Maximising the Benefits of 700MHz Clearance

Response to consultation by Ofcom
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1 Introduction

I am grateful for the opportunity to respond to the Ofcom consultation on Maximising the Benefits of 700MHz Clearance. The early release of the 700MHz band is important for citizens and consumers, because it will provide low frequency spectrum that is needed to provide coverage and building penetration as demand for mobile data by consumers continues to grow. The steps proposed in this consultation to accelerate this release are therefore to be welcomed. However, it must be recognised that this release will still be later than in some other European countries where DTT is less important for the delivery of TV programme content.

This response addresses one aspect of the consultation - the optimal use of the 700MHz centre gap. The option proposed by Ofcom - supplementary downlink (SDL) - is probably the best of the four included in the Commission Decision for the 700MHz band. However, TDD might be a more optimal use of this spectrum, because of the challenges of deploying 700MHz SDL in a multi-band mobile network and the opportunities that TDD could provide for promoting competition and innovation.

2 Summary of Response

Ofcom is correct to aim to release the 700MHz band for mobile use as quickly as possible, and to conclude that the most valuable use of the centre gap is for mobile data. However, the Commission Decision (EU) 2016/687 restricts the use of the centre gap for mobile networks to base station (downlink-only) transmission. For mobile broadband, Ofcom has therefore only considered SDL in this consultation. However, there are significant challenges in implementing SDL in the centre gap, both in terminals and on cell sites, and it is unclear how effectively it would be used.

For a mobile network operator with paired spectrum in the 700MHz and 800MHz bands and perhaps the 900MHz band, it would be quite challenging to also deploy TDD in the 700MHz centre gap - probably, more challenging than SDL. However, a player without other spectrum below 1GHz would not face most of these challenges. The centre gap may therefore provide an opportunity to promote innovation in 5G or to encourage competition. The prices that have been paid for 700MHz paired spectrum in other countries would make it very difficult for any new player to enter the market, and

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1 This response is based on two decades of experience in spectrum management for mobile services. I contributed to the work in CEPT on the development of the harmonised technical conditions for the 700MHz band that are now contained in Commission Decision (EU) 2016/687, as well as the equivalent conditions for the 1452-1492MHz, 800MHz, 2.6GHz and 3.3-3.8GHz bands. It is submitted in a personal capacity.

2 Commission Implementing Decision (EU) 2016/687 of 28 April 2016 on the harmonisation of the 694-790 MHz frequency band for terrestrial systems capable of providing wireless broadband electronic communications services and for flexible national use in the Union.

3 It seems something of a contradiction that the Decision states that "Member States should also have the flexibility to use portions of the 700 MHz frequency band in response to specific national needs", and then limits this flexibility to four options specified in great detail.
there are no other spectrum releases in the foreseeable future with comparable potential for these applications.

The Commission Decision would need to be amended to allow the authorisation of TDD in the centre gap. However, this could be done quite quickly for the central 15MHz, because the existing studies already provide the necessary technical information to define the parameters for TDD for this frequency range.

It is therefore appropriate for Ofcom to include TDD in its consideration of maximising the benefits of 700MHz clearance - particularly the optimal use of the spectrum in the centre gap.

3 The optimal use of the Centre Gap

Question 3: Do you agree with our provisional assessment that SDL is likely to represent the optimal use of the centre gap?

No. There are two reasons why the assessment in the consultation document is incomplete:

- It has not considered the potential use of the spectrum in the centre gap for TDD
- It assumes that the utility, and therefore value, of 700MHz SDL is comparable to the 1452-1492MHz band.

TDD is likely to be a more optimal use of the centre gap than SDL. It would provide opportunities for innovation in 5G and promoting competition in mobile services. These opportunities may not otherwise be available, due to the lack of any other suitable, available and affordable spectrum. There are a number of technical factors which are likely to reduce the value of SDL in the centre gap to existing mobile network operators; these relate to the challenges of implementing 700MHz SDL in smartphones and deployment in multi-band networks. SDL is obviously of no value to any player that does not also have access to suitable spectrum for a mobile uplink. The existing four mobile network operators are therefore the only potential bidders for spectrum constrained to SDL use.

The following sections provide the analysis to support the conclusion that SDL may not be the optimal use of the 700MHz centre gap.

3.1 Carrier aggregation and band combinations

In LTE, downlink-only bands are supported through carrier aggregation with a paired band. The implementation of carrier aggregation in a terminal involves a separate RF chain for each band to be aggregated. In the standard implementation of a multi-band terminal, the RF signal to/from its antenna is separated into two paths using a diplexer, for bands below and above 1GHz⁴, each with its own RF transmitter and receiver chains (because of the limited frequency range of one RF chain). As a consequence, carrier aggregation of the combination of any one band below 1GHz with any one band above 1GHz can be supported without adding complexity to the RF subsystem. The great majority of smartphones (if not all) should therefore support this type of carrier aggregation.

⁴ The implementation of 1452-1492MHz in terminals is less well developed, but I understand that the transition of the diplexer will be located between 960MHz and 1452MHz. It will therefore also be a "band above 1GHz".
The two paths for below and above 1GHz each comprise a matrix of filters and switches, linking the transmitter and receiver ports of the RF chain to the antenna, and keeping the two ports isolated from each other. If carrier aggregation of two or more bands below 1GHz or above 1GHz is to be supported, the relevant path will will need additional RF chain(s), and the matrix of filters and switches will become more complicated. Each supported combination of bands needs to be considered individually in the design process. Some combinations are more challenging than others, and some are not feasible (for example, aggregation of 700MHz paired with 700MHz SDL will not be possible).

There is a limit to the overall complexity of the RF subsystem of a terminal, based on feasibility of implementation and considerations of cost and performance (which inevitably degrades with an increase in the number of supported bands). This 'envelope' of complexity is increasing in size quite rapidly due to advances in technology, but it is not catching up with the number of new mobile bands being released and licensed around the world. Therefore, terminal manufacturers are forced to make difficult choices on the bands and combinations of bands for carrier aggregation that their products will support. They are likely to choose bands with the greatest global use, and ones for which there is widespread co-ordinated deployment (most often, when there is a coordinated licence award process for a band and the band is brought into use immediately after the licence award).

If a downlink-only carrier is aggregated with a paired carrier, then the downlink traffic can be shared dynamically between the two carriers. However, the control channels and the uplink traffic must be supported by the paired carrier (i.e., it is the primary carrier). Therefore, the performance of the aggregated combination is largely determined by the characteristics of the paired carrier - and particularly its frequency. The market scale of 700MHz SDL may not be sufficient for it to be supported in terminals as a dedicated combination with the 800MHz and/or 900MHz bands. However, as explained above, a 700MHz SDL channel could inherently be aggregated with any band above 1GHz (in practice, this means a band around 2GHz or 2.6GHz).

Counter-intuitively, this would result in a 700MHz SDL channel effectively having the performance of the 2GHz band and an SDL channel in the 1452-1492MHz band effectively having the performance of a band below 1GHz. The simple extrapolation of valuation of SDL spectrum in paragraph 4.27 of the consultation document is therefore not valid.

3.2 The potential market for 700MHz SDL and TDD

The current Commission Decision offers four options for the use of the 700MHz centre gap:
- High power broadcasting networks
- Public safety
- PMSE
- Supplementary downlink for mobile broadband

5 There is a further complication with aggregating spectrum in the 700MHz range with the 800MHz or 900MHz bands. It is generally only possible to fit a single antenna structure for the frequency range below 1GHz into a handheld terminal (the higher frequency bands are generally supported by a different antenna structure). An antenna with such a wide frequency range will not be very efficient, particularly toward the bottom of the range. Technologies are being developed to 'tune' the antenna, which substantially improves its efficiency. However, a single antenna structure can only be tuned to one frequency at a time. It therefore cannot support two aggregated bands below 1GHz.
The large centre gap in the 700MHz band in Europe is a consequence of the partial implementation of the APT 700MHz bandplan of 2 X 45MHz, because the upper portion of this bandplan overlaps with the European 800MHz bandplan in Europe. Therefore, the market for 700MHz SDL is largely limited to Europe. However, some EU countries are likely to reserve the centre gap for other options, particularly public safety. To be useful, it is likely that an operator will need at least 10MHz of spectrum in the centre gap, which means a maximum of two operators per market using this spectrum. For these reasons, the potential market for 700MHz SDL is likely to be substantially less than the whole of Europe.

As discussed in the previous section, the current state-of-the-art for the RF subsystem of terminals does not allow all of the mobile bandplans defined in 3GPP standards to be implemented in a single terminal. This RF technology is advancing rapidly, but it is not catching up with the number of new mobile frequency bands being released and licensed around the world. The number of bands that must be supported in a global phone adds a significant percentage to its bill-of-materials cost, and degrades the RF performance (which reduces coverage and quality of service)\(^6\).

In contrast, many of the potential applications for TDD in the 700MHz centre gap would not need to support roaming, or many other frequency bands. The devices for these applications are likely to be less subject to size or power constraints, and would probably be less highly integrated. The development cost of such devices would be far lower than for a smart phone, and a national market such as UK would be likely to provide a viable economy of scale for design and manufacturing.

### 3.3 Challenges for infrastructure deployment

The 700MHz SDL band is immediately below the 700MHz band paired uplink, which is separated from the 800MHz band uplink by a gap of only 3MHz. This makes a total of 83MHz of almost continuous downlink spectrum, with 5MHz separation to uplink below and 11MHz separation above. This is probably beyond what is feasible for a single duplex filter in a base station. The gap of 3MHz between 700MHz and 800MHz band is too narrow to comfortably split it into two frequency ranges with the transition between the two duplexers in the 3MHz gap. It is therefore likely that supporting this frequency range will require two bandpass filters, with a transition that falls within the 700MHz or 800MHz band (but away from the spectrum used by the operator in question). This means that the base station filters will need to be specific to each operator and the spectrum that it has in each country. This becomes a greater challenge when two operators share sites and antennas.

For some operators, the 700MHz SDL band might increase the number of its channel groups below 1GHz to four. This greatly increases the likelihood of intermodulation products\(^7\) desensitising a receive channel, or the difficulty of acquiring spectrum in different bands that have frequency

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\(^6\) Terminals that support the European 700MHz paired band will be designed to support the full 700 MHz APT bandplan of 2 X 45MHz. The 700MHz SDL spectrum will therefore overlap with the uplink of the APT band. This overlap of uplink of one band with downlink of another can be more challenging to implement in terminals.\(^7\) Intermodulation products are signals that are generated when transmissions on two or more different frequencies interact to generate new low level signals on different frequencies. These low level signals can fall on receiver frequencies, which then desensitise of 'jam' the reception. The frequencies of the intermodulation products are well defined, related to the difference between the frequencies of the transmissions. At the very low levels at which these products can cause problems, they can even be generated by a dirty metal-to-metal contact - called passive intermodulation or PIM.
relationships such that this does not occur. This problem is compounded when operators share sites and antennas, because the number of channel groups is higher. This is a particular problem when these operators participate in licence awards by auction; to achieve optimal use of spectrum, they should coordinate the spectrum that they acquire so as to minimise the impact of intermodulation, but the auction rules generally prevent this.

3.4 Opportunities for TDD in the 700MHz centre gap

It is generally recognised that spectrum below 1GHz is particularly valuable for wide-area mobile applications. Apart from 700MHz band, there are no other spectrum releases planned in UK that could provide comparable capabilities. The price of 700MHz paired spectrum could well be beyond the reach of companies with innovative ideas for use of the spectrum, so the 700MHz band centre gap could well provide a unique opportunity to foster innovation and competition. This is addressed in more detail in section 5.1 of this response.

4 Demand for spectrum for SDL

Question 4: When is the demand for spectrum for SDL likely to arise?

Question 7: Do you agree with our working assumption that there will be significant demand for SDL spectrum in the centre gap in the early 2020s?

There are two essential factors for the 700MHz SDL spectrum to be used effectively:

- Operators must find it cost effective to deploy infrastructure in this band, compared with other alternatives.
- There must be an ecosystem for both infrastructure and devices.

The 700MHz SDL band would form a small part of the spectrum portfolio of a mobile network operator, and is therefore unlikely to be an essential element of fulfilling its future business plans. As the band is 'supplementary', its use would probably follow other bands, and the timeframe in which different operators might wish to start making use of this spectrum is likely to vary significantly.

As discussed in section 3.3, there are challenges in integrating 700MHz SDL into cell sites that support other mobile bands below 1GHz, and particularly the 700MHz paired band. If provision is not made for 700MHz SDL at the time that a cell site is upgraded for 700MHz paired spectrum, the cost of retrofitting this capability later would be significantly higher. However, if the capability for 700MHz SDL is added at the time of upgrading a site for the 700MHz paired band, the timeframe for making use of this investment would probably not be clear.

By 2020, mobile industry R&D and investment will be focused on 5G. Obviously, as downlink-only spectrum, the 700MHz SDL band cannot be used for the initial deployment of 5G.

The timeframe for operators to find demand for SDL spectrum is therefore uncertain, and is likely to vary between them. It is therefore unclear that an ecosystem will develop for the 700MHz SDL band, especially given its small potential market size compared with 5G - which will be the main focus of the mobile industry by 2020.
The challenges to a mobile network operator of integrating 700MHz SDL into its network and to a smart phone manufacturer of implementing 700MHz SDL in its products are probably comparable in magnitude to the 1900-1920MHz band (though the specific challenges are different). The available bandwidth of 20MHz is also the same. Ofcom may therefore find it useful to compare the 700MHz SDL band with the 1900-1920MHz band, as well as with the 1452-1492MHz band.

5 Enabling the option of TDD in the centre gap

Question 8: Do you have any further comments or views on other aspects of the consultation which are not covered above?

5.1 Promoting innovation and competition

Under the Wireless telegraphy Act of 2006, Ofcom must have regard to the desirability of promoting "the development of innovative services" and "competition in the provision of electronic communications services", as mentioned in paragraph 2.24 of the consultation document.

Supplementary downlink spectrum, as its name suggests, can only be used by mobile operators that already have mobile spectrum. The 20MHz of SDL spectrum in the 700MHz centre gap represents a small proportion of their spectrum portfolio, so will not substantially change their business model. Release of this spectrum as SDL is therefore unlikely to significantly promote innovation and cannot promote competition.

It is generally recognised that spectrum below 1GHz is particularly valuable for many wide-area mobile applications. Studies on 5G in the last year have identified a number of vertical applications for 5G, many of which would need wide area coverage. It has been suggested that some of these vertical applications might benefit from having a dedicated network. The increasing recognition of the importance of these verticals to 5G would justify a reconsideration of the restrictions of the Commission Decision on the use of the centre gap.

Access to spectrum below 1GHz might also be valuable to players that have (or acquire in future) spectrum in higher frequency bands such as the 1781MHz or 3.4-3.8GHz bands. Even a small amount of spectrum below 1GHz might enable them to provide services that are more compelling to consumers or to offer services across a larger proportion of the UK.

5.2 Implementing an EU regulatory framework for TDD in the 700MHz centre gap

The Commission Implementing Decision for the 700MHz band2 has already been published in the Official Journal of the EU, though it is perhaps surprising that this has happened while the Decision of the Parliament and the Council that it is intended to implement is still under consideration by those bodies. To enable TDD to be authorised by Ofcom in the centre gap, this Decision will need to be amended8.

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8 Obviously, if the Decision of the Parliament and Council were to make specific reference to TDD in the centre gap, then the Commission would be required to revise the Decision.
The parameters contained in the Commission Decision were developed by CEPT in response to a Mandate from the Commission. This Mandate called for CEPT to "develop a preferred technical (including channelling) arrangement and identify common and minimal (least restrictive) technical conditions for wireless broadband use in the 694-790 MHz frequency band for the provision of electronic communications services". CEPT was requested that this should contribute to several important EU policy objectives, including to "promote innovation and investment through enhanced flexibility in spectrum use".

The response by CEPT to this Mandate is contained in CEPT Report 053 and CEPT Report 060. There is nothing in either report explaining why TDD was ruled out or, indeed, whether it was considered as an option.

The Commission Decision for the 700MHz band contains parameters for FDD downlink and for coexistence between uplink and downlink with 5MHz separation (between the paired uplink at 733Mhz and below and SDL at 738Mhz and above). These together are sufficient to define the parameters for FDD downlink in the middle 15 MHz of the centre gap. The CEPT studies on the 2500 - 2690MHz band also provides insight into the use of the centre gap of a paired frequency arrangement.

The normal procedure of the European Commission is to define the spectral emission requirements of terminals through Harmonised Standards, rather than in a Commission Decision for the band concerned. This is likely to require some further technical studies, which could probably re-use the methodology for the 2 500 - 2 690 MHz band. These standards would be needed for the development of TDD equipment for the 700MHz band, but not necessarily by the time of licence award. These studies could also consider the extent to which the remaining two 5MHz blocks in the centre gap could be used for TDD as "restricted blocks".

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9 Mandate to CEPT to develop harmonised technical conditions for the 7694-790MHz (’700MHz’) frequency band in the EU for the provision of wireless broadband electronic communication services in support of EU spectrum policy priorities; 13 February 2013

10 Report A from CEPT to the European Commission in response to the Mandate “To develop harmonised technical conditions for the 694 -790 MHz (’700 MHz’) frequency band in the EU for the provision of wireless broadband and other uses in support of EU spectrum policy objectives”; 28 November 2014

11 Report B from CEPT to the European Commission in response to the Mandate “to develop harmonised technical conditions for the 6941-790 MHz (’700 MHz’) frequency band in the EU for the provision of wireless broadband and other uses in support of EU spectrum policy objectives”; 1 March 2016