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BENEFITS AND LIMITATIONS OF SINGLE FREQUENCY NETWORKS (SFN) FOR DTT

TECHNICAL REPORT

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Benefits and limitations of Single Frequency Networks (SFNs) for DTT

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1. Summary

Single Frequency Networks (SFNs) have a number of advantages over Multiple Frequency Networks (MFNs), in particular they have a potentially higher spectrum efficiency, the possibility to improve the quality of coverage and more flexibility for network implementation. Broadcasters currently benefit from these capabilities as they have implemented SFNs in many European countries. For broadcasters Single Frequency Networks are a well-established and mature technique.

A number of technical and non-technical constraints are associated with the benefits of SFNs described below. Consequently, not all the benefits of SFNs can be maximized at the same time.

A principal requirement for broadcast networks is to provide coverage over a service area defined by political, editorial, economic and practical considerations. Public service broadcasters also have constitutional obligations to meet specific service and coverage objectives. These requirements must all be taken into account and will influence the degree to which the benefits of SFNs can be achieved.

At the same time, technical issues require trade-offs to be made between the geographical size of a Single Frequency Network, its robustness, its capacity and cost. The larger the size of the SFN, the more difficult, and costly, it is to ensure that a given capacity is available throughout the service area. These constrains are not present in MFNs which could be better suited in some cases.

In principle, SFNs are more spectrally efficient than MFNs if service areas are large, of similar shape and size, and do not overlap. Conversely, where there are many small service areas, differing significantly in shape and size and that are either adjacent or overlapping, there will be marginal difference in the spectrum efficiency, if any, between SFNs and MFNs. In practice, service areas are different and therefore the choice between MFNs and SFNs will depend on what option is most efficient.

National regulators and broadcasters alike are strongly motivated to opt for SFNs whenever practical because of the potentially large benefits. The use of SFNs is appropriate so long as they help to fulfil the requirements for the network coverage and performance while taking into account all the other considerations.

2. Background

Broadcast networks are designed to provide coverage over a given, pre-defined geographical area, commonly called the service area. These areas could be as large as an entire country or as small as a single town. In practice one can distinguish between national, regional and local areas. In all cases service areas are defined by a mixture of political, editorial, economic and practical considerations.

Broadcast networks are planned to match an intended service area as closely as possible. In most cases service areas are large enough to require multiple transmitters to provide the desired coverage.

The introduction of digital broadcast systems such as DVB-T/T2 and T-DAB gave the possibility of using Single Frequency Networks (SFNs), in which the same frequency is assigned to all transmitters in a given service area. This is a different approach to the traditional one where each transmitter is assigned its own, separate channel frequency. The latter is known as Multiple Frequency Networks (MFNs).

One of the main benefits expected of SFNs is their ability to use spectrum (a scarce resource) in a more efficient way than with MFNs. With an SFN it may be possible to provide coverage over a large area using only a single channel frequency, whereas an MFN would require multiple channels, although they would not be used throughout the whole service area. However, the improved spectral efficiency of an SFN comes with trade-offs and constraints that do not exist in an MFN. These trade-offs and constraints require broadcasters to choose the network type that best suits their needs. Based on these considerations, broadcasters have already implemented SFNs in many European countries since digital broadcasting services were introduced.

This document elaborates on the main benefits, constraints and trade-offs of SFNs and provides some background to the implementation of SFNs in Europe.

3. Benefits of SFNs

3.1 Improved spectrum efficiency

Compared to an MFN of similar capability, a well-designed SFN can offer improvements in spectrum efficiency and this is realised in many cases in Europe where broadcasters use SFNs in their networks.

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In reality service areas are not homogeneous because they are defined by editorial requirements and take into account topography, infrastructure and population distribution. The choice between MFNs and SFNs will therefore depend on what option is most efficient.

Networks in one country have an impact on the networks in nearby countries. The overall spectrum efficiency must therefore be assessed by taking into account the outcome across the entire planning area, not within a single country in isolation.

Furthermore, there is a trade-off between the choice of the network configuration (SFN or MFN) and the achievable transmission capacity (e.g. in Mbit/s). This will be further explained in § 4.1.

3.2 Network gain

SFNs can exhibit network gain, where signals from more than one transmitter contribute towards a higher received signal level and lower variability from one location to another. These qualities can improve coverage compared to an MFN network. For portable or mobile reception, the network gain can be an essential contribution to overall coverage, improving the signal’s reliability and potentially allowing lower transmitter powers. In networks relying on roof-top antenna reception, this benefit may not be significant.

3.3 Increased flexibility

SFNs give more flexibility to broadcasters and network operators when coordinating and implementing their networks.

SFNs enable allotment planning which can simplify the technical aspects of the frequency coordination process as the detail of the transmission network does not need to be known in advance - the details can be determined later in the implementation phase. Overall there is no reduction in network planning effort because work is shifted from the coordination phase to the network implementation phase. This does not mean that the network implementation is easier than in the case of MFN, as explained in § 4, but it may just be more flexible.

SFN allotments also allow network coverage to be progressively modified or improved by adding further transmitters without the need for re-planning frequency use or additional frequency coordination as long as the constraints of the frequency plan are respected. This would make it easier to improve the coverage quality step by step, as for example when enhancing coverage from fixed rooftop reception to portable reception.

4. Constraints and trade-offs of SFNs

4.1 Regionality

Regional and local transmissions are one of the key advantages of terrestrial transmissions compared to other delivery platforms. In most countries Public Service Broadcasters have a constitutional requirement to provide regional and local content, as well as national services, in order to realise important social and cultural benefits. For example, in the UK, approximately 27 regions are required for each of the two main national programmes.

Commercial broadcasters usually have similar requirements for regionality, but with the added incentive to provide targeted advertising for local and regional businesses. The ability to provide regional advertising is often integral to the broadcasters' business plan and highly valued by regional and local businesses that are willing to pay a premium for that service.

As the content distributed within an SFN has to be identical throughout the SFN area, it is not efficient to offer different regional content within a single SFN covering multiple regions (e.g. national). To do so would not be economically or spectrally efficient and would rule out the possibility of a European-wide SFN or national SFNs that all use the same channel over Europe.

Even without the constraints imposed by editorial requirements, SFNs cannot be used over arbitrarily large areas because of self-interference. The larger the SFN area, the more difficult it is to mitigate self-interference.

There are three main ways of overcoming self-interference; adopting a more robust transmission mode, increasing the guard interval[1] or by adding new transmission sites to increase the network density. The first two options reduce capacity while the third significantly increases costs. SFNs therefore introduce an additional trade-off between the competing factors of cost, capacity and coverage.

[1] A key parameter in a Single Frequency Network is the 'guard interval'; this defines the size of a SFN's area and has an inverse relationship to the capacity in a DTT signal. Making the SFN's area larger requires a longer guard interval, which decreases capacity.

The potential impact of self-interference in SFNs, together with editorial, commercial and capacity requirements necessitate broadcasters to choose the network architecture that best suits their needs in each case. In particular it cannot always be assumed that SFNs will be more efficient than MFNs.

4.2 Increased network complexity and cost

SFNs are technically more complex than MFNs. As such, SFNs require timing synchronisation and more complicated signal distribution.

As all transmitters in an SFN network use the same channel they cannot be operated independently. Subsequently, to work correctly the transmitters require a high degree of timing synchronisation, which makes network design and operation more demanding compared to an MFN. This entails some additional cost.

One of the main costs of a network is the distribution of content to the transmitters. In an MFN it is common to take the off-air signal from a main transmitter and re-broadcast it with relay transmitters. This network architecture is extremely cost efficient and is subsequently widely adopted. In SFNs this relay system becomes more difficult to implement and may not be possible in many cases. The consequence could be a significant rise in network costs as a dedicated means of distributing the signal could be required[2].

4.3 Hotspots

In some parts of Europe, despite the use of SFNs, it has already become difficult to accommodate the required number of multiplexes[3] in the available spectrum. Such areas are commonly called 'hotspots'. They usually occur because of their geographical situation but also because of the need to serve many different cultural and linguistic communities within small geographical areas. Examples of 'hotspots' in Europe are the areas around Luxembourg and the Baltic and the Adriatic seas. These areas have the highest spectrum demand in an equitable frequency plan and therefore set the minimum number of frequency channels allocated in a successful plan.

In these areas administrations are already making extensive use of SFNs to satisfy as many requirements as possible, which has permitted the spectrum efficiency in these areas to approach the practical maximum.

5. SFN enhancements with DVB-T2

DVB-T2 is a significant upgrade of the DVB-T specification and would allow more efficient SFNs. However, although DVB-T2 has the ability to enhance SFNs[4], and therefore introduces more flexibility, it does not remove the constraints mentioned above, in particular the non-technical considerations. These constraints must be taken into account and will influence the degree to which the benefits of DVB-T2 and SFNs can be realised.

Using DVB-T2, it may be an option to cover large service areas with a single SFN, larger than those currently possible with DVB-T. However, DVB-T2 may not always offer enough enhancements for SFNs to efficiently cover arbitrarily large geographical areas because self-interference cannot be

[2] These are usually either physical optical-fibre lines or dedicated microwave links.

[3] A multiplex carries several broadcast programmes combined in a single transmission signal.

[4] With similar conditions of reception and for similar data capacity, the guard interval can be increased to reduce the SFN self interference and therefore extend and improve coverage.

entirely overcome[5].

6. Existing SFNs

Since the introduction of DVB-T, many countries in Europe such as the Netherlands, Denmark, Germany, Sweden, Norway, Belgium, Luxembourg, France and Italy, have deployed SFNs for all or significant parts of their current networks. The use of broadcast SFNs is now a mature and well established technique.

If a service area is already covered with SFNs the maximum spectrum efficiency in that area has already been reached. In areas which are covered by MFNs or multiple 'small' SFNs, spectrum efficiency might be improved by using a single SFN where appropriate. It is however unclear whether this would significantly improve spectrum efficiency over the entire planning area.

In those countries that already use SFNs extensively there is limited scope for further spectrum efficiency improvements given broadcasters’ current and future requirements, including regionality.

[5] A study of the national SFN in Denmark has shown that it may be difficult to achieve the same coverage using a national SFN using DVB-T2 and achieve the same population coverage as the existing DVB-T network consisting of regional SFNs.