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
Protecting the Privacy of Customers of Broadband and Other Telecommunications Services	)	WC Docket No. 16-106

COMMENTS OF NOKIA

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COMMENTS OF NOKIA

Nokia respectfully submits comments in response to the Commission's Further Notice of Proposed Rulemaking ("FNPRM")[1] seeking comment on specific spectrum bands above 24 GHz to promote the next generation of wireless.

[1] *Use of Spectrum Bands Above 24 GHz For Mobile Radio Services*, GN Docket Nos. 14-177 et al., Further Notice of Proposed Rulemaking (rel. July 14, 2016) ("*FNPRM*").

I. INTRODUCTION AND SUMMARY

Nokia commends the Commission on the tremendous progress it is making in the area of spectrum policy. From its innovative 600 MHz Incentive Auction, to introducing commercial dynamic sharing into the 3.5 GHz band, to unlocking the 28 GHz band for terrestrial wireless sharing with fixed satellite service (FSS) systems, the Commission is positioning the U.S. to be a global leader in the next generation of wireless. In addition to praising the Commission, these Comments open by cautioning the Commission to recognize that network providers and equipment vendors face substantial economic headwinds in our efforts to innovate and deploy 5G systems. Nokia urges the Commission to consider the ramifications of such regulatory frameworks that dampen investment incentives and the financial ability to engage in the record-levels of investment that will be required to make 5G a reality.

Nokia next voices its support for each of the individual bands identified for terrestrial mobile in the FNPRM, in general agreement with the Commission. Nokia agrees that the proposal to share between commercial and Federal users is feasible where proposed, but asks that the Commission not provide special rights to Federal users, such as priority and preemption, in those bands. With respect to all sharing considerations, Nokia generally favors less complex sharing frameworks where workable. Spectrum Access System- (SAS)-based systems show promise, as do other sharing frameworks, which should all be considered before settling on a sharing framework in any particular band. In the 70/80 GHz band, Nokia opposes the concept of special in-building rights, even if found to be technically workable in this band. This proposal for the 37 GHz band was soundly rejected on policy grounds that remain valid at 70/80 GHz. With respect to 95 GHz and above, Nokia recommends a number of bands be explored for use in providing backhaul for mobile services.

In these Comments, Nokia provides additional technical considerations the Commission should weigh when reviewing SAS and other non-SAS sharing frameworks for particular bands. Nokia also augments the record, as requested by the Commission, on terrestrial 5G-FSS sharing issues in the 24 GHz, 28 GHz, and similar bands. The appendices to these Comments provide valuable data for evaluating 5G-Fixed Service and 5G-FSS sharing, with a focus on the 70/80 GHz Band (Appendix 1) and the 28 GHz Band (Appendix 2) respectively. These Comments also address other technical issues raised in the FNPRM, such as minimum bandwidth for Base Station (BS) transmit power levels and sharing analysis and modeling.

II. COMMISSION POLICIES SHOULD FACILITATE CONTINUED INVESTMENT IN NEXT GENERATION NETWORKS

With the issuance of the FNPRM, the Commission has demonstrated a continued commitment to unlocking the promise of spectrum, so that the market can put that spectrum to work to drive the future of wireless and, more broadly, economic growth in the United States. While the most frequently discussed aspects of next-generation wireless are applications and edge devices, it is important to remember that none of these solutions would be possible without billions of dollars in investment in network infrastructure.

Nokia is pleased with Chairman Wheeler's recent remarks where he recognized the importance of the network as the engine that drives the broadband economy. As the Chairman recently said in remarks on the future of wireless, "Leadership in networks leads to leadership in uses, which quickly moves across borders."[2] The Chairman also stated the following in his recent speech stating that "5G must be a national priority:"[3]

[2] Prepared Remarks of FCC Chairman Tom Wheeler, The Future of Wireless: A Vision for U.S. Leadership in a 5G World, National Press Club, Washington, D.C at 3 (rel. June 20, 2016).
[3] *Id.* at 1.

> We will be repeating the proven formula that made the United States the world leader in 4G: one, make spectrum available quickly and in sufficient amounts; two, give great flexibility to companies that can use the spectrum in expansive ways; and three, stay out of the way of technological development.[4]

Nokia applauds this statement of regulatory humility – an understanding that no one knows what the future will bring, especially in the lightening-fast field of technology development. As Chairman Wheeler explained, "[t]urning innovators loose is far preferable to expecting committees and regulators to define the future."[5]

This philosophy should not only be the guide for spectrum policy, but also more broadly as the Commission looks to encourage network deployment and innovation. In order for consumers to benefit from the promise of 5G, service providers and equipment vendors need to make an economic case for deploying 5G networks. Industry – not regulatory mandates – led the U.S. to 4G leadership, and the same will be the case for 5G. Network operators are considering innovative business models that can create value in all segments of the broadband ecosystem, helping to make the business case for investment by means other than solely looking at subscription fees. The Commission should encourage these business models.

The Commission's broadband privacy proceeding provides a prime example – one of many potential tipping points where the Commission has the opportunity to tilt the playing field or let the market work. While the Commission considers consumer protection measures, it should also recognize that the mobile broadband ecosystem, from the devices, application and services level all the way down to equipment design and network management activities, requires access to an array of information ranging from how and where devices and services are used to the experience of individual consumers using specific applications. Rather

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[4] *Id.* at 3.
[5] *Id*.

than rush to bright line rules, the Commission must identify the range of business models, practices, and uses potentially impacted by the adoption rules that may block use of customer data without any hard evidence of actual harm. The Commission should not over-value speculative consumer harms while giving short shrift to the consumer benefits of network monetization and the virtuous cycle of innovation that could be achieved through use of customer data by the service provider.

Zero Rating (or "free data") provides another example of service providers simply trying to win customers and improve their bottom line in a competitive marketplace where margins are shrinking. The Open Internet proceeding prohibited service providers from multiple avenues for network monetization – even requiring service providers to refuse consumer requests to prioritize content of the users' choosing. With respect to zero rating, the Commission took a different approach by recognizing potential benefits across the entire value chain, preserving consumer choice and innovative business practices.

Wireless carriers and equipment vendors are constantly finding ways to make the network smarter and more efficient, creating unprecedented value for consumers. Nokia urges the Commission to reject arguments that would stunt innovation in favor of "dumb pipes," and embrace an environment that gives ample weight to the network as driving the virtuous cycle of innovation.

III. NOKIA SUPPORTS EXPLORATION OF EACH OF THE IDENTIFIED BANDS, AND URGES THE COMMISSION TO INVESTIGATE MORE LOW- AND MID-BAND SPECTRUM

Nokia is pleased that the Commission's FNPRM seeks comment on fixed and mobile use of the following bands: 24.25-24.45 GHz together with 24.75-25.25 GHz (24 GHz band), 31.8-33.4 GHz (32 GHz band), 42-42.5 GHz (42 GHz band), the 47.2-50.2 GHz (47 GHz band), 50.4-52.6 GHz (50 GHz band), and the 71-76 GHz band together with the 81-86 GHz bands (70/80 GHz band). Each of these bands were identified by Nokia in our initial Comments in this proceeding, and we continue to advocate for review of these bands. We also support the Commission seeking comment on use of bands above 95 GHz.

Nokia continues to urge the Commission to also investigate mid-band (6 GHz to 24 GHz) and low-band (below 6 GHz) spectrum as critical pieces to the future of wireless networks. For example, Nokia continues to advocate for the Commission to seek comment on 3.1-3.55 GHz and 3.7-4.2 GHz. When combined with 3.5 GHz (3.55-3.7 GHz), this could open 1.1 GHz of contiguous spectrum below 6 GHz. Nokia also requests that the Commission seek comment on the 1300-1390 MHz band.

As in prior phases of this proceeding, Nokia continues to urge caution as many bands being explored for mobile use are used to provide backhaul for existing and future mobile systems. As such, they are essential for the delivery of mobile broadband. That caution does not mean that these bands are not appropriate in all circumstances for 5G. As discussed further below, with appropriate safeguards, sharing between microwave backhaul and mobile broadband access in these bands should be feasible.

Nokia provides the following brief Comments on each of the bands proposed in the FNPRM:

24 GHz. Nokia supports the Commission's proposal to add a mobile allocation to the 24.25-24.45 and 24.75-25.25 GHz segments of the 24 GHz band, a fixed allocation to 24.75-25.05 GHz, and to authorize both mobile and fixed operations in those segments under the new Part 30 Upper Microwave Flexible Use Service (UMFUS) rules. These bands are immediately adjacent to the 28GHz (27.5-28.35GHz) band and part of 24.25-27.5GHz range which is being studied in International Telecommunication Union (ITU) the towards the World Radiocommunication Conference of 2019 (WRC-19). That spectrum range presents an excellent opportunity for global harmonization and implementation, at least via use of a tuning range when developing products that covers both the 24 GHz and 28 GHz bands.

With respect to effective sharing between satellite and mobile users, since the current use of satellite in 24GHz is very limited,[6] we view that the existing limits and coordination procedures on satellite operations in the 25.05-25.25 GHz band can apply to the 24.75-25.05 GHz band also. Existing licensees could also be transitioned to the UMFUS rules.

We support the Commission's proposal to convert the 24 GHz band plan to unpaired blocks, and to license the 24.25-24.45 GHz band segment as a single, unpaired block of 200 MHz, and the 24.75-25.25 GHz band segment as two unpaired blocks of 250 megahertz each. As discussed in our NPRM Comments,[7] Nokia prefers larger block sizes while providing opportunities for multiple operators to hold a license.

32 GHz. The 32 GHz Band was proposed for IMT by all regional organizations at WRC-15 and provides an opportunity for global harmonization. It is being studied at the ITU in a WRC-19 Agenda item. It should be investigated further, keeping in mind that radio astronomy service in the adjacent 31.3-31.5 GHz band must be protected. This might also add complexity to a tuning range solution that would include the 28 GHz range. Nokia also supports licensing the spectrum in four blocks of 400 MHz each.

42 GHz. The FNPRM proposes to add Federal fixed and mobile allocations into this band on a co-primary basis. As an initial matter, Nokia would prefer that the Commission not complicate this band by adding a Federal allocation. However, assuming that the

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[6] *See FNPRM*, ¶¶ 379-381, 384.
[7] Comments of Nokia, GN Docket No. 14-177 *et al.*, filed Jan. 27, 2016, 20-24 ("NPRM Comments").

Commission does adopt its proposal, we urge that the sharing mechanism truly be co-primary. Federal users should not be provided priority or preemption rights. The Commission also tentatively concludes that "simple methods of coordination (to enable geographic sharing)" could facilitate coexistence and asks about other sharing approaches, such as an SAS. Nokia generally favors less complexity where possible, and agrees with the Commission that simple geographic sharing would be feasible in this band. We also support licensing the spectrum into two blocks of 250 MHz each.

47 GHz and 50 GHz. As with other bands considered in this proceeding, the 47 GHz and 50 GHz bands were identified for sharing compatibility studies with an eye toward identifying the band for IMT-2020. One of the difficulties the Commission identifies in the FNPRM is potential sharing between terrestrial and FSS user equipment. One key aspect to this review, however, should be a consideration of the likelihood (or lack thereof) that satellite will actually deploy services in these bands. Whereas there were at least *some* existing satellite operations at 28 GHz to contend with, here there are zero existing satellite operations despite service rules being in place. As such, in its analysis of technical coexistence parameters, the Commission should also weigh the relative likelihood of deployment.

With respect to co-primary sharing between commercial and Federal services in the 48.2-50.2 GHz band, Nokia again would like to focus the Commission on the meaning of "co-primary" and the fact that there are currently no Federal incumbent operations in the band. As the Commission and the Federal government look for ways to explore increased sharing between commercial and Federal uses, the norm should be true "co-primary" without preemption or other Federal rights that would harm the utility of the spectrum for commercial uses.

Nokia also supports licensing the 47 GHz band into six blocks of 500 MHz each and the 50 GHz band into five blocks of 400 MHz each, with one extra 200 MHz block.

70/80GHz. The 71-76 GHz and 81-86 GHz Band offer great opportunity, with the large amounts of spectrum available, but the successful fixed microwave usage that already exists needs to be protected. Nokia believes that sharing is feasible though, and provides further analysis on sharing considerations below. While Nokia is at the forefront of in developing SAS-related technologies, we have also studied other sharing approaches in the 70 and 80 GHz as we discussed below for the Commission's consideration.

Nokia opposes the concept of carving out special "Swiss cheese" spectrum rights zones for indoor or other micro-users. Despite a dearth of support paired with overwhelmingly vocal opposition for this concept in the 37 GHz Band, the Commission has now proposed this idea for the 71-76 GHz Band. Moreover, Nokia is concerned that the comments for the latest proposal are focused solely on technical feasibility questions to the exclusion of the very real administrative and transactional costs licensees would bear if indoor uses are excluded from their licenses. These concerns already were voiced in the context of 37 GHz and continue to be concerns at 70 GHz. More fundamentally, Nokia cautions the Commission that, even if the technical concerns of special indoor rights can be overcome, that is not enough. While technical feasibility is critical, the Commission should also weigh whether anyone demonstrates interest on the record of deployment of such a service, and how indoor carve-outs may impact the overall desirability of the band to those parties who do show interest in deploying equipment in this nascent band.

95GHz and up. Nokia supports the Commission's decision to make additional spectrum available above 95GHz. With the amount of spectrum being made available for access in the mmWave range, we recommend the exploration of bands above 95GHz for fixed service that could be used for backhaul. We want to bring to the attention of the Commission that the European Conference of Postal and Telecommunications Administrations (CEPT) approved two new work items to study fixed service above 92 GHz in the following ranges:

- 92 – 94 GHz; 94.1 – 95 GHz; 95 – 100 GHz; 102 – 109.5 GHz and 111.8 – 114.5 GHz;
- 130 – 134 GHz; 141 – 148.5 GHz; 151.5 – 164 GHz and 167 – 174.7 GHz.

We recommend that the Commission also study some of the ranges mentioned above for fixed service.

IV. NOKIA RECOMMENDS THAT THE COMMISSION STUDY VARIOUS TOOLS BEFORE ADOPTING A SHARING FRAMEWORK IN THE mmWAVE BANDS

The Commission should be commended for working at the regulatory equivalent of light-speed in this high-band proceeding. At the same time, the Commission should not propose sharing arrangements that will delay or even jeopardize commercial deployments in the mmWave bands. For example, the very notion of commercial-Federal sharing in the 37 GHz Band was added very late in the process prior to issuance of the Order. Nokia fully agrees with the Commission's determination in its Order that it would seek comment on the appropriate sharing framework in that band and other bands as part of the FNPRM. The Commission is, wisely, building a complete record as it develops the sharing framework in mmWave bands. Nokia respectfully requests that the Commission take this approach to the other bands discussed in the FNPRM.

In the FNPRM, the Commission asked if a SAS that coordinates uses among different tiers of users, like the one being developed for the 3.5 GHz Citizens Broadband Radio

Service, could be used to facilitate sharing in various mmWave bands. For instance, the Commission asked if a "SAS-based sharing approach [would] facilitate Federal and non-Federal sharing" of the 42 GHz band.[8] Similarly, the Commission asked about the use of a SAS "to facilitate sharing between terrestrial operations and FSS user equipment" in the 47GHz band[9] or "to establish a SAS-based regulatory framework adapted to the constraints and the opportunities of the 71-76 and 81-86 GHz bands."[10]

At the same time, the Commission asked if there are "other tools we can leverage to create a robust sharing environment that allows this spectrum to meet both Federal and non-Federal needs"[11] or if there are "additional considerations in addition to leveraging the sharing regime adopted for the co-primary coordinated sharing in the 37 GHz band."[12] While Nokia is investing substantial resources to develop SAS-related technologies that will drive the 3.5 GHz band, we are of the view that the application of SAS and other sharing techniques to a given band should be properly studied so that the most effective sharing scheme can be implemented for a given band. In the following sections, Nokia describes its ongoing technical review of SAS and other sharing technologies that the Commission should weigh as it determines how best to implement various shared bands in this proceeding.

A. Further Study of a SAS Solution is Required for mmWave Bands

Given the variety of mmWave deployment configurations, the narrow beamwidths and propagation in these bands, a SAS employing a computational method—

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[8] *FNPRM*, ¶ 407.
[9] *Id.*¶ 413.
[10] *Id.* ¶ 440.
[11] *Id.* ¶ 407.
[12] *Id.*

specifically a statistical propagation model[13]—to determine mutual interference between a specific set of transmit and receive pairs could prove to be either ineffective or inefficient. The SAS could be ineffective as it may determine that non-Line of Sight (non-LOS) paths between transmit and receive pairs are immune from interference even though a single reflection off a small surface will redirect the mmWave signal. The shorter wavelength in this band allows smaller objects to act as efficient reflectors. One or two reflections combined at random angles may generate objectionable interference of an unaligned victim receiver.

Conversely, the SAS could be inefficient, as a seemingly LOS path may be obstructed such that an aligned transmitter will not contribute interference to the victim receiver. Many materials, such as concrete, can be very effective attenuators and combined with the limited diffraction can serve to completely eliminate interference. Thus, a SAS employing a computational method may inadvertently green-light a transmitter even though a reflective path causes interference or red-light a transmitter even though no interference is generated. To guarantee protection of incumbents, a SAS may need to define worst-case exclusion zones around existing receivers.

One might propose that the SAS incorporate a building database such that it more accurately calculate obstructions. However, this appears to be impractical. Effectively, this would require that the SAS perform a complicated ray tracing simulation to identify all the opportunities for reflection in the environment between victim and interferer.[14] Ignoring the computational complexity, a ray tracer can provide a good statistical representation of an environment. However, small inaccuracies in the environmental database will make it almost

[13] *See* "5G Channel Model for bands up to 100 GHz," available at http://www.5gworkshops.com/5gcm.html (visited Sept. 29, 2016).
[14] S.G. Larew, T.A. Thomas, M. Cudak, and A. Ghosh, "Air interface design and ray tracing study for 5G millimeter wave communications," 2013 IEEE Globecom Workshops (GC Wkshps), pp. 117, 122, 9-13, December 2013.

impossible to accurately predict real reflections between victim and interferer or whether a perforated object—such as decorative trim or even foliage—will attenuate the signal or allow it pass via a small gap.[15] While such inaccuracies could still end up in useful coverage of the wireless broadband systems in the low frequencies such as 3.5 GHz, such inaccuracies could create major coverage holes for mmWave systems where the cell sizes tend to be smaller than in the lower bands. The level of detail required to make accurate predictions is impractical as this would require the composition of construction materials, the relative smoothness of surfaces, and precise dimensions of exterior features.

The introduction of mobile base stations may further diminish the utility of the SAS as they represent a time-varying and statistically omni-directional radiator into the environment. A street level deployment will be designed to serve consumers where they exist. One envisioned configuration is a 4-sector base station mounted on a light pole serving consumers on a Manhattan grid.[16] Each sector could be configured with a 512 element dynamic beamformer subdivided as a two panels having horizontal and vertical polarization with each panel having a 16 by 16 element array.

An array such as this might employ a grid of 16 beams to cover a 90 degree sector in azimuth and more limited range in elevation of only 4 beams. Beamwidths for the mobile base station would be on order of 6 degrees much larger than traditionally used by point-to-point backhaul. The combination of all 4 sectors would provide omni-directional coverage for the mobile base station. Although the aggregate interference of the mobile base station might not be great since each beam is only illuminated for a short period of time, the omni-directional nature

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[15] *See* "5G Channel Model for bands up to 100 GHz," available at http://www.5gworkshops.com/5gcm.html (visited Sept. 29, 2016).

[16] M. Cudak, A. Ghosh, T. Kovarik, R. Ratasuk, T. Thomas, F. Vook, P. Moorut, "Moving Towards mmWave-Based Beyond-4G (B-4G) Technology," in Proc. IEEE VTC-Spring 2013, June 2-5, 2013.

could be rejected by the SAS and therefore creating a coverage hole in the mobile systems for a few blocks surrounding the victim receiver. This exclusion zone would unnecessarily harm consumers as their service would be diminished due to a conservative decision by the SAS.

B. Parallel Study Should Be Considered on Non-*SAS* Sharing Mechanisms

While Nokia is putting substantial resources toward enabling SAS-based sharing, we also look beyond the SAS to other solutions that may be superior in certain bands or situations. For example, one non-SAS solution—consistent with the state-of-the art technology—would have the mobile base station calculate or learn the offending beams and then defer transmission on only a subset of beams effectively notching small slices of the coverage area in azimuth and elevation. The end result would leave the consumer better served as ubiquitous street level could still achieved by providing signal from an adjacent mobile base station serving the user from a different angle.

One question is then how would a mobile base station identify or learn of offending beams. Two possible methods could be used to achieve this goal:

1) The database of victim node receive antenna angle, antenna gain and noise margin could be provided to the mobile base station; or
2) A mobile compatible probe receiver could be co-located with the victim nodes within the coverage area detecting and identifying offending beams.

Method (1) has similar limitations to the SAS described previously. However, the burden would fall on the manufacturer who would have more detailed knowledge of the beam used by the particular model of mobile base station. Additionally, a specialized one-time installation procedure could be used to manually verify non-interference of incumbent nodes in areas of high demand.

Method (2) is a more promising solution as co-located 5G compatible probe would be able to detect and identify offending beams and, through feedback, disable those beams in the interfering mobile base station. The probes would be of low-cost as the operation of a probe is similar to mobile stations and the probe could take advantage of low-cost components resulting from economies of scale. Moreover, method (2) would be immune to computational errors due to imperfect knowledge since the probes would reside at the victim node measuring the real environment. A 5G mobile base station will periodically scan all beams in the coverage area in order to allow new users to acquire and attach. This periodic scan can also be used by the probe receiver to identify the offending beam. Unlike data transmission, the beam scans have very short dwell periods, on the order of a few microseconds, contributing minimal interference before being detected and disabled. Both LOS and non-LOS reflected paths could be detected using a 5G compatible probe receiver.

Appendix 1 to these Comments provides a study of coexistence of fixed service with mobile service and the solution proposed above, where the mobile 5G base station transmits on only a subset of beams. Our simulation results showed that the 5G APs into Fixed link interference is the most significant, and the technique of shutting down 5G beams as explained above is effective in suppression of 5G-to-Fixed link interference while keeping the performance of the 5G system acceptable.

We therefore strongly recommend that the Commission take into account the characteristics of the mmWave bands and other factors when developing the sharing framework in those bands.

V. ADDITIONAL TECHNICAL DATA ON COEXISTENCE OF FSS AND 5G SYSTEMS IN THE 24 GHZ, 28 GHZ AND SIMLAR BANDS

In this section, Nokia responds to the Commission's request for comments on whether the sharing regime they have adopted for the 28 GHz band is appropriate for bands like 24 GHz.[17] Nokia was instrumental during the months leading up the Order, leading industry efforts to coordinate future coexistence of 5G networks with FSS in the 28 GHz Band. Specifically, Nokia led a series of meetings with terrestrial wireless service providers and individual satellite operators, convened through the Satellite Industry Association, to exchange information on the technical parameters of terrestrial operations and satellite operations in the band. To amplify the value of the information exchange, Nokia also devoted substantial engineering resources to run simulations and provide technical analysis for discussion of such coexistence, which were presented at a series of meetings. Results from these coexistence studies were also submitted to the Commission.[18] Nokia is pleased that these studies are reflected favorably in the Commission's Order.

The simulations Nokia submitted based on reasonable engineering assumptions demonstrated that interference from existing transmit FSS earth stations into 5G networks can be addressed by requiring those satellite earth stations to reduce their power flux density ("PFD") at 10 meters above ground level to -77.6 dBm/m2/MHz at 200 meters.

As part of the coexistence framework between FSS and UMFUS adopted in the Order, the Commission set forth conditions that would allow authorization of FSS earth stations

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[17] *FNPRM*, ¶ 384.

[18] *See, e.g.*, Letter from AT&T Services Inc., ("AT&T"); Nokia ("Nokia"); Samsung Electronics America ("Samsung"), T-Mobile USA, Inc. ("T-Mobile") and Verizon ("Verizon") (together, the "Joint Filers") to Marlene H. Dortch, Secretary, Federal Communications Commission, GN Docket No. 14-177 *et al*. (filed May 6, 2016); *See* Letter from the Joint Filers to Marlene H. Dortch, Secretary, Federal Communications Commission, GN Docket No. 14-177 *et al*. (filed May 12, 2016); Letter from the Joint Filers and Ericsson to Marlene H. Dortch, Secretary, Federal Communications Commission, GN Docket No. 14-177 *et al*. (filed June 1, 2016) ("*June 1 Joint Letter*").

in the 27.5-28.35 GHz band without a requirement to take any additional actions to provide interference protection to UMFUS licenses. One of these conditions is as follows:

> an FSS applicant must demonstrate in its license application that the permitted interference zone around its earth station, which we will define as the contour within which FSS licensees generate a power flux density (PFD), at 10 meters above ground level, of no more than -77.6 dBm/m^2/MHz, together with any preexisting earth stations located in the same county on a protected basis, will, in the aggregate, cover no more than 0.1 percent of the population of the county license area where the earth station is located.[19]

Nokia has conducted measurements and technical analysis to assist the Commission's analysis of whether this condition is met so as to not cause harmful interference into terrestrial operations. Specifically, in these Comments, Nokia provides a sampling of measurements of Power Flux Density (PFD) from satellite earth stations at various distances and azimuth angles from the FSS sites that the Commission can use to compare with the limit of -77.6 dBm/m^2/MHz proposed in the 28 GHz rules as the Commission authorizes FSS earth stations in the future while considering the deployments of 5G in the vicinity of these earth stations. *See* Appendix 2.

Measurements were conducted at five different FSS earth station sites and the following observations were made based on the data collected:

- Measurement data from site to site was consistent in showing the same data trends. In general, the emissions were lower as the measurement antenna was moved farther away horizontally from the source and higher as the measurement antenna was moved vertically up. This was expected and is supported by the Joint Filers' simulation.
- The test results have qualitatively and quantitatively increased our understanding of the RF environment around the FSS earth station sites.

[19] *FNPRM,* ¶ 54.

Based on the measured data, it can be concluded that the emission levels are higher and cover a greater angular area as compared to the information previously shared by the Joint Filers with the Commission.

- The measured levels were higher than expected in front of the dish and were typically 20 to 30 dB above the -77.6 dBm/m2/MHz at 200m. The PFD levels measured in the vertical plane were typically 1 to 2 dB higher than the Horizontal.
- The measured levels to the sides and to the rear of the sites were much higher than expected. It was also observed that there was no roll-off detected as a function of the azimuth angle as suggested by the Satellite Industry Association (SIA) and used in the Joint Filers' letter.[20]
- There was relatively equal levels of PFD measured at all angles. In general there was only about a 10 dB reduction in the PFD that was detected at 22.5º, 90º, 120º and 180º as compared to that measured at 0º. For example, if the measurement for 100 meters at 0º was -48 dBm/m2/MHz then the level measured at 100 meters / 90º angle was typically -58 dBm/m2/MHz. These levels were well beyond what could have been expected in the way of spillover from the feed structure and the front of the dish.

These measurements and observations lead to an important conclusion that is critical to evaluating this condition: the source(s) of the side and rear emissions are more likely due to transmitter/transmit path leakage than spillover. It is not unusual for transmitters to leak

[20] *See*, *supra*, note 18.

energy at their transmit frequency. This is especially true over time as the performance of shielding interfaces degrade with environmental corrosion.

Thus, any 5G installation close to a 28 GHz FSS earth station site must be assessed for potential interference levels from the FSS earth station, and appropriate measures may be needed at the FSS earth station sites to mitigate interference to the 5G system.

VI. OTHER TECHNICAL ISSUES

A. Minimum bandwidth for given BS Transmit Power Levels

Nokia proposes that the Commission adopt power levels for the bands discussed in the FNPRM that are aligned with what was adopted for 28GHz, 37GHz and 39GHz bands. We also support the base station power limits to scale the maximum power over a 100 MHz bandwidth. The Commission should not adopt any Out-of-Band Emission limits that are more stringent than what was adopted for 28 GHz, 37 GHz and 39 GHz bands.

B. Sharing Analysis and Modeling

In the FNPRM, the Commission requested that commenters address issues pertaining to spectrum sharing and modeling, noting that the record thus far was limited. Nokia provides the following information to assist in the Commission's evaluation of the interference potential for various sharing environments.

a. Antenna characteristics and operational aspects

The antenna systems under development for 5G offer higher levels of performance than the antennas currently used in cellular systems. 5G antennas of access points (base stations) in mmWave range are likely to be composed of numerous antenna elements spatially arranged in panels (arrays). The composite radiation pattern of the antenna array is the result of the individual antenna element contributions, that are appropriately controlled to provide narrow-width and high-gain beams at specific directions and attenuation of side lobe beams. The antenna elements in the array are likely to be arranged in two dimensions (rows and columns), enabling pointing the beam to specific azimuth and elevation angles. The 5G antenna system with antenna array also has the ability to avoid or minimize radiation on specific directions. Regarding devices, antennas are likely to be arrays with reduced number of antenna elements. Device antennas with this configuration are able to provide a directive radiation pattern, with lower gain and wider beamwidth than access point antennas.

These antenna characteristics make essential that sharing and compatibility analysis involving 5G consider the spatial configuration between interferer and victim in order to capture the spatial attenuation or discrimination of 5G antennas and the other system of interest. As mentioned, the 5G antenna system is capable of utilizing beamforming to reach high gains in different directions. For the assessment of interference levels caused by a 5G access point or device to a victim in a fixed location, to a victim in movement, or towards a given direction, a statistical analysis is required to take into account the variability and associated probability of occurrence of the radiated interference signal power at that location or direction, according to the spatial attenuation or discrimination of antennas at both interferer and victim. Reciprocally, the assessment of interference levels caused by other systems to a 5G access point or device must follow similar statistical procedure.

In outdoor deployments, the access point antenna is commonly elevated and has a tilt downwards for appropriate signal provision to devices within the coverage area. The cell size of 5G in mmWave frequency range is expected to be small, resulting in pronounced antenna down tilt. The 5G antenna down tilt reduces substantially the radiation of interference signal towards horizon, space or far away victim on earth due to antenna side lobe attenuation. Regarding the device, transmit power control minimizes the radiation of the devices by reducing the transmit power level of devices experiencing lower path loss. When beamforming is utilized at both ends of the link, the radiated power level is optimized, with reduced transmit power needed for a given received signal quality requirement. By utilizing beamforming, the device also decreases the radiation of interference signal towards directions other than the main beam, which is likely to point upwards. It is likely that the higher the elevation angle of the device transmission towards the access point, the lower the power of the radiated signal, as the device is likely to be placed closer to the access point.

b. Suitable propagation models for sharing and compatibility studies

Propagation models for mmWave frequency range have been developed and continuously refined by academia and industry with the help of measurement results. These models such as the Close In (CI) and alpha-beta-gamma (ABG) free space reference distance models adopted by 3GPP are in general short distance models, with applicability range in the order of one kilometer distance. Additionally, these models do not provide time percentages for which a given propagation loss value is not exceeded, a fundamental aspect in some sharing and compatibility analysis for inter-service interference between terrestrial-based transmitters and receivers of different services. Other group such as ITU-R Study Group 3 (SG3) provides appropriate long-range propagation models for such sharing and compatibility analysis.

The long-range propagation loss models provided by SG3 include the following cases of interest for 5G:

Earth-space propagation: The Recommendation ITU-R P.619 provides methods or information to the appropriate Recommendations for predicting signal propagation losses for interfering signals between stations in space and stations on the surface of the Earth. The principal basic transmission loss mechanisms on interfering signal paths occur during clear-air conditions and may include in some cases, tropospheric and ionospheric scintillation, multipath, and mechanisms associated with signal path obstructions (clutter, diffraction over terrain, and building entry loss). Prediction methods for some of the loss mechanisms are reliable over narrower frequency ranges, and some of the loss mechanisms are not significant at certain frequency ranges. This Recommendation is being updated by SG3 in order to be applicable to the overall frequency range of 100 MHz to 100 GHz. However, some propagation mechanisms still have to be verified by measurements and/or updated to mmWave frequency range. This Recommendation provides methods to predict the propagation losses not exceeded for 0.001%-50% of the time. Guidance is given for single entry as well as multiple entry propagation losses in analyses that determine interfering signals, where correlations of temporal variability and location variability may be influential. If a cumulative distribution function of Earth-space basic transmission loss is needed, Recommendation ITU R P.618 could be consulted to determine basic transmission losses that are exceeded for percentages of time less than 50%.

Terrestrial-to-terrestrial propagation: Recommendation ITU-R P.452 provides prediction procedures for the evaluation of interference between stations on the surface of the Earth, including calculation of the line-of-sight, diffraction, tropospheric scatter, and ducting layer reflection effects for terrestrial systems. The models within Recommendation ITU-R P.452 are designed to calculate propagation losses not exceeded for time percentages over the range 0.001%-50%. It has been recognized that the current clutter loss model is not appropriate for the mmWave frequency range. Clutter loss refers to additional diffraction losses available to antennas which are imbedded in local ground clutter (buildings, vegetation, etc.). Currently, the maximum additional loss is 20 dB above 0.9 GHz, and progressively less at lower frequencies, down to 5 dB at 0.1 GHz. Several measurement data sets are being contributed to SG3 by academia and industry for the development of a new or modified clutter loss model applicable to the mmWave frequency range in urban environments. Substantially higher cluster loss has been observed by measurements in these conditions.

Building penetration loss: Although guidance on the effects of building materials and structures on radio-wave propagation are given in Recommendation ITU-R P.2040 and a compilation of measurement data relating to building entry loss is found in Report ITU-R P.2346, there is no general model for building entry (or exit) loss. For the assessment of these additional losses when interferer and victim are spatially separated by obstacles as walls, glass windows, wood, etc., typically one outdoors and other indoors, a new Recommendation is under development in SG3 for appropriate building entry loss model for mmWave frequency range.

SG3 is expected to provide mentioned updates and development of new or modified models for propagation loss mechanisms by March 2017, according to the ITU-R agenda towards WRC-19. Differently from short or medium range propagation loss models, the long-range models provided by SG3 do not contain mechanisms to consider and apply a probability of a communication link or a set of communication links being in line-of-sight (LOS) or non-line-of-sight (NLOS) condition. The probability of LOS or NLOS between interfering and interfered links proved to be critical to the study that Nokia did in 28 GHz.[21] However, this is considered out of the scope of SG3, since it is strongly dependent on deployment and system characteristics.

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[21] *See, supra,* note 18.

VIII. CONCLUSION

Consistent with these Comments, Nokia requests that the Commission adopt service rules for each of the bands proposed in the FNPRM and consider, on a band-by-band basis, the various sharing frameworks as discussed above to determine the best fit for each band. Further, Nokia continues to urge the Commission to also investigate mid-band (6 GHz to 24 GHz) and low-band (below 6 GHz) spectrum as critical pieces to the future of wireless networks.

Respectfully submitted,

Nokia

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APPENDIX

Appendix 1
Coexistence of Fixed Service and Mobile Service in the 70 and 80 GHz bands

Appendix 2
Measurements of 28 GHz FSS Earth Stations' Power Flux Density (PFD)