Fixed links bands review – conclusions and recommendations

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Background

What are fixed links?

Fixed links are used for many different applications. They may provide links within telecoms networks, such as links to remote cell sites. Utilities companies use fixed links for telemetry and control of equipment. Broadcasters may use them to distribute content streams to transmitter sits.

Increased reach of fibre networks is not diminishing the need for fixed links; indeed they may be used to connect customers and sites and extend beyond the reach of fibre networks. They may also be used as backup to fixed networks.

Bands for fixed links

There are a many different bands used for fixed links, spanning two orders of magnitude of frequency. The bands in use are established by international harmonisation. There are strong economies of scale in global equipment manufacturing. As a result, most countries have largely the same bands in use.

Lower frequency bands for fixed links propagate further and are less susceptible to disturbance by atmospheric conditions, but less spectrum is available and link bandwidth is more limited. Higher frequency bands propagate less far but provide for greater bandwidth. Different applications have different 'sweet spots' in terms of the ideal band, but there is usually some flexibility to move to nearby bands.

Link licensing

With the exception of the 26 GHz band, where dedicated spectrum has been assigned nationally as 'block licences', users apply for and license each fixed link separately.

This study reviews the current licensing regime. This report sets out our overall conclusions and recommendations to ComReg. It follows up on an earlier report and public consultation in November 2020.

Scarcity

Our previous report found that demand for fixed links is growing, with increasing demand for higher bandwidth links requiring wider channels. Whilst there is plenty of spectrum overall for fixed links, there is scarcity in particular bands at particular locations: in particular the 11, 13,15 and 23 GHz bands in Dublin. Therefore, whilst there is not acute scarcity, there is value to ensuring that new links make best use of the available spectrum and do not unnecessary preclude other users, including potential future users. Once fixed links are installed, the equipment has a long life and moving to a different band would be costly and typically involve replacing that equipment.

Bands

1.3 and 1.4 GHz harmonisation

The 1.3 and 1.4 GHz fixed link bands are both partially affected by European Decisions[1] to harmonise frequencies for ECS/MFCN services. There is no immediate need to close these bands for fixed link use. Nevertheless, we recommend that ComReg sets out future plans to avoid wasted new investment in these bands. The 2 GHz band provides a reasonable alternative. Parts of the 1.3 and 1.4 GHz bands fall outside of the harmonization decision and could continue to be used for fixed links, though bandwidth would be limited.

Re-opening 13 and 15 GHz bands in Dublin

Use of 13 GHz and 15 GHz bands in the congested Dublin area has declined since ComReg closed them to new applications. We recommend that they are re-opened.

17 GHz band

The 17 GHz band should continue to be available for fixed links as licence-exempt spectrum.

26 GHz is being considered separately by ComReg

Fixed links in the 26 GHz face the risk that part of this band will need to be available for MFCN services (in practice, 5G mobile) on foot for ECC Decision 18(06). Whilst this does not affect the whole band, there is the potential that more of the band might be made available for 5G in the future. Again, clarity is needed to avoid investment in fixed links that might need to be replaced. ComReg has a separate study underway on these issues.

32 GHz band – testing future demand

The 32 GHz band is currently unused in Ireland, but used in other jurisdictions, often on a block licence basis. The 32 GHz band is a potential alternative to the 26 GHz band, though existing 26 GHz users would need to replace equipment.

Whilst there is no urgency to release spectrum in the 32 GHz band, we recommend that ComReg put out a public request for expressions of interest in using the band well in advance of expiry of block licences in the 26 GHz band in 2028. Over that longer timeframe there may be new uses that have yet to emerge, such high-capacity FWA services, and it should not be

[1] Commission Implementing Decision (EU) 2015/750 and 2018/661.

assumed that the only potential users are MNOs migrating block licences from the 26 GHz band.

42 GHz band

The 42 GHz band has been identified as a priority band for 5G services by the EC and a harmonisation decision from CEPT is expected in late 2022. There is no current necessity to close this band to new fixed links, but stakeholders should be aware of these possibilities.

D and W bands are likely to be important for future high capacity links and are potentially useful in easing scarcity in the 80 GHz band. These bands should not be opened until ETSI standards have been established and there is demand for this spectrum.

Licensing framework

Wider channel where compatible with international standards

There is growing demand for wider channels, especially in 11, 13 and 15 GHz bands. Some users are already bolting together two adjacent channels to obtain wider bandwidth. Whilst ComReg has sought to follow CEPT/ITU recommendations on channel arrangements, there appears to be additional opportunities to use wider channels without deviating from international standards:

- The latest ITU recommendations allow 112 MHz channels in the 15 GHz band, which is planned for adoption in Ireland, but has yet to be implemented
- Latest guidelines for the upper 8 GHz band allow 28 MHz channels, whereas ComReg currently only licences 14 MHz channels;
- Even where not formally recommended, the CEPT/ITU provide guidelines for channel merging that NRAs may implement.

We recommend that ComReg allow the widest channels allowed with the bounds set by ITU and CEPT standards. (Channel merging is discussed in depth in Annex D.) Some respondents were concerned that this could raise scarcity problems, but this can be address by measures to improve information available to potential licensees and the through changes to the fee structure.

Increasing risk of fragmentation

As typical channel sizes increase (often by doubling), this creates a risk of fragmentation; if users of smaller channels are not efficiently arranged (in terms of frequency) this may unnecessarily restrict spectrum available for wider channels. This is not currently a significant problem, and it would be disproportionate to move existing licensees to defragment bands. However, we recommend that ComReg reserve the right to move applications for new links to alternative frequencies within a band for spectrum management reasons. It is not necessary to require users to change channels on licence renewal.

Improving information for new applicants

Efficient use of the various fixed link bands is encouraged by applicants having good information about emerging scarcity. For instance, a new user might be able to substitute to a different band to avoid a band in which future scarcity is likely. It is difficult to summarise this information within an incentive pricing mechanism, as opportunity costs are difficult to assess with any accuracy given the complexities of potential substitution by different users between different bands and the difficulties of assessment future demand.

Therefore, we recommend that ComReg regularly publish simple summary statistics, such as the proportion of applications rejected for interference management reasons, disaggregated by band and geographical area. This would build on the format of information released in ComReg's 2020 fixed links annual report.

ComReg's recently introduced Frequency Band Usage Checker tool is also a helpful measure to allow applicants to assess relative scarcity in different bands. This should also reduce the number of applications rejected for interference management reasons, but also means that information about rejections is not so informative about scarcity. Therefore, we propose an alternative format for reporting the number of unused channels across a geographical grid (described in Annex C), which gives a good indication of spectrum availability.

Technical parameters and link aggregation

The technical parameters in ComReg's fixed link licence are currently well-aligned with international standards (see Annex D). Whilst there is nothing within licence conditions to prevent band aggregation (e.g. pairing 18 GHz and 80 GHz links), we recommend that ComReg invites comments from stakeholders on whether average link availability requirements and/or path length requirements might be barriers to link aggregation.

Licence-exempt spectrum

Many stakeholders reported that licence-exempt bands (5 GHz, 17 GHz and 24 GHz) are important, especially for rural FWA and that the 60 GHz is important for emerging technologies and use cases. Broadly, users did not have problems with interference. Despite growing demand for 60 GHz spectrum, we do not see any reason that 60 GHz would need a 'light' licensing regime for interference management reasons, and we recommend that it remains licence exempt. If operators require high frequency links with formal interference protection through licensing, the W and D bands may be able to meet such needs in future. Therefore, we recommend no change be made to licence-exempt fixed link spectrum.

Block licensing

Block licensing (as it currently used in the 26 GHz band) has some attractions where spectrum might be densely used and there could be complex interference management issues if individual link licences were used. Whilst it is arguable that, in retrospect, this might have been a possible approach for the 80 GHz band, we are not starting from a clean slate. We do not recommend moving any existing fixed link bands to block licences, primarily due to the costs of moving existing users.

Stakeholder calls for block licensing

ESBN suggested block licensing for 6-8 GHz spectrum, but we have not identified any congestion issues that suggest current users are unable to use this spectrum efficiently. Three suggested block licences for the 42 GHz band, but there is little reason to change the licensing regime given that the future availability of this band for fixed links may be in question.

We do see potential for block licensing to be used for future new bands, primarily 32 GHz and, once standards are settled and equipment available, W- and D-bands. Block licences would provide greater certainty about spectrum availability where users are deploying many links (for example, as part of an urban FWA deployment) and allow users to manage their own interference.

Impact of block licensing on smaller users and options for block licensing

For the most part stakeholders agreed that there were potential benefits from block licensing. However, there were also concerns that block licensing could be unfavourable to smaller users and unnecessarily deny access to spectrum, However, there are many options for how block licensing could be implemented that can mitigate these concerns. Block licences can be geographically subdivided. They could be offered in limited locations (e.g. urban areas) whilst individual link licensing is retained elsewhere. Provisions can be included in block licences to facilitate sub-licensing of smaller users where efficient. There are also options for overlaying spectrum rights, such as allowing a limited number of individual links in parallel with block licences, or even having a limited number of shared use licenses (which users are under obligation to coordinate with each other).

Block licences for 32 GHz, W- and D-bands

We recommend that ComReg explore the potential of block licensing for the 32 GHz, W- and D-bands. However, it will be important to consult with potential users to better understand what approach is likely to be best given the wide range of options available.

Fees

Objectives for fees

When looking at the incentives that licence fees create for efficient spectrum use, we are primarily trying to ensure efficiency in choices made in installing new links though licensees may, where appropriate, make changes to existing links also. Although there is limited spectrum scarcity at present, demand for fixed links is growing and equipment long-lived and expensive to switch out; therefore, decisions to install links now can have long term consequences and might contribute to future scarcity.

Current changes

ComReg currently charges for individual fixed links according to frequency band and channel size. A 20% congestion premium is applied for 18 and 23 GHz bands where one end is within a defined congestion area within Dublin. Fees are lower in higher frequency bands. They increase slower than proportionately with increasing bandwidth used and are entirely flat with regard to any bandwidth exceeding 40 MHz.

Problems with the current approach

This fee structure has three main problems:

- The congestion surcharge is quite modest, and much smaller than any reasonable estimate of the opportunity cost that such users cause to others.
- Fees do not reflect the impact of larger channels, as they do not increase proportionately with spectrum used.
- There is a limited amount of spectrum at lower frequencies and some users need lower frequencies for their superior propagation; there should be an incentive for new licensees to prefer other bands unless they specifically need low frequency bands to avoid future lack of availability of lower bands.

Although these problems might not appear immediately pressing, in an environment in which demand for fixed link spectrum is growing, they will increasing become evident. Given that investments in equipment for fixed links is largely sunk and difficult to modify subsequently, there is merit in creating incentives for reasonably efficient use of fixed link bands now, rather than trying to unravel inefficient choices by licences later at considerable cost.

Formula-based fees

We propose an approach to setting fees that using a formula-based approach that seeks to proxy short run marginal costs through a small number of parameters. The approach is primarily based on short run marginal cost, as we take into account current scarcity of bands as a factor in pricing, rather than trying to anticipate future scarcity. However, at the same time we seek to reflect some of the general structure of likely long-run opportunity costs even though we cannot readily estimate through setting a premium (of a per MHz basis) for lower bands that are more likely to face future scarcity.

The key features of this formula-based approach are:

- charging by bandwidth, with fees increasing in proportionate to bandwidth (subject to the proviso below);
- a surcharge on channels smaller than the typical size for the band in question, reflecting that any excluded user is likely to be using a larger channel;
- a gradient on a per MHz basis across bands, with lower bands being at a premium to higher ones, reflecting the greater potential scarcity in lower bands (with a ratio of about 1:30 between 1.3/1.4 GHz and 42 GHz bands), implemented as a schedule of band factors;
- a congestion surcharge, though in the range of a factor of 2-4 rather than the current 20% surcharge;
- an administrative cost floor, representing the average cost of the licensing and interference management activities that ComReg undertakes (approximately €100 per licence).

Congestion and closed bands

We recommend retaining the current definition of congestion, so that 13, 15, 18 and 23 GHz in Dublin and high sites to the south of the city would be considered congested. Whilst there is clustering of links in other urban areas (notably Cork) this is not sufficient to justify treating these areas as congested. The 13 and 15 GHz are currently closed to new applications, but we recommend that they reopen, but subject to the congestion charge.

Future-proofness

This approach is intended to be future-proof, in that ComReg can subsequently adjust parameters within the formula if necessary, but the general approach can be maintained. This should aid predictability of future fees for licensees,

High usage

We recommend that ComReg maintains a high usage path surcharge to discourage hoarding, but that the criterion for applying this is based on licensees using more than half of the available spectrum in a band on a particular route. For these purposes 1.3/1.4 GHz bands and lower/upper parts of 6-8 GHz bands would be grouped. In the case of high usage, the congestion premium would be applied.

Dual polarisation

Dual polarisation links allow efficient use of spectrum. We recommend that ComReg continues to apply no premium to dual polarisation links to encourage their use.

P-MP systems

For point to multipoint systems, ComReg currently charges four times the point-to-point fee. We propose a minor modification to alight this better with opportunity cost principles. Once a 'hub' has more than a certain number of fixed links radiating from it operated by the same licensee, fees for additional links would be charged a reduced rate. We tentatively propose that beyond 8 'spokes' from the hub – which would effectively sterilise that location for other operators at those frequencies – further links be charged at 25% of the full rate. This is intended to ensure that there are efficient incentives to deploy point-to-multipoint systems. This approach would require registration of individual links within P-MP systems and we would welcome feedback from operators on how burdensome it might be to provide such information in order to access this proposed discount.

General level of charges

Overall, we have proposed parameters for the pricing formula that reflect reasonably robust insights from our modelling process in terms of setting the relative fees between different bands and the congested/uncongested cases. However, given the unavoidable uncertainties in estimating the general level of opportunity costs, we have calibrated the proposed new fees to be largely revenue-neutral noting that this fee level does not appear to have choked off demand and fees set too low might not encourage efficient use of fixed links . Some licences will see increases, but others decreases in fees. For many classes of user, these changes will largely net out. Therefore, the proposed pricing formula is largely a restructuring of fees, rather than a general shift in level. In any case, we propose that changes are phased in over three years.

1 Introduction

The Commission for Communications Regulation (ComReg) has engaged DotEcon Ltd (DotEcon) and Axon Consulting (Axon) to assist with its review of the fixed links bands and licensing framework in Ireland.

1.1 Background

Reviews following from the RSMSS

As part of its Radio Spectrum Management Statement (RSMSS) for 2019 – 2021[2], ComReg proposed to conduct a review of the current fixed links regime and the technical guidelines for fixed radio links. This includes:

- the potential for opening up new bands to fixed links;
- a review of the fee schedule; and
- recommendations on any relevant adjustments to the technical guidelines.

Previous consultation

In November 2020, ComReg published a public consultation[3] covering its preliminary views on potential adjustments to the fixed links licensing framework, but without detailed proposals for a new fee schedule[4]. Alongside this, ComReg published a report prepared by DotEcon and Axon.[5] Based on a combination of stakeholder engagement, desk research and analysis of ComReg's licence data, this set out our preliminary views on:

- the main use cases for fixed links;
- likely future demand for the fixed links bands; and
- characteristics of a suitable licensing framework.

Our previous findings

The key initial findings were that:

- There is a wide range of existing use cases for fixed links in Ireland, plus the potential for new advanced fixed wireless access services and/or specialist low latency links to emerge in the future.

[2] ComReg 18/118

[3] ComReg 20/109

[4] ComReg set out a number of different methodologies for setting fees and sought views on which methodologies would be suitable for some or all of the Fixed Link Bands.

[5] ComReg 20/109a

- Spectrum requirements vary substantially across use cases (in terms of link lengths, bandwidth and the number of links needed).
- There is a fundamental trade-off between longer, more reliable links (supported by lower frequencies) and access to bandwidth (with more available in the higher frequencies). Use use cases vary in the extent to which of these factors is the priority.
- For any given use case there is typically a range of bands that could be used (although outside that range use of different bands may be unfavourable or even infeasible). Therefore, when new links are installed there is a degree of flexibility over which band is used and potentially some scope for steering users away from congested bands (e.g. through price signals). However, switching existing links into different bands is likely to be costly due to the need for replacing equipment.
- Demand for bandwidth (expressed via wider channels and greater numbers of links) is increasing, driven largely by the MNOs and FWA operators, with a shift towards higher frequencies. Some stakeholders expressed an interest in wider channels being made available in certain bands, in particular the 11 GHz, 13 GHz and 15 GHz bands. We saw no downside to making wider channels available wherever feasible and in line with CEPT/ITU recommendations.
- Fibre is likely to replace some fixed links, but there will still be a strong need for fixed links for the foreseeable future. There will remain areas that fibre networks cannot reach. There is also increasing demand for backup wireless connections. Fibre rollout may even complement and create demand for additional fixed links; as the fibre network expands it may lead to further opportunities for using fixed links to reach previously inaccessible customers, or it may encourage businesses to open in rural areas that currently lacked connectivity, increasing demand for wireless backup connections.
- There is plenty of spectrum for fixed links overall across the bands available, but there is congestion in Dublin in the 13 GHz, 15 GHz, 18 GHz and 23 GHz bands. We do not see strong evidence of congestion elsewhere, but this does not mean it will not arise in the future (particularly in the other cities).
- A congestion charge in bands/areas where congestion arises is appropriate to incentivise use of alternative bands and/or spectral efficient technologies (e.g. XPIC, carrier

aggregation) where possible, but management of congestion is likely to also be supported by ComReg providing clear information about developments in demand and bands/areas where congestion might be emerging.

- For some of the fixed links bands there may be advantages to block licensing, or a mix of block licences in urban centres and individual licensing elsewhere. This is particularly relevant to the higher frequency bands where links are likely to be densely deployed and radio modelling of interference at a sufficiently fine geographical level may not be feasible. However, it is unlikely to be desirable or feasible to introduce block licensing in bands where individual licences are already significantly in use, due to the high cost and complexity of clearing/moving existing users. Therefore, block licensing is likely to be more appropriate in a greenfield band that could be opened for fixed links.
- The 1.3/1.4 GHz, 26 GHz and 42 GHz bands have all been identified at international level as important bands for 5G. While there does not appear to be any need for immediate action from ComReg in this regard, stakeholders should be aware of the situation and ComReg should ensure plenty of notice is given about any changes. This seems particularly important for the 1.3/1.4 GHz band where international harmonisation for ECS is more developed.
- There is potential for additional bands to be opened for fixed links in the future. In particular, the D band, W band and 32 GHz band were all suggested as potential bands for fixed links. These bands should not be made available until there is a clear need for the spectrum (in particular the D and W bands where international harmonisation and development of technical standards is ongoing). In any case, there may be benefit in ComReg consulting with industry periodically (e.g. through its spectrum strategy consultations) on whether these bands are required to deliver certain use cases.

1.2 Scope and structure of this report

This second report sets out our conclusions and recommendations to ComReg on the fixed links licensing framework, considering feedback received from stakeholders in response to the consultation. Where these conclusions relate to specific bands or features of the licensing framework, they largely follow from the interim conclusions set out in our first report.

Formula-based pricing proxying opportunity cost

We also propose a new formula-based methodology for setting fees. The proposed approach adjusts the fee structure to address some identified shortcomings with the existing approach and to provide a future-proof methodology that can be readily adjusted in the light of any new circumstances. This should better incentivise efficient use of the spectrum, as the pricing formulate broadly seeks to increase fees where scarcity is more likely and reduce fee where it is unlikely. Overall, it does not significantly change the general level of fees, either in aggregate, or for most classes of user.

Finally, we provide recommendations on the technical guidelines for fixed links, informed by a review of international standards and relevant findings in the first report. The detailed technical review is provided as an annex to this report.

The remainder of the report is structured thus:

- Section 2 covers our recommendations for each band in turn (only for bands where significant changes were considered);
- Section 3 sets out our recommendations on the licensing framework; and
- Section 4 provides details of the proposed methodology for determining fees for individually licenced links.

The report also contains various annexes:

- Annex A gives an evaluation of alternative potential methods for setting fees:
- Annex B describes the methodology for and results of opportunity cost estimates;
- Annex C presents a screening method for potential congestion; and
- Annex D contains a detailed review of the technical parameters found in ComReg’s fixed links guidelines.

2 Spectrum available to fixed links

2.1 The 1.3 GHz and 1.4 GHz bands

ECS/MFCN harmonisation

In our first report, we noted that the 1.4 GHz band has been identified for electronic communications services (ECS) and/or mobile and fixed communications networks (MFCN) use. The band as described in the ECS/MFCN harmonisation measures comprises:

- a 'centre band' (1452 – 1492 MHz), to be made available for ECS by the end of 2015[6]; and
- 'extension bands' (1427 – 1452 MHz & 1492 – 1517 MHz), to be made available for ECS by October 2018.[7] However, existing fixed wireless services may continue to operate in the bands until 1 January 2023 if no demand has been identified for wireless broadband ECS.

Impacted fixed link bands

This could mean that fixed links need to be cleared from two of ComReg's existing fixed links bands, namely:

- the 1.3 GHz band (1370 – 1375 MHz & 1512 – 1517 MHz); and
- the 1.4 GHz band (1375 – 1385 MHz & 1427 – 1437 MHz).

The upper parts of the 1.3 GHz and 1.4 GHz bands currently allocated for fixed links both overlap with the extension bands. However, any award of the centre band only for ECS would not require the bands to be closed to fixed links (though the entire 1427 – 1517 MHz range is now covered by the harmonisation measure so such an approach would require careful consideration).

ComReg considered whether it would be appropriate to include the centre band in its upcoming multi-band spectrum award (MBSA2), but has decided[8] it is better to wait until the extension bands are available. This is in line with ComReg's wider approach of seeking to award substitutable spectrum simultaneously in pursuit of an efficient allocation of spectrum.

[6] Commission Implementing Decision (EU) 2015/750

[7] Commission Implementing Decision (EU) 2018/661

[8] ComReg 20/122, Annex 4

Timescales for clearance – respondents' views

In our first report, we recommended that ComReg should give as much notice as possible to current fixed link users within the band, and invited views from stakeholders on:

- when the band might be needed for mobile use; and
- alternative fixed links bands should the 1.3 GHz/1.4 GHz bands become unavailable.

In response, Eir commented that the equipment ecosystem for mobile use of the band is currently underdeveloped, and as such there is no need for an award process in the next few years. Vodafone suggested that availability of the band for SDL would add considerably to mobile capacity in rural areas and expects it to be useful at some point from 2024 onwards.

Future coexistence

A number of current users also suggested that the extension bands continued to be used for fixed links after the centre band was awarded for mobile, with some suggesting that part of the band should be kept available for fixed links indefinitely. In particular, ESBN commented that there should be no award of the 1.4 GHz band for mobile use in the medium term, and that the extension bands should continue to be used for fixed links in the long run. In any case, ESBN suggested ComReg should make clear its plans for the band as soon as possible, giving ample notice and providing alternative low frequency spectrum if it is to close the band for fixed links, noting that existing users would have to undergo a lengthy process to procure new equipment. Various FWA operators also suggested that part of the band be reserved for fixed links in rural areas.

We recognise that the 1.3 GHz and 1.4 GHz bands are used for long-range links, often to remote areas where installing fibre would be costly (and in some cases might be used for redundancy even if fixed networks are available). However, as both the centre band and the 1.4 GHz extension bands are harmonised for MFCN at the European level, the expectation is that ComReg will at some point need to close the band to fixed links to comply with the EC Implementing Decision. The emphasis should, therefore, be on supporting a smooth transition out of the harmonised spectrum for current users.

Conclusion – ComReg to put 1.4 GHz fixed links users on notice

While there is no immediate need to require existing users to vacate the bands (and indeed we see little reason for moving existing users until necessary), ComReg should, as soon as possible, provide clear and sufficient notice of its plans in relation to those bands and any transition process.

In terms of options for users that are ultimately required to move, we expect that the 2 GHz band would provide a suitable alternative for a large proportion of the affected links, although there would likely be some overhead in terms of replacing radio equipment. For this reason, it is important that current uses are given plenty of time to make any necessary adjustments to their networks.

Spectrum not subject to harmonisation

The frequency ranges 1370 – 1375 MHz and 1375 – 1385 MHz, part of the 1.3 GHz and 1.4 GHz fixed links bands respectively, are not covered by the harmonisation decision. Therefore, that spectrum could potentially continue to be used for fixed links applications that require small amounts of spectrum in the low frequency bands, if equipment is available (given that this could not be used in its current FDD configuration). This option could be considered as part of any future migration process or 1.4 GHz SDL award, subject to equipment availability.

UK approach to 1.3 and 1.4 GHz

Other European countries have found themselves in a similar situation, whereby implementing the 1.4 GHz harmonisation decision leaves little low frequency spectrum available to fixed links. For example, Ofcom (the UK telecoms NRA) published a review of its fixed links licensing regime in 2018, in which it announced that new applications would no longer be accepted in the 1.4 GHz band from six months after the publication of the review, and as of March 2021, it has written to all existing users of the band to confirm its decision to revoke their licences.[9] Ofcom considered alternative options for these operators, including:

- leaving 1350 – 1375 MHz open for TDD fixed links use, but it found no evidence that solutions for this band were likely to be available; and
- making 1350 – 1400 MHz available for future FDD fixed links, which it was unable to do because the 1375 – 1400 MHz range was used the UK Ministry of Defence (this restriction does not apply to ComReg's case).

Potential equipment availability

We are not aware of equipment that currently uses just the 1.4 GHz frequencies that could continue to be available to fixed links. However, we note that equipment manufacturer SAF Tehnika stated in its response to Ofcom's consultation that it had "concluded that it is possible to customise and tune

[9] https://www.ofcom.org.uk/consultations-and-statements/category-2/fixed-wireless-spectrum-strategy

existing 1.4 GHz fixed FDD products to use the 1350 – 1400 MHz band".

2.2 The 13 GHz and 15 GHz bands in the congested area

In the Dublin congested area, the 13 GHz and 15 GHz bands are currently closed to new fixed links. However, we observed that use of the bands in the congestion area has declined over time and that it may now be possible to accept new applications. All stakeholders were either supportive of reopening the bands or expressed no strong view on the matter.

Conclusion – re-open the 13 GHz and 15 GHz bands in Dublin

Therefore, we recommend that ComReg begins to accept applications for new links in the 13 GHz and 15 GHz bands in the Dublin congested area. There are better ways to address congestion, such as through information available at the application stage and/or congestion charging, that reduce the risk of spectrum being inefficiently unused.

2.3 The 17 GHz band

Licence-exempt use

The frequency range 17.1 – 17.3 GHz (the '17 GHz band') is available, and used, in Ireland for fixed links on a licence-exempt basis. These frequencies have been removed from ERC/REC 70-03 for short range devices (SRDs), but there are no harmonisation measures that mean the band cannot be used for fixed links. Individual NRAs are free to make the band available for licence-exempt fixed links use, as ComReg does.

We noted in our first report that licence-exempt spectrum, including the 17 GHz band, is particularly important for some operators, such as rural FWA operators. These users face limited interference problems and appear content with the use of licence-exempt spectrum despite the lack of protection from interference. Various FWA operators responded to the consultation and confirmed that this is the case. If users require protection from potential interference, alternative bands are available.

We recommend that the band continues to be available for fixed links on a licence-exempt basis.

2.4 The 26 GHz band

As set out in our first report, the 26 GHz band has been harmonised for ECS[10], and ECC Decision (18)06 stipulates that *"CEPT administrations shall make available by the end of 2020 at least 1 GHz for MFCN in this band, subject to market demand"*. Although there is over 1 GHz of spectrum in the band that is currently unused, there is nevertheless potential for more of the band to be made available for 5G in future, which might require fixed links to be migrated from the band. If this is the case, we recommend that current users are given sufficient notice of plans for future use of the band, because although suitable alternative spectrum is likely to be available for these users, advance notice of the band becoming unavailable will allow them to avoid unnecessary costs of replacing recently installed equipment.

The 26 GHz band is subject to a separate ongoing study[11] by ComReg, and therefore more specific recommendations are beyond the scope of this report.

2.5 The 32 GHz band

The 32 GHz band is currently unused in Ireland, although it is used for fixed links, often on a block licence basis, in other jurisdictions.

Use cases for 32 GHz

We identified two possible sources of demand for the band, specifically:

- as a replacement for the 26 GHz block licences currently allocated to the MNOs, should the 26 GHz band be repurposed for 5G when the fixed link block licences expire in 2028; and/or
- as a sweet-spot for advanced fixed wireless access (A-FWA) services.

Recent awards of similar spectrum in other countries have attracted interest from FWA operators, for example:

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[10] Commission Implementing Decision (EU) 2019/784

[11] See ComReg Document 21/07a and responses to same.

https://www.comreg.ie/publication-download/proposed-strategy-for-managing-the-radio-spectrum-2022-to-2024

- EOLO won 26 GHz spectrum in Croatia in August 2021;
- Pentanet and Dense Air[12] (which currently has 3.6 GHz rights of use in Ireland) won access to 26 GHz spectrum in a regional award in Australia in April 2021;
- Global Connect won 23 GHz and 38 GHz licences in Norway in May 2020; and
- Starry won licences in the 24 GHz band in the US in 2019.

Respondents' views

The MNOs expressed support for making the 32 GHz band available in the form of block licences, although Eir commented that the band should not be seen as a direct replacement for the 26 GHz block licences, because of the need to replace equipment when moving between bands. If 32 GHz block licences are to be a direct replacement for the existing 26 GHz block licences, Vodafone states that it would need a sufficient notice and then an implementation period to make the transition, therefore, it requests that ComReg make a decision on the use of the 26 GHz band by the end of 2023. The consultation responses did not indicate any clear demand from A-FWA operators, but this does not mean there will not be interest in the coming years and before expiry of the 26 GHz licences. It may be that potential operator have yet to emerge.

At present there is no apparent urgent demand for the 32 GHz spectrum, and as a result we do not see any need to make the band available immediately. At the same time, there is no good argument to 'reserve' it for the MNOs for if/when the 26 GHz band is repurposed for 5G, if it could be put to good use in advance of that. Vodafone sees the band as a potential direct replacement for the 26 GHz block licences and suggests individual link applications in the 31 GHz band (included in the fixed links framework but unused) should not be accepted to ensure that block licensing remains feasible, but this does not require that these block licences are not assigned until 2028, and it may even support MNOs' migration between the bands if there is some overlap in licence terms.

Conclusion – ComReg to find out when the band can usefully be made available

ComReg may wish to consider putting out a public request for expressions of interest for access to the spectrum, to further explore the potential demand for the band before 2028, and with a clear intent to make the band available if/when there is sufficient demand. The lack of immediate interest in the band indicated by the consultation responses suggests that demand might not arise within the next few years. However, it may also

[12] https://denseair.net/successful-acquisition-of-mmwave-spectrum-at-26-ghz-by-dense-air-in-australias-premier-cities-sydney-and-melbourne/

be the case that the consultation reports were not seen by all relevant parties, and there could be merit in a further, more focussed, effort to establish interest. Furthermore, indicating intent to make the band available when needed (for example via a high-level roadmap for the band) may help to encourage interest by reducing investment uncertainty.

2.6 The 42 GHz band

The 40.5 – 43.5 GHz band (the 42 GHz band) has been identified as a priority band for 5G services, and the EC issued a mandate to the CEPT to develop the harmonised technical decisions. At present there is no ECC harmonisation Decision in relation to 5G in the 42 GHz band, but this is expected in late 2022 and there may be consequences for fixed links in the band when it arises. In our first report, we formed the view that there does not appear to be any reason to migrate fixed links users out of the band at present (as we would not expect 42 GHz to be required before the pioneer the 26 GHz band). Equally, stakeholders should be aware of possible future changes and make network planning decisions accordingly. We are not aware of any reason to adjust this view.

In its response to consultation, Three suggested that the 42 GHz band might be a reasonable candidate for block licensing (in particular as current use of the band in Ireland is limited) but also noted that demand could be limited as the 80 GHz band offers a higher capacity alternative. We would not recommend introducing block licences in the 42 GHz band, not least because it would not seem appropriate to make such significant changes at a point where there is uncertainty over future availability of the band for fixed links, but also because of the potential impact on existing users (even if limited).

Conclusion – wait for harmonisation decision

At present we remain of the view that there is no need for changes in relation to the 42 GHz band but recommend that ComReg monitors the situation regarding international harmonisation and provides stakeholders with clear and timely information, if necessary, when more information about future use of the band is available.

2.7 D-band and W-band

There is broad agreement from stakeholders with our interim conclusions that:

- the D-band and W-band are likely to be important for high-capacity links; but
- there is no immediate need for the spectrum, and the bands should not be opened for fixed links until ETSI standards have been finalised and there demand for the spectrum in the bands.

In the responses to the consultation documents:

- Vodafone notes that equipment testing for these bands will take place in 2022 (W-band) and 2023 (D-band);
- Virgin Media suggests that ComReg should not delay opening the bands beyond the point that equipment becomes available; and
- Siklu submits that both bands are inferior to the 80 GHz band (less contiguous spectrum is available in the W-band, and inferior propagation in the D-band), meaning fixed links demand will be limited.

We recognise that the 80 GHz band will be preferable for some users, but greater spectrum availability in an environment of growing bandwidth requirements is still expected to be beneficial, as those who can make use of higher frequencies doing so will help to ease potential congestion at 80 GHz. The stakeholder engagement used as input to the first report, and several responses to the consultation support the view that even though there may be little need for the bands to be available now, there will be demand at some point in the future when equipment is available and technical standards have been finalised

As the bands will likely used for dense deployment of high-capacity links in urban areas where detailed interference analysis is difficult, the bands are potentially strong candidates for block licensing. Most respondents agree that these new bands are the strongest candidates for block licensing.

Conclusion – set out conditions under which the bands will be released

We maintain our recommendation that ComReg does not open the bands for the time being but sets out its plans for the bands over the coming years. In doing so, it should consider that there is little use in the band being available unless international harmonisation measures are in place, equipment is available, and there is some evidence that there will be demand for the spectrum.

3 Licensing framework

3.1 Available channel sizes

3.1.1 Increasing the maximum channel size in a band

Growing demand for larger channels

With growing demand for bandwidth for some services, there is interest from operators for wider channels than are currently available in Ireland, particularly in the 11, 13 and 15 GHz bands. We formed the preliminary view that in general there seems to be little downside in making wider channels available wherever feasible and in line with international recommendations, noting that ComReg (appropriately) adheres to CEPT/ITU recommendations on channel arrangements.

Benefits of wider channels

Availability of wider channels is likely beneficial to users where demand for higher bandwidth links is growing and could help to enable faster rollout of higher capacity services. It may also help to support efficient assignment of the spectrum and reduce overheads during the licence application process. In particular, given our understanding that some operators are already acquiring licences for two adjacent channels in order to use them as if they were a single wider channel, making the larger channels available under one licence would:

- ensure that these wider channels are operated in accordance with the internationally recommended channel plans, and positioned in the band in a manner that maximises the number of larger channels available to other users;
- remove the need for operators to submit, and for ComReg to process, two applications when the same outcome could result from just one application process; and
- reduce the burden on operators trying to find two adjacent channels that are both available (in particular in popular bands/areas)

Unused opportunities for wider channels

While we believe that ComReg's approach to following CEPT/ITU recommendations is appropriate, we identified in our first report that:

- ComReg has not yet adopted the most recent ITU recommendations to allow 112 MHz channels in the 15 GHz band, although we understand that it plans to do so; and

- to date, ComReg has tended to only provide the channel widths formally recommended by CEPT or the ITU, and not those permitted under channel merging guidelines (i.e. where the guidelines state that NRAs may consider allocating larger channels by 'merging' two smaller ones, in line with given channel plans).

Since then, it has also come to our attention that the latest ITU guidelines for the upper 8 GHz band include 28 MHz channels, whereas the current fixed links licensing framework in Ireland only allows channels of up to 14 MHz.

Therefore, there is scope for ComReg to expand the channel widths available for a number of bands within the bounds set by the ITU and CEPT.

Consultation responses

In the consultation responses, stakeholders were generally supportive of wider channels being made available, but some suggest caution is needed with introducing wider channels in congested areas to avoid making the situation worse. In that respect, we believe that there are changes to the fees and information policy that provide a better way of addressing congestion than excluding certain users/applications by restricting access to bandwidth. Existing users will not lose access to smaller channels, and we propose adjustments to the fees that improve incentives to use alternative bands if congestion becomes an issue, and better reflect bandwidth used, imposing an additional cost to hoarding and encouraging use of larger channels only when needed. Further details of the proposed new fee schedule are provided in Section 4 below.

Similarly, some consultation respondents highlight that it is important that wider channels do not create interference with existing links or other uses. We agree with this broad point, but do not believe it is a cause for concern in practice, because:

- we would expect this to be taken into account by the ITU / CEPT when forming recommendations; and
- in any case, ComReg conducts a detailed interference analysis whenever an application for a new link is received, so there should not be any issues of interference.

Conclusion – open wider channels in line with updates to CEPT/ITU recommendations

We therefore remain of the view that it is desirable to make wider channels available where permitted by CEPT/ITU recommendations. We recommend that ComReg proceeds to introduce 112 MHz channels in the 15 GHz band and 28 MHz channels in the upper 8 GHz band, and considers, where relevant, allowing for larger channels via channel merges (keeping to the CEPT/ITU guidelines in relation to this). Further details on where channel merging might be applied can be found in Annex D , but we highlight here that it could allow access to:

- 80 MHz channels in the 11 GHz band;
- 220 MHz channels in the 18 GHz band[13];
- 224 MHz channels in the 28 GHz band[14]; and
- 224 MHz channels in the 38 GHz band.[15]

3.1.2 Fragmentation

Potential for fragmentation

If the common channel size within a band increases, but many operators continue to use smaller channels, there is a risk of the band becoming inefficiently fragmented if users of smaller channels within the band are not organised effectively and prevent access to wider channels even if there would be sufficient spectrum available. Neither the analysis in our interim report, nor any consultation responses, suggest that this is a significant problem at present, but it could be a growing concern as typical link bandwidths increase.

Limited current fragmentation

In theory this might be dealt with by, for example, charging higher fees for links that unnecessarily fragment the band, or requiring new links to be positioned in a way that minimises fragmentation. However, in practice these approaches (and other formalised methods) are likely to be very difficult for ComReg to implement, due to the complexity of monitoring and organising the assigned frequencies. Furthermore, given that fragmentation does not currently appear to be a significant issue, and is only likely to be a problem where there is emerging scarcity and typical channel sizes are increasing, it would likely be disproportionate for ComReg to try and introduce a complex and costly regime.

Maintaining the option to move new users

A more broad-brush approach is likely to be appropriate, whereby ComReg *may* require applicants for new licences to apply for an alternative channel, on spectrum management grounds, where it is deemed that assigning the channel asked for would risk inefficiently fragmenting the band. We would recommend that any such coordination measures taken by

[13] ERC/REC 12-03, Annex 2

[14] ERC Recommendation T/R 13-02, Annex 5

[15] ERC Recommendation T/R 12-01, Annex 2

ComReg are limited to applications for new links, as the high costs of replacing equipment is likely to mean any reorganisation of existing links would be disproportionate.

Licence renewals

Some consultation respondents suggested that ComReg could require users to change channels on renewing their licences, if they could do so without needing to purchase new equipment (and with compensation for doing so in some cases). However, as the problem is limited, we do not believe that even this modest approach to reorganising the band is necessary.

The pricing structure proposed (see Section 4) should also help by creating incentives for users to use larger channels rather than multiple small channels with the same total bandwidth, increasing the potential for spectrum in use to be kept contiguous and better organised in the formal channel plan.

3.2 Individual link applications

3.2.1 Application process and information policy

Information about scarcity

In our interim report, we suggested that ComReg should encourage efficient use of fixed links spectrum by providing operators with regular, predictable information about emerging scarcity. This is more appropriate than relying on fees to incentivise efficient use because it is difficult to measure opportunity costs with great accuracy, as discussed in Annex A . Moreover, we propose setting fees with reference to short run opportunity costs (i.e. ComReg does not need to forecast demand and add an increment to prices now to address future congestion), which requires users to anticipate future congestion, and therefore it is appropriate for ComReg to help operators form accurate expectations.

In the first instance, we suggest that the type of information provided on emerging congestion could be simple statistics readily available to ComReg, such as the proportion of applications that were rejected following interference analysis in a band in a given area (applications rejected for being incorrectly completed are not relevant). We note that ComReg has already published similar information in its 2020 fixed radio links annual report[16], albeit not disaggregated by area or reason for rejection.

Frequency Band Usage Checker

ComReg also introduced a Frequency Band Usage Checker as part of its fixed radio link application process on eLicensing, to help address application processing issues. The purpose of the checker is to enable applicants to view the number of links by band and bandwidth within a 1km, 5km or 10km radius of a proposed site before applying for a licence. The checker assists applicants in determining the likelihood of an application for a channel being successful. This should support a more streamlined application process by reducing the number of applications rejected following interference analysis (as users can assess the likelihood of conflict with other operators and avoid submitting applications they expect to be rejected). It may also assist applicants with the design of their networks, by helping operators to understand the availability of spectrum in the areas of operation.

Reporting spectrum availability

It should be noted that if the Frequency Band Usage Checker is successful in reducing the number of rejected applications, using the number of rejections as an indicator/predictor of congestion will become less effective. It is possible to construct more sophisticated ways of measuring congestion that are not reliant on there being a significant volume of applications for new links. For example, Annex C describes a 'grid method', where spectrum availability (congestion) is estimated according to the number of unused channels in a given grid square of size assumed to be small enough that other links are unlikely to be able to use the same channel within that area. While this is unlikely to be completely accurate in measuring congestion, it should provide a useful estimate of spectrum availability that can be used as a screening methodology to identify bands/areas where congestion might be arising and could become more of an issue in the future. This exercise could potentially be re-run periodically and included in the information made available to stakeholders by ComReg, complementing the Frequency Band Usage Checker and any other statistics published in ComReg's annual reports.

Application processing times

Respondents to the consultation were supportive of providing more information, in particular with a focus on existing congestion and application volumes, with an aim of reducing turnaround times for applications (e.g. information about

[16] ComReg 20/93, Chapter 3

available channels or expected processing times). The changes made to ComReg's application process in 2020 (i.e. the introduction of the Frequency Band Usage Checker) already provides information on the channels that are available to users, thereby reducing the risk of a long licensing process due to applications being rejected, and this may be further supported by making available additional information about emerging scarcity. However, there is likely to be little that ComReg can do to reduce application processing times when they are driven by a temporary surge in demand for new links, as this is simply a matter of resources. Some stakeholders suggested that ComReg could offer priority applications (whereby stakeholders each have a limited number of applications that can be elevated to priority status and put to the top of the queue). However, we would not expect this to be particularly effective as priority applications would only be useful at particular times (i.e. when there is a long wait due to a high volume of applications), at which point we could expect several operators wanting to use their priority applications all at the same time, but without the increase in resources required to process these applications any faster.

Conclusion – provide information on current and emerging congestion

In conclusion, we believe that the information already provided by ComReg through the Frequency Band Usage Checker should help users to understand the current state of availability/congestion, and thereby speed up the application process by reducing the number of applications that cannot be accepted. In addition, ComReg could consider:

- refining the information it publishes regularly (e.g. data on rejected applications, or results of the proposed grid method for assessing spectrum availability, if/when adopted), to improve the support to users with forming expectations on where congestion may emerge in the future; and/or
- making live data on current links more readily available on its website, to assist operators with planning their own networks, noting that this might also be a useful tool to help providers of other services avoid interference to/from fixed links.

3.2.2 Technical guidelines

Conclusion – the technical guidelines are generally aligned with international standards

In our interim report, we suggested that ComReg should regularly review its guidelines to ensure they keep up with international recommendations and do not obstruct the use of efficient technologies, but in general we understand that the guidelines work well at present. A detailed review of the technical parameters set out in those guidelines, including a comparison with international standards, can be found in Annex D . In summary, ComReg is generally well aligned with international harmonisation measures, and minor differences between its guidelines and those used in other countries are typically justified.

The use of band aggregation technology (e.g. pairing 18 GHz and 80 GHz links to provide both high capacity and high availability) is expected to become increasingly common. We are not aware of anything in the technical guidelines that prevents operators from deploying this type of technology, but we recommend that ComReg invites comments from stakeholders on this matter including, but not limited to, whether two specific issues merit adjustments to the guidelines, in particular whether:

- the average link availability requirements are suitable or could potentially prohibit use of the higher frequencies in a band aggregation arrangement; and/or
- the minimum path length requirements for band are suitably aligned with the links lengths likely to be used with band aggregation technology (in particular in relation to the lower frequency bands) or if these requirements might be a barrier.

3.3 Licence exempt spectrum

Stakeholders have confirmed both that the lower frequency licence exempt bands (5 GHz, 17 GHz, and 24 GHz) are important for existing use cases, particularly rural FWA, and that the 60 GHz band is important to emerging technologies/use cases.

No evidence of interference problems for licence-exempt spectrum

In general, operators using licence exempt spectrum do not appear to be experiencing serious interference problems that would merit ComReg moving towards a light licensing approach. Some respondents to the consultation offered some support for light licensing, and in particular we note that Virgin Media suggests some interference protection could be beneficial as demand for the 60 GHz band increases. However, while it is not clear at present exactly what an optimal form of light licence would be, there would always be a trade-off between applying additional protective measures and restricting some of the benefits of licence exempt spectrum (e.g. the ability to deploy links quickly and cost-effectively).

In our first report we formed the view that the number of restrictions for licence exempt spectrum should be minimised, with new conditions introduced only where necessary and this seemed to be generally supported by existing users. While demand for 60 GHz band may increase, we would expect it to be used for short, densely deployed links in urban areas, where interference is unlikely to be a significant issue, but also harder to assess accurately. Therefore, a light licensing scheme for 60 GHz is unlikely to be needed, and could in fact overly restrict access to the spectrum that unnecessarily prohibits efficient use of the band. Moreover, we highlight that additional high frequency spectrum is likely to be made available in future on a licensed basis in the W-band and D-band, which could potentially be used by operators that require the interference protection not offered in the licence exempt bands.

Conclusion – no change to licence exempt bands

Users of licence exempt spectrum are generally satisfied with the framework as it is, and do not report interference problems that would require amendments to the use of the licence exempt bands. While there was some suggestion that light licensing might be appropriate for the 60 GHz band as demand increases, we do not see sufficient evidence to suggest that the benefits would outweigh the loss of flexibility for users. Overall, we do not see the need for or recommend any changes to the conditions on licence exempt use of fixed links spectrum.

3.4 Block licences

3.4.1 Currently available bands

In our first report we concluded that, in general, introducing (new) block licences in any of the existing fixed links bands was unlikely to be appropriate. In particular, the significant complexity and cost of migrating existing users would likely significantly outweigh any benefits that could be gained.

80 GHz band

We did raise the question of whether block licensing might still be feasible in the 80 GHz band, in particular because usage of the 80 GHz (for high-capacity links in high density networks in urban areas) makes it a good candidate for block licences, potentially on a regional basis. However, this was unlikely to be feasible in Dublin (where over 50% of existing links in the band are deployed) which is where block licences would be most beneficial if ComReg was starting from a clean slate (i.e. it is where links are densely deployed and interference management is difficult). Introducing block licences in rural areas and cities other than Dublin might be possible, but the benefits are questionable if Dublin is not included, especially when there would still likely be significant cost to migrating existing users).

Some stakeholders were against block licensing in the 80 GHz band, for example due to concerns that it could preclude access to smaller users, or that it might limit operators' ability to expand into using higher bandwidths as technologies evolve. Other respondents suggested that block licensing in 80 GHz might be feasible, but only outside Dublin. Overall, we did not receive sufficiently strong support or arguments from stakeholders to change our view that introducing block licences in the 80 GHz is not recommended as:

- use of the 80 GHz band in urban areas other than Dublin is relatively low (so the benefits of block licensing may be small) but there would still be a cost to migrating existing users;
- stakeholders have not expressed a need for block licences in the band; and
- we expect further high-capacity spectrum to become available in the W-band and D-band that could be made available through some form of block licensing.

Bands already in use

In terms of the other bands, although stakeholders are generally in agreement that block licences are not suitable for bands already licensed for fixed links:

- ESBN suggested ComReg offer block licences in the 6 – 8 GHz bands to allow users to plan and deploy links efficiently; and
- Three suggested that the 42 GHz could be a candidate for block licensing.

Regarding the 6 – 8 GHz spectrum, we do not agree that ComReg needs to consider block licensing as:

- we have not identified any congestion issues that would prevent operators from deploying links in these bands; and
- there would potentially be significant costs to other existing users of the bands if required to migrate their links to different frequencies.

In terms of the 42 GHz band, as set out in Section 2.6, we are of the view that (in addition to concerns over the cost of migrating existing users) it would not be appropriate to make significant changes to the licensing regime while the future availability of the band for fixed links is in question.

Conclusion – no block licences in existing bands

Overall, we remain of the view that ComReg should not introduce new block licences in any of the bands currently used for fixed links.

3.4.2 New bands

Benefits of block licences

We continue to believe that there is a strong case for block licences in new bands that may be opened to fixed links (i.e. 32 GHz, W-band, and D-band). In new fixed links bands, where there are no costs associated with forced migration of existing users, block licences come with both direct benefits (more certainty for network planning and equipment procurement), and indirect benefits (larger operators consolidating links onto block licences and freeing up spectrum in other bands).

Stakeholder views

For the most part, stakeholders agree that there are potentially significant benefits to block licensing, such as providing certainty to operators on the availability of spectrum and allowing them to procure equipment cost effectively in large volumes, or allowing them to manage their own interference. However, some stakeholders have expressed concerns, in particular:

- Various FWA operators comment that national block licences are out of reach for smaller fixed links users, and it is of paramount importance that ample spectrum is available at low cost. Block licences should only be available where a considerable proportion of spectrum is reserved for individual links. There is a risk that block licence holders 'sit on' rather than fully utilise their licences, and ComReg should seek to streamline the application process in other ways;
- Siklu contends that block licensing leads to inefficient use of spectrum, as it limits the maximum channel size available

to operators, and significant re-use of high frequency spectrum can be achieved using up to date technology on individual link licences; and
- Viasat would oppose block licences in bands allocated on a co-primary basis to fixed links and satellite services, unless it was shown that coexistence was viable.

Interference with other uses

Dealing first with Viasat's concern, we would not expect block licence holders to be permitted to interfere with other use cases assigned to the band on a co-primary basis. This would be a matter for the detailed technical requirements within a block licence in a certain band (and so would depend on the specifics of that band). There is no obvious reason why the management of interference between co-primary uses would be materially affected by whether a single block licence or many individual link licences are used for fixed links. Indeed, the block licence approach might even have an advantage, in that any interference issues in regard of other users would have to be considered in advance and reflected in the licence itself, providing clarity and certainty for other users; in contrast with individual link licences, it may be necessary to consider the cumulating effect of successive individual licence applications on other users.

Limitation on channel sizes

Turning to Siklu's concern, we can see no particular reason why the use of block licences should constrain the maximum channel size available to them. If we compare a situation with many individual link licences within the same band in a geographical area and block licensing within that same area, the constraints on the bandwidth that can be assigned to users at that location are essentially the same. Siklu's concern may have some validity if block licences were created that spanned too great a geographical area (say nationally); this could prohibit outcomes in which one user had need for a large bandwidth at one location and a different user need for a large bandwidth at a different location, with it being impossible to satisfy both bandwidth requirements on a uniform geographical basis within the available spectrum. However, in such situations where there is spectrum scarcity and the efficient split of spectrum within a band between different users varies from location to location, block licences would need to be regionalised to reflect this.

Impacts on small users

We agree with respondents that it is important for ComReg to consider the needs of different potential users, especially smaller users. However, block licensing need not be detrimental to smaller users if appropriately implemented. There are a wide range of options for how block licensing, or similar approaches might be used.

Innovative licensing models

First, even if ComReg introduces further block licences, these would only be in a minority of the bands available for fixed links. A wide range of individual link and licence-exempt spectrum would remain available. Instead of denying access to spectrum to smaller users, we would expect there to be indirect benefits, as operators who are using block licences could be expected to reduce their demand for individual links, freeing up spectrum for those needing access to individual link licences. This has already happened to some extent with the 26 GHz block licences, noting Three states that it is "*is in the process of migrating away from some 'traditional' bands and mostly using 18 GHz, 26 GHz, and 80 GHz links*".[17]

Second, block licences do not need to be national (as the 26 GHz licences currently are) but can be broken down into geographically limited licences to allow different users at different locations. For example, urban centres could be broken out, as well as regions. This does not preclude someone holding a block licence nationally if they hold all the component areas, but national coverage is not required.[18]

Third, the primary benefit of block licensing to ease interference management and provide certainty that spectrum is available in geographical areas where many links are needed. This scenario is likely to arise primarily in urban areas, for example if a FWA network is deployed or if many short fixed links at high frequencies are needed to backhaul small cell networks. Therefore, it may be possible to offer block licences in areas where spectrum might be heavily used, but to retain individual link licensing in other areas (rural areas in these examples). Block licensing does not need to be applied on a geographically uniform basis.

Fourth, block licensees can sub-licence spectrum for others to deploy individual links. They should have a commercial incentive to do this where it does not interfere with their own usage. It is also possible to include obligations within block

[17] Three response to ComReg 20/109

[18] An appropriate award process can be used to limit risks for those wanting to combine different geographical licenses if there are synergies across these. Therefore, it is potentially feasible to divide block licences into many geographical areas if this were helpful for achieving efficient use.

licences to facilitate this (for example, that consent for sub-licensing may not be withheld without good reason).

Fifth, there are a large variety of options for overlaying spectrum rights. A block licence could be overlayed with a limited number of individual link licences within its geographic extent. Clearly the terms of such overlay link licences need to be clear and the limits on the number and characteristics of such licences would need to be set prior to awarding block licences. Another option is to issue a small number of shared use licenses, so that within a geographical area there are a limited number of fixed link users sharing frequencies but with an obligation to coordinate amongst themselves; a block licence is then the special case of shared use licensing in which these is just one licensee within an area.

Sixth and finally, we can achieve some of the benefits of a block licence or a shared user licence, in terms of users taking on coordination and interference management themselves, within an individual link licensing regime by discounting fees where a licensee has multiple links within the same area (i.e. a quantity discount). This would provide incentives to limit the number of different licensees within an area and encourage arrangements where a limited number of licensees coordinate with each other; other parties might then sublicense links as this would be cheaper than becoming a new licensee.

It is beyond the scope of this study to consider the merits and demerit of these various options. However, in the medium term, new bands are likely to become important (32 GHz, W-band and D-band specifically). There will be opportunity to consider new licensing models that might be more appropriate to situations in which there are dense deployments of short links at high frequencies than licensing of individual links. In these situations, use of interference modelling may be less useful that practical 'on-the-ground' coordination amongst licensees. New licensing models be important for encouraging innovative new services relying on high-capacity, high-frequency fixed links for backhaul.

Conclusion – consider block licensing the 32 GHz, W- and D-bands

While the exact case for, and potential design of, block licences would have to be considered (and consulted on) separately for each of the bands, we recommend ComReg considers block licensing in the 32 GHz band, W-band, and D-band when they are made available. Clearly there are a potentially large number of options for how block licensing might be implemented, as set out above. Therefore, it will be important to consult with stakeholders (including potential new users) to understand better the feasibility of different licensing models and which is likely to yield the best outcomes according to ComReg's objectives.

4 Fees

4.1 Current fees

ComReg currently charges fees for individually licensed P-P links based on the frequency band and channel size (bandwidth) used. A congestion charge is applied for links in the 18 GHz and 23 GHz bands where at least one end of the link is within a defined congestion area that includes Dublin and some high sites to the south of the city. In addition, a high usage fee applies when a licensee has five or more links over the same path.

Table 1 sets out the standard individual P-P link annual licence fees (i.e. when neither the congestion charge nor the high usage fee is applied).

Table 1: Annual fee for a P-P link

Frequency band	0.25 – 3.5 MHz link fee (EUR)	3.5 – 20 MHz link fee (EUR)	20 - 40 MHz link fee (EUR)	40 – 2000 MHz link fee (EUR)
< 1 GHz[19]	750	NA	NA	NA
1.3 – 15 GHz	1,000	1,100	1,200	1,500
17 – 37 GHz	750	825	900	1,125
37 – 39.5 GHz	550	605	660	825
42 - 80 GHz	100	110	120	150

Table 2 details the fees that apply for links that are within the congestion area or on a high usage path, where a 20% premium is applied to the standard price.

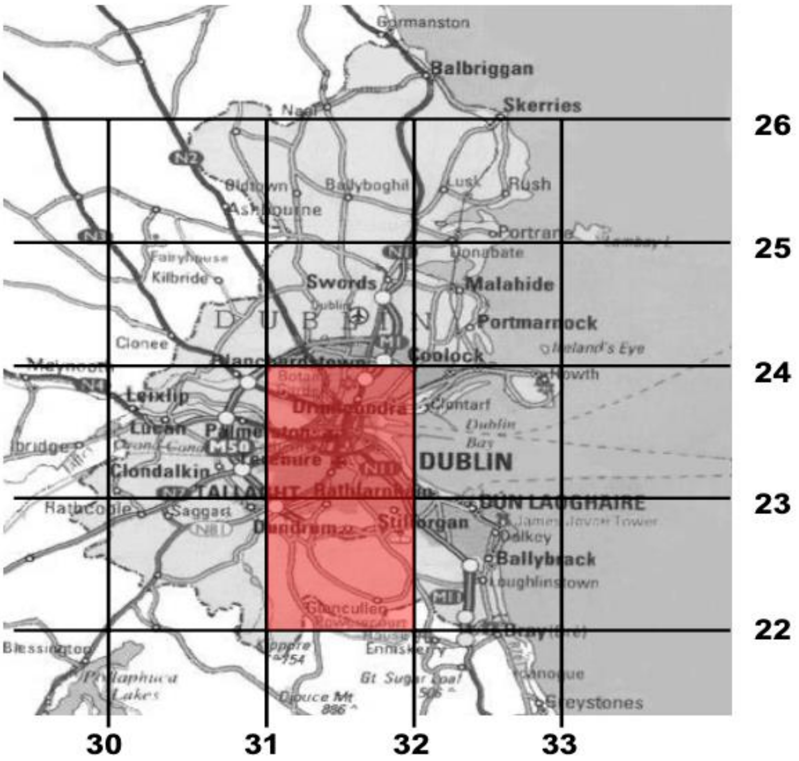
[19] ComReg no longer grants new licences for frequencies below 1 GHz, but there remains a small number of links still live in the sub- 1 GHz bands.

Table 2: Annual fee for a P-P link in the congested area (18 GHz and 23 GHz bands only) or on a high usage path

Frequency band	0.25 – 3.5 MHz link fee (EUR)	3.5 – 20 MHz link fee (EUR)	20 - 40 MHz link fee (EUR)	40 – 2000 MHz link fee (EUR)
< 1 GHz	900	NA	NA	NA
1.3 – 15 GHz	1,200	1,320	1,440	1,800
17 – 37 GHz	900	990	1,080	1,350
37 – 39.5 GHz	660	726	792	990
42 - 80 GHz	120	132	144	180

Congestion charging is currently limited to Dublin and part of the Dublin Mountains to the south that includes high sites used for supporting links into the city centre (see below).

Figure 1: Location of the congested area for the 18 GHz and 23 GHz bands



Source: ComReg 09/89R2 ('Guidelines to Applicants for Radio Links Licences')

4.2 Concerns with current charging structure

The broad features of the current charging regime are that:

- the **congestion surcharging is quite modest**, adding only 20% of the corresponding uncongested fee;
- **fees are lower in higher frequency bands** for given bandwidth; and
- **fees increase slower than proportionately with bandwidth** used and above 40 MHz bandwidth are entirely unaffected by additional bandwidth.

Whilst the general structure of these charges is sensible, there are some significant limitations with the current approach that needs addressing.

4.2.1 Scarcity charges and opportunity cost

Efficiency and opportunity cost

ComReg has an objective to promote the efficient use of spectrum. When there is scarcity, not all potential users can be accommodated in a band (as has been the case in the 13 – 23 GHz bands in the Dublin congestion area). Efficient allocation is achieved by assigning the spectrum to the users who value it most. Consequently, this leaves a group of 'excluded users' who do not get access to the band. This gives rise to an opportunity cost of assigning the spectrum set by the valuation of the marginal excluded user (i.e. the one that would get access to the band if an additional channel was available and assigned efficiently). Setting fees based on opportunity cost supports an efficient assignment of spectrum as the 'excluded users' under the efficient allocation would have incentives to use other (cheaper) fixed links bands or alternative technologies such as fibre, leaving the spectrum available for the higher value users.

Efficient choices for new links

Our focus is primarily on **the incentive potential an appropriate charging structure creates for the installation of new links**. Once installed, links have a long lifetime (15-20 years) and it is our view that ComReg should not set charges with a view to shifting existing links (especially those that have been installed recently, due to the long asset life of equipment). Opportunity costs are set by the additional costs incurred by excluded users as a result of not getting access to the preferred band. Because ComReg allows existing users to renew licences each year, the excluded users are always operators wishing to install new links. Therefore, only the *difference* in the cost of installing a *new* link in different bands is relevant to opportunity cost calculations, because excluded users would have to purchase new equipment regardless of whether they get access to their preferred band.

Current or anticipated scarcity

Even with a focus on choices made for new links, there is still a choice whether opportunity costs reflect current scarcity, or else some anticipation of future scarcity. In the latter case, there could be an opportunity cost to a new licence even if there is no current scarcity in that band, as the new fixed link is likely to be in place for many years and scarcity may emerge over that lifetime. However, this requires assumptions about future demand growth and scarcity to evaluate a long-run opportunity cost. Given the practical difficulties of estimating a true long-run opportunity cost that includes future effects of new licences in terms of excluding potential *future* users of spectrum, our focus is on short run opportunity cost.

The difference between these two approaches is not as much as it might first appear. Because investment in equipment for new fixed links is largely sunk and has a long lifetime, users will most likely consider costs, including licence fees, over the economic life of the link. Even if using a pricing approach based on short run opportunity cost, users can anticipate that ComReg will charge higher licence fees in future if congestion occurs and so should factor this in. Forming such expectations is aided by ComReg applying a predictable policy framework, and regularly sharing licensing data that helps operators form expectations on scarcity. In contrast, under a long-run opportunity cost approach, anticipation of future congestion needs to be formed by ComReg and included within the definition of opportunity cost.

Short-run opportunity cost vs long run opportunity cost

Overall, we recommend a largely **short run opportunity cost** approach, whereby fees are raised for bands and locations where there is current congestion through some congestion surcharge reflective of short run opportunity cost. This approach is preferred primarily as any attempt to estimate long run opportunity costs will be highly dependent on assumptions and lacking robustness.

However, at the same time we know that demand for fixed links is increasing and that there is the likelihood of greater scarcity in future. For this reason, we consider that it is beneficial to try to reflect at least some of the likely structure of long run opportunity costs within fees. Primarily this means establishing some reasonable differential in per MHz fees across different bands reflecting the intrinsically more limited supply of low frequency spectrum and to provide an incentive for users with flexibility to leave lower bands available for those with less flexibility. This is discussed further in Sections 4.2.2 and 4.2.3 below.

Current congestion surcharge

The current congestion surcharge of 20% is very likely too small. Where scarcity occurs, there is potential for opportunity costs to be high if users need to move to bands less suited to their applications. In particular, a key concern is that if lower frequency bands (with better propagation) become congested, this could force some users up to higher frequency bands, requiring additional intermediate stations (or possibly a shift to fibre in some cases). In this scenario, opportunity costs could plausibly be in the range of €20,000 per annum or more, due to the costs of having to install and maintain intermediate stations and associated equipment.

Incentives to switch

The surcharges do not necessarily need to be at such a high level to promote efficient use of the spectrum, as at least some users are likely to be able to shift bands more easily and so would do so in response to more modest fee differentials between congested and uncongested band. However, differentials certainly need to be large enough to at least compensate for possible equipment cost differences between bands[20] and somewhat less robust connections at higher frequencies[21], otherwise there would be no incentive to switch.

Cases for congestion

In terms of identifying bands/areas where a congestion surcharge might apply (and in light of the preceding discussion) we can contrast between the following cases:

- **No scarcity**, where current and potential users can be accommodated in a band;
- **'Modest' scarcity**, where there is sufficient spectrum available in a given location to accommodate those users who have a strong need for that particular band. However, price incentives still may be needed to divert potential users with flexibility to use other bands in order to avoid inflexible users being inefficiently denied access to this band. In this case, the marginal users determining opportunity cost are flexible users, so opportunity costs are modest (set by the costs of flexible users moving band);
- '**Acute' scarcity**, where there is insufficient spectrum available for even inflexible users within a band. In this case opportunity costs may be high if potential inflexible users are forced from lower bands to higher ones, requiring additional intermediate stations. Marginal users are inflexible, so there is a much higher opportunity cost.

The methodology for estimating opportunity cost and the results of the model are described in greater detail in Annex B and are based on the assumptions that:

- a group of bands becomes unavailable, and all users of those bands instead use other fixed links bands (not fibre);
- some proportion of these face additional costs as they need to move into higher frequency bands and install intermediate stations (or use dual polarisation to achieve similar capacities, in the case of the 80 GHz band); but

[20] We found that there is little price difference between equipment in different bands. However, there was evidence that manufacturers may be absorbing higher costs at higher frequencies to a degree, to simplify their pricing and we cannot necessarily presume that this persists (especially if there were significant substitution between bands in response to changes in licence fees).

[21] 'Robust' refers primarily to link availability, which might be lower in the higher frequencies at a given link length e.g. due to rain fading.

- equipment costs (faced by any operator installing a link) do not vary significantly between bands and are not relevant to opportunity cost calculations.

Modelled opportunity costs are stylised

Therefore, our modelled opportunity cost estimates relate to the acute scarcity case, so are an upper estimate of the true opportunity cost. In practice, there may be other opportunities (such as moving to a close band without need to install an additional intermediate station) that may be available to users. However, these may still be some (opportunity) costs to the user if it not able to use its most preferred band.

Furthermore, we expect the costs of a user moving from a lower band to a higher band to be polarised: either this is possible without significant change, or an intermediate station (or fibre alternative) is needed. Therefore, **a reasonable simplifying assumption is to treat potential users as either frequency flexible or inflexible, and opportunity costs to fall into these two scarcity cases (i.e. no scarcity or acute scarcity)**. However, this is somewhat stylised and in practice there may be a distribution of costs faced by marginal users denied access to a band. We refer to flexible and inflexible users throughout the remainder of this document.

In the case of acute congestion (as has occurred, for example, in the 13 and 15 GHz bands in Dublin, which have been closed for new applications since 2014), the current charging structure does not reflect the scale of opportunity costs likely to be present. Therefore, where a congestion charge is to be applied, although we do not believe it is necessary to charge full opportunity cost as calculated by our model (as this is likely an overestimate), the markup on standard prices required to have any significant effect will likely need to be higher than the 20% currently applied, otherwise there may be little incentive impact.

4.2.2 Gradient across frequency bands

If, hypothetically, we had both lower and higher frequency bands that were congested under the current charging scheme, then the ratio between fees for the lowest (above 1 GHz) and highest frequency categories for a given bandwidth is 1:10. However, **our estimates of the difference in opportunity cost between these bands if there were acute scarcity is significantly greater**. Therefore, whilst there is significant uncertainty around these opportunity cost estimates, the current charging scheme does not appear to provide a strong enough incentive to avoid the lower bands if they were acutely congested.

Even without acute congestion at present, there is a still good case for maintaining a differential between lower and upper bands on a precautionary basis. Maintaining some differential avoids the problem that lower frequency bands become occupied with users who could have easily moved to alternative higher bands when initially installing links, not needing the superior propagation of lower bands, precluding less flexible users needing access to lower bands would subsequently seek licences.[22] It is difficult to judge precisely what gradient between upper and lower bands might be appropriate where the marginal user is 'flexible' in the terminology above, and it may not need such a strong differential as in the case of acute scarcity. However, in the fee schedule proposed below **we have adopted a similar differential in the relative fees for higher and lower bands as for the acute scarcity case, given the difficulty of creating more refined estimates**.

As we discuss subsequently, having established parameters defining the structure of fees, ComReg then has the option of revising those parameters subsequently if evidence emerges that they are not having the desired effect. If the fee differential between lower and higher bands were insufficient, we would see scarcity (or at least relatively less availability of spectrum) in lower bands and

4.2.3 Charging by bandwidth

The current structure does not reflect opportunity cost

The current charging structure is increasing with bandwidth in steps up to 40 MHz. For bandwidths beyond 40 MHz, the fees are flat, with additional bandwidth having no impact on the amount charged. However, 56 MHz channels are already being licensed in many bands and there is growing demand for even wider channels. Therefore, **the current charging structure cannot reflect emerging demand for higher bandwidths**. Furthermore, current charges only increase gently with bandwidth (in particular, much slower than proportionately).

[22] For example, if the propagation of the lower frequencies makes them marginally preferable but not essential, or if the operator had compatible equipment already in stock.

Proportionality of cost with spectrum used

If there is a high level of scarcity in a band (at some location), this implies that the opportunity cost should be approximately proportional to the bandwidth used by licensees. For example, suppose that a licensee might use one or two channels in a band. If it uses one channel, this precludes some other potential users (with the opportunity cost defined by the highest value amongst these potential alternative users). If it uses two channels, this precludes those same potential alternative users, plus some further potential alternative users. The opportunity cost associated with being licensed two channels cannot be more than double the opportunity cost associated with just one channel (as the highest value alternative uses are precluded by the first channel used, and the next highest value alternative users by the second channel). However, if there are many excluded alternative users (reflecting a high level of scarcity), this effect of diminishing returns will be weak, as there will be some other next highest value excluded user with closely similar value as the highest value excluded user.

Therefore, at least where there is congestion, efficient pricing requires licensees to pay in proportion to bandwidth used.

Future vs current congestion

Even where there is no current issue of acute scarcity, charging by bandwidth would seem to be appropriate, to ensure operators do not acquire licences for larger channels than they need and minimise the risk of avoidable congestion arising in the future. This is likely to be particularly relevant for cases where congestion is not currently an issue, but demand is increasing and inefficiently assigned spectrum might become an issue.

One additional issue is that where there is a commonly used channel size, then the effect of a user licensing a smaller channel may be to preclude a marginal user of the typical channel size. This means that **opportunity costs would not reduce proportionately below the typical channel size. Users of smaller than typical channels should, therefore, pay a premium.** Notice that this would give an incentive for smaller channel users to come together and share a wider channel, which is desirable as it avoids these smaller users scattering across the band, leaving unusable gaps.

Multiband aggregation links

In its consultation response, Vodafone raised the potential for setting prices in a way that incentivises use of multiband aggregation technologies. In particular, it proposes that the fee for a multiband aggregation link should be less than the sum of the two individual link fees for the bands involved, reflecting the sub-optimal use of the high capacity/low availability link. In this regard we note that there would already be incentives for operators to use the technology arising from the ability to deliver services with greater capabilities, and there does not seem to be any need for ComReg to provide additional incentives through the licensing framework. Furthermore, there would be no difference in terms of the impact, or potential impact, on spectrum availability for other operators between using the spectrum for running a single multiband aggregation link or two separate links over the same path. It therefore seems appropriate that users of multiband aggregation technologies should pay for the full bandwidth used.

4.3 Setting fixed links fees based on a formula

Formula-based pricing

Our recommendation is to set fees according to a formula which includes factors intended to proxy for opportunity cost.[23] This would be set up to apply the general principles in a systematic and transparent way (i.e. fees are increasing in bandwidth, decreasing in the frequency of the band, and higher in congested areas), but also to address the concerns with the current fee structure identified in section 4.2. Whilst reflecting opportunity cost, this is a proxy method, as we are not trying to create a detailed estimate of opportunity cost in different circumstances. Indeed, that would be fraught with difficulty given the large number of assumptions needed. Rather we will take robust observations about the general structure of opportunity costs between bands and currently congested/uncongested situations and use those to inform parameter choices within our formula.

Future-proofness

Use of a formula-based approach also helps to ensure the pricing regime is future-proof and robust to changes in demand (i.e. for bandwidth, and across different bands) and developments in congestion (which may increase or decrease in different bands and/or locations). We highlight that a formula-

[23] Opportunity cost estimates are useful in setting parameter values, but setting fees directly in relation to these would be impractical, complex, and produce a less predictable fee schedule. See Annex A for an evaluation of methodologies for fee regimes.

based approach is used by a number of other NRAs, including in Germany and the UK, amongst others (see Annex A.3). We anticipate that it should be possible to revise the parameters in the formula in the light of new circumstances whilst maintain the same general structure.

Parameters

The pricing formula we propose would be based on a number of parameters, specifically:

- a base price per MHz, x;
- a schedule of band specific values r_i, that determine the relative base per MHz fees across bands;
- for each band, a 'typical bandwidth', typically reflecting the most common channel size used within that band, $\widehat{h_i}$;
- a 'small link gradient', m, that applies to links with a channel size smaller than the typical bandwidth for the band;
- levels that the congestion intensity, c, can take; and
- an administrative cost floor, A.

We discuss each of these in turn in the following subsections.

4.3.1 Relative base prices across bands

The standard (base) price per MHz for a given band (i.e. before adjusting for bandwidth and congestion) is set according to a schedule of parameters that determines the relative fee levels across each of the bands available (as described in section 4.2.2). This would be designed such that the relative prices of links in different bands encourages flexible users to utilise frequencies that are more difficult for inflexible users to use, minimising the risk of inflexible users being unable to access spectrum – currently the aim of this is to incentivise use of the higher frequencies where long links are not needed, leaving more spectrum in the lower bands available for operators that need the more favourable propagation.

4.3.2 The small link gradient and typical bandwidth

The small link gradient is intended to reflect the potential for links that use a fraction of the typical bandwidth in a band to preclude access to the band for users of larger channels.

Fees for smaller links would be set according to the weighted average of the fee for a typical bandwidth link in the band, and the implied fee if the smaller link was charged the same per

MHz fee as a typical link. The small link gradient, m, is used as the weight, and therefore should be a number between 0 and 1, where:

- $m = 0$ would mean that the (total) fee for a small link is the same as the total fee for typical bandwidth links; and
- $m = 1$ would mean that small links face the same fee per MHz as for typical bandwidth links.

All links in a band with channel width at least the typical bandwidth would be charged the same price per MHz.

4.3.3 Congestion charging

We can think of ComReg's current congestion charge as defining two levels for the congestion intensity parameter, namely 1 and 1.2. Then, links in the 18 GHz and 23 GHz bands in the Dublin congested area or on high usage paths have $c = 1.2$, and every other links has $c = 1$.

How many levels for congestion?

If we could perfectly measure congestion and opportunity cost, we might set levels of 0 and 1, but in practice targeting fees is very difficult. In particular, setting a value of 0 would imply a flat charge set by the administrative cost floor (given the formula below). However, we do not recommend this, as some differential should be maintained between higher and lower frequency bands to avoid lower frequencies being filled by users who could easily use higher frequencies, precluding lower bands to users who need their propagation advantages.

ComReg may wish to maintain an option to define additional levels, for example for slightly congested regions, even if nowhere currently falls into the slightly congested category. However, we do not see any need for more than at most three levels for the congestion parameter. Our view of how opportunity costs are likely to be determined (set out above) implies three main cases:

- no scarcity;
- the marginally excluded user can flex to another band at low cost and opportunity cost is modest;
- the marginally excluded user cannot flex easily to another band and opportunity cost is significant.

Polarised opportunity costs suggest two cases

Above, we explained that opportunity costs in the modest scarcity case are likely to be low, and that we believe it is a reasonable simplification to consider only two scenarios when applying a congestion charge: no scarcity or acute scarcity. We therefore we only need two congestion levels (although maintaining the option to differentiate these would be prudent even if we do not currently need to). Given this, we have only one parameter to choose, as we can maintain $c = 1$ for the uncongested case (as a normalisation) and then choose the markup for the congested case.

4.3.4 High-usage path charge

We recommend that **ComReg should continue to apply a high-usage path charge.** This is likely to be more effective in preventing localised hoarding, than encouraging use of fibre (the reason given for the charge in the guidelines), although both effects are possible and would justify the charge. However, we need to avoid creating perverse incentives by making the total fees that a licensee would pay significantly different dependent on whether it licenses a given bandwidth as a single channel or as multiple channels across different links. This problem is present in the current charging structure (as fees do not increase beyond a 40 MHz bandwidth). However, the proposed formula makes charges linear in bandwidth (subject to surcharges for small channels) and so is neutral between more channels or larger channels if this leads to the same overall bandwidth in use.

Measuring high usage

Given this, **a superior approach might be to apply a high usage path surcharge where a licensee, regardless of the number of licensed links on a particular route, occupies more than a certain proportion of the spectrum available in the band on that route.** Therefore, we suggest that a high usage path surcharge applies if a user occupies more than half of the available spectrum in the band. Bands that are very close substitutes should be grouped together, so a high usage path charge only applies if more than half of the total spectrum across the group of bands is used. We suggest that the bands to be grouped together are the 1.3 and 1.4 GHz bands and the upper and lower parts of each of the 6 – 8 GHz bands (i.e. there are four sub-10 GHz bands for the purpose of evaluating high usage; 1.3/1.4 GHz, 6 GHz, 7 GHz and 8 GHz).

Adjacent subsistute bands

A more general approach could involve applying a high usage charge based on the proportion of spectrum used over a particular path in a given band and the adjacent bands (i.e. the band immediately below, and the band immediately above).

However, the proposed approach is simpler, and we do not see any strong reason to complicate it.

High usage similar to congestion

The level of the high usage charge would be equal to the level of the corresponding congestion charge, and this applies to all the users links in the band on that path. This is because the motivation for setting a high usage charge is similar to that of the congestion charge, in the sense that a high usage path operator creates very localised congestion, with an associated opportunity cost from denying access to spectrum for other users operating nearby links that would cause interference. For the avoidance of doubt, however, high usage path and congestion charges would not accumulate – if a link is both on a high usage path and in a congested area, the fee would be twice that of an uncongested link, not four times.

We recommend that ComReg continues to apply no additional fee for dual polarisation links. This is highly desirable to encourage use of dual polarisation, rather than taking up additional channels.

4.3.5 Stability and predictable fees

Fixed links licences are annual, but the equipment used for fixed links has a long asset life, often over ten years. Therefore, it is important that fees for fixed links are predictable, if ComReg is to encourage efficient investment. Otherwise, it could create a hold up problem, where investment is avoided because of highly uncertain and potentially large future fees (which operators cannot easily avoid by moving to other bands or alternative technologies such as fibre once equipment is installed).

ComReg should be free to adjust the fees in response to changes in fixed links demand, but it should be clear on its reasons for doing so, any major changes it does make should be phased in and operators should be given sufficient notice of any changes ComReg is considering. Setting the fees using a formula provides a limited and transparent set of ways in which ComReg can changes the fees – this should help users form reasonably accurate expectations on the fees they will pay over the lifetime of a link they are about to install.

4.3.6 Administrative cost recovery

A minimum requirement for fixed links fees is that ComReg recovers its administrative costs associated with managing fixed links licences. These administrative costs can generally be split into those that are incremental to granting a licence, and the common costs of operating ComReg's fixed links framework. In theory, the administrative cost of a licence could vary across links, if incremental costs are substantial relative to common costs and differ between bands/locations (e.g. because the time spent on interference assessment and management differs across locations). However, it is unclear how administrative costs are split between links (or how to accurately measure that) and we do not have any evidence that the variation is significant.

Average cost

Similarly, it would in principle be possible to recover administrative costs jointly across all links rather than on a link-by-link basis. Congestion charges could be used to contribute to common costs, so expected congestion charging fees could be subtracted from the common costs of the licensing regime for the purpose of setting fees. However, there is significant uncertainty around the fees that would accrue from congestion charging and which could be used to cover administrative costs, so either ComReg would have to continuously adjust fees in response to congestion charging fees, reducing the predictability of fees, or risk its costs not being fully recovered. Therefore, we recommend that **administrative costs are recovered by setting average administrative cost as a floor on fees**.

ComReg's costs fall into three categories:

- one-off (e.g. equipment used to assess interference complaints);
- recurring (e.g. support and maintenance fees for the interference modelling software); and
- staff costs (e.g. salaries).

For each item in these categories, we take the annual expenses (for one-off costs, the total investment divided by the useful life of the asset), multiply this by the estimated proportion of the expense attributable to fixed links, and sum these to give an estimate of ComReg's total annual fixed links administrative cost. This comes to approximately EUR 835,000 per year. Dividing this by the total number of links in operation (as of 2021) gives an average cost estimate of EUR 67 per link.

To set the administrative cost floor, we round this up to EUR 100 per link, to take into account uncertainty around some inputs (i.e. proportion of costs that relate to fixed links), likely increases in the near future, and potential fluctuations in the number of links that could prevent costs from being fully recovered.

4.3.7 The formula

The fee for an individual P-P link of bandwidth h in band i, and area s is given by

$$\text{Fee} = \max\left[x \times r_i \times c_{is} \times b(i,h), \qquad A\right]$$

where b is a function giving 'effective' bandwidth taking into account any adjustment for small channels.

Let $\widehat{h_i}$ be the typical bandwidth of band i. Then effective bandwidth is equal to bandwidth for links at or above typical size and the weighted average of bandwidth and typical bandwidth for smaller links, that is:

$$b(i,h) = \begin{cases} h & \text{if } h \geq \widehat{h_i} \\ \widehat{h_i} + m\left(h - \widehat{h_i}\right) & \text{if } h < \widehat{h_i} \end{cases}$$

Note that almost all fixed links in Ireland use FDD technology, so when we refer to a 56 MHz channel, this is in fact 2×56 MHz of spectrum. However, ComReg's guidelines do allow TDD links in the 80 GHz band – the bandwidth used to calculate the fee for a TDD link in the formula would be half of the channel width.

4.3.8 Setting parameter values

Determining the level at which the various parameters should be set is not straightforward, as it is impossible to predict exactly what the impact will be and how stakeholders will respond and to establish the precise points that will achieve the desired effects.

Rationale for action now

As a general rule, we would not want to make changes to the prices without good reason and expected benefit. The current pricing regime has worked reasonably well to date and does not appear to have set fees at an excessive level that is inefficiently choking off demand. However, the current approach has several structural problems (discussed above). Increasing demand for bandwidth will eventually expose these problems, at which point users will have made sunk investments in equipment and unravelling inefficient choices of licensees will be costly. Therefore, there is a strong argument to rectify these structural problems now.

We recommend that the parameters are set in a way that restructures the prices to deal with the identified issues and better incentivise operators to organise themselves efficiently within the bands. We do not propose significant changes to the general level of prices or the way they are applied and the overall changes are largely revenue neutral, as explained below.

Ongoing review

In this section we set out some considerations and proposals for the general levels at which ComReg might initially set the parameters. We expect that ComReg would review the parameters periodically (e.g. every 2-3 years) and make any adjustments deemed necessary in light of changes in demand and any other relevant factors. For example, ComReg may choose to increase the level of the congestion surcharge if it considers the initial premiums set are not sufficiently incentivising flexible users to switch away from congested bands. This approach gives ComReg flexibility to establish the relevant pricing structure over time, but given the formula-based approach and clear role of each of the parameters, should still provide users with reasonably predictability over the fees they will face.

Base price and band schedule parameters

For a given band, i, the values of x and r_i work in combination to set the minimum price per MHz for that band, before any adjustments are made to account for the bandwidth used and whether a congestion charge should be applied i.e. for band i, the minimum price per MHz is calculated as $x \cdot r_i$.

Schedule parameters for bands up to 42 GHz

The level of the band schedule parameter r_i in each band should be set according to a schedule defined by ComReg. Initially, we propose that ComReg sets the schedule for existing fixed links bands (other than 80 GHz) based on the approximate ratio of the estimated opportunity costs for the highest frequencies and the lowest frequencies, which offers an approximation of the relative values across the bands.

Let F_i be the frequency midpoint of band i, and number the bands from 1 to N, in ascending order of frequency. For these purposes, we treat 1.3/1.4 GHz as one band and 42 GHz as the highest band. Then the band schedule parameter for band i is given by:

$$r_i = 1 + (R - 1)\,\frac{F_i - F_N}{F_1 - F_N}$$

where R represents the ratio of estimated opportunity costs for the highest band and the lowest band (i.e. if the ratio is 1:30 then $R = 30$)

The opportunity cost modelling set out in Annex B suggests that the ratio of opportunity costs in congested areas between the lowest and highest bands (up to 42 GHz) is in the order of 1:15 to 1:54, depending on bandwidth used and the location of links considered. However:

- 1:15 is unreasonably low (because it is based on high bandwidth links that are unavailable below 11 GHz); and
- all ratios likely underestimate the difference in opportunity cost across the full range of bands, because the bands were grouped for the opportunity cost calculations (i.e. these are ratios of average opportunity cost in the 1.3 – 8 GHz band to average opportunity cost in the 23 – 38 GHz bands).

There is an asymmetric risk when choosing how steep to set the frequency gradient (within the range suggested by opportunity cost estimates). If fees for the low frequency bands are set too low relative to higher bands, the gradient may not be effective in encouraging operators who can do so to install equipment in the higher bands. On the other hand, because operators will not use bands that provide insufficient propagation unless fees are extremely high (i.e. at or above the acute scarcity opportunity cost), setting a relatively steep gradient is unlikely to lead to inefficient use of the spectrum. Whilst we would not want to set the differentials across bands higher than necessary, the risk from setting them too low would appear to be stronger.

Based on the opportunity cost estimates, we expect that an initial ratio of at least 1:30 across bands from 1.3/1.4 GHz up to 42 GHz would be appropriate, but there may be a case for a steeper gradient, up to around 1:40.

Schedule parameter for 80 GHz

The 80 GHz band differs from the other fixed links bands in that there is a significantly greater amount of spectrum available, wider channel widths are used, and interference between links is highly localised. The opportunity cost modelling suggests that opportunity cost for the 80 GHz band is higher than for bands in the 23 – 42 GHz range – this is largely because the large bandwidths used mean that it is not possible to switch into alternative (lower frequency) bands, and opportunity costs are driven by the need to use dual polarisation. Given the different considerations for the band, and the fact that the opportunity cost estimates for the 80 GHz band do not fit with the general pattern observed and expected for the other bands, it is not feasible or appropriate to use the same methodology for determining where the 80 GHz band fits within the band schedule. If we were starting from a clean slate, we would recommend a different approach to licensing and setting fees for 80 GHz compared with the other bands, probably along the lines of the block licensing options described in section 3.4. However, this would not be practical given the large number of links already deployed, particularly in Dublin.

Therefore, we need to include 80 GHz in the same overall P-P pricing framework as the other bands, and the (initial) band schedule parameter should be set in a way that ensures 80 GHz fees are consistent with those for other bands. As a base, 80 GHz fees need to be matched to (uncongested) 42 GHz prices to avoid inefficient migration between the two bands. However, the greater availability and larger channels at higher frequencies needs to be reflected. Applying a 1:4 ratio for the 80 GHz band relative to the 42 GHz band would roughly reflect both relative channel sizes and relative supply in the two band, leaving fees for 80 GHz broadly unchanged. Therefore, we propose to set $r_i = 0.25$ in the initial set of band schedule parameters for the 80 GHz band.

As an example, if we set $R = 30$ then the band schedule parameters would be as set out in the table below.

Table 3: Schedule of band r values (R=30)

Band (GHz)	Mid-point (MHz)	r_i
1.3/1.4	1,444	30
2	2,158	29.5
L6	6,175	26.6
U6	6,775	26.2
L7	7,275	25.8
U7	7,575	25.6
L8	8,000	25.3

U8	8,388	25
11	11,200	23
13	13,000	21.7
15	14,925	20.4
18	18,700	17.7
23	22,800	14.7
26	25,865	12.5
28	28,697	10.5
31	31,400	8.6
38	38,250	3.7
42	42,000	1
80	78,500	0.25

It is important to be aware that using **this approach to setting the schedule would not be a formal part of the formula** going forward. ComReg should be free to adjust the schedule accordingly if, for example, the proposed relativities do not appear to provide the right incentives, if considerations over the source of opportunity costs change, or if the set of fixed links bands changes (i.e. if bands are added to or removed from those available individual fixed link licences).

The level of the base price per MHz, x, determines the general level of fees, and to some extent follows from the band schedule that has been set. As discussed above, our recommendation would be to set the formula parameters in a way that restructures the fees rather than leading to a fundamental change in the fee levels. On this basis, a reasonable approach might be to set x such that (given the band schedule) the standard fees for typical bandwidths in the most commonly used bands, 11 – 23 GHz, remain similar to those under the current regime. The fees for other bands would then be rebalanced according to the schedule. For example, if $R = 30$, then setting $x = 1.3$ would keep the general level of charges for uncongested links at typical bandwidth broadly similar for the 11 - 23 GHz bands.

Small link gradient and typical bandwidths

It is difficult to determine what the most appropriate value should be for the small link gradient. We need it to be sufficiently small to incentivise use of larger channels (rather than multiple smaller channels) where relevant, but at the same time we do not want to encourage operators to hold licences for larger channels than they need (e.g. if $m = 0$ then there no benefit to operators acquiring licences for channel sizes under the typical bandwidth as the effective bandwidth, and therefore the price, price would be the same. Setting m in the region of 0.4 – 0.6 would seem to offer a reasonable compromise, noting that ComReg may adjust this in the future if it considers doing so would be beneficial.

For most of the fixed links bands, we suggest that the present modal channel sizes are used to define typical bandwidths. However, there is a strong trend towards wider channels (at least above 11 GHz) and it may be more appropriate to use 56 MHz as the typical bandwidth wherever this is feasible within the respective channel plan for the band (and the modal channel size is not larger). This would suggest setting the typical bandwidth at 56 MHz for the 38 GHz band, even though the modal channel size is currently (as of 2021) 28 MHz. 55/56 MHz is already the most used channel size for the 13 GHz, 15 GHz, 18 GHz, 23 GHz, 28 GHz and 42 GHz bands.

Administrative fee floor

As set out in Section 4.3.6, we believe that EUR 100 is a reasonable level at which to set the administrative cost floor.

Congestion intensity

The congestion intensity c_{is}, for band i in location s, takes one of the values for c set by ComReg, based on the current level of congestion for that band/location.

As discussed above, we expect that it would be appropriate to have only two levels of congestion intensity, with $c_{is} = 1$ wherever a congestion surcharge would not be applied.

Under the current licensing regime, the congestion charge is set such that fees are 20% higher for links in relevant bands within the congested area than for equivalent links outside the congested area (i.e. this is analogous to setting c = 1 for the uncongested case and 1.2 for where a congestion charge applies). However, as discussed above, we are of the view that there it is necessary to increase the differential between congested and uncongested cases. For example, **the estimated opportunity cost for the congested 13, 15 and 18 GHz bands for a 56 MHz bandwidth is over €10k per annum.** This is estimated on an 'acute scarcity' basis, where users need to migrate up to higher bands and may need additional intermediate stations (although in practice opportunity costs might be lower than this). To implement congestion charging to reflect opportunity costs of that scale would require setting $c \approx 6$ for congested cases, rather than the current $c = 1.2$.

Given the impracticality of increasing charges for congested bands sharply, uncertainty around the opportunity cost estimates, and because the relative scarcity in particular bands may in any case be reduced by the proposed pricing formula, **we recommend that ComReg only partially adjusts congested prices towards these estimated opportunity costs, and then reviews the situation before applying any further increase.** Therefore, a first step in realignment might be to set c in the region of 2 - 4 for congested bands/areas.

4.3.9 Example fees compared to existing fees

The table below shows an example of how fees for typical bandwidth links in each band might be set under the proposed approach. The parameters are set purely for illustrative purposes at this stage, rather than being specific recommendations, but are in line with the suggested ranges set out above. In particular, we use:

- $x = 1.3$ (calibrated to keep the general level of charges for uncongested links at typical bandwidth broadly similar for the 11 - 23 GHz bands)
- $R = 30$
- $m = 0.5$ (so that fees fall at half the rate below typical channel size)

- $A = 100$
- $c = 3$ for the 13 GHz, 15 GHz, 18 GHz and 23 GHz bands in the Dublin congested area and 1 otherwise.

Typical bandwidths in the example are the modal bandwidth for links in the band in November 2021 for the majority of bands. For the 38 GHz band, we set the typical bandwidth to 56 MHz (rather than the modal bandwidth of 28 GHz) to reflect expectations that demand for 56 MHz channels will become the modal channel size in the near future.

The table also shows example fees for links with bandwidth one step down and one step up from the typical channel size (based on the channel sizes available in each band). For the 15 GHz band, 112 MHz channels are recommended by the ITU. This has yet to be adopted by ComReg, but we understand that the fixed links guidelines will be updated accordingly to adhere to the ITU recommendation. As such, the prices set out in the example below assume that 112 MHz channels are available in the 15 GHz band.

Table 4: Old and new fees for common links

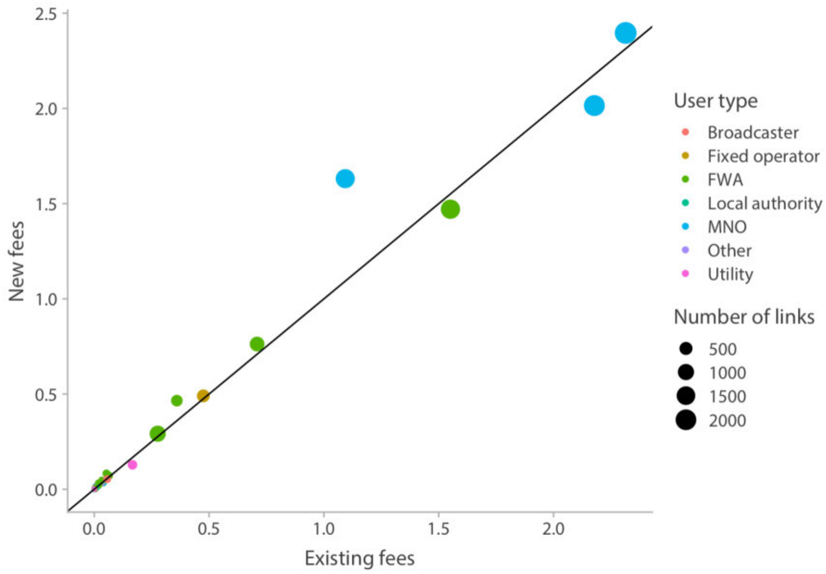
Band (GHz)	Small bandwidth (MHz)	Old fee (€)	New fee (€)	Typical bandwidth (MHz)	Old fee (€)	New fee (€)	Large bandwidth (MHz)	Old fee (€)	New fee (€)
1.3	0.5	1,000	100	1	1,000	100	n/a		
1.4	0.25	1,000	100	0.5	1,000	100	1	1,000	100
2	7	1,100	403	14	1,100	537	n/a		
L6	n/a			29.65	1,200	1,026	n/a		
U6	20	1,200	1,021	40	1,500	1,362	n/a		
L7	n/a			14	1,100	470	28	1,200	940
U7	14	1,100	699	28	1,200	932	n/a		
L8	n/a			29.65	1,200	976	n/a		

U8	3.5	1,100	171	7	1,100	228	14	1,100	456
11	n/a			40	1,500	1,197	n/a		
13	28	1,200	1,187	56	1,500	1,582	n/a		
13 congested	28	1,440	3,560	56	1,800	4,747	n/a		
15	28	1,200	1,112	56	1,500	1,482	112	1,500	2,964
15 congested	28	1,440	3,335	56	1,800	4,447	112	1,800	8,894
18	27.5	900	947	55	1,125	1,263	110	1,125	2,525
18 congested	27.5	1,080	2,841	55	1,350	3,788	110	1,350	7,576
23	28	900	804	56	1,125	1,072	112	1,125	2,145

23 congested	28	1,080	2,413	56	1,350	3,217	112	1,350	6,434
26	14	825	342	28	900	456	n/a		
28	28	900	574	56	1,125	765	112	1,125	1,531
31	14	825	234	28	900	312	n/a		
38	28	660	201	56	825	268	112	825	536
42	28	120	100	56	150	100	112	150	146
80	250	150	122	500	150	163			

The total fee payments for most users would remain at a similar level, as shown in Figure 2.

Figure 2: Total fixed links fee payments (EUR m) by user



4.4 Definition of congested areas and bands

ComReg currently applies measures to address congestion in the 13 GHz, 15 GHz, 18 GHz and 23 GHz bands in a defined area that includes Dublin and some high sites to the south of the city. These bands are those that offer a favourable balance of available bandwidths and link lengths that can reach from a limited number of high sites just south of Dublin (e.g. Three Rock, Tallaght, RTÉ Donnybrook) into the city centre.

Under the current measures, no new licences are assigned in the congestion area in the 13 GHz and 15 GHz bands, whereas a congestion charge applies for links in the 18 GHz and 23 GHz band.

Closed bands

As discussed above, in preparing our first report we found that there has been a reduction in the number of links (and bandwidth used) in the 13 GHz and 15 GHz bands in the congested area. On that basis we have recommended that ComReg re-open these bands for new links in the congested area, to avoid leaving spectrum inefficiently unused, especially where it particularly valuable.

Assuming that the 13 GHz and 15 GHz bands will be re-opened for new links in Dublin, **we recommend that a congestion**

charge is applied to links in the 13 GHz, 15 GHz, 18 GHz and 23 GHz bands in the congestion area defined under the current framework.

Congestion outside Dublin

In our first report, we did not find any strong evidence of sufficient congestion outside Dublin, or in bands not already subject to congestion measures. Although there is clear clustering of links in Dublin in all bands above 11 GHz, and some clustering in other urban areas (most notably in Cork) this in itself is not evidence of congestion being an issue. We did not receive any information from stakeholders to suggest that the findings were incorrect.

Since the first report was published, we have run some further analysis on spectrum availability using a 'grid method', that places a grid over Ireland and measures spectrum availability as the proportion of typical size channels that are unused within each square (see Annex C for a more detailed description). The grid squares are assumed to be small enough such that two links could not use the same channel in the same area, and a link is considered to be in a square if either:

- one or both of the end points lies within the square; or
- the link path bisects the square.

We have run the analysis using this method using ComReg licence data from November 2021, and the results appear to be consistent with our initial view that, although there are pockets of low availability outside of the congested area, there is no strong evidence to suggest that the congestion area needs to be extended.

Evidence in Dublin for congestion by band

Within Dublin, the analysis supports the view that the 18 GHz and 23 GHz remain significantly congested, and so we recommend continuing to apply a congestion surcharge for these bands. There is more availability in the 13 GHz and 15 GHz bands, however we would not recommend removing the congested status from these bands at this time. Although the bandwidth used in the 13 GHz and 15 GHz bands in the congestion area has fallen, we do not see this as sufficient evidence to conclude that scarcity in the bands is not an issue, at least for the time being, since:

- there is still high usage of the bands in the congested area, despite some fall in the number of licences;
- the fall in demand does not necessarily tell us that the bands are becoming less popular and that we do not need to be concerned about congestion, as the fact that no new links have been possible since 2014 means that we do not

know how true demand has evolved (only that some pre-existing licensees have cancelled or not renewed some licences); and
- information received from stakeholders suggests that those bands are expected to continue to be important for links running from high sites into the centre of Dublin for the foreseeable future.

The 28 GHz band is also shown to have low availability within Dublin. This could be evidence that congestion is arising, but we do not believe it is necessary at this stage to add this to the list of congested bands. Whilst we believe the grid method is a very useful tool, the results cannot be considered in isolation to provide a full picture of congestion, as whether there is an issue or not depends on a variety of factors that cannot be practically accounted for in the calculations e.g. many links operating over the same popular path is likely to be more of an issue (in terms of congestion) than the same number of links in the same area but all pointing in different directions. The grid methodology can therefore be used to provide evidence of where congestion *might* be an issue, but needs to be taken into account alongside a less formulaic assessment of other factors e.g. large numbers of applications being rejected (as with 13 GHz and 15 GHz), identification of popular routes, feedback from stakeholders. In that respect, we have not seen any further evidence to suggest that congestion is currently a big problem in the 28 GHz band, and we would therefore not suggest applying a congestion charge in the band. Nevertheless, ComReg should continue to monitor the situation.

Recommendations

In summary, we recommend that the congestion area remains as currently defined, and that a congestion charge is applied within that area for the 13 GHz, 15 GHz, 18 GHz and 23 GHz bands. For other bands, we have not identified any evidence of congestion that would at this stage warrant a congestion charge to be applied. However, stakeholders should be on notice that further congestion charges may be introduced in the future depending on development of demand, and that there are some bands/areas that are already showing signs of low availability.

Future updates

In the future, the grid method could be used by ComReg as a screening method, to identify any bands/locations that are potentially congested and should be considered for further investigation.

If ComReg finds it appropriate to adjust the definition of the congested area, or add further congested areas, at a later stage, it could also consider adjusting the definition of links that count as being in the congestion area. Currently, only links that have one end in the congestion area are subject to a congestion charge. However, links that only pass through the area, without either end point lying within it, would also have an impact on spectrum availability within the area, so should arguably also be subject to a congestion charge. With the congestion area as currently defined, we would not expect this to be relevant as we understand that the end points of the links causing the congestion all lie within the congestion area. We therefore do not recommend making such a change now, but ComReg may consider this in light of any future developments.

4.5 Phasing and closed bands

Adopting the approach set out above will lead to higher fees for bandwidths above 40 MHz and potentially in the congested area.

Three year phasing

We would suggest a phased implementation of any new charges to help licensees adjust to the new framework. The simplest way to do this would be to run both old and new charging schemes in parallel and then take a weighted average of the two. For example, with 3-year phasing:

- 1/3 weight to new prices and 2/3 to old prices in year 1;
- 2/3 weight to new prices and 1/3 to old prices in year 2; and
- new prices from year 3.

This approach would allow the new prices to be made transparent to existing licensees, which should be helpful in demonstrating the trajectory for prices and encourage more efficient choices for new links even prior to the phasing completing. We think there would still be good incentive benefits with slower phasing, given that new links will usually be expected to last a long time (15 years or more).

Reopened bands

At present, the 13 and 15 GHz bands are closed to new applications (and have been for a number of years) but, as discussed above, we have recommended that ComReg make these available again, subject to congestion charges set at a sufficient level (noting that the level of congestion with very likely be higher than suggested by the licence data once the bands are re-opened). We would suggest re-opening these two bands for new applications as soon as possible following the conclusion of this review, applying the congestion charge described above on the new charging scheme only, as the new fees are phased in. For example, in the first year fees would be 1/3 of the new fees including a congestion charge, plus 2/3 of the old fees with no congestion charge (given that the 13 and 15 GHz bands are not currently subject to a surcharge).

4.6 P-MP licences

Whilst licensed P-MP use has declined as rural fixed line services have improved, there is potential for re-emergence of P-MP for high-capacity broadband services. This could include urban areas and demand is likely to be for lower-end millimetre wave spectrum (e.g. 26 GHz, 32 GHz and similar) which provide a sweet-spot for these services between reach and reuse.

Current approach

Fees for P-MP licences are current set at four times the annual fee for a P-P licence in the same band and with equivalent bandwidth. However, P-MP fees need to reflect increased impact on availability for others, and the current approach may not be going far enough in this regard when more than four links are run on the licence. Up to a certain number, links operating on a P-MP licence are effectively the same, in terms of the impact on other users, as a collection of P-P links originating from the same location (the 'hub'). In that sense, there is an argument for setting fees for a P-MP on a per link basis (i.e. as if they were separate P-P links coming from the same point).

Opportunity cost logic for a 'spoke cap'

However, beyond a certain number of links, the marginal impact on others of an additional link *at the hub* of the P-MP system will be zero, as the required angle of separation for avoiding interference means that no other operator could use the same frequencies to run a link from the same location in any direction. Therefore, although there would still be some effect on spectrum availability at the other end of the link, the overall impact on others would be lower, and charging the full P-P link price for these additional links is likely to be excessive.

On the basis of the arguments above, our proposal is that ComReg charges for P-MP use on a per link basis up to a certain number of links, the 'spoke cap'. For any additional links beyond the spoke cap, the licensee would be charged a reduced rate equal to some proportion of the full P-P fee (call the resulting per link discount the '*excess spoke discount*').

We expect that eight links is a reasonable estimate of the number of links required at a particular site before no other users can fit; we therefore recommend setting the spoke cap at eight, but would welcome the views of stakeholders on the appropriate threshold.

Marginal price beyond the spoke cap

In terms of the reduced rate for additional links, we do not propose setting this to zero (given that there will still be some marginal impact away from the hub), but we do expect that setting it at relatively low level will be appropriate, as:

- at one of the two ends of the link there is zero incremental cost to other users, so setting the reduced rate at half that of the full P-P price is arguably an upper limit in what is likely to be reasonable;
- P-MP links can be expected to be fairly short with end points relatively close to one another, so where there is a large number of spokes there is likely to be some overlap in the areas in which each spoke creates interference (and prohibits use of the spectrum) for others, even away from the hub – therefore the reduced rate should be even less than half the full P-P fee; and
- it is important to ensure that the total P-MP fees are not prohibitively expensive.

We are of the view that charging 25% of the individual P-P fee for each additional link beyond the spoke cap (i.e. an excess spoke discount of 75%) would provide a reasonable balance.

There is arguably a case that beyond a certain number of links the fee for additional links should be reduced to zero, as the density of links means that no other operators can use the spectrum within the area covered by the hub and all end points, so further spokes on the P-MP system have no effect on others anywhere. We do not suggest taking such an approach at this point, as it is unclear where the cut-off should be or even if that level would/could be reached. However, ComReg may want to monitor technology developments and P-MP usage to determine whether the scenario described occurs, and consider setting a incremental link fees to zero.

Congestion of P-MP systems

The fee for a P-MP licence would be set on the basis of each individual link operating under the licence. In that regard, any links operating outside the congestion area would be charged based on the standard P-P rates, whereas links falling within the congestion area would be subject to the congestion surcharge. P-MP technology is not used to cover long distances, and we do not expect this to change in the future. Therefore, in most cases we would expect that either all end points and the hub will be in the congested area, or none will be, and the per link fee would not vary across links on the same P-MP licence (other than to take account of the reduced rate for higher numbers of links). In the event that a congestion surcharge applies to some, but not all, links on the same P-MP licence, and there are more than eight links on the licence, the total licence fee would be calculated by applying a discount based on the average per link fee.

Specifically, the fee for a P-MP licence would be calculated as follows:

- find the relevant P-P fee for each spoke – the sum of these is the uncapped price;
- if the number of spokes is greater than the spoke cap, find the average price per spoke;
- multiply the average price by the product of the excess spoke discount and the difference between the number of spokes and the spoke cap – this is the discount;
- the P-MP fee is the uncapped price minus the discount.

Example:

Suppose that an operator wishes to obtain a P-MP licence with 10 links (spokes) running from the hub.

The spoke cap is eight, and links in excess of the spoke cap are charged at 25% of the individual P-P fee (i.e. the excess spoke discount is 75%).

The hub is not in the congestion area, but five of the spokes end in the congestion area (and so a congestion surcharge would apply to those five links).

Suppose that, for the given band and channel size applied for:

- the standard fee for an individual P-P link is €100; and
- the fee for a P-P link subject to a congestion charge is €300.

Then the fee for each spoke would be €100 for five of the spokes to be on the P-MP licence and €300 for the other five. The uncapped price is therefore (5 x €100) + (5 x €300) = €2,000.

This gives an average fee per spoke of €2,000/10 = €200.

The total discount is calculated by multiplying the average fee per spoke by the product of the excess spoke discount (0.75)

<u>and difference between the total number of spokes and the spoke cap:</u> <u>Discount = €200 x 0.75 x (10 – 8) = €300</u> <u>The annual fee for the P-MP licence applied for is therefore €2,000 - €300 = €1,700</u>

Adjustments in the term of a licence

With the proposed approach there is the obvious point that the total P-MP fee is dependent on the specific number of links run on the licence, which the licensee may want to adjust during the course of the licence term (e.g. to accommodate new customers). We suggest that if a new link is added part way through a licence term, the licensee would be required to pay a pro-rata fee in proportion to the remaining licence term at the point the new link is added (and then the full annual fee for the following licence term if renewed). We also propose that it should not be possible for a licensee to remove a link from a P-MP licence during the licence term, which would avoid undue administrative burden on ComReg.

Registration requirements

Another consideration is that charging on a per link basis would require registration of each individual link operating on the P-MP licence with ComReg. We understand that this is currently how the P-MP licensing works in Ireland so there may be no issues with continuing to take this approach in the future. However, we would welcome feedback from operators on this, with regard to whether this has already created any issues/difficulties, and also whether developments in P-MP usage in the future are likely to mean that needing to register each link will become prohibitively impractical (e.g. if P-MP becomes more prominently used for dense small-cell systems with large numbers of links).

Subject to comments from stakeholders, we are of the view that the proposed approach to setting P-MP fees will be suitable for the foreseeable future. However, we recommend that ComReg keeps this under review, as changing technologies/use cases may create a need for further adjustments.

Annex A Fee methodologies

A.1 Criteria for fee regimes

Here, we set out the criteria that an effective fixed links fee regime should meet, the first four of which we use to assess whether the methodologies described below are suitable to inform changes to ComReg's fee schedule.

First, promoting competition and **efficient** use of the radio spectrum, including ensuring that the most valuable users should be prioritized where spectrum is scarce. This has a number of aspects:

- Ideally users face opportunity cost where their particular usage conflicts other users, though this may be difficult to define and to measure due to the complex and nature of interference interactions between users;
- Users are able to access spectrum in channel sizes and formats compatible with global equipment standards. In the first instance this is achieved by adopting new harmonization recommendations in a timely manner, but the fee regime should not unduly penalise users of certain channel sizes and should be robust to future technology/harmonisation changes;
- Incentives for installation of new fibre, which may bring wider external economic benefits, are not undermined;
- Incentives for pre-emptive hoarding of link capacity are avoided (though users may want to hold options to install links later which may be entirely compatible with efficient use);
- Where bands are substitutes, incentives to choose bands reflects relative scarcity and inefficient arbitrage incentives (to pick one band rather than another) are avoided; and
- Excessive fragmentation of bands that unnecessarily precluding issuing of wider channels is avoided.

Second, **simplicity for users**, to ensure that users and potential users do not face undue burdens. In particular, new users are not discouraged from applying (which reinforces a dynamic efficiency objective).

Third, charges should be **predictable**, so that users do not face future price shocks. Current and potential users should have access to market-aggregate information about usage of spectrum to allow informed assessment of future scarcity in different bands, so that they are able to assess likely future charges to the fees (given the long investment horizon of alternative equipment).

Fourth, **practicality** of implementation for ComReg. It is of no use if a methodology provides theoretically optimal fees if it requires inputs which are impossible to measure or otherwise unavailable to ComReg.

There are two further criteria that are essential for the fee regime, but are relatively easy met using any of the potential methodologies. The first of these is that ComReg's administrative costs, both those incremental to individual applications and of the licensing platform overall, are recovered. Although there are questions around how to distribute the opportunity costs across links, if incremental costs vary significantly, it is always possible to add administrative costs as an input to the model, or a floor on fees, and we do not need to consider this further in this annex. Administrative cost recovery can be thought of as a default position for fees, from which the fee regime may diverge if alternative methods are better able to meet the previous four criteria.

Finally, it is necessary for efficiency that the fee regime protects and promotes downstream competition, by ensuring that foreclosure of spectrum access cannot harm downstream markets. However, we have not identified any particular concerns in this regard, and we expect that any methodology that met all of the preceding requirements would be unlikely to adversely affect downstream competition.

A.2 Description of pricing methodologies

A.2.1 Administrative incentive pricing (AIP)

An efficient allocation requires that the highest value users have access to the spectrum. Suppose that spectrum in a given band over a given path was scarce, such that we assigned all of the available spectrum to the highest value users, and this still left a group of 'excluded users', who all had some value for, but were not granted access to the spectrum. The opportunity cost is set by the marginal excluded user, i.e. the excluded user with the highest value, such that if there was one extra channel available, that user would gain access to the band.

AIP, or opportunity cost pricing, attempts to set prices equal to opportunity cost, such that only the highest value users have an incentive to take up licences in the band, and we achieve an efficient allocation of spectrum. The size of opportunity costs varies significantly, being close to zero if there is no scarcity, low if there is modest scarcity and the marginal excluded users can easily make use of other bands, and very high where marginal excluded users are inflexible, therefore an assessment of scarcity is critical to the estimates/application of opportunity cost prices. This raises the question of whether a short run opportunity cost approach, where fees reflect the current level of scarcity, or a long run opportunity cost approach is more appropriate – we focus on short run opportunity costs, as operators are better placed to make judgements on likely future congestion when making decisions about installing new links for up to 20 years, and provided the fee regime is predictable, they should be able to factor in expectation on future congestion/fee changes at relatively little risk.

Practical implementation

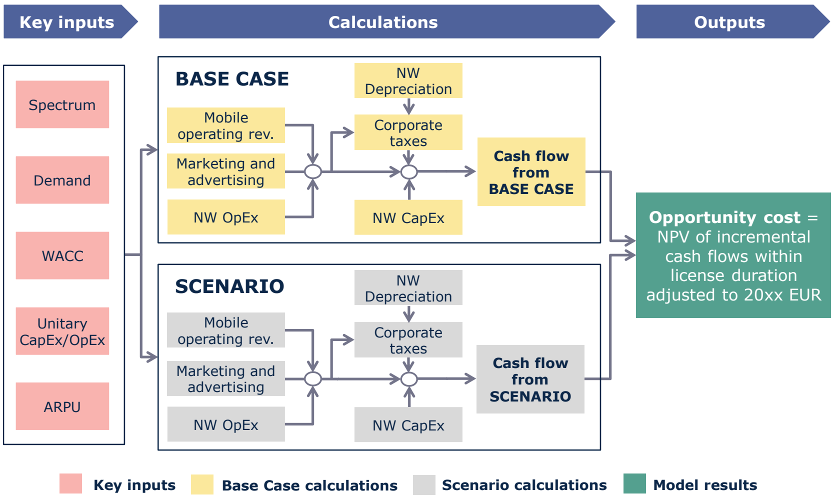
In practice, even without requiring estimates of changes to congestion, measuring opportunity cost is very difficult. Therefore, we compare the current state of affairs with a counterfactual in which a group of bands are closed, and the existing users make use of spectrum in other bands (e.g. instead of installing fibre connections). This implies that:

- the relevant excluded users are the existing fixed links licensees; and
- we are considering a scenario of severe scarcity and deriving an upper estimate of opportunity costs.

Under these simplifying assumptions, the determination of the opportunity cost of the spectrum requires ComReg to calculate the discounted cash-flow of market players with and without access to the spectrum under assessment. The opportunity cost of the spectrum is estimated as the difference between the Net Present Value (NPV) of the incremental cash flow from the ‘scenario’ in which the band(s) are closed, and the NPV in the ‘base case’ (i.e. current spectrum holdings).

Cost models of this type are widespread in radio access spectrum valuation, and the figure below illustrates the cost and revenue items considered in typical models of this sort, as well as the interrelations between them. However, this cannot be applied directly, because of the difference between the valuation of radio access spectrum and fixed links bands set out below.

Figure 3: Overview of the logical structure of opportunity cost models



Additional spectrum vs existing spectrum: when used for radio access spectrum valuation, opportunity cost pricing models take operators current spectrum holdings as an anchor point to define the 'base case' while the 'scenario' aims at reflecting the revenues and costs of the operator were they to acquire additional spectrum. However, when used for fixed links bands, given the need to re-assess the fees for all the spectrum bands, this anchor point no longer exists. Instead, the opportunity cost of the fixed bands needs to be understood as the incremental costs of switching off a band (or group of bands).

Predictability of future network requirements: the evolution of the number of assets (e.g. towers, SingleRAN elements) in an operators access network can typically be forecasted as a function of the evolution of the end users' demand and the coverage objectives, as it is done in Bottom-Up cost models. However, the future deployment of fixed links is also affected by other qualitative factors such as strategic decisions or preferences with regards to network deployment, availability of suitable locations to deploy the links, availability of alternative transmission options, etc, making these much harder to project.

Relevance of revenue forecasts: when quantifying the economic value of the radio access spectrum, it is important to assess the revenue differentials between the 'base case' and the 'scenario', given that access to more spectrum is commonly expected to generate additional revenues (independently of whether they come from an increase in ARPU or in the subscribers base). However, this should not be expected to be the case for fixed bands links. This is, having access to more bandwidth for the fixed links (for most use cases) is unlikely to lead to increased revenues, all else being equal. Consequently, revenues may be taken out of the equation when it comes to the assessment of the opportunity cost of fixed links bands.

We consider a version of the AIP model that is appropriate for fixed links and is implemented as follows. First, identify the fixed links in place, including their coordinates (origin and destination), bandwidth, frequency of operation, capacity, polarization modality and distance, among others.

Second, determine the key variables related to fixed links usage, particularly in terms of:

- Availability – whether a given range of frequencies is available in a specific region of the country;
- Reach – maximum distance that can be reached through a fixed link operating under the different fixed links bands in the different regions of the country; and
- Spectral efficiency – amount of bps that can be transmitted in a Hz of spectrum (although we find no evidence of material differences in spectral efficiency across bands).

Third, assess the long-term incremental costs of switching away from a band (or groups of bands). In this third step, the opportunity costs of a band (or group of bands) are obtained by assessing the additional costs, in the long term, an operator would face if it no longer had access to that band (or group of bands)[24]. The steps involved in this calculation are described below:

- Calculate the optimal number of assets (towers and antennas) required to replace the existing links. This calculation is to be performed through the following sub-steps:
    1. Determine the assets required to replace an existing link through all the other fixed links bands, considering the capacity requirements of the link as well as its reach. For instance, if a 20 km link operating in the 6 GHz band is to be migrated to the 80 GHz band (with a maximum reach of 2 km), it is

[24] Opportunity costs are determined based on the premise that there will always be alternative fixed links bands available to replace an existing link (i.e. there is no need to deploy wired links instead).

easy to conclude that 11 towers will be required instead of the original 2.

2. Identify the optimal (cost efficient) substitutable band, defined as the one that requires the least number of additional assets to replace an existing link operating in a different band, and which has enough spectrum available to accommodate this link. For instance, continuing with the previous example, if there is enough spectrum available in the 8 GHz band, it will make more sense to switch the link operating in the 6 GHz band to the 8 GHz band than to the 80 GHz band.

- Calculate the incremental costs of switching off a band (or group of bands). Once the number of assets required to replace a link operating in a band that is switched off is known, the incremental spectrum cost of band (or groups of bands) i per link is:

$$\frac{\sum_{links\ (band\ i)} Cost\ Assets\ (alternative\ bands) - Cost\ Assets\ (band\ i)}{\#\ of\ links\ in\ band\ i}$$

Finally, note that, when implementing this methodology:

- results depend significantly on how the fixed links bands are grouped;
- provided sufficient spectrum is available in lower frequency bands, opportunity costs will be close to zero; and
- opportunity costs are considerably below the estimates yielded by this methodology in regions/bands with little scarcity.

A.2.2 Universal system performance pricing

The Universal System Performance Pricing methodology (USPP) estimates the value of spectrum based on a set of relevant factors that are selected in advance. If these factors are the key determinants of opportunity cost, then USPP can be used as a proxy for AIP.

According to the ITU 2016 report[25], the basic principle of this approach is to identify the technical parameters to measure the spectrum volume used or define the "pollution area" of a radio system as a common basis for establishing spectrum fees. In effect, this penalises a licensee in relation to the spectrum its licence denies to other users – this is the same logic as found in full opportunity cost models, as USPP also attempts to encourage efficient use of spectrum.

The USPP methodology establishes a universal model for spectrum price determination which uses to take the following standard shape:

$$P = \frac{V}{M} \cdot K_f \cdot K_s \cdot C_s$$

where:

- P is the spectrum price;
- V/M is a ratio that takes into consideration the efficiency on the use of the fixed links spectrum, taking into account the area or length "polluted" by the fixed link in the numerator and the capacity or number of customers served in the denominator;
- K_f is the coefficient reflecting the specific characteristics of the band used;
- K_s is the coefficient considering the region where the fixed link is deployed; and
- C_s reflects the underlying annual spectrum management costs of a particular band.

The formula above may also account for other factors such as a coefficient reflecting the social benefit of radio systems or a coefficient reflecting the level of spectrum access demand, although they are less common.

The universal definition of the formula serves as a starting point for regulators to develop their own approaches that best suit the situation in each country or the necessities of each regulator. It also needs to be tailored to fixed links use in this case, for example, the V/M term is unlikely to be necessary, as links are licensed over a defined path, rather than an area of a given size, and factors such as link length or capacity are

[25] "*Guidelines for the review of spectrum pricing methodologies and the preparation of spectrum fees schedules*"; ITU (2016); Available at https://www.itu.int/en/ITU-D/Spectrum-Broadcasting/Documents/Publications/Guidelines_SpectrumFees_Final_E.pdf

implicitly covered by characteristics such as frequency band or channel size.

From a practical perspective, the choices made by regulators both on the parameters to include and the levels to set them at means that USPP naturally relates to other methodologies. We consider a version that can reasonably considered a proxy for AIP, which means that the formula should:

- include some parameters that would be significant in a full opportunity cost model; and
- set them at a level that is related to opportunity cost estimates.

A.2.3 Benchmarking

Benchmarking estimates the value of spectrum based on the prices paid by operators in other countries for access to equivalent spectrum. Fees could, for example, be set to the average paid by operators in other countries, possibly filtered/weighted to focus on the most relevant observations.

Implementing the benchmarking methodology is highly dependent on the information available on the spectrum fees applied in other countries. However, we are confident that benchmarking would be feasible for ComReg, as the preliminary analysis in the table below demonstrates that there are at least four international references for each band (that is not to say that the references in the table are sufficient to give robust estimates for the value of the spectrum in Ireland, e.g. as some of the countries included are not in Europe, and market conditions may differ significantly).

Table 5: Availability of price references by band (GHz)

Country	1.3	1.4	2	L6	U6	L7	U7	L8	U8	11	13	15	18	23	26	28	31	38	42	80
UK				√	√	√	√	√	√		√	√	√	√	√			√		√
Canada	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Denmark	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
France				√	√			√	√	√	√		√	√	√			√		
Germany															√	√				
Greece	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Hong Kong			√	√	√	√	√	√	√	√										
India											√	√	√		√	√		√	√	
Pakistan				√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Qatar	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		
Singapore				√	√	√	√	√	√	√	√	√	√	√						
Lebanon			√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		
Zambia			√	√	√	√	√	√	√	√	√	√	√	√						
Sri Lanka				√	√	√	√	√		√	√	√	√	√	√	√		√		√

TOTAL	**4**	**4**	**7**	**12**	**12**	**11**	**11**	**12**	**11**	**11**	**12**	**11**	**12**	**11**	**11**	**9**	**6**	**10**	**5**	**6**

When calculating benchmark prices, it is always necessary to define a set of correction factors that will make the fees from other countries comparable to potential fees in Ireland. Among others, these correction factors may include:

- exchange rates;
- financial capacity of operators/spectrum bidders (e.g. purchasing power parity index);
- level of competitiveness in the market and/or level of spectrum scarcity;
- regulatory obligations attached to the licences; and
- applicability to single/double polarization links.

A.2.4 Administrative cost recovery

The cost recovery methodology in an administrative-based approach that sets total spectrum fees equal to the overall spectrum management costs. This is one of the simplest methodologies available, albeit widely adopted, especially when there is no threat of spectrum scarcity, and it may contribute to fostering spectrum demand.

In the simplest case, fees could be set at a constant price (per MHz) for all links, calculated as the total amount of (direct and indirect) spectrum management costs, divided by the total amount of spectrum in use. However, it could also be appropriate to split administrative costs differently between links, if they the incremental administrative cost of a link varies (e.g. interference analysis may be considerably more involved for some applications).

Spectrum management costs include pure administrative costs of spectrum plus all associated spectrum planning, management, and monitoring costs, for example:

- salaries for monitorisation, enforcement and administration of spectrum;
- investments in IT assets such as spectrum management tools, frequency allocation databases and monitorisation systems;
- CapEx and OpEx for spectrum management equipment, such as IT systems that register and manage the status and operations of the fixed links grid; and
- some proportion of ComReg's wider costs (e.g. offices, utilities, research activities, etc.).

If ComReg has objectives other than simple cost recovery, then it may wish to recover an amount that differs from its total spectrum management costs, and in general it has three options:

- partial cost recovery – fees are set slightly below spectrum management costs. In this case, the government is said to partially subsidise the usage of spectrum.
- full cost recovery – fees are set exactly at the same level as the spectrum management costs.
- full cost recovery with surplus – in this case, a mark-up is applied on top of spectrum management costs when setting the spectrum fees.

A.2.5 Other methodologies

There are many other methods for setting spectrum fees that are not broadly used internationally, as they are not easily adapted to different circumstances. These are all inferior to the methodologies above in terms of our criteria and are excluded from a full assessment, but are included here for completeness.

Equipment cost differentials (or differential rent spectrum price):

- **Conceptual description**: Spectrum fees are set as the difference between equipment costs for systems providing the same service but using different spectrum ranges.
- **Practical implementation:** This methodology aims at unifying the total cost (equipment plus spectrum fees) across all bands. Therefore, in order to implement it, the average costs of deploying a link in all the different bands needs to be calculated. The difference between the costs of deploying a link in the most expensive band and in the band under assessment is then added to the spectrum management costs of that band to set its fees.
- **Reason for exclusion:** does not contribute to efficient use of spectrum or provide adequate solutions to deal with spectrum scarcity, more complex for users and ComReg than e.g. administrative cost pricing as it requires additional cost calculations.

Contribution of spectrum to the national economy (or economic modelling):

- **Conceptual description:** Spectrum fees are set in a way that the ICT sector's contribution to the national economy is maximised.
- **Practical implementation:** Although the rationale behind this model is quite clear, its implementation is rather complex. Theoretically, several sensitivity assessments would be performed evaluating the implications of setting lower/higher spectrum fees on the national economy, by looking not only at the direct implications from the deployment of more/less fixed links, but also at its side-effects (e.g. impact on the deployment of wired fibre links). The price levels resulting in the highest contribution to the national economy would be set.
- **Reason for exclusion:** complexity of implementation and number of assumptions required, make it impractical for ComReg, complex for users, and very poor in terms of predictability (e.g. changes in the split of fixed links in place over time may significantly distort the outcomes of the exercise). A more direct approach to encouraging efficient use (e.g. AIP) would be more likely to be effective and likely bring about the same benefits.

Contribution of spectrum to the user's business (or business-based valuation):

- **Conceptual description:** Spectrum fees are set in a way that the profits of the fixed links bands users are maximised, while still allowing the different spectrum seekers to get access to it.
- **Practical implementation:** Similar to the approach described above with regards to the national economy, this methodology would involve setting up a number of sensitivity analyses that would end up in a level of fees that maximises the operators' profits.
- **Reason for exclusion:** less likely to support efficient use than AIP. Very poor in terms of predictability, simplicity for users (especially if effect of fixed links on profits is unclear), and practicality for ComReg.

A.3 Overview of common European practices

ComReg issued a request for information to BEREC members prior to publication of the initial consultation that included a question on the methodologies used to set fixed links fees.

Responses to this question are summarised in Table 6. From these responses:

- of NRAs who referred to a specific methodology, USPP was most common;
- there is a clear preference for setting fee by formula rather independently for each band;
- band and bandwidth are commonly affect fees, link length, region, and whether the link is P-P or P-MP are also included in a number of cases.

Table 6: Spectrum valuation methodology and fee schedule type by country

Country	Methodolog y	Schedule of fees
Austria	-	Per band
Bulgaria	USPP	Formula
Czech Rep.	USPP	Formula
Croatia	USPP	Formula
Estonia	AIP	Per band
France	-	Formula
Germany	AIP	Formula
Hungary	USPP	Formula
Lithuania	-	Formula
Malta	-	Formula
Norway	Cost recovery	-
Poland	-	Per band
Portugal	-	Formula
Serbia	-	Formula
Slovakia	USPP	Formula
Slovenia	Cost recovery	-
Switzerland	Cost recovery	-

Turkey	-	Formula
UK	AIP	Formula

Table 7: Frequency with which variables appear in fee schedules

Variable	Number of countries
Polarity	3
Power	3
Bandwidth	13
Frequency	14
P-P/P-MP	6
User density	3
Spectral efficiency	2
Exclusivity	3
Range	5

A.4 Evaluation against criteria

Table 8 assesses the four the methodologies described in detail above against the criteria for fixed links fee regimes.[26]

First, we note that both benchmarking and simple cost recovery perform very poorly in terms of efficiency:

- fees for fixed links internationally are not set in a way that reflects opportunity cost of spectrum (such as competitive award processes), therefore the benchmarks would not be grounded in anything meaningful; and

[26] For the avoidance of doubt, this assessment relates only to the suitability of the methodologies discussed for setting the fees for fixed links in Ireland. It is not intended as a general assessment of the methodologies or their suitability for other purposes, where prevailing circumstances and considerations may be different.

- given that ComReg has taken action to address congestion in the past, it is highly likely that opportunity costs are material in some cases, and no reason to expect this to be captured by benchmarks.

Neither of these methodologies performs significantly better than AIP or USPP on the other criteria, and we do not consider that they are appropriate ways to set fixed links fees.

The extent to which full AIP or USPP as an AIP proxy can bring about an efficient outcome are linked, as the latter requires some formal assessment of opportunity costs to avoid being arbitrary. However, the other aspects of efficiency described above are better met by a proxy measure if opportunity costs are uncertain and difficult to measure. For example, because existing scarcity may vary between neighbouring bands, estimated opportunity costs could jump from one band to the next in a way that is not consistent with encouraging efficient substitution between bands, whereas approximating opportunity costs by a formula would give a more coherent schedule of fees, and constitutes a more realistic attitude to our ability to measure opportunity cost – it is entirely reasonable to suggest we can identify important drivers of opportunity cost (e.g. channel size), but less so to suggest we can accurately determine opportunity cost for each band/region combination without relying on assumptions that are unlikely to prove robust.

Moreover, USPP as an AIP proxy is unambiguously better than full AIP when checked against the other criteria. Limiting the factors that affect fees to a handful of key parameters is clearly simpler for users, but also improves predictability, as it offers the assurance that, if ComReg needs to update fees in future in response to developments in demand or the bands available to fixed links, it will do so by adjusting the level of one of those parameters. ComReg can further improve predictability by regularly sharing information it users to inform such adjustments with fixed links users.

Similarly, it is more practical for ComReg, both in initially defining the schedule of fees, and when it comes to update fee parameters. Although opportunity cost modelling is still necessary, the assumptions become less critical (e.g. ComReg can calculate opportunity costs under the assumption that there is scarcity, and use this as one of a number of inputs to the fees, rather than relying on detailed congestion estimates, which are complex given the interference analysis required).

Therefore, we suggest that a proxy for opportunity cost prices based on a formula that sets fees for all bands is the appropriate way to set fees for fixed links. It is more likely to support efficient use of the spectrum than simpler methods, but remains more predictable and practical than using model estimates directly as fees.

Table 8: Evaluation of fee methodologies against criteria

	AIP	USPP as an AIP proxy	Benchmarking	Administrative cost recovery only
Efficiency	Potentially good, but may be difficult to measure opportunity costs with accuracy	Potentially good if opportunity costs are reasonably approximated by the pricing formula	Likely very poor, due to highly varied basis of setting fixed link charges used by other NRAs and different scarcity environment in other countries	Very poor, as unlikely to reflect opportunity cost and encourage more efficient use.
Simplicity for users	May be complex if many drivers of opportunity cost included	Reasonable and significantly simpler than full AIP	Simple	Simple
Predictability	Moderate – opportunity cost	Good – provided price formula anticipates future requirements	Moderate-low	Moderate-high

	estimates may be unstable over time			
Practicality of implementation	Challenging due to difficulty of measuring opportunity cost, so in practice likely to fall back to some proxy approach anyway	Reasonable	Reasonable, though question of which benchmarks to use where there is significant variation across NRAs	Good

Annex B Opportunity cost estimates

B.1 Methodology

Costs for inflexible users relate to repeater stations and dual polarisation equipment

As set out in Annex A , it is possible to estimate opportunity costs of fixed links use by comparing the costs incurred by fixed links operators to those they would incur in a counterfactual scenario in which some fixed links bands were switched off. We assume that the costs to a user of being denied access to its preferred band when installing a new link fall into three categories. There are operators who can use:

- lower frequency bands, and face no additional costs, because these bands have superior propagation characteristics;
- higher frequency bands but not lower bands, and may have to install repeater stations due to the lower reach of higher frequency links; and users who can
- only use lower bands if they reduce the channel size, and instead have to use a potentially more expensive dual polarisation antenna to achieve the same capacity.

We are interested in the short run opportunity cost of installing new links, and we understand that differences in equipment prices between bands are minimal. Therefore, the model does not use the level of equipment costs, but takes two inputs for the additional costs potentially incurred per link (both calculated as the fixed cost, divided by the useful life, plus opex):

- the annual cost of an additional repeater, (EUR 11,500); and
- the annual cost of switching to dual polarisation, (EUR 1,750).

In the counterfactual scenario, a group of bands is closed to new links...

If we only considered shutting down one fixed links band at a time, we would derive very low estimates of opportunity cost, because the characteristics of adjacent bands are similar, and few users would incur additional costs. This is not appropriate when we are reviewing fees for all fixed links, as it would imply the combined opportunity cost of closing all fixed links bands was very low. Therefore, we group the bands as follows:

- 1 – 8 GHz;
- 11 – 18 GHz;
- 23 – 42 GHz; and
- 80 GHz.

Creating acute scarcity that causes some users to incur the additional equipment costs

Shutting down a group of bands takes away the opportunity to move into adjacent bands with similar propagation and available bandwidths, meaning that some users of a specific frequency band moving to higher bands would require additional stations as the link lengths supported by these bands are lower, and some users moving to lower bands require costly dual polarisation equipment, as the channel widths available are smaller. For both cases, these users moving to alternative bands would incur in additional costs.

All in all, we estimate the proportion that would need additional repeater stations or dual polarity equipment, and the average number of additional stations that would be required for users incurring the additional costs using ComReg licence data (e.g. on path lengths, frequency, and channel size of each link). This process is carried out following 3 main steps:

- first, when a group of bands is shut down, all its links should be relocated in other available bands;
- then, the affected links are relocated in the most cost-efficient way, this is, allocating as much links as possible in lower bands to those shut down, where no additional stations are required to provide the same (or higher) path lengths;
- finally, all the remaining links to be allocated in higher bands to those shut down, require additional stations.

Once the process is completed, it is possible to count the total number of additional stations required per sample and per group of bands and, therefore:

- The number of extra stations is calculated by taking the average of additional stations required to relocate all the links (being 1 the minimum number, when additional cost is incurred).
- The proportion of links requiring additional repeaters is calculated as the percentage of links that require more than 1 station to provide the same (or higher) path lengths.

Then, the opportunity cost per annum for bands below 80 GHz is equal to the:

- average number of extra links required, if additional repeaters have to be installed;
- multiplied by the proportion of users that would require extra links if they did not have access to the preferred group of bands;
- multiplied by the annual cost of an additional repeater.

For the 80 GHz band (the highest frequency band, in which much greater channel widths are available than in the lower bands), all links would require dual polarisation equipment to relocate all the bandwidth currently occupied in the 80 GHz band. Therefore, the opportunity cost is equal to the annual cost of switching to dual polarisation equipment.

The calculations are carried out separately for each group of bands in of three region types, Dublin, urban (Cork, Limerick, Galway), and rural.

Opportunity costs are roughly linear in bandwidth

This gives an average cost per link in each group of bands/region combination. Except for the 80 GHz band (where all channel widths are above 40 MHz), we convert this to an average opportunity cost for each bandwidth range in the current fee schedule, assuming that opportunity costs are linear in bandwidth. To do this, we define a 'cost ratio' as the average link bandwidth in that group of bands, in that range, divided by 3.5 (generally the smallest available link bandwidth). The bandwidth adjusted opportunity cost is the:

- average opportunity cost per link;
- multiplied by the cost ratio;
- divided by the weighted average cost ratio (where the weights are the proportion of links in the group of bands that fall into that bandwidth range).

B.2 Results

The tables below show the results of the opportunity cost model, for each of the bandwidth categories in ComReg's current fee schedule. Opportunity costs generally decrease with frequency, because link lengths decrease, meaning that switching to a lower band would be straightforward, although they are higher for 80 GHz links than 23 – 42 GHz, because the large channels used at 80 GHz are not available in the lower bands, so like for like switching is not possible and dual polarisation equipment is required.

The opportunity costs estimates are typically well above the fees charged by ComReg, especially for lower frequency bands where very expensive intermediate stations would have to be installed if users moved to a higher band. However, these opportunity cost estimates are only reflective of the actual opportunity costs imposed by users where there is congestion, and new users are not able to access their preferred bands.

There is generally little scarcity in the bands where the estimates are highest, meaning that actual opportunity costs are considerably lower. The level of opportunity costs cannot be used directly to set fees, as it requires assumptions about congestion, which is difficult to measure due to the complex nature of interference between links.

Nevertheless, the ratio between the highest opportunity cost and lowest opportunity cost for links of a given size, and given level of congestion, is informative of the relative prices at which flexible operators may prefer one band over another. This ratio mostly falls in between 1:23 to 1:33, although it is significantly higher for the urban estimates, and lower for the highest bandwidth range (bandwidths above 40 MHz are not available in the sub-10 GHz bands, so cost estimates are set at the same level as the 20 – 40 MHz group, and 1:15 therefore understates the difference between opportunity costs of different bands for wide channels).

Table 9: Estimate opportunity cost (EUR) - Dublin

Range of frequencies	< 3.5 MHz	3.5 MHz < x < 20 MHz	20 MHz < x < 40 MHz	>40 MHz
1 GHz - 8 GHz	2,065	7,167	23,051	23,051
11 GHz - 18 GHz	697	1,943	6,580	11,483
23 GHz - 42 GHz	89	262	708	1,498
80 GHz				1,750
Ratio	1:23	1:27	1:33	1:15

Table 10: Opportunity cost estimates (EUR) - urban

Range of frequencies	< 3.5 MHz	3.5 MHz < x < 20 MHz	20 MHz < x < 40 MHz	>40 MHz
1 GHz - 8 GHz	862	2,990	9,617	9,617
11 GHz - 18 GHz	2,116	5,898	19,973	34,854

23 GHz - 42 GHz	47	141	380	803
80 GHz				1,750
Ratio	1:45	1:43	1:54	1:44

Table 11: Opportunity cost estimates (EUR) - rural

Range of frequencies	< 3.5 MHz	3.5 MHz < x < 20 MHz	20 MHz < x < 40 MHz	>40 MHz
1 GHz - 8 GHz	889	3,087	9,929	9,929
11 GHz - 18 GHz	1,011	2,819	9,545	16,657
23 GHz - 42 GHz	88	261	706	1,493
80 GHz				1,750
Ratio	1:23	1:27	1:33	1:15

Annex C Measuring scarcity

In this annex we set out a method for measuring the availability of spectrum for new links. In summary, we place a grid over Ireland and in each square of that grid, for each band, we ask how many new links of a given channel width could be installed in that location, measured as a proportion of the number of links of that size that could be accommodated if the band was currently empty. Where availability is very low, this may indicate that congestion charges could be required in future.

We assume that if (any part of) a channel is in use in a square, then it is not possible for new link to use those frequencies in that square. This requires that the square lengths are small, but the grid should not be so fine that links in one square would interfere with those in neighbouring squares.

This is considerably simpler than the full interference analysis carried out by ComReg when it processes fixed links applications, because it ignores angular separation between links, power levels, etc. Therefore, we recommend that this is used as a screening method for congestion, and to help stakeholders form expectations on future scarcity, but it should not be used to justify additional congestion measures without further investigation from ComReg.

C.1 Methodology

Step 1 Define grids

- Set the origin of the grid ($O = (o_1, o_2)$)[27] – we use the bottom left corner of the congested area (320,000 , 220,000).
- For each band, define a grid with squares of length l_b, where O is a corner of one square.
- Grid squares should be small enough that it is not possible to install a new station at the same frequency in the square, given existing links passing through the square.
- We set l_b to 1 km for all bands.

[27] We use the OSI Northings/Eastings coordinate reference system used by ComReg. Under other coordinate reference systems, the description of step 3 would be incomplete.

Step 2 Account for different grid sizes

- For each band, set a reference channel width $\bar{h}$ (this could be, for example, the minimum/maximum available channel size, or the typical channel size) – we want to know which channels of the reference size are (partly) filled by links of any channel width
- We look only at the lower frequency halve of the paired channel, for convenience
- For each link, find the lowest and highest frequency of the channel (i.e. the midpoint plus/minus half the channel width), F_1 and F_2
- For each channel of the reference size included in the band plans, find the equivalent f_{1c} and f_{2c}, check whether the link overlaps with this channel by checking whether $F_1 < f_{2c}\ and\ F_2 > f_{1c}$
- Keep a list of all reference channel numbers (partly) filled by each link

The table below sets out the typical channel sizes used for each of the bands.

Table 12: Typical channel widths by band

Band (GHz)	Typical channel size (MHz)
1.3	1
1.4	0.5
2	14
L6	29.65
U6	40
L7	14
U7	28
L8	29.65
U8	7
11	40

13	56
15	56
18	55
23	56
26	28
28	56
38	56
42	56
80	500

Step 3 Match links to grid squares

- Label the grid squares such that if the coordinates of the bottom left hand corner of the grid square are (x_1, x_2), the square ID is $\left(\frac{x_1-o_1}{l_b}, \frac{x_2-o_2}{l_b}\right)$
- Find the grid square that a point is in by rounding down $\frac{x_i-o_i}{l_b}$ to the nearest integer
- A link is in a square if either:
    1. one or both ends are in the square; or
    2. any part of the link passes through the square
- Formally, a link is represented by the line $\alpha x + (1-\alpha)y, \alpha \in [0,1]$, where x and y are the end points of the link, and a link is in a square if any point on that line is in the square
- Test whether a link passes through a square by checking N values for α equally spaced between 0 and 1, including both end points
- Find the distinct square IDs that a link passes through, and split the data so that for each link, we have one observation for every square that the link passes through
- We use N = 1,000 for all links[28]

[28] It would be more efficient to set a different N for each link, that is proportional to link length and inversely proportional to square length, but this has little effect on the results

Step 4 Measure spectrum availability

- Define spectrum availability as the number of links of the reference channel size that we could fit in the band given the existing links, as a proportion of the number of channels of that size included in the band plans
- If the reference channel size is the smallest channel width available, this is roughly the proportion of the spectrum (in MHz) that is not being used. If the reference channel width is larger (e.g. typical or maximum available size), this takes into account fragmentation in the band
- For each grid square/band combination, find the links associated with all link points that fall in the square (i.e. all links with an end in or passing through the square)
- Count the distinct reference channel numbers covered by any of those links.
- Divide this by the number of reference channels included in the band plans to give a measure of spectrum in use. One minus this is the '**availability**' for that band in the square.
- Optionally, we can group neighbouring squares and take the minimum or average availability within a group.

C.2 Results

We calculate availability according to this method using ComReg's licence data from November 2021, setting the typical bandwidths for each band (as described in relation to the fees formula in section 4.3.2 and listed in the table below) as the reference channel widths. The figures shown in the analysis below show heatmaps where each square in the grid containing at least one link is coloured according to the availability of these typical channels (e.g. in the 15 GHz band this is the number of empty 56 MHz channels in the square divided by seven, which is the number of 56 MHz channels included in the 15 GHz band plan).

It is important to recognise that the evidence provided by this analysis needs to be considered alongside other sources of information about where congestion might be occurring (e.g. feedback from stakeholders, rejected applications). We believe that the methodology offers a useful tool for helping to identify areas/bands where congestion *might* be an issue, but is not refined enough to give a fully accurate picture, and in particular is likely to overstate congestion. Therefore, any decisions on the areas/bands where congestion measures should be applied need to take into account relevant complementary evidence.

Potential changes to the congestion measures applied by ComReg (other than the pricing) would fall into three categories:

- definition of new congestion areas;
- extension of the current congestion area; and
- adjusting the set of bands that are considered congested within the congested area(s).

Overall, we do not think that the results of this congestion analysis suggest any need to change either the geographic definition of the congested area, or the bands that are subject to congestion measures.

The maps in Figure 4 and Figure 5 below represent the results of the availability assessment for each band across the whole of Ireland (regions drawn on the maps are from ComReg’s 3.6 GHz award).

Figure 4: Availability heatmaps - bands currently subject to congestion measures

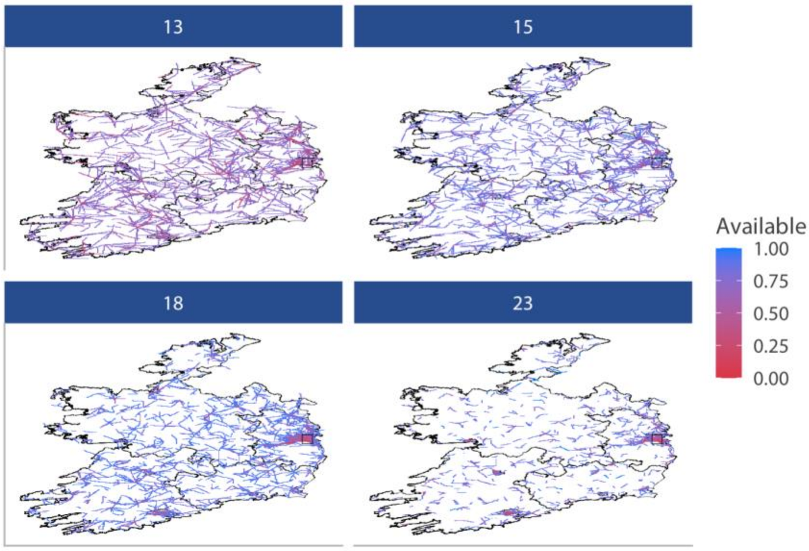
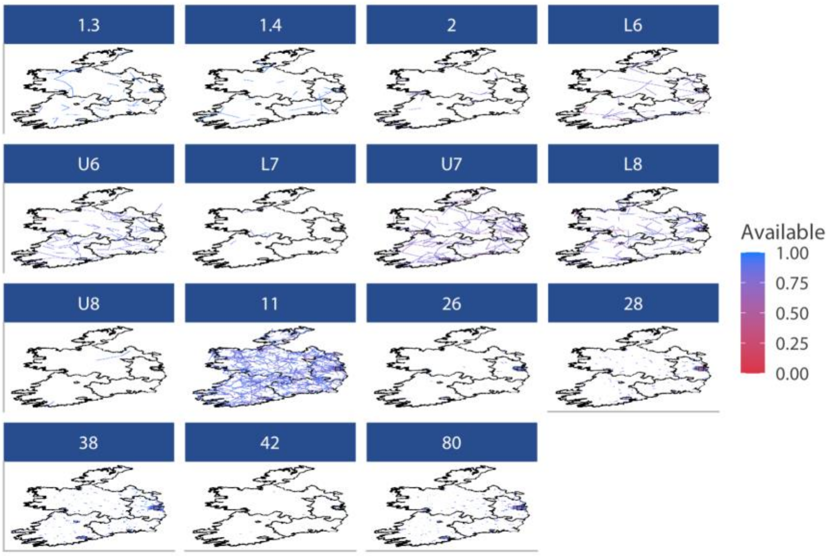
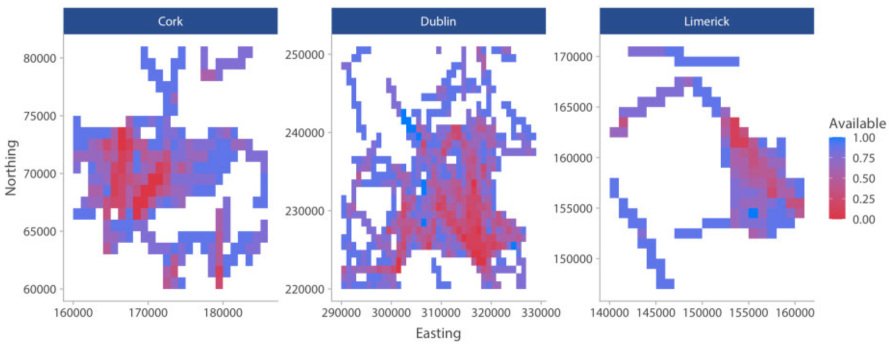


Figure 5: Availability heatmaps - all other bands



General usage across Ireland (in terms of the proportion of available spectrum licensed) appears to be greatest in the 11 – 18 GHz bands, and (unsurprisingly) there is typically a cluster of lower availability in and around the Dublin area. The analysis suggests that there are also pockets of potentially low availability for some bands in other areas, in particular in other cities, but that scarcity in these areas is still not at the same level as in Dublin. By way of example, Figure 6 shows the availability heat map for the 23 GHz band (one of the most congested bands in urban areas) in each of the three most populated cities (Dublin, Cork and Limerick). Although there are one or two paths with very low availability in each of Cork and Limerick, use of the band is clearly well below that in Dublin.

Figure 6: Availability of the 23 GHz band in the three largest cities



There is also evidence of high usage (in particular in the 11 – 38 GHz bands) immediately to the West of the congested area. However, this is limited to only a small number of squares/paths outside of the congested area, and we do not see this, in itself, as sufficient evidence that the congestion area needs to be extended at this point in time.

On top of this, we are not aware of any other information to suggest that there is a scarcity issue outside the Dublin congestion area. We therefore do not see any immediate need to create new congestion areas, but recommend that ComReg continues to monitor the situation, in particular:

- in and around the other cities; and
- over paths operating immediately to the west of the congestion area (noting, for example, that a large proportion of links operating in this area run into/out of Tallaght).

In terms of the existing congestion area, we can see from the heatmaps that a lot of links are (unsurprisingly) clustered in and around Dublin, in particular in the 11 – 23 GHz range, as well as in the 28 GHz band). This would support the view that congestion may still be a problem in Dublin. As well as heavy usage within the city centre itself, we know (from the licensing data and feedback from stakeholders) that a significant factor in the congestion around Dublin comes from running links from high sites to the south into the city centre, and that demand for these links is unlikely to fall soon. It would therefore seem relevant and appropriate to continue including both Dublin city centre and the areas that cover the favourable high sites to the south of the city in the congestion area.

The question then is about which bands, if any, should be considered congested. As an indication of scarcity in the Dublin congestion area, for each band we take all of the relevant grid squares that fall within the Dublin congested area and determine the:

- minimum level of availability amongst those squares; and
- the mean level of availability across those squares.

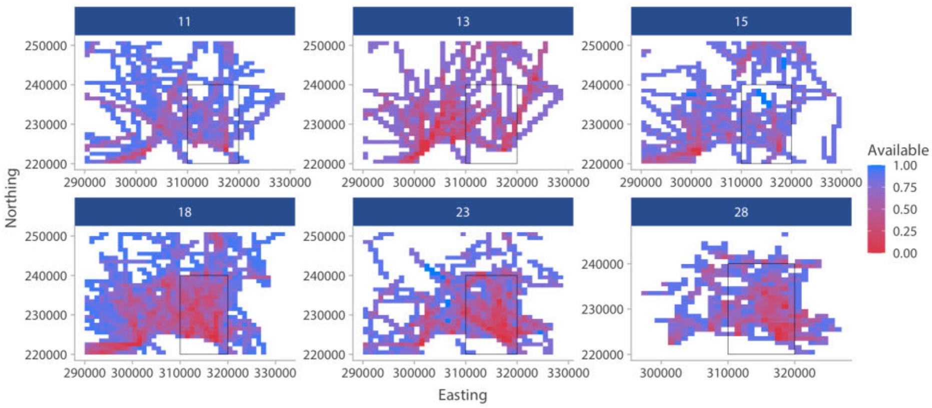
Table 13 sets out a summary of these measures for each band where the minimum availability falls below 30%, and Figure 7 shows the heatmaps (covering Dublin) for those bands with minimum availability of zero.

Table 13: Bands with minimum availability below 30% in the Dublin congested area

Band (GHz)	Min. availability (%)	Mean availability (%)
U7	20	65

11	0	74
13	0	59
15	14	77
18	0	46
23	0	50
28	0	59
38	10	76

Figure 7: Other bands with minimum availability in Dublin of zero



The 18 GHz and 23 GHz bands, which are currently considered congested by ComReg, have both the (joint) lowest minimum availability and mean availability, which (along with the demand analysis conducted in our first report) does not provide any evidence to suggest that ComReg should not continue to treat the band as congested going forward.

The 13 GHz and 15 GHz bands, since 2014, have been closed to applications for new links within the congestions area due to the lack of free spectrum available. As discussed above, we have recommended that ComReg re-open these bands to new applications given that the number of links (and bandwidth used) in these bands in the congestion area has fallen since they were closed, and therefore it may be possible to allow for new links and avoid leaving valuable spectrum unused. However, although usage has fallen, we recommend continuing to treat these bands as congested as:

- the analysis above and in our first report suggests that the bands are still heavily used in and around Dublin;

- the fact that the bands have been closed to new links means that there is a significant chance that current usage underestimates the true demand for the spectrum, and we cannot assume that usage will not return to pre-2014 levels if the band is reopened; and
- feedback from stakeholders suggests that the bands will continue to be valuable for links around Dublin for the foreseeable future, and in particular for those that run from the high sites south of the city into the centre (noting that the 15 GHz band may become even more attractive if ComReg increases the maximum channel width available).

We therefore recommend keeping maintaining the congested status of the 13 GHz and 15 GHz bands for the time being, at least until ComReg has been able to observe how demand changes following reopening of the bands.

The 11 GHz and 28 GHz bands also have minimum availability of zero and, based on the figures presented above, would appear to have scarcity levels comparable to the 13 GHz and 15 GHz bands. This could be an indicator that these bands also need to be subject to a congestion charge. However, as discussed earlier, the results of this analysis do not provide conclusive evidence of congestion problems and need to be considered alongside other factors. While we see strong arguments for continuing to consider the 13 GHz and 15 GHz bands as congested, but those argument do not apply to the 11 GHz and 28 GHz bands, and we are not aware of any other evidence that would suggest measures are required to combat congestion in these bands at present. We therefore do not recommend including the 11 GHz band or the 28 GHz band in the set of congested bands at this point, but suggest ComReg continues to monitor the situation and adjust the approach accordingly in the future if/when it becomes apparent that congestion is a problem.

The other two bands with minimum availability of below 30% are the U7 GHz and 38 GHz bands. However, in neither of these bands does the minimum availability fall below 20% anywhere in the congestion area, and the mean availability is well over 50% for both bands. We therefore do not see any reason to consider these congested.

Overall, our recommendation is that ComReg maintains the current definition of the congestion area and continues to apply congestion measures for the 13 GHz, 15 GHz, 18 GHz and 23 GHz bands. However, it should continue to monitor congestion elsewhere and in other bands and adjust the regime as appropriate if further issues are identified.

Annex D Review of technical guidelines

This section looks at each of the mandatory technical conditions laid out in the ComReg's fixed links guidelines[29] and assesses their applicability to Ireland, in the light of the relevant CEPT and ITU recommendations and the international best practices. Specifically, it focuses on the following technical factors:

- band plans and channel spacing;
- maximum transmit power and ATPC;
- minimum path length;
- minimum transmission capacity;
- minimum antenna requirements;
- high/low designation conflict; and
- multi-band aggregation.

D.1 Band plans and channel spacing

ComReg offers individual link licences in 20 bands. For each of these there is a band plan that defines channels of varying bandwidths (i.e. the specific frequencies) that operators can apply for. ComReg bases these band plans on ECC and/or ITU recommendations, which ensures compatibility with the equipment ecosystem and international harmonisation. As demand for bandwidth increases and technology evolves, the ECC and ITU publish updates to their recommendations, which ComReg then implements in Irish regulation – there are some cases where ComReg could consider amending the channels available to align with current international recommendations and support potential future demand for bandwidth.

The table below provides an overview of the band plans currently adopted in the Guidelines, whether based on CEPT or ITU-R recommendations, together with the most up to date recommendations in place and our suggested modifications for each of the fixed links bands.

[29] ComReg 09/89R2

Table 14: Channel plan recommendations

Band	Recommendation currently followed	Most up-to-date recommendation	Modifications suggested?
1.3 GHz	CEPT Recommendation T/R 13-01 E, Annex A	CEPT Recommendation T/R 13-01 E, Annex A	No
1.4 GHz	CEPT Recommendation T/R 13-01 E, Annex B	CEPT Recommendation T/R 13-01 E, Annex B	No
2 GHz	CEPT Recommendation T/R 13-01 E, Annex C	CEPT Recommendation T/R 13-01 E, Annex C	No
L6 GHz	CEPT/ERC/REC 14-01 E, Annex 1	CEPT/ERC/REC 14-01, Annex 1	Allowing the 59.3 MHz channel spacing possibility (see bullet “Consider channel merging” below)
U6 GHz	CEPT/ERC/REC 14-02 E, Annex 1	CEPT/ERC/REC 14-02, Annex 1	Allowing the 80 MHz channel spacing possibility (see bullet “Consider channel merging” below)

L7 GHz	CEPT/ECC/REC 02-06 Annex 1	CEPT/ECC/REC 02-06 Annex 1	Allowing the 56 MHz channel spacing possibility (see bullet "Consider channel merging" below)
U7 GHz	CEPT/ECC/REC 02-06 Annex 1	CEPT/ECC/REC 02-06 Annex 1	Allowing the 56 MHz channel spacing possibility (see bullet "Consider channel merging" below)
L8 GHz	ITU-R F. 386-8, Annex 6	ITU-R F. 386-9, Annex 6	Update the band plan to the ITU-R 386-9, even though there are no major changes compared to the 368-8. Allowing the 59.3 MHz channel spacing possibility (see bullet "Consider channel merging" below)
U8 GHz	ITU-R F. 386-8, Annex 2	ITU-R F. 386-9, Annex 2	Update the band plan to the ITU-R 386-9, allowing the 28 MHz channel spacing arrangement. Allowing the 56 MHz channel spacing possibility (see bullet "Consider channel merging" below)
11 GHz	CEPT/ERC/REC 12-06 E	CEPT/ERC/REC 12-06 Annex 1	Allowing the 80 MHz channel spacing possibility (see bullet "Consider channel merging" below)

13 GHz	CEPT/ERC/REC 12-02 E	CEPT/ERC/REC 12-02 E Annexes A & B	No
15 GHz	ITU-R F. 636-4	ITU-R F. 636-5	Update the band plan to the ITU-R 636-5, allowing the 112 MHz spacing arrangement.
18 GHz	CEPT/ERC/REC 12-03 E, Annex A	CEPT/ERC/REC 12-03, Annex 1	Allowing the 220 MHz channel spacing possibility (see bullet "Consider channel merging" below)
23 GHz	CEPT Recommendation T/R 13-02 E, Annex A	CEPT Recommendation T/R 13-02 Annex 1	Allowing the 224 MHz channel spacing possibility (see bullet "Consider channel merging" below)
26 GHz	CEPT/ERC/REC 13-02 E, Annex B	CEPT Recommendation T/R 13-02 Annex 2	No Note: Currently there are no users of 3.5 MHz channels.
28 GHz	CEPT/ERC/REC T/R 13 02 Annex C	CEPT Recommendation T/R 13-02 Annex 3 & 5	Allowing the 224 MHz channel spacing possibility (see bullet "Consider channel merging" below) Note: Currently there are no users of 3.5 MHz channels.

31 GHz	CEPT ECC/REC/(02)02 Annex	CEPT ECC/REC/(02)02 Annex	No
38 GHz	CEPT Recommendation T/R 12-01 E, Annex A	CEPT Recommendation T/R 12-01, Annex 1	Allowing the 224 MHz channel spacing possibility (see bullet "Consider channel merging" below)
42 GHz	CEPT Recommendation (01)04	CEPT Recommendation (01)04 Annex 5	No Note: Currently there are no users of 3.5 MHz channels
70/80 GHz	ECC/REC/(05)07	CEPT ECC/REC/(05)07 Annex 4	No

There are two themes to our recommendations in terms of the band plans and channel spacings are presented listed in the table:

Update of the band plans: There are new ITU-R recommendations for the L8 GHz, U8 GHz and 15 GHz bands. The only material modification when compared to current guidelines followed by ComReg is the opening of the 112 MHz spacing configuration in the 15 GHz band. We suggest adopting the most up-to-date references.

The situation with the U8 GHz band is also noteworthy and may require consideration by ComReg. No ITU recommendation from F.386-4 (03/1992) to F.386-9 (02/2013) specifically defines the 3.5 MHz spacing configuration. However, all spacings currently allowed are all multiples of 3.5 MHz, with this characteristic being explicitly stated in the regulation in place. All in all, this 3.5 MHz configuration is accepted in the Guidelines and used by Irish operators. On the other hand, even though these recommendations allow for 28 MHz channels, these are not accepted as per ComReg's Guidelines. Therefore, with regards to the U8 GHz band, we advise to allow the use of 28 MHz channels.

Consider channel merging: All of the CEPT/ECC recommendations on channel arrangements for fixed links from 6 GHz to 40 GHz bands include a specific recommendation about channel merging. These recommendations state that CEPT administrations may consider merging two adjacent channels of the highest spacing to create a channel twice as wide with centre frequency lying in the central point of the distance between the merged channels. Given the demand for larger channels, allowing for channel mergers where consistent with the CEPT/ECC documents is likely to support efficient use of the spectrum, in particular as our understanding is that some operators are already doing this in effect by licensing two adjacent channels and using them as one. In that sense, allowing for the larger channels may also help to improve the efficiency/ease of the licensing process by reducing the number of applications that need to be submitted and processed (potentially several times if the two adjacent channels initially applied for are not both available) to gain access to the larger channel. We also do not see any downside to creating larger channels via channel mergers, especially as the revised fee structure (whereby fees increase in bandwidth), along with the risk of triggering a congestion charge if the band gets too congested, should reduce incentives for hoarding. Therefore, we encourage ComReg to allow for wider channels by including channel merging into the Guidelines on Fixed Links, in accordance with the channel merging options set out in the relevant CEPT/ECC recommendations. This is more relevant to those bands where operators have expressed a demand for larger channels than are currently allowed (e.g. 11 GHz), but we do not see any reason not to apply this approach across all of the fixed links bands.

D.2 Maximum transmit power and ATPC

For the assessment of the different technical requirements for the provision of fixed links, we have carried out a benchmark of the practices adopted by other European NRAs, namely:

- Ofcom (UK);
- Ofcom (Switzerland);
- ARCEP (France);
- CTU (Czech Republic);
- NMHH (Hungary);
- UVO (Slovakia);
- RRT (Lithuania); and
- ANACOM (Portugal).

This set of countries is preserved throughout the assessment of the different technical requirements, even if some of these NRAs do not set specific obligations in some of these fields.

In terms of the maximum transmit power allowed, the table below illustrates the requirements laid out in ComReg's Guidelines as well as in other European jurisdictions.

Of the eight countries benchmarked:

- four define specific EIRP limits for all the fixed links bands;
- two define EIRP limits only for a subset of fixed links bands; and
- two do not set any explicit obligations with regards to the maximum transmit power.

In general, EIRP limits are typically set to ensure efficient use of spectrum and to avoid potential interference. We note that ComReg has a similar requirement in this regard ("Minimum required to obtain required availability level"). It is our understanding that the requirement is not a strict cap since the Guidelines do not establish a specific maximum transmitter power for each band. Contrary, the Guidelines pursue a proper dimensioning of the links' EIRP since the following is established: "*ComReg aims to licence a radio link with a […] transmitter EIRP (Equivalent Isotropic Radiated Power) that are consistent with the minimum capacity and availability requirements for that link*".

Nevertheless, this is a sufficiently robust and detailed approach to implementing power limits, because ComReg provides information on its propagation availability requirements, and directs applicants to the relevant ITU-R documents containing the formulas used for calculating path length calculation (which determines the minimum transmitter EIRP). The fact that ComReg presents the requirement in a different way to other regulators makes it more difficult to directly compare to the approaches taken elsewhere, but does not suggest that there is any need to change the guidelines. We are of the view that ComReg's current approach is well grounded in internationally recognised technical recommendations from the ITU, and it sensible to link power limits directly to availability requirements. We have not identified any evidence to suggest that this is not the case. Therefore, our recommendation is to keep the requirement as it is and only consider setting up specific power limits if stakeholders specifically suggest that carrying out path length calculations themselves is unduly burdensome.

Table 15: Benchmark of maximum transmit power

Band	Ireland	UK	Switzerland	France	Czech Republic	Hungary	Slovakia	Lithuania	Portugal
1.3 GHz	Min, required to obtain availability	N.C	N.C	N.C	N.C	N.C	-	N.C	The NRA carries out a case-by-case frequency assignment for each link, usually based on channel arrangements adopted from CEPT/ERC/ECC and ITU-R Recommendation
1.4 GHz		N.C	N.C	EIRP 40 dBW	N.C	N.C	-	N.C	
2 GHz		N.C	N.C	N.C	-	EIRP 40 dBW	EIRP 6 dBW/8MHz	-	
L6 GHz		EIRP 50 dBW	EIRP 55 dBW	EIRP 40 dBW	-	EIRP 40 dBW	-	-	
U6 GHz		EIRP 50 dBW	EIRP 55 dBW	EIRP 40 dBW	-	EIRP 40 dBW	-	-	
L7 GHz		N.C	EIRP 50 dBW	N.C	-	EIRP 40 dBW	EIRP 50 dBW	-	
U7 GHz		EIRP 40 dBW	EIRP 50 dBW	N.C	-	EIRP 40 dBW	-	-	
L8 GHz		EIRP 40 dBW	N.C	EIRP 40 dBW	-	EIRP 40 dBW	N.C	-	
U8 GHz		EIRP 40 dBW	N.C	EIRP 40 dBW	-	EIRP 40 dBW	N.C	-	
11 GHz		N.C	EIRP 55 dBW	EIRP 40 dBW	-	EIRP 50 dBW	-	-	

13 GHz	EIRP 45 dBW	EIRP 55 dBW	EIRP 40 dBW	-	EIRP 50 dBW	-	-
15 GHz	EIRP 50 dBW	EIRP 55 dBW	N.C	-	EIRP 50 dBW	-	-
18 GHz	EIRP 55 dBW	EIRP 46 dBW	EIRP 40 dBW	-	EIRP 55 dBW	-	-
23 GHz	EIRP 55 dBW	EIRP 50 dBW	EIRP 40 dBW	-	EIRP 50 dBW	-	-
26 GHz	EIRP 43 dBW	EIRP 41,5 dBW	EIRP 40 dBW	-	EIRP 50 dBW	EIRP 41,5 dBW	N.C
28 GHz	N.C	EIRP 40 dBW	N.C	-	N.C	EIRP 32 dBW	-
38 GHz	EIRP 55 dBW	EIRP 50 dBW	EIRP 40 dBW	-	EIRP 50 dBW	EIRP 41,5 dBW	-
42 GHz	N.C	EIRP 50 dBW	N.C	EIRP 40 dBW	N.C	EIRP 5 dBW/MHz	-
80 GHz	EIRP 55 dBW	EIRP 55 dBW	EIRP 45 dBW	EIRP 55 dBW	EIRP 55 dBW	EIRP 55 dBW	-

Automatic Transmit Power Control (ATPC) is a feature of P-P links that automatically adjusts the output power of equipment depending on the signal reception level. The ATPC system increases the power during bad weather conditions that might weaken the signal and reduces the power to normal when these conditions are over. We note that ComReg has not enacted any specific literature in the Guidelines on this matter.

The table below illustrates the requirements applied with regard to ATPC in other European jurisdictions.

Of the eight countries benchmarked:

- two define specific ATPC obligations for all the fixed links bands;
- two define ATPC allowance only for a subset of fixed links bands;
- two define ATPC obligations only for a single fixed links band; and
- two do not set any explicit obligations with regards to the ATPC.

Since the Guidelines pursue a dimensioning of the links' EIRP according to the required availability level per link and no comments have been received regarding spectrum interferences under bad weather conditions, our recommendation is to keep the Guidelines chapter about radio propagation availability and power as it is.

Table 16: Benchmarks on ATPC

Band	Ireland	UK[30]	Switzerland	France	Czech Republic	Hungary	Slovakia	Lithuania	Portugal
1.3 GHz	-	N.C	N.C	N.C	N.C	N.C	-	N.C	The NRA carries out a case-by-case frequency assignment for each link, usually based on channel arrangements adopted from CEPT/ERC/ECC and ITU-R Recommendation
1.4 GHz	-	N.C	N.C	-	N.C	N.C	-	N.C	
2 GHz	-	N.C	N.C	N.C	-	-	-	-	
L6 GHz	-	Capped at EIRP (50 dBW)	Control range 15 dB to 20 dB	-	-	-	-	-	
U6 GHz	-	Capped at EIRP (50 dBW)	Control range 15 dB to 20 dB	-	-	-	-	-	
L7 GHz	-	N.C	Control range 15 dB to 20 dB	N.C	-	-	-	-	
U7 GHz	-	Capped at EIRP (40 dBW)	Control range 15 dB to 20 dB	N.C	-	-	-	-	
L8 GHz	-	Capped at EIRP (40 dBW)	N.C	-	-	-	N.C	-	
U8 GHz	-	Capped at EIRP (40 dBW)	N.C	-	-	-	N.C	-	
11 GHz	-	N.C	Control range 15 dB to 20 dB	Allowed ETSI EN 302 217	-	-	-	-	

[30] Operators are allowed to deploy fixed links of any length. However, if these are below a given threshold, they must pay an additional fee.

13 GHz	-	Capped at EIRP (45 dBW)	Control range 10 dB to 20 dB	Allowed ETSI EN 302 217	-	-	-	-
15 GHz	-	Capped at EIRP (50 dBW)	Control range 10 dB to 20 dB	N.C	Allowed	-	-	-
18 GHz	-	Capped at EIRP (55 dBW)	Control range 12 dB to 20 dB	Allowed ETSI EN 302 217	Allowed	-	-	-
23 GHz	-	Capped at EIRP (55 dBW)	Control range 10 dB to 20 dB	Allowed ETSI EN 302 217	-	-	-	-
26 GHz	Allowed[31]	Capped at EIRP (43 dBW)	Control range 10 dB to 20 dB	Allowed ETSI EN 302 217	-	Allowed with mitigation techniques	-	N.C
28 GHz	-	N.C	Control range 10 dB to 20 dB	N.C	Allowed	N.C	-	-
38 GHz	-	Capped at EIRP (55 dBW)	Control range 10 dB to 20 dB	Allowed ETSI EN 302 217	-	-	-	-
42 GHz	-	N.C	Control range 10 dB to 20 dB	N.C	-	N.C	-	-
80 GHz	-	Capped at EIRP (55 dBW)	-	-	-	-	Control range max 35 dB	-

[31] Decision available at link

D.3 Minimum path length

ComReg applies a minimum link length policy in its fixed links licensing regime which, for a given frequency band, sets a lower bound on the hop length of links that would be licensed in that band. The lower the frequency band, the greater the minimum link length, in light of the better propagation of lower frequencies that is needed to support longer links. This is to support efficient and orderly use of the spectrum, helping to ensure that operators use spectrum in bands that are appropriate for the links they are running. In particular, it helps to prevent the lower frequencies being filled up by licensees operating links that are short enough to operate in the higher frequencies and blocking access to users that need the spectrum to cover greater distances.

The table below illustrates the requirements laid out in ComReg's Guidelines as well as in other European jurisdictions with regards to the minimum path length under the different fixed links bands. As the table shows, of the eight countries benchmarked:

- five do not set any explicit obligations with regards to the minimum path length. One of them, however, applies a surcharge if the length of a fixed link is below a given threshold.
- one defines minimum path length values for all the fixed links bands.
- two have only set minimum path length requirements for a subset of low to mid bands.

The analysis performed shows that there is not a common trend in Europe with regards to the definition of minimum path length requirements. Including Ireland, there are four references that set explicit minimum path length requirements and five that do not.

The minimum thresholds set by ComReg are well aligned with those in place in the countries where explicit minimum path length requirements have been set. Given this, the fact that setting minimum path length requirements is not uncommon amongst other European jurisdictions, and that the minimum path lengths currently applied appear to be in line with the path lengths used for each band, our recommendation is that the minimum path lengths set out in the Guidelines do not need to be changed (subject to findings related to multi-band aggregation technology – see Section D.8 below).

Table 17: Benchmark on minimum path length

Band	Ireland	UK[32]	Switzerland	France	Czech Republic	Hungary	Slovakia	Lithuania	Portugal
1.3 GHz	-	N.C	N.C	N.C	N.C	N.C	-	N.C	The NRA carries out a case-by-case frequency assignment for each link, usually based on channel arrangements adopted from CEPT/ERC/ECC and ITU-R Recommendation
1.4 GHz	-	N.C	N.C	-	N.C	N.C	-	N.C	
2 GHz	25 Km	N.C	N.C	N.C	-	-	-	20 Km	
L6 GHz	25 Km	-	30 Km	-	-	-	-	16 Km	
U6 GHz	25 Km	-	30 Km	-	-	-	15 Km	16 Km	
L7 GHz	25 Km	N.C	20 Km	N.C	-	-	15 Km	12 Km	
U7 GHz	25 Km	-	20 Km	N.C	-	-	20 Km	12 Km	
L8 GHz	25 Km	-	N.C	-	-	-	N.C	12 Km	
U8 GHz	25 Km	-	N.C	-	-	-	N.C	12 Km	
11 GHz	10 Km	N.C	10 Km	-	-	-	8 - 10 Km	-	
13 GHz	9 Km	-	10 Km	-	-	-	6 - 7 Km	-	
15 GHz	9 Km	-	10 Km	N.C	-	-	8 Km	-	
18 GHz	0-6 Km	-	3 - 8 Km	-	-	-	4 Km	-	

[32] Operators are allowed to deploy fixed links of any length. However, if these are below a given threshold, they must pay an additional fee.

23 GHz	0-3 Km	-	3 - 5 Km	-	-	-	1 - 3 Km	-
26 GHz	0-3 Km	-	2 Km	-	-	-	-	N.C
28 GHz	0-3 Km	N.C	1,5 - 2 Km	N.C	-	N.C	-	-
38 GHz	-	-	1 Km	-	-	-	-	-
42 GHz	-	N.C	0,5 Km	N.C	-	N.C	-	-
80 GHz	-	-	0,1 Km	-	-	-	-	-

D.4 Minimum transmission capacity

ComReg sets a minimum transmission capacity (a required speed in Mbps) for each band, which is sometimes increasing with channel width within a band. This is to help promote efficient use of the wider channels available in higher frequency bands, which support higher capacity services than can be achieved in the available bandwidth in the lower bands.

The table below illustrates the requirements laid out in ComReg's Guidelines as well as in other European jurisdictions with regards to the minimum transmission capacity under the different fixed links bands. When the minimum transmission capacity is linked to a specific bandwidth, this is specified between parentheses.

As the table below shows, of the eight countries benchmarked:

- four do not set any explicit obligations with regards to the minimum transmission capacity.
- three define specific minimum transmission capacity requirements for all their fixed links bands.
- one defines minimum transmission capacity requirements only for a subset of its fixed links bands.

Similar to the situation for the minimum path length requirements, there is no clear trend when it comes to the practices adopted by European NRAs. However, when assessing the situation of the countries which have set specific minimum thresholds the minimum requirements set by ComReg are, on average, somewhat above those set by other NRAs.

In summary, even though the requirements set by ComReg are above average, as there is broad compliance with these minimum thresholds, we do not recommend adjusting them.

Table 18: Benchmarks for minimum transmission capacity

Band	Ireland	UK	Switzerland	France	Czech Republic	Hungary	Slovakia	Lithuania	Portugal
1.3 GHz	-	N.C	N.C	N.C	N.C	N.C	(2) 0,01/2 Mbps	N.C	The NRA carries out a case-by-case frequency assignment for each link, usually based on channel arrangements adopted from CEPT/ERC/ECC and ITU-R Recommendation
1.4 GHz	-	N.C	N.C	-	N.C	N.C	(2) 0,01/2 Mbps	N.C	
2 GHz	(ANY) 4 Mbps	N.C	N.C	N.C	-	(1,7) 2 Mbps (3,5) 4 Mbps (7) 8 Mbps (14) 16 Mbps	-	-	
L6 GHz	(ANY) 140 Mbps	No minimum. Indicative (nominal) values for each Spectral Efficiency Class are provided instead	(28) 137 Mbps	(29,65) - 155 Mbps	-	(29,65) - 140/155 Mbps	(29,65) 140 Mbps	-	
U6 GHz	(ANY) 140 Mbps	No minimum. Indicative (nominal) values for each Spectral Efficiency Class are provided instead	(30) 137 Mbps	-	-	(40)– 140/155 Mbps	-	-	
L7 GHz	(28) 140 Mbps	N.C	(7) 16 Mbps (14) Mbps	N.C	-	(3.5) - 4 Mbps (7) 8 Mbps (14) 16 Mbps (28) 34 Mbps	(28) 140 Mbps	-	

U7 GHz	(ANY) 140 Mbps	No minimum. Indicative (nominal) values for each Spectral Efficiency Class are provided instead	(14) 68 Mbps (28) 137 Mbps	N.C	-	(1.75) 2 Mbps (3.5) 4 Mbps (7) 8 Mbps (14) 16 Mbps (28) 34 Mbps	(3.5) 4 Mbps	-
L8 GHz	(ANY) 140 Mbps	No minimum. Indicative (nominal) values for each Spectral Efficiency Class are provided instead	N.C	-	-	(1,7) 2 Mbps (3,5) 4 Mbps (7) 8 Mbps (14) 16 Mbps (28) 34 Mbps	N.C	-
U8 GHz	(ANY) 4 Mbps	N.C	N.C	-	-	(1,7) 2 Mbps (3.5) 4 Mbps (7) 8 Mbps (14) 16 Mbps (28) 34 Mbps	N.C	-
11 GHz	(ANY) 140 Mbps	N.C	(28) 137 Mbps	(40) 155 Mbps	-	(40) 140/155 Mbps (80) 140/155 Mbps	(28) 140 Mbps	-
13 GHz	(ANY) 4 Mbps (56) 310 Mbps	No minimum. Indicative (nominal) values for each Spectral Efficiency Class are provided instead	(7) 8/16 Mbps (14) 32 Mbps (28) 64 Mbps	-	-	(3.5) 4 Mbps (7) 8 Mbps (14) 16 Mbps (28) 34 Mbps	(3.5) 4 Mbps	-

15 GHz	(ANY) 4 Mbps (56) 310 Mbps s	No minimum. Indicative (nominal) values for each Spectral Efficiency Class are provided instead	(7) 8/16 Mbps (14) 16/32 Mbps (28) 64 Mbps	N.C	-	(7) 8 Mbps (14) 16 Mbps (28) 34 Mbps (56) 140 Mbps	(7) 4 Mbps	-	
18 GHz	(ANY) 34 Mbps (55) 310 Mbps (110) 620 Mbps	No minimum. Indicative (nominal) values for each Spectral Efficiency Class are provided instead	(7.5) 8/16 Mbps (13.75) 16/32 Mbps (13.75) 49/58 Mbps (27.5) 64/117 Mbps	-	-	(27.5) 34 Mbps (55) 140/155 Mbps (110) 140/155 Mbps	(5) 4 Mbps	-	
23 GHz	(ANY) 4 Mbps (56) 310 Mbps (112) 620 Mbps	No minimum. Indicative (nominal) values for each Spectral Efficiency Class are provided instead	(7) 8/16 Mbps (14) 16/32 Mbps (28) 64 Mbps	-	-	(3.5) 2 Mbps (7) 8 Mbps (14) 16 Mbps (28) 34 Mbps	(3.5) 4 Mbps	-	
26 GHz	(ANY) 4 Mbps	No minimum. Indicative (nominal) values for each Spectral Efficiency Class are provided instead	(28) 137/156 Mbps (56) 274/313 Mbps	-	-	(3.5) 2 Mbps (7) 8 Mbps (14) 16 Mbps (28) 34 Mbps (56) 140 Mbps (112) 140 Mbps	(3.5) 4 Mbps	N.C	
28 GHz	(ANY) 4 Mbps (56) 310 Mbps (112) 620 Mbps	N.C	(28) 64 Mbps (56) 128 Mbps (112) 256 Mbps	N.C	-	N.C	(3.5) 2 Mbps	-	

38 GHz	(ANY) 4 Mbps (56) 310 Mbps (112) 620 Mbps	No minimum. Indicative (nominal) values for each Spectral Efficiency Class are provided instead	(7) 8/16 Mbps (14) 16/32 Mbps (28) 64 Mbps (56) 128 Mbps	-	-	(3.5) 2 Mbps (7) 8 Mbps (14) 16 Mbps (28) 34 Mbps (56) 140 Mbps (112) 140 Mbps	(3.5) 4 Mbps	-
42 GHz	(ANY) 4 Mbps (56) 310 Mbps (112) 620 Mbps	N.C	(28) 64 Mbps (56) 128 Mbps (112) 256 Mbps	N.C	-	N.C	-	-
80 GHz	(ANY) 150 Mbps	No minimum. Indicative (nominal) values for each Spectral Efficiency Class are provided instead	(250) 285/570 Mbps (500) 570/1140 Mbps (1000) 2280 Mbps	-	-	-	-	-

D.5 Minimum antenna requirements

ETSI defines antenna classes based on their suitability for different interference environments. ComReg sets a minimum antenna class for each band, which helps to maximise spectrum re-use possibilities and support efficient use of the spectrum.

The table below illustrates the requirements laid out in ComReg's Guidelines as well as in other European jurisdictions with regards to the minimum antenna requirements under the different fixed links bands.

Of the eight countries benchmarked:

- four define specific minimum antenna requirements for all the fixed links bands; and
- four do not define any minimum antenna requirements.

On the other hand, and for the sake of clarity, the radiation pattern envelope (RPE) that represents how the maximum gain (dBi) of the antenna varies depending on the azimuth angle to the main beam axis, is classified by the ETSI according to the classes below:

- Class 1: antennas required for use in networks where there is a low interference potential (e.g. low-density deployment areas).
- Class 2: antennas required for use in networks where there is a high interference potential (e.g. high-density deployment areas).
- Class 3: antennas required for use in networks where there is a very high interference potential.
- Class 4: antennas required for use in networks where there is an extremely high interference potential.

In conclusion, the benchmarking shows that i) it is a reasonably common practice to set minimum antenna requirements for the different fixed links bands, and ii) the minimum requirements set by ComReg are aligned with those applied by other NRAs. Moreover, given the demography and the high density of antennas in urban areas of Ireland, a Class 3 seems to be an appropriate type of antenna for the Country. As a result, our recommendation is to keep the current minimum antenna requirements.

Table 19: Benchmark on minimum antenna requirement

Band	Ireland	UK	Switzerland	France	Czech Republic	Hungary	Slovakia	Lithuania	Portugal
1.3 GHz	Class 2 EN 302 217-4	N.C	N.C	N.C	N.C	N.C	-	N.C	The NRA carries out a case-by-case frequency assignment for each link, usually based on channel arrangements adopted from CEPT/ERC/ECC and ITU-R Recommendation
1.4 GHz	Class 2 EN 302 217-4	N.C	N.C	-	N.C	N.C	-	N.C	
2 GHz	Class 3 EN 302 217-4	N.C	N.C	N.C	-	-	EN 302 326-3	-	
L6 GHz	Class 3 EN 302 217-4	Class 2 EN 302 217	Class 3 EN 302 217-4	Class 3 EN 302 217	-	-	EN 302 217-4-1 EN 302 217-4-2	-	
U6 GHz	Class 3 EN 302 217-4	Class 2 EN 302 217	Class 3 EN 302 217-4	Class 3 EN 302 217	-	-	EN 302 217-4-1 EN 302 217-4-2	-	
L7 GHz	Class 3 EN 302 217-4	N.C	Class 3 EN 302 217-4	N.C	-	-	Class 3 EN 302 217-4-2	-	
U7 GHz	Class 3 EN 302 217-4	Class 2 EN 302 217	Class 3 EN 302 217-4	N.C	-	-	EN 302 217-4-1 EN 302 217-4-2	-	
L8 GHz	Class 3 EN 302 217-4	Class 2 EN 302 217	N.C	Class 3 EN 302 217	-	-	N.C	-	
U8 GHz	Class 3 EN 302 217-4	Class 2 EN 302 217	N.C	Class 3 EN 302 217	-	-	N.C	-	
11 GHz	Class 3 EN 302 217-4	N.C	Class 3 EN 302 217-4	Class 3 EN 302 217	-	-	EN 302 217-4-1 EN 302 217-4-2	-	
13 GHz	Class 3 EN 302 217-4	Class 2 EN 302 217	Class 3 EN 302 217-4	Class 3 EN 302 217	-	-	EN 302 217-4-1 EN 302 217-4-2	-	

15 GHz	Class 3 EN 302 217-4	Class 2 EN 302 217	Class 3 EN 302 217-4	N.C	-	-	Class 3 EN 302 217-4-2	-
18 GHz	Class 3 EN 302 217-4	Class 2 EN 302 217	Class 3 EN 302 217-4	110 MHz - Class 4 EN 302 217 Rest - Class 3 EN 302 217	-	-	EN 302 217-4-1 EN 302 217-4-2	-
23 GHz	Class 3 EN 302 217-4	Class 2 EN 302 217	Class 3 EN 302 217-4	≥56 MHz - Class 4 EN 302 217 Rest - Class 3 EN 302 217	-	-	-	-
26 GHz	P-P: Class 3 EN 302 217-4 P-MP: EN 302 326-3	Class 2 EN 302 217	Class 3 EN 302 217-4	112 MHz - Class 4 EN 302 217 Rest - Class 3 EN 302 217	-	-	Class 3 EN 302 217-4-2	N.C
28 GHz	Class 3 EN 302 217-4	N.C	Class 3 EN 302 217-4	N.C	-	N.C	EN 302 217-4-1 EN 302 217-4-2	-
38 GHz	Class 3 EN 302 217-4	Class 2 EN 302 217	Class 3A, 3B, 3C EN 302 217-4	≥56 MHz - Class 4 EN 302 217 Rest - Class 3 EN 302 217	-	-	EN 302 217-4-1 EN 302 217-4-2	-

42 GHz	Class 3 EN 302 217-4	N.C	Class 3A, 3B, 3C EN 302 217-4	N.C	-	N.C	EN 301 215-3	-
80 GHz	Class 3 EN 302 217-4	Class 2 EN 302 217	Class 3 EN 302 217-4	Class 3 EN 302 217	-	-	-	-

D.6 Mandatory equipment class

ComReg also defines mandatory equipment classes based on ETSI standards which, alongside the antenna and transmission capacity requirements, ensure the equipment used for fixed links is compatible with efficient use of the spectrum.

The table below illustrates the requirements laid out in ComReg's Guidelines as well as in other European jurisdictions with regards to the mandatory equipment classes under the different fixed links bands. As the table shows, of the eight countries benchmarked:

- four define a specific standard for the equipment class for all the fixed links bands; and
- four do not define any standard for equipment class.

In conclusion, the benchmark performed above shows that it is a reasonably common practice to refer to the ETSI norm "EN 302 217", or any of its derivative documents, to set the standards for equipment class for the different fixed links bands; and ii) the standards set by ComReg are aligned with those applied by other NRAs. As a result, our recommendation is to keep the current standards for the equipment class.

Table 20: Benchmark on mandatory equipment class

Band	Ireland	UK	Switzerland	France	Czech Republic	Hungary	Slovakia	Lithuania	Portugal
1.3 GHz	Classes 1, 2, 3 EN 302 217-2	N.C	N.C	N.C	N.C	N.C		N.C	The NRA carries out a case-by-case frequency assignment for each link, usually based on channel arrangements adopted from CEPT/ERC/ECC and ITU-R Recommendation
1.4 GHz	Classes 1, 2, 3 EN 302 217-2	N.C	N.C	EN 302 217	N.C	N.C		N.C	
2 GHz	Classes 2, 3 EN 302 217-2	N.C	N.C	N.C	-	-	-	-	
L6 GHz	Class 3 EN 302 217-2	EN 302 217-2-2	EN 302 217-1 EN 302 217-2	EN 302 217	-	-	-	-	
U6 GHz	Class 3 EN 302 217-2	EN 302 217-2-2	EN 302 217-1 EN 302 217-2	EN 302 217	-	-	-	-	
L7 GHz	Class 3 EN 302 217-2	N.C	EN 302 217-1 EN 302 217-2	N.C	-	-	EN 302 217-2-1 EN 302 217-2-2	-	
U7 GHz	Class 3 EN 302 217-2	EN 302 217-2-2	EN 302 217-1 EN 302 217-2	N.C	-	-	EN 302 217-2-1 EN 302 217-2-2	-	
L8 GHz	Class 3 EN 302 217-2	EN 302 217-2-2	N.C	EN 302 217	-	-	Class 5A EN 302 217-2-2	-	
U8 GHz	Classes 1, 2, 3 EN 302 217-2	EN 302 217-2-2	N.C	EN 302 217	-	-	EN 302 217-2-1 EN 302 217-2-2	-	
11 GHz	Class 3 EN 302 217-2	N.C	EN 302 217-1 EN 302 217-2	EN 302 217	-	-	N.C	-	
13 GHz	Classes 1, 2 EN 302 217-2	EN 302 217-2-2	EN 302 217-1 EN 302 217-2	EN 302 217	-	-	N.C	-	

15 GHz	Classes 1, 2 EN 302 217-2	EN 302 217-2-2	EN 302 217-1 EN 302 217-2	N.C	-	-	EN 302 217-2-1 EN 302 217-2-2	-
18 GHz	Classes 1 & 2 (PDH). Classes 4,5 (SDH). EN 302 217-2	EN 302 217-2-2	EN 302 217-1 EN 302 217-2	EN 302 217	-	-	EN 302 217-2-1 EN 302 217-2-2	-
23 GHz	Class 2 (PDH). Class 3 (SDH). EN 302 217-2	EN 302 217-2-2	EN 302 217-1 EN 302 217-2	EN 302 217	-	-	EN 302 217-2-1	-
26 GHz	Class 2 (PDH). Class 3 (SDH). EN 302 217-2 Class B (PDH & SDH) EN 302 326-1	EN 302 217-2-2	EN 302 217-1 EN 302 217-2	EN 302 217	-	-	EN 302 217-2-1 EN 302 217-2-2	N.C
28 GHz	Class 2 (PDH). Class 3 (SDH). EN 302 217-2	N.C	EN 302 217-1 EN 302 217-2	N.C	-	N.C	-	-
38 GHz	Class 2 (PDH). Class 3 (SDH). EN 302 217-2	EN 302 217-2-2	EN 302 217-1 EN 302 217-2	EN 302 217	-	-	EN 302 217-2-1 EN 302 217-2-2	-
42 GHz	Class 2 (PDH). Class 3 (SDH). EN 302 217-2	N.C	EN 302 217-1 EN 302 217-2	N.C	-	N.C	-	-

80 GHz	EN 302 217-3	EN 302 217-2-2	EN 302 217-1 EN 302 217-2	EN 302 217	-	-	-	-

D.7 High/low designation

Fixed links generally operate using FDD technology[33], and there is a choice over whether to transmit using the high channel ('transmit high') or low channel ('transmit low') of the duplex pair. ComReg requires that fixed link operators using the same frequencies within a given radius of each other (the 'site-sharing radius') either all transmit high or all transmit low. This is to avoid harmful interference between operators, and in particular ensures receivers are not subject to interference from transmitters at the same location operating over the same frequencies. The site-sharing radius decreases for higher frequency bands, since their inferior propagation means less distance is needed between sites for interference to not be an issue.

The table below illustrates the requirements laid out in ComReg's Guidelines as well as in other European jurisdictions with regards to the high/low designation conflict protocol to be followed by the fixed links licences.

Table 21: Benchmark on high/low designation protocol

Country	Recommendation currently followed
Ireland	No licences under high/low conflict
UK	Licences under high/low conflict only under very special circumstances ("dirty sites")
Switzerland	No licences under high/low conflict
France	-
Czech Republic	-
Hungary	-
Slovakia	-
Lithuania	-
Portugal	-

As the table above shows, of the 8 countries benchmarked:

- one defines a protocol of not licensing links in conflict under no circumstance;

[33] the only exception being that there is an option to use TDD technology for links in the 80 GHz band.

- one defines a protocol of not licensing links in conflict, doing it only under special circumstances; and
- six do not set any explicit obligations with regards to the high/low designation conflict protocol.

The analysis performed shows that only a couple of countries in Europe address a high/low conflict protocol in their guidelines. Including Ireland, there are 3 references that set an explicit protocol and 6 that do not.

The protocol set by ComReg is well aligned with those in place in the countries where an explicit high/low conflict protocol has been set. As a result, given that the practice of setting a high/low designation conflict protocol is not uncommon and that the criteria established by ComReg is aligned with those defined by other European NRAs, our recommendation is to keep the current approach adopted by ComReg.

With regards, to the high/low site-sharing radius, the table below illustrates the requirements laid out in ComReg's Guidelines as well as in European jurisdictions that define a high/low conflict protocol.

Table 22: Benchmarks on high/low site sharing radius

Band	Ireland	UK	Switzerland
1.3 GHz	-	-	-
1.4 GHz	-	-	-
2 GHz	-	-	-
L6 GHz	500m	500m	600m
U6 GHz	500m	500m	600m
L7 GHz	500m	500m	600m
U7 GHz	500m	500m	600m
L8 GHz	500m	500m	-
U8 GHz	500m	500m	-
11 GHz	500m	500m	900m
13 GHz	500m	500m	600m

15 GHz	400m	500m	600m
18 GHz	300m	300m	400m
23 GHz	100m	200m	200m
26 GHz	100m	200m	200m
28 GHz	100m	200m	200m
31 GHz	100m	100m	150m
38 GHz	100m	100m	150m
42 GHz	100m	100m	150m
60 GHz	100m	100m	100m
70/80 GHz	100m	100m	50m

The site-sharing radius is the minimum distance to be respected between neighbouring stations that have different band settings (high and low). We note that, in the recent years, ComReg has been softening the restrictions on this parameter (e.g. with the 2012 Fixed Links Survey and Decision).

As the table above shows, the 2 countries benchmarked apply a high/low site-sharing radius that is at least as large (and in some cases larger) than that imposed by ComReg for the majority of bands, with the only exception being the 80 GHz band in Switzerland.

For 70/80 GHz, the high/low site-sharing radius is the same in the UK as in Ireland (100m) but is only 50m in Switzerland. On this basis, the benchmark values suggests that, for the 80 GHz band, a value of 100m is not unreasonable, but it might be feasible for ComReg to reduce the radius to around 50m. ComReg may even consider reducing the radius to below 50m (potentially removing it altogether) on the basis that, given the very narrow width of the beam, interference between stations operating with these frequencies is highly unlikely in practice. Our recommendation is to get feedback from stakeholders on this matter before determining whether to reduce/remove the high/low radius restrictions on the high frequencies.

D.8 Multi-band aggregation

Multi-band aggregation uses link bonding to aggregate a wide high-frequency channel with a narrow low-frequency channel within the scope of the same operator and same usage. This combination of frequency bands under the same point-to-point link allows operators to run higher capacity links over longer distances than would otherwise be feasible using the bands individually i.e. higher capacities are provided by the higher band under favourable weather conditions, while the lower band offers more robust availability to support the link length under severe climate conditions. Operators have recently started to adopt use of multiband aggregation techniques (with the most common pairing currently being 18 GHz combined with 80 GHz), which will provide flexibility to the mobile microwave networks, will improve the efficient use of spectrum, and will foster and accelerate use of higher frequency bands.

At present we do not see any barrier in the Guidelines that may prohibit the use of this technology. However, there are certain points of attention when introducing multiband aggregation in the regulatory landscape. Specifically, two points have been identified as worthy of further analysis:

- **Link availability:** most administrations (including ComReg) require a specific link availability percentage. When multiband technology is being used (with a combination of high and low frequency bands), it may not be feasible for the availability requirement to be met for the higher frequency band. An appropriate alternative approach might be to instead impose the availability requirement only on the lower band, while the higher band availability should be planned from an interference point of view.
- **Minimum link length:** some administrations (including ComReg) define a minimum path length for each link, depending on the frequency range. Where multiband aggregation technology is being used, it would likely be over link lengths that are shorter than those typically operated as a single-band link in the lower frequency band. If the appropriate length of (some or all) links using multiband technology falls below the minimum requirement for the lower band, those links might be unduly prohibited, and it may be advisable to adjust the minimum link length requirements in the Guidelines. A suitable alternative approach might, for example, be to apply a minimum link length requirement for multiband

links that falls somewhere between the minimums currently set for individual links in the higher band and the lower band.

It is currently unclear whether these considerations are material in the Irish context and whether adjustments need to be made to the Guidelines. We therefore recommend that ComReg invites views on the matter from the relevant stakeholders, to identify whether any concerns exist and what an appropriate solution might require (i.e. whether it is necessary to add a provision to the Guidelines that specifies a lower availability requirement for the higher frequency link and/or a lower minimum link length for the lower frequency link in a multiband system).