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April 21, 2016

VIA ELECTRONIC FILING

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

Re: ViaSat, Inc. Notice of *Ex Parte* Presentation; GN Docket No. 14-177; IB Docket Nos. 15-256 & 97-95; RM-11664; and WT Docket No. 10-112

Dear Ms. Dortch:

On April 19, 2016, Chris Murphy, Associate General Counsel, Regulatory Affairs, and Daryl Hunter, Senior Director, Regulatory Affairs of ViaSat, Inc. ("ViaSat"), and ViaSat's counsel, John Janka and Elizabeth Park of Latham & Watkins LLP, met with the Commission staff listed below.

This *ex parte* submission provides notice of the meeting, responds to questions raised at the meeting, and includes additional technical analysis with respect to certain sharing issues discussed at the meeting.

During the meeting, ViaSat focused on its four-pronged approach to sharing between FSS satellite operations and 5G.

As a threshold matter, ViaSat's sharing approach is premised on Chairman Wheeler's direction to the satellite and wireless industries to work cooperatively to ensure that the critical spectrum resources being examined in this proceeding can be used efficiently and intensively by both industries. Notably, in his remarks at the Spectrum Frontiers Workshop held on March 10, 2016, Chairman Wheeler described sharing between satellite and terrestrial wireless as being "a two-way street," and expressed "hope that the satellite industry and the mobile industry would get together and work on how they can coexist because the future of spectrum in the 21st century is a future of sharing" and that "there are expectations on the mobile industry to meet the satellite interests in a fair and open and equal manner."[1] Indeed, spectrum sharing requires cooperation

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[1] *See* Remarks of Chairman Wheeler, Spectrum Frontiers Workshop, FCC, Washington, DC, Mar. 10, 2016, *video recording available at* https://www.fcc.gov/news-events/events/2016/03/spectrum-frontiers-workshop.

by all parties to ensure room for all authorized services to operate and grow as technology and services evolve.

Regarding the 27.5-28.35 GHz portion of the Ka band ("28 GHz Band"), ViaSat explained that its approach to sharing includes three elements: (i) protecting satellite receivers from aggregate 5G transmissions; (ii) facilitating deployment of individually-licensed earth stations on a co-primary basis along with 5G deployment; and (iii) facilitating deployment of blanket-licensed satellite user terminals on a secondary basis, also along with 5G deployment. Regarding the 37.5-40 GHz Band, ViaSat explained its proposal to maintain the co-primary allocation for satellite downlinks in the entirety of the 37.5-40 GHz band. The discussion of each of these elements, as well as some additional analysis provided in this submission, is outlined below.

- **Protecting Satellite Receivers**

The issue of protecting satellite receivers from 5G emissions was identified in the NPRM and was specifically addressed during the comment cycle.[2] In particular, ViaSat explained that "suitable 5G operating parameters will need to be developed to ensure the compatibility of 5G services with satellite operations in the 28 GHz Band,"[3] and ViaSat also provided a preliminary technical assessment of the impact on satellite receivers of one possible 5G deployment scenario. Under that scenario, 5G transmitters were assumed to operate at power levels of 30 dBm, 43 dBm and 82 dBm, which reflected both the power level on which comment was sought in the NPRM, and a power level advocated by certain commenters.[4] ViaSat identified satellite receiver protection and the appropriate aggregate power limits for 5G in the 28 GHz Band as issues requiring further evaluation in this proceeding.

In the meeting, ViaSat provided an overview of the further technical analysis included as <u>Attachment 1</u> to this letter, which details the protection levels needed to ensure the operation of a number of spacecraft, including those licensed to ViaSat. Included with the electronic filing of this submission is an Excel spreadsheet containing this data, which allows the calculation to be modified for alternative assumptions for the 5G operations (*e.g.*, changes to the assumed 5G transmitter power level, gain reduction toward the GSO arc).

In order to protect satellite receivers from 5G interference, ViaSat explained that it would be necessary to develop a limit on the aggregate power density received by satellites from all 5G

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2 *See Use of Spectrum Radio Bands Above 24 GHz for Mobile Radio Services*, GN Docket No. 14-177, *et al.*, Notice of Proposed Rulemaking, FCC 15-138 ¶¶ 297-99 (rel. Oct. 23, 2015) ("*NPRM*"); *see also* Reply of the EMEA Satellite Operators Association, GN Docket No. 14-177, *et al.* at 4, Annex (filed Feb. 26, 2016) (urging the Commission to examine and develop a full understanding of the potential impact of 5G on satellite receivers and to address such issues in workable operating rules for 5G).

3 *See* Reply Comments of ViaSat, Inc., GN Docket No. 14-177, *et al*., at 22 (filed Feb. 26, 2016) ("ViaSat Reply Comments").

4 *See id*. at Exhibit 1.

transmitters, and then apportion that limit among the various 5G licensees. ViaSat believes this can be done in a manner that provides the 5G operators with significant latitude in how they design and operate their networks while still satisfying the limit.

ViaSat was asked as a follow up to comment on the relevance to satellite receiver protection of information and analyses submitted by Samsung before the NPRM was issued.[5] Notably, Samsung's analysis addressed only the impact of out-of-band 5G emissions into satellite receivers. Samsung did not analyze the impact of 5G operating in the same frequency band as a satellite receiver.

- **Facilitating Deployment of Individually-Licensed Earth Stations**

During the meeting, ViaSat discussed the need to accommodate individually-licensed satellite earth stations in the 28 GHz band, on a co-primary basis, both before and after the auction for terrestrial wireless licenses. Specifically, we discussed the need to accommodate the deployment of critical satellite gateway-type earth stations, such as ViaSat's aggregation and interconnection facilities ("AIF"). ViaSat explained the basis for its conclusion that 5G service would likely be compatible with ViaSat's AIF facilities outside a tear-drop shaped zone that extends no more than about 170 meters from the front of those facilities.[6] ViaSat explained that its earth stations would provide significant gain discrimination toward the horizon, and urged that in establishing such compatibility zones around individually-licensed earth station facilities actual operating parameters of earth stations be considered, and not theoretical antenna patterns under Section 25.209 of the Commission's rules.

Attachment 2 to this letter provides a more detailed assessment of the EIRP density toward the horizon for ViaSat's AIF earth stations, and further illustrates the maximum size of the 5G compatibility zone in the case of those facilities.[7]

ViaSat discussed the expectation that 5G deployment will occur in a manner that is focused on densely populated areas and/or in places where large numbers of people regularly congregate. For example, even inside "urban cores," there are likely to be large numbers of pockets that will not be part of a 5G base station coverage area. As the attached analysis illustrates, the small size of the compatibility zones would enable deployment of such earth

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5 *See* Letter from Robert Kubik, Samsung, to Marlene H. Dortch, FCC, *Use of Spectrum Bands Above 24 GHz for Mobile Radio Services*; GN Docket No. 14-177; Written *Ex Parte* Communication, at Appendix (Aug. 28, 2015) (identifying anticipated parameters for 5G operations); Comments of Samsung Electronics America, Inc. and Samsung Research America, GN Docket No. 14-177, RM-11664, at 42, Appendix D (filed Jan. 15, 2015) (providing a compatibility study between 5G and FSS in bands adjacent to the 28 GHz Band, but not for co-frequency operations within the LMDS Band).

6 *See* Comments of ViaSat, Inc., GN Docket No. 14-177, *et al.*, at 16 (filed Jan. 28, 2016).

7 This analysis is based on a power flux density, measured at ground level of -106 dBW/m^{2}*MHz, which is the equivalent of a 5G protection criteria of 47 dBuV/m per 5.5 MHz channel—a value on which comment was sought in the NPRM. *See NPRM* ¶ 290.

station facilities even within “urban cores” within these pockets where 5G base stations are unlikely to be deployed.

- **Facilitating Blanket-Licensed Satellite User Terminals on a Secondary Basis**

During the meeting, ViaSat discussed the realistic potential for accommodating satellite user terminals on a secondary basis in a manner that protects and does not impede 5G deployment. Allowing satellite user terminals on a secondary, non-interference basis would facilitate more intensive use of spectrum by allowing satellite earth station operators to “work around” 5G deployments. In the vast majority of the geographic area of the United States, 5G deployment is unlikely to occur. And, as discussed above, there are likely to be pockets in major metropolitan areas where 5G base stations are not located. Thus, by employing a mechanism that would allow satellite earth station operators to determine whether spectrum is being used by 5G operators in a particular location at any given time, satellite user terminals may successfully be operated on a secondary, non-interference basis with respect to 5G services.

- **Maintaining Satellite Access to the V Band**

ViaSat also discussed the position of ViaSat and other satellite operators that access to the 37.5-40 GHz portion of the V band is critical to meeting burgeoning consumer demands for satellite-based broadband services. The Commission currently provides co-primary status for satellite gateway-type earth stations in the 37.5-40 GHz.

ViaSat discussed its proposal that satellite operators retain their current access to the entire 37.5-40 GHz band on a co-primary basis with terrestrial services. The current pfd limits should not impair 5G deployment, nor would the Commission’s proposal to allow downlink operations at higher pdf levels to overcome attenuation due to heavy rain.[8]

- **Continuing Discussions among Satellite and Wireless Industries**

ViaSat explained that the satellite industry and the wireless industry continue to work closely on technical analyses that are needed to develop successful sharing mechanisms, and that modeling and additional important information is expected from the wireless industry in the near term. ViaSat believes that these technical details are critical and remains committed to working on approaches that enable the deployment of 5G while also enabling the continued deployment of satellite services.

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[8] *See NPRM* ¶ 160.

Please contact the undersigned if you have any questions.

Respectfully submitted,

/s/

John P. Janka
Elizabeth R. Park

Attachments

cc: Brian Regan, WTB
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Attachment 1

The following documents the derivation of protection criteria for satellite receivers and also reviews some example 5G UE EIRP scenarios for potential impact to satellite receivers.

Table 1 shows the relevant values and the following text describes the derivation of each row entry.

Frequency	28000	MHz					
Lambda	0.01071	m					
Meter square area gain	50.393	dB/(m^2)					
	Satellite Receiver Protection Values						
Satellite	VS 1st Gen	VS 2nd Gen	VS 3rd Gen	Jupiter-97W	Inmarsat-5-F3		
Total receiving noise temperature	1349.0	1050.0	650.0	1259.0	1047.0	K	
Noise floor (No) at receiver input	-197.301	-198.389	-200.472	-197.601	-198.402	dBW/Hz	
Delta T/T protection criteria	6	6	6	6	6	%	
Equivalent I/N	-12.218	-12.218	-12.218	-12.218	-12.218	dB	
Max interference (Io) at input to meet prot criteria	-209.520	-210.608	-212.691	-209.819	-210.620	dBW/Hz	
Satellite antenna gain	53	61	61	56.9	44.2	dBi	
Interference (Io) level at antenna input	-262.520	-271.608	-273.691	-266.719	-254.820	dBW/Hz	
Meter square area gain	50.393	50.393	50.393	50.393	50.393	dB/(m^2)	
Equivalent power flux density at GSO	-152.127	-161.215	-163.298	-156.327	-144.427	dBW/(m^2*MHz)	
Spreading loss to mid CONUS	162.636	162.636	162.636	162.636	162.636	dB(m^2)	
Equivalent EIRP density at ground level	10.509	1.421	-0.662	6.309	18.208	dBW/MHz	

Table 1 Satellite Protection Criteria

- **Frequency**: Operating frequency in MHz
- **Lambda (λ)**: The wavelength in meters at the operating frequency
- **Meter squared area gain:** gain of 1 m^2 area at operating frequency, i.e., $10 \log(4*\pi/\lambda^2)$
- **Satellite:** Name or class of referenced satellite
- **Total receiving noise temperature:** The effective receive noise temperature T_e of the satellite in kelvin (K)
- **Noise floor (N_O) at receiver input:** Thermal noise at receiver, i.e., kT_eB
- **Delta T/T protection criteria**: The allowable rise over thermal due to other systems with co-primary status (ITU-R S.1432-1 *recommends* 4)
- **Equivalent I/N:** The 6% delta T/T criteria in dB form, i.e., $10^{(\text{“delta T/T”}/10)}$
- **Max interference (I_O) at receiver:** The maximum allowable interference density I_O that will meet the 6% delta T/T protection criteria
- **Satellite antenna gain:** The measured gain of the satellite receiving antenna relative to an isotropic source
- **Interference (I_O) level at antenna input**: The I_O at the satellite receiver minus the gain of the satellite receiving antenna
- **Equivalent power flux density at GSO**: The I_O at antenna input plus the meter squared area gain referenced to a one MHz bandwidth
- **Spreading loss to mid CONUS**: The spreading loss assuming a satellite longitude near CONUS to a central CONUS location, i.e., $10 \log(4*\pi*r^2)$. This value is equal to the path loss minus the meter squared area gain.

- **Equivalent EIRP density at ground level**: Equivalent isotropically radiated power in a one MHz reference bandwidth (does not include atmospheric losses)

Reviewing the list of satellites, it can be seen that the ViaSat 3rd generation satellite has the lowest total receiving noise temperature of 650 K and the highest receiving antenna gain. The allowable aggregate power flux density from all other systems having co-primary status arriving at the GSO orbital location that protects the satellite in accordance with ITU Radio Regulations Appendix 8 and ITU-R Recommendation S.1432-1 is -163.3 dBW/(m^2*MHz).

An evaluation of the potential impact from 5G UE to victim satellite receivers is performed for two scenarios, one where UE equipment transmits at an EIRP of 23 dBm/100 MHz and one at an EIRP of 43 dBm/100 MHz. These two example scenarios do not include the aggregating effect of transmissions from 5G base stations which is expected to be a significant contributor in its own right.

The density of UE deployment in users per km^2 and total area in km^2 of the satellite's receiving beam are important inputs to the evaluation. The UE EIRP and off-axis gain reduction toward the GSO as well as an estimate of the linear to circular polarization coupling loss are additional inputs.

In the first example in Table 2 below, the assumed UE density is 1 UE per km^2 transmitting co-frequency and co-time. The expected density in urban areas is much higher, but it is likewise assumed deployment in rural areas will be lower, so this value represents an estimate of the average over the satellite's receiving beam area. The number of UEs transmitting in this case matches the number of square kilometers in the beam.

The individual 5G UE on-axis EIRP density in dBm per 100 MHz is converted to a dBW/Hz value and the off-axis gain reduction toward the GSO is subtracted from that value and then the total power of all 5G UE transmitters is aggregated by adding 10 times the log of the number of all UEs transmitting in the beam. The aggregate power of the 5G UE transmissions at the satellite receiver is then determined by subtracting the spreading loss and the meter squared antenna gain, adding the satellite receiving antenna gain, and subtracting the linear to circular polarization loss. The satellite's noise value N_O is subtracted from the resulting I_O value yielding the I/N ratio. The delta T/T is calculated by $10^{((I/N)/10)} * 100$.

	5G UE Impact To Satellite Receiver (BS not included)					
UEs transmitting per km^2	1	1	1	1	1	
Beam area	123816	31000	31000	35640	412442	km^2
UEs transmitting co-frequency in beam	123816	31000	31000	35640	412442	
Individual 5G UE on-axis EIRP density	23	23	23	23	23	dBm/100 MHz
Individual 5G UE on-axis EIRP density	-87	-87	-87	-87	-87	dBW/Hz
Off-axis gain reduction toward GSO	6	6	6	6	6	dB
Aggregate 5G EIRP density to GSO in beam area	-42.072	-48.086	-48.086	-47.481	-36.846	dBW/Hz
Spreading loss from mid CONUS	162.636	162.636	162.636	162.636	162.636	dB(m^2)
Equivalent power flux density at GSO	-204.708	-210.722	-210.722	-210.116	-199.482	dBW/(m^2*Hz)
Interference density (Io) at antenna input	-255.101	-261.115	-261.115	-260.509	-249.875	dBW/Hz
Linear to circular polarization loss	3	3	3	3	3	dB
Interference (Io) at receiver input	-205.101	-203.115	-203.115	-206.609	-208.675	dBW/Hz
I/N	-7.800	-4.726	-2.643	-9.008	-10.273	dB
Delta T/T	16.596	33.684	54.413	12.565	9.390	%
Noise floor impact	0.667	1.261	1.887	0.514	0.390	dB

Table 2 5G UE Impact to Satellite Receiver at 23 dBm/100 MHz EIRP

Lastly, the impact to the satellite's noise floor in dB form is calculated as -10 * log(1 / (1 + $10^{((I/N)/10)}$)). In this first scenario, each of the satellites receive greater interference than the interference criteria given in ITU Radio Regulations Appendix 8 and ITU-R Recommendation S.1432-1.

The second scenario in Table 3 below follows the same steps but changes only the 5G UE EIRP density to 43 dBm/100 MHz.

	5G UE Impact To Satellite Receiver (BS not included)					
UEs transmitting per km^2	1	1	1	1	1	
Beam area	123816	31000	31000	35640	412442	km^2
UEs transmitting co-frequency in beam	123816	31000	31000	35640	412442	
Individual 5G UE on-axis EIRP density	43	43	43	43	43	dBm/100 MHz
Individual 5G UE on-axis EIRP density	-67	-67	-67	-67	-67	dBW/Hz
Off-axis gain reduction toward GSO	6	6	6	6	6	dB
Aggregate 5G EIRP density to GSO in beam area	-22.072	-28.086	-28.086	-27.481	-16.846	dBW/Hz
Spreading loss from mid CONUS	162.636	162.636	162.636	162.636	162.636	dB(m^2)
Equivalent power flux density at GSO	-184.708	-190.722	-190.722	-190.116	-179.482	dBW/(m^2*Hz)
Interference density (Io) at antenna input	-235.101	-241.115	-241.115	-240.509	-229.875	dBW/Hz
Linear to circular polarization loss	3	3	3	3	3	dB
Interference (Io) at receiver input	-185.101	-183.115	-183.115	-186.609	-188.675	dBW/Hz
I/N	12.200	15.274	17.357	10.992	9.727	dB
Delta T/T	1659.647	3368.397	5441.256	1256.501	939.003	%
Noise floor impact	12.454	15.401	17.436	11.324	10.166	dB

Table 3 5G UE Impact to Satellite Receiver at 43 dBm/100 MHz EIRP

The results indicate that the interference criteria are exceeded significantly – 5441% delta T/T versus the allowed 6% and a noise floor impact of 17.4 dB versus the 0.25 dB allowed by the ITU Radio Regulations and ITU-R Recommendations.

Importantly, the above analysis only considers the 5G UE transmitters and does not include the 5G base stations, which must be taken into account. ViaSat plans to update this analysis to include the 5G base stations when the characteristics are available from the 5G community.

Attachment 2

Analysis of EIRP density toward the horizon for ViaSat site licensed aggregation and interconnection facilities (AIF).

ViaSat employs or plans to employ principally three different size classes for its AIF stations. Our first generation HCS satellite uses 7.3 m antennas for its AIFs. The second generation HCS will use 4.1 m antennas. The third generation HCS will use 1.8 m antennas for its AIFs.

Each of these antenna classes offer significant gain discrimination toward the horizon when operated at the typical 35 degree elevation angle. The discrimination used in ViaSat's earlier analysis was 79.75 dB, 74.4 dB, and 63.0 dB for the 7.3 m, 4.1 m, and 1.8 m antennas respectively. This is based on actual antenna pattern data – see attached plots.

Table 1 shows the relevant values and the following text describes the derivation of each row entry.

HCS Class	1st Gen	2nd Gen	3rd Gen	
Antenna Diameter	7.3	4.1	1.8	m
Antenna Gain	65.3	59.6	51.0	dB(i)
EIRP	74.0	66.0	65.0	dB(W)
Modulated Spectrum	1500.0	2000.0	2000.0	MHz
Antenna Input Density	-23.061	-26.610	-19.031	dB(W/MHz)
EIRP Density	18.260	9.010	7.979	dB(W/4 kHz)
EIRP Density	42.239	32.990	31.959	dB(W/MHz)
Antenna Disc toward Horizon	79.750	74.400	63.000	dB
Density toward Horizon	-37.511	-41.410	-31.041	dB(W/MHz)
Additional losses toward victim	10.000	10.000	20.000	dB
Gain of m^2 area (28.35 GHz)	50.501	50.501	50.501	dB(m^2)
Boundary Limit per 5.5 MHz	47.167	47.167	47.167	dB(uV/m)/5.5 MHz
Boundary Limit per MHz	39.763	39.763	39.763	dB(uV/m)/MHz
Boundary Limit in flux density	-106.000	-106.000	-106.000	dB(W/(m^2/MHz))
Boundary Limit in pwr density	-156.501	-156.501	-156.501	dB(W/MHz)
Needed attenuation	108.990	105.090	105.459	dB
Required distance	237.1	151.3	157.9	m

- **Antenna Diameter**: based on physical dimensions of the reflector
- **Antenna Gain:** measured performance value
- **EIRP:** product of antenna gain and operating point of power amplifier (PA)
- **Modulated Spectrum**: the total of the modulated uplink spectrum through the PA
- **Antenna input density:** the power of the modulated spectrum as applied to the antenna input
- **EIRP density:** the EIRP divided by the bandwidth of the modulated spectrum
- **Antenna Disc toward Horizon:** the measured gain reduction at 35 degrees below boresight

- **Density toward Horizon**: EIRP density divided by the gain reduction toward the horizon
- **Additional losses toward victim**: estimates of attenuation due to ground clutter or other blockage
- **Gain of m^2 area**: standard (4*PI)/lambda^2 formula
- **Boundary limit per 5.5 MHz**: 47 dBuV field strength as proposed by FCC
- **Boundary limit per MHz**: above value divided by 5.5
- **Boundary limit in flux density**: conversion per FD = E^2/377 formula
- **Boundary limit in power density**: flux density limit divided by m^2 area gain
- **Needed attenuation**: density toward horizon divided by additional losses, divided by boundary limit in power density
- **Required distance**: square root of ((density toward horizon divided by additional losses divided by boundary limit in flux density) divided by (four times PI))