DotEcon Report: Assessment of responses to ComReg Document 22/93

Consultant's Report

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Fixed links review

Assessment of responses to the Draft Decision

June 2023

1 Introduction

ComReg received comments from two stakeholders on its response to consultation and Draft Decision, published in November 2022. The responses were submitted by:

- Inmarsat, on the possible future award of the 1.4 GHz band for mobile and fixed communications networks (MFCN); and
- Siklu, in relation to the level of the new fees in the 80 GHz band.

In this note, we provide our assessment of Siklu's comments on the 80 GHz fees. Inmarsat's points in relation to the 1.4 GHz band are beyond the scope of our review and not considered here.

We also provide clarification on our recommendations for the determination of fees for time division duplex (TDD) links in the 80 GHz band under the revised framework. This point was not covered by our previous report and we are including it here for the avoidance of doubt.

In the interests of providing future-proofness, we also set out how the pricing formula we have previously recommended, and which forms the basis of the parameters in the Draft Regulations, extends to situations in which bandwidths in use do not have a simply doubling relationship amongst this. Mathematical details are given in the annex.

2 Fees in the 80 GHz band

Siklu submits that the 80 GHz band is an important high-capacity alternative to fibre and that the increase in fees for 2 GHz links in the band will price off many users of such links, leaving some consumers without access to a fast and reliable broadband connection. Siklu does not engage with any of the reasoning supporting the fees set out in the Draft Decision, but claims that *"the proposed increase will result in one of the highest* *fees compared to other developed countries"*, presenting a comparison of fees for a 2 GHz link in Ireland to that in a selection of other countries.

Opportunity cost-based pricing

We do not agree with Siklu that the new fees are likely to choke off demand for 80 GHz links, nor do we think that the international comparisons made are relevant to the proposals.

The new fees are designed to promote the efficient use of fixed links spectrum. They are based on the overall structure of opportunity costs across the various available fixed links bands to create incentives for operators to organise themselves efficiently within the available spectrum. This is necessary because of the potential for scarcity in some of the bands. We emphasise that the price of different bands need to be treated in an integrated and coherent manner due to the potential for at least some users to substitute between bands. Therefore, adjusting the fee level for 80 GHz such that it is no longer aligned with the structure of fees for other bands would undermine this approach.

We agree with Siklu that there is good scope for frequency reuse in the 80 GHz band and have previously acknowledge that any issues of interference are likely to be highly localised. This, along with the significantly greater amount of spectrum available compared to other bands, is already accounted for in the fees. Specifically, the fees for 80 GHz have been set at a level that is much lower than suggested by the opportunity cost estimates (and that would result from using the same methodology as setting fees for other bands). However, as above, we still believe that there is a need for keeping the 80 GHz fees aligned with the overall structure of fees across fixed links bands to support efficiency. To achieve this, 80 GHz fees were first matched to prices in the 42 GHz band (to avoid inefficient migration between the two), and then adjusted to account for the much greater availability of spectrum and channel sizes in the higher band.[1]

Siklu has not provided any argument or evidence as to why this is not a reasonable approach or why it is unnecessary to keep

[1] See ComReg document 21/134a for further details.

80 GHz fees aligned with the fees for other bands. Similarly, Siklu has not provided any details to support its claims that the proposed fees would price off users, or any suggestion of what a more appropriate fee level might be and how that would fit with the revised framework and objectives.

ComReg has already calibrated the level of new fees to the existing levels of fees for common links, with a focus on the most heavily used bands. In the 80 GHz band, the new annual fee for a 500 MHz link (the modal bandwidth used in the band) is €150, the same as under the current fee structure. For smaller channels the fees will be lower, and the majority of licensees in the 80 GHz band will see no increase in the amount they are paying for those links.

Under the new framework, the prices of links in a given band are increasing in bandwidth (which is not the case under the current fee structure for any links with bandwidth above 40 MHz). In the 80 GHz band, fees for channels larger than 500 MHz will increase relative to current prices, but we do not see any reason why operators wanting access to large channels (with significantly more bandwidth than typically used) should not be required to pay more. Whilst interference may be limited, there is still some potential opportunity cost of using the spectrum over a given path at a localised level, in particular where these links are operating in urban areas (where 80 GHz links are most heavily used) with a large proportion of the available spectrum within the band (the example given by Siklu of a 2 GHz link would utilise half of the channels of that size currently available for fixed links).

Overall, we do not see any convincing reason for ComReg to deviate from the proposed approach to setting fees for links in the 80 GHz band, which has been established on the back of a carefully considered assessment.

International comparisons

Siklu has provided several references to the fees charged for 2 GHz links in the 80 GHz band in other countries, which they claim demonstrate that ComReg’s proposed fees are much higher than elsewhere. However, the licence types considered in several of the examples shown are not comparable to those offered by ComReg. For example, the fees quoted for the UK are for light licences that offer limited protection and require operators to self-coordinate with one-another, which clearly not the same as the fixed links licences offered by ComReg.

Moreover, even if fees for comparable licences were in some cases lower elsewhere, it would not automatically follow that the new fees in Ireland were too high or that they would choke off demand. As above, the new fees in Ireland have been set for specific reasons, and the simple fact that prices are lower in certain other countries does not provide any argument as to why lowering fees in Ireland might be a better approach.

In any case, setting the fee levels with regard to what other countries charge would essentially be a benchmarking methodology, which has already been considered and rejected on the grounds that it would not promote efficient use of the available spectrum, because:

- fixed links fees internationally are highly variable and not typically set to reflect the opportunity cost of spectrum, so that benchmarks would not be grounded in anything meaningful; and
- opportunity cost is likely to be relevant, at least in some cases, for setting fixed links fees in Ireland (given historic congestion in some bands/areas), and this is unlikely to be addressed by setting fees on the basis of international benchmarks.

In conclusion, we do not believe that Siklu has provided any convincing arguments or evidence to suggest that the proposed new fees for fixed links in the 80 GHz band are too high and likely to cause problems, and we do not recommend any changes to the fees set out in the Draft Decision and Draft regulations.

3 Fees for TDD links

We have subsequently identified a need to clarify the Draft Regulations regarding the fees applicable to TDD fixed links. This is a minor issue and is simply a matter of clarifying how bandwidth is counted for calculating fees for TDD links. There are no significant changes to the fee proposals required and, given all existing fixed links operate over FDD, no operators are affected at present.

Effective bandwidth used by TDD links

Recall that the new fixed links fees are based on 'effective bandwidth', applying a premium to per MHz fees for links that use a smaller bandwidth than the largest bandwidth in common use in the band. This recognises the risk that smaller links will preclude access to spectrum for potential larger bandwidth links, creating incentives for operators of lower bandwidth links to avoid fragmenting the band (using an alternative band with smaller typical bandwidth if possible) and for operators to use single large channels rather than multiple smaller ones.

TDD links using channels smaller than the largest typically used in a band create similar problems to FDD links using small channels, in terms of fragmenting the band and preventing access to users of larger channels. In addition, a TDD link potentially precludes access to the spectrum licensed as well as the corresponding (unlicensed) uplink/downlink channel that, if there is no other TDD user to use the spectrum, could remain fallow. In that sense, a TDD link may create more disruption than the licensed bandwidth might suggest. For example, a 500 MHz TDD link potentially blocks access to a user of 2x1 GHz links (the largest bandwidth in common use in the 80 GHz band) but could also preclude a 2x500 MHz link that would only have access to one half of the duplex pair. This is the same impact as a 2x500 MHz FDD link, which has double the total licensed bandwidth. This raises the question of whether fees for TDD links therefore ought to be the same as for a FDD link with double the total bandwidth i.e. should a TDD link with bandwidth x MHz be priced the same as a $2\times x$ MHz FDD link?

On the other hand, the corresponding (unlicensed) uplink/downlink channel could be used for another TDD link if there is demand. Moreover, TDD may have long term advantages for spectrum management, since the possibility for flexible and dynamic capacity allocation may support more efficient assignment where operators have asymmetric uplink/downlink traffic patterns (and FDD licences may lead to operators licensing more spectrum in total than they need). Given these considerations, the potential impact of a TDD link is arguably less than that of an FDD link with double the total bandwidth.

Overall, the extent of the potential disruption caused by a TDD link relative to FDD, and the associated opportunity cost, depends on a number of factors including, but not necessarily limited to:

- the mix of FDD and TDD users (and expectations over whether another TDD user might use the corresponding unlicensed channel);
- the relative value of TDD links and FDD links (e.g. are two 500 MHz TDD links worth more to the licensees than a single 2x500 MHz FDD link?); and
- the extent of the efficiency gains and spectrum management benefits that might result from TDD.

We cannot realistically predict how things will develop over time, how “disruptive” a TDD link might be relative to FDD, and what grounds (if any) there might be for treating TDD and FDD differently when setting fees. We therefore do not currently see any strong reason for differentiating between the per MHz charges that should apply for TDD vs FDD.

The proposed general approach to fixed link pricing is not to fully cover opportunity costs for each and every licence, but to reflect the overarching structure of long-run opportunity costs to promote efficient self-organisation amongst operators. With this principle in mind there is no need to formulate a different approach to pricing for TDD. Provided we are clear on the interpretation of bandwidth/channel size for TDD links, the new fees framework already accounts (at least partially) for some potential opportunity cost arising from TDD links that preclude access either to users of larger channels or FDD links that cannot access both parts of a duplex pair, due to the small bandwidth premium.

The new fee structure applies a premium for all links with effective bandwidth less than the largest bandwidth in common use. For an FDD link, effective bandwidth is in fact calculated as the effective channel size, which is only half of the total bandwidth licensed. Our expectation/recommendation is that the effective bandwidth for a TDD link is calculated to give the same fee as for an FDD link if the same the total bandwidth is licensed, meaning, for example, that a 500 MHz TDD link would cost the same as a 2x250 MHz FDD link.

TDD use at 80 GHz

At present, to the best of our knowledge, there are no TDD licences in the 80 GHz band. However, high bandwidth 80 GHz links are used for mobile backhaul and FWA in urban areas, which are likely to have asymmetric uplink/downlink traffic patterns (especially relative to long distance links in core networks, where similar amounts of traffic would be going in each direction). Given the advantages of TDD links for these use types of application, discussed above, we might therefore expect an increase in demand for 80 GHz TDD links in the foreseeable future.

In the 80 GHz band, the largest bandwidth in common use is currently 2x1 GHz FDD links (corresponding to 2 GHz total bandwidth licensed). Therefore, if effective bandwidth for a TDD link is calculated as above, the new fee structure would apply a small bandwidth premium to TDD links with up to 2 GHz bandwidth. This would seem appropriate for links up to at least this bandwidth since:

- it applies a premium for those, links representing some of the potential opportunity cost of precluding access to larger bandwidth users; and
- it ensures TDD fees are consistent with FDD fees, in terms of the per MHz charge, and avoids incentives for operators to use one technology over the other simply because it is cheaper.

High bandwidth TDD links

There might be an argument that TDD links with bandwidths of more than 2 GHz should also face a premium, since all TDD links create a risk of unused spectrum if there is no other TDD user that can use the corresponding channel. However:

- it is not feasible to assess the impact of TDD links on the efficiency of spectrum assignment in the 80 GHz band, in particular as we do not know the future mix of TDD/FDD, how the different users might fit together in the band, or what the implications will be for spectrum management – we do not even know if the net impact will be positive or negative;
- favouring FDD links could reduce incentives for use of large TDD links that may well be the most efficient use of the spectrum if those links become more heavily used for dealing effectively with asymmetric traffic;
- charging a premium for TDD links with more than the largest common bandwidth would create an inconsistency with fees for FDD links with the same total bandwidth;
- such large TDD links (with total bandwidth in excess of that in the largest FDD links in common use) would be expected to be fairly uncommon and the potential benefits of

adjusting the fee structure specifically for links of that nature are likely to be limited; so
- on balance there does not seem to be a strong need for a premium on larger TDD links.

Conclusions on pricing for 80 GHz TDD links

In conclusion, we do not see any particular need for adjusting the fee structure to accommodate TDD links in the 80 GHz band as the current approach already does what is needed and there is no clear justification for doing anything different.

However, we believe there is a need for clarification in the regulations that fees relate to the amount of spectrum licensed, and therefore that the fee for a TDD link is found by looking up the fee for an FDD link using a channel half the size (or, alternatively, adding a TDD fee table for the 80 GHz band). At present the regulations could be interpreted to mean that the fee for a TDD link would be the same as the fee for an FDD link using the same channel size (and double the total bandwidth) e.g. a 500 MHz TDD link would cost the same as a 2x500 MHz FDD link.

The fee tables in the Draft Regulations include values for all available FDD channel sizes. The intention was that, where TDD links are available, the TDD fees could be found by reading off the value of the FDD channel with the same total bandwidth. However, for some TDD channel widths, the corresponding FDD channel is not available (e.g. 750 MHz TDD links are available in the 80 GHz band, but the Draft Regulations do not include a fee for a 2x375 MHz FDD link). Fees for these “missing” TDD channel sizes are detailed in the table below.

Table 1: Fees for potential TDD links not covered in the regulations

Bandwidth (MHz)	FDD channel for equivalent fee (MHz)	Fee (EUR)
250	125	100
750	375	118
1,250	625	178
1,750	875	223

Note that because these channel sizes are not equal to the largest bandwidth in common use multiplied by some (whole number) power of a half, it is necessary to use the generalised version of the formula for calculating effective bandwidth, rather than the simple version that was specified in our previous report. This is also the case for 2x750 MHz links in the 80 GHz band and could affect other links in the future if the largest bandwidth in common use changes for one or more bands or other channel widths are made available.

For the avoidance of doubt, this does not affect the recommendations for or calculation of effective bandwidth (and resulting fees) for any of the bands/channels already covered in the Draft Regulations – indeed, the generalised formula was already used for this purpose (including for 2x750 MHz links), but the calculation was presented in our report in a simpler form that is equivalent under the assumption that the available channels all conform to a certain structure.[2] Since this assumption is not valid, and also for future proofing against potential changes to the structure of available channels and/or the largest bandwidth in common use for one or more bands, the generalised formula is relevant. For transparency and

[2] The simplified version of the effective bandwidth calculation, $b(h) = (1-m)h + mb(2h)$, can be applied for any bandwidth equal to the largest bandwidth in common use multiple by $\frac{1}{2^n}$, and our previous report assumed that all available channels conformed to this structure. This is clearly not the case with the available TDD channels or 2x750 MHz channels in the 80 GHz band, and the generalised formula needs to be used.

completeness, this is set out in detail in the annex to this document.

There is also a small error in the fee for a 2x750 MHz link reported in the Draft Regulations. However, this appears to simply be a typographical error and is not due to any adjustment of the effective bandwidth calculation.

Annex - Generalised effective bandwidth formula

In any given fixed links band, a series of channels are available where each one is double the width of the last (e.g. 28 MHz, 56 MHz, 112 MHz). This is also the case for the channels currently in common use in the 80 GHz band (i.e. 250 MHz, 500 MHz, 1 GHz), but in addition, every multiple of 250 MHz is available as a channel width.

Recall that our effective bandwidth formula is $b(i,h) = (1-m)h + mb(i,2h)$. This is used for stepping down to channels smaller than the largest in common use through successive halving of the bandwidth. For channel widths equal to or greater than the largest in common use, effective bandwidth is equal to bandwidth. In nearly all cases bandwidths within a band are related by doubling, so this formula is enough to derive effective bandwidths, and so prices, for all the bandwidths.

We cannot directly use this formula for channel widths that are not derived by the largest channel width in common use through successive halving. For example, consider a 1750 MHz TDD link - we would charge this as if it was a 2x875 MHz FDD link. The effective bandwidth for an 875 MHz link cannot be obtained from 1000 MHz (as that is the largest bandwidth in common use) by successive halving. Therefore, our simple effective bandwidth formula cannot be applied to work out the effective bandwidth for a 875 MHz link.

However, the formula can be easily generalised to deal with any bandwidth below the largest bandwidth in common use. Suppose that , in a certain band, we have a largest bandwidth in common use, $\hat{h}$. We can apply the formula above to deal with bandwidths than can be obtained by successive halving of $\hat{h}$. By applying the formula recursively, we get a formula for effective bandwidth in terms of how many times you have to half the largest bandwidth in common use.

On first applying the formula $b(h) = (1-m)h + mb(2h)$ to the largest typical bandwidth in use $\hat{h}$ we have

$$b\left(\frac{\hat{h}}{2}\right) = \left[(1-m)\frac{1}{2} + m\right]\hat{h}$$

Applying it a second time

$$b\left(\frac{\hat{h}}{4}\right) = (1-m)\frac{\hat{h}}{4} + m\, b\left(\frac{\hat{h}}{2}\right)$$

$$=\left[(1-m)\tfrac{1}{4} + (1-m)m\tfrac{1}{2} + m^2\right]\hat{h}$$

Then in general after n applications of the rule we have that

$$b\left(\frac{\hat{h}}{2^n}\right) = \left[(1-m)\sum_{k=0}^{n}\left(\frac{1}{2}\right)^k m^{n-k} + m^{n+1}\right]\hat{h}$$

$$= \left[(1-m)\frac{m^{n+1} - (1/2)^{n+1}}{m-(1/2)} + m^{n+1}\right]\hat{h}$$

$$= \left[\frac{m^{n+1} - (1-m)2^{-n}}{2m-1}\right]\hat{h}$$

The general expression uses the fact that the $m^n = (1-m)m^n + m^{n+1}$ and the penultimate line uses the formula for a telescoping sum.

We can allow n to take non-integer values, thereby allowing to consider any bandwidth smaller than $\hat{h}$. If $h = \frac{\hat{h}}{2^n}$ then

$$n = log_2\left(\frac{\hat{h}}{h}\right) = \frac{\ln(\hat{h}/h)}{\ln 2}$$

and so

$$m^n = \exp[n\ln m] = \exp\left[\frac{\ln(m)}{\ln 2}\ln\left(\frac{\hat{h}}{h}\right)\right] = \left(\frac{\hat{h}}{h}\right)^{\frac{\ln(m)}{\ln 2}}.$$

Therefore, putting this all together, for any $h \leq \hat{h}$

$$b(h) = \frac{\hat{h}}{2m-1}\left[m\left(\frac{\hat{h}}{h}\right)^{\frac{\ln(m)}{\ln 2}} - (1-m)\frac{h}{\hat{h}}\right]$$

This formula gives the effective bandwidth for any bandwidth less than $\hat{h}$. It coincides with the simpler rule for bandwidths that can be obtained from $\hat{h}$ by successive halving.