study and goes some way to covering these issues.

1.5 Approach taken

Given the limited time available to complete this report the approach taken was to seek guidance from experts in the various fields that are employed by Mott MacDonald.

In the case of the radio aspects of this review, which is central to the operational requirement, this included individuals with a detailed working knowledge of:

1. Built Environment in terms of:
   a. Structures, and the materials used in construction
   b. Mechanical & Electrical (M&E), and the infrastructure that is installed in such buildings
   c. In the context of existing and emerging Building Regulations.
2. Radio use:

   a. Generally, in order to be able to provide a technical view

   b. By fire and rescue services, in order to be able to provide a operational view

   c. In the context of emerging national and international frameworks governing such aspects as spectrum management.

It is not intended to be an exhaustive or rigorous approach but is considered to be representative and sufficient for the purpose at this time.

1.6 Contents

The contents of each of the following sections of this report are as follows:

- Section 2 – Reference Documents, lists the key material referred to in subsequent sections
- Section 3 – Stakeholders Consulted, provides details of the organisations and individuals contacted in producing this report with their contact details
- Section 4 – The Built Environment – UK and Internationally, gives a general overview of current practices and emerging trends in construction
- Section 5 – Communications Technologies – UK and Internationally, provides details of the various technologies available with their advantages and disadvantages for At-Incident use
- Section 6 – Risk Review, giving an initial Risk Log that identifies example risks associated with the built environment and the different technologies.
- Section 7 – Summary and Conclusions, which draws on the previous three sections (4, 5 and 6) and lists the key findings, observations, strengths and weaknesses of current arrangements.
Chapter 2

Reference Documents

2.1 Fire Research and Statistics Division (RSD) and Mott MacDonald

Table 2.1, below, shows the FRSD documents that are referenced in this report:

<table>
<thead>
<tr>
<th>Reference</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Ref. 1-2]</td>
<td>‘Consultancy Proposal for the Incident Ground Communications Study’, Revision A1, Mott MacDonald, February 2006</td>
</tr>
</tbody>
</table>

2.2 Other organisations

Table 2.2, below, shows the other documents that are referenced in this report:

<table>
<thead>
<tr>
<th>Reference</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Ref. 2-1]</td>
<td>‘Fire detection and fire alarm systems for buildings – Part 9: Code of practice for the design, installation and commissioning and maintenance of emergency voice communication systems’, BS 5839-9:2003, British Standards</td>
</tr>
<tr>
<td>Reference</td>
<td>Title</td>
</tr>
<tr>
<td>-----------</td>
<td>-------</td>
</tr>
<tr>
<td>[Ref. 2-4]</td>
<td>‘Application of FSS [Frequency Selective Surface] Structures to Selectively Control the Propagation of signals into and out of buildings’, ERA Report 2004-0072; ERA Technology, Building Research Establishment (BRE) and QinetiQ for the Office of Communications (Ofcom), March 2004</td>
</tr>
<tr>
<td>[Ref. 2-10]</td>
<td>‘Spectrum Options for Public Safety Services’, PSSPG 21(03)10r4, Ofcom</td>
</tr>
<tr>
<td>[Ref. 2-12]</td>
<td>‘Propagation Data and Prediction Methods for the Planning of Indoor Radio-communication Systems and Radio Local Area Networks in the Frequency Range 900MHz to 100GHz’ P.1283-3 (04/03) and P.3/11 (Rev.1) (03/05)</td>
</tr>
<tr>
<td>[Ref. 2-13]</td>
<td>‘Propagation Effects Relating to Terrestrial Land Mobile Services in the VHF and UHF Bands’ P.1406 (07/99)</td>
</tr>
<tr>
<td>[Ref. 2-14]</td>
<td>Construction (Design and Management) Regulations, SI 1994-3140, Parliament,</td>
</tr>
</tbody>
</table>
Chapter 3

Stakeholders Consulted

3.1 Built environment

Table 3.1, below, shows the Built Environment organisations that were contacted to supplement our own in-house knowledge and literature review findings, if required, and contributed in the completing this report:

<table>
<thead>
<tr>
<th>Organisation</th>
<th>Individual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pilkington Plc</td>
<td>Mr Stephen DAY</td>
</tr>
<tr>
<td><a href="http://www.pilkington.com">www.pilkington.com</a></td>
<td>Pilkington</td>
</tr>
</tbody>
</table>

3.2 Communications technologies

Table 3.2, below, shows the IT and Telecommunications organisations that were contacted to supplement our own in-house knowledge and literature review findings, if required, and contributed in the completing this report with the contact details of the individuals for future reference:

<table>
<thead>
<tr>
<th>Organisation</th>
<th>Individual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Department for Communities and Local Government</td>
<td>Mr Chris BOWLING</td>
</tr>
<tr>
<td><a href="http://www.communities.gov.uk">www.communities.gov.uk</a></td>
<td>Technical Manager</td>
</tr>
<tr>
<td></td>
<td>Fire Services and Resilience Directorate</td>
</tr>
</tbody>
</table>
Chapter 4

The Built Environment – UK and Internationally

4.1 UK

4.1.1 Introduction
The construction of buildings generally follows a set pattern in that an Architect agrees the brief with the Client. The brief will outline the use of the building and any overall special requirements. At a suitable juncture the Structural Engineer (SE) and Mechanical & Electrical (M&E) Engineer will be appointed as part of the design team. Other specialists such as fire engineers may also be appointed.

The brief will be considered by the design team and a scheme developed to accommodate the requirements of the brief. The form of the structure will generally be determined by the structural engineer to accommodate spatial, economic, and aesthetic requirements of the brief.

Types of structural construction materials and building types are given later in this section and there is no specific correlation between the two. For example a hospital building with a 9m span grid could be constructed from:

1. Solid in-situ reinforced concrete (RC) slab supported upon in situ RC columns
2. Waffle or other weight saving configuration of RC slab supported upon in situ RC columns
3. Pre-cast concrete (PC) floor units supported by in situ RC beams and RC columns
4. PC floors on structural steel beams and columns
5. In situ RC floor on permanent metal deck support shuttering on structural steel beams and columns
6. Combination of the above.

Some building types utilise dense RC concrete for specific reasons such as nuclear facilities and deep underground structures.
The M&E engineer will consider the brief from a different point of view determining the requirements for heating, ventilation, power, and communication. Unless the building is designed specifically for low or efficient energy use then the building would not normally be M&E driven in terms of the form of the structure.

Having established the principles of the building the design team will proceed with the design process:

1. Obtain planning approval, which is usually undertaken by the Architect and varies throughout the UK regions

2. Submit a Building Regulation application which varies across the UK regions but generally includes, but not limited to the following:
   - Structure
   - Fire safety
   - Ventilation
   - Electrical installations

3. Compliance with British Standards.

As a part of the above the local fire and rescue authority is consulted.

The issue of emergency services communication within buildings does not fall within the general remit of the design team unless specifically directed by the Client.

4.1.2 Current Building Regulations
In respect of mandates and guidance for the provision of communications systems within buildings there are minimal requirements within the current Building Regulations.

The current Approved Document ‘B’ of the Building Regulations includes provision of fixed communications systems for use in emergency refuges for the disabled but no requirement for assisting emergency service radio communication, or providing communication links for emergency service use, exists within the Building Regulations.

4.1.3 Regulatory Reform (Fire Safety) Order 2005
The Fire Safety Order applies in England and Wales. Northern Ireland and Scotland have their own laws. The Order requires fire precautions to be put in place “where necessary” and to the extent that it is reasonable and practicable in the circumstances of the case.

Responsibility for complying with the Fire Safety Order rests with the ‘responsible person’. In a workplace, this is the employer and any other person who may have control of any part of the premises, eg the occupier or owner.
It could perhaps be justified that supporting infrastructure in the built environment for at-incident communications is reasonable and practicable under the Order.

4.1.4 Consultation with Emergency Services
Consultation with the Fire Service takes place as a matter of course on all developments, but again this is focused primarily on the physical aspects of life safety, ie provision of fire extinguishers, dry risers, etc.

Consultation with the other emergency services, eg police, ambulance, is more dependent upon the nature of the facility and is generally focused on identifying risks, access routes, etc as opposed to dealing with communications issues.

Where buildings require enhanced radio transmission properties it is normally achieved by the installation of repeaters, the location of which is established by survey on completion of the building structure.

4.1.5 Structural Issues

General
The issues of emergency communications within the Structural Engineer (SE) remit is not considered and if required would form part of the client’s M&E brief.

The form of construction, as already mentioned, varies considerably from structure to structure as the combination of design requirements based upon loading, centres of structural support, service zones, vibration, and cost. Consequently it is not possible to define a typical form of construction for analysis in respect of its effect on radio transmission in a building. Indeed none of the British Standards used in typical structural design even makes mention of the effect on communications.

Steel, whether it be in the form of hot or cold rolled sections, reinforcement bars, permanent metal shuttering, or metal roof and floor cladding, will be used widely whichever form of construction is adopted. Some traditional architectural materials act as Faraday shields in practice. These include plaster with metal lath, and rebar reinforced concrete. These affect the use of cordless phones and wireless networks inside buildings and houses. A Faraday cage is best understood as an approximation to an ideal hollow conductor. Electric fields produce forces on the charge carriers (usually electrons) within the conductor. As soon as an electric field is applied to the surface of an ideal conductor, it generates a current that causes displacement of charge inside the conductor that cancels the applied field inside. Thus electromagnetic signals (radio waves) are either blocked or significantly reduced inside the cage from outside.
The detailed dynamic response of a building is not generally determined unless it is specifically required to demonstrate a structure's ability to resist adverse deflection; for example in stadia or hospital operating theatres. However, resonance is avoided by limiting natural frequency, so that the vertical frequency is greater than 8.4 Hz and the horizontal frequency is greater than 4.0 Hz.


**Materials with known issues**

Some types of glass including, K-glass, used for thermal blocking has a 20dB attenuation factor as a general rule of thumb. The gaps between the glass panes are more likely to be leaky to RF than the panes.

There are specific glass products that will block RF transmissions and the more modern buildings are becoming more ‘radio proof’ at specific frequencies due to building products and construction techniques. There is anecdotal evidence, for example that some schools with mobile base stations concerns are being targeted for the sale of particular glass types in part because of its high attenuation of mobile and emergency service radio frequencies.

**Frequency Selective Surfaces and Structures**

Research has been carried out for Ofcom into the Application of Frequency Selective Surfaces (FSS) Structures to Selectively Control the Propagation of signals into and out of buildings [Ref. 2-4]. This report noted that no regulations are currently in force which cover the “RF transparency” of buildings and that there is substantial use of metal within current buildings which causes major problems for radio propagation. Glazing structures have been identified as being most amenable to enhancement technologies. Some of the conclusions and recommendations derived from the work are summarised below:

1. ‘Modern building techniques do not take into account the requirement for radio signals to penetrate into buildings. For example, many modern offices are constructed with metal cladding and low-emissivity glass which severely restricts propagation into buildings. Future buildings should be designed with radio propagation in mind

2. The presence of dead zones within buildings can potentially be serious in emergency situations when radio is used to coordinate the emergency services. The access to emergency service radio in large buildings should be assessed for all new construction and steps such as those described here taken to improve it
3. In order to mitigate for dead zones, cellular radio operators use a higher margin in their radio link budgets than is necessary to reach the cell boundary. This means that more radio power and/or base station sites are needed, which decreases the overall spectrum efficiency of the network. It has been shown that even a small increase in building penetration can lead to much higher utilisation of the cellular radio spectrum. This should be considered for future building design.

4. Several methods have been developed that will allow better building penetration. These include:
   a. Use of frequency selective surfaces to re-direct energy inside buildings
   b. Balanced probes inserted into walls and floors to help propagate radio energy
   c. Use of the ceiling and floor voids to propagate energy deeper inside buildings
   d. Revised designs of low-emissivity glass that will allow penetration of radio signals, which can include ‘radio windows’ or glass that allows the passage of radio signals at strategic points.

5. Longer term developments in radio transmission technology will see the possibility of switching radio signals into buildings on and off. The cost effective application of the techniques to a wide range of materials needs to be explored.

Related research [Ref. 2-5] within the Treasury-funded research programme Spectrum Efficiency Scheme (SES) notes that ‘Ofcom … suggested that provision should be made for emergency service radio transmissions to propagate … adding a passband from 380MHz to 450MHz’.

This demonstrates that Ofcom appear to be aware of the need to pass emergency services radio frequencies (current frequencies) although the identified band does not include the bands currently used to provide fire and rescue service at-incident communications (but do include Firelink using the O₂ Airwave service).

However, their focus is on enhancing spectral efficiency (in this case isolating IEEE 802.11x bands) and is ongoing (2003/04 through to 06/07) with the aim to ‘encourage the sharing of information between members of the radio community at the earliest opportunity’.

It might therefore be worthwhile contacting Ofcom. Contacts are Dr Ahmed Atefi, ahmad.atefi@ofcom.org.uk or Dr Christos Politis, christos.politis@ofcom.org.uk.

4.1.6 M&E Issues

**Current Practice in Large and Complex Buildings**

A Fire Control Centre is generally provided within the building to enable the emergency services to assume control of an incident immediately on arrival on site.
This can be a dedicated room, but is much more commonly combined with the overall Management Centre, where aspects such as fire alarm, Closed Circuit Television (CCTV), access control, public address, etc are all centrally controlled and monitored from. The emergency services can make use of the information available on these systems to assist them deal with an incident.

Plans of the building are normally displayed near the emergency services access points showing the emergency and escape facilities.

Building Regulations are generally more focused on the physical aspects of preserving life, and then property, with a concentration on physical matters such as: maximum travel distances for escape, number and width of escape stairs, incorporation of firefighting shafts, sprinklers and so on. That said there are some requirements for communications as summarised below.

**Mobile Phone Communications**
Mobile phone (and indeed most forms of wireless) communication can be particularly problematic in heavy mass buildings ie concrete.

Most hospitals also have policies prohibiting the use of mobile phones within their buildings due to the potential of interference with critical medical systems.

**Emergency Voice Communications (Fire Telephone Systems)**
Fire telephones are typically provided at strategic points, eg firefighting lobbies, and all entrances, to enable communication between emergency services personnel and the Control Centre.

Current building regulations relating to emergency communications in-building may be found in the following key references, and the references therein:

- BS5839-9:2003
- BS5588-5:2004
- BS5588-11:1997

In relation to radio and mobile communications these regulations state that:

‘Personal radio sets have disadvantages such as occasional poor reception due to local screening and battery life’.

Mobile communications should preferably be supplemented by some form of fixed communications system, eg a fire telephone system. Fire telephone handsets should be provided at strategic points, at each entrance, in fire-fighting lobbies and in the control room and should be permanently fixed equipment.’
4.1.7 Health and Safety

All new building projects are required by the Construction (Design and Management) regulations [2-14] to have a health and safety file which “should include information about all the following topics, where this may be relevant to the health and safety of any future construction work. The level of detail should be proportionate to the likely risks involved in such work:

1. A brief description of the work carried out

2. Residual hazards and how they have been dealt with (for example surveys or other information concerning asbestos, contaminated land, water bearing strata, buried services)

3. Key structural principles incorporated in the design of the structure (eg, bracing, sources of substantial stored energy – including pre- or post-tensioned members) and safe working loads for floors and roofs, particularly where these may preclude placing scaffolding or heavy machinery there

4. Any hazards associated with the materials used (for example hazardous substances, lead paint, special coatings which should not be burnt off)

5. Information regarding the removal or dismantling of installed plant and equipment (for example lifting arrangements)

6. Health and safety information about equipment provided for cleaning or maintaining the structure

7. The nature, location, and markings of significant services, including fire-fighting services

8. Information and as-built drawings of the structure, its plant and equipment (eg the means of safe access to and from service voids, fire doors and compartmentation). “

The regulations do not specify where the information should be kept but ideally on the premises to which they relate and in electronic and paper copies.

Where buildings have excessive amounts of information there are several Visual Management systems available which store the information electronically in databases. There is interaction between the electronic drawings and database which if altered on the drawing will automatically update the database.

The system can be costly to set up and customise but does have benefits in that the information is a working document.
As an example this system is used at the Trafford Centre where the Visual Management Systems include a database of drawings and information allowing quick and easy access. The developer will hand over the system to the tenant once the development was complete, but it is noted that updating the system and keeping control of revisions can be difficult.

4.2 Internationally

4.2.1 Introduction
The following countries were considered as to their approach in enforcing or encouraging consideration of fire and rescue service radio communications in building development as they appear to be the most advanced:

1. US
2. Singapore.

4.2.2 US
The Federal Communications Commission Rules CFR Part 47 ‘Private Land Mobile Radio Services’, 90.219 ‘Use of Signal Boosters’ requires ‘building structures which cannot support the required level of radio coverage to be equipped with any of the following in order to be able to achieve the required level of adequate coverage: a radiating cable system or an internal distributed antenna system with or without signal boosters as needed’ [Ref. 2-11].

These rules find themselves implemented locally across the US in various ways, but often in local codes or ordinances. An example is provided at Appendix F.

4.2.3 Singapore
There do not appear to be any building regulations relating to communications in Singapore that go further than those in the UK. In other words, the installation of emergency telephones is covered by regulations and it refers to fire and rescue service use on attending an incident, but nothing more.

However, there is in Singapore a good amount of encouragement of improving building design, such as improving mobile phone coverage in building – see Infocomm Authority (IDA) Code of Practice for Information in Buildings (COPIF).

The Singapore Civil Defence Force (SCDF) together with the Building and Construction Agency (BCA) and others publish a document ‘Enhanced Building Security – Useful and Practical Tips’ with Item 11 being ‘Provide Cell Enhancers’ [Ref. 2-9]. This section encourages the provision of ‘cell enhancers to facilitate communication by emergency responders’ and states that:
'Deep basement floors and buildings with relatively small window openings could potentially stop radio communication with emergency responders who are inside the building. With the installation of cell enhancers, communication by radio among emergency responders becomes possible between the interior and exterior of the building and within the building between the different storeys including the basement levels'.

4.3 Matters arising but considered out of scope

Incidents occurring in Ships, although not specifically the built environment (in port/repair/dry docks – not at sea) cause major problems for fire fighters, the availability of effective communications is essential for their safety – presently UHF handhelds and repeaters are used in conjunction with ships engineers to guide personnel around the vessel using a system known as ‘talk down’. However, FRSs are increasingly using Infra-red (IR) cameras to assist in this area – images are relayed back to supervisors via RF in some cases.

Another area not covered within the document concerns incidents involving terrorist activities and suspected bombs/ordnance – current guidance involves the restriction of RF within 10m for handheld equipment and 50m for vehicle mounted equipment.

4.4 Summary

4.4.1 In the UK consultation occurs between developers and the local fire and rescue service on all large and complex developments as a matter of course but the focus is primarily on physical aspects and not communications. Within this UK context we note the following:

1. Generally consultation with the fire and rescue service takes place as a matter of course on all large and complex developments, but tends to be focused primarily on the physical aspects of life safety and not radio communications

2. Structural issues:
   a. The issue of emergency services communication within buildings does not fall within the general remit of the design team unless specifically directed by the Client
   b. Building Regulations and British Standards do not give requirements for the transmission of radio-waves or mention structural provision for such
   c. Some materials, such as K-glass, are known to be problematic in their inhibition of radio wave propagation into the building
d. Frequency Selective Surfaces and Structures are being researched currently by Ofcom. This research is aware of emergency services radio issues in the built environment, the opportunities to improve it and need to not inhibit it further. The research includes building design with radio propagation in mind but the research programme is ongoing.

3. M&E Issues

   a. The issue of emergency services communication within buildings is typically limited to consideration of emergency voice communication systems (fire telephone systems).

   b. Building Regulations place requirements for lift communication systems and emergency telephone systems in large and complex buildings. They accept that firefighters ‘personal radio sets have disadvantages such as occasional poor reception due to local screening and battery life’. Where buildings have a fire control room a direct link should be provided between it and all fire fighting lobbies and fire service access points, and ‘Safe Haven/Refuge’ locations under the Disability Discrimination Act.

3. Outside of radio communications directly, there is information, much as a result of Health & Safety legislation, that should be maintained and available to the fire and rescue service from the management centre at large and complex sites.

4.4.2 Investigations internationally show that the situation varies between jurisdictions, some of which cover countries but others which cover smaller geographical areas. Within these the US and Singapore are notable for their particular consideration of emergency services radio coverage in-buildings, with:

1. The US setting national guidance for in-building coverage and authorities across the US progressively adopting similar rules in the form of relatively detailed specifications and applying these as Ordnances. Compliance against these can be required in order to gain and maintain the buildings occupancy certificate.

2. Singapore, whilst not mandating in-building radio coverage, does provide guidance on the installation of equipment in order to promote it.
4.5 Conclusions

4.5.1 Current Situation
Key conclusions on the current situation are as follows:

1. Consideration of Emergency Services radio communications is not mandated in UK building regulations, but consultation between developers and local fire and rescue services are commonplace for large and complex buildings.

2. Where consultation concludes that buildings require enhanced radio transmission properties it is normally achieved by the installation of repeaters the location of which is established by survey on completion of the building structure.

3. Frequency selective surfaces and structures are emerging but as yet are not common. Research is ongoing at present into their effects and best use, with Ofcom aware of the emergency service issue.

4. Emergency Services radio communications is mandated some parts of the US.

4.5.2 For the Future
Key conclusions on the future needs are as follows:

There is a need to monitor developments in the built environment including:

1. The extent that materials such as K-glass are used in the built environment.

2. The Ofcom research into frequency selective surfaces and structures.

There is a need to monitor the Ofcom research and represent the fire and rescue service needs within that programme of work.

There should be consideration of the need for national guidance on practical measures to assist in-building coverage with reference to the various approaches internationally.
Chapter 5

Communications Technologies

5.1 Introduction

5.1.1 Section Overview
This section considers current and future communications technologies, particular issues associated with the built environment and for providing At-Incident communications. The section is structured in terms of consideration the following in the order shown:

1. The regulatory situation
   a. Licensed versus licensed exempt spectrum
   b. Private versus public network provision
   c. Spectrum available to the emergency services

2. The range of technologies
   a. Mobile radio (which can be used for At-Incident and wide area communications)
   b. Wireless technology
      i. Personal Area Networking (PAN) and Local Area Networking (LAN)
      ii. Metropolitan Area Networking (MAN) and Wide Area Networking (WAN)
   c. Supporting technologies in the built environment
      i. Leaky feeders
      ii. Cell enhancers/repeaters.

3. Public safety applications using communications technologies
   a. Current fire and rescue service usage
   b. Developments in wireless applications
4. At-Incident and the built environment
   
a. At-Incident needs

b. Radio wave propagation in the built environment

5. Summary and Conclusion.

Through this process the summary and conclusion is that list of communications technologies considered with a subset selected for analysis.

5.1.2 Communications Technology Overview

The traditional technology for public safety voice ground communications is Private Mobile Radio (PMR), which provides exclusive use, reliable voice communications, which is adapted to suit the public safety market. The PMR technology available now and in the near future is listed at Appendix B, detailing the technical characteristics of the technology, which is discussed later in the section.

PMR technology is adaptable to work in any of the network areas described below, which is why we have separated out PMR technology and discussed this in addition to the networked areas in this document. PMR is currently being used for at incident communications but there have been advances in technology which would need to be re-examined as to whether new PMR technology would meet the future needs of the fire and rescue service.

Wireless technology, primarily aimed at data transfer available now and in the near future is presented below in Figure 5.1 – Wireless Technologies.

---

**Figure 5.1: Wireless Technologies**

<table>
<thead>
<tr>
<th>Technology</th>
<th>Bandwidth</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bluetooth</td>
<td>&lt;1m</td>
<td></td>
</tr>
<tr>
<td>Wi-Fi 802.11n</td>
<td>10m</td>
<td></td>
</tr>
<tr>
<td>Wi-Fi 802.11a/b/g</td>
<td>100m</td>
<td></td>
</tr>
<tr>
<td>WiMax 802.16</td>
<td>Up to 50km</td>
<td></td>
</tr>
<tr>
<td>4G</td>
<td>Up to 30Km</td>
<td></td>
</tr>
<tr>
<td>3G</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5G</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---
These technologies are developed to meet the following specific network area:

1. Personal Area Networks (PANs)
2. Local Area Networks (LANs)
3. Metropolitan Area Networks (MANs)
4. Wide Area Networks (WANs).

There has been a lot of development in these areas, particularly PAN, LAN and MAN, where the wireless devices for these network types have only been available over the last five to ten years. These devices have strong links with the Personal Computer (PC) and mobile phones sectors, so development has been rapid and the technological advances are quickly integrated into the latest technology. The main drivers for such change are:

1. Near-global harmonisation of frequencies used, therefore the global economies of scale drive down process costs. Most devices are in support of Broadband or Cellular technology

2. Licence-exemption of the frequencies used, enables a ‘use off the shelf’ technology enabling (market entry) simple and low cost.

There are also other technologies such as: Digital Enhanced Cordless Telecommunications (DECT), applications such as Voice over Internet Protocol (VoIP), network topologies such as mesh and ancillaries such as leaky feeder to consider.

5.2 The regulatory situation

5.2.1 Licensed versus Licensed Exempt Spectrum

Generally in the UK, radio spectrum can be categorised by whether an authorisation (licence) is required or not (licence exempt) to use the spectrum.

Licences are either on a first-come-first served basis for a particular service (Land Mobile, Fixed, Satellites), are awarded through auction (eg 3G mobiles) or ‘ring fenced’ for government (eg Ministry of Defence, Public Safety Services, etc). The licences contain the conditions of use, such as maximum transmitted power and bandwidth and also the amount of protection from interference from other radio services. A licence usually involves a fee, which is to be paid periodically, for a licence of fixed duration, which may be renewed.

Licence exemption enables technology to be sold straight from the shelves, direct to the consumer. However the radio devices have to conform to the licence exemption regulations, which detail spectrum, bandwidth and transmission power for a particular
application/technology (eg Radio microphones & WiFi). No licence is required and there is no fee. In the UK, at least five years notice is given before licence exemption of a particular service is removed (eg 418MHz low cost, telemetry key fobs – mainly garage door openers). Table 5.1 summarises the advantages and disadvantages.

<table>
<thead>
<tr>
<th>System</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Licensed</td>
<td>Usually exclusive use of spectrum, no interference or queuing to use the channel. No contention with other users.</td>
<td>Annual Licence fee. Expensive Equipment (no economy of scale).</td>
</tr>
<tr>
<td>Licence Exempt</td>
<td>No licence fee. Low cost equipment.</td>
<td>Share spectrum with other users, with possibility of interference and queuing to use the channel. Contention with other users.</td>
</tr>
</tbody>
</table>

### 5.2.2 Public versus Private Network Provision

A radio network can be either self provided (private) or procured as a service (public). The definitions below look at the three types of service provision, which would be most common to a Public Safety service.

**Private Mobile Radio (PMR) Definition**

PMR is part of the land mobile service based on the use of simplex, half and possibly full duplex modes at the terminal level in order to provide closed user group communications. PMR can be:

1. A traditional, self provided and self-owned by business users’ small area networks. Example: network in an industrial plant; or

2. A tightly controlled set of inter-related closed user groups. Can either be outsourced, or can be owned by a dominant user who allows other related user groups to use the network (predominantly local networks but could be national). For example a closed network of inter-related municipal organisations such as utility, public transportation, water supply and road maintenance.

**Public Access Mobile Radio (PAMR) Definition**

PAMR is an operator provided, commercially open networks designed for business professional users, dedicated user groups but no limitation on the nature or type of the user groups and no need for these to be related. It is not generally intended for these groups to communicate with each other.
**Public Land Mobile Networks (PLMN) Definition**

PLMN is completely open for all subscribers on an operator provided network. For example Vodafone using Global Systems for Mobile Communications (GSM) or Universal Mobile Telecommunications Systems (UMTS) for a mobile phone service, T-Mobile using WLAN technology for hotspots.

Table 5.2 summarises the advantages and disadvantages of these three types of service.

<table>
<thead>
<tr>
<th>System</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>PMR</td>
<td>Self provided, so own reliability designed into the network technology. Choice of technology, highly configurable. Robust design and explosive atmosphere (ATEX) approved products.</td>
<td>Compared to other technology it is bulky. Low user data rate. Mainly half duplex.</td>
</tr>
<tr>
<td>PAMR</td>
<td>Robust design and ATEX approved products available. Offers the same features of PMR, with added advantage of full duplex calls on some technology and connectivity to the PLMN if required.</td>
<td>Operators, not likely to offer peer-to-peer as difficult to charge on a usage basis. Operator provided, therefore little control over the service level and configuration.</td>
</tr>
<tr>
<td>PLMN</td>
<td>Some robust products available. Call anybody anywhere.</td>
<td>Unknown whether ATEX approved products are available. Peer-to-peer communications available, but limited and slow. Operator provided, therefore little control over the service level and configuration.</td>
</tr>
</tbody>
</table>

5.2.3 **Spectrum Available to the Emergency Services**

Spectrum for the fire and rescue service is available from either the ring fenced spectrum, licensed exempt spectrum or from the spectrum open to all services. If the fire and rescue service wishes to use the spectrum identified for Public Safety, an application has to be made to the Public Safety Spectrum Policy Group (PSSPG). The application would be assessed for efficient use of spectrum, co-ordination with other users, anticipated traffic and network management statistics. In addition the PSSPG will consider requests for additional spectrum for systems as Public Safety users expand the services or introduce new applications.
Appendix A gives details the spectrum bands available to the PSSPG for assignment to Public Safety Services.

5.3 The range of technologies

5.3.1 Mobile Radio
Mobile radio in the professional environment mainly consists of the technology listed at Appendix B in the comparison table where the technology can be either self provided (PMR) or provided through an operator (PAMR). The technology is all similar in performance and data rates, except TERrestrial Trunked RAdio (TETRA), which claims data rates of 28kbit/s. TETRA Advanced Packet Service (TAPS), similar to GSM General Packet Radio Service (GPRS), has not been included in the comparison table because even though the standard is complete enough to manufacture equipment to the best of our knowledge no manufacturer has currently developed any products, or has plans to do so at this time.

The main differences from a procurement point of view is the proprietary technology, which although claimed by some of the manufacturers to have an open standard, they licence others to manufacture.

Mobile radio is the technology of choice for emergency services throughout the world for slow data telemetry and voice. Its range, reliability and robustness are key factors along with all informed channels, and the controlled conversation approach that two-frequency simplex voice communications provides to a command and control environment.

Spectrum
Most of the radios can operate on a variety of radio channel spacing and Duplex Split, except TETRA, which only works on 25 kHz channels and 10MHz split in low UHF. The TETRA 25kHz channel is also different spectrally to an analogue 25kHz channel, which causes problems when acquiring spectrum for TETRA as guard channels are usually required by regulators to ensure protection of other services. Therefore specific frequency blocks are usually identified for TETRA channels, of which there is a very limited number.

Interference
Interference is limited as mobile technology usually has dedicated channels either assigned (PMR) or managed (PAMR). The contention for a channel is usually managed by either queuing to access the channel, by either listening to an all informed channel or by the technology indicating that the channel is busy. Queuing can be mitigated by switching to other licensed channels, either manually or automatically.
5.4 Wireless technology (WPAN and WLAN)

Technology away from traditional technologies and services such as PMR has been branded as Wireless Technologies, which have been developed over the last decade into commercial mainstream technologies that are accessible to the general public. Many of the wireless technologies are used on a daily basis by the general public with no licence fee, available from non-specialist shops and usually integrated into devices offering more than one of the technologies eg Bluetooth and WiFi on a 3G mobile. The growth in the inclusion of these technologies within high-volume consumer products may affect future capacity, availability and interference in these bands

The wireless technology discussed in this section, is believed not to have been used in a Public Safety environment to-date, and therefore further development would be required to bring intrinsically safe and robust equipment to the market.

5.4.1 Wireless Personal Area Network (WPAN)

WPAN technology usually involves technology that is worn or at least carried around by the user. There are currently two technologies, Bluetooth which is established and Ultra Wide Band (UWB), which will be available later this year. The IEEE 802.15 working groups are the main developers of PAN standards. For further detail see Appendix C.

**Bluetooth**

Bluetooth technology communicates with other Bluetooth enabled technology wirelessly through short range ad-hoc networks known as piconets. The technology can communicate simultaneously with up to seven other devices within a single piconet, with each device being able to belong to several other piconets. Piconets are established dynamically and automatically as Bluetooth enabled devices enter and leave radio proximity. Both voice and data applications can be communicated simultaneously and the most popular applications of the technology are wireless headsets and Personal Digital Assistant (PDA) to computer wireless synchronising.

**Spectrum**

Bluetooth technology operates in the unlicensed Industrial, Scientific and Medical (ISM) band at 2.4GHz to 2.485GHz, using a spread spectrum, frequency hopping, full-duplex signal at a nominal rate of 1600 hops/sec. The 2.4GHz ISM band is available and unlicensed in most countries.

**Interference**

Bluetooth technology’s Adaptive Frequency Hopping (AFH) capability was designed to reduce interference between wireless technologies sharing the 2.4GHz spectrum. AFH works within the spectrum to take advantage of the available frequency. This is done by detecting other devices in the spectrum and avoiding the frequencies they are using. This adaptive hopping allows for more efficient transmission within the spectrum, providing
users with greater performance even if using other technologies along with Bluetooth technology. The signal hops among 79 frequencies at 1MHz intervals to give a high degree of interference immunity.

**Ultra Wide Band (UWB)**
UWB is a developing technology, which has many applications such as ground penetrating radar, wall imaging systems, surveillance systems and WPANs. The technology will be mainly used for home networking and is being promoted as the wireless USB2.0, where cables between monitors and PCs could be replaced by UWB.

**Spectrum**
UWB will operate in the spectrum between 3.1GHz and 10.6GHz, with a specific spectral mask currently being defined by the European Community (EC). The technology is considered to be underlay, whereby the technology exists underneath (spectrally) other technology, where other technology is protected from interference from UWB, by either restricted UWB power levels or UWB detecting and avoiding other restricted systems before transmitting.

**Interference**
The signals of most UWB impulse radios generally appear as white noise to other radios in operation over the operating frequency band. Most UWB systems transmit power lower than that a standard PC is allowed to radiate unintentionally. UWB has secondary access to the band so it may receive interference from time-to-time. However the device, depending on technology, would either reduce in data rate or move to another channel that doesn’t have interference.

**Zigbee (IEEE 802.15.4)**
Zigbee is aimed at the control and sensory market for devices that don’t require high bandwidth or low latency but require excellent battery life. The network can adopt any topology, where meshing allows extended range from the controller.

**Spectrum**
Zigbee technology operates in the unlicensed ISM band at 2.4GHz to 2.485GHz, using a direct sequence spread spectrum, 11chips/symbol using GFSK and O-QPSK. The 2.4 GHz ISM band is available and unlicensed in most countries.

**Interference**
The Medium Access Control (MAC) layer of Zigbee uses Carrier Sense Multiple Access-Collision Avoidance, which provides a polite protocol, so interference from on-channel Zigbee users will be kept to a minimum. However, this unlicensed spectrum band has many applications that are not polite, so from other users, the interference potential depends on whether there are any other 2.4GHz devices within the radio reception coverage of a Zigbee device.
5.4.2 Wireless Local Area Networking (WLAN)
WLAN standards are mainly the domain of the Institute of Electrical and Electronic Engineers (IEEE), which are listed below in Table 5.3. The WLAN technology of interest is IEEE 802.11.a/b/g/n, where the technology operates in the licensed exempt bands at 2.4GHz and 5GHz, with polite access protocols. For further detail see Appendix C.

<table>
<thead>
<tr>
<th>IEEE</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>802.11</td>
<td>The original WLAN standard. Supports 1Mbit/s to 2Mbit/s.</td>
</tr>
<tr>
<td>802.11a</td>
<td>High speed WLAN standard for 5GHz band. Supports 54Mbit/s.</td>
</tr>
<tr>
<td>802.11b</td>
<td>WLAN standard for 2.4GHz band. Supports 11Mbit/s.</td>
</tr>
<tr>
<td>802.11d</td>
<td>International roaming – automatically configures devices to meet local RF regulations.</td>
</tr>
<tr>
<td>802.11e</td>
<td>Addresses quality of service requirements for all IEEE WLAN radio interfaces.</td>
</tr>
<tr>
<td>802.11f</td>
<td>Defines inter-access point comms to facilitate multiple vendor-distributed WLAN.</td>
</tr>
<tr>
<td>802.11g</td>
<td>Establishes an additional modulation technique for 2.4GHz band. Speeds to 54Mbit/s.</td>
</tr>
<tr>
<td>802.11h</td>
<td>Defines the spectrum management of the 5GHz band.</td>
</tr>
<tr>
<td>802.11i</td>
<td>Addresses the current security weaknesses for both authentication and encryption protocols. The standard encompasses 802.1X, TKIP, and AES protocols.</td>
</tr>
<tr>
<td>802.11n</td>
<td>Provides higher throughput improvements. Intended to provide speeds up to 500Mbit/s.</td>
</tr>
<tr>
<td>802.11s</td>
<td>Wireless Mesh Networking.</td>
</tr>
</tbody>
</table>

Spectrum
WiFi (IEEE 802.11b/g) technology like Bluetooth technology operates in the unlicensed ISM band at 2.4GHz to 2.485GHz, using a Direct Sequence Spread Spectrum (DSSS) for IEEE 802.11b and OFDM for IEEE 802.11g. The 2.4GHz ISM band is available and unlicensed in most countries. The IEEE 802.11a and g technology will operate in the 5.8GHz licence exempt bands.

Interference
Interference can be either radio noise from other sources (microwave ovens – they operate in the same band) or other devices sharing the radio channel. The result of interference is a reduction in data rate, dependant on the number of devices sharing the channel or the severity of the noise.
5.5 Wireless technology (WMAN and WWAN)

Wireless technology for WWAN and WMAN look at different markets, a WWAN is usually cellular and would have national coverage, at medium to high data rates, owing to the mobility of the users. A WMAN has higher data rates, and would typically serve nomadic users, whereby the user would move around an area, but would be stationary when using the WMAN, mainly considered as a point-to-multi-point service. WMAN sees the cross over from licence-exempt to licensed services, mainly for network operators. For further detail see Appendix D.

5.5.1 Wireless Metropolitan Area Networking (WMAN)

*WiMax (IEEE 802.16) & WiBro*

WiMax is a standards-based wireless technology that provides high-throughput broadband connections over long distances. WiMax can be used for a number of applications, including “last mile” broadband connections, hotspots and cellular backhaul, and high-speed enterprise connectivity for business. WiMax is similar to WiFi but with extended range and the protocol to enable a quality of service delivery essential for real-time applications such as voice and video. WiBro is an extension of the WiMax standard that enables the user to communicate whilst mobile, with a different air-interface and less data throughput for the user.

*Spectrum and Interference*

WiMax is aimed at both licenced exempt and licenced (operator) services, with the 3.4GHz band currently being harmonised within Europe. Interference depends on whether it is licenced or licence-exempt, but WiMax has similar polite access protocols as WiFi. The main difference is the contention for access onto the network, which is random access, but once on the network the user is allocated a ‘channel’ with a level of service.

*Time-Division CDMA (TD-CDMA)*

Time-Division Duplex (TDD) is used, according to the standard, to allow operation on unpaired spectrum anywhere in these bands. Chip rates of 3.84 megachips/sec (Mcps) and 7.68Mcps are supported, for operation in channelisation of 5MHz and 10 MHz. Similar to WiMax, the markets are the same, aimed at wireless broadband for nomadic use.

*Spectrum and Interference*

TD-CDMA is only aimed at licensed services that would usually be provided by an operator. The air-interface is dynamic in that users are provided data rates based on the operators wishes or the amount of traffic afforded to the particular node.

5.5.2 Wireless Wide Area Networking (WWAN)

Wireless access technology is restricted to the cellular market, although satellite could have been considered, satellite mobiles were not considered appropriate for Incident ground communications. The cellular services are in a constant state of evolution, currently
the latest is 3G, where there are a number of competing technologies. We have only considered the technology currently deployed in Europe.

Peer-to-peer communication is not common over WAN and implementations have suffered from latency and proved to be costly to the subscriber and/or costly to implement for the operator. No private WWAN (cellular) networks are in existence, or are likely due to a variety of reasons, but mainly cost. Spectrum is harmonised globally, and awarded mainly through an auction process (UK raised £22.5bn for 3G licenses).

The main reason for using WAN technology is the mobile connectivity afforded by the network and the user data rates, which are steadily increasing with evolution in technology.

5.6 Supporting technologies in the built environment

**Leaky Feeders**
Leaky feeders are basically cables with slots along the length, which enables transmission to penetrate radio-quiet areas, such as tunnels and underground car parks. The leaky feeder connects to a transmitter where the desired signal radiates along the cable. At a certain length the signal becomes too weak to receive, where the option could be to use a repeater that amplifies the signal. The larger the section of the leaky feeder cables, the lower the loss, which means that the signal can be received further along the length of the feeder. Some leaky feeders are permanently deployed in the built environment to support fire and rescue service at incident and wide-area communications as an alternative to fixed antennae. Lightweight leaky feeders are also used as temporary means of improving At-Impact communications in the built environment.

**Cell Enhancers/Repeaters**
Cell enhancers are essentially repeaters, which are usually placed at the edge of radio coverage to provide extended range. These devices are used to extend cellular coverage to underground stations in other countries, but could be used in a built environment to extend the range of emergency radio communications.

5.7 Public safety applications using communications technologies

5.7.1 Current Fire and Rescue Service Usage

**Voice (Self-Provided)**
Voice communications between fire crew at the incident consists of analogue VHF FM radios, operating at 25kHz channel spacing, with four single frequency simplex channels and two two-frequency half duplex channels. The simplex channels are for direct peer-to-peer communications. The half duplex channels are for use through a deployable repeater
system, which extends the range of communications. The hand portables have a maximum Effective Radiating Power (ERP) of 1W, for the intrinsically safe radios, and are currently limited to 1W for other uses although 4W/5W radios are technically possible.

**Telemetry – Breathing Apparatus (Self Provided)**
Telemetry is provided from the breathing apparatus equipment with some distress and status messaging. This equipment uses its own dedicated spectrum. The telemetry system from Breathing Apparatus (BA) equipment is not currently widely used.

### 5.7.2 Developments in Wireless Applications
There are a number of applications that could assist at incident ground communications, the foremost are bulleted below:

1. **Auto Range Transponder System (ARTS™)** – Set a home radio unit (eg Fire Officer) and when the radio is out of range from the home radio an alarm sounds; but there may be operational considerations to be taken into account in considering such facilities

2. **Range Extender** – A system that works like a MESH network that stores and forwards voice messages from mobile to mobile

3. **MESH** – Forms a network of devices that have multiple connections that ensure that a message from one device is relayed through other devices onto the desired device, effectively extending the range.

### 5.8 At-incident needs and the built environment

#### 5.8.1 Fire and Rescue Service At-Incident Needs
The fire fighter wants instant voice communications from immediate colleagues at the incident only in a structured operational way. It is envisaged that in the future more telemetry may be required such as body temperature sensors and perhaps in the future real-time streaming video maybe required. This would be the most demanding wireless application although it is recognised that there may be operational issues about using some of these data.

In addition, the technology must work in harsh environments, be robust and for particularly hazardous environments must be intrinsically safe.

The technology must also be free from interference or congestion on the channels particularly for speech, which effectively means that the spectrum must be licensed for the specific use (not licensed exempt) and must be a closed user group which rules out cellular, but not PAMR (Airwave).
5.8.2 Radio Wave Propagation in the Built Environment

Generally UHF (300MHz to 3000MHz) is recognised as the ideal frequency band (supported by ITU-R P.1238-2 [Ref 2-12] and ITU-R P.1406 [Ref.2-13]) for mobile communications, particular for in-building coverage. The spectrum around 400MHz is ideal and the higher up the frequency band the more difficult communications in-building typically become. Radio propagation in-building involves two main propagation factors, described below:

1. Multi-path – where the radio signals bounce off surfaces and arrived at the receiver from multiple directions and if out of phase from each other can be disruptive and reduce the signal at the mobile

2. Each material attenuates a signal to a certain degree, some more than others, which is dependent on frequency used.

The result is that the transmitted signal within a building is greatly attenuated so the received signal has a smaller range than if it were outdoors. There are a few ways of counteracting this:

1. Increasing the power of the transmitted signals
2. Employing digital techniques to recover the signal
3. Variable data rates to improve signal recovery in varying signal environments
4. Different modulation schemes have different effects on multi-path and receiver sensitivity
5. Increasing the bandwidth of the signal
6. The use of supporting infrastructure in buildings to enhance coverage.

5.9 Summary and conclusion

The technology listed in this Section falls into several categories: PMR, WPAN, WLAN, WMAN and WWAN. At a high level, the areas of technology are looked at as to whether they are appropriate to put forward to the next stage of the report are:

Comparing the technologies described earlier against the fire and rescue service needs we conclude that the technologies are included, or excluded, in the analysis as follows:

1. **PMR** – Operates on the frequencies available to the fire and rescue service in UHF, is very adaptable, and has available robust and intrinsically safe products. PMR provides voice communications, in a structured form (simplex, PTT) that is
ideal for command and control operations. The data/telemetry aspect would support status messaging and other low data rate applications, not video. The PMR technologies are similar in technical characteristics, and on balance would be difficult to choose between them on technical grounds. However, the TETRA technology is used on the Airwave network and should be looked at further from an operational view as there may be advantages in using this technology over other PMR technologies. This should be INCLUDED in analysis.

2. **WPAN** – Are devices that may be used between devices on the fire-fighter, i.e. Bluetooth headset. However, they will not really provide communications between fire fighters, particularly as the technology is only available in licence exempt frequency bands, where the communication path is shared by others. In addition the range of the devices is typically 10m, but it should be noted that Bluetooth has been developed to increase the range. This should be EXCLUDED from analysis on the basis of lack of range and shared spectrum products and frequency bands only.

3. **WLAN** – The technology has the data rate to support VOIP (voice) and video, however it is believed that no robust intrinsically devices are available and the technology is only available in licence exempt frequency bands. It is envisaged that the spectrum for these devices will be more intensely used, where it is probable in the future that the frequency bands become congested in certain areas (hot spots). The regulators are looking at the congestion issue but have no plans to introduce more spectrum at present. This should be EXCLUDED from analysis on the basis of technology only available in frequency bands that are likely to become congested; therefore there may be difficulties in communicating in particular areas.

4. **WMAN** – The technology has the data rate to support VOIP (voice) and video, however it is believed that no robust intrinsically devices are available but the technology is available in licensed frequency bands. The licensed frequency bands are the most important element to this for Public Safety, but the spectrum and or service may need to be procured from an operator. Depending on whether a service is procured or installed the topology could be MESHED to provide resilience, but the voice functionality of such systems particularly for mobile devices is in its infancy and would not be recommended for the next few years for something as critical as voice. However, as the technology matures, voice should be looked at further, but video would be an ideal application for this technology. This should be INCLUDED in analysis as a possible future technology for video.
5. **WWAN** – For cellular the technology supports voice and data, and video, however it is believed that no intrinsically safe devices are available and no dedicated spectrum, which is usually owned by operators. It is believe that the technology would be prohibitively expensive. However, WAN technology when referred to as a PAMR network, with a closed user group may be an area for further consideration, particular Airwave, which could enable portables to use the infrastructure like ad-hoc repeaters (TMO) to extend range, with the default being peer-to-peer (DMO). **This should be EXCLUDED from analysis with the exception of Airwave/Firelink. In the case of Airwave issues in its use, such as Direct Mode Operation (DMO), will need investigation.**
## Chapter 6

### Risk Review

Table 6.1: shows an Initial Risk Log with three examples included at this stage for illustration only:

<table>
<thead>
<tr>
<th>Ref.</th>
<th>Threat</th>
<th>Risk</th>
<th>Consequence</th>
<th>Level (Probability and Impact)</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>General – Built Environment complexity increases.</td>
<td>Current radio limitations are encountered more often.</td>
<td>Existing alternate arrangements are used.</td>
<td>Low.</td>
<td>Reinforce the use of existing practice with developments.</td>
</tr>
<tr>
<td></td>
<td>Incidence and/or extent of complexity in new build increases significantly over coming years.</td>
<td>Use becomes less effective and presents greater challenges in fire fighting with, logically, an impact on life and property.</td>
<td>Use of radio becomes less frequent with line equipment and repeaters being used more often with associated costs.</td>
<td></td>
<td>Co-operation between the local fire and rescue service and the developer to continue.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Consider ODPM publication to both groups to assist in enhancing fire safety.</td>
</tr>
</tbody>
</table>
Table 6.1: Initial Risk Log (continued)

<table>
<thead>
<tr>
<th>Ref.</th>
<th>Threat</th>
<th>Risk</th>
<th>Consequence</th>
<th>Level (Probability and Impact)</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>02</td>
<td>General – Interoperability demands increase. Communication needs with others, especially police and ambulance services, rises or changes significantly.</td>
<td>Current inter-communication constraint becomes limiting. Current constraint, i.e. removal of ability to shared channels with police since their migration to Airwave, begins to affect fire fighting.</td>
<td>Incident handling, including fire fighting, restricted. Limits ability and approach to intercommunicate dictating the procedures rather than procedures being developed essentially unhindered by technology.</td>
<td>Low. As above, unfortunately ‘you don’t know what you don’t know’. However, current procedures understood to be robust in short-term and interoperability to be eased longer-term by fire and rescue service migration to Airwave.</td>
<td>Current practice of face-to-face, or radio swap, communication between organisations is robust. Firelink expected to provide interoperability as likely to select Airwave also.</td>
</tr>
<tr>
<td>Ref.</td>
<td>Threat</td>
<td>Risk</td>
<td>Consequence</td>
<td>Level (Probability and Impact)</td>
<td>Mitigation</td>
</tr>
<tr>
<td>------</td>
<td>--------</td>
<td>------</td>
<td>-------------</td>
<td>-------------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>03</td>
<td>Built Environment – Use of Frequency Selective Surfaces (FSS) increases.</td>
<td>Prevents or reduces radio penetration into the building. Prevents of reduces radio use without additional equipment or other arrangements.</td>
<td>As ‘General – Built Environment complexity increases’ (01 above)</td>
<td>Medium. The incorporation (by design) of FSS materials into buildings is still relatively uncommon and where it does occur focus is on preventing passage of the 2.4GHz and 5GHz bands (PAN/LAN) rather than lower frequency.</td>
<td>Coverage into buildings for mobile cellular networks (900MHz – 2.2GHz) is often improved rather than prevented and below that is not specifically inhibited (exception being some sensitive sites – typically known already to fire and rescue service and MoD). Consider encouragement of Cell Enhancers covering mobile and/or emergency service frequencies (as 01 above).</td>
</tr>
</tbody>
</table>

Note
All materials exhibit some properties of this type but this is concerned with those specifically designed with these properties in mind.

There are also FSS materials that assist radio frequencies passing.

In Stage 2 of this study, Analysis, these examples may be joined by more in order to form a fuller picture of the threats facing current operations and associated with possible new technologies and other changes under consideration. They will also be considered in the awareness of the other Interim Deliverable of Stage 1, the Current Situation Report.
Chapter 7

Summary and Conclusions

7.1 Built environment – UK and internationally

7.1.1 Current Situation
Key conclusions on the current situation are as follows:

1. Consideration of Emergency Services radio communications is not mandated in UK building regulations, but consultation between developers and local fire and rescue services are common place for large and complex buildings.

2. Where consultation concludes that buildings require enhanced radio transmission properties it is normally achieved by the installation of repeaters the location of which is established by survey on completion of the building structure.

3. Frequency selective surfaces and structures are emerging but as yet are not common. Research is ongoing at present into their effects and best use, with Ofcom aware of the emergency service issue.

4. Support for emergency services radio communications within building infrastructure is mandated in some parts of the USA.

7.1.2 For the Future
Key conclusions on the future needs are as follows:

1. There is a need to monitor developments in the built environment including:
   a. The extent that materials such as K-glass are used in the built environment.
   b. The Ofcom research into frequency selective surfaces and structures.

2. There is a need to monitor the Ofcom research and represent the fire and rescue service needs within that programme of work.

3. There should be consideration of the need for national guidance on practical measures to assist in-building coverage with reference to the various approaches internationally.
7.2 Communications technologies

Key conclusions on communications technologies are as follows:

1. Professional Mobile Radio (PMR) – Should be INCLUDED in the analysis
2. Personal Area Networking (PAN) – Should be EXCLUDED from the analysis
3. Local Area Networking (LAN) – Should be EXCLUDED from the analysis
4. Metropolitan Area Networking (MAN) – Should be INCLUDED from the analysis as a possible future technology for video
5. Wide Area Networking (WAN) – Should be EXCLUDED from the analysis with the exception of airwave.

7.3 Risk review

The initial risks considered, albeit a limited number of examples only at this time, suggest that their quantification may be difficult. However, it also suggests that many of these risks are likely to be relatively low level and that they can be mitigated by existing arrangements and are unlikely to justify radical changes in the near term.
## Chapter 8

### Glossary

<p>| <strong>3GPP</strong> | 3rd Generation Partnership Project. The 3GPP oversees the creation of industry standards for the 3rd generation of mobile wireless communication systems (W-CDMA). The key members of the 3GPP include standards agencies from Japan, Europe, Korea, China and the United States. More information about 3GPP can be found at <a href="http://www.3GPP.org">www.3GPP.org</a>. |
| <strong>APCO25</strong> | Standard developed by chief police officers under Project 25 in the USA. |
| <strong>ASTRO</strong> | Standard developed by Motorola. |
| <strong>CEPT</strong> | The European Conference of Postal and Telecommunications Administrations. |
| <strong>Channel separation</strong> | Channel separation is the width of a channel in Hz. |
| <strong>DAB</strong> | Digital Audio Broadcasting (Digital Radio). |
| <strong>Simplex</strong> | Simplex communication is the transmission of voice and/or data signals that allows only one way communication. |
| <strong>GSM</strong> | Global System for Mobile. |
| <strong>GPRS</strong> | Global Packet Radio Service. |
| <strong>Semi Duplex</strong> | Semi Duplex communication is the transmission of voice and/or data signals that allows two-way communication but not simultaneously. |
| <strong>Duplex</strong> | Duplex communication is the transmission of voice and/or data signals that allows simultaneous 2-way communication. |
| <strong>Duplex Separation</strong> | Duplex separation is the separation in frequency (Hz) between the two channels used for 2-way communication. |
| <strong>EDGE</strong> | Enhanced Data GSM Environment. |
| <strong>ERP</strong> | Effective Radiated Power. Effective radiated power is the increase or decrease in the radiated power from a transmitting antenna that results from the directional characteristics of the antenna. For example, signals transmitted from an antenna in land mobile service are aimed toward the surrounding terrain, and not toward the sky, effectively increasing the signal strength at the receiver. ERP is the product of the power put into an antenna and the antenna gain or loss, and is expressed in Watts. |
| <strong>FM</strong> | Frequency Modulation. |</p>
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross Bit Rate</td>
<td>A measurement of the transfer rate of digital signals through a channel.</td>
</tr>
<tr>
<td></td>
<td>The bit rate is the number of bits transmitted in a specified amount of</td>
</tr>
<tr>
<td></td>
<td>time. Bit rate is usually expressed as bits per second (bps). The gross</td>
</tr>
<tr>
<td></td>
<td>bit rate is the maximum number of bits being transmitted.</td>
</tr>
<tr>
<td>iDEN</td>
<td>Integrated Digital Enhanced Network, a standard developed by Motorola.</td>
</tr>
<tr>
<td>IEEE</td>
<td>Institute of Electrical &amp; Electronic Engineers.</td>
</tr>
<tr>
<td>Maximum User Bit rate</td>
<td>Of the gross bit rate, some of the bits are for control, synchronisation</td>
</tr>
<tr>
<td></td>
<td>and error correction. The maximum user bit rate is the bits which the user</td>
</tr>
<tr>
<td></td>
<td>can furnish with information to be transmitted onwards.</td>
</tr>
<tr>
<td>Ofcom</td>
<td>Office of communications (UK Communications Regulator</td>
</tr>
<tr>
<td></td>
<td><a href="http://www.ofcom.org.uk">www.ofcom.org.uk</a>).</td>
</tr>
<tr>
<td>PAMR</td>
<td>Public Access Mobile Radio.</td>
</tr>
<tr>
<td>PMR</td>
<td>Professional/Private Mobile Radio. Private mobile radio is a mobile</td>
</tr>
<tr>
<td></td>
<td>communication system that is used by a controlled (private) group of users</td>
</tr>
<tr>
<td></td>
<td>(typically business enterprises or institutions).</td>
</tr>
<tr>
<td>PTT</td>
<td>Push To Talk. Push to talk (PTT) is a process of initiating transmission</td>
</tr>
<tr>
<td></td>
<td>through the use of a push-to-talk button. The push to talk process</td>
</tr>
<tr>
<td></td>
<td>involves the talker pressing a talk button (usually part of a handheld</td>
</tr>
<tr>
<td></td>
<td>microphone) that must be pushed before the user can transmit. If the</td>
</tr>
<tr>
<td></td>
<td>system is available for PTT service (other users in the group not talking),</td>
</tr>
<tr>
<td></td>
<td>the talker will be alerted (possibly with an acknowledgement tone) and</td>
</tr>
<tr>
<td></td>
<td>the talker can transmit their voice by holding the talk button. If the</td>
</tr>
<tr>
<td></td>
<td>system is not available, the user will not be able to transmit/talk.</td>
</tr>
<tr>
<td>Rx Sensitivity</td>
<td>Receiver sensitivity is capability of the receiver to respond to a minimal</td>
</tr>
<tr>
<td></td>
<td>signal input level and still produce an acceptable level of reliable</td>
</tr>
<tr>
<td></td>
<td>operation.</td>
</tr>
<tr>
<td>TD-CDMA</td>
<td>Time Division-Code Division Multiple Access. A 3GPP-based technology is</td>
</tr>
<tr>
<td></td>
<td>the mobile broadband solution designed for GSM operators. Its high average</td>
</tr>
<tr>
<td></td>
<td>sector capacity, strong cell edge performance, and low cost per megabit</td>
</tr>
<tr>
<td></td>
<td>make it an ideal technology for mass market mobile broadband and</td>
</tr>
<tr>
<td></td>
<td>multimedia networks. UMTS TD-CDMA has emerged as a leading global standard</td>
</tr>
<tr>
<td></td>
<td>for mobile broadband with commercial deployments in numerous countries</td>
</tr>
<tr>
<td></td>
<td>around the world including Australia, the Czech Republic, Germany, Japan,</td>
</tr>
<tr>
<td></td>
<td>Lithuania, Malaysia, New Zealand, Nigeria, Portugal, South Africa, Sweden,</td>
</tr>
<tr>
<td></td>
<td>the United Kingdom, and the United States.</td>
</tr>
<tr>
<td>TDD</td>
<td>Time-Division Duplex.</td>
</tr>
<tr>
<td>TETRAPOL</td>
<td>Trunking standard developed by EADS Telecom.</td>
</tr>
<tr>
<td>UHF</td>
<td>Ultra High Frequency 300 – 3000MHz.</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------</td>
</tr>
<tr>
<td><strong>UMTS</strong></td>
<td>Universal Mobile Telecommunications System. A Universal Mobile Telecommunications System (UMTS) that offers personal telecommunications services that uses the combination of wireless and fixed systems to provide seamless telecommunications services to its users. It is expected that UMTS will allow on-demand transmission capacities of up to 2 Mb/s in some of its radio locations. It should be compatible with broadband ISDN services.</td>
</tr>
<tr>
<td><strong>USB</strong></td>
<td>Universal Serial Bus.</td>
</tr>
<tr>
<td><strong>UTRA</strong></td>
<td>Universal Terrestrial Radio Access. A worldwide standard for the 3rd generation wireless communications system developed by the 3rd generation partnership project (3GPP).</td>
</tr>
<tr>
<td><strong>UWB</strong></td>
<td>Ultra Wide Band.</td>
</tr>
<tr>
<td><strong>VHF</strong></td>
<td>Very High Frequency 30 -300MHz.</td>
</tr>
<tr>
<td><strong>VOIP</strong></td>
<td>Voice Over Internet Protocol. A process of sending voice telephone signals over the Internet or other data network. If the telephone signal is in analogue form (voice or fax) the signal is first converted to a digital form. Packet routing information is then added to the digital voice signal so it can be routed through the Internet or data network.</td>
</tr>
<tr>
<td><strong>WLAN</strong></td>
<td>A wireless local area network (WLAN) allows computers and workstations to communicate with each other using radio propagation as the transmission medium. The wireless LAN can be connected to an existing wired LAN as an extension, or can form the basis of a new network. While adaptable to both indoor and outdoor environments, wireless LANs are especially suited to indoor locations such as office buildings, manufacturing floors, hospitals and universities.</td>
</tr>
<tr>
<td><strong>WMAN</strong></td>
<td>Wireless Metropolitan Area Networking. WMANs are usually private wireless packet radio networks often that cover an urban or city geographic area. They are commonly used for law-enforcement, utility or public safety applications.</td>
</tr>
<tr>
<td><strong>WPAN</strong></td>
<td>Wireless personal area networks (WPANs) are temporary (ad-hoc) short-range wireless communication systems that typically connect personal accessories such as headsets, keyboards, and portable devices to communications equipment and networks.</td>
</tr>
<tr>
<td><strong>WWAN</strong></td>
<td>WWANs are wireless data transmission systems that cover large geographic areas using cellular or public packet radio systems. These systems are typically limited to data transfer rates below 20 kbps.</td>
</tr>
</tbody>
</table>
### Appendix A

#### Public Safety Spectrum Bands

<table>
<thead>
<tr>
<th>Spectrum Bands</th>
<th>PSSPG Comments [Ref. 2-10]</th>
<th>Further Detail</th>
<th>Mott MacDonald Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>55MHz</td>
<td>This band is already CEPT aligned and vacant. The 55.75 – 68MHz band will be dedicated spectrum for mobile communications networks. There are no assignments at present and 380 pairs of 12.5KHz channels are available for PMR and CBS (Common Base Stations).</td>
<td></td>
<td>No mobile wireless products of note and none in development, mainly owing to the propagation characteristics of the band &amp; size of antenna.</td>
</tr>
<tr>
<td>70/83MHz</td>
<td>These bands are currently used by the Fire Service in England and Wales and are not CEPT-aligned. They should become available in 2007, and may then be used to support low-band VHF re-alignment in accordance with CEPT recommendation T/R25-08. Regional allocations may become available from around 2004. There are 98 PMR channels of 12.5 KHz available in the 68-87.5MHz range, plus spectrum that will be released by the Fire Service following the replacement of their wide area communications system. (More detailed information is available on request)</td>
<td></td>
<td>Firelink recently awarded which will see the services that used to be used for the FRS in this band moved onto Airwave.</td>
</tr>
<tr>
<td>Spectrum Bands</td>
<td>PSSPG Comments [Ref. 2-10]</td>
<td>Further Detail</td>
<td>Mott MacDonald Comment</td>
</tr>
<tr>
<td>---------------</td>
<td>-----------------------------</td>
<td>----------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>143-144/152-153MHz &amp; 146-148/154-156MHz</td>
<td>The current availability of VHF high band assignments is severely limited in many geographical areas due to wide-scale use of the band by emergency service mobile radio schemes. Future availability of allocations is primarily dependent on the release of assignments following the migration of existing police and fire services to alternative spectrum. As the police migrate to Airwave some allocations in the VHF high band in England and Wales may be released. These could be used to support fire services currently using the 70/80 MHz allocations whilst these are realigned.</td>
<td>Firelink recently awarded which will see the services that used to be used for the FRS in this band moved onto Airwave.</td>
<td></td>
</tr>
<tr>
<td>Band III Sub band 3 209.20625 – 215.26875MHz</td>
<td>This band is already CEPT aligned. There are 108 pairs of 12.5kHz channels reserved for private operators. In addition a further 108 pairs currently reserved for public networks could be made available for public safety services. The UK is consulting on the future use of this band, as it is a candidate for T-DAB. This band is used for broadcast services within Europe.</td>
<td>Ofcom intends to licence DAB multiplexes within this band, so MM believe that access to this spectrum would now be denied, see Ofcom statement: <a href="http://www.ofcom.org.uk/consult/condocs/vhf/statement/band3statement.pdf">http://www.ofcom.org.uk/consult/condocs/vhf/statement/band3statement.pdf</a></td>
<td></td>
</tr>
<tr>
<td>Spectrum Bands</td>
<td>PSSPG Comments [Ref. 2-10]</td>
<td>Further Detail</td>
<td>Mott MacDonald Comment</td>
</tr>
<tr>
<td>----------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>380-385 &amp; 390-395MHz</td>
<td>These bands are harmonised for public safety use throughout Europe. In accordance with the European Radiocommunications Committee Decision ERC/DEC/(96)01 of 7 March 1996, a total of 10 MHz (2 x 5 MHz) of spectrum has been allocated for public safety use within the UK. In view of the spectrum requirement of existing services in these bands, it is not possible to accommodate any new national networks. In some geographical areas, limited assignments within these bands may be possible.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>410-412 &amp; 420-422MHz</td>
<td>No comments</td>
<td>The ex-Dolphin spectrum, has been carved up, 410-412 paired with 420-422MHz (2x2Mhz) has been identified for emergency services, with the remainder subject of an auction.</td>
<td></td>
</tr>
<tr>
<td>415-420 &amp; 425-429MHz</td>
<td>The 425-429MHz portion is used in defined areas (mainly conurbations) by CBS, a public mobile data operator, UHF 1 PMR services, and programme making, and is unlikely to be released for some time. The North East and North Central parts of the UK are not available and stringent co-ordination requirements apply in all other regions. It is therefore considered that this band is not suitable for a national public safety solution.</td>
<td></td>
<td>See above.</td>
</tr>
<tr>
<td>Spectrum Bands</td>
<td>PSSPG Comments [Ref. 2-10]</td>
<td>Further Detail</td>
<td>Mott MacDonald Comment</td>
</tr>
<tr>
<td>----------------</td>
<td>----------------------------</td>
<td>----------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>450/470MHz</td>
<td>This band is not yet CEPT aligned. Spectrum released by the police service after migration to Airwave will be used to support a project to re-align the 450-470MHz band in accordance with CEPT recommendation T/R25-08. In view of the need to realign remaining users possibly on a case-by-case basis, large-scale assignments may not be possible until 2010. Following the re-alignment of this band over 2x3 MHz will be available in a suitable configuration to support both commercial and public safety services. The RA is currently consulting on the re-alignment plans for this band.</td>
<td>The re-alignment project was cancelled.</td>
<td></td>
</tr>
<tr>
<td>862 – 863MHz</td>
<td>No comment</td>
<td>4 x 25kHz channels not contiguous</td>
<td></td>
</tr>
<tr>
<td>900MHz</td>
<td>There is 2x1MHz available now. It is not possible to extend the band beyond 2x1 MHz. However as it is adjacent to the GSM band it could offer dedicated additional spectrum for a GPRS solution.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spectrum Bands</td>
<td>PSSPG Comments [Ref. 2-10]</td>
<td>Further Detail</td>
<td>Mott MacDonald Comment</td>
</tr>
<tr>
<td>----------------</td>
<td>----------------------------</td>
<td>----------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>1668-1670 &amp; 1698-1700 &amp; 1790-1798 &amp; 2302-2310 MHz</td>
<td>These bands are used to support fixed links for current police and fire services and their availability will depend on police and fire services migrating to alternative spectrum. The current plans are to return these assignments to the RA for assignments to the civil services. In the 1600MHz bands, there are national requirements to protect satellite and radio astronomy services. Allocations could be made available for other mobile use, however, it should be recognised that; new specifications may be required industry may be reluctant to invest in development of equipment for small markets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1670-1675 &amp; 1800-1805MHz (TFTS band)</td>
<td>CEPT have decided to withdraw Terrestrial Flight Telephone Services, TFTS, in these bands but retain these bands for the introduction of future harmonised services. These bands are currently co-ordinated for aircraft use. Subject to a successful submission to CEPT, these allocations could be made available for land mobile and air ground air services on a pan European basis.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spectrum Bands</td>
<td>PSSPG Comments [Ref. 2-10]</td>
<td>Mott MacDonald Comment</td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td>-----------------------------</td>
<td>------------------------</td>
<td></td>
</tr>
<tr>
<td>Higher Frequency Bands</td>
<td>Other options are available at significantly higher frequency ranges. Current equipment specifications exist but may be unsuitable within the public safety environment.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Further Detail</td>
<td></td>
</tr>
</tbody>
</table>
## Appendix B

### Professional Mobile Radio (PMR) Technology Comparison Table

<table>
<thead>
<tr>
<th></th>
<th>Proprietary Equipment</th>
<th>European Standards</th>
<th>Future European Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TETRAPOL</td>
<td>iDEN</td>
<td>EDACS</td>
</tr>
<tr>
<td>Duplex separation</td>
<td>10MHz</td>
<td>45MHz</td>
<td>4 – 45MHz</td>
</tr>
<tr>
<td>Channel separation</td>
<td>10 &amp; 12.5kHz</td>
<td>25kHz</td>
<td>12.5 and 25kHz</td>
</tr>
<tr>
<td>Tx Power Hand Portable</td>
<td>≤33dBm</td>
<td>22-35dBm</td>
<td>38dBm</td>
</tr>
<tr>
<td>Gross Bit Rate</td>
<td>8 kbit/s</td>
<td>64 kbit/s</td>
<td>9.6 kbit/s</td>
</tr>
<tr>
<td>Maximum User Bit rate</td>
<td>7.4, 4.6, 3.4 kbit/s</td>
<td>9.6, 7.2 kbit/s</td>
<td>9.1, 7.77 kbit/s</td>
</tr>
<tr>
<td>Rx Sensitivity (hand portable)</td>
<td>-111dBm dynamic</td>
<td>-105.5dBm dynamic</td>
<td>-115/116dBm static for 12.5/25kHz</td>
</tr>
<tr>
<td>Mode of Operation</td>
<td>S,SD,D</td>
<td>S,SD,D</td>
<td>S,SD,D</td>
</tr>
<tr>
<td>Voice and Data</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>

1. Transparent
2. With Weak Forward Error Correction
3. With Strong Forward Error Correction
4. Rayleigh fading only
5. S=Simplex, SD = Semi Duplex, D=Duplex.
## Appendix C

### Wireless Technology (PAN and LAN) Comparison Table

<table>
<thead>
<tr>
<th></th>
<th>PAN</th>
<th>LAN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>UWB</td>
<td>Bluetooth</td>
</tr>
<tr>
<td><strong>Frequency band</strong></td>
<td>3.1 – 10.6 GHz</td>
<td>2.4GHz</td>
</tr>
<tr>
<td><strong>Peak Data Rate</strong></td>
<td>≈500Mbps</td>
<td>1Mbps/3Mbps (Enhanced data rate)</td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td>&lt;10m</td>
<td>10m/100m</td>
</tr>
<tr>
<td><strong>Wall penetration</strong></td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td><strong>Availability</strong></td>
<td>Est. Q4 2006</td>
<td>yes</td>
</tr>
</tbody>
</table>
## Appendix D

### Wireless Technology (MAN) Comparison Table

<table>
<thead>
<tr>
<th></th>
<th>WiMax 802.16a</th>
<th>WiBro 802.16e</th>
<th>TD-CDMA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frequency band</strong></td>
<td>2 – 11 GHz</td>
<td>2.3 – 2.4GHz</td>
<td>450 – 480 MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>850 – 900 MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1900 – 1920 MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2010 – 2025 MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2053 – 2082 MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2500 – 2690 MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3400 – 3600 MHz</td>
</tr>
<tr>
<td><strong>Peak Data Rate</strong></td>
<td>70Mbps</td>
<td>18.432Mbps</td>
<td>Up to 16Mbps</td>
</tr>
<tr>
<td><strong>Range to base station</strong></td>
<td>40km, radius 8km</td>
<td>1-5km radius</td>
<td>Up to 29km</td>
</tr>
<tr>
<td><strong>Wall penetration</strong></td>
<td>yes</td>
<td>yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Availability</strong></td>
<td>yes</td>
<td>yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
## Appendix E

### Wireless Technology (Cordless and Cellular Telephony (WAN)) Comparison Table

<table>
<thead>
<tr>
<th></th>
<th>Digital Cordless Telephony</th>
<th>W-CDMA</th>
<th>HSDPA</th>
<th>Digital Cellular Telephony</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frequency band</strong></td>
<td>DECT 1.880 – 1.9GHz</td>
<td>Rx: 869-894 MHz, Tx: 824-849 MHz, Rx: 1.930-1990GHz, Tx: 1.850 -1.910GHz</td>
<td>Rx: 869-894 MHz, Tx: 824-849 MHz, Rx: 1.930-1990GHz, Tx: 1.850 -1.910GHz</td>
<td>Rx: 925-960 MHz, Tx: 880-915 MHz, Rx: 1.805 -1.880GHz, Tx: 1.710 – 1.785GHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Peak Data Rate</strong></td>
<td>1152kbps</td>
<td>1.2288Mbps</td>
<td>10.8Mbps</td>
<td>GSM: 14.4kbps/ GPRS: 115kbps</td>
</tr>
<tr>
<td><strong>Range to base station</strong></td>
<td>300-500m</td>
<td>300m (Urban indoor) to &gt;20km</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Wall penetration</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Availability</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Appendix F

Example US Public Safety Radio Coverage Building Ordinance

City of Irvine California
Signal Booster Ordinance

The City of Irvine code was derived from a county-wide standard developed by the Orange County communications department. Very similar ordinances are expected to be adopted by other cities in this county.

CHAPTER 6. PUBLIC SAFETY RADIO SYSTEM COVERAGE

Sec. 5-9-601. Intent and purpose.
The intent of the chapter is to provide a regulatory framework for the purpose of providing effective 800 MHz Countywide Coordinated Communication System coverage throughout the City of Irvine for police and fire emergency services. (Ord. No. 05-09, § 1, § 1, 5-10-05)

Sec. 5-9-602. Definitions.
The following words, terms, and phrases when used in this chapter shall have the meanings ascribed to them in this section, except where the context clearly indicates a differing meaning:

City of Irvine Public Safety Radio System Coverage Specifications: Those specifications designed to provide optimum coverage and radio effectiveness within buildings and structures under the Countywide Coordinated Communication System.

Countywide Coordinated Communication System: That radio system used by local law enforcement, fire, lifeguard, and public works departments within the County of Orange for emergency and non-emergency radio communication on the 800 MHz radio band.

FCC-Certified Technician: An individual who is qualified with a General Radiotelephone Operator License (GROL/PG), or equivalent, to review design plans and perform tests in affected structures to measure City of Irvine Public Safety Radio System Coverage Specifications.

Local Fire Department: That fire agency that provides fire protective services and rescue/paramedic services for the City of Irvine (e.g. OCFA).
OCFA: Orange County Fire Authority.

OCSD/Communications: Orange County Sheriff-Coroner Department/Communications Division.

Special Inspector: An FCC-certified technician who is approved by the City of Irvine.

(Ord. No. 05-09, § 1, § 1, 5-10-05)

**Sec. 5-9-603. Use and occupancy.**
Except as otherwise provided, no person shall own, erect, construct or occupy, any building or structure, or any part thereof, or cause the same to be done, which fails to support adequate radio coverage for City emergency service workers operating on the 800 MHz Countywide Coordinated Communication System. Further, owners must maintain a reasonable standard of reliable radio communication within their buildings and structures once a Certificate of Occupancy is issued. For the purposes of this section, adequate radio coverage shall include those specifications in the City of Irvine Public Safety Radio System Coverage Specifications, attached and incorporated herein as Exhibit A (see end of this Chapter).

(Ord. No. 05-09, § 1, § 1, 5-10-05)

**Sec. 5-9-604. Testing procedures.**
Test of radio coverage will be conducted pursuant to those specifications in the City of Irvine Public Safety Radio System Coverage Specifications, attached and incorporated herein as Exhibit A, as summarized below.

A. **Initial tests.** Initial tests will be performed by FCC-certified technicians in accordance with test standards as listed in the City of Irvine Public Safety Radio System Coverage Specifications, attached and incorporated herein as Exhibit A. A Certificate of Occupancy shall not be issued if said structure, or any part thereof, fails to comply with these test standards.

B. **Annual tests.** Annual tests will be conducted by OCFA, the local fire department personnel, or their agent in accordance with the test standards as listed in the City of Irvine Public Safety Radio System Coverage Specifications, attached and incorporated herein as Exhibit A.

(Ord. No. 05-09, § 1, § 1, 5-10-05)
Sec. 5-9-605. Amplification systems allowed.
Buildings and structures that cannot support the required level of radio coverage shall be
equipped with amplification systems as specified in the City of Irvine Public Safety Radio
System Coverage Specifications, attached and incorporated herein as Exhibit A, or any
other system approved by the OCSD/Communications, in writing.

(Ord. No. 05-09, § 1, 5-10-05)

Sec. 5-9-606. Exemptions.
This chapter shall not apply to the following:

(1) Existing buildings or structures;
(2) Elevators; and
(3) Structures that are three stories or less without subterranean storage or parking.
(4) Wood-constructed residential structures four stories or less without subterranean
storage or parking.

Should construction that is three stories or less include subterranean storage or parking,
then this ordinance shall apply only to the subterranean areas.

(Ord. No. 05-09, § 1, 5-10-05)

Sec. 5-9-607. Costs.
The FCC-certified technician is the special inspector who shall be employed by the owner,
the engineer or architect of record, or agent of the owner, but not the contractor or any
other person responsible for the building or structure construction.

(Ord. No. 05-09, § 1, 5-10-05)

Sec. 5-9-608. Non-compliance.
After discovery of non-compliance, the building owner is provided six months to
remedy the deficiency and gain compliance.

(Ord. No. 05-09, § 1, 5-10-05)
EXHIBIT A. CITY OF IRVINE PUBLIC SAFETY RADIO SYSTEM COVERAGE SPECIFICATIONS

1. **Performance.** Specifications are provided to assist property owners in satisfying a delivered audio quality (DAQ) of three with a 90 percent reliability factor for emergency personnel using radio communication in their buildings and structures. Property owners who can demonstrate full compliance with the reliability factor without adhering to all of the following specifications may be excused from all or part of these provisions. Property owners who adhere to all of the specifications and fail to reach the reliability factor must employ all resources necessary to ensure full compliance. Performance and compliance will be inspected annually as part of the Orange County Fire Authority’s Fire Inspection.

2. **Signal strength, signal rejection, modulation compatibility, and delivered audio quality.** The following defines the minimum required level of radio signal strength:

   - A minimum signal strength of (-95dBm) in 90 percent of the area of each floor of the building from both the 800 MHz Countywide Communications Systems and from within the building is required.

   - The frequency range supported from the 800 MHz Countywide Communications System shall be 851 – 869 MHz (base transmitter frequencies).

   - The frequency range supported to the 800 MHz Countywide Communications System shall be 806 – 824 MHz (radio field transmit frequencies).

   - A public safety radio amplification system shall include filters to reject frequencies below 851 MHz and frequencies above 869 MHz by a minimum of 35 dB.

   - All system components must be 100 percent compatible with analogue and digital modulations after installation without additional adjustments or modifications. The systems must be capable of encompassing the frequencies stated herein and capable of future modifications to a frequency range subsequently established by the City of Irvine. If the system is not capable of modification to future frequencies, then a new system will need to be installed to accommodate the new frequency band.

   - Active devices shall have a minimum of -50 dB 3rd order intermodulation protection.

   - All active in-building coverage devices shall be FCC Part 90 Type Certified.

   - UL listing is required for any AC operated power supplies.

   - Active devices shall include a minimum of 12 hours of battery backup power.

   - Any in-building coverage system shall be installed by a City approved, manufacturer-trained and certified installer.
The delivered audio quality is defined below:

<table>
<thead>
<tr>
<th>DAQ Delivered Audio Quality</th>
<th>Subjective Performance Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Unusable, speech present but unreadable.</td>
</tr>
<tr>
<td>2</td>
<td>Understandable with considerable effort. Frequent repetition due to noise/distortion.</td>
</tr>
<tr>
<td>3</td>
<td>Speech understandable with slight effort. Occasional repetition required due to noise/distortion.</td>
</tr>
<tr>
<td>3.5</td>
<td>Speech understandable with repetition only rarely required. Some noise/distortion.</td>
</tr>
<tr>
<td>4</td>
<td>Speech easily understood. Occasional noise/distortion.</td>
</tr>
<tr>
<td>4.5</td>
<td>Speech easily understood. Infrequent noise/distortion.</td>
</tr>
<tr>
<td>5</td>
<td>Speech easily understood.</td>
</tr>
</tbody>
</table>

3. **Remedies to achieve compliance (acceptable amplification systems).** If needed to ensure compliance with the 90 percent reliability factor, the property owner must install each of the following:

- An in-building coverage system composed of a radiating cable system or an internal multiple antenna system with FCC-certified bi-directional 800 MHz amplifier(s), distribution system, and subcomponents.

- Any active devices (e.g. signal booster(s)) must be encased in a NEMA 4 (or equivalent) dust/waterproof case and clearly labelled “City of Irvine Public Safety Radio.”

- Multi-band pass filters as required.

In the event of a power outage, all electrical components must be equipped with independent auxiliary battery power or generators to function at full capacity for at least 12 hours.

Once a system is installed, a Spectrum Analyzer will be used to evaluate the system for harmful interference to the 800 MHz Countywide Coordinated Communications System backbone initially, and annually thereafter by an OCSD/Communications Division FCC-certified technician. Any interference must be identified and removed before the system can be accepted.
4. **Applicable Federal Communications Commission rule compliance.** All active devices used to provide extended coverage must be FCC-certificated.

A. **Test standards.** Design review and certification.

1. Prior to issuance of a building permit, the applicant shall:

   i. Retain an FCC-certified technician who will review construction plans in order to ensure that such plans meet aforementioned radio communication criteria, and recommend, if needed, an in-building solution for reliable radio communication;

   ii. Submit copies of plans certified with the signature of the technician to the Chief Building Official of the City of Irvine, OCFA, and OCSD/Communications;

2. Prior to issuance of a Certificate of Occupancy, the applicant shall:

   i. Retain an FCC-certified technician who will test all areas of the building or structure, verify installation and operation of in-building solutions, if needed, and certify all of the findings stated herein on the date of inspection with his/her signature. A passing test is one that demonstrates DAQ 3 with a 90 percent reliability factor on each floor. Owners of buildings that fail to meet this standard will not be in compliance with this ordinance.

   ii. The building owner must retain all records of initial and annual inspections and submit copies to the Chief Building Official of the City of Irvine, OCFA, and CSD/Communications.

B. **Initial test procedure.** For purposes of testing, each floor of the building shall be divided into a grid of approximately 20 equal areas. A maximum of two nonadjacent areas will be permitted to fail the test. In the event that three of the areas fail the test, and to provide greater statistical accuracy, the floor may be divided into 40 equal areas. In such an event, a maximum of four nonadjacent areas will be permitted to fail the test. As specified by the authority having jurisdiction, the test shall be conducted by using a Motorola XTS 3000/XTS 5000 or equivalent portable radio talking through the 800 MHz Countywide Coordinated Communications System. A spot located approximately in the center of a grid area will be selected for the test. The radio will then be keyed to verify two-way communication to and from the outside of the building through the 800 MHz Countywide Communications System. Once the spot has been selected, prospecting for a better spot within the grid area will not be permitted.
All auxiliary power systems shall be tested under load for a period of one hour to verify that the system will operate properly in the event of a power outage. The testing technician reserves the discretion to determine whether or not the battery exhibits symptoms of failure. The FCC-certified technician will ultimately decide if the auxiliary system needs to be replaced or upgraded.

C. Annual test procedure. After a Certificate of Occupancy is issued, the OCFA Inspector or appointed agent will annually test the in-building system components to determine general functional operability. If non-compliance is found, an approved FCC-technician will reassess the improvement upon scheduling by the building owner.

D. Every two years battery back-up systems shall be replaced per manufacturer's specifications.

5. Additional equipment feature requirements. Active devices shall be alarmed. A phone line (plain old telephone service or POTS) will provide dial tone to an alarm device. The alarm device will be programmed to activate a pager on the County of Orange's 900 MHz paging system. Access to the active components of the in-building coverage system (if any) is required 24 hours a day by County technicians/engineers. The minimum alarms will indicate loss of AC failure and operational failure. The device shall also have modem access to allow remote monitoring.

6. New building construction. All new building construction shall have a two-inch conduit installed between the first and bottom subterranean floor and said conduit shall extend along the center of the building to the roof. At each floor and the roof, an opening shall be made to afford easy access to the conduit from the ceiling. Access in either the form of drop ceiling or conduit shall be made available along hallways and through firewalls. All subterranean parking garages shall have a similar conduit installation.

(Ord. No. 05-09, § 1, 5-10-05)