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# Licence Exempt Mobile Phone Repeaters

Indoor and in-vehicle

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**STATEMENT:**

Publication Date: 24 October 2017

## About this document

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This document sets out Ofcom's decision to make regulations that will allow consumers to operate two categories of mobile phone repeaters on a licence-exempt basis i.e. with no need for a licence:

1. static mobile phone repeaters for indoor use; and
2. low gain mobile phone repeaters for in-vehicle use.

Mobile phone repeaters amplify signals between a mobile phone and a network operator's base station and can enhance coverage in situations where the signal is weak. Their use by consumers is currently unlawful, as the types of wideband repeaters that we come across today can cause undue interference or other adverse effects to mobile services for other consumers. The only exception is if the repeaters are supplied and operated under the control of a mobile network operator.

This document sets out the technical requirements that need to be met for mobile phone repeaters to be lawfully used by consumers on a licence exempt basis whilst ensuring they are not likely to be a source of undue interference or have an adverse effect on technical quality of service. This relates specifically to static mobile phone repeaters for indoor use; and low gain mobile phone repeaters for in-vehicle use.

It should be noted that, until the licence exemption regulations come into force in early 2018, the use of mobile phone repeaters, apart from those supplied and operated under the control of a mobile network operator, will be unlawful.

The use of other types of mobile phone repeaters, apart from those supplied and operated under the control of a mobile network operator, will continue to be unlawful even after the regulations come into force.

# Contents

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## Section

1. Executive Summary	1
2. Background	4
3. Responses to the April 2017 consultation	9
4. Our decision to exempt indoor and in-vehicle mobile phone repeaters	30

## Annex

A1. List of non-confidential respondents	33
A2. Mobile phone repeater deployment scenarios and aggregate noise power	34
A3. IRs	40

# 1. Executive Summary

- 1.1 Accessing the mobile network within their own home can be troublesome for some consumers, particularly where they live towards the edge of mobile network coverage. The same can be said of accessing the network from within a vehicle. In both cases, the signal loss through the building / vehicle involved can mean that, where the mobile phone signal is weak outdoors, it falls below a usable level once inside. One potential solution to this problem is to use a device called a mobile phone repeater (sometimes also referred to as signal booster or signal enhancer).
- 1.2 At present, the use of a mobile phone repeater is only authorised if it is supplied and operated under the control of a mobile network operator (under its Wireless Telegraphy licence). The use of consumer stand-alone (self-installed) repeaters is unlawful. However, such repeaters are sometimes used (often without a real appreciation by the consumer that the use of the device they buy is unlawful). Typically, these are crude wideband amplifiers that can cause harm to the mobile operators' networks and therefore to other consumers. The interference or other adverse effects on the technical quality of service caused by the unlawful use of such wideband mobile phone repeaters has become one of the categories of complaint most reported to us. Ofcom has a duty to secure efficient use of the spectrum and we have, and use, powers to enforce against unlawful use.
- 1.3 In our April 2017 consultation, "Mobile Phone Repeaters Indoor and in-vehicle" we consulted on a set of technical requirements for mobile phone repeaters that would allow them to be used without the need for an individual licence (licence exemption). These proposed technical requirements followed discussions with the Mobile Network Operators ("MNOs") and equipment manufacturers on what was necessary to ensure that undue interference or other adverse effects on technical quality of service was unlikely, thus avoiding the risk of harm to other consumers.
- 1.4 We considered the technical requirements that would allow consumers to operate two categories of mobile phone repeaters on a licence-exempt basis:
  - a) static mobile phone repeaters for indoor use; and
  - b) low gain mobile phone repeaters for in-vehicle (in-car) use.
- 1.5 Static mobile phone repeaters for indoor use will typically have an antenna situated in a location where a good connection to the base station can be made. This may for example be in the window of an upstairs room. Such repeaters can vary in design; some may be single integral units whilst others may come in two separate parts (where the separate parts are linked together, for example by cable or by a 5 GHz Wi-Fi connection). Where it comes in two parts, one part can be positioned so it has a good connection to the base station and the other positioned to give the best coverage within the home. We refer to these types of repeater as 'static.' By this, we mean they are intended to be placed indoors and remain in-situ when operating. They are not intended to be used whilst in motion (e.g. in a vehicle).

- 1.6 Low gain mobile phone repeaters for in-vehicle use typically consist of a specially designed cradle within the vehicle that is connected to an external antenna on the roof via a two-way amplifier. A mobile phone handset placed inside the cradle will therefore appear to the mobile phone network as if it were outside the vehicle. The consumer can therefore expect the same level of mobile phone coverage as is available outside the vehicle at the same location<sup>1</sup>.
- 1.7 We received 16 non-confidential and three confidential responses to the April 2017 consultation. These came from the four MNOs (BT/EE, O2, H3G and Vodafone), HMG departments, the Scottish Government, one repeater vendor (Nextivity), industry bodies, and several individuals and consultants. We also received a few enquiries from organisations asking about how repeaters might help improve mobile coverage in their buildings.
- 1.8 Several respondents were positive about the introduction of licence exempt mobile phone repeaters and noted the possible benefits for improving coverage, especially in rural areas. The four MNOs raised concerns about the risk of interference to mobile networks. The Ministry of Defence (“MOD”), National Air Traffic Services (“NATS”), BT/EE and one confidential respondent were concerned about the risk of interference to services adjacent to mobile bands.
- 1.9 Having carefully considered the responses we received, our decision is that we should make the use of certain mobile phone repeaters lawful on a licence exempt basis. However, we have made several changes to the technical requirements to remove some ambiguity and to ensure that the operation of repeaters is not likely to involve undue interference or adversely affect the technical quality of service of mobile networks or other services. We will:
- make it clear that transmissions on downlink frequencies shall only be authorised indoors or in-vehicle as appropriate and remove the wording “*intended for*”;
  - make the radiated limits explicit with a TRP<sup>2</sup> limit for in-vehicle repeaters and an EIRP<sup>3</sup> limit for indoor repeaters;
  - limit mobile phone repeaters, when re-transmitting GSM uplink signals in the 900 MHz band to a maximum power of 2 Watts and in the 1800 MHz band to a maximum power of 1 Watt<sup>4</sup>;
  - not include the 2.6 GHz band in the licence exemption for the time being pending further discussion with the MOD and the Civil Aviation Authority (“CAA”);
  - specify the downlink power limit as 10 dBm / 5 MHz, capped at 17 dBm for wider bandwidth systems. This limit will facilitate the use of wider channels, such as 10 or 20 MHz LTE carriers;

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<sup>1</sup> In essence, this produces a similar set up to that which would be achieved if it were possible to plug the cable from the external aerial directly into the phone – however, with modern phones there is no socket into which it is possible to connect an external aerial (hence the need for the wireless connection between the cradle and the phone).

<sup>2</sup> TRP: Total radiated power

<sup>3</sup> EIRP: Equivalent isotropically radiated power

<sup>4</sup> GSM900 classes 3 & 4 and GSM1800 (DCS) classes 1&2, see TS.02.06

<https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=32>

- clarify that the 100 dB gain limit for indoor mobile phone repeaters is a maximum system gain limit; and
  - include a maximum noise figure of 7 dB in our technical requirements.
- 1.10 These changes strike an appropriate balance between maximising benefits to consumers using repeaters and avoiding negative impacts on other consumers of mobile services and spectrum users in adjacent frequency bands. For further details of these changes see Section 4.
- 1.11 This document is structured as follows:
- in Section 2 we set out the background to this statement and explain our statutory duties when regulating the use of spectrum in the UK;
  - in Section 3 we summarise the responses to our April 2017 consultation and how we have taken these responses into account; and
  - in Section 4 we explain our decision to make licence exemption regulations for mobile phone repeaters and explain our decision to modify the technical regulations.
- 1.12 This document contains the following annexes.
- a) Annex 1 lists the respondents who gave non-confidential responses to the April 2017 consultation;
  - b) Annex 2 details the evidence supporting our view that it is very unlikely that more than 50 repeaters in a cell will simultaneously amplify an individual mobile network carrier; and
  - c) Annex 3 lists our updated interface requirements (IRs) for the licence exemption of mobile phone repeaters.

## 2. Background

### Summary of proposals in the April 2017 consultation

- 2.1 In our consultation of 5 April 2017 (the “April 2017 consultation”), we set out proposals that static mobile phone repeaters, intended for indoor use and meeting a certain set of technical requirements, should be allowed to be used on a licence exempt basis. The technical requirements included requirements that the repeaters operate only over the frequency bands of any single licensed network operator at a given time, adjust their power to the minimum necessary to make a reliable connection, and incorporate anti-oscillation measures. See section 3, paragraphs 3.13 to 3.23 of the April 2017 consultation for details of the technical requirements.
- 2.2 The April 2017 consultation also proposed that low gain mobile phone repeaters, intended for in-vehicle use and meeting a certain set of technical requirements, should be allowed to be used on a licence exempt basis. The technical requirements included requirements that the repeaters have a limited maximum transmit power and have a limited maximum gain. See section 4, paragraphs 4.6 to 4.8 of the April 2017 consultation for details of the technical requirements.
- 2.3 The proposals did not encompass the use of other types of mobile phone repeaters, the use of which would remain unlawful unless they are supplied and operated under the control of a mobile network operator within the terms of their licence.
- 2.4 The proposals in the April 2017 consultation followed our statement of 18 March 2016 (the “2016 statement”), where we set out the important role consumer installed mobile phone repeaters could potentially play in improving coverage, particularly inside buildings, vehicles and trains; and in remote rural locations.
- 2.5 In the 2016 statement, we recognised that a legitimate retail market for consumer-installed mobile phone repeaters would help reduce the likelihood that consumers unwittingly purchase unauthorised illegal repeaters which may cause undue interference to other mobile networks. We also highlighted the challenges associated with ensuring that the use of these repeaters, which boost and retransmit mobile signals, is not likely to involve adverse effects, such as causing undue interference to other spectrum users. We provided some high-level guidance on the types of interference management approaches likely to be required to help ensure that consumer installed mobile phone repeaters are not likely to have adverse effects on other users.
- 2.6 The proposals in our 2017 consultation followed further technical analysis and discussions with mobile phone repeater vendors and the mobile network operators, with the aim of identifying an appropriate set of technical requirements that would allow mobile phone repeaters to be used on a licence exempt basis whilst ensuring undue interference or other adverse effects on technical quality of service is unlikely.
- 2.7 It should be noted that the MNOs are already authorised to deploy repeaters under the terms of their licences. These repeaters can vary from large high power repeaters that

form key parts of their network infrastructure to small, smart/intelligent low power repeaters supplied direct to their customers intended for use indoors in domestic and other premises. In our 2017 consultation, we did not propose any changes that would affect the authorisation of repeaters under the terms of the MNOs' licences.

## Statutory duties

2.8 Ofcom's responsibilities for spectrum management are set out primarily in two Acts of Parliament which confer on us our specific functions, powers and duties: The Communications Act 2003 (the "2003 Act") and the Wireless Telegraphy Act 2006 (the "WT Act").<sup>5</sup> Amongst our functions and powers are the making available of frequencies for use for particular purposes and the granting of rights of use of spectrum through wireless telegraphy licences and licence exemptions.

### The 2003 Act

2.9 Our principal duties under the 2003 Act, when carrying out our functions and exercising our powers, are to further the interests of citizens and consumers, where appropriate by promoting competition. In doing so, we are also required (among other things) to secure the optimal use of spectrum and the availability throughout the United Kingdom of a wide range of electronic communications services.

2.10 We must also have regard to (i) the desirability of promoting competition in relevant markets; (ii) the desirability of encouraging investment and innovation in relevant markets; (iii) the different needs and interests, so far as the use of the electro-magnetic spectrum for wireless telegraphy is concerned, of all persons who may wish to make use of it; and (iv) the different interests of persons in the different parts of the United Kingdom, of the different ethnic communities within the United Kingdom and of persons living in rural and in urban areas.

2.11 The 2003 Act also sets out certain regulatory principles. It says that in performing our duties we must have regard to the principles under which regulatory activities should be transparent, accountable, proportionate, consistent and targeted only at cases in which action is needed.

### The WT Act

2.12 Additionally, in carrying out our spectrum functions we have a duty under section 3 of the WT Act to have regard in particular to: (i) the extent to which the spectrum is available for use or further use for wireless telegraphy; (ii) the demand for use of that spectrum for wireless telegraphy; and (iii) the demand that is likely to arise in future for such use.

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<sup>5</sup> The European Common Regulatory Framework for electronic communications (in particular, the Framework Directive and the Authorisation Directive) sets out the broad legal framework for how spectrum should be authorised and managed in the UK and aims to harmonise the regulation of electronic communications networks and services throughout the European Union.



- 2.13 We also have a duty to have regard to the desirability of promoting: (i) the efficient management and use of the spectrum for wireless telegraphy; (ii) the economic and other benefits that may arise from the use of wireless telegraphy; (iii) the development of innovative services; and (iv) competition in the provision of electronic communications services.
- 2.14 Ofcom’s powers in relation to spectrum licences and exemptions include those in section 8 of the WT Act. Section 8(1) says it is unlawful for a person to use wireless telegraphy apparatus except under and in accordance with a licence granted by us. Section 8(3) gives us power to make regulations exempting the use of certain wireless telegraphy apparatus from the need for a licence, either absolutely or subject to such terms, provisions and limitations as we specify. Section 8(3A) and (3B) restrict the terms, provisions and limitations we can specify. The latter requires that they must be:
- objectively justifiable in relation to the wireless telegraphy apparatus to which they relate;
  - not such as to discriminate unduly against particular persons or against a particular description of persons;
  - proportionate to what they are intended to achieve; and
  - in relation to what they are intended to achieve, transparent.
- 2.15 Section 8(4) says Ofcom has an obligation to make licence exemption regulations under sub-section (3) in respect of apparatus of particular descriptions where certain conditions are met. These conditions are set out in section 8(5), and include that the use of apparatus of the particular description is not likely to:
- involve undue interference with wireless telegraphy;
  - have an adverse effect on technical quality of service;
  - lead to inefficient use of the part of the electromagnetic spectrum available for wireless telegraphy; or
  - endanger safety of life.
- 2.16 Accordingly, Ofcom must authorise the use of consumer installed repeaters of particular descriptions on a licence exempt basis if they satisfy the appropriate conditions. We may do so subject to specified terms, provisions and limitations.

## Radio Equipment Directive

- 2.17 The placing on the market and putting into service of radio equipment (including mobile repeaters) is regulated by the Radio Equipment Directive<sup>6</sup> (the “RED”), which passed into EU law on 14 June 2016, repealing Directive 1999/5/EC. As of 13 June 2017, only the new RED is applicable. At the time of publication, the UK has not yet transposed the RED into

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<sup>6</sup> The Radio Equipment Directive (RE-D) 2014/53/EU **came into force on the 13th June 2016, replacing Directive 1999/5/EC.**

UK law<sup>7</sup>. However, products can be placed on the market in the European single market under the RED.

- 2.18 One requirement of this regime is that radio equipment may only be placed on the market and put into service if it meets certain essential requirements. These include that it must be constructed such that it uses the relevant radio spectrum so as to avoid harmful interference.
- 2.19 One way in which these requirements may be satisfied is by meeting an applicable Harmonised Standard. Equipment that meets an applicable Harmonised Standards enjoys a presumption of conformity with the essential requirements. There are some Harmonised Standards that apply to certain types of repeaters.<sup>8</sup>

## Application

- 2.20 In the April 2017 consultation we explained that we cannot be satisfied, on the basis of the evidence currently available, that the use of consumer installed repeaters available in the UK at present is not likely to involve undue interference to, or otherwise affect the technical quality of service for, other spectrum users. However, we proposed to licence-exempt certain consumer installed mobile repeaters in future. That is, repeaters of particular descriptions which adhere to terms, provisions and limitations (including technical requirements) such that their use would meet the conditions in sections 8(4) and 8(5) of the WT Act described above.
- 2.21 Our provisional view was that such repeaters could operate without causing harm to mobile networks and other spectrum users. On that basis, their use should be authorised via licence-exemption, so that, in common with many other types of low power radio equipment, they could be used without the need for a specific licence.
- 2.22 In particular, we consulted on the proposal to exempt use of low power mobile phone repeater equipment from requiring a licence when operating in the frequency bands presently licensed to MNOs. The relevant licence exemption regulations would include the applicable technical conditions by referring to two interface requirements, to be titled:
- “UK Interface Requirements 2102.1 Licence Exempt Static Mobile Phone Repeaters, Intended for Indoor Use”; and
  - “UK Interface Requirements 2102.2 Licence Exempt Low Gain Mobile Phone Repeaters, Intended for In-Vehicle Use”.
- 2.23 We formulated our proposals by reference to our statutory duties. For the reasons set out in the consultation document, our provisional assessment was that that they were consistent with those duties and the terms, provisions and limitations would meet the requirements in section 8(4).

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<sup>7</sup> The Government consulted on new draft UK implementing regulations in the summer of 2017. For the time being, however, the Radio Equipment and Telecommunications Terminal Equipment Regulations 2000 (the “R&TTE Regulations”) continue to apply.

<sup>8</sup> See EN 301 908-11, EN 301 908-15 and EN 303 609.

2.24 They would be:

- **objectively justified** in that they would address risks of undue interference and/or adverse effects on the technical quality of service that would otherwise arise from the use of consumer-installed repeaters;
- **not unduly discriminatory** against particular persons or against a particular description of persons in that they would apply to all users of relevant repeaters (and, indirectly, to all manufacturers and sellers);
- **proportionate** to what they are intended to achieve, in that they would be necessary to ensure that use of the relevant repeaters would not be likely to have relevant adverse effects; and
- **transparent** in relation to what they are intended to achieve, in that they were described and explained in our consultation document and would be explained in our decision statement and specified in the relevant interface requirements and exemption regulations.

2.25 We proposed that they would also encourage the development of a retail market for lawful consumer-installed mobile phone repeaters. This would help provide coverage solutions for consumers who need them, without involving undue interference to other users. It would also help reduce the likelihood that consumers purchase unauthorised (and unlawful) repeaters which do cause such harm, and so reduce the market for such devices.

2.26 We posited that, in these ways, the proposals would help secure optimal use of the spectrum. They would also help encourage investment and innovation, and promote competition, in relevant markets, as well as furthering the different needs and interests, so far as the use of the electro-magnetic spectrum for wireless telegraphy is concerned, of all persons who may wish to make use of it in the United Kingdom, including those in rural areas (where mobile coverage is often less).

## 3. Responses to the April 2017 consultation

### Introduction

- 3.1 We received 16 non-confidential and three confidential responses to our April 2017 consultation. These came from the four MNOs, HMG departments, the Scottish Government, one repeater vendor (Nextivity), industry bodies, and several individuals and consultants. We also received a few enquiries from organisations asking about how repeaters might help improve mobile coverage in their buildings. See annex A1 for a list of non-confidential respondents.
- 3.2 Several respondents were positive about the introduction of licence exempt mobile phone repeaters and noted the possible benefits for improving coverage, especially in rural areas. The four MNOs raised concerns about the risk of interference to mobile networks from licence exempt mobile phone repeaters. MOD, NATS, BT/EE and one confidential respondent were concerned about the risk of interference to services adjacent to mobile bands from new licence exempt mobile phone repeaters.
- 3.3 The first section below considers general issues that are applicable to both indoor repeaters and in-vehicle repeaters. The subsequent sections consider other matters that are specific to each type of repeater on its own.

### General Issues

#### **Several stakeholders agreed that we should make licence exempt mobile phone repeaters available, but some MNOs argued that alternative solutions for in-building coverage exist**

- 3.4 Several stakeholders saw the benefits of both indoor and in-vehicle mobile phone repeaters and agreed that we should make these available on a licence exempt basis. They agreed that mobile phone repeaters could provide some improvement in coverage in some circumstances. A few respondents sought our advice on how to improve coverage in their properties and were considering mobile phone repeaters as a possible solution. Whilst welcoming licence exemption of mobile phone repeaters, one confidential respondent cautioned that in-vehicle mobile phone repeaters still depend on there being mobile coverage along roads and so the licence exemption of in-vehicle mobile phone repeaters does not entirely address its concerns about mobile coverage on roads.
- 3.5 BT/EE and MOD highlighted that alternative approaches for providing in-building coverage already exist, such as Wi-Fi which can support both voice and data services and they noted that Wi-Fi is often installed in vehicles by manufacturers. H3G was sceptical about the value of in-vehicle mobile phone repeaters.

### **Ofcom's response**

- 3.6 These responses do not, in general, provide a basis for us to change our overall view that mobile phone repeaters can play a role in improving in-vehicle and indoor coverage. We are well aware that other solutions for improving indoor coverage are available to consumers, including the use of femtocells and Wi-Fi (with new Wi-Fi Calling capabilities meaning that Wi-Fi can be used for voice as well as data). These technologies need a good quality broadband connection and, where this exists, may often provide a suitable solution for the consumer. However, ongoing consumer demand for licence exempt mobile phone repeaters is clear, as shown by the existing market for illegal mobile phone repeaters (which we continue to enforce against) and by the responses to our April 2017 consultation.
- 3.7 In any case, under Section 8 of the WT Act we must make licence exemption regulations in respect of apparatus where use of that apparatus is not likely to involve, amongst other things, undue interference with wireless telegraphy or have adverse effects on technical quality of service (see paragraph 2.15 above). We currently enforce against devices which are causing interference to mobile networks. Mobile phone repeaters operating on a licence exempt basis in accordance with the appropriate technical requirements are not likely to involve undue interference to mobile networks. What is key to that is identifying the appropriate technical requirements.

### **The MNOs argued that a registration scheme would be necessary**

- 3.8 All four MNOs noted that mobile phone repeaters have the potential to cause interference to mobile networks and that all the repeaters in their networks are currently under their control. They said that a registration scheme or geolocation database was necessary so that consumer-installed indoor mobile phone repeaters could be quickly identified when there is an incident of interference in the mobile network. O2 was also concerned about the risk of interference from in-vehicle mobile phone repeaters and believed that this might be reduced by allowing only vehicle manufacturers to install mobile phone repeaters.

### **Ofcom's response**

- 3.9 Illegal repeaters – those which do not comply with a set of technical requirements which make them suitable for licence exemption – pose a much higher risk of interference than those which comply with such requirements. They are, however, highly unlikely to be registered. Indeed, they would not be capable of registration (but it is unlikely their owners would request it).
- 3.10 In any event, a licence exemption will be subject to a general condition that repeaters do not in fact cause undue interference. Any repeater which does so could be easily identified and removed from service.
- 3.11 Given all those points, our judgment is that a registration scheme will not aid in enforcement against illegal repeaters and is unnecessary.

- 3.12 We also note significant downsides to a registration scheme. A scheme run by Ofcom (or MNOs) would take time to set up and would delay the introduction of licence exempt repeaters. A scheme run by Ofcom is likely to consume significant resources without helping to ensure that undue interference or adverse technical effects on quality of service are not likely, given that we are setting appropriate technical requirements for licence exempt mobile phone repeaters.

### **Some stakeholders were concerned that the enforcement burden might increase and that consumers might not be able to identify legal from illegal mobile phone repeaters**

- 3.13 BT/EE said that it could be difficult to test whether a mobile phone repeater conforms with our technical requirements and that testing would add to the enforcement burden. O2 were concerned that an increase in the complexity of enforcement could lead to it taking longer to resolve cases of interference, resulting in consumers experiencing longer periods of poor network performance.
- 3.14 Several stakeholders believed that some form of labelling scheme, online conformance database or certification scheme was necessary to help consumers distinguish between legal and illegal mobile phone repeaters. The Orkney Digital Forum and Scottish Government emphasised that consumers must be protected when they buy mobile phone repeater equipment in good faith. BT/EE added that any labelling scheme should make it clear that the mobile phone repeater was not provided by an MNO and that consumers should contact the mobile phone repeater manufacturer for customer support.
- 3.15 Vodafone suggested that Ofcom test and approve all mobile phone repeaters or register a trademarked logo and encourage vendors to use this logo. O2 suggested that some suppliers might engage in “sharp practices”, labelling their devices as conforming to the standards when they did not.
- 3.16 H3G was concerned that we had not considered the extra costs associated with manufacturing licence exempt mobile phone repeaters which conformed with our technical requirements and that illegal mobile phone repeaters would continue to proliferate if licence exempt alternatives were significantly more expensive.

### **Our response**

- 3.17 We agree that consumers will often be unaware of the distinction between legal and illegal repeaters once legal repeaters become available. This is not very different from the situation we have today where consumers buy illegal repeaters over the internet without being aware that they are illegal. However, we do not consider that consumers will need to distinguish between legal and illegal repeaters once the availability of legal repeaters becomes an established feature of the market. Reputable retailers will be keen to uphold the law and avoid compromising their reputations and so will likely prominently market compliant equipment meeting the technical requirements of the licence exemption.

- 3.18 Those points being so, we are confident that, following implementation of the exemption regulations, consumers searching for a mobile phone repeater will be much more likely to find legal rather than illegal ones. Currently, when searching online, the only repeaters available to purchase are illegal devices masquerading as legal ones. We are confident these will be superseded in the search results by legal repeaters when they become available and illegal devices will become harder to find. We do not think the risk of an expanding illegal market is credible. That view is consistent with the experience of the Federal Communications Commission of the United States (“FCC”) when the US went through a similar process of authorising the use of specific types of mobile repeater. It has told Ofcom that, in the US, the availability of legal alternatives has largely eliminated illegal mobile phone repeaters.
- 3.19 Our judgment is that creating the licence exemption will streamline enforcement activities by making a clear distinction between legal and illegal products and ultimately stem consumer demand and the availability of illegal repeaters.
- 3.20 We will continue to police on-line sales which will also help ensure that legal repeaters achieve greater prominence in online search results than illegal ones. We will also continue to respond to repeater related interference cases. We do not intend to reduce our resourcing of enforcement against illegal repeaters when legal licence exempt alternatives become available on the market.
- 3.21 Ofcom has taken enforcement action to stem the supply of illegal repeaters. Some on-line organisations have sought to continue the supply of such repeaters into the UK from outside our jurisdiction. However, we think it likely, based in part on experience in the US market, that illegal repeater sales will decline for the kinds of reasons set out above.
- 3.22 Again, in any event, a key safeguard, in addition to the technical requirements, will be that the exemption will be subject to a general condition that the repeater does not in fact cause undue interference. If it does, this would be traceable, the repeater would fall outside the exemption and its use could be stopped.
- 3.23 We have also considered a labelling scheme, perhaps something like a “green triangle” logo as suggested by Vodafone. Our assessment is that it would be easy to spoof, and we note that retailers of illegal repeaters have a track record of using misleading information to give their products the veneer of legality. As we discuss above, we are confident that reputable retailers will take steps to ensure they only sell legal repeaters and that these retailers, which might include major electronics retailers, will effectively displace retailers of illegal wideband repeaters when searching for repeaters online.
- 3.24 Similarly, we also do not consider that a logo trademarked by Ofcom would be useful for reducing the number of illegal repeaters bought by consumers. However, we note that a successful route in the past has been for MNOs to pursue retailers of illegal equipment for copyright infringement when those retailers use MNO logos in their sales materials.
- 3.25 For those reasons, we have decided not to include such labelling requirements as part of the exemption.

- 3.26 We have also decided not to specify that manufacturers must label exempt mobile phone repeaters with their customer support contact details. Identification of the customer support contact is not a technical requirement necessary for the prevention of undue interference or maintaining the technical quality of service of the mobile network. Manufacturers will be incentivised to provide customer support to avoid damage to their brand and we therefore expect they would label their products appropriately anyway.
- 3.27 We do not believe that it is necessary for Ofcom to test and approve mobile phone repeaters. Ofcom is not responsible nor does it have a mandate to test and approve the conformity of products against any certification scheme and we are not resourced to undertake such a role. Like any other radio product, mobile phone repeaters must comply with the requirements of the RED (see paragraphs 2.17 to 2.19 above). It is the responsibility of manufacturers and/or importers to ensure their products meet those requirements and that they follow the appropriate conformity assessment procedures set out in the Directive. The RED also requires manufacturers and/or importers to 'CE' mark their equipment as compliant with the RED and to provide information with their products on their intended use (including restrictions applicable to such use) and to include their name, registered trade name or registered trade mark and the postal address at which they can be contacted.
- 3.28 We acknowledge that licence exempt mobile phone repeaters may be higher cost than certain illegal repeaters (especially the crude wideband devices) because of additional complexity associated with operating in accordance with our technical requirements. However, we know from discussion with colleagues at the FCC that, when legal mobile phone repeaters were introduced in the USA, the market for illegal repeaters contracted quickly. We have discussed our proposed technical requirements with one of the main repeater vendors, Nextivity, and it considers that products which operate in accordance with our technical requirements can be supplied to the domestic market at reasonable cost.

### **Some stakeholders were concerned that our proposed interface requirements did not include elements they believed were necessary**

- 3.29 Some MNOs said that the technical requirements we proposed in the April 2017 consultation did not include some elements which they believed were necessary for licence exempt repeaters to operate without a risk of causing undue interference.
- 3.30 BT/EE said that the technical requirements fell short of what it requires for mobile phone repeaters in its own network. H3G said that it believed that FCC repeater standards are not appropriate for wholesale transfer to the UK and that the proposed regulations did not adequately deal with the situation where multiple mobile phone repeaters are used close to one another. O2 also identified further elements which it believed should be included in the technical requirements for licence exempt mobile phone repeaters which are discussed later in this document.



- 3.31 BT/EE also contended that the technical requirements for licence exempt mobile phone repeaters should be agreed on a pan-European basis under an ETSI<sup>9</sup> harmonised standard. It added that this was especially important for in-vehicle mobile phone repeaters which might travel from the UK to other countries in Europe.
- 3.32 Vodafone and O2 commented on the language used in the proposed interface requirement. Vodafone considered that the restriction “intended for indoor use” opened a legal loophole which would allow for equipment to be installed outdoors, even if it was intended for indoor use. O2 considered that “indoor” was too broad a definition and that this would allow “mis-use” of devices in non-residential locations such as offices, industrial units, hotels and universities.
- 3.33 O2 also believed that Ofcom should specify behaviour for self-diagnosis and shut down in the event of hardware fault in the mobile phone repeater and O&M (operation and maintenance) functionality.
- 3.34 The MOD sought confirmation that licence exempt mobile phone repeaters would operate in FDD<sup>10</sup> bands only and not TDD<sup>11</sup> bands. One confidential respondent proposed that all mobile bands supported in mobile user equipment should also be supported by mobile phone repeaters and recommended that the frequency bands supported in the mobile user equipment ETSI standards<sup>12</sup> be referenced directly in the IR.

### Our response

- 3.35 We have considered these points very carefully. Identifying the appropriate technical conditions – those necessary, but no more than necessary, to ensure the use of exempt repeaters is not likely to involve undue interference or have an adverse effect on technical quality of service – is key to the making (or not) of any exemption.
- 3.36 We are confident that the technical requirements we have decided to impose – those we proposed, together with the modifications we have decided to make to them (see paragraph 1.9 above and Section 4 below) – are appropriate. We deal with specific comments stakeholders made in response to particular aspects of the technical requirements in later paragraphs below.
- 3.37 The technical requirements are in addition to the requirements of the RED. The RED allows EU Member States to, “... *introduce additional requirements for the putting into service and/or use of radio equipment for reasons related to the effective and efficient use of the radio spectrum, to the avoidance of harmful interference, to the avoidance of*

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<sup>9</sup> ETSI, the European Telecommunications Standards Institute. This is the standards body responsible for the development of harmonised standards for the RED under mandate from the European Commission.

<sup>10</sup> FDD, frequency division duplex

<sup>11</sup> TDD, time division duplex

<sup>12</sup> 2G user equipment – ETSI EN 301 511

3G user equipment – ETSI EN 301 908-2

4G user equipment – ETSI EN 301 908-13

*electromagnetic disturbances or to public health.*” Both our technical requirements and the requirements of the RED must be complied with in respect of an exempt repeater.

- 3.38 ETSI has developed several European harmonised standards for mobile phone repeaters that can be used to give a presumption of conformity with the essential requirements of the RED. These standards are not specific to mobile phone repeaters intended for use under licence exemption, however. Rather, they cover all types of mobile phone repeaters, from large devices that are intended to form part of the operators’ network infrastructure to small domestically oriented devices.<sup>13</sup>
- 3.39 The standards do not contain all of the elements necessary for mobile phone repeaters intended for use of spectrum under a licence exemption in the UK although, where they do contain relevant elements, it is not necessary to duplicate these in our technical requirements. We include in our technical requirements elements which are not adequately covered by the existing harmonised standards.
- 3.40 We will continue to work in relevant European fora (e.g. in ECC PT1<sup>14</sup>) to identify technical solutions for indoor coverage and will seek to promote our work on repeaters. We note that in-vehicle mobile phone repeaters are already installed in many vehicles across Europe<sup>15</sup> and we are bringing this under appropriate regulation in the UK. We discuss responses regarding coexistence in more detail later in this section.
- 3.41 We have reworded the mobile phone repeater IRs in certain respects. We have removed “intended for” from the “intended for indoor use” and “intended for in-vehicle use” usage restrictions. We will make clear in our technical requirements that the downlink frequencies can only be used indoors or in-vehicle as appropriate. We have made this change because we recognise that widespread use of downlink frequencies by mobile phone repeaters outdoors could increase the risk of undue interference to mobile networks.
- 3.42 However, it is not necessary, in our judgment, to limit use of mobile phone repeaters to residential properties. We acknowledge that our policy goals, as set out in the April 2017 consultation, were focussed on improving residential indoor coverage, but we did not exclude other indoor scenarios. We do not consider that the risk of undue interference (from licence exempt mobile phone repeaters that meet our technical requirements) to other services to be any greater in non-residential scenarios.
- 3.43 The self-diagnosis and shut down behaviour we have specified in the technical requirements is suitable to mean the repeaters whose use we authorise would not involve

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<sup>13</sup> Such as the ‘smart low power’ repeaters that the operators sometimes provide to their customers under the terms of their licence.

<sup>14</sup> ECC PT1 work item on “Best practices on indoor coverage for Mobile services (MFCN)”, <http://eccwp.cept.org/default.aspx?groupid=27&go=true>

<sup>15</sup> For example, in Germany, BMW offer an external antenna with repeater for mobile phones as an optional add-on: <http://www.bmw.de/de/topics/service-zubehoer/original-bmw-zubehoer-finden/accessoryDetail.accessoryId=9910.html> Similarly, the Mercedes E-class has a built-in mobile phone cradle and repeater: [https://www.mercedes-benz.de/content/germany/mpc/mpc\\_germany\\_website/de/home\\_mpc/passengercars/home/servicesandaccessories/zubehoer/telefonie\\_multimedia.html](https://www.mercedes-benz.de/content/germany/mpc/mpc_germany_website/de/home_mpc/passengercars/home/servicesandaccessories/zubehoer/telefonie_multimedia.html)

the proscribed negative effects. The technical requirements we have decided to impose mean licence exempt mobile phone repeaters must detect when they go into oscillation and shut themselves down swiftly to prevent those effects. We have not included “O&M functionality” because we are of the view that our technical requirements, as modified, are sufficient.

- 3.44 Our decision only exempts mobile phone repeaters from licencing requirements in the FDD mobile bands. The IRs we are imposing only cover those bands (see Annex A3). Existing harmonised standards for mobile phone repeaters only support those bands too. It is likely that TDD bands will be supported in harmonised standards for mobile phone repeaters in the future. We will consider whether to include these bands in the licence exemption as and when they are supported in the harmonised standards.

### **Some stakeholders were concerned about coexistence with systems adjacent to mobile bands including radars, terrestrial television and vehicle communications**

- 3.45 Some stakeholders were concerned about coexistence between licence exempt repeaters and other systems. BT/EE submitted that each mobile band has specific characteristics and coexistence arrangements and aggregate interference from repeaters could break these limits. The MOD was concerned that we had not directly addressed the protection of sites which currently require coordination with MNOs and any additional risk repeaters might cause to systems at these sites.
- 3.46 NATS noted that MNOs must currently coordinate with air traffic control radar sites at 2.7 GHz but that licence exempt repeaters could not be coordinated because they would be installed by consumers. NATS sought reassurance that licence exempt repeaters would not have an impact upon radar operations. BT/EE believed that the marginal increase in interference from a single repeater in the adjacent band was unlikely to be significant, but that the aggregate impact of multiple simultaneously active repeaters near a radar might significantly add to the total interference.
- 3.47 BT/EE was also concerned that an installed licence exempt repeater might inadvertently cause interference to digital terrestrial television (“DTT”) reception, either for the homeowner using the licence exempt repeater or their neighbours.
- 3.48 One confidential respondent said that in-vehicle licence exempt repeaters must be able to operate without causing interference to the vehicle’s own embedded communication system. It noted that vehicle manufacturers wishing to install low-gain mobile phone repeaters for their vehicle models in the factory will test and validate coexistence, but that there was little evidence whether self-installed licence exempt repeaters could coexist or not.

## Our response

- 3.49 Again, we have taken careful account of these responses. Co-existence between spectrum uses is another important consideration when authorising such use, not least in respect of safety critical services like air traffic control radar.
- 3.50 In this case, the risk of undue interference to systems in adjacent bands from mobile phone repeaters is no more likely than that from existing mobile user equipment. The uplink power limits we have decided to impose for mobile phone repeaters are the same as for mobile user equipment, and there are appropriate out-of-band emissions limits in the mobile phone repeater harmonised standards to protect adjacent users. We discuss this in more detail later in this summary of responses.
- 3.51 We have also considered the impact of aggregate interference from in-building repeaters to mobile networks later in this Statement and found that the sensitivity to large numbers of simultaneous active repeaters is low. This analysis applies similarly to coexistence with the other systems mentioned in the responses.
- 3.52 The mobile phone repeater downlink, meanwhile, is not likely to significantly increase the risk of undue interference to other systems. The downlink power limit is low (i.e. 10 dBm / 5 MHz with a total power cap of 17 dBm) and the downlink will be operating in an enclosed space providing additional signal losses; i.e. in a vehicle or in a building.
- 3.53 On these footings, our decision is that the power limits in the technical requirements are set at the appropriate levels.
- 3.54 The risk of interference to air traffic control radars from 2.6 GHz mobile phone repeaters is also likely to be low. Nevertheless, we recognise that it is not practical for licence exempt mobile phone repeaters to be coordinated with air traffic control radars. We will, therefore, exclude the 2.6 GHz band from the licence exemption at this time.
- 3.55 We will continue the current discussions with the MOD and the CAA in relation to mobile phone repeaters and other devices operating in the 2.6 GHz bands at a low power (e.g. femtocells) with a view to seeing if it is possible to exclude these types of devices from the coordination requirement without adversely affecting air traffic control radar performance. If we reach an appropriate position with the MOD and the CAA we will look to include this band in the licence exemption for mobile phone repeaters at an appropriate time in the future.
- 3.56 Protection of DTT is explicitly included in the harmonised standards for mobile phone repeaters.<sup>16</sup> We therefore judge that we do not need to impose further technical requirements to prevent undue interference to DTT.
- 3.57 In-vehicle communication systems already must coexist with mobile phone devices used in and around vehicles. The risk of undue interference from low gain in-vehicle mobile phone repeaters to in-vehicle communications systems is unlikely to be higher than that of other

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<sup>16</sup> See §4.2.2.2.5 of ETSI EN 301 908-11 V11.1.2 (2017-01) for 3G repeaters and §4.2.2.2.4 of ETSI EN 301 908-15 V11.1.2 (2017-01) for 4G repeaters

mobile phone user equipment because they will have similar technical characteristics. For example, the maximum uplink power radiated power limits will be the same for low gain in-vehicle mobile phone repeaters as they currently are for mobile phone user equipment. It is therefore not necessary to impose further technical requirements to prevent undue interference to in-vehicle communications systems from low gain in-vehicle mobile phone repeaters.

- 3.58 It should be noted that our technical requirements do not supersede any specific vehicle related requirements that may apply (see the Vehicle Certification Agency website for information <http://www.dft.gov.uk/vca/>).

### **Some stakeholders were concerned about unwanted emissions from repeaters including noise, non-linear power amplifier effects and oscillation**

- 3.59 BT/EE and the MOD were concerned about the limits on out-of-band emissions and intermodulation products from mobile phone repeaters. The MOD believed that the FCC limits for repeater out-of-band emissions were 6 dB below the limits for equivalent mobile devices. Both believed that limits on intermodulation products should be included in the technical requirements for repeaters and BT/EE went further, saying that mobile phone repeaters should be limited to amplifying no more than two bands to reduce the likelihood that harmful intermodulation products would be generated.
- 3.60 BT/EE expressed some further concerns about in-band noise generated by licence exempt repeaters and said that the noise figure should be specified and should be no higher than 6 dB. It also considered the uplink noise power limit of -70 dBm / MHz when the repeater is in standby mode to be too high and proposed that the limit should be set at -80 dBm / MHz.
- 3.61 BT/EE believed that the gain control in licence exempt repeaters must be sufficiently advanced to prevent a state of oscillation from ever occurring. It believed that degradation to the mobile network could occur in the period before a repeater reaches oscillation and so it felt that our proposals fell short of protecting consumers from the harmful effects of interference.

#### **Our response**

- 3.62 Limits on out-of-band emissions and the generation of intermodulation products are already specified in the harmonised standards for repeaters.<sup>17</sup> These standards are the product of detailed technical consideration. On that basis, our judgment is that we do not need to impose further restrictions on licence exempt mobile phone repeaters or limit the number of bands which can be amplified at any one time. Provided a repeater meets

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<sup>17</sup> The 2G repeater standard is ETSI EN 303 609 V12.5.1 (2016-04) and attenuation of intermodulation products is specified in §4.2.3 whilst out-of-band gain limits are specified in §4.2.4.

The 3G repeater standard is ETSI EN 301 908-11 V11.1.2 (2017-01) and general limits on unwanted emissions are specified in §4.2.2; out-of-band gain limits are specified in §4.2.6; and output intermodulation limits are specified in §4.2.8.

The 4G repeater standard is ETSI EN 301 908-15 V11.1.2 (2017-01) and general limits on unwanted emissions are specified in §4.2.2; out-of-band gain limits are specified in §4.2.6; and output intermodulation limits are specified in §4.2.8.

those standards, and our technical requirements, its use is not likely to involve undue interference or have adverse effects on the technical quality of service.

- 3.63 We have reviewed whether a noise figure should be specified in our technical requirements and we agree with BT/EE that it should. We are making this change accordingly. This is because in-band noise is not dealt with in the harmonised standards and the indoor mobile phone repeater gain control equation that forms part of our technical requirements implicitly assumes that the mobile phone repeater has a similar noise figure to a mobile phone base station receiver.
- 3.64 We have also reviewed the 3GPP<sup>18</sup> specifications and other relevant literature<sup>19</sup> and consider that a 7 dB limit is consistent with assumptions underlying the specification of mobile phone base station receiver sensitivity.<sup>20</sup> We will therefore include this value in our technical requirements to ensure that undue interference or other adverse effects on technical quality of service are not likely in the mobile network. This noise figure limit should be achievable by most manufacturers as evidenced by the report we commissioned in 2015 from PA Consulting (“The PA Report”)<sup>21</sup> which found that most of the repeaters it reviewed stated that they had a noise figure of less than 6 dB with only a few having a noise figure of up to 8 dB.<sup>22</sup>
- 3.65 We have further considered the standby power limits in the harmonised standards for mobile phone user equipment. We have found that the -70 dBm / MHz limit we proposed for mobile phone repeaters was more stringent than the standby power limits for mobile phone user equipment in use today.<sup>23</sup>
- 3.66 We agree that a conservative value for the standby power limit is appropriate for mobile phone repeaters, particularly for the fixed, indoor repeaters which might represent a continuously present interference source if a mobile phone base station were installed

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<sup>18</sup> 3<sup>rd</sup> Generation Partnership Project

<sup>19</sup> E.g. LTE for UMTS Evolution to LTE-Advanced by Holma and Toskala

<sup>20</sup> The reference sensitivity for mobile phone base stations is calculated assuming a noise figure of 5 dB plus an additional 2 dB implementation margin. See: Equation 14.6, §14.4, “LTE for UMTS: Evolution to LTE-Advanced”, Harri Holma and Antti Toskala, Wiley, Second edition, 2011.

<sup>21</sup> “An assessment of the effects of repeaters on mobile networks”, PA Consulting, 17 November 2015, <https://www.ofcom.org.uk/research-and-data/technology/telecoms/effects-of-repeaters-on-mobile-networks>

<sup>22</sup> *ibid.* §4.1.2

<sup>23</sup> The 2G mobile user equipment idle spurious emissions limits, once normalised to one MHz, are in the range -49 to -37 dBm / MHz depending on the band of operation, see §12.2.2, ETSI TS 151 010-1 V13.4.0 (2017-08),

[http://www.etsi.org/deliver/etsi\\_ts/151000\\_151099/15101001/13.04.00\\_60/ts\\_15101001v130400p.pdf](http://www.etsi.org/deliver/etsi_ts/151000_151099/15101001/13.04.00_60/ts_15101001v130400p.pdf)

The 3G mobile user equipment idle spurious emissions limits, once normalised to one MHz, are in the range -69 to -61 dBm / MHz depending on the band of operation, see §4.2.10, ETSI EN 301 908-2 V11.1.1 (2016-07)

[http://www.etsi.org/deliver/etsi\\_en/301900\\_301999/30190802/11.01.01\\_60/en\\_30190802v110101p.pdf](http://www.etsi.org/deliver/etsi_en/301900_301999/30190802/11.01.01_60/en_30190802v110101p.pdf)

The 4G mobile user equipment limits for emissions in the idle state are not specified, but the receiver spurious emissions limit is -47 dBm / MHz and the transmitter spurious emissions limit is in the range -50 to -5 dBm / MHz depending on the band of operation,

see §4.2.4 and §4.2.10, ETSI EN 301 908-13 V11.1.2 (2017-07),

[http://www.etsi.org/deliver/etsi\\_en/301900\\_301999/30190813/11.01.02\\_60/en\\_30190813v110102p.pdf](http://www.etsi.org/deliver/etsi_en/301900_301999/30190813/11.01.02_60/en_30190813v110102p.pdf)

nearby. However, the standby power limit for mobile phone repeaters does not need to be significantly more stringent than that for mobile phone user equipment because mobile phone user equipment can also be installed in fixed locations, with examples including H3G's HomeFi<sup>24</sup> and BT/EE's Wireless Home Broadband.<sup>25</sup> It is appropriate to compare the mobile phone repeater standby power limit with mobile phone user equipment standby power limit because both can be installed in similar locations. On that basis, our judgment is that -70 dBm / MHz is an appropriate standby power limit for mobile phone repeaters.

- 3.67 We agree that positive feedback close to the point of oscillation can push power amplifiers into non-linear modes of operation resulting in distorted transmissions and intermodulation which can look like interference to a base station. However, high positive feedback modes of operation are inherently unstable and a mobile phone repeater will quickly either fall back into stable operation or shut down after going into oscillation, rather than remaining in a distorted mode for extended periods. We therefore consider the anti-oscillation measures we proposed in the April 2017 consultation to be sufficient to ensure undue interference to, or adverse effects on the technical quality of service of, mobile networks is not likely.

### **Some stakeholders sought further clarity about uplink power limits and uplink antenna gain for mobile phone repeaters**

- 3.68 BT/EE believed that we had not specified the class of handset when setting the maximum transmit power for the uplink and sought further clarity as to whether "power" limits referred to radiated power or conducted power at the output of the repeater uplink port. One confidential respondent proposed that the power limits set out in the harmonised standards for mobile user equipment<sup>12</sup> ought to be referenced directly in our regulations for licence exempt repeaters.
- 3.69 BT/EE and the Orkney Digital Forum were concerned that there should be limits on antenna gain, especially in cases where directional antennas are being used. The Orkney Digital Forum considered a scenario where a "savvy consumer" might replace a basic omnidirectional antenna with a high gain Yagi, but acknowledged that the gain control in the repeater would likely take this into account and reduce the power to the antenna accordingly.
- 3.70 VSCL considered the benefits of high gain antennas for repeater use, noting that a highly directional antenna would be able to unambiguously target a specific donor cell site in areas where there might be multiple potential donor base stations.

### **Our response**

- 3.71 We agree that the radiated power limits were ambiguous in our April 2017 consultation. We have amended the technical requirements to make the radiated limits explicit with a total radiated power (TRP) limit for in-vehicle repeaters and an equivalent isotropically

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<sup>24</sup> [http://www.three.co.uk/Store/Mobile\\_Broadband#homefi](http://www.three.co.uk/Store/Mobile_Broadband#homefi)

<sup>25</sup> <https://shop.ee.co.uk/family-home/home-broadband/4g-home-broadband>

radiated power (EIRP) limit for indoor repeaters. This aligns with how we currently define radiated power limits for existing mobile phone user equipment (e.g. TRP for mobile and nomadic devices and EIRP for fixed/installed devices).

- 3.72 We proposed in the April 2017 consultation that we would exempt mobile phone repeaters from a requirement for licensing with a maximum uplink power equivalent to that of mobile phone handsets. We have reviewed the power classes under our current mobile phone user equipment licence exemption<sup>26</sup>; the higher power GSM 900 terminal classes are intended for vehicular use, and they are not supported in modern hand held devices. We will therefore limit mobile phone repeaters, when re-transmitting GSM uplink signals in the 900 MHz band, to a maximum power of 2 Watts and in the 1800 MHz band to a maximum power of 1 Watt.<sup>27</sup>
- 3.73 We will specify the uplink power limits in our technical requirements rather than referencing the power levels given in the harmonised standards for mobile phone user equipment. This allows us to make sure that uplink power levels are set at levels which are appropriate for the UK. This also aligns with how we have exempted mobile phone user equipment from licensing requirements in the relevant technical requirements.
- 3.74 We expect that the limits on uplink power that we have set will mean that there is little benefit to be gained by employing very high gain antennas and that the clear majority of mobile phone repeaters will use approximately omni-directional antennas.<sup>28</sup> A few installations may use directional antennas, but we anticipate the gain will still be fairly low. For example, in further discussions with Nextivity it said that some of its antennas are electrically steerable flat-panel designs with 6 to 10 dBi of gain.<sup>29</sup> These antennas can change the direction of the main beam if there are any changes in the donor network, for example, if a new base station is built nearby.
- 3.75 The limits on uplink power that we have specified mean that mobile phone repeaters should look similar to mobile phone user equipment from the perspective of the mobile phone network. We also note that the gain control equation already takes antenna gain into account, so a repeater with a higher gain antenna will correspondingly reduce the amplifier gain to maintain the overall system gain at the appropriate level. For both these reasons we consider that indoor mobile phone repeaters with some antenna gain should pose no additional risk of undue interference or negatively impacting technical quality of service of the mobile network.

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<sup>26</sup> Annex 5 to The April 2017 consultation:

[https://www.ofcom.org.uk/data/assets/pdf\\_file/0016/100276/Annex-5-Current-National-Frequency-bands-and-National-Interfaces-for-Mobile-use.pdf](https://www.ofcom.org.uk/data/assets/pdf_file/0016/100276/Annex-5-Current-National-Frequency-bands-and-National-Interfaces-for-Mobile-use.pdf)

<sup>27</sup> GSM900 classes 3&4 and GSM1800 (DCS) classes 1&2, see TS.02.06

<https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=32>

<sup>28</sup> For example, the Nextivity Cel-Fi Duo:

<https://www.cel-fi.co.uk/boosters/celfi-duo-3g-4g-signal-booster-ee-three-bt-for-homes-small-businesses.html/>

<sup>29</sup> For example, the Nextivity Cel-Fi Quatra:

<https://www.cel-fi.co.uk/boosters/cel-fi-quatra-3g-4g-signal-booster-for-o2-ee-three-vodafone-medium-large-enterprises.html/>



- 3.76 On these footings, our judgment is that the power limits we have decided to impose on licence exempt repeaters means their use is not likely to result in the sorts of negative effects described in section 8(4) of the WT Act.

### **Some stakeholders believed that the maximum downlink power may be too restrictive**

- 3.77 Nextivity and NET Coverage Solutions said that the repeater downlink limit of 10 dBm EIRP across all bands should be modified to a power spectral density (PSD) limit of 10 dBm / 5 MHz EIRP to achieve a constant PSD for all amplified carriers and to align with the FCC regulations.
- 3.78 The MOD believed that the downlink power limit of 10 dBm EIRP across all bands might not be high enough to give indoor coverage and observed that the power limit for Wi-Fi at 2.4 GHz was 20 dBm EIRP and the total power limit for repeaters under FCC regulations was 17 dBm EIRP. It was concerned that the low power for indoor coverage might drive consumers to purchase illegal repeaters which typically transmit up to 17 dBm EIRP.
- 3.79 One confidential respondent queried whether the maximum downlink power should be increased at higher frequencies to take higher propagation attenuation into account.

### **Ofcom's response**

- 3.80 We have reviewed the downlink power limit. Based on our further assessment, we think that the limit we set in the April 2017 consultation could reduce the indoor coverage for wider carriers, such as those used for LTE which can have up to 20 MHz bandwidth. We have decided, therefore, to modify the downlink power limit to a power spectral density limit of 10 dBm / 5 MHz, with a total power cap of 17 dBm. Our judgment is that these levels will maintain the indoor coverage range for wider carriers whilst still ensuring the risk of undue interference to mobile networks is unlikely.
- 3.81 We accept that mobile phone repeater indoor coverage might not be as good for higher frequency carriers when compared to lower frequency carriers with the same power levels, but we consider that the indoor coverage at higher frequencies should be adequate. We will keep this under review, however, and, if appropriate, amend the power limits in future.

### **O2 and BT were concerned about the RF safety of licence exempt repeaters**

- 3.82 BT/EE submitted that licence exempt repeaters should be limited to a maximum of two bands to minimise the radiated RF power and meet ICNIRP<sup>30</sup> limits. O2 said that ICNIRP / EMF<sup>31</sup> safety limits should be referenced in the regulations and that RF<sup>32</sup> safety was particularly important in residential properties.

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<sup>30</sup> ICNIRP: International Commission on Non-Ionizing Radiation Protection

<sup>31</sup> EMF: Electromagnetic field

<sup>32</sup> RF: Radiofrequency

## Our response

- 3.83 We agree that RF safety is very important. All devices must continue to comply with all applicable safety legislation. However, it is not within Ofcom's remit to regulate on safety issues. We have published advice on our website about exposure to radiation including contact information for official bodies with responsibilities in that area.<sup>33</sup>

## Issues specific to indoor mobile phone repeaters

### Some stakeholders were concerned about mobile phone repeater attachment behaviour in complex mobile networks which change over time

- 3.84 All stakeholders agreed with our proposals to limit indoor mobile phone repeaters to amplifying the bands of a single operator at a time. However, BT/EE expressed some scepticism over how a repeater supplier could manage the reconfiguration of mobile phone repeaters to different bands or networks.
- 3.85 O2 said that mobile phone repeaters should automatically shut down if a new base station is installed nearby and the donor signal at the mobile phone repeater exceeds a certain threshold. This would prompt the users to reassess whether the mobile phone repeater was still required or if the coverage provided by the new base station was now sufficient.
- 3.86 O2 also said that mobile phone repeaters should automatically shut down for a short period if the donor signal falls below a certain threshold. This would be a way that operators could remotely shut down a mobile phone repeater when fault-finding in a network.
- 3.87 BT/EE were concerned about how the mobile phone repeater would behave as mobile networks evolve. It gave the example of voice traffic which might travel over circuit-switched or VoLTE<sup>34</sup> bearers and how this might change over time. BT/EE sought further information on whether a mobile phone repeater would amplify all the signals in an MNO's sub-bands of operation with no knowledge of the occupancy of those bands.
- 3.88 VSCL questioned whether the requirement for calculating path loss between the mobile phone repeater and the base station might lead to perverse attachment behaviour in complex heterogenous networks.<sup>35</sup> It was concerned that mobile phone repeaters might attempt to attach to a nearby small cell when attaching to a macrocell which is further away, but higher power, might be more appropriate.

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<sup>33</sup> <https://www.ofcom.org.uk/manage-your-licence/radiocommunication-licences/mobile-wireless-broadband/cellular-wireless-broadband/policy-and-licensing-information/exposure-electro-magnetic-fields>

<sup>34</sup> VoLTE: Voice over LTE

<sup>35</sup> Heterogenous networks combine small cells, macrocells and other mobile data technologies to provide good coverage and capacity for users. For a single frequency network technology like LTE, this could mean that an "umbrella" cell could cover an area with several co-channel small cells.

## Our response

- 3.89 We acknowledge that mobile networks are complex and dynamic systems and recognise that mobile phone repeaters must be able to operate appropriately in this environment. Ofcom's judgment is that the technical requirements we have decided to impose are appropriate for the operation of mobile phone repeaters on a licence exempt basis whilst ensuring that undue interference to, or adverse effects on the technical quality of service of, mobile networks is not likely. They will, essentially, exempt the use of repeaters that have similar effects on mobile networks to mobile handsets (which are the subject of a licence exemption without being likely to involve undue interference or have other adverse technical effects on technical quality of service).
- 3.90 It is reasonable to expect that mobile phone repeaters can be reconfigured for attaching to carriers in different mobile networks. Nextivity informed us that reconfiguration of its mobile phone repeaters can be managed by the user using a mobile app which connects to the repeater using a Bluetooth connection. The app allows selection of one mobile operator at a time from a drop-down menu. Provided the repeater complies with the technical requirements we have decided to specify, this should not be problematic.
- 3.91 We do not consider it necessary to specify network attachment behaviour in our technical requirements. In our judgement, only particularly perverse behaviours could risk undue interference to mobile networks. The risk of these occurring in practice is very low because manufacturers will be incentivised not to implement them. Rather, it is in their interests to implement this behaviour sensibly. This will provide the best user experience and protect the reputation of their brand. Sensible attachment behaviour might include simply attaching to the strongest carrier, or something more sophisticated. For example, Nextivity told us in further correspondence that its repeaters take several factors into account when deciding which base station to attach to, including signal strength and base station loading. That kind of attachment behaviour is unlikely to result in undue interference to or other relevant negative effects on the mobile network. In any event, in the very unlikely case that a mobile phone repeater does cause undue interference, the safeguard already mentioned (see paragraph 3.22), that the exemption will be subject to a general condition that the repeater does not in fact cause undue interference, will again apply.
- 3.92 We do not consider it necessary for a mobile phone repeater to shut down when the donor signal falls below a certain threshold, which might occur when a mobile operator switches base stations off when fault-finding. In this circumstance, a mobile phone repeater is likely to react similarly to existing mobile phone user equipment and seek the next most appropriate carrier to attach to, if available.
- 3.93 We also do not consider it necessary for a mobile phone repeater to shut down when the donor signal strength increases, perhaps as a result of a new base station being built. When a new base station is built with lower path loss than the original donor base station, the mobile phone repeater gain control algorithm, which is part of the technical

requirements we have imposed, would automatically reduce the repeater gain to take this into account.

- 3.94 In circumstances where spectrum use changes, for example when spectrum is re-farmed, mobile phone repeaters operating in accordance with our technical requirements will either adapt automatically or stop operating (as a consequence of the gain control requirement). It is unlikely that a mobile phone repeater will cause undue interference to mobile networks in such cases.
- 3.95 In further conversation with Nextivity, for example, it observed that the gain control requirement requires the mobile phone repeater to decode SIBs<sup>36</sup> transmitted by the base station. This means that its equipment knows the local spectrum occupancy and can adapt as the spectrum use changes in a similar way to mobile phone user equipment. If a repeater operating in accordance with our technical requirements cannot adapt to changing spectrum use, it will no longer be able to decode the information it needs for the gain control algorithm and so will cease to function.
- 3.96 In response to VSCL, we note that the requirement for calculating path loss between the base station and the mobile phone repeater is for the gain control algorithm, rather than its network attachment behaviour. As we have discussed above, we expect that manufacturers of mobile phone repeaters will implement sensible attachment behaviour.

### **Stakeholders acknowledged that the gain control algorithm was conservative but cautioned that it might not be appropriate in all scenarios**

- 3.97 Vodafone cautiously welcomed our approach to setting the values for the gain control algorithm and acknowledged that the assumption that there might be up to 50 simultaneously active repeaters in a sector was conservative. However, it believed that this number of simultaneous repeaters was not based on any evidence and should be revisited if there is a very large take up of repeaters. BT/EE also sounded a cautious note and was concerned that we had not provided a sensitivity analysis to show how noise in the network base station might vary if there were a large change in the number of simultaneously active repeaters.
- 3.98 VSCL said that we had been too conservative, particularly in the rural case. In rural areas, it believed there might be up to 20 simultaneously active mobile phone repeaters in a cell at most and so a 4 dB higher gain should be permitted. It believed that this higher power could be used to deliver higher 4G throughputs in rural areas.

#### **Our response**

- 3.99 We have carefully reviewed our assumptions which informed our proposed technical requirements for the gain control algorithm. We present the full details of our analysis in annex A2.

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<sup>36</sup> System Information Blocks, this is information that user equipment needs from the mobile network to successfully attach.

3.100 On the basis of that analysis, our judgment is that it is very unlikely that there will be more than 50 simultaneously active repeaters amplifying an individual carrier in a sector at any one time. In forming that view, we considered typical mobile phone network sectors as well as scenarios where large numbers of repeaters might feasibly be deployed including in large rural macrocells and dense urban cells containing tower blocks.

3.101 By way of a summary here, our technical requirements contain three mechanisms which have the effect of limiting the number of mobile phone repeaters which will be amplifying an individual carrier in a sector at any one time:

*No wideband amplification permitted*      1 Mobile phone repeaters cannot amplify all the carriers in a band but must amplify each carrier separately, applying the gain control equation to each carrier separately.

*No amplification of multiple MNO carriers*      2 Mobile phone repeaters can only amplify the carriers of a single MNO at any one time which the user selects during setup.

*Repeaters must go into standby after 5 minutes*      3 The repeater will go into standby mode when not used for 5 minutes and so is not active when it is not needed. For example, the repeater will go into standby mode when all the members of a household have left with their mobile devices.

3.102 We provide a sensitivity analysis in Figure 1 to show how aggregate noise at the base station would change if the number of simultaneous active repeaters in the network varies over a wide range. This analysis is based on the equation we produced in the April 2017 consultation which controls the gain of the repeater such that it is 30 dB less than the coupling loss between the mobile phone repeater and the mobile phone base station, “BSCL-30 dB”.

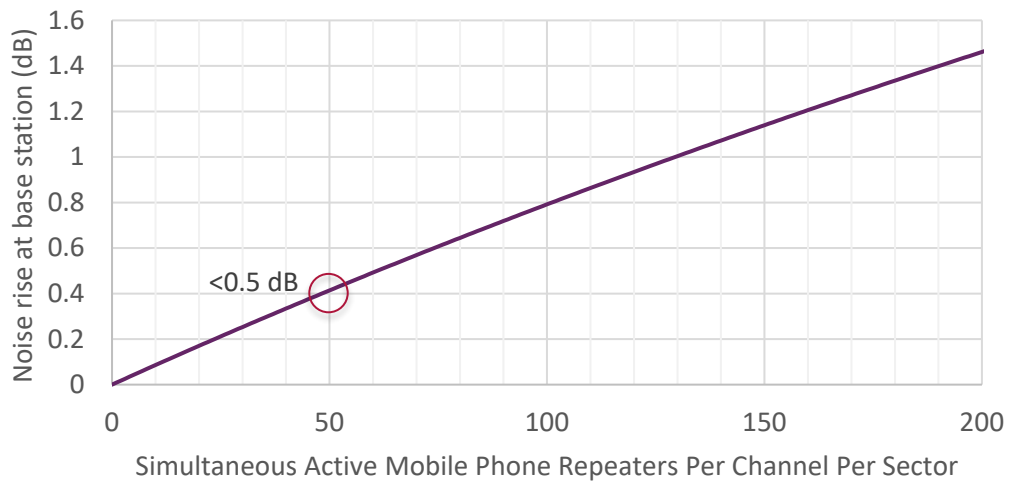
3.103 We considered a gain of 30 dB below the coupling loss between the mobile phone repeater and the base station to be appropriate because this meant only a minimal noise rise, less than 0.5 dB, would be observed at the mobile phone base station. The 30 dB figure considers an I/N<sup>37</sup> at the mobile phone base station of -10 dB, aggregate interference from up to 50 simultaneously active repeaters (17 dB) plus a further 3 dB protection margin.

3.104 Our analysis shows that the noise rise is insensitive to the number of simultaneous active mobile phone repeaters. For example, over 130 simultaneous active repeaters amplifying a carrier in a sector at any one time would be required for the noise rise to exceed 1 dB, even when considering the additional 3 dB protection margin.

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<sup>37</sup> I/N: Interference to noise ratio

**Figure 1: Sensitivity analysis of the aggregate noise rise at the mobile base station plotted against the number of simultaneous active mobile phone repeaters in the sector**



3.105 We also judge that our approach to the gain control algorithm is appropriate for both urban and rural areas and that we should not specify a more relaxed gain control algorithm for rural areas. This is for two reasons:

- First, there are some large rural macrocells which contain large numbers of premises, similar to the numbers of premises covered by sectors in urban areas, as we show in our analysis in annex A2. This means that there might be similar numbers of repeaters deployed in rural sectors and the aggregate noise contribution from repeaters in these rural sectors to the noise floor of the mobile phone base station receiver could be similar to the aggregate noise contribution from repeaters in urban sectors.
- Second, it would be very difficult to enforce the use of different technical requirements in urban and rural areas and we currently have the same regulations in both urban and rural areas for all other licence exempt device categories. The sole exception to this is licence exempt television white-space (TVWS) devices, however these devices must provide geo-location data to a central database before being allowed to transmit.

3.106 For all these reasons, and those in annex A3, the gain control requirements we have decided to adopt mean, in our judgment, that use of mobile phone repeaters, in line with our technical requirements, is not likely to involve undue interference or have an adverse effect on the technical quality of service.

### **One respondent sought clarity about the total in-building licence exempt repeater gain limit whilst another believed it was set too high**

3.107 BT/EE observed that, in our proposed technical requirements, the 100 dB gain limit for in-building licence exempt repeaters applied only to the active part of the repeater, the amplifier, but that the overall system gain could be much higher when the antenna gain of both the repeater and the donor base station were taken into account. VSCL believed that a maximum gain of 100 dB might be unrealistically high and that 60 to 70 dB gain would be

more than sufficient in most cases, whilst BT/EE considered an overall maximum gain limit of 70 to 80 dB should be set in our technical requirements.

### **Our response**

- 3.108 We have reviewed the 100 dB maximum gain limit. We recognise that the proposal set out in the April 2017 consultation could be seen as ambiguous as to whether it is intended as a system gain or should be applied just to the amplifier in isolation.
- 3.109 To remove the ambiguity, we will modify the requirement to specify that it is a maximum system gain limit for the mobile phone repeater, i.e. inclusive of repeater amplifier gain, repeater antenna gain and repeater cabling losses. We note that this maximum gain limit is unlikely to be reached in most circumstances because the gain control algorithm, “BSCL – 30 dB”, will be the greater constraint. This means that any mobile phone repeater operating at its full system gain of 100 dB will only do so under conditions where it will not cause undue interference to mobile networks. The 100 dB limit on maximum system gain is intended as a “backstop” to prevent any unintended consequences which might result from mobile phone repeaters with extremely high system gain, greater than 100 dB.
- 3.110 We consider that the 100 dB system gain upper limit for indoor mobile phone repeaters will not be overly restrictive. The PA Report found that typical indoor mobile phone repeaters might have a gain of around 55-75 dB, but that newer, smart repeaters with advanced gain control algorithms may achieve system gains of up to 100 dB.<sup>38</sup>
- 3.111 In further correspondence, Nextivity gave an example of a scenario where a gain of 100 dB might be required. It considered a building where the mobile signal outside was -90 dBm which would be representative of a building at the edge of a mobile cell. In this scenario, it noted that that 100 dB of gain would be required for the maximum downlink power of 10 dBm / 5 MHz EIRP to be reached. We consider that this is a realistic scenario where a mobile phone repeater might be used and up to 100 dB of system gain is appropriate.

## **Issues specific to in-vehicle mobile phone repeaters**

### **Some respondents proposed different gain limits for in-vehicle licence exempt repeaters**

- 3.112 VSCL were concerned that the proposed gain limits of 21 dB above 1 GHz and 15 dB below 1 GHz for in-vehicle licence exempt repeaters may need to be increased to 30 dB to provide a useful gain for cradle-mounted mobile devices. It also recommended considering a gain of 45-50 dB so that mobile devices freely roaming within the vehicle but not in the cradle could also benefit from improved coverage.
- 3.113 Quantel emphasised that the gain should be sufficient so that the in-vehicle user receives a “boosted signal” which is stronger than that outside of the vehicle. It explained that a user

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<sup>38</sup> Page 19, “An assessment of the effects of repeaters on mobile networks”, PA Consulting, 17 November 2015, <https://www.ofcom.org.uk/research-and-data/technology/telecoms/effects-of-repeaters-on-mobile-networks>

might expect a better connection strength when using a licence exempt mobile phone repeater rather than just the signal outside repeated.

- 3.114 BT/EE said that it expected the gain of in-vehicle licence exempt mobile phone repeaters to be controlled by a feedback mechanism which can detect the signal loss passing through the vehicle and only compensates for this. It observed that such a feedback loop controlling the gain would mean that the maximum power limits for in-vehicle licence exempt repeaters would rarely be reached.

### **Ofcom's response**

- 3.115 Our decision is that the gain limits we proposed are appropriate for in-vehicle licence exempt repeaters. The gain for in-vehicle licence exempt repeaters is for overcoming the cabling and air-gap coupling losses between the cradle and the mobile device, and not the loss associated with the vehicle bodywork. The vehicle loss is overcome by the cabling which runs between the external antenna outside the vehicle and the cradle inside.
- 3.116 A higher gain limit would not offer users a "boosted signal" because repeaters amplify both the wanted signal as well as noise, so a repeater cannot offer a higher signal-to-noise ratio than that received at the outside of the vehicle. However, a mobile device using an in-vehicle licence exempt mobile phone repeater may, in practice, receive a slightly better signal than just using a mobile device outside of the vehicle because the external antenna mounted on the vehicle is likely to be more efficient and be oriented with the correct polarisation when compared with a typical mobile device antenna.
- 3.117 We understand that a gain of 45-50 dB could allow for devices in a vehicle to use the in-vehicle licence exempt repeater even when they are not in a cradle. However, we consider the interference risks associated with this mode of operation to be too high because the uplink and downlink will be within one to two meters of each other and so could have low RF isolation from one another. Without anti-oscillation measures, higher gains coupled with low isolation between the uplink and downlink could increase the risk of the repeater experiencing increased positive feedback, going into oscillation and causing undue interference to, or an adverse effect on the technical quality of service of, the mobile network. We note that the mobile phone in the cradle could be put into Wi-Fi hotspot mode to provide mobile data services to passengers using devices in the vehicle.



## 4. Our decision to exempt indoor and in-vehicle mobile phone repeaters

- 4.1 As stated in section 2 above, Ofcom has an obligation to make licence exemption regulations in respect of apparatus of particular descriptions where the use of the apparatus is not likely to:
- involve undue interference with wireless telegraphy;
  - have an adverse effect on technical quality of service;
  - lead to inefficient use of the part of the electromagnetic spectrum available for wireless telegraphy; or
  - endanger safety of life.
- 4.2 Such an exemption may be subject to such terms, provisions and limitations as are objectively justified, not unduly discriminatory, proportionate and transparent. These may be terms, provisions and limitations meeting those tests which are appropriate to secure that the use of a repeater is not likely to have the effects described in the previous paragraph. Ofcom must authorise the use of consumer installed repeaters of particular descriptions on a licence exempt basis if they satisfy such terms, provisions and limitations as are appropriate.
- 4.3 Having carefully considered the responses to the April 2017 consultation, we are satisfied that the use of mobile phone repeaters meeting a set of technical requirements largely based on those set out in that consultation will not be likely to have the effects described in paragraph 4.1 above. Our decision, therefore, is to authorise their use on a licence exempt basis.
- 4.4 Considering some of the specific issues raised in the responses, we have also decided to make a number of adjustments to the technical requirements we originally proposed. These adjustments, summarised below, are necessary to avoid ambiguity in the requirements and to ensure that use of mobile phone repeaters operating under the licence exemption are not likely to have the relevant negative effects. The rationale for these adjustments are discussed in detail in Section 3 above.

**Removing “intended for” from usage restrictions** We make it clear in our technical requirements that transmissions on downlink frequencies shall only be authorised for the use of mobile phone repeaters indoors and in-vehicle and remove the wording “*intended for*” to avoid ambiguity.

**Explicit definition of radiated power limits** We will amend the technical requirements to make the radiated limits explicit with a TRP limit for in-vehicle repeaters and an EIRP limit for indoor repeaters. This aligns with how we currently define radiated power limits for existing

mobile phone user equipment (e.g. TRP for mobile and nomadic devices and EIRP for fixed/installed devices).

**Limiting GSM repeater power levels to that of GSM handsets** We will limit mobile phone repeaters, when re-transmitting GSM uplink signals in the 900 MHz band, to a maximum power of 2 Watts and in the 1800 MHz band to a maximum power of 1 Watt.<sup>39</sup> The higher power GSM terminal classes were originally intended for vehicular use, and they are not supported in modern hand held devices.

**We will not include the 2.6 GHz band in the licence exemption at this time** We are currently in discussions with the MOD and the CAA with respect to mobile phone repeaters and the 2.6 GHz coordination procedure. For the time being, the 2.6 GHz band will be excluded from the licence exemption pending further consideration of the matter with them. Provided we can satisfactorily resolve those matters, we will include 2.6 GHz in the exemption regulations at the next opportunity.

**We will adjust the downlink power limit to facilitate use of wider channels** We will specify the downlink power limit as 10 dBm / 5 MHz, capped at 17 dBm. This limit will pose no greater risk of undue interference whilst allowing for adequate amplification of wider channels, such as 20 MHz LTE carriers.

**We will provide a specific system gain limit** We will clarify that the 100 dB gain limit for indoor mobile phone repeaters is a maximum system gain limit.

**We will include a maximum noise figure in our technical requirements** We will include a maximum noise figure of 7 dB in our technical requirements to ensure that undue interference or other adverse effects on technical quality of service are not likely.

4.5 The full technical requirements that will apply to mobile phone repeaters for use on a licence exempt basis, indoor and in-vehicle, are set out in the Interface Requirements in annex A3. A mobile phone repeater meeting all these requirements would be likely to have a similar overall effect, in terms of interference and technical effects, to a licence-exempt mobile phone handset. The use of such handsets is not likely to involve undue interference or adverse effects on technical quality of service on mobile networks. Neither, accordingly, would use of an exemption-compliant repeater.

4.6 Making a licence exemption subject to those technical requirements is, in our judgment, consistent with our duties under the 2003 Act and the WT Act. It is likely to encourage the development of a retail market for lawful consumer-installed mobile phone repeaters. This will provide coverage solutions for consumers who need them, without causing harmful effects on other spectrum users. It will help reduce the likelihood that consumers

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<sup>39</sup> GSM900 classes 3 & 4 and GSM1800 (DCS) classes 1&2 , see TS.02.06 <https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=32>

purchase unauthorised (and unlawful) repeaters which do cause such harm, and so reduce the market for such devices.

4.7 In those ways, the exemption will help secure optimal use of the spectrum. It will also help encourage investment and innovation, and promote competition, in relevant markets, as well as furthering the different needs and interests, so far as the use of the electromagnetic spectrum for wireless telegraphy is concerned, of all persons who may wish to make use of it in the United Kingdom, including those in rural areas (where mobile coverage is often less).

4.8 The technical requirements are also consistent with section 8(4) of the WT Act. They will comprise terms, provisions and limitations of a licence exemption that, for the reasons set out in detail in section 3 above, are:

- **objectively justified** in that they address risks of undue interference and/or adverse effects on the technical quality of service that would otherwise arise from the use of consumer-installed repeaters;
- **not unduly discriminatory** against particular persons or against a particular description of persons in that they apply to all users of relevant repeaters (and, indirectly, to all manufacturers and sellers);
- **proportionate** to what they are intended to achieve, in that they are necessary to ensure that use of the relevant repeaters is not likely to have relevant adverse effects; and
- **transparent** in relation to what they are intended to achieve, in that they are described and explained in this document and would be specified in the relevant interface requirements and exemption regulations.

# A1. List of non-confidential respondents

- Alan Rankin (Individual)
- BT/EE
- Caterpillar
- H3G
- MOD
- NATS
- NET Coverage Solutions Ltd
- Nextivity
- O2
- Peter Oswald (Individual)
- Quantel
- Scottish Government
- Sony
- VSCL
- Vodafone

## A2. Mobile phone repeater deployment scenarios and aggregate noise power

- A2.1 We have decided to impose technical requirements to control the amount of noise that repeaters generate so that their use is not likely to involve undue interference to, or have adverse effects on the technical quality of service of, the mobile phone network. As we noted in our April 2017 consultation, if a repeater radiates too much noise it can cause such interference or effects by raising the noise floor and desensitising the mobile phone base station receiver. This desensitisation of the mobile network can be caused by a single mobile phone repeater or the aggregate noise of several mobile phone repeaters.
- A2.2 We have taken two complimentary approaches in our technical requirements to reducing the risk of undue interference to mobile phone networks from mobile phone repeaters. First, the gain control algorithm which, together with a noise figure we have specified, will have the effect of limiting the noise radiated in any individual channel by a mobile phone repeater. Second, we have specified behaviours for mobile phone repeaters to reduce the number that are simultaneously amplifying a given channel. The overall effect, in our judgment, is that the use of repeaters meeting our technical requirements is not likely to have the effects proscribed by section 8(4) of the WT Act.

### Repeater gain is limited by the gain control algorithm: “BSCL – 30 dB”

- A2.3 Mobile phone repeaters will amplify both the wanted signal and in-band noise. In-band noise is a common problem for all radio devices and, in most circumstances, the dominant source will be the thermal noise generated by components in the radio.
- A2.4 We have decided to control the thermal noise that can be generated by a mobile phone repeater by setting a maximum noise figure of 7 dB in our technical requirements. This figure is consistent with assumptions for mobile phone base station receiver sensitivity and we discuss this in more detail in paragraph 3.63.
- A2.5 We control the amplification of this in-band noise in our technical regulations by limiting the gain of the mobile phone repeater to be a maximum of 30 dB below the coupling loss between the base station and the repeater, “BSCL – 30 dB”. This ensures that any noise arriving at the mobile phone base station receiver from any mobile phone repeater is at least 30 dB below the noise floor of the mobile phone base station receiver. This takes into account:

<i>Noise rise in the mobile network limited to 0.5 dB</i>	-10 dB	The target I/N <sup>40</sup> at the mobile phone base station receiver is -10 dB which means that the noise rise in the mobile network base station will not exceed 0.5 dB.
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<sup>40</sup> I/N: Interference to noise ratio

<i>Aggregate noise from 50 repeaters per carrier</i>	-17 dB	By building in an additional 17 dB margin, this allows for up to 50 mobile phone repeaters to amplify each individual carrier in a sector without exceeding the target I/N threshold. We discuss why we consider that 50 mobile phone repeaters attached to a carrier in a sector is a reasonable assumption later in this annex.
<i>Headroom for other effects</i>	-3 dB	These effects might include amplifier overdriving, when a handset is briefly held too close to a repeater, for example.
<i>TOTAL</i>	-30 dB	

A2.6 We have also included a “backstop” overall maximum system gain limit of 100 dB to avoid any unintended consequences from extremely high gain repeaters.

### **We have limited the number of mobile phone repeaters that are simultaneously amplifying an individual carrier in a sector**

A2.7 The second approach we have taken in our technical requirements to reduce the noise radiated by mobile phone repeaters is to reduce the number that are simultaneously amplifying a given channel. This is achieved through three main mechanisms which combine to reduce the number of repeaters that are amplifying a given carrier:

- |   |   |   |
|---|---|---|
| <i>No wideband amplification permitted</i>            | 1 | Mobile phone repeaters cannot amplify all the carriers in a band but must amplify each carrier separately, applying the gain control equation to each carrier separately.   |
| <i>No amplification of multiple MNO carriers</i>      | 2 | Mobile phone repeaters can only amplify the carriers of a single MNO at any one time which the user selects during setup.   |
| <i>Repeaters must go into standby after 5 minutes</i> | 3 | The repeater will go into standby mode when not used for 5 minutes and so is not active when it is not needed. For example, the repeater will go into standby mode when the members of a household have left with their mobile devices. |

A2.8 Combining these factors together, we have estimated the total number of repeaters that could be tolerated in a sector to be approximately 1000 as shown below in Figure A3.1. We consider that we have made some conservative assumptions and we have additionally considered a very conservative case to fully test our assumptions.

A2.9 To estimate the number of carriers per band, we assumed a future scenario where all the MNOs have refarmed their spectrum to support a single LTE carrier for each MNO in each mobile band (800, 900, 1800 and 2100). This is very conservative because it represents the fewest number of carriers across the bands whereas, in practice, we anticipate that MNOs will continue to use 2G and 3G carriers for some time to support legacy devices and so

MNOs will support more than one carrier per band. We have excluded the 2.6 GHz band because we will not be including the band in the licence exemption as discussed in paragraph 3.54.

**Figure A3.1: Calculation of the total tolerable repeaters per sector**

Mitigation factor	Conservative		Very Conservative	
	multiplier	total	multiplier	total
Maximum of 50 repeaters per carrier	-	50	-	50
Assume 4 carriers at 800 MHz; 2 at 900 MHz; 4 at 1800; 4 at 2100. Exclude 2100 for very conservative case. Assume equal likelihood of channel attachment.	×14	700	×10	500
Assume 70% of repeaters active during the busy hour and the remaining 30% are in standby mode	×1.4	1000	×1.4	714
Assume one channel active per repeater; two for the very conservative case (e.g. could represent carrier aggregation or simultaneous use of two carriers independently)	×1	1000	×0.5	357
<b>Total tolerable repeaters per sector</b>		<b>1000</b>		<b>357</b>

### **It is very unlikely that aggregate noise radiated by repeaters will cause a noise rise in the mobile network of more than 0.5 dB**

- A2.10 We examined the number of premises in sectors to understand the penetration rates that would be necessary for over 1000 repeaters to be used in a sector. Across the UK, there might typically be 667 premises in a sector because there are 30 million premises in the UK and each MNO has around 15 thousand macro sites, typically split into three sectors. However, we recognise that this can vary significantly from sector to sector so we also investigated a rural scenario and the tower block scenario as mentioned by BT/EE in its response to our April 2017 consultation.
- A2.11 We set out our results in Figure A2.2 below and we show that for a typical UK sector there would have to be an extraordinarily high penetration of repeaters, more than one in every premise, for the number of repeaters in a sector to exceed 1000. Even for the very conservative case, more than one in two premises would need to install a repeater and we do not consider this to be realistic.

- A2.12 Indoor mobile phone repeaters “get the outside signal indoors” and so will be of greatest use to those users in premises who have outdoor coverage, but no indoor coverage. Our most recent Connected Nations report showed that around 5 to 10% of premises are in that position.<sup>41</sup> We consider that these premises are those most likely to benefit from a mobile phone repeater and users in these premises may decide to install one. However, users in these premises may also use alternative indoor solutions such as femtocells and Wi-Fi and so not all of these users in such premises will install indoor mobile phone repeaters.
- A2.13 Turning to Figure A2.2, we can see that the mobile phone repeater penetration rate would have to be very high even in very extreme scenarios including very large rural sectors (e.g. Watton) and ultra-dense urban sectors containing many tower blocks (e.g. Jewellery Quarter, Birmingham). We therefore do not consider it realistic that the aggregate noise radiated by mobile phone repeaters will cause a noise rise of greater than 0.5 dB in mobile networks.

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<sup>41</sup> Figures 18 and 19, §5 “Mobile voice and data services”, Connected Nations 2016, Ofcom, 16 December 2016, [https://www.ofcom.org.uk/\\_data/assets/pdf\\_file/0037/95896/CN16-05.pdf](https://www.ofcom.org.uk/_data/assets/pdf_file/0037/95896/CN16-05.pdf)



**Figure A2.2: Repeater deployment scenarios and the maximum mobile phone repeater penetration rates necessary to limit noise rise in the mobile network to less than 0.5 dB**

Location	Scenario	Cell Radius	Premises in the cell	Premises per sector <sup>[a]</sup>	Max penetration rate (cons.) <sup>[b]</sup>	Max penetration rate (v. cons.) <sup>[c]</sup>
Typical UK	UK-wide average	-	2000	667	150%	54%
Glamis Scotland	Cons. Rural <i>Few villages</i>	7 km	868	289	346%	103%
Watton Norfolk	V. Cons. Rural <i>Lots of villages</i>	7 km	7701	2567	39%	14%
Paddington London	Cons. Urban <i>Tower Blocks</i>	250 m	3731	1244	80%	29%
Jewellery Quarter Birmingham	V. Cons. Urban <i>Tower Blocks</i>	1 km	9687	3229	31%	11%

[a] Assuming three sectors per cell

[b] The percentage of premises in each sector which would have to install a repeater for the total number of repeaters in the sector to exceed 1000, as calculated using our conservative assumptions in Figure A3.1.

[c] The same as for [b], but using the very conservative values from Figure A3.1 to calculate the percentage of premises in each sector which would have to install a repeater for the total number of repeaters in the sector to exceed 357.

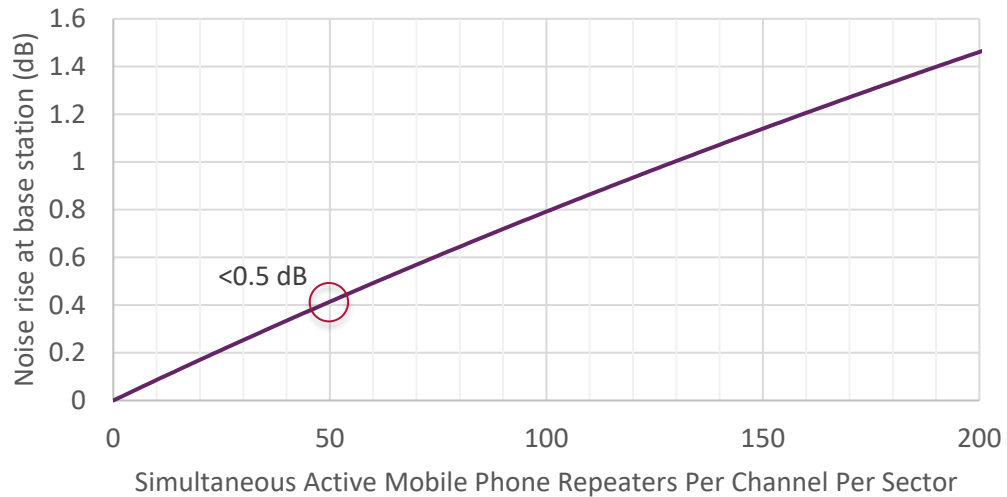
### **In the unlikely case where more than 50 repeaters amplify an individual carrier in a sector the noise rise in the mobile network will remain low**

A2.14 In its response to our April 2017 consultation, BT/EE requested a sensitivity analysis to determine how sensitive the rise in noise in the mobile phone base station receiver would be to changes in the number of simultaneous users. We give our sensitivity analysis below in Figure A3.3 based on the “BSCL – 30 dB” equation we set out in the April 2017 consultation and assuming all the additional 3 dB margin has been used.

A2.15 Our analysis shows that the noise rise is relatively insensitive to the number of simultaneous active mobile phone repeaters. For example, over 130 simultaneous active users would need to attach to a single carrier for the noise rise in the mobile phone base station receiver to exceed 1 dB, even when considering that the additional 3 dB protection

margin has been fully used. The impact of this would be to slightly desensitise the mobile phone base station on that carrier, consequently slightly reducing the sector size and slightly reducing uplink throughput on that carrier. However, as we say above, we think that more than 50 repeaters attaching simultaneously to a given carrier is very unlikely to occur in practice.

**Figure A3.3: Sensitivity analysis of the aggregate noise rise at the mobile base station plotted against the number of simultaneous active mobile phone repeaters in the sector**



**We therefore consider the conditions in our technical requirements are sufficient to prevent undue interference to mobile networks**

- A2.16 Our technical requirements for mobile phone repeaters limit the noise rise in mobile networks by setting a gain control equation and establishing rules which reduce the number of repeaters which will simultaneously amplify an individual carrier at any one time. We examined typical scenarios as well as more extreme scenarios including large rural macrocells and ultra-dense urban sectors containing tower blocks and found that even in these scenarios, the number of repeaters that might be deployed would be unlikely to cause more than a 0.5 dB noise rise in the mobile phone base station receiver.
- A2.17 Putting the point another way, the technical requirements we have decided to impose, assuming the use of 50 repeaters to amplify an individual carrier, would allow, in effect, for 1000 repeaters being used in a sector without being likely to cause the negative effects proscribed by section 8(4) of the WT Act. For the reasons explained, that level of use, and those effects, are not likely to occur.

## A3. IRs

A3.1 A copy of the draft interface requirement can be found at [https://www.ofcom.org.uk/data/assets/pdf\\_file/0018/107253/DRAFT-IR\\_mobile-repeaters.pdf](https://www.ofcom.org.uk/data/assets/pdf_file/0018/107253/DRAFT-IR_mobile-repeaters.pdf). The document is currently going through the European Union notification process. A summary of the draft technical tables is listed below.

IR2102.1: Minimum requirements for the use of: Static Mobile Phone Repeaters, for Indoor Use		
Mandatory (1-11)		
1	Radiocommunication Service	Mobile
2	Application	Static mobile phone repeaters for indoor use
3	Frequency band	<p><b>800</b> 791-721 MHz (Downlink) 832-862 MHz (Uplink)</p> <p><b>900</b> 880-915 MHz (Uplink) 925-960 MHz (Downlink)</p> <p><b>1800</b> 1710-1785 MHz (Uplink) 1805-1880 MHz (Downlink)</p> <p><b>2100</b> 1920-1980 MHz (Uplink) 2110-2170 MHz (Downlink)</p>
4	Channelling	Not specified
5	Modulation/Occupied bandwidth	Not specified
6	Direction/Separation	Repeater transmit/receive
7	Transmit power/Power density	See Table A1
8	Channel access and occupation rules	<p><b>Transmit Gain Control</b></p> <p>The uplink and downlink system gain in dB of a repeater, referenced to its input and output ports, shall not exceed BSCL-30, where BSCL (base station coupling loss) is the path loss between the base station and the repeater. Where BSCL cannot be determined, the repeater must not transmit</p> <p>The uplink and downlink system gain of a repeater shall not exceed 100 dB.</p>

		<p>The apparatus shall determine the value of BSCL by calculating the difference between the carrier power received at the repeater and the carrier power transmitted from the base station. The carrier power transmitted by the base station may be determined from the system information messages sent by the base station on its control channels.</p>
		<p><b>Automatic Standby</b></p> <p>When the repeater is no longer serving an active device connection it must, after no more than 5 minutes, reduce any uplink noise power to no more than <math>-70</math> dBm/MHz EIRP.</p>
		<p><b>Anti-Oscillation</b></p> <p>Repeaters must detect and mitigate (i.e. by automatic gain reduction or shut down) any oscillations in uplink and downlink bands. Oscillation detection and mitigation must occur automatically within:</p> <ul style="list-style-type: none"> <li>• 0.3 seconds in the uplink band; and</li> <li>• 1 second in the downlink band.</li> </ul> <p>In cases where oscillation is detected, the repeater must continue this mitigation for at least one minute before restarting. After five such restarts, the repeater must not resume operation until manually reset.</p>
		<p><b>Single Operator configuration</b></p> <p>The amplified frequencies shall be limited to those licensed to a single mobile network operator.</p> <p>The equipment may be re-configured to alternate frequencies, but may only operate using frequencies licensed to a single operator when configured.</p>
		<p><b>Noise figure</b></p> <p>The repeater system noise figure shall not exceed 7 dB</p>

9	Authorisation regime	Licence Exempt
10	Additional essential requirements	Nil
11	Frequency planning assumptions	Not specified
<b>Informative (12-15)</b>		
12	Planned changes	Nil
13	Reference	EN 303 609 EN 301 908-11 EN 301 908-15
14	Remarks	xxx
15	Notification Number	2xxxx/xxx/UK

**Table A1**

Band	Technology	Maximum Uplink Power	Maximum Downlink power (indoor use only)
800	Technology Neutral	23 dBm EIRP	PSD 10 dBm / 5 MHz EIRP; and Total 17 dBm EIRP
900	GSM	33 dBm EIRP	10 dBm EIRP
1800	GSM	30 dBm EIRP	10 dBm EIRP
900, 1800 & 2100	3G	24 dBm EIRP	PSD: 10 dBm / 5 MHz EIRP; and Total: 17 dBm EIRP
900 & 1800	LTE & WiMAX	23 dBm EIRP	PSD: 10 dBm / 5 MHz EIRP; and Total: 17 dBm EIRP
2100	Technology Neutral	24 dBm EIRP	PSD: 10 dBm / 5 MHz EIRP; and Total: 17 dBm EIRP
Where PSD is power spectral density			

## IR2102.2: Minimum requirements for the use of: - Low gain mobile phone repeaters for in-vehicle use

### Mandatory (1-11)

1	Radiocommunication Service	Mobile
2	Application	Low gain mobile phone repeaters for in-vehicle use; no fixed installations
3	Frequency band	<p><b>800</b> 791-721 MHz (Downlink) 832-862 MHz (Uplink)</p> <p><b>900</b> 880-915 MHz (Uplink) 925-960 MHz (Downlink)</p> <p><b>1800</b> 1710-1785 MHz (Uplink) 1805-1880 MHz (Downlink)</p> <p><b>2100</b> 1920-1980 MHz (Uplink) 2110-2170 MHz (Downlink)</p>
4	Channelling	Not specified
5	Modulation/Occupied bandwidth	Not specified
6	Direction/Separation	Repeater transmit/receive
7	Transmit power/Power density	See Table A2
8	Channel access and occupation rules	<p><b>Maximum permitted Gain</b></p> <p>In both the Uplink and the Downlink the maximum permitted gain is:</p> <ul style="list-style-type: none"> <li>• 21 dB in relevant frequency bands above 1 GHz; and</li> <li>• 15 dB in relevant frequency bands below 1 GHz.</li> </ul>
		<p><b>Automatic Standby</b></p> <p>When the repeater is no longer serving an active device connection it must, after no more than 5 minutes, reduce any uplink noise power to no more than -70 dBm/MHz TRP.</p>
9	Authorisation regime	Licence Exempt
10	Additional essential requirements	Nil
11	Frequency planning assumptions	Not specified

Informative (12-15)		
12	Planned changes	
13	Reference	EN 303 609 EN 301 908-11 EN 301 908-15
14	Remarks	
15	Notification Number	

**Table A2**

Band	Technology	Maximum Uplink Power	Maximum Downlink power (in-vehicle use only)
800	Technology Neutral	23 dBm TRP	PSD 10 dBm / 5 MHz TRP; and Total 17 dBm TRP
900	GSM	33 dBm TRP	10 dBm TRP
1800	GSM	30 dBm TRP	10 dBm TRP
900, 1800 & 2100	3G	24 dBm TRP	PSD: 10 dBm / 5 MHz TRP; and Total: 17 dBm TRP
900 & 1800	LTE & WiMAX	23 dBm TRP	PSD: 10 dBm / 5 MHz TRP; and Total: 17 dBm TRP
2100	Technology Neutral	24 dBm TRP	PSD: 10 dBm / 5 MHz TRP; and Total: 17 dBm TRP
Where PSD is power spectral density			