

LTE-U Forum:

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Samsung Electronics & Verizon**

LTE-U SDL Coexistence Specifications V1.2 (2015-06)

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Foreword

This Technical Specification has been produced within the LTE-U Forum.

1 Scope

The present document establishes the coexistence requirements for LTE-U SDL operation on E-UTRA Base Station (BS).

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- [1] [“User Equipment \(UE\) minimum requirements for LTE-U SDL”](#), LTE-U Forum
- [2] [“Base Station \(BS\) minimum requirements for LTE-U SDL”](#), LTE-U Forum
- [3] [“Voice over Wi-Fi Enterprise Certification Program Test Plan Version 1.1”](#), Wi-Fi Alliance.
- [4] [“IEEE 802.11ac-2013 specifications”](#), IEEE

3 Abbreviations

AP	Wi-Fi Access Point
BS	Base Station
CCA	Clean Channel Assessment
CCA-CS	CCA-Carrier Sensing
CCA-ED	CCA-Energy Detection
DUT	Device Under Test
LTE-U	LTE-Unlicensed
OTA	Over The Air
PCell	Primary Cell
SCell	Secondary Cell
SDL	Supplemental DownLink
STA	Wi-Fi Station
WGN	White Gaussian Noise

4 Backgrounds

LTE-U is a radio access technology that has been proposed for providing carrier-grade wireless service in the 5GHz unlicensed band. Until today, Wi-Fi (WLAN that uses the IEEE 802.11 standard) has been the most popular choice for radio access in the unlicensed space. However, recent studies have highlighted that LTE technology, originally envisioned for cellular operation in licensed bands, has significant performance gains over Wi-Fi when operating in the unlicensed band. The main advantages for LTE-U over Wi-Fi as an access technology stem from better link performance, medium access control, mobility management, and excellent coverage. These benefits combined with the vast amount of available spectrum (> 400MHz) in the 5GHz band make LTE-U a promising radio access technology in the unlicensed arena.

Since Wi-Fi devices are already widespread in the 5GHz unlicensed band, there is a need for newly deployed LTE-U Small Cell (SC) to coexist with the Wi-Fi ecosystem. Moreover, different LTE-U operators may occupy the same spectrum in the unlicensed band to provide data services to their users. Such an unplanned and unmanaged deployment of LTE-U SCs (femtocells, picocells) may result in excessive RF interference to the existing co-channel Wi-Fi and other operator LTE-U nodes in the vicinity. It is therefore critical for LTE-U SCs to choose the best operating channel while minimizing the interference caused to nearby Wi-Fi and LTE-U networks. However, there are scenarios where all available channels are occupied by Wi-Fi devices which forces LTE-U SC to operate on the same channel as Wi-Fi. Wi-Fi devices do not back off to LTE-U unless its interference level is above the energy detection threshold (-62dBm over 20MHz). Without proper coexistence mechanisms, LTE-U transmissions could cause considerable interference on Wi-Fi network relative to Wi-Fi transmissions.

Among many possible LTE-U deployment options, this document focuses on supplemental downlink (SDL) deployment in unlicensed band, which will be paired with a licensed LTE carrier as carrier aggregation mode in legacy LTE (up to 3GPP Rel-12). This deployment will target the regions without listen-before-talk (LBT) requirements such as US (for example, U-NII radio bands in the US covering 5.15 GHz – 5.85 GHz regulated by the FCC).

The following three sub-clauses summarize the LTE-U band & EARFCN numbering and CA combinations defined in [1] and [2].

4.1 Band definitions for LTE-U in 5 GHz

The 5GHz unlicensed spectrum in the US is divided into mainly three different bands with different RF requirements. These are the three Unlicensed National Information Infrastructure (U-NII) bands. These three bands are U-NII-1 (5150-5250MHz), U-NII-2 (5250-5725MHz), and U-NII-3 (5725-5850MHz). Note that 5350-5470MHz segment in U-NII-2 is restricted from usage by FCC. In addition, the 60MHz in 5590-5650MHz are currently blocked by FCC for TDWR interference issues.

Considering that U-NII-2 band has the additional requirement of DFS, it is recommended that U-NII-2 band can be considered for LTE-U in the future.

It should be noted that for SDL, only FDD carrier aggregation (CA) is needed for the CA with a LTE FDD licensed carrier. The following band numbering will be used for the U-NII bands.

- U-NII-1
 - Band number 252 for U-NII-1 spectrum (5150-5250MHz).
- U-NII-2
 - Band numbers 253 and 254 are reserved for U-NII-2 spectrum (5250-5725MHz) for future usage.
- U-NII-3
 - Band number 255 for U-NII-3 spectrum (5725-5850MHz).

4.2 Channel numbers (EARFCN) for LTE-U bands

The existing LTE has a 100 kHz channel raster. This will be problematic for a very wide spectrum such as 5 GHz unlicensed band, given that the search space (hypothesis) is too large for eNB (or UE).

Considering that LTE deployment of interest in 5 GHz unlicensed spectrum is 20 MHz, it makes sense to align the channel raster with 20 MHz Wi-Fi channel, which is one every 20 MHz. In addition to these carrier frequencies (e.g., f_1 , $f_2 (=f_1+20\text{MHz})$, $f_3 (=f_1+40\text{MHz})$, ...), it would be necessary to introduce additional carrier frequencies around 20 MHz channel raster to allow aligning the subcarriers for the case of intra-band contiguous CA where the carrier spacing should be a multiple of 300 kHz as per the current specification. For example, around f_1 , $f_1-200\text{kHz}$, $f_1-100\text{kHz}$, f_1 , $f_1+100\text{kHz}$, $f_1+200\text{kHz}$ can be introduced, around f_2 , $f_2-200\text{kHz}$, $f_2-100\text{kHz}$, f_2 , $f_2+100\text{kHz}$, $f_2+200\text{kHz}$, and so on.

In order to allow future extension for additional channel locations, all the channels with a 100 kHz channel raster will be reserved over 700 MHz (5150 – 5850 MHz) spectrum in 5 GHz unlicensed spectrum. However, the LTE-U operation will be limited only to the following carrier frequencies for U-NII-1 and U-NII-3, respectively.

- U-NII-1
 - $\{f-0.2, f-0.1, f, f+0.1, f+0.2 \mid f = 5160, 5180, 5200, 5220, 5240\}$ MHz
- U-NII-3
 - $\{f-0.2, f-0.1, f, f+0.1, f+0.2 \mid f = 5745, 5765, 5785, 5805, 5825\}$ MHz

With these reduced set of carrier frequencies, the search space by eNB (or UE) can be significantly reduced. The proposed EARFCN is illustrated in Figure 4.2-1 and presented in Table 4.2-1.

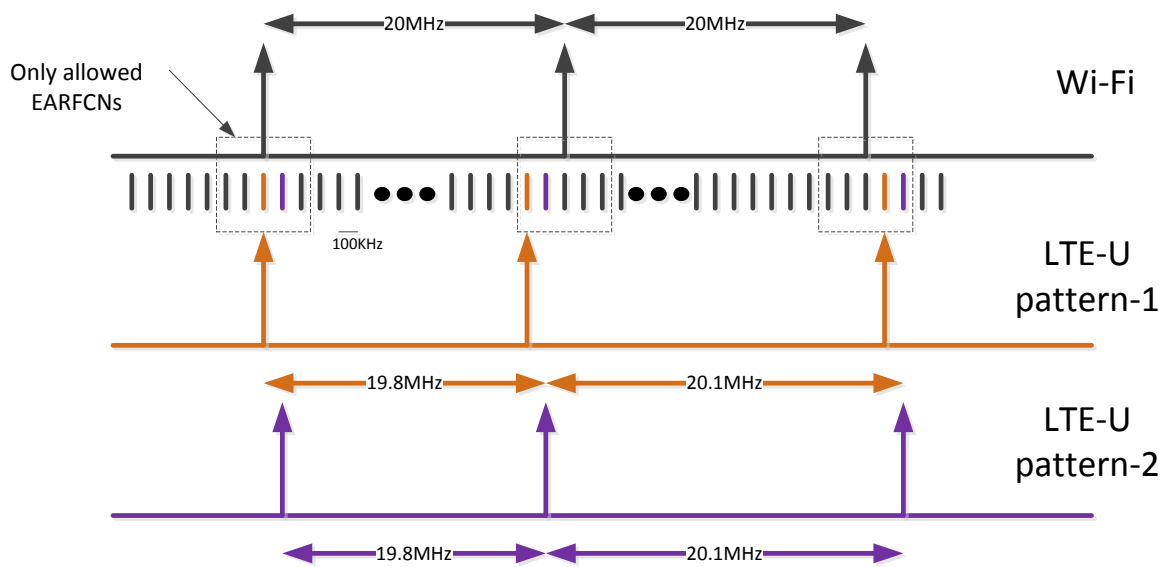


Figure 4.2-1: Example of EARFCN for LTE-U

Table 4.2-1: EARFCN and band numbers for LTE-U

Band Number	F_{DL_low} [MHz]	$N_{Offs-DL}$	Range of N_{DL}
252	5150	255144	255144-256143
255	5725	260894	260894-262143

For operations in Band 252, only the following set of DL EARFCNs is allowed.

$$N_{DL,allowed} = \{n-2, n-1, n, n+1, n+2 \mid n = 255244, 255444, 255644, 255844, 256044\}$$

For operations in Band 255, only the following set of DL EARFCNs is allowed.

$$N_{DL,allowed} = \{n-2, n-1, n, n+1, n+2 \mid n = 261094, 261294, 261494, 261694, 261894\}$$

Note 1: There is no Wi-Fi channel at 5160 MHz. The first 20 MHz Wi-Fi channel starts at 5180 MHz. Therefore, the first 5 allowed EARFCNs (255242-255246) for band 252 do not correspond to the 20 MHz Wi-Fi channel.

Note 2: There is no EARFCN corresponding to the lower edge (5725-5735 MHz) and the upper edge (5835-5850) of U-NII-3 due to the lack of 20 MHz channel availability.

4.3 LTE-U SDL CA scenarios

The LTE-U SDL CA scenarios under consideration are summarized in Table 4.3-1. All cases are FDD CA with unlicensed being DL only, i.e., SDL use case.

Table 4.3-1: LTE-U SDL CA scenarios

#	Band Combination	Licensed Band	Unlicensed Band	BW (MHz)	CA configuration
1	B13+B252+B252	B13	U-NII-1	10+20+20	inter-band + unlicensed intra-band contiguous DL CA w/o UL CA
	B13+B255+B255	B13	U-NII-3	10+20+20	
2	B13+B252	B13	U-NII-1	10+20	inter-band DL CA without UL CA
	B13+B255	B13	U-NII-3	10+20	
3	B2+B252+B252	B2	U-NII-1	[5,10,15,20]+20+20	inter-band + unlicensed intra-band contiguous DL CA w/o UL CA
	B2+B255+B255	B2	U-NII-3	[5,10,15,20]+20+20	
4	B2+B252	B2	U-NII-1	[5,10,15,20]+20	inter-band DL CA without UL CA
	B2+B255	B2	U-NII-3	[5,10,15,20]+20	
5	B4+B252+B252	B4	U-NII-1	[5, 10, 15, 20] +20+20	inter-band + unlicensed intra-band contiguous DL CA w/o UL CA
	B4+B255+B255	B4	U-NII-3	[5, 10, 15, 20] +20+20	
6	B4+B252	B4	U-NII-1	[5, 10, 15, 20] +20	inter-band DL CA without UL CA
	B4+B255	B4	U-NII-3	[5, 10, 15, 20] +20	

5 Coexistence Requirements

5.1 Secondary Cell in unlicensed spectrum operation

- eNB shall be able to create an ON/OFF time pattern on SCell. when other Wi-Fi or other operator LTE-U co-channel nodes are sensed with energy level above CCA-ED (=-62 dBm). It is left to optimization for behavior for the nodes below CCA-ED.
 - SCell ON-state: SCell is transmitting according to 3GPP LTE Rel-10 or later releases specification.
 - SCell OFF-state: SCell ceases all transmissions, including sync signal, SI signals, CRS, and etc., except 3GPP Rel-12 discovery signal when configured.
 - The duty cycle can change over time for instance based on channel usage.
- Network should manage the duty cycle of LTE-U activity to pass the coexistence tests listed in clause 6, and shall meet coexistence requirements in the operating band.
- eNB shall transmit MIB and SIB1 on SCell in unlicensed spectrum when SCell is ON-state.

5.2 Opportunistic Secondary Cell OFF in unlicensed spectrum

- eNB shall put SCell in OFF-state when SCell is not needed such as no UE in SCell coverage or there is no data in buffer for users in SCell coverage.

6 Test Cases

6.1 Channel selection

6.1.1 Clean channel selection

Test objective:

This test is to verify that LTE-U eNB (DUT) selects the clean channel among available channels in unlicensed spectrum.

Test setup:

Test shall assume the two available channels for SCell in unlicensed spectrum to be CH₁ and CH₂ each of 20MHz bandwidth.

A Wi-Fi link (between an AP and a STA) with full buffer UDP traffic shall be configured on CH₁.

Test layout shall ensure that the Wi-Fi RSSI from the Wi-Fi AP on DUT is above CCA-ED threshold (= -62 dBm) and shall ensure a line of sight between all the nodes in the test. This test is performed in OTA.

DUT shall be turned on with 20 MHz SCell in unlicensed spectrum. Only available channels for SCell in DUT shall be CH₁ and CH₂.

Test metrics/criteria:

DUT shall choose CH₂ for SCell operation within [the manufacturer declared time].

The rate of correct events observed during repeated tests shall be at least 90%.

6.1.2 Channel selection for inter-operator LTE-U

Test objective:

Orthogonalization in frequency for different LTE-U operators is an important coexistence tool for inter-operator LTE-U when the number of available channels is enough for orthogonalization. This test is to verify that LTE-U eNB (DUT) selects the channel with the same operator LTE-U eNB over the channel with a different operator LTE-U eNB when all the conditions in the channels are equivalent.

Test setup:

Test shall assume the two available channels for SCell in unlicensed spectrum to be CH₁ and CH₂ each of 20MHz bandwidth.

A LTE-U transmission (eNB₁) with the same PLMN ID as DUT shall be configured on CH₁ and a LTE-U transmission (eNB₂) with a different PLMN ID on CH₂. eNB₁ on CH₁ shall be the part of test equipment and not the part of DUT.

Full-buffer UDP traffic shall be configured on all downlinks. Test shall ensure 100% channel occupancy from eNB₁ and eNB₂ on CH₁ and CH₂ respectively.

Test configuration shall have the RSSI from eNB₁ at DUT on CH₁ is -60 dBm, and the RSSI from eNB₂ at DUT on CH₂ -60 dBm. This test is performed in conducted.

DUT shall be turned on with 20 MHz SCell in unlicensed spectrum. Only available channels for SCell in DUT shall be CH₁ and CH₂.

Test metrics/criteria:

DUT shall choose CH₁ for SCell operation within [the manufacturer declared time].

The rate of correct events observed during repeated tests shall be at least 90%.

6.2 Co-channel coexistence

6.2.1 Channel sharing with a full buffer Wi-Fi link

Test objective:

This test is to verify the maximum medium occupancy for LTE-U eNB (DUT) when the channel is shared with a full buffer Wi-Fi link.

Test setup:

Test shall assume a single available channel for SCell in unlicensed spectrum of 20MHz bandwidth.

DUT shall be configured with 20 MHz SCell on that channel with a LTE-U UE. Full buffer UDP traffic shall be configured for DUT. The distance between DUT and UE shall not exceed 12 feet and not be less than 1 foot.

A Wi-Fi link (between an AP and a STA) with full buffer UDP traffic shall be configured on that channel. The distance between the AP and STA shall not exceed 12 feet and not be less than 1 foot.

Test layout shall ensure that the Wi-Fi RSSI from the Wi-Fi AP on DUT is above CCA-ED threshold (= -62 dBm) and shall ensure a line of sight between all the nodes in the test. This test is performed in OTA.

Test metrics/criteria:

In each test, DUT shall meet the following requirements from the manufacturer declared time (after warm-up period).

- DUT SCell duty cycle (= integral of T_{on}/integral of (T_{on}+T_{off})) ≤ 50 %.
 - T_{on}: SCell ON-state duration

- T_{off} : SCell OFF-state duration
- DUT SCell $T_{\text{on,max}} \leq 50$ msec.
 - $T_{\text{on,max}}$ is defined as the maximum continuous ON duration within SCell ON-state. Almost blank subframe is not considered to be ON in SCell ON-state.
- Wi-Fi throughput ≥ 4 Mbps.
- LTE-U throughput on SCell ≥ 4 Mbps.

The rate of correct events observed during repeated tests shall be at least 90%.

6.2.2 Channel sharing with two full buffer Wi-Fi links

Test objective:

This test is to verify the maximum medium occupancy for LTE-U eNB (DUT) when the channel is shared with two full buffer Wi-Fi links.

Test setup:

Test shall assume a single available channel for SCell in unlicensed spectrum of 20MHz bandwidth.

DUT shall be configured with 20 MHz SCell on that channel with a LTE-U UE. Full buffer UDP traffic shall be configured for DUT. The distance between DUT and UE shall not exceed 12 feet and not be less than 1 foot.

Two Wi-Fi links (each between an AP and a STA) with full buffer UDP traffic shall be configured on that channel.

Test layout shall ensure that the Wi-Fi RSSI from the Wi-Fi AP on DUT is above CCA-ED threshold (= -62 dBm) and shall ensure a line of sight between all the nodes in the test. This test is performed in OTA.

Test metrics/criteria:

In each test, DUT shall meet the following requirements from the manufacturer declared time (after warm-up period).

- DUT SCell duty cycle (= integral of T_{on} /integral of ($T_{\text{on}}+T_{\text{off}}$)) ≤ 33 %.
- DUT SCell $T_{\text{on,max}} \leq 50$ msec.
 - $T_{\text{on,max}}$ is defined as the maximum continuous ON duration within SCell ON-state. Almost blank subframe is not considered to be ON in SCell ON-state.
- LTE-U throughput on SCell ≥ 4 Mbps.

The rate of correct events observed during repeated tests shall be at least 90%.

6.2.3 Channel sharing with two up-link full buffer Wi-Fi links

Test objective:

This test is to verify the maximum medium occupancy for LTE-U eNB (DUT) when the channel is shared with two full buffer Wi-Fi links running up-link traffic from STA to APs

Test setup:

Test shall assume a single available channel for SCell in unlicensed spectrum of 20MHz bandwidth.

DUT shall be configured with 20 MHz SCell on that channel with a LTE-U UE. Full buffer UDP traffic shall be configured for DUT. The distance between DUT and UE shall not exceed 12 feet and not be less than 1 foot.

Two Wi-Fi links (each between an AP and a STA) with full buffer UL UDP traffic shall be configured on that channel.

Test layout shall ensure that the Wi-Fi RSSI from the Wi-Fi STA on DUT is above CCA-ED threshold (= -62 dBm) and shall ensure a line of sight between all the nodes in the test. This test is performed in OTA.

Test metrics/criteria:

In each test, DUT shall meet the following requirements from the manufacturer declared time (after warm-up period).

- DUT SCell duty cycle (= integral of T_{on} /integral of ($T_{\text{on}}+T_{\text{off}}$)) ≤ 33 %.

- DUT SCell $T_{on,max} \leq 50$ msec.
 - $T_{on,max}$ is defined as the maximum continuous ON duration within SCell ON-state. Almost blank subframe is not considered to be ON in SCell ON-state.
- LTE-U throughput on SCell ≥ 4 Mbps.

The rate of correct events observed during repeated tests shall be at least 90%.

6.2.4 Channel sharing with a full buffer + VoIP Wi-Fi links

Test objective:

This test is to verify the performance of multiple VoIP links over WiFi under interference from a full buffer traffic of LTE-U eNB (DUT) when the channel is shared. In addition to VoIP the Wi-Fi AP also runs downlink full buffer traffic.

Test setup:

Test shall assume a single available Wi-Fi primary channel for SCell in unlicensed spectrum of 20MHz bandwidth.

A Wi-Fi link (between an AP0 and a STA0) with downlink full buffer UDP traffic shall be configured on that channel. Wi-Fi VoIP links from extra 4 STAs (i.e. STA1, STA2, STA3, STA4) to the same AP shall be configured such that the Wi-Fi AP is serving 5 links with one full buffer and rest are VoIP. All links use Chariot tool for traffic generation. Refer to the details on voice configuration below to setup multiple concurrent voice streams and UDP full buffer traffic in Chariot.

For the baseline setup, AP1 that is same vendor/model as AP0, shall be configured with 20 MHz primary on that channel with a Wi-Fi STA5 instead of the DUT (a LTE-U eNB and a UE). Downlink full buffer UDP traffic shall be configured for AP1. The distance between AP1 and STA5 shall not exceed 12 feet and not be less than 1 foot.

For the final test setup, DUT (a LTE-U eNB) shall be configured with 20 MHz SCell on that channel with a LTE-U UE. Downlink full buffer UDP traffic shall be configured for DUT. The distance between DUT and UE shall not exceed 12 feet and not be less than 1 foot.

Test layout for the baseline shall ensure that the RSSI from AP1 on Wi-Fi AP0 and associated STAs is above CCA-ED threshold (= -62 dBm for 20MHz). The final test layout shall ensure that the RSSI from DUT on Wi-Fi AP0 and associated STAs is above CCA-ED threshold (= -62 dBm for 20MHz). This test is performed in OTA and shall be run for 120sec [3].

The required Wi-Fi AP0 & AP1 shall be the 802.11ac Cisco Aironet 3700e AP and the required STAs shall be the Samsung Galaxy S5 devices.

The following voice configuration shall be used to configure voice QoS profile in Chariot.

- Voice codec: Enterprise grade G.711 (64kbps) voice codec shall be used
- Jitter Buffer: A nominal de-jitter buffer delay of 40ms shall be set
- AC Tagging: DSCP marking shall be enforced by setting qWAVE=111000
- EDCA Parameters: IEEE 802.11 default EDCA parameters shall be used per Table 8-105 in the IEEE 802.11ac-2013 spec [4]

Test metrics/criteria:

Start with baseline having AP1-STA5 as the jammer and collect the following results for DL AP0-STA1 VoIP link from Chariot:

- The one-way delay, x_delay
- The packet jitter, x_jitter
- The packet loss rate, $x_per\%$
- The probability of 4 or more consecutive packet loss, x consecutiveErrors%

Repeat the test with DUT replacing AP1. The following test results should be expected [3]:

- The one way delay and packet jitter should not exceed the maximum of baseline results and 50msec more than 5% of the time
- Packet loss rates should not exceed the maximum of baseline results and 1%

- The probability of 4 or more consecutive packet loss shall not exceed baseline
- The DUT (LTE-U) throughput on SCell ≥ 4 Mbps.

The rate of correct events observed during repeated tests shall be at least 90%.

6.2.5 Channel sharing for inter-operator LTE-U and Wi-Fi

Test objective:

When the number of channels is not enough for orthogonalization in frequency for different LTE-U operators, bounding maximum LTE-U duty cycle in co-channel is another coexistence tool for inter-operator LTE-U. This test verifies the coexistence with Wi-Fi as well as opportunistic (probabilistic) coexistence with other operator LTE-U on co-channel.

Test setup:

Test shall assume a single available channel for SCell in unlicensed spectrum of 20MHz bandwidth.

A non-full buffer (a fixed 33% channel occupancy) LTE-U transmission (eNB₁) with a different PLMN ID from DUT shall be configured on that channel.

A Wi-Fi link (between an AP and a STA) with full buffer UDP traffic shall be configured on that channel.

DUT (eNB₂) shall be configured with 20 MHz SCell on that channel with a LTE-U UE. Full buffer UDP traffic shall be configured for DUT.

Test configuration shall have the RSSI from eNB₁ at DUT is -40 dBm, and the RSSI from DUT (eNB₂) at eNB₁ -40 dBm. This test is performed in conducted.

Test metrics/criteria:

In each test, DUT shall meet the following requirements from the manufacturer declared time (after warm-up period).

- DUT SCell duty cycle (= integral of T_{on}/integral of (T_{on}+T_{off})) ≤ 33 %.
- DUT SCell T_{on,max} ≤ 50 msec.
 - T_{on,max} is defined as the maximum continuous ON duration within SCell ON-state. Almost blank subframe is not considered to be ON in SCell ON-state.

The rate of correct events observed during repeated tests shall be at least 90%.

6.2.6 Channel sharing between intra-operator LTE-U eNBs

Test objective:

This test verifies that same operator LTE-U eNBs (DUT) are able to run a higher reuse when the conditions are favourable.

Test setup:

Test shall assume a single available channel for SCell in unlicensed spectrum of 20MHz bandwidth.

Two LTE-U links (between an eNB₁ (DUT) and a UE₁, between an eNB₂ (DUT) and a UE₂) with full buffer UDP traffic shall be configured on that channel. Both eNB₁ and eNB₂ shall have the same PLMN ID and shall be from the same vendor.

Test configuration shall have the following setting.

- LTE-U₁ link SNR (eNB₁ RSSI at UE₁ / WGN) = LTE-U₂ link SNR (eNB₂ RSSI at UE₂ / WGN) = 30 dB
- LTE-U₁ link INR (eNB₂ RSSI at UE₁ / WGN) = LTE-U₂ link INR (eNB₁ RSSI at UE₂ / WGN) = -10 dB
- eNB₁ RSSI at eNB₂ = eNB₂ RSSI at eNB₁ = -60 dBm

This test is performed in conducted.

DUT (eNB₁ and eNB₂) shall be configured with 20 MHz SCell on that channel with a LTE-U UE.

Test metrics/criteria:

In each test, DUT shall meet the following requirements from the manufacturer declared time (after warm-up period).

- $80\% \leq \text{DUT SCell duty cycle} < 100\%$.
- LTE-U $T_{\text{on,max}} \leq 50$ msec.
 - $T_{\text{on,max}}$ is defined as the maximum continuous ON duration within SCell ON-state. Almost blank subframe is not considered to be ON in SCell ON-state.

The rate of correct events observed during repeated tests shall be at least 90%.

6.3 Opportunistic SDL

6.3.1 Opportunistic SCell OFF

Test objective:

This test verifies that LTE-U eNB (DUT) puts SCell in OFF-state when SCell is not needed such as no UE in SCell coverage or there is no data in buffer for users in SCell coverage.

Test setup:

Test shall assume a single available channel for SCell in unlicensed spectrum of 20MHz bandwidth.

DUT shall be configured with 20 MHz SCell on that channel with a LTE-U UE. Full buffer UDP traffic shall be configured for DUT in the beginning.

UE shall be removed from the coverage of SCell or no DL data is scheduled for SCell for the UE in the test. Vendors will choose either method to pass the test.

Test metric/criteria:

SCell shall be in SCell OFF-state within [the manufacturer declared time] from the time the associated UE has been removed or no DL data has been transmitted for SCell for the UE in the test.

The rate of correct events observed during repeated tests shall be at least 90%.