Impact assessment for the Receiver Parameters Pilot Project

The alarm SRD sub-band (868.6 – 868.7 MHz) in the context of the band 863 – 870 MHz

A report for ECO

Brian Williamson and Paul Hansell

August 2009

Plum Consulting, 17-19 Bedford Street, Covent Garden, London, WC2E 9HP
T: +44(20) 7868 5340, **www.plumconsulting.co.uk**

Table of Contents

Executive Summary 1

1 Introduction 3
1.1 Terms of reference and purpose of study 3
1.2 Impact assessment 3
1.3 Structure of report 3

2 Desk based research and consultation process 5
2.1 Desk based research 5
2.2 Interviews and discussions 5

3 Alarm systems in the band 868.6–868.7 MHz and non specific SRDs in adjacent bands 7
3.1 Alarm systems in 868.6-868.7 MHz 7
3.2 Non specific SRDs in adjacent bands 10

4 Background on standards 11
4.1 ERC Recommendation 11
4.2 ETSI standards 12
4.3 CENELEC standards 12
4.4 Conclusion 14

5 Interference modelling using SEAMCAT 15
5.1 Background on interference 15
5.2 Interference modelling 15
5.3 Conclusion 18

6 FM22 – SRD/RFID monitoring campaign 20

7 Analysis of impacts 21
7.1 The aim is to measure incremental impacts 21
7.2 Findings relevant to this impact assessment 22
7.3 Applying the decision framework 23
7.4 Incremental costs and benefits of restricting receiver Categories 25
7.5 Conclusion 32

8 Conclusions 33

Appendix A: Terms of reference 34

Appendix B: Common interview questions 36

Appendix C: Interview summaries 37

Executive Summary

This is the Final Report for an Impact Assessment study to support the ECO receiver parameters project which is focussed on the sub –band 868.6 to 868.7 MHz (designated for alarms). We were asked to consider the costs and benefits of adopting Category 1 or Category 1 and Category 2 receiver standards only, instead of the status quo where three categories are available.

The ETSI standard in which these receiver categories are specified applies over a wide range from around 25 MHz to 1 GHz. Whilst our general approach could have wider application, our conclusions in relation to 863 – 870 MHz would not necessarily apply to other frequencies. No general conclusion regarding the appropriateness of changing receiver categories should therefore be inferred from this study.

The analysis is a pilot study to illustrate the application of impact assessment, and in particular the procedure developed in the ECC Impact Assessment Guidelines (ECC Report 125). We assume that the objective of the receiver standards is to maximise over all social welfare. We considered the following options:

- Regulatory options
  - The status quo (maintaining Category 1, 2 and 3)
  - Adopting Category 1 only
  - Adopting Category 1 and 2 only
  - Waiting (until there is more information or an interference problem emerges)
- Other stakeholders' options: For example, manufacturers/users of alarm system can adopt other means of mitigating interference and/or adopt wired systems.

During this study a number of methodological points were identified which may be relevant more widely, namely:

- The alarm band was chosen in part because the category of use within the band was known. However, as both adjacent bands are for non-specific SRDs it is difficult to identify the number and nature of potential interferers. In the interference modelling a worst case assumption that devices were operating at their allowed performance envelopes in terms of power and duty cycle was made (as is normal practice). However, as SRDs in both the adjacent bands and band in question are operating within one or two orders of magnitude within the interference modelling assumptions. This suggests that more than one round of modelling may be required or considerable judgement must be exercised in interpreting the interference modelling results.
- Manufacturers are conscious of the risk of interference (primarily from systems within their own frequency sub-band). They generally adopt higher Category receivers than the minimum allowed and protocols such as sending messages 3 times to ensure that systems work well in practice. This finding points to the fact that the costs and benefits of a number of key design choices are "internal" to manufacturers and end users, and one might expect them to adopt the appropriate Category of receiver given the balance of costs and benefits for a given application. Reinforcing this conclusion is the fact that CENELEC alarm standards (Grades 1-4) indicate quality of system in the market place. Further, adoption of options such as listen before talk (LBT) is possible if interference is anticipated to become a problem in future.

In terms of the conclusions of our analysis we found:

- The majority of alarm systems based on the sample of manufacturers we spoke to utilise Category 2 receivers. Requiring all systems to utilise Category 1 receivers would involve a cost penalty of perhaps €5 per receiver or around €10-30 million per annum (assuming 1 in 5 devices is operating in receive mode and 10-30m sold p.a.) and €50-150 million per annum (assuming all devices operate in receive mode, which may be the case if LBT is adopted).
- Requiring the use of Category 1 receivers would not only increase the cost of devices but also increase their size as a single chip solution achieving Category 1 is currently not available. This increase in size is acceptable for some systems, but may not be for others for practical or aesthetic reasons. Particular examples cited including power and lighting control in buildings where SRD based controllers need to fit in small spaces and the use of alarm systems on windows where large devices may not be acceptable to customers.
- Provided the risk of out of band interference is negligible or is managed by protocols such as message repetition there would be no offsetting benefits. Whilst out of band interference was not currently identified as a problem it could become so in future. Two adjacent band applications may involve the deployment of large numbers of SRDs in future, namely smart metering and automotive tyre pressure monitoring. For smart metering, device densities as high as perhaps 20,000 per km^2 in denser urban areas are plausible.
- The interference modelling considered densities as high as 10,000 devices per km^2 which produced interference probabilities of 99%-100% across Category 1 through 3 devices and significant probabilities of interference at densities of 1000 devices per km^2. If this were the case in practice then the Category of device chosen would be irrelevant as none would work in high device density areas.
- A number of factors suggest that interference probabilities may be far lower in practice than those modelled. In particular, the duty cycle (proportion of time they transmit) of out of band systems may be several orders of magnitude lower than the 1% limit assumed for interference modelling purposes (for example, for hourly meter reading) and the adjacent band applications are not at the band boundary as assumed for the interference modelling.

In conclusion, we find that imposing a higher Category of receiver would involve costs, and might result in little if any benefit. There is a high degree of uncertainty over the interference risk as this depends on the extent to which known new devices that operate below the regulatory limits (such as smart meter readers and automotive tyre monitors) are deployed and/or whether other new devices are developed that operate according to the regulatory envelopes.

In addition we observe that manufacturers we spoke to appear to “internalise” the benefits and costs when deciding the design of their systems in order to avoid interference, suggesting that the market may achieve a socially desirable outcome. Our analysis suggests the regulator needs to use information on what is actually happening in the market and the nature of the incentives facing market players before deciding the appropriate approach to interference modelling.

Given the uncertainties over the future deployment of devices in adjacent bands, the policy conclusion is to maintain the status quo and monitor developments in use of adjacent bands. We suggest that further analysis of likely adjacent band applications and modelling of anticipated duty cycles etc (rather than regulatory envelopes) could be justified.

1 Introduction

1.1 Terms of reference and purpose of study

On the 9th of June ECO (the then ERO) appointed Plum Consulting and Aegis Systems to conduct an Impact Assessment study to support the ECO receiver parameters project which is focussed on the sub –band 868.6 to 868.7 MHz (designated for alarms). Information on the project is on the ECO website (http://www.ero.dk/rx) and the full terms of reference are attached as Appendix A.

We were asked to assess the costs and benefits of adopting Category 1 or Category 1 and Category 2 receivers only, instead of the status quo where three categories are available. We note that whilst we were asked to consider applications in the band 863 – 870 MHz and the costs and benefits of limiting allowed ETSI receiver Categories to 1 and 2 or 1 only, receiver parameters apply to a wide band from around 25 kHz to 1 GHz. Our general approach could have wider application however our conclusions in relation to the 863 – 870 MHz would not necessarily apply to other frequencies. No general conclusion regarding the appropriateness of changing receiver Categories should therefore be inferred from this study.

1.2 Impact assessment

The motivation for impact assessment is to improve decision making. Impact assessment covers a range of methodologies including multi-criteria analysis (comparing apples and oranges), cost-effectiveness analysis (comparing apples and money) and cost-benefit analysis (comparing apples with apples by representing impacts in money terms).

In carrying out impact assessment both the methodology and the procedure are important. The key steps in the procedure developed in the ECC Impact Assessment guidelines (ECC Report 125) are set out below:

i. Identification of the issue/problem(s)
ii. Describe the policy/measure and identify the objectives
iii. Identify and describe the regulatory options
iv. Determine the impacts on all stakeholders including relevant spectrum incumbents
v. Determine the impact on competition (if relevant)
vi. Assess the impacts and choose the best option
vii. Monitoring and evaluation

Investing effort in the first three steps can aid and simplify subsequent steps involving analysis and decision making, and may lead to a redefinition of the problem. Further, the initial steps involve taking a view about the preferred option before the analysis of impacts and this may need to be revised once the analysis has been undertaken.

1.3 Structure of report

Our report is structured as follows:

Section 2 (and associated Appendices B and C) sets out the results of our desk based research and interviews.

Section 3 discusses the use of the band 868.6 – 868.7 MHz for alarms on a licence-exempt basis.

Section 4 discusses background on relevant regulatory texts – ERC, ETSI and CENELEC.

Section 5 discusses the results of the interference modelling and their relationship to the radio and operational characteristics of the applications in the band in question and adjacent bands.

Section 6 discusses the FM22 SRD/RFID monitoring campaign and implications for this study.

Section 7 presents our framework, analysis and findings.

Section 8 gives our conclusions.

Appendices A through C respectively cover the terms of reference for the study, the interview questions and the findings from the interviews.

2 Desk based research and consultation process

We carried out desk based research and contacted trade associations and manufacturers in order to inform the study. Some organisations specialised in alarm systems but others had a much wider interest in SRDs using a range of sub-bands.

2.1 Desk based research

Based on desk based research:

- We identified a variety of devices/uses including personal alarms, individual alarms triggered by falls, fire and burglar alarm within building links. There is some overlap of functionality with 'social alarms'.
- None of the alarms identified were labelled in terms of receiver Category (but we inferred the category based on device specifications to be Category 2).
- The alarms used 25 kHz channels (none use 100 kHz channels).

2.2 Interviews and discussions

During the study we approached a number of individuals and organisations, though in some cases responses were constrained by availability of relevant people during the summer vacation period. We were also, in some instances, constrained in terms of what we report for reasons of commercial confidentiality, though information that fell into this category was nevertheless very helpful in giving us an understanding of the market.

The questions we put to people are set out in Appendix B and the responses in Appendix C. The following conclusions flow from our desk research and discussions with industry:

- There is a wide range of applications in the band in question (863 - 870 MHz), and there is a lack of information on the total number of devices within the alarm band itself (868.6 – 868.7 MHz) or in the adjacent bands.
- Manufacturers and system integrators did not point to any evidence of significant interference problems at present.
- There appears to be a low level of visibility of ETSI device categories and other requirements such as CENELEC standard (grades of alarm system) are considered to be more directly relevant to device design.
- There is a range of options for addressing interference in addition to adopting tighter receiver parameters including: repeating messages, using a low duty cycle and, potentially in future, adopting bidirectional transmission and frequency agility.
- Whilst wired systems are an alternative for some applications they are more expensive for skilled installers to install – requiring approximately a day per security system versus 3 systems per day for wireless systems. In part this installation cost difference explains the growth of wireless systems.

- LBT is not utilised in the alarm band at present. Concern was raised during interviews that LBT in adjacent bands might introduce continuous data streams and therefore raise the likelihood of interference. In addition, LBT might be jammed deliberately.
- Adopting requirements for Category 1 devices would increase cost around 2-fold and would increase device size perhaps four 4-fold.

It is clear from the above that requiring the use of Category 1 devices would impose financial costs on manufacturers and would impose both costs and potentially size related constraints in terms of installation and end use, with no offsetting benefits at present. It was not clear that eliminating Category 3 would impose costs, or generate benefits, though those we spoke to did not manufacture this Category of receiver (with one exception).

If interference problems did arise there is a range of current and potential mitigation techniques that would allow manufacturers to manage the problem. At some point these techniques might be exhausted, though there were no indications of concern (aside from concern regarding LBT systems in adjacent bands).

3 Alarm systems in the band 868.6–868.7 MHz and non specific SRDs in adjacent bands

3.1 Alarm systems in 868.6-868.7 MHz

Alarm systems are able to operate in the band 868.6 – 868.7 MHz on a licence-exempt basis providing they operate within the technical envelope of ERC Recommendation 70-03 (as detailed later).

In their most general form these alarm systems consist of one or more control panels containing a radio receiver and the necessary processing equipment associated with a number of devices / sensors each of which contains a radio transmitter. The control panel is likely to be connected to a central security monitoring site or directly to the authorities (e.g. the police). The devices / sensors include such items as motion, smoke and door / window opening detectors, but also include alert / emergency transmitters relating to personal safety. These latter devices are mainly related to the security of workers rather than social alarms which have their own designated frequency bands, although clearly it is difficult to distinguish between the two from a regulatory point of view.

It can be seen from this description that the centralised architecture is based around a control panel receiver with multiple sensor transmitters. Each sensor in a system is recognised by the control unit from its unique code and they all transmit on the same radio frequency channel, relying on some of the mitigation techniques (especially very low duty cycle and message repetition), as discussed in the box below, to operate satisfactorily.

Interference and its mitigation

An alarm system operating in this frequency band can expect to receive interference from a number of sources:

- Other alarm devices in the same system (operating on the same channel)
- Other alarm devices / systems operating on the same channel
- Other alarm devices / systems operating on different channels in the alarm frequency band
- Other devices / systems operating in the non-specific frequency bands on either side of the alarm frequency band – the focus of this study but note that the other interference sources maybe as important or more important to the system designer.

Mitigating these interference entries is largely in the hands of the system designer but the regulatory framework ensures that at least some techniques are mandatory. This ensures the frequency band does not become unusable because of anti-social behaviour which might have a tendency to occur in licence-exempt bands.

The mandatory mitigation techniques for the alarm band are:

- A limited power level, in this case the use of 10 mW or less
- A relatively low duty cycle, in this case the use of 1% or less

Other techniques are available to the system designer, including:

- Message repetition as a matter of course (potentially with random times between each message repeat) – applicable to transmit-only devices

- Message repetition as required by an acknowledgement or other such protocol – devices need to be able to transmit and receive
- Listen Before Talk (LBT) whereby a device ensures the channel is not being used by another device before transmitting itself
- Frequency agility whereby a device moves to another channel if a channel is being used by another device

Note that these techniques can be implemented singly or in combination and that some have a message overhead which in effect also has the potential to increase the probability of interference to others and shorten battery life.

These techniques can of course be used in other SRD sub-bands and some are mandatory[1] in the frequency bands adjacent to the alarm band. For example LBT and frequency agility are identified as mitigating factors in ERC Recommendation 70-03 for the two frequency sub-bands immediately adjacent to the alarm band.

It has been found from discussions with alarm system suppliers that their alarm systems are based on this centralised architecture using uni-directional radiocommunication links from sensors / devices to a central control unit. However, the requirements of other mitigation techniques which appear not to be widespread yet but which are being considered by alarm system developers (e.g. Listen Before Talk and more sophisticated protocols), means that there will be a requirement for bi-directional radiocommunication links between the sensors / devices and the central control unit. The alternative architectures are shown in Figure 3-1 and Figure 3-2.

Another important aspect of the alarm systems operating in this band is that, even though there is an option to use 25 kHz channels or the whole band as a single 100 kHz channel, it appears that there is little or no use of the 100 kHz channel option. This is for two main reasons:

- To improve the range given the maximum power is fixed and bandwidth independent. This reduces the noise in the receive bandwidth.
- To reduce the impact of interference from non-specific SRDs operating in adjacent bands. Greater selectivity can be achieved with the narrower channel.

The wider bandwidth is not required by the application which inherently transfers very small amounts of data. It might be argued that transferring the data at a higher data rate (in the larger channel bandwidth) for a shorter period of time reduces the number of collisions thereby accommodating more devices. However, it is not evident that a greater density of devices is required by the application and if it were, three additional 25 kHz channels are available anyway.

[1] In the sense that they have to be used if an alternative mitigation techniques is not used.

Figure 3-1: Alarm architecture using transmit-only devices / sensors

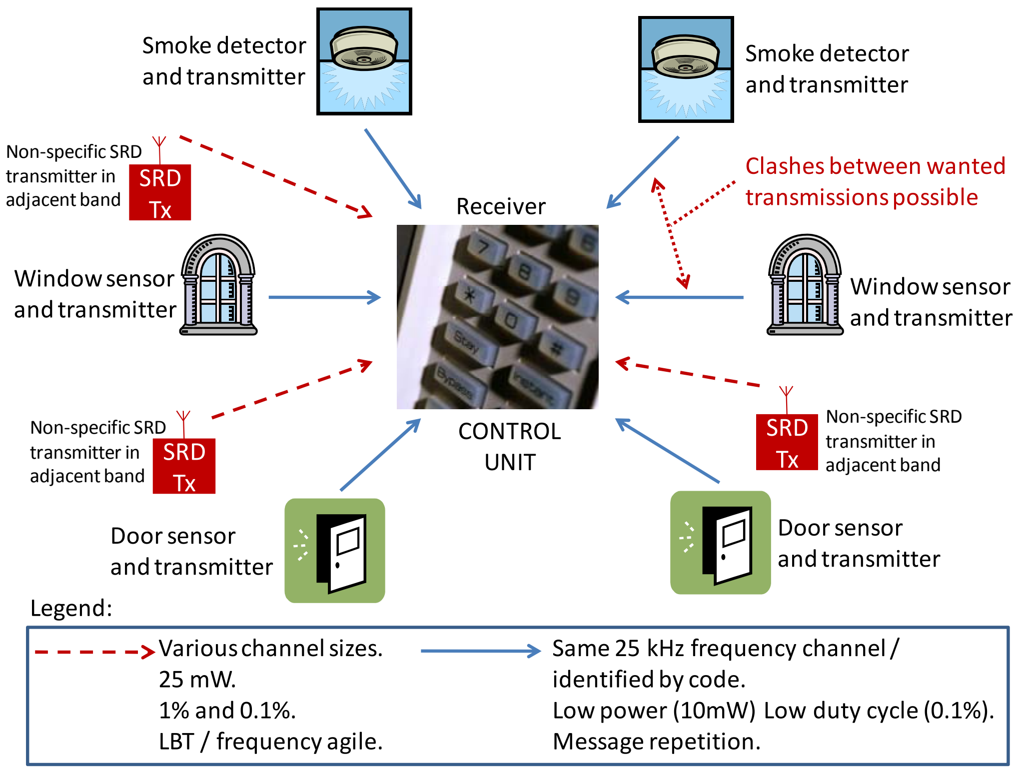
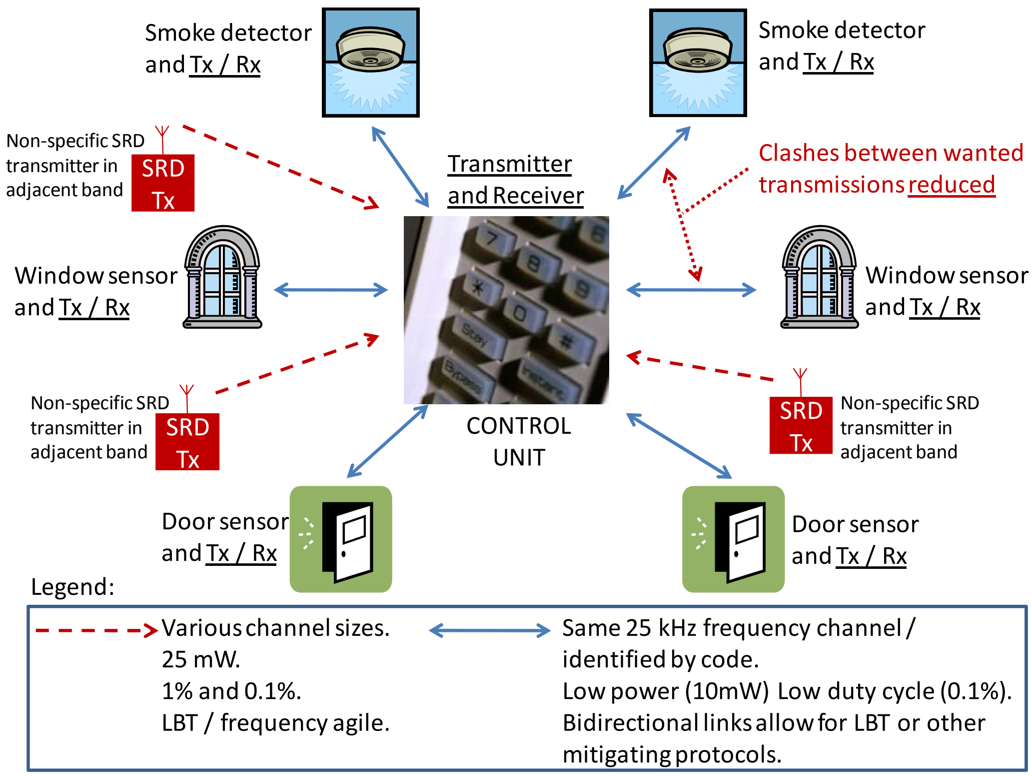


Figure 3-2: Alarm architecture where devices / sensors can receive as well as transmit



3.2 Non specific SRDs in adjacent bands

Whilst the focus of our research was on the alarm band, in the course of our discussions with manufacturers of alarm systems we found that there was a possibility of potentially large numbers of SRDs in the adjacent bands to support smart metering and automotive tyre pressure monitoring (there are also other applications, and given the non-specific licence-exempt nature of the band other mass market applications could potentially enter the band in future).

Germany and The Netherlands are leading the implementation of smart metering systems utilising adjacent bands for meter/s (gas, electricity and water) to communicate readings to a central unit once per hour. In urban areas this alone might see device densities of up to around 20,000 per square km.

Automotive monitoring of tyre pressure would see 4 devices per car and an overall density approximating that for smart metering. We do not know the characteristics in terms of transmit frequency of these devices, though we do know that they have the capability to turn themselves off when a car is stationary.[2]

[2] Whilst such devices may sleep when cars are stationary. http://www.sensorland.com/HowPage040.html

4 Background on standards

4.1 ERC Recommendation

The framework for SRD operations originates in ERC Recommendation 70-03[3] which is updated on a regular basis by the SRD Management Group. The high level technical parameters that define how SRDs can operate in the alarm band and the two adjacent bands are shown in Table 4-1.

Table 4-1: Device requirements in band in question and adjacent bands

Frequency band (MHz)	Power (e.r.p. in mW)	Duty cycle	Channel spacing	Notes
868.0 – 868.6 (g1) Non-specific SRDs	25	≤1% or LBT	None – whole frequency band may be used. Preferred channel spacing = 100 kHz allowing for subdivision into 50 kHz and 25 kHz.	For frequency agile devices the duty cycle applies to the total transmission unless LBT is used. For LBT devices without frequency agility, the duty cycle limit applies.
868.6 – 868.7 (a) Alarms	10	<1%	25 kHz – whole frequency band may be used as one channel (100 kHz).	Note there is NO requirement for alarms to use LBT or frequency agility.
868.7 – 869.2 (g2) Non-specific SRDs	25	≤0.1% or LBT	None – whole frequency band may be used. Preferred channel spacing = 100 kHz allowing for subdivision into 50 kHz and 25 kHz.	For frequency agile devices the duty cycle applies to the total transmission unless LBT is used. For LBT devices without frequency agility, the duty cycle limit applies.

Source: ERC Recommendation 70-03 Annexes 1 and 7

In addition to the SRDs identified in Table 3-1 there is an additional category of non-specific SRDs that are allowed to operate across the whole band 863 – 870 MHz (apart from alarm sub-bands). These SRDs are allowed to use FHSS, DSSS and narrowband/wideband modulation. They are restricted to an e.r.p. ≤25 mW and a duty cycle of ≤0.1% (or the use of LBT). From a technical and interference point of view these characteristics largely fall within the technical envelope for the adjacent bands g1 and g2 as summarised in Table 4-1.

[3] ERC Recommendation 70-03 (Tromsø 1997 and subsequent amendments). Relating to the use of Short Range Devices (SRD). Recommendation adopted by the Frequency Management, Regulatory Affairs and Spectrum Engineering Working Groups. Version of 2 June 2009.

4.2 ETSI standards

The ETSI standard EN 300 220 applicable to SRDs is wide ranging in that it addresses a number of device characteristics and also encompasses devices operating over an extensive part of the spectrum, namely 25 kHz to 1 GHz.[4] Of most importance to this case study is the fact that it specifies three categories of receiver selectivity as shown in Tables 4-2 and 4-3 below, the first for devices using a channelisation of 25 kHz or less, and the second for devices using a channelisation greater than 25 kHz.

Table 4-2: For devices using a channel size/spacing ≤25 kHz

Device category	Adjacent channel selectivity	Adjacent channel saturation	Blocking within ±2 MHz	Blocking within±10 MHz
1	≥ -50 dBm	≥ -20dBm	≥ -20dBm	≥ -20 dBm
2	Not specified	Not specified	≥ -69 dBm	≥ -44 dBm
3	Not specified	Not specified	≥ -80 dBm	≥ -60 dBm

Source: EN 300 220 v2.3.1 (2009-04)

Table 4-3: For devices using a channel size/spacing >25 kHz

Device category	Adjacent channel selectivity	Adjacent channel saturation	Blocking within ±2 MHz	Blocking within±10 MHz
1	≥ -44 dBm	≥ -10 dBm	≥ -20dBm	≥ -20 dBm
2	Not specified	Not specified	≥ -69 dBm	≥ -44 dBm
3	Not specified	Not specified	≥ -80 dBm	≥ -60 dBm

Source: EN 300 220 v2.3.1 (2009-04)

4.3 CENELEC standards

Part 1 of the CENELEC standard for alarm systems contains many requirements that relate to the security grading of equipment[5] where the grade of a system is that of the lowest graded component. The following grades are given by the standard:

- Grade 1: Low risk. An intruder or robber is expected to have little knowledge of Intrusion and Hold-up Alarm Systems (I&HAS) and be restricted to a limited range of easily available tools.
- Grade 2: Low to medium risk. An intruder or robber is expected to have a limited knowledge of I&HAS and the use of a general range of tools and portable instruments (e.g. a multi-meter).

[4] Draft ETSI EN 300 220-1 v2.3.1 (2009-04) - Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Radio equipment to be used in the 25 MHz to 1,000 MHz frequency range with power levels ranging up to 500 mW; Part 1: Technical characteristics and test methods.

Draft ETSI EN 300 220-2 v2.3.1 (2009-04)) - Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Radio equipment to be used in the 25 MHz to 1,000 MHz frequency range with power levels ranging up to 500 mW; Part 2: Harmonized EN covering essential requirements under article 3.2 of the R&TTE Directive.

[5] CENELEC EN 50131-1:2006 – Alarm systems - Intrusion and hold-up systems. Part 1: System requirements.

- Grade 3: Medium to high risk. An intruder or robber is expected to be conversant with I&HAS and have a comprehensive range of tools and portable electronic equipment.
- Grade 4: High risk. To be used when security takes precedence over all other factors. An intruder or robber is expected to have the ability or resource to plan an intrusion or robbery in detail and have a full range of equipment including means of substitution of components in an I&HAS.

The requirements relate to ensuring system integrity in one way or another. Of particular relevance to this study are those requirements which relate to interconnection integrity and the security of signals.

The interconnection requirements of the system standard (Part 1) are addressed in more detail for interconnections using radio frequency techniques in Part 5-3.[6] Here, there are requirements relating to:

- Immunity to attenuation (on the radio propagation path)
  - 3 dB (Grade 1)
  - 6 dB (Grade 2)
  - 9 dB (Grade 3)
  - 12 dB (Grade 4)
- Immunity to collision (of message transmissions)
  - Maximum 10% occupation in 240 minutes (Grade 1)
  - Maximum 10% occupation in 120 minutes (Grade 2)
  - Maximum 10% occupation in 100 seconds (Grade 3)
  - Maximum 10% occupation in 10 seconds (Grade 4)
  - In addition it is noted that all regulatory requirements concerning the duty cycle shall be complied with and that for Grade 3 & 4 equipment, all types of message shall be acknowledged by the receiving equipment to the transmitting equipment.
- Number of correctly interpreted messages
  - 999 out of 1,000 (Grades 1 & 2)
  - 9,999 out of 10,000 (Grades 3 & 4)
- Immunity to interference
  - From outside the assigned band = 10 V/m (Grades 1 & 2)
  - Within the assigned band = Error threshold signal level[7] + 11 dB[8] (Grades 1 & 2)
  - From outside and within the assigned band = 10 V/m (Grades 3 & 4)

[6] CENELEC EN 50131-5-3:2005 + A1:2008 – Alarm systems - Intrusion and hold-up systems. Part 5-3: Requirements for interconnections equipment using radio frequency techniques.

[7] The received signal level (in dBm) at which point 12 to 15 alarm messages out of 50 are not received.

[8] This value a combination of three factors; +3 dB reference level correction, +20 dB level A correction and -12 dB the interference specification itself.

Importantly, there is a requirement to monitor interference and failures in periodic communication. While it is mandatory for the system control unit to undertake this monitoring for all Grades of system, it is only mandatory for Grade 3 & 4 devices and optional for Grade 1 & 2 devices. The implication of this is that systems using devices that only transmit can only ever be Grade 2 systems at best.

It can be seen from the summary above that there are a number of detailed requirements relating to the performance of RF interconnections in an uncoordinated interference environment. There is no reference to ETSI EN 300 220 in the CENELEC standard so it is not at all clear how these CENELEC requirements relate to the radio related performance requirements in the more general ETSI standard. There is solely a reference to ETSI EN 301 489-1 but this relates to the common technical requirements for ElectroMagnetic Compatibility (EMC) pertaining to radio equipment and services.

It is also interesting to note that the CENELEC standard requires devices to be marked with the appropriate Security Grade and Environment Class whereas the ETSI standard only requires the Receiver category to be recorded in the User's Manual (and test report).

4.4 Conclusion

Manufacturers we have spoken to see the CENELEC standard as more relevant in practical terms than the ETSI standard and choice of receiver Category[9]. We have not established whether this is because in meeting the CENELEC standard the requirements of the ETSI standard are essentially met, or whether the CENELEC standard is more material in terms of its design and cost implications.

In meeting the requirements of CENELEC Grade 2 systems, which allows for sensors that are transmit-only, it appears that receivers will meet the ETSI Category 2 requirements by default.

Little evidence was obtained regarding CENELEC Grade 3 & 4 systems[10] so it is not possible to be definitive regarding the relationship with ETSI receiver categories. However, the far more stringent requirements associated with Grade 3 & 4 systems suggests that ETSI Category 1 receivers might have to be employed to ensure the high levels of message integrity required. This was also the opinion of one of the component manufacturers contacted during the course of the study.

[9] This is not to say that manufacturers disregard the ETSI standard. They recognise it is a standard that has to be met and act accordingly.

[10] It is thought that these more sophisticated systems are likely to be designed for a specific use/customer rather than for the mass market.

5 Interference modelling using SEAMCAT

5.1 Background on interference

Unwanted interference is related to the signal to noise ratio, where noise is made up of thermal noise in the system and unwanted interference from outside the system. A certain signal to noise ratio is required for the demodulator to be able to decode the signal accurately.

Interference can come from devices operating on the same channel (which will be the case for alarms because there is no discrimination at the receiver). This is the reason alarms use a low duty cycle in practice to avoid signal collisions and use message repetition in case a single signal is lost.

However, we are focussed on interference into the receiver from non-specific SRDs operating in an adjacent channel. There are effectively two parts to this interference:

- The full power (i.e. main part of the transmitter emission) of the interfering device entering the receiver through the side response of its filter which provides some discrimination. This is sometimes quantified using the term Adjacent Channel Selectivity (ACS).
- The out-of-band power of the transmitter (which will be at a much lower level than the main part of the emission) entering the pass band of the receiver where there is no discrimination. This is sometimes quantified using the term Adjacent Channel Leakage Ratio (ACLR).

Interference is the sum of these and one or other may dominate or they might give roughly equal contributions depending on the relative forms of the transmitter emission mask and the receiver selectivity performance.

Filtering in the receive chain can occur in several places and it has a cumulative effect. By the time the wanted signal gets to the demodulator a lot of the interference will have been filtered out and an adequate signal to noise ratio achieved for the demodulator to operate effectively. However, at the very front end of the receiver the frequency response of the amplifier is relatively wide (particularly for small and inexpensive devices) and the risk is that a relatively powerful input signal some way away from the wanted frequency can drive the low noise amplifier into saturation or at least make its performance non-linear because little or no filter discrimination has been applied. This desensitisation effect is called blocking and has an effect in terms of an absolute signal level. In contrast, the ACS and ACLR interference (as opposed to blocking) has an effect in terms of a signal to noise ratio and is relevant further down the receive chain.

5.2 Interference modelling

Seamcat[11] is a Monte Carlo model which derives a statistical result expressed as a probability of unacceptable interference based on a number of snapshots (trials). Unacceptable interference is defined as a criterion expressed at the physical level (i.e. RF signal strengths) in terms of carrier to interference ratio or other such measure. Seamcat calculates the impact of interference in two parts (and combined):

[11] See http://www.ero.dk/seamcat for further details

- Due to the adjacent channel leakage effect (i.e. the out-of-band power of the interfering transmitter falling within the passband of the receiver). In Seamcat this is termed **unwanted interference**.
- Due to the adjacent channel selectivity of the receiver (i.e. whereby the main part of the interfering transmitter emission is discriminated against according to the performance of the receiver selectivity). Seamcat aims to combine this effect with the desensitisation[12] effect in terms of an overall selectivity response which in Seamcat is called **blocking**.

Examination of these effects separately shows which effect dominates but, since in practice a receiver cannot separate them out, it is the result which combines the two effects which represents the real impact on a receiver.

It is assumed that the victim receiver is receiving a message and each snapshot looks at the effect of unwanted interference and blocking on that message due to a number of interfering transmitters that (a) have been placed randomly in the same area as the victim and (b) may or may not be transmitting because of their duty cycle. The probability of interference therefore equates to the probability of a message getting through in the victim system. This is irrespective of the duty cycle of the receiver (i.e. whether it is receiving or not) as we are not interested in the probability with respect to all time. We are interested in the probability with respect to a message being interfered with when the receiver is meant to be receiving a message and not when it is not meant to be receiving a message[13].

Duty cycle and message length

Duty cycle when used in relation to SRDs is expressed as a percentage and represents the amount of time a transmitter transmits on one carrier frequency relative to a one hour period. For the types of system we are dealing with here it is likely that the receiver is always on and waiting for messages to arrive (i.e. no synchronisation is employed).

It is known that some alarm systems mitigate interference within their own system from other alarm systems by repeating messages (e.g. three times with random times in between). This is likely to be effective with respect to mitigating interference between alarm systems as the transmission characteristics are either known or likely to be similar and the probability of message collisions is therefore likely to be uncorrelated.

However, since duty cycle is expressed as a ratio it provides no indication of how long or how short an individual transmission might be. In the case where a victim system uses message repetition as an interference mitigation technique it is difficult to ascertain with any certainty the impact of interference from one system employing a particular duty cycle on another system employing another or even the same duty cycle without additional information on transmission lengths[14].

How effective this message repetition will be at mitigating interference from systems in adjacent bands is unknown because the transmission characteristics could be very different even though duty cycle

[12] The desensitisation of the receiver is defined here in terms of a 3 dB increase in the noise floor.

[13] It might be thought that the duty cycle of the receiver would have an influence on the probability of interference as it appears that the interference simulations represent a situation where the receiver is always on. However, combining the interference probability results (assuming for the moment that the interference probability is just related to time - i.e. without the location variation) with the receiver duty cycle probability, while correct in principle, gives a probability with respect to all time (i.e. including when the receiver is off). Since we are only interested in probability with respect to when a message is being received we do not have to combine the probabilities. To be completely circular, if the combined probability (all time) is normalised with respect to the receiver "on time" you simply arrive back at the interference probability (receiver always on).

[14] It can be noted that CEPT Recommendation 70-03 provides advisory limits for different duty cycles in terms of maximum transmitter on time in seconds and minimum transmitter off time in seconds. These are designed to facilitate sharing in the same frequency band.

requirements are similar. If the alarm system designers were to take into account the advisory transmitter on time limits in CEPT Recommendation 70-03 in setting the repetition interval in their system then it is possible that message repetition might mitigate adjacent band interference as well as interference between and within alarm systems.

A number of scenarios consisting of a victim receiver located within an area populated by a number of interferers have been modelled.[15] In summary these scenarios use various victim receiver and interfering transmitter characteristics as shown in Table 5-1, with the variations identified in bold:

Table 5-1: Interference scenarios

Device	Characteristics
Victim receiver	Adjacent Channel Selectivity (ACS) and blocking performance for the **three categories of receiver**, in association with receiver selectivity and C/I criterion. ACS values assumed for Categories 2 & 3 as there are none in EN 300 220. Bandwidth: **25 kHz or 100 kHz** Centre frequency (for the 25 kHz channel case): **random across band or at edges of band**
Interfering transmitters	Power, bandwidth and duty cycle for band above and band below fixed (and different). Interferers **above or below or both** considered. **Various densities** of interferer considered.

The results of modelling these scenarios are summarised in Table 5-2and Table 5-3.

Table 5-2: Results of the Probability of interference in % with a C/I = 8 dB for all the steps with difference bandwidth (unw: unwanted, block: blocking, unw+block:unwanted + blocking)

	Probability of interference in % with a C/I = 8 dB								
	Category 1			Category 2			Category 3		
	unw	block	Unw+ block	unw	block	Unw+ block	unw	block	Unw+ block
Step 1	2	0	2.19	2.1	0.17	2.1	2.1	0.4	2.1
Step 1 bis	0.431	0	0.432	0.5	0.2	0.54	0.5	0.53	0.7
Step 2	0	0	0	0	1.62	1.6	0	4.6	4.6
Step 2 bis	2.6	0	2.6	2.5	1.58	3.37	2.6	5.1	6.28
Step 3	1.1	0	1.1	1.1	0.18	1.1	1.1	0.25	1.1
Step 4	0.3	0	0.3	0.3	1.7	1.77	0.3	4.8	4.8
Step 5	2.2	0	2.2	2.27	1.8	3.8	2.1	5.1	6.8
Step 6	2.1	0	2.1	2.2	1.8	3.76	2.1	5.3	6.99
Step 7	2.9	0	2.9	2.9	1.7	3.8	2.9	5.4	6.7

Source: WP2 report on inventory of cases and case studies of interferer to victim interactions.

It can be seen that the highest probability of interference for the three categories amounts to:

[15] Draft ERO Report on Inventory of Cases and Case Studies of Interferer to Victim Interactions. Revision 4.3 (considers the latest version of EN 300220-1).

ECC Report 37 – Compatibility of planned SRD applications with currently existing radiocommunication applications in the frequency band 863 – 870 MHz. Granada, February 2004, revised Nicosia, May 2008.

- Category 1 – 2.9% (Scenario 7)
- Category 2 – 3.8% (Scenarios 5 & 7)
- Category 3 – 7.0% (Scenario 6)

Table 5-3: Impact of the transmitter density on the probability of interference

	Density of transmitters (1/km²)	Probability of interference in % with a C/I = 8 dB								
		Category 1			Category 2			Category 3		
		unw	block	Unw+ block	unw	block	Unw+ block	unw	block	Unw+ block
Step 1 bis	10	0	0	0	0	0	0	0	0	0
	100	0.431	0	0.432	0.5	0.2	0.54	0.5	0.53	0.7
	1000	4.8	0	4.8	5	1.8	5.58	4.6	4.6	7.1
	10000	35.2	0	35.2	33.9	15.2	38.75	35.5	44.6	57.6
Step 6	10	0.2	0	2.2	0.2	0.19	0.39	0.2	0.48	0.65
	100	2.1	0	2.1	2.2	1.8	3.76	2.1	5.3	6.99
	1000	22	0	22	22.35	17.6	36	22.2	47.26	60
	10000	99	0	99	99	94	99.9	99	100	100

Source: WP2 report on inventory of cases and case studies of interferer to victim interactions.

It can be seen that the band becomes unusable when the density of interfering transmitters at the band edge approaches 10,000 per square kilometre. Even at 1,000 per square kilometre probabilities of interference are significant.

5.3 Conclusion

The outcome of the interference modelling reported in the "Inventory of Cases and Case Studies of Interferer to Victim Interactions" can be summarised at a high level as follows:

- For category 1 receivers blocking does not occur under any of the envisaged scenarios and the probability of a single message failing increases directly in line with the density of interfering transmitters as would be expected. It appears that the alarm band would be completely unusable if the density of interfering transmitters on the immediately adjacent channel ever became 10,000 per km^2 and not particularly good at 1,000 per km^2.
- Blocking becomes part of the issue for Category 2 and 3 receivers, the latter being worse than the former. It can be noted that in general blocking is the dominant effect for Category 3 receivers whereas it is more evenly balanced in effect with respect to the impact of unwanted interference for Category 2 receivers. As might be expected the same comment regarding transmitter densities in the bullet above also applies to Category 2 and 3 receivers.
- The effect of unwanted interference (as opposed to blocking) is much the same for all three receiver categories. This is as expected as this represents the transmitter out-of-band emissions falling in the receiver passband. The level of transmitter out-of-band emissions is not varied between the various scenarios being modelled and changes to receiver performance only relate to its adjacent band selectivity (which directly affects blocking results) and not its passband.

For the interference modelling results to be related to the findings of our research and to be used in the impact assessment there are three questions that need to be answered:

i. **Do the system parameter values used for the modelling reflect what is implemented in practice?** We have already established that the duty cycle of the victim alarm receiver is not important even though alarm systems tend to use a much lower duty cycle (<0.1%) compared to that allowed (up to 1%). However, on the alarm side we have also established that message repetition is used to mitigate interference within and between alarm systems. Depending on the relationship between the alarm message structure and the message structure used by interfering SRDs in adjacent bands this may also mitigate the interference / blocking. The level of such mitigation is not however known but could be determined if message structures were known in detail. With regard to the duty cycle of the interfering devices (which does have a direct impact on the probability of alarms receiving interference), the modelling has assumed the regulatory limits specified in CEPT Recommendation 70-03 for the two adjacent bands. It has been suggested that one of the main applications using the adjacent bands in the future is remote meter reading. For this application the duty cycle will be considerably lower that the duty cycles used in the modelling so this could suppress results by an order of magnitude or more. In addition, the frequencies planned for this application are not immediately adjacent to the band edge which ameliorates the situation even further.
ii. **What constitutes an acceptable probability of interference/blocking in an alarm system due to SRDs operating in adjacent bands?** Reference to the CENELEC standard suggests that messages need to be interpreted correctly 999 times out of a 1,000 (0.1% failure) for Grade 1 & 2 systems and 9,999 out of 10,000 (0.01% failure) for Grade 3 & 4 equipment. Note that a certain (large) proportion or possibly this entire failure rate will be attributable to interference within and between alarm systems themselves. It could be suggested that in line with other apportionments of intra- and inter-system interference the allowance for the impact of "external" interference should be an order of magnitude lower than that allowed for "self" interference. This would give probabilities of 0.01% and 0.001% which are clearly very stringent in the context of the interference modelling results. In any event, the apportionment suggested is generally applied to licensed frequency bands where there is a formal duty to protect systems which is not the case here. It is therefore difficult to assess what might be an acceptable level of "external" interference especially since it appears that alarm system manufacturers largely disregard this aspect.
iii. **What density of interfering SRD transmitters in adjacent bands can be expected?** This will have to come from market data noting that we are interested in the density of transmitters in the immediately adjacent channel not the density across the whole adjacent band. In terms of applications in the adjacent bands, two potentially widespread applications have been identified for the future; remote meter reading (in bands g1 and g2) and automotive tyre pressure reading (in band g1). Based on device density estimates, discussed later in Section 7.4.2, of somewhere between 6,000 to 20.000 devices per km^2, at face value examination of the interference modelling results in Table 5-3 suggests a potentially serious problem for alarm systems in the future. However, as noted in (i) above, the duty cycle of the meter reading devices is likely to be far lower that the regulatory maximum allowed (as used in the modelling) and the channels used are not immediately adjacent to the frequency sub-band edge.

6 FM22 – SRD/RFID monitoring campaign

The FM22 monitoring campaign has presented a wide range of measurement results from a number of different locations across Europe.[16] The results give some idea of the utilisation of the different SRD sub-bands between 863 and 870 MHz at representative locations including airports, shopping centres and industrial areas. The measurement methods were to a large extent standardised and, because of the large quantity of data generated by such an exercise, the derivation of results has been automated.

The most striking characteristic of the three example plots in FM(09)077 is the presence or otherwise of the four high power RFID channels between 865 and 868 MHz. However, when it comes to the band of interest to this study, namely 868.6 – 868.7 MHz, only one of the three examples shows any level of activity in the band and this is to an occupancy level of 30%. In the same location represented by this plot there is also some activity in the adjacent non-specific SRD bands but little or no activity that is immediately adjacent to the alarm band of interest.

We have not examined all the data that is available because it is so extensive. However, a more interesting result comes from one of the locations identified as having a relatively high total calculated occupancy, namely Manchester. The results obtained on 1st February 2009 clearly show the four 25 kHz channels in the 868.6 to 868.7 MHz being used, the top two channels being used more frequently than the bottom two channels. The plot also shows significant utilisation by non-specific SRDs in the band below the alarm band but little utilisation in the band above.

However, while these RF measurements are able to indicate whether a frequency is being used in aggregate in a particular area, they are not able to characterise the behaviour of individual transmitters or the density of transmitters in an area. For this reason they have limited application to our impact assessment.

[16] FM(09)077 – 27th April 2009, Monitoring Campaign 863 – 870 MHz on behalf of SRD/MG and SE24.

7 Analysis of impacts

7.1 The aim is to measure incremental impacts

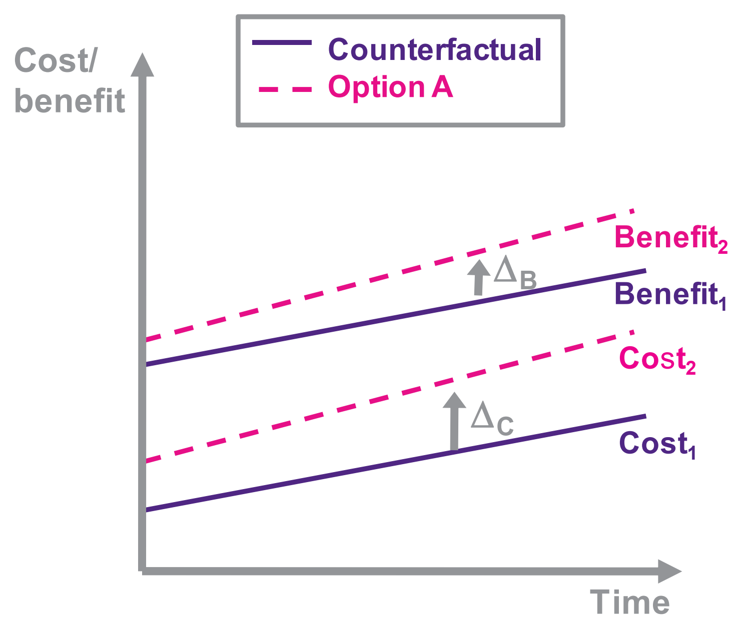
Two basic considerations apply to impact assessment:

- First, clearly identify the relevant question or choice and alternatives (there is almost always more than one).
- Second, compare the impact of the most favourable option for change with what would have happened otherwise (i.e. the counterfactual).

In doing these two things the aim is to evaluate the right decision and only to consider the incremental costs and benefits of the change relative to what would have happened with no change (i.e. overall costs and benefits of each option are not calculated). When estimating the incremental costs and benefits any elements of costs or benefits that are unchanged between the counterfactual and the alternatives do not need to be considered.

Figure 7-1 illustrates the costs and benefits of two alternatives over time. A counterfactual or base case (purple solid lines) and an alternative (magenta dotted lines) are considered. These lines are not calculated in an impact assessment. Rather we calculate the differences between the lines which are marked as Δ_B and Δ_C in Figure 7-1.

Figure 7-1: Incremental costs and benefits of the counterfactual versus an alternative (Option A)



Is Δ_B ($Benefit_2 - Benefit_1$) > Δ_C ($Cost_2 - Cost_1$)?

The policy decision is then guided by the answer to the question at the bottom of Figure 7-1 – are the incremental benefits of the alternative greater than the incremental costs? If the answer to this question is yes, then the policy alternative should be adopted. If the answer is no then the counterfactual i.e. the status quo should continue.

Ensuring the analysis of appropriate alternatives against the counterfactual on an incremental basis sounds simple, but typically it involves a lot of work prior to the actual estimation of impacts or costs and benefits (if quantification is feasible). In essence almost everything in this report up to this point involves an effort to clearly define the relevant question.

7.2 Findings relevant to this impact assessment

In summary our findings reported in previous Sections, which are relevant to the decision whether or not to mandate a more limited set of receiver Categories, are as follows:

- All of the people we spoke to, with one exception, and all of the alarm systems we found from online desk based research utilise Category 2 receivers. The exception was one manufacturer who produced Category 1 and Category 3 systems only.
- The adoption of Category 1 would involve a cost, size and power consumption penalty (a single chip solution is not possible) relative to Category 2 receivers and was not seen as offering any advantage for general use. The cost penalty might be around €5 per device.
- A key application within the band is alarm systems which may involve multiple sensors communicating information to a central controller. At present devices overwhelmingly appear to operate in send only mode, but may in future operate in receive mode as well if LBT is adopted.
- Manufacturers focus on the risk of within band interference in equipment design and, in general, the risk of interference from out of band devices was considered negligible.
- Manufacturers have taken various steps to reduce the risk of interference and to minimise its impact on system performance including utilising Category 2 rather than Category 3 receivers, utilising narrow 25 kHz channels, repeating signals three times at random intervals, and utilising other 25 kHz channels in the available 100 kHz.
- The use of wireless alarm systems is growing in absolute terms and when compared to the use of wired systems. Wireless systems reduce installation time from around 1 system per day to around 3 systems per day. In addition, they may have aesthetic advantages over wired systems because of the absence of wiring.
- There are 4 grades of CENELEC standard for alarm systems, and market participants are conscious of these grades. Where higher quality systems are specified they tend to be in terms of these grades rather than in terms of ETSI receiver parameter categories, however, compliance with Category 2 and potentially Category 1 for Grade 1 devices appears to go hand in hand with this. In addition, both the police and insurance companies in Norway have promoted adoption of higher standard equipment based on the CENELEC standards.
- The use of adjacent bands is unclear since the regulation allows non-specific devices. We did establish that Germany and The Netherlands are leading in the implementation in adjacent bands of smart metering systems for meter/s (gas, electricity and water) to communicate readings to a

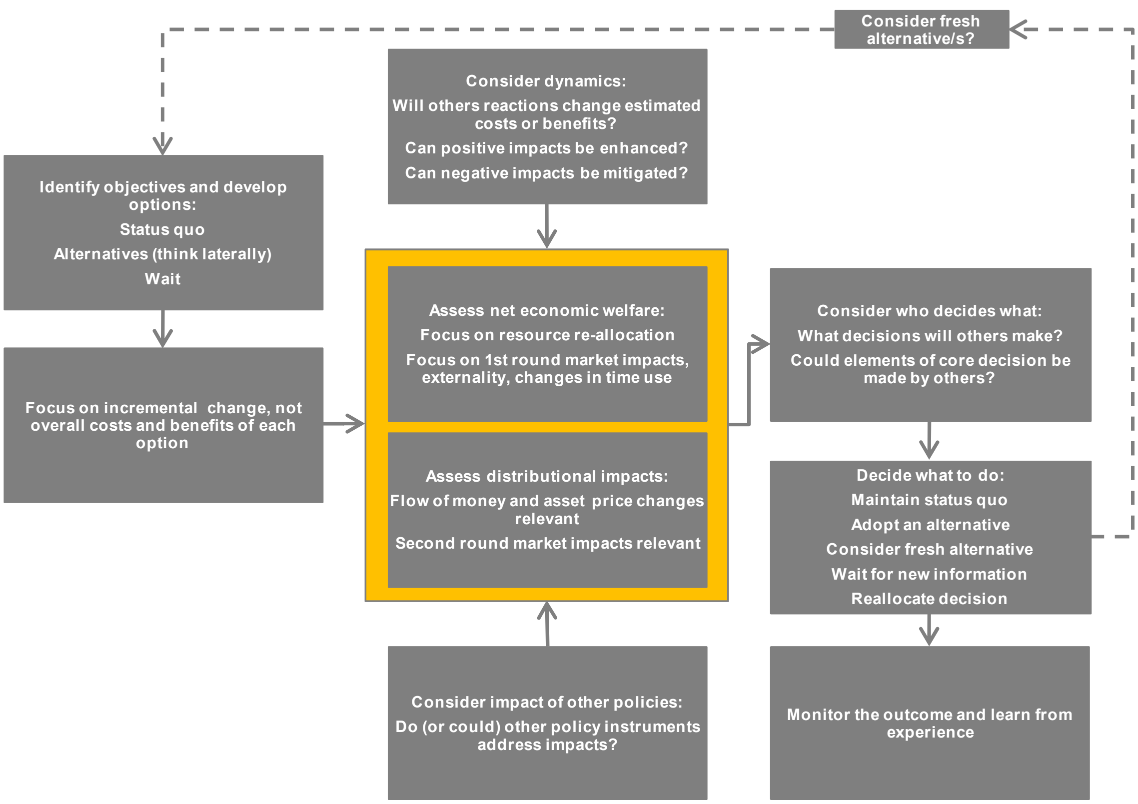
central unit once per hour. In urban areas this alone might see device densities of up to around 20,000 per square km.

7.3 Applying the decision framework

The decision framework needs to focus on the relevant incremental decision taking account of the full set of options. It must also consider the role decisions by others may play and the impact of other regulation on costs and benefits.

Figure 7-2 sets out an extended decision framework which includes dynamics in terms of the reaction of other stakeholders to alternative policies and market developments, and the possibility that the process is iterative. The reason for introducing this general framework is that it is easy to lose sight of these dynamics once one embarks on a specific impact assessment.

Figure 7-2: Framework for analysis of impacts



The framework builds on the ECC Report 125 on impact assessment in the following ways:

- It explicitly introduces the possibility that other stakeholders, in particular market players, consumers and other regulatory bodies, will make decisions that either impact on the balance of costs and benefits or may internalise the balance of costs and benefits. A policy of doing nothing or ensuring that private decisions by manufacturers and consumers take full account of costs and benefits may then be the best option.

- It divides impact assessment into two parts – evaluation of impacts which exposes distributional impacts and evaluation of net incremental benefits which relies more on an economic framework to isolate the net impact and sidestep identification of each and every distributional impact. Depending on the problem one or the other or both approaches may be appropriate.
- It introduces the possibility that at the end of the analysis it becomes clear that a different alternative option/s in terms of policy should be considered.

We also note that the direction of travel may not always be one way as the answer to the question someway along the decision process might lead one to reframe the set of options. This is not an uncommon outcome of impact assessment – rather than a precise answer to the initial question one is guided to a better question. The various boxes are now applied to the decision being examined in this study:

- **Identify objectives and develop options**
  - The objective adopted in this impact assessment is the maximisation of overall social welfare (the default assumption in cost benefit analysis).
  - Regulatory options include the status quo (maintaining Category 1, 2 and 3), adopting Category 1 only, adopting Category 1 and 2 only, and waiting (until there is more information or an interference problem emerges).
  - Other stakeholders also have options, for example, manufacturers/users of alarm system can adopt other means of mitigating interference and/or adopt wired systems.
- **Focus on incremental impacts of a change in policy versus a clear counterfactual – the outcome without policy change**.
  - We have found that under the current policy of allowing Category1, 2 and 3 alarms most alarms that are sold are Category 2. We assume that this will also be the case in future under the counterfactual situation. We also make the simplifying assumption that all receivers under the counterfactual are Category 2[17]. This means that mandating Category 1 and 2 receivers will have similar effects to the current policy and so this option is not considered.
  - The alternative policy is therefore to mandate Category 1 receivers.
  - Wired systems are also an option. If this option were cheaper than adopting Category 1 receivers it would be relevant. However wired systems have an installation time of 1 day versus a third of a day for wireless systems. Wired systems therefore involve a significantly higher cost increment (at average European labour rates) than adopting Category 1 receivers. This option is not therefore relevant to our analysis.
  - In summary, we focus on the incremental costs and benefits of mandating Category 1 receivers versus the counterfactual situation in which all receivers sold are assumed to be Category 2.
- **Consider dynamics.** In particular will other stakeholders' reactions change relevant costs or benefits? We found that manufacturers are in general choosing to adopt alternatives such as repeat signals and narrow channel bandwidths rather than moving to Category 1 receivers to

[17] It is assumed that the fact there are a small number of Category 3 and Category 1 alarms results in offsetting biases in the benefit and cost calculations.

reduce the risk of interference. These alternatives are preferred because they are (so far) effective, less costly and allow small low power consumption devices to be made which offers advantages in terms of installation and use. There is scope to further develop such measures, for example by adopting LBT. The cost of these measures represents the incremental cost of interference, since revealed behaviour suggests they are lower cost than adopting Category 1 receivers i.e. critical decisions are made by manufacturers at present.

- **Consider impact of other policies.** We have identified the fact that CENELEC alarm categories 1-4 are relevant to the market. They are not a substitute for receiver standards, but may in practice dictate adoption of Category 1 or 2 receivers. In addition, they provide a "focal point" around which the market can signal the quality of systems including their robustness to interference. The CENELEC standard therefore reinforces our view that market players face the costs and benefits of their actions and are reasonably well informed. Private decisions should therefore appropriately weigh costs and benefits regarding receiver parameters in this case, potentially negating the need to impose an administrative judgement based on very imperfect estimates of costs and benefits.
- **Assess net economic welfare and distributional impacts.** In this instance we are focussed on net benefits rather than the distribution of costs and benefits (a consideration that is more likely to arise when some group in society might be adversely impacted even if there were net benefits overall). In the next section we consider the magnitude of the incremental costs and benefits.
- **Consider who decides what and decide what to do.** In this instance it appears that consumers and manufacturers are making reasonably good decisions under the current regulations. If this is the case, then if the benefits of Category 1 exceeded the costs they would be adopted anyway. If it is believed that manufacturers and consumers make this assessment anyway then maintaining the status quo and potentially to monitor developments in terms of the interference environment could be appropriate. Nevertheless we consider the incremental costs and benefits of making a decision to restrict receiver parameters to Category 1.
- **Monitor outcomes and learn**. A conclusion of this study is that the specific use of adjacent bands and the real world characteristics of devices in adjacent bands will determine levels of interference and the appropriate response by both manufacturers and policy makers. Use of these bands should therefore be monitored.

7.4 Incremental costs and benefits of restricting receiver Categories

In this section we assess the incremental costs and benefits of the decision to mandate Category 1 receivers versus a counterfactual situation in Categories 1, 2 and 3 are permitted but only Category 2 receivers are sold. (Recall that all but one of the manufacturers we have spoken to had adopted Category 2 (one manufacturer produces Category 1 and Category 3 alarms systems) under current regulation.)

7.4.1 Incremental costs

Under the alternative option all new devices would be required to be Category 1. The additional cost of Category 1 over Category 2 devices is then incurred regardless of the future interference environment.

To estimate this cost over time we need forecasts of alarm sales. Estimates of the European market given in our interviews suggest sales of wireless alarm systems of around 30 million per year, and a CEPT report reports the EEA market for alarms at 32-40m systems per year though it is unclear whether this refers to wired and wireless systems or just wireless systems[18]. We observe that sales levels of 30m systems per year is very high given that there are just over 200m households and 20m enterprises in the EEA. We have therefore tested the impact of two values for future sales levels - 30m p.a. and 10m p.a..

The differential cost per device, based on a range of estimates from manufacturers, is about €5. Existing systems typically have 1 receiver per installation in the master unit, though in future if LBT is adopted all devices would have receivers (and on average there are around five transmit devices per receiver currently). The implied incremental costs are therefore as follows:

- If one-fifth of devices sold operate in receive mode then the incremental financial costs of imposing Category 1 would be €10-30 million per year.
- If in future all devices operated in receive mode (if LBT is adopted) the incremental cost would be €50-150 million per year.

Further, the larger size of Category 1 devices could cause some additional costs to be incurred. Some applications such as home and building automation where devices need to be installed in walls with standardised electrical boxes might be infeasible. The foregone economic benefits as a result of this might be considerable, and might include modest environmental impacts if automatic control of building lighting and heating were more limited as a result. Finally, non-financial costs could be substantial in terms of aesthetic impacts (or the financial costs of attempting to minimise the visual impact of larger devices). We have not quantified these incremental costs.

In summary, the additional costs of requiring Category 1 devices rather than the counterfactual under which Category 2 alarms are sold could be at least €10-30m p.a. and could rise to over €50-150m if LBT is implemented.

7.4.2 Incremental benefits

The incremental benefits from mandating Category 1 receivers arise from the potential reduction in interference relative to a situation where receivers are Category 2. The incremental benefits in a given year are therefore the product of the following three factors:

- The reduction in the probability an alarm experiences out-of-band interference.
- The benefits (i.e. avoided cost) per alarm of not experiencing interference.
- The total number of alarms sold each year (that are mandated to be Category 1).

We consider each of these elements of the calculation in turn, recognising that the interference environment could be changing over time as more devices of different kinds are deployed in the

[18] http://www.erodocdb.dk/Docs/doc98/official/pdf/CEPTREP014.PDF

adjacent band and that the adjacent band is designated as non-specific so there is considerable uncertainty about the nature of these devices in future. We have noted in Section 7.2 that the likely uses of the band in some countries are smart meter readers and automotive tyre pressure monitoring, and this provides a possible scenario to consider.

We know from our research that at present few devices of any sort are deployed meaning that interference impacts are not experienced[19] and so benefits are zero at present but this could change in future.

Reduction the probability an alarm experiences out-of-band interference

The probability that an alarm experiences out-of-band interference depends on:

- the density of devices in the adjacent band, and
- the transmission characteristics of the these devices, in particular their power level and duty cycle.

Density of devices

The assumed density of devices depends on what they are doing. The Seamcat modelling considers densities ranging from 10 to 10,000/square km but takes no view on which scenario applies. One approach would be to calculate benefits for all these cases.

However, we know that smart meters are being deployed in some countries and tyre pressure monitoring is also planned, so we considered densities for these applications.

We examined urban densities to estimate the potential number of smart meters per km^2 in particular. The range of population densities across Europe is very wide.

- Averaged over countries as a whole it varies from a high of 1304 per km^2 in Malta to 396 per km^2 in The Netherlands and down to 16 per km^2 in Finland.[20]
- For cities as a whole it is around 5,000 per km^2 in Athens, Madrid and London for example.[21] Adjusting for average household size this yields average urban densities of around 2000 households per km^2.
- However, within cities densities vary considerably. For example, within London Kensington and Chelsea have densities of around 14,000 people per km^2, or approximately 5,600 households per km^2.[22]

With three devices per household the densities for cities and inner city locations considered above range from around 6,000 to 20,000 devices per km^2.

Based on the interference modelling results presented in Section 5 the alarm band would become unusable when the density of interfering transmitters at the band edge approaches 10,000 per square kilometre (for all receiver categories). Even at 1,000 devices per square kilometre probabilities of

[19] Manufacturers were not in general concerned about out of band interference (though there awareness of the possibility in future). They focussed much more on ensuring their own systems worked well given the risk of within band interference.

[20] http://www.prb.org/pdf08/08WPDS_Eng.pdf

[21] http://www.citymayors.com/statistics/largest-cities-density-125.html

[22] http://www.statistics.gov.uk/StatBase/ssdataset.asp?vlnk=7645&Pos=1&ColRank=1&Rank=224

interference are significant, reaching 22% for Category 1, 36% for Category 2 and 60% for Category 3 devices. This assumes that transmissions are at the regulatory envelope which is not expected to be the case in practice.

Another application which is likely to see large numbers of devices deployed is automotive monitoring of tyre pressure which would see 4 devices per car and an overall density approximating that for smart metering. We do not know the characteristics in terms of transmit frequency of these devices.[23]

Transmission characteristics

Seamcat results, using the regulatory envelope and assuming the interfering channels are immediately adjacent to the band edges show:

- There is benefit (reduced probabilities of interference) in moving from Category 3 to 2 to 1 receivers.
- The benefit is only to those receivers identified as receiving interference. There is cost but no benefit to those receivers not receiving interference.
- There is always the effect of unwanted interference (as opposed to blocking) which changing receiver category does not affect. The benefit of using Category 1 receivers (vis a vis blocking) is limited by the unchanging presence of unwanted interference. It appears (from the probability of interference values derived by Seamcat and reported in Table 5-3) that the benefit of moving from Category 2 to Category 1 is somewhat less that the benefit of moving from Category 3 to Category 2 largely because of the greater and irreducible[24] unwanted interference contribution.

These results are based on the probability of a single alarm message getting through where that probability is a mixture of location and time. No account is taken of the mitigating effect of message repetition by the victim system as the efficiency of this would require knowledge of the relative interferer and victim message structures. Such information could only be obtained from a survey of the message structures used by victim and interfering systems. There is little data in the public domain (alarm systems are largely proprietary in this regard) so the data would have to be collected by interviews with manufacturers. There is some standardisation of the meter reading message structures but there is still flexibility for specific implementations by manufacturers.

Real world applications (e.g. meter reading) will use much lower duty cycles and the channels used may not be immediately adjacent to the sub-band boundaries. In order to assess the benefit in this case we would need to redo the modelling taking account of:

- The frequencies and channel sizes planned for the interfering applications.
- The duty cycles planned for the interfering applications and any mitigating techniques (or protocols) that might be used.
- The message lengths of the planned interfering applications.
- The density of interfering transmitters.
- Mitigation techniques (or protocols) and message lengths for the victim (alarm) system.

---

[23] Such devices may sleep when cars are stationary. http://www.sensorland.com/HowPage040.html

[24] Irreducible with respect to changing receiver category. The unwanted interference effect can be reduced by changing the interfering transmitter characteristics but that is not the focus of this study.

Summary

In summary, we could either:

- Use the Seamcat results recognising these present a very worst case interference scenario.
- Generate other scenarios based on current information about possible uses of the adjacent band and characteristics of existing alarm systems. However, the Seamcat tool does not take account of the message structure and so it would have to be supplemented by external modelling of these impacts.

The second option is beyond the scope of this pilot study but illustrates what might be done.

In respect of the first option we have the results shown in Table 5-3 of this report. The reduced probability of interference is given by the difference between the columns marked unw+block for Cat 2 and Cat 1 devices as shown in Table 7-1. We observe that most of the differences are quite small except for the last but one scenario (highlighted in the Table). Here the unwanted interference probability (at 22% and above) is so high as to mean that both Category 1 and Category 2 alarms would likely be perceived as not sufficiently reliable and a wired system would be used instead. The same comment also applies to both scenarios with transmitter densities of 10,000 per square km. We therefore set the differences to zero when we calculate the benefits for these three cases (see Table 7-2 below).

Table 7-1: Difference in probabilities of interference between Category 1 and 2 systems

CEPT scenario	Density of transmitters	Category 1 Unw+ block	Category 2 Unw+ block	Difference
Step 1 bis	10	0	0	0
	100	0.432	0.54	0.11
	1000	4.8	5.58	0.78
	10000	35.2	38.75	3.55
Step 6	10	0.2	0.39	0.19
	100	2.1	3.76	1.66
	1000	22	36	14
	10000	99	99.9	0.9

Benefits per alarm of not experiencing interference

If an alarm experiences interference for a particular location and time the alarm message will fail to get through. It is possible that the message repetition they use to mitigate interference between alarm systems might also mitigate external interference but we do not know this with any certainty. So, we need to consider what might happen if alarm messages fail.

We do not consider the possibility it is a false alarm (in which case there are no benefits) and assume that the alarm has registered an intruder, a fire etc. In this case costs will be incurred by the user. The economic costs of burglaries[25], fire[26] etc have been calculated in other studies and these could be applied. For the purposes of illustration we have taken estimates for the UK of the benefit of fitting a home alarm – these were estimated at £80 p.a. per home in 2006[27]. We have converted this to a lump sum by assuming a 15 year life for the alarm and corrected for general inflation to give a net present value of €775.

Total number of alarms affected

As discussed above we assume 10-30 million systems are sold each year.

Summary of incremental benefits

The incremental benefits in a given year are calculated as the product of the difference in interference probability multiplied by the benefit of having an alarm multiplied by the number of alarms sold. Table 7-2 gives estimates of incremental annual benefits at a point in time for two cases – 10m and 30 m devices sold per annum.

Table 7-2: Annual snapshot of estimated incremental benefits by scenario

Seamcat scenario	Density of transmitters	Difference in probability of interference	Benefits = diff x €775 x 10m devices €m	Benefits = diff x €775 x 30m €m
Step 1 bis	10	0	0	0
	100	0.11	8.5	25.6
	1000	0.78	60.5	181.4
	10000	0	0	0
Step 6	10	0.19	14.7	44.1
	100	1.66	128.7	387.0
	1000	0	0	0
	10000	0	0	0

As we have indicated in the text there are uncertainties at all steps in the calculations, and perhaps most importantly the results correspond to the conservative assumptions used in the Seamcat modelling. This means the benefits could well be overestimated by one or two orders of magnitude.

[25] http://www.costsofcrime.org/TheoryAndPracticeToDate/

[26] http://www.communities.gov.uk/documents/fire/pdf/144524.pdf

[27] See p112, Annexes to "The Economic Value of Licence Exempt Applications", Indepen, et al 2006 http://www.ofcom.org.uk/research/technology/research/exempt/econassess/

7.4.3 Implications for net incremental benefits

The estimated incremental benefits from mandating Category 1 devices range from €0-390m versus costs ranging from €10-150m depending on the density scenario chosen. In Table 7-3 we provide an annual snapshot of the estimated net incremental benefits (incremental benefits less incremental costs) for a range of population density, device sales and device technology scenarios.

Note that we have not created estimates for a continuous time period (say from now to 2019) because this requires further assumptions about the forecast level of alarms sales, adoption of LBT and forecasts for the deployment of equipment in the adjacent bands. Additional interference modelling and more detailed investigation of the use of the adjacent band is required before even reasonable assumptions could be made. This is beyond the scope of this pilot study.

Table 7-3: Annual snapshot of estimated incremental benefits and costs by scenario

Seamcat scenario	Density of transmitters	Net Incremental Impact – 10m devices sold €m	Net Incremental Impact – 10m devices sold with LBT €m	Net Incremental Impact – 30m devices sold €m	Net Incremental Impact – 30m devices sold with LBT €m
Step 1 bis	10	-10	-50	-30	-150
	100	-1.5	-41.5	-4.4	-124.4
	1000	50.5	10.5	151.4	31.4
	10000	-10	-50	-30	-150
Step 6	10	4.7	-35.3	14.2	-105.8
	100	118.7	78.7	356	236
	1000	-10	-50	-30	-150
	10000	-10	-50	-30	-150

As we have said earlier the interference modelling was based on conservative assumptions and therefore represents a worst case scenario and values at least one or two orders of magnitude lower could be possible in which case the net benefits would be lower than shown in the table.

A further issue concerns the density of transmitters, for as can be seen if densities are either very low or high (above 1000/square km) then net benefits are likely to be negative. If the applications deployed in the adjacent band are used in most households (e.g. smart meters) then such high densities could occur. For example in the UK 70% of the population live in areas with household densities that imply transmitter densities of more than 1000/square km, assuming all households have transmitters and there are three transmitters per household (as would be the case with smart meters).

We conclude that it is possible that the incremental costs of mandating Category 1 receivers will exceed the incremental benefits for some and possibly many countries in Europe, but this is uncertain because the future market penetration and transmission characteristics of systems in adjacent bands are highly uncertain and will probably vary across countries. However, if it turns out that out of band interference is a minor issue, as manufacturers in general appear to expect, then adopting Category 1 only would involve substantial costs and little if any benefit. Alternatively, if it turns out interference is a problem – particularly given the prospect of mass market applications in adjacent bands – then adopting Category 1 or 1 and 2 receivers might not alleviate the problem in high density areas and would therefore produce limited benefits.

7.4.4 Impact on competition

We found that limiting available receiver categories to Category 1 in particular would raise costs and make some applications difficult or impossible given the larger size of device utilising currently available technology. In turn these impacts could be expected to reduce market size relative to what it would be otherwise (noting that the use of wireless alarm systems is currently growing).

It is possible that a smaller market and/or reduced market growth would lead some manufacturers and/or installers to exit the market. In turn it is possible, though not certain, that this would result in reduced competition. However, we note that interference could also limit the development of the market. No conclusive impact on competition from policy change can be established based on available evidence.

7.5 Conclusion

In summary we conclude that it is likely the incremental costs of mandating Category 1 receivers will exceed the incremental benefits costs for some and possibly many countries in Europe, but this is uncertain because the future market penetration and transmission characteristics of systems in adjacent bands are highly uncertain and will probably vary across countries.

In terms of costs, we find that mandating Category 1 receivers would impose financial costs and added size in relation to devices which are currently manufactured according to Category 2. The cost penalty from adopting Category 2 rather than Category 3 devices is more modest and we understand there is no size penalty. However, all but one of the manufacturers we spoke to had adopted Category 2 in any case.

In relation to benefits we find that there may be little if any benefit from adopting Category 1 (or potentially Category 1 and 2) if there is little interference risk (which is possible) or if the population of devices is large and they operate according to the regulatory envelopes in which case even Category 1 devices would be subject to interference. This conclusion suggests that further analysis of likely adjacent band applications and modelling of anticipated duty cycles etc (rather than regulatory envelopes) could be justified. The findings of this study therefore confirm some of the issues highlighted by ECC Report 127[28] (e.g. improved receivers leading to increased cost and size).

The results of the impact analysis, taken to together with our observation that manufacturers we spoke to appear to “internalise” the benefits and costs when deciding the design of their systems in order to avoid interference, suggest that the appropriate policy response is to maintain the status quo and monitor the development of devices for the adjacent bands.

[28] ECC Report 127 – The impact of receiver standards on spectrum management. Cordoba, October 2008.

8 Conclusions

This study has confirmed not surprisingly that applications operating in the alarm sub-band are relatively uniform in nature (the sub-band carries a specific designation), and the applications currently operating and expected to operate in the adjacent frequency bands (with a non-specific designation) are much more varied and potentially extensive e.g. in future remote meter reading and tyre pressure monitoring (the adjacent frequency bands are designated for non-specific SRDs).

The current situation is that alarm manufacturers concentrate on mitigating in-band interference (i.e. within and between alarm systems) and meeting the requirements of the CENELEC alarm standard. In practice most alarms appear to operate at ETSI Category 2 level. Manufacturers are aware of, but less concerned about interference from adjacent bands because of the low levels of current use in the bands. It can be noted that there are several techniques still available to mitigate interference both between alarm systems and with respect to external interference (i.e. from the adjacent bands) should the interference environment deteriorate, and this can be done within the existing regulatory framework.

The interference modelling that has been carried out is based on interfering non-specific SRDs (at various densities) operating at the regulatory envelope specified by ERC Recommendation 70-03. The results confirm that there are potential benefits in tightening the alarm receiver performance (i.e. Categories 1, 2 & 3 in the ETSI standard) in terms of a reduced probability of interference in some circumstances. However, at present such benefits are would not be realised because there appears to be relatively little use of non-specific SRDs in adjacent bands. Substantial costs (€10-150m p.a.) would be incurred in requiring receiver to conform to Category 1 requirements.

In future, a possible scenario involves deployment of smart meter readers and automotive tyre pressure monitors in the adjacent non-specific SRD band. Manufacturers of these devices are planning to use a duty cycle at least two orders of magnitude less that the regulatory limit. This means that if devices are deployed at low density then no interference issues are likely arise under the current regulatory framework. Alternatively if these receivers are deployed at high density (which is quite possible) then even Category 1 receivers could suffer harmful interference, meaning there will be no net benefit to changing the regulatory framework. However whether there will be interference or not is uncertain because the interference modelling does not address the scenario where devices have a low duty cycle. Given the uncertainties over the future deployment of devices in adjacent bands, the policy conclusion is to maintain the status quo and monitor developments in use of adjacent bands.

More generally the results of interference modelling are a key input to ECC regulatory decisions. What this study indicates is that while using the regulatory envelope as the starting point for the interference modelling is a perfectly justifiable and reasonable thing to do – as there is nothing to stop a new application from operating in this way – this may not reflect the market situation. Indeed market players may anticipate the interference problems and adjust their behaviour accordingly or may have other reasons for operating below the regulatory envelope. This study shows the regulator therefore faces a dilemma. Should the regulator assume the characteristics of applications that are foreseen and going to be used in practice or the characteristics allowed by the regulations? We do not have a definitive answer to this question. Our analysis suggests the regulator needs to use information on what is actually happening in the market and the nature of the incentives facing market players before deciding the appropriate approach to interference modelling.

Appendix A: Terms of reference

Invitation to Tender for Impact Assessment study to support the ERO Receiver Parameters Pilot Project

1. Introduction

The European Radiocommunications Office (ERO) is the permanent office supporting the Electronic Communications Committee (ECC) of the CEPT. ECC is the Committee that brings together the radio- and telecommunications regulatory authorities of the 48 CEPT member countries. More information about ERO is available on the ERO website (www.ero.dk).

In October 2008 ECC adopted its Report 127 addressing the impact of receiver standards on spectrum management. As a follow-up to this work ERO was requested by the ECC to proceed with a Receiver Parameters Pilot Project (Rx Pilot) which is expected to further the understanding within the ECC of the present and possible future role of receiver parameters in spectrum management. The project also provides an opportunity to test the possible role of impact assessment in formulating conclusions and recommendations in the work of the ECC.

2. Current stage of the Project

The Project is divided into a number of Work Packages (WPs) described in detail in the Rx Pilot Project Plan. WP2 'Case studies' has mainly been completed, thus creating a background for WP3 'Impact Assessment' (IA) and WP4 'Conclusions'.

The work carried out under WP2 was focused on the band 863-870 MHz, which is identified in particular for Short Range Devices (SRDs) in CEPT. More specifically the sub-band from 868.6 to 868.7 MHz was examined since it is used by a limited number of applications. It was decided to consider simple scenarios where the social alarm system (victim) is impacted by interfering applications such as non-specific SRDs. A summary of the receiver (Rx) parameters for the victim system and the transmitter (Tx) parameters for the interferer system has been defined for a number of specific case studies. This includes the definition of various scenarios to be considered when assessing the impact of interferer(s) on the victim. The aim of defining these scenarios was to feature different alternative parameter values as given in the relevant ETSI standards for the receiver parameters.

This work has resulted in the conclusion that the 'blocking' effect tends to dominate as an interference mechanism and that for different categories of receivers it leads to a different increase in the interference probability with the increase of interference. It was also found that interference probability ranges from 0% to more than 10% depending on the receiver category.

More details related to the work under WP2 can be found in the draft 'Report on Inventory of Cases and Case Studies of Interferer to Victim Interactions'.

3. ERO's requirement for Impact Assessment study

In the Impact Assessment part of the Rx Pilot the results of the case studies carried out under WP2 should be taken into account. WP3 should create a background for formulating conclusions of the whole Project.

WP3 should assess the differences in cost between the three categories of receivers considered under WP2 and also the distribution of the three categories of receivers currently on the market.

Account should be taken, to the extent possible, of the economies of scale which would apply if all receivers would comply to a higher standard.

It would also be necessary to evaluate the overall economic impact of limiting the relevant ETSI standard to categories 1 and 2 (more stringent case in terms of requirements to Rx parameters) and to category 1 only (the most stringent case in terms of requirements to Rx parameters) and compare these against the current situation where all 3 categories of receivers are allowed by the standard.

However, additional scenarios may also need to be considered if appropriate, during the course of the study.

The study should be based on the framework methodology for impact assessment presented in ECC Report 125 on Guidelines for implementation of impact assessment in relation to spectrum matters.

If necessary, simulations in addition to those already carried out under WP2 could be performed by the ERO to support the IA study. ERO will be also available for consultations during the course of the IA study.

The principal deliverable expected of the work is a written report which concludes and summarises on the main regulatory and economic consequences of the introduction of hypothetical receiver standards as compared to those observed for the existing ETSI standards for the considered frequency sub-band.

Based on the above an informed policy recommendation should be drawn (WP4).

Appendix B: Common interview questions

As input to the study we wish to establish, at least approximately, the following:

- Existing and possible future end uses for alarms in the frequency band of interest and other similar frequency bands.
- The approximate number of devices in use, now and in the future.
- Whether current devices comply with relevant ETSI categories 1, 2 or 3.
- The cost differential between category 1, 2 and 3 devices.

(1) and (2) above are necessary to estimate the benefits of SRDs, whilst (3) and (4) are necessary to estimate the costs of complying with a possibly more stringent receiver standard (the possibility of limiting the standard to categories 1 and 2 or 1 only). We note that the primary purpose of the study is to illustrate the application of impact assessment methodology and as an input to the ECO workshop on impact assessment on 31 August-1 September. The primary purpose is not as a basis for any decision over standards.

Questions relating to the use of the frequency band 868.6 – 868.7 MHz (a) for alarms and the adjacent bands, 868.0 – 868.6 MHz (g1) and 868.7 – 869.2 MHz (g2), for non-specific short range devices:

1. What are the applications / uses?
2. Why has the frequency band been selected as opposed to the other frequency bands that are available?
3. What bandwidth channels are used and are there any plans to use channels greater than 25 kHz?
4. What category of device is it and is it labelled as such?
5. If the category is not known are performance specifications available for adjacent channel selectivity/saturation and blocking?
6. If not in the alarm band, is Listen Before Talk (LBT) used and/or frequency agility?
7. What is the duty cycle of transmissions?
8. How is the channel (or channels) shared within the system?
9. How is the channel (or channels) shared with other systems?
10. How reliable is the radio channel and are any particular steps taken to mitigate degradations?
11. What is the market size (now and future) for these devices?
12. What is expected to happen (i.e. interference environment) if the density of devices grows significantly?
13. What substitutes are available for the application?
14. What is the cost of the system and what proportion is the cost of the RF module?
15. What are the size and cost implications of the three categories?

Appendix C: Interview summaries

We approached two groups who provided feedback - the Low Power Radio Association and ETSI ERM-RM. We also approached a number of manufacturers of devices and alarm system integrators in the alarm band (some of whom may also produce equipment for adjacent bands). A summary of their responses is provided below.

Figure C-1: Organisations and individuals approached and feedback

LPRA invited members to contribute to ERO RX study, but did not receive any answers. LPRA noted that last year ETSI investigated under the request from the EC the need for additional Rx parameters in ETSI standards, where LPRA actively participated with involvement in TGRx, TG28 and ERM. LPRA is fully in line with ETSI members supporting that Rx parameters as currently specified in existing standards are sufficient to assure good coexistence between SRDs. Noted that they have never received any complaints from members on Rx parameters.
ETSI ERM-RM identified the potential feedback between the level of requirement and number of devices sold as a higher number could coexist and costs would differ. These feedbacks would apply to the band in question and adjacent bands if receiver parameter Category requirements were changed more generally.
Manufacturer wireless home and building automation and wireless alarms (fire and intrusion detectors). All devices are Category 2. These devices represent 80% of the current use of generic allowed sub-band at 433 MHz and 868-870 MHz for SRDs. The major part of sales is for intrusion alarms, the remaining devices are based on the open standard for home and building automation (www.knx.org). Approximate number of Home Automation wireless devices is around 30 million additions per year in Europe. In future demand will increase: • Automotive tyre pressure monitoring systems will add 80 million devices per year in band g1 (4 per car and 20 million new cars per year). • Smart metering would lead to hundreds of millions of additional devices (currently in Europe mostly in g1, in UK in band h). Due to the forecast increase in the number of devices there is an ETSI SRdoc requesting additional spectrum from 870 to 876 MHz. As long as band g is not available through the whole of Europe, no industry player will invest in devices using this band. For RF IC Category 3 cost is a few euros, an upgrade to Category 2 involves a 40% increase in cost. Moving to Category 1 would increase cost further, but more importantly make the devices larger and make products unworkable, for example, in home and building automation where devices need to be installed in walls with standardised electrical boxes. For alarms it would result in unacceptably large devices for installation on windows. Have never received complaints about interference.
Growing acceptance of wireless devices contributing to market growth and reduced cost of installing wireless systems (installer might manage 3 per day versus 1 wired system). Noted that even though duty cycle had been increased to 1% duty cycle is less than previous 0.1% limit to increase battery life and reduce transmission clashes. Market Category 2 devices and did not think Category 1 RF integrated circuits existed. Considered that alarm standard EN 50131 was close to Category 2 (EN 300 220). LBT not relevant to transmit-only devices. Messages sent three times with random delay. Category 3 relevant to wide band systems as narrow band system would be expected to fall into category 2 (because the width of frequency response both at the front end (re blocking) and further down the receive chain at the demodulator (re interference) will be narrower and therefore almost automatically meet Category 2 requirements).

Adoption of Category 1 could double the cost and increase the size of peripheral devices to accommodate additional intermediate frequency (IF) oscillator and filters.

Wide range of applications in the adjacent non-specific SRD bands including security, telemetry and remote control, industrial monitoring, remotely operated vehicles and digitised pictures. Higher power in adjacent band allows greater range for alarm systems.

Understood some use of 100 kHz channel equipment in band (lower grade lower range).

LBT could be jammed so not be appropriate for security systems.

Bidirectional transmissions and frequency agility could in future mitigate interference problems.

Category 1 devices cannot be implemented using a single chip, might be 1.5-3x cost of Category 2 device and might be 2-4x the size.

No interference issues from adjacent bands to date. Possible concern is introduction of LBT and more continuous data streams. Had been a problem historically with a particular DECT phone.

Selection of alarm band driven by the need to use narrowband transmissions for performance reasons, but also to comply with old Class 6 specification. Association of Chief Police Officers in UK had expressed concern about false alarms with wideband systems.

Unclear whether systems labelled with EN 300 220 categories.

Repeat messages to mitigate interference risk and utilise high quality narrow band receivers.

More important than ETSI EN 300 220 compliance in terms of constraints was CENELEC standard EN 50131-5-3 (2005) and -1 which specifies Grades 1, 2, 3 and 4. Systems must be at least Grade 2 (equivalent to old Class 6).

Category 1 devices challenging to design and much more costly. Not possible with a single chip – requires external components.

Expect highest grade of alarm would require Category 1 devices.

Understand lower adjacent band (g1) was previously designated for wireless audio (little use).

Both g1 and upper adjacent g2 bands being used for new metering systems for gas, electricity and water. Based on M-Bus standard (13757.4 is the physical layer) which may become a European standard.

SRDs used to send information to central unit within household and fixed or wireless GSM used to send information to utility on hourly basis.

Use of SRDs for metering occurring first in The Netherlands and Germany and utilising frequencies 868.3 kHz supporting 32 kbps (same as Comex) and 868.9 KHz supporting 100 kbps with a 250 kHz bandwidth.

Metering systems have such a low duty cycle that interference between them is unlikely, and the information could be sent in the next hour in any case. Further, we note that the frequencies are some way from the band edge (whereas for the interference modelling it is assumed that interferers are adjacent).

Has proprietary RF protocols.

May implement LBT and frequency agility in future. Modules have a receiver (most chips have receiver signal strength indication already) – little cost to adding functionality via software.

Comex standard mainly used in Germany for lighting control etc in large buildings.

In terms of market size for metering there might be 3 devices per household (there are other unknown applications using the band). However, apart from standards based applications in g1 and g2, and alarms in sub-band a, most people want to operate in sub-band g4 because of the 100% duty cycle (though has 5 mW power limit) or sub-band g3 because of the higher power limit of 500 mW.

Systems may not comply with duty cycle requirements in practice as manufacturers produce module and make information available, but do not have information on compliance.

View that Category 1 only required for specific devices, have had few requests.

All devices manufactured fall into Category 2. Modules are category 2 (narrowband 25 kHz) or category 3 (wideband > 25 kHz). Class 1 very costly and requires discrete design.

Customers chose 868.6-868.7 MHz for alarms to get protection from low duty cycle and narrowband. In Norway insurance companies require narrowband for certification of wireless alarms (“FG” approvals).

Module cost around US$ 10 for category 3 and US$20 for category 2.

Category 1 would be bulky and perhaps cost US$30.

Produces residential and light commercial security systems and fire security network utilising 25 kHz channels and with duty cycles <0.1%. Systems scan for adjacent systems within the same product family, and self configure to use alternate channels if possible.

The band 868 MHz is chosen because it represents the European security band which is reserved for intrusion and fire alarms and therefore there is less chances of interference.

For Intrusion: devices are category 3 (and not labelled as such) whilst for fire devices are category 1 and 3 (and not labelled as such).

The channel is very reliable, and after intensive field investigations we have no known cases of interferers or blocking. Steps to mitigate degradation are: to monitor for interference and report its' presence as a trouble condition and to monitor for packet loss (2-way fully acknowledged messaging system) and change channels if packets are lost.

If device density within the security band increases significantly it is expected that the quality of service for our systems will degrade in a manner that causes increased message retries, and therefore decreased battery life. Because the channels are restricted to 0.1% transmit duty cycle, and this frequency is heavily attenuated by the brick and concrete construction materials we do not expect degradation to occur until the density reaches a level of several thousand per km^2.

Could also operate at 433 MHz, but with significantly lower reliability.