QUALCOMM Incorporated

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April 3, 2014

Ms. Marlene Dortch
Secretary
Federal Communications Commission
445 12th Street, SW
Washington, DC 20554

Re: Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions -- GN Docket No. 12-268

Dear Ms. Dortch:

QUALCOMM Incorporated ("Qualcomm") hereby responds to the March 3, 2014, *ex parte* filing from Broadcom in the above-referenced docket. Qualcomm's February 19, 2014 filing showed that to protect LTE user equipment ("UE") receivers from suffering blocking interference from unlicensed operations in the guard band between TV and LTE, the guard band would have to be at least 14 MHz wide[1] and the Commission would have to impose a strict power limit on unlicensed base stations. In this latest filing, Broadcom claims that interference from unlicensed device out-of-band emissions ("OOBE") to LTE user equipment is the limiting interference case. Broadcom discounts the impact of the blocking use cases that Qualcomm previously explained to be more problematic, but Broadcom's blocking analysis is based upon a set of unreasonably optimistic assumptions.

As explained in the attached slides, there are at least four major problems with Broadcom's analysis of the blocking use cases:

i. Broadcom's assessment of filter performance is based upon results from so-called typical filters, and Broadcom's analysis of filter performance fails to account for temperature and manufacturing variances, which impact all filters;

ii. Broadcom wants the FCC to assume that all LTE UEs will exceed the 3GPP blocking specifications by approximately10 dB based on handset RFPs from two carriers; the FCC, however, cannot adopt regulations based upon specifications that are not universal in the industry and may be waived, modified, or not enforced by the carriers. In addition, the blocking capability of particular devices and chips varies;

iii. The FCC has no basis to assume anything other than performance in accordance with the 3GPP specification that all device and chipset manufacturers must meet for all devices operating on all networks. The FCC cannot base regulations on an assumption that performance may exceed the standard; and

[1] In fact, if unlicensed operations are placed within this guard band, the size of the guard band would have to be much larger than 14 MHz to prevent unlicensed operations from interfering with LTE UE (on the upper end of the guard band) and TV receivers (on the lower end of the guard band).

iv. As GE Healthcare recently noted in the context of interference from unlicensed to WMTS, "the possibility of free space propagation occurring between an uncoordinated portable device and [LTE UE] is undeniable." *See* GEHC Mar. 7, 2014 filing at 2. Broadcom's analysis depends on antenna and propagation losses that often are not present.

Notably, Broadcom also completely overlooks the OOBE interference that unlicensed operations in the duplex gap would suffer due from LTE UEs. As Qualcomm shows in the attached slides, the potential for such interference is great.

As noted above, Qualcomm's February 19, 2014 filing explained that at least 8 MHz of separation between the band edge of unlicensed operations and that of the LTE downlink is required to prevent blocking of the LTE UE, so the guard band must be at least 14 MHz wide (6+8 MHz). When unlicensed operations are kept out of the guard band, the required size of the guard band between LTE downlink and broadcast TV is 10 MHz. Also, attempting to insert as little as 6 MHz of unlicensed spectrum in a guard band at 600 MHz can require 22 MHz of total guard band (2 x 8 + 6 MHz), if the guard band is in between two LTE DL blocks. Furthermore, Qualcomm showed in its February 19 filing that inserting unlicensed operations into the duplex gap requires a minimum guard band of 47 MHz for a 2 x 35 MHz FDD band plan.

Thus, inserting unlicensed services in the 600 MHz band, without unduly expanding the size of the guard band(s) and duplex gap, would violate the voluntary incentive auction statute, impair the adjacent licensed mobile spectrum blocks, and destroy the fungibility of the mobile spectrum that the Commission is working to repurpose. Indeed, inserting unlicensed services in the 600 MHz band is inconsistent with statute and is a poor choice from both technical and economic perspectives, and should be avoided.

Respectfully submitted,

Dean R. Brenner
Senior Vice President, Government Affairs

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April 3, 2014

Discussion of 3/3/14 Broadcom *Ex Parte*

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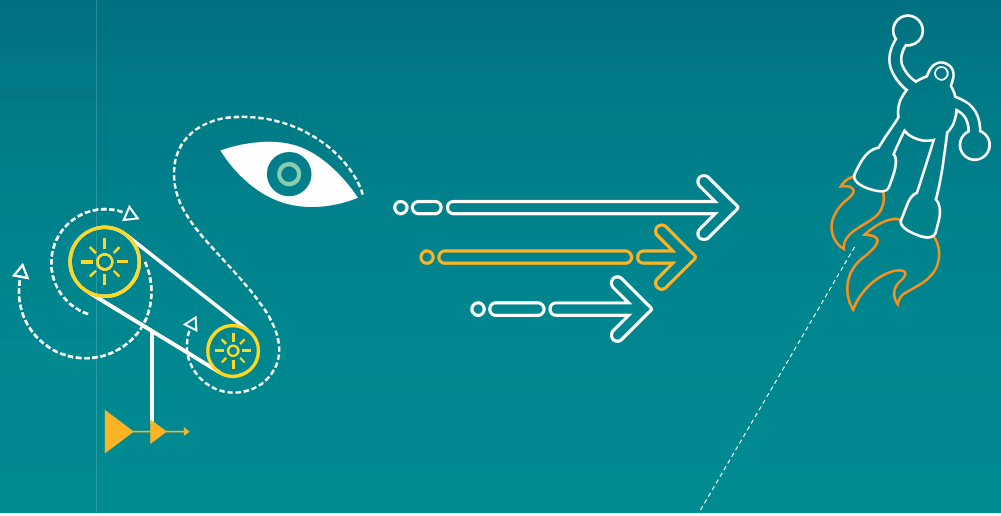


Response to 3/3/14 Broadcom *Ex Parte* Filing

- Broadcom's 1/30/14 filing considered one OOBE use case for unlicensed interference to LTE User Equipment ("UE")
- Qualcomm's 2/19/14 filing explained that there are several relevant blocking use cases that are limiting factors in determining the amount of frequency separation between unlicensed and LTE, that OOBE is not the limiting factor, and that 1 m is an appropriate electro-compatibility distance between such disparate devices
- Broadcom's 3/3/14 filing claims that OOBE is the limiting case, causing a separation distance of 2 m between LTE UEs and unlicensed operations, based upon a set of unreasonably optimistic assumptions for the blocking use cases
- Broadcom also overlooks the impact of interference that LTE operations can cause to unlicensed operations in the duplex gap

Response to 3/3/14 Broadcom *Ex Parte* (Cont'd)

- There are at least four major problems with Broadcom's analysis of blocking interference from unlicensed operations to LTE UEs:
  1. Filter performance assumptions must account for temperature and manufacturing tolerances. Broadcom's analysis overlooks these factors.
  2. The FCC should not assume, as Broadcom did, that all LTE UEs will exceed the 3GPP blocking specifications by ~10 dB. Broadcom asks the FCC to so speculate based on handset RFPs from two carriers, but carriers are free to waive, modify, and or not enforce their RFPs at any time. In fact, the blocking capability of individual chips and particular devices varies.
  3. The FCC has no basis to assume anything other than performance in accordance with the 3GPP specification that device and chipset manufacturers must meet for all devices operating on all networks. The FCC should not assume that performance will exceed the applicable standard requirements.
  4. As GE Healthcare noted in the context of interference from unlicensed to WMTS, "the possibility of free space propagation occurring between an uncoordinated portable device and [LTE UE] is undeniable." *See* GEHC Mar. 7, 2014 filing at 2. Broadcom's analysis depends on losses that often do not occur.

Response to 3/3/14 Broadcom *Ex Parte* (Cont'd)

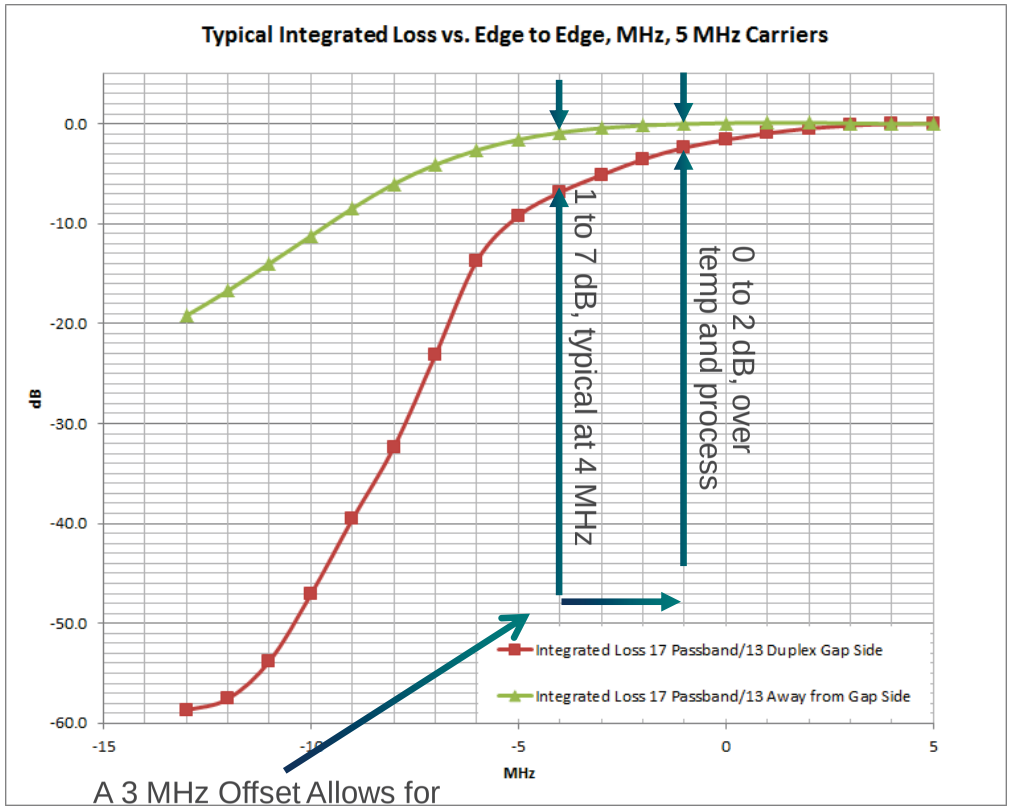
- A more reasonable interference analysis, which is presented herein, shows that unlicensed operations will block LTE UE receivers within a 20 meter radius for the 4 MHz offset that was proposed

- As a result, in order meet the applicable 3GPP blocking interference specifications, there must be at least 8 MHz separation between the edges of unlicensed and LTE operations to support coexistence at a 1 m separation distance, as Qualcomm previously has shown

- Broadcom fails to consider the OOBE interference that will occur from LTE UEs to unlicensed portables and base stations. This factor also necessitates a much wider guard band than Broadcom is urging the FCC to adopt

Filter Performance Calculations Must Account for Process, Temperature, and Unlicensed Carrier Location

- Broadcom's filter attenuation claims are based on results for typical filters
  - A correct metric is integrated loss over temperature and manufacturing variation
  - Allowing 3 MHz margin is typical for variations
- Broadcom fails to recognize that filters are not symmetrical and that both sides may see an unlicensed carrier
  - There are two skirts on every filter, and the side closer to the duplex gap is typically steeper
- Figure on the right depicts integrated loss of a commercial Lower 700 MHz Band 12 filter with 13 MHz gap, 17 MHz pass band for the 4 MHz edge to edge offset used by Broadcom
- There is far less integrated attenuation than Broadcom claims



A 3 MHz Offset Allows for Temp and Process

Likelihood of Free Space Propagation Between Unlicensed Operations and LTE UE is "Undeniable"*

- Broadcom assumes non-guaranteed antenna and propagation losses
- Page 4 of Broadcom's filing includes 8 dB of losses attributed to various factors that often are not present
  - The effective antenna efficiency achieved for a handset held against the head during a call can reach -13 dB
  - Time spent on calls in this manner is a very small fraction of a LTE device's active operation, as smartphones are always on while in users' pockets, purses, etc.
  - For popular uses such as texting, social networking, web browsing & media consumption, the effective efficiency can be in the range of -10 dB, only fingers are close to the UE
  - For voice calls when the user uses a hands-free headset or speakerphone, the results could be close to free space efficiency, *i.e.*, approximately -6 dB
- It is unrealistic to assume a low duty cycle, high loss use case when determining blocking performance

These losses are achievable only under a specific set of circumstances for a low duty cycle use case

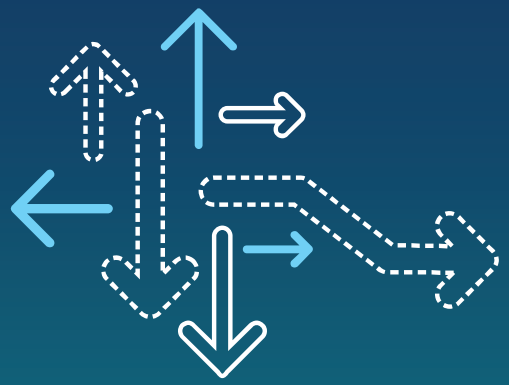
Frequency	665MHz	
LTE device to WiFi device distance	2m	3m
Free space loss	35dB	38.5dB
Body loss	3dB	
Antenna polarization mismatch	2dB	
Shadowing	3dB	
LTE antenna Gain	-5dB	
Total propagation Loss	48dB	51.5dB
LTE noise level	-101.5dBm	
Interference level 3dB higher	-98.5dBm	
Allowed WiFi noise level into LTE band	-50.5dBm	-47dBm

* *See* GEHC Mar. 7, 2014 filing

All LTE UEs Perform 10 dB Better than 3GPP Specification?

- Broadcom claims that two major wireless carriers have device RFPs with blocking specs that are 10 dB higher than those of 3GPP
- The FCC should base its rules on published 3GPP specifications, not carrier RFPs
- Performance of individual chips and UEs will vary, but the spec is the standard to which manufacturers must design their equipment for all carriers
- Individual carriers also are always free to waive, modify, or decline to enforce their internal device RFPs
- Handsets and tablets are designed to 3GPP specifications – not hypothetical performance claims and wishful thinking

Blocking Analysis Details



Summary of Blocking Analysis

- The following values are reasonable, relative to the 4 MHz offset Broadcom proposed
  - Jamming levels from 3GPP -56 dBm, -44 dBm †
  - Antenna efficiency -6dB
  - Moderate antenna proximity losses -4 dB
  - Integrated loss for 4 MHz offset
    - Typical 1 - 7 dB
    - Over temperature 0 - 2 dB
  - Restrict unlicensed transmit level +16 dBm current WSD max level is +36 dBm
- Blocking distance in every case is greater than the 2 m claimed by Broadcom for OOBE unlicensed to LTE UE, even when using the most favorable typical filter results, as shown below
- Blocking is the limiting interference use case, when the appropriate 3GPP specification is considered

Blocking Level †	Typ. +16 dBm, 7 dB Loss	Over Temp & Process, +16 dBm, 2 dB Loss
-56 dBm < 5 MHz edge to edge	20 m	31 m
-44 dBm > 10 MHz edge to edge	5 m	9 m

Applicable 3GPP use case for 4 MHz offset

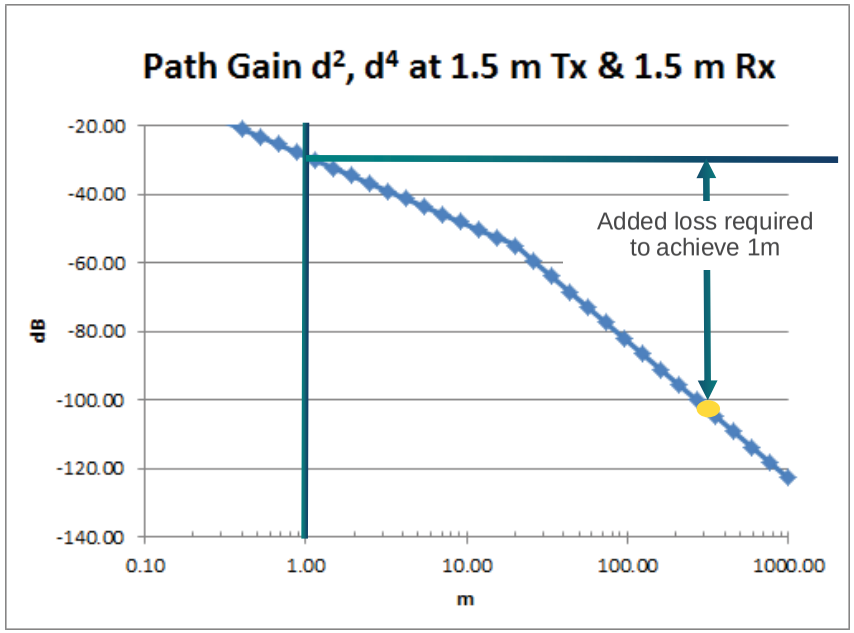
† 3GPP T S 36.101 V11.2.0 (2012-09), Tables 7.6.1.1-1 and 1-2: In-band blocking

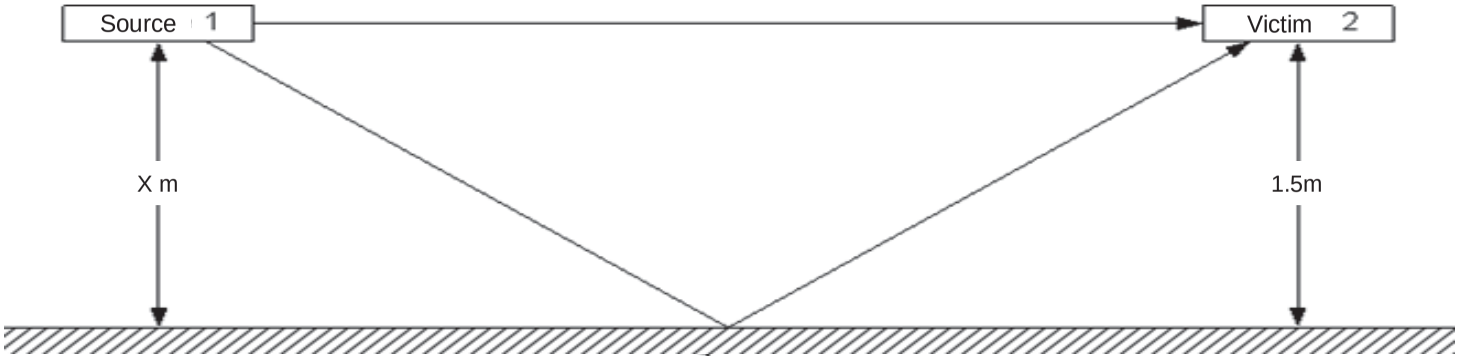
Propagation Model for Unlicensed <–> LTE UE Interference

- For the analysis of LTE device interference, the path loss is modeled as n=2 (free space) and then n=4
- The transition distance is defined as

$$\frac{4\,h_b h_m}{\lambda}$$

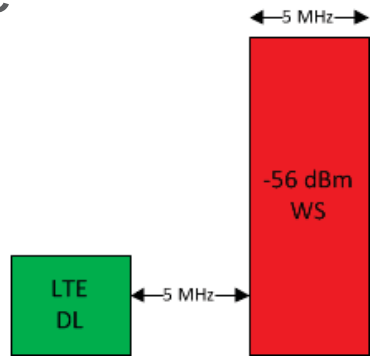
- The heights are set to 2 m and 1.5 m (UE) respectively for base station to UE, else 1.5 m for UE to UE
- See ITU-R 1411-2 Sec 4.1 or ITU-R P.341 for more details



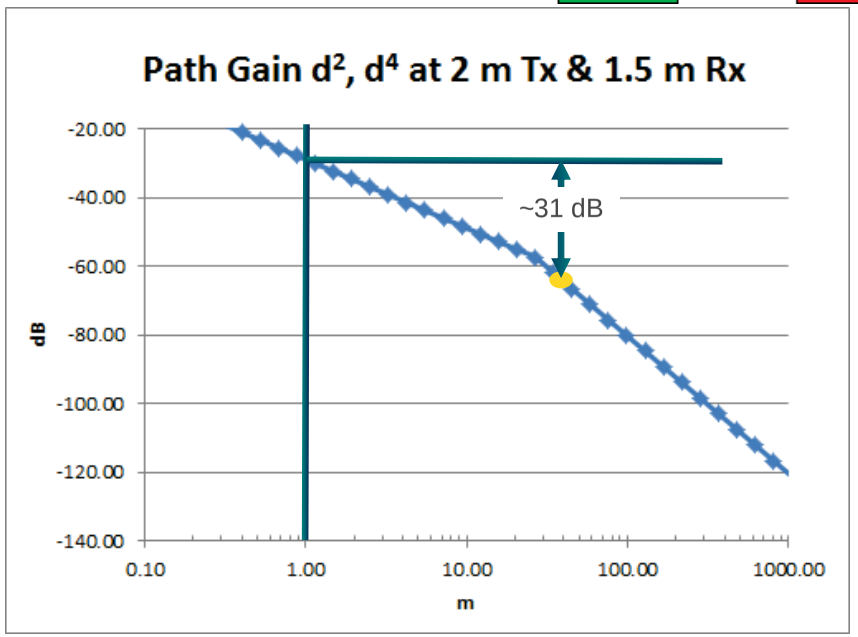


Unlicensed Block of LTE UE Case 1, Duplex Gap Side

- Unlicensed operations can block LTE UE 20 to 31 m away
- Potentially blocked radius is defined as area with received undesired signal strength greater than that defined as blocking in the LTE specification Case 1, -56 dBm
- Considering temperature and process variance, 31 dB additional loss is needed to achieve a 1 m separation distance

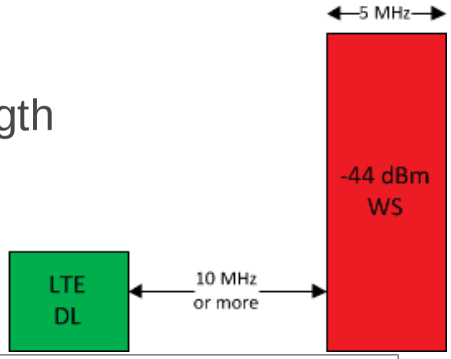


Parameter	Value		Units
Unlicensed Base Station Transmit Height	2		m
LTE UE Receive Height	1.5		m
RF Frequency	665		MHz
LTE UE Blocking Level	-56		dBm
Unlicensed Base Station EIRP	16		dBm
UE Free Space Antenna Efficiency	-6		dB
Moderate Proximity Losses	4		dB
Integrated Loss Typical / Temp & Process	7	2	dB
Blocking Path Loss	55	60	dB
Distance to Path Loss	20	31	m

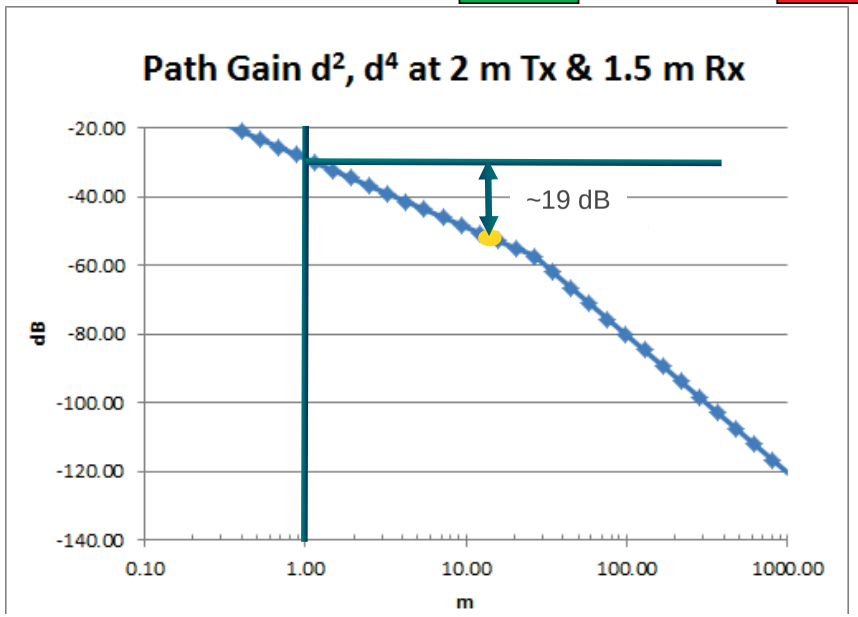


Unlicensed Block of LTE UE Case 2, Duplex Gap Side

- Unlicensed can block an LTE UE located 5 to 9 m away
- Potentially blocked radius is defined as area with received undesired signal strength greater than that defined as blocking in the LTE specification Case 2, -44 dBm
- Considering temp and process, 19 dB greater loss is needed for 1 m separation
- This use case is not applicable to a 4 MHz offset

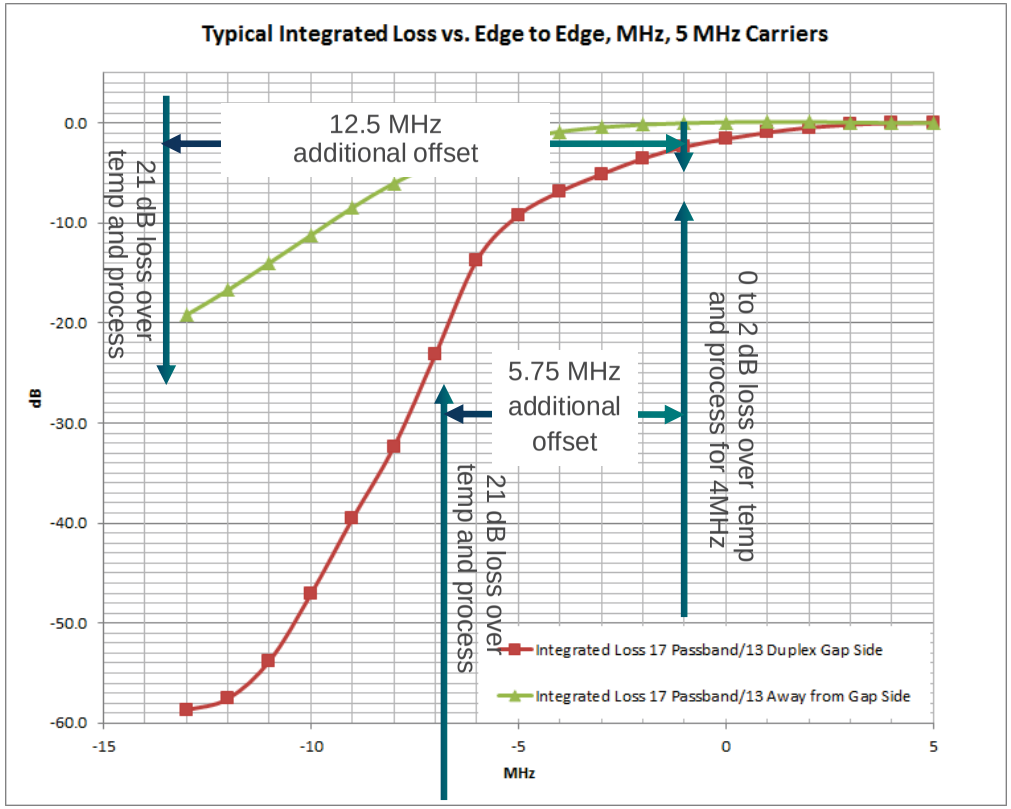


Parameter	Value		Units
Unlicensed Transmit Height	2		m
LTE UE Receive Height	1.5		m
RF Frequency	665		MHz
Unlicensed Blocking Level	-44		dBm
Unlicensed Base Station EIRP	16		dBm
UE Antenna Efficiency	-6		dB
Moderate Proximity Losses	4		dB
Integrated Loss Typical / Temp & Process	7	2	dB
Blocking Path Loss	43	48	dB
Distance to Path Loss	5	9	m



Achieving 1 m Separation Distance for Blocking

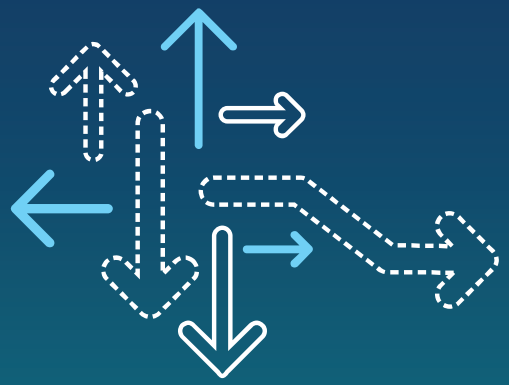
- Since the -56 dBm spec applies only to a 5 MHz offset, the Case 2 3GPP requirement is used; this raises the blocking level to -44 dBm
  - The duplex gap side of the filter requires 5.75 MHz of additional offset to achieve good compatibility, so a total 9.75 MHz edge to edge offset[*] is needed
  - Less favorable side of filter requires 12.5 MHz more offset, so 16.5 MHz total offset edge to edge
- This analysis of a commercially available Band 12 filter shows that even with a +16 dBm transmit power level for unlicensed and a higher blocking level, at least a 9.75 MHz edge to edge offset is needed to achieve good electromagnetic compatibility (1 m separation)



This analysis confirms previous results; the guard band needs to be widened significantly

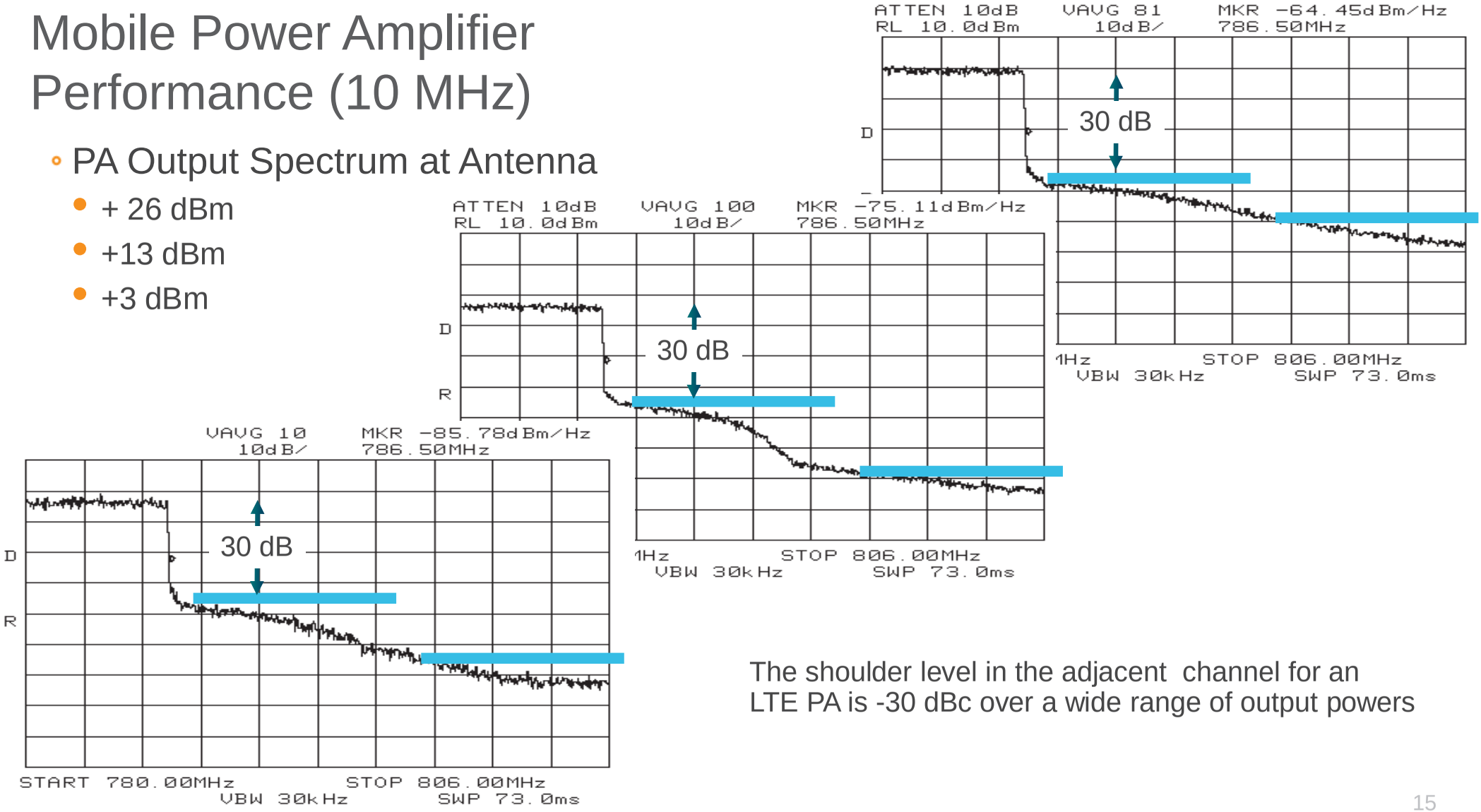
[*] The results on this slide and on slide 17 were derived using a commercial lower 700 MHz Band 12 filter, whereas the 8 MHz edge-to-edge separation Qualcomm recommends was derived using 25MHz-wide 600MHz duplexer simulations provided by major filter vendors.

LTE OOBE to Unlicensed



Mobile Power Amplifier Performance (10 MHz)

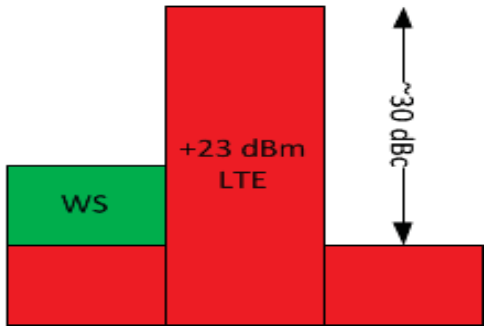
- PA Output Spectrum at Antenna
  - + 26 dBm
  - +13 dBm
  - +3 dBm



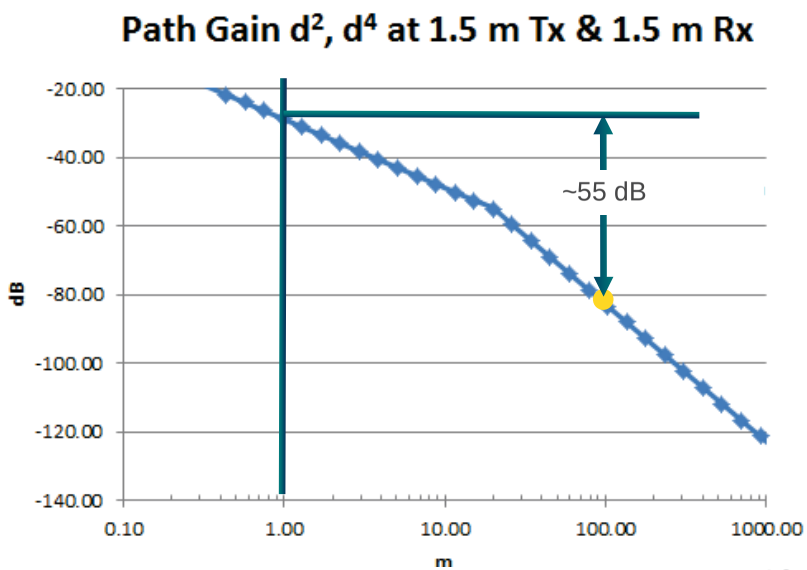
The shoulder level in the adjacent channel for an LTE PA is -30 dBc over a wide range of output powers

LTE UE 3 dB Desense of Unlicensed Portable

- Distance to path loss is 110 m @ 200 mW radiated power, -30 dBc shoulder
- Defined criteria is 3 dB of sensitivity loss for a typical unlicensed portable
  - Unlicensed portable is assumed to be similar to LTE UE in terms of RF parameters
- Broadcom assumption of 2 MHz offset provides no significant benefit from LTE transmit filter or spectrum roll off

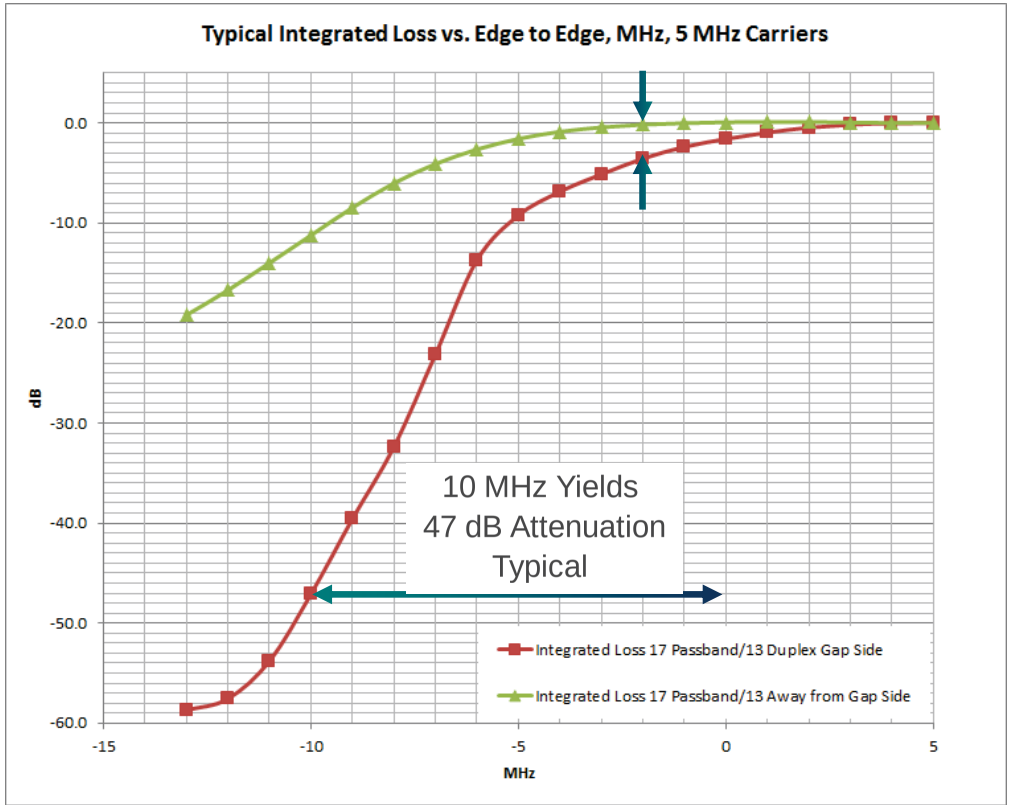


Parameter	Value	Units
RF Frequency	665	MHz
Transmit / Receive Height	1.5	m
System Temperature	290	K
Boltzman's constant	1.38E-23	J/K
Receiver Bandwidth	4.5	MHz
Reference Noise Power (kTB)	-107.4	dBm
Noise Figure	6	dB
0 C/N Conducted	-101.4	dBm
Desense	3	dB
Interference Input level for 3 dB loss	-98.4	dBm
Antenna Efficiency	-7	dB
Radiated Power 3dB Sensitivity Loss	-91.4	dBm
Radiated Power LTE UE	23	dBm
First Side Lobe Level	-30	dB Carrier Density
Radiated Power In Receive Bandwidth	-7	dBm
Path Loss to Achieve 3 dB Desense	84.4	dB
Distance to 3 dB Desense due to OOBE	110	m

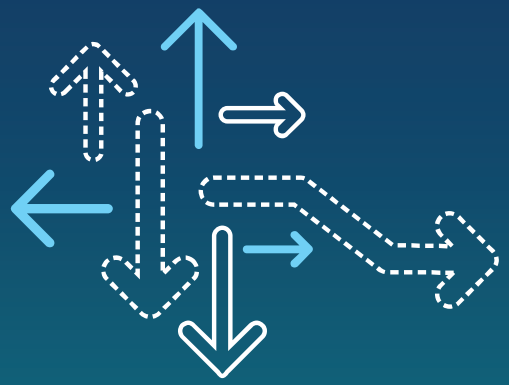


LTE UE Desense of Unlicensed Equipment - Summary

- The operation of just one LTE UE within 100 m of an unlicensed device or base station placed at 2 MHz edge to edge will substantially desense unlicensed portables and base stations
  - The LTE UE filter has a 0 to 2 dB integrated loss at a 2 MHz edge to edge offset as proposed by Broadcom
- Increasing the frequency separation to 10 MHz edge to edge can come close achieving a 1 m separation for a typical filter assuming ~8 dB spectrum roll off and 47 dB integrated attenuation to achieve the net required 55 dB
- Over temperature and process variance, this widens to a required offset to 13 MHz edge to edge offset (*i.e.*, 10 MHz + 3 MHz)



Summary & Conclusions

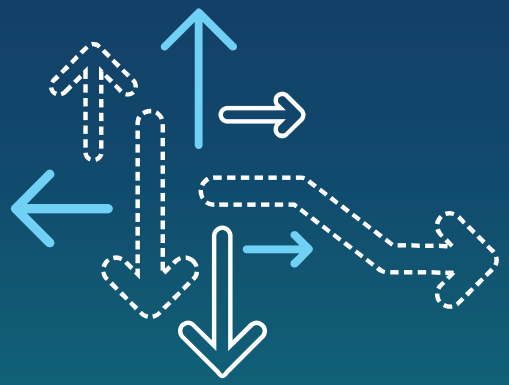


Summary

- Substantial technical analyses by Qualcomm and others have shown that a minimum reasonable edge to edge distance between transmit and receive frequencies for LTE (*i.e.*, OFDM) signals in the 600 MHz band is 10 to 12 MHz
- In the foregoing slides, Qualcomm demonstrated that appropriate electromagnetic compatibility (*i.e.*, 1 m separation) between an unlicensed OFDM signal and a licensed OFDM signal requires a guard band of at least approximately 14 MHz (including 8 MHz of separation edge to edge between unlicensed and LTE)[¥]
- In order to protect the unlicensed receiver from LTE UE OOBE, even more separation in the duplex gap is required than the 14 MHz necessary for a guard band, as Qualcomm has previously explained
- Relying upon wishful thinking when considering device capabilities and filter performance to narrow the required guard band(s) will impair the adjacent licensed spectrum blocks – both technically and economically

[¥] The 14 MHz width does not consider the OOBE interference from the LTE UE to unlicensed; it also does not account for the further increased guard band size that is needed to protect TV receivers from unlicensed operations.

Summary (Cont'd)

- Inserting unlicensed services in the 600 MHz band – without enlarging the guard bands and duplex gap in violation of the statute – creates wide areas of spectrum interference to other services and impairs the value of the adjacent licensed spectrum blocks
- Allowing unlicensed services in the 600 MHz band guard bands and duplex gap, without improperly expanding the guard bands and duplex gap, will destroy the fungibility of the adjacent licensed mobile spectrum
- Inserting unlicensed services in the 600 MHz band is inconsistent with statute and is a poor choice from both technical and economic perspectives, and must therefore be avoided

Thank You