Improving mobile coverage

Enabling the benefits of consumer installed mobile repeaters

Summary of Call For Input responses and recommended next steps

Statement

Publication date: 18 March 2016

About this document

In this document we set out a recommended way forward for enabling consumers and businesses to benefit from the future use of mobile repeaters in improving mobile coverage where it is needed. We anticipate that the future use of these devices could play an important role, in particular in helping improve coverage inside buildings, vehicles, trains; and in more remote rural locations.

The recommended approach is based on industry stakeholders submitting to Ofcom devices whose use is not likely to involve undue interference to other mobile users. This would open the way for Ofcom to identify repeaters of particular descriptions that could be used by consumers in the UK on a licence exempt basis.

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Section 1

Executive Summary

Overview

1.1 In this document we set out the potentially important role consumer installed repeaters could play in improving coverage in particular inside buildings, vehicles and trains; and in remote rural locations.

1.2 We also highlight the challenges associated with ensuring that the use of these devices, which boost and retransmit the mobile signals, is not likely to involve adverse effects, such as causing undue interference to other spectrum users. Based on the findings of Ofcom commissioned research, we provide some high level guidance on the types of interference management approaches likely to be required to help ensure that consumer installed repeaters are not likely to have these adverse effects on other users.

1.3 Finally, given the mobile coverage benefits the future use of mobile repeaters could provide to consumers, we set out that Ofcom will authorise the future use, on a licence exempt basis, of repeater devices of particular descriptions that can be shown are not likely to:

1.3.1 involve undue interference to other spectrum users; or

1.3.2 have an adverse effect on technical quality of service.

There is an increasing demand for mobile services to work wherever we are

1.4 Mobile services have become an increasingly important part of our daily lives be it: keeping in contact with friends and family, using online services or conducting business. With this has come a growing expectation that mobile services will reliably work wherever we are.

1.5 Whilst mobile coverage continues to improve with investment in new mobile sites and better mobile technology there are a particular set of challenges associated with achieving good indoor, on train and in-vehicle coverage. This is because mobile signal levels reduce as they enter buildings, trains and vehicles. In addition, these challenges are set to become greater with the increasing use of metal loaded thermal insulation construction materials and glass, which further reduce mobile signal levels.

1.6 There are also challenges associated with achieving good mobile coverage in sparsely populated rural areas where mobile base stations are generally more distant from the user and provide weaker and hence less reliable mobile signals.

1.7 Based on responses to our Call for Input[1] and our own analysis, we set out a recommended approach in this document aimed at enabling consumers and local communities to improve mobile coverage for themselves in the locations that are of importance to them, using self-installed mobile repeaters. In particular, the proposed approach seeks to allow the coverage benefits of these types of repeaters to be

[1] Mobile Coverage Enhancers and their use in licensed spectrum

achieved without being likely to cause undue interference or other adverse effects on the technical quality of service to other users.

Consumer installed repeaters could play a potentially important role in helping improve coverage

1.8 There are a number of ongoing initiatives aimed at helping improve mobile coverage, including:

1.8.1 The inclusion of coverage obligations in mobile operator licences;

1.8.2 Enabling the release of additional lower frequency UHF spectrum for use by mobile services, which has good wide area and indoor propagation characteristics[2];

1.8.3 Making information available to consumers on which mobile operator is likely to provide the best coverage in the locations that are of most importance to them. This helps consumers to make a better choice of operator and also helps encourage mobile operators to further compete in providing better coverage.

1.9 However, it is unlikely that these initiatives alone will provide a complete solution to ensuring mobile coverage is available everywhere it is needed. In particular, a range of different technical solutions are helping improve coverage inside buildings and in other difficult to reach locations. These solutions include mobile operator controlled repeaters, Femtocells, Picocells, Distributed Antenna Systems (DAS) and Voice and data over Wi-Fi (VoWiFi).

1.10 Figure 1 shows the high level features of these different approaches, which are compared with consumer installed repeaters. For the purpose of this document we use the term consumer installed repeater to refer to those devices that can be purchased and installed by consumers or by car and train manufactures (i.e. without the need to get them through a mobile operator). From figure 1 it can be seen that consumer installed repeaters can provide an attractive solution in situations where: cost, multi-operator support, ease and speed of installation, and the absence of a fixed broadband backhaul connection are important considerations. This makes consumer installed repeaters particularly well suited to:

1.10.1 *Improving coverage inside domestic and small business premises:* the low cost of consumer installed repeaters and their potential to support more than one mobile network makes them attractive proposition for use in homes and smaller sized businesses. In addition, only 78% of households currently have the fixed broadband subscription needed by most of the alternative indoor coverage improvement approaches.

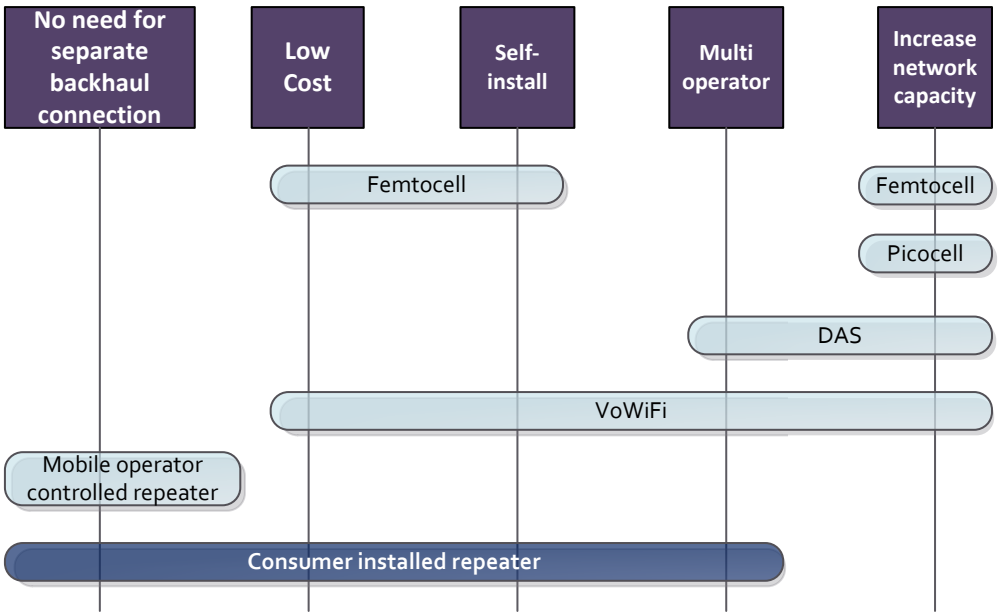
1.10.2 *Improving coverage inside vehicles and trains:* repeaters that can be installed by vehicle and train manufactures to improve in-vehicle and on trains coverage for all mobile networks make consumer installed repeaters an attractive proposition for in-vehicle and on trains use.

1.10.3 *Improving coverage in rural communities:* the ability of low cost consumer installed repeaters to be purchased and installed by local communities

[2] Future use of the 700 MHz band

makes them an attractive proposition for improving coverage in remote rural locations.

Figure 1: High level characteristics of the different coverage solutions



Potential interference to other mobile users

1.11 Consumer installed repeaters are already being purchased and installed by consumers and businesses in the UK. However, these devices have not been authorised to use spectrum in UK, and Ofcom's Spectrum Enforcement Team has found some of these devices in some locations are causing interference to other mobile users.

1.12 An Ofcom commissioned study[3] identified a wide spread in the technical operation and performance of consumer installed repeaters currently available for sale in the UK. The study also predicted that many of these devices, when used within a few hundred meters of mobile base stations, have the potential to reduce mobile network performance for other users.

1.13 The study also went on to identify a number of high level interference avoidance measures, which if supported by consumer installed repeaters, are likely to help significantly reduce the likelihood of them causing undue interference (or other relevant adverse effects) to other users. These included:

1.13.1 Only amplifying the mobile channel being used by the mobile user and not all of the other mobile channels;

1.13.2 Automatically switching repeaters off when not in use or if they start to self-oscillate or malfunction;

[3] An Assessment of the Effects of Repeaters

1.13.3 Adapting the transmitter repeater power to the minimum required to make a reliable connection.

1.14 Over and above these measures, additional installation steps may be required to help ensure that repeaters are not likely to cause undue interference (or other relevant adverse effects), including a requirement for registering the location of the device on a database.

1.15 Whilst some of the consumer installed repeaters appear, in the first instance, to already support some or all the interference avoidance features listed above, we cannot be satisfied, without further detailed investigation, whether use of any of these devices[4] is not likely to involve undue interference (or have other relevant adverse effects, such as adverse effects on the technical quality of service) because:

1.15.1 The actual details of the implementation of the interference avoidance measures are likely to be material to determining whether those measures are sufficient to mean that the use of these repeaters is not likely to have those effects;

1.15.2 The need for additional controls over who can install repeaters and the need to log their location has not yet been established.

1.16 Given this, we are not able to conclude today whether any of the consumer installed mobile repeaters currently available in the UK could be used, and under what if any conditions, without being likely to have the negative effects referred to earlier. Hence, we are unable today to authorise their use on a licence exempt basis.

1.17 A number of repeater manufacturers have informed Ofcom, however, that the inclusion of the types of interference avoidance measures listed above in repeaters is unlikely to significantly increase their cost in mass production. We also note that similar interference avoidance functionality is required by the Federal Communications Commission (FCC) for mobile repeaters used in the US.

Enabling the future benefits of consumer installed repeaters

1.18 Given the above points, Ofcom is keen to develop an approach aimed at enabling the future mobile coverage benefits that consumer installed repeaters can provide without being likely to cause undue interference or other relevant adverse effects to other mobile users. We set out such an approach below.

1.19 This approach involves a recommendation that relevant stakeholders submit to Ofcom consumer installed repeaters with detailed specifications and characteristics that are not likely to have these effects. In addition, Ofcom is willing to facilitate discussions across industry stakeholders on appropriate interference avoidance measures and procedures for the installation and use of repeaters.

1.20 When presented with appropriate consumer installed repeater devices, Ofcom would be able to authorise the use, on a licence exempt basis, of repeaters having the relevant specifications and characteristics.[5] Sections 8(4) and 8(5) of the WTA 2006

[4] That is, devices of that particular description.

[5] This would be an exemption from the need for a WTA 2006 licence for the installation and use of repeaters of a particular description (i.e. any having the specifications, characteristics and conditions of installation and use we identify, as a result of the proposed process, as suitable for exemption). Any such exemption would not be specific to the repeater(s) assessed under the process nor the

of the Wireless Telegraphy set out conditions under which exemptions must be made. These include that the use of devices of a particular description is not likely to:

1.20.1 involve undue interference with wireless telegraphy;

1.20.2 have an adverse effect on technical quality of service;

1.20.3 lead to inefficient use of the part of the electromagnetic spectrum available for wireless telegraphy; or

1.20.4 endanger safety of life.

1.21 Whilst we will consider the authorisation of repeater devices having the relevant specifications and characteristics, we also recognise the benefit of establishing standardised specifications that are agreed and harmonised at an international level to help facilitate the development of a mass market for low cost consumer installed repeaters.

1.22 If repeaters were authorised for use in the UK on a licence exempt basis, it could deliver the following benefits for consumers:

1.22.1 It would create a legitimate retail market for consumer-installed mobile repeaters, allowing consumers, businesses, vehicle and trains manufacturers, and local communities to install and use low cost mobile repeater equipment to improve coverage in the locations that are of importance to them;

1.22.2 It would help reduce the likelihood that consumers unwittingly purchase unauthorised illegal repeaters which cause undue interference (or other relevant adverse effects) to other mobile users;

1.22.3 It would make it easier for consumers and businesses to improve mobile coverage in locations where the broadband backhaul connection required by alternative coverage improvement approaches cannot be easily provided, such as vehicles, trains and inside buildings with no fixed broadband subscription;

1.22.4 Unlike the alternative coverage improvement approaches, it would open the potential to enable mobile coverage to be improved for more than one mobile operator using one device.

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particular manufacturer. Neither would it amount to an approval or authorisation of the specific device (or devices of that description) for any purposes, such as an authorisation for its or their placing on the market or sale.

Section 2

Introduction

Mobile services are increasingly important to consumers, but are not available everywhere

2.1 Consumers and businesses are making an increasing use of mobile services[6]:

2.1.1 There are now over 83.7 million active mobile connections in the UK;

2.1.2 Mobile users spend on average 147 minutes each month making outbound mobile voice calls and consume on average 870MB of data each month, a 64% increase from 2014[7].

2.2 With this increasing usage has come an increasing consumer expectation that mobile services will reliably work wherever we are, including difficult to reach locations inside buildings, vehicles, trains and remote rural areas.

2.3 There is a number of ongoing initiatives aimed improving mobile coverage, including the inclusion of coverage obligations in mobile licences to help encourage further investment in new mobile infrastructure. In the longer term Ofcom is planning to make available more sub 1 GHz spectrum in the 700 MHz band for mobile use, which has good wide area and indoor propagation characteristics. Despite these ongoing initiatives, however, challenges remain in achieving good coverage; in particular in the following locations:

2.3.1 *Rural areas:* Mobile coverage is generally lower in rural than urban areas. For example, whilst it is possible to make a voice call outside 99% of urban premises, this falls to 72% in rural areas. One of the main reasons for this is that mobile infrastructure costs per user are generally higher in remote rural areas than in urban areas.

2.3.2 *Indoor locations:* Mobile signals reduce as they pass through building walls and windows. This makes it harder to achieve good reception indoors than outdoors. For example, whilst 72% of rural households can reliably make a voice call outdoors, only 31% have reliable indoor voice call coverage. The increasing use of metallic construction materials to improve the thermal insulation performance of buildings is further increasing building losses, making indoor reception harder to achieve.

2.3.3 *Vehicles and trains:* Mobile signals levels also reduce when they pass through vehicles. The use of heat reflecting metallised glass to make it easier to control the inside temperature of vehicles is further increasing mobile signal losses, making in-vehicle reception harder to achieve. Today, in-vehicle 2G coverage by all operators is available for only 41% of A and B roads. Similar to vehicles, trains present the same challenge in terms of providing coverage on the move inside the carriages.

[6] Connected Nations 2015
[7] The Communications Market Report, August 2015,

Mobile repeaters are being used by mobile operators and consumer to improve coverage in difficult to reach locations

2.4 Mobile repeaters can help improve mobile coverage in the difficult to reach locations described above by boosting and retransmitting the available mobile signals. However, only repeaters that have been approved and operate under the direct control of mobile operators are currently authorised for use in the UK. The cost of these repeaters and need for mobile operator approval has in general limited their use to improving coverage in public areas, such as under road bridges and in railway tunnels as opposed to private use in consumers' homes and cars.

2.5 To help meet their mobile coverage needs many consumers and business have purchased and installed their own mobile repeaters, which in general provide a relatively low cost and easy to implement option for improving coverage. However, these consumer installed repeaters have not been authorised for use in the UK, and their construction and the way they operate means that their transmissions present a risk of undue interference to other spectrum users. In particular, Ofcom's Spectrum Enforcement Team has identified cases where unauthorised mobile repeaters were causing undue interference (or other adverse effects on technical quality of service) to other mobile users.

Enabling a future legitimate market for consumer installed mobile repeaters

2.6 In this document we consider the benefits and the steps required to enable the legitimate use of consumer installed repeaters in the UK, informed by stakeholder responses to our CFI and our own analysis.

2.7 **In section 3** we consider the benefits that consumer installed mobile repeaters could bring alongside other coverage improvement approaches. We conclude that consumer installed repeaters can play an important role in improving coverage in homes, small businesses, vehicles, trains and rural communities where cost, ease of installation and the lack of the need for a fixed or wireless broadband backhaul connection are often important considerations.

2.8 **In section 4** we consider the interference (and other) risks posed by consumer installed repeaters to other spectrum users. Based on the findings of Ofcom commissioned research and the cases of interference found by Ofcom's Spectrum Enforcement Team, we conclude that the consumer installed repeaters sold in the UK can, when used in some locations, cause (or are likely to cause) undue interference or adverse effects on the technical quality of service to the other mobile users. We also identify that with changes to their technical operations the risk of consumer installed repeaters causing undue interference or other adverse effects to other spectrum users can be significantly reduced. While we provide some high level guidance, we also recognise that more work needs to be done to determine whether this high level guidance will be sufficient to licence exempt repeaters in the UK.

2.9 **In section 5** we set out a recommended way forward for enabling the future legitimate use of consumer installed repeaters. This involves relevant industry stakeholders submitting to Ofcom consumer installed mobile repeaters with detailed specifications such that they are not likely to cause undue interference to, or otherwise adversely affect the technical quality of service of mobile connections for, other spectrum users. Over and above these measures, we note that additional steps such as registration may be required to ensure that such repeaters do not have these

negative effects. Ofcom would then be able to identify the characteristics, and any conditions of installation and use, required for repeaters of particular descriptions to be authorised for use in the UK on a licence exempt basis. In addition to that, we also recognise that, if standards were developed and harmonised at international level, it would enable a low cost mass market for repeaters.

Section 3

The role mobile repeaters can play in improving mobile coverage

3.1 In Ofcom's Call for Inputs (CFI) [8] we asked for stakeholders' views and evidence on the role that consumer installed mobile repeaters might play alongside other mobile coverage improvement approaches in extending and improving mobile coverage in difficult to reach locations.

3.2 In particular we asked for views and evidence on:

3.2.1 **Consumer demand:** the consumer demand for improved indoor coverage solutions and the circumstances and locations where their use would provide the greatest benefits;

3.2.2 **Technology evolution:** the current operation and likely evolution of repeaters and other alternative coverage enhancing approaches such as femtocells.

3.2.3 **Consumer utility and benefits:** the potential benefits of consumer installed repeaters compared to alternative mobile coverage improvement approaches.

Consumer installed mobile repeaters can a play a potentially important role alongside other technical approaches for improving coverage

3.3 Based on stakeholders' responses and our own research we have identified a number of different technical approaches that can be used to improve mobile coverage in difficult to reach locations:

3.3.1 *Femtocells*: These are relatively low cost low power base stations, making them well suited to smaller scale domestic and business use. However, the current generation of femtocells only improve indoor coverage for one mobile network and femtocells supplied by different operators are needed to support more than one network. We are aware of ongoing industry initiatives aimed at providing multi-operator femtocells coverage solutions, but these are not yet widely available to consumers. Furthermore femtocells require the use of a fixed broadband connection to provide a backhaul connection. In 2015, only 78% of UK households had a fixed broadband subscription.

3.3.2 *Picocells*: These are similar to femtocells but can provide wider area coverage and support higher number of simultaneous users. They are more expensive to install than Femtocells and only support one mobile network.

3.3.3 *Distributed antenna systems (DAS):* This is the most widely used technical approach for improving mobile coverage and capacity in larger sized commercial buildings. Multiple antennas distributed across the building are

[8] Mobile Coverage Enhancers and their use in licensed spectrum

used to improve coverage and capacity and are connected via cable to a central base station in the building. Some stakeholders noted that DAS is generally difficult and expensive to install in existing buildings, making it generally only a commercially viable proposition in new buildings.

3.3.4 *Voice and SMS over Wi-Fi (VoWiFi) services:* These enable Wi-Fi compliant mobile devices to benefit from Wi-Fi as well as mobile network coverage. All UK operators now support VoWiFi services. This approach requires: good Wi-Fi coverage being available, which can be problematic in larger homes and businesses, that consumers have a compatible VoWiFi handset, and access to fixed broadband backhaul connection.

3.3.5 *Mobile operator controlled repeaters*: Some stakeholders noted that some mobile operators are already making use of repeaters operating under their direct control in their networks to extend coverage to hard-to-reach public locations, such as under road bridges and in railway tunnels. They also noted that some mobile operators have made repeaters available to improve coverage in some business premises. However, mobile operators have not widely made repeaters available to domestic users.

3.3.6 Mobile operator controlled repeaters are sometimes combined with a DAS system help improve in building coverage. Unlike the in-building solutions described above, mobile operator controlled repeaters do not require a broadband connection, but they do not provide additional network capacity. Hence, this approach is more suited for use in relatively low demand locations with poor coverage, as opposed to high demand locations.

3.3.7 *Consumer controlled repeaters*: These are similar to the mobile operator controlled repeaters described above, but are bought and installed directly by the consumer. In the UK the use of spectrum by consumer installed repeaters is not currently authorised. We estimate that at least 3,000 of these unauthorised repeaters were sold in UK in 2014. As we set out in Section 4, there is a wide spread in the technical performance and operation of these unauthorised repeaters and they have the potential to cause undue interference, or adverse effects on technical quality of service, to other mobile users when used within a few hundred meters of mobile base stations. In addition, the operation of some of these devices means they do not always deliver the coverage benefits anticipated by consumers.

3.3.8 However, as can be seen from figure 2 consumer installed repeaters have the potential to provide important benefits over other alternative solutions in scenarios where: cost, ease of installation, freedom from the need to provide a fixed broadband backhaul connection and multi operator support are important considerations. As with mobile operator controlled repeaters, consumer installed mobile repeaters do not increase network capacity and are only suited to improving coverage.

Figure 2: Comparison of the different coverage solutions

	Cost	Self-install	Need for separate backhaul connection	Multi operator support	Increase network capacity
Femtocell	Low	Yes	Yes	No (multi operator not widely available)	Yes
Picocell	Medium	No	Yes	No	Yes
DAS	High	No	Yes	Yes	Yes
VoWiFi	Low	Yes	Yes	Yes	Yes
Mobile operator controlled repeater	High	No	No	No	No
Consumer installed repeater	**Low**	**Yes**	**No**	**Yes (either single or multi operator)**	**No**

3.4 Based on the high level features of consumer installed repeaters we have identified three main scenarios where they could play an important role in delivering improved mobile coverage: inside homes and buildings, in-vehicles and on trains, and in remote rural communities.

Improving indoor coverage using repeaters

3.5 Mobile signal levels reduce as they enter buildings making them more difficult to receive indoors. A range of different factors can affect the level of mobile signals available inside buildings including: the number and size of the windows, the construction materials used, the angle of arrival of the mobile signals with respect to the building, the frequency of the mobile signals, and the internal layout of the building. As a consequence, mobile coverage inside buildings is generally lower and more variable than outdoors. In addition, the challenge associated with providing good indoor coverage is increasing with an increasing use of metallic thermal insulation materials which further reduce indoor mobile signal levels.

3.6 Consumer installed repeaters can provide an attractive option for providing improved mobile coverage inside domestic and Small Office Home Office (SOHO) premises when compared to other approaches[9], in particular, in situations where costs, ease of installation, support for more than one mobile network and the lack of a need for a fixed broadband backhaul connection are important requirements. More specifically:

[9] Consumer installed repeaters can also be potentially used in larger scale buildings where increased network capacity is not required such as: multi-storey car parks, shopping centres, hotels, universities, and SMEs.

3.6.1 Whilst mobile operator supplied femtocells and picocells are being used to improve indoor coverage in some smaller sized buildings, a limitation of these approaches is that they currently only support a single mobile network, making them less attractive in situations where different mobile users in the same building want to connect to different mobile networks. This can be case in homes where different family members have different mobile device subscriptions with different mobile operators. In addition, these approaches require access to a fixed backhaul connection in the building which is not always available.

3.6.2 Whilst DAS systems are being used in larger buildings to improve coverage for more than one mobile operator their high deployment costs makes them generally unsuited to domestic and small business use.

3.6.3 Whilst VoWiFi can be used to improve indoor coverage it requires: consumers to have compatible handsets; and good indoor Wi-Fi coverage being available, which can be problematic in larger buildings or in dense urban areas where there is Wi-Fi congestion. In addition this approach requires the building to have a broadband subscription.

Consumer installed repeaters are not subject to these limitations.

Improving in-vehicle and on trains coverage using repeaters

3.7 A number of automobile manufacturers highlighted a growing need for good in-vehicle mobile reception to:

3.7.1 Provide more reliable access to mobile voice and data services;

3.7.2 Support new broadband streaming entertainment and navigation applications;

3.7.3 Support new remote vehicle diagnostic systems, which allow manufacturers and mechanics to monitor their performance for servicing purposes and/or improve the design of future vehicles.

3.8 Looking further ahead, reliable in-vehicle and on trains mobile coverage is likely to be an increasingly important part of achieving the future vision for smart cities, where smart vehicles, buildings and other structures communicate to improve traffic flow, reduce accidents and become more energy efficient.

3.9 A number of automobile manufacturers also highlighted the challenge of providing good in-vehicle coverage in vehicles fitted with metallic infrared-reflective (IRR) glazing. This glazing is being used to make it easier to control the temperature of the vehicle cabin and improve energy efficiency, but also has the undesired effect of further reducing mobile signal levels inside vehicles.

3.10 Automobile manufacturers also noted that solutions for improving in-vehicle coverage need to be able to support multiple handsets at the same time operating on different mobile networks. They also a noted a requirement for these solutions to remain operational over the lifetime of the vehicle.

3.11 The current simplest approach for improving in-vehicle coverage is to use an external mobile antenna on the vehicles to increase the level of the received mobile signals. Some mobile devices are equipped with an external antenna port, which can be connected to these external antennas. However, some mobile devices do not provide

this connectivity and this approach also requires physical modifications to the vehicle. It is also only capable of supporting one mobile device connected to the external antenna.

3.12 Some newer vehicles are being equipped with external antennas that can connect to mobile devices in the vehicle using Bluetooth. A 'remote SIM access profile' is also used to replicate the mobile device's SIM card, and any mobile device supporting this profile can benefit from improved in-vehicle coverage. However, this approach is only applicable to new vehicles and also only allows one mobile device to be connected at any given time.

3.13 We are also aware of the potential use of Wi-Fi as an emerging solution to address indoor coverage in vehicles. This solution allows the creation of a Wi-Fi hotspot within the vehicle. Our current understanding is that these solutions are primarily focused on supporting data services.

3.14 Mobile repeaters could provide a potentially attractive alternative to the approaches described above for improving in-vehicle, and on trains, coverage, in particular where support for multiple handsets and networks is required. If consumer installed repeaters capable of authorisation were available, these devices could be fitted as standard equipment by car or train manufacturers without the need for approval by mobile operators.

Improving coverage in rural areas using mobile repeaters

3.15 Mobile coverage is generally lower in rural than urban areas, reflecting the higher costs per user of providing mobile infrastructure in these areas[10]. In addition, practical deployment issues such as access to new sites and the lack of suitable backhaul options can make it difficult to deploy new mobile sites in these areas.

3.16 One option is to use Wi-Fi hotspots to provide coverage to local communities, which can be accessed using new VoWiFi technology. This approach is capable of supporting consumers with subscriptions to different mobile operators but does require broadband backhaul connection, which may be difficult to provide in some locations.

3.17 Alternatively, a consumer installed mobile repeater solution could provide an attractive alternative, were a suitable device developed and available, given it could be purchased at relatively low cost by a local community, support all mobile networks and would not require a fixed broadband backhaul connection.

Conclusion

3.27 Based on our analysis and responses to the CFI, we have concluded that mobile repeaters, when suitably developed, could play a potentially important role alongside other approaches in meeting the demand for improved mobile coverage, in particular inside domestic and smaller sized buildings, vehicles, trains and rural communities.

[10] Economic geography - An analysis of the determinants of 3G and 4G coverage in the UK

Section 4

Potential interference issues caused by mobile repeaters

4.1 In this section we consider the potential inference issues, and other adverse effects, that mobile repeaters can cause to other spectrum users and how these might be mitigated.

4.2 In their response to Ofcom's CFI, mobile operators were of the view that consumer installed repeaters do present a significant risk of causing interference. In particular, they highlighted:

4.2.1 The adverse effects that repeaters installed and operating outside their direct control could have in reducing their ability to efficiently utilise the mobile spectrum they have been licensed to use;

4.2.2 The challenges associated with locating consumer installed repeaters which are causing interference to their networks, and how this can lead to prolonged periods of interference occurring to their services until the repeaters are removed.

4.3 In contrast, repeater manufacturers were of the view that their current products do not present a risk of interference to other spectrum users. In particular, they noted that some of their products incorporate some interference avoidance features and some of them claimed that this is sufficient to enable their operation to be authorised on a licence exempt basis by Ofcom. Some repeater manufacturers highlighted that their products contain similar interference management features, such as limits on the uplink power of repeaters and oscillation control, to the repeaters authorised for use by mobile operators within their own networks.

4.4 To address concerns relating to the potential interference caused by consumer installed repeaters, some stakeholders suggested an arrangement, similar to that used in electricity and gas industry for the installation of usage meters, whereby trained third parties may install approved repeaters in agreement with, and under the strict supervision and control of, the mobile operators. This would enable operators to monitor and access the repeater if needed and guarantee that it complies with certain specifications.

There is a wide variation in operation of mobile repeaters and their likelihood of causing interference to other mobile users

4.5 Ofcom's Spectrum Enforcement Team has evidence that the use of unauthorised consumer and unauthorised third party installed repeaters made available in the UK has caused interference to wireless telegraphy or had an adverse effect on technical quality of service. Since 2009 Ofcom has investigated 494 complaints where such repeaters were likely to have been causing these effects. Typically these are characterised as reduced coverage, an inability to connect with a base station and dropped calls.

4.6 This experience is backed up by an Ofcom commissioned study[11] into the operation of commercially available repeaters in the UK which found a wide variation in their technical operation including: the mobile frequency bands supported, their transmitter power and the use of interference avoidance features, such as reducing the transmitted power to the minimum level required to make a reliable mobile connection and only amplifying and transmitting in the mobile frequencies being used.

4.7 According to the study, many of the consumer installed repeaters currently sold and used on an unauthorised basis in the UK are likely to cause undue interference to, or otherwise adversely affect the technical quality of service of mobile connections for, other mobile users. This likelihood of this interference or effect occurring was found to be dependent on the distance of the repeaters from the base stations and the interference avoidance measures they support. Repeaters operating with no interference avoidance measures and sited within a few hundred meters of a base station were found to be those most likely to cause a reduction in the performance of other mobile users' connections. Simulations found that these repeaters would cause call drop rates to exceed 1% when being used within 400m of a 2G 900MHz base station, within 290m of a 3G 900MHz base station, and 586m of a 4G 1800MHz base station.

New technical and operational features could significantly reduce the risks of consumer installed mobile repeaters causing interference to other users

4.8 The Ofcom commissioned study also considered the technical steps that could be taken to reduce the risks of consumer installed repeaters causing undue interference, or other adverse effects on technical quality of service, to other spectrum users. It identified that repeaters supporting the following features would significantly reduce the risks of causing such interference or effects:

4.8.1 Only amplifying the mobile channel being used and not the other mobile channels;

4.8.2 Automatically switching the repeater off when not in use or if the repeater starts to self-oscillate or malfunction;

4.8.3 Adapting the transmitted uplink power of the repeater to the minimum needed to make a reliable connection.

4.9 We understand that similar interference management functionality is already incorporated into the repeaters currently used by mobile operators in their own networks. We also understand that similar functionality is already required to be included in repeaters used in the US market by the FCC[12]. In the US an additional registration mechanism of consumer repeaters with service providers is in place to allow future identification of the location of the equipment, if any issue occurs.

4.10 Some repeater manufacturers have indicated that this interference management functionality could be supported at relatively low cost in mass produced consumer installed repeaters.

[11] An Assessment of the Effects of Repeaters
[12] https://www.fcc.gov/document/use-and-design-signal-boosters-report-and-order

4.11 Note that while the features above are initial high level guidelines, over and above these measures additional installation steps may be required to help ensure that repeaters do not cause undue interference (or other relevant adverse effects), including a requirement for registering the location of the device on a database.

4.12 Whilst some of the consumer installed repeaters appear on their face to already support some or all of the relevant interference avoidance features, we cannot, in light of our enforcement experience and the findings of the study described, be satisfied, without further detailed investigation, that use of any of these devices[13] is not likely to involve undue interference (or have other relevant adverse effects, such as adverse effects on the technical quality of service) because:

4.12.1 The actual details of the implementation of the interference avoidance measures are likely to be material to determining whether those measures are sufficient to mean that the use of these repeaters is not likely to have those effects;

4.12.2 The need for additional controls over who can install repeaters and the need to log their location has not yet been established.

Conclusion

4.13 Based on our analysis and stakeholder responses to our CFI we have concluded that:

4.13.1 We cannot yet be satisfied that use of the repeaters of the particular description(s) being sold directly to consumers in the UK is not likely to involve undue interference to, or have an adverse effect on technical quality of service of, mobile connections for other users.

4.13.2 With relatively low cost adjustments to their technical operation, the risk that consumer installed repeaters would cause interference or other relevant adverse effects to other mobile users can be significantly reduced.

4.13.3 We provide some high level guidance, but more work needs to be done to determine whether the identified features are sufficient not to cause any relevant adverse effect to other mobile users.

[13] That is, devices of that particular description.

Section 5

A recommended way forward for enabling the benefits of consumer installed repeaters

5.1 In section 3, we concluded that consumer installed mobile repeaters could play a potentially significant role in helping improve coverage in homes, smaller businesses, vehicles, trains and rural communities.

5.2 In section 4, we concluded that the consumer installed repeaters available for sale in the UK are likely to cause undue interference to, or otherwise adversely affect the technical quality of service of, mobile connections for other spectrum users. We also concluded that the inclusion of interference management features could significantly reduce the risk of them causing such effects, and could be included at relatively low cost. We provide some high level guidance, but more work needs to be done to determine whether this is sufficient to remove the likelihood of adverse effects to other mobile users.

5.3 Given the potential benefits that consumer installed repeaters can provide to consumers, Ofcom would like to enable their legitimate use in the UK, if this can be achieved without being likely to cause undue interference to, or otherwise adversely affect the technical quality of service for, other spectrum users.

5.4 To help achieve this, we set out a recommendation in this section that relevant industry stakeholders submit to Ofcom consumer repeaters with appropriate and detailed specifications, such that their use is not likely to involve undue interference to, or other relevant adverse effects on, other spectrum users. Over and above these measures additional procedural steps may be required to ensure that such repeaters are not likely to have these effects. This would allow Ofcom to identify the characteristics, and any conditions of installation and use, required for repeaters of particular descriptions to be authorised for use in the UK on a licence exempt basis.[14] In addition to this we also recognise the benefit of developing and agreeing compliance standards on an international basis to help create a low cost mass market for consumer installed repeaters. We invite industry stakeholders to also pursue this route in parallel.

Licence exemption of repeaters

5.5 The use of spectrum by mobile repeaters requires Ofcom's consent under a licence or an exemption. Mobile operators have been granted this consent in their spectrum licences, but consumer installed repeaters operating outside their control have not currently been authorised for use in the UK.

[14] Again, this would not be a process under which Ofcom authorises the placing on the market or sale of any specific device, nor the authorisation of the installation or use of spectrum by any specific device or manufacturer in particular. It would be a process by which we identify the specifications, characteristics and conditions required for repeaters of a particular description to be installed and used under a WTA licence exemption, and all meeting that description, from any manufacturer, would benefit from the exemption.

5.6 Ofcom has an obligation to licence exempt devices of particular descriptions that are not likely to cause any relevant adverse effect to other users of the licensed spectrum. More specifically, we must authorise the use of consumer installed repeaters of particular descriptions on a licence exempt basis if they satisfy the appropriate Wireless Telegraphy Act (WTA) 2006 conditions. These conditions are set out in Sections 8(4) and 8(5) of the WTA 2006 and include that the use of a device of the particular description is not likely to:

5.6.1 involve undue interference with wireless telegraphy;

5.6.2 have an adverse effect on technical quality of service;

5.6.3 lead to inefficient use of the part of the electromagnetic spectrum available for wireless telegraphy; or

5.6.4 endanger safety of life.

5.7 Ofcom is not currently in a position to license exempt the use of consumer installed repeaters available for sale and use in the UK. As set out in section 4, we cannot be satisfied, on the basis of the evidence, that the use of those of the particular description(s) currently available is not likely to involve undue interference to, or otherwise affect the technical quality of service for, other spectrum users. However, we would licence exempt future consumer installed mobile repeaters of particular descriptions adhering to specifications that meet the conditions described above in Sections 8(4) and 8(5) of the WTA 2006.

High level guidance for consumer installed repeaters

5.8 Ofcom would welcome steps taken by industry stakeholders to submit devices with technical specifications for consumer installed repeaters that meet the WTA 2006 conditions described above. We would consider those submissions and whether we are satisfied the relevant conditions are met so as to enable us to authorise the licence exempt use in the UK of repeaters having the relevant specifications and characteristics. Such exemption may itself be subject to conditions.

5.9 As set out in section 4, the relevant specifications are likely to include, amongst others, the following high level interference avoidance features:

5.9.1 Only amplifying the mobile channel being used and not the other mobile channels;

5.9.2 Automatically switching off when not in use or if the repeater starts to self-oscillate or malfunction;

5.9.3 Adapting the transmitted uplink power of the repeater to the minimum needed to make a reliable connection.

5.10 We recognise that further detailed technical work will be required by industry stakeholders to develop the appropriate technical specifications. In addition to that, the approval of the use of some devices may require other measures, such as their location to be logged.

5.11 In parallel to this, we recognise the benefit of a standardised approach and also recommend that the definition of the specifications should be internationally

harmonised to create economies of scale and lower prices, for example, using the ETSI standardisation process.

5.12 As highlighted in section 4, we also recognise that, while the features above are initial high level guidelines, more work needs to be done to determine whether this high level guidance will be sufficient to licence exempt repeaters in the UK. Additional installation steps may be required, including, for example, a requirement for registering the location of the device on a database.

The licence exempt use of consumer installed repeaters could deliver significant benefits to consumers

5.13 If the licence exempt authorisation of future consumer installed repeaters were enabled, it could help deliver a number of important benefits for consumers, local communities and businesses:

5.13.1 It would help create a legitimate retail market for consumer-installed mobile repeaters, allowing consumers, businesses, vehicle and train manufacturers, and local communities to install and use low cost mobile repeater equipment to improve coverage in the locations that are of importance to them;

5.13.2 It would help reduce the likelihood that consumers unwittingly purchase unauthorised illegal repeaters which cause undue interference (or other relevant adverse effects) to other mobile users;

5.13.3 It would make it easier to improve mobile coverage in locations where the broadband backhaul connection required by alternative coverage improvement approaches cannot be easily provided, such as vehicles, trains and inside buildings with no fixed broadband subscription;

5.13.4 Unlike alternative coverage improvement approaches, it would open the potential to enable mobile coverage to be improved for more than one mobile operator using one device.