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Technical Report

3rd Generation Partnership Project;

Technical Specification Group Radio Access Network;

Evolved Universal Terrestrial Radio Acces (E-UTRA) 2.4 GHz Time Division Duplex (TDD) Band for US

(Release 16)

** 

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# Foreword

This Technical Report has been produced by the 3rd Generation Partnership Project (3GPP).

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# 1 Scope

The present document is a technical report for the work item of the E-UTRA 2.4 GHz TDD Band for US. The work item elements reflected in this document are (a) study of impact of operations from 2483.5 MHz to 2495 MHz on unlicensed Bluetooth and 802.11 operations in the ISM band, and (b) standardization of a new E-UTRA band from 2483.5 MHz to 2495 MHz (Band 53).

# 2 References

[1] 3GPP TR 21.905 “Vocabulary for 3GPP Specifications.”

[2] Terrestrial Use of the 2473[2483.5]-2495 MHz Band for Low-Power Mobile Broadband Networks; Amendments to Rules for the Ancillary Terrestrial Component of Mobile Satellite Service Systems, IB Docket No. 13-213, Report and Order, FCC 16-181

[3] 47 CFR Part 15.247. “Operation within the bands 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz.”

[4] Satellite Communications, Title 47, Part 25 of e-CFR, <https://www.law.cornell.edu/cfr/text/47/part-25>

[5] 3GPP TR 36.816, Study on Signaling and Procedure for Interference Avoidance for In-Device Coexistence (Release 11)

[6] Federal Communications Commission Report TR 15-1002 (IB Docket No. 13-213), Electromagnetic Emissions Characterization of Samples Used at TLPS Demonstration, May 7, 2015

[7] R2-114331, Solutions for IDC interference in LTE + BT voice scenario, Ericsson, ST-Ericsson

[8] R2-115088, DRX for avoiding IDC interference with TDD configuration 6, Ericsson, ST-Ericsson

# 3 Abbreviations

## 3.1 Abbreviations

For the purposes of the present document, the abbreviations given in 3GPP TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in 3GPP TR 21.905 [1].

ACLR Adjacent Channel Leakage Ratio

ATC Ancillary Terrestrial Component

BAS Broadcast Auxiliary Service

BRS Broadband Radio Service

BLER Block Error Ratio

BS Base Station

BT Bluetooth

BW Bandwidth

CDF Cumulative Distribution Function

CFR Code of Federal Regulation

CW Continuous Wave

DL Downlink

DRX Discontinuous Reception

DUT Device Under Test

EARFCN E-UTRA Absolute Radio Frequency Channel Number

EBS Educational Broadband Service

EIRP Effective Isotropic Radiated Power

E-UTRA Evolved UTRA

FCC Federal Communications Commission

FDD Frequency Division Duplex

GNSS Global Navigation Satellite System

HARQ Hybrid Automatic Repeat Request

IDC In-Device Coexistence

IMD Intermodulation Distortion

ISM Industrial, Scientific and Medical Band

LA Local Area

LNA Low Noise Amplifier

LO Local Oscillator

LTE Long Term Evolution

MCL Maximum Coupling Loss

MCS Modulation Coding Scheme

MIMO Multiple Input Multiple Output

MPR Maximum Power Reduction

MSS Mobile Satellite Service

NF Noise Figure

NOS Network Operating System

OFDM Orthogonal Frequency Division Multiplexing

PA Power Amplifier

PHY Physical Layer

PRB Physical Resource Block

PSD Power Spectral Density

QPSK Quadrature Phase Shift Keying

RBW Receiver Bandwidth

RF Radio Frequency

RSSI Received Signal Strength Indication

RX Receiver

SEM Spectrum Emission Mask

SINR Signal to Interference plus Noise Ratio

STA Station

TCP Transmission Control Protocol

TDD Time Division Duplex

TDM Time Division Multiplexing

TX Transmitter

UDP User Datagram Protocol

UE User Equipment

UL Uplink

US United States

VoIP Voice over Internet Protocol

WLAN Wireless Local Area Network

# 4 Background

## 4.1 Justification

The FCC has recently adopted rules for terrestrial use of the 2.4 GHz MSS band [2]. This band is authorized for TDD operation and spans 11.5 MHz from 2483.5 MHz to 2495 MHz.



Figure 4.1-1: US 2.4 GHz Terrestrial Band

FCC rules permit low-power terrestrial services that may be deployed independently of a satellite service and without conventional population coverage or other substantial service requirements. This regulatory treatment and the physical propagation characteristics associated with these wavelengths bias the band towards small cell applications.

To facilitate 2.4 GHz LTE ecosystem development, RAN has approved a work item to standardize a new E-UTRA operating band based upon the 11.5 MHz terrestrial band authorized by the FCC (*see* RP-181419).

## 4.2 Objectives

The work item consists of two parts.

Part 1 is the study phase of the WI, which is intended to define the impact of operations from 2483.5 MHz to 2495 MHz on unlicensed Bluetooth and 802.11 operations in the ISM band. The core objectives of the study phase of the WI are:

- Define impact on 2.4 GHz Bluetooth operations.

- Define impact on 2.4 GHz 802.11 operation.

- Address potential Bluetooth and 802.11 coexistence issues.

Part 2 is the working phase of the WI, which is intended to complete the remainder of the work item. The core objectives of the working phase of the WI are:

- Standardization of new TDD E-UTRA band spanning 2483.5 MHz to 2495 MHz (compliant with FCC 16-181, including power, out of band emissions limits, and interference protection rules).

- Specify band numbering and RF characteristics of the new band.

- Address potential BS and UE coexistence issues.

- Update the related E-UTRA technical specifications to include support for the new band.

# 5 Frequency Band Arrangement and Regulatory Background

## 5.1 Frequency band arrangement and channel bandwidths

### 5.1.1 Frequency band arrangement

The proposed band plan for the E-UTRA 2.4 GHz TDD Band for US (2.4 GHz Terrestrial Band) is presented below. As shown in Table 5.1.1-1, the TDD configuration of the band places BS receive / UE transmit and BS transmit / UE receive on the same frequencies. Channels may be placed from 2483.5 MHz to 2495 MHz.

Table 5.1.1-1: Operating band arrangement

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Uplink (UL) operating band BS receive  UE transmit | | | Downlink (DL) operating band BS transmit  UE receive | | | Duplex Mode |
| **FUL\_low** | **– FUL\_high** | | **FDL\_low** | **–** | **FDL\_high** |
| 2483.5 MHz | – | 2495 MHz | 2483.5 MHz | – | 2495 MHz | TDD |

As shown in Figure 5.1.1-1, the US 2.4 GHz Terrestrial Band exists between the ISM band and BRS / EBS bands. The ISM band terminates at 2483.5 MHz, with commonly used unlicensed services such as 802.11 Wi-Fi and Bluetooth terminating at 2473 MHz and 2480 MHz respectively. BRS / EBS bands begin with the BRS-1 channel at 2496 MHz. A 1 MHz guard band exists between the termination of the US 2.4 GHz Terrestrial Band at 2495 MHz and the beginning of the first BRS channel at 2496 MHz.

A screenshot of a cell phone

















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Figure 5.1.1-1: US 2.4 GHz Terrestrial Band and Adjacent Band Services

### 5.1.2 Channel bandwidths

The FCC authorized band spans 2483.5 MHz to 2495 MHz and the regulator has not divided the band into discrete channels or blocks. As shown in Table 5.1.2-1, the 11.5 MHz allocation supports operating bandwidths up to 10 MHz.

Table 5.1.2-1: Proposed operating bandwidths

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1.4 MHz | 3 MHz | 5 MHz | 10 MHz | 15 MHz | 20 MHz |
| Yes | Yes | Yes | Yes | No | No |

## 5.2 Adjacent 3GPP Bands

### 5.2.1 Introduction

Nearby 3GPP bands are summarized in Figure 5.2.1-1. Band 7 and Band 38 are not used in the US regulatory domain, where the 2.4 GHz Terrestrial Band is currently authorized by the FCC. However, Band 41 is commonly used in all areas of the US.

A picture containing screenshot

















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Figure 5.2.1-1: US 2.4 GHz Terrestrial Band and Adjacent 3GPP Bands

### 5.2.2 Co-Existence Between 2.4 GHz and 3GPP Band 41

3GPP Band 41 is a TDD band, which spans 2496 MHz to 2690 MHz. In the US, Band 41 operation is licensed through the Broadband Radio Service (BRS) and the Educational Broadband Service (EBS). Figure 5.2.2-1 illustrates the 35 channel blocks that comprise the BRS / EBS services and their relationship with the 2.4 GHz Terrestrial Band. The 5.5 MHz and 6 MHz channel blocks associated with BRS / EBS licenses are a vestige of educational television use of this spectrum. While educational services still operate in the EBS channel blocks, Band 41 commercial LTE operations predominate across most of the US. The 2.4 GHz Terrestrial Band spanning 2483.5 MHz to 2495 MHz is separated by a 1 MHz guard band from BRS-1, which is the lowest frequency channel block available for Band 41 operations.

Co-existence between the proposed 2.4 GHz Terrestrial Band and Band 41 was a central consideration during the FCC rule making process. These co-existence requirements were addressed with power limits, emissions limits, and the mandated integration of a Network Operating System (NOS) to administer use of the 2.4 GHz Terrestrial Band (*see* Section 5.4). While not required by the regulator, Band 41 and 2.4 GHz Terrestrial Band operators may also rely upon TDD synchronization to resolve interference issues that may be experienced as a result of co-located base stations.

A close up of a logo

















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Figure 5.2.2-1: US 2.4 GHz Terrestrial Band and Adjacent BRS / EBS Spectrum Comprising Band 41

### 5.2.3 Co-Existence Between 2.4 GHz and 3GPP Bands 7 and 38

The proposed 2.4 GHz TDD band spanning 2483.5 MHz to 2495 MHz is adjacent to 3GPP Bands 7 and 38. 3GPP Band 7 is an FDD band, with uplink spanning 2500 MHz to 2570 MHz and downlink spanning 2620 MHz to 2690 MHz. 3GPP Band 38 is a TDD band spanning 2570 MHz to 2620 MHz.

Currently, the proposed 2.4 GHz TDD band has terrestrial license authority only in the US. Due to the presence of Band 41, neither Band 7 nor Band 38 is utilized in the US regulatory domain.

## 5.3 Nearby non-3GPP Unlicensed Services

### 5.3.1 Co-Existence Between 2.4 GHz and Part 15 Services

Title 47 of the CFR, Part 15 permits unlicensed operations from 2400 MHz to 2483.5 MHz [3]. The 2.4 GHz unlicensed band (commonly known as the ISM band) is especially notable for the heavy presence of 802.11 Wi-Fi and Bluetooth operations. In the US, 802.11 channel 11 is the highest channel effectively permitted by Part 15 rules, terminating at approximately 2473 MHz. Across all regulatory domains, Bluetooth channel 39 is the highest, terminating at approximately 2480 MHz. Figure 5.3.1-1 illustrates the relationship between the 2.4 GHz Terrestrial Band and adjacent non-3GPP unlicensed services in the ISM band.

A screenshot of a cell phone

















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Figure 5.3.1-1: S 2.4 GHz Terrestrial Band and Adjacent Unlicensed Band

## 5.4 FCC Regulatory Requirements

### 5.4.1 Introduction

Licensed wireless communications services in the 2.4 GHz band are governed by Part 25 of Title 47 of the Code of Federal Regulations [4].

### 5.4.2 Frequency Limits

Frequency limits for the 2.4 GHz band are governed by Title 47 of the CFR, Part 25.149. Terrestrial operation is limited to the licensed band from 2483.5 MHz to 2495 MHz. Bonding or aggregation with unlicensed services below 2483.5 MHz is prohibited by Title 47 of the CFR, Parts 15.205, 15.209, 15.247 and 15.249.

### 5.4.3 Power Limits

Power limits for the 2.4 GHz band are governed by Title 47 of the CFR, Part 25.149(c)(4)(i)-(iv). These power limits are identical to those found in Part 15 for unlicensed services authorized from 2400 MHz to 2483.5 MHz and they do not distinguish between base station and user equipment. The relevant rules for operational equipment are listed below:

(4) Applications for equipment authorization of terrestrial low-power system equipment that will operate in the 2483.5-2495 MHz band shall demonstrate the following:

(i) The transmitted signal is digitally modulated;

(ii) The 6 dB bandwidth is at least 500 kHz;

(iii) The maximum transmit power is no more than 1 W with a peak EIRP of no more than 6 dBW;

(iv) The maximum power spectral density conducted to the antenna is not greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission;

### 5.4.4 Emissions Limits

Emissions limits for the 2.4 GHz Terrestrial Band are governed by Title 47 of the CFR, Part 25.149(c)(4)(v)-(vii). Figure 6.4.4-1 is a graphical summary of emissions limits for the 2.4 GHz Terrestrial Band, assuming a 10 MHz emission bandwidth. The relevant rules for operational equipment are listed below:

(v) Emissions below 2483.5 MHz are attenuated below the transmitter power (P) measured in watts by a factor of at least 40 + 10 log (P) dB at the channel edge at 2483.5 MHz, 43 + 10 log (P) dB at 5 MHz from the channel edge, and 55 + 10 log (P) dB at X MHz from the channel edge where X is the greater of 6 MHz or the actual emission bandwidth.

(vi) Emissions above 2495 MHz are attenuated below the transmitter power (P) measured in watts by a factor of at least 43 + 10 log (P) dB on all frequencies between the channel edge at 2495 MHz and X MHz from this channel edge and 55 + 10 log (P) dB on all frequencies more than X MHz from this channel edge, where X is the greater of 6 MHz or the actual emission bandwidth;

(vii) Compliance with these rules is based on the use of measurement instrumentation employing a resolution bandwidth of 1 MHz or greater. However, in the 1 MHz bands immediately above and adjacent to the 2495 MHz a resolution bandwidth of at least 1 percent of the emission bandwidth of the fundamental emission of the transmitter may be employed. If 1 percent of the emission bandwidth of the fundamental emission is less than 1 MHz, the power measured must be integrated over the required measurement bandwidth of 1 MHz. A resolution bandwidth narrower than 1 MHz is permitted to improve measurement accuracy, provided the measured power is integrated over the full required measurement bandwidth (i.e., 1 MHz). The emission bandwidth of the fundamental emission of a transmitter is defined as the width of the signal between two points, one below the carrier center frequency and one above the carrier center frequency, outside of which all emissions are attenuated at least 26 dB below the transmitter power. When an emission outside of the authorized bandwidth causes harmful interference, the Commission may, at its discretion, require greater attenuation than specified in this section;

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Figure 5.4.4-1: US 2.4 GHz Terrestrial Band Emissions Limits (10 MHz Emission BW)

### 5.4.5 Network Operating System

Special requirements for control of the 2.4 GHz band are governed by Title 47 of the CFR, Part 25.149(g)(2). The relevant rules are listed below:

(2) An ATC licensee seeking to modify its license to add authority to operate a terrestrial low-power network shall certify in its modification application that its operations will utilize a Network Operating System (NOS), consisting of a network management system located at an operations center or centers. The NOS shall have the technical capability to address and resolve interference issues related to the licensee’s network operations by (a) reducing operational power; (b) adjusting operational frequencies; (c) shutting off operations; or (d) any other appropriate means. The NOS shall also have the ability to resolve interference from the terrestrial low-power network to the licensee’s MSS operations and to authorize access points to the network, which in turn may authorize access to the network by end-user devices. The NOS operations center shall have a point of contact in the United States available 24 hours a day, seven days a week, with a phone number and address made publicly-available by the licensee.

# 6 Special Co-Existence Considerations for Unlicensed Operations in the 2.4 GHz ISM Band

## 6.1 Introduction

While Part 15 services in the 2.4 GHz band are not entitled to interference protection under FCC rules [4], unlicensed 2.4 GHz applications like 802.11 Wi-Fi and Bluetooth are of special significance. This section outlines the regulatory history and technical basis for co-existence between the US E-UTRA 2.4 GHz TDD Band and non-3GPP unlicensed operation in the 2.4 GHz ISM Band.

## 6.2 2.4 GHz Terrestrial Band Plan Evolution

The Globalstar satellite network operates in a downlink configuration from 2483.5 MHz to 2500 MHz. Following the establishment of the ATC regulatory construct, 2483.5 MHz to 2495 MHz became available for terrestrial allocation. The satellite downlink band from 2496 MHz to 2500 MHz was already allocated for terrestrial use as a portion of the high power BRS-1 service, which is now integrated into 3GPP Band 41.

More details concerning the FCC ruling on this specific band could be found in [3].

## 6.3 Ratified 2.4 GHz Terrestrial Band Relative to Common Unlicensed Applications

### 6.3.1 2.4 GHz Terrestrial Band Relative to Entire Unlicensed Band in the United States

This band is dedicated only for US usage. From regulatory perspective, FCC approved this band after balancing the needs of coexistent WLAN and BT access technologies in the ISM band. More details could be found in [3].

For informative purposes, Figure 6.3.1-1 depicts a spectrogram taken between 2400 MHz and 2483.5 MHz in Boston, which reflects some of the challenges related to deploying this band in US band. Overlaid atop the spectrogram are available 802.11 and Bluetooth channel configurations. As expected, the three channel 802.11 system predominates, with significant activity on Channels 1, 6, and 11. Intermediate (overlapping) 802.11 channel use and microwave oven activity contribute to a generally high noise and interference floor. In this example, all three Bluetooth advertising channels are clearly evident.

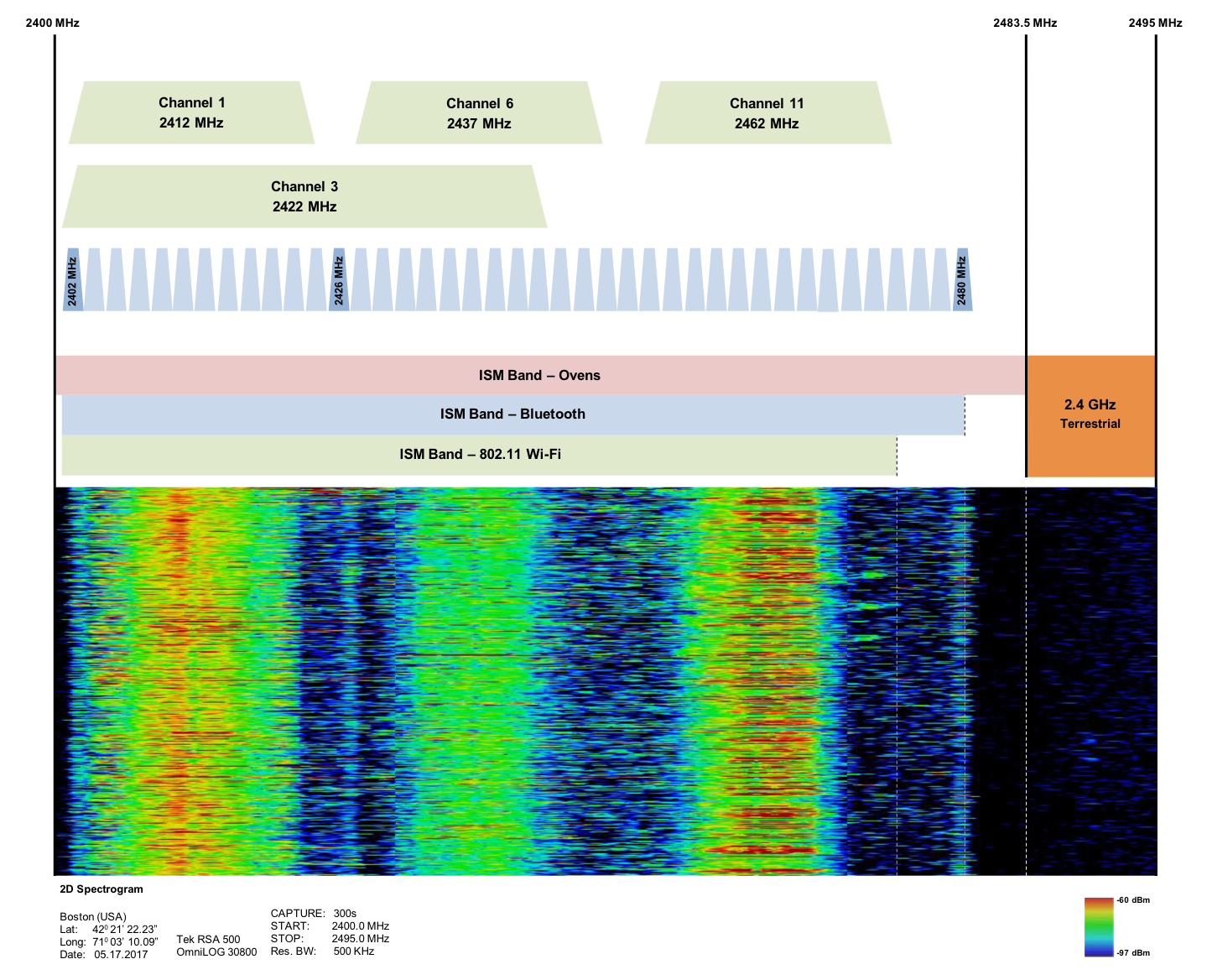


Figure 6.3.1-1: Informative Spectrogram of 2.4 GHz Band Spanning 2400 MHz to 2495 MHz (Boston, US)

### 6.3.2 2.4 GHz Terrestrial Band Relative to Unlicensed Band in the Rest of World (RoW)

It should be noted that the band plan and configuration of the 2.4 GHz Terrestrial Band is currently specific to the US. The US band many not be deployable outside of the US, due to regulatory restrictions concerning the ISM band, outside US.

## 6.4 FCC Specifications for the 2483.5-2495 LTE Band

### 6.4.1 Special Emissions and Operations Rules to Protect Unlicensed Band

Conventional Part 15 unlicensed operations in the 2400 MHz to 2483.5 MHz band are subject to the conditions that no harmful interference is caused, and that interference must be accepted that may be caused by the operation of an authorized radio station. The operator of a Part 15 unlicensed radio frequency device is required to cease operating the device upon notification by an FCC representative that the device is causing harmful interference. Radiated out of band emissions from Part 15 unlicensed operation across 2400 to 2483.5 are limited to 500 microvolts/meter at a measurement distance of 3 meters.

In authorizing the 2.4 GHz Terrestrial Band, FCC regulations were adapted to ensure co-existence between licensed services in the band above 2483.5 MHz and unlicensed services in the band below 2483.5 MHz. To protect the coexistent Wi-Fi and Bluetooth services, special operating rules and conditions were integrated into Part 27 rules. Summaries of key protective rules are listed below.

(A) **Frequency Limits:** Commercial operations are limited solely to licensed spectrum above 2483.5 MHz, and Part 25 licensed spectrum above 2483.5 MHz may not be bonded with Part 15 unlicensed spectrum below 2483.5 MHz.

(B) **Power Limits:** Power limits are identical to those in the unlicensed band with maximum permitted conducted power of 1 W (30 dBm) and EIRP of 6 dBW (36 dBm).

(C) **Emissions Limits:** For a 10 MHz channel (maximum effective channel width), emissions at must be attenuated by a factor of 40 + 10 log (P) dB (-10 dBm) at 2483.5, by a factor of 43 + 10 log (P) dB (-13 dBm) at 2478.5 MHz, and 55 + 10 log (P) dB at 2473.5 MHz (-25 dBm).

(D) **Network Operating System:** Operations must be under the control of a Network Operating System (NOS). The NOS will have the ability to resolve interference issues related to commercial operations of the 2.4 GHz licensed service.

### 6.4.2 Frequency Limits and Prohibition Against Bonding and Aggregation below 2483.5 MHz

Frequency limits for the 2.4 GHz band are governed by Title 47 of the CFR, Part 25.149. Terrestrial operation is limited to the licensed band from 2483.5 MHz to 2495 MHz. Bonding or aggregation with unlicensed services below 2483.5 MHz is prohibited by Title 47 of the CFR, Parts 15.205, 15.209, 15.247 and 15.249.

This limitation of operational frequency is further clarified by FCC Report and Order 16-181, Paragraph 32.

### 6.4.3 Power Limits for Operations Between 2483.5 MHz and 2495 MHz that Equal Levels for Part 15 Services Below 2483.5 MHz

Power limits for the 2.4 GHz Terrestrial Band are governed by Title 47 of the CFR, Part 25.149(c)(4)(i)-(iv). These power limits are identical to those found in Part 15 for unlicensed services authorized from 2400 MHz to 2483.5 MHz and they do not distinguish between base station and user equipment.

Power limits for the 2.4 GHz Terrestrial Band were justified in FCC Report and Order 16-181, Paragraph 22.

### 6.4.4 Emissions Limits Below 2483.5 MHz for Unlicensed Band Protection

Emissions limits for the 2.4 GHz Terrestrial Band are governed by Title 47 of the CFR, Part 25.149(c)(4)(v)-(vii). Figure 6.4.6-1 is a graphical summary of emissions limits for the 2.4 GHz Terrestrial Band, assuming a 10 MHz emission bandwidth. OOBE limits to protect unlicensed operations below 2483.5 MHz are justified by FCC Report and Order 16-181, Paragraphs 28-30.



Figure 6.4.6-1: FCC Mandated Emissions Limits for ISM Protection (RBW=1MHz)

### 6.4.5 Mandatory Deployment of Network Operating System

Special requirements for continuous centralized control of the 2.4 GHz band are governed by Title 47 of the CFR, Part 25.149(g)(2). These provisions provide a unique mechanism for identification and resolutions of environmental interference issues associated with the 2.4 GHz Terrestrial Band.

## 6.5 Co-Existence Evaluation for 10 MHz LTE Emission within FCC Ratified Band Plan (2483.5 MHz to 2945 MHz)

### 6.5.1 UE Worst Case Emissions to ISM band

For uplink transmissions, the unwanted emissions that leak to the ISM band were simulated using RAN4 minimum RF performance assumptions. The power amplifier was calibrated so that after 4 dB post-PA losses, 22 dBm fully populated QPSK signal is output at the antenna connector, with the emissions profile just meeting 30 dB E-UTRA ACLR requirement. The model is based on measured data from an LTE PA, related to a 23 dBm UE. No filter selectivity has been assumed in order to evaluate the close-in emission margins to the regulatory limits. The carrier frequency is placed at the lowest and the highest position within the band.

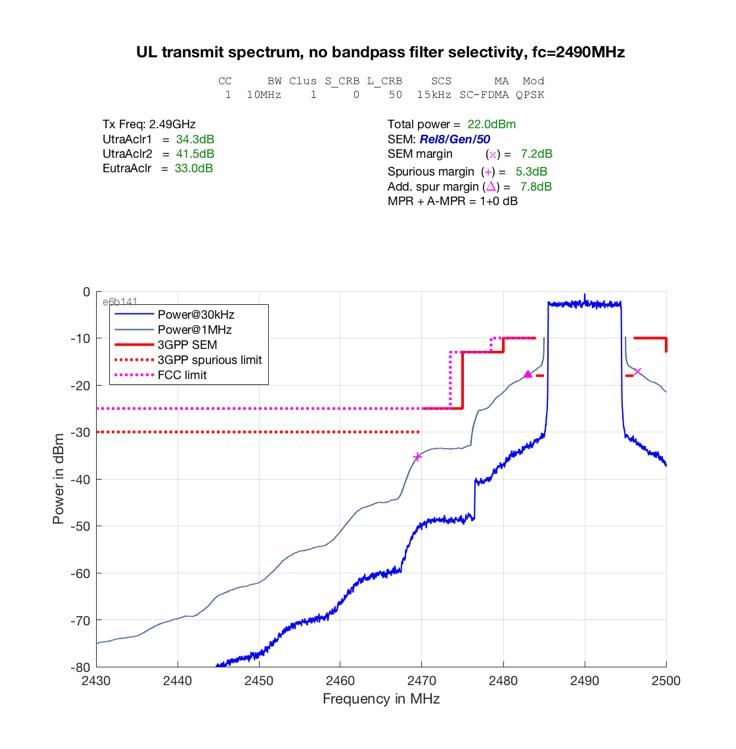
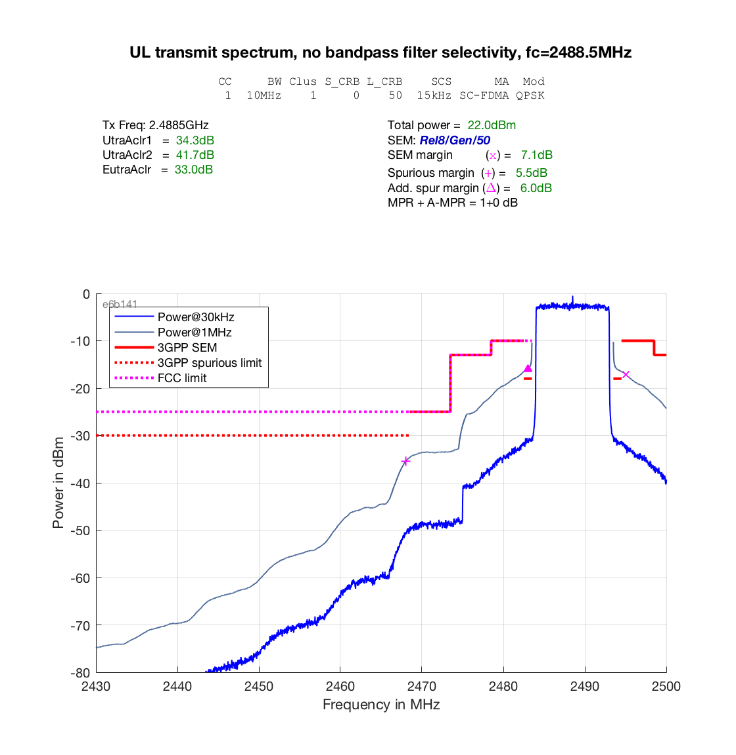


Figure 6.5.1-1: Worst Case UE TX Leakage to ISM Band, at the maximum output power for Power Class 3 UE (22 dBm for fully populated QPSK signal). Carrier frequencies at 2488.5 MHz (left) and 2490 MHz (right) shown for LTE10. Emission spectrum with 30 kHz and 1 MHz measurement bandwidth shown

It can be seen that the FCC emission mask is more relaxed than the LTE SEM (or the same as the LTE SEM in case of 2488.5 MHz carrier frequency), guaranteeing that the FCC limits are met. Also, the general spurious emission limit of   
-30 dBm/MHz is tighter than the FCC requirement on the ISM band, meaning that UEs have no trouble meeting the limits regardless of whether the general spurious limit applies. Placing the LTE10 carrier at the highest position within the band slightly alleviates the out-of-band emissions towards the ISM band.

To further improve the coexistence with ISM band services, a conservative emissions case assuming a TDD band filter have been studied. The assumptions for the filter design are as follows:

- Synchronization with Band 41 networks is assumed. This allows a relaxed response on the upper side of the band, and the lower side may be designed with a steep edge. Note that the LTE SEM should be sufficient to meet the FCC unwanted emission limits above the band, without assuming any filter selectivity.

- Filter passband is 2485-2495 MHz, i.e. the transition band starts already inside the 2.4 GHz Terrestrial Band.

- Two different filter topologies have been considered. Both are based on publicly available data sheets for 2.4 GHz (ISM) and 2.3 and 2.5 GHz (LTE) acoustic wave filters, usually referenced by RAN4.

- The first filter achieves 11 dB min., 13 dB typical attenuation at 12 MHz offset from the passband edge, with max. 3 dB insertion loss.

- The second filter achieves 20 dB min., 29 dB typical attenuation at 18.5 MHz offset from the passband edge, with max. 2.5 dB insertion loss.

- Additional insertion loss is added due to RF Front end’s switches and mismatch losses amounting to a total of 4 dB on the RF passband filter.

The emission profiles are shown in Figure 6.5.1-2.

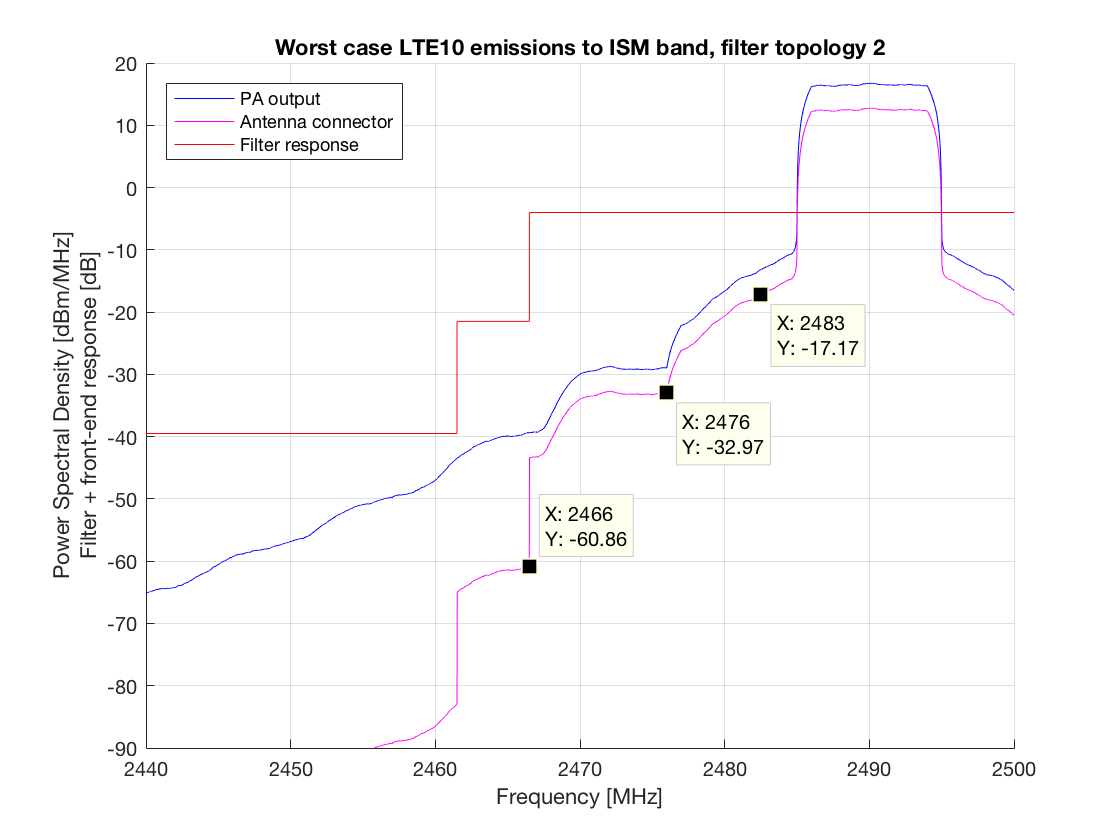
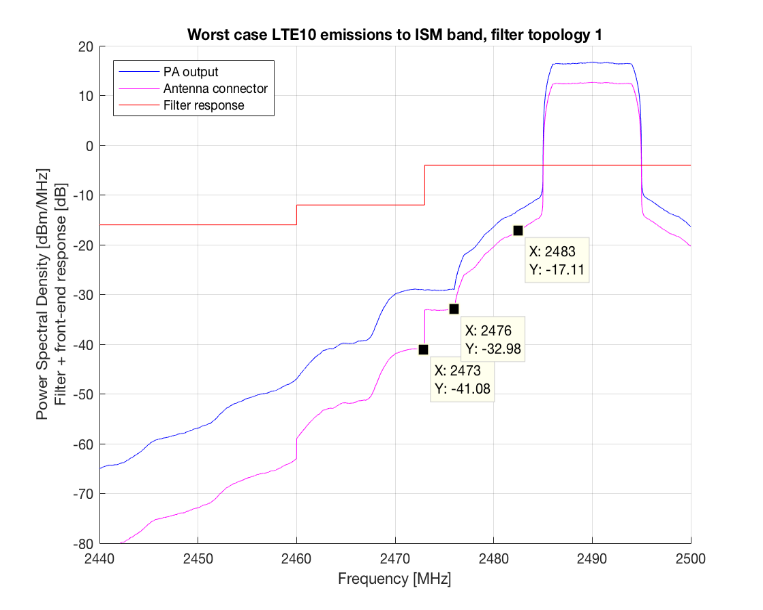


Figure 6.5.1-2: Worst Case UE TX Leakage to ISM Band Including Band Filter Minimum Response. The blue curves represent the baseline front end response without any pass band RF filter

### 6.5.2 UE Typical Emissions to ISM Band

The previous section detailed worst case unwanted emissions at the RAN4 minimum RF performance level, which is not a typical design target for any equipment. The worst-case conditions may occur across extreme temperature and operating conditions (e.g. voltage) and manufacturing tolerances, and the UE must still meet the regulatory requirements at these corners.

- Normally, e.g. 3-5 dB margin is targeted for ACLR in typical testing conditions, which indicates e.g. 5-7 dB improvement in the alternate adjacent channel (where 5th order intermodulation dominates the spectrum). This directly reduces the PA and antenna output unwanted emissions on the ISM band by a similar amount, depending on the offset from the channel edge.

- The band filter typical performance at the stopband edge depends heavily on temperature (due to frequency drift) and manufacturing tolerances. Across the stopband, it is normal to see 15-20 dB differences in the minimum vs. typical attenuation. Again, in typical conditions and across UE samples, the ISM band unwanted emissions will be lower than in the simulations shown above.

When fewer than the maximum amount of resource blocks are scheduled for a UE, the transmission bandwidth is narrower, and also the PA spectral regrowth does not reach as far as when transmitting full resource allocation. The emissions vs. resource allocation size was simulated, assuming minimum RF performance and Topology 1 filter (min. response, not typical). The results are shown in Figure 6.5.2-1 for QPSK modulation. In all cases, the transmit output power was set at maximum, i.e. 22 or 23 dBm depending on the allowed MPR.

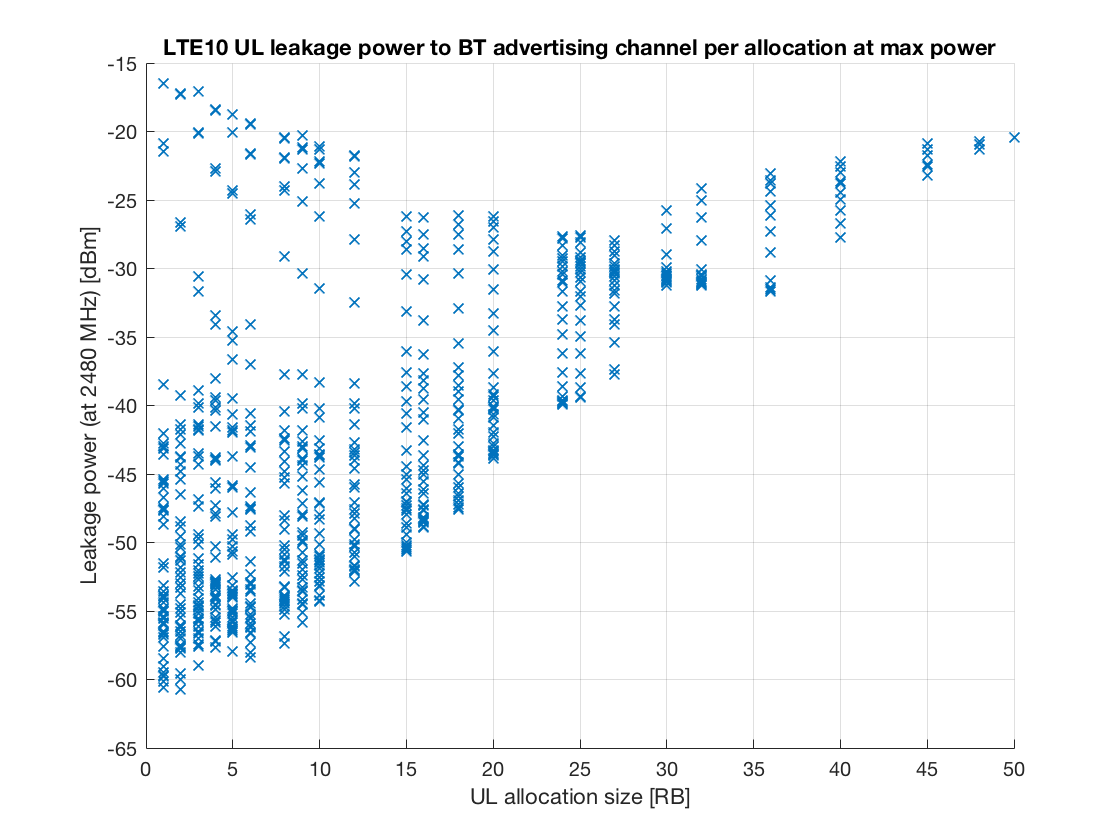
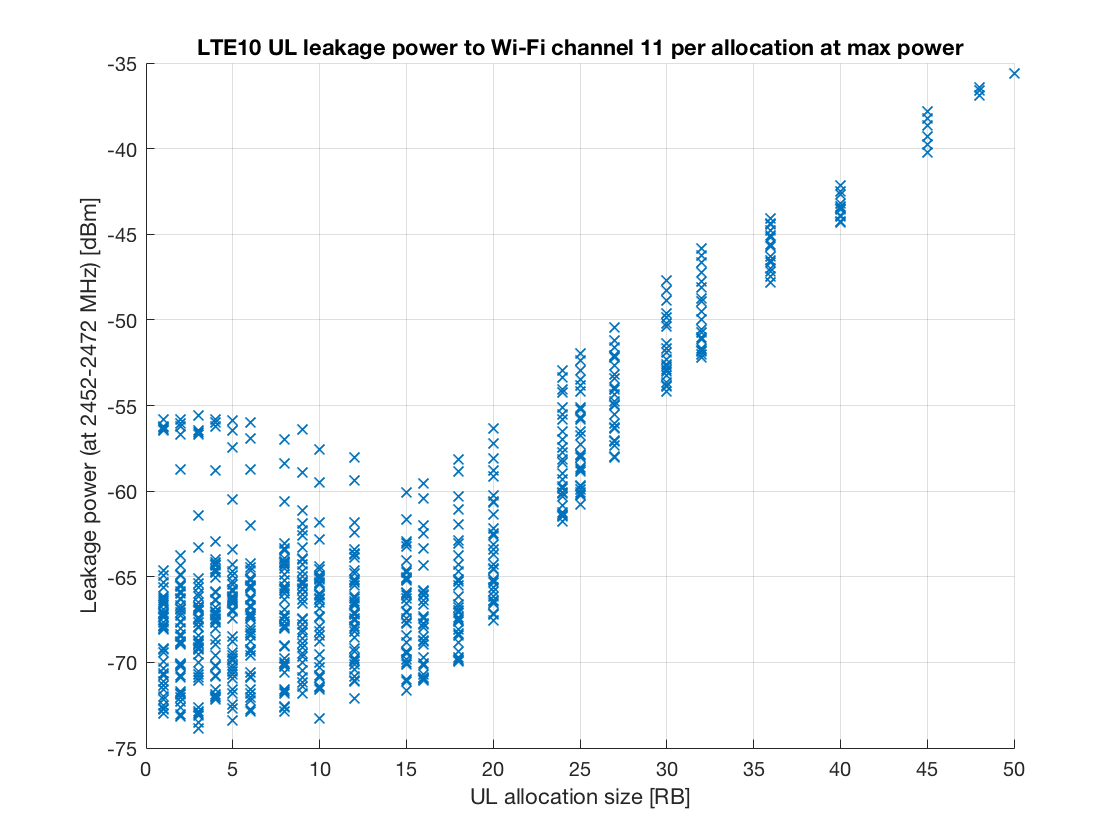


Figure 6.5.2-1: Impact of PRB allocation on the UE TX leakage to ISM band

A conservative emissions case on Wi-Fi channel 11 (integrated over 2452-2472 MHz) spans from below -65 dBm/20MHz to below -40 dBm/20MHz, with only the largest uplink allocations creating emissions reaching towards -35 dBm/20MHz. Regarding emissions to the Bluetooth advertising channel at 2480 MHz, most of the worst-case emissions are below -40 to -35 dBm/MHz, and in some rare cases the emissions may reach up to -20 or even -16 dBm/MHz. Modulation indexes 16-QAM and above will in practice show slightly lower emission profile.

The edge PRB allocations, which are used for the uplink control channel, may be typical narrowband resource configurations and deserve more detailed analysis. Figure 6.5.2-2 shows the unwanted emissions spectrum at the maximum 23 dBm output power, using the same minimum RF performance requirement assumptions as in Figure 6.5.1-1.

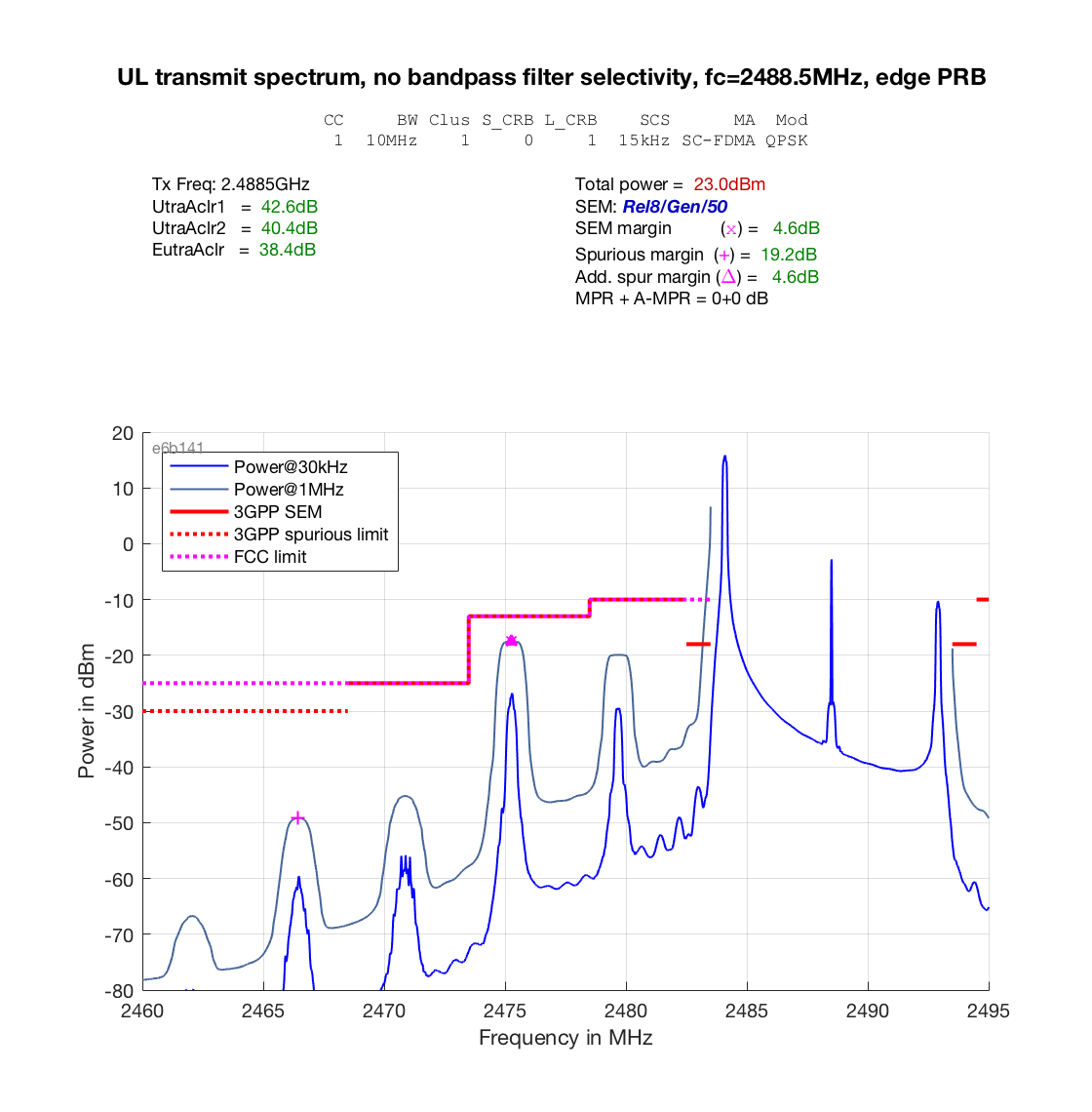


Figure 6.5.2-2: Worst case UE TX leakage to ISM band in case of edge PRB allocation

The emission spectrum shows intermodulation peaks at around 2475 and 2480 MHz frequencies. These are unwanted products of the transmit signal and its IQ image or LO leakage, forming at the non-linear PA. The IMD products don’t reach Wi-Fi ch#11 but do reach the Bluetooth frequency range, explaining the results shown in Figure 6.5.2-1. The magnitude of these IMD peaks depends heavily on the PA implementation, and the LO and IQ image suppression of the transmit chain; the result shown here represents the worst-case magnitude found in simulation models.

As a potential mitigation for the impact of IMD products, the transmit power spectral density of the PUCCH will be similar as for the PUSCH for any given UE. For a UE transmitting 22 dBm 50 PRB QPSK signal, the PUCCH transmission will be in the order of 5 dBm, significantly reducing the unwanted IMD magnitude. Uplink control information is also piggybacked on PUSCH if such allocation is scheduled, thereby reducing the amount of standalone PUCCH transmissions.

LTE also uses UL closed loop power control. In the cases when a UE doesn’t operate in cell edge conditions, it may not operate at maximum power. The unwanted emissions of practical UE transmitters would get reduced on average by at least 1:1 in dB scale, when the output power is lowered from maximum. To estimate this effect, a system simulation was performed, using Urban Macro and Urban Micro TD-LTE scenarios, and the cumulative distribution functions of the resulting output power is shown in figure 6.5.2-3. Since not all the assumptions behind the UL Total TX power, presented below, are not available, this simulation is considered informative.

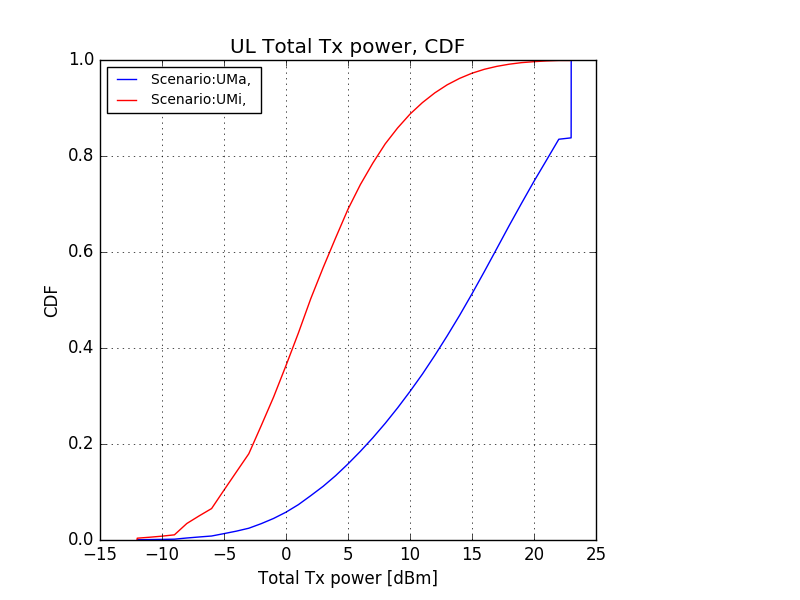


Figure 6.5.2-3: Informative System Simulation of Total UL TX Power CDF in Urban Macro and Micro Scenarios

The informative simulation results indicate that 50% of the UE transmissions occur at power levels below about 2-3 dBm in Urban Micro deployment. In indoor or small cell environments, typical transmit powers could be even lower. This presents a significant reduction in the leakage power towards the ISM band, compared to a conservative case figures shown above.

Concerning the typical emissions leaking to the ISM band we can summarize:

- Worst case emissions with full UL allocation: -35 dBm/20MHz (Wi-Fi ch#11), -20 dBm/MHz (BT 2480 MHz)

- Effect of PA operation point: -5 to -7 dB (Wi-Fi ch#11), -3 to -5 dB (BT 2480 MHz)

- Effect of filter typical vs. minimum performance: -2 to -5 dB (Wi-Fi ch#11), 0 dB (BT 2480 MHz)

- Effect of typical UL resource allocation (conservative estimates): 0 to -20 dB (Wi-Fi ch#11), 0 to -5 dB (BT 2480 MHz)

- Effect of typical UL TX power (90th and 50th percentiles, conservative 1:1 estimate on emissions): -12 to -20 dB (both Wi-Fi and BT)

- Typical emissions in the order of: **-54 to -87 dBm/20MHz** (Wi-Fi ch#11), **-31 to -50 dBm/MHz** (BT 2480 MHz)

### 6.5.3 Base Station Worst Case Emissions to ISM Band

The base station classes are defined in TS 36.104 clause 4.2, and the maximum conducted output power in clause 6.2. [Y1]

- Medium Range Base Stations are characterized by requirements derived from Micro Cell scenarios with a BS to UE minimum coupling loss equal to 53 dB.

- Maximum rated power ≤ 38 dBm (conducted)

- Local Area Base Stations are characterized by requirements derived from Pico Cell scenarios with a BS to UE minimum coupling loss equal to 45 dB.

- Maximum rated power ≤ 24 dBm (conducted)

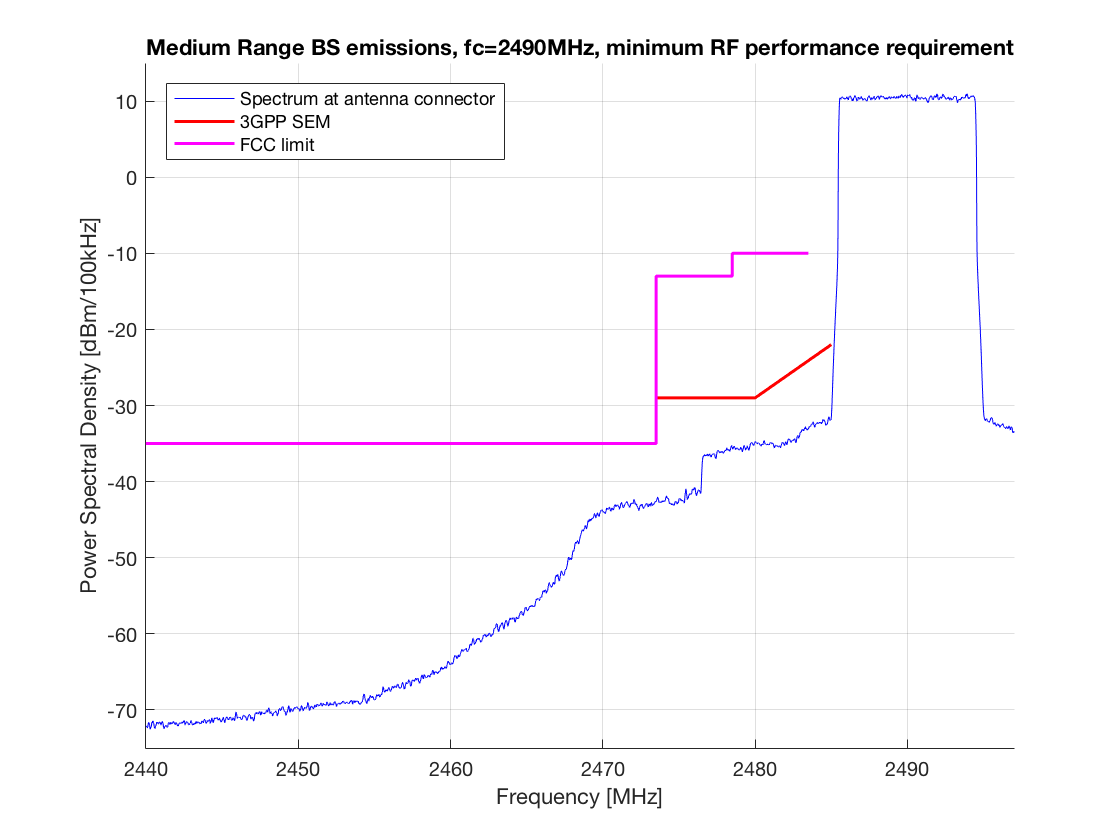
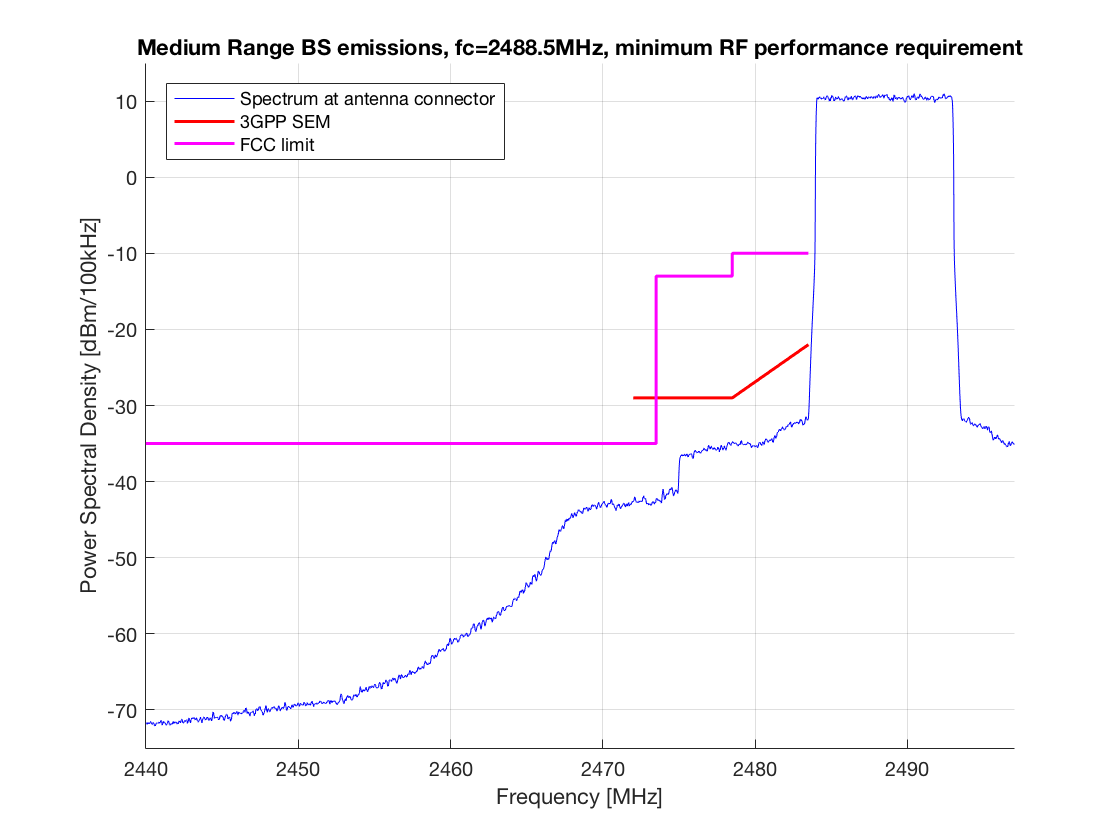
The two classes described above are considered. The Medium Range base station is limited to 1W (30 dBm) conducted power by the FCC rules applied to the 2.4 GHz Terrestrial Band, hence all calculations are based on that power. For indoor operations, the Local Area base station class is assumed. Note that the operation of equipment is not defined if the minimum coupling loss to the UE is smaller than assumed. The 53 dB MCL for Medium Range base station means in practice that it cannot be easily accessible by others than installation professionals (MCL is equivalent to 4.3 meters in free space loss).

The adjacent channel leakage ratio requirement for Medium Range and Local Area base stations on similar frequency bands is 45 dB (TS 36.104 clause 6.6.2). In addition to the adjacent channel leakage ratio requirement, unwanted emission masks apply (operating band unwanted emissions, and the spurious emissions).

The operating band unwanted emissions are defined in TS 36.104 clauses 6.6.3.2A (for Local Area base station) and 6.6.3.2C (for Medium Range base station). The operating band unwanted emissions apply up to 10 MHz offset from the band edge, i.e. above 2473.5 MHz.

The general spurious emissions applicable for the US at 1 GHz to 12.75 GHz frequency range is -13 dBm/MHz. The FCC limit for the 2.4 GHz Terrestrial Band is -25 dBm/MHz across the ISM band ≤ 2473.5 MHz, i.e. more stringent than the general spurious emission limit.

Figure 6.5.3-1 shows the emission masks as well as simulated eNB TX emissions which just meet the minimum RF requirements (ACLR = 45 dB). The FCC emission mask is scaled to 100 kHz measurement bandwidth, i.e. to -35 dBm/100 kHz. Center frequencies of 2488.5 MHz and 2490 MHz are shown. No TDD band filter has been applied.



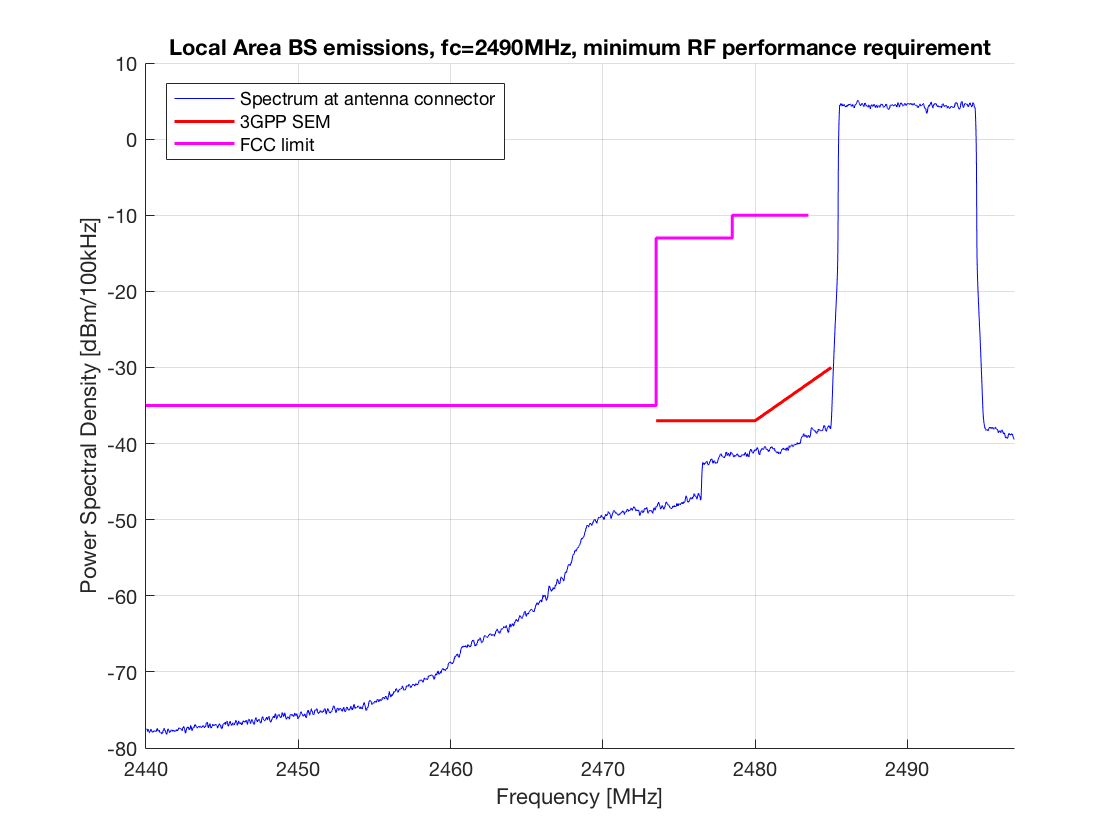
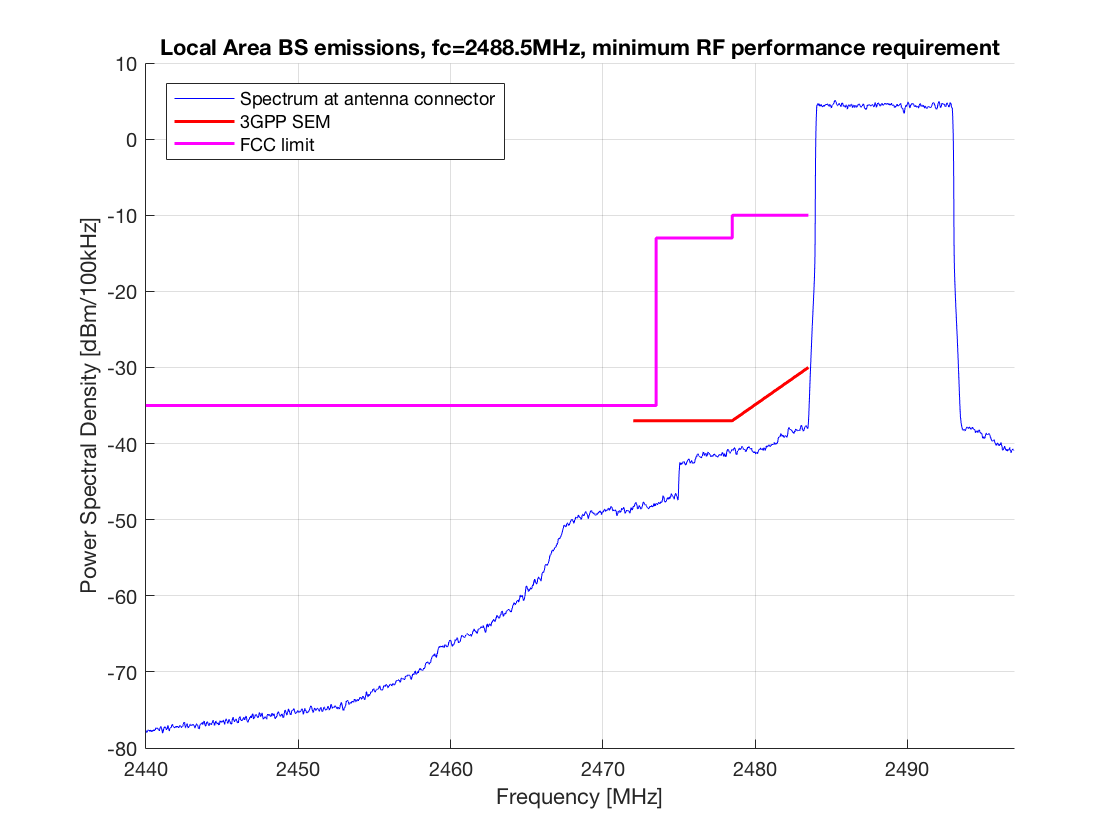


Figure 6.5.3-1: eNB emissions and emission limits toward the ISM band

It can be seen that the FCC limit is tighter than the 3GPP SEM only in the case when Medium Range base station is transmitting LTE10 at fc = 2488.5 MHz. In other cases, the 3GPP SEM is approximately 15 - 25 dB tighter on the adjacent channel. Also, the ACLR requirement is tighter than the 3GPP SEM.

### 6.5.4 Base Station Typical Emissions to ISM Band

Typical ACLR design target for BS transmitters 50 - 55 dB. This implies that the transmitter linearity is somewhat better than the simulated emissions shown in clause 6.5.3.

A practical base station includes a TDD band filter, to improve receiver blocking performance from out-of-band blockers (e.g. ISM band equipment), and to suppress the emissions towards the ISM band. While there are no existing filters for this band, publicly available data sheets of Band 41 infrastructure (small cell) bulk acoustic wave filters indicate that 24 dB typical (10 dB minimum) attenuation at 14.5 MHz offset from passband edge may be achieved, at <4 dB passband insertion loss. The attenuation increases at higher offset, with better than 38 dB minimum attenuation at 25 MHz offset. Hence, with an implementation using this filter, the unwanted emissions would be further suppressed by >34 dB below ~2460 MHz, and between 6-20 dB at 2460 MHz - 2470 MHz.

### 6.5.5 Analysis of Environmental Coexistence Impacts of 10 MHz LTE Emission Upon ISM Band Technologies

#### 6.5.5.1 General

Environmental coexistence analysis is presented for three scenarios. A 2.4 GHz terrestrial band base station is operating LTE10 with center frequency at 2488.5 MHz (i.e. at the low edge of the band), and coexisting ISM equipment that are close-by are considered. Both outdoor (Medium Range) and indoor (Local Area) scenarios are considered. No TDD band filter selectivity has been assumed in the base station transmitter, in order to estimate the worst case. Emissions are calculated from the same simulation data source as in Figure 6.5.3-1 for the frequencies in question.

The ISM band equipment included in the analysis are a low-power Bluetooth headset and mobile phone, and a Wi-Fi station and an access point.

#### 6.5.5.2 Bluetooth Coexistence

The assumptions for this scenario are listed in Table 6.5.5.2-1. Wi-Fi AP operating on Ch#11 has been included for reference. The Wi-Fi unwanted emissions at 2480 MHz have been estimated from the spectrum emission mask using 5 dB margin. All power levels are referred at the antenna connector of the equipment.

Table 6.5.5.2-1: Parameters for the Bluetooth coexistence evaluation

|  |  |
| --- | --- |
| Parameter | Value |
| Bluetooth carrier frequency | 2480 MHz |
| Bluetooth channel bandwidth | 1 MHz |
| Bluetooth data rate | 1 Mbps |
| Bluetooth TX power | -26 dBm |
| Bluetooth Signal-to-Interference requirement  - 1 Mbps rate (GFSK, 0.1% BER) | 11 dB |
| LTE carrier frequency | 2488.5 MHz |
| LTE channel bandwidth | 10 MHz |
| Medium Range BS transmit power | 30 dBm |
| Medium Range BS leakage power at 2480 MHz | -25 dBm/MHz |
| Medium Range BS maximum antenna gain | 6 dBi |
| Local Area BS transmit power | 24 dBm |
| Local Area BS leakage power at 2480 MHz | -31 dBm/MHz |
| Wi-Fi AP carrier frequency | 2462 MHz |
| Wi-Fi AP transmit power | 24 dBm |
| Wi-Fi AP leakage power at 2480 MHz | -20 dBm/MHz |

The path loss available for the 1 Mbps Bluetooth link as a function of line-of-sight distance (free space loss) from the LTE base station is presented (note that this is not the same as total link budget – to get the total link budget, the minimum SNR may be added to the available path loss). The minimum distances shown in Figure 6.5.5.2-1 illustrate the assumed minimum coupling loss for the base station classes that are considered. Bluetooth path loss calculation in the proximity of a Wi-Fi access point at Ch#11 has been included for reference. Note that in this scenario, Bluetooth has no frequency agility and cannot hop to a channel with less interference.

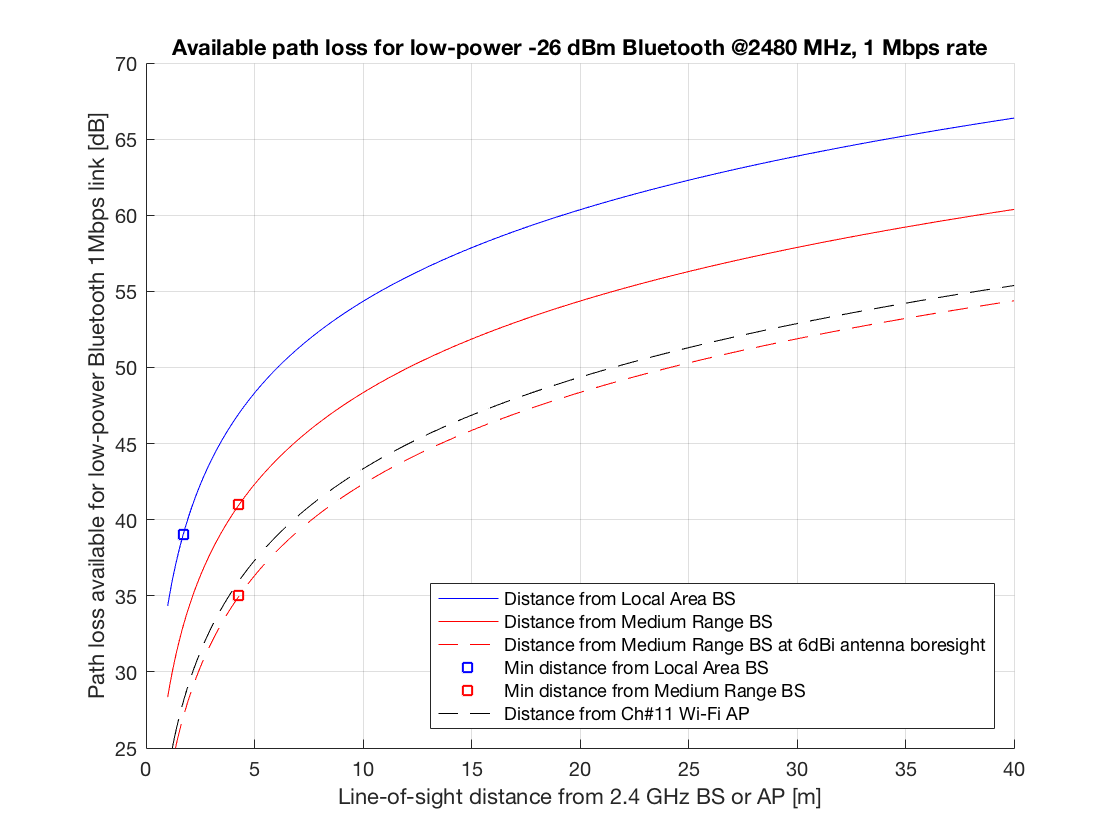


Figure 6.5.5.2-1: Available path loss for low-power Bluetooth link

It can be seen, that the link budget for the low-power Bluetooth operation is restricted in the proximity of an LTE base station using the 2.4 GHz terrestrial band. The interference level of a Medium Range base station when the victim Bluetooth receiver is at the boresight of the antenna is similar compared to a Wi-Fi access point using Ch#11. In other cases, the amount of interference is lower from the LTE base station.

If the link budget for the Bluetooth connection is insufficient during the LTE DL subframes, there is still opportunity for ISM operations during the UL subframes, which are about 20% to 80% of the radio frame in TD-LTE. This pattern is also predictable, as the TDD configuration is static for a given LTE network. Bluetooth also uses frequency hopping and may be able to switch the operating frequency to a channel with less interference.

#### 6.5.5.3 Coexistence with Wi-Fi Stations at Ch#11

In this scenario, a Wi-Fi station at Ch#11 is receiving from its serving access point. The link budget (or SINR) available for the Wi-Fi link is evaluated at different distances between the Wi-Fi station and the interfering LTE base station.

The assumptions for this scenario are listed in Table 6.5.5.3-1. Wi-Fi AP operating on Ch#6 has been included for reference; the unwanted emissions at Ch#11 have been estimated from the OFDM PHY spectrum emission mask using 5 dB margin (resulting in 36 dB ACLR)

Table 6.5.5.3-1: Parameters for the Wi-Fi station coexistence evaluation

|  |  |
| --- | --- |
| Parameter | Value |
| Ch#11 Wi-Fi carrier frequency | 2462 MHz |
| Ch#11 Wi-Fi channel bandwidth | 22 MHz |
| Ch#11 Wi-Fi AP transmit power | 23 dBm |
| Ch#11 Wi-Fi STA noise floor (9 dB NF) | -91.6 dBm/22MHz |
| LTE carrier frequency | 2488.5 MHz |
| LTE channel bandwidth | 10 MHz |
| Medium Range BS transmit power | 30 dBm |
| Medium Range BS leakage power at Ch#11 | -25 dBm/22MHz |
| Medium Range BS maximum antenna gain | 6 dBi |
| Local Area BS transmit power | 24 dBm |
| Local Area BS leakage power at Ch#11 | -31 dBm/22MHz |
| Ch#6 Wi-Fi AP carrier frequency | 2437 MHz |
| Ch#6 Wi-Fi AP transmit power | 23 dBm |
| Ch#6 Wi-Fi AP leakage power at Ch#11 | -13 dBm/22MHz |

The available link budget (for path loss and required SINR) is presented as a function of Ch#11 stations’ distance from the interfering LTE10 base station or Ch#6 Wi-Fi access point.

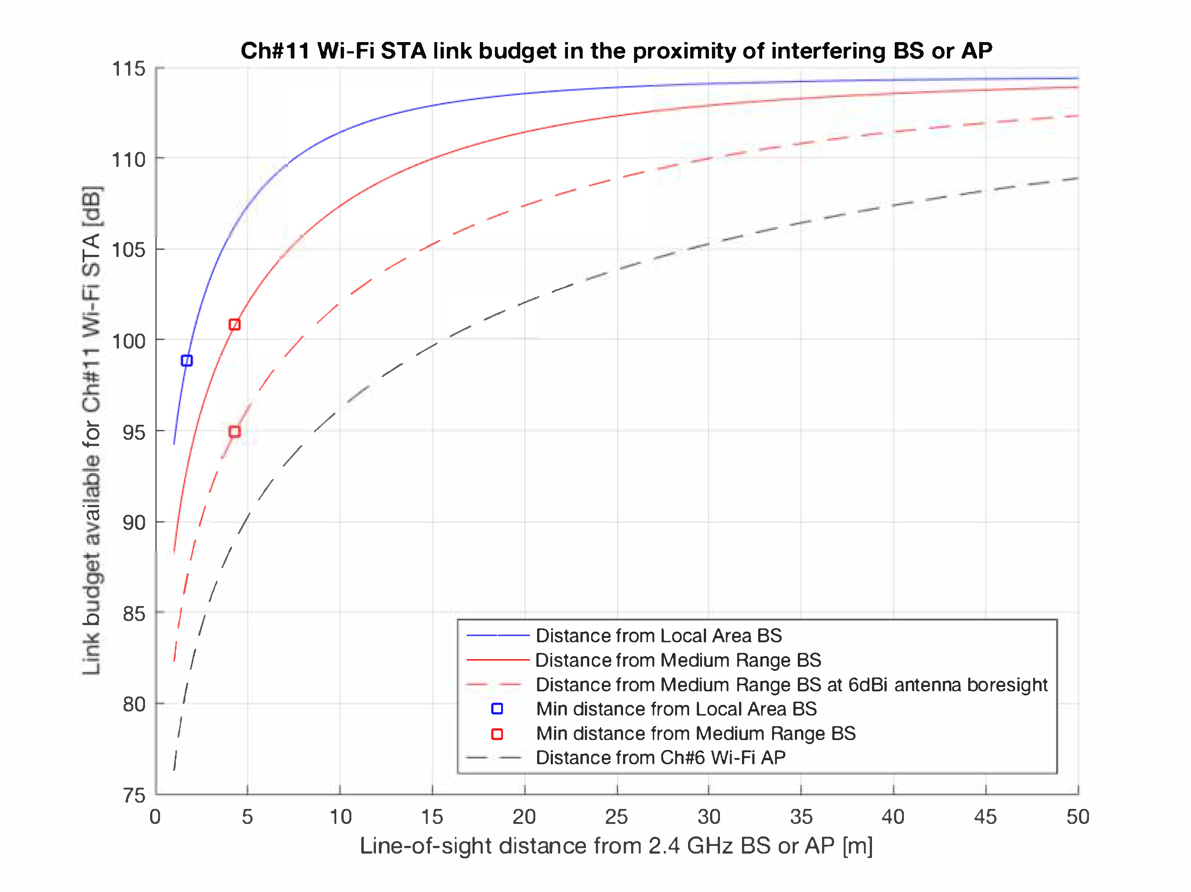


Figure 6.5.5.3-1: Available link budget for Ch#11 Wi-Fi station

The LTE base station unwanted emissions at the Ch#11 do constrain the Wi-Fi link budget by up to 15 dB, when the Wi-Fi station is very close to the base station, or by up to 20 dB if the victim Wi-Fi station is also at the boresight of the Medium Range base station antenna. The emissions characteristics of Wi-Fi at Ch#6 have more impact than an LTE base station of any type.

For the scenario, where the Wi-Fi Ch#11 station is at an equal distance from its serving access point and an LTE10 base station, Figure 6.5.5.3-2 shows the spectrum from the station’s receive antenna perspective. 36 dBm BS EIRP has been used in the figure to illustrate the potential worst case, and the emission profile is based on the minimum requirements as described in clause 6.5.3. The Wi-Fi mask is used for illustrative purposes only, to show the relative power spectral density between the BS and the AP. Note that the FCC emission limit is based on conducted measurement with 30 dBm power and is scaled to suit the 36 dBm EIRP level.

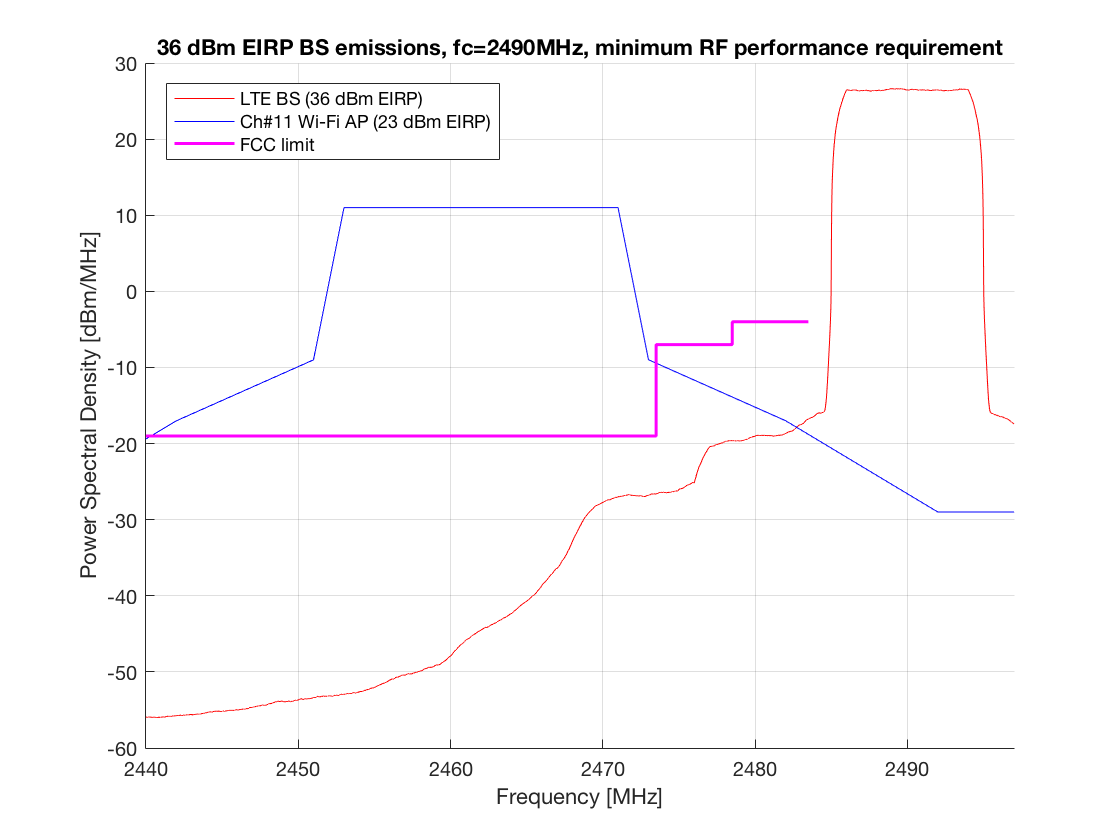


Figure 6.5.5.3-2: Available SINR for Ch#11 Wi-Fi station

The receiver SINR is summarized in Table 6.5.5.3-2 for different base station classes and distances from the serving and interfering nodes. The table also includes the scenario in which the victim Wi-Fi station is at 10x distance from its serving access point than the interfering node. Wi-Fi Ch#6 interfering node is included for reference.

Table 6.5.5.3-2: Results for Wi-Fi station coexistence evaluation

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **General parameters** | | | | |
| Interfering device | Local Area BS | Medium Range BS | Medium Range BS, victim at antenna boresight | Wi-Fi Ch#6 AP |
| Interferer EIRP | 24 dBm | 30 dBm | 36 dBm | 23 dBm |
| Leakage power | -31 dBm/22MHz | -25 dBm/22MHz | -19 dBm/22MHz | -13 dBm/22MHz |
| Serving AP transmit EIRP | 23 dBm | 23 dBm | 23 dBm | 23 dBm |
| **Scenario a** | | | | |
| Distance and path loss from interferer | 1.7 m / 45 dB | 4.3 m / 53 dB | 4.3 m / 53 dB | 1.7 m / 45 dB |
| Distance and path loss from serving AP | 1.7 m / 45 dB | 4.3 m / 53 dB | 4.3 m / 53 dB | 1.7 m / 45 dB |
| SINR | 54 dB | 48 dB | 42 dB | 36 dB |
| **Scenario b** | | | | |
| Distance and path loss from interferer | 1.7 m / 45 dB | 4.3 m / 53 dB | 4.3 m / 53 dB | 1.7 m / 45 dB |
| Distance and path loss from serving AP | 17 m / 65 dB | 43 m / 73 dB | 43 m / 73 dB | 17 m / 65 dB |
| SINR | 34 dB | 28 dB | 22 dB | 16 dB |

The interference from the LTE base station does restrict the Wi-Fi receiver SINR, when the victim receiver is very close to the interfering base station. The impact is smaller from an LTE base station than from a Wi-Fi access point on an adjacent channel, especially in the indoor scenarios (Local Area base station).

If the link budget for the Wi-Fi connection is insufficient during the LTE DL subframes, there is still opportunity for ISM operations during the UL subframes, which are about 20% to 80% of the radio frame in TD-LTE.

#### 6.5.5.4 Coexistence with Wi-Fi Access Point at Ch#11

In this scenario, a Wi-Fi access point at Ch#11 is receiving from a station that it serves. The link budget (or SINR) available for the Wi-Fi link is evaluated at different distances between the Wi-Fi access point and the interfering LTE base station.

The assumptions for this scenario are listed in Table 6.5.5.4-1. Wi-Fi AP operating on Ch#6 has been included for reference; the unwanted emissions at Ch#11 have been estimated from the OFDM PHY spectrum emission mask using 5 dB margin (resulting in 36 dB ACLR).

Table 6.5.5.4-1: Parameters for the Wi-Fi AP coexistence evaluation

|  |  |
| --- | --- |
| Parameter | Value |
| Ch#11 Wi-Fi carrier frequency | 2462 MHz |
| Ch#11 Wi-Fi channel bandwidth | 22 MHz |
| Ch#11 Wi-Fi STA transmit power | 17 dBm |
| Ch#11 Wi-Fi AP noise floor (6 dB NF) | -94.6 dBm/22MHz |
| LTE carrier frequency | 2488.5 MHz |
| LTE channel bandwidth | 10 MHz |
| Medium Range BS transmit power | 30 dBm |
| Medium Range BS leakage power at Ch#11 | -25 dBm/22MHz |
| Medium Range BS maximum antenna gain | 6 dBi |
| Local Area BS transmit power | 24 dBm |
| Local Area BS leakage power at Ch#11 | -31 dBm/22MHz |
| Ch#6 Wi-Fi AP carrier frequency | 2437 MHz |
| Ch#6 Wi-Fi AP transmit power | 23 dBm |
| Ch#6 Wi-Fi AP leakage power at Ch#11 | -13 dBm/22MHz |

The available link budget (for path loss and required SINR) is presented as a function of Ch#11 access point’s distance from the interfering LTE10 base station or Ch#6 Wi-Fi access point.

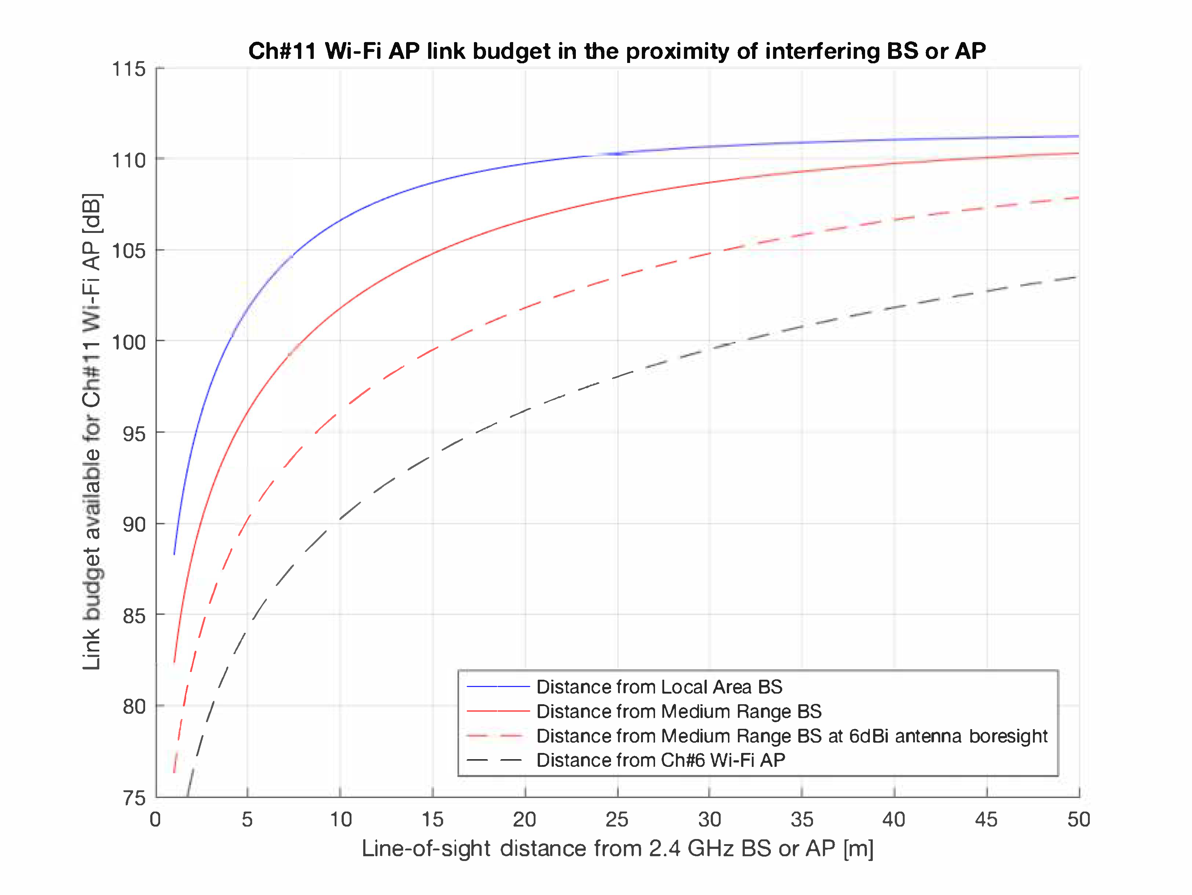


Figure 6.5.5.4-1: Available link budget for Ch#11 Wi-Fi access point

Careless deployment of Wi-Fi access points and LTE base stations will introduce some interference to the Wi-Fi AP receiver due to TX leakage from the LTE base station. The same is true in the other direction, i.e. LTE base station will suffer from some interference from the Wi-Fi AP leakage. However, the adjacent channel interference to a Ch#11 Wi-Fi AP from a Ch#6 Wi-Fi AP is higher than from any of the LTE base stations.

For the scenario, where the Wi-Fi Ch#11 access point is at an equal distance from a transmitting station and an LTE10 base station, Figure 6.5.5.4-2 shows the spectrum from the station’s receive antenna perspective. 36 dBm BS EIRP has been used in the figure to illustrate the potential worst case, and the emission profile is based on the minimum requirements as described in clause 6.5.3. The Wi-Fi mask is used for illustrative purposes only, to show the relative power spectral density between the BS and the AP. Note that the FCC emission limit is based on conducted measurement with 30 dBm power and is scaled to suit the 36 dBm EIRP level.

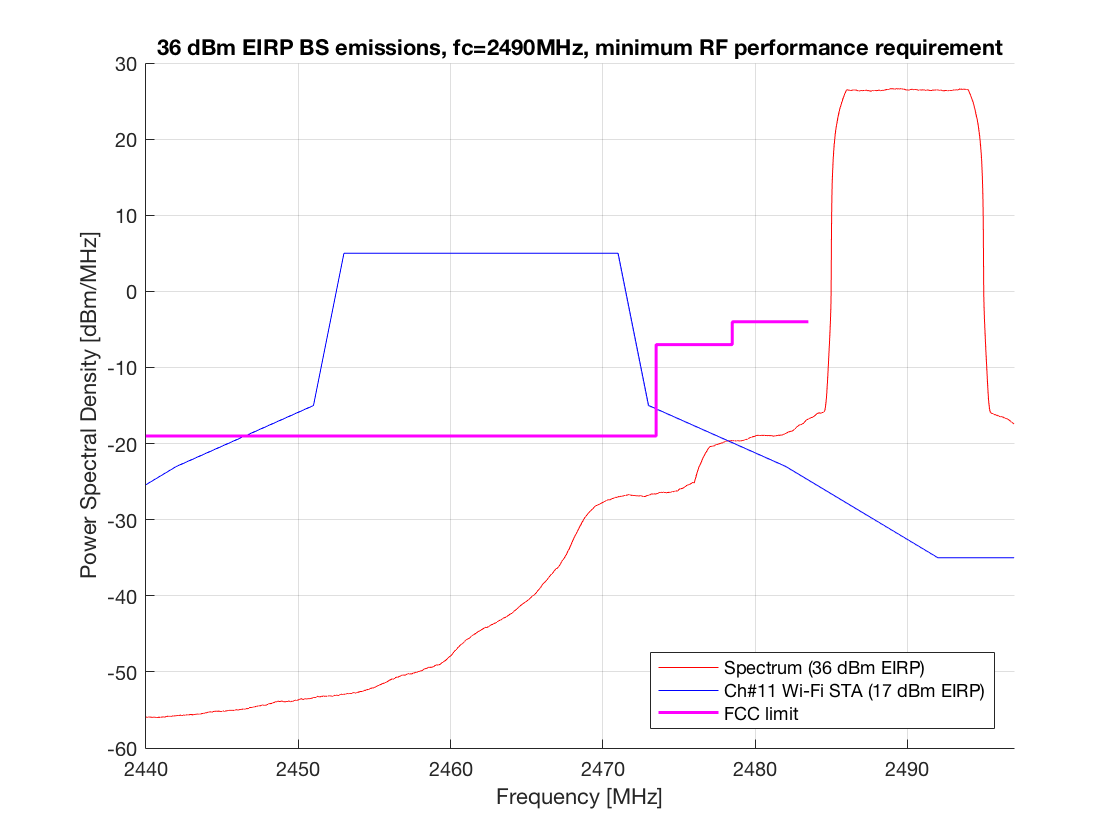


Figure 6.5.5.4-2: Available SINR for Ch#11 Wi-Fi access point

The receiver SINR is summarized in Table 6.5.5.4-2 for different base station classes and distances from the served and interfering nodes. The table also includes the scenario in which the victim Wi-Fi access point is at 10x distance from the transmitting station than from the interfering node. Wi-Fi Ch#6 interfering node is included for reference.

Table 6.5.5.4-2: Results for Wi-Fi access point coexistence evaluation

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **General parameters** | | | | |
| Interfering device | Local Area BS | Medium Range BS | Medium Range BS, victim at antenna boresight | Wi-Fi Ch#6 AP |
| Interferer EIRP | 24 dBm | 30 dBm | 36 dBm | 23 dBm |
| Leakage power | -31 dBm/22MHz | -25 dBm/22MHz | -19 dBm/22MHz | -13 dBm/22MHz |
| Transmitting station EIRP | 17 dBm | 17 dBm | 17 dBm | 17 dBm |
| **Scenario a** | | | | |
| Distance and path loss from interferer | 1.7 m / 45 dB | 4.3 m / 53 dB | 4.3 m / 53 dB | 1.7 m / 45 dB |
| Distance and path loss from station | 1.7 m / 45 dB | 4.3 m / 53 dB | 4.3 m / 53 dB | 1.7 m / 45 dB |
| SINR | 48 dB | 42 dB | 36 dB | 30 dB |
| **Scenario b** | | | | |
| Distance and path loss from interferer | 1.7 m / 45 dB | 4.3 m / 53 dB | 4.3 m / 53 dB | 1.7 m / 45 dB |
| Distance and path loss from station | 17 m / 65 dB | 43 m / 73 dB | 43 m / 73 dB | 17 m / 65 dB |
| SINR | 28 dB | 22 dB | 16 dB | 10 dB |

Based on the SINR results, it seems that in the indoor scenario (Local Area BS), deploying Wi-Fi access points will require a higher degree of network planning from adjacent channel coexistence perspective, than does the deployment of LTE base stations; this seems to be the case for Medium Range base stations as well. Also due to the potential interference from Wi-Fi Ch#11 access points to the LTE base stations, care must be taken to ensure sufficient separation.

If the available link budget for the Wi-Fi radio link is insufficient during the LTE DL subframes, there is still opportunity for ISM operations during the UL subframes, which are about 20% to 80% of the radio frame in TD-LTE.

#### 6.5.5.5 Laboratory Testing of LTE Coexistence with Ch#11 AP and STA

Laboratory testing was performed that confirms the conclusions of coexistence simulations and provides throughput performance relative to incident interference power in real-world Wi-Fi AP and STA hardware.

##### 6.5.5.5.1 Test Environment, Setup and Execution

Testing was performed inside an anechoic chamber to isolate the test environment from any external interference as well as to maintain test conditions constant through different test iterations. A setup diagram of the test is given in Figure 6.5.5.5.1-1.

A Wi-Fi link is established between a Wi-Fi Station (STA) and a Wi-Fi Access Point (AP) separated by approximately one meter. Wi-Fi STA and Wi-Fi AP antennas are placed approximately at the same height facing each other. The Wi-Fi signal level between STA and AP is controlled by placing a RF attenuator between AP and AP antennas. A signal generator was used to generate both TD-LTE and Wi-Fi interference signals.

The antenna connected to the signal generator is located approximately one meter away from the Wi-Fi STA and 1.35 meters away from the Wi-Fi AP. Wi-Fi AP is placed 1.35 meters away from the Wi-Fi STA.

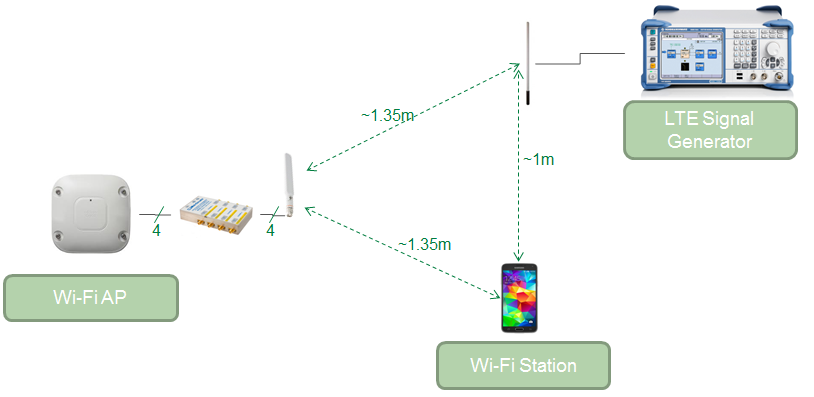


Figure 6.5.5.5.1-1: Wi-Fi Ch.11 and LTE coexistence test setup diagram

The traffic was generated by sending TCP or UDP packets directly to the transport layer from application layer. In the case of TCP flows, packets are transmitted continuously based on TCP protocol functionality.

An LTE interference signal with CF of 2490 MHz was generated using a signal generator configured to a 10MHz TDD waveform and TDD Frame Structure Configuration 1. Configuration 1 has DL/UL distribution of 60/40, which translates in an approximately channel occupancy of 60% in DL scenario and 40% in the UL scenario. The Wi-Fi Ch#6 interference signal was generated using a signal generator configured to 20MHz waveform and MCS 7, 64QAM 5/6 Modulation. Duty cycle was set to 60% for DL signal and 40% for UL Wi-Fi interference scenarios.

Data was collected via the procedure outlined in Figure 6.5.5.5.1-2. For Wi-Fi Ch#11, RSSI values of -55 dBm, -65 dBm, and -75 dBm are used. TD-LTE interference levels at the DUT are stepped in 1 dBm increments from OFF, -55 dBm to -25 dBm. DL and UL Wi-Fi traffic directions are measured subject to DL and UL TD-LTE interference sources.



Figure 6.5.5.5.1-2: Wi-Fi Ch.11 and LTE coexistence test execution flow chart

##### 6.5.5.5.2 Ch#11 Wi-Fi Data Throughput with TD-LTE Interference

Using the test configuration and methodology outlined in Section 6.5.5.5.1, absolute and relative Wi-Fi Ch#11 DL (AP to STA) throughput was measured in the presence of an LTE interference source. Figure 6.5.5.5.2-1 shows absolute Ch#11 DL throughput in the presence of a DL and UL LTE interference signals, while Figure 6.5.5.5.2-2 shows the same test in relative throughput terms.

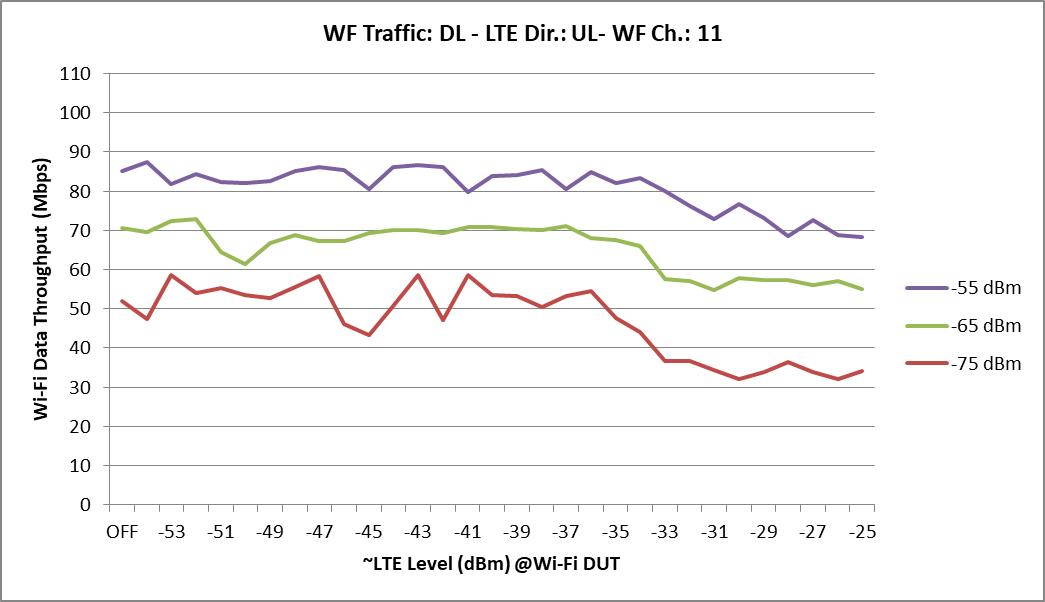
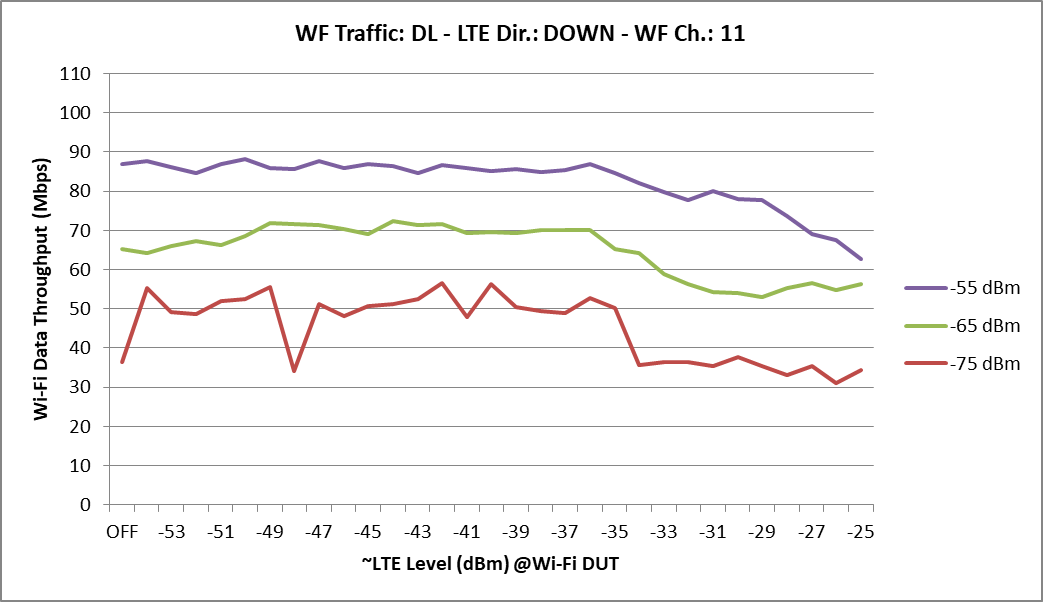


Figure 6.5.5.5.2-1: DL Wi-Fi Ch#1 absolute throughput in presence of DL and UL LTE interference signal

At all Wi-Fi RSSI levels, statistically significant impact to Ch#11 DL throughput is observed at incident LTE interference powers ≥ -34 dBm. The average impact to Ch#11 DL throughput is slightly higher for DL LTE interference signals than for UL LTE interference signals. This is as expected due to the higher channel occupancy of the DL LTE signal in Frame Structure Configuration 1.

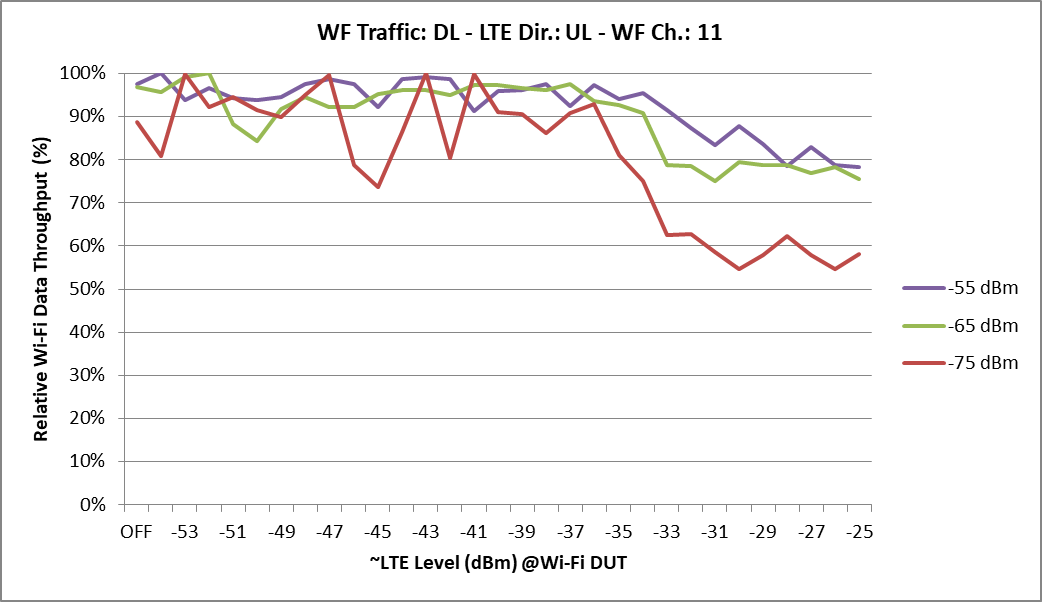
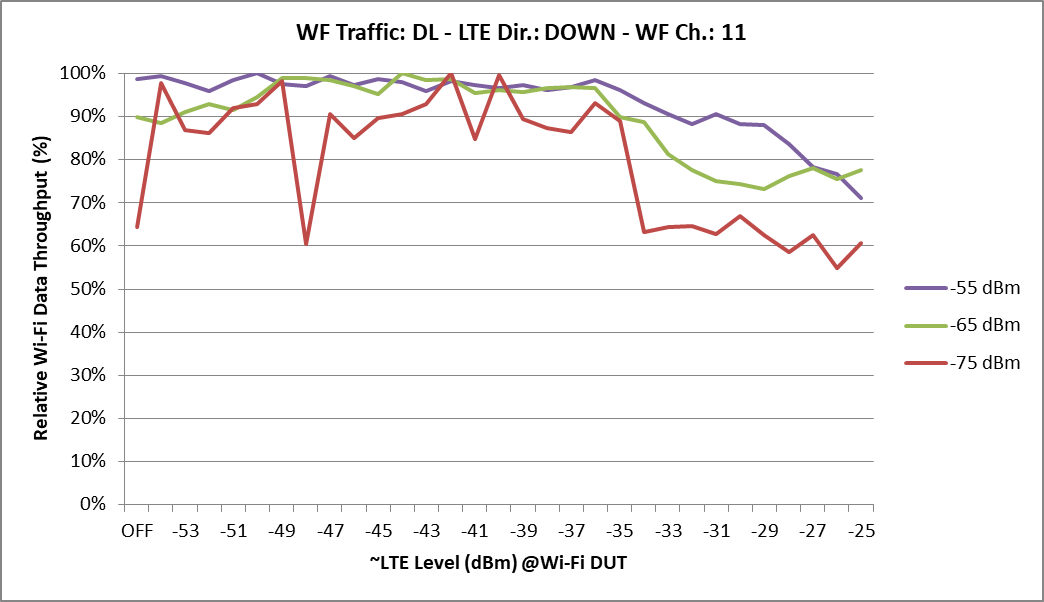


Figure 6.5.5.5.2-2: DL Wi-Fi Ch#11 relative throughput in presence of DL and UL LTE interference signal

Also using the test configuration and methodology outlined in Section 6.5.5.5.1, absolute and relative Wi-Fi Ch#11 UL (STA to AP) throughput was measured in presence of an LTE interference source. Figure 6.5.5.5.2-3 shows absolute Ch#11 UL throughput in the presence of a DL and UL LTE interference signals, while Figure 6.5.5.5.2-4 shows the same test in relative throughput terms.

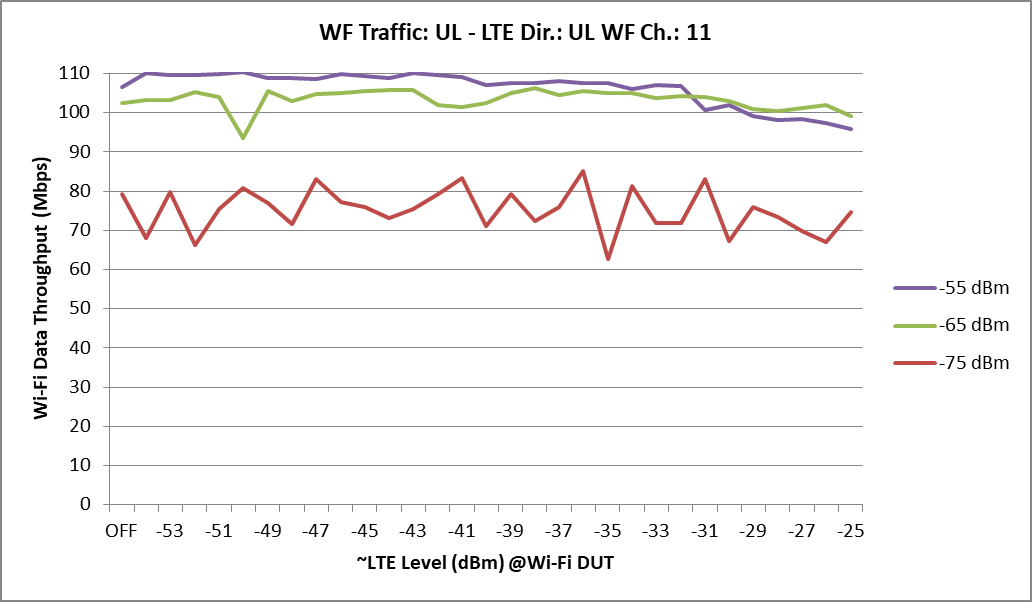
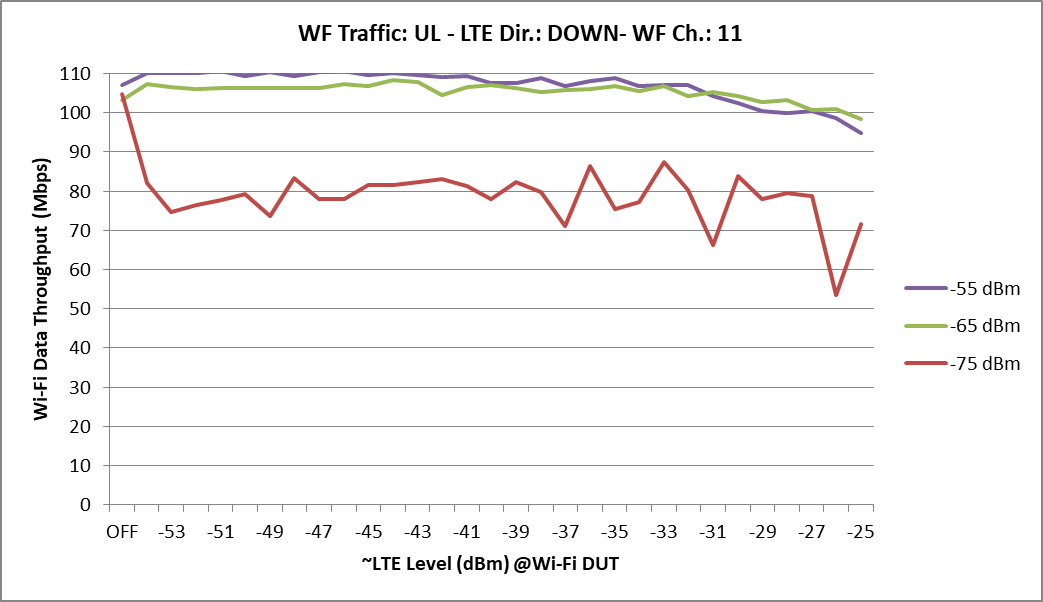


Figure 6.5.5.5.2-3: UL Wi-Fi Ch#11 absolute throughput in presence of DL and UL LTE interference signal

At all Wi-Fi RSSI levels, statistically significant impact to Ch#11 UL throughput is observed at incident LTE interference powers ≥ -32 dBm. As in the UL case, the average impact to Ch#11 UL throughput is higher for DL LTE interference signals than for UL LTE interference signals. This is as expected due to the higher channel occupancy of the DL LTE signal in Frame Structure Configuration 1. Ch#11 UL is less impacted than Ch#11 downlink, especially at higher RSSI levels (-55 dBm and -65 dBm).

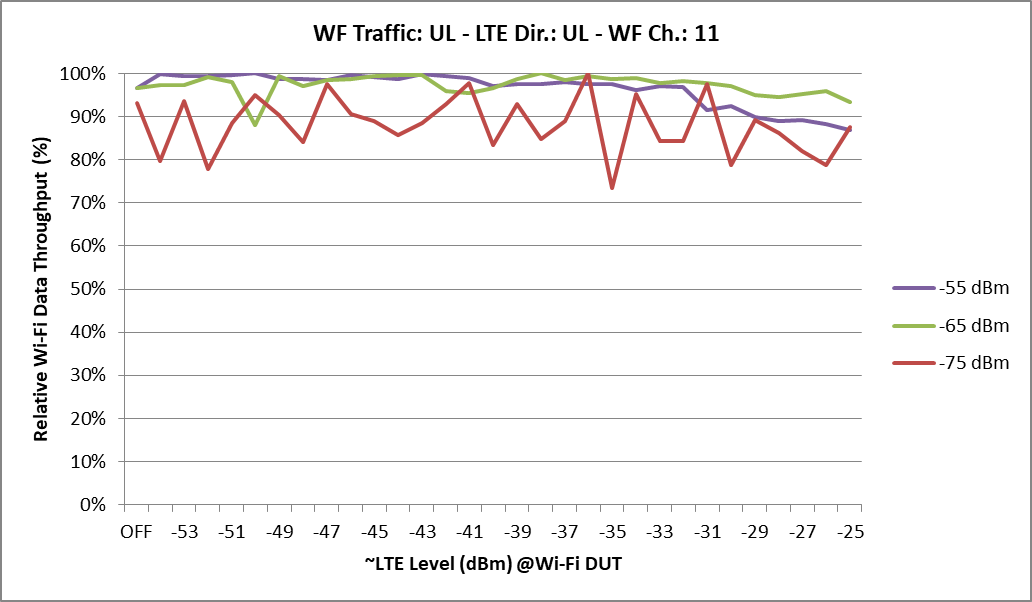
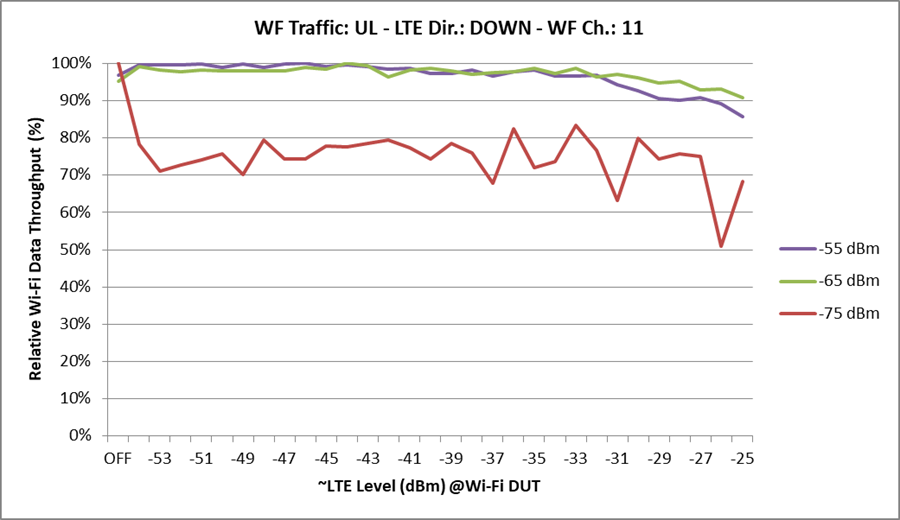


Figure 6.5.5.5.2-4: UL Wi-Fi Ch#11 relative throughput in presence of DL and UL LTE interference signal

##### 6.5.5.5.3 Ch#11 Wi-Fi Data Throughput with Ch#6 Wi-Fi Interference

Using the test configuration and methodology outlined in Section 6.5.5.5.1, absolute and relative Wi-Fi Ch#11 DL (AP to STA) and throughput was measured in the presence of a Wi-Fi Ch#6 DL interference source with similar channel occupancy to a DL LTE signal in Frame Configuration 1. Figure 6.5.5.5.3-1 shows absolute Ch#11 throughput in the presence of a DL Ch#6 interference signal, while Figure 6.5.5.5.3-2 shows the same test in relative throughput terms.

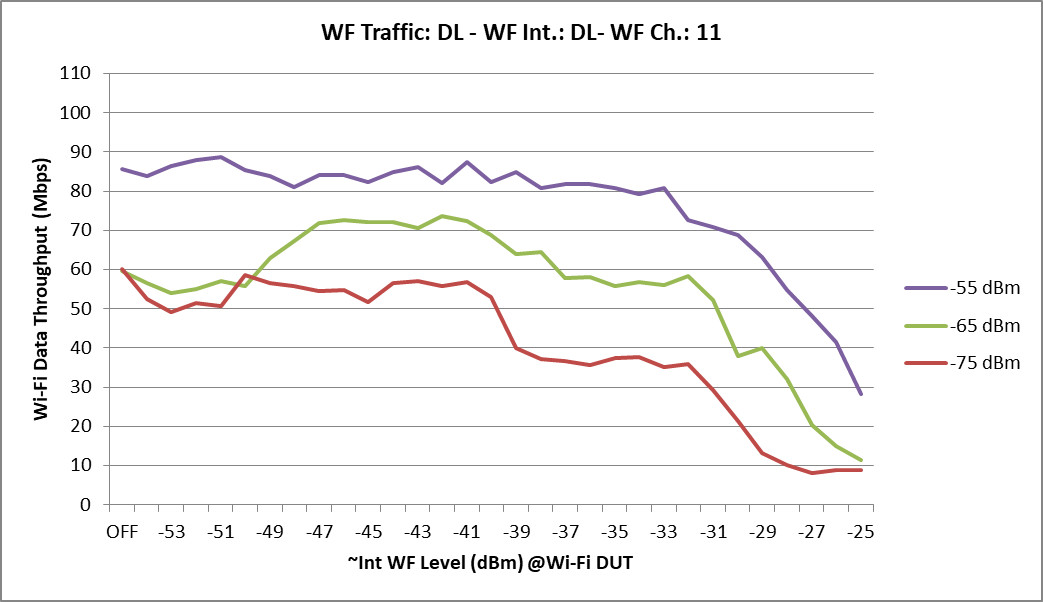


Figure 6.5.5.5.3-1: DL Wi-Fi Ch#11 absolute throughput in presence of DL Wi-Fi Ch#6 interference signal

At all Wi-Fi RSSI levels, statistically significant impact to Ch#11 DL throughput is observed at incident Ch#6 interference powers ≥ -40 dBm. The impact to Ch#11 DL throughput from Ch#6 DL interference is meaningfully higher than the impact to Ch#11 DL throughput from LTE DL interference.

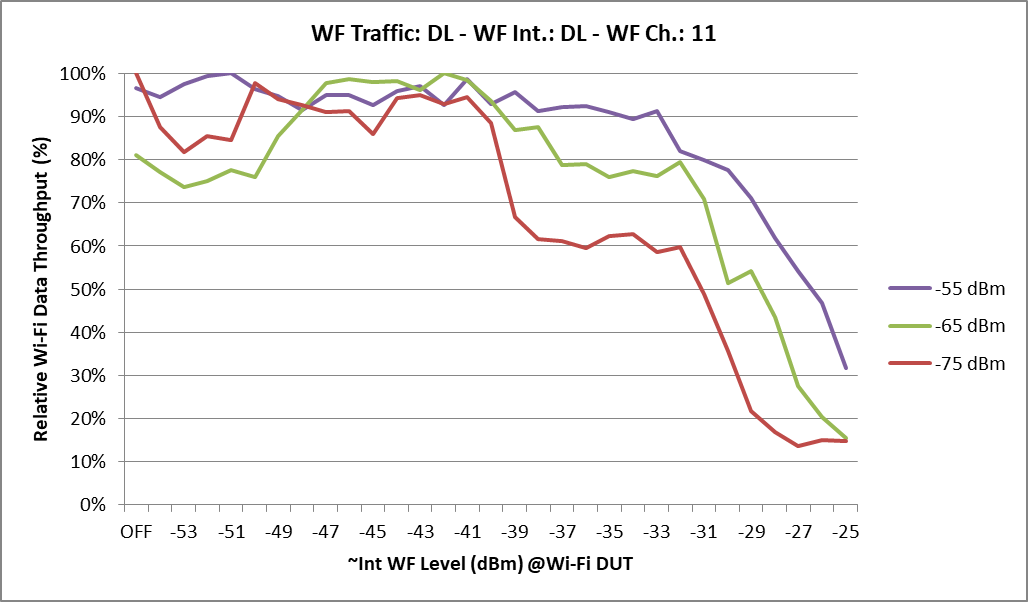


Figure 6.5.5.5.3-2: DL Wi-Fi Ch#11 relative throughput in presence of DL Wi-Fi Ch#6 interference signal

### 6.5.6 Analysis of In-Device Coexistence Impacts of 10 MHz LTE Emission Upon ISM Band Technologies

#### 6.5.6.1 General

This clause presents frequency and time domain analysis of In-Device Coexistence (IDC) within a UE incorporating 2.4 GHz TDD LTE radio and Wi-Fi / Bluetooth 2.4 GHz ISM band radio(s).

TR 36.816 [5] presents the study results on IDC interference, and potential solutions to address the impact. The usage scenarios identified in [5] are:

1a) LTE + BT earphone (VoIP service)

1b) LTE + BT earphone (Multimedia service)

2) LTE + WiFi portable router

3) LTE + WiFi offload

4) LTE + GNSS Receiver

No issues with GNSS Receiver are expected due to the large frequency separation to the satellite receiver frequencies (<1600 MHz). Sufficient coexistence has been demonstrated with LTE bands significantly closer than the 2.4 GHz E-UTRA TDD band, hence no study has been done.

#### 6.5.6.2 Frequency Domain Analysis

##### 6.5.6.2.1 General

Similar as in [5], for the IDC interference with Bluetooth and Wi-Fi, the assumptions are made:

Table 6.5.6.2.1‑1: IDC assumptions for the RF analysis

|  |  |
| --- | --- |
| Parameter | Value |
| LTE Band | 2483.5-2495 MHz |
| LTE center frequency | 2490 MHz |
| ISM technology considered | BT, WLAN |
| Interference directions considered | LTE to BT/WLAN;  BT/WLAN to LTE |
| Interference mechanisms considered | Spurious emission and blocking |
| Filter | FBAR |
| Antenna Isolation | 12 dB |
| LTE Tx power | 23 dBm |
| WLAN Tx power | 20 dBm |
| BT Tx power | 20 dBm |
| LTE RSSI (as victim) | -94 dBm |
| WLAN RSSI | -79 dBm |
| BT RSSI | -90 dBm |
| LTE Bandwidth | 10 MHz |
| WLAN Bandwidth | 22 MHz |
| BT Bandwidth | 1 MHz |
| Performance measure | Desensitization (in dB) |

The interference mechanisms considered are both spurious emissions (TX leakage) and receiver blocking.

The LTE band filter is according to the filter topology 1 as outlined in clause 6.5.1. Based on initial studies, this is the worst of the two topologies overall for coexistence purposes. The ISM band filter does not provide selectivity on the considered LTE frequency band, i.e. has a flat frequency response in this context. 4 dB insertion loss across the passband has been used for filters of all radio technologies.

The victim receiver is assumed to be in the max gain mode, and 9 dB Noise Figure has been assumed. The effect of TX leakage is evaluated against this noise level. For receiver blocking, a 3-stage cascaded amplifier noise model has been assumed (the stages being RF filter, LNA, and the rest of the RX chain). At max gain, the model has 9 dB NF, and the LNA gain is assumed to be lowered in the presence of a strong blocking signal in order to prevent RF front-end overload. The actual blocking performance depends on receiver implementation and gain control algorithms.

##### 6.5.6.2.2 LTE to ISM Interference

The LTE TX leakage is based on RAN4 minimum RF performance simulation as shown in clause 6.5.1.

Table 6.5.6.2.2‑1: IDC impact from LTE TX leakage to ISM receiver noise level

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| LTE->ISM | Wi-Fi | | | Bluetooth | | | |
| Ch#11 | Ch#6 | Ch#1 | 2480 | 2460 | 2440 | ≤2430 |
| TX leakage power | -27 dBm/ 22 MHz | -52 dBm/ 22 MHz | -75 dBm/ 22 MHz | -16 dBm/ MHz | -60 dBm/ MHz | -77 dBm/ MHz | -88 dBm/ MHz |
| Antenna isolation | 12 dB | 12 dB | 12 dB | 12 dB | 12 dB | 12 dB | 12 dB |
| TX leakage at ISM input | -39 dBm/ 22 MHz | -64 dBm/ 22 MHz | -89 dBm/ 22 MHz | -28 dBm/ MHz | -72 dBm/ MHz | -89 dBm/ MHz | -100 dBm/ MHz |
| ISM input-referred noise | -91 dBm/ 22 MHz | -91 dBm/ 22 MHz | -91 dBm/ 22 MHz | -105 dBm/ MHz | -105 dBm/ MHz | -105 dBm/ MHz | -105 dBm/ MHz |
| **ISM noise level increase** | **52 dB** | **27 dB** | **4.1 dB** | **77 dB** | **33 dB** | **16 dB** | **6.2 dB** |

Regarding receiver blocking, the ISM receiver desense can be estimated as follows:

Table 6.5.6.2.2‑2: IDC impact of ISM receiver blocking

|  |  |
| --- | --- |
| LTE->ISM | Wi-Fi/BT Any |
| LTE TX power | 23 dBm |
| Antenna isolation | 12 dB |
| LTE blocking power at ISM input | 11 dBm |
| LTE blocking power at LNA input | 7 dBm |
| LNA gain to prevent mixer from saturating (assuming 0 dBm peak output power and 10 dB peak-to-average power ratio) | -17 dB |
| **Effect to RX NF due to AGC** | **>28 dB** |

The NF effect is based on the assumption, that the LNA-mixer saturation is largely independent on frequency offset, as the 2.4 GHz E-UTRA band is practically inside the RF input passband. The LNA gain is lowered in order to prevent saturation in the following receiver stages, and this increases the front-end Noise Figure.

As a conclusion, the IDC interference from LTE10 uplink transmissions may cause significant desense to the whole 2.4 GHz ISM band (in the excess of >28 dB to as much as 77 dB, depending on the victim receiver type and operating frequency).

##### 6.5.6.2.3 ISM to LTE Interference

The TX leakage of Wi-Fi is based on measured Wi-Fi unwanted emissions [6], Annex A (Conducted emissions test data). The measured Wi-Fi equipment are access points, and it is estimated that similar or worse unwanted emissions spectrum would be applicable for practical Wi-Fi mobile chipsets. The far-away spurious emissions noise floor is assumed at -135 dBm/Hz (at around fc+50 MHz), and the emission spectrum is decaying from the shown level (at fc+25 MHz) linearly in the dB domain.

The TX spectral regrowth of Bluetooth is assumed to be narrowband, and the TX leakage is based on wideband noise only. The level is estimated at -122 dBm/Hz. The IDC analysis is based on TX leakage and LTE receiver blocking.

Table 6.5.6.2.3-1: IDC impact of IDC TX leakage to LTE receiver noise level

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Wi-Fi->LTE | Wi-Fi | | | Bluetooth |
| Ch#11 | Ch#6 | Ch#1 | Any channel |
| TX leakage power | -15 dBm/9 MHz | -60 dBm/9 MHz | -65 dBm/9 MHz | -52 dBm/9 MHz |
| Antenna isolation | 12 dB | 12 dB | 12 dB | 12 dB |
| TX leakage at LTE input | -27 dBm/9 MHz | -72 dBm/9 MHz | -77 dBm/9 MHz | -40 dBm/9 MHz |
| LTE input-referred noise | -95.5 dBm/9 MHz | -95.5 dBm/9 MHz | -95.5 dBm/9 MHz | -95.5 dBm/9 MHz |
| **LTE noise level increase** | **69 dB** | **24 dB** | **19 dB** | **55.5 dB** |

Table 6.5.6.2.3-2: IDC impact of LTE receiver blocking

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| ISM->LTE | Wi-Fi | | | Bluetooth | | |
| Ch#11 | Ch#6 | Ch#1 | 2480 | 2470 | ≤2460 |
| ISM TX power | 20 dBm | 20 dBm | 20 dBm | 20 dBm | 20 dBm | 20 dBm |
| Antenna isolation | 12 dB | 12 dB | 12 dB | 12 dB | 12 dB | 12 dB |
| ISM blocking power at LTE input | 8 dBm | 8 dBm | 8 dBm | 8 dBm | 8 dBm | 8 dBm |
| LTE filter suppression | 11 dB | 16 dB | 16 dB | 4 dB | 11 dB | 16 dB |
| ISM blocking power at LNA input | -3 dBm | -8 dBm | -8 dBm | 4 dBm | -3 dBm | -8 dBm |
| LNA gain to prevent mixer from saturating (assuming 0 dBm peak output power and 10 dB peak-to-average power ratio) | -7 dB | -2 dB | -2 dB | -4 dB | 3 dB | 8 dB |
| **Effect to RX NF due to AGC** | **18 dB** | **13 dB** | **13 dB** | **15 dB** | **8 dB** | **4 dB** |

As a conclusion, the IDC interference from IDC transmitter to LTE receiver may be dominated by the TX unwanted emissions, the noise floor increase being from 19 dB up to 69 dB. LTE receiver blocking is also not insignificant and may be an important contributor.

#### 6.5.6.3 Time Domain Analysis

##### 6.5.6.3.1 General

Table 5.3-1 of TR 36.816 [5] lists the applicability of different identified TDM solutions for each usage scenario. It may be noted that no 3GPP specification for HARQ process reservation-based solution was developed during the IDC WI; however, some additions to the DRX parameter values were done during Rel-11, to make the DRX based solution more applicable to the usage scenarios.

The DRX based solution is applicable to all usage scenarios listed in TR 36.816 [5]. As a complementary solution, some LTE uplink subframes may be blocked by the UE autonomously, if the transmission would jeopardize critical ISM signalling.

The basics of the DRX based solution is shown below (TR 36.816 [5] Figure 5.2.1.2.1-2):



Figure 6.5.6.3.1-1: Example of DRX configured by eNB to enable TDM [5]

The Rel-11 improvements to DRX to better work as a TDM solution for IDC allow relatively sharp transition from the LTE active duration to the off-period. This is achieved by using short DRX inactivity and retransmission timer values, low maximum retransmission count, and by restricting the scheduling towards the end of the active time. The penalty is ~1% data loss at HARQ level (due to typical 10% BLER target), but may be compensated by more robust MCS selection at the scheduler. In the following analysis, 8 ms of the LTE on-duration is left unscheduled and still unavailable for ISM operations.

The theoretical data rate for TD-LTE 10 MHz channel is around 15-58 Mbps in DL (20-80% of subframes), and 7-21 Mbps in UL (20-60% of subframes). This assumes 64-QAM modulation (256-QAM is an optional capability), 2 MIMO streams in DL and a single stream in UL.

All of the TDM analysis are based on bi-directional interference scenario, i.e. LTE TX causes interference to ISM RX, and ISM TX to LTE RX. In practical cases, one of the interference directions may be missing, e.g. if the TX power levels are sufficiently low.

##### 6.5.6.3.2 LTE + BT Earphone (VoIP Service)

Annex B of TR 36.816 [5] contains analysis for this scenario, when no specific LTE solution is applied. The TD-LTE subframes and Bluetooth TX and RX slots align so that TX and RX are not concurrent. For EV3 Bluetooth voice connection, the following results have been obtained (TR 36.816 [5] Table B.2.1A-1). Note that only the interference scenario which corrupts all available Bluetooth channels is shown in the below table.

Table 6.5.6.3.2-1: BT EV3 and LTE collision ratio [5]

|  |  |  |
| --- | --- | --- |
| LTE TDD UL/DL Configuration | BT Collision ratio | LTE Collision ratio |
| 0 | 0% | 0% |
| 1 | 0% | 0% |
| 2 | 0% | 8.3% |
| 3 | 0% | 14.3% |
| 4 | 0% | 16.7% |
| 5 | 12.5% | 18.5% |
| 6 | 25% | 0% |

For some TDD configurations, the amount of collisions may be significant. Note that in the VoIP service scenario, LTE will typically only require some DL and UL subframes during each VoIP period, so that some of the potential collisions may be recovered by re-transmissions.

For TDD configurations 1 and 2, which are in use on E-UTRA Band 41, [5] shows the time-domain analysis without any LTE IDC solution. The analysis assumes that the Bluetooth link timing can be adjusted relative to the LTE frame timing, which should be possible at least if the IDC Bluetooth is the master.

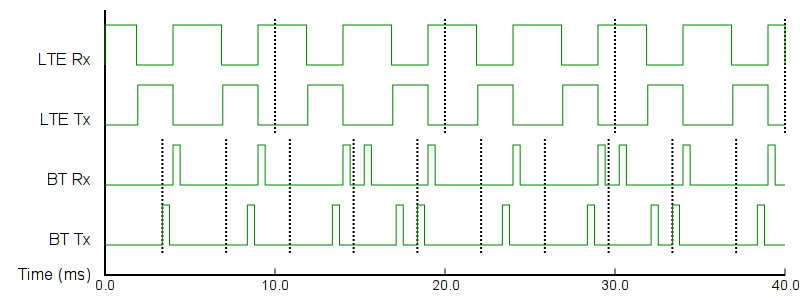


Figure 6.5.6.3.2-1: TDD Configuration 1 and BT EV3 (Offset of BT relative to LTE frame: 3.375 ms) [5]

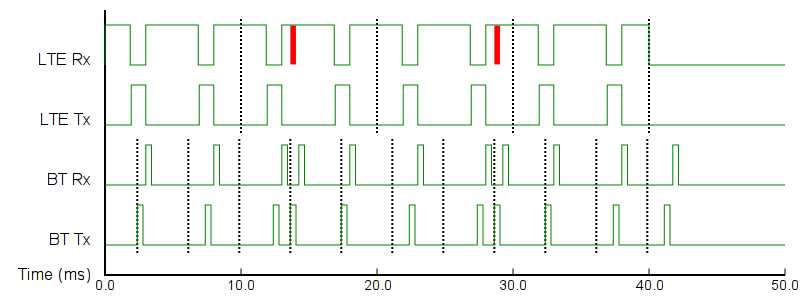


Figure 6.5.6.3.2-2: TDD Configuration 2 and BT EV3 (Offset of BT relative to LTE frame: 2.375 ms) [5]

The UE requires a TDM solution for the Bluetooth earphone scenario. In this case, some HARQ processes may be left unscheduled by the eNB. The UE may provide bitmap assistance data in the IDC indication, and the eNB may configure a suitable DRX cycle to allow sufficient time slots for BT operation in all master and slave modes in all TDD configurations [7, 8].

Furthermore, knowledge of a fixed LTE frame structure and LTE TDD frame configuration are basic elements which allow a TDM solution.

6.5.6.3.3 LTE + BT Earphone (Multimedia Service)

Based on the analysis done for VoIP scenario, it can be seen that the collisions with Bluetooth may be mostly avoided in TD-LTE by aligning the frame structures properly [5]. Further, since the multimedia streaming application is somewhat delay tolerant, a reasonable DRX cycle may be applied in addition to the synchronization mechanism between the UE’s radio modules, in case the Bluetooth frame structure cannot be aligned (e.g. when operating in slave mode).

Based on [5], the LTE on-duration of the DRX cycle should be less than [60] ms, and the opportunity for ISM transmissions around [15-60] ms. The LTE throughput available using this solution would be roughly 48-77%. However, as the performance in many TD-LTE configurations may already be manageable, the performance using DRX should be sufficient.

Same as in previous use case, knowledge of a fixed LTE frame structure and LTE TDD frame configuration are basic elements which allow a TDM solution.

6.5.6.3.4 LTE + Wi-Fi Portable Router

Based on [5], DRX is a potential solution for this usage scenario. The LTE on-duration and the opportunity for ISM transmissions should be typically not more than [20-60] ms. The LTE throughput available using this solution would be roughly 15-65%, depending on the choice of DRX cycle parameters.

Since 54 Mbps PHY rate is available in Wi-Fi, the router usage scenario may be satisfied by roughly equal time share, or by allocating more time for LTE than for Wi-Fi.

6.5.6.3.5 LTE + Wi-Fi Offload

For the offload usage scenario, DRX based solution is also applicable [5]. The difference to the portable router scenario is that the time shares should be roughly proportional to the amount of traffic over both radio interfaces, and the Wi-Fi beacon transmissions should align with the LTE off-time of the DRX cycle. Some overhead for each DRX cycle (e.g. 8 ms as assumed in earlier analysis) should be taken into account in the time share estimations.

In the IDC indication assistant information, the UE may indicate suitable DRX cycle parameter values for on-duration, cycle length, and offset, to accommodate best the traffic on both radios and the Wi-Fi beacon periods.

#### 6.5.6.4 IDC conclusions

The RF interference analysis shows that the IDC interference may be severe in both directions and affect the whole 2.4 GHz ISM band. The situation is similar as for the highest 20-25 MHz of E-UTRA band 40, according to analysis done in [5]. However, the LTE receiver may be made somewhat immune to at least Bluetooth transmissions on the lower part of the ISM band, by using a TDD band filter that provides sufficient suppression.

In case the RF interference is strong enough to be an issue, the TDD configuration may in some scenarios provide sufficient time slots for ISM operations, especially if the amount of traffic through LTE is small.

In case the UE is not able to solve the IDC issues by itself, the IDC solution specified in Rel-11 allows to indicate to the network a suitable TDM pattern (DRX parameters or HARQ bitmap), and the network may then configure DRX with suitable parameters to facilitate coexistence between the UE’s radios. There are DRX based solutions to cover all usage scenarios considered in this clause. Any DRX based solution will impact maximum LTE throughput, and the sharp transition from on-duration to off-time will typically incur in small probability of data loss at HARQ level.

The TDM solutions for LTE BT IDC require the collocated BT device to have knowledge of a fixed LTE frame structure and of the LTE TDD frame structure.

# 7 E-UTRA Specific Issues

## 7.1 UE Aspects

### 7.1.1 Power Spectral Density limit

According to the FCC power limits outlined in clause 5.4.3, the maximum power spectral density conducted to the antenna is not greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission. For UE transmissions, the highest PSD may be found during narrowband 1 PRB transmissions. Such resource allocation is simulated to verify that the limit is not exceeded.

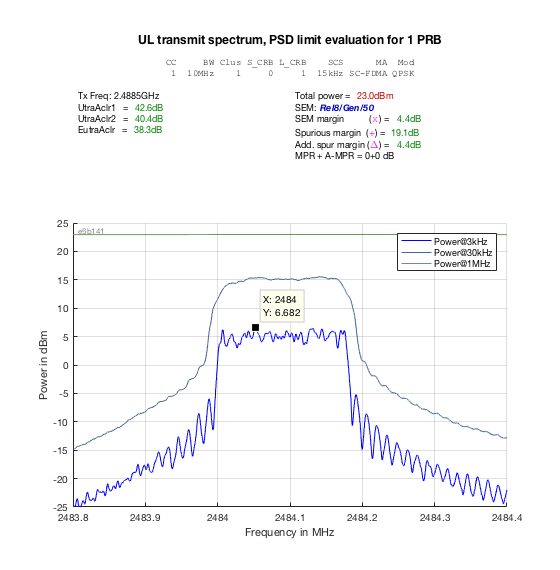
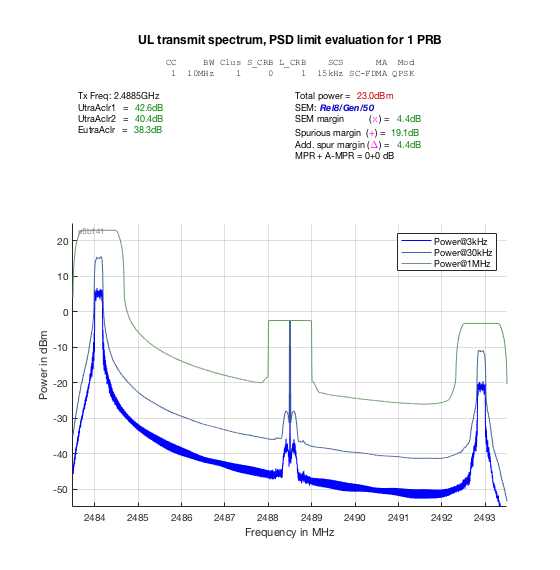


Figure 7.1.1-1: Power Spectral Density of 1 PRB UL transmission at maximum 23 dBm output power, complete channel bandwidth (left) and zoomed to the transmitter resource block (right). The maximum PSD is 6.7 dBm/3 kHz.

At the maximum power, the highest power spectral density is 6.7 dBm/3 kHz, thereby no special measures are required to meet the FCC requirement.

## 7.2 BS Aspects

The following BS specific TS 36.104 changes are expected due to introduction of Band 53 (since -25dBm/MHz FCC limit was developed to protect ISM unlicensed band on the lower side and Band 41 on the upper side, the proposed frequency range for this requirement is 2400-2473.5/2477.5 MHz and 2501/2505-2690 MHz).

6.6.3 Operating band unwanted emissions

6.6.3.3 Additional requirements

The following requirement may apply to E-UTRA BS operating in Band 53 in certain regions. Emissions shall not exceed the maximum levels specified in Table 6.6.3.3-12.

Table 6.6.3.3-12: Additional operating band unwanted emission limits for Band 53

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Channel bandwidth [MHz] | Frequency range [MHz] | Frequency offset of measurement filter ‑3dB point, Δf | Frequency offset of measurement filter center frequency, f\_offset | Minimum requirement | Measurement bandwidth (Note 8) |
| 1.4, 3, 5 | 2400 - 2477.5 | 6 MHz ≤ Δf < 83.5 MHz | 6.5 MHz ≤ f\_offset < 83 MHz | -25 dBm | 1 MHz |
| 10 | 2400 - 2473.5 | 10 MHz ≤ Δf < 83.5 MHz | 10.5 MHz ≤ f\_offset < 83 MHz | -25 dBm | 1 MHz |
| 1.4, 3, 5 | 2477.5 - 2478.5 | 5 MHz ≤ Δf < 6 MHz | 5.5 MHz | -13 dBm | 1 MHz |
| 10 | 2473.5 - 2478.5 | 5 MHz ≤ Δf < 10 MHz | 5.5 MHz ≤ f\_offset < 9.5 MHz | -13 dBm | 1 MHz |
| All | 2478.5 - 2483.5 | 0 MHz ≤ Δf < 5 MHz | 0.5 MHz ≤ f\_offset < 4.5 MHz | -10 dBm | 1 MHz |
| 1.4, 3, 5 | 2495 - 2501 | 0 MHz ≤ Δf < 6 MHz | 0.5 MHz ≤ f\_offset < 5.5 MHz | -13 dBm | 1 MHz |
| 10 | 2495 - 2505 | 0 MHz ≤ Δf < 10 MHz | 0.5 MHz ≤ f\_offset < 9.5 MHz | -13 dBm | 1 MHz |
| 1.4, 3, 5 | 2501 - 2690 | 6 MHz ≤ Δf < 195 MHz | 6.5 MHz ≤ f\_offset < 194.5 MHz | -25 dBm | 1 MHz |
| 10 | 2505 - 2690 | 10 MHz ≤ Δf < 195 MHz | 10.5 MHz ≤ f\_offset < 194.5 MHz | -25 dBm | 1 MHz |

6.6.4.3 Additional spurious emissions requirements

6.6.4.3.1 Minimum Requirement

Table 6.6.4.3.1-1: BS Spurious emissions limits for E-UTRA BS for co-existence with systems operating in other frequency bands

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| System type for E-UTRA to co-exist with | Frequency range for co-existence requirement | Maximum Level | Measurement Bandwidth | Note |
| E-UTRA Band 41 | 2496 - 2690 MHz | -52 dBm | 1 MHz | This is not applicable to E-UTRA BS operating in Band 41 or 53. |
| E-UTRA Band 53 | 2483.5 - 2495 MHz | -52 dBm | 1 MHz | This is not applicable to E-UTRA BS operating in Band 41 or 53. |

6.6.4.4 Co-location with other base stations

6.6.4.4.1 Minimum Requirement

Table 6.6.4.4.1-2: BS Spurious emissions limits for Local Area BS co-located with another BS

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Type of co-located BS | Frequency range for co-location requirement | Maximum Level | Measurement Bandwidth | Note |
| LA E-UTRA Band 41 | 2496 – 2690 MHz | -88 dBm | 100 kHz | This is not applicable to E-UTRA BS operating in Band 41 or 53 |
| LA E-UTRA Band 53 | 2483.5 – 2495 MHz | -88 dBm | 100 kHz | This is not applicable to E-UTRA BS operating in Band 41 or 53 |

Table 6.6.4.4.1-3: BS Spurious emissions limits for Medium range BS co-located with another BS

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Type of co-located BS | Frequency range for co-location requirement | Maximum Level | Measurement Bandwidth | Note |
| LA E-UTRA Band 41 | 2496 – 2690 MHz | -91 dBm | 100 kHz | This is not applicable to E-UTRA BS operating in Band 41 or 53 |
| LA E-UTRA Band 53 | 2483.5 – 2495 MHz | -91 dBm | 100 kHz | This is not applicable to E-UTRA BS operating in Band 41 or 53 |

7.6.1 General blocking requirement

7.6.1.1 Minimum requirement

Table 7.6.1.1-1a: Blocking performance requirement for Local Area BS for E-UTRA

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Operating Band | Center Frequency of Interfering Signal [MHz] | | | Interfering Signal mean power [dBm] | Wanted Signal mean power [dBm] | Interfering signal center frequency minimum frequency offset from the lower/upper Base Station RF Bandwidth edge or sub-block edge inside a sub-block gap [MHz] | Type of Interfering Signal |
| 53 | (FUL\_low -20) | to | (FUL\_high +12) | -35 | PREFSENS +6dB\* | See table 7.6.1. 1-2 | See table 7.6.1.1-2 |
| 1  (FUL\_high +12) | to  to | (FUL\_low -20)  12750 | -15 | PREFSENS +6dB\* | ⎯ | CW carrier |

Table 7.6.1.1-1c: Blocking performance requirement for Medium Range BS for E-UTRA

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Operating Band | Center Frequency of Interfering Signal [MHz] | | | | Interfering Signal mean power [dBm] | Wanted Signal mean power [dBm] | Interfering signal center frequency minimum frequency offset to the lower/higher Base Station RF Bandwidth edge or sub-block edge inside a sub-block gap [MHz] | Type of Interfering Signal |
| 53 | (FUL\_low -20) | | to | (FUL\_high +20) | -38 | PREFSENS +6dB (Note 1) | See table 7.6.1.1-2 | See table 7.6.1.1-2 |
| 1  (FUL\_high +20) | to  to | | (FUL\_low -20)  12750 | -15 | PREFSENS +6dB (Note 1) | ⎯ | CW carrier |

7.6.2 Co-location with other base stations

7.6.2.1 Minimum requirement

Table 7.6.2.1-2: Blocking performance requirement for Local Area BS when co-located with BS in other frequency bands.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Co-located BS type | Center Frequency of Interfering Signal (MHz) | Interfering Signal mean power (dBm) | Wanted Signal mean power (dBm) | Type of Interfering Signal |
| LA E-UTRA Band 53 | 2483.5 - 2495 | -6 | PREFSENS + 6dB\* | CW carrier |

Table 7.6.2.1-3: Blocking performance requirement for E-UTRA Medium Range BS when co-located with BS in other frequency bands.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Co-located BS type | Center Frequency of Interfering Signal (MHz) | Interfering Signal mean power (dBm) | Wanted Signal mean power (dBm) | Type of Interfering Signal |
| MR E-UTRA Band 53 | 2483.5 - 2495 | +8 | PREFSENS + 6dB\* | CW carrier |

# 8 Channel Numbering

The E-UTRA Absolute Radio Frequency Channel Numbers (EARFCNs) allocated for Band 53 are outlined in Table 8-1.

Table 8-1: E-UTRA channel numbers

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| E-UTRA Operating Band | Downlink | | | Uplink | | |
| FDL\_low [MHz] | NOffs-DL | Range of NDL | FUL\_low [MHz] | NOffs-UL | Range of NUL |
| 53 | 2483.5 | 60140 | 60140 - 60254 | 2483.5 | 60140 | 60140 - 60254 |

Annex A:  
Change history

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Change history** | | | | | | | |
| Date | Meeting | TDoc | CR | Rev | Cat | Subject/Comment | New version |
| 2018-08 | RAN4#88 | R4-1811130 |  |  |  | Initial TR skeleton | 0.0.1 |
| 2018-10 | RAN4#88-Bis | R4-1813458 |  |  |  | The following agreed text proposals have been included:  R4-1811133; TP to TR36.791: Frequency Arrangement and Regulatory Background; Nokia and Globalstar  R4-1811570; TP to TR36.791: Special Co-Existence Considerations for Unlicensed Operations in the 2.4 GHz ISM Band; Nokia and Globalstar | 0.1.0 |
| 2018-11 | RAN4#89 | R4-1815354 |  |  |  | The following agreed text proposals have been included:  R4-1813377; TP to TR36.791: Outstanding Items for Co-Existence Evaluation; Nokia and Globalstar  R4-1814101; TP to TR36.791: In-Device Co-Existence Considerations for Unlicensed Operations in the 2.4 GHz ISM Band; Nokia and Globalstar  R4-1814102; TP to TR36.791: Base Station Emissions and Environmental Co-Existence with Unlicensed Operations in the 2.4 GHz ISM Band; Nokia and Globalstar  R4-1813393; TP to TR36.791: Channel Numbering; Nokia and Globalstar  R4-1813357; TP to TR36.791: PSD Limit Evaluation for UE; Nokia and Globalstar  R4-1813357; TP to TR36.791: BS Aspect Issues; Nokia and Globalstar | 0.2.0 |
| 2018-12 | RAN#82 | RP-182407 |  |  |  | Final TR Version 1.0.0 | 1.0.0 |
| 2018-12 | RAN#82 | RP-182717 |  |  |  | Editorial corrections applied to Version 1.0.0 | 1.0.1 |
| 2018-12 | RAN#82 |  |  |  |  | Approved by plenary – Rel-16 spec under change control | 16.0.0 |