GTI White Paper

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TDD SPECTRUM WHITE PAPER

V 3.1

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Global TD-LTE Initiative

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Annex A: Document History

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2013.06.05	GTI 7th workshop	Draft for discussion		1.0
2013.07.18		Internal review of Spectrum WG	1.0	2.0
2016.06.27		Update the WP in spectrum WG	2.0	3.0
2016.09.02		Update the WP in spectrum WG	3.0	3.1

Executive Summary

To provide information and suggestions for facilitating the efficient utilization and fast deployment of TD-LTE globally, this white paper summarizes the advantage of TDD spectrum, TDD deployment and product availability. Further, the spectrum related issues in TD-LTE application and network deployment are discussed and the corresponding solutions for the commercial deployment are presented. To facilitate fast development of TD-LTE global deployment, this white paper also proposes some recommendations and suggestions as below for operators/standardization organizations/regulators,

- TDD spectrum should be made available and assigned on a timely manner to operators to facilitate deployment of advanced technical solutions and to achieve increased overall spectrum efficiency
- Implementation of a full TDD band plan in 2.3 GHz, 2.6 GHz, 3.5GHz and 3.7GHz bands is recommended for the countries/areas where those bands have not yet been made available
- Contiguous TDD spectrum assignments employing wide blocks is beneficial for improving mobile broadband experience and spectrum efficiency of the networks
- The synchronized operation amongst multiple TD-LTE networks is recommended for best spectrum utilization while the guard bands must be used to ensure the coexistence of unsynchronized TDD
- Lower frequency bands (e.g. L-band) and higher frequency bands (above 6GHz) should be made available for TDD and harmonized TDD band plans should be developed for them in the future

As the fast progress in the industrialization and commercial deployment, the latest information is captured in the annex.

Contents

1 Introduction

1.1 Background

Today, TD-LTE growth is accelerating around the world in terms of operator commitments and commercial launches as well as subscriber numbers. **By April 7, 2016，76 TD-LTE networks were commercially launched in 43 countries with 1.4 million base stations installed.** China Mobile has built the world's largest TD-LTE network, which covers 1.2 billion people and contains more than 1.1 million base stations. Many other operators are about to deploy commercial TD-LTE systems, or are engaged in trials and studies.

TD-LTE has already become a mainstream technology supported by a very well established and fast growing ecosystem. It has set up a complete end-to-end industry chain involving widespread participation of global industries and highly mature products including system equipment, chipsets, user devices and test instrument. By achieving maximum commonality with LTE FDD and offering comparable performance characteristics, TD-LTE can share global market scale with LTE FDD and speed up the network deployment and commercial launch. Statistics show[1] that by the end of April 2016 there were over 2650 TD-LTE terminals and over 1320 FDD/TDD terminals.

Spectrum always plays a central role for mobile communications. A significant amount of unpaired spectrum has been assigned for TDD networks facilitating deployment of TD-LTE networks and growth of the TDD market overall.

1.2 Objectives of this white paper

The objective of this white paper is to present a common view amongst GTI members about TDD Spectrum availability and utilization. Aligning the views allows the TDD Industry to work towards the same targets and achieve economies of scale resulting in cost efficient network deployments and affordable services.

This White paper covers:

- Drivers for TDD spectrum demand

[1] China Mobile statistics

- Availability of TDD Spectrum bands
- TDD Standardization Roadmap
- TDD Network Deployment aspects
- TDD related recommendations for Regulators and Operators

1.3 Terminology

Term	Description
BWA	Broadband Wireless Access
CA	Carrier Aggregation
CDMA	Code Division Multiple Access
CoMP	Coordinated Multi-Point
CSPC	Coordinative schedule Power Control
DCMS	Department for Culture, Media and Sport
eICIC	Enhanced Inter-cell Interference Coordination
GSM	Global System for Mobile Communications
LSA	Licensed Shared Access
LTE FDD	Long Term Evolution Frequency-Division Duplexing
MBB	Mobile broadband
MIIT	Ministry of Industry and Information Technology of China
MoD	Ministry of Defence
NBTC	National Broadcasting and Telecommunications Commission
NPRM	Notice of Proposed Rulemaking
NTIA	National Regulatory Authority

PCT	Protocol Conformance Testing
PHS	Personal Handy-phone System
PMSE	Programme-Making and Special Events
RCT	RF conformance testing system
RRM	Radio resource management
TD-LTE	Time Division Long Term Evolution
TD-SCDMA	Time Division-Synchronous Code Division Multiple Access
WCDMA	Wideband Code Division Multiple Access
WCS	Wireless Communication Service
WGFM	Working Group for Frequency Management
WiMAX	Worldwide Interoperability for Microwave Access

2 What is driving the demand for TDD spectrum

Utilization of TDD technology offers significant advantages with respect to spectrum efficiency, network performance and capacity and it offers a viable evolution path from 4G towards 5G networks and services.

2.1 TDD facilitates advanced antenna solutions

Due to uplink and downlink channel reciprocity (ensured by the fact that the same portion of spectrum is used in both link directions), TDD technology has unique coordination abilities which are used in a number of technical areas including Beamforming. Beamforming improves the system performance by utilising channel state information to achieve transmit-array gain. FDD requires a very high signal overhead to obtain DL channel state information at the eNB thus making it less efficient when implementing Beamforming.

Network test results show that single-layer, dual-layer and multi-user Beamforming can generate cell throughput gains of 15%, 15% and 10% respectively. Adoption of both Beamforming and Coordinated Multi-Point operation (CoMP), an approach called 'Co-ordinated Beamforming' (CBF), can further enhance network performance because interference is mitigated between eNodeBs.

Other advanced antenna solutions like massive MIMO and Distributed MIMO (D-MIMO) also utilise TDD's uplink and downlink channel reciprocity to improve performance and capacity.

3GPP has standardized "4.5G", under the name LTE Advanced Pro, which employs some of these advanced features including Massive MIMO. Massive MIMO will also be deployed also in the 5G.

2.2 TDD supports traffic asymmetry efficiently and flexibly

The UL/DL adaptivity of TDD allows for the adjustment of the downlink and uplink resource ratios. Downlink-to-uplink ratios can be e.g. 8:1, 3:1, 2:2 and 1:3. A downlink-oriented configuration fits perfectly with the current and foreseeable user behavior where streaming and data downloads use more downlink resources than uplink resources.

There are several predictions about the future trends for the traffic asymmetry. Cisco forecasts that there will be a dramatic increase in the downlink-oriented applications and that the use of DL-centric applications will result in more than 90% of mobile traffic being in the downlink in 2017.

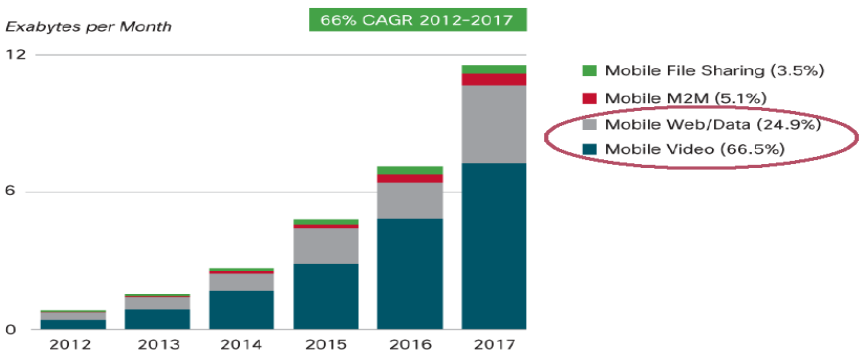


Figure 2-1: Cisco mobile forecast

There are also other developments trying to solve the issue of traffic asymmetry for the FDD networks. There is an approach where additional bands have been designated for FDD DL only (also referred to as Supplementary Downlink or SDL). Such arrangements can provide some room for asymmetry. However in this case there is a technological limit for the achieved asymmetry, which means that for achieving high asymmetry there needs to be significantly more spectrum for DL traffic than for UL traffic. Spectrum allocations/assignments would need to be changed if efficient spectrum use is to be maintained; such changes require a time-consuming regulatory process and significant changes to network deployment. Clearly TDD enjoys an advantage over the FDD approach in dealing with traffic asymmetry and TDD's adaptivity allows for system characteristics to match the data traffic characteristics they are serving.

2.3 Unpaired TDD bands can be made available more easily than paired bands

High performing mobile networks requires wide channel bandwidths; currently spectrum between 2GHz to and 5GHz are the best candidates for obtaining these wide channels. From a spectrum management perspective there are challenges making sufficient spectrum and wide channels available. Unpaired spectrum bands are generally easier to make available than paired bands simply because re-farming of one band is easier than re-farming two equally wide bands. This benefit is becoming increasingly important as re-farming of spectrum is the main source of new mobile spectrum.

From a worldwide regulatory perspective WRC-19 (part of ITU-R) is expected to identify a significant amount of new, additional spectrum for IMT which will be used by 5G. This new spectrum will undoubtedly include unpaired bands that can be used by TDD.

3 Availability of TDD spectrum is secured

TDD spectrum availability depends on regulatory decisions made at both the global level and on the national level and is usually based the market demand. While ITU-R is responsible for

spectrum allocations globally, national administrations are responsible for licensing and assigning spectrum for operators. In some cases there is also relevant regulation on the Regional level, like within the European Union.

In addition to the regulatory process, the issue of spectrum is addressed also by standardization. 3GPP defines spectrum bands for TDD based on how the products will need to use the spectrum.

This chapter addresses how TDD bands are defined both within regulation and standardization.

3.1 ITU-R bands and the way forward

The ITU-R Radio Regulations (RR) identifies the spectrum for IMT (International Mobile Telecommunications), which comprises of IMT-2000, IMT Advanced and IMT-2020 technologies, also known as 3G, 4G and 5G cellular technologies. A commonly used term for both 3G and 4G is Mobile Broadband or "MBB".

Spectrum identifications are done individually for each of the three ITU Regions. In some cases the allocations and identifications are global, covering all three Regions.

The ITU-R has addressed the spectrum for IMT in several World Radiocommunication Conferences (WRCs), and currently identified spectrum for IMT is a result of decisions taken by WARC-92, WRC-2000, WRC-07, WRC-12, and WRC-15.

In addition to the allocations and identifications, the ITU-R defines spectrum arrangements for all bands identified for IMT which are presented in the ITU-R Recommendation M.1036. The spectrum arrangements define whether TDD or FDD arrangements are to be used in a particular band. There is a clear trend that more recently identified bands are unpaired bands and have TDD band plans defined for them.

At the time of the preparation of this White Paper the frequency arrangements are not yet defined for the latest IMT bands that were identified by the WRC-15, but it is very likely that the C-band (3-5 GHz) and also the L-band (1.4 GHz) will have TDD band plans.

TDD bands that have been defined by the ITU-R are presented in Table 3-1 and the bands identified for IMT by the WRC-15 are shown in Table 3-2.

Table 3-1. TDD bands defined by the ITU-R.

TDD Frequency Band (MHz)	Bandwidth (MHz)
450-470	20
457,500-462,500	5
698-716, 716-728, 728-746, 746-763, 776-793 **(Several combinations possible]**	12-82
698-806	108
1880-1920	40
1920-1930	10
2010-2025	15
2300-2400	100
2500-2690	190
2570-2620	50
3400-3600	100 (200?)

Table 3-2. New bands identified for IMT by the WRC-15.

Frequency Band (MHz)
470-698
1427-1518
3300-3400
3600-3700
4800-4990

WRC-19 Agenda Item 1.13 addresses further spectrum for IMT. The most likely outcome is that new, additional spectrum will be identified for IMT at WRC-19 and that the spectrum arrangements for the identified bands will be defined around 2020. Until that time the currently identified bands need to fulfil new spectrum requirements. There are currently 11 candidate bands in the range above 24 GHz. Most of them can offer very wide bandwidths, much wider than those. It is expected that most, if not all of the new spectrum bands will be unpaired with TDD playing a significant role.

TDD spectrum availability is different in the three ITU Regions due to different identifications, but also due to different national availability. The regional difference can be generalized as shown below. Thus, similar to FDD, TD-LTE devices have to perform global roaming in multiple bands.

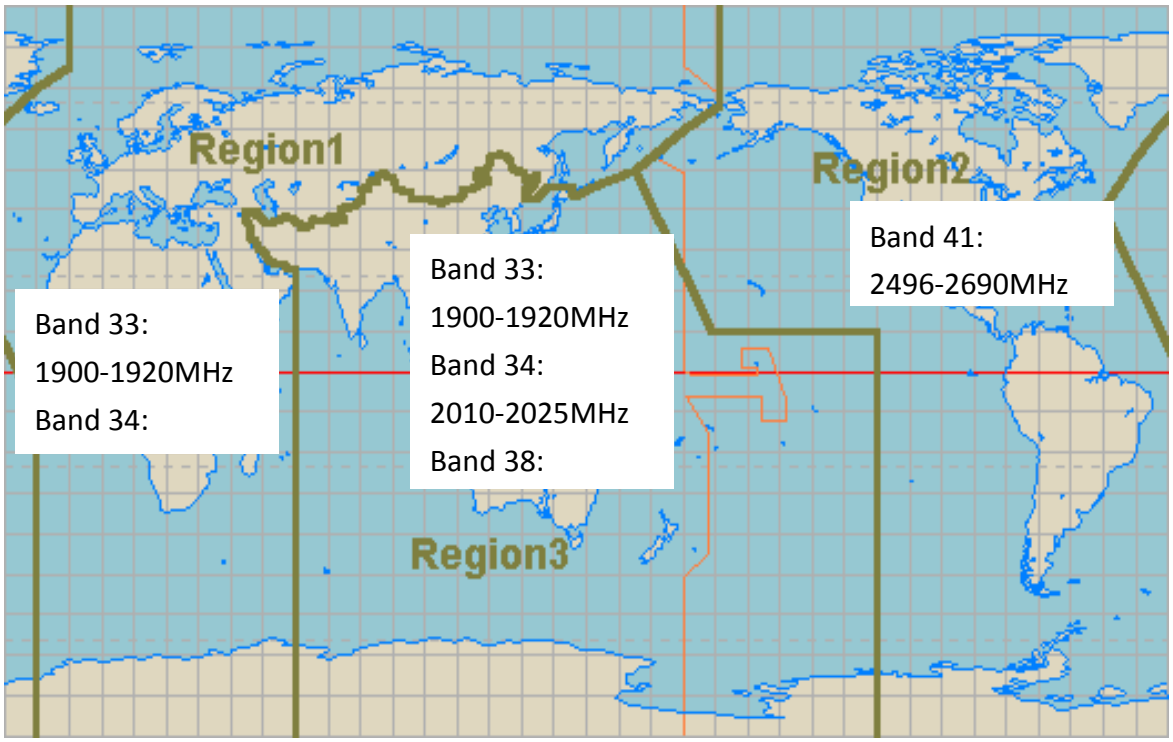


Figure 3-1. Regional summary of TDD bands.

3.2 TDD bands in standardization

3GPP defines TDD bands and their variants that are to be implemented in actual products (see Table 3-3). Most of the current TDD products operate at frequencies around 1.9GHz, 2.3GHz, 2.6GHz, 3.5GHz and 3.7GHz.

New TDD bands will emerge as the ITU-R defines TDD frequency arrangements for them in Recommendation M.1036. TDD arrangements will be potentially implemented for the bands identified by the WRC-15, i.e. the L-band (1.4 GHz), and in the C-band (e.g.3.3 GHz and 4.9 GHz).

3GPP will standardize new TDD bands as soon as the ITU-R has defined the frequency arrangements and there is a market need for equipment operating in those specific bands.

Table 3-3: TDD Bands standardized by the 3GPP

3GPP band	*Frequencies (MHz)*	*Bandwidth (MHz)*
Band 33	1900–1920	20
Band 34	2010–2025	15
Band 35	1850–1910	60
Band 36	1930–1990	60
Band 37	1910–1930	20
Band 38	2570–2620	50
Band 39	1880–1920	40
Band 40	2300–2400	100
Band 41	2496–2690	194
Band 42	3400–3600	200
Band 43	3600–3800	200
Band 44	703–803	100

4 TDD Standardization Roadmap

TD-LTE, a technology developed by 3GPP, has been supported together with FDD-LTE since the beginning of LTE standardization in Rel-8.

In 3GPP specification [36.101] bands 33-44 have been standardized for TDD. Widely used TDD bands include Band 38 (2570-2620MHz), Band 40 (2300-2400MHz), Band 41 (2500-2690MHz) and Band 42 (3400-3600MHz).

From a system design perspective the main difference between TDD and FDD LTE variants is the timing relationship for some procedures in the Physical layer. Almost all of the Physical layer and Higher layer designs, including main procedures and protocols, are common. The motivation to maximize commonality is to enable re-using the same product for both technologies, and thus enjoy more benefits from economies of scale. For this reason almost all new features and functionalities introduced in the evolution from LTE to LTE-Advanced to LTE-Advanced Pro, are equally supported by both FDD-LTE and TD-LTE. However there are still features and functionality that are specific to TDD or tuned for TDD. This will be covered in the next section.

Multi-Antennas

Channel reciprocity is a well-known benefit of TDD. One challenge in multi-antenna systems is to obtain knowledge of channel status seen by the receiver at the transmitter; for FDD it requires transmission of reference signals by the transmitter and feedback from the receiver. With a large number of antennas employed at the transmitter the efficiency and overhead of this approach is problematic. This issue does not exist with TDD, since by utilising TDD's channel reciprocity property, the transmitter itself can estimate the channel status seen by the receiver.

Beamforming transmission mode based on channel reciprocity has been supported from Rel-8 and is a key method in implementing multi-antennas in LTE. For TDD DL Beamforming transmission mode involves estimation of the DL channel from the UL sounding reference signal (SRS), demodulation of the reference signal (DM-RS). Unlike FDD it does not requires

transmission of the reference signal for channel status (CSI-RS) and feedback of precoding information (PMI/RI) from user equipment.

For 5G, multi-antenna techniques are considered as corner stone technology particularly in higher frequency bands. Massive numbers of antennae are expected to be employed to compensate for large propagation losses in the higher bands so utilizing TDD's channel reciprocity is a very attractive option for 5G.

UL/DL configuration

Flexible UL/DL configuration is another well-known benefit of TDD. Due to the asymmetry in traffic patterns the capacity demands for UL and DL are different depending on the time and location of the service. LTE FDD requires the same amount of spectrum blocks to be reserved for both the UL and DL. In contrast, seven UL/DL configurations have been defined for TDD from Rel-8 [36.211], enabling flexible utilization of the spectrum for UL or DL.

In Rel-12, the feature of dynamic UL/DL configuration was introduced for the enhancement of small cell deployments. The motivation is to allow the base station to adaptively change the UL/DL configuration based on the short term or instantaneous traffic pattern in the coverage area. The change can be done in the order of ten milliseconds, and studies have shown considerable throughput gain in small cell scenarios. Interference management is used to handle cross-link interference if neighbouring base stations are using different UL/DL configurations at the same time.

For 5G flexible spectrum utilization is considered as a common design target. As a result TDD is the main-stream technology when discussing 5G frame structure. Furthermore, with shorter symbol/TTI lengths the switching between UL and DL in a TDD system can be much faster than the 5ms supported in TD-LTE today. TDD then can then offer a similar radio interface latency as FDD while allowing flexible UL/DL usage of the spectrum.

Carrier aggregation

Carrier aggregation is an important feature introduced in Rel-10 and evolved in every release that followed. It allows the operator to use fragmented spectrum as one block while maintaining backwards compatibility with single-carrier UEs. Benefits of carrier aggregation include higher peak rates and higher user throughputs in low or medium loaded networks, as well as fast load balancing between bands making the network more efficient.

In Rel-11 inter-band TDD CA with different UL/DL configurations is supported. The motivation is to support deployment scenarios where one UL/DL configuration is used in one band (for example to provide coverage with sufficient UL resources) and a different one is used in another band (for example to provide capacity boost with more DL resources). In Rel-12, the supported was extended to aggregating TDD carriers with dynamic UL/DL configurations. In Rel-12, aggregation of TDD and FDD carriers is supported. For operators who own both FDD and TDD spectrum a unified FDD and TDD network can be achieved.

The list of TDD-TDD and TDD-FDD CA combinations defined up-to-date can be found in Annex 4.

For 5G aggregating bandwidth across a wide frequency range up to 100GHz is attractive, and depending on the regional/national regulation, aggregation across different radio technologies (5G NR, TD-LTE and FDD-LTE) may also be needed.

5 TDD Network deployment related aspects

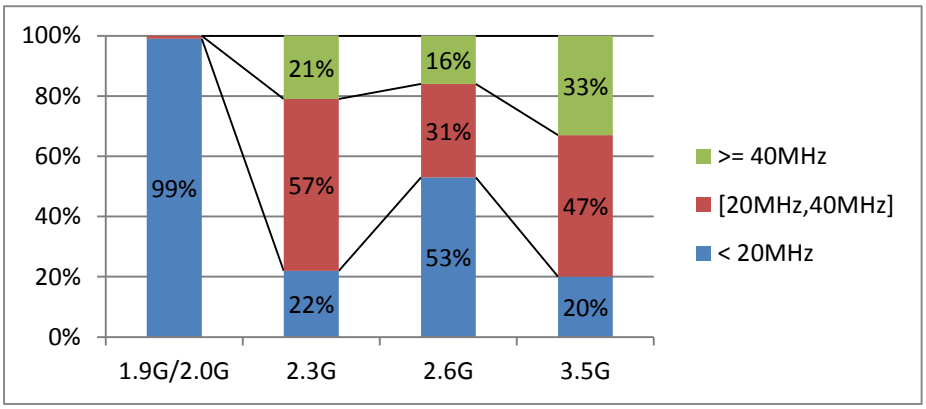
This chapter summarizes some key issues and solutions related to TDD network deployment to be taken into account when TD-LTE networks are deployed globally.

5.1 TDD Bandwidth Requirements

Assignment of large contiguous bandwidths or large blocks is strongly recommended when spectrum is made available since they are better able to provide high data rates and cope with continued traffic growth.

Current bands for TDD are 1.9GHz/2.0GHz, 2.3GHz, 2.6GHz and 3.5GHz/3.7GHz. In total there is 755MHz of potential spectrum available. According to market information (Figure 5-1), most operators possess a contiguous TDD spectrum of 20MHz bandwidth or more, with the exception of those operating in the 1.9GHz/2.0GHz band.

Figure 5-1 TDD spectrum block continuity



Besides contiguous bands some operators have a few fragmented TDD bands. Most of these bands remain unused, especially 1.9GHz in the EU. Table 5-1 shows as an example of how TDD spectrum is assigned to operators in a European country. Each operator possesses only 5MHz bandwidth of 1.9GHz with no guard bands between the 5 MHz assignments. For operators the economics of deploying a 5MHz network are questionable. Narrow bands of 5MHz also pose a challenge for manufacturers to choose which bands to support in their devices.

Table 5-1 TDD spectrum allocation of 1.9GHz in some EU country

Operator	**Frequency downlink**	**Frequency uplink**	**Bandwidth/MHz**
operator-1	1900	1905	5
operator-2	1905	1910	5
operator-3	1910	1915	5
operator-4	1915	1920	5

1900-1920MHz (Band 33) is licensed throughout the EU and 2010-2025MHz (Band 34) in some EU countries but the spectrum remains unused.

Spectrum exchanges/pooling or use of carrier aggregation technology are potential solutions to utilise this fragmented spectrum block. Spectrum swaps (where they are allowed from a regulatory perspective) are common. CA (carrier aggregation) also provides a feasible solution to help aggregate an operator's fragmented spectrum.

[Does the whitepaper need to discuss about Block Edge Mask approach for interference management?]

5.2 TDD spectrum harmonization

Spectrum harmonization can help the TD-LTE ecosystem to gain from economies of scale and facilitate global roaming. Harmonized spectrum could also help manufactures to reduce the complexity of equipment design and boost investment in TDD infrastructure and devices.

The diversity of the TDD spectrum plan results in a challenge for the whole industry ecosystem to deliver globally compatible LTE products, devices and chipsets.

For sustainable development and global harmonization countries such as Indonesia, Malaysia, India, which have deployed BWA applications in the 2.3GHz band are considering to migrate the 2.3GHz spectrum to TD-LTE.

Harmonization is strongly recommended for on-going and future spectrum arrangements. Countries including China, Spain, the United Kingdom and Italy have deployed TD-LTE networks on Band 38 or Band 42 and the users of TD-LTE are increasing rapidly which further enhances the TDD ecosystem.

5.3 Coexistence issues

As TD-LTE grows in popularity more regulators are looking to make TDD channel assignments. Before the release of the spectrum and during the TD-LTE network deployment, some operators and regulators seek help from the GTI to resolve some coexistence issues they face. In this section, we summarize the common issues that are mentioned by regulators and operators and also recommend solutions to make TD-LTE deployment easier.

The most common coexistence issues related to TD-LTE deployment can be classified into the following scenarios:

- Between multiple TD-LTE networks

- Between TD-LTE networks and LTE FDD networks
- Between TD-LTE networks and WiFi/WiMAX networks
- Between TD-LTE networks and Satellite networks

5.3.1 Multiple TD-LTE networks coexistence issues

When several TDD networks are overlaid in the same geographic areas in the same band with adjacent channels, severe interferences of DL to UL or UL to DL may happen if the networks are uncoordinated. Using techniques like synchronization, sub-band filtering, site coordination and restricted blocks can efficiently resolve interference between TDD networks.

A better way to avoid interference is to synchronize neighbour BSs in order to make them transmit and receive at the same time. There are three mechanisms which are often used and have been mostly standardized by 3GPP, including synchronization by GPS/GNSS, synchronization over the backhaul network, and over-the-air synchronization. Synchronization is not only needed for the cells operating in the same frequency, but also for the cells operating in the same band if the guard band is not sufficient.

5.3.2 TD-LTE network and LTE FDD network coexistence issues

Some regions and countries' operators have deployed large-scale LTE FDD networks. In these areas, TD-LTE and LTE FDD network interference need to be considered. BS-BS and UE-UE interference both exist in the mixed network.

According to the CEPT's rule[6], to avoid the BS-BS interference, two 5MHz guard bands shall be reserved between TDD and FDD, costly filters should be used at base stations, and thoughtful site deployment utilised. However, according to tests conducted by China Mobile[1], UE-UE interference still can't be solved due to cost and volume limitations of UE, which may result in high interference when UEs are close to each other. Additional approaches such as limiting UE data rates can be considered to mitigate the interference.

Although the coexistence between FDD and TDD can be solved, the band plan of mixed FDD and TDD should be avoided in general to avoid difficult interference scenarios and inefficient spectrum use.

5.3.3 TD-LTE network and WiFi coexistence issues

WiFi works in 2.4GHz, which is neighbour to the 2.3GHz TD-LTE and 2.6GHz LTE FDD/TDD systems including Band40 (2300-2400MHz), Band41 (2496-2690MHz), Band38 (2570-2620MHz) and Band7 (2500-2570MHz). Better filtering in devices can efficiently solve the interference from LTE on the 2.3GHz band to WiFi. However, legacy WiFi devices will have a range of different receiver filtering characteristics and some may be vulnerable to interference.

When TD-LTE networks and WLAN are deployed at the same place, the WLAN with poor filter could suffer blocking interference from TD-LTE while TD-LTE receive less affect from WLAN because of its better RF performance. According to field tests done by China Mobile LTE and Wi-Fi devices can coexist in most cases if LTE is operated below 2370MHz. Wi-Fi APs receiving performance (uplink) will decrease by 64% when there's a LTE eNB within 1 meter. Wi-Fi client device receiving performance (downlink) will decrease by 41% when there's a LTE UE within 0.5 meters. We propose that in some scenarios extending the guard band or space distance between LTE and WiFi will reduce interference risks. [extend the guardband to how much?]

5.3.4 TD-LTE networks and Satellite networks coexistence issues

3GPP has defined a TDD arrangement for the bands 3400MHz-3600MHz (Band 42) and 3600MHz-3800MHz (Band 43). The 3.4-3.6GHz band is also used for Fixed Satellite Service (FSS), Fixed Service (FS) and Wireless Broadband Service around the world. TD-LTE working on 3.5GHz must avoid causing harmful interference to FSS when there is FSS using the same or adjacent band.

Table 5-2 ITU allocations for the band 3400-3600 MHz
Source: ITU-R Radio Regulations

Region 1	**Region 2**	**Region 3**
3400-3600MHz	**3400-3500MHz**	**3400-3500MHz**
Fixed	Fixed	Fixed
Fixed-Satellite	Fixed-Satellite	Fixed-Satellite
(space-to-earth)	(space-to-earth)	(space-to-earth)

Mobile 5430A Radiolocation	Amateur Mobile 5431A Radiolocation	Amateur Mobile 5432B Radiolocation 5433

According to CCSA (China Communications Standards Association) WG8 report[2]on IMT system coexistence with FSS system which working on 3400-3600MHz spectrum and ITU-R S.1432-1 Recommendation, Earth stations of FSS may be interfered by LTE base-stations or devices which are working in 3.5GHz.

According to ITU-R Recommendation [3], techniques are recommended to increase the potential for sharing between IMT base stations and FSS earth stations:

- Sector disabling
- Multi antenna techniques (e.g. adaptive beam forming, MIMO technique)
- Site shielding of earth stations
- Antenna down tilting
- Geo-location and database access

Sector disabling can reduce the transmitted output power of LTE base stations in the direction of the interfered-with FSS earth station. Disabling the antenna sector that points towards the FSS earth station can efficiently reduce the transmitted output power level in the direction of interfered-with FSS earth stations. Using antenna techniques, such as MIMO, could also reduce the interference. The technique of site shielding of earth stations can reduce the interference from LTE transmitters.

Antenna down tilting of LTE base stations is another method to improve the possible of coexistence. A tailored antenna down tilt can mitigate the interference from LTE base stations.

The technique of Geo-location and database access may provide a higher level of protection because it can reduce interference from LTE terminals. Geolocation and database access can support FSS-IMT co-existence that allows each LTE base station in an area, based upon the prior agreed conditions by the neighbouring administration regarding protection requirements for FSS earth stations, to dynamically determine which frequencies are available for use in its coverage area and under which conditions.

6 Recommendations for TDD spectrum utilization

1) <u>TDD spectrum should be made available and assigned in a timely manner to operators to facilitate deployment of advanced networks and to achieve increased overall spectrum efficiency</u>

The growth of mobile data traffic calls for timely availability of sufficient TDD spectrum. The relevant TDD bands include the 2.3 GHz, 2.6GHz, 3.5 GHz and 3.7 GHz for European countries, the 2.6GHz, 3.5 GHz and 3.7 GHz for North America, the 2.3 GHz for Southeast Asia and the 2.6 GHz for China and South Africa[2]. There is a need to follow a common approach in order to gain benefits from economies of scale through the growth and evolution of the TDD ecosystem. It is also important to make room for exploration of the latest technical developments which helps in the smooth evolution towards the 5G networks and services.

2) <u>Implementation of a full TDD band plan in 2.3 GHz, 2.6 GHz, 3.5GHz and 3.7GHz bands is recommended for the countries/areas where those bands have not yet been made available</u>

The 1.9 GHz, 2.3 GHz, 2.6 GHz and 3.5 GHz have become the global bands for TDD. A full TDD band plan will avoid complicated coexistence issues resulting from mixing of FDD and TDD duplex modes in one band. The unified, globally common TDD assignments will enlarge the global market scale for standardised products, bring the benefits of economies of scale and facilitate cost-efficient solutions for global roaming.

The 3.4-3.8GHz (Bands 42 and 43), where 400MHz of available spectrum in Europe, will play a key role in helping to meet the mobile data demands in high traffic areas. TDD is the choice for this spectrum: it is the preferred band plan for Band 42 in Europe and the only band plan for Band 43.

[2] The detail TDD network information can be found in Annex 2.

3) Contiguous TDD spectrum assignments employing wide blocks is beneficial for improving mobile broadband experience and spectrum efficiency of networks

Contiguous wide spectrum assignments are critical to TDD performance, while fragmented assignments may not be able to support the highest data rates and offer sufficient capacity. Operation in fragmented spectrum requires more complex and costly technical solutions. It is suggested that a minimum assigned block size for each operator should be ≧20 MHz in the 2.3 GHz and 2.6 GHz bands, and ≧40 MHz in the 3.5 GHz and 3.7 GHz bands.

4) Synchronized operation amongst multiple TD-LTE networks is recommended for the best spectrum utilization while guard bands must be used to ensure the coexistence of unsynchronized TDD

The synchronized operation is the most economical and feasible way for to maximize spectrum utilization and coexistence management of TDD networks. Synchronization solutions are mature and validated in real network deployments. Over 90 percent of commercial TDD networks have adopted DL/UL ratio = 3:1, but in the future higher asymmetry is expected to be commonly used in TDD networks.

Unsynchronized operation is also possible, but requires sufficient guard bands. There is also a need for more stringent RF requirements and careful site engineering to avoid coexistence interference.

5) Lower frequency bands (e.g. L-band) and higher bands (above 6GHz) should be made available for TDD and harmonized TDD band plans should be developed for them

Traffic asymmetry is encountered not only in the high traffic areas but also in rural areas. TDD is the most flexible and spectrum efficient technology to deal with the asymmetry.

7 References

[1] R4-125214, “Band 7 and Band 38 UE-UE coexistence test”.

[2] CCSA, Research Report on the coexistance of 3400-3600MHz band IMT indoor coverage system and FSS system

[3] ITU-R, Techniques designed to increase the potential for sharing between IMT systems and FSS networks in the 3 400-3 600 MHz band

[4] ITU-R Recommendation M.1036-5 “Frequency arrangements for implementation of the terrestrial component of International Mobile Telecommunications (IMT) in the bands identified for IMT in the Radio Regulations (RR)”

[5] GSA Evolution to LTE report, April 7,2016

[6] CEPT Report 019, Least restrictive technical conditions for WAPECS frequency bands, 03/10/2018

Annex 1: Spectrum Situation in different countries.

1) Region 1

In **EU**, on one side, some of 1900-1920MHz (Band 33) and 2010-2025MHz (Band 34) are currently allocated to TDD networks and the total number of 1.9GHz/2.0GHz licenses allocated by TDD or neutral mode surpasses 100. On the other side, most of the spectrum remains unused throughout the EU for the fragmented allocation.

In **Sweden**, the regulator is considering an auction of licenses in the 2.3GHz band to meet a policy target of releasing up to 500MHz of spectrum before 2020.The operator of Hutchison 3 is deploying an LTE FDD network and also using 50 MHz of 2.6G TDD spectrum bought from Intel.

In **Russia**, the deployment of TDD in this band is already permitted. Vainakh Telecom has commercial deployed 2.3GHz TDD spectrum from September, 2013. Military operator OJSC Osnova Telecom has a licence for 2.3 GHz TD-LTE. Vainakh Telecom deployed a commercial LTE TDD network in 2.3 GHz (band 40) in Chechnya.

In **Finland**, Operator Pirkanmaan Verkko Ltd and Ukko Mobile has already deployed TD-LTE using 2.6GHz spectrum. Ukko Mobile has commercial deployed TD-LTE since November 2014.The operator UKKO has commercially launched LTE TDD with limited coverage on August 14, 2015.

In **South Africa**, the operator Telkom Mobile (formerly 8ta) has 70 MHz of 2.3 GHz TDD spectrum (band 40). Communications Authority of South Africa has released the frequency band 2500 to 2570 MHz and 2620 to 2690MHz for FDD and TDD deployment.

In **UK**, 3.5GHz and 3.7GHz bands have been licensed in the same way – both are technology and service neutral. The operator UK Broadband is rolling out TD-LTE network on both Band 42 and 43 to provide mobile and fixed services.

2) Region 2

In **USA**, Sprint additionally commercially launched TD-LTE service in band 41 on July 19,2013. Sprint offered LTE service in over 470 markets. DISH Network and Sprint wholesale partner nTelos Wireless are understood to be planning to launch a fixed wireless LTE TDD service using a portion of nTelos Band 41 spectrum. Shentel is acquiring nTelos in a deal set to close early 2016. WiMAX™ operator SpeedConnect commercially launched LTE TDD in the Quad Cities using Band 41 spectrum on May 19, 2015.

In **Canada**, the 2600 MHz band is facilitated by Inukshuk Wireless and SaskTel.

In **Brazil**, spectrum Band 38 is used by SKY Brasil Services. SKY had previously used Band 38 for MMDS, but now uses it for TDD to compete with its rivals that are able to offer triple-play packages including broadband.

3) Region 3

In **China**, Band 38, Band 40, Band 34 and Band 39 are assigned as TD-LTE or TD-SCDMA. China Mobile gets access to 130MHz of spectrum (1880-1900 MHz, 2320-2370 MHz, 2575-2635 MHz), China Unicom gets 40MHz (2300-2320 MHz, 2555-2575 MHz) and China Telecom has 40MHz (2370-2390 MHz, 2635-2655 MHz) for TD-LTE operation.

In **Australia**, 1900-1920MHz is licensed to UMTS TDD and Optus, Telstra and Vodafone have part of the band.

In **Japan**, a part of Band 41 is assigned as AXGP (TD-LTE) and WiMAX, while PHS uses a part of Band 39. Japan's Ministry of Internal Affairs and Communications issued TDD 3.5GHz to three operators.

In **India,** Bharti Airtel launched a TDD network on the 2.3GHz in April 2012. The operator Reliance Industries Ltd (RIL) is deploying an TD-LTE BWA and FDD network targeting commercial launch in 2016 using 2.3GHz (Band 40) spectrum, and is also trialling VoLTE.

Annex 2: Commercial TDD Network Deployments, reference list.

Since the world's first commercial TD-LTE network was launched by Mobily of Saudi Arabian in September 2011, a total of 76 TD-LTE systems are commercially launched in 43 countries by April 2016. (see Table A.2-1).

Table A.2-1 Commercial launched TD-LTE networks (2016/04)

No	Region	Country	Operator	Launch	Band
1	Europe	Poland	Aero2	2011.05	TDD Band 38
2	Asia	Saudi Arabia	Mobily	2011.09	TDD Band 38
3	Asia	Saudi Arabia	STC	2011.09	TDD Band 40
4	Asia	Japan	SoftBank（Wireless City Planning ）	2011.11	TDD Band 41
5	South America	Brazil	Sky Brazil	2011.12	TDD Band 38
6	Oceania	Australia	NBN Co. Australia	2012.04	TDD Band 40
7	Asia	India	Bharti Airtel	2012.04	TDD Band 40
8	Europe	Sweden	3 Sweden	2012.04	TDD Band 38
9	Europe	UK	UK Broadband	2012.06	TDD Band 42/ TDD Band 43
10	Asia	Oman	Omantel	2012.07	TDD Band 40

11	Europe	Russia	Megafon/Yota	2012.09	TDD Band 38
12	Europe	Russia	MTS Russia	2012.09	TDD Band 38
13	Asia	China	China Mobile HK	2012.12	TDD Band 40
14	Asia	Sri Lanka	Dialog	2012.12	TDD Band 40
15	South America	Brazil	On Telecomunicacoes	2013.03	TDD Band 38
16	Europe	Spain	COTA (Murcia4G)	2013.03	TDD Band 38
17	Africa	South Africa	Telkom Mobile / 8ta	2013.04	TDD Band 40
18	Africa	Uganda	MTN Uganda	2013.04	TDD Band 41
19	Europe	Spain	Vodafone	2013.05	TDD Band 38
20	Europe	Spain	Neo-Sky	2013.06	TDD Band 42
21	Oceania	Australia	Optus	2013.06	TDD Band 40
22	North America	USA	Sprint	2013.07	TDD Band 41
23	Africa	Nigeria	Spectranet	2013.08	TDD Band 40
24	Europe	Russia	Vainakh Telecom	2013.09	TDD Band 40
25	North America	Canada	Sasktel	2013.09	TDD Band 41
26	Asia	Japan	KDDI(UQ Communications)	2013.10	TDD Band 41

27	Africa	Nigeria	Swift Networks	2013.11	TDD Band 40
28	Asia	Indonesia	PT Internux	2013.11	TDD Band 40
29	Asia	Bahrain	Menatelecom	2013.11	TDD Band 42
30	Asia	China	China Mobile	2013.12	TDD Band 39/ TDD Band 40/ TDD Band 41
31	South America	Argentina	DirecTV Argentina	2013	TDD Band 43
32	Asia	Sri Lanka	SLT	2014.01	TDD Band 38
33	Africa	Ghana	NITA(National Information Technology Agency)	2014.02	TDD Band 41
34	Asia	Sri Lanka	Lanka Bell	2014.02	TDD Band 40
35	Asia	China	China Telecom	2014.02	TDD Band 41
36	Asia	China	China Unicom	2014.03	TDD Band 40/ TDD Band 41
37	Africa	Côte d'Ivoire	YooMee Côte d'Ivoire	2014.03	TDD Band 40
38	Africa	Madagascar	Blueline	2014.04	TDD Band 41
39	North America	Canada	Telus	2014.04	TDD Band 40/TDD Band 42
40	Oceania	Vanuatu	WanTok	2014.04	TDD Band 40

41	Europe	Belgium	B.lite	2014.04	TDD Band 42
42	North America	Canada	ABC Communications	2014.04	TDD Band 42
43	Asia	Philippines	PLDT（Smart Communications）	2014.04	TDD Band 42
44	Asia	India	Aircel	2014.07	TDD Band 40
45	South America	Colombia	DirecTV Colombia	2014.07	TDD Band 41
46	Africa	Angola	Net One	2014.08	TDD Band 41
47	Asia	Oman	Ooredoo Oman(Nawras)	2014.09	TDD Band 40
48	Europe	Russia	Antares	2014.09	TDD Band 39
49	North America	Canada	Bell Mobility	2014.10	TDD Band 42
50	South America	Peru	Americatel (Entel)	2014.10	TDD Band 40
51	Africa	Ghana	Blu Telecoms(G-kwiknet)	2014.10	TDD Band 41
52	Asia	Bangladesh	Banglalion	2014.12	TDD Band 41
53	North America	Canada	CCI Wireless	2014.12	TDD Band 42
54	North	Canada	Xplornet	2014.12	TDD Band 38/TDD

	America		Communications		Band 42
55	Europe	Italy	AFT-Linkem	2014.12	TDD Band 42
56	North America	Trinidad and Tobago	TSTT	2014.12	TDD Band 41
57	Africa	Uganda	Vodafone (Afrimax)	2015.02	TDD Band 38
58	North America	Dominican R.	Wind Telecom	2015.02	TDD Band 41
59	Africa	Gambia	Netpage	2015.03	TDD Band 40
60	Europe	Romania	Idilis/2K Telecom	2015.03	TDD Band 38
61	Europe	Slovak Rep	4ka	2015.03	TDD Band 43
62	Asia	Uzbekistan	Super iMAX(EVO)	2015.04	TDD Band 40
63	North America	USA	Speedconnect	2015.05	TDD Band 41
64	North America	USA	Redzone Wireless	2015.06	TDD Band 41
65	Asia	Indonesia	Smartfren	2015.07	TDD Band 40
66	Africa	Nigeria	MTN Nigeria	2015.07	TDD Band 42
67	Africa	Nigeria	Cyberspace	2015.08	TDD Band 42
68	Europe	Finland	Ukko Mobile	2015.08	TDD Band 38
69	Africa	Tanzania	Smart Telecom	2015.08	TDD Band 40

70	Europe	Italy	GO Internet	2015.09	TDD Band 42
71	Asia	Bangladesh	Ollo/BIEL	2015.09	TDD Band 38
72	Europe	Romania	DigiMobil (RCS & RDS)	2015.10	TDD Band 41/TDD Band 43
73	Europe	Netherlands	T-Mobile Netherlands	2015.10	TDD Band 38
74	Europe	Lithuania	Mezon/Telecentras	2015.11	TDD Band 40
75	Africa	Cameroon	MTN	2015.12	TDD Band 41
76	Africa	Tanzania	TTCL	2015.12	TDD Band 40

(Source: GTI spectrum database)

Besides the commercial network, According to GTI spectrum database, over 93 TD-LTE commercial networks in 60 countries are in progress or planned (see Table A.2-2).

Table A.2-2 TD-LTE commercial networks in deployment or planned status(2016/04)

Region	Country	Operator	Band	Mode
Africa	Côte d'Ivoire	MTN Côte d'Ivoire	TDD Band 41	TDD
Africa	Côte d'Ivoire	VipNet	TDD Band 42	TDD
Africa	Gambia	Gamtel	TDD Band 40	TDD
Africa	Jordan	Umniah Telecommunications	TDD Band 40	TDD
Africa	Morocco	Meditel	TDD Band 42, TDD Band 43	TDD

Africa	Nigeria	Bitflux	TDD Band 40	TDD
Asia	Azerbaijan	Delta Telecom	TBC	TDD
Asia	Azerbaijan	Sazz(Azqtel)	TDD Band 42	TDD
Asia	Cambodia	EMAXX	TDD Band 41	TDD
Asia	China	3 HK	TDD Band 40	TDD
Asia	India	BSNL	TDD Band 41	TDD
Asia	India	RIL(Reliance Jio Infocomm)	TDD Band 40	TDD
Asia	India	Tikona Digital Networks	TDD Band 40	TDD
Asia	Indonesia	Berca Hardayaperkasa	TDD Band 40	TDD
Asia	Iraq	Tishknet	TDD Band 41	TDD
Asia	Japan	NTT Docomo	TDD Band 42	TDD
Asia	Japan	SoftBank	TDD Band 42	TDD
Asia	Japan	KDDI	TDD Band 42	TDD
Asia	Malaysia	Asiaspace	TDD Band 40	TDD
Asia	Malaysia	P1 Networks	TDD Band 40	TDD
Asia	Malaysia	Telekom Malaysia	TDD Band 38	TDD
Asia	Malaysia	YTL Communications	TDD Band 40	TDD

Asia	United Arab Emirates	ET	TDD Band 42	TDD
Europe	Ireland	Imagine Group	TDD Band 42, TDD Band 43	TDD
Europe	Poland	Milmex	TDD Band 42	TDD
North America	Puerto Rico	Aeronet Puerto Rico	TDD Band 41	TDD
North America	US Virgin Islands	Aeronet USVI	TDD Band 41	TDD
North America	USA	Viearo	TDD Band 41	TDD
South America	Argentina	Claro Argentina	TDD Band 42	TDD
South America	Argentina	Telefonica	TDD Band 42	TDD
South America	Peru	DirecTV Peru	TDD Band 40	TDD
South America	Venezuela	DirecTV Venezuela	TDD Band 41	TDD
Africa	Angola	Multitel	TDD Band 42, TDD Band 43	TDD
Africa	Cameroon	YooMee Cameroon	TDD Band 40	TDD
Africa	Congo	Orange Congo	TDD Band 41	TDD
Africa	Côte d'Ivoire	B2A	TDD Band 40	TDD
Africa	Côte d'Ivoire	Orange Cote d'Ivoire	TDD Band 40	TDD

Africa	Democratic Republic of Congo	Netherlands-based Afrimax Group	TBC	TDD
Africa	Democratic Republic of Congo	Orange Democratic Republic of Congo	TDD Band 38	TDD
Africa	Democratic Republic of Congo	Vodacom Democratic Republic of Congo	TDD Band 42	TDD
Africa	Kenya	iWayAfrica	TDD Band 41	TDD
Africa	Nigeria	ADIV	TDD Band 42	TDD
Africa	Nigeria	Mobitel	TDD Band 40	TDD
Africa	Nigeria	Zoda Fones	TDD Band 41	TDD
Africa	Somalia	Sahal Telecoms	TBC	TDD
Africa	Sudan	Sutel	TDD Band 41	TDD
Africa	Tanzania	4G Mobile	TDD Band 41	TDD
Africa	Tanzania	BOL	TBC	TDD
Africa	Tanzania	Vodacom Tanzania	TDD Band 42	TDD
Asia	Bangladesh	BTCL	TDD Band 38	TDD
Asia	Bangladesh	Qubee	TDD Band 38	TDD
Asia	China	21 Vianet Group	TDD Band 40	TDD
Asia	China	Global Mobile	TDD Band 38	TDD

Asia	Indonesia	PT Indosat Mega Media(IM2)	TDD Band 40	TDD
Asia	Iran	Mobinnet Telecom Co. (MTC)	TBC	TDD
Asia	Iraq	MaxyTel	TBC	TDD
Asia	Kazakhstan	Altel	TDD Band 40	TDD
Asia	Mongolia	Ulusnet	TDD Band 42	TDD
Asia	Nepal	Nepal Telecom	TDD Band 40	TDD
Asia	Philippines	Globe Telecom	TDD Band 41	TDD
Asia	Saudi Arabia	ITC	TDD Band 42	TDD
Asia	Thailand	AIS	TDD Band 40	TDD
Europe	Belgium	BUCD	TDD Band 38	TDD
Europe	Bulgaria	Max	TDD Band 42	TDD
Europe	Croatia	Velatel Croatia	TDD Band 42	TDD
Europe	Denmark	3 Denmark	TDD Band 41	TDD
Europe	France	Bollore Telecom	TDD Band 42	TDD
Europe	France	SFR	TDD Band 42	TDD
Europe	Germany	DBD（Deutsche Breitband Dienste）	TDD Band 42	TDD
Europe	Germany	E-Plus	TDD Band 38	TDD

Europe	Italy	3 Italy	TDD Band 38	TDD
Europe	Latvian	LMT	TDD Band 38	TDD
Europe	Montenegro	Velatel Montenegro	TDD Band 42	TDD
Europe	Netherlands	KPN	TDD Band 38	TDD
Europe	Norway	Telenor	TDD Band 42	TDD
Europe	Russia	Rostelecom	TDD Band 40	TDD
Europe	Russia	Smoltelecom	TDD Band 42	TDD
Europe	Russia	Osnova Telecom	TDD Band 40	TDD
Europe	Spain	Euskaltel	TDD Band 38	TDD
Europe	UK	Niche Spectrum Ventures (NSV) (BT)	TDD Band 38	TDD
Europe	Uruguay	Dedicado	TDD Band 42	TDD
North America	Bahamas	BTC	TDD Band 42	TDD
North America	Costa Rica	IBW International Costa Rica	TDD Band 40	TDD
North America	Ecuador	Claro Ecuador	TDD Band 42	TDD
North America	El Salvador	IBW International El Salvador	TDD Band 40	TDD
North America	Guatemala	IBW International Guatemala	TDD Band 40	TDD
North America	Nicaragua	IBW International Nicaragua	TDD Band 40	TDD

North America	USA	Plateau	TBC	TDD
North America	USA	nTelos Wireless	TDD Band 41	TDD
South America	Argentina	Movistar	TDD Band 42	TDD
South America	Argentina	SKY	TBC	TDD
South America	Mexico	MVS Comunicaciones	TDD Band 41	TDD
South America	Peru	Americantel	TDD Band 40	TDD
South America	Peru	Olo	TBC	TDD
South America	Venezuela	Movilmax	TDD Band 38	TDD

(Source: GTI spectrum database)

Annex 3: Product Availability, reference list.

Currently, the system equipment for all 1.9GHz/2.3GHz/2.6GHz/3.5GHz/3.7GHz bands are matured with commercial operation ability, and the user devices for 1.9GHz/2.3GHz/2.6GHz /3.5GHz bands are sufficient to meet various customer requirements. TD-LTE has set up a complete end-to-end industry chain involving widespread participation of global industries and highly matured products.

1) User device and chipset

TD-LTE networks are deployed globally in several bands. GSA's analysis of how the main TD-LTE bands are supported by the devices ecosystem is shown in Table A.3-1.

Table A.3-1 TD-LTE Operating Frequencies (2016/04)

Frequency	Band	Device number	Status
1900MHz	39	996	Matured and in accelerating
2300MHz	40	1,435	Matured
2600MHz	38	1,207	Matured
	41	1,121	Matured and in accelerating
3400MHz-3800MHz	42 & 43	64	Matured and in accelerating

(Source: GSA Evolution to LTE report)

With the joint efforts by global chip vendors, the technologies for TD-LTE multi-mode multi-band smart phones are getting mature increasingly. Currently, multi-mode multi-band TD-LTE dongles and CPEs are commercially available from all major chipset and device manufacturers.

2) System equipment

TD-LTE system equipment for all 1.9GHz/2.3GHz/2.6GHz/3.5GHz/3.7GHz bands, including equipment products such as RAN, CN and network management, etc., is mature as a whole and has commercial operation successfully. It's worth noting that the maturity level of TD-LTE system equipment is close to that of LTE FDD, with basically the same industry support. In terms of RAN products, the maturity degree of TD-LTE is close to that of LTE FDD; in CN and network management, TD-LTE is the same as LTE FDD; in commercial operation, the gap between TD-LTE and LTE FDD is rapidly narrowing.

Table A.3-2 Multi-vendor Supply TD-LTE System Equipment Status

Vendor	Commercial Network	Band
Huawei	China Mobile	1.9GHz
	Bharti AirTel in India, China Mobile, Dialog Axiata in Sri Lanka, Omantel in Oman, STC in Saudi Arabia,	2.3GHz

	Telkom Mobile (8ta) in South Africa	
	Aero2 in Poland, China Mobile, Hi3G in Denmark, Mobily in Saudi Arabia,On Telecom in Brazil, SoftBank in Japan	2.6GHz
	UK Broadband in UK	3.5GHz/3.7GHz
Ericsson	China Mobile	1.9GHz
	China Mobile, China Mobile Hong Kong, NBN in Australia, Omantel in Oman, STC in Saudi Arabia	2.3GHz
	China Mobile	2.6GHz
Nokia Siemens	Bharti AirTel in India, China Mobile, STC in Saudi Arabia	2.3GHz
	China Mobile, Megafonin and MTSRussia, SKY TV in Brazil	2.6GHz
ZTE	China Mobile	1.9GHz
	Bharti AirTel in India, China Mobile, China Mobile Hong Kong	2.3GHz
	China Mobile, Hi3G in Sweden, SoftBank in Japan	2.6GHz
Alcatel-Lucent	China Mobile, STC in Saudi Arabia	2.3GHz
	China Mobile	2.6
Datang	China Mobile	1.9GHz, 2.3GHz, 2.6GHz

(Source:GTI)

Annex 4: 3GPP CA spectrum combinations.

E-UTRA carrier aggregation is designed to operate in the operating bands defined in Tables A.4-1, A.4-2, A.4-3, A.4-4 and A.4-5.

Table A.4-1: Intra-band contiguous CA operating bands

E-UTRA CA Band	E-UTRA Band	Uplink (UL) operating band			Downlink (DL) operating band			Duplex Mode
		BS receive / UE transmit			BS transmit / UE receive			
		F_{UL_low} – F_{UL_high}			F_{DL_low} – F_{DL_high}			
CA_1	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
CA_2	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
CA_3	3	1710MHz	–	1785MHz	1805MHz	–	1880MHz	FDD
CA_5	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	FDD
CA_7	7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	FDD
CA_8	8	880 MHz	–	915 MHz	925 MHz	–	960 MHz	FDD
CA_12	12	699 MHz	–	716 MHz	629 MHz	–	746 MHz	FDD
CA_23	23	2000 MHz	–	2020 MHz	2180 MHz	–	2200 MHz	FDD
CA_27	27	807 MHz	–	824 MHz	852 MHz	–	869 MHz	FDD
CA_38	38	2570 MHz	–	2620 MHz	2570 MHz	–	2620 MHz	TDD
CA_39	39	1880 MHz	–	1920 MHz	1880 MHz	–	1920 MHz	TDD
CA_40	40	2300 MHz	–	2400 MHz	2300 MHz	–	2400 MHz	TDD
CA_41	41	2496 MHz	–	2690 MHz	2496 MHz	–	2690 MHz	TDD
CA_42	42	3400 MHz	–	3600 MHz	3400 MHz	–	3600 MHz	TDD
CA_66	66	1710 MHz	–	1780 MHz	2110 MHz	–	2200 MHz	FDD

Table A.4-2: Inter-band CA operating bands (two bands)

E-UTRA CA Band	E-UTRA Band	Uplink (UL) operating band			Downlink (DL) operating band			Duplex Mode
		BS receive / UE transmit			BS transmit / UE receive			
		F_{UL_low} – F_{UL_high}			F_{DL_low} – F_{DL_high}			
CA_1-3	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	
CA_1-3-3	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	
CA_1-5	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	
CA_1-7	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	
CA_1-8	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	8	880 MHz	–	915 MHz	925 MHz	–	960 MHz	
CA_1-11	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	11	1427.9 MHz	–	1447.9 MHz	1475.9 MHz	–	1495.9 MHz	
CA_1-18	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	18	815 MHz	–	830 MHz	860 MHz	–	875 MHz	
CA_1-19	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	19	830 MHz	–	845 MHz	875 MHz	–	890 MHz	
CA_1-20	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	20	832 MHz	–	862 MHz	791 MHz	–	821 MHz	
CA_1-21	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	21	1447.9 MHz	–	1462.9 MHz	1495.9 MHz	–	1510.9 MHz	

CA_1-26	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	26	814 MHz	–	849 MHz	859 MHz	–	894 MHz	
CA_1-28	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	28	703 MHz	–	748 MHz	758 MHz	–	803 MHz	
CA_1-40	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	40	2300 MHz	–	2400 MHz	2300 MHz	–	2400 MHz	TDD
CA_1-41	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	41	2496 MHz	–	2690 MHz	2496 MHz	–	2690 MHz	TDD
CA_1-42	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	42	3400 MHz	–	3600 MHz	3400 MHz	–	3600 MHz	TDD
CA_1-46	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	46	5150 MHz	–	5925 MHz	5150 MHz	–	5925 MHz	TDD
CA_2-4	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	
CA_2-4-4	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	
CA_2-5	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	
CA_2-2-5	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	
CA_2-7	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	
CA_2-12	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	12	699 MHz	–	716 MHz	729 MHz	–	746 MHz	

CA_2-2-12	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	12	699 MHz	–	716 MHz	729 MHz	–	746 MHz	
CA_2-13	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	13	777 MHz	–	787 MHz	746 MHz	–	756 MHz	
CA_2-2-13	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	13	777 MHz	–	787 MHz	746 MHz	–	756 MHz	
CA_2-17	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	17	704 MHz	–	716 MHz	734 MHz	–	746 MHz	
CA_2-28	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	28	703 MHz	–	748 MHz	758 MHz	–	803 MHz	
CA_2-29	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	29	N/A			717 MHz	–	728 MHz	
CA_2-30	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	30	2305 MHz	–	2315 MHz	2350 MHz	–	2360 MHz	
CA_2-46	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	46	5150 MHz	–	5925 MHz	5150 MHz	–	5925 MHz	TDD
CA_3-5	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	
CA_3-3-5	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	
CA_3-7	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
	7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	
CA_3-8	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
	8	880 MHz	–	915 MHz	925 MHz	–	960 MHz	

CA_3-3-8	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
	8	880 MHz	–	915 MHz	925 MHz	–	960 MHz	
CA_3-19	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
	19	830 MHz	–	845 MHz	875 MHz	–	890 MHz	
CA_3-20	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
	20	832 MHz	–	862 MHz	791 MHz	–	821 MHz	
CA_3-26	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
	26	814 MHz	–	849 MHz	859 MHz	–	894 MHz	
CA_3-27	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
	27	807 MHz	–	824 MHz	852 MHz	–	869 MHz	
CA_3-28	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
	28	703 MHz	–	748 MHz	758 MHz	–	803 MHz	
CA_3-31	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
	31	452.5 MHz	–	457.5 MHz	462.5 MHz	–	467.5 MHz	
CA_3-38	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
	38	2570 MHz	–	2620 MHz	2570 MHz	–	2620 MHz	TDD
CA_3-40	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
	40	2300 MHz	–	2400 MHz	2300 MHz	–	2400 MHz	TDD
CA_3-41	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
	41	2496 MHz	–	2690 MHz	2496 MHz	–	2690 MHz	TDD
CA_3-42	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
	42	3400 MHz	–	3600 MHz	3400 MHz	–	3600 MHz	TDD
CA_3-46	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
	46	5150 MHz	–	5925 MHz	5150 MHz	–	5925 MHz	TDD

CA_4-5	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	
CA_4-4-5	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	
CA_4-7	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
	7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	
CA_4-4-7	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
	7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	
CA_4-12	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
	12	699 MHz	–	716 MHz	729 MHz	–	746 MHz	
CA_4-4-12	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
	12	699 MHz	–	716 MHz	729 MHz	–	746 MHz	
CA_4-13	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
	13	777 MHz	–	787 MHz	746 MHz	–	756 MHz	
CA_4-4-13	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
	13	777 MHz	–	787 MHz	746 MHz	–	756 MHz	
CA_4-17	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
	17	704 MHz	–	716 MHz	734 MHz	–	746 MHz	
CA_4-27	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
	27	807 MHz	–	824 MHz	852 MHz	–	869 MHz	
CA_4-28	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
	28	703 MHz	–	748 MHz	758 MHz	–	803 MHz	
CA_4-29	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
	29	N/A			717 MHz	–	728 MHz	

CA_4-4-29	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
	29	N/A			717 MHz	–	728 MHz	
CA_4-30	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
	30	2305 MHz	–	2315 MHz	2350 MHz	–	2360 MHz	
CA_4-4-30	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
	30	2305 MHz	–	2315 MHz	2350 MHz	–	2360 MHz	
CA_4-46	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
	46	5150 MHz	–	5925 MHz	5150 MHz	–	5925 MHz	TDD
CA_5-7	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	FDD
	7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	
CA_5-12	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	FDD
	12	699 MHz	–	716 MHz	729 MHz	–	746 MHz	
CA_5-13	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	FDD
	13	777 MHz	–	787 MHz	746 MHz	–	756 MHz	
CA_5-17	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	FDD
	17	704 MHz	–	716 MHz	734 MHz	–	746 MHz	
CA_5-25	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	FDD
	25	1850 MHz	–	1915 MHz	1930 MHz	–	1995 MHz	
CA_5-29	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	FDD
	29	N/A			717 MHz	–	728 MHz	
CA_5-30	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	FDD
	30	2305 MHz	–	2315 MHz	2350 MHz	–	2360 MHz	
CA_5-38	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	FDD
	38	2570 MHz	–	2620 MHz	2570 MHz	–	2620 MHz	TDD

CA_5-40	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	FDD
	40	2300 MHz	–	2400 MHz	2300 MHz	–	2400 MHz	TDD
CA_7-8	7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	FDD
	8	880 MHz	–	915 MHz	925 MHz	–	960 MHz	
CA_7-12	7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	FDD
	12	699 MHz	–	716 MHz	729 MHz	–	746 MHz	
CA_7-20	7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	FDD
	20	832 MHz	–	862 MHz	791 MHz	–	821 MHz	
CA_7-22	7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	FDD
	22	3410 MHz	–	3490 MHz	3510 MHz	–	3590 MHz	
CA_7-28	7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	FDD
	28	703 MHz	–	748 MHz	758 MHz	–	803 MHz	
CA_7-40	7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	FDD
	40	2300 MHz	–	2400 MHz	2300 MHz	–	2400 MHz	TDD
CA_7-42	7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	FDD
	42	3400 MHz	–	3600 MHz	3400 MHz	–	3600 MHz	TDD
CA_7-42-42	7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	FDD
	42	3400 MHz	–	3600 MHz	3400 MHz	–	3600 MHz	TDD
CA_7-46	7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	FDD
	46	5150 MHz	–	5925 MHz	5150 MHz	–	5925 MHz	TDD
CA_8-11	8	880 MHz	–	915 MHz	925 MHz	–	960 MHz	FDD
	11	1427.9 MHz	–	1447.9 MHz	1475.9 MHz	–	1495.9 MHz	
CA_8-20	8	880 MHz	–	915 MHz	925 MHz	–	960 MHz	FDD
	20	832 MHz	–	862 MHz	791 MHz	–	821 MHz	

CA_8-40	8	880 MHz	–	915 MHz	925 MHz	–	960 MHz	FDD
	40	2300 MHz	–	2400 MHz	2300 MHz	–	2400 MHz	TDD
CA_8-41	8	880 MHz	–	915 MHz	925 MHz	–	960 MHz	FDD
	41	2496 MHz	–	2690 MHz	2496 MHz	–	2690 MHz	TDD
CA_8-42	8	880 MHz	–	915 MHz	925 MHz	–	960 MHz	FDD
	42	3400 MHz	–	3600 MHz	3400 MHz	–	3600 MHz	TDD
CA_8-42-42	8	880 MHz	–	915 MHz	925 MHz	–	960 MHz	FDD
	42	3400 MHz	–	3600 MHz	3400 MHz	–	3600 MHz	TDD
CA_11-18	11	1427.9 MHz	–	1447.9 MHz	1475.9 MHz	–	1495.9 MHz	FDD
	18	815 MHz	–	830 MHz	860 MHz	–	875 MHz	
CA_12-25	12	699 MHz	–	716 MHz	729 MHz	–	746 MHz	FDD
	25	1850 MHz	–	1915 MHz	1930 MHz	–	1995 MHz	
CA_12-30	12	699 MHz	–	716 MHz	729 MHz	–	746 MHz	FDD
	30	2305 MHz	–	2315 MHz	2350 MHz	–	2360 MHz	
CA_18-28	18	815 MHz	–	830 MHz	860 MHz	–	875 MHz	FDD
	28	703 MHz	–	733 MHz [1]	758 MHz	–	788 MHz [1]	
CA_19-21	19	830 MHz	–	845 MHz	875 MHz	–	890 MHz	FDD
	21	1447.9 MHz	–	1462.9 MHz	1495.9 MHz	–	1510.9 MHz	
CA_19-28	19	830 MHz	–	845 MHz	875 MHz	–	890 MHz	FDD
	28	718 MHz [1]	–	748 MHz	773 MHz [1]	–	803 MHz	
CA_19-42	19	830 MHz	–	845 MHz	875 MHz	–	890 MHz	FDD
	42	3400 MHz	–	3600 MHz	3400 MHz	–	3600 MHz	TDD
CA_20-31	20	832 MHz	–	862 MHz	791 MHz	–	821 MHz	FDD
	31	452.5 MHz	–	457.5 MHz	462.5 MHz	–	467.5 MHz	

CA_20-32	20	832 MHz	–	862 MHz	791 MHz	–	821 MHz	FDD
	32	N/A			1452 MHz	–	1496 MHz	
CA_20-38	20	832 MHz	–	862 MHz	791 MHz	–	821 MHz	FDD
	38	2570 MHz	–	2620 MHz	2570 MHz	–	2620 MHz	TDD
CA_20-40	20	832 MHz	–	862 MHz	791 MHz	–	821 MHz	FDD
	40	2300 MHz	–	2400 MHz	2300 MHz	–	2400 MHz	TDD
CA_20-42	20	832 MHz	–	862 MHz	791 MHz	–	821 MHz	FDD
	42	3400 MHz	–	3600 MHz	3400 MHz	–	3600 MHz	TDD
CA_20-42-42	20	832 MHz	–	862 MHz	791 MHz	–	821 MHz	FDD
	42	3400 MHz	–	3600 MHz	3400 MHz	–	3600 MHz	TDD
CA_20-67	20	832 MHz	–	862 MHz	791 MHz	–	821 MHz	FDD
	67	N/A			738 MHz	–	758 MHz	
CA_21-42	21	1447.9 MHz	–	1462.9 MHz	1495.9 MHz	–	1510.9 MHz	FDD
	42	3400 MHz	–	3600 MHz	3400 MHz	–	3600 MHz	TDD
CA_23-29	23	2000 MHz	–	2020 MHz	2180 MHz	–	2200 MHz	FDD
	29	N/A			717 MHz	–	728 MHz	
CA_25-26	25	1850 MHz	–	1915 MHz	1930 MHz	–	1995 MHz	FDD
	26	814 MHz	–	849 MHz	859 MHz	–	894 MHz	
CA_25-41	25	1850 MHz	–	1915 MHz	1930 MHz	–	1995 MHz	FDD
	41	2496 MHz	–	2690 MHz	2496 MHz	–	2690 MHz	TDD
CA_26-41	26	814 MHz	–	849 MHz	859 MHz	–	894 MHz	FDD
	41	2496 MHz	–	2690 MHz	2496 MHz	–	2690 MHz	TDD
CA_28-40	28	703 MHz	–	748 MHz	758 MHz	–	803 MHz	FDD
	40	2300 MHz	–	2400 MHz	2300 MHz	–	2400 MHz	TDD

CA_28-41	28	703 MHz	–	748 MHz	758 MHz	–	803 MHz	FDD
	41	2496 MHz	–	2690 MHz	2496 MHz	–	2690 MHz	TDD
CA_28-42	28	703 MHz	–	748 MHz	758 MHz	–	803 MHz	FDD
	42	3400 MHz	–	3600 MHz	3400 MHz	–	3600 MHz	TDD
CA_29-30	29	N/A			717 MHz	–	728 MHz	FDD
	30	2305 MHz	–	2315 MHz	2350 MHz	–	2360 MHz	
CA_38-40	38	2570 MHz	–	2620 MHz	2570 MHz	–	2620 MHz	TDD
	40	2300 MHz	–	2400 MHz	2300 MHz	–	2400 MHz	
CA_39-41	39	1880 MHz	–	1920 MHz	1880 MHz	–	1920 MHz	TDD
	41	2496 MHz	–	2690 MHz	2496 MHz	–	2690 MHz	
CA_41-42	41	2496 MHz	–	2690 MHz	2496 MHz	–	2690 MHz	TDD
	42	3400 MHz	–	3600 MHz	3400 MHz	–	3600 MHz	
CA_41-46	41	2496 MHz	–	2690 MHz	2496 MHz	–	2690 MHz	TDD
	46	5150 MHz	–	5925 MHz	5150 MHz	–	5925 MHz	
CA_42-46	42	3400 MHz	–	3600 MHz	3400 MHz	–	3600 MHz	TDD
	46	5150 MHz	–	5925 MHz	5150 MHz	–	5925 MHz	
NOTE 1: The frequency range in band 28 is restricted for this CA band combination.								

Table A.4-3: Inter-band CA operating bands (three bands)

E-UTRA CA Band	E-UTRA Band	Uplink (UL) operating band			Downlink (DL) operating band			Duplex Mode
		BS receive / UE transmit			BS transmit / UE receive			
		F_{UL_low} – F_{UL_high}			F_{DL_low} – F_{DL_high}			
CA_1-3-5	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	
	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	
CA_1-3-7	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	
	7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	
CA_1-3-8	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	
	8	880 MHz	–	915 MHz	925 MHz	–	960 MHz	
CA_1-3-19	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	
	19	830 MHz	–	845 MHz	875 MHz	–	890 MHz	
CA_1-3-20	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	
	20	832 MHz	–	862 MHz	791 MHz	–	821 MHz	
CA_1-3-26	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	
	26	814 MHz	–	849 MHz	859 MHz	–	894 MHz	
CA_1-3-28	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	

	28	703 MHz	–	748 MHz	758 MHz	–	803 MHz	
CA_1-3-40	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	
	40	2300 MHz	–	2400 MHz	2300 MHz	–	2400 MHz	TDD
CA_1-3-42	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	
	42	3400 MHz	–	3600 MHz	3400 MHz	–	3600 MHz	TDD
CA_1-5-7	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	
	7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	
CA_1-5-40	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	
	40	2300 MHz	–	2400 MHz	2300 MHz	–	2400 MHz	TDD
CA_1-7-8	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	
	8	880 MHz	–	915 MHz	925 MHz	–	960 MHz	
CA_1-7-20	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	
	20	832 MHz	–	862 MHz	791 MHz	–	821 MHz	
CA_1-7-28	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	
	28	703 MHz	–	748 MHz	758 MHz	–	803 MHz	
CA_1-8-11	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	8	880 MHz	–	915 MHz	925 MHz	–	960 MHz	

	11	1427.9 MHz	–	1447.9 MHz	1475.9 MHz	–	1495.9 MHz	
CA_1-8-40	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	8	880 MHz	–	915 MHz	925 MHz	–	960 MHz	
	40	2300 MHz	–	2400 MHz	2300 MHz	–	2400 MHz	TDD
CA_1-11-18	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	11	1427.9 MHz	–	1447.9 MHz	1475.9 MHz	–	1495.9 MHz	
	18	815 MHz	–	830 MHz	860 MHz	–	875 MHz	
CA_1-18-28	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	18	815 MHz	–	830 MHz	860 MHz	–	875 MHz	
	28	703 MHz	–	733 MHz [1]	758 MHz	–	788 MHz [1]	
CA_1-19-21	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	19	830 MHz	–	845 MHz	875 MHz	–	890 MHz	
	21	1447.9 MHz	–	1462.9 MHz	1495.9 MHz	–	1510.9 MHz	
CA_1-19-28	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	19	830 MHz	–	845 MHz	875 MHz	–	890 MHz	
	28	718 MHz [1]	–	748 MHz	773 MHz [1]	–	803 MHz	
CA_1-19-42	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	19	830 MHz	–	845 MHz	875 MHz	–	890 MHz	
	42	3400 MHz	–	3600 MHz	3400 MHz	–	3600 MHz	TDD
CA_1-21-42	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	21	1447.9 MHz	–	1462.9 MHz	1495.9 MHz	–	1510.9 MHz	
	42	3400 MHz	–	3600 MHz	3400 MHz	–	3600 MHz	TDD
CA_2-4-5	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	

	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	
CA_2-2-4-5	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	
	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	
CA_2-4-4-5	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	
	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	
CA_2-4-7	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	
	7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	
CA_2-4-12	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	
	12	699 MHz	–	716 MHz	729 MHz	–	746 MHz	
CA_2-4-13	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	
	13	777 MHz	–	787 MHz	746 MHz	–	756 MHz	
CA_2-4-29	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	
	29	N/A			717 MHz	–	728 MHz	
CA_2-4-30	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	
	30	2305 MHz	–	2315 MHz	2350 MHz	–	2360 MHz	
CA_2-5-12	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	

	12	699 MHz	–	716 MHz	729 MHz	–	746 MHz	
CA_2-2-5-12	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	
	12	699 MHz	–	716 MHz	729 MHz	–	746 MHz	
CA_2-5-13	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	
	13	777 MHz	–	787 MHz	746 MHz	–	756 MHz	
CA_2-5-29	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	5	824 MHz	–	849 MHz	869 MHz	–	894MHz	
	29	N/A			717 MHz	–	728 MHz	
CA_2-5-30	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	
	30	2305 MHz	–	2315 MHz	2350 MHz	–	2360 MHz	
CA_2-7-12	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	
	12	699 MHz	–	716 MHz	729 MHz	–	746 MHz	
CA_2-12-30	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	12	699 MHz	–	716 MHz	729 MHz	–	746 MHz	
	30	2305 MHz	–	2315 MHz	2350 MHz	–	2360 MHz	
CA_2-29-30	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	29	N/A			717 MHz	–	728 MHz	
	30	2305 MHz	–	2315 MHz	2350 MHz	–	2360 MHz	
CA_3-5-40	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	

	40	2300 MHz	–	2400 MHz	2300 MHz	–	2400 MHz	TDD
CA_3-7-8	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
	7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	
	8	880	–	915	925	–	960	
CA_3-7-20	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
	7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	
	20	832 MHz	–	862 MHz	791 MHz	–	821 MHz	
CA_3-7-28	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
	7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	
	28	703 MHz	–	748 MHz	758 MHz	–	803 MHz	
CA_3-8-40	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
	8	880 MHz	–	915 MHz	925 MHz	–	960 MHz	
	40	2300 MHz	–	2400 MHz	2300 MHz	–	2400 MHz	TDD
CA_3-19-42	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
	19	830 MHz	–	845 MHz	875 MHz	–	890 MHz	
	42	3400 MHz	–	3600 MHz	3400 MHz	–	3600 MHz	TDD
CA_3-7-38	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
	7	N/A			2620 MHz	–	2690 MHz	
	38	N/A			2570 MHz	–	2620 MHz	TDD
CA_3-28-40	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
	28	703 MHz	–	748 MHz	758 MHz	–	803 MHz	
	40	2300 MHz	–	2400 MHz	2300 MHz	–	2400 MHz	TDD
CA_3-41-42	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
	41	2496 MHz	–	2690 MHz	2496 MHz	–	2690 MHz	TDD

	42	3400 MHz	–	3600 MHz	3400 MHz	–	3600 MHz	
CA_4-5-12	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	
	12	699 MHz	–	716 MHz	729 MHz	–	746 MHz	
CA_4-4-5-12	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	
	12	699 MHz	–	716 MHz	729 MHz	–	746 MHz	
CA_4-5-13	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	
	13	777 MHz	–	787 MHz	746 MHz	–	756 MHz	
CA_4-5-29	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	
	29	N/A			717 MHz	–	728 MHz	
CA_4-5-30	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	
	30	2305 MHz	–	2315 MHz	2350 MHz	–	2360 MHz	
CA_4-4-5-30	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	
	30	2305 MHz	–	2315 MHz	2350 MHz	–	2360 MHz	
CA_4-7-12	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
	7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	
	12	699 MHz	–	716 MHz	729 MHz	–	746 MHz	
CA_4-12-30	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
	12	699 MHz	–	716 MHz	729 MHz	–	746 MHz	

	30	2305 MHz	–	2315 MHz	2350 MHz	–	2360 MHz	
CA_4-4-12-30	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
	12	699 MHz	–	716 MHz	729 MHz	–	746 MHz	
	30	2305 MHz	–	2315 MHz	2350 MHz	–	2360 MHz	
CA_4-29-30	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
	29	N/A			717 MHz	–	728 MHz	
	30	2305 MHz	–	2315 MHz	2350 MHz	–	2360 MHz	
CA_4-4-29-30	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
	29	N/A			717 MHz	–	728 MHz	
	30	2305 MHz	–	2315 MHz	2350 MHz	–	2360 MHz	
CA_7-8-20	7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	FDD
	8	880 MHz	–	915 MHz	925 MHz	–	960 MHz	
	20	832 MHz	–	862 MHz	791 MHz	–	821 MHz	
CA_7-20-38	7	N/A			2620 MHz	–	2690 MHz	FDD
	20	832 MHz	–	862 MHz	791 MHz	–	821 MHz	
	38	N/A			2570 MHz	–	2620 MHz	TDD
CA_19-21-42	19	830 MHz	–	845 MHz	875 MHz	–	890 MHz	FDD
	21	1447.9 MHz	–	1462.9 MHz	1495.9 MHz	–	1510.9 MHz	
	42	3400 MHz	–	3600 MHz	3400 MHz	–	3600 MHz	TDD
NOTE 1: The frequency range in band 28 is restricted for this CA band combination.								

Table A.4-4: Inter-band CA operating bands (four bands)

E-UTRA CA Band	E-UTRA Band	Uplink (UL) operating band			Downlink (DL) operating band			Duplex Mode
		BS receive / UE transmit			BS transmit / UE receive			
		F_{UL_low} – F_{UL_high}			F_{DL_low} – F_{DL_high}			
1-3-5-40	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	
	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	
	40	2300 MHz	–	2400 MHz	2300 MHz	–	2400 MHz	TDD
1-3-7-8	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	
	7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	
	8	880 MHz	–	915 MHz	925 MHz	–	960 MHz	
1-3-7-28	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	
	7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	
	28	703 MHz	–	748 MHz	758 MHz	–	803 MHz	
1-3-8-40	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	
	8	880 MHz	–	915 MHz	925 MHz	–	960 MHz	
	40	2300 MHz	–	2400 MHz	2300 MHz	–	2400 MHz	TDD
1-3-19-42	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	
	19	830 MHz	–	845 MHz	875 MHz	–	890 MHz	
	42	3400 MHz	–	3600 MHz	3400 MHz	–	3600 MHz	TDD

1-19-21-42	1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
	19	830 MHz	–	845 MHz	875 MHz	–	890 MHz	
	21	1447.9 MHz	–	1462.9 MHz	1495.9 MHz	–	1510.9 MHz	
	42	3400 MHz	–	3600 MHz	3400 MHz	–	3600 MHz	TDD
2-4-5-12	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	
	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	
	12	699 MHz	–	716 MHz	729 MHz	–	746 MHz	
2-4-5-29	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	
	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	
	29	N/A			717 MHz	–	728 MHz	
2-4-5-30	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	
	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	
	30	2305 MHz	–	2315 MHz	2350 MHz	–	2360 MHz	
2-4-7-12	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	
	7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	
	12	699 MHz	–	716 MHz	729 MHz	–	746 MHz	
2-4-12-30	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	
	12	699 MHz	–	716 MHz	729 MHz	–	746 MHz	
	30	2305 MHz	–	2315 MHz	2350 MHz	–	2360 MHz	

2-4-29-30	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	
	29	N/A			717 MHz	–	728 MHz	
	30	2305 MHz	–	2315 MHz	2350 MHz	–	2360 MHz	

Table A.4-5: Intra-band non-contiguous CA operating bands (with two sub-blocks)

E-UTRA CA Band	**E-UTRA Band**	**Uplink (UL) operating band**			**Downlink (DL) operating band**			**Duplex Mode**
		BS receive / UE transmit			**BS transmit / UE receive**			
		F_{UL_low} – F_{UL_high}			**F_{DL_low} – F_{DL_high}**			
CA_2-2	2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
CA_3-3	3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
CA_4-4	4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
CA_5-5	5	824 MHz	–	849 MHz	869 MHz	–	894 MHz	FDD
CA_7-7	7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	FDD
CA_23-23	23	2000 MHz	–	2020 MHz	2180 MHz	–	2200 MHz	FDD
CA_25-25	25	1850 MHz	–	1915 MHz	1930 MHz	–	1995 MHz	FDD
CA_40-40	40	2300 MHz	–	2400 MHz	2300 MHz	–	2400 MHz	TDD
CA_41-41	41	2496 MHz	–	2690 MHz	2496 MHz	–	2690 MHz	TDD
CA_42-42	42	3400 MHz	–	3600 MHz	3400 MHz	–	3600 MHz	TDD
CA_66-66	66	1710 MHz	–	1780 MHz	2110 MHz	–	2200 MHz	FDD