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RM-11660

February 29, 2012

Marlene H. Dortch, Secretary
Federal Communications Commission
Office of the Secretary
445 12th Street, SW,
Room TW-A325
Washington, DC 20554

FILED/ACCEPTED

FEB 29 2012

Federal Communications Commission
Office of the Secretary

Re: In the Matter of Amendment of the Commission's Rules Governing Radiated Power Limits in the Cellular Radio Service Frequency Bands

Dear Ms. Dortch:

Enclosed for filing are an original and four copies of AT&T's petition for expedited rulemaking and a request for a waiver in the matter captioned above. Please stamp one copy as filed and return that copy to me.

Very truly yours,

William L. Roughton, Jr.

BEFORE THE
FEDERAL COMMUNICATIONS COMMISSION
WASHINGTON, D.C.

FILED/ACCEPTED

FEB 29 2012

Federal Communications Commission
Office of the Secretary

In the Matter of	)
	)
Amendment of the Commission's Rules	)
Governing Radiated Power Limits in the	)
Cellular Radio Service Frequency Bands	)
	)

PETITION FOR EXPEDITED RULEMAKING AND REQUEST FOR WAIVER

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February 28, 2012

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INTRODUCTION AND SUMMARY

AT&T Services, Inc., on behalf of AT&T, Inc. and its subsidiaries ("AT&T"), hereby petitions the Federal Communications Commission ("the Commission" or "the FCC") to initiate a rulemaking to modify the current rules for cellular base station Effective Radiated Power ("ERP") contained in Section 22.913 of the Commission's rules, 47 C.F.R. § 22.913, to be consistent with other mobile broadband services.[1] AT&T proposes that the current ERP limits for cellular base stations should be restated as power spectral density ("PSD") limits to eliminate unintended penalties on the deployment of advanced digital broadband modulation schemes. AT&T recommends a PSD limit of 250 watts/MHz in non-rural areas and 500 watts/MHz in rural areas, which will enable the broader roll-out of broadband systems without creating harmful interference to any adjacent licensees or services. For the reasons set out below, the current rule inhibits the deployment of desperately needed mobile broadband capacity. Therefore, AT&T is seeking both an expedited rulemaking and a waiver of Section 22.913 pending the outcome of the rulemaking.

Leading the world in mobile broadband is a key objective of the Obama administration and the FCC.[2] Robust wireless broadband networks bring a myriad of benefits to the public, including, among other things: (i) better healthcare through everything from apps that monitor chronic conditions to High Definition video consultations with medical personnel, (ii) better

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[1] These changes would be similar to the FCC's revision of the radiated power rules for certain wireless services, notably personal communications service ("PCS") and advanced wireless service ("AWS"). *In the Matter of Biennial Regulatory Review -- Amendment of Parts 1, 22, 24, 27 and 90 to Streamline and Harmonize Various Rules Affecting Wireless Radio Services,* 23 FCC Rcd 5319 Third Report and Order (2007) (the "PSD Order") at ¶ 11.

[2]. *See, e.g.*, President Obama Details Plan to Win the Future through Expanded Wireless Access, Office of the Press Secretary (Feb. 10, 2011), available at: http://www.whitehouse.gov/the-press-office/2011/02/10/president-obama-details-plan-win-future-through-expanded-wireless-access (last visited Feb. 28, 2012).

access to education through long-distance learning and digital textbooks, and (iii) better civic engagement through access to online government services. The transformative effects of advanced wireless broadband technologies can only be realized, however, if technical rules for wireless services are updated to reflect current wider channel 4G technologies, and, specifically Long Term Evolution ("LTE").

LTE is the premier next-generation wireless broadband technology, bringing faster speeds and reduced latency, and its deployment provides a richer, more robust consumer experience. In addition, LTE is more spectrally efficient than other previously deployed commercial wireless broadband technologies.[3] The greater spectral efficiency from the use of LTE, in fact, will help AT&T address the skyrocketing demand for wireless services by utilizing its cellular spectrum to the greatest extent possible, providing more capacity on the same amount of spectrum. A change in a technical rule—such as how to compute power measurements—may seem almost ministerial, but the change has wide ranging implications for wireless broadband deployment. [4]

To fulfill the promise of mobile technologies under the Commission's National Broadband Plan,[5] wireless carriers will need to exploit all of their spectrum resources as efficiently as possible. Unfortunately, the current rules for cellular licensees unnecessarily

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[3] See, e.g., Mobile Broadband Explosion: 3GPP Broadband Evolution to IMT-Advanced, Rysavvy Research (Sept. 2011), available at: http://www.4gamericas.org/documents/Mobile%20Broadband%20Explosion_Rysavy_Sept2011.pdf (last visited Feb. 28, 2012).

[4] LTE ("Long Term Evolution") is a set of enhancements to the Universal Mobile Telecommunications System ("UMTS"), which was introduced in 3rd Generation Partnership Project ("3GPP") Release 8.

[5] Connecting America: The National Broadband Plan (Mar. 17, 2010) ("NBP") at 75 (stating "Wireless broadband is poised to become a key platform for innovation in the United States over the next decade. As a result, U.S. spectrum policy requires reform to accommodate the new ways that industry is delivering wireless services.").

constrain use of the spectrum allocated to cellular radio service because the rules impose upon cellular base stations a measure for power emissions that favors narrowband systems over more efficient wideband systems. Currently, the power emission rules for cellular radio service penalize wideband emissions like LTE and wideband cellular base stations cannot achieve the same coverage footprint as less efficient narrowband technologies.[6] This, in turn, delays, and may in fact preclude, deploying the most up-to-date wideband technologies in the cellular bands to the broadest population. Updating the cellular power emission rule to measure power output not only by channel but also by megahertz – a change that has already been implemented without issue in other wireless bands – will permit efficient deployment of broadband wireless in the cellular frequencies and will help to achieve the Commission's goal of broadly available wireless broadband service.

AT&T also believes that rapid action is critical. For AT&T to deploy LTE in its cellular spectrum in early 2013, which it must do to meet meteorically rising data demands, it must begin testing devices for certification in the second half of 2012. Under the circumstances, AT&T requests that the FCC not only proceed with an expedited rulemaking proceeding, but also by granting a waiver to AT&T of Section 22.913, conditioned on the outcome of the rulemaking. This would allow AT&T to move ahead with its LTE implementation, promote the achievement of goals set forth in the National Broadband Plan, allow more efficient use of licensed spectrum, and encourage wider availability of broadband wireless services. A delay in the implementation of LTE in the cellular band would not be in the public interest.

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[6] *See infra* at Section 2.

Background

In 2008, in response to a CTIA proposal,[7] the FCC revised the radiated power rules for certain wireless services, including the Personal Communications Service ("PCS") and the Advanced Wireless Service ("AWS"), to permit the use of a PSD model for measuring equivalent isotropically radiated power ("EIRP"). Notwithstanding that it found great benefits in using a PSD model, the Commission declined to extend the power revision to cellular radio service for a very narrow reason—because the frequencies immediately adjacent to the cellular bands were, at that time, undergoing significant restructuring. The Commission concluded that it would be prudent to maintain the existing cellular power limits "until [it could] better assess the impact of additional power limit changes" on the possibility of harmful interference to adjacent bands.[8]

The fundamental benefits of PSD measurement of ERP were well documented in CTIA's Proposal. CTIA argued that the then-current radiated power rules[9] for PCS and AWS favored

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[7] Letter to Marlene Dortch, Secretary, FCC from Paul Garnett, Executive Director, CTIA dated October 20, 2004 ("CTIA Proposal").

[8] "Also, because frequencies immediately adjacent to the 800 MHz cellular band and the 2500 MHz BRS/EBS band are still undergoing significant restructuring to support a mixture of technologies and services, we decide to maintain the radiated power limits set forth in the current rules for BRS and EBS stations operating in the 2500 MHz bands, as well as stations operating in the 800 MHz or other bands -- at least until we can better assess the impact of additional power limit changes." *PSD Order* at ¶ 51.

[9] The prior versions of 47 C.F.R. §§ 24.232 (PCS) and 47 C.F.R. § 27.50(d) (AWS) provided that for antennas at heights above average terrain (HAAT) greater than 300 meters, the maximum allowable EIRP for PCS stations would be lower in accordance with tables found in the prior Section 24.232 of the rules. With respect to AWS stations, there were no reductions in power limits for antennas with HAATs greater than 300 meters under the old rules. Radiated power limits, then as now, are higher in rural areas for PCS and AWS (among other services). *See Facilitating the Provision of Spectrum-Based Services to Rural Areas and Promoting Opportunities for Rural Telephone Companies to Provide Spectrum-Based Services, WT Docket No. 02-381, Report and Order and Further Notice of Proposed Rulemaking*, 19 FCC Rcd 19078 (2004).

narrowband emissions systems and penalized systems using wideband emissions.[10] CTIA noted that systems operating in narrower bandwidths were effectively permitted to operate with higher power spectral densities than those operating in wider bandwidths.[11] For example, a licensee deploying six 200 kHz GSM[12] emissions in a 1.25 MHz bandwidth could transmit up to six times the aggregate power of a licensee deploying a single 1.25 MHz CDMA[13] carrier. CTIA contended that the per-emission power constraint in the former rules put wideband technologies such as CDMA, Wideband-CDMA ("WCDMA"), and orthogonal frequency-division multiplexing ("OFDM") at a disadvantage.[14] As a remedy, CTIA proposed use of a PSD model with radiated power levels calculated on a "watts-per-MHz" basis, which yielded effective power limits that increased proportionally with bandwidth used. This proposal not only addressed the

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[10] CTIA Proposal at 2.

[11] *Ibid.*

[12] The Global System for Mobile Communication ("GSM") is a narrowband cellular network technology that employs 200 kHz channels, each divided into 8 distinct time slots, thus shared by 8 users.

[13] Code Division Multiple Access ("CDMA") is a wideband spread-spectrum technology that employs a special coding scheme, with each signal assigned a digital code.

[14] CTIA Proposal at 2. The narrowband technologies of the time – GSM and Time Division Multiple Access ("TDMA") (which, like GSM, divides channels into time slots) -- carried 8 and 3 voice conversations, respectively, per emission, compared to wideband technologies such as CDMA, which carried as many as 20 to 40 voice conversations per emission. *See* In the Matter of Biennial Regulatory Review -- Amendment of Parts 1, 22, 24, 27, and 90 to Streamline and Harmonize Various Rules Affecting Wireless Radio Services, *Report and Order and Further Notice of Proposed Rulemaking,* 20 FCC Rcd 13900, 13927 (2005) ("Further Notice")..Under the prior rule, therefore, assuming systems were fully loaded and operating at the maximum power permitted by rule, wideband emission systems would only provide about one-fifth of the radiated power per voice conversation, as compared to narrowband emission systems. Hence, as stated in the *Further Notice,* "the average voice conversation on the wide emission system would have a lower signal-to-noise ratio, which, despite the partially compensating processing gain provided by signal spreading, would reduce the coverage range." *Ibid.* For data transmissions, a reduced signal-to-noise ratio could result in a lower data throughput. *See id.* (citing Qualcomm White Paper, "*1xEV: 1x Evolution IS-856 TIA/EIA Standard, Airlink Overview,*" dated Nov. 7, 2001 at 10).

broadly recognized need to "level the playing field" for wideband emissions systems, but also facilitated deployment of wideband technologies and resulted in lower costs for subscribers.[15] The Commission concurred with CTIA, and, in fact, expanded the proposal to include cellular radio and other wireless services when it sought public comment on the petition.[16] At the conclusion of this proceeding, the Commission revised the power limit rules for certain services – notably PCS and AWS – by permitting the use of a PSD measurements.[17] However, owing to a narrow concern about interference in the bands adjacent to the cellular bands, which were undergoing a transition, the Commission declined to extend the power limit revision to cellular radio service.[18]

Since the Commission's order in 2008, re-banding of the services adjacent to the cellular bands has nearly finished. Real-world experience has been gained with the adoption of PSD rules in the PCS and AWS bands. Given its experience with PSD-based power limits in other services, AT&T conducted an analysis to demonstrate that a PSD rule for cellular service would not increase the possibility of harmful interference in the bands adjacent to the cellular bands. AT&T's analysis, which is attached hereto, shows that a power limit based on a PSD measure will not increase the possibility of harmful interference to adjacent bands. Under these circumstances, AT&T requests the Commission to reassess the impact of additional power limit changes in the cellular frequencies by instituting a rulemaking proceeding to modify the current ERP limits for cellular base stations with ones restated as power spectral density limits.

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[15] *See* CTIA Proposal at 1.

[16] Further Notice at 13927 *et seq.*

[17] PSD Order at ¶ 24.

[18] *Id.* at ¶ 51.

Argument

1. Wireless Carriers Must Deploy Their Spectrum Resources As Efficiently As Possible To Fulfill the Promise of Mobile Broadband in the National Broadband Plan

There is no doubt that spectrum is an increasingly important component of the FCC's National Broadband Plan.[19] In recent years, mobile broadband demand has grown explosively, and the trend is expected to continue.[20] However, even as wireless access to broadband services expands in popularity and ubiquity, carriers are bumping up against spectrum constraints.[21] In the face of these trends, it becomes ever more important that wireless carriers utilize their spectrum as efficiently as possible so that they can continue to meet the public's increasing demand for ubiquitous, mobile data connections.

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[19] *Ibid.*

[20] "The 2010 mobile data traffic growth rate was higher than anticipated. Last year's forecast projected that the growth rate would be 149 percent. This year's estimate is that global mobile data traffic grew 159 percent in 2010. [...] Global mobile data traffic in 2010 (237 petabytes per month) was over three times greater than the total global Internet traffic in 2000 (75 petabytes per month). [...]Mobile data traffic will grow at a compound annual growth rate (CAGR) of 92 percent from 2010 to 2015, reaching 6.3 exabytes per month by 2015." *See,* Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2010-2015 (http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.html) February 1, 2011.

[21] *See,* NBP at 81 ("The broadband spectrum needs of the U.S. are growing as it is becoming more difficult to identify large swaths of spectrum—both federal and commercial—that can be reclaimed for auction.") *See also, Mobile Broadband Capacity Constraints And the Need for Optimization,* Rysavy Research LLC (February 24, 2010) at 4 ("Powerful smartphones, fast networks, compelling applications, and user awareness are causing a dramatic surge in the use of mobile-broadband technology. Previously relegated to business executives or vertical-market applications, wireless data is now experiencing mass-market adoption. The advantages are obvious – flexible lifestyles, greater productivity, and the addictive sensation of always being connected. [...] But there is a problem. There simply is not enough network capacity to address the emerging demand, and we are already witnessing the effects of network congestion, with many users complaining of slow network operation on some networks. Capacity is based on a number of factors, but foremost is the amount of spectrum available for broadband services.")

Today, the wireless industry is implementing the latest in a series of network improvements: the fourth generation of wireless standards ("4G"), which will offer comprehensive and secure mobile broadband solutions to laptop computer wireless modems, smartphones, and other mobile devices. The process of making wireless networks more compatible with data transmission has led to important changes in how carriers configure the use of their assigned radio frequency bands. Both analog cellular service and the succeeding digital formats broke the frequency blocks into narrow 30 or 200 kHz channels, reflecting the voice-centric nature of those services. As the importance of data transmission grew, it became clear that narrow voice-centric channels were unsuited to the needs of a broadband wireless network. However, because of the way in which CMRS power limitations for base stations were expressed in the Commission's rules, a change to wide band channelization could have resulted in degraded, or more costly, broadband wireless service.[22] As discussed earlier, this led to changes in the power emission rules for PCS and AWS. This change was not, however, applied to the cellular frequency band, which remains subject to the same kind of per emission power restriction that accompanied the commercial debut of analog cellular service in 1984.

The current FCC rule[23] governing radiated power in the cellular radiotelephone service frequencies forces cellular licensees using wider carrier channels to operate at lower total power than is allowed for multiple narrow-bandwidth carriers occupying the same bandwidth. To illustrate: the current power rules for the cellular band allow an ERP of 500 Watts in a 200 kHz GSM channel in non rural markets. Because there are five 200 kHz channels in one megahertz of spectrum, the existing cellular power rule permits a cellular base station to have a lawful PSD

[22] PSD Order at ¶ 12.

[23] 47 C.F.R. § 22.913

of 2500 watts per MHz.[24] By contrast, as shown in Table 1 below, applying the existing cellular power rules to 4G OFDM-based technologies results in much lower PSDs.[25] Under the current rule, then, the cellular band suffers a disadvantage when deploying broadband 4G systems; a disadvantage that translates into reduced coverage per cell site.

TABLE 1 - CURRENT POWER RULES

		GSM Non Rural (5 x 200 kHz)	**UMTS Non Rural** (5 MHz)	**LTE Non Rural** (10 MHz)	**GSM Rural** (5 x 200 kHz)	**UMTS Rural** (5 MHz)	**LTE Rural** (10 MHz)
Allowed by Rules	ERP/Channel	500 W	500 W	500 W	1,000 W	1,000 W	1,000 W
	ERP / MHz	2,500 W	100 W	50 W[26]	5,000 W	200 W	100 W[26]

The broadband power disadvantage also has ramifications for a carrier's signal-to-noise ("S/N") ratio, which is critical for system performance and throughput. The base station's transmit power and the channel bandwidth are interrelated in determining the system's S/N—the base station's transmit power relates directly to the transmit signal ("S") and the channel's bandwidth relates directly to the receiver noise floor ("N"). The problem facing cellular carriers in the current environment is that a change to a wideband format increases the channel bandwidth, which increases the receiver's noise floor, but because of the current ERP rule, the base station transmit power cannot be increased. In other words, the value of the S/N ratio is reduced, which results in less reliable communication and reduced system capacity. Modifying the rule to permit use of a power spectral density model to measure base station emissions would

[24] Five 200 kHz carriers with 500 W each amounts to 5 x 500 W, or 2500 W in one MHz, or 2500 W/MHz.

[25] UMTS uses a 5 MHz channel, which section 22.913 limits to 500 watts ERP resulting in a power spectral density of 100 watts per MHz. LTE uses a 10 MHz channel, which results in a power spectral density of 50 watts per MHz.

[26] Total per sector; with 2X2 MIMO, each antenna's output would be limited to 25 W/MHz & 50 W/MHz respectively, *see* n. 24 *supra*.

address this problem by permitting an increase in the power output of the base station and thereby improving – or at least keeping constant - the S/N ratio.

2. A PSD-Based Cellular Power Limit Will Not Cause Increased Harmful Interference to Adjacent Frequency Bands

AT&T compared the potential interference effects[27] of various wireless network arrangements on public safety receivers. The study looked at five different cases that represent AT&T's past, present, and future wireless networks. The cases are composed of GSM (2G), UMTS (3G) and LTE (4G) systems in various configurations in the cellular band. The purpose of this comparison was to show that future deployments of 2X2 MIMO[28] LTE (represented by Cases 4 and 5) in the cellular bands under a PSD limit would maintain the *status quo* with respect to the potential interference impacts on adjacent services—and in particular, the Public Safety services.

As discussed in the attachment, the study addresses three near/far interference mechanisms common in public safety interference environment – Intermodulation, Out of Band Emissions ("OOBE"), and Receiver Overload. The benchmark used to measure significant interference was a rise in the receiver's noise floor greater than 1 dB for intermodulation and OOBE interference. For receiver overload, the benchmark was a received interference level higher than the overload limit of the affected receiver. Public safety receiver performance was based upon current models with relatively wide open front end filtering encompassing the range from 851-869 MHz. The Public Safety receiver bandwidths of 12.5 and 25 KHz were assumed

[27] The study's results are attached as Appendix A.

[28] To multiply throughput of a radio link, multiple antennas (and multiple RF chains accordingly) are put at both the transmitter and the receiver. This system is referred to as Multiple Input Multiple Output ("MIMO"). A MIMO system with a similar count of antennas at both the transmitter and the receiver in a point-to-point ("PTP") link is able to increase the system throughput with every additional antenna.

for the study. Notably, however, the completion of 800 MHz rebanding will allow new public safety radios to be built with narrower front ends that will result in significant reductions in their susceptibility to OOBE and Receiver Overload.

The results of AT&T's study demonstrate that a paradigm shift to PSD power measurement will not increase the potential for harmful interference to adjacent band users. With respect to intermodulation interference, at the three distances from the cellular base station site (40 meters, 200 meters, and 1000 meters) for all migration paths, the noise floor rise for LTE deployments with MIMO and PSD rules relief were significantly less than present technology deployments. For OOBE at the three distances from the cellular base station site for all migration paths, all noise floor rises were below 1 dB. This rise in the interference floor is insignificant in practice and is still well under the 1 dB degradation in the noise floor of the public safety mobile receiver. Finally, for overload interference, the study showed LTE deployments did not increase the number of possibilities of such interference above that of existing deployments.

The study results demonstrate that the interference environment into Public Safety units from 2X2 MIMO LTE cellular deployments planned by AT&T is not appreciably different from that of existing cellular deployments—and in some cases it is better. The study results also showed that a power spectral density limit based on a maximum power level of 2500 watts (2500 Watts/10 MHz or 250 Watts/MHz for non-rural areas) and 5000 watts (5000 Watts/10 MHz or 500 Watts/MHz in rural areas) should exhibit about the same or less interference impacts as existing deployments.

3. Grant of a Waiver Pending Completion of the Expedited Rulemaking is in the Public Interest.

Under the FCC's standards, a waiver is appropriate if special circumstances warrant a deviation from the general rule, and such deviation would better serve the public interest than strict adherence to the general rule.[29] Generally, the Commission grants a rule waiver only if the relief requested would not undermine the policy objective of the rule in question, and would otherwise serve the public interest.[30] In this case, as discussed below, AT&T submits that a waiver of the power limits to permit AT&T to use a PSD measurement pending the outcome of the proposed rulemaking would be in the public interest.

It is a matter of public record that carriers have experienced a meteoric increase in the volume of data generated by consumers and businesses with the advent of smartphones and other data-enabled devices. AT&T has also documented the fact that, having pioneered devices like the iPhone and aggressively promoted the latest technologies and applications, its network has borne the brunt of a substantial amount of this newly generated traffic. Between 2008—the year the 3G iPhone was introduced—and the end of 2010, AT&T invested almost $33 billion in new spectrum and capital expenditures to upgrade its wireless network, including a 50% increase in wireless network investment from 2009 to 2010.[31] Notwithstanding that massive investment, AT&T remains critically spectrum-constrained and, therefore, to maintain a high level quality of service for its customers, AT&T must rapidly and aggressively roll-out LTE services.

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[29] *See Northeast Cellular Telephone Co. v. FCC*, 897 F.2d 1164, 1166 (D.C. Cir. 1990); *see also WAIT Radio v. FCC*, 418 F.2d 1153, 1157-1159 (D.C. Cir. 1969), *aff'd*, 459 F.2d 1203 (1972), *cert. denied*, 93 S.Ct. 461 (1972) ("*WAIT Radio*") (Commission may consider hardship, equity, or more effective implementation of overall policy on an individual basis).

[30] *WAIT Radio*, 418 F.2d at 1157.

[31] AT&T Inc. 2008 Annual Report at 35, 41; AT&T Inc. Quarterly Report (1Q 2008 10-Q), at 23 (May 7, 2008); AT&T Inc. 2009 Annual Report at 68, 71; AT&T Inc. 2010 Annual Report at 48, 71. This figure also includes the price for Qualcomm spectrum.

To this end, AT&T plans to deploy LTE carriers on cellular spectrum in a number of markets beginning the first quarter of 2013. While that timeline may not appear imminent, the need for relief is critically important as soon as possible. If AT&T can make use of its existing 800 MHz cell spacing for LTE services, there are great efficiencies in deployment, since the roll-out will utilize existing infrastructure. Even so, site upgrades in terms of backhaul may have to take place to convert the existing network to maximize LTE benefits. If AT&T is required to adopt a cell spacing that is more dense than its existing site inventory, it must begin site selection immediately, and begin the process of extending its network infrastructure to a range of new sites. As AT&T has previously documented, it has become increasingly difficult and time consuming to identify and secure suitable sites.[32] For example, of the new sites AT&T placed in use in 2010 in Los Angeles, San Francisco, Chicago, New York, Baltimore and Washington DC, it took an average of more than two and a half years from the time AT&T initiated the search for the site to the time the site was fully acquired with all approvals obtains. This statistic is conservatively low because it only includes locations where site approval was obtained; it omits sites where AT&T was unable to obtain approval and had to start over. See AT&T Comments WC Docket No.11-59, July 18 2011. Both paths require the commitment of resources and investment that could be stranded depending upon the outcome of regulatory proceedings. Couple the systemic network investment decisions with the need to field test and seek equipment approval for new base station equipment—as well as the length of the budgeting and procurement process—and the inescapable conclusion is that deployment in 2013 necessitates decisions to be made now.

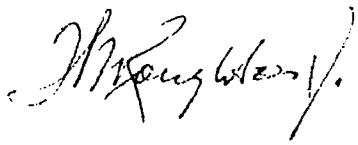
[32] *See, e.g.*, Reply Declaration of William Hogg, Applications of AT&T Inc. and Deutsche Telekom AG, WT Docket No. 11-65 (filed June 10, 2011) at 26 (available at: http://apps.fcc.gov/ecfs/document/view?id=7021686835 (last visited Feb. 28, 2012)).

For this reason, AT&T requests that the FCC grant it a waiver to permit it to use the PSD measurements specified in this petition in lieu of the power limits currently specified in section 22.913 of the rules. AT&T fully expects that any such waiver would be conditioned on the outcome of the rulemaking proceeding proposed herein. Grant of the requested relief would be in the public interest because: (i) the waiver would remove disparities between radio services that limit cellular carriers' ability to deploy the most efficient and advanced modulation techniques; and (ii) the waiver would promote the deployment of mobile broadband services consistent with the policy goals enumerated in the National Broadband Plan. Moreover, the waiver—conditioned on the outcome of the proposed rulemaking—would not undermine the deliberative process relative to adopting PSD limits for cellular carriers more broadly. Nor, as demonstrated in the technical appendix, would the waiver result in harmful interference to any parties. For the foregoing reasons, AT&T urges the Commission to act quickly and grant AT&T permission to use PSD-based power measurements for its cellular systems.

Conclusion

For the foregoing reasons, AT&T respectfully petitions the FCC for an expedited rulemaking to amend the Commission's rules governing radiated power limits in the cellular radio service frequency bands to permit the use of a power spectral density model for measuring effective radiated power. AT&T also requests that the Commission grant it a waiver of 47 C.F.R. § 22.913 pending the resolution of the expedited rulemaking.

Respectfully submitted,



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February 28, 2012

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APPENDIX A

Subject: **A Further Comparison of the Impacts on Public Safety Receivers from the Various Wireless Technologies used in AT&T's Migration from Narrowband GSM to Broadband LTE in the 850 MHz CMRS Cellular Band**

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Abstract

The FCC Rules for the 850 MHz band were designed to accommodate first generation AMPS (Advanced Mobile Phone System) analog cellular service. Over the years, carriers deployed digital services in the 850 MHz bands, and eventually sunset analog services. Carriers currently use the 850 MHz band for technologies that support mobile broadband, such as UMTS. As the industry moves toward fourth generation LTE (Long Term Evolution) technology coupled with the use of MIMO (Multiple Input Multiple Output) techniques for spectral efficiency improvements, it is appropriate to consider whether the rules for this band relating to power measurement, which were adapted for technology deployed almost 30 years ago, should be revised to accommodate LTE. In band plans adopted more recently to accommodate mobile broadband deployment, the Commission has adopted a Power Spectral Density approach. This paper presents the results of a further study that considers whether making such a change to the 850 MHz rules to accommodate contemporary commercial mobile broadband deployments would increase the likelihood of interference to adjacent users of Public Safety bands.

The study, which employed conservative assumptions, addressed the interference impacts on Public Safety receivers under five different cases that are representative of AT&T's past, present, and future network comprising GSM, UMTS and LTE systems in various configurations in the cellular band. Results of this "real world" study again leads AT&T to conclude that a power limit based on a Power Spectral Density measure will not increase the possibility of harmful interference to adjacent bands and will maintain the "status quo" with respect to the potential impact on users of adjacent spectrum, such as the Public Safety Radio Service. The "real world" study results also support a Power Spectral Density limit of 250 Watts/MHz in non-rural areas and 500 Watts/MHz in rural areas. As a result of this study, AT&T will file a petition at the FCC proposing to supplement the current per-emission ERP limits for cellular base stations with ones restated to include power spectral density limits.

1. Introduction

The FCC Rules for the 850 MHz band were designed to accommodate first generation AMPS (Advanced Mobile Phone System) analog cellular service. Over the years, carriers deployed digital services in the 850 bands, and eventually sunset analog services. Carriers currently use the 850 MHz band for technologies that support mobile broadband, such as UMTS (Universal Mobile Telecommunications System). As carriers migrate their wireless networks to fourth generation (4G) LTE (Long Term Evolution) technology and use MIMO (Multiple Input Multiple Output) techniques for spectral efficiency improvements, the appropriateness of the FCC Rules governing the radiated power of transmitters in the Cellular Radiotelephone Service have come into question. MIMO uses multiple antennas or multiple antenna elements at both the transmitter and receiver to create multiple distinct spatial channels between the transmitter and the receiver using the same radio channel. AT&T plans to use 2x2 MIMO in its 850 MHz LTE deployments. 2x2 MIMO uses two transmitters operating on the same carrier channel but carrying two different information streams to create two separate spatial channels. Because two spatial channels are created using a single radio carrier, spectral efficiency is increased. The current FCC Rule governing radiated power in the Cellular Radiotelephone Service (Section 22.913) states - *the effective radiated power of base transmitters and cellular repeaters must not exceed 500 watts*. Because this power limit was enacted prior to the development and use of MIMO techniques, it was generally understood that a single transmitter used a single carrier frequency and that the power requirement was related to this carrier frequency. A 2x2 MIMO deployment, which employs a single carrier channel on two transmitters, must split the maximum radiated power given in the FCC Rules between the two MIMO transmitters. This power split reduces the service coverage area of the transmitters operating in the MIMO mode compared to that of a single transmitter deployment.

In 2004, recognizing the problem posed by the then current power limitation rules, CTIA offered a technologically neutral proposal to modify base station power limits for PCS licensees. Subsequently, the Commission expanded this proposal to include not only PCS, but also cellular radio service and other service bands. In 2008, following comments on the proposal, the FCC revised the radiated power rules for certain services, notably PCS and AWS, but declined to extend the revision to cellular radio service "until [it could] better assess the impact of additional power limit changes" on the possibility of harmful interference to adjacent bands – which were undergoing significant restructuring at that time. Since then, re-banding of services adjacent to the cellular band is almost complete and there has been adequate time to understand the interference concerns, if any, due to the adoption of Power Spectral Density (PSD) rules in PCS and AWS bands. Such a PSD limit would allow the use of MIMO techniques in the 850 MHz band without requiring a reduction in the service coverage area, and would be more consistent with FCC broadband power limit rules in other bands. A PSD limit specifies the amount of power that is distributed with frequency and, in the case of the cellular radiotelephone service, it is the amount of power distributed over a radio channel. If the maximum radiated power in a 5 MHz channel is 1500 watts, the PSD would be 300 watts/MHz (1500 watts/5 MHz).

Believing that a PSD measure should now be adopted for the cellular bands, AT&T conducted a technology interference comparison analysis of its third generation (3G) UMTS and 4G LTE

technologies to show that a power limit based on a Power Spectral Density measure would not increase the possibility of harmful interference to adjacent bands and would also maintain the "status quo" with respect to the potential impact on users of adjacent spectrum, such as the Public Safety Radio Service. The results of the technology interference comparison supported AT&T's belief. The study results also supported a Power Spectral Density limit greater than 100 Watts/MHz.

To further bolster AT&T's belief that a power limit based on a Power Spectral Density measure would not increase the possibility of harmful interference to adjacent bands, AT&T completed a second "real world" study which determined the interference impacts on users of adjacent spectrum as a result of its technology migration through the years – from second generation (2G) GSM (Global Systems for Mobile Communications) to 4G LTE with MIMO. AT&T's technology migration study commences with the deployment of 2G GSM technology employing a tri-sectored frequency reuse pattern of N=12 that typically allowed on average up to five GSM carriers per sector. With the migration to broadband 3G UMTS technology, some GSM carriers were replaced with a single UMTS carrier. A typical sector in an initial 3G network would include one UMTS and three GSM carriers. As broadband demand increased, the spectrum for a second UMTS carrier was again re-farmed from existing GSM carriers. A typical congested metro market deploys two UMTS carriers along with two GSM carriers per sector. As the data traffic demand increased, a migration to 4G LTE in the cellular bands will be necessary. LTE deployments will proceed by replacing one of the UMTS carriers with a 5 MHz LTE carrier employing 2X2 MIMO. Initial deployments of LTE will include a 5 MHz UMTS carrier, a 5 MHz LTE carrier, and two GSM carriers in the cellular band. The final migration will be to replace the remaining UMTS and GSM carriers and to upgrade the 5 MHz LTE carrier to a 10 MHz LTE carrier. The LTE deployments will be with two transmitters per carrier/sector as compared to a single transmitter per carrier/sector with UMTS. This paper documents the final results of that study.

1. Modeling the Interference Environment

Modeling the interference environment consisted of the following five steps:

1. Model the interference path
2. Determine the transmitter and receiver characteristics
3. Model the interference mechanisms
4. Calculate the interference levels and determine their impacts

1.1 Modeling the Interference Path

Since the interference network environment is that of a standard cellular architecture, two propagation loss models were used to calculate path loss. These two propagation loss models were the HATA loss models and the modified Friis Transmission Loss model. The HATA models are the most widely used radio frequency propagation models for predicting the behavior of cellular transmissions. Since the HATA models are accurate for link distances between 1 and 20 kilometers, another model was needed for paths closer to the cell site. The Friis Transmission Loss model is ideal for paths between two isotropic antennas in free space (Line-of-Sight) and

can be modified for paths other than free space (Non-Line-of-Sight). All loss models were incorporated into the Friis Transmission Equation which relates received power, transmit power, antenna gains and path loss in order to calculate interference levels. For line-of-sight paths a propagation constant of 2 was used and for non-line-of-sight paths, a propagation constant of 2.4 was used. Cellular antenna heights for non-rural areas used the average antennas height in AT&T's non-rural network – 30 meters. For rural areas where antenna heights are generally higher, antenna heights of 47 and 92 meters were used.

1.2 Determining the Transmitter and Receiver Characteristics

The transmitter and receiver characteristics were:

- Maximum transmit power
- Base station antenna gains and discrimination
- Transmission line loss
- Transmitter sideband emission levels
- Public Safety receiver noise floor
- Minimum mobile Adjacent Channel Rejection Ratio
- Minimum portable Adjacent Channel Rejection Ratio
- Public Safety mobile antenna gain: From an Internet site on Public Safety equipment
- Public Safety portable antenna gain: From an Internet site on Public Safety equipment
- Public Safety Receiver Overload level
- Third Order Intercept Point calculation: From *Motorola paper by Bruce Oberlies – "Public Safety Interference Environment – Raising Receiver Performance Requirements"*
- Third Order Interference Level calculation: From Aeroflex Application Note on Intermodulation Distortion on the website www.aeroflex.com.

1.3 Modeling the Interference Mechanism

The three near/far interference mechanisms common in Public Safety interference environments were modeled in the following manner:

1. Intermodulation – The receive interference level at the input to the Public Safety receiver's front end was calculated using the appropriate Friis Transmission Equation. The study assumed that the GSM channels were transmitting at 500 Watts, UMTS channels were transmitting at 500 Watts, and LTE at 500 Watts/transmitter-antenna for a 5 MHz channel and 1000 Watts/transmitter-antenna for a 10 MHz channel. Since Effective Radiated Power level is the power level radiating from the base station's antenna, no transmission line loss or base station antenna gain was included in this calculation. It was assumed that these levels were the levels of the two interfering signals creating the intermodulation product. The third order intercept point was calculated using the formula in the Motorola paper and this value was used in the Aeroflex equation with the interference levels calculated from the Friis Transmission Equation to obtain the level of the third order product in the receiver.

2. Transmitter Sideband Emissions - The transmitter sideband emission level at the input to the Public Safety receiver's front end was calculated using the appropriate Friis Transmission Equation. The sideband transmit power level at the output of the transmitter used in this equation was the measured spurious emissions level given by the manufacturer. For this calculation in the Friis Transmission Equation, transmission line loss and base station antenna gain were included.

3. Receiver Overload - The received interference level at the input to the Public Safety receiver's front end was calculated using the appropriate Friis Transmission Equation. The cellular base station transmit power level used in this equation was the maximum Effective Radiated Power level specified in the FCC Rules for Cellular services in the 850 MHz cellular band for 2G and 3G technologies (GSM channels were transmitting at 500 Watts, UMTS channels were transmitting at 500 Watts, and LTE at 500 Watts/transmitter-antenna for a 5 MHz channel and 1000 Watts/transmitter-antenna for a 10 MHz channel). Since Effective Radiated Power level is the power level radiating from the base station's antenna, no transmission line loss or base station antenna gain was included in this calculation.

1.4 Interference Levels and Their Impacts

An Excel spreadsheet was developed to make the above mentioned calculations and determine the impacts of the various interference mechanisms. For the intermodulation interference calculation and the transmitter sideband emission interference calculation, the criteria used to determine impact was a rise in the receiver's noise floor. For Receiver Overload interference calculations, the criteria used to determine impacts was that any interfering level that was less than the specified overload point of the receiver is an acceptable interfering level. For this study only the relative levels of the interference environments are compared. Only in situations where a technology's interference environment level is no worse than the existing technology's interference environment level can the interference level be deemed acceptable (Status Quo).

The study addresses the interference impacts on Public Safety receivers under five different cases that are representative of AT&T's past, present, and future network comprising GSM, UMTS and LTE systems in various configurations in the cellular band. Case one represents an initial 2G GSM deployment of five GSM carriers. Case two addresses the migration to one UMTS carrier and three GSM carriers. Case three represents the migration to two UMTS carriers along with two GSM carriers per sector. Case four represents a migration to 4G LTE with a 5 MHz UMTS carrier, a 5 MHz LTE carrier with MIMO, and two GSM carriers. The final migration, Case five, will be to a single 10 MHz LTE carrier with MIMO.

2. Study Results

With a single GSM channel's transmit power level set to 500 Watts, a single UMTS channel set to 500 Watts, and a LTE channel set to 500 Watts/transmitter-antenna for a 5 MHz channel and 1000 Watts/transmitter-antenna for a 10 MHz channel, the results of the Excel spreadsheet calculations of interference into Public Safety receivers with bandwidths of 25 and 12.5 KHz from the five migration cases for non-rural and rural environments are shown in Tables 1

through 12. Bracketed numbers in the overload tables are received overload interference levels in dBm.

2.1 Intermodulation Interference Impacts

	PS RECEIVER BANDWIDTH = 25 KHz				
DISTANCE TO MOBILE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	2500 W	2000 W	2000 W	2500 W	2000 W
Allowed Now	YES	YES	YES	NO	NO
40	9.4362	9.4362	9.4362	9.4362	0.0173
200	6.4700	6.4700	6.4700	6.4700	0.0076
>1000	0.0482	0.0482	0.0482	0.0482	0.0000

	PS RECEIVER BANDWIDTH = 12.5 KHz				
DISTANCE TO MOBILE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	2500 W	2000 W	2000 W	2500 W	2000 W
Allowed Now	YES	YES	YES	NO	NO
40	18.0114	18.0114	18.0114	18.0114	0.1363
200	14.5468	14.5468	14.5468	14.5468	0.0607
>1000	0.3717	0.3717	0.3717	0.3717	0.0002

TABLE 1. Non-Rural Mobile Intermodulation Impacts

	PS RECEIVER BANDWIDTH = 25 KHz				
DISTANCE TO PORTABLE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	2500 W	2000 W	2000 W	2500 W	2000 W
Allowed Now	YES	YES	YES	NO	NO
40	0.0043	0.0043	0.0043	0.0043	0.0000
200	0.0019	0.0019	0.0019	0.0019	0.0000
>1000	0.0482	0.0482	0.0482	0.0482	0.0000

	PS RECEIVER BANDWIDTH = 12.5 KHz				
DISTANCE TO PORTABLE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	2500 W	2000 W	2000 W	2500 W	2000 W
Allowed Now	YES	YES	YES	NO	NO
40	0.0339	0.0339	0.0339	0.0339	0.0000
200	0.0104	0.0104	0.0104	0.0104	0.0000
>1000	0.0000	0.0000	0.0000	0.0000	0.0000

TABLE 2. Non-Rural Portable Intermodulation Impacts

	PS RECEIVER BANDWIDTH = 25 KHz (Ant Height = 47 m)				
DISTANCE TO MOBILE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	5000 W	4000 W	4000 W	5000 W	4000 W
Allowed Now	YES	YES	YES	NO	NO
40	0.5766	0.5766	0.5766	0.5766	0.0000
200	8.9790	8.9790	8.9790	8.9790	0.0019
>1000	1.0994	1.0994	1.0994	1.0994	0.0001

	PS RECEIVER BANDWIDTH = 12.5 KHz (Ant Height = 47 m)				
DISTANCE TO MOBILE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	5000 W	4000 W	4000 W	5000 W	4000 W
Allowed Now	YES	YES	YES	NO	NO
40	3.2957	3.2957	3.2957	3.2957	0.0003
200	17.5004	17.5004	17.5004	17.5004	0.0076
>1000	5.1913	5.1913	5.1913	5.1913	0.0006

	PS RECEIVER BANDWIDTH = 25 KHz (Ant Height = 92 m)				
DISTANCE TO MOBILE RECEIVER	CASE 1 5 GSM CXRS	CASE 2 1 UMTS & 3 GSM CXRS	CASE 3 2 UMTS CXRS & 2 GSM CXRS	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS	CASE 5 1 TEN MHz LTE CXR

(METERS)	(dB)	(dB)	(dB)	(dB)	(dB)
Power/Sector	5000 W	4000 W	4000 W	5000 W	4000 W
Allowed Now	YES	YES	YES	NO	NO
40	0.0000	0.0000	0.0000	0.0000	0.0000
200	0.0076	0.0076	0.0076	0.0076	0.0000
>1000	3.3683	3.3683	3.3683	3.3683	0.0003

	PS RECEIVER BANDWIDTH = 12.5 KHz (Ant Height = 92 m)				
DISTANCE TO MOBILE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	5000 W	4000 W	4000 W	5000 W	4000 W
Allowed Now	YES	YES	YES	NO	NO
40	0.0003	0.0003	0.0003	0.0003	0.0000
200	0.0601	0.0601	0.0601	0.0601	0.0000
>1000	10.1597	10.1597	10.1597	10.1597	0.0026

TABLE 3. Rural Mobile Intermodulation Impacts

	PS RECEIVER BANDWIDTH = 25 KHz (Ant Height = 47 m)				
DISTANCE TO PORTABLE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	5000 W	4000 W	4000 W	5000 W	4000 W
Allowed Now	YES	YES	YES	NO	NO
40	0.0001	0.0001	0.0001	0.0001	0.0000
200	0.0038	0.0038	0.0038	0.0038	0.0000
>1000	0.0002	0.0002	0.0002	0.0002	0.0000

	PS RECEIVER BANDWIDTH = 12.5 KHz (Ant Height = 47 m)				
DISTANCE TO PORTABLE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	5000 W	4000 W	4000 W	5000 W	4000 W
Allowed Now	YES	YES	YES	NO	NO

40	0.0006	0.0006	0.0006	0.0006	0.0000
200	0.0301	0.0301	0.0301	0.0301	0.0153
>1000	0.0013	0.0013	0.0013	0.0013	0.0000

	PS RECEIVER BANDWIDTH = 25 KHz (Ant Height = 92 m)				
DISTANCE TO PORTABLE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	**5000 W**	**4000 W**	**4000 W**	**5000 W**	**4000 W**
Allowed Now	**YES**	**YES**	**YES**	**NO**	**NO**
40	0.0001	0.0001	0.0001	0.0001	0.0000
200	0.0038	0.0038	0.0038	0.0038	0.0000
>1000	0.0006	0.0006	0.0006	0.0006	0.0000

	PS RECEIVER BANDWIDTH = 12.5 KHz (Ant Height = 92 m)				
DISTANCE TO PORTABLE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	**5000 W**	**4000 W**	**4000 W**	**5000 W**	**4000 W**
Allowed Now	**YES**	**YES**	**YES**	**NO**	**NO**
40	0.0000	0.0000	0.0000	0.0000	0.0000
200	0.0000	0.0000	0.0000	0.0000	0.0000
>1000	0.0051	0.0051	0.0051	0.0051	0.0000

TABLE 4. Rural Portable Intermodulation Impacts

The results above show that for intermodulation interference at the three distances from the cellular base station site (40 meters, 200 meters, and 1000 meters) for all migration paths, the noise floor rise for LTE deployments with MIMO were below 1 dB and were significantly less than present technology deployments. The higher and consistently uniform interference level for those cases involving GSM are driven only by much higher PSD of the GSM carrier. Thus, this worst case interference effect remains the same regardless of the number of GSM carriers that are present. In practice, where interference cases have been identified, judicious shuffling of the GSM carriers amongst various frequencies has allowed IM interference to be mitigated.

Tables 1 through 4 show that Case 4, which is represented by each sector deploying one UMTS carrier transmitting at 500 W, one 5 MHz LTE carrier transmitting at 1000 W and two GSM carriers transmitting 500 watts each, will not cause any additional interference from

intermodulation (IM) into Public Safety receivers as compared to existing UMTS or GSM systems.

2.2 Sideband Interference Impacts

	PS RECEIVER BANDWIDTH = 25 KHz				
DISTANCE TO MOBILE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	2500 W	2000 W	2000 W	2500 W	2000 W
Allowed by FCC Rules	Yes	Yes	Yes	No	No
40	0.0271	0.0216	0.0216	0.0271	0.0271
200	0.0207	0.0164	0.0164	0.0207	0.0207
>1000	0.0024	0.0019	0.0019	0.0024	0.0031

	PS RECEIVER BANDWIDTH = 12.5 KHz				
DISTANCE TO MOBILE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	2500 W	2000 W	2000 W	2500 W	2000 W
Allowed by FCC Rules	Yes	Yes	Yes	No	No
40	0.0271	0.0216	0.0216	0.0271	0.0271
200	0.0207	0.0164	0.0164	0.0207	0.0207
>1000	0.0024	0.0019	0.0019	0.0024	0.0031

TABLE 5. Non-Rural Mobile Sideband Impacts

	PS RECEIVER BANDWIDTH = 25 KHz				
DISTANCE TO PORTABLE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	2500 W	2000 W	2000 W	2500 W	2000 W
Allowed Now	YES	YES	YES	NO	NO
40	0.0136	0.0108	0.0108	0.0136	0.0136
200	0.0104	0.0082	0.0082	0.0104	0.0104
>1000	0.0012	0.0010	0.0010	0.0012	0.0015

	PS RECEIVER BANDWIDTH = 12.5 KHz				
	CASE 1	CASE 2	CASE 3	CASE 4	CASE 5

DISTANCE TO PORTABLE RECEIVER (METERS)	5 GSM CXRS (dB)	1 UMTS & 3 GSM CXRS (dB)	2 UMTS CXRS & 2 GSM CXRS (dB)	1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	1 TEN MHz LTE CXR (dB)
Power/Sector	2500 W	2000 W	2000 W	2500 W	2000 W
Allowed Now	YES	YES	YES	NO	NO
40	0.0136	0.0108	0.0108	0.0136	0.0136
200	0.0104	0.0082	0.0082	0.0104	0.0104
>1000	0.0012	0.0010	0.0010	0.0012	0.0015

TABLE 6. Non-Rural Portable Sideband Impacts

	PS RECEIVER BANDWIDTH = 25 KHz (Ant Height = 47 m)				
DISTANCE TO MOBILE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	5000 W	4000 W	4000 W	5000 W	4000 W
Allowed Now	YES	YES	YES	NO	NO
40	0.0036	0.0028	0.0028	0.0036	0.0036
200	0.0131	0.0104	0.0104	0.0131	0.0065
>1000	0.0045	0.0036	0.0036	0.0045	0.0045

	PS RECEIVER BANDWIDTH = 12.5 KHz (Ant Height = 47 m)				
DISTANCE TO MOBILE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	5000 W	4000 W	4000 W	5000 W	4000 W
Allowed Now	YES	YES	YES	NO	NO
40	0.0036	0.0216	0.0216	0.0036	0.0036
200	0.0131	0.0104	0.0104	0.0131	0.0131
>1000	0.0045	0.0036	0.0036	0.0045	0.0045

	PS RECEIVER BANDWIDTH = 25 KHz (Ant Height = 92 m)				
DISTANCE TO MOBILE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	5000 W	4000 W	4000 W	5000 W	4000 W
Allowed Now	YES	YES	YES	NO	NO

40	0.0001	0.0001	0.0001	0.0001	0.0001
200	0.0008	0.0007	0.0007	0.0008	0.0008
>1000	0.0072	0.0057	0.0057	0.0072	0.0072

	PS RECEIVER BANDWIDTH = 12.5 KHz (Ant Height = 92 m)				
DISTANCE TO MOBILE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	5000 W	4000 W	4000 W	5000 W	4000 W
Allowed Now	YES	YES	YES	NO	NO
40	0.0001	0.0001	0.0001	0.0001	0.0001
200	0.0008	0.0007	0.0007	0.0008	0.0008
>1000	0.0072	0.0057	0.0057	0.0072	0.0072

TABLE 7. Rural Mobile Sideband Impacts

	PS RECEIVER BANDWIDTH = 25 KHz (Ant Height = 47 m)				
DISTANCE TO PORTABLE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	5000 W	4000 W	4000 W	5000 W	4000 W
Allowed Now	YES	YES	YES	NO	NO
40	0.0018	0.0014	0.0014	0.0018	0.0018
200	0.0065	0.0052	0.0052	0.0065	0.0033
>1000	0.0023	0.0018	0.0018	0.0023	0.0023

	PS RECEIVER BANDWIDTH = 12.5 KHz (Ant Height = 47 m)				
DISTANCE TO PORTABLE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	5000 W	4000 W	4000 W	5000 W	4000 W
Allowed Now	YES	YES	YES	NO	NO
40	0.0018	0.0014	0.0014	0.0018	0.0018
200	0.0065	0.0052	0.0052	0.0065	0.0065
>1000	0.0029	0.0018	0.0018	0.0029	0.0023

	PS RECEIVER BANDWIDTH = 25 KHz (Ant Height = 92 m)				
DISTANCE TO PORTABLE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	5000 W	4000 W	4000 W	5000 W	4000 W
Allowed Now	YES	YES	YES	NO	NO
40	0.0001	0.0001	0.0001	0.0001	0.0001
200	0.0004	0.0003	0.0003	0.0004	0.0004
>1000	0.0036	0.0029	0.0029	0.0036	0.0036

	PS RECEIVER BANDWIDTH = 12.5 KHz (Ant Height = 92 m)				
DISTANCE TO PORTABLE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	5000 W	4000 W	4000 W	5000 W	4000 W
Allowed Now	YES	YES	YES	NO	NO
40	0.0001	0.0001	0.0001	0.0001	0.0001
200	0.0004	0.0003	0.0003	0.0004	0.0004
>1000	0.0036	0.0029	0.0029	0.0036	0.0036

TABLE 8. Rural Portable Sideband Impacts

Similarly, for Sideband emissions at the three distances from the cellular base station site (40 meters, 200 meters, and 1000 meters) for all migration paths, all noise floor rises were below 1 dB. The tables show a slight increase in interference from Sideband emissions between some scenarios deploying LTE with increased power and less cable loss (Case 4 and Case 5) than existing GSM and UMTS systems as represented by Cases 1, 2 and 3. This rise in the interference floor is insignificant in practice and is still well under the 1 dB degradation in the noise floor of the Public Safety mobile receiver.

2.3 Overload Interference Impacts

	PS RECEIVER BANDWIDTH = 25 KHz				
DISTANCE TO MOBILE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	**2500 W**	**2000 W**	**2000 W**	**2500 W**	**2000 W**
Allowed Now	**YES**	**YES**	**YES**	**NO**	**NO**
40	YES (-21.1)	YES (-22)	YES (-22)	YES (-21.1)	YES (-22)
200	YES (-22.2)	YES (-23.2)	YES (-23.2)	YES (-22.2)	YES (-23.2)
>1000	NO	NO	NO	NO	NO

	PS RECEIVER BANDWIDTH = 12.5 KHz				
DISTANCE TO MOBILE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	**2500 W**	**2000 W**	**2000 W**	**2500 W**	**2000 W**
Allowed Now	**YES**	**YES**	**YES**	**NO**	**NO**
40	YES(-21.1)	YES(-22.0)	YES (-22)	YES(-21.1)	YES (-22)
200	YES(-22.2)	YES(-23.2)	YES (-23.2)	YES(-22.2)	YES (-23.2)
>1000	NO	NO	NO	NO	NO

TABLE 9. Non-Rural Mobile Overload Impacts

	PS RECEIVER BANDWIDTH = 25 KHz				
DISTANCE TO PORTABLE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	**2500 W**	**2000 W**	**2000 W**	**2500 W**	**2000 W**
Allowed Now	**YES**	**YES**	**YES**	**NO**	**NO**
40	YES(-24.1)	YES(-25)	YES (-25)	YES(-24.1)	YES(-25)
200	YES(-25.2)	YES(-26.2)	YES (-26.2)	YES(-25.2)	YES(-26.2)
>1000	NO	NO	NO	NO	NO

	PS RECEIVER BANDWIDTH = 12.5 KHz				
DISTANCE TO PORTABLE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	**2500 W**	**2000 W**	**2000 W**	**2500 W**	**2000 W**
Allowed Now	**YES**	**YES**	**YES**	**NO**	**NO**
40	YES(-24.1)	YES(-25)	YES (-25)	YES(-24.1)	YES(-25)
200	YES(-25.2)	YES(-26.2)	YES (-26.2)	YES(-25.2)	YES(-26.2)
>1000	NO	NO	NO	NO	NO

TABLE 10. Non-Rural Portable Overload Impacts

	PS RECEIVER BANDWIDTH = 25 KHz (Ant Height = 47 m)				
DISTANCE TO MOBILE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	**5000 W**	**4000 W**	**4000 W**	**5000 W**	**4000 W**
Allowed Now	**YES**	**YES**	**YES**	**NO**	**NO**
40	YES(-26.8)	YES(-27.8)	YES(-27.8)	YES(-26.8)	NO
200	YES(-21.2)	YES(-22.2)	YES(-22.2)	YES(-21.2)	YES(-25.2)
>1000	YES(-25.8)	YES(-26.8)	YES(-26.8)	YES(-25.8)	YES(-29.8)

	PS RECEIVER BANDWIDTH = 12.5 KHz (Ant Height = 47 m)				
DISTANCE TO MOBILE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	**5000 W**	**4000 W**	**4000 W**	**5000 W**	**4000 W**
Allowed Now	**YES**	**YES**	**YES**	**NO**	**NO**
40	YES(-26.8)	YES(-27.8)	YES(-27.8)	YES(-26.8)	NO
200	YES(-21.2)	YES(-22.2)	YES(-22.2)	YES(-21.2)	YES(-25.2)
>1000	YES(-25.8)	YES(-26.8)	YES(-26.8)	YES(-25.8)	YES(-29.8)

	PS RECEIVER BANDWIDTH = 25 KHz (Ant Height = 92 m)				
DISTANCE TO MOBILE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	5000 W	4000 W	4000 W	5000 W	4000 W
Allowed Now	YES	YES	YES	NO	NO
40	NO	NO	NO	NO	NO
200	NO	NO	NO	NO	NO
>1000	YES(-23.8)	YES(-24.8)	YES(-24.8)	YES(-23.8)	YES(-27.8)

	PS RECEIVER BANDWIDTH = 12.5 KHz (Ant Height = 92 m)				
DISTANCE TO MOBILE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	5000 W	4000 W	4000 W	5000 W	4000 W
Allowed Now	YES	YES	YES	NO	NO
40	NO	NO	NO	NO	NO
200	NO	NO	NO	NO	NO
>1000	YES(-26.8)	YES(-27.8)	YES(-27.8)	YES(-26.8)	NO

TABLE 11. Rural Mobile Overload Impacts

	PS RECEIVER BANDWIDTH = 25 KHz (Ant Height = 47 m)				
DISTANCE TO PORTABLE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	5000 W	4000 W	4000 W	5000 W	4000 W
Allowed Now	YES	YES	YES	NO	NO
40	YES(-29.8)	NO	NO	YES(-29.8)	NO
200	YES(-24.2)	YES(-25.2)	YES(-25.2)	YES(-24.2)	YES(-28.2)
>1000	YES(-28.8)	Yes(-29.8)	Yes(-29.8)	YES(-28.8)	NO

	PS RECEIVER BANDWIDTH = 12.5 KHz (Ant Height = 47 m)				
DISTANCE TO PORTABLE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	5000 W	4000 W	4000 W	5000 W	4000 W
Allowed Now	YES	YES	YES	NO	NO
40	YES(-29.8)	NO	NO	YES(-29.8)	NO
200	YES(-24.2)	YES(-25.2)	YES(-25.2)	YES(-24.2)	YES(-28.2)
>1000	YES(-28.8)	YES(-29.8)	YES(-29.8)	YES(-28.8)	NO

	PS RECEIVER BANDWIDTH = 25 KHz (Ant Height = 92 m)				
DISTANCE TO PORTABLE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	5000 W	4000 W	4000 W	5000 W	4000 W
Allowed Now	YES	YES	YES	NO	NO
40	NO	NO	NO	NO	NO
200	NO	NO	NO	NO	NO
>1000	YES(-26.8)	Yes(-27.8)	Yes(-27.8)	YES(-26.8)	NO

	PS RECEIVER BANDWIDTH = 12.5 KHz (Ant Height = 92 m)				
DISTANCE TO PORTABLE RECEIVER (METERS)	CASE 1 5 GSM CXRS (dB)	CASE 2 1 UMTS & 3 GSM CXRS (dB)	CASE 3 2 UMTS CXRS & 2 GSM CXRS (dB)	CASE 4 1 FIVE MHz LTE CXR, 1 UMTS CXR & 2 GSM CXRS (dB)	CASE 5 1 TEN MHz LTE CXR (dB)
Power/Sector	5000 W	4000 W	4000 W	5000 W	4000 W
Allowed Now	YES	YES	YES	NO	NO
40	NO	NO	NO	NO	NO
200	NO	NO	NO	NO	NO
>1000	YES(-26.8)	YES(-27.8)	YES(-27.8)	YES(-26.8)	NO

TABLE 12. Rural Portable Overload Impacts

For overload interference, the tables show that such interference is possible close to the cellular base station sites, but LTE deployments did not increase the number of possibilities of such interference above that of existing deployments. The small difference in the overload levels for the near site calculations can be attributed to the path loss difference and the base station antenna discrimination. The tables also show that such cases of overload interference into Public Safety receivers could be reduced with the use of newer Public Safety receivers with overload limits

around – 20 dBm (well within present design even at the current wider front end bandwidths) or the incorporation of front end filtering.

2.4 The PSD Limit

Reviewing the above tables leads to the conclusion that overload is the controlling interference mechanism. Based on this conclusion, the PSD that can be implemented and still maintain the *status quo* in the interference environment can be determined. The study determined that a PSD of 250 watts/MHz for non-rural areas and 500 watts/MHz for rural areas would not cause any additional interference into bands adjacent to the 850 MHz cellular band.

3. Conclusions

This study addressed the interference impacts on Public Safety receivers under five different cases that are representative of AT&T's past, present, and future network comprising GSM, UMTS and LTE systems in various configurations in the cellular band. The study used the operating parameters of Public Safety portable and mobile units which were considered poor by present industry standards. The study results in Tables 1 through 12 suggest that the interference environment into Public Safety portable and mobile units from 2X2 MIMO LTE cellular deployments is not appreciably different than that from existing technologies in the cellular band.

Results of this "real world" study support AT&T's belief that a power limit based on a Power Spectral Density measure will not increase the possibility of harmful interference to adjacent bands and will maintain the "status quo" with respect to the potential impact on users of adjacent spectrum, such as the Public Safety Radio Service. The "real world" study results also support a Power Spectral Density limit of 250 Watts/MHz in non-rural areas and 500 Watts/MHz in rural areas. As a result of this study, AT&T will file a petition at the FCC proposing to supplement the current per-emission ERP limits for cellular base stations with ones restated as power spectral density limits.