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March 23, 2018

VIA ELECTRONIC FILING

Ms. Marlene H. Dortch
Secretary
Federal Communications Commission
445 12th Street, S.W.
Washington, D.C. 20554

Re: Viasat, Inc. *Ex Parte* Submission, IB Docket No. 17-95

Dear Ms. Dortch:

Viasat, Inc. (“Viasat”) submits the attached analysis demonstrating that ESIMs operating in the 28.35-28.6 GHz band segment would not cause unacceptable interference to terrestrial wireless systems operating in the adjacent 27.5-28.35 GHz band, and that the existing Section 25.202(f) limits for out-of-band emissions are sufficient to protect adjacent band operations. This analysis supplements Viasat’s reply comments and its *ex parte* submission filed on February 5, 2018 in this proceeding,¹ to provide more specific information discussed in paragraph 55 of the Notice of Proposed Rulemaking.²

If you have any questions regarding this submission, please contact the undersigned.

Respectfully submitted,

/s/

John P. Janka
Elizabeth R. Park

¹ See Reply Comments of Viasat, Inc., IB Docket No. 17-95, at 13-14 (filed Aug. 30, 2017); Viasat, Inc., Notice of *Ex Parte* Presentation, IB Docket No. 17-95, at 5-10 (filed Feb. 5, 2018).

² See *Amendment of Parts 2 and 25 of the Commission’s Rules to Facilitate the Use of Earth stations in Motion Communicating with Geostationary Orbit Space Stations in Frequency Bands Allocated to the Fixed Satellite Service*, IB Docket No. 17-95, Notice of Proposed Rulemaking, FCC 17-56, ¶ 55 (rel. May 19, 2017).

LATHAM & WATKINS^{LLP}

Attachment

cc: Jose Albuquerque
Chip Fleming
Kathryn Medley
Diane Garfield
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Cindy Spiers
Paul Blais
Michael Mullinix

L-ESIM vs 5G Out-of-band Interference Analysis

This analysis demonstrates that an earth station in motion (ESIM) operating at the lower end of the 28.35-28.6 GHz band with emissions complying with the FCC's 25.202(f) out-of-band emissions (OOBE) mask does not cause unacceptable interference to 5G systems operating at the upper edge of the adjacent 27.5-28.35 GHz band.

More specifically, this analysis considers a land-based ESIM (L-ESIM) operating at the lower end of the 28.35-28.6 GHz GSO FSS band in close proximity to a 5G network operating at the upper edge of the 27.5-28.35 GHz band. Use of an L-ESIM versus an aeronautical ESIM (A-ESIM) or maritime ESIM (M-ESIM) represents a more likely worse-case scenario, as the L-ESIMs can operate in closer proximity to 5G base stations (BS), and also because the operational antenna height of the L-ESIM is lower than that of the A-ESIM and M-ESIM and closer to the height of 5G end user terminals (UE) and is more likely to result in the 5G BS antenna pointing toward the L-ESIM than in the case of either the A-ESIM or M-ESIM. Further, access near A-ESIMs is generally restricted in airports resulting in very few outdoor 5G end-users near the A-ESIM. The results show that for even the worst-case link, -6 dB I/N of protection is provided more than 99.98% of the time for the L-ESIM carrier closest to the band edge. As carriers higher in frequency further from the band edge are considered, this level of protection is met for more than 99.99% percent of time.

The simulation for the analysis was developed using the Visualyse Pro interference analysis software available from Transfinite Systems, Ltd, which implements methods and formulae found in "*INTERFERENCE ANALYSIS, Modeling Radio Systems For Spectrum Management*" by John Pahl.¹ The Visualyse software provides facilities for generating dynamic scenarios and capturing statistics as the simulation runs and for performing Monte Carlo operations at each time step of the simulation.

Use of a dynamic and statistical approach to model the interaction of the L-ESIM and the 5G network, both dynamic systems, is supported by various submissions from Intel, Samsung, and CTIA in the Spectrum Frontiers proceeding:²

- "The methodology chosen to model coexistence must properly reflect the dynamic nature of these systems."

¹ "Interference Analysis, Modeling Radio Systems For Spectrum Management", by John Pahl, © 2016 John Wiley & Sons, Ltd.

² See CTIA Ex Parte, GN Docket No. 14-177 at 2 (filed June 9, 2016) ("The Commission should reject use of any static or beyond worst-case modeling suggested by the FSS industry as overly conservative and inconsistent with real-world effects."); Samsung NPRM Comments at 22 (describing compatibility study finding that a mobile base station does not cause significant interference to space station FSS). See also Intel Ex Parte, GN Docket No. 14-177 (filed May 24, 2016) ("The methodology chosen to model coexistence must properly reflect the dynamic nature of these systems.").

- “The Commission should reject use of any static or beyond worst-case modeling . . . as overly conservative and inconsistent with real-world effects.”

Accordingly, this Viasat analysis uses a statistical approach including Monte Carlo simulations and dynamic movement of stations, both 5G and ESIM, as well as realistic emission mask data for the ESIM. The simulation, run in Visualyse, produces statistics for the frequency with which a given I/N value was observed over the simulation period. During the simulation, the L-ESIM is moved continuously around a typical 5G base station and user population while I/N calculations and associated statistics are accumulated over the duration of the simulation run.

In contrast, a prior submission in the reply comments of the Global Mobile Suppliers Association (GSA) on August 30, 2017³ provided a static analysis that was based on unrealistic worst-case assumptions and modeling. GSA’s reliance on a deterministic method, rather than dynamic scenarios, is contrary to the approach supported by its own members, as discussed above. Further, the static GSA analysis used worst-case or beyond worst-case antenna elevation angles and main beam alignments and also used an unrealistically wide integration range for its consideration of the spectral masks which contributed to the infinite frequency separation results reported. Moreover, figures 2 and 3 of the GSA analysis inexplicably show the 5G receive adjacent channel selectivity (ACS) mask passband centered at 28.5 GHz, which is 150 MHz above the end of the UMFUS band and well into the GSO FSS band where 5G should not be operating.

In the Viasat analysis, to calculate the effects of out-of-band emissions (OOBE) from the ESIM, an emissions mask needs to be defined for use in Visualyse. Likewise, a notional carrier channel plan is needed to establish the adjacency of the 5G and FSS satellite networks.

While nominal carrier spacing for many satellite networks is in the range of 1.2 to 1.3 times the carrier symbol rate (see Figure 1), the Viasat Afterburner modems operate at a lower spacing of 1.125 times the carrier symbol rate.

³ Reply Comments of Global Mobile Suppliers Association, IB Docket No. 17-95 (filed Aug. 30, 2017).

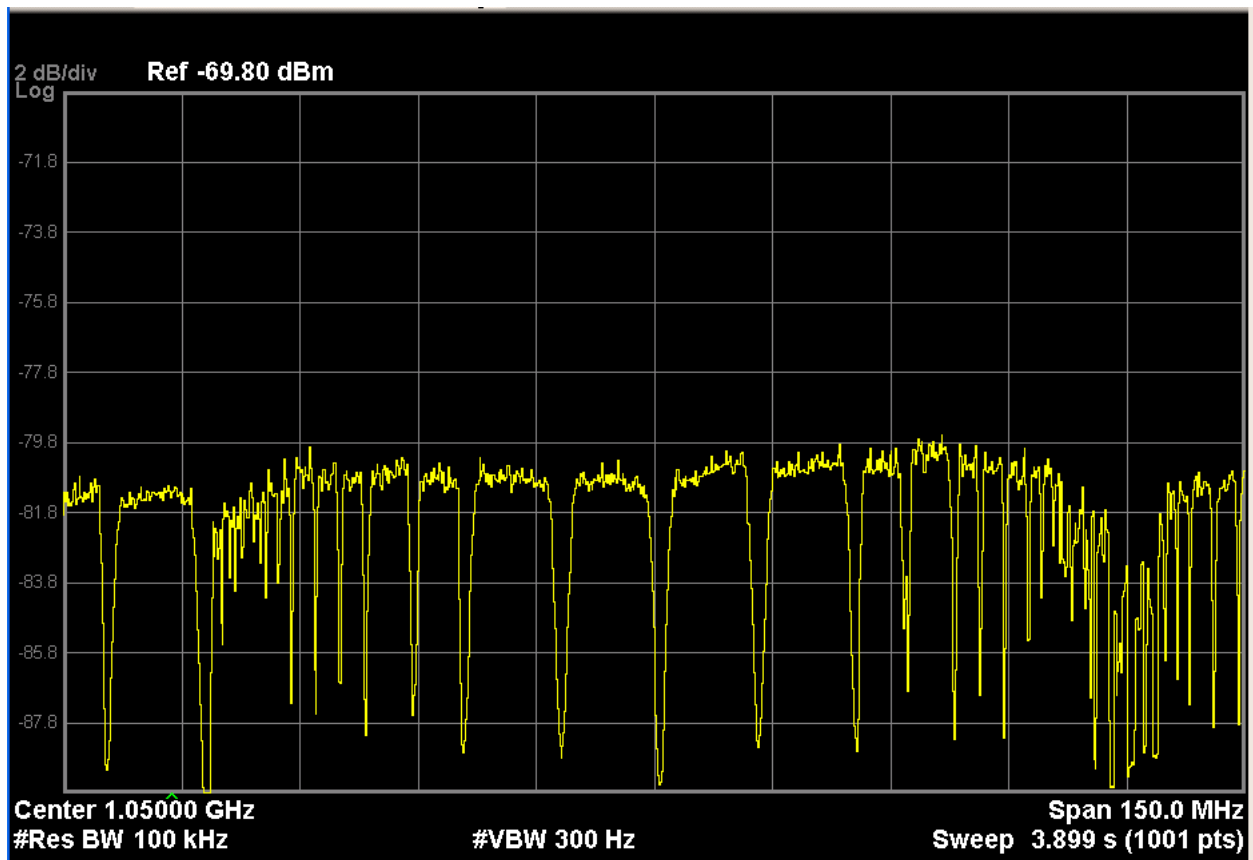


Figure 1, Capture of operational downlink carriers on WildBlue-1 from ESIM and FSS earth stations

Figure 2 is a simulated plot two typical Afterburner modem operating at 160 MBd and at the nominal 1.125 times the symbol rate spacing.

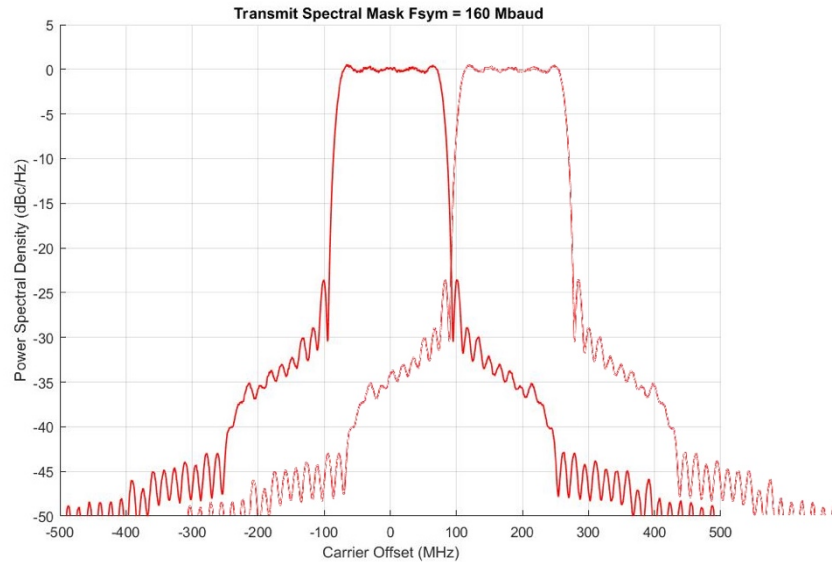


Figure 2, Simulation of typical Afterburner modems operating at nominal carrier spacing.

From Figures 1 and 2 it can be seen that in normal operation the FSS earth station equipment functions as desired with channels assigned immediately to either side in very close spacing with some OOBE energy from the adjacent channel falling inside the desired carrier's receiver passband. As this energy is 25 to 30 dB reduced in amplitude from the desired carrier, it results in a small, but manageable, reduction of the total $C/(N+I)$.

A representative spectral mask was created for the various Afterburner operational symbol rates, as well as for the 5G system. The operating characteristics of the ESIM are summarized in Table 1.

Table 1, ESIM parameters

Parameter	Unit	Value
Frequency range	GHz	28.35-28.6
Carrier symbol rates	MBd	5 – 320, in x2 steps
20 dB Carrier bandwidth	MHz	1.142 x symbol rate
Channel spacing	MHz	1.125 x symbol rate
Antenna input power	W	25

Parameter	Unit	Value
Antenna type	–	Elliptical
Antenna beamwidth (major, minor) axis	°	0.95 x 6.7
Peak transmit antenna gain	dBi	40.5
Antenna gain pattern	–	Bessel
Antenna polarization	–	Circular
Nominal antenna elevation angle	°	44.3
Antenna height	M	2.0

The development of the 5G IMT simulation and the characteristics of the 5G equipment are based on technical notes from Transfinite,⁴ and from filings in the Spectrum Frontiers proceeding. The relevant characteristics are given in Table 2.

Table 2, 5G system parameters

Parameter	Unit	Value (BS)	Value (UE)
Frequency range	GHz	27.5-28.35	27.5-28.35
Carrier bandwidth	MHz	60	60
Channel spacing	MHz	60	60
Adjacent Channel Selectivity (ACS) (first adjacent)	dB	24	23
Noise Figure	dB	6.5	6.5
Antenna type	–	Visualyse IMT-Model 28 GHz BS	Visualyse IMT-Model 28 GHz UE
Peak transmit antenna gain	dBi	28.78	11.95
Antenna polarization	–	Linear	Linear
Antenna down-tilt angle (mechanical)	°	-10	+90 to -90
Antenna azimuth angle (mechanical)	°	0, 120, -120	+60 to -60
Antenna height	M	10.0	1.5
I/N Protection criterion	dB	-6	-6

⁴ Technical Notes: “Building a 5G Network in Visualyse Professional”, and “Building a 5G Reference System in Visualyse Professional”. See: <https://www.transfinite.com/content/downloadsvisualyse>

Based on these system characteristics for the ESIM and the 5G system, the notional channel allocation plan was set up in Excel. Figures 3 and 4 show the channel plan for the 5G system and adjacent ESIM channels using symbol rates of 5 MBd, 10 MBd, 20 MBd, 40 MBd, 80 MBd, 160 MBd, and 320 MBd.

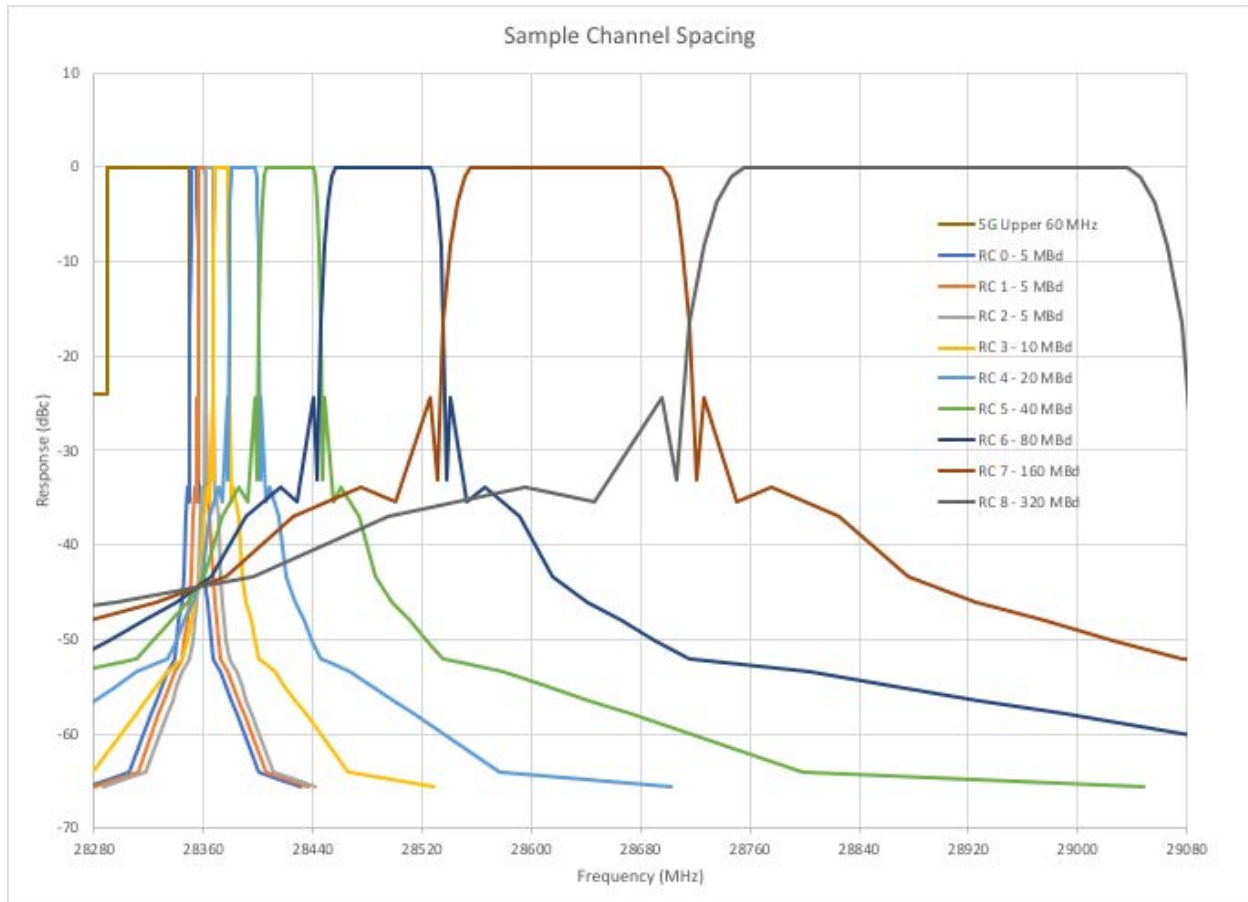


Figure 3, Notional channel plan

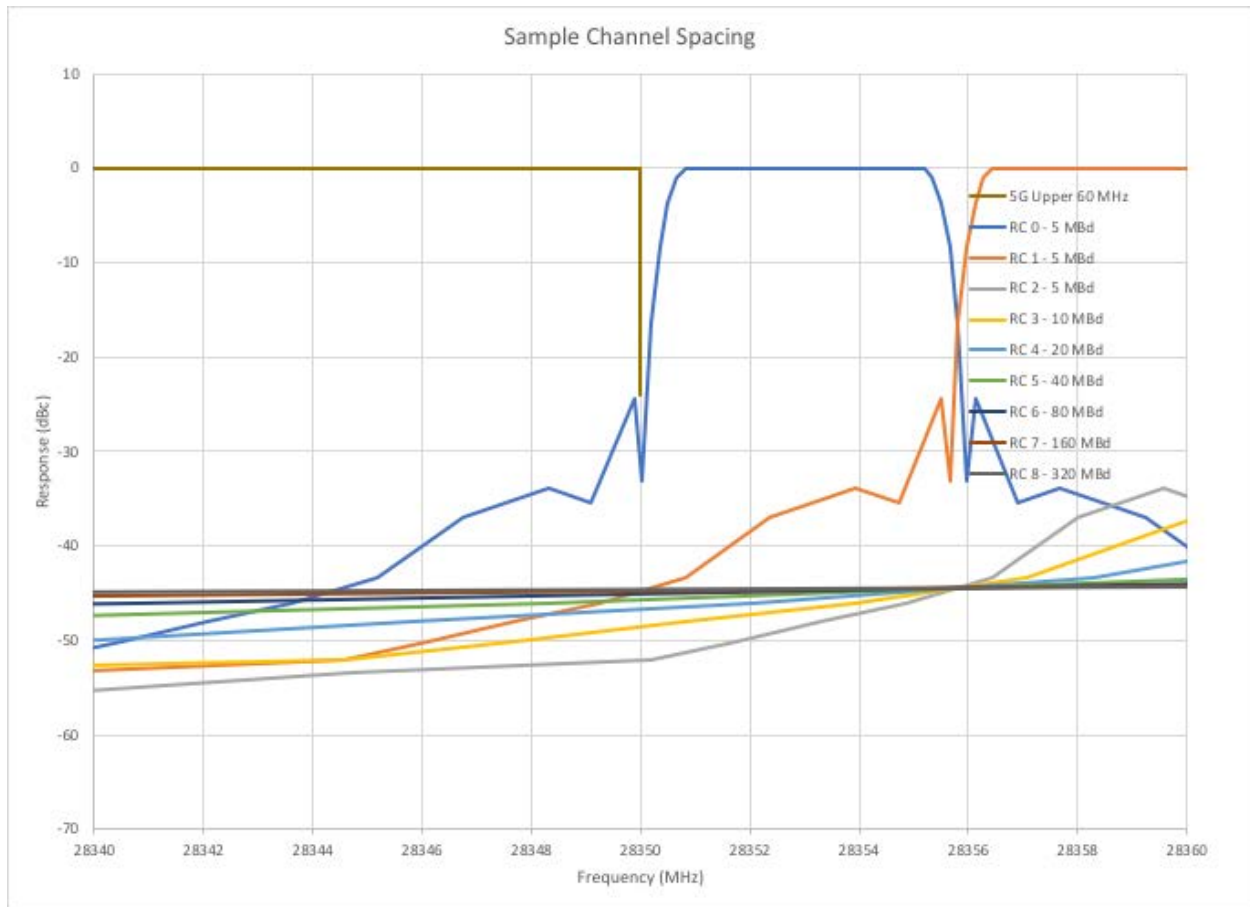


Figure 4, Zoom view of channel plan near band edge

Figures 5 and 6 show the spectral masks as implemented in Visualyse of the upper 60 MHz 5G channel centered at 28319 MHz compared with ESIM return channel 0 (5 MBd) centered at 28353 MHz and ESIM return channel 7 (160 MBd) centered at 28625.8125 MHz respectively. The figures show that while some overlap of the 5G and ESIM masks exists, in most of the 5G receiver passband the OOB from the ESIM is more than 40 dB attenuated from the peak of the ESIM carrier.

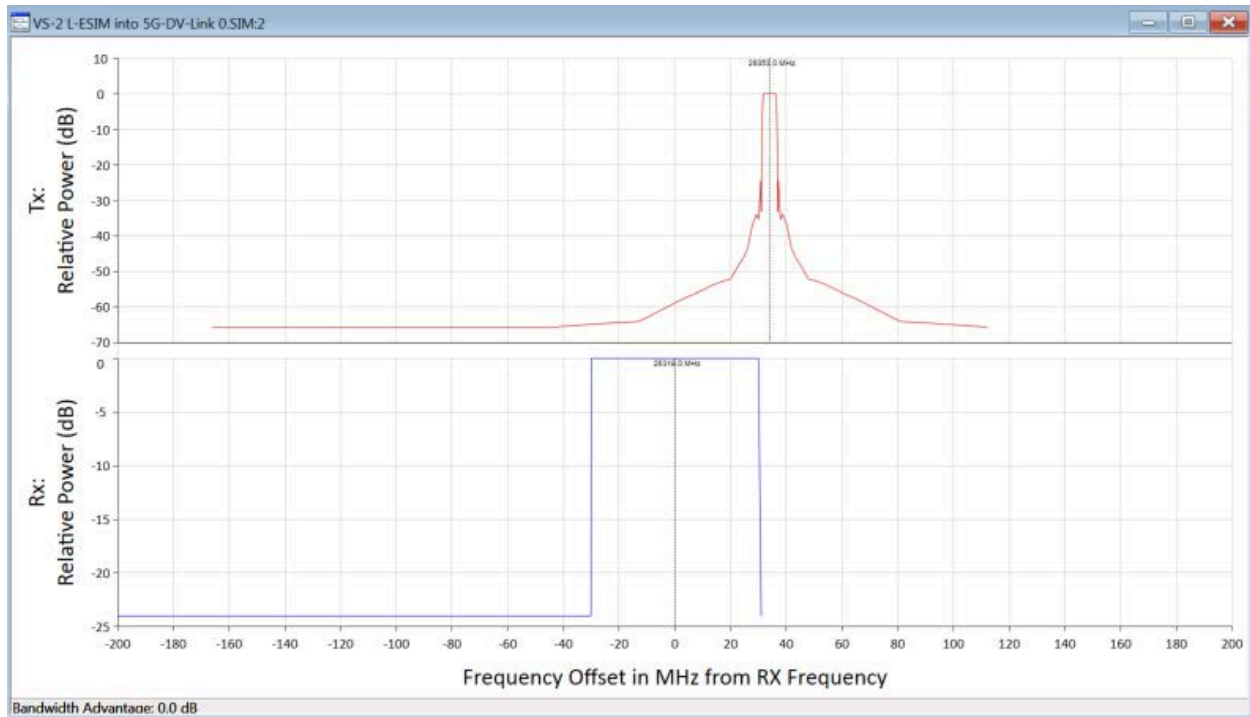


Figure 5, 5G and ESIM return channel 0 filter masks

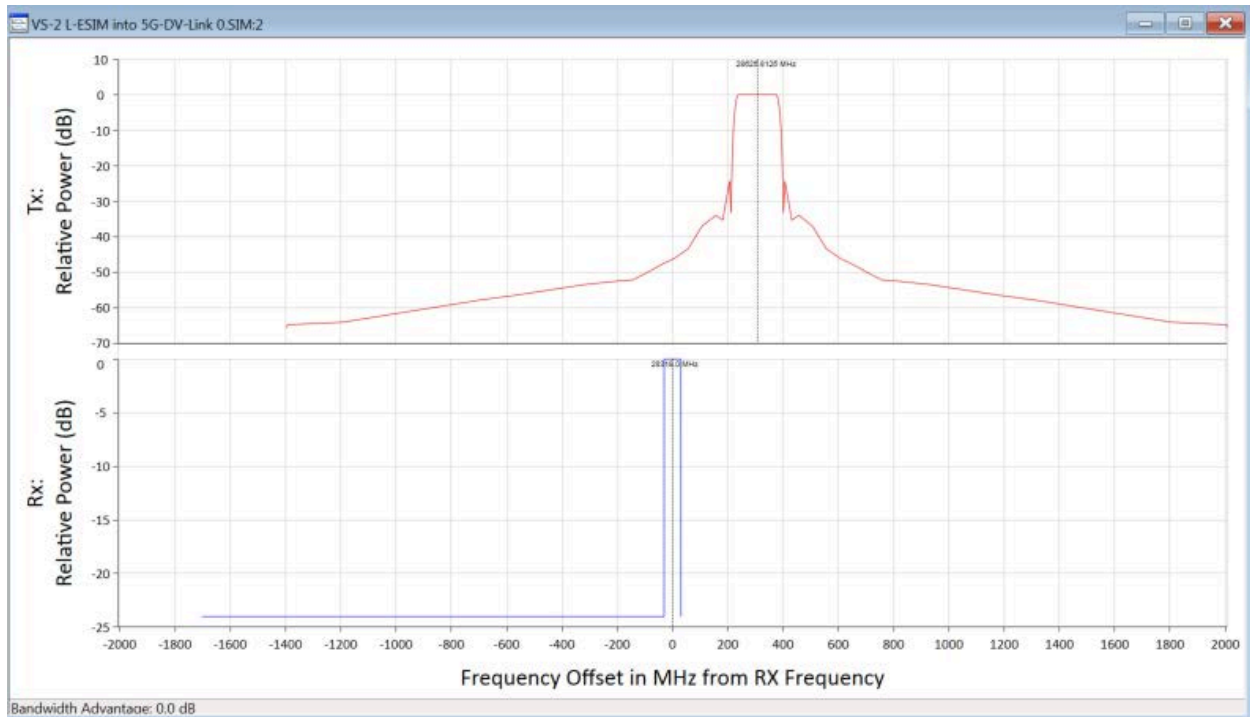


Figure 6, 5G and ESIM return channel 7 filter masks

To simulate realistic antenna pointing angles for the L-ESIM as well as for the 5G IMT equipment, a notional three sector 5G BS was set up in Washington, D.C. Each 5G BS sector had three UE devices assigned to communicate with it. The L-ESIM location was initially set at Waypoint 1 as shown in Figure 8, then the Visualyse define variable feature is used to move the L-ESIM continuously throughout the during of the simulation. The L-ESIM moves at a constant 35 MPH on a loop around the surface streets near the 5G network.



Figure 7, Station configuration near 901 K St, NW, Washington, D.C.

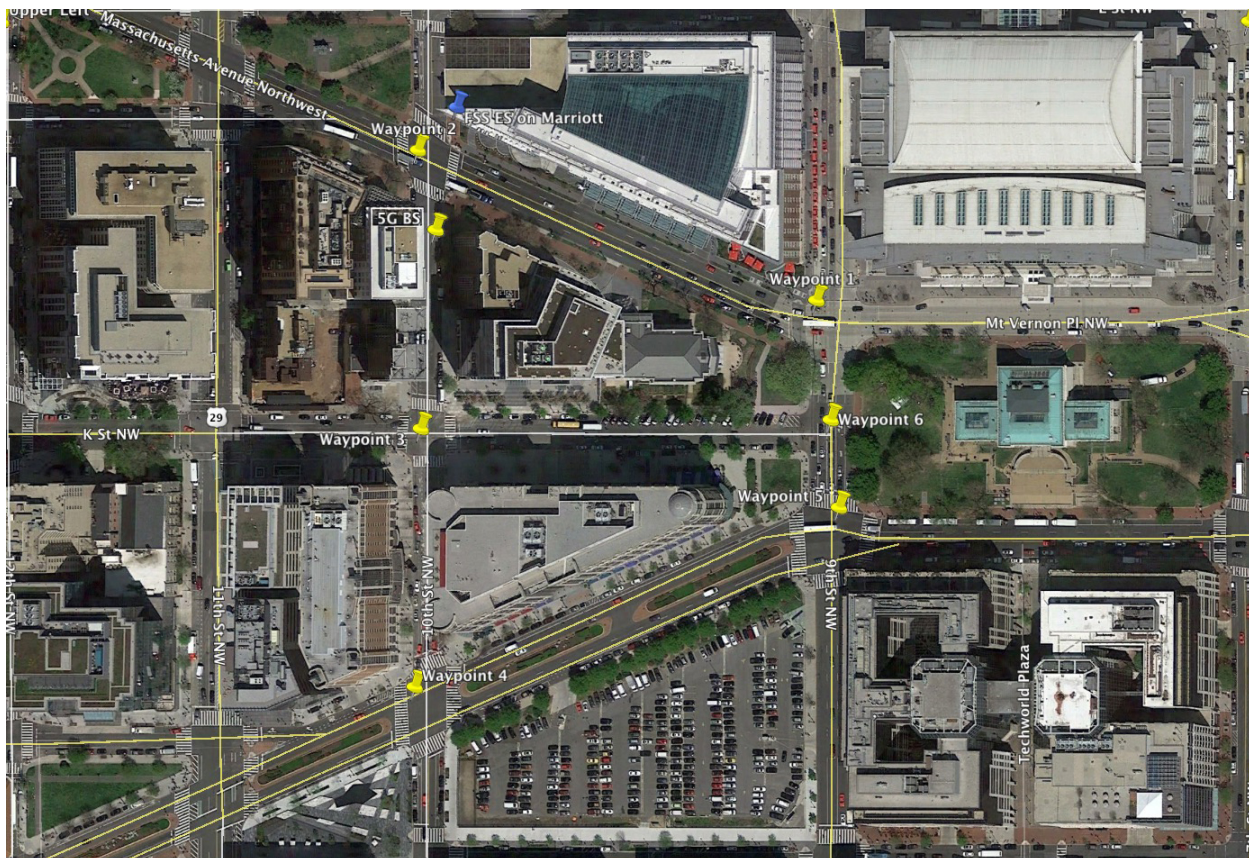


Figure 8, L-ESIM path following waypoints

Examining Figure 8, it should be clear that significant blockage of emissions from the L-ESIM will occur towards the 5G IMT system when the L-ESIM travels between waypoint 4, 5, and 6, due to the multi-story building between the 5G equipment and L-ESIM along this path, however, due to the fact that the distances are less than 250 m the Visualyse ITU P.Clutter propagation model does not add any additional attenuation over free space loss for sub 250 m length paths. Therefore, the I/N in this area and the associated percentage of time observed would be expected to be lower in actual operation.

In the simulation, the location of the 5G UE stations and the L-ESIM are updated each time step. The 5G BS location remains fixed as does the mechanical pointing of the BS antenna array. The mechanical pointing of the UE devices is randomly set within the limits and then the electronic pointing of the BS and UE devices is updated to point at each other. This occurs each time step in the simulation as the UE devices move to ensure they keep pointing at each other.

While the Visualyse model does include transmit characteristics for the 5G BS and UE, these are only considered when the simulation is initially set up in order to generate a realistic deployment model. When the simulation is running, the calculation of the received I/N takes into account the receive characteristics of the 5G equipment and the antenna pointing of 5G and the L-ESIM for each time step of the Monte Carlo simulation. The I/N criterion of -6 dB

specified in the ITU 5D Liaison Statement⁵ was used in the simulation. Note however that time statistics for short term exceedances have not yet been provided by SG 5.

Figure 9 shows the cumulative distribution of the I/N measured for each of the links between the various UE and BS sectors as a function of time when the L-ESIM is assigned to use return channel 0 (5 MBd symbol rate centered at 28353 MHz). The start to end link is configured as the BS transmitting to the UE and the end to start link is the UE transmitting to the BS.

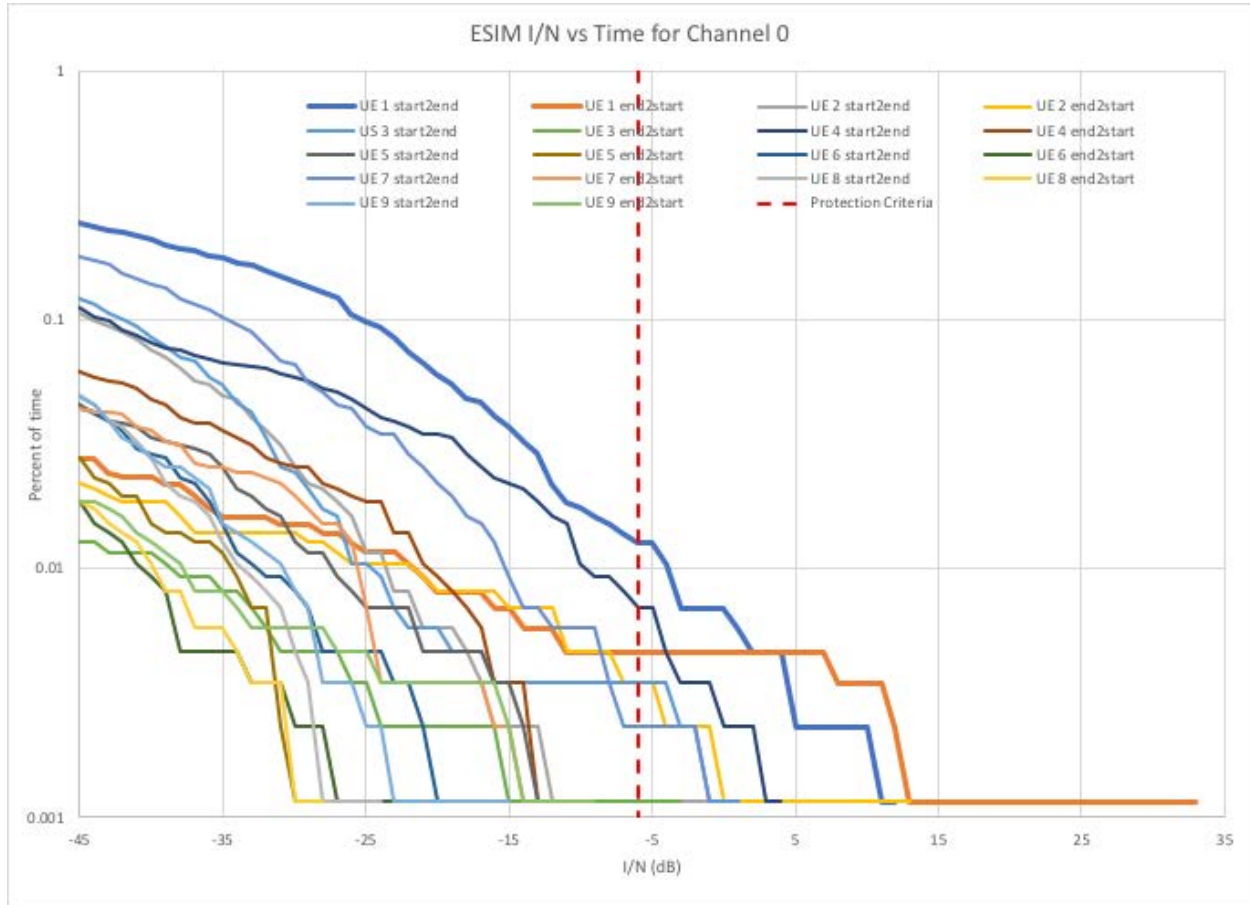


Figure 9, I/N statistics for ESIM return channel 0

The I/N curves for the start to end and end to start links of UE 1 represent the worst-case links of the nine UE devices. This result was generally true for each of the various ESIM return channel frequencies evaluated. UE devices 1, 2, and 3 are associated with BS sector 1, which is the sector pointed in a northern direction in the simulation. These UE devices are typically closest to the path of the L-ESIM as it passes, and this BS sector is looking north at them while the L-ESIM is transmitting toward the south, resulting in more direct antenna alignments than the other BS sectors.

⁵ ITU 5D Liaison Statement to TG 5/1, Document 5-1/36-E, 28 February 2017

The result show that for the worst-case BS to UE link, a -6 dB I/N was met 99.987% of the time and that for the worst-case UE to BS link, a -6 dB I/N was met 99.995% of the time. A -6 dB I/N was exceeded for the BS to UE link eleven times in 24 hours for one second per event for a total of eleven seconds in a 24 hour period, and was exceeded four times over a 24 hour period for the UE to BS link for one second per event for a total of four seconds in 24 hours.

Figure 10 shows the results for ESIM return channel 1 (5 MBd symbol rate centered at 28358.625 MHz). A -6 dB I/N for the worst-case BS to UE and UE to BS links is met for 99.994% and for 99.996% of the time, respectively.

The BS to UE link I/N was exceeded five times over a 24 hour run for one second each, for a total of 5 seconds in 24 hours. The worst-case UE to BS link I/N was exceeded three times over a 24 hour run for one second each time, for a total of three seconds in 24 hours.

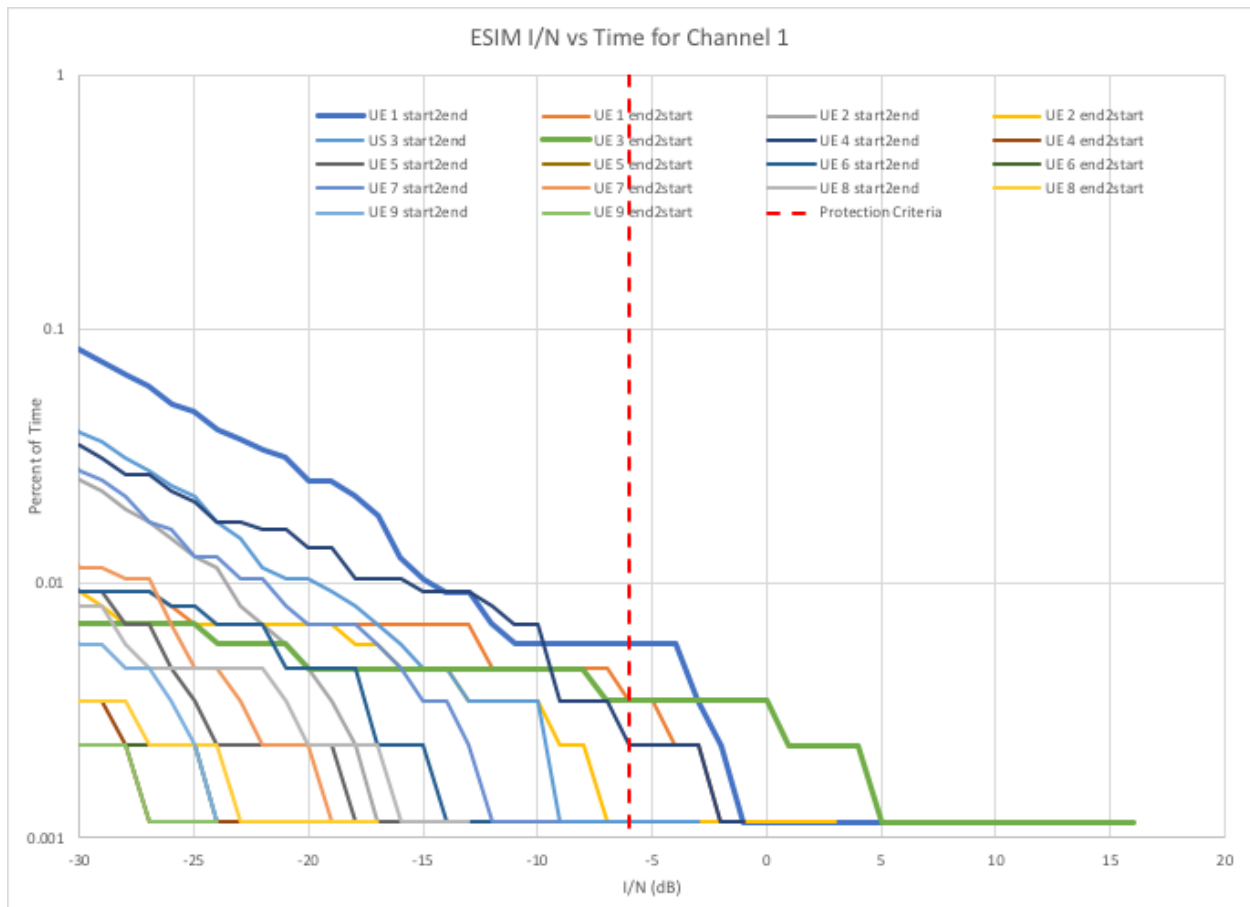


Figure 10, ESIM return channel 1 I/N plot

Conclusions

The analysis shows that operation of a L-ESIM on frequencies directly adjacent to a 5G network while traveling in close proximity (less than 10 m in some cases) to the 5G BS and UE devices will provide -6 dB I/N of protection to the 5G network more than 99.98% of the time and that any short-term exceedances of -6 dB I/N that might occur would be very limited in duration.

DECLARATION

I, Daryl T. Hunter, hereby make the following declarations under penalty of perjury. I understand that this Declaration will be submitted to the Federal Communications Commission.

1. I am the Chief Technology Officer, Regulatory Affairs of ViaSat, Inc.
2. I am the technically qualified person responsible for preparation of the technical information contained in the foregoing L-ESIM vs 5G Out-of-band Interference Analysis ("Analysis").
3. I have either prepared or reviewed the information in the Analysis, and the information contained therein is true and correct to the best of my knowledge, information and belief.




Daryl T. Hunter, P.E.

Executed March 23, 2018