Straight Path Communications, Inc.
5300 Hickory Park Drive, #218
Glen Allen, VA 23059
www.straightpath.com

VIA ECFS

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

August 5, 2015

Re: ***Use of Spectrum Bands Above 24 GHz for Mobile Radio Services*; GN Docket 14-177; Written *Ex Parte* Communication**

Dear Ms. Dortch:

Straight Path Communications, Inc. ("Straight Path") has been an active participant in the above-referenced proceeding. It strongly supports the Commission's initiative to ensure that spectrum is available to deploy fifth generation ("5G") mobile communication technologies. The comments and reply comments submitted in response to the Commission's *Notice of Inquiry* show that the Commission must act so that the United States can continue to be a world leader in this area. Accordingly, the Commission should promptly take the next steps in this proceeding and propose rules under which 5G mobile operations may occur. As Straight Path has stated before, the 39 GHz band is ideally suited to deploy 5G mobile technology. In order to facilitate the development of regulations, Straight Path hereby suggests changes to the Commission's technical rules necessary to support 39 GHz mobile services. Included as an Appendix to this letter are proposed revised regulations.

Background

The Table of Allocations already allows mobile service in the 38.6 – 40 GHz band.[1] However, unlike mobile services such as Cellular Radiotelephone Service, Personal Communications Service ("PCS"), Advanced Wireless Service ("AWS"), Wireless Communications Service ("WCS"), and 700 MHz mobile services, neither Parts 101 nor 27 contains provisions that are typically relevant for regulation of mobile services in the 39 GHz band.

As a general principle, the rules should enable the most flexible and efficient use of the 39 GHz band to maximize the utilization of spectrum resources. To that end, different terrestrial services including fixed point-to-point, fixed point-to-multi-point, and mobile services should be allowed. In addition, as mobile communications technology continues to advance, the FCC's rules should allow innovation on antenna structure and duplexing schemes. In other words, the minimum antenna gain

[1] *See* 47 C.F.R. § 2.106.

requirement and limitation on antenna polarization should be removed while both FDD and TDD should be allowed. These suggestions are already outlined in our comments[2] to the 5G Notice of Inquiry ("*NOI*").[3]

The channel bandwidth of a 5G system is expected to be between 100 megahertz and 1 gigahertz. We believe there is no need to change the current 50 megahertz channel bandwidth in the 39 GHz band as it is compatible with existing licenses and granular enough to support different bandwidth configurations of 5G system deployments. Multiple of these 50-megahertz channels can be aggregated to accommodate 5G systems with different channel bandwidths.

In addition to these suggestions, below we recommend changes to the following aspects of the technical rules to enable 5G mobile service in the 39 GHz band:

- Power and EIRP limits
- Out-of-band emissions
- Co-channel interference

Power and EIRP Limits

The primary purpose of regulating the maximum transmit power is to safeguard against potential harmful interference to other devices and harmful radiation to the public. Both the maximum transmit power and the maximum EIRP should be regulated for those reasons. The following shows the relationship between the Total Radiation Power ("TRP"), *i.e.*, the total transmit power, and the Effective Isotropic Radiation Power ("EIRP")

$$TRP = \frac{1}{4\pi}\int_{\phi=0}^{2\pi}\int_{\theta=0}^{\pi} EIRP(\theta,\phi)\, sin\theta d\theta d\phi$$

where θ is the angle in elevation and ϕ is the angle in azimuth. In other words, if we integrate the EIRP along a sphere that encloses the transmitter, we will arrive at the Total Radiation Power. *While the maximum EIRP limits the radiation along a specific spatial direction, the maximum TRP limits the aggregated radiation along all spatial directions*. By specifying both limits, the transmit power and EIRP of a 5G device can be regulated without compromising the capability to perform sophisticated antenna array-based processing such as dynamic beamforming and massive multiple-input multiple-output ("MIMO").

The maximum transmit power can be measured as the transmitter conducted output power attenuated by the antenna efficiency. The technology trend is to integrate antenna arrays with power amplifiers on the same printed circuit board – or even on the same chip package or integrated circuit – which can make the measurement procedure difficult. Fortunately, the industry is already working on testing and measurements for millimeter-wave devices as commercial millimeter-wave equipment (*e.g.*, 60 GHz devices) become available in the next few years. We expect the testing and measurement

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[2] *See* Comments of Straight Path Communications, Inc., GN Docket No. 14-177, *et al.*, at ii (filed Jan. 15, 2015) ("Straight Path Comments").

[3] *See Use of Spectrum Bands Above 24 GHz For Mobile Radio Services, et al.*, Notice of Inquiry, 29 FCC Rcd. 13020 (2014) ("*NOI*"); *Wireless Telecommunications Bureau and Office of Engineering and Technology Extend Period to File Comments and Reply Comments in Response to Notice of Inquiry on Use of Spectrum Bands Above 24 GHz for Mobile Radio Services*, Public Notice, 29 FCC Rcd. 14342 (2014) (extending the comment and reply comment deadlines).

methodology for millimeter-wave frequency devices to become more mature when 5G devices are introduced in the marketplace.

Under Section101.113,[4] the maximum allowable EIRP for fixed stations in the 39 GHz band is 55 dBW (or 85 dBm) per polarization. While this maximum allowable EIRP for fixed stations certainly does not hinder the deployment of 39 GHz base stations, it is not needed for a successful deployment of 39 GHz mobile services. To be technologically competitive and commercially successful, 5G mobile broadband systems need to provide *affordable wide area Gbps mobility*. The "sweet spot" configuration parameters for 5G systems are as follows:

- 100 MHz – 1 GHz system bandwidth
- 100 meter – 1 km cell radius
- 10 – 100 Gbps peak rate
- 1 – 10 Gbps typical user experience
- 100 Mbps – 1Gbps at cell edge

We hence derive our recommended limits based on transmit power and EIRP needed to achieve these configurations. These limits may be conservative for certain deployment scenarios and can be further increased if the Commission believes it is important to provide better provision to deployments beyond the "sweet spot" configurations as outlined above.

Base Stations

It is likely that 5G transmitters will have multiple transmit chains and can generate multiple beams simultaneously. The transmit power of a 5G transmitter should be the aggregate transmit power of all transmit chains. Our link budget analysis[5] shows that a transmission power of 38 dBm (6.3 Watts) per sector will be sufficient to provide more than 100 Mbps at the cell edge for a 1-km cell radius. A total transmission power limit of 40 Watts (46 dBm) should be adequate for a 5G base station with 3 – 6 sectors. The maximum transmit power should not be defined on a per beam basis as the definition of beam itself can be complicated and ambiguous.

In order to provide a good link budget for a 39 GHz link with a cell radius of 1 kilometer, our link budget calculation[6] shows that an EIRP of 65 dBm (3160 Watts) for base transmitters is sufficient. This is in line with the maximum power (EIRP) limitation of the Cellular Radiotelephone Services[7], Broadband PCS[8], WCS[9], AWS[10], and the 700 MHz band[11]. This maximum allowable EIRP is 100 times

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[4] *See* 47 C.F.R. § 101.113.

[5] *See* Appendix B.

[6] *See id.*

[7] In Section 22.913, the maximum ERP of base transmitters for CMRS is 500 watts (equivalent to 820 watts or 29.1 dBW EIRP). *See* 47 C.F.R. § 22.913.

[8] In Section 24.232, the maximum EIRP of base stations for Broadband PCS with emission bandwidth less than 1 megahertz is 1640 watts (32.1 dBW of EIRP) for antenna heights up to 300 meters; the maximum EIRP of base stations with emission bandwidth greater than 1 megahertz is 1640 watts / MHz for antenna heights up to 300 meters. The maximum allowable EIRP is further doubled for base stations deployed in counties with population densities less than 100 people per square mile. *See* 47 C.F.R. § 24.232.

[9] In Section 27.50(a), the maximum EIRP of base stations for the WCS A & B Blocks is 2000 watts per 5 megahertz and must not exceed 400 watts within any 1 megahertz of authorized bandwidth. *See* 47 C.F.R. § 27.50(a).

less than the current allowable maximum EIRP (55 dBW or 85 dBm per polarization) for 39 GHz fixed stations. It is beneficial for the industry to operate 39 GHz mobile networks within a much lower power limit that is in line with other mobile services. This also reduces the possibility and severity of potential interference issues and allows better interference coordination among different licensees and between fixed and mobile use. This proposed EIRP limitation does not apply to fixed point-to-point or point-to-multi-point services. These services should continue to be subject to the 55 dBW (85 dBm) maximum EIRP limitation under Part 101 of the rules.[12]

It is likely that in 5G there will be a (potentially significant) increase in the percentage of small cells, which are typically deployed in low profile locations with lower height than the fully configured macro or micro cell sites. For example, one frequently mentioned configuration is the lamppost installation. Another popular configuration is the building-mounted small cell site. For both cases, these base stations may be closer to people than macro or micro base stations installed on cell towers. Existing rules already govern RF protection in the 39 GHz band – the Maximum Permissible Exposure ("MPE") limit is 1 mW/cm^2 averaged over 30 minutes for base stations.[13] Therefore, an Environmental Assessment ("EA") would be required if the 5G base stations would cause human exposure to a level of radiofrequency radiation in excess of the limits specified in Section 1.1310. For existing mobile services, including Cellular Radiotelephone Service, Personal Communications Service, and Wireless Communications Service, the power level (ERP or EIRP) and antenna height that require an EA are specified in Table 1 in Section 1.1307(b). We recommend similar power level and antenna height limits for 39 GHz mobile service base stations. More specifically, we recommend that EA should be required for non-building-mounted 39 GHz base stations that are less than10 meters above the ground and transmit with EIRP greater than 1640 watts, and for building-mounted 39 GHz base stations that transmit with EIRP greater than 1640 W regardless of the antenna height. Since the 5G base stations only reach the peak EIRP with high gain beams (20 to 30 dB) that have narrow beamwidth (5 to 10 degrees in both elevation and azimuth domain), we expect the RF exposure generated by 5G base stations averaged over a period of time (*e.g.*, 30 minutes) at any one specific location to be significantly less than the RF exposure caused by mobile services at lower frequencies with similar level of EIRP.

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[10] In Section 27.50(d), the maximum EIRP of base stations for AWS with emission bandwidth less than 1 megahertz is 1640 watts, and the maximum EIRP of base stations for AWS with emission bandwidth greater than 1 megahertz is 1640 watts / MHz. The maximum allowable EIRP is further doubled for base stations deployed in counties with population densities less than 100 people per square mile. *See* 47 C.F.R. § 27.50(d).

[11] In Sections 27.50(b) and 27.50(c), the maximum EIRP of base stations for various blocks in the 700 MHz band is also in the range of a few kilowatts, with up to 50 kW maximum ERP allowed for the lower 700 MHz Block D and Block E channels. *See* 47 C.F.R. §§ 27.50(b), (c).

[12] As noted below, new rules for mobile services in the millimeter-wave bands can be included under Part 101, where rules for those services currently exist, or added to Part 27, which governs other mobile services. Our suggested changes are to Part 101, but the Commission may wish to retain that section of the rules for fixed operations and modify Part 27 to accommodate mobile service use of millimeter-wave bands.

[13] *See* 47 C.F.R. § 1.1310.

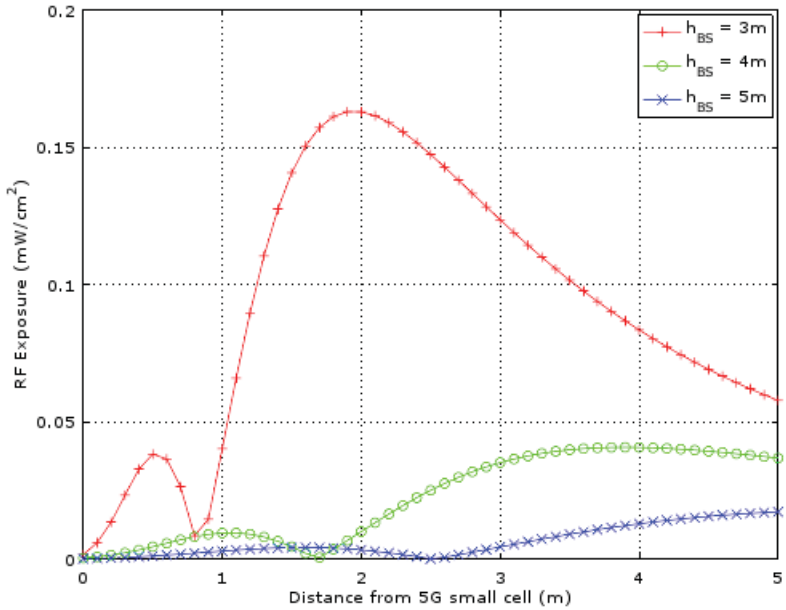

Figure 1. Example of RF exposure with 5G small cells

Figure 1 shows an example of RF exposure with 5G small cells. The base station transmits with 62 dBm EIRP using 256 antenna elements. The antenna array is down-tilted by 5 degrees and the base station transmits with equal probability in all directions within its coverage. In this configuration, we can lower the base station down to 3 meters without exceeding the 1 mW/cm^2 RF exposure limit (assuming 2 meter height for human body). This example shows that even with 62 dBm EIRP and low-height deployment of 5G small cells, RF exposure to human body can be effectively managed. For 5G small cells deployed less than 3 meters high, a more conservative EIRP threshold that triggers the EA can be considered. Certainly clearance or signage can also be required for 5G base stations deployed less than 3 meters high, if the EIRP exceeds a certain level. Should the Commission consider such an approach, we recommend that EA be required for 5G base stations that are deployed less than 3 meters high with greater than 57 dBm and less than 1 meter clearance from human body.

Mobile and Portable Transmitters

The regulation of mobile and portable stations transmitting in the bands below 3 GHz generally covers only output power or EIRP, partially because the large wavelength of these electromagnetic waves (*e.g.*, 10 cm wavelength for 3 GHz frequency) limits the amount of antenna gain achievable in the form factor of a mobile station or hand-held device, which means a small practical difference between output power and EIRP for mobile devices. However, a considerable amount of antenna gain can be achieved in a mobile station or hand-held device that communicates in 39 GHz. It is therefore important to provide clear rules in both output power and EIRP limitations for millimeter-wave mobile stations. Our link budget analysis[14] for 39 GHz mobile networks shows that 30 dBm maximum output power and 43 dBm maximum peak EIRP for mobile stations are adequate for an acceptable level of communication at a cell edge with a 1-km cell radius, and are in line with the mobile station power limitations for Cellular

[14] *See* Appendix B.

Radiotelephone Service[15], Broadband PCS[16], WCS[17], AWS[18], the 700 MHz band[19], Wi-Fi[20], and the maximum peak EIRP limitations for 60 GHz[21] communications.

We particularly recommend this EIRP limit for mobile devices because this enables high data rate uplink operation in 5G mobile services, which is a key enabler for new business cases such as autonomous and remote-controlled transportation (self-driving cars, trucks, drones, etc.) that may become disruptive forces in other parts of the economy and that can generate tremendous economic benefits far beyond the information and communications technology ecosystem. We recognize that the MPE limit is 1 mW/cm^2 without time averaging for mobile and portable devices.[22] Nevertheless, the maximum limit for portable devise should be 43 dBm while recognizing that the MPE limit without time averaging may force the portable device to lower EIRP or reduce duty cycle of uplink transmission. The benefit of millimeter-wave will be severely – and unnecessarily – limited if the EIRP limit for 5G is set to the same level as other mobile services in lower frequencies. Since millimeter-wave transmissions are highly directional (~10x higher gain than other mobile services), forcing millimeter-wave transmissions to the same EIRP as other mobile services would mean ~10x lower transmission power than that available for other mobile services, while at the same time we expect 10 – 100x higher data rate and 1000x capacity improvement for 5G. Alternatively, if a nominally lower maximum EIRP limit is more appealing, provision for short time averaging (*e.g.*, 1 second) and/or spatial averaging can be considered to recognize the dynamic beamforming behavior of millimeter-wave 5G transmitters.

In summary, our recommendation on maximum transmit power and EIRP limit for 5G base stations and mobile stations is shown in the table below:

Table 1. Maximum Power and EIRP limits for the 39 GHz band

	Maximum Transmit Power (dBm)	Maximum EIRP (dBm)
Base Station	46	65
Mobile Station	30	43

These values are derived based on a 500-MHz system, which we believe is on the high end of the system bandwidth that an operator can practically acquire and deploy. If systems with even larger bandwidth are contemplated, the maximum power and EIRP values can be increased accordingly. For example, if a 1-

[15] In Section 22.913, the maximum ERP of mobile transmitters for the Cellular Radiotelephone Service is 7 watts (equivalent to 11.5 Watts or 40.6 dBm EIRP). *See* 47 C.F.R. § 22.913.

[16] In Section 24.232, the maximum EIRP of mobile stations for Broadband PCS is 2 watts. *See* 47 C.F.R. § 24.232.

[17] In Section 27.50(a), the maximum EIRP of mobile stations for the WCS A & B Blocks is 250 milliwatts per 5 megahertz. *See* 47 C.F.R. § 27.50(a).

[18] In Section 27.50(d), the maximum EIRP of mobile stations for AWS is 1 watt. *See* 47 C.F.R. § 27.50(d).

[19] In Sections 27.50(b) and 27.50(c), the maximum ERP of control and mobile stations is 30 watts (equivalent to 50 watts or 47 dBm EIRP), while the maximum ERP of portable stations (hand-held devices) is 3 watts (equivalent to 5 watts or 37 dBm EIRP). *See* 47 C.F.R. § 27.50(b), (c).

[20] In Section 15.247, for 2.4 GHz and 5 GHz unlicensed transmissions (*e.g.*, Wi-Fi 11 a/b/g/n), the maximum output power is 1 watt for antennas with directional gain less than 6 dBi. Section 15.247 (c)(2)(ii) allows in 2.4 GHz even higher EIRP with output power reduced by 1 dB for each 3 dB that the directional gain of the antenna/antenna array exceeds 6 dBi. *See* 47 C.F.R. § 15.247.

[21] In Section 15.255, for 60 GHz unlicensed transmissions (*e.g.*, Wi-Fi 11ad), the maximum average EIRP is 40 dBm with maximum peak EIRP of 43 dBm. *See* 47 C.F.R. § 15.255.

[22] *See* 47 C.F.R. § 2.1310.

GHz system is contemplated, the maximum transmit power and EIRP limit for a 5G base station as shown in Table *1* can be increased by 3 dB each. We do not recommend a further increase to the transmit power or EIRP limit for 5G mobile stations as those limits are sufficient for uplink operations.

Out-of-Band Emissions ("OOBE")

Most of the transmissions from 5G base stations will be highly directional, which serves as a natural way of avoiding interference. In addition, as the time slots in 5G will be on the order of 100 nanoseconds, there is ample time to recover even if a transmission fails due to unexpected interference. Furthermore, as traffic becomes more data-centric, it will be more delay tolerant than two-way voice traffic. In short, mobile broadband is becoming more capacity driven, with higher tolerance of delay than voice traffic, which requires end-to-end delay of around 100 milliseconds. The OOBE limits should be defined accordingly to maximize utilization of the radio resources. It is not necessary to make OOBE limits overly stringent. In fact, doing so may reduce the utilization of precious spectrum resources and make it difficult and expensive for device manufacturers to meet the spectrum mask.

The current OOBE criteria are outlined in Section 101.111.[23] More specifically, the spectrum mask is defined in Sections 101.111 (a)(2)(ii) and 101.111 (a)(2)(iii) as follows:

> (ii) For operating frequencies above 15 GHz, in any 1 MHz band, the center frequency of which is removed from the assigned frequency by more than 50 percent up to and including 250 percent of the authorized bandwidth: As specified by the following equation but in no event less than 11 decibels:
>
> A = 11 + 0.4(P−50) + 10 Log10 B. (Attenuation greater than 56 decibels or to an absolute power of less than −13 dBm/1MHz is not required.)
>
> (iii) In any 1 MHz band, the center frequency of which is removed from the assigned frequency by more than 250 percent of the authorized bandwidth: At least 43 + 10 Log10 (the mean output power in watts) decibels, or 80 decibels, whichever is the lesser attenuation. The authorized bandwidth includes the nominal radio frequency bandwidth of an individual transmitter/modulator in block-assigned bands. Equipment licensed prior to April 1, 2005 shall only be required to meet this standard in any 4 kHz band.[24]

In Sections 101.111 (a)(2)(iv) and 101.111 (a)(2)(v), the nominal bandwidth B used in calculating the spectral mask is defined for the Local Multipoint Distribution Service ("LMDS") (B = 40 MHz) and E-band (B = 500 MHz). This allows systems with different bandwidths to be subject to the same emission mask, ensuring fairness and consistent OOBE protection regardless of the system bandwidth. The 39 GHz licensees are already allowed to bond contiguous channels. This unified spectral mask for different system bandwidths will allow more flexible deployment of the system and better utilization of the spectrum. As such, the Commission should add the nominal bandwidth definition (*e.g.*, B = 50 MHz) for calculating the spectral mask for the 39 GHz band.

As an example, if a 5G base station can emit 60 dBm EIRP at the broadside across 200 megahertz system bandwidth, the PSD is 37 dBm / MHz. Thus, the emission limit will be:

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[23] *See* 47 C.F.R. § 101.111.

[24] *See id.* §§ 101.111(a)(2)(iv), (a)(2)(v).

$$A - 10\text{Log}10\text{B} = \begin{cases} 11 + 0.4(P - 50) \text{ dB}, & 50 \leq P < 147.5 \\ 50 \text{ dB}, & 147.5 \leq P < \infty \end{cases}$$

By defining the nominal bandwidth of B = 50 megahertz, $P = 50$ corresponds to 25 megahertz away from the center frequency of the edge 50 megahertz channel, *i.e.*, the edge of the authorized bandwidth, whereas $P = 147.5$ corresponds to 73.75 megahertz away from the center frequency of the edge 50 megahertz channel, *i.e.*, 48.75 megahertz from the edge of the authorized bandwidth. With the suggested definition of nominal bandwidth, the out-of-band emission mask is the same regardless of the actual authorized bandwidth, which could be a few hundred megahertz in a typical deployment of 5G.

If the Commission wishes to further address adjacent-channel interference at the channel boundary, the initial suppression value of 11 dB (at P = 50) can be increased. However, a larger suppression will mean more expensive filters and more guard band at the edge. In our view, any value between 10 dB and 30 dB should be reasonable, providing different tradeoffs between reducing adjacent-channel interference and maximizing spectrum utilization.

The spurious emission limit (emission limit for $P > 250$) as defined by Section 101.111 (a)(2)(iii) will mostly be governed by the "43 + 10 Log10 (the mean output power in watts) decibels" limit, which is equivalent to -13 dBm/MHz with typical configurations of 5G systems.[25] This limit is more than adequate for spurious emissions because of the reduced likelihood of interference in millimeter-wave 5G systems due to directional transmit and receive operations.

The OOBE should be defined in reference to the average EIRP across the whole authorized bandwidth. Because different beam steering vectors may be used in different frequencies within the authorized bandwidth, it makes sense to select the spatial direction with the strongest mean EIRP (averaged across frequency) as a reference while the OOBE limit should apply to any spatial direction. This will likely result in much lower overall spurious emission averaged among all spatial directions. For example, for a mobile station with 15 dB antenna gain along the main lobe, a -13 dBm/MHz spurious emission along the main lobe would result in a -28 dBm/MHz average spurious emission among all spatial directions, assuming beamforming only changes the power distribution along spatial directions, but not the envelop of the power spectral density of the signal.

The OOBE averaging bandwidth of 1 megahertz is adequate as the main purpose of this limit is to guard against out-of-band frequency spurs that may inadvertently hurt systems in adjacent bands.

Co-Channel Interference

Co-channel interference can be defined either in power flux density ("PFD") or field strength. The relationship between PFD and field strength is simply

$$S = \frac{E^2}{120\pi}$$

where S is the PFD and E is the electric field strength. The receiver antenna gain should be taken into account when setting the co-channel interference limit. The typical receiver antenna gain for a 5G mobile station is expected to be around 10 – 20 dB. Assuming a 5 dB noise figure at the mobile station receiver, the thermal noise at the base station receiver is -109 dBm/MHz. We assume the co-channel interference at the economic area boundary to be controlled is 10 dB below the thermal noise floor, which leads to the co-channel interference limit of -119 dBm/MHz after receiver beamforming gain. This level of co-

[25] *See id.* §§ 101.111(a)(2)(iii).

channel interference is only acceptable if the performance degradation caused by the co-channel interference quickly disappears as the receiver moves towards the interior of the economic area, which is generally the case for terrestrial services. Assuming 20 dB gain from a mobile station antenna, the co-channel interference limit at the economic area boundary should be -139 dBm/MHz, which can be related to the PFD and field strength as follows:

$$I = S \cdot \frac{\lambda^2}{4\pi} = \frac{E^2}{120\pi} \cdot \frac{\lambda^2}{4\pi}$$

where I is the co-channel interference received at an isotropic antenna. The PFD that can produce -139 dBm/MHz co-channel interference at 39 GHz is -86 dBm/m^2/MHz, which translates to electric field strength of 30 dBuV/m/MHz. For a 100-MHz channel, this corresponds to a 50 dBuV/m electric field strength.

In summary, we recommend a PFD limit of -86 dBm/m^2/MHz or, equivalently, an electric field strength limit of 30 dBuV/m/MHz as the co-channel interference limit at the economic area boundary for 39 GHz mobile services.

* * *

The text to accommodate the proposed 39 GHz mobile services is straightforward, as illustrated by the proposed changes in Appendix A. The proposed rules, shown as amendments to Part 101 can certainly be provisioned as changes to Part 27 or otherwise to best accommodate mobile use of the 39 GHz bands.

We look forward to working with all stakeholders to develop rules governing the 39 GHz band for mobile wireless operations. If there are any questions regarding the foregoing or the attached Appendices, please contact the undersigned directly.

Very truly yours,

/s/ Jerry Pi

Jerry Pi
Chief Technology Officer

Attachment

Appendix A – Proposed Rule Changes

The following are proposed changes to the Commission's rules. Deletions are show as ~~struck through~~ and additions are shown as highlighted. We do not recommend changes to text that do not appear below.

Section 1.1307

For the case of the Cellular Radiotelephone Service, subpart H of part 22 of this chapter; the Personal Communications Service, part 24 of this chapter; ~~and~~ the Specialized Mobile Radio Service, part 90 of this chapter;~~,~~ and the Millimeter-wave Mobile Broadband Service, part 101 of this chapter, the phrase *total power of all channels* in column 2 of table 1 means the sum of the ERP or EIRP of all co-located simultaneously operating transmitters owned and operated by a single licensee.

TABLE 1—TRANSMITTERS, FACILITIES AND OPERATIONS SUBJECT TO ROUTINE ENVIRONMENTAL EVALUATION

Service (title 47 CFR rule part)	Evaluation required if:
…	…
Local Multipoint Distribution Service (subpart L of part 101) and 24 GHz (subpart G of part 101)	Non-building-mounted antennas: height above ground level to lowest point of antenna <10 m and power >1640 W EIRP.
	Building-mounted antennas: power >1640 W EIRP.
	LMDS and 24 GHz Service licensees are required to attach a label to subscriber transceiver antennas that:
	(1) provides adequate notice regarding potential radiofrequency safety hazards, *e.g.*, information regarding the safe minimum separation distance required between users and transceiver antennas; and
	(2) references the applicable FCC-adopted limits for radiofrequency exposure specified in §1.1310.
Millimeter-wave Mobile Broadband Service (part 101)	Non-building-mounted antennas: height above ground level to lowest point of antenna <10 m and power >1640 W EIRP.
	Building-mounted antennas: power >1640 W EIRP.
70/80/90 GHz Bands (subpart Q of part 101)	Non-building-mounted antennas: height above ground level to lowest point of antenna <10 m and power >1640 W EIRP.
	Building-mounted antennas: power >1640 W EIRP.
	Licensees are required to attach a label to transceiver antennas that:
	(1) provides adequate notice regarding potential radiofrequency safety hazards, *e.g.*, information regarding the safe minimum separation distance required between users and transceiver antennas; and
	(2) references the applicable FCC-adopted limits for radiofrequency exposure specified in §1.1310.

(2)(i) Mobile and portable transmitting devices that operate in the Commercial Mobile Radio Services pursuant to part 20 of this chapter; the Cellular Radiotelephone Service pursuant to part 22 of this chapter; the Personal Communications Services (PCS) pursuant to part 24 of this chapter; the Satellite Communications Services pursuant

to part 25 of this chapter; the Miscellaneous Wireless Communications Services pursuant to part 27 of this chapter; the Maritime Services (ship earth stations only) pursuant to part 80 of this chapter; the Specialized Mobile Radio Service, the 4.9 GHz Band Service, or the 3650 MHz Wireless Broadband Service pursuant to part 90 of this chapter; ~~or~~ the Wireless Medical Telemetry Service (WMTS), or the Medical Device Radiocommunication Service (MedRadio) pursuant to part 95; or the Millimeter-wave Mobile Broadband Service pursuant to part 101 of this chapter are subject to routine environmental evaluation for RF exposure prior to equipment authorization or use, as specified in §§2.1091 and 2.1093 of this chapter.

Section 2.1091

(c)(1) Mobile devices that operate in the Commercial Mobile Radio Services pursuant to part 20 of this chapter; the Cellular Radiotelephone Service pursuant to part 22 of this chapter; the Personal Communications Services pursuant to part 24 of this chapter; the Satellite Communications Services pursuant to part 25 of this chapter; the Miscellaneous Wireless Communications Services pursuant to part 27 of this chapter; the Maritime Services (ship earth station devices only) pursuant to part 80 of this chapter; ~~and~~ the Specialized Mobile Radio Service, and the 3650 MHz Wireless Broadband Service pursuant to part 90 of this chapter; and the Millimeter-wave Mobile Broadband Services pursuant to part 101 of this chapter are subject to routine environmental evaluation for RF exposure prior to equipment authorization or use if:

Section 2.1093

(c)(1) Portable devices that operate in the Cellular Radiotelephone Service pursuant to part 22 of this chapter; the Personal Communications Service (PCS) pursuant to part 24 of this chapter; the Satellite Communications Services pursuant to part 25 of this chapter; the Miscellaneous Wireless Communications Services pursuant to part 27 of this chapter; the Maritime Services (ship earth station devices only) pursuant to part 80 of this chapter; the Specialized Mobile Radio Service, the 4.9 GHz Band Service, and the 3650 MHz Wireless Broadband Service pursuant to part 90 of this chapter; the Wireless Medical Telemetry Service (WMTS) and the Medical Device Radiocommunication Service (MedRadio), pursuant to subparts H and I of part 95 of this chapter, respectively~~,~~; the Millimeter-wave Mobile Broadband Services pursuant to part 101 of this chapter; and unlicensed personal communication service, unlicensed NII devices and millimeter wave devices authorized under §§15.253(f), 15.255(g), 15.257(g), 15.319(i), and 15.407(f) of this chapter are subject to routine environmental evaluation for RF exposure prior to equipment authorization or use.

Section 101.105 Interference protection criteria.

Section 101.105 (a):

(5) *38,400 – 40,000 MHz*. The predicted or measured median field strength at any location on the geographical border of a licensee's service area shall not exceed 30 dBuV/m per MHz unless the adjacent affected service area licensee(s) agree(s) to a different field strength.

(6) *71,000-76,000 MHz; 81,000-86,000 MHz.* In these bands the following interference criteria shall apply:

…

Section 101.111 Emission limitations

Section 101.111 (a)(2):

(iv) The emission mask for LMDS and the 24 GHz Service shall use the equation in paragraph (a)(2)(ii) of this section and apply it only to the band edge of each block of spectrum, but not to subchannels established by licensees. The value of P in the equation is the percentage removed from the carrier frequency and assumes that the carrier frequency is the center of the actual bandwidth used. The emission mask can be satisfied by locating a carrier

of the subchannel sufficiently far from the channel edges so that the emission levels of the mask are satisfied. The LMDS or 24 GHz emission mask shall use a value B (bandwidth) of 40 MHz, for all cases even in the case where a narrower subchannel is used (for instance the actual bandwidth is 10 MHz) and the mean output power used in the calculation is the sum of the output power of a fully populated channel. For block assigned channels, the out-of-band emission limits apply only outside the assigned band of operation and not within the band.

(v) The emission mask for the 38.6 - 40 GHz band used in the equation in paragraph (a)(2)(ii) of this section applies only to the edge of each channel, but not to sub-channels established by licensees. The value of P in the equation is for the percentage removed from the carrier frequency and assumes that the carrier frequency is the center of the actual bandwidth used. The value of B will always be 50 MHz. In the case where a narrower sub-channel is used within the assigned bandwidth, such sub-carrier will be located sufficiently far from the channel edges to satisfy the emission levels of the mask. The mean output power used in the calculation is the sum of the output power of a fully populated channel.

(vi) The emission mask for the 71-76 GHz, 81-86 GHz, 92-94 GHz, and 94.1-95 GHz bands used in the equation in paragraph (a)(2)(ii) of this section applies only to the edge of each channel, but not to sub-channels established by licensees. The value of P in the equation is for the percentage removed from the carrier frequency and assumes that the carrier frequency is the center of the actual bandwidth used. The value of B will always be 500 MHz. In the case where a narrower sub-channel is used within the assigned bandwidth, such sub-carrier will be located sufficiently far from the channel edges to satisfy the emission levels of the mask. The mean output power used in the calculation is the sum of the output power of a fully populated channel.

Section 101.113 Transmit power limitations

Section 101.113(a):

On any authorized frequency, the average power delivered to an antenna in this service must be the minimum amount of power necessary to carry out the communications desired." "In no event shall the average equivalent isotropically radiated power (EIRP), as referenced to an isotropic radiator, exceed the values specified below." "Further, the output power of a transmitter on any authorized frequency in this service may not exceed the following:

Frequency band (MHz)	Maximum allowable EIRP	
	Fixed (dBW)	Mobile (dBW)
…	…	…
38,600 – 40,000	+55 +35[x]	13[x]
…	…	…

[x] For 39 GHz mobile services, the maximum allowable output power of base transmitters is 16 dBW with maximum allowable EIRP being 35 dBW; the maximum allowable output power of mobile transmitters is 0 dBW with maximum allowable EIRP being 13 dBW.

Section 101.115 Directional antennas

Section 101.115(b):

Fixed stations (other than temporary fixed stations and DEMS nodal stations) operating at 932.5 MHz or higher must employ transmitting and receiving antennas (excluding second receiving antennas for operations such as space diversity) meeting the appropriate performance Standard A indicated below, except that in areas not subject to frequency congestion, antennas meeting performance Standard B may be used, subject to the requirements set forth in paragraph (d) of this section." "Licensees shall comply with the antenna standards table shown in this paragraph in the following manner:

ANTENNA STANDARDS

Frequency (MHz)	Category	Maximum beamwidth to 3 dB points[1] (included angle in degrees)	Minimum antenna gain (dbi)	Minimum radiation suppression to angle in degrees from centerline of main beam in decibels						
				5° to 10°	10° to 15°	15° to 20°	20° to 30°	30° to 100°	100° to 140°	140° to 180°
…	…	…	…	…	…	…	…	…	…	…
38,600 to 40,000[14]	A	n/a	38	25	29	33	36	42	55	55
	B	n/a	38	20	24	28	32	35	36	36
…	…	…	…	…	…	…	…	…	…	…

[1]If a licensee chooses to show compliance using maximum beamwidth to 3 dB points, the beamwidth limit shall apply in both the azimuth and the elevation planes.

[14]Stations authorized to operate in the 38,600-40,000 MHz band that only provide fixed services may use antennas other than those meeting the Category A standard. However, the Commission may require the use of higher performance antennas where interference problems can be resolved by the use of such antennas. Stations authorized to operate in the 38,600-40,000 MHz band that provide Millimeter-wave Mobile Broadband Services may use any antenna pattern as long as the stations meet other technical rules including transmit power limits, OOBE limits, and co-channel interference limits.

Section 101.117 Antenna Polarization

Except as set forth herein, stations operating in the radio services included in this part are not limited as to the type of polarization of the radiated signal that may be employed. However, in the event interference in excess of permissible levels is caused to the operation of other stations as a result of employing other than linear polarization, the Commission may order a licensee to change its system polarization to mitigate the interference. No change in polarization may be made without prior authorization from the Commission. Unless otherwise allowed, only linear polarization (horizontal and vertical) shall be used. For LMDS systems, unless otherwise authorized, system operators are permitted to use any polarization within its service area, but only vertical and/or horizontal polarization for antennas located within 20 kilometers of the outermost edge of their service area. For systems operating in the 38,600-40,000 MHz band, unless otherwise authorized, system operators are permitted to use any polarization within its service area.

Section 101.129 Transmitter location

Section 101.129(a):

For fixed stations, the applicant must determine, prior to filing an application for a radio station authorization, that the antenna site specified therein is adequate to render the service proposed. In cases of questionable antenna locations, it is desirable to conduct propagation tests to indicate the field intensity which may be expected in the principal areas or at the fixed points of communication to be served, particularly where severe shadow problems may be expected. In considering applications proposing the use of such locations, the Commission may require site survey tests to be made pursuant to an experimental license under part 5 of this chapter. In such cases, propagation tests should be conducted in accordance with recognized engineering methods and should be made with a transmitting antenna simulating, as near as possible, the proposed antenna installation. Full data obtained from such surveys and its analysis, including a description of the methods used and the name, address and qualifications of the engineer making the survey, must be supplied to the Commission.

Section 101.131 Transmitter construction and installation

Section 101.131(a):

The equipment of fixed stations at the operating and transmitting positions must be so installed and protected that it is not accessible to, or capable of being operated by, persons other than those duly authorized by the licensee.

Section 101.147 Frequency assignments

Section 101.147(a):

Frequencies in the following bands are available for assignment for fixed and mobile microwave services.

Section 101.147(v)

"(v)(1) Assignments in the band 38,600-40,000 MHz must be according to the following frequency plan:

Channel Group A		Channel Group B	
Channel No.	**Frequency band limits (MHz)**	**Channel No.**	**Frequency band limits (MHz)**
1-A	38,600-38,650	1-B	39,300-39,350
2-A	38,650-38,700	2-B	39,350-39,400
3-A	38,700-38,750	3-B	39,400-39,450
4-A	38,750-38,800	4-B	39,450-39,500
5-A	38,800-38,850	5-B	39,500-39,550
6-A	38,850-38,900	6-B	39,550-39,600
7-A	38,900-38,950	7-B	39,600-39,650
8-A	38,950-39,000	8-B	39,650-39,700
9-A	39,000-39,050	9-B	39,700-39,750
10-A	39,050-39,100	10-B	39,750-39,800
11-A	39,100-39,150	11-B	39,800-39,850
12-A	39,150-39,200	12-B	39,850-39,900
13-A	39,200-39,250	13-B	39,900-39,950
14-A	39,250-39,300	14-B	39,950-40,000

(v)(2) Channels Blocks 1 through 14 are assigned for use within Economic Areas (EAs). Both paired and unpaired uses are allowed. Applicants are to apprise themselves of any licensed rectangular service areas within the EA for which they seek a license and comply with the requirements set forth in §101.103. All of the channel blocks may be subdivided as desired by the licensee and used within its service area as desired without further authorization subject to the terms and conditions set forth in §101.149.

Section **101.149 Special requirements for operation in the band 38,600-40,000 MHz**

Assigned frequency channels in the band 38,600-40,000 MHz may be subdivided and used anywhere in the authorized service area, subject to the following terms and conditions:

(a) No interference may be caused to a previously existing station operating in another authorized service area;

(b) Each operating fixed station must have posted a copy of the service area authorization;

Appendix B – Examples of 39 GHz mobile network link budget

39 GHz mobile network link budget	Downlink cell edge	Uplink cell edge	Downlink cell center	Uplink cell center
PA output power (dBm)	20	18	20	18
Number of PAs	64	16	64	16
Total output power (dBm)	**38**	**30**	**38**	**30**
Number of Tx antenna element	256	16	256	16
Tx antenna element gain (dB)	6	6	6	6
Antenna & feed network loss (dB)	3	5	3	5
Total Tx antenna array gain (dB)	**27**	**13**	**27**	**13**
EIRP (dBm)	**65.14**	**43.08**	**65.14**	**43.08**
Distance (m)	1000.00	1000.00	100.00	100.00
Path loss = 72 + 29.2log10(d) (dB)[26]	**159.60**	**159.60**	**130.40**	**130.40**
Received power (dBm)	-94.46	-116.52	-65.26	-87.32
Bandwidth (MHz)	500.00	500.00	500.00	500.00
Thermal noise (dBm)	-87.01	-87.01	-87.01	-87.01
Noise Figure (dB)	5.00	5.00	5.00	5.00
SNR (dB) per Rx antenna element	-12.45	-34.51	16.75	-5.31
Number of Rx antenna element	16	256	16	256
Rx antenna element gain (dB)	6	6	6	6
Rx antenna feed network loss (dB)	5	3	5	3
Total Rx antenna array gain (dB)	**13**	**27**	**13**	**27**
SNR after beamforming (dB)	**0.60**	**-7.42**	**29.80**	**21.78**
Implementation loss (dB)	3.00	3.00	3.00	3.00
Number of MIMO streams	1	1	8	8
Spectral efficiency (bit/channel use)	0.66	0.13	47.40	27.06
System overhead	40%	40%	40%	40%
Duty cycle	62.50%	37.50%	62.50%	37.50%
Throughput throughput (Mbps)	**122.86**	**14.09**	**8887.91**	**3044.15**

[26] Akdeniz, M.R.; Yuanpeng Liu; Samimi, M.K.; Shu Sun; Rangan, S.; Rappaport, T.S.; Erkip, E., "Millimeter Wave Channel Modeling and Cellular Capacity Evaluation," *Selected Areas in Communications, IEEE Journal on* , vol.32, no.6, pp.1164,1179, June 2014.