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Advice to Government on spectrum suitable for improving rail passenger access to data services

Update to 2018 rail connectivity advice

ADVICE TO GOVERNMENT

June 2020

Contents

Section

1. Overview

1.1 In 2018, Ofcom provided advice to the UK Government on spectrum bands suitable for providing trackside to train connectivity to support Wi-Fi access points or mobile small cells on passenger trains, in order to provide rail passengers with a good quality data connection on the train.[1] In response to a further request from the Government, we are providing an update to that advice to reflect various changes in the regulation and usage of spectrum bands in the past two years. We are also including a section addressing the relative merits of the 39 GHz band, a band not discussed in the 2018 advice.

1.2 In our view spectrum availability is not a barrier to improving trackside connectivity. We will continue to work with governments and industry to support their efforts to improve connectivity on the railway.

Our advice

The best spectrum options to provide trackside to train connectivity supplying backhaul for Wi-Fi access points or mobile small cells on passenger trains are likely to be the **39 GHz band** (39-40 GHz), and the **66-71 GHz band.**

These bands:

- can support large bandwidths (so could be used to support the amounts of data traffic we expect rail passengers will need by the mid-2020s and beyond); and
- are relatively lightly used (so it would be easier to find spectrum in these bands than in other bands for trackside to train connectivity without causing significant problems for existing users elsewhere).

In addition, relevant equipment to make use of these bands is already available, or is expected to become available soon.

In addition to the two bands mentioned above we continue to believe that the **26 GHz band** (24.25-27.5 GHz) is also suitable. We are currently considering our future licensing approach for this band to facilitate its use for 5G. Part of this consideration will be how we might facilitate its use for trackside to train connectivity if there is demand for this.

The other bands discussed in our 2018 advice are much less suitable. This is because we don't think they will be able to support the high data speeds that are likely to be needed to provide passengers with a good wireless connection by the mid-2020s.

1.3 Ofcom wants people and businesses to be able to get the mobile and broadband connections they need, wherever they are. Helping people access reliable Wi-Fi and mobile services – including when travelling on the UK's rail network – is an important part of this.

[1] Ofcom, *Advice to Government on improving rail passenger access to data services*, August 2018

1.4 In December 2017, the Department for Digital, Culture, Media & Sport (DCMS) asked Ofcom for advice on using trackside infrastructure to improve rail passengers' access to data services while on board trains. Specifically, DCMS asked Ofcom to assess:

a) **the passenger data requirements per train**, to provide a good Wi-Fi and mobile service to customers, both now and in the future;

b) **which spectrum solutions** had the potential to meet these passenger data requirements, today and over time; and

c) **how Ofcom could authorise** suitable spectrum bands to make them available for this purpose, including the likely timescales.

1.5 We published our advice in October 2018; in summary, we outlined in our advice that:

a) An 800-passenger train was likely to require around 120 Mbit/s to provide a good level of connectivity to passengers based on 2017 figures, but that this was liable to increase tenfold or more by 2025, to 1.2 Gbit/s or higher.[2]

b) Although there were a number of spectrum bands which could in theory support the levels of data needed to supply passengers today, considering the likely increase in demand for data by the mid-2020s, the most promising spectrum bands that could be used for a trackside connectivity solution were likely to be the upper and lower 26 GHz bands, and the 66-71 GHz band.

c) Depending on the band chosen, users might be able to operate under an existing authorisation (such as a licence exemption), or a new licence product might be required. We advised that it would be possible to do this if there was clearly demand, however it would be quicker to create new licence products for some bands (such as upper 26 GHz), while others would take longer due to the need to coordinate with existing users.

1.6 We have now been asked by DCMS and the Department for Transport (DfT) to provide an update to our 2018 advice (specifically on point b) above), to cover any changes which might affect the suitability of spectrum bands for improving online services for rail passengers and to discuss any other relevant changes.

1.7 The spectrum bands that we consider are the most suitable to provide trackside to train connectivity for rail passengers are as follows:

- **39 GHz (39-40 GHz):** This band was not included in our 2018 advice, however as explained in more detail in Section 2 below, we now believe it may be a good candidate for rail passenger connectivity. The band has relatively few current users (fixed links in the lower 500 MHz and some use by the Ministry of Defence (MOD) in the upper 500 MHz) and will benefit from the 5G equipment ecosystem being developed for the wider 37.5-43.5 GHz band, including equipment currently available for 5G applications already in use in the USA.

[2] Ofcom, *Advice to Government on improving rail passenger access to data services*, August 2018, p.2

- **66-71 GHz:** Access to this band for rail passenger connectivity applications is available today under a licence exemption approach up to a maximum power of 40 dBm EIRP and we are aware of equipment currently available in the UK for this purpose. Since we issued our original advice in 2018, CEPT Recommendation 70-03 has been amended to allow for fixed outdoor devices to operate in the band using higher powers. Access to the band for higher power applications in line with the maximum power in Recommendation 70-03 could be facilitated via a licensing approach.
- **26 GHz (24.25-27.5 GHz):** We continue to think that this band would be suitable for trackside base stations for rail connectivity, and the band was identified for IMT worldwide at the 2019 World Radio Conference (WRC-19), which will likely accelerate the development of suitable equipment. We are currently considering our future licensing approach for this band to facilitate its use for 5G. We will, if requested by parties wishing to offer rail passenger connectivity, consider how we might facilitate its use for this purpose as part of our future licencing approach.

1.8 These bands are suitable to backhaul data to and from the train; connectivity direct to individual passenger devices is expected to be provided within the carriage by other means, such Wi-Fi access points or mobile small cells.

1.9 Prospective rail passenger connectivity service providers who wish to use any of the three bands above are encouraged to contact us as soon as they are ready to discuss their requirements and we will, as necessary, identify an appropriate authorisation approach to cover their needs.

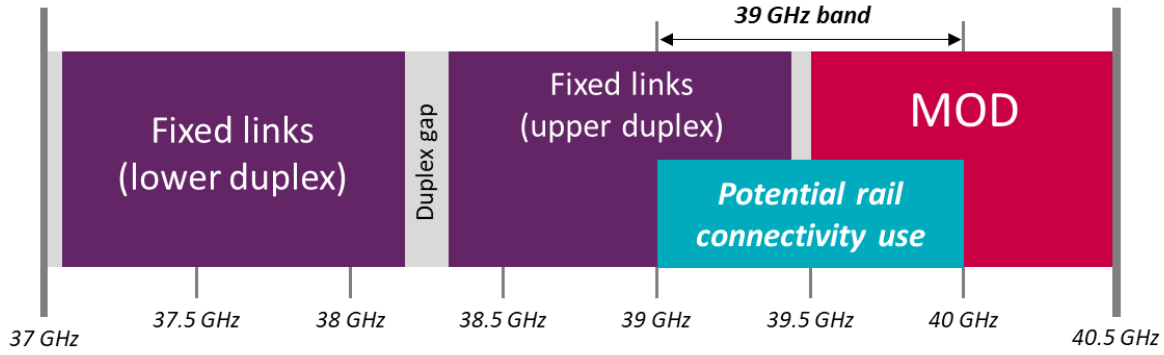
1.10 The other bands discussed in our 2018 advice are much less suitable for trackside to train connectivity. In our view, they aren't able to support the high speeds that passengers will require beyond the mid-2020s. Changes since we published our original advice in 2018, and which are relevant to these bands, are outlined in Section 3 below.

2. The 39 GHz band

Overview of the band

2.1 The spectrum between 39 and 40 GHz ("the 39 GHz band") is currently used in the UK by fixed links (up to 39.5 GHz) and to a limited extent by the Ministry of Defence (from 39.5 GHz upwards). There are also allocations in the ITU Radio Regulations in this band for the satellite data downlink (space-to-Earth) portions of both fixed and mobile satellite services, and the Earth Exploration Satellite Service (EESS), however currently we are not aware of any use of this type in the UK.

Figure 1: 39 GHz band, showing fixed links, MOD and potential rail connectivity use



2.2 The 39 GHz band overlaps with the 38 GHz fixed links band, which runs from 37 GHz up to 39.5 GHz. This is a duplex band used for bi-directional fixed links, and there are currently 2,578 duplex links in the band.

2.3 The band has multiple channel options (on the duplex spacing) for links of various bandwidths from 3.5 to 112 MHz,[3] and there are 320 duplex channels in the band in total (based on the smallest 3.5 MHz channels). These channel options overlap with each other as part of the standard channel plan arrangements.[4]

2.4 The distribution of fixed links throughout the frequencies available in the band is skewed towards particular parts of the band, as shown in the graph below. Introducing a new type of user at 39-40 GHz would therefore impact 1 GHz of spectrum[5] currently used by fixed links, as it would affect the top 120 duplex channels of the 38 GHz fixed links band, which contain a total of 465 links, approximately 18% of all links in this band. This distribution can be seen in Figure 2 below.

2.5 Fixed links are highly directional (as they are used to transfer data wirelessly between two points only) and in a higher frequency band such as 39 GHz generally have quite a short range due to the high propagation losses in this band when it rains. For the 465 current

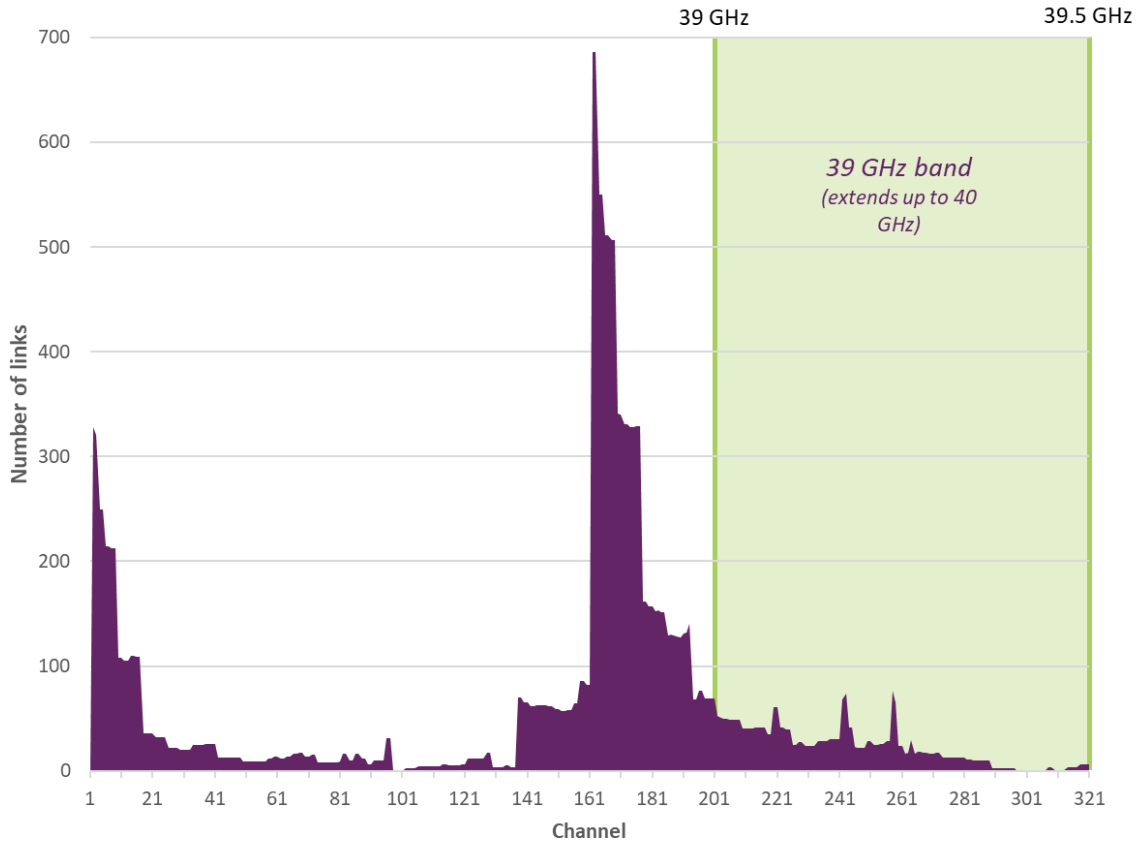
[3] The available fixed link channel bandwidths are: 3.5, 7, 14, 28, 56 and 112 MHz

[4] For example, channel 1 on the 28 MHz channel plan means the same frequencies as channels 1 and 2 for 14 MHz links, or channels 1-4 for 7 MHz links, or channels 1-8 for 3.5 MHz links, etc.

[5] Taking into account 500 MHz in the lower duplex

fixed links between 39.5-40 GHz, the longest link is just over 7.5km, the shortest is 130m and the average is 2.25km, although due to the nature of radio propagation co-ordination distances can be much larger (potentially tens of kilometres).

Figure 2: Graph showing number of links by channel in 38 GHz fixed links band (based on 3.5 MHz channel plan) as of 26 February 2020



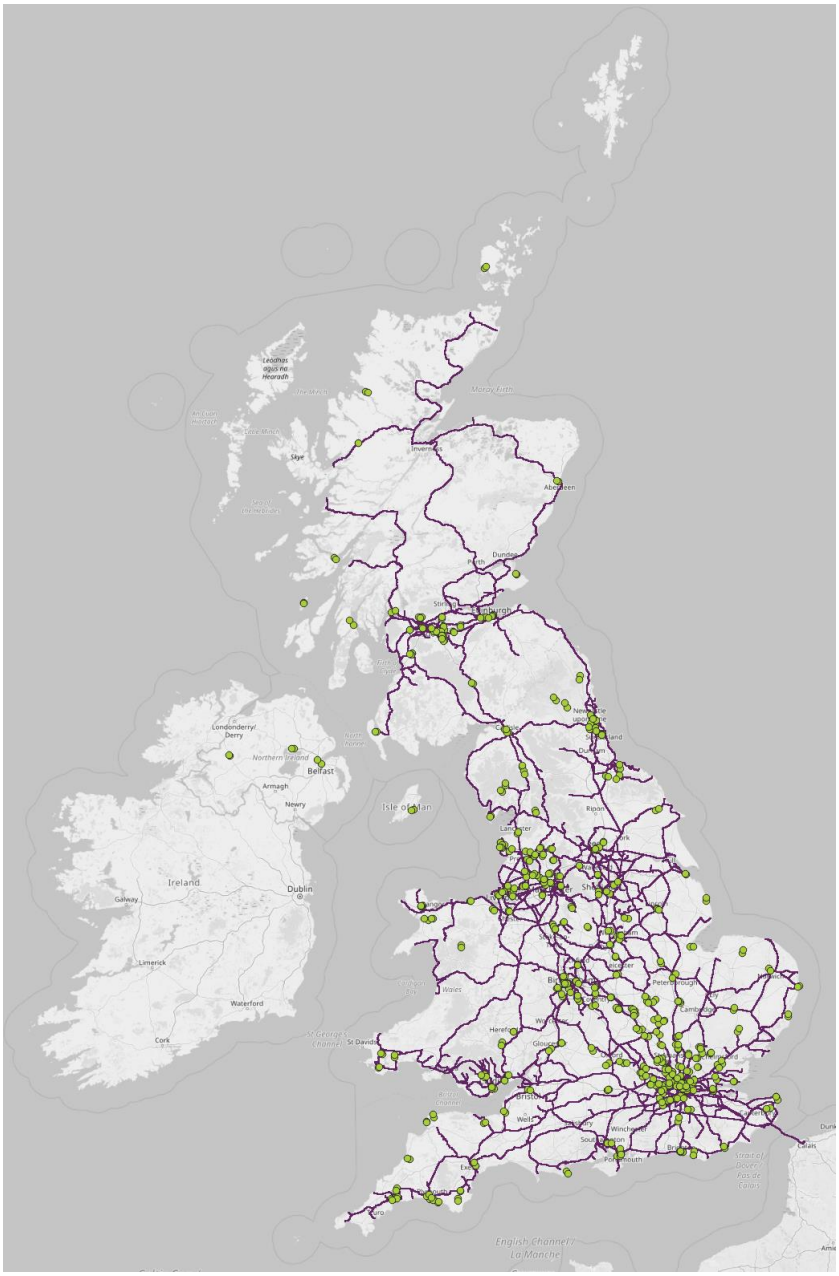
2.6 The three maps below show the 38 GHz band fixed links which operate between 39-39.5 GHz; as explained above, this represents 120 out of a total 320 channels within the band. As can be seen in the maps, these links can be found across the UK, but with particular concentrations in the areas around major cities.

2.7 The first map shows the lower 200 MHz portion of the band (from 39 to 39.2 GHz), the second shows the next 200 MHz (from 39.2 to 39.4 GHz) and the third shows the highest 100 MHz (from 39.4 to 39.5 GHz). The lower 200 MHz is the busiest, with 320 links currently using these frequencies; the middle 200 MHz has 161 links;[6] and there are 6 links currently using the highest 100 MHz.

[6] There are 22 links which use spectrum in both the 39-39.2 GHz and 39.2-39.4 GHz portions of the band. This is the case because, for example, channel 16 on the 56 MHz channel plan spans 39.158-39.214 GHz.

2.8 These maps are intended to give an overall indication of the locations of fixed links, rather than a detailed analysis of how much spectrum we expect to be available at any given point along the rail network.[7]

Figure 3: Fixed links in 39-39.2 GHz (green dots) mapped against GB rail routes (purple)



[7] Publicly available information on fixed links in this band can be found in the Wireless Telegraphy Register at this location: https://www.ofcom.org.uk/spectrum/information/spectrum-information-system-sis/spectrum-information-portal

Figure 4: Fixed links in 39.2-39.4 GHz (green dots) mapped against GB rail routes (purple)

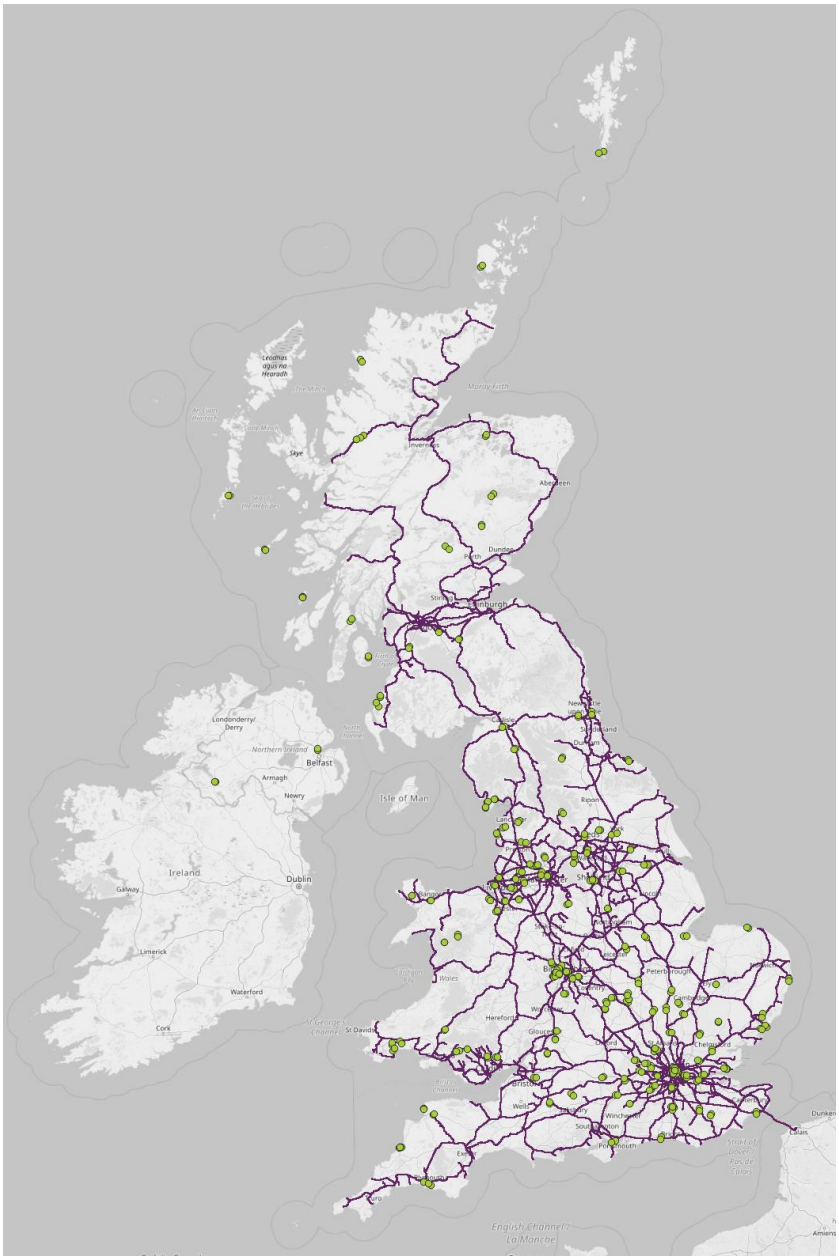
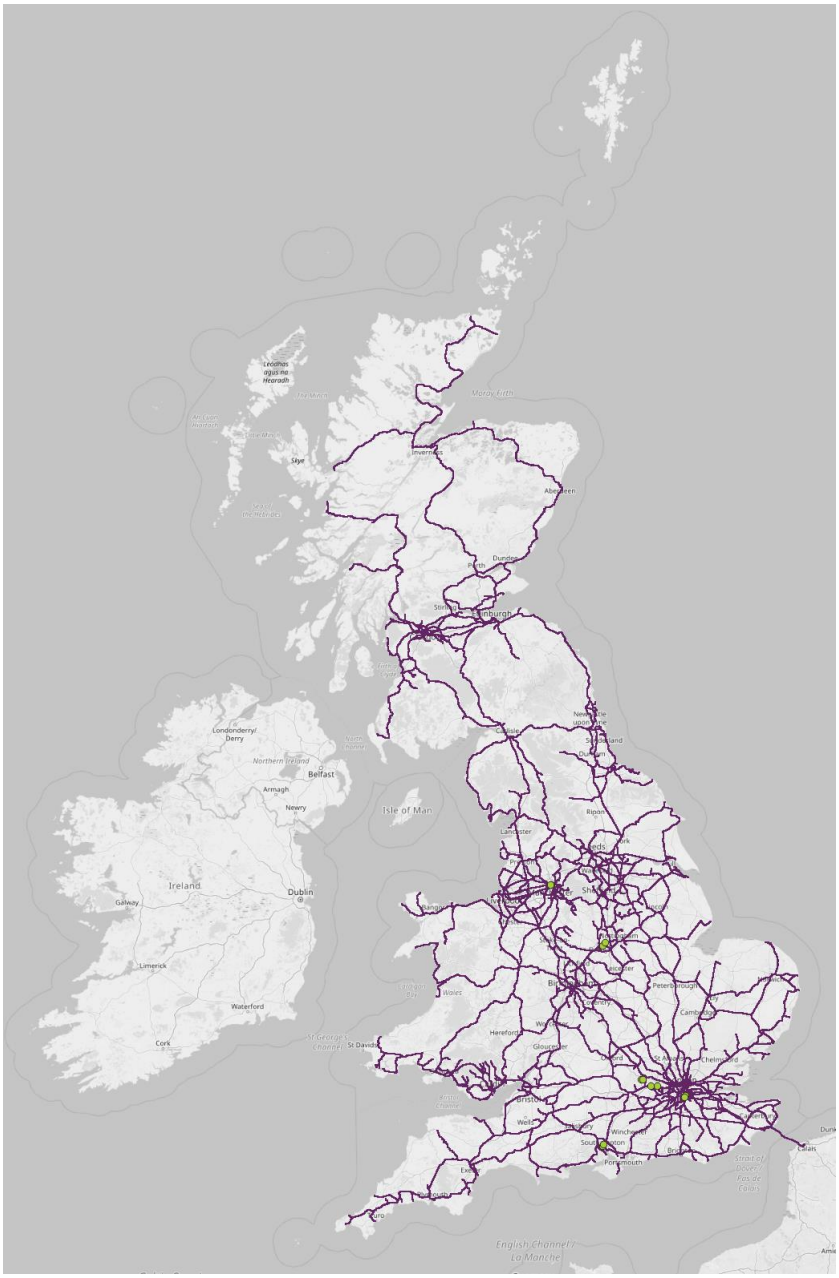


Figure 5: Fixed links in 39.4-39.5 GHz (green dots) mapped against GB rail routes (purple)



Suitability of the band for rail connectivity

2.9 There are several factors which we believe would make the 39 GHz band a promising option for trackside to train connectivity.

2.10 The 39 GHz band is part of the wider 37.5-43.5 GHz band, which was identified at the 2019 World Radio Conference (WRC-19) as a harmonised band for mobile. This means that the band is likely to benefit from a highly developed ecosystem of devices, including chipsets and base stations. As an example, we are aware that operators in the US are deploying 5G equipment in the band up to 39.5 GHz. In Europe, we expect the upper part of this wider

band (i.e. from 40.5-43.5 GHz) to become available for mobile services, meaning that use of the 39-40 GHz band won't conflict with 5G deployment in the 40.5-43.5 GHz band.

2.11 Up to 1 GHz of spectrum could potentially be made available for trackside to train connectivity in the band, subject to more detailed technical analysis necessary to ensure existing fixed links and MOD use of the band is able to continue without being affected by harmful interference. This means that this spectrum could in theory deliver download data rates of 2-4 Gbit/s per train (and these data rates are likely to improve over time as technology advances). This is likely to be enough to satisfy the levels of demand we expect to see by the mid-2020s, as outlined in Section 3 of our 2018 advice.

Work needed to licence rail connectivity use of the band

2.12 Introducing new use along the rail corridor would require some work to determine how to coordinate between the existing fixed point-to-point service and new trackside to train systems. We are not proposing clearing existing use in the band to accommodate trackside to train systems, however we think there is likely to be spectrum that can be made available for such systems to work alongside existing use.

2.13 We understand that use in the 39.5-40 GHz portion of the band by the MOD is relatively limited. However, introducing a new user in this band would require Ofcom to work with the MOD to establish appropriate protections for Defence use of the band. This could be done concurrently with any work on coordination with fixed links.

2.14 The band will remain open to new fixed links on the current first come, first served basis.

3. Update on spectrum bands discussed in 2018 advice

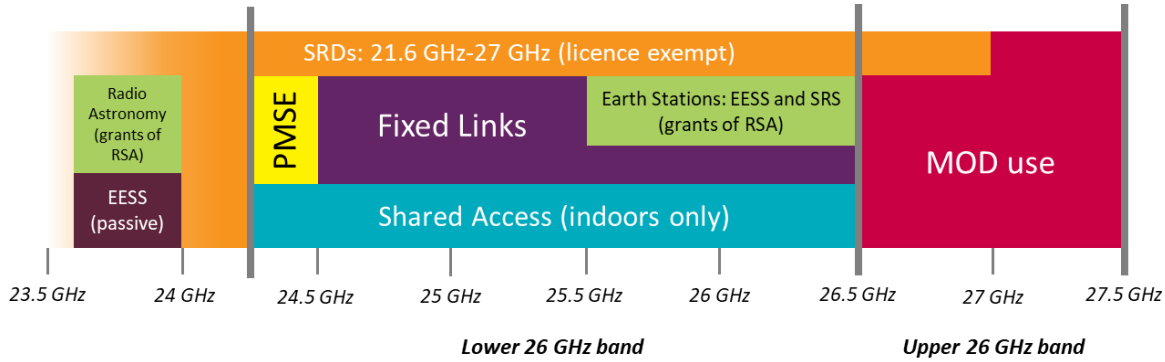
3.1 Having presented the 39 GHz band in the previous section, as the only new addition to our advice on spectrum bands suitable for rail connectivity use, in this section we provide an update on the bands we discussed in our 2018 advice.

26 GHz

3.2 The 26 GHz band (24.25-27.5 GHz) is formed of a large block covering a number of allocations including for fixed links, SRDs and satellite earth stations. The band has been identified for 5G internationally.[8]

3.3 Due to the different authorisations for existing users, we considered the lower (24.25-26.5 GHz) and upper (26.5-27.5 GHz) parts of the band separately in our 2018 advice.

Figure 6: UK authorisations and permissions for use for 26 GHz band[9]



Our assessment of the band in the 2018 advice

3.4 In our 2018 advice, our assessment of the band was that:

a) Assuming 100 MHz could be made available in the short term, with as much as 800 MHz in total across the lower and upper parts of the band in the long term, the band could support speeds of 1 Gbit/s or more;

b) There would likely be equipment available shortly, firstly with equipment from the adjacent 28 GHz band and latterly across the whole 24.25-27.5 GHz range;

[8] The band was identified as the pioneer 5G mmWave band in Europe – see RSPG, *Strategic spectrum roadmap towards 5G for Europe: RSPG Second Opinion on 5G networks*, 30 January 2018. It was then also identified for IMT globally at the 2019 World Radio Conference (WRC-19).

[9] At the time of our 2018 advice the Shared Access licence product (represented by the light blue portion of this diagram) did not yet exist; applications for this new type of licence first opened in December 2019.

c) While there are a large number of potential future applications which could be deployed using this spectrum, features such as beamforming and dynamic channel selection may make sharing of spectrum in this band slightly easier.

3.5 We also advised that authorising users in the upper portion of the band would be more straightforward (subject to coordination with MOD use of this spectrum) whereas authorising new users in the lower portion of the band would require more detailed coordination with a wider range of existing civilian users.

The 26 GHz band is now harmonised for IMT use globally, which should be beneficial for the development of the equipment ecosystem in this band

3.6 At the time that we wrote our 2018 advice on rail connectivity, the 26 GHz band had been identified as the pioneer 5G mobile band in Europe. However, last year, one of the outcomes of WRC-19 was the global identification of this band for IMT.[10]

3.7 For rail connectivity purposes, the key benefit in the short to medium term of this decision is likely to be the quicker and more extensive development of an equipment ecosystem to support 5G devices using this band. In our 2018 advice we said that we expected a significant ecosystem of equipment to develop in this band, and the band's global identification should further this development.

The new Shared Access licence only enables indoor use of this band and should not reduce spectrum availability for rail use

3.8 In December 2019 we opened applications for our new Shared Access licence. This licence, which is discussed in more detail in the section on 3.8-4.2 GHz below, can be used to access spectrum in the lower 26 GHz band (i.e. 24.25-26.5 GHz) indoors and at low power (up to 23dBm),[11] which would not be suitable for trackside to train connectivity.

We are currently considering future uses of this band

3.9 The propagation properties of the 26 GHz band mean the band will likely be deployed on a very localised basis, rather than for nationwide coverage. We are currently considering how best to authorise licences across the full 26 GHz band (for uses such as outdoor high power mobile) in a way that ensures efficient use of the spectrum.

3.10 It is not yet clear what impact this could have on rail connectivity using this spectrum. On the one hand an increase in users in the band could lead to less spectrum being available for systems providing trackside to train connectivity. On the other hand, the relatively large amount of spectrum in the band (>3 GHz) and its propagation characteristics should help make sharing in this band more feasible.

[10] WRC-19 globally identified the three bands (24.25-27.5 GHz, 37-43.5 GHz and 66-71 GHz) for IMT use.
[11] Ofcom, *Enabling wireless innovation through local licensing: Shared access to spectrum supporting mobile technology*, 25 July 2019, Section 5

3.11 Prospective users looking to this band to fulfill their needs for trackside to train connectivity should approach Ofcom in the first instance to discuss their requirements, to enable us to incorporate this into our thinking around the wider authorisation of the 26 GHz band.

66-71 GHz

3.12 At the time of our 2018 advice, the 66-71 GHz band was free of incumbent use in the UK. As part of our Fixed Wireless Strategy[12] we had consulted on this band, and proposed to make this band available by introducing a licence exemption authorisation with technical conditions aligned with those in the 57-66 GHz range below. We implemented the proposed changes in November 2018, and the full 57-71 GHz band is therefore now available under an exemption that allows an EIRP of up to 40 dBm for SRDs and up to 55 dBm for fixed wireless systems.[13]

3.13 As use in the band is licence exempt, we do not hold specific records of how many users are now operating in the band. However, we are aware that the band has proved popular for some specific use cases, such as last mile broadband connectivity in cases where fibre is unavailable; and 'smart city' applications including providing connectivity to CCTV systems. We are also aware of suppliers currently providing equipment in the UK for trackside to train connectivity using this spectrum.

3.14 We do not expect that the introduction of new users in the band will have had a material impact on the availability of the 66-71 GHz band for trackside to train connectivity (which is already one of the applications that could be deployed under the new regulations at EIRP levels up to 40dBm), particularly due to the nature of the current technology used and the amount of spectrum available over the wider 57-71 GHz band.

Our assessment of the band in the 2018 advice

3.15 Our advice in 2018 was that the band had an existing equipment ecosystem available based on WiGig technology; that the opportunity cost of authorising rail use was likely to be very low due to the band's limited use (and the short-range nature of devices using this band); and that due to the large amount of spectrum available in the band it would certainly be feasible to deliver speeds of 1 Gbps or higher.

3.16 However, we also cautioned that over longer distances performance could be limited by atmospheric absorption, and that while higher power options were available for fixed devices (which would help to address the absorption issue), to enable higher power for mobile devices would require further study.

[12] Ofcom, *Review of spectrum used by fixed wireless services*, 5 July 2018
[13] Ofcom, *Decision to make the Wireless Telegraphy (Exemption and Amendment) (Amendment) (No.2) Regulations 2018*, 8 November 2018

Recent changes to international regulations will allow higher power devices in this band, which may increase the viability of trackside to train systems

3.17 At the time of our 2018 advice, we were actively working within CEPT to harmonise the band for equipment operating at higher powers (above 40 dBm EIRP). We said that following completion of the CEPT work, we would review our national authorisation approach for equipment operating at an EIRP above 40 dBm.

3.18 Since then, the work at CEPT has been completed, and in June 2019 CEPT published its latest update to the relevant recommendation, ERC Recommendation 70-03.[14] This change allows the use of higher-power equipment, which could mean longer range from a single base station.

3.19 Prospective users can access the band under the existing licence exemption regime (at an EIRP of 40 dBm or lower). Those prospective users who wish to use higher power base stations (above 40 dBm EIRP) should approach Ofcom to discuss their requirements.

5 GHz

3.20 The 5 GHz band covers a range of allocations and is a key band for short-range devices that are licence exempt, notably Wi-Fi. There are three sub-bands within 5 GHz: 5150-5350 and 5470-5725 MHz are currently available for both mobile and fixed applications whilst 5725-5850 MHz is available for fixed applications only.[15]

Our assessment of the band in 2018

3.21 In 2018 we advised that in the short term, only the sub-band 5470-5725 MHz would be suitable for rail use, as the band supports use up to 1W (30dBm) by mobile applications outdoors.[16]

3.22 On the one hand, this band has a substantial ecosystem of equipment available to use, and, subject to the power limits outlined above, can be used on a licence exempt basis right now.

3.23 However, users attempting to set up a trackside connectivity system using this spectrum would be sharing the band with other users also operating on a licence exempt basis, and as such it could be difficult to guarantee any quality of service in busy areas. The band also does not have as much bandwidth available as the higher-frequency bands, so would not be able to support the speeds of 1 Gbit/s or higher per train which we predicted would be needed to meet passenger data demand by the mid-2020s.

[14] CEPT, *ERC Recommendation 70-03, Relating to the use of Short Range Devices (SRD)*, 7 June 2019
[15] There is a mobile allocation for SRDs in 5725-5850 MHz, but this is limited to 25mW so is not relevant for trackside to train systems.
[16] We explained that the sub-band 5150-5350 MHz was only available for indoor use, while the sub-band 5725-5850 MHz allows a higher power limit of 4W (36dBm), but only for fixed use.

5470-5725 MHz remains the most viable 5 GHz sub-band for trackside to train connectivity, but does not have the capacity of mmWave bands

3.24 Since we published our advice in 2018, there have not been any changes to these bands which would alter our assessment.

3.25 At the 2019 World Radio Conference, it was agreed that the sub-band 5150-5250 MHz could be made available for outdoor use, under the same maximum power limit as existing indoor use (200mW/23dBm). This has not yet been authorised in the UK, but even if it was, there is a good chance that due to the low power limit this sub-band would not be suitable for trackside to train connectivity.

3.26 Therefore, the sub-band 5470-5725 MHz may be suitable for trackside connectivity in some situations and can be used right now under existing licence exemptions. However, with its more limited bandwidth, it would not be suitable for a nationwide, high-capacity solution.

3.8-4.2 GHz

3.27 This band is used by receiving satellite earth stations (space-to-Earth), as well as a small number of fixed links and some fixed wireless access (FWA) broadband installations. The satellite earth stations in this band are authorised under a mixture of Permanent Earth Station (PES) licences and grants of Recognised Spectrum Access for Receive-Only Earth Stations (grants of RSA), operating at 14 different locations around the UK. There are fewer than 50 fixed links remaining in this band, and most of the fixed link channels in this band have been closed to new applicants[17] as the band is managed on a duplex basis with spectrum in the adjacent 3.6-3.8 GHz band, which is currently being cleared as part of a future award of the band for 5G mobile use.[18]

Our assessment of the band in the 2018 advice

3.28 In our 2018 advice, our assessment of the band was that:

a) although there is 400 MHz of spectrum available in total in this band, the requirement to protect existing users means that in practice there will be some parts of the country where little or no spectrum is available in this band, especially around London;

b) there was evidence that a significant equipment ecosystem would develop in the band, as the band has a 3GPP standard associated with it; and that

c) while we planned to increase opportunities for spectrum sharing in the band, we did not expect that new indoor and industrial use would have much effect on the potential

[17] There are two paired fixed link channels still open in the band.
[18] Ofcom, *Improving consumer access to mobile services at 3.6GHz to 3.8GHz*, 26 October 2017; Ofcom, *Award of the 700 MHz and 3.6-3.8 GHz bands: Revised proposals on auction design*, 28 October 2019

for rail use of the band. We did, however, warn that new use by FWA operators could create some additional constraints on rail use in some areas.

3.29 Overall, we concluded that this band could, in some places, likely support a higher throughput than the 2.7-2.9 GHz band as more spectrum would be available, though not as much as the mmWave bands we also considered. Additionally, we cautioned that due to limited spectrum availability in certain parts of the UK, this band would be unlikely to provide a single solution for the entire country.

The new Shared Access licence will provide a new way for users to access this spectrum; in select cases this may be relevant for rail connectivity

3.30 Since we published our advice in October 2018, we have consulted and subsequently published a statement on our new framework for spectrum sharing, which we have initially applied to a number of spectrum bands, including 3.8-4.2 GHz.[19]

3.31 As part of our new spectrum sharing framework, we have introduced a new type of spectrum licence, designed to facilitate localised access to spectrum. This is the Shared Access licence, which provides access to bands including 3.8-4.2 GHz.

3.32 The Shared Access licence has two variants with different maximum EIRP. The low power licence, which authorises any number of base stations within a 50m-radius circle, has a maximum EIRP of 23 dBm, whereas the medium power licence, which authorises a single base station, has a higher maximum EIRP of 42 dBm.

3.33 This new form of spectrum licence will allow new users to access spectrum for a range of different industrial and enterprise applications, and we anticipate this could be beneficial for a range of sectors including agriculture, mining, manufacturing, logistics and others.

3.34 This new licence product could potentially be useful for rail connectivity, subject to the power limits included in the licence conditions. However, it should be noted that due to the localised nature of the licence (and the existing users in the 3.8-4.2 GHz band) it is unlikely that sufficient spectrum would be available all the way along a transport corridor. The introduction of new users in the band could also lead to less spectrum being available for trackside to train connectivity in the longer term.

3.35 In summary, our assessment of the band's suitability has not fundamentally changed since 2018. Although this band could be used to provide trackside connectivity in certain areas, there would likely be limitations on the available bandwidth and, hence, on how much data the band could support, and any rail use would have to coexist with existing users. The introduction of the Shared Access licence may provide a useful route for licensing some rail use of the band, however an increase in the number of users in the band using this new licence could also limit the spectrum available for rail use.

[19] Ofcom, *Enabling wireless innovation through local licensing: Shared access to spectrum supporting mobile technology*, consultation December 2018 and statement July 2019

2.7-2.9 GHz

3.36 The 2.7-2.9 GHz band is mostly used for air traffic control in the vicinity of both civil and military airfields, as well as for military radar surveillance on land and sea, and for weather research using radar by the Meteorological Office.

Our assessment of the band in the 2018 advice

3.37 In our 2018 advice to DCMS, our assessment of the band was that:

a) around 40 MHz could be made available nationally (with maybe 100 MHz available in some areas);

b) there was some evidence of a suitable equipment ecosystem using LTE; and

c) subject to ongoing changes to radar installations there appeared to be no other potential shared users of this band which trackside use would limit.

3.38 However, we also cautioned that making spectrum available in this band to support trackside connectivity could be a very lengthy process involving both the MOD who manage military radar deployments, and the Civil Aviation Authority (CAA) who administer civil air traffic radar on a coordinated basis with MOD. We also warned that there was no guarantee that this process would necessarily result in any more spectrum being made available. Additionally, we had not undertaken any coexistence analysis to confirm the estimate of 40 MHz of spectrum available nationwide (i.e. taking into account existing protection criteria).

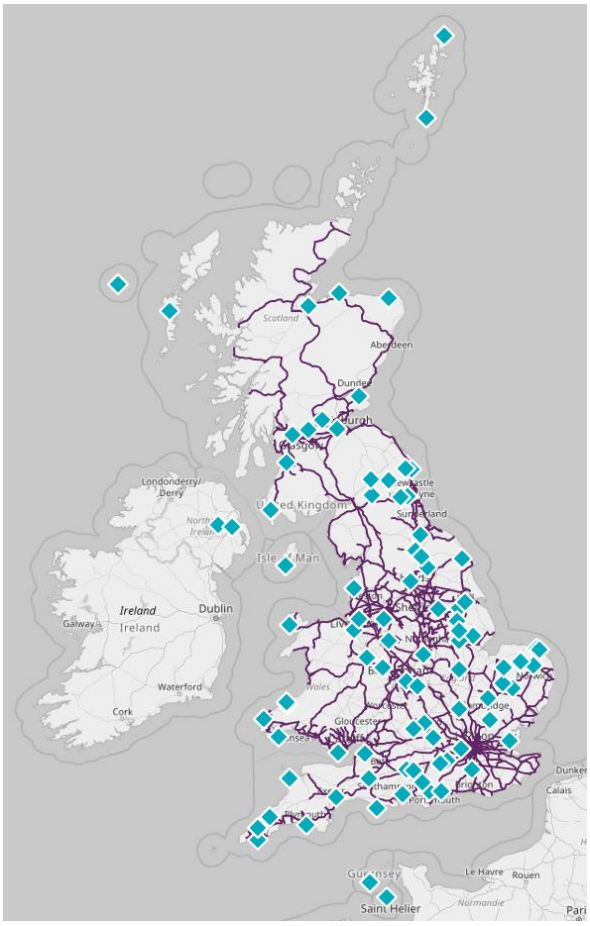
3.39 Our overall conclusion was that the band would likely be of limited use if any trackside connectivity system was intended to fulfil projected rail passenger data demand by the mid-2020s, however it could potentially be useful if the aim was only to meet today's demand levels.

Coexistence analysis has now shown spectrum availability in this band to be worse than we had originally predicted

3.40 In 2019 we undertook some coexistence analysis work looking at the 2.7-2.9 GHz band. We assessed how much spectrum in this band could be made available for trackside base stations, while maintaining the existing protection criteria used to prevent harmful interference to radar installations.

3.41 We modelled 98 radar sites across the UK using the frequencies from 2.7-2.9 GHz, spread all over the country and split roughly evenly between civil and military locations. These sites are shown on the map below, which also appeared in our 2018 advice.

Figure 7: Radar deployments in 2.7-2.9 GHz band (blue) mapped against GB rail routes



3.42 To protect these radars from harmful interference from high-power mobile operating in the adjacent 2.6 GHz band, the bottom 20 MHz of this band (i.e. 2700-2720 MHz) has already been cleared. Additionally, filtering was added to the radars as part of a remediation programme in advance of the award of the 2.6 GHz mobile band in 2013, in order to protect the radars from 4G mobile signals in the adjacent band.

3.43 For our study, we modelled trackside antennas at 15m height above ground, transmitting at 47 dBm EIRP, and train-borne antennas at 5m above ground, transmitting at 36 dBm EIRP. We considered the band as ten non-overlapping 20 MHz channels.

3.44 We considered two criteria:

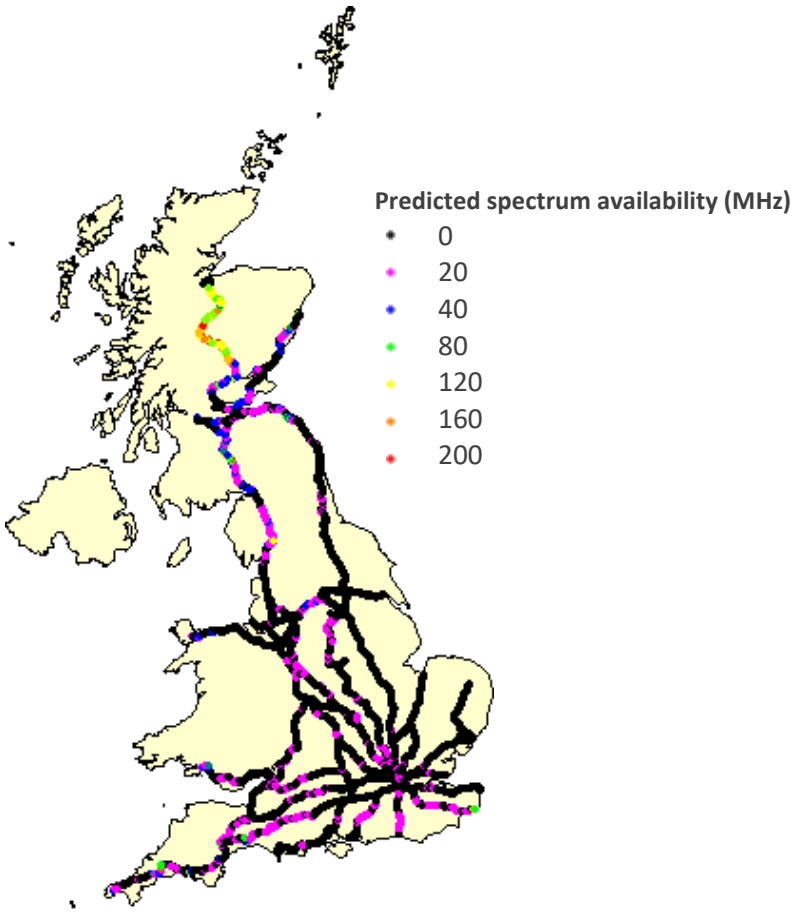
a) the potential to overload the radar (blocking); and

b) the co-channel interference caused by a base station using the same frequency as a radar, albeit some distance away.

3.45 As illustrated in Figure 8 below, we found that across most of the GB rail network, there is little available spectrum that could be used for this type of system. There are small parts of the rail network where one or two 20 MHz channels might be available, however across most of Great Britain not even one 20 MHz channel could be made available for such a system. To a large extent this lack of availability is down to the need to protect the

overload requirement of the radars, and this renders even the cleared 2700-2720 MHz channel unavailable for shared use across most of Great Britain.

Figure 8: Map showing total predicted spectrum availability in 2.7-2.9 GHz on the GB rail network, for trackside antennas at 47 dBm EIRP



3.46 To put this limited spectrum availability in context, we would generally expect a channel of 20 MHz to be able to support download speeds between 40-80 Mbps, based on an assumed spectral efficiency of 2-4 bits per second per Hz.[20] As we outlined in our 2018 advice, to supply rail passengers with a high-quality onboard data service is likely to require much higher speeds than this.

3.47 In summary our assessment shows that, without significant changes to the existing protection criteria for civil and military radar installations, it is not possible to effectively utilise spectrum in the 2.7-2.9 GHz band given the limited availability of even a single 20 MHz channel across the whole of the GB rail network. Therefore, our updated assessment of the band is that we do not think it would be practical to try to set up a trackside rail connectivity system using the 2.7-2.9 GHz band, especially if the aim was for this to be used to provide high-capacity data connectivity to trains.

[20] This is the same figure for spectral efficiency we used in our 2018 advice.

14.25-14.5 GHz

3.48 Although this band has a co-primary allocation to mobile, it is mostly used for both permanent and transportable transmitting satellite earth stations (Earth-to-space), as well as fixed links. While the band is closed to new fixed link applications and their number is falling, the band is quite active for transportable earth stations, which are licensed on a temporary basis at a rate of around 700 per month and used for applications like satellite news gathering. There are also a number of permanent earth station locations.

Our assessment of the band in the 2018 advice

3.49 In our 2018 advice to DCMS, our assessment of the band was that, with up to 250 MHz available (subject to coordination with fixed link deployments and satellite earth stations), using 5G technology with a 200 MHz channel could achieve speeds of 400-800 Mbit/s. However, this level of availability would make the 14 GHz band the worst-performing of the three mmWave bands we looked at, as both the 26 GHz band and 66-71 GHz band have at least 1 GHz of spectrum available.

3.50 Additionally, we noted that the 3GPP standards do not include this band and that we were not aware of any plans by vendors to make suitable equipment for this band.

3.51 Finally, we noted that while using the band today would involve coordination with fixed links and both permanent and transportable earth stations, there was also the potential that in the future the band could be used by mobile terminals connecting to Low Earth Orbit (LEO) satellites. This could require additional assessments of interference potential in the future, and additionally meant that rail use of the band carried a currently unknown opportunity cost.

We are expecting to consult shortly on future uses of this band; in the meantime our assessment of the band has not changed

3.52 In the past two years, there have been no major changes relevant to the potential use of this band for potential trackside to train connectivity systems.

3.53 However, we are expecting to publish a call for inputs later this year asking for stakeholders' views on the potential future users of this band. Any stakeholder wishing to be informed when the call for inputs is published can sign up for update emails from Ofcom.[21]

Conclusion and next steps

3.54 In summary, our view is that for users or industry looking to deploy a trackside solution to improve connectivity along the rail corridor, there is suitable spectrum available to do this

[21] You can subscribe to email updates from Ofcom on a variety of topics by visiting this webpage.

in a range of bands. In particular, we would suggest that the 26 GHz, 39 GHz and 66-71 GHz bands appear to be the most promising options for providing a home to this sort of system

3.55 We do not see any reason why access to spectrum should be a limiting factor for the deployment of systems providing trackside to train connectivity.

3.56 We would encourage users interested in this area to explore the range of authorisation options currently available, including existing licence exemptions as well as licensing products. However, should none of these options work for a prospective user, we would encourage them to approach us in the first instance to discuss their requirements for a bespoke licensing solution.