



5G TDD Synchronisation

Guidelines and Recommendations for the
Coexistence of TDD Networks in the 3.5 GHz Range

April 2020

Contents

Executive summary	1
Background	2
What is synchronisation?	4
Awarding spectrum	5
Recommendation No 1: The default national TDD synchronisation parameters should be defined before awarding the spectrum	5
Recommendation No 2: A migration roadmap of all LTE and WiMAX legacy systems in the relevant bands should be defined	5
Synchronisation at a national level	6
Recommendation No 3: All networks should use the same frame structure at a national level	6
Synchronisation at an international level	8
Recommendation No 4: Networks should be synchronised at an international level whenever possible	8
Recommendation No 5: To manage cross-border coordination, use a common frame structure or consider alternatives to find localised solutions	9
Recommendation No 6: Consider using the following options to identify practical solutions to coexistence of networks using different synchronisation frame structures	9
Synchronisation at a local level	10
Recommendation No 7: Operators should be permitted to agree on localised arrangements including different synchronisation frame structures	10
Updates to the preferred frame structure	11
Recommendation No 8: Public mobile operators should be permitted to update the agreed national TDD synchronisation parameters	11
Clock and special slot formats	12
Recommendation No 9: All networks should use the same UTC clock reference with a common starting point	12
Recommendation No 10: All networks should use the same Special slot “S” format at a national level	12
Annex 1 – List of abbreviations	14
Annex 2 – Cross-border interference - Case study: Switzerland, Germany and France	15

Executive summary

With a growing number of commercial networks, 5G is already off to an impressive start. While a mixture of bands are needed to realise its full potential, a majority of mobile operators are initially depending on spectrum in the 3.5 GHz range (3.3 GHz–4.2 GHz) to roll out their commercial networks. It is on the way to become a globally harmonised band for 5G, which will help drive down the cost of network equipment and devices.

From a technical point of view, the 3.5 GHz range is also a great environment for much of the earliest 5G connectivity because it offers a good balance between coverage and capacity. Also, recent technical advancements enables it to provide similar downlink coverage to current LTE bands 2.6 GHz and 1800 MHz with the same cell-site grids.

The ultimate success of services is dependent on how the spectrum is awarded. Regulators should aim to make available 80-100 MHz of contiguous spectrum per operator. Governments and regulators should also avoid inflating 5G spectrum prices as this risks can limit network investments and drive up the cost of services.

However, some technical issues have a major impact on coverage as well as performance levels. Importantly, the combination of the 3.5 GHz range and 5G NR is becoming the first major rollout of Time Division Duplex (TDD) cellular networks in many countries. To utilize the spectrum most efficiently, all TDD networks, either LTE or 5G NR, operating in the same frequency range and within the same area have to be synchronised. Base stations need to transmit at the same fixed time periods and all devices should only transmit in dedicated time periods. The chosen approach to synchronisation also impacts the possible use cases.

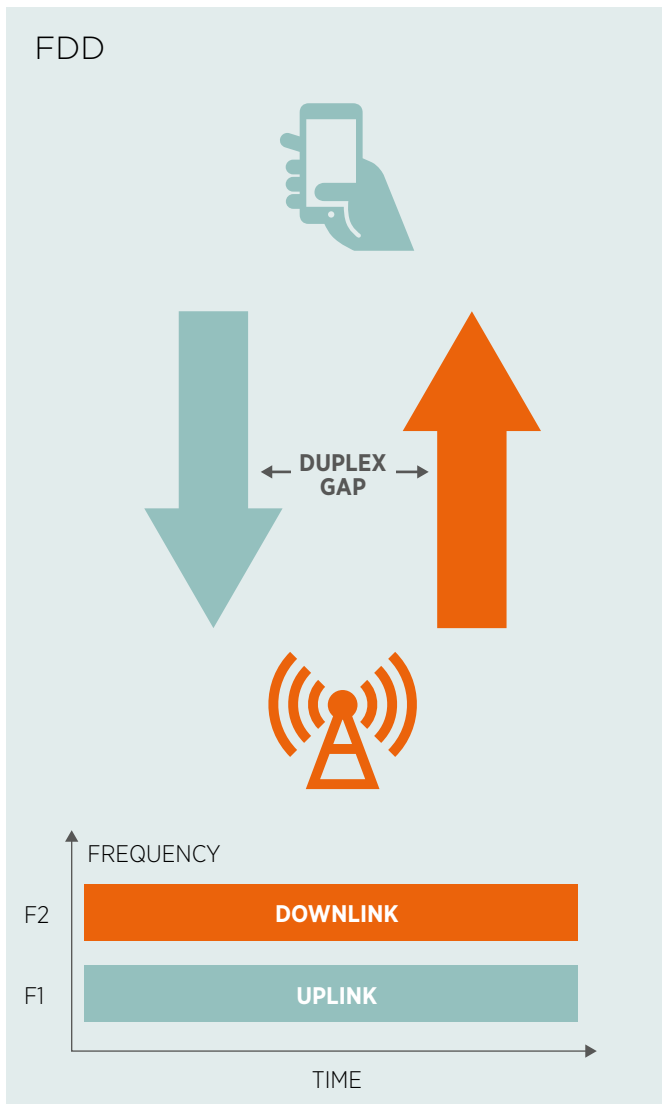
On behalf of the mobile industry, the GSMA urges regulators to prioritise TDD synchronisation, or other suitable alternatives, to address interference issues among networks, from both a national and an international perspective. By doing so, a bright future for 5G is one step closer.

Background

This report and the included guidelines represent the GSMA's views on synchronisation. It aims to inform policymakers and mobile operators on TDD synchronisation for 5G in the 3.5 GHz range. Furthermore, it provides the mobile community's views on the preferred frame structure for initial 5G launches in 3.5 GHz. There is also basic information about how and why synchronisation can and should be achieved.

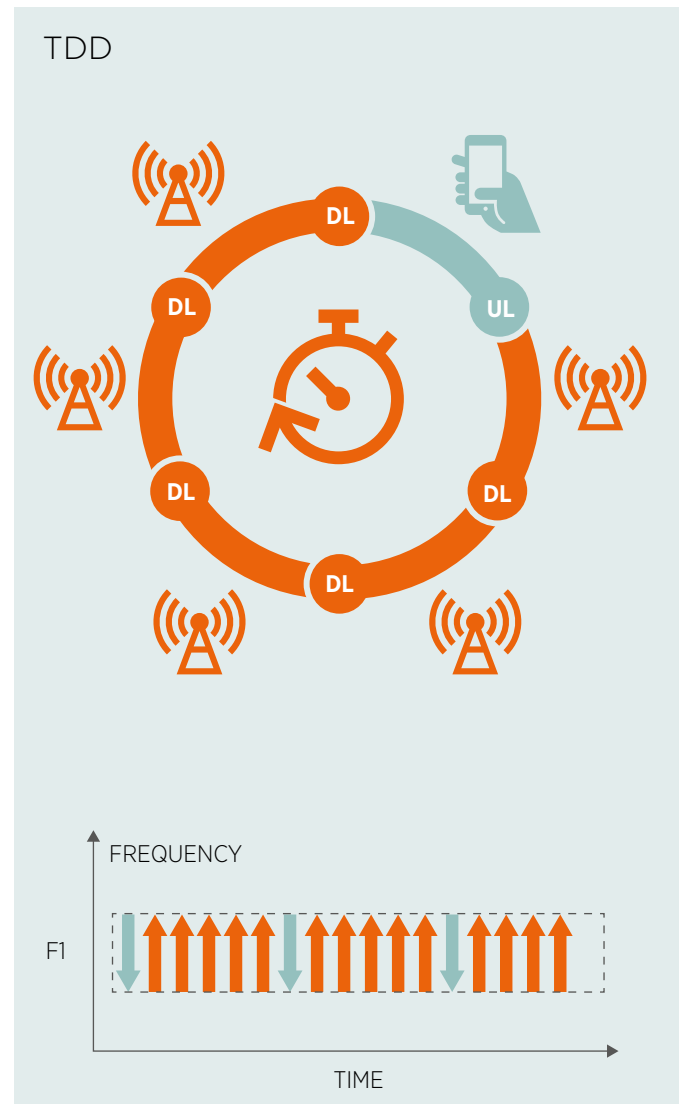
In today's networks, the amount of traffic between the user terminal and the base station (the uplink) and vice versa (the downlink) is often asymmetrical (because users download more than they upload). In FDD bands the channel size is the same for both directions. At the same time, more advanced features such as 256QAM modulation and higher order MIMO (4x4) are typically limited to the downlink, thereby supporting the increased download capacity demands. A focus on downlink capacity has worked out well so far. However, as traffic patterns are changing, more uplink heavy applications are anticipated (e.g. cloud storage and personal broadcasting) and flexibility with uplink and downlink spectrum usage is desirable.

To increase flexibility as well as make spectrum usage more efficient, Time Division Duplex (TDD) is becoming increasingly common and important. TDD uses the same frequency for each duplex direction, with a frame that includes different time periods and slots for uplink or downlink communications. By changing the duration of these, network performance can be tailored to meet different needs and help provide the best possible experience.



Two dedicated frequency bands at the same time

A key advantage of 5G is that it supports a variety of usage scenarios, such as enhanced mobile broadband (which requires uplink and/or downlink heavy networks but is not latency critical) and ultra-reliable low-latency communications (which relies on regular sequences of uplink and downlink for reduced latency). Different scenarios (and by extension, commercial offerings) require customised performance characteristics, so getting the right uplink to downlink duration ratio is very important. As the multiplicity of configurations could lead to coexistence issues, getting TDD synchronisation right is very important for the development of 5G. Although there is no one-size-fits-all solution, mobile operators can overcome performance limits of any frame format selection in the 3.5GHz range by, for example, using a variety of other bands.



One dedicated frequency band but different time slots

Due to the impact of synchronisation on network performance and therefore commercial offerings, the MNOs are well placed to help define the framework. However, prior to an auction it is almost impossible to identify all the players and to get everyone to come to an agreement on matters which could reveal clues about their commercial plans. Therefore, administrations should propose configurations that can be modified once all the spectrum owners are identified.

What is synchronisation?

Synchronisation between TDD mobile networks refer to parameters that make sure adjacent networks send and receive data from mobile or fixed devices at the same time, in order to avoid interference.

Three main approaches have been considered by the industry:

1. The use of synchronised networks where all networks are in uplink or downlink mode at the same time. This helps avoid interference between the transmission of one base station and the reception of another base station in the same or an adjacent network. The same is true for devices.
2. The use of unsynchronised networks where each network is in uplink or downlink mode without considering other networks. This would likely result in interference. According to ECC report 296¹, the separation distance between two unsynchronised macro base stations/networks is up to 60km for a co-channel configuration and up to 14km for adjacent channel operation.

Additional mitigation techniques such as using clutter (where, for example, buildings decrease signal propagation), antenna direction, reduced in-band power or both guard bands and filters between two networks using adjacent channels² can also be considered for minimising the impact. Still, it should be noted that use of both guard band and filters is neither spectrally efficient nor commercially viable.
3. The use of semi-synchronised networks where part of the frame is synchronised, while the other part of the frame is without coordination, results in possible coexistence issues during the unsynchronised periods. In some countries, it should be noted that use of semi-synchronisation requires the use of restricted emissions and therefore the use of guard band and filters, hence again not providing spectral efficiency or commercial viability.

In conclusion, without synchronisation at a national level between operators, it will be impossible to deploy networks without impacting performance due to interference. It is therefore paramount to carefully consider this issue before awarding spectrum.

For a successful outcome, all of the following parameters need to be agreed upon:

1. A common phase clock reference (e.g. UTC - Coordinated Universal Time) and its accuracy
2. A common frame structure as defined by 3GPP TS 38.211 V16.0.0 (2019-02):
 - a. Selection of a timing reference (beginning of the frame)
 - b. Selection of a frame format
 - c. Selection of SubCarrier Spacing (SCS)
 - d. Selection of normal or extended prefix
 - e. Selection of a special slot configuration

1. ECC Rep 296: National synchronisation regulatory framework options in 3400-3800 MHz: a toolbox for coexistence of MFCNs in synchronised, unsynchronised and semi-synchronised operation in 3400-3800 MHz

2. Use of guard band and filters will not be useful for co-channel networks.

Awarding spectrum

Recommendation No 1:

The default parameters for national TDD synchronisation should be defined before awarding the spectrum

The GSMA recommends that the initial national TDD synchronisation parameters are defined and made public before awarding the spectrum. Operators need to be able to evaluate the usability of the spectrum when preparing for an award, and synchronisation impacts that. Unless the award conditions are clear, there is a risk that only one operator (by not agreeing or failing to synchronise) can cause severe difficulties for the others. If this happens, all operators would at a minimum need to implement guard bands and filters. But, again, this is not an efficient or commercially viable solution. The regulatory parameters should only be enforced in case there is no consensus

between the operators. Also, operators may propose to amend these parameters (see the 'Updates to the preferred frame structure' section).

So, to use the spectrum as efficiently as possible, all operators deploying in same and adjacent areas should implement the same synchronisation approach. This should be the case regardless whether the license is local, nationwide, or regional. Exceptions may be allowed only in the cases where a network does not cause interference to other networks, e.g. isolated networks far from other networks or potentially some indoor networks.

Recommendation No 2:

A migration roadmap of all LTE and WiMAX legacy systems in the relevant bands should be defined

In a number of countries, there are legacy LTE TDD or WiMAX networks in the 3.5 GHz range. The GSMA recommends that these systems, taking potential market distortion issues into account, are upgraded to 5G NR as soon as possible. Alternatively, they could possibly be migrated out of the band or switched off, so that public network performance is optimised to meet the needs of consumers and businesses. Considering there are very limited ecosystems for LTE and WiMAX in the 3.5 GHz TDD range, a solution should be possible without a negative impact on existing services.

In the meantime, coexistence between LTE and 5G NR networks within a country or a common coverage area can be achieved by selecting a compatible frame structure. However, it should only be considered as a short-term solution because a mandatory configuration prevents the industry to adapt to market demand.

Synchronisation at a national level

Recommendation No 3:

All networks should use the same frame structure at a national level

To ensure coexistence at a national level, it is strongly recommended that all networks operating within the 3.5 GHz range use the same synchronisation parameters. The choice of synchronisation parameters is influenced by:

- The required network performance;
- Incumbent users in the band; and
- What the neighbouring countries do or plan to do.

Because of the global nature of mobile networks, it is important to find a balance between national and international realities. The priority should be to identify the optimal solution for the operators at a national level. However, the impact on cross-border coexistence with neighbouring countries also needs to be taken into account.

The GSMA's preferred national approaches are in this section, followed by recommendations on international synchronisation (including cross-border coordination). For synchronisation at a national level, the best way forward is based on whether or not there are incumbent users in the band.

Case a) Incumbent systems are not present in the band

Where incumbent systems such as LTE are not in the 3.5 GHz range, it is strongly recommended that all networks operating within the 3.5 GHz range use a common 5G NR frame structure and the same clock reference (UTC).

The preferred frame structure is DDDSU, with 30 kHz SCS, a normal cyclic prefix (corresponding to 3GPP numerology 1). A radio frame with a 10ms duration contains 10 sub-frames and 20 slots, with each 0.5ms slot containing 14 symbols.

The Special slot "S" format used in the SCS 30 kHz 5G NR DDDSU frame configuration should be configured with a ratio of 10 Downlinks, a 2 Symbol Guard Period and 2 Uplinks (10:2:2). For more information, see the chapter dedicated to the special slot.



Case b) Incumbent systems are present in the band

On the other hand, where there are incumbent systems in the 3.5 GHz range, they have to be taken into consideration as long as they haven't been upgraded, migrated or switched off. Synchronisation is still strongly recommended when incumbents are deployed nationwide, but a different approach is needed.

Because while there are similarities between LTE and 5G frame structures, there are also differences that can cause interference if not properly managed. For LTE TDD, the frame structure has the same duration of 10ms as the 5G NR³ with SCS 30 kHz. However, each frame contains 10 slots instead of 20, and each LTE slot has double the duration compared to 5G NR with SCS 30 kHz. Unchecked, this would at times lead to unsynchronised uplink and downlinks, which would, in turn, result in interference issues.

The solution requires all LTE operators and all 5G NR operators use a compatible frame structure:

- LTE networks are required to use the frame structure **DSUDDDSUDD**, corresponding to the standardised uplink-downlink configuration #2 with a downlink-to-uplink switch-point periodicity of 5ms and a downlink-to-uplink ratio of 3.75. If LTE networks are currently using a different configuration, they will be required to change it – this may require policymakers to update the current regulation where the frame structure is mandated; and
- 5G NR networks are required to use one of the two following possible frame structures **DDDDDDDSUU (with a 3ms shift)** or **DDDSUDDDD**. Using these frame structures is the best compromise for coexistence with incumbent LTE systems.

There are currently two main TDD formats considered by the ecosystem in 3.5 GHz range. The main performance difference between these two is the radio latency.

- **DDDSU** (5G compatible format)
The frame structure **DDDSU** provides best compromise for performance where coexistence between 5G NR systems is required; and
- **DDDDDDDSUU** (compatible with TD-LTE)
The frame structures **DDDDDDDSUU** (with a 3ms shift) or **DDDSUDDDD** provide the best compromise for performance where coexistence with incumbent LTE systems is required.

Theoretical analysis and measurements show a latency difference of up to 5ms between these frame structures.

Although choosing a 5G NR compatible frame format may be better from radio latency point of view, its impact from an end-to-end system point of view would be much less visible in first generation 5G networks. This is mainly due to the 5G NSA (non-standalone) architecture (with 4G core network) and long distances between network elements, which makes the end-to-end latency dominated by the non-radio part.

With migration to the 5G SA (standalone) core network and the introduction of edge computing, the benefits of 5G-compatible TDD format would be more visible. Such evolution would probably take a couple of years and in the meantime, using a 4G compatible frame format could resolve operators' operational constraints in areas where LTE networks need to be considered for synchronisation.

Alternatively, mobile operators can overcome performance limits of any frame format selection in the 3.5 GHz range by making use of a variety of other bands.

Case c) Incumbent systems are present in the band, but only on a local basis

In countries where incumbent systems, such as LTE systems are in the band but limited to localised areas, alternative solutions to synchronisation may be more appropriate.

3. Assuming that the 5G NR is configured with an SCS of 30 kHz



Synchronisation at an international level

Recommendation No 4:

Networks should be synchronised at an international level whenever possible

To ensure coexistence at an international level, it is recommended that all mobile operators in the band agree to synchronise their networks. This means using the same frame structure and the same clock reference. However, selecting a common national solution should be the priority. This decision should consider what neighbouring countries may have already decided. Harmonising a single frame structure across countries is extremely difficult due to:

- **A lack of agreed band plans for the 3.5 GHz range.** Operators from one country to the other may be using different block size and centre frequencies;
- **Agreements at a national level agreed under a different time frame.** An operator in a given country may have to negotiate/agree on the best frame structure with multiple operators per neighbouring country;
- **The number of countries involved.** A country may have more than one neighbouring country which in turn may also have multiple neighbouring countries to explore an agreement (the domino effect); and
- **Different migration and implementation timescales.** Depending on the timing of migrating incumbent users to other alternatives and the speed at 5G NR is deployed.

The preferred frame structures are:

- **DDDSU** with 30 kHz SCS;
- **DDDDDDDSUU (with a 3ms shift);** or
- **DDDSUDDDD** could also be considered.

The two latter options should only be considered where LTE is still in use.

It is anticipated that these three frame structures will be the most popular. However, as they are not compatible and other frame structures may have been selected (including localised solution), the sharing of information will be extremely useful.

Recommendation No 5:

To manage cross-border coordination, use a common frame structure or consider alternatives to find localised solutions

Cross-border coordination is challenging, but is easier to manage if countries sharing a border agree to use the same frame structure and timing. In practice, this is unlikely because of the domino effect which may affect a large number of countries and not all countries are in the same situation. As a result, agreeing on a single frame structure across multiple countries is no longer pursued due to the complexity and some temporary aspects (LTE is expected to be used for a limited time in a small set of countries).

Case a) Countries are using the same frame structure and timing reference.

In the border areas where neighbouring countries have selected the same frame structure, all the synchronised base stations can be used on either side of the border with limited coordination efforts, triggered by a simple field strength level at the borderlines.

It is worth noting that, when subject to the same field strength, the probability of interference from AAS is lower than the probability of interference from non-AAS system.

Case b) Countries are using different frame structure and/or timing reference.

In the border areas where neighbouring countries have not selected the same frame structure, although field strength limits at the borderlines could also apply, it is expected that operators will need to engage in additional coordination efforts. Mobile operators are expected to discuss cross-border coordination issues on a bilateral, or multilateral basis and additionally in respective industry forums. The involvement of policymakers and/or administrations in these discussions can, if required, be a useful complement. In some cases the final implementation can only be achieved by including a wider group of stakeholders, such as other license holders.

Recommendation No 6:

Consider using the following options to identify practical solutions to coexistence of networks using different synchronisation frame structures

Discussions between operators are encouraged. Where no agreements on the frame structure is found, the following options to identify practical solutions to coexistence of networks are recommended:

- Localised change of frame structure (i.e. indoor usage);
- Network optimisation (such as base station location, antenna direction, and power limits);
- Protection of 4G systems should take into account their real deployment (i.e. take into account that they are mainly fixed wireless access systems);
- Downlink blanking where operators, on both sides of the border, agree to stop the use of some of their downlink slots when the other operators are using an uplink slot. Although, this will impact performance and may not be supported, especially legacy 4G equipment;
- A step-by-step migration based on the regional timings of 5G deployments and 4G migrations;
- Migrate 4G networks to a different band or to 5G technology;
- Commercial agreement between 5G operators and incumbent 4G operators (including acquisitions, re-farming, and reprogramming);

- Reduce capacity near the borders, i.e. by only using a part of allocated spectrum;
- Use alternative bands within the cross border area (including existing bands, mmWaves, additional new/temporary frequencies, or LSA in a different band);
- Avoid co-channel use and aim to have operators only using adjacent channels – temporary band plan at the border; or
- Use club licences, spectrum and infrastructure sharing along borders.

The GSMA suggests countries also agree on acceptable signal strength levels at borders (on a bilateral, multilateral or regional level). These agreements should aim at allowing 5G rollouts, including in the border areas. Operators should therefore take part in the discussions.



Synchronisation at a local level

Recommendation No 7:

Operators should be permitted to agree on localised arrangements including different synchronisation frame structures

Network requirements may need to vary locally to address special needs from users such as verticals or events. To meet these requirements, operators should be allowed to propose changes to the frame structure at local level. As part of the process, other operators in the band should be consulted to ensure no additional interference occurs due to the changes.

Alternatives to changing the national agreement include:

- Localised change of frame structure (i.e. DSDU)
- Network planning (for example, base station location)
- DL blanking
- Time-limited usage (investigate accelerating the migration of LTE systems or delaying the deployment of 5G NR where the clashes are likely)



Updates to the preferred frame structure

Recommendation No 8:

Public mobile operators should be permitted to update the agreed national TDD synchronisation parameters

As 5G NR use cases and network requirements evolve over time, operators should periodically be able to trigger a process to propose changes to the previously agreed TDD synchronisation

parameters at national, local, or international level. This process should be defined through engagement between policymakers and mobile operators.

Clock and special slot formats

Recommendation No 9:

All networks should use the same UTC clock reference with a common starting point

Synchronisation will rely on timing to be aligned between different networks. The UTC (Coordinated Universal Time) clock reference is an ideal candidate to use.

The timing reference can be obtained via different means, including different global navigation satellite systems, packet-based networks or over-the-air synchronisation. The use of multiple sources can cause some issues if their differences exceed the shift allowance, i.e. the required accuracy, which varies with the cell size and technology (LTE and 5G NR +/-1.5µs). Jamming

may also impact timing (i.e. if using GPS) and therefore the means of getting the clock reference should be decided after having considered carefully all the risks and options.

The means of providing the timing information to the base station will also vary according to local circumstances and there is no recommendation on the best way to achieve that. Once selected, the source of the timing must be monitored and a back-up solution for operational continuity in case of loss of timing signal must be defined.

Recommendation No 10:

All networks should use the same Special slot “S” format at a national level

The Special slot is identified by the letter “S” in all frame structures i.e. **DDDSU** or **DDDDDDDSUU**. Like all slots, it contains 14 symbols which can be Uplink, Downlink like any other slots. The only difference is that it contains a Guard Period.

The Guard Period (GP) is the time between Downlink and Uplink transmission. Its purpose is to avoid interference within a cell and ensure coexistence among cells by compensating for propagation delays. Conversely, the GP is not required between uplink and downlink, as there is less chance of collision because of the base station timing advance feature.

The GP duration varies with the size of the cells and depends on the propagation delays. When using 5G NR with a SCS (subcarrier spacing) 30 kHz, the 10ms frame contains 10 sub-frames and each sub-frame contains 2 slots, which means that each radio frame has 20 slots. Each slot contains 14 OFDM symbols. Each OFDM symbol is 33.33µs long and with its Cyclic Prefix the OFDM Symbol including CP is 35.68µs long.

In this case, the correspondence between the GP, expressed as a number of OFDM symbols, and the maximum cell size is the following:

- A GP of 2 symbols would cater for cell sizes of up to 10.7 km;
- A GP of 4 symbols would cater for cell sizes of up to 21.4 km; and
- A GP of 6 symbols would cater for cell sizes of up to 32.1 km.

As a GP of 2 symbols is considered compliant with the envisaged cell size and considering the chosen NR frame format (i.e., the DL/UL ratio), the Special slot “S” in the SCS 30 kHz NR **DDDSU** configuration should be configured with a ratio of 10 Downlinks, 2 Symbols Guard Period and 2 Uplinks **(10:2:2)**.

Where specific deployments require, e.g. in cases where base stations are placed in exposed positions with very long Line-Of-Site ranges towards other synchronised base stations, there might be a need to extend the Guard Period in the “S” slot. More than 2 symbols should be allowed to be configured as guard period by reducing number of symbols available for the downlink. As to the uplink and downlink parts in the Special slot “S”, the GSMA recommends the following configuration:

Case a) Incumbent systems are not present in the band

The Special slot “S” format used in the SCS 30 kHz 5G NR DDDSU frame configuration should be configured with a ratio of 10 Downlinks, 2 Symbols Guard Period and 2 Uplinks (10:2:2).

Where specific deployments require, it will be possible on either systems to extend the Guard Period in the “S” slot by converting further DL symbols to gaps without impacting the other networks.

Case b) Incumbent systems are present in the band

In a number of countries, there are legacy LTE TDD or WiMAX networks in the 3.5 GHz range. There are seven different standardised LTE frame structure configuration options. In the LTE TDD, the frame structure has a duration of 10ms with double slot duration compared to the SCS 30 kHz 5G NR⁴. This leads to having unsynchronised uplink and downlinks at times which will result in interference issues, unless specific solutions are adopted.

Where there are legacy systems deployed using a “S” slot structure of 10:2:2 based on an SCS of 15 kHz, a full timing alignment can be achieved by choosing the LTE compatible NR frame structure with an SCS of 30 kHz and a ratio of 6 Downlinks, 4 Symbols Guard Period and 4 Uplinks (6:4:4).

Where specific deployments require, it will be possible on either systems to extend the Guard Period in the “S” slot by converting further DL symbols to gaps without impacting the other networks.



4. Assuming that the 5G NR is configured with an SCS of 30 kHz

Annex 1 – List of abbreviations

3GPP	Third Generation Partnership Project
4G	4th generation of Mobile Network
5G	5th generation of Mobile Network
5G NR	5G New Radio
5GC	5G Core Network
AAS	Active Antenna System
CEPT	European Conference of Posts and Telecommunications
CN	Core Network
DL	Downlink
DL/UL	Downlink/Uplink ratio
eMBB	Enhanced Mobile Broadband
FDD	Frequency Division Duplexing
FWA	Fixed Wireless Access
GP	Guard Period
GPS	Global Positioning System
HARQ	Hybrid Automatic Repeat reQuest
ITU-R	International Telecommunication union – Radiocommunication Sector
LSA	Licensed Shared Access
LTE	Long Term Evolution
mmWave	Millimetre Wave
NR	New Radio
OFDM	Orthogonal Frequency-Division Multiplexing
SCS	SubCarrier Spacing
TDD	Time Division Duplexing
UL	Uplink
UL/DL	Uplink/Downlink ratio
UTC	Universal Time Code
WiMAX	Worldwide Interoperability for Microwave Access

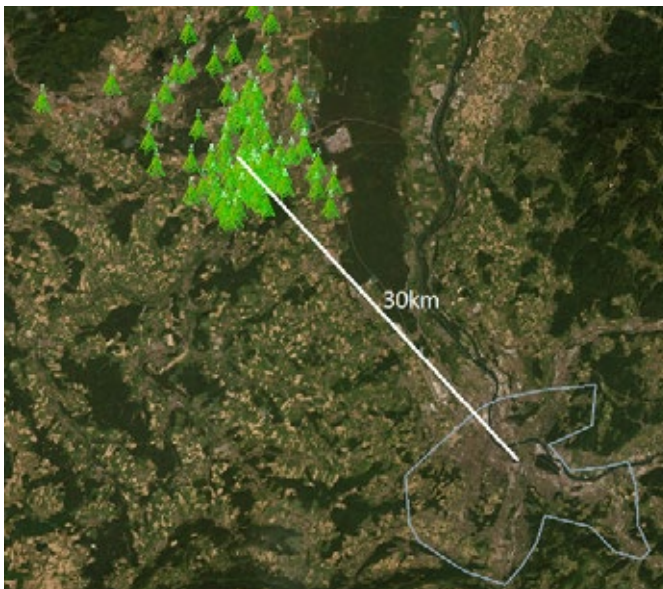
Annex 2 – Cross-border interference

Case study:

Switzerland, Germany, and France

This case study investigates compatibility between networks in two cities, Mulhouse in France and Basel in Switzerland. The distance between the two is 30km.

FIGURE 1: SITUATION OVERVIEW



The base station to base station interference scenario is assessed, which could result from two unsynchronised TDD networks operated in the two countries.

The interfering field strength generated on Basel by a hypothetical 5G network in Mulhouse is simulated.

The receiving height is 35m to model the interference at a typical base station antenna height.

The EIRP of the sites in Mulhouse is set to 1600W per 5 MHz, and the network counts 250 sectors.

Median propagation conditions are assumed, and diffraction on hills and buildings (5m resolution) is considered.

The seven maps below show the number of sites exceeding 10, 20, 30, 40, 50, 60 and 70 dB μ V/m/5 MHz respectively.

The following scale is used:

One sector or more exceeds the threshold
5 sectors or more exceed the threshold
10 sectors or more exceed the threshold
15 sectors or more exceed the threshold
20 sectors or more exceed the threshold
30 sectors or more exceed the threshold
40 sectors or more exceed the threshold

FIGURE 2: NUMBER OF SECTORS EXCEEDING 10 dB μ V/m/5MHz

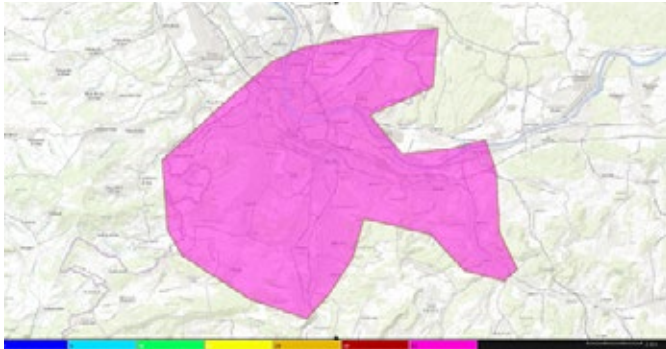


FIGURE 6: NUMBER OF SECTORS EXCEEDING 50 dB μ V/m/5MHz

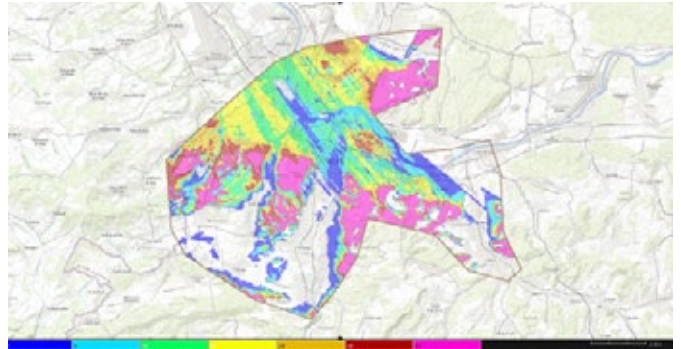


FIGURE 3: NUMBER OF SECTORS EXCEEDING 20 dB μ V/m/5MHz

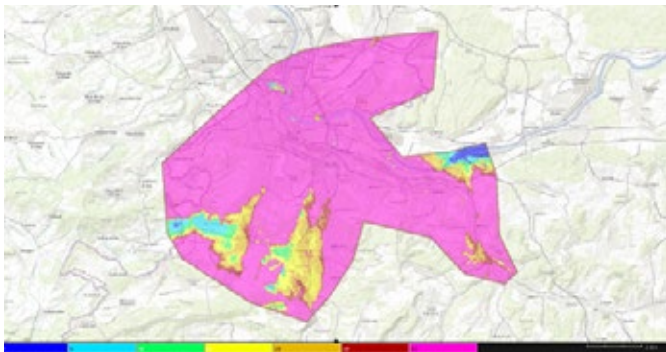


FIGURE 7: NUMBER OF SECTORS EXCEEDING 60 dB μ V/m/5MHz

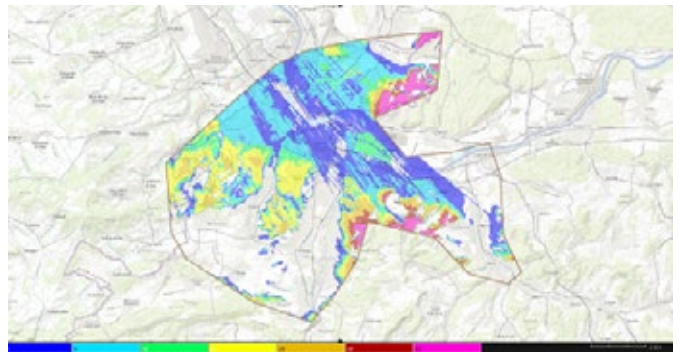


FIGURE 4: NUMBER OF SECTORS EXCEEDING 30 dB μ V/m/5MHz

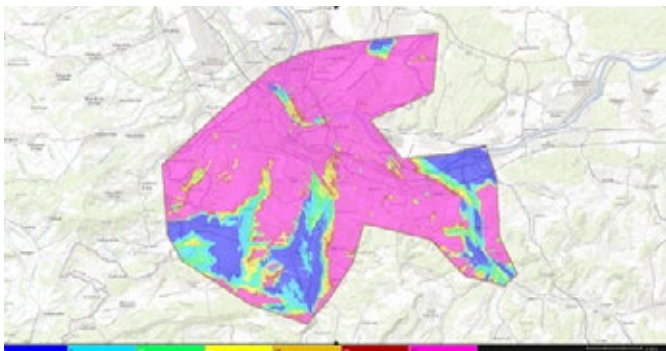


FIGURE 8: NUMBER OF SECTORS EXCEEDING 70 dB μ V/m/5MHz

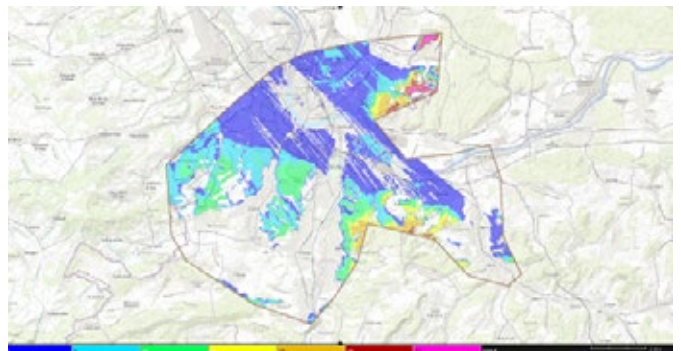
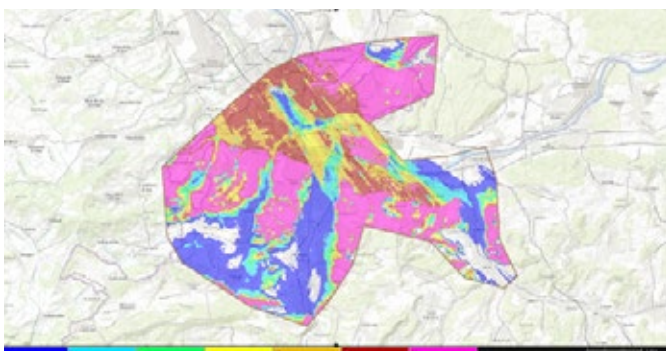


FIGURE 5: NUMBER OF SECTORS EXCEEDING 40 dB μ V/m/5MHz





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