QUALCOMM Incorporated

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May 8, 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:

In filings dating back to its initial reply comments in this proceeding,[1] QUALCOMM Incorporated ("Qualcomm") has consistently maintained and repeatedly demonstrated that allowing unlicensed devices to operate within the 600 MHz duplex gap or guard bands at levels permitted under the Commission's TV whitespace rules[2] — without unlawfully enlarging the width of the duplex gap or guard bands — will result in harmful interference to licensed mobile LTE services.

In a series of filings that began in January, Broadcom has claimed that such unlicensed operations can occur within a guard band of 10 MHz and a duplex gap of 11 MHz without interfering with licensed services in the 600 MHz band.[3] Qualcomm has repeatedly explained why Broadcom is wrong and that Broadcom's filings on this issue have used changing and contradictory assumptions to reach its predetermined conclusions.

Qualcomm responds in detail in the attached slides to Broadcom's April 23rd filing. The major flaws with that filing are as follows:

i. Broadcom has presented different versions of total path losses; its April 23, 2014 filing shows total propagation losses that are 7 to 11 dB greater than those shown in its January 30, 2014 filing;

ii. Broadcom ignores the fact that there is no body loss for any use case involving an unlicensed base station and inappropriately relies on non-existent body loss to avoid recognition of interference from unlicensed base stations;

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1 *See* Qualcomm Reply Comments (Mar 12, 2013, refiled with corrected page numbers on Apr. 3, 2013, "Qualcomm Reply Comments") at iv, 4-17.

2 *See* Broadcom April 23, 2014 Letter (stating that for 600 MHz unlicensed operations would need to occupy a 6 MHz wide channel and transmit with 40 mW of power to be commercially viable).

3 *See, e.g.*, May 2, 2014 *Ex Parte* Letter from Broadcom.

iii. Broadcom cites an allegedly more appropriate 3GPP document containing propagation models that actually are not valid for interference ranges less than 10 meters and thus are not applicable here; Qualcomm's analysis, in contrast, uses an internationally recognized propagation model and device performance requirements, *i.e.*, the applicable 3GPP specifications;

iv. Broadcom's "exemplary filter" fails to provide sufficient integrated attenuation for the limiting use case; the filter data submitted by Broadcom actually demonstrates that LTE devices will be unable to receive due to blocking interference from unlicensed base stations;

v. Broadcom continues to claim that there is sufficient attenuation by analyzing a single point of a filter curve, but a single data point cannot be used to assess the required loss for broadband spectrum;

vi. Based on measurements from a single LTE device, Broadcom wants the FCC assume that all LTE products similarly perform 10 dB better than 3GPP specifications, but there are over 1500 different LTE device models worldwide, and the FCC cannot rely upon such unsupported assumptions;

vii. Broadcom fails to consider device operating variability associated with power supply voltage, operating temperature or manufacturing process; and

viii. Broadcom wrongly claims that unlicensed might achieve signal levels similar to LTE, so unlicensed operations in the guard bands will be satisfactory, but LTE utilizes joint management of macros and small cells to achieve inter-operation within a band; there is no joint management among unlicensed TDD and LTE FDD services.

For these reasons, the record of this proceeding shows that allowing unlicensed operations in the duplex gap and guard band will cause harmful interference to licensed LTE services, and there is no sound technical basis for the FCC to find to the contrary now or in any future proceeding.

Earlier today, Sumit Verma, Kent Walker, John Kuzin and the undersigned from Qualcomm, discussed the attached slide deck with Brendan Carr, legal advisor to Commissioner Pai.

Respectfully submitted,

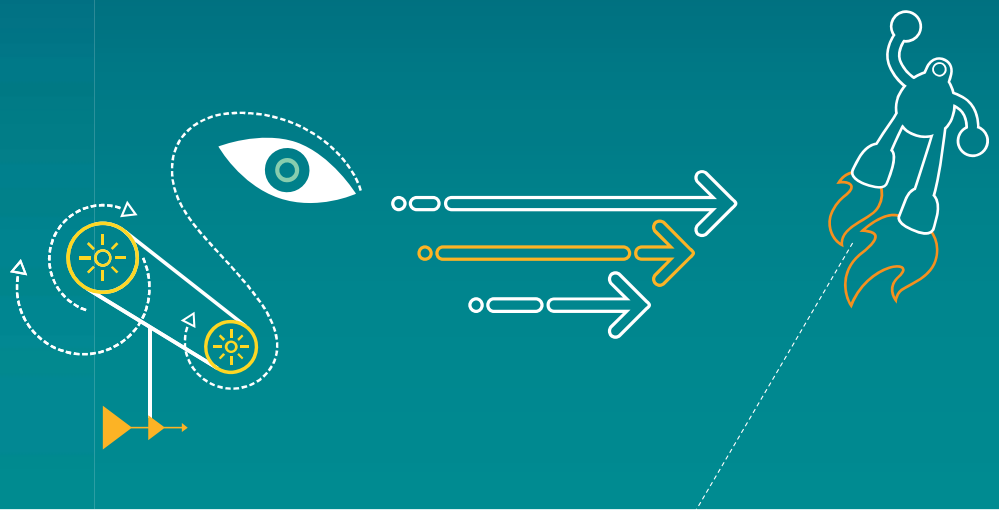
Dean R. Brenner
Senior Vice President, Government Affairs

Att.

cc w/ Att.	Gary Epstein	Julius Knapp	Louis Peraertz
(via email)	Brendan Carr	John Leibovitz	Blaise Scinto
	Martin Doczkat	Uri Livnat	Roger Sherman
	David Goldman	Madelaine Maior	Edward Smith
	AJ Glusman	Paul Malmud	Alan Stillwell
	Renee Gregory	Geraldine Matise	Howard Symons,
	Chris Helzer	Erin McGrath	Jennifer Tomchin
	Matthew Hussey	Paul Murray	Hugh Van Tuyl
	Ira Keltz	Jeffrey Neumann	Robert Weller

May 8, 2014

Qualcomm Response to Broadcom *Ex Parte* Filing of April 23, 2014



Qualcomm Has Shown Repeatedly That Unlicensed Operations at 600 MHz Will Cause Harmful Interference to Licensed LTE Devices

- Broadcom's latest filings claim that operating unlicensed devices at 40 mW transmit power in a 6 MHz channel within the 600 MHz band is commercially viable
- Broadcom claims that such unlicensed operations can occur within a guard band of 10 MHz and a duplex gap of 11 MHz without interference to licensed services
- Broadcom's filings since January have relied on changing and contradictory assumptions to reach predetermined conclusions
- Qualcomm has shown consistently and repeatedly that such unlicensed operations cannot operate without causing harmful interference to licensed LTE devices
- Broadcom has strained to present a rationale to reach its desired outcome in light of Qualcomm's rebuttals, but once again, the ultimate technical conclusion remains that unlicensed operations at 600 MHz in an appropriately sized duplex gap or guard bands will cause harmful interference to licensed LTE operations

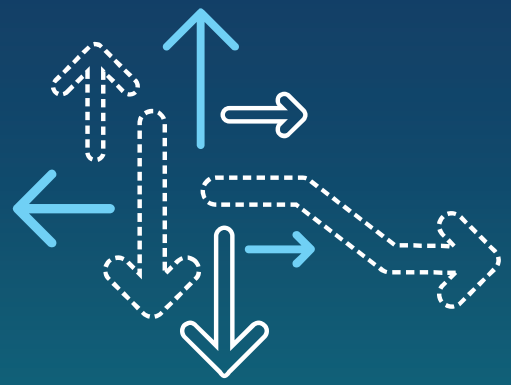
There Are Many Technical Flaws in Broadcom's Analysis (1 of 2)

- Broadcom has presented different versions of total path losses; its latest filing shows total propagation losses that are 7 to 11 dB greater than those shown in its prior filing (*see* slide 6, *infra*)
- Broadcom chose to ignore the fact that there is no body loss for any use case involving an unlicensed base station, and inappropriately relies on this non-existent body loss to avoid recognition of interference from unlicensed base stations (*see* slides 6-7, *infra*)
- Broadcom cites an allegedly more appropriate 3GPP document containing propagation models that are not valid for interference ranges that are less than 10 meters and are therefore inapplicable here (*see* slides 9-13, *infra*)
- Qualcomm uses an internationally recognized propagation model and device performance requirements, *i.e.*, the applicable 3GPP specifications, for its analysis and has provided consistent and conclusive results showing that unlicensed operations at 600 MHz will cause harmful interference to licensed operations (*see* slide 13, *infra*)

There Are Many Technical Flaws in Broadcom's Analysis (2 of 2)

- Broadcom's "exemplary filter" fails to provide sufficient integrated attenuation for the limiting use case – the filter data submitted by Broadcom shows that LTE devices will be unable to receive due to the blocking interference they can suffer from unlicensed base stations (*see* slides 15-16, *infra*)
- Broadcom continues to claim that there is sufficient attenuation by analyzing a single point of a filter curve, but a single data point cannot be used to assess the required loss for broadband spectrum (*see* slide 18, *infra*)
- Broadcom wants the FCC assume that all LTE products perform 10 dB better than 3GPP specifications based on measurement of a single LTE device, but there are over 1500 different LTE device models worldwide. The FCC cannot make such unsupported assumptions (*see id*.)
- This Broadcom assertion fails to consider device operating variability associated with power supply voltage, operating temperature or manufacturing process (*see id*.)
- Broadcom wrongly claims that unlicensed might achieve signal levels similar to LTE, so unlicensed operations in the guard bands will be satisfactory (*see* slides 19-21, *infra*)
- LTE utilizes joint management of macros and small cells to achieve inter-operation within a band. There is no joint management among unlicensed TDD and LTE FDD services (*see id*.)

Broadcom’s Propagation Loss Anomalies



Broadcom's Propagation Loss Analysis Disparity

- Broadcom has presented two entirely different versions of total propagation loss
- The path loss claimed in its latest filing is 7 to 11 dB higher than what it claimed in its January filing
- Broadcom claims that body losses should be doubled due to body loss on each end of the link, but unlike a handheld device, an unlicensed base station (or access point) has no body loss
- **There is no body loss for any use case related to an unlicensed base station (access point)**
- There will be unlicensed access point(s) in the same room as an LTE device
- Broadcom's newly invented losses should be ignored for all blocking analyses involving an unlicensed base station, which are the limiting use cases

13 dB total losses;
Qualcomm expects 10 dB typical
based on actual device measurements

January 30th, 2014

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

April 23, 2014

Now 17 to 21 dB

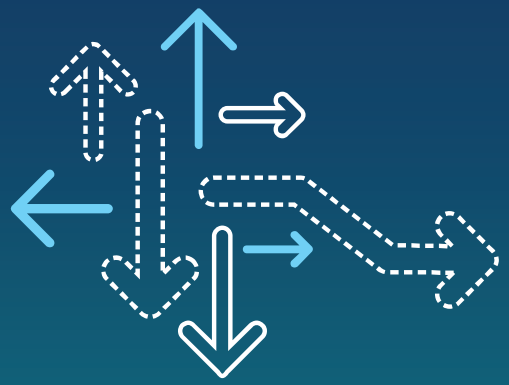
Frequency	665MHz	
LTE device to WiFi device distance	2m	3m
Free Space Loss	35dB	38.5dB
Body loss (both WiFi and LTE devices)	8-12dB	
Antenna polarization mismatch	3dB	
Shadowing	3dB	
LTE antenna Gain	-6dB	
Total Propagation Loss	55-59dB	58.5-62.5dB

“Revised Path Loss” Leads to Invalid Conclusions

- Broadcom’s “revised path loss” ignores the existence of unlicensed access points in making the following conclusion:

> “Broadcom agrees with Qualcomm that, due to expected filter asymmetry, lower power or a larger gap would be required to support unlicensed device operation in the guard band relative to duplex gap operations; nevertheless, the margin provided in Broadcom’s previous analysis, **combined with the revised path loss analysis in the enclosed slides**, confirms that the guard band can accommodate unlicensed operations at the power levels described in Broadcom’s January 30, 2014 filing.”

Propagation Model Distance Dependent Path Loss



Broadcom's Changing Propagation Models

- Qualcomm has consistently referenced and used the well known and widely used ITU-R 1411-3 LOS UHF model,[1] which is based on free space plus ground reflection
- Broadcom has referenced multiple propagation model(s) in its various filings
  - January 17, 2014 ITU-Umi (This was in the context of WMTS)
  - March 3, 2014 Free Space
  - April 23, 2014 3GPP 36.872, but Free Space mentioned in a table
- Broadcom in its most recent response references 3GPP 36.872[2] as containing more appropriate higher loss models, which are in turn defined in 3GPP 36.814 Table B.2.2.1-1.[3] These models, ITU-UMa, ITU-Umi, or ITU-InH, can be used for small cell applications
- **However, none of these models is appropriate for the interference use cases at issue here, a unlicensed base station or UE interfering with a nearby LTE UE, because the models apply exclusively to ranges greater than 10 meters**

1. ITU-R P.1411-3 1Propagation data and prediction methods for the planning of short-range outdoor radiocommunication systems and radio local area networks in the frequency range 300 MHz to 100 GHz.
2. 3GPP TR 36.872 V12.1.0 (2013-12) Technical Spec. Group Radio Access Network; small cell enhancements for E-UTRA and E-UTRAN Physical layer (Rel. 12).
3. 3GPP TR 36.814 V9.0.0 (2010-03) Further advancements for E-UTRA physical layer aspects.

ITU-UMa

- The UMa model as shown to the right and referenced in 3GPP 36.872 is not valid for a separation less than 10 m
- The use cases that are relevant to a electro-compatibility discussion are less than 10 m
- One meter is a well accepted electro-compatibility distance, and in any case there would be LTE operation within the same room as an unlicensed UE or base station; very few rooms assure >10 m separation

Table B.1.2.1-1 Summary table of the primary module path loss models

Scenario		Path loss [dB] Note: f_c is given in GHz and distance in meters!	Shadow fading std [dB]	Applicability range, antenna height default values
Urban Macro (UMa)	LOS	$PL = 22.0\log_{10}(d) + 28.0 + 20\log_{10}(fc)$	$\sigma = 4$	$10\text{ m} < d < d'_{BP}$ [1)]
		$PL = 40.0\log_{10}(d_1) + 7.8 - 18.0\log_{10}(h'_{BS}) - 18.0\log_{10}(h'_{UT}) + 2.0\log_{10}(f_c)$	$\sigma = 4$	$d'_{BP} < d < 5\,000\text{ m}$ [1)] $h_{BS} = 25\text{ m}$ [1)], $h_{UT} = 1.5\text{ m}$ [1)]
	NLOS	$PL = 161.04 - 7.1\log_{10}(W) + 7.5\log_{10}(h) - (24.37 - 3.7(h/h_{BS})^2)\log_{10}(h_{BS}) + (43.42 - 3.1\log_{10}(h_{BS}))(\log_{10}(d)-3) + 20\log_{10}(f_c) - (3.2(\log_{10}(11.75\,h_{UT}))^2 - 4.97)$	$\sigma = 6$	$10\text{ m} < d < 5\,000\text{ m}$ h = avg. building height W = street width $h_{BS} = 25\text{ m}$, $h_{UT} = 1.5\text{ m}$, $W = 20\text{ m}$, $h = 20\text{ m}$ The applicability ranges: $5\text{ m} < h < 50\text{ m}$ $5\text{ m} < W < 50\text{ m}$ $10\text{ m} < h_{BS} < 150\text{ m}$ $1\text{ m} < h_{UT} < 10\text{ m}$

This model is not valid for ranges less than 10 m

ITU-UMi

- The UMi model as shown to the right is not valid for a separation range that is less than 10 m
- The most relevant use cases for an electro-compatibility discussion are less than 10 m
- 1 meter is a well accepted electro-compatibility distance
- There would be LTE UE operation within the same room as an unlicensed UE or base station; very few rooms assure >10 m separation

Table B.1.2.1-1 Summary table of the primary module path loss models

Scenario		Path loss [dB] Note: f_c is given in GHz and distance in meters!	Shadow fading std [dB]	Applicability range, antenna height default values
Urban Micro (UMi)	LOS	$PL = 22.0\log_{10}(d) + 28.0 + 20\log_{10}(f_c)$	$\sigma = 3$	$10\text{ m} < d_1 < d'_{BP}$ [1)]
		$PL = 40\log_{10}(d_1) + 7.8 - 18\log_{10}(h'_{BS}) - 18\log_{10}(h'_{UT}) + 2\log_{10}(f_c)$	$\sigma = 3$	$d'_{BP} < d_1 < 5000\text{ m}$ [1)] $h_{BS} = 10\text{ m}$ [1)], $h_{UT} = 1.5\text{ m}$ [1)]

This model is not valid for ranges less than 10 m

ITU-UnH

- The UnH model as shown to the right is not valid for a separation of less than 10 m
- 1 meter is a well accepted electro-compatibility distance
- There would be LTE UE operation within the same room as an unlicensed UE or base station; very few rooms assure >10 m separation

Table B.1.2.1-1 Summary table of the primary module path loss models

Scenario		Path loss [dB] Note: f_c is given in GHz and distance in meters!	Shadow fading std [dB]	Applicability range, antenna height default values
Hotspot	LOS	$PL = 16.9\log_{10}(d) + 32.8 + 20\log_{10}(f_c)$	$\sigma = 3$	$3\text{ m} < d < 100\text{ m}$ h_{BS} =3-6 m h_{UT} =1-2.5 m
Indoor (InH)	NLOS	$PL = 43.3\log_{10}(d) + 11.5 + 20\log_{10}(f_c)$	$\sigma = 4$	$10\text{ m} < d < 150\text{ m}$ h_{BS} = 3-6 m h_{UT} = 1-2.5 m

This model is not valid for ranges less than 10 m

Broadcom: "QCOM's analysis of this topic assumed an outdoor to outdoor path loss model. Indoor WiFi operation is more likely at these powers and as such a different path loss formula (which includes wall loss) should be used (See 3GPP 36.872 for such formula), which renders the required geographic separation much smaller than QCOM's numbers even under their unrealistic assumptions."

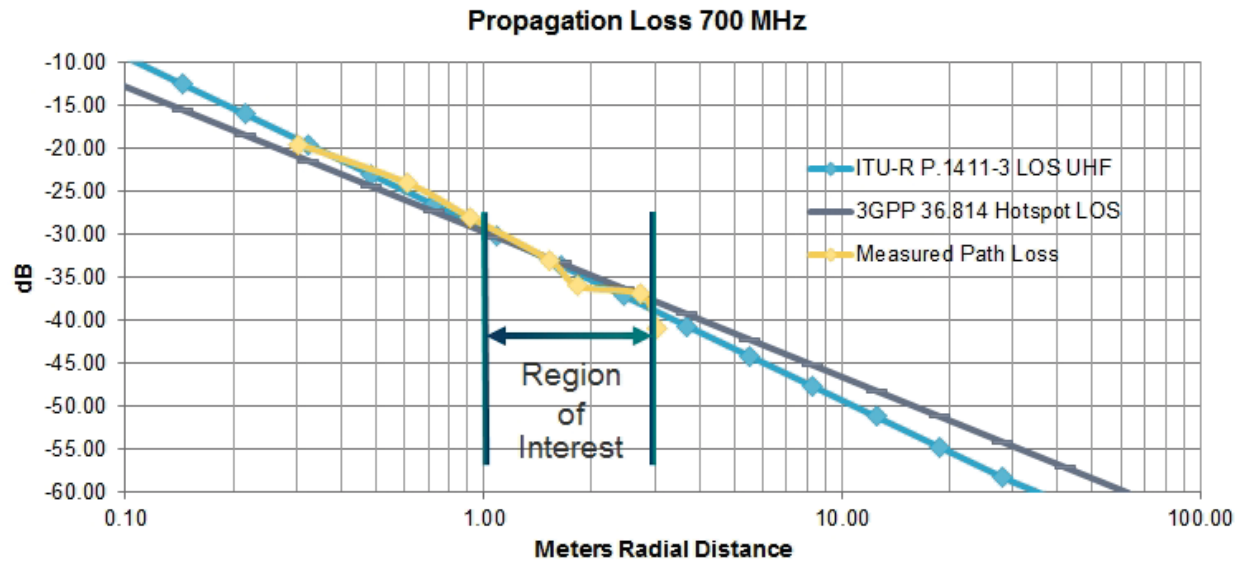
The ITU small cell models in 3GPP 36.872 alleged as more appropriate <u>are not valid</u>

Appropriate Model?

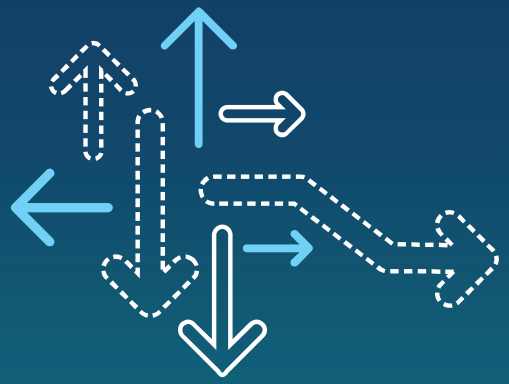
- There is only one model in 3GPP 36.814 Table B.2.2.1-1 that is valid for distances less than 10 m
- The Hotspot LOS model is valid to 3 m, which is not a good electro-compatibility distance, it is but far more appropriate than >10m
- The figure to the right compares the 3GPP Hotspot LOS model to the ITU-R 1411-3 LOS UHF model used by Qualcomm
- There is no material difference between the two models within the region of interest (*i.e.*, 1 to 3 m)
- **The closest applicable 3GPP propagation loss model and indoor measurements confirm the validity of Qualcomm's analysis model**

Table B.1.2.1-1 Summary table of the primary module path loss models

Scenario		Path loss [dB] Note: f_c is given in GHz and distance in meters!	Shadow fading std [dB]	Applicability range, antenna height default values
Hotspot	LOS	$PL = 16.9\log_{10}(d) + 32.8 + 20\log_{10}(f_c)$	$\sigma = 3$	$3\text{ m} < d < 100\text{ m}$ h_{BS} =3-6 m h_{UT} =1-2.5 m
Indoor (InH)	NLOS	$PL = 43.3\log_{10}(d) + 11.5 + 20\log_{10}(f_c)$	$\sigma = 4$	$10\text{ m} < d < 150\text{ m}$ h_{BS} = 3-6 m h_{UT} = 1-2.5 m



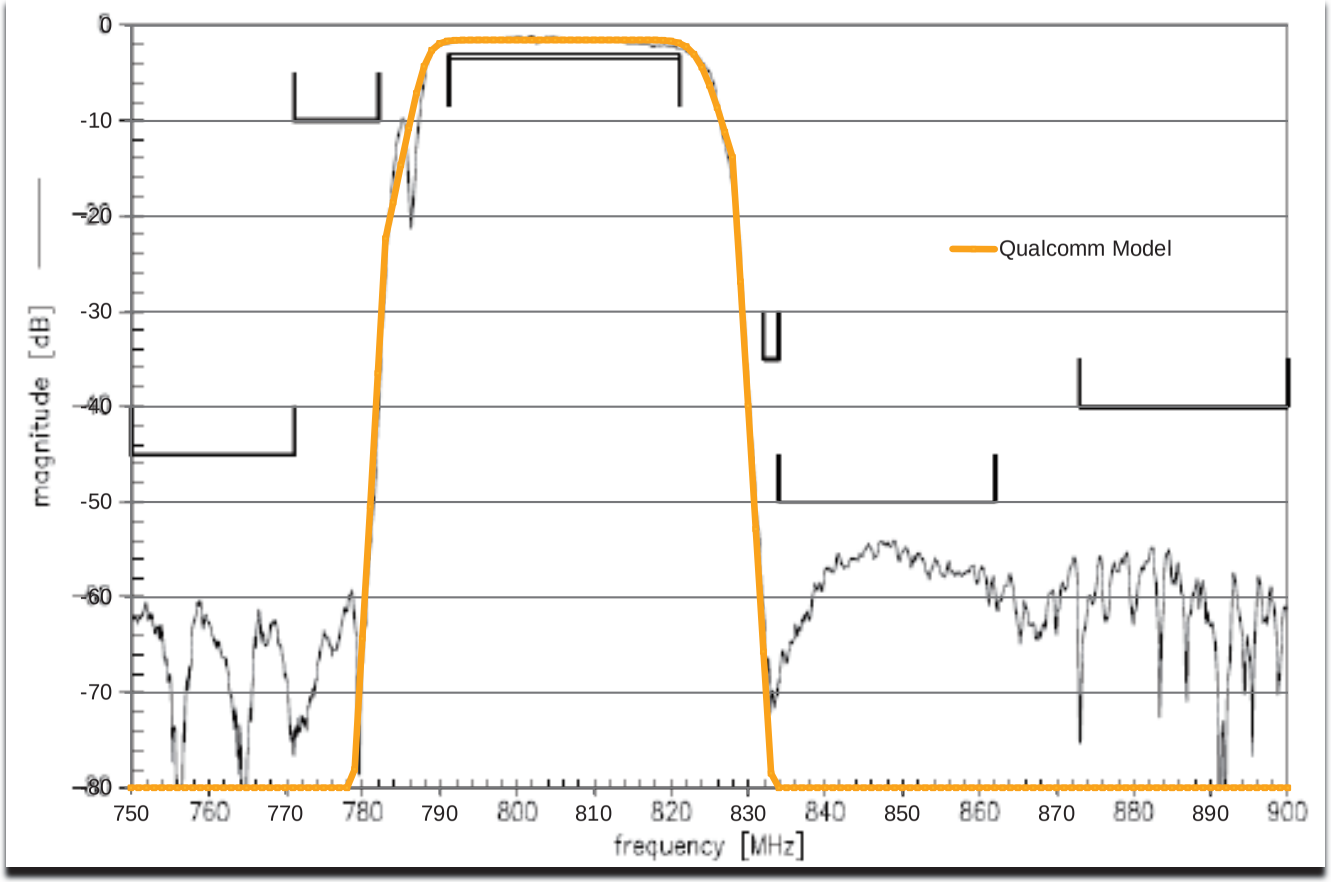
Filter Losses



Filter Losses

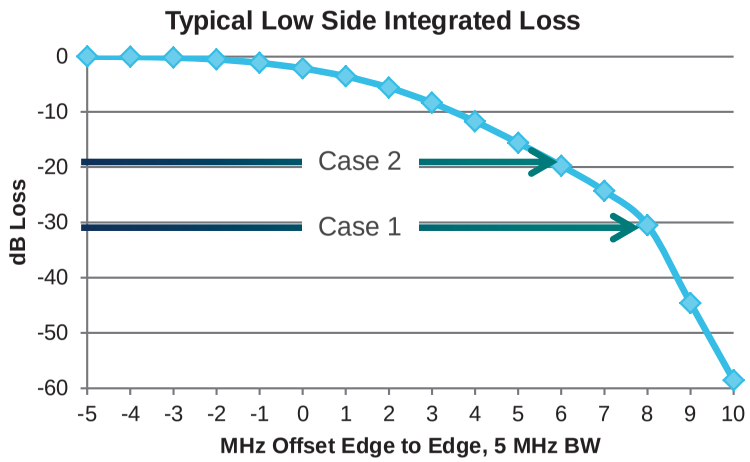
This band 20 filter is cited as exemplary in Broadcom's April 23, 2014 *ex parte*

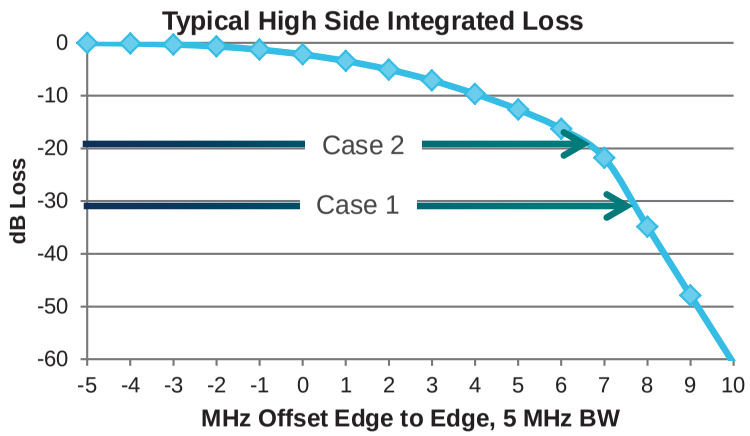
- Broadcom rejected the integrated loss results provided by Qualcomm for a Band 12 filter as being not applicable and pointed to the filter to the right as being exemplary
- Broadcom's "exemplary filter" fails to provide sufficient integrated attenuation for the limiting access point blocking use cases
- An amplitude matched model was created to enable integrated loss to be calculated
- Close correspondence between the model and the typical performance is easily seen for the pass band
- The model's stop band attenuation is quite generous relative to the performance shown in the typical plot



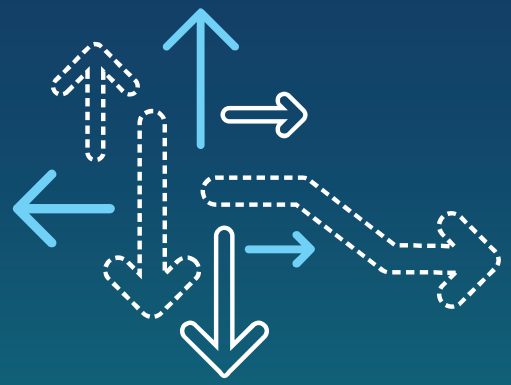
Required Integrated Filter Loss[1]

- Qualcomm's previous analysis showed that 31 dB of integrated loss is required to meet the Case 1 blocking specification for a base station with +16 dBm EIRP
- For the typical "exemplary filter" the required offset is ~8 MHz
- A hypothetical temperature compensated device would require another 0.5 MHz of margin, which provides 8.5 MHz edge to edge
- This required offset is clearly greater than 5 MHz, so one may consider the less stringent Case 2, which requires 19 dB of integrated loss for a base station limited to +16 dBm, typically valid for >10 MHz edge to edge
- This significantly relaxed Case 2 specification still requires 7 MHz, even with the "exemplary filter" & temperature compensated to 0.5 MHz stability
- **Broadcom includes no margin for manufacturing tolerance which further increases the required edge to edge offset**
- **Broadcom's "exemplary filter," even with best case assumptions, cannot achieve a 4 MHz offset; this explains why Broadcom avoids the correct metric, which is integrated loss**





[1] See "recap" slides at the end of this deck for previously supplied blocking analysis for 3GPP Cases 1 and 2

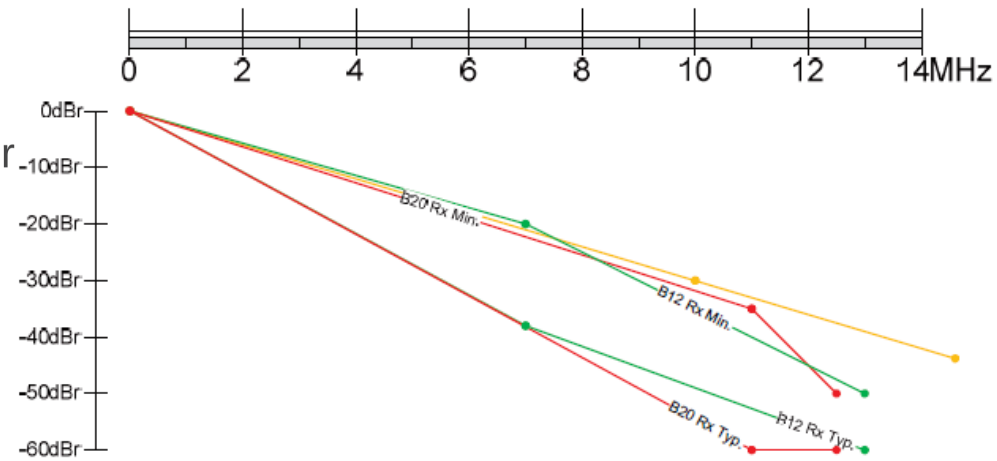


Other Technical Flaws

Other Technical Flaws

- Previous Broadcom filings have asserted that there is sufficient loss based on point analysis of filters, as shown in the adjacent Broadcom figure
- **A single data point cannot be used to assess the required loss for a broadband spectrum**
- Broadcom further maintains that it is appropriate for the FCC to assume that all LTE devices perform 10 dB better than 3GPP specifications based on one LTE device, when over 1500 different types of LTE devices have been in the marketplace from more than 150 suppliers,[1] and further without consideration for the variability associated with power supply voltage, operating temperature, or manufacturing process
- **Broadcom claims LTE devices will operate at 12 resource blocks instead of the licensed 25 for 5 MHz or 50 for 10 MHz. Interference analysis cannot ignore waveforms that use all the licensed spectrum**

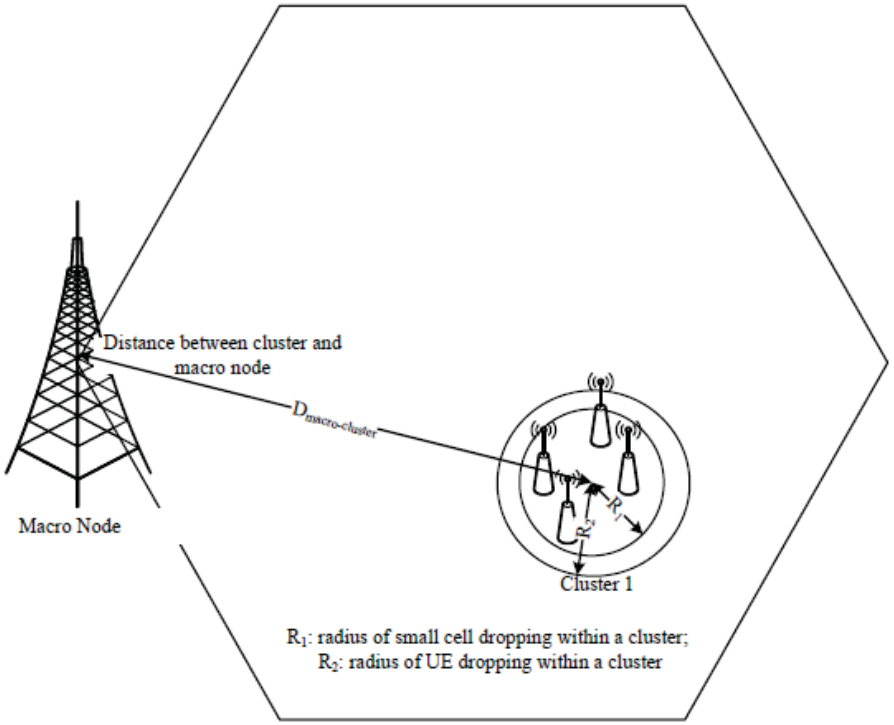
A point specification cannot be used to properly assess attenuation performance for a wide band interference spectrum



1. Global mobile Suppliers Association (GSA) Status of LTE Ecosystem Report (Mar. 19, 2014)

FDD LTE Uses Similarity of Levels and Joint Management to Achieve Successful Operation

- Broadcom claims that unlicensed would achieve signal levels similar to LTE, so therefore the two systems are compatible
- FDD only functions successfully for mixed small and macro cells, when there is correlation between the losses from the various macro base stations, and both types of base stations are jointly managed and coordinated
- Unlicensed TDD base stations even when restricted to +16 dBm EIRP are potentially much closer to LTE UEs than the LTE macro, and unlicensed levels are definitely not correlated to FDD macro base stations
- **LTE requires joint management of macros and small cells within a band to achieve inter-operation**
- **There is no joint management among unlicensed TDD and LTE FDD services**



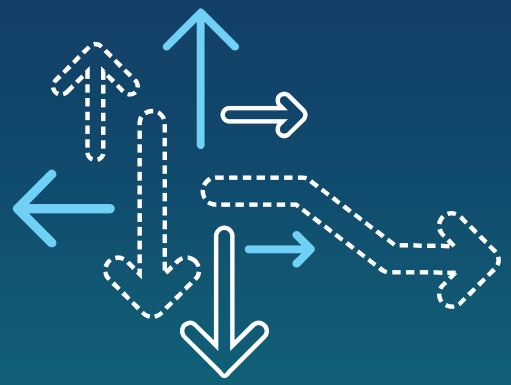
Similarity of Levels and Joint Management Is Required to Achieve Successful Operation for FDD LTE (1 of 2)

- With adjacent LTE deployments, co-located base stations are used to avoid the well-known "near far problem" and to keep the UE Transmit (Uplink) OOBE below the other in-band channel Uplink at the base station
- With TD-LTE bands, for example, in-band carriers are time aligned, so there would be no OOBE UE to UE interference from one UL to the other DL.
- For FDD-LTE bands, in-band carriers would meet the following UE requirements:
  1. -50dBm/MHz conducted emissions into the DL of the other carrier at aggressor UE output; and
  2. Victim UE has to meet ACS (Adjacent Channel Selectivity) of 33dB, as well as Case 1 (-56dBm) and Case 2 (-44dBm) in-band blockers

Similarity of Levels and Joint Management Is Required to Achieve Successful Operation for FDD LTE (2 of 2)

- Placing unlicensed Wi-Fi operations 4 MHz from an FDD Downlink presents the following problems:
  1. Jammer level will be higher than -56dBm (Case 1 jammer) at the victim, requiring significant attenuation from filters not currently known to be feasible for 4MHz offset in the 600 MHz band
  2. Unlicensed OOBE would exceed the -50dBm/MHz limit at the aggressor, expected of LTE UE to UE
  3. There is no possibility of co-locating base stations or time aligning Wi-Fi and Macro-cell LTE
- Thus, placing unlicensed Wi-Fi operations near an FDD downlink band is a very different coexistence problem than what is present with in-band FDD channels, which use co-located base stations, and well known 3GPP coexistence specifications.
- Broadcom ignores these factors and simply concludes that LTE and Wi Fi are compatible

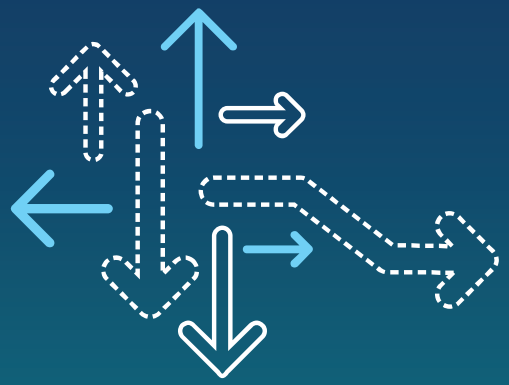
Conclusions



Conclusions

- Over a series of submissions, Broadcom has made numerous incorrect claims and unsupported statements to contend that 4 MHz of guard band is sufficient for operation of unlicensed in a 10 MHz duplex gap or guard band including:
  - propagation assumptions and models that are unquestionably invalid
  - speculative claims about the performance of LTE devices consistently meeting specifications 10 dB better than that required by 3GPP specifications
  - failure to demonstrate that any filter (or provide a filter specification) that can meet the integrated loss requirements
  - relying on operating schemes that require the joint management of LTE FDD and unlicensed TDD operations, that do not exist
- Inserting unlicensed operations in a 10 MHz guard band or 10-12 MHz duplex gap will result in harmful interference and thus destroy the fungibility of the adjacent licensed spectrum
- There is no valid technical argument that supports unlicensed operation in the 600 MHz guard bands or duplex gap

Brief Recap of Qualcomm’s Earlier Analysis

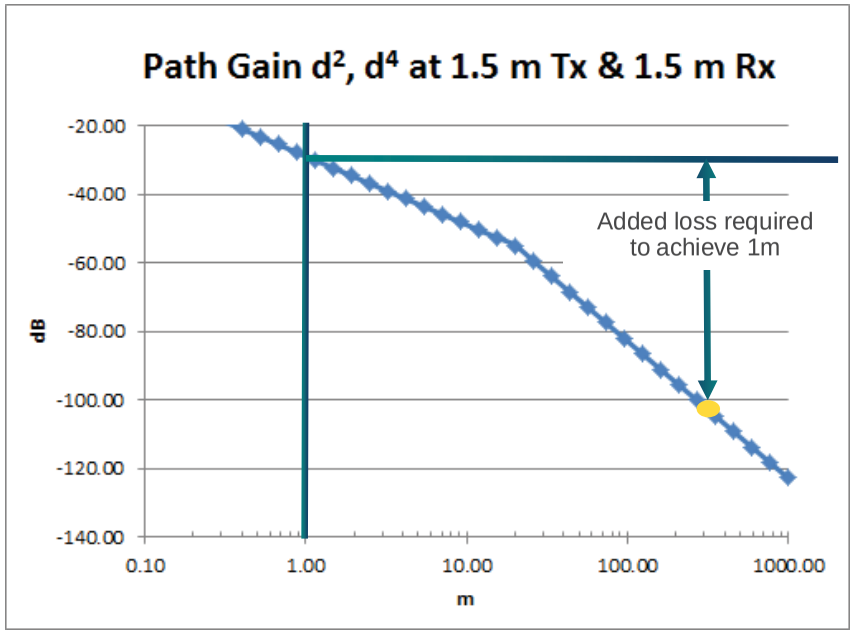


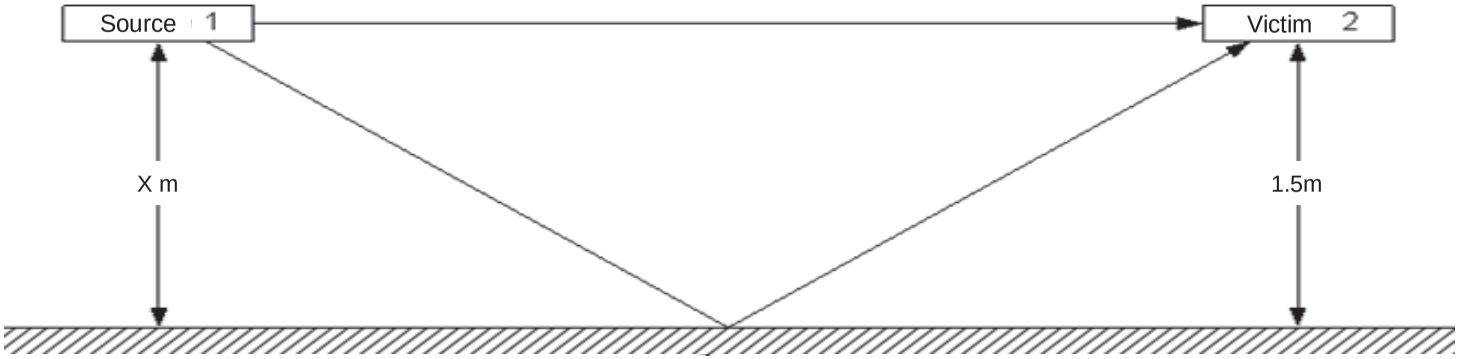
Propagation Model for Unlicensed <–> LTE UE

- 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

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

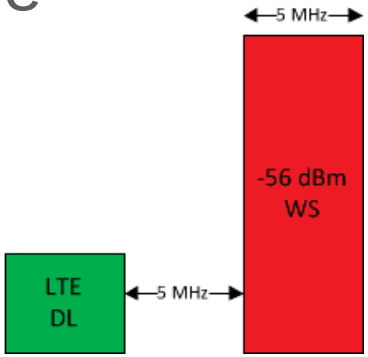
- The heights are set to 2 m and 1.5 m (UE) respectively for base station to UE, else 1.5 m for UE to UE
- See ITU-R 1411-2 Sec 4.1 or ITU-R P.341 for more details



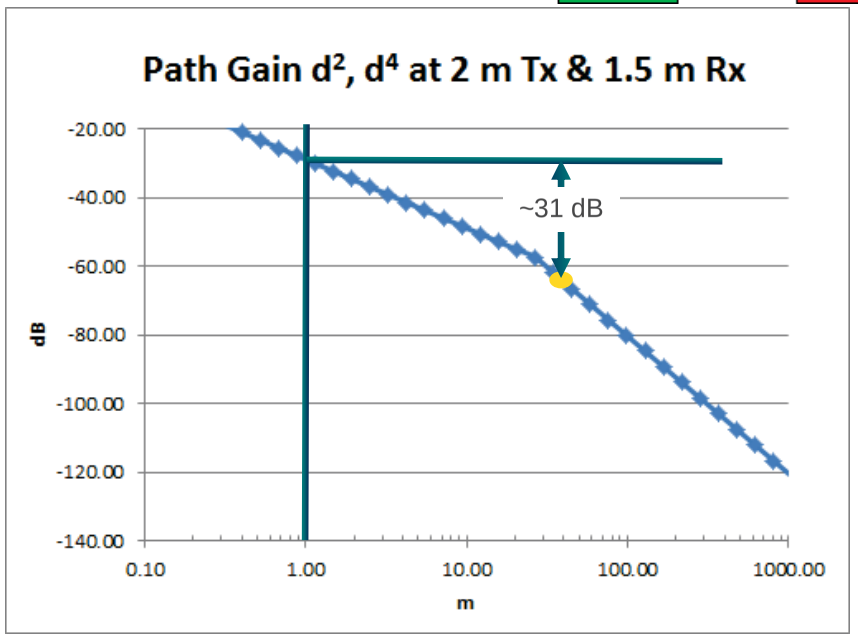


Unlicensed Block of LTE UE Case 1, Duplex Gap Side

- 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
- Over temperature and process **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



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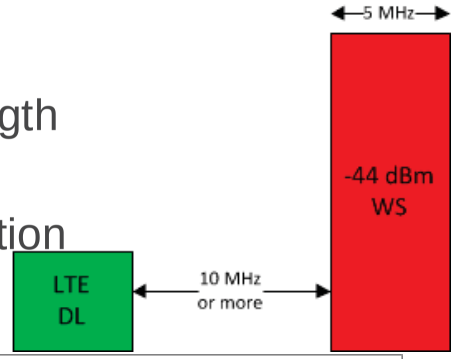
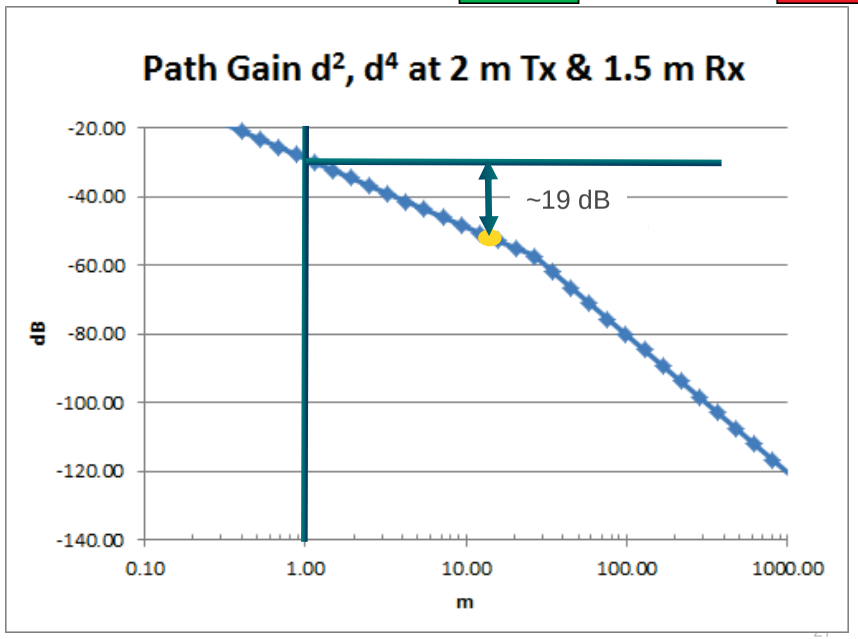
Unlicensed Block of LTE UE Case 2, Duplex Gap Side

- 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
- Over temp and process **19 dB additional loss** is needed to achieve 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
Typical Integrated Loss	7	2	dB
Blocking Path Loss	43	48	dB
Distance to Path Loss	5	9	m



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