WILTSHIRE & GRANNIS LLP

April 23, 2014

Ex Parte

Marlene H. 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:

On April 21, 2014, Vinko Erceg, Senior Technical Director of Systems Design Engineering, Ron Porat, Senior Principal Engineer of Systems Design Engineering, and Christopher Szymanski, Director of International Government Relations of Broadcom Corporation ("Broadcom"), Austin Schlick, Director, Communications Law at Google Inc., and I spoke via telephone with Gary Epstein, Howard Symons, and Edward Smith of the Incentive Auction Task Force; Julius Knapp of the Office of Engineering and Technology; and John Leibovitz and Chris Helzer of the Wireless Telecommunications Bureau, regarding the above-referenced docket.

During this meeting, we explained that some of the most important broadband uses contemplated under the 802.11af draft standard would not be available if the 600 MHz band is unable to accommodate unlicensed operations using 40 mW transmit power in 6 MHz channels. Broadcom observed that, while some unlicensed operations would still be possible if there were significant decreases in range and/or throughput, the use cases most likely to drive large scale equipment investment would fall off if devices had to significantly reduce transmit power or could only access spectrum at reasonable transmit power in increments of less than 6 MHz.

In addition, the parties reviewed the attached presentation, which responds to several claims made in QUALCOMM Incorporated's ("Qualcomm") April 3, 2014 ex parte filing. Broadcom explained that its analysis supports the conclusion that unlicensed broadband operations in the guard band(s) and duplex gap are feasible, and demonstrates that its January 30, 2014 recommendations for Wi-Fi transmit power may actually be *increased* without causing harmful interference to the LTE downlink.

Broadcom also explained that Qualcomm's attempt to dismiss Broadcom's analysis as "hypothetical performance claims and wishful thinking" misses the mark. Indeed, Broadcom's recent testing of a leading smartphone (which has been sold in the United States since 2013) exceeded by several dB the in-band blocking assumptions used in Broadcom's March 3, 2014 *ex parte* filing (10 dB better than 3GPP specifications). Qualcomm, in contrast, would have the

Commission ignore actual device performance altogether and look solely at 3GPP specifications. Accordingly, Broadcom explained that the Commission's assessment of accommodating unlicensed broadband operations should reflect real world device performance, and should also reasonably assume some potential improvement in future device performance.

Additionally, Broadcom noted that Qualcomm's assertion that Broadcom's analysis is based on typical filters is similarly incorrect. Rather, Broadcom included a conservative filter assumption based upon performance guaranteed by the manufacturer across temperature and process.[1] Even employing this assumption, Broadcom found that a device that performs 10 dB better than the 3GPP blocking specification would have a 6 dB margin.[2]

Finally, with respect to the issue of potential LTE uplink interference to Wi-Fi, Broadcom explained that Qualcomm's assumption that Broadcom overlooked this issue is again mistaken. As indicated in Broadcom's January 30 filing, Wi-Fi can work at distances of two to three meters from LTE uplink, assuming a 2 MHz gap. Broadcom further addressed this issue in the enclosed presentation.

For these reasons, Broadcom's analysis confirms that Wi-Fi devices can transmit at 40 mW with a 4 MHz gap from LTE downlink without causing harmful interference to licensed operations.

Pursuant to the Commission's rules, a copy of this notice is being filed electronically in the above-referenced docket. If you require any additional information please contact the undersigned.

Sincerely,

/s/ Rob Carter

S. Roberts Carter

Enclosure

cc: meeting participants

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[1] *See* Letter from Jennifer K. Bush, Associate General Counsel, Broadcom Corporation to Marlene H. Dortch, Secretary, Federal Communications Commission, GN Docket No. 12-268 (filed Mar. 3, 2014) at 8-9 (pages 6-7 of enclosure).

[2] 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.

ANALYSIS OF WIFI-LTE INTERFERENCE

April 21, 2014

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OUTLINE

- **In their April 3rd filing QCOM made the following main claims:**
  - The FCC should rule based on 3GPP specs;
  - BRCM filtering assumptions were based only on typical filters;
  - BRCM overlooked the interference from LTE UL to unlicensed operation in the duplex gap.

- **In this filing we refute QCOM claims and show that:**
  - The FCC can and should rule based on current technology as deployed in the field as tests of a product validate our claims;
  - Our previous filing did include in the analysis a conservative assumption of filter performance and our previously proposed transmit power levels provide margin even relative to that; and
  - Our previous filing did include an analysis of interference from LTE UL to unlicensed operation in the duplex gap and found it to not be an issue.

- **We conclude that under realistic path loss assumptions and in band blocking and filter performance our previously suggested transmit powers may actually be increased without causing harmful interference to LTE DL.**

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DISCUSSION – REAL WORLD PRODUCTS AND FILTERS

- **Our previous filing analyzed blocking performance based on BRCM products that exceed the 3GPP specification by at least 10dB and explained why we expect this to be the case with other manufacturers as well.**
- **Subsequently, we tested a leading smartphone sold in the US since 2013 and found our claim to be correct because the subject smartphone exceeded the in band blocking assumption provided in our filing (10dB better than 3GPP) by a significant margin.**
- **Based on our tests it is clear that the QCOM claim that** "Handsets and tablets are designed to 3GPP specifications" **is without foundation and should not influence the Commission's decision in this proceeding.**
- **QCOM's assertion that BRCM only looked at typical filter performance is similarly mistaken. A more careful reading of our March 3rd filing in slides 8 and 9 (also attached) demonstrates that BRCM actually included a conservative filter assumption based on performance guaranteed by the manufacturer across temperature and process. Our analysis showed that even in this case, a device that performs only 10dB better than the 3GPP blocking spec will have 6dB margin using BRCM transmit power assumptions, for example with 10MHz size band (4MHz edge to edge): 34mW (assuming the same -56dBm 3GPP level for 4MHz edge to edge).**
- **However, we do agree with QCOM that in the down from 51 plan, LTE filtering will be weaker in the guard band than the duplex gap. Hence the margin provided in our analysis can be used to justify transmission in the guard band using our proposed transmit powers. Conversely, for operation in the duplex gap the transmit power can be increased.**

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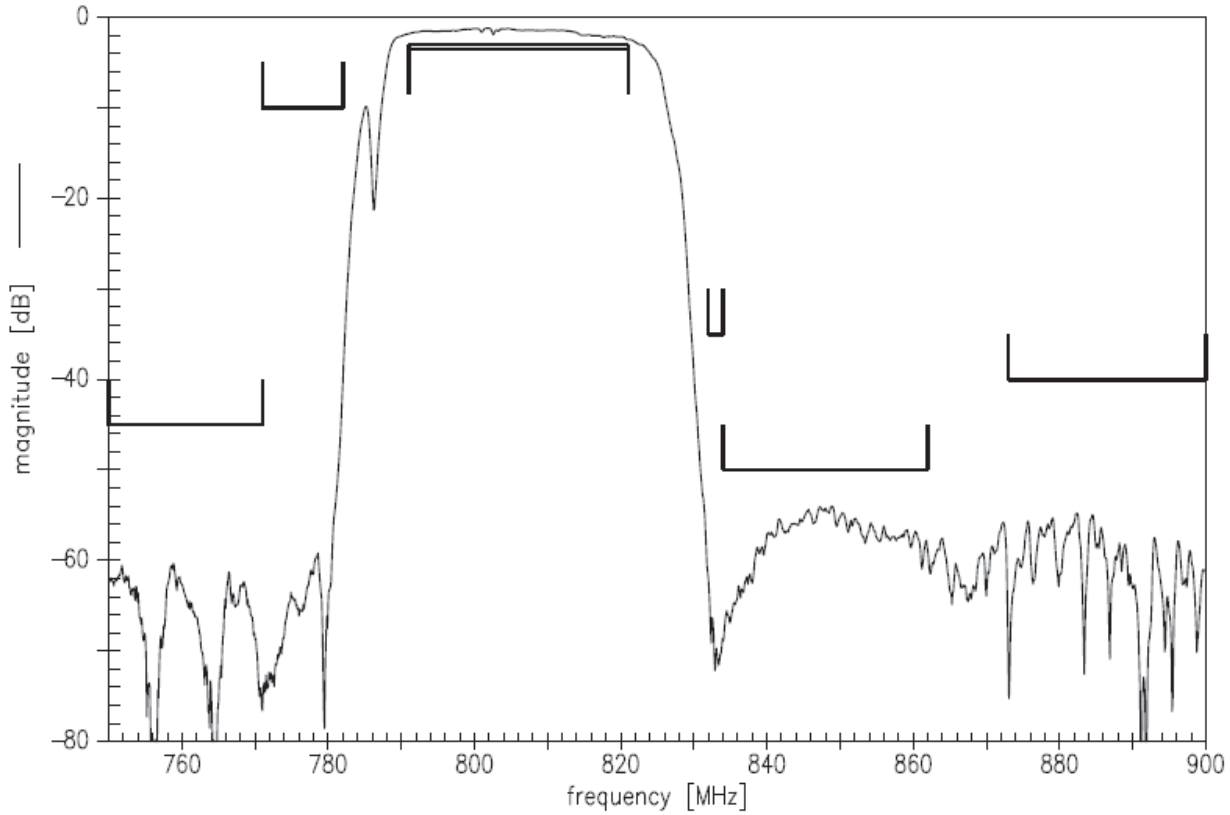
REAL WORLD PRODUCTS AND FILTERS CONT.

- When it comes to filters QCOM chose in their April 3rd slide 7 filing a filter for B12 not representing the scenario in 600MHz that requires tight attenuation on both sides (the B12 duplexer doesn't need to protect against interference for 30MHz on the weak side).
- A more suitable example band is B20 as shown below where the Rx filter needs to attenuate DTV EU channels at 782MHz, just 9MHz below the B20 DL lower edge at 791MHz.
- Future TC-SAW filters will also provide reduced variability over temperature and manufacturing (variability over temperature expected at less than 0.5MHz).



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REAL WORLD PRODUCTS AND FILTERS CONT.

- **To re-iterate, the measured performance on a smartphone currently sold in the marketplace adds to the margin in our previous filing (making it even more conservative), or conversely allows even higher transmit power.**
- **We would like to further emphasize that interference between WiFi and LTE is highly probabilistic in nature – it requires geographic proximity and concurrent transmission by a WiFi device and reception by an LTE device. This is very unlikely to happen because even if two nearby (2-3m separation) WiFi and LTE devices are active at the same time they both could be working on other channels in the 600MHz or other higher frequency bands. In fact, interference from one LTE DL channel to an adjacent LTE channel is as or more likely given that LTE is deployed using high power Macro cells that serve large number of devices and are therefore on all the time transmitting continuous pilots and data (which is the reason for the in band blocking specification in the first place).**
- **We therefore think that a technical analysis of interference between a low power device and LTE DL should assume a typical expected performance in the field (in band blocking and filters) rather than a highly conservative set of assumptions.**

- **Conclusions:**
  - A leading smartphone product testing shows higher in-band blocking capability than 10dB.
  - Even with a conservative filtering assumption 6dB margin exists in the duplex gap.
  - Due to some level of LTE duplexer asymmetry, for the same gap between WiFi and LTE, transmit powers of unlicensed devices in the duplex gap could be higher than in the guard band.

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DISCUSSION - PATH LOSS

- **The Commission should review all of QCOM claims with caution. QCOM borrowed a sentence from a GE filing, changed it to refer to [LTE UE] instead of the original wording, and claimed relevancy to this filing. Not only we find this modified quote strange, inappropriate and wrong, GE's sentence is completely irrelevant to this filing since we have assumed free space propagation between WiFi and LTE in our January 30th filing.**
- **To further re-iterate our January 30th path loss assumptions, to ensure a conservative analysis, we assumed free space propagation with several other factors contributing to the total path loss such as:**
  - Counting body loss only in the LTE device and not in the WiFi device - in this filing we change this assumption to include body loss in both WiFi and LTE devices;
  - Conservative 3dB body loss;
  - 2dB antenna polarization mismatch;
  - 3dB shadowing; and
  - 5dB antenna loss.
- **We note that using QCOM assumptions for antenna loss of 6dB and body loss of 4dB (which we here assume to be on both sides) yields an additional 3dB loss relative to our previous assumptions even without assuming any shadowing loss.**
- **In [1], experimental results were reported on the body loss for the mobile handset in data mode operation. Large variations are seen which depend on the phone type and other factors (2-15dB) with mean quoted below 6dB. The table on the next slide summarizes these new numbers and our revised assumptions that lead to a new total path loss.**

[1] "User Influence on the Mean Effective Gain for Data Mode Operation of Mobile Handsets" - EuCAP 2012

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PATH LOSS CONT.

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

- **Under these assumptions, at least 7dB higher total path loss is seen when compared to our previously filed numbers of 48dB and 51.5dB for 2m and 3m separation respectively.**
- **Assuming even a conservative 3dB increase in total path loss leads to a doubling of our previously calculated transmit powers.**
- **To summarize, we re-iterate without reservation our recommendation that the Commission take into account in its ruling that:**
  - LTE devices currently on the market exceed 3GPP specification by greater than 10dB; and
  - LTE blocking performance on either side of LTE DL band is not an issue when devices transmit with powers in accordance with BRCM's recommendation.
- **Furthermore BRCM believes that its earlier analysis was likely conservative. Based on the analysis of total path loss in this filing, power levels exceeding our previous recommendation could be assumed without causing harmful interference to LTE DL.**

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PATH LOSS CONT.

- **We also disagree with QCOM claim that at least 14MHz guard band is required:**
  - Issues related to guard band and duplex gap size are solely a function of broadcast TV interference into LTE DL and vice versa and interference from LTE UL into LTE DL respectively.
  - If the Commission chooses band sizes that allow at least 4MHz separation between WiFi and LTE, unlicensed operation can work with similar powers as is currently allowed for mobile devices under TVWS rules.
  - From an engineering point of view there is always an appropriate power for unlicensed operation that will not materially impact LTE DL considering all the phenomena that we analyzed – OOBE into LTE, LTE blocking performance and IM3 issues.
    - Note again that our March 3rd filing did provide an analysis that refutes QCOM claim for IM3 issues in the duplex gap.

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DISCUSSION – LTE UL INTERFERENCE TO WIFI

- **QCOM also wrongly assumed that BRCM overlooked the potential interference from LTE UL to unlicensed operation in the Duplex gap. Slide 20 in our Jan 30 filing (also attached) demonstrates that WiFi can work at distances of 2-3m from LTE UL assuming 2MHz gap.**
- **To further explain the gap between our results and QCOM we note the following:**
  - QCOM fails to include both sides antenna losses in its analysis.
  - QCOM assumes LTE OOBE at -30dBr while its own plots show lower values especially when averaged across WiFi 5MHz BW. We measured much lower values for OOBE when LTE occupies the full 5MHz BW (25 RB) and even further lower values when LTE occupies a more likely 12RB scenario, consistent with practical LTE implementations and device performance which are again better than 3GPP spec.
  - Differences in filtering performance assumptions between BRCM and QCOM. Note that as far as operation in the duplex gap is concerned, the LTE filtering is as in BRCM filing which helps unlicensed operation in this band.
  - The above contribute in total several 10's of dB for the difference of OOBE LTE interference.
- **We would further like to point out that unlicensed operation is best effort and as such:**
  - Rise in interference over thermal noise can be tolerated; and
  - Larger than 2-3m separation distances can be tolerated.
- **In addition, 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.**

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CONCLUSIONS

- **Field deployments of LTE systems present high levels of in-band and out-of-band interference (within the system). Devices are designed to operate in such environments.**
- **Hence, operation of low power (<100mW) WiFi in the guard band and duplex gap is not fundamentally different than adjacent channel interference from cellular or other systems and doesn't destroy the fungibility of the LTE spectrum.**
- **Allowing operation of unlicensed devices in the guard band and duplex gap is always possible from an engineering point of view and with our latest assumptions in slide 7 we believe that 40mW transmit power is viable for at 4MHz separation from LTE.**

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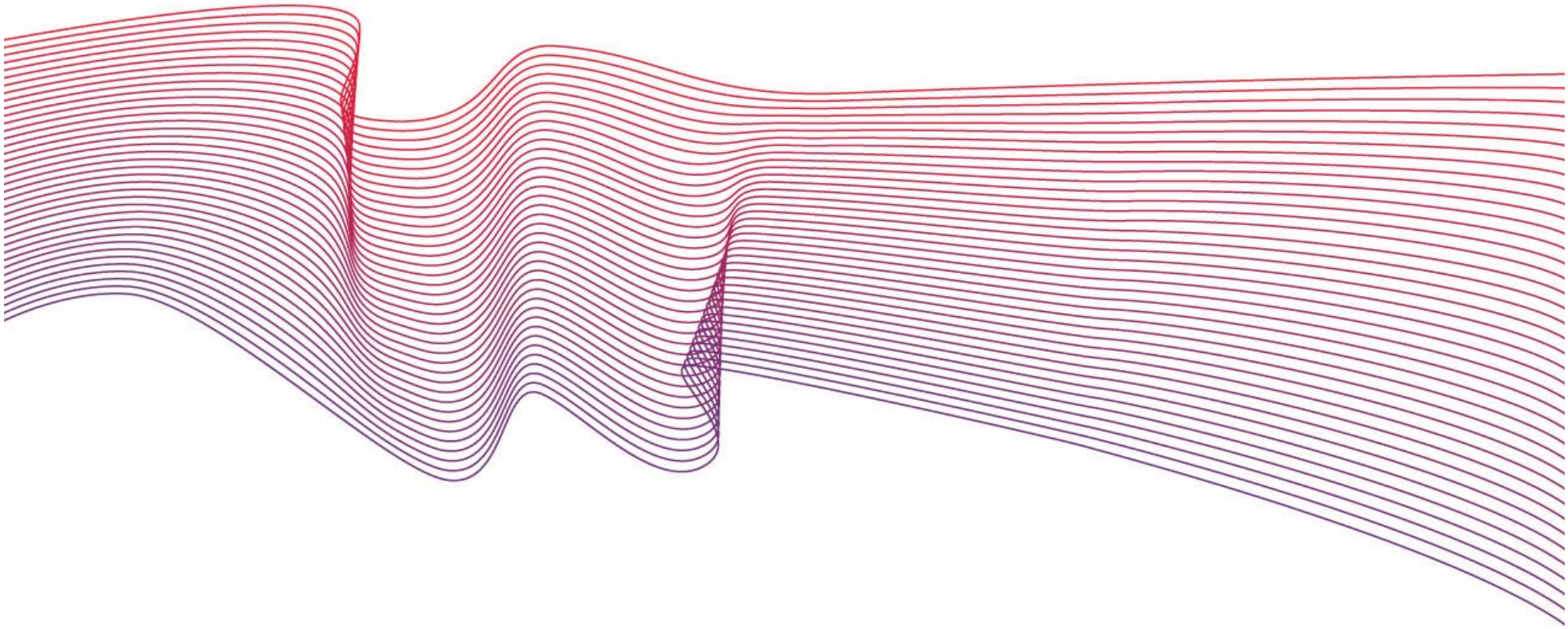
APPENDIX



Relevant Information Contained in Broadcom's January 30th and March 3rd Filing

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REMINDER - OUR JANUARY 30TH ANALYSIS

- **In subsequent slides we analyze an example of 48dB attenuation between WiFi and LTE devices operating at 2m of separation as demonstrated in the table below .**

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

- **In subsequent slides we analyze two cases – 0MHz and 4MHz – the resulting WiFi EIRP based on OOBE is 7.6dBm and 15.3dBm respectively.**

Integrated OOBE into LTE 4.5MHz BW and resulting allowed WiFi EIRP			
LTE device to WiFi device distance		2m	3m
WiFi 6MHz to LTE 5MHz channels gap	Integrated WiFi OOBE into LTE	Maximum WiFi EIRP	
0MHz	-58.2dBr	7.6dBm	11.1dBm
1MHz	-60.2dBr	9.6dBm	13.1dBm
2MHz	-62.5dBr	11.9dBm	15.4dBm
3MHz	-64.3dBr	13.7dBm	17.2dBm
4MHz	-65.9dBr	15.3dBm	18.8dBm
6MHz	-69.2dBr	18.6dBm	22.1dBm

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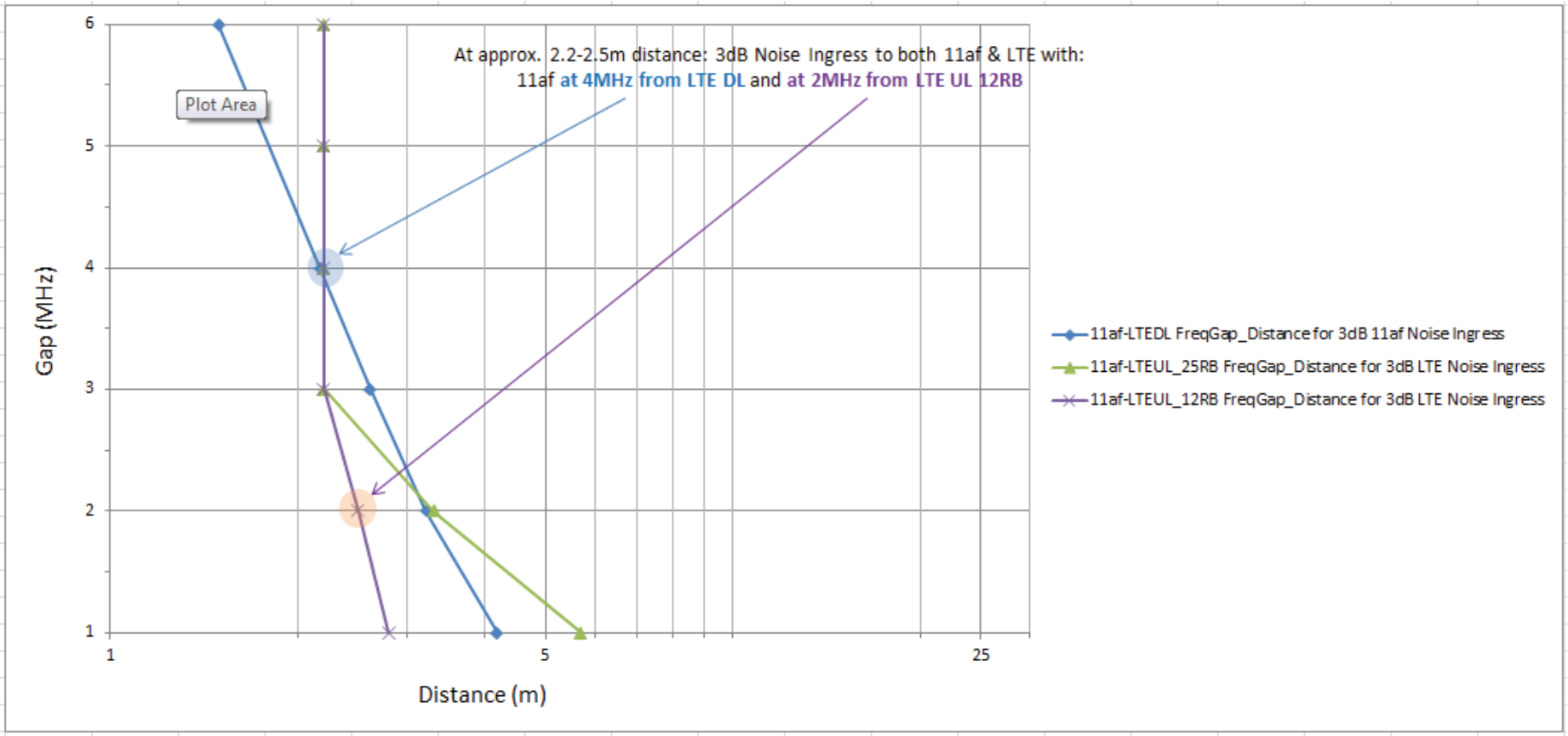
REMINDER - OUR JANUARY 30TH ANALYSIS ANALYSIS OF LTE UL INTERFERENCE INTO WIFI

- **Similar to the previous analysis, we reviewed WiFi blocking performance and LTE UL OOBE and provide an overall summary of the required gap and distances in the plot below.**
- **The same assumptions from Slide 3 continue to apply, except that here we:**
  - Assume LTE UL transmissions at 23dBm (and WiFi at 16dBm) as the input to the analysis;
  - Look at the separation distance and gap to achieve the same 3dB noise ingress to WiFi; and
  - Note that LTE UL may use a portion of the BW (especially cell edge devices) and we observed reduced OOBE in this case.



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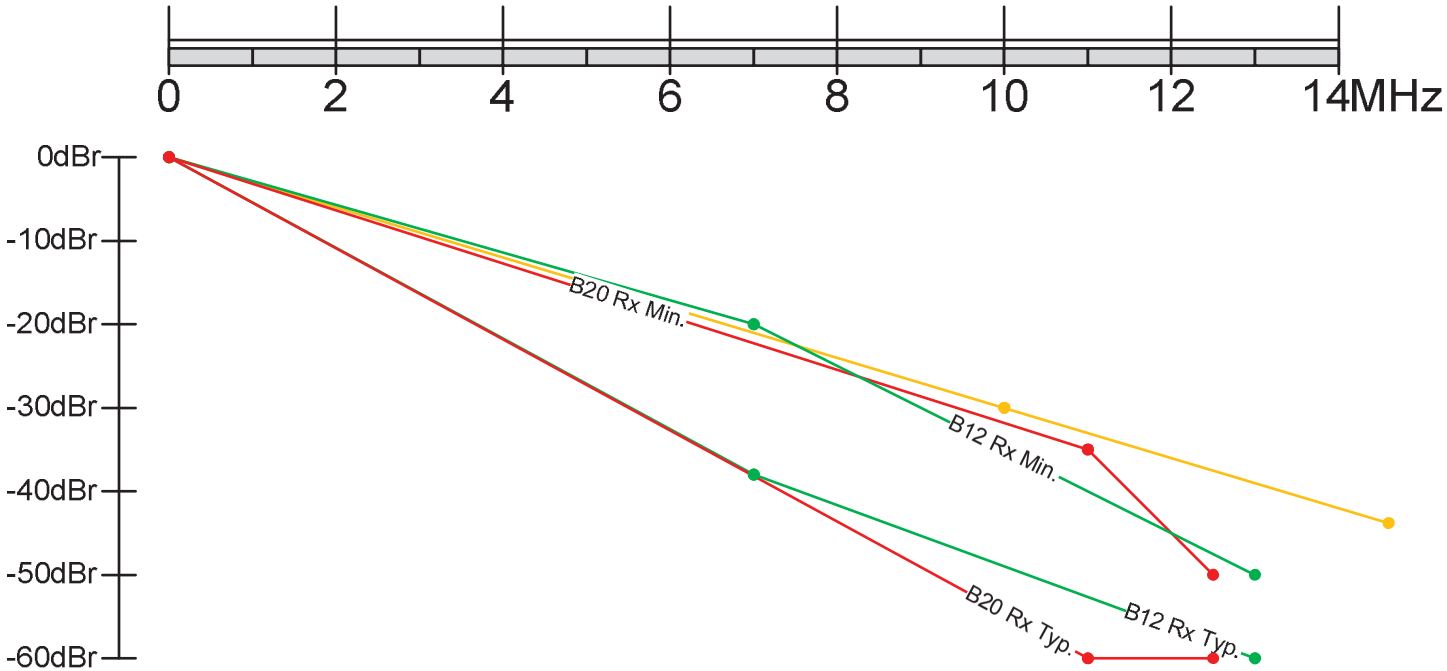
REMINDER - OUR MARCH 3RD ANALYSIS SAW FILTER

- **Filter assumptions are shown below and are based on a leading SAW filter vendor.**
  - Conservative – yellow line.
  - Typical – B20 red line.

ANT-Rx filter attenuation of leading SAW vendor B12 Duplexer: 13MHz duplex gap (699-716MHz UL, 729-746MHz DL).
ANT-Rx filter attenuation of leading SAW vendor B20 Duplexer: 11MHz duplex gap (791-821MHz DL, 832-862MHz UL).

Conservative ANT-Rx filter assumption: 30dB Att. at 10MHz from band bdge.
Typical ANT-Rx filter assumption: B20 Duplexer typical attenuation was used.



- **The average attenuation across a 5MHz WiFi signal bandwidth is calculated based on the WiFi to LTE separation gap and shown in the following analysis.**

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REMINDER - OUR MARCH 3RD ANALYSIS - ACS

- **3GPP specifies -51.5dBm as the required ACS threshold for signals adjacent to LTE. This, coupled with our assumption from slide 3 leads to a device ACS capability of -41.5dBm.**
- **The bottom row shows that:**
  - With a conservative filter assumption: There is 5.9dB ACS margin relative to OOBE-based EIRP limits; and
  - With a typical filter assumption: There is 9.6dB ACS margin relative to OOBE-based EIRP limits.

WiFi to LTE channel gap	0MHz
Total path loss assumed @ 2m	48dB
Allowed WiFi EIRP	7.6dBm
WiFi signal at LTE device antenna connector	-40.4dBm
Average filter attenuation [Conservative Typical]	[7 10.7]dB
WiFi signal power after filter [Conservative Typical]	[-47.4 -51.1]dBm
LTE device performance threshold	-41.5dBm
Margin relative to LTE device [Conservative Typical]	[5.9 9.6]dB

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REMINDER - OUR MARCH 3RD ANALYSIS - BLOCKING

- **3GPP specifies -56dBm as the required blocking threshold at 5MHz separation. Our analysis here assumes 4MHz separation; to compensate for the 1MHz difference we estimate 1-2dB difference relative to the specification and use the value -58dBm threshold. This, coupled with our assumption from slide 3 leads to a device blocking capability of -48dBm.**
- **The bottom row shows that:**
  - With a conservative filter assumption: There is 3.7dB Blocking margin relative to OOBE-based EIRP limits; and
  - With a typical filter assumption: There is 17.2dB Blocking margin relative to OOBE-based EIRP limits.

WiFi to LTE channel gap	4MHz
Total path loss assumed @ 2m	48dB
Allowed WiFi EIRP	15.3dBm
WiFi signal at LTE device antenna connector	-32.7dBm
Average filter attenuation [Conservative Typical]	[19 32.5]dB
WiFi signal power after filter [Conservative Typical]	[-51.7 -65.2]dBm
LTE device performance threshold	-48dBm
Margin relative to LTE device [Conservative Typical]	[3.7 17.2]dB

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