Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Use of Spectrum Bands Above 24 GHz for Mobile Radio Services	)	GN Docket No. 14-177
	)	
Establishing a More Flexible Framework to Facilitate Satellite Operations in the 27.5-28.35 GHz and 37.5-40 GHz Bands	)	IB Docket No. 15-256
	)	
Petition for Rulemaking of the Fixed Wireless Communications Coalition to Create Service Rules for the 42-43.5 GHz Band	)	RM-11664
	)	
Amendment of Parts 1, 22, 24, 27, 74, 80, 90, 95, and 101 To Establish Uniform License Renewal, Discontinuance of Operation, and Geographic Partitioning and Spectrum Disaggregation Rules and Policies for Certain Wireless Radio Services	)	WT Docket No. 10-112
	)	
Allocation and Designation of Spectrum for Fixed-Satellite Services in the 37.5-38.5 GHz, 40.5-41.5 GHz and 48.2-50.2 GHz Frequency Bands; Allocation of Spectrum to Upgrade Fixed and Mobile Allocations in the 40.5-42.5 GHz Frequency Band; Allocation of Spectrum in the 46.9-47.0 GHz Frequency Band for Wireless Services; and Allocation of Spectrum in the 37.0-38.0 GHz and 40.0-40.5 GHz for Government Operations	)	IB Docket No. 97-95

<u>COMMENTS OF MVDDS 5G COALITION</u>

September 30, 2016

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EXECUTIVE SUMMARY

Thanks to the Commission's efforts, several bands of valuable, underused spectrum will become available to support the development and deployment of Fifth Generation ("5G") mobile broadband technologies. But more work remains to be done.

The need for additional mobile broadband spectrum is skyrocketing. Mobile data traffic has grown 4,000-fold over the past 10 years—almost 400-million-fold since 2000—and is projected to grow another six-fold by the end of the decade. The Internet of Things will drive a growing share of the increase in demand as billions of new devices seek access to network resources. And new high-throughput, low-latency services promise to tax network resources as never before. To meet the growing and diverse demands on mobile broadband networks, the Commission unanimously agreed to allocate additional spectrum to support 5G mobile services.

Additional bands beyond those already identified by the Commission can readily support 5G. Several bands in the 6-24 GHz range—the so-called centimeter wave bands—are as well suited as, and in some respects better suited than, the bands under consideration by the Commission for use for 5G. The 12 GHz band is an ideal band for the provision of 5G. First, the propagation characteristics of the 12 GHz band will permit operators to establish service coverage over a wide area with a more limited capital investment and with fewer recurring expenses than possible on higher-frequency spectrum. Second, the relative ease of equipment production for the 12 GHz band allows for significant cost savings at every step in the deployment of 5G relative to higher-frequency bands. Manufacturers not only can readily update existing designs and production lines to produce 12 GHz equipment at scale, but also can use advances in 12 GHz production to catalyze the technological innovation that must occur before

the widespread production of higher-frequency 5G equipment can occur. Third, the 12 GHz band meets all four of the Commission's criteria for 5G spectrum.

Updating the spectrum-sharing and interference-mitigation framework to account for technical and marketplace developments that have occurred in the fifteen years since the Commission first authorized terrestrial services in the 12 GHz band would promote the rapid and widespread deployment of 5G services. Performance requirements that take into account the specific characteristics of the 12 GHz band, including the degree of incumbency for existing uses, would ensure fairness and flexibility in the deployment of new services on the band. And retaining the existing geographic area licenses would best support the deployment of 5G services in the 12 GHz band.

By acting now to ensure the 12 GHz band can support 5G broadband deployments, the Commission can stimulate the market for ground-breaking 5G services and advance the technical, operational and marketplace innovations that the industry will need to deploy 5G services above 24 GHz.

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COMMENTS OF THE MVDDS 5G COALITION

I. INTRODUCTION AND SUMMARY

The MVDDS 5G Coalition submits these comments in response to the Federal Communications Commission's ("FCC's" or "Commission's") *Further Notice of Proposed Rulemaking* exploring "new opportunities to make additional bands available" for 5G.[1] The rapid development and imminent deployment of 5G technologies are driving demand for more spectrum suitable for mobile broadband. The Commission has already identified a number of potential bands for the deployment of 5G,[2] but will need to continue to identify additional spectrum to meet market demand and to ensure consumers realize the high throughput, low latency and other benefits possible from 5G.[3] Bands in the 6-24 GHz range have propagation

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[1] *Use of Spectrum Bands Above 24 GHz For Mobile Radio Service, et al.*, Report and Order and Further Notice of Proposed Rulemaking, 31 FCC Rcd 8014 ¶ 1 (July 14, 2016) ("*Spectrum Frontiers FNPRM*").

[2] *See generally id*.

[3] *See Use of Spectrum Bands Above 24 GHz for Mobile Radio Services, et al.*, Notice of Proposed Rulemaking, 30 FCC Rcd. 11878, 12007 (2015) ("*Spectrum Frontiers NPRM*") (Statement of Chairman Tom Wheeler) (to "capitalize on the 5G opportunity" the Commission will have to "leverage [its] flexible use spectrum policies" and "make low-band, mid-band, [and] high-band … spectrum available for wireless broadband.").

characteristics and other features that make them well suited for rapid deployment of mobile broadband. Consideration of these centimeter wave bands for 5G use would diversify and expand the spectrum available for next-generation services in the United States and accelerate the deployment of 5G service to the American public.

The projected increase in traffic demand for mobile services over the next decade[4] as well as the advanced capabilities envisioned for 5G will require substantial additional spectrum beyond the bands the Commission has already identified.[5] Consideration of additional spectrum bands to support the provision of 5G will help fulfill President Obama's and the Commission's mission to make more spectrum available for broadband use by 2020.[6] In the *Spectrum Frontiers FNPRM*, the Commission acknowledged that the time is ripe for considering additional bands for mobile use for the deployment of 5G in preparation for the anticipated surge in demand.[7]

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[4] Naga Bhushan, *et al*., *Network Densification: The Dominant Theme for Wireless Evolution into 5G*, IEEE Communications Magazine, at 82, 88 (Feb. 19, 2014) (projecting a 1,000-fold increase in mobile traffic demand); *see also* 5G Americas, *Mobile Broadband Transformation LTE to 5G*, at 9 (Aug. 2016) ("*5G Americas*") (projecting services supporting the Internet of Things will contribute to demand by a factor of ten or a hundred).

[5] *See Spectrum Frontiers NPRM* ¶ 8 (citing John Thompson *et al., 5G Wireless Communications Systems: Prospects and Challenges*, IEEE Communications Magazine, at 62 (Feb. 2014) ("*5G Wireless*") and Rakesh Taori, Samsung Research America, *On Feasibility of mmWave Bands for 5G Cellular Access*, slide presentation to Telecommunications Industry Assn. Workshop, *Beyond 2020: A Vision of 5G Networks* (Nov. 21, 2013)). While use cases continue to take shape, engineers envision high-bandwidth content delivered at 10 gigabit speeds; transmission delays as low as one-thousandth of a second; and transmissions among a multitude of devices in an Internet of Things. *Id.*

[6] Presidential Memorandum, Unleashing the Wireless Broadband Revolution, 75 Fed. Reg. 38387 (July 1, 2010).

[7] *Spectrum Frontiers FNPRM* ¶ 372; *see also id*. ¶ 1 ("[W]e will also continue to explore new opportunities to make additional bands available").

In the *Spectrum Frontiers FNPRM*, the Commission examined seven additional bands that the 2015 World Radio Conference ("WRC") identified for international mobile telecommunication ("IMT") 2020 services.[8] The Commission has explained that it "may consider additional bands in the future" and added that the omission of some bands from initial identification for 5G use "does not foreclose future Commission action on the band or bands."[9]

Spectrum bands in the 6-24 GHz range are as well suited as, and in many respects better suited than, the bands under consideration by the Commission for use for 5G.[10] The 12.2-12.7 GHz band (the "12 GHz band") has technical, economic, and regulatory characteristics that allow for more rapid, robust, and cost-effective deployment of 5G than will be possible in those bands already identified. The identification and use of this additional spectrum band for 5G will accelerate the deployment of next-generation broadband services in the United States.

II. 12 GHZ IS AN IDEAL BAND FOR 5G.

The 12 GHz band offers a promising foundation for 5G mobile broadband service. The 12 GHz band has allocations for fixed satellite communications, space-to-Earth or direct-broadcast satellite ("DBS") service on a primary basis;[11] multichannel video distribution and data service ("MVDDS"), which is limited under the rules to one-way digital fixed non-broadcast

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[8] *Id*. ¶ 373.

[9] *Spectrum Frontiers NPRM* ¶ 20. The Commission repeated its intention to consider additional bands in the future when it sought comment on whether it should apply the same small business and bidding credit framework it adopted in this proceeding to "any other spectrum bands that we may subsequently decide to include." *Spectrum Frontiers FNPRM* ¶ 376.

[10] Commissioner Michael O'Rielly has called for the use of this spectrum for 5G. He has said to reach the full potential of 5G the Commission will need to "target additional bandwidth between 6 and 24 GHz." *See Spectrum Frontiers NPRM* at 12014 (statement of Commissioner Michael O'Rielly).

[11] *See* 47 C.F.R. § 2.106 n.5.487A.

service;[12] and non-geostationary-satellite orbit systems in the fixed-satellite service ("NGSO FSS").[13] DBS has proven successful, but NGSO FSS and MVDDS have not. One NGSO FSS applicant has sought access to the band,[14] but the scope of the applicant's service in the band as well as the feasibility of its business model remain in doubt. As for MVDDS, the Commission imposed "very conservative" technical requirements for MVDDS licensees to protect other co-primary services when it established the service nearly fifteen years ago.[15] The requirements include prohibitions on using the spectrum for two-way communications, stringent power limitations, and extensive coordination procedures. These prohibitions currently preclude use of the band for mobile data services.

Since the FCC adopted service rules for the 12 GHz band in 2003, demand for mobile broadband services and the concomitant need for broadband spectrum has exploded. A coalition of MVDDS licensees has relied on more sophisticated interference-mitigation analyses than were available in 2003 to demonstrate how the Commission could relax some of the technical

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[12] *Amendment of Parts 2 and 25 of the Commission's Rules to Permit Operation of NGSO FSS Systems Co-Frequency with GSO and Terrestrial Systems in the Ku-Band Frequency Range; Amendment of the Commission's Rules to Authorize Subsidiary Terrestrial Use of the 12.2-12.7 GHz Band by Direct Broadcast Satellite Licensees and Their Affiliates; and Applications of Broadwave USA, PDC Broadband Corporation, and Satellite Receivers, Ltd. to Provide a Fixed Service in the 12.2-12.7 GHz Band*, Memorandum Opinion and Order and Second Report and Order, 17 FCC Rcd 9614 at 9802 (2002) (Joint Statement of Chairman Michael Powell and Commissioner Kathleen Q. Abernathy).

[13] *See* 47 C.F.R. 2.106.

[14] *See* WorldVu Satellites Limited, Petition for a Declaratory Ruling Granting Access to the U.S. Market for the OneWeb System, IBFS File No. SAT-LOI-20160428-00041 (filed Apr. 28, 2016).

[15] *Amendment of Parts 2 and 25 of the Commission's Rules to Permit Operation of NGSO FSS Systems Co-Frequency with GSO and Terrestrial Systems in the Ku-Band with Frequency Range*, Memorandum Opinion and Order and Second Report and Order, 17 FCC Rcd 9614 ¶ 43 (2002).

constraints on 12 GHz operations while protecting DBS operations against harmful interference.[16] The evolution of technology, including the use and deployment of small cells, has also changed the interference analysis framework. While the petition for rulemaking remains pending before the Commission, addressing that petition in the context of this proceeding would not only provide a consolidated platform for consideration of similar issues, but also offers the opportunity to accelerate the deployment of 5G service.

Spectrum development has occurred in stages because the commercial production of lower-frequency radio equipment is, for a variety of historical and technical reasons, easier to manufacture at scale than higher-frequency equipment. The evolution of mobile-phone technology from the cellular frequencies at 800 MHz into the PCS bands provides a case in point. Production of the briefcase-sized car phones of the early 1990s were a far cry from today's pocket-sized smartphones, but the development work that occurred in the 800 MHz and 850 MHz bands laid the foundation for progressively improved designs, features and functions capable of operating at new and progressively higher frequencies, such as the PCS band at 1.9 GHz and the AWS band at 2.1 GHz. Operators also preferred the lower-frequency spectrum because the extensive propagation characteristics of these bands allowed for wide-area coverage without having to incur extensive capital and operating expenses during the initial stages of deployment when usage was low.

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[16] *See* Petition of MVDDS 5G Coalition for Rulemaking, RM-11768 (filed Apr. 26, 2016), http://bit.ly/2ccx1rf ("*MVDDS Coalition Petition*").

At present, the lowest frequency band proposed for 5G deployment in the *Spectrum Frontiers FNPRM* is in the 24 GHz range.[17] But these frequencies are at least twice as high as those in the 12 GHz band and possess none of the existing design, equipment and manufacturing base for production that the widespread deployment of DBS equipment has already generated in the 12 GHz band.[18]

The identification of 12 GHz frequencies for 5G will allow manufacturers an early opportunity to commercialize 5G services as they continue to refine the products and production techniques necessary for cost-effective and efficient deployment in the higher frequency bands. Likewise, the comparatively favorable propagation characteristics of the centimeter wave bands to the millimeter wave bands will reduce risk and initial deployment expenses and complement higher band deployments for wireless operators.

A. Developing Centimeter-Wave Band Spectrum Promises to Accelerate the Deployment of Millimeter Wave Spectrum for 5G.

Removing unnecessary constraints on 5G deployment from the 12 GHz band will allow for rapid deployment of 5G services to the public and has the potential to serve as a catalyst for more rapid commercialization and deployment of the frequency bands already adopted or under consideration for 5G use. Broadband spectrum allocations throughout the world are concentrated at lower frequencies because lower-band spectrum travels farther and penetrates

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[17] *Spectrum Frontiers FNPRM* ¶ 385.

[18] *See, e.g.,* Uwe Ruddenklau, *mmWave Semiconductor Industry Technologies: Status and Evolution*, ETSI, at 10-11 (July 2016) ("*ETSI Paper*"); *see also generally Spectrum Frontiers FNPRM* (discussing a lack of use of the millimeter wave spectrum proposed for 5G prior to this proceeding, which implies that there is little existing equipment in the band).

obstacles more readily than higher band spectrum.[19] The more favorable propagation characteristics of lower-band spectrum permit operators to establish a layer of service over a relatively wide area for a more limited capital investment and with fewer recurring expenses than possible using higher band spectrum. Operators generally prefer to deploy on lower-band spectrum at the outset of a new service because doing so allows for better network investment choices: operators establish coverage first to ensure a seamless experience for end users.[20] While the capacity of this initial deployment may be limited, the wide-area system will function well because initial traffic on the network is relatively sparse, too.[21] Once demand increases, operators then expend additional capital resources on higher-frequency deployments to supplement their existing network capacity.[22]

The Commission has long recognized the economic benefits of this coverage-first model of network deployment for 2G, 3G and 4G services.[23] The 5G candidate spectrum will operate in the same way. While the frequencies available for 5G are higher and the coverage of any individual cell smaller than current-generation services, enabling the deployment of a high capacity "coverage layer" of 5G services at relatively low frequencies will allow network operators to establish a market for data services more rapidly and in a less risky and capital-intensive manner than possible through higher band deployments. Deployment on 12 GHz

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[19] Boyd Bangerter, Shilpa Talwar, Reza Arefi, and Ken Stewart, *Networks and Devices for the 5G Era*, IEEE Communications Magazine, at 95 (Feb. 2014), http://bit.ly/2d44OjY.

[20] *See, e.g.*, *Policies Regarding Mobile Spectrum Holdings*, Report and Order, 29 FCC Rcd 6133 ¶ 59 (2014).

[21] *See id*.

[22] *Id*. ¶ 61.

[23] *See, e.g.*, *id*.

spectrum will require lower capital investment than deployment on higher frequencies, yet provide consumers with a true 5G experience. The 12 GHz spectrum band experiences less path loss than higher-frequency bands, passes through rain and foliage with less loss, and is less susceptible to the signal attenuation caused in higher frequencies by atmospheric conditions.

Based on free space loss, spectrum bands at 28 GHz and above (the "millimeter wave" or "mmW" bands) have at least a 7 dB basic loss penalty compared to 12 GHz.[24] Using path loss models specified by 3GPP for frequencies greater than 6 GHz also demonstrates a great propagation advantage for 12 GHz over higher frequencies. For example, the Line Of Sight Urban Micro model for an Indoor Hotspot in a shopping mall shows the 12 GHz band has 5.7 dB lower path loss than the 24 GHz band, and a 10.5 dB lower path loss than the 42 GHz band, as illustrated by the following chart:[25]

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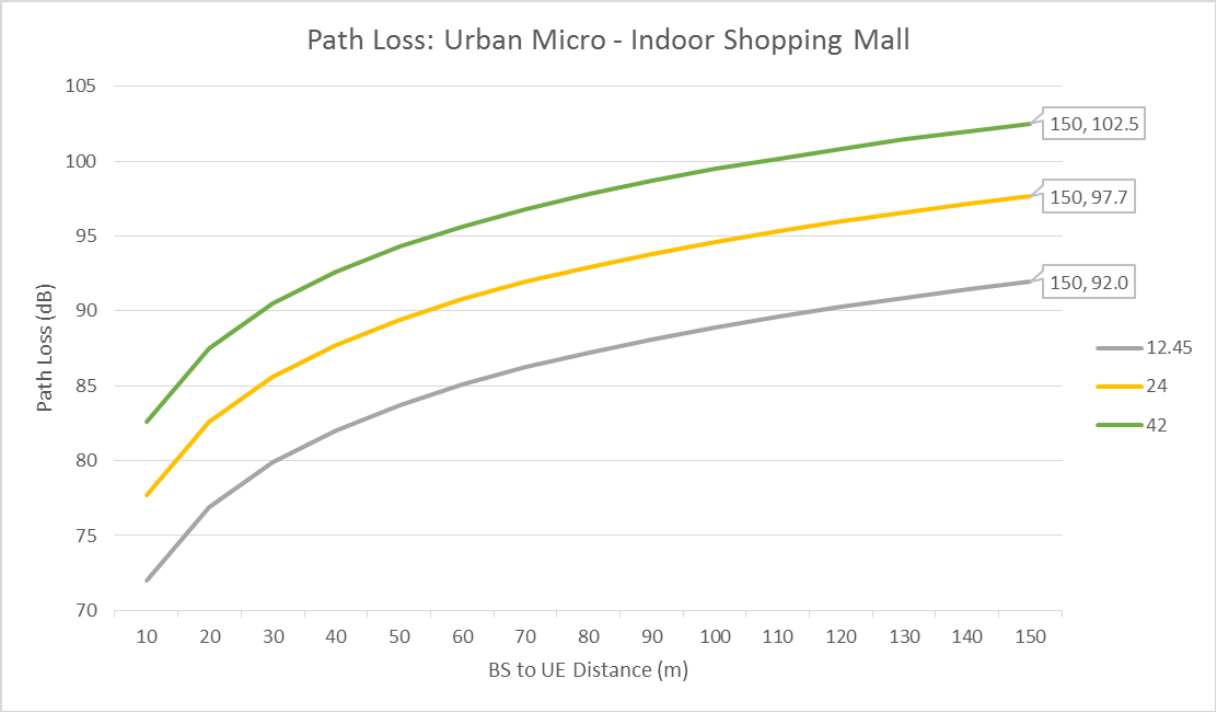
[24] *Millimeter Wave Propagation: Spectrum Management Implications*, Bulletin No. 70 (OET July 1997), *available at* http://bit.ly/2cCysPu ("*mmW Bulletin*").

[25] *See* 3GPP TR 38.900 V14.0.0 (2016-06), Table 7.4.1-1: Path loss models showing the "InH – Shopping mall LOS model as $PL = 32.4 + 17.3\log_{10}(d_{3D}) + 20\log_{10}(f_c)$.



1. Only a line-of-sight model is defined for this Urban Micro – Indoor Shopping Mall scenario in TS 38.900
2. Model defined for base station to user-equipment distance of up to 150 meters

These higher frequency bands also experience approximately 3 dB/km of additional path loss with just moderately heavy rain of 25 mm/hour.[26] Losses due to foliage are also lower at 12 GHz than at higher frequencies because foliage losses are proportional to frequency raised to the 0.3 power.[27] For example, a 12 GHz signal passing 10 meters through a large tree (or two trees

[26] *See mmW Bulletin at 13, Figure 10*, showing rain fade for a 25 mm/hr rain rate of about 1 dB/km for 12 GHz and about 4 dB/km for 28 GHz. *See also* *http://scool.larc.nasa.gov/lesson_plans/RainfallRatesWaterVolume.pdf* defining "heavy" rain as 10-40 mm/hr. Thus, 25 mm/hr can be accurately characterized as "moderately heavy."

[27] *See id.* at 14 (showing that signal loss due to traversing foliage less than 400 meters can be modeled as $L = 0.2 * f^{0.3} * R^{0.6}$ where f is in MHz and R is in meters).

in tandem) would experience 13.5 dB of foliage loss, whereas a 28 GHz signal passing through the same tree(s) would experience 17.2 dB of loss.[28]

While the millimeter wave bands also have a limited range and are expected to be deployed in small cells with low base station antenna heights and ranges on the order of a few hundred meters to provide 5G service, the propagation advantages of 12 GHz will result in meaningful efficiencies for network operators. For example, using 3GPP's Urban Micro Line-of-Sight ("LOS") Street Canyon model,[29] a Maximum Allowed Path Loss ("MAPL") of 111 dB, and base station height of 10 meters, the calculated ranges for 12 GHz, 24 GHz and 42 GHz are 500 meters, 270 meters, and 160 meters, respectively. These coverage differentials are shown in the following chart:

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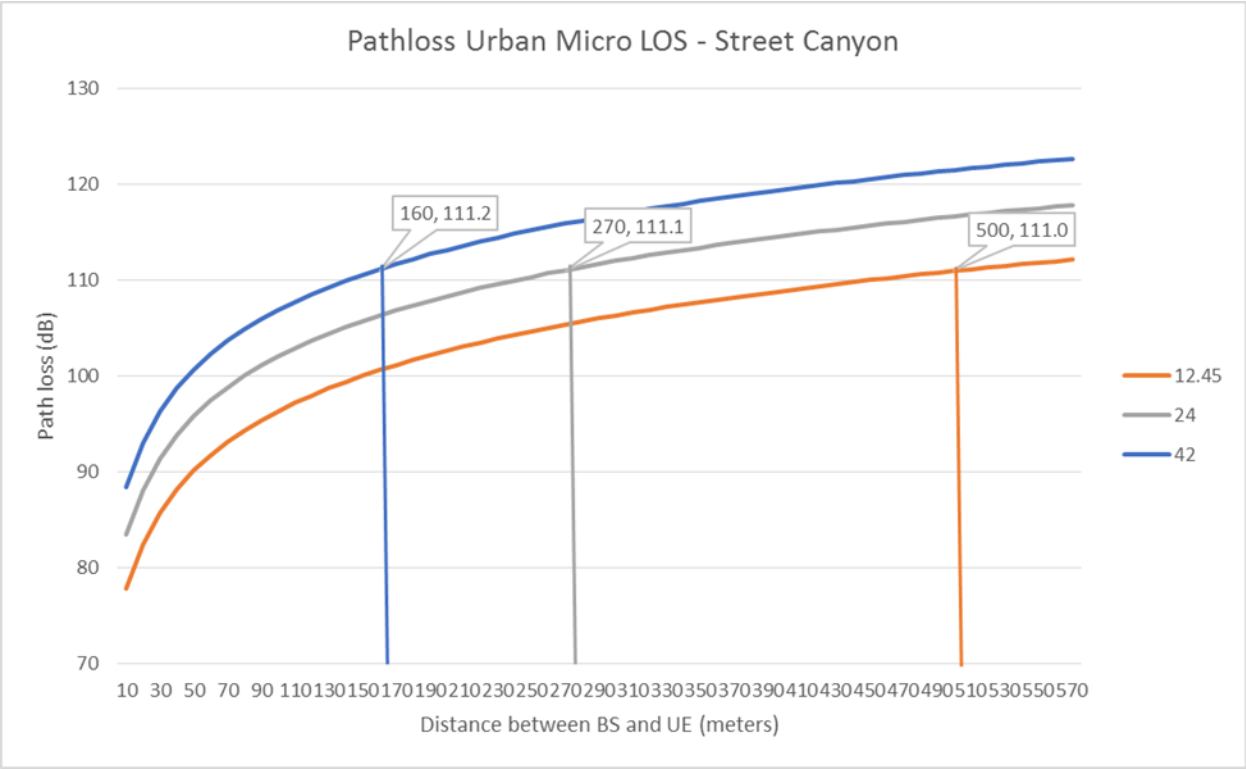
[28] At these higher frequencies, atmospheric gases including water vapor, oxygen and other gaseous atmospheric molecules cause signal attenuation that can also degrade system performance. *Id.* at 2. These losses, however, would be relatively minor over the distances expected for 5G. Due to the mechanical resonant frequencies of specific atmospheric molecules, peaks in the absorption loss curve occur at 24 GHz and 60 GHz, while the loss per kilometer for 12 GHz spectrum is lower than all higher frequencies. *Id.* at 6, Figure 4.

[29] To be consistent with MVDDS Coalition's previous analyses, a LOS model for coverage comparison was used. In a dense urban, small-cell setting, however, some coverage would likely be provided on a non-LOS basis.



Thus, in an urban canyon environment in which an operator wants to cover 10 kilometers of streets, a 12 GHz deployment would require 10 sites; a 24 GHz deployment would require 19 sites; and a 42 GHz deployment would require 32 sites. The lower site count possible through the use of lower frequency bands implies a more efficient and less expensive 5G deployment. In this way, identification of the 12 GHz band for 5G can provide an important first step toward further developing and refining the market and use cases for next-generation broadband services.

Deployment in the 12 GHz band will also be less complex to implement than in the higher frequency bands. As Ericsson has noted, the technology already used in bands below 6 GHz can be adapted to frequency ranges above 10 GHz, "with lower degrees of difficulty

towards the lower end of the range."[30] Adaptive antenna arrays and beamforming, for example, do not need to be nearly as robust at 12 GHz as at 24 GHz or above to provide the same service coverage and capacity.[31] According to Ericsson, for systems using bands above 24 GHz, high directivity for the systems "will have to be achieved by [antenna] arrays of many elements."[32] Incorporating multiple elements into next-generation broadband equipment, as Ericsson has explained, is "by no means a trivial task" and the considerable work necessary to produce the equipment capable of supporting these functions is still in the research and development phase.[33] For this reason, Ericsson has said that, other things being equal, 5G research and development should focus first on below-6-GHz spectrum, followed by spectrum between 10 and 30 GHz, and only then on spectrum above 30 GHz.[34] Ericsson therefore advised the Commission to "focus on spectrum above 10 GHz (rather than above 24 GHz) as today's evolving technology can more easily transition to those frequencies."[35] The relatively low-frequency 12 GHz band offers an ideal platform for 5G development, investment and growth.

B. The 12 GHz Band Offers Significant Production Cost Savings Compared to Higher Frequency Bands.

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[30] Comments of Ericsson Inc., GN Docket No. 14-177, at 13 (filed Jan. 15, 2015), http://bit.ly/2bRrUJk ("*Ericsson Comments*"); *see also, e.g.*, White Paper, *Ten key rules of 5G deployment*, Nokia 9 (2016), http://bit.ly/2cD7Z3X; White Paper, *Deployment Strategies for Heterogeneous Networks*, Nokia 6 (2015), http://bit.ly/2cjRuJI ("The lower spectrum is ideal for macro coverage in both rural and urban areas, while the upper frequencies can be used as dedicated small cell spectrum or even as a macro deployment in dense urban areas.").

[31] *See, e.g., Ericsson Comments* at 16-17.

[32] *Id*. at 17.

[33] *Id*. at 17.

[34] *See id*. at 11.

[35] *Id*. at 1.

Cost savings will arise at nearly every link in the production chain when the 12 GHz band is used for 5G. The efficiencies include: lower costs of equipment components, reduced production costs, and numerous operational efficiencies through reduced site-acquisition count, consolidated backhaul, and streamlined base operations. These factors will combine to expedite the timeline for the launch of 5G technologies, which will spur deployment in the 12 GHz band and other frequencies and create competition in the market for next generation services.

Equipment for 12 GHz is less expensive and less complicated to produce than equipment for bands at and above 28 GHz. Devices for the higher frequencies require a greater number of components than 12 GHz equipment.[36] Moreover, the materials required for each component are generally more expensive than for 12 GHz devices given the exotic nature of the required semiconductor materials, the difficulty of manufacturing, assembling and packaging the analog RF components designed to receive and process signals with wavelengths that are a centimeter or less, and the lack of mass production techniques for those components, assemblies and packages.[37]

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[36] The device bill of materials ("BoM") for RF parts is lower for 12 GHz equipment than for devices in the higher frequency bands. For example, generating higher frequency local oscillators ("LO's") with low phase noise is expensive and requires additional parts such as multipliers.

[37] The circuit design techniques used at 12 GHz on silicon and other materials cannot be used at mmW frequencies due to the impact of parasitic capacitance at these frequencies. *See infra* n.57. Materials must be even thinner than in the microwave bands in order to avoid interference in the circuitry, making them harder to manufacture. *See ETSI Paper* at 5, 27. Moreover, this delicate process requires more expensive substrate materials, hybrid assembly techniques, and manual (rather than computer-assisted) adjustments, all of which add time and expense to production. *See* John Coonrod, *Choosing Circuit Materials for Millimeter Wave Applications*, High Frequency Electronics, at 22 (July 2013) ("*Coonrod Paper*") (suggesting manufacturers use "a laminate that is thinner than one-eighth wavelength at the highest operating frequency, to eliminate unwanted resonances between different circuit plans in a circuit assembly").

i. RF Components

The key RF components needed for deployment in the 12 GHz band, such as power amplifiers, driver amplifiers, low-noise amplifiers ("LNAs") and mixers, are all generally less expensive than the same type of equipment used to provide service on the higher frequencies. This lower cost per component is driven by the more affordable base materials used in 12 GHz equipment as well as the simpler packaging those materials permit. For instance, silicon is an inexpensive material that is in mainstream use at lower frequencies due to its integration density, yield, and functionality on a single chip.[38] But higher frequencies require the use of Gallium Arsenide ("GaAs") or even less common and less proven semiconductor materials such as Indium Phosphide ("InP") or Gallium Nitride ("GaN"). These materials have excellent low noise performance, better linearity, and can produce more power at millimeter wave frequencies than silicon, but they are much more difficult and costly to produce.[39]

Moreover, volume manufacturing for the shorter wavelengths at higher frequencies is more expensive than for 12 GHz devices due to the need for exotic raw materials, such as GaAs, and the challenges presented by parasitic and material losses when producing products capable of operating in higher band frequencies, such as 24 GHz and above.[40]

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[38] *ETSI Paper* at 5, 27.

[39] *See id*. at 5 ("low cost silicon chips providing frequency conversion functions and moderate levels of performance for small cell applications may be supplemented with GaAs devices to provide the power and noise figure performance needed for the more demanding use cases"); *see also ETSI Paper* at 9 ("Silicon transistors cannot compete with III-V compounds (GaAs, InP, GaN) for low noise performance, linearity and output power at frequencies above 20 GHz").

[40] Device manufacturers must take into account parasitic capacitance, which is the unwanted effect of the electric charges stored by conductors at different potentials when the conductors are close to each other. At lower frequencies (under 15 GHz), parasitic capacitance can usually be ignored, but in high frequency circuits, it can cause issues, including interference, unreliable

The cost to manufacture some of the key components for radiofrequency devices demonstrates this issue. In general, LNA equipment in frequency bands of 28 GHz and above has a higher noise figure (by 1dB or more) and costs up to twice as much to manufacture as the same equipment for the 12 GHz band. Similarly, power amplifiers in the bands at 28 GHz and above cost at least twice as much to produce as power amplifiers for 12 GHz, as illustrated by the following chart:[41]

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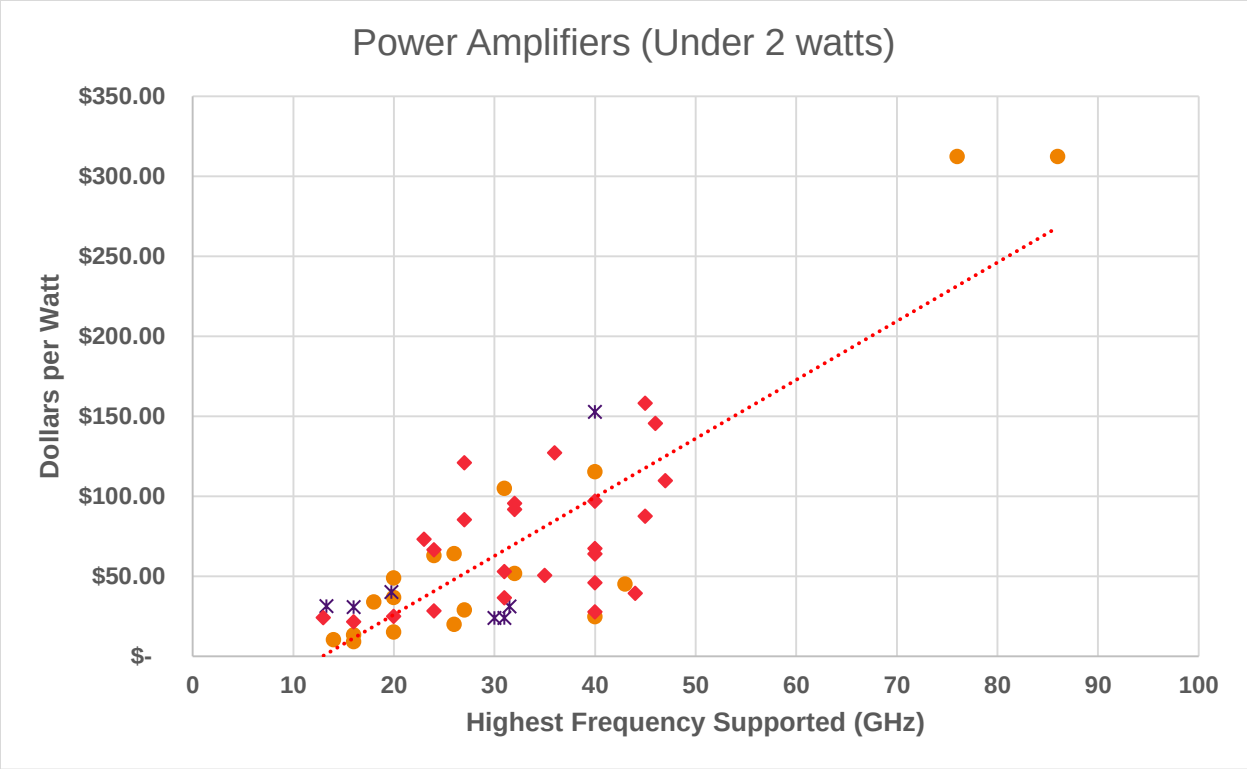
operation, or oscillations. Packaging for 12 GHz equipment that reduces parasitic capacitance has been developed as the device marketplace has matured. However, engineers are still struggling with how to design low parasitic packaging for higher frequency equipment. So far, efforts have resulted in more expensive "module" packaging where costly, time-consuming hybrid assembly techniques are used.

[41] *See also Power Amplifiers*, Qorvo, http://bit.ly/2cyPUoR (last visited Sep. 20, 2016); *see also* MACOM, http://bit.ly/2d4GyyT (last visited Sep. 20, 2016).



ii. Circuit boards and test equipment

Due to the relationship between laminate thickness and wavelength, it is also challenging to produce printed-circuit-boards ("PCBs") that provide high performance levels in higher frequencies at reasonable prices. As an example, in frequencies above 20 GHz, copper and nickel are not effective finishes for PCBs, and more expensive gold finish is necessary to reduce insertion loss.[42]

Test equipment, too, is less expensive to produce for 12 GHz than for higher frequencies. Testing equipment for higher frequencies is specialized and must make precise measurements at very small wavelengths, resulting in a higher cost per unit. The Keysight Network Analyzer, for

[42] *Coonrod Paper* at 28.

example, a key piece of test equipment, costs about $81,000 for 12 GHz operations compared to about $123,000 for operations in the 28 to 43 GHz frequencies.[43]

iii. Existing manufacturing infrastructure

A robust device manufacturing ecosystem is also already in place for devices using 12 GHz frequencies, which is readily adaptable for the production of 5G technologies. Receivers and amplifiers using 12 GHz spectrum are widely available and inexpensive. There are approximately 34 million low-noise downconverters ("LNBs")[44] with LNAs[45] and integrated waveguide/antenna interfaces already in the 12 GHz DBS marketplace. LNBs can cost as little as $29.[46] By contrast, the mass market for devices operating above 20 GHz has not yet developed for high-volume deployments.[47] And many millimeter wave applications are still in the laboratory stages, due to a lack of existing electronic devices for use in the bands, which are difficult and costly to manufacture.[48] The availability of a mature manufacturing infrastructure

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[43] *See PNA Network Analyzers, 300 kHz to 1.1 THz*, KEYSIGHT TECHNOLOGIES, http://bit.ly/2c8RgGH (last visited Sept. 13, 2016) (showing a chart comparing product specifications and pricing).

[44] LNBs receive the signal from the satellite, downconvert it, and allow the signal to be carried to the indoor satellite TV receiver via relatively cheap coaxial cable.

[45] LNAs minimize extraneous noise and amplify the low-power signal to deliver a higher-quality signal to the receiver.

[46] *See DirecTV DSS KU LNBF*, Sadoun Satellite Sales, http://bit.ly/2d4rD99 (last visited Sep. 20, 2016).

[47] "High-volume deployments" are defined as a few hundred thousand to millions of devices. *See ETSI Paper* at 10. For example, the market for millimeter wave backhaul/fronthaul devices in 2015 was estimated to be less than 100,000 units per year, which is a "negligible" demand, making the business case for producing devices for higher frequency services a difficult one. *Id.* at 11.

[48] The smaller wavelengths of the higher frequencies make high-volume manufacturing of equipment more difficult because circuit laminates thinner than one-eighth wavelength and thinner circuits (less than 0.762 millimeters thick for 49 GHz) are required for mmW equipment.

will enable the development of 5G technologies for the 12 GHz band faster than for other spectrum bands, for which no such infrastructure exists. This is especially true when one considers the scale of production necessary to support the deployment envisioned for 5G.

C. Licensees Can Deploy 5G on 12 GHz Spectrum With Less Dense Infrastructure Than Necessary for Higher Frequency Spectrum.

A more dense infrastructure is required for the millimeter wave bands than for lower-frequency bands. The relative density of higher-frequency deployment is due to the limited range, greater propagation loss characteristics, poor foliage penetration and greater rain fade of the higher frequency bands. The infrastructure necessary for deployment of 5G on 12 GHz spectrum would cost less and could be built more quickly than the infrastructure necessary for the deployment of 5G at higher frequencies. It will also be easier to add capacity in the 12 GHz band resulting in improved coverage and signal strength and a better user experience; adding a single antenna for use in the 12 GHz band would improve service exponentially more than making the same investment in equipment for the higher-frequency bands due to the network density needed to support 5G services.[49]

Acquiring sites for 5G deployment could also be slowed by local authority review processes, which are ill-equipped to accommodate the large-scale acquisition mmW 5G services are projected to require. Chairman Wheeler recently acknowledged that this is "a major

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See Coonrod Paper at 22. Some studies estimate that technologies for mmWave applications will require at least a 1-2 year development cycle, with as long as 3 to 5 years required if the need for new techniques necessitate longer-term research. *See ETSI Paper* at 17.

[49] *See, e.g.*, Tianyang Bai and Robert W. Heath, *Coverage and Rate Analysis for Millimeter Wave Cellular Networks*, ARXIV, at 2, *available at* https://arxiv.org/pdf/1402.6430.pdf ("Our analysis indicates that the coverage and rate are sensitive to the density of base stations and the distribution of blockages in mmWave networks.").

concern" for 5G deployment in the higher frequencies: "[i]f siting for a small cell takes as long and costs as much as siting for a cell tower, few communities will ever have the benefits of 5G."[50] Deployment on the 12 GHz band will require fewer sites, face fewer potential deployment delays and has better prospects for timely deployment.

D. The 12 GHz Band Meets the Commission's Criteria for 5G spectrum.

The 12 GHz band also satisfies each of four criteria the Commission has identified as making spectrum especially suitable for 5G broadband deployment. First, 5G spectrum should consist of at least 500 megahertz of contiguous spectrum to support the throughput requirements of 5G service.[51] Carriers, vendors and trade associations have consistently told the Commission that operators will need bandwidths on the order of several hundred MHz or more to achieve multi-gigabit per second broadband connections envisioned for 5G.[52] The 12 GHz band offers 500 megahertz of contiguous spectrum. This wide spectrum band can support the peak data rates necessary for 5G use.[53]

Second, 5G spectrum should have a flexible regulatory framework to ensure the broadest and best possible use of the spectrum in the future. The market for 5G services, which is still in

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[50] Remarks of FCC Chairman Tom Wheeler at CTIA Super Mobility Show 2016, Las Vegas (Sept. 7, 2016), http://bit.ly/2cZUITC ("We . . . are committed to working to lessen these burdens and costs to ensure that 5G is available nationwide, while respecting the vital role that the communities themselves play in the siting process.")

[51] *Spectrum Frontiers NPRM* ¶ 20.

[52] *See* 4G Americas, *The Voice for 5G in the Americas 5G Spectrum Recommendations*, at 8 (Aug. 2015), http://bit.ly/2bHjNyk.

[53] *See Ex Parte* Presentation of MVDDS 5G Coalition, RM-11768, at 1 (filed Aug. 19, 2016) ("The 12.2-12.7 GHz band offers 500 MHz of contiguous, underutilized MVDDS spectrum that is ideally suited for 5G deployments.").

its very early stages, is likely to be a very dynamic one, with significant changes over time.[54] Flexible regulatory frameworks for 5G bands will allow the spectrum to accommodate a variety of services and uses, including some not yet anticipated, as they develop.[55] The 12 GHz band has the requisite flexibility. The 12 GHz proposed rulemaking for the 12.2-12.7 GHz band, in particular, will make the band more flexible by removing outdated restrictions on MVDDS licensees and allowing for the provision of both mobile broadband services and the DBS operations in the band.[56] This rulemaking will also implement interference mitigation procedures to ensure compatibility between the proposed two-way mobile broadband use of the band and existing DBS uses.[57] These changes will increase the flexibility of the band to allow multiple simultaneous uses of the spectrum, including uses suitable for the provision of 5G.

Third, 5G spectrum should promote "international harmonization," meaning the FCC would like to consider for 5G in the U.S. the same bands under consideration for mobile broadband and 5G in the international community.[58] International harmonization will promote the deployment of 5G worldwide by "reducing development and equipment costs and promoting a unified world market."[59] The 12.2-12.7 GHz band is allocated for mobile services

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[54] *Spectrum Frontiers NPRM* ¶ 23.

[55] *Id*.

[56] *See MVDDS Coalition Petition*.

[57] *See id*.

[58] *Spectrum Frontiers NPRM* ¶ 21.

[59] *Id*.

internationally (except in Region 1).[60] Thus allocation of this band for 5G in the U.S. would harmonize the U.S. use of the spectrum band with the use of the spectrum band internationally.

Fourth and finally, 5G spectrum should accommodate sharing of 5G uses with existing uses. The use of spectrum that can accommodate new mobile uses and existing uses will ensure ease of coordination in the band and avoid overly-complex revisions to the rules of each band.[61] Since the 12 GHz band is already allocated for terrestrial one-way use, allowing two-way mobile broadband use in the band would not be burdensome and will allow for rapid deployment of 5G.[62] The 12 GHz band has no more encumbrances or regulatory hurdles than any of the other bands identified in this proceeding.

E. The Coordination Required for the 12 GHz Band Will be No More Challenging than for Other Bands Identified for 5G.

While the 12 GHz band is not without coordination requirements, the sharing arrangements necessary for the 12 GHz band appear no more taxing to resolve than the arrangements required in the bands already identified for 5G.

Deployment of 5G in the 12 GHz band will require 12 GHz band licensees to determine whether the signal levels from their systems could affect DBS operations, and then commence a coordination process with DBS licensees, to ensure no negative effects on DBS operations. Use of the 70 and 80 GHz bands for 5G, by comparison, would require coordination with hundreds of non-exclusive, nationwide licensees currently using the bands "based on a set of spectrum rights

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[60] *See* 47 C.F.R. § 2.106 (codifying the International Table of Frequency Allocations, which allocates the 12.2-12.7 GHz band for mobile use).

[61] *Spectrum Frontiers NPRM* ¶ 22.

[62] *See* Study, *MVDDS 12.2-12.7 GHz Co-Primary Service Coexistence* (June 2016), *available at* Attachment I to Comments of MVDDS 5G Coalition, RM-11768 (filed June 8, 2016) ("*Coalition Study*").

and sharing mechanisms between Federal and non-Federal users, and among different types of non-Federal uses (fixed and satellite)."[63] The 47 GHz band will require sharing among terrestrial, mobile, and the FSS operations authorized for use in this band.[64] The 12 GHz band would not require this level of coordination or sharing. The 12 GHz band is also unencumbered by government interests, unlike the 32 and 37 GHz bands.[65]

III. THE MVDDS 5G COALITION PROPOSALS DEMONSTRATE A FEASIBLE SHARING AND INTERFERENCE MITIGATION FRAMEWORK EXISTS FOR THE 12 GHZ AND OTHER SPECTRUM BANDS.

The MVDDS 5G Coalition has proposed a sharing and interference mitigation framework that demonstrates the feasibility of the deployment of mobile services in the 12.2-12.7 GHz band. The FCC's existing rules for the 12.2-12.7 GHz band allow for sharing of the band between DBS and MVDDS. Stringent restrictions on the MVDDS use of the band, however, have prevented extensive deployment of MVDDS operations.[66] The Commission now has the opportunity to modernize these rules to enable the deployment of mobile broadband services in the 12.2-12.7 GHz band.

While the Commission has been concerned in the past that mobile operations in the 12.2-12.7 GHz band would have the potential to interfere with DBS operations, the MVDDS 5G Coalition's recently developed 12 GHz sharing framework and interference mitigation techniques would allow mobile use in the band while protecting DBS licensees.[67] The MVDDS

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[63] *Spectrum Frontiers FNPRM* ¶ 426.

[64] *See id.* ¶ 411.

[65] *Id.* ¶¶ 391-93.

[66] *See MVDDS Coalition Petition*.

[67] *See id.*

5G Coalition conducted a study of the potential for interference from the mobile use of the MVDDS spectrum to existing DBS users in the band. The study found that deployment of the 12.2-12.7 GHz band spectrum for mobile broadband services is feasible without adverse impact on the DBS licensees.[68]

The MVDDS 5G Coalition's proposal contains an interference-mitigation framework that would direct MVDDS and DBS licensees to coordinate to ensure the protection of incumbent DBS operations. The proposal eliminates the current power-level restrictions to accommodate 5G operations. A 12.2-12.7 GHz licensee would also be required to conduct an analysis of each area in which it intends to operate a transmitter to ensure that the equivalent power flux density ("EPFD") from the transmitting antenna will be within the values listed for the appropriate region pursuant to the FCC's rules.[69] For those areas in which the MVDDS licensee determines the signal levels from its system could affect DBS operations, the licensee would have to commence a coordination process with those DBS licensee(s), to ensure no negative effects on the DBS operations would occur. The MVDDS 5G Coalition notes that NGSO FSS operations in this band would be incompatible with this proposal and, indeed, with the current non-5G MVDDS operations.[70]

By adopting the framework proposed by the MVDDS 5G Coalition, the Commission would make 500 megahertz of spectrum available for 5G, while protecting DBS licensees in the band. Many of the principles therein would also apply to devising coexistence frameworks in

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[68] *See Coalition Study*.

[69] *See* 47 C. F.R. §101.105(a)(4)(ii).

[70] *See MVDDS Coalition Petition* at 22-24.

other bands; like the 12 GHz band, the millimeter wave bands also have the capability to support multiple deployment scenarios. Using accurate information in making interference predictions for each band would maximize both spectrum utilization and spectrum sharing.[71]

IV. LICENSING AND PERFORMANCE REQUIREMENTS SHOULD REFLECT THE CHARACTERISTICS AND LIMITATIONS OF EACH SPECTRUM BAND TO ADVANCE THE TIMELY, EFFECTIVE DEPLOYMENT OF 5G.

The Commission should tailor the 5G licensing and performance requirements to each individual spectrum band to ensure that the rules promote the rapid and successful deployment of 5G service. For the 12 GHz band, well-tailored performance requirements and the retention of the existing geographic area licenses would support deployment of the spectrum for 5G.

A. Performance Requirements Tailored to Band-Specific Limitations, Including the Requirements for Incumbents, Would Ensure Both Fairness and Timely Deployment.

Performance requirements for bands identified as suitable for 5G should reflect existing band limitations to ensure efficiency, fairness, and timely deployment. Effective tailoring of these performance requirements would include taking into account the degree of incumbency for existing uses in the band. Given the differences among the spectrum bands proposed for 5G use here and under consideration at the Commission, a single "one-size-fits-all" framework is unlikely to be effective.

For the 12.2-12.7 GHz band, for example, any performance requirements adopted by the Commission must include exemptions that account for the DBS exclusion zones as 12.2-12.7 GHz licensees are not permitted to transmit in areas in which DBS operations would be

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[71] LiDAR-based methodology provides the most accurate information for coexistence studies, in particular for proposed urban deployment areas with deployment heights lower than the average clutter.

interfered with.[72] Any performance requirements would therefore need to account for the inability of licensees in this band to provide service in certain geographic areas.

B. Retention of the Existing 12 GHz Band Geographic Area Licenses Would Encourage Coordination Among Licensees.

Maintenance of the existing geographic area licenses for the 12 GHz band (*i.e.*, Designated Marketing Areas or DMA's) would simplify coordination among licensees and promote deployment.[73] County-sized license areas result in more and denser license-area borders and thus complicate build-out and coordination of the spectrum use.[74] The areas along county lines can also be densely populated, and population density tends to complicate the coordination among license holders. The population-density complications will compound the increased complexity of coordination attendant to the development of hybrid mobile and fixed deployments in these bands.[75]

In short, given the nature and extent of the coordination required for the 12 GHz band, county-level licenses in this band could impose technical and economic burdens on licensees resulting in slower and more limited service deployment with little if any offsetting benefit.

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[72] *See* 47 C.F.R. § 101.1440.

[73] *See id*.

[74] *See, e.g.*, Comments of SkyRiver Communications, Inc., GN Docket No. 14-177, at 1 (filed Jan. 27, 2016) ("Larger areas like BTAs and EAs afford licensees greater economies of scale than smaller geographic service areas, promote deployments in rural areas that would not be served if subject to county-based performance requirements, and minimize the operational and economic costs of interference coordination with neighboring licensees.").

[75] *Id*. at 10-11.

V. CONCLUSION

The Commission will need to identify spectrum bands beyond those already identified to meet the dramatic increases in demand for mobile broadband spectrum projected over the coming years. The 12 GHz band meets the criteria outlined by the Commission for 5G spectrum and is as viable for the provision of 5G as any band already identified by the Commission. Indeed, due to the propagation characteristics of the spectrum as well as existing manufacturing infrastructure, 5G could be deployed in the 12 GHz band faster, more easily, and more cost-effectively than in higher frequency bands. Providers could use this lower frequency band to establish consistent coverage for consumers, which would complement higher-frequency spectrum deployments.

The MVDDS 5G Coalition has already developed a sharing and interference mitigation framework that demonstrates the feasibility of sharing the 12 GHz band. Performance requirements tailored to the specific characteristics of each band would also ensure that the rules encourage the rapid deployment of the bands for 5G. The MVDDS 5G Coalition therefore urges the Commission to broaden the bands under consideration in this proceeding to include the 12 GHz band for the deployment of 5G.

Respectfully submitted,

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