Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
	)	
Revision of Part 15 of the Commission's	)	ET Docket No. 13-49
Rules To Permit Unlicensed National	)	
Information Infrastructure (U-NII)	)	
Devices in the 5 GHz Band	)	

MIMOSA NETWORKS, INC.

PETITION FOR PARTIAL RECONSIDERATION

Mimosa Networks, Inc. ("Mimosa"), by its attorneys and pursuant to Section 405 of the Communications Act of 1934 ("Act")[1] and Section 1.429 of the Commission's Rules,[2] hereby respectfully requests that the Commission reconsider the First Report and Order adopted in the above-captioned proceeding, as it relates to out-of-band emissions rules for Unlicensed National Information Infrastructure ("U-NII") devices operating in the 5.15-5.25 GHz (U-NII-1) band and the 5.725-5.850 GHz (U-NII-3) band.[3]

I. INTRODUCTION.

Stringent out-of-band emissions limits imposed by the *First Report and Order* on fixed point-to-point operations and devices in the U-NII-1 and U-NII-3 bands would likely have the unintended consequence of disrupting efforts to bring fixed broadband services to unserved and

[1] 47 U.S.C. § 405.

[2] 47 C.F.R. § 1.429.

[3] *Revision of Part 15 of the Commission's Rules To Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band*, ET Docket No. 13-49, First Report and Order, 29 FCC Rcd 4127 (2014) ("*First Report and Order*" or "*Order*"). A summary of the *Order* and notice of the final rules adopted in the *Order* was published in the Federal Register on May 1, 2014. *Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band*, 47 C.F.R. Parts 2 and 15, ET Docket No. 13-49, FCC 14-30, 79 Fed. Reg. 24569 (May 1, 2014).

underserved communities throughout rural America.[4] Moreover, an engineering analysis accompanying this Petition demonstrates that various options for attempting to comply with the low emission limits adopted by the Commission are costly, unmanageable, and impractical.[5] Mimosa therefore advocates in this Petition that the Commission should reconsider its decision in the *Order* and modify its Part 15 rules to permit an increase in emissions limits based upon the higher gain of certain transmitting antennas.[6]

II. BACKGROUND.

In the *U-NII Devices Notice* the Commission, seeking to harmonize the antenna gain requirements in Section 15.247 and Section 15.407 of its rules,[7] proposed to apply to fixed point-to-point systems the more stringent 23 dBi maximum antenna gain that is currently required under Section 15.407.[8] Several commenters objected to this approach, arguing that the addition of an

[4] This consequence would be contrary to the Commission's statutory mandate to make "available . . . to all the people of the United States . . . a rapid, efficient, Nation-wide, and world-wide wire and radio communication service with adequate facilities at reasonable charges." Section 1 of the Act, 47 U.S.C. § 151.

[5] Appendix A, Mustafa Rangwala, *Engineering Analysis of Out-of-Band Emissions Requirements Adopted by the FCC in the U-NII Devices First Report and Order* ("Rangwala Analysis" or "Analysis"). Mr. Rangwala serves as the Director of Hardware for Mimosa. He holds Bachelor of Science degrees in Mathematics and Electrical Engineering, and a Master of Science degree in Electrical Engineering, from the University of Michigan.

[6] *See* 47 C.F.R. § 1.429(c) (requiring that a petition for reconsideration must "[s]tate with particularity the respects in which [the] petitioner believes the action taken [by the Commission] should be changed"). Mimosa is an interested party in this proceeding because, as a manufacturer of wireless broadband products, it has a stake in Commission actions that could adversely affect the efficient and cost-effective utilization of spectrum by fixed wireless broadband network access providers. *See* 47 C.F.R. § 1.429(a) (permitting "any interested person" to submit a petition for reconsideration of any final action taken by the Commission).

[7] 47 C.F.R. §§ 15.247, 15.407.

[8] *Revision of Part 15 of the Commission's Rules To Permit Unlicensed National Information Infrastructure (UNII) Devices in the 5 GHz Band*, ET Docket No. 13-49, Notice of Proposed Rule Making, 28 FCC Rcd 1749, 1780 (para. 33) (2013) ("*U-NII Devices Notice*").

EIRP limit for fixed point-to-point applications would hamper deployment of longer links in hard-to-reach rural areas.[9]

Convinced by these objections, the Commission decided not to adopt its proposal, and instead modified Section 15.407 to permit point-to-point operations under the same gain requirements currently contained in Section 15.247, finding that "[t]he current rules allow service providers to deploy cost-effective wireless links in what would otherwise be considered high cost areas, and allow for the quick setup and transitioning of unlicensed and licensed microwave links."[10]

Unfortunately, however, the Commission then proceeded to undo the benefits that would have been realized by its decision regarding antenna gain requirements. Specifically, the Commission decided to adopt a proposal made in the *U-NII Devices Notice* to apply the more restrictive out-of-band emissions limits in Section 15.407 of its rules for unlimited gain antennas, rather than applying the more lenient emissions limit currently in Section 15.247.[11] For the reasons discussed in this Petition, and in the Rangwala Analysis, Mimosa respectfully requests that the Commission reconsider this decision.

III. THE COMMISSION SHOULD RECONSIDER ITS DECISION TO IMPOSE STRINGENT OUT-OF-BAND EMISSIONS LIMITS ON FIXED POINT-TO-POINT OPERATIONS UTILIZING HIGH-GAIN ANTENNAS.

In adopting the more restrictive emissions limits contained in Section 15.407 of its rules, the Commission recognized that high-gain point-to-point systems "may have to be modified to

[9] *See, e.g.*, Cambium Networks Ltd. ("Cambium") Comments (filed May 28, 2013) at 4, *cited in First Report and Order*, 29 FCC Rcd at 4156 (para. 106 n.163).

[10] *First Report and Order*, 29 FCC Rcd at 4158 (para. 112).

[11] *Id*. at 4159 (para. 119). The requirement to comply with the restrictive Section 15.407 emissions limits becomes applicable two years after the effective date of the *First Report and Order*. Use of devices sold within this period will be grandfathered for the life of the equipment. *See id*. at 4162 (para. 129 & n.199), 4163 (para. 134).

comply with the lower out-of-band emissions limit from Section 15.407."[12] Although the Commission acknowledged the impact that its decision will have on network operators and equipment suppliers, it dismissed concerns in the record regarding any imposition of the lower Section 15.407 emissions limits by pointing out that equipment "[m]anufacturers have the flexibility to determine how they should meet the lower out-of-band emissions limit whether by reducing power, decreasing antenna gain, or utilizing tighter filters."[13]

Undercutting Broadband Deployment in Rural Areas.—Implementation of these or other options by equipment manufacturers, however, will severely undercut the ability of fixed wireless Internet access providers to continue efforts to make broadband services available in remote rural areas throughout the Nation. According to the Commission, approximately 24 percent of Americans living in rural areas—14.5 million people—do not have any access to high-speed broadband (compared to 1.8 percent in non-rural areas).[14] Fixed wireless broadband providers have been effective in filling this broadband gap in rural areas,[15] but the Commission's decision in the *First Report and Order* to impose low out-of-band emissions limits will inadvertently act as a roadblock to future progress in rural broadband deployment.

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[12] *First Report and Order*, 29 FCC Rcd at 4159 (para. 119).

[13] *Id*. at 4160 (para. 119).

[14] *Inquiry Concerning the Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion, and Possible Steps to Accelerate Such Deployment Pursuant to Section 706 of the Telecommunications Act of 1996, as Amended by the Broadband Data Improvement Act*, GN Docket No. 11-121, Eighth Broadband Progress Report, 27 FCC Rcd 10342, 10370 (para. 47) (2012).

[15] *See* Wireless Internet Service Providers Association ("WISPA") Comments, ET Docket No. 13-49 (filed May 28, 2013) ("WISPA Comments") at 2 (estimating that wireless Internet service providers ("WISPs") "serve more than 3,000,000 people, many of whom reside in rural, unserved and underserved areas where wired technologies like DSL and cable Internet access services may not be available. In some of these areas, WISPs provide the only terrestrial source of fixed broadband access.").

Cambium, for example, has explained that meeting the more restrictive Section 15.407 emissions limits would require device manufacturers to "incorporate transmitter sections of considerably greater complexity than those found in Section 15.247 devices, including the use of additional high performance RF filters."[16] Cambium explained that "[t]he additional complexity would result in higher manufacturing costs, increasing the selling price of unlicensed devices to the extent that many existing applications for lower-tier U-NII band devices may well cease to be cost effective."[17]

The Commission's suggestion that the stringent emissions limits can be met by reducing power or decreasing antenna gain ignores the realities of fixed wireless broadband deployment in sparsely populated areas. Taking these steps would likely diminish the distances achieved and the reliability of fixed point-to-point systems, requiring the use of additional access points and transmission equipment.[18] WISPA has observed that, "because of the more demanding Section 15.407 [emissions] requirements, any new equipment produced may not have the same throughput capability, channelization capability or power output capability as existing equipment certified under Section 15.247."[19] This adverse impact on equipment performance will impede efficient use of the 5 GHz spectrum, adding to the difficulties faced by fixed wireless providers seeking to deploy

[16] Cambium Comments at 3.

[17] *Id*., *cited in First Report and Order*, 29 FCC Rcd at 4159 (para. 116). *See* Exalt Communications Inc. ("Exalt") Comments (filed July 18, 2013) at 4 (unpaginated) (explaining that restrictive emissions limits are likely to "have an impact on prices for devices operating in these [5 GHz] bands, . . . thus restricting the usage of these devices for applications such as rural broadband, which will become more expensive to deploy as a result"). Moreover, the Rangwala Analysis demonstrates that the utilization of filters to meet the restrictive emissions limits is not a manageable option. *See* Rangwala Analysis at 4-5.

[18] *See* WISPA Comments at 14.

[19] Ex Parte Letter from Stephen E. Coran to Marlene H. Dortch, Secretary, FCC, ET Docket No. 13-49 (filed Mar. 21, 2014) ("WISPA Ex Parte") at 1.

broadband in rural areas. Specifically, the stringent emissions requirements will severely impede deployment of long-distance, point-to-point backhaul links that are critical for this deployment.[20]

Reliance on 5 GHz Spectrum for Public Safety and Industrial Applications.—In addition to its adverse impact on broadband deployment in rural areas, the Commission's imposition of more restrictive out-of-band emissions requirements on operations in the U-NII-1 and U-NII-3 bands will inadvertently disrupt use of this spectrum for public safety and industrial applications.

For example, government agencies at the federal, state, and local level rely upon spectrum in the 5 GHz band for a variety of public safety services, including video surveillance. In addition, electrical power grids as well as oil, gas, and other pipeline networks utilize 5 GHz spectrum in their operations. Modifying the restrictive emissions limits adopted by the Commission, as requested by Mimosa in this Petition, would avert the risk of compromising the efficient operation of these applications and systems.

No Evidence of Interference.—A further problem with the Commission's decision to impose restrictive out-of-band emissions limits on devices used for fixed point-to-point operations in the U-NII-1 and U-NII 3 bands is that the stringent requirements adopted by the Commission seek to address a problem that appears not to exist.

The Commission justified its decision by stating that its imposition of the Section 15.407 emissions limits will provide "appropriate protection to incumbent services."[21] Cambium has indicated, however, that it is not aware of any evidence that out-of-band emissions for devices certified under the less stringent emissions standards in Section 15.247 of the Commission's Rules

[20] *See* WISPA Comments at 12-13 (explaining that "[i]n many cases a WISP would be unable to provide broadband access to distant communities using a link operating under the more stringent requirements of Section 15.407").

[21] *First Report and Order*, 29 FCC Rcd at 4159 (para. 119).

have caused interference to Terminal Doppler Weather Radar ("TDWR") operations in the 5600 MHz-5650 MHz band.[22]

While Mimosa joins WISPA in supporting the Commission's goal of reducing unwanted emissions,[23] Mimosa also agrees with WISPA and Cambium that, in this case, the imposition of stringent emissions limits serves no purpose because the protection intended to be provided by these limits is not needed,[24] while the adverse effects that these limits are likely to cause have been well documented in the record. In addition, the Commission's adoption in the *First Report and Order* of enhanced security requirements for all U-NII device software[25] will significantly reduce any risk of interference to TDWR facilities caused by the modification of U-NII devices to enable operations outside the parameters for which the devices have been certified.[26]

Impact on the Use of High-Gain Antennas.—WISPA has explained that, "because the Section 15.407 [out of band emissions] requirements are based on EIRP, the ability to use higher-gain antennas that provide cost-effective point-to-point backhaul connectivity to rural unserved

[22] Cambium Comments at 4. *See* WISPA Ex Parte at 2 (observing that "there are no on-the-record cases of [out-of-band emissions] from currently-produced legally-operating Section 15.247 equipment causing interference problems for any other licensed or unlicensed radio system"). The absence of any evidence of interference can be attributed in part to the fact that the closest edge of the U-NII-3 band is separated from the edge of the TDWR band by 75 MHz, and to the fact that most TDWR stations are located in, or in close proximity to, major metropolitan areas.

[23] *See* WISPA Ex Parte at 2.

[24] In fact, Exalt has argued that imposition of the restrictive Section 15.407 emissions limits "will likely result in a more restrictive tuning range," which, in turn, will cause an "increasing interference potential within the operating band, as more devices will need to be tuned to a more restrictive spectrum." Exalt Comments at 3.

[25] *See First Report and Order*, 29 FCC Rcd at 4141-45 (paras. 47-60).

[26] *See* WISPA Reply Comments, ET Docket No. 13-49 (filed July 24, 2013) at 7; *First Report and Order*, 29 FCC Rcd at 4141 (para. 47).

and underserved communities will be restricted with a consequent loss of broadband service to many distant communities."[27]

This impact of the stringent Section 15.407 emissions limits on high-gain antennas is discussed in the Rangwala Analysis, with Mr. Rangwala concluding that "[t]his requirement harshly limits the use of this [5 GHz] spectrum, especially for extremely long-distance backhaul links where the 5 GHz band has traditionally been very useful."[28] Mr. Rangwala provides calculations showing that the Commission's decision in the *First Report and Order* will result in unrealistic emissions limits that are at least 30+ dB more stringent that the Institute of Electrical and Electronics Engineers ("IEEE") 802.11 mask requirements "when used with a high-gain antenna for point-to-point applications."[29]

Mr. Rangwala reviews several options for meeting the stringent emissions limits imposed by the Commission, but concludes that they would be costly, impractical, and ineffective. For example, Mr. Rangwala discusses various amplifiers currently available for use in the U-NII-3 band, and his analysis demonstrates that meeting the emissions requirements reflected in his calculations "is not viable with today's commercially available amplifiers."[30] Next, Mr. Rangwala discusses filtering as a possible means of meeting the Section 15.407 emissions limits, showing that the filter specifications that would be necessary to achieve compliance are impractical and unmanageable.[31] Finally, Mr. Rangwala explores the possibility of relying on various predistortion

[27] WISPA Ex Parte at 1.

[28] Rangwala Analysis at 1.

[29] *Id*. at 3.

[30] *Id*. at 4.

[31] *Id*. at 4-6.

techniques to meet the emissions restrictions, but he concludes that these techniques would provide only limited improvements and would "add significant complexity and cost to the radio design."[32]

Emissions Limits Should Be Modified.—Based on the record in this proceeding, and the analysis provided by Mr. Rangwala, Mimosa respectfully requests the Commission to modify the emissions limits adopted in the *First Report and Order*, and reflected in Section 15.407(b) of its rules, that are applicable to the U-NII-1 and U-NII-3 bands.[33] As Mr. Rangwala explains, the Commission's decision to impose severe emissions limits conflicts with its decision to allow higher EIRP by permitting the use of unlicensed high gain point-to-point antennas in the U-NII-3 band.[34]

The Commission should ensure that its antenna gain rules and emissions requirements work in harmony with each other. An effective way to achieve this result is for the rules to provide that, in the case of transmitting antennas with directional gain greater than 6 dBi, the emissions limit should increase to match the amount by which the directional gain of the antenna exceeds 6 dBi.[35] As Mr. Rangwala explains, this approach would not result in any significant interference because of the narrow beamwidth, and the directional nature of the radiation pattern, of high-gain antennas.[36]

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[32] *Id*. at 7.

[33] Mr. Rangwala explains that the Commission decided in the *First Report and Order* to permit outdoor operation of U-NII devices in the U-NII-1 band, but that out-of-band emissions restrictions in Section 15.407 impede the usability of this band. *Id*. at 1. *See First Report and Order*, 29 FCC Rcd at 4137 (para. 34).

[34] Rangwala Analysis at 7. *See First Report and Order*, 29 FCC Rcd at 4158 (para. 112).

[35] *See* Rangwala Analysis at 7. Mimosa proposes amendments to the Commission's rules to accomplish this result. See Appendix B.

[36] Rangwala Analysis at 7.

IV. CONCLUSION.

For the reasons discussed in this Petition, Mimosa Networks, Inc., respectfully requests the Commission to partially reconsider the *First Report and Order* and to revise its rules to eliminate restrictive out-of-band emissions limits applicable to antennas used in the U-NII-1 and U-NII-3 bands that have directional gain greater than 6 dBi.

Respectfully submitted,

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APPENDIX A

Engineering Analysis of Out-of-Band Emissions Requirements Adopted by the FCC in the U-NII Devices First Report and Order

Prepared by Mustafa Rangwala
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Introduction

With its adoption of the *First Report and Order* in the 5 GHz U-NII rulemaking proceeding, the FCC has implemented the first set of rules in unifying the varying regulations governing the unlicensed use of the 5 GHz band.[1] Since the old Section 15.247 rules provided high EIRP/output power usage in what is now known as the U-NII-3 band while Section 15.407 allowed usage in the U-NII-1 and U-NII-2 bands, it was common practice by equipment vendors to certify the same product under multiple regulations to "get the best of both worlds." This was a convoluted process for all parties involved: equipment vendors, test labs and the FCC. The *First Report and Order* aligns both regulations under the common Section 15.407 framework, greatly simplifying the certification process and reducing costs.

For the most part, the *First Report and Order* maintains the benefits of the U-NII-3 band for outdoor use, maintaining the "unlimited antenna gain" provision in Section 15.247. However, the FCC has applied the more stringent emissions limit from the Section 15.407 U-NII regulations which effectively negates any benefits that could have been obtained from the "unlimited antenna gain" provision. This requirement harshly limits the use of this spectrum, especially for extremely long-distance backhaul links where the 5 GHz band has traditionally been very useful.

The FCC has also introduced the usage of the U-NII-1 band for outdoor use, but similar emissions requirements impede its usability. We will show through link and radio design examples that maintaining this stringent requirement is infeasible, and we will conclude by proposing a modification to the emissions requirement that will ensure fairness for all equipment vendors in their radio design, regardless of antenna directionality.

U-NII-1 and U-NII-3 Specifications

We begin by briefly reviewing the specifications governing the use of the U-NII-1 (5150-5250 MHz) and U-NII-3 (5725-5850 MHz) bands for outdoor use:

- 30 dBm conducted power (maximum)

[1] 47 C.F.R. §§ 15.247, 15.407.

- Up to 6 dBi antenna with no power reduction, then dB-for-dB reduction for PtMP access networks
- No antenna gain limit for PtP, in U-NII-3
- 23 dBi antenna gain limit for PtP, in U-NII-1. dB-for-dB reduction after that.
- PSD limit: 17 dBm/MHz (maximum)
- Emissions limit for U-NII-3: -17 dBm/MHz at band edge and -27 dBm/MHz at 10 MHz from band edge (maximum)
- Emissions limit for U-NII-1: -27 dBm/MHz at band edge (maximum)

Typical Backhaul Link

Let's take a typical use case for a long-distance backhaul point-to-point link:

- U-NII-1 or U-NII-3
- 30 dBm conducted power
- 23 dBi gain antenna, although this calculation will show that even this is unrealistic, let alone being able to utilize the "unlimited antenna gain" provision retained by the FCC in the *First Report and Order*
- 80 MHz channel bandwidth as supported in IEEE 802.11ac
- 256-QAM modulation
- TDD protocol, same channel shared in time by both sides of link

Calculating some link parameters:

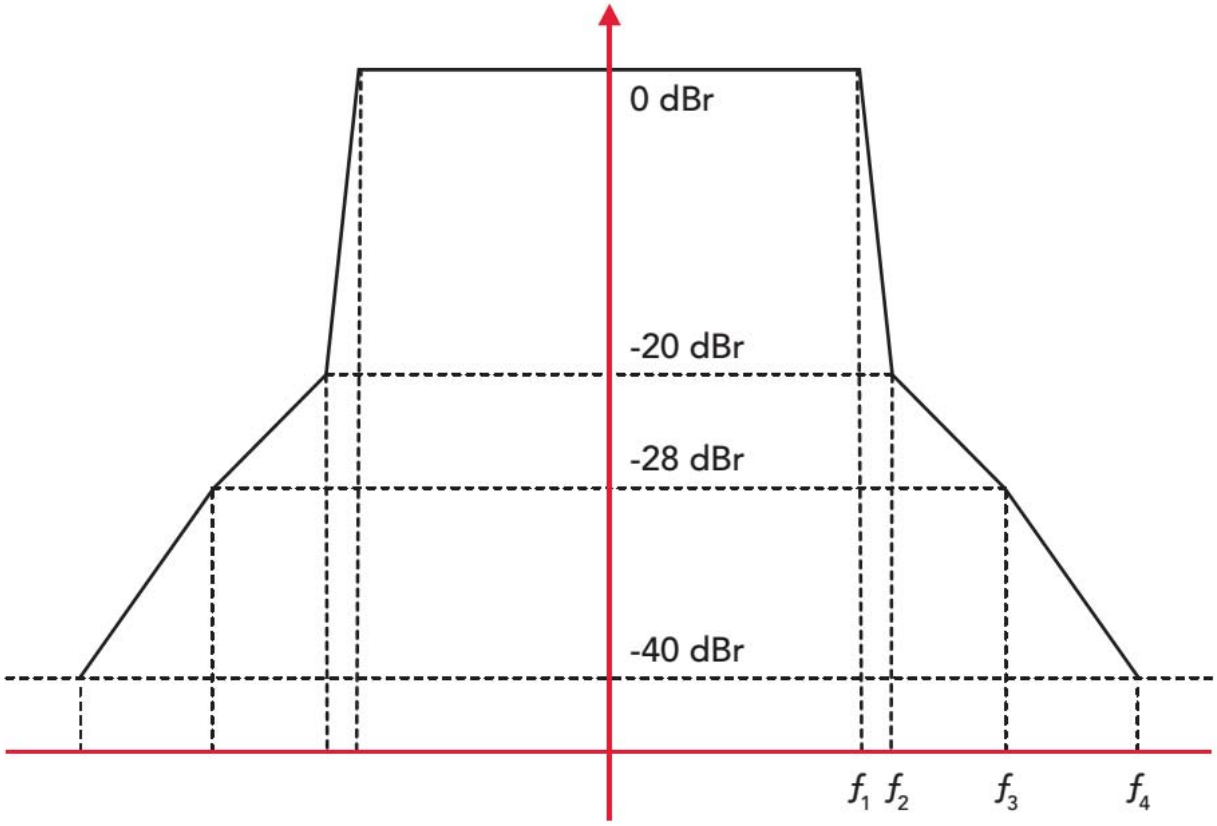
- PSD: 30 dBm/80 MHz = 11 dBm/MHz
- EIRP: 30 dBm + 23 dBi = 53 dBm
- EIRP/MHz: 53 dBm/80 MHz = 34 dBm/MHz
- Emissions limit: -17 dBm/MHz (51 dBr) at band edge and -27 dBm/MHz (61 dBr) at 10 MHz from band edge
- Taking the most optimal case of parking the channel at the center of the band for U-NII-3, 5785.5 MHz. Channel spans from 5747.5-5827.5 MHz, and channel edge to band edge is 22.5 MHz.
- Thus, the emissions limit we need to meet is 51 dBr by 22.5 MHz and 61 dBr by 32.5 MHz when using U-NII-3.
- These numbers become more problematic, to 61 dBr by 20 MHz, when using the U-NII-1 band (parking the channel at 5170-5250 MHz), since that band is only 100 MHz wide.

These are unrealistic numbers. For example, IEEE 802.11ac specifications for 80 MHz channels require 28 dBr by 40 MHz and 40 dBr by 80 MHz of channel edge.[2] Thus, the emissions

[2] LitePoint, "IEEE 802.11ac: What Does It Mean for Test?", accessed at http://litepoint.com/whitepaper/80211ac_Whitepaper.pdf.

limits, as adopted by the FCC, are, at the very least, 30+ dB more stringent than even the IEEE 802.11 mask requirements when used with a high-gain antenna for point-to-point applications.

Figure 1: IEEE 802.11ac Mask Requirements[3]



Channel Size	f_1	f_2	f_3	f_4
20 MHz	9 MHz	11 MHz	20 MHz	30 MHz
40 MHz	19 MHz	21 MHz	40 MHz	60 MHz
80 MHz	39 MHz	41 MHz	80 MHz	120 MHz
160 MHz	79 MHz	81 MHz	160 MHz	240 MHz

[3] *Id.*

Radio Design

Amplifiers

To meet such stringent requirements, the first avenue to investigate would be what performance is obtained from typical commercially available amplifiers in this band. The most common amplifier type used by IEEE 802.11 equipment is a Class AB GaAs amplifier that gives the best compromise between distortion (for high peak-to-average ratio signals) and efficiency. Typical efficiencies are in the 10% range to maintain sufficient linearity, so generating 30 dBm with such an amplifier topology would cost 10 W in power, which is already extremely challenging to dissipate in an outdoor environment with no forced thermal convection (*i.e.*, fans). Typical GaAs amplifiers have a mask performance of approximately 35 dBr by ½ channel bandwidth away,[4] so in our case 40 MHz. This is far from our desired 61 dBr by 32.5 MHz.

We could look at more linear amplifiers, such as Class A, but they would provide extremely poor efficiencies (less than 5%) to achieve the distortion specifications required for these high modulation rates. Such low efficiencies lead to impractical thermal designs, increasing the size of the product and OPEX for network operators. There are other amplifier technologies worth investigating that promise higher efficiencies, such as the upcoming GaN. However, those are notorious for a very "soft" compression,[5] with GaN vendors generally specifying a P3dB point as a distortion metric. This would further degrade mask performance from GaAs, not providing the adequate mask requirements we need.

Thus, it is evident that there is a fundamental tradeoff between amplifier efficiency and distortion, and meeting emissions requirement as calculated earlier is not viable with today's commercially available amplifiers.

Filters

The next logical place to look to meet our design requirements would be filtering. However, even the filter requirements are unrealistically stringent. Assuming we get 30 dB mask suppression from the amplifier, we need another 30 dB rejection from the filter. Thus, the ideal filter requirements would look as such:

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[4] *See* Lu Ye, *Design and Analysis of Digitally Modulated Transmitters for Efficiency Enhancement* (2013), accessed at http://www.eecs.berkeley.edu/Pubs/TechRpts/2013/EECS-2013-99.pdf; Yus Ko, *Design and Optimization of 5 GHz CMOS Power Amplifiers with the Differential Load-Pull Techniques* (Dec. 2005), accessed at http://etd.fcla.edu/UF/UFE0013036/ko_y.pdf.

[5] Aethercomm, *Gallium Nitride HEMTs for High Efficiency Power Amplifiers* (May 2007), accessed at http://www.mpdigest.com/issue/Articles/2007/may/aethercomm/.

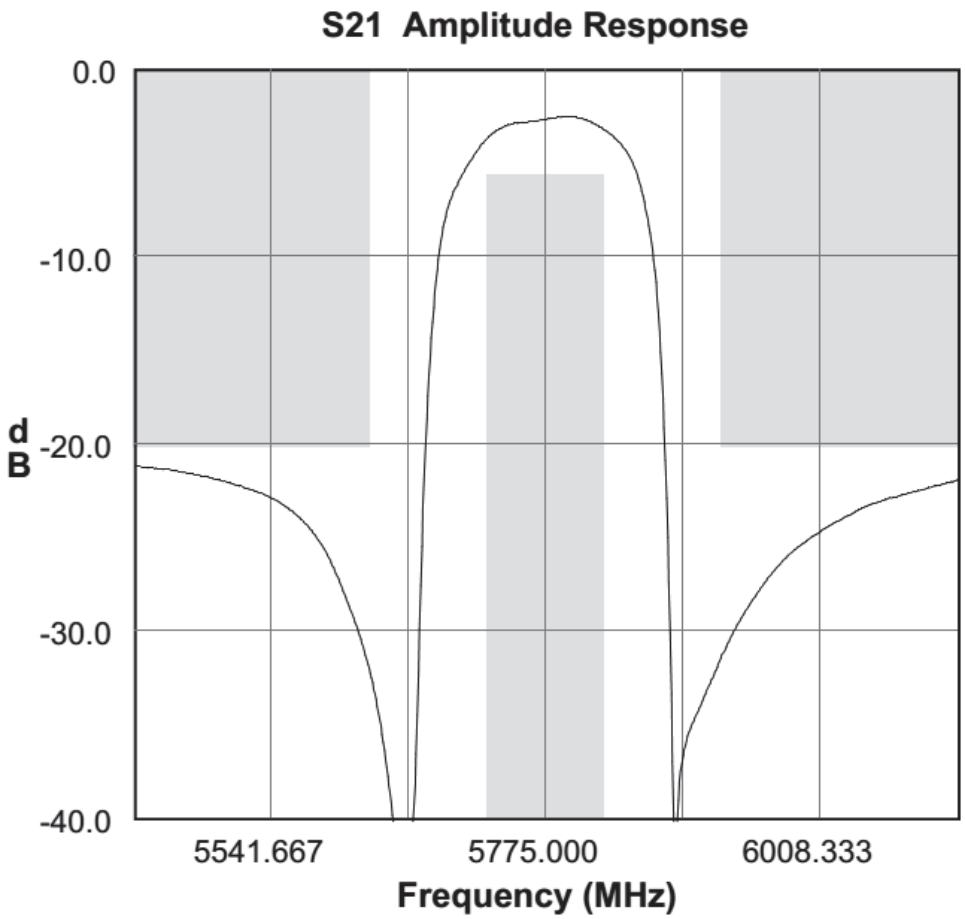
- Center Frequency: 5787.5 MHz
- Passband: 5747.5-5827.5 MHz
- Percent Bandwidth: 1.4%
- Rejection: 30 dB at 5725, 5850 MHz

Any filter designer will immediately realize these are impractical requirements, even for an extremely high order filter. Size and insertion loss of any structure that comes close to these requirements would be unmanageable. Also, this filter would be placed after the power amplifier, so any insertion loss would adversely affect link performance. We can compare this to a commercially available filter in this band, for example the Triquint 880369 BAW filter.[6] This is a large device, measuring 3.3x1.6mm. It has a typical insertion loss of 3 dB, reducing usable range of the device by a factor of 1.4. With a center frequency of 5775 MHz, it has its first rejection null of 40 dB at 5658 MHz – far from the rejection requirements we need at 5725 MHz.

See Figure 2 – Triquint 880369 Filter Performance, on the following page.

[6] Triquint 880369 BAW Filter, accessed at http://www.triquint.com/products/p/880369.

Figure 2: Triquint 880369 Filter Performance[7]



The other fundamental problem with filters is that they result in a narrow-band design, restricting product SKUs to particular a region or use-case. In addition, narrow-band designs are not well suited to take advantage of carrier aggregation, a common technique used in newer standards such as LTE and IEEE 802.11ac to make use of wider bandwidths by using disparate channels. This would be ideal for outdoor point-to-point links utilizing U-NII-1 and U-NII-3 simultaneously to double the link capacity, but a narrow-band solution such as a filter would prevent a single radio from operating in such a manner.

Predistortion

Other more involved digital signal processing techniques such as predistortion can be investigated to meet such stringent mask requirements. Digital predistortion is a common technique,

[7] *Id*.

where a look-up table in inserted before the digital to analog converter of a radio transmitter that attempts to invert the distortion introduced by the power amplifier. Memory-less predistortion, where the power amplifier is characterized *a priori*, has been shown to produce very limited improvements,[8] on the order of 10 dB or less in mask improvement. This is mainly due to the transient and thermal effect of these high power amplifiers that makes it hard for accurate non-feedback compensation. More complicated algorithms exist that involve real-time feedback, but those are unrealistic in TDD systems where the radio receiver is not active during transmit phases. Such techniques also add significant complexity and cost to the radio design.

Conclusions

The fundamental problem that exists here is that the FCC's regulations allow for higher EIRP (through higher antenna gain) in point-to-point cases, but they don't proportionately allow for a higher emissions limit. This is counter-intuitive, since a higher antenna gain by nature focuses all its power in a very narrow volume in space and, thus, the emissions EIRP limit should be increased proportionately. The probability that high gain radios cause interference decreases with the increasing gain, since they only emit power in a small volume.

Based on the analysis presented here, the emissions EIRP limit should increase dB-for-dB with antenna gain for antennas above 6 dBi, because these systems have high gain and focus the power. This maintains the same stringent requirements on the radio design, but decouples the radio emissions requirement from the type of antenna used. This also makes sense in the context of equipment vendors selling individual radios and leaving the choice of antenna to the end user, allowing the user to choose an antenna size appropriate for their link design. As long as the radio meets emissions and spectral mask requirements with a reference antenna, it will continue to do so under the approach proposed here with a higher or lower gain antenna since the emissions requirement simply scales.

In the above case, this approach would increase the emissions limit by 23-6= 17 dB, so 34 dBm/MHz at band edge and 44 dBm/MHz 10 MHz from band edge. Even though this number is high, it is only applicable to high gain antennas and thus would not be a major cause of interference due to the narrow beamwidth and directional nature of the radiation pattern. A typical point-to-point backhaul link is ground based and a 23 dBi antenna would have a beamwidth on the order of 8 degrees, thus illuminating a very limited conical volume in space that is directly pointed at its peer. This would not be a cause of interference to any nearby devices.

[8] Lei Ding, *Digital Predistortion of Power Amplifiers for Wireless Applications* (Mar. 2004), accessed at https://smartech.gatech.edu/bitstream/handle/1853/5184/ding_lei_200405_phd.pdf.

APPENDIX B

Proposed Revisions to the Commission's Rules

[Text proposed to be added is underlined]

PART 15 – RADIO FREQUENCY DEVICES

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§ 15.407 General technical requirements.

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(b) *Undesirable emission limits.* Except as shown in paragraph (b)(7) of this section, the maximum emissions outside of the frequency bands of operation shall be attenuated in accordance with the following limits:

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(1) For transmitters operating in the 5.15-5.25 GHz band: all emissions outside of the 5.15-5.35 GHz band shall not exceed an e.i.r.p. of -27 dBm/MHz. If transmitting antennas of directional gain greater than 6 dBi are used, the emissions limit shall be increased by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

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(4) For transmitters operating in the 5.725-5.85 GHz band: all emissions within the frequency range from the band edge to 10 MHz above or below the band edge shall not exceed an

e.i.r.p. of -17 dBm/MHz; for frequencies 10 MHz or greater above or below the band edge, emissions shall not exceed an e.i.r.p. of -27 dBm/MHz. If transmitting antennas of directional gain greater than 6 dBi are used, the emissions limit shall be increased by the amount in dB that the directional gain of the antenna exceeds 6 dBi.