Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)		
	)		
	)		
Application of KVH Industries, Inc. for	)	File Nos.	SES-LIC-20060824-01502
Modification of License to Operate a	)		SES-LIC-20070504-00563
Network of Earth Stations Onboard Vessels	)		SES-LIC-20081104-01450
("ESVs") in the 14.0-14.5 GHz (Transmit)	)		
and 10.95–11.2 GHz, 11.45–11.7 GHz and	)	Call Signs	E060335
11.7-12.2 GHz (Receive) Frequency Bands	)		E070085
	)		E090001

APPLICATION FOR LICENSE MODIFICATION

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SUMMARY

KVH Industries, Inc. ("KVH") hereby submits this application for license modification to consolidate its three Ku-band earth station onboard vessel ("ESV") licenses into a single license, Call Sign E090001. Although KVH's ESV operating authority was originally issued as separate licenses due to a unique procedural background, a single ESV license is appropriate because KVH controls its entire ESV network, including communications with all terminals and hub earth stations, through a single network control center.

KVH also seeks to make certain conforming adjustments to its surviving ESV license. Specifically, the permissible frequency bands, emissions designators and number of terminals specified in the consolidated license should appropriately reflect the operating a parameters included in the underlying licenses and instant proposal.

In addition, KVH seeks to add ALSAT authority to its consolidated license. ALSAT authority is appropriate in this case because, as specified in the Commission's Report and Order adopting the Ku-band ESV licensing rules, all KVH ESV terminals comply with the off-axis EIRP spectral density limits set forth in the rules to protect Ku-band Fixed-Satellite Service ("FSS") satellite operations from harmful interference.

Finally, KVH seeks to add authority to operate up to 1,000 V3 terminals, a new Ku-band ESV model that uses a 0.37m antenna, to its consolidated ESV license. The V3 terminal complies with the Commission's ESV rules and policies and can be authorized pursuant to ITU Radio Regulation Article 4.4. Because the V3 is highly efficient and affordable, it will enhance competition by extending the reach of maritime broadband communications to smaller private, commercial and government vessels operating in U.S. waters and open ocean regions around the world.

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	)		E090001

APPLICATION FOR LICENSE MODIFICATION

KVH Industries, Inc. ("KVH"), by its attorneys and pursuant to Section 25.117 of the Commission's rules, 47 C.F.R. § 25.117, hereby submits this application for license modification to consolidate its three Ku-band earth station onboard vessel ("ESV") licenses into a single license, Call Sign E090001, and to make certain conforming adjustments and add ALSAT authority to its license. KVH also seeks to add authority to operate up to 1,000 V3 terminals, a new Ku-band ESV model that uses a 0.37m antenna, to its consolidated ESV network license. The V3 terminal complies with the Commission's ESV rules and policies, and will provide high-speed Internet access for various maritime communications applications to private, commercial and government vessels operating in U.S. waters and beyond.

I. CONSOLIDATION OF KVH'S ESV NETWORK LICENSES AND ADDITION OF ALSAT AUTHORITY

KVH currently holds three Ku-band ESV network licenses to operate up to 4,600 V7 terminals, which utilize a 0.6m antenna, to communicate with three separate satellite points of communication. Call Sign E060335 authorizes KVH's ESV network to communicate with the

AMC-21 satellite at 125º degrees W.L. using a hub earth station located in Miami, Florida;[1] Call Sign E070085 authorizes communication with the AMC-15 satellite at 105º W.L. using a hub earth station located in Carlsbad, California;[2] and Call Sign E090001 authorizes KVH's ESVs to communicate with the GE-23 satellite at 172º E.L. using a hub earth station located in Kapolei, Hawaii.[3] Each ESV network license contains slightly different particulars of operation associated with the individual satellite points of communication.

A. Consolidation of ESV Network Licenses

KVH seeks to consolidate its authority into a single ESV network license for purposes of administrative efficiency. As the Commission may recall, the procedural history of KVH's ESV licenses is somewhat lengthy and complex, with multiple special temporary authorizations ("STAs") being granted to both SES Americom, Inc. and KVH before ESV network licenses were ultimately granted in KVH's name.[4] As a result of this background, each satellite/hub earth station pair was separately licensed even though all ESV network operations are controlled by KVH from its headquarters via a single network operations center located in Carlsbad, California.[5]

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[1] *See* IBFS File No. SES-LIC-20060824-01502. The separately licensed hub earth station's Call Sign is E040267.

[2] *See* IBFS File No. SES-LIC-20070504-00563. The separately licensed hub earth station's Call Sign is E030131.

[3] *See* IBFS File No. SES-LIC-20081104-01450. The separately licensed hub earth station's Call Sign is E010236.

[4] *See, e.g.*, Call Sign E070085, File Nos. SES-STA-20070329-00421, SES-STA-20070529-00728, SES-STA-20070720-00973, SES-STA-20080110-00035, SES-STA-20080801-01010, SES-STA-20080916-01214 and SES-STA-20090219-00196.

[5] KVH maintains ultimate direction and control of its Ku-band ESV operations via a network management agreement with ViaSat, Inc.

For purposes of administrative and operational efficiency, KVH now seeks to operate its Ku-band ESV network under a single license. Because KVH has implemented centralized network control and the Commission specifically contemplated ESV network licenses with multiple hub stations in its ESV rules,[6] consolidation of KVH's existing authority into a single ESV network license is appropriate and fully consistent with the public interest.

Several other modifications to Call Sign E090001 should be made in the context of the instant application. First, KVH's three ESV network licenses together provide operating authority for a total of 4,600 V7 terminals. In the context of consolidating the licenses, KVH believes authority for 3,500 V7 terminals communicating with all hubs would be appropriate at this time. Combined with the addition of 1,000 V3 terminals requested in this application, the modification results in a net decrease in the number of authorized ESV terminals that may be operated by KVH.

Second, Call Sign E090001 appears to limit Ku-band uplink authority to the 14.4-14.5 GHz band. As the original ESV application narrative and associated satellite operator coordination agreements correctly suggest,[7] KVH seeks authority to operate throughout the 14.0-14.5 GHz band like other U.S.-licensed Ku-band ESV operators, subject to compliance with coordination arrangements and FCC rules to protect radio astronomy sites and National Aeronautics and Space Administration ("NASA") Tracking and Data Relay Satellite System

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[6] *See Procedures to Govern the Use of Satellite Earth Stations on Board Vessels in the 5925-6425 MHz/3700-4200 MHz Bands and 14.0-14.5 GHz/11.7-12.2 GHz Bands*, IB Docket No. 02-10, Report and Order, FCC 04-286, ¶ 3 (2005) ("ESV Report and Order") ("We also provide for system licensing (consisting of ESV hub stations and/or blanket licensing for ESV earth stations) in order to give both C- and Ku-band ESV operators greater flexibility in structuring their operations.").

[7] *See, e.g.*, IBFS File No. SES-LIC-20081104-01450, Call Sign E090001, Application Narrative at 1.

("TDRSS") operations. Consistent with the Ku-band ESV rules and the public interest, KVH seeks to ensure that its ESV terminals have the flexibility to transmit throughout the 14.0-14.5 GHz band.

Finally, KVH seeks to add authority for its Ku-band ESV terminals to receive in the 10.95-11.2 GHz and 11.45-11.7 GHz bands with the GE-23 satellite.[8] The Commission authorized ESV receive operation in those bands in the original ESV Report and Order,[9] and KVH requested authority to operate in the bands in the application for Call Sign E090001.[10] Grant of access to these extended Ku-band receive frequencies is consistent with the Commission's ESV rules and would expand KVH's operational flexibility, thereby serving the public interest.

B. Addition of ALSAT Authority

Given their unique procedural history and uncertainty regarding Ku-band ESV pointing accuracy requirements, KVH's original ESV applications only requested authority to communicate with individual satellite points of communication.[11] Since that time, the Commission adopted new ESV rules on reconsideration that allow operators to declare a

[8] In the 10.95–11.2 GHz and 11.45–11.7 GHz frequency bands, KVH will not claim protection from interference from any authorized terrestrial stations to which frequencies are either already assigned, or may be assigned in the future. *See* 47 C.F.R. § 25.222(a)(7).

[9] *See* ESV Report and Order, ¶¶ 85-86.

[10] *See* IBFS File No. SES-LIC-20081104-01450, Call Sign E090001, Application Narrative at 1.

[11] Note that the coordination affidavits filed with the original ESV applications acknowledge that KVH's proposed ESV operations satisfied the off-axis EIRP density mask set forth in the Commission's rules.

maximum antenna pointing error in excess of the 0.2º value originally included in the rules.[12] As a result, and because KVH has demonstrated that its ESV terminals (including the new V3 terminal) comply with the off-axis EIRP spectral density limits governing Ku-band ESV operations,[13] KVH seeks to add ALSAT authority to its consolidated license.

In the original ESV Report and Order, the Commission properly concluded that affording ALSAT authority to Ku-band ESV operators was appropriate because it increases operational flexibility, reduces costs, enhances competition and eliminates the administrative burden of having ESV operators file an application every time they seek to change satellite providers.[14] On reconsideration, the Commission limited the availability of ALSAT authority to those ESVs that comply with the Commission's specified off-axis EIRP spectral density levels.[15] KVH's technical demonstrations are fully consistent with ALSAT authority, and the same public benefits referenced by the Commission would result from grant of such authority in this case.[16]

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[12] *See Procedures to Govern the Use of Satellite Earth Stations on Board Vessels in the 5925-6425 MHz/3700-4200 MHz Bands and 14.0-14.5 GHz/11.7-12.2 GHz Bands*, IB Docket No. 02-10, Order on Reconsideration, FCC 09-63, ¶ 25 (rel. July 31, 2009) ("ESV Order on Reconsideration").

[13] *See* IBFS File No. SES-LIC-20060824-01502, Call Sign E060335, Application Narrative at 3-9 and Technical Appendix B at 1-8 (demonstrating how the V7 terminal meets the ESV mask); IBFS File No. SES-LIC-20070504-00563, Call Sign E070085, Application Narrative at 2-8 and Technical Appendix B at 1-7; IBFS File No. SES-LIC-20081104-01450, Call Sign E090001, Application Narrative at 3-9 and Waiver Request at 1-6; and *infra* Section II.B.1.

[14] *See* ESV Report and Order, ¶¶ 106-107.

[15] *See* ESV Order on Reconsideration, ¶ 11 ("…ESV operators seeking to operate at higher off-axis power-density levels may not access satellites pursuant to ALSAT authority, and, therefore, must specifically list all of the satellites in their application that they plan to access at higher off-axis power-density levels." (citation omitted)).

[16] KVH acknowledges that ALSAT authority would allow communications with U.S.-licensed satellite and foreign licensed satellites on the Permitted Space Station List in conventional Ku-band frequencies (11.7-12.2 GHz and 14.0-14.5 GHz) only.

C. Emissions Designators

The V7 terminal was authorized to operate over channel bandwidths of 22 MHz (transmit) and 30 MHz (receive).[17] KVH seeks in the instant application to add bandwidths of 18 MHz, 27 MHz and 36 MHz. Only communications with the GE-23 satellite will use a 27 MHz bandwidth channel. The AMC-15 and AMC-21 satellite communications will use 18 MHz and 36 MHz bandwidth channels in addition to those currently authorized. This addition will be consistent with operations of the V3 terminal discussed below, which will also operate over the 18 MHz, 27 MHz and 36 MHz bandwidth channels. The requested additional emissions designators are as follows:

Satellite(s)	Frequencies	Emissions Designators
AMC-15 at 105° WL	11.7-12.2 Receive	18M0G7D, 36M0G7D
	14.0-14.5 Transmit	18M0G7D, 36M0G7D
AMC-21 at 125° WL	11.7-12.2 Receive	18M0G7D, 36M0G7D
	14.0-14.5 Transmit	18M0G7D, 36M0G7D
GE-23 at 172° EL	11.7-12.2 Receive	18M0G7D, 36M0G7D
	14.0-14.5 Transmit	18M0G7D, 27M0G7D, 36M0G7D
	10.95-11.2 Receive	27M0G7D
	11.45-11.7 Receive	27M0G7D
ALSAT	11.7-12.2 Receive	18M0G7D, 36M0G7D
	14.0-14.5 Transmit	18M0G7D, 36M0G7D

[17] *See* IBFS File No. SES-LIC-20081104-01450, Call Sign E090001. The authorized emissions designators were 22M0G7D and 30M0G7D.

II. AUTHORITY TO OPERATE THE V3 TERMINAL

As noted above, KVH's existing licenses authorize operation of up to 4,600 V7 ESV terminals communicating with three separate satellites. In the context of consolidating its ESV licenses, KVH is reducing that number to 3,500 but also seeks to add 1,000 V3 terminals to its ESV network license.[18] The V3 terminal operates in the 14.0-14.5 GHz band (transmit) and 10.95-11.2 GHz, 11.45-11.7 GHz and 11.7-12.2 GHz bands (receive) and**,** as demonstrated below, complies with the Commission's Ku-band ESV rules and policies, 47 C.F.R. § 25.222.

A. Description of the V3 Terminal

The V3 terminal employs a 0.37m parabolic reflector with a rear-fed sub-reflector feed assembly design. The terminal will automatically search for and acquire the designated satellite and maintain precise pointing via automatic control of the azimuth, elevation and polarization angles. The associated RF equipment is integrated into the base of the terminal and includes a three watt (3W) block upconverter.

[18] KVH has also filed an experimental STA application to facilitate testing of the V3 in advance of receipt of full commercial authority. *See* ELS File No. 0027-EX-ST-2011.

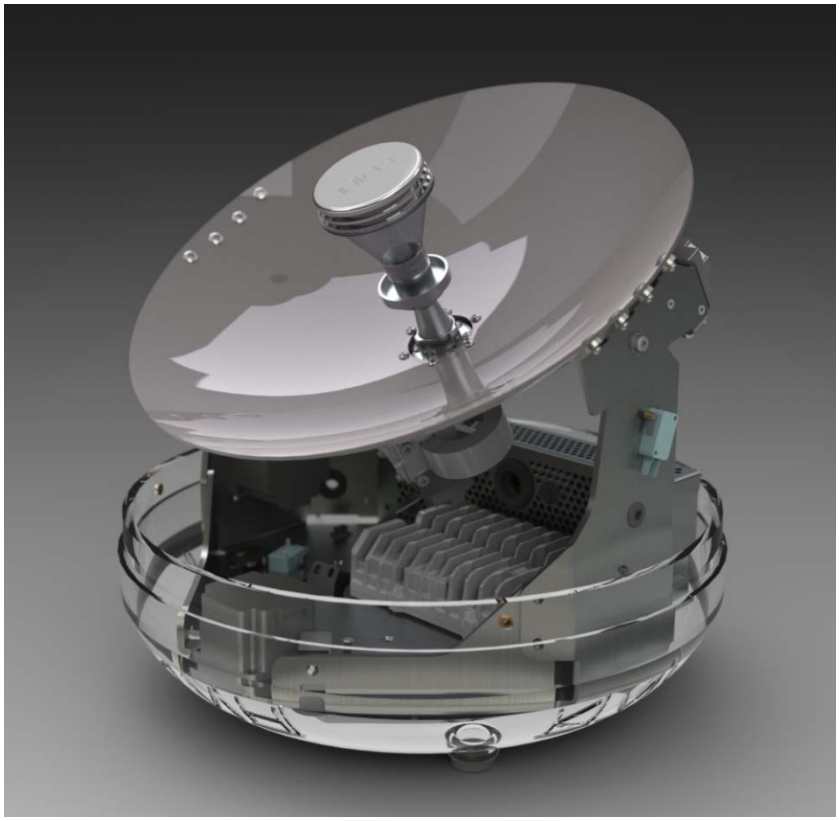

Figure 1: KVH V3 0.37m Ku-band ESV

The proposed ESV uplink return transmission (inbound) channel supports data rates of 32 kbit/s, 64 kbit/s, 128 kbit/s, 256 kbit/s, and 512 kbit/s. The ESV uplink transmission utilizes a spread spectrum modulation that will require channel bandwidths of 18 MHz and 36 MHz. The forward channel (outbound from the hub earth station to the ESV) will be between 3-10 Mbits/s aggregate with individual end user rates at 0.5-2 Mbit/s. The forward channel is also spread over the 18 MHz or 36 MHz channel and is overlaid onto the same transponder spectrum using a technique called PCMA.[19]

A summary of the V3 terminals operating characteristics are set forth in Tables 1 and 2, below.

[19] Paired Carrier Multiple Access ("PCMA") is a proprietary technique developed by ViaSat for its spread spectrum ArcLight service.

Antenna diameter	0.37 m
Type of Antenna	Parabolic rear-fed
Peak Power (SSPA)	3 watts
Transmit Bandwidth	18, 36 MHz
Transmit Gain	33 dBi at 14 GHz
EIRP	38 dBW
Transmit Data Rate	32 kbps to 512 Mbps
Transmit Polarization	Horizontal or Vertical
Transmit Max PSD	<10 dBW/4kHz
Transmit Azimuth, Elevation Beamwidth	3.5° (symmetrical antenna)
Receive G/T	10 dB/K minimum
Receive Bandwidth	500 MHz
Receive Polarization	Dual Vertical and Horizontal

Table 1. V3 Terminal Operating Parameters

Azimuth	Continuous coverage over full 360º
Elevation	10 to 80º antenna elevation
Position accuracy (AZ)	Conscan 0.6º RMS; 0.8º RMS in-motion accuracy; Declared Maximum Pointing Error: 1.5º
Dynamic Tracking capability	Roll: +/-25° at 8 second period Pitch: +/-15° at 5 second period Yaw: +/-8° at 50 second period Azimuth Turn rate: 12°/s and 15°/s^2 acceleration

Table 2. V3 Terminal Antenna Control Parameters

The target end users of this terminal are small and medium size vessels operated by private, commercial and government customers, including leisure vessels, fishing boats, cargo ships and United States Coast Guard and military vessels. The V3 terminal will provide high-speed connectivity for a range of maritime communications applications such as e-mail, Internet access and voice services.

B. Compliance with the Ku-band ESV Rules

The V3 terminal complies with Commission rules and policies designed to protect other users of the Ku-band from harmful interference from ESV transmit operations.

1. Off-Axis EIRP Spectral Density Limits

The V3 will operate in accordance with the off-axis EIRP spectral density limits for Ku-band ESV terminals in the Commission's rules.[20] The data rates transmitted from the terminal will vary from 32 kbits/s to 512 kbits/s. Additionally, the ESVs will transmit using CRMA

[20] *See* 47 C.F.R. § 25.222(a)(1)(i). The V3 terminal complies with off-axis EIRP spectral density limits in both the azimuth and elevation plane.

spreading[21] over either an 18 MHz channel bandwidth or a 36 MHz channel bandwidth. The co-polarized off-axis EIRP spectral density levels of the KVH ESV terminal are shown in Figures 2 through 5 below at +/-10 degrees and +/- 180 degrees off-axis angle. Note that a calculated worst case aggregate EIRP occurs when N=13 users for the 36 MHz channel and when N=6 users for the 18 MHz channel. Figure 6 below shows the V3's worst-case cross-polarization off-axis EIRP density plots versus the Commission's ESV off-axis EIRP spectral density limits.

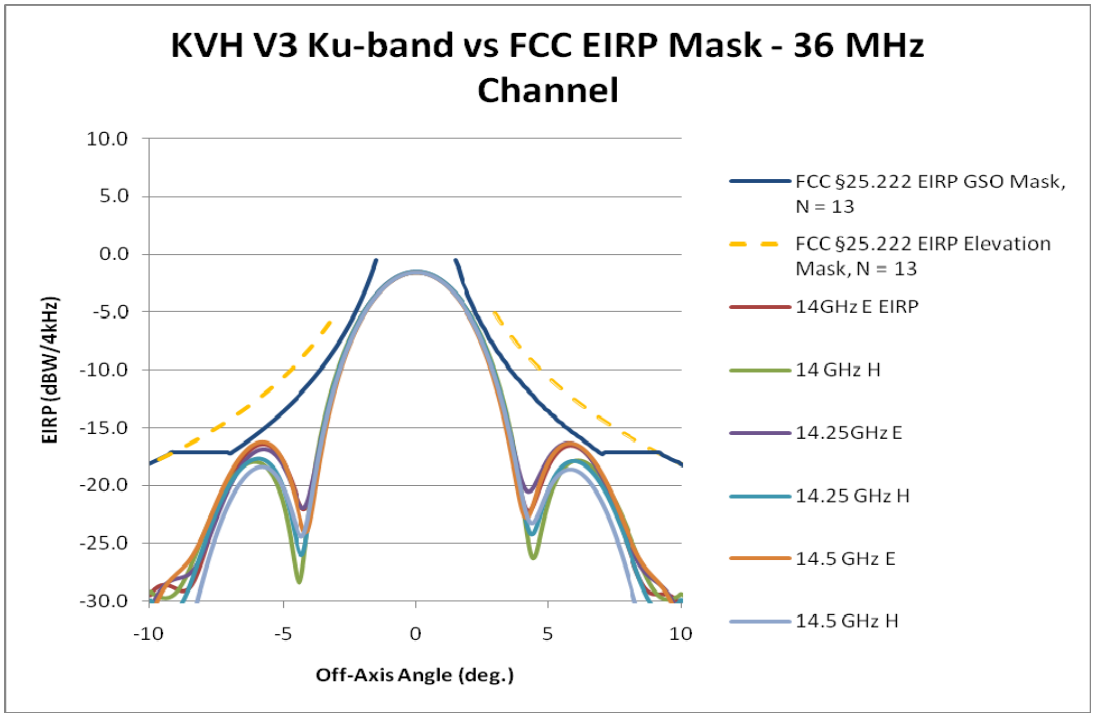

Figure 2 - V3 Off-Axis EIRP Spectral Density – 36 MHz Channel

[21] CRMA, or Code Reuse Multiple Access, is a ViaSat proprietary spread spectrum technique, similar to CDMA, used in the ArcLight satellite system.

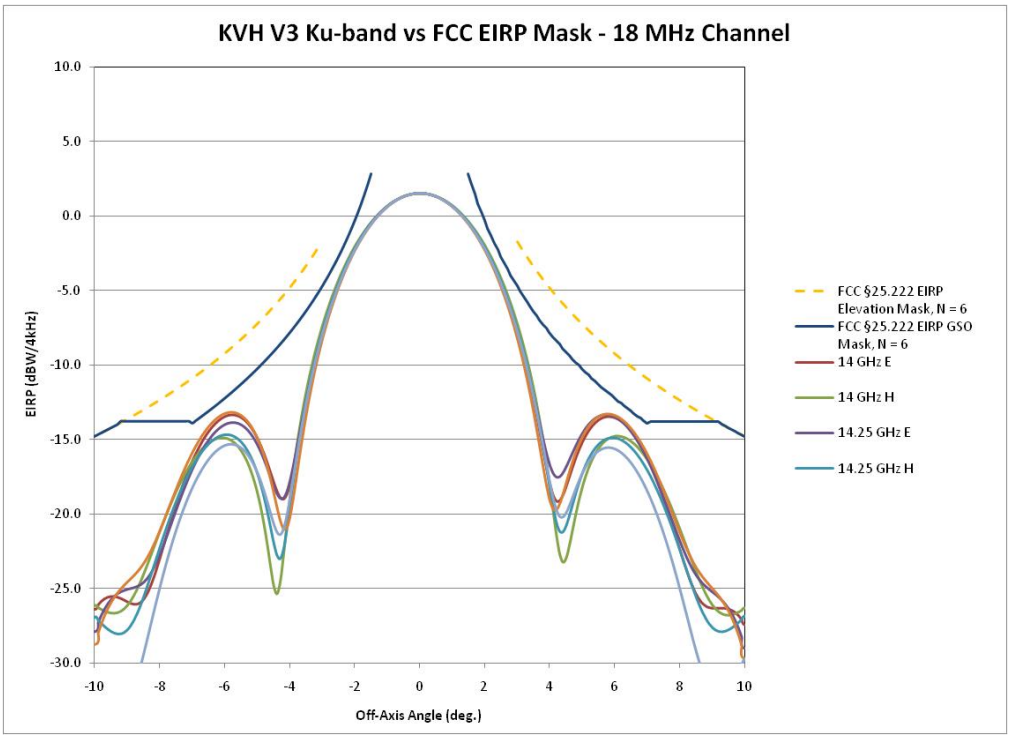

Figure 3 - V3 Off-Axis EIRP Spectral Density – 18 MHz Channel

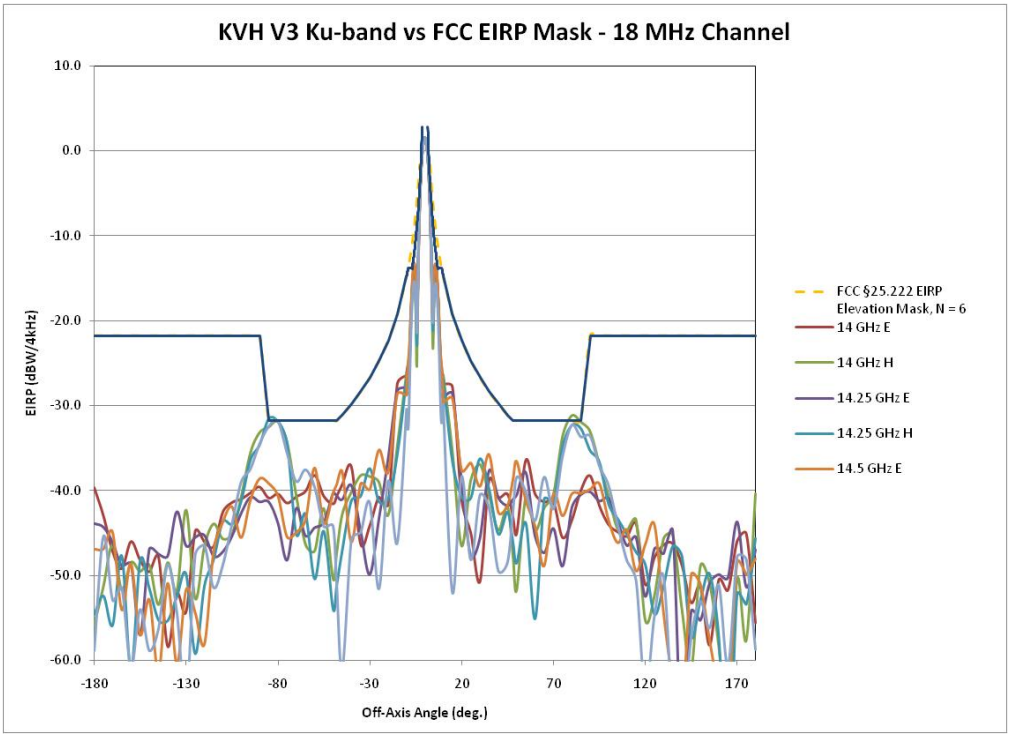

Figure 4 – 18 MHz Off-Axis EIRP Spectral Density

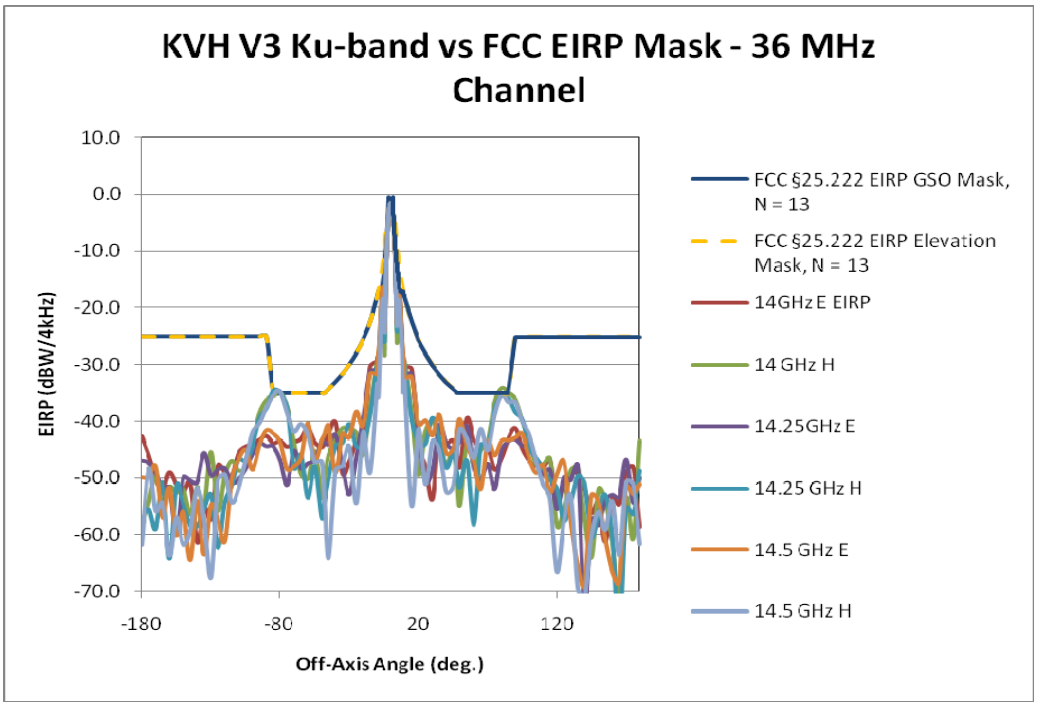

Figure 5 – 36 MHz Channel Off-Axis EIRP Spectral Density

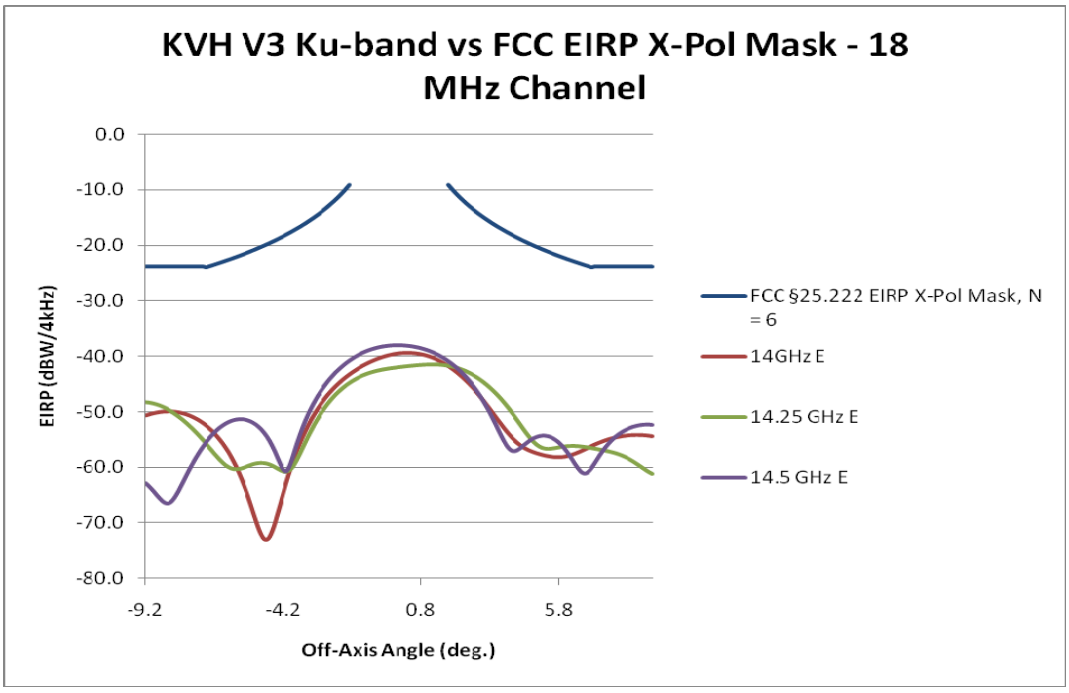

Figure 6 – 18 MHz Channel Cross-Pol Off-Axis EIRP Spectral Density

KVH has provided in Exhibit 1 measured antenna gain data required by Section 25.132 of the Commission's rules. In addition, pursuant to Section 25.222(a)(1)(i) and (b)(1), KVH has included in Exhibit 1 the required tables.[22] Table 1 contains the co-polarized E and H plane antenna patterns for the parabolic antenna, the E and H plane EIRP charts and the Commission's GSO and Elevation masks. Table 2 provides the X-Polarized E and H plane antenna gain and EIRP charts versus the Commission's ESV off-axis EIRP spectral density limits.

The foregoing off-axis EIRP spectral density plots, and the attached antenna gain plots and tables, demonstrate that the V3 terminal complies with the spectral density levels set forth in Section 25.222 of the rules and the Commission's two-degree spacing policies. Because the V3 complies with the off-axis EIRP spectral density limits contained in Section 25.222(a)(1) of the rules, target satellite operator coordination letters are not required for authorization. Out of an abundance of caution and so that adjacent satellite operators are aware of and do not object to KVH's ESV operations, KVH is pursuing coordination agreements between its serving satellite operators and adjacent operators, and will submit these coordination materials in the record of this proceeding.

2. V3 Terminal Antenna Pointing Control

The V3 terminal will meet the ESV off-axis EIRP spectral density limits with a declared maximum antenna mispointing of 1.5°.[23] Upon reaching mispointing of 1.5°, the terminal will inhibit transmission within 100 milliseconds and, out of an abundance of caution, will not resume until the pointing error value is back to within 0.8°.[24]

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[22] *See* Exhibit 1.

[23] *See* 47 C.F.R. § 25.222(b)(1)(iv)(A).

[24] *See* 47 C.F.R. § 25.222(b)(1)(iv)(B). Although KVH could resume transmission upon bringing pointing offset within the declared maximum pointing error of 1.5°, its system is

The antenna system utilizes a conical scanning function and rate gyros to stabilize the antenna and keep it pointed properly at the desired satellite. The conscan is currently set to worst case 0.6º from boresight. The additional dynamic pointing error for the vessel accelerations during operation is expected to be approximately 0.2º. Thus the total expected mean pointing error for each vessel while under way, including both conscan and dynamic error, is 0.8º.

The ESV V3 terminal will utilize a motion stabilized tracking antenna and a direct sequence spread spectrum ("DSSS") burst modem manufactured by ViaSat to access the satellite. Each terminal will use the CRMA common spreading code and a random access method to access the satellite. CRMA is closely analogous to the more generally understood code division multiple access ("CDMA") multiple access method, but differs in that all terminals use a common spreading code rather than a number of individual codes for each transmitter. Individual bursts are distinguished by time difference of arrival. The use of this spreading technique allows the EIRP spectral density for each ESV to be significantly lower than typical TDMA systems operating in Ku-band.

If conditions cause the antenna pointing offset to exceed the declared maximum pointing error limit of 1.5°, the antenna system will send a message to the modem, and the modem will inhibit transmission until the aggregate conscan plus dynamic pointing error value is back to within 0.8°. The time lag from the time that the mispointing exceedance is detected to the time when transmissions are inhibited will be less than 100 milliseconds.

The KVH ESV network uses a spread spectrum multiple access technique whereby the individual off-axis EIRP density of each ESV terminal is well below the maximum aggregate

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conservatively designed to recommence transmissions when the pointing offset reaches the expected conscan plus error value of 0.8°.

network limit. Thus, each antenna individually will not generate harmful levels of interference – even if the antenna were pointed directly at an adjacent satellite. Random pointing errors across this ESV fleet will not cause objectionable levels of adjacent satellite interference because the antenna on each ESV will be pointing in a different direction with a different error component. There is an extremely low probability that multiple antennas will be mispointed at an adjacent satellite at the same time in such a way that results in harmful interference. Because the pointing error is random and momentary, each ESV antenna actually has a higher likelihood of being pointed away from the geostationary satellite arc than at an adjacent satellite in the arc.

As described in Exhibit 1, Section 5 (Pointing Accuracy), KVH has analyzed the off-axis EIRP spectral density associated with multiple ESVs transmitting at various pointing offsets and has concluded that its network will operate well below the permissible mask. In particular, Figure 11 shows the aggregate effect of 15 simultaneously transmitting ESVs. Note that the aggregate emissions (sum) are well below the mask, even though KVH include two extra ESV terminals (N=13) and included contributions from terminals transmitting beyond a 1.5 degree offset (when the terminals will shut down). This extremely conservative analysis firmly establishes that, like the presently authorized V7 terminal, the V3 will operate consistent with the Commission's two-degree spacing policies and will not cause harmful interference to other Ku-band operations.

3. Compliance With Additional ESV Requirements

KVH will comply with the additional requirements for ESV applicants.

Section 25.222(a)(3), (b)(4) Points of Contact and Section 25.222(a)(6) Hub Earth Station in the United States. The KVH points of contact for the proposed ESV operations, available 24 hours, 7 days a week, with authority to cease all emissions from the ESVs are:

Robert Bourget
KVH Industries, Inc.
Phone: 401.851.3830
Mobile: 401.864.8458
Email: rbourget@kvh.com

The KVH contact information for its network control station in Carlsbad, California is:

6155 El Camino Real
Carlsbad, San Diego County, CA 92009
Tel: 760-476-2583

For filing issues involving this authorization request please contact:

Carlos Nalda
Squire, Sanders & Dempsey L.L.P.
1201 Pennsylvania Ave, NW
Suite 500
Washington, DC 20004
Office: (202) 626-6659
Fax: (202) 626-6780
Cell: (571) 332-5626
Email: cnalda@ssd.com

For technical issues involving this authorization request:

Kenneth G. Ryan, P.E., Skjei Telecom, Inc.
Regulatory Engineering Consultant
Office: (703) 917-4020
Fax: (703) 917-0098
Cell: (703) 919-0361
Email: ken@skjeitelecom.com

Section 25.222(a)(4) Recordkeeping. KVH will maintain, for each ESV transmitter, a time-annotated record of the ship location, transmit frequency, channel bandwidth and satellite used for at least one year. The location and time of all transmissions, at time intervals no greater than every 20 minutes while the ESV is transmitting, will be stored on a server at the hub. This information will be sent to the network control facility in Carlsbad, CA. It will be available, as required by the Commission rules, to a coordinator, fixed system operator, FSS operator, the NTIA or the Commission within 24 hours of the request.

Section 25.222(a)(5) Communications With Vessels of Foreign Registry. Records of communications with vessels of foreign registry will be downloaded to the ESV hub earth station and forwarded to the network control facility in Carlsbad, California for storage and retrieval.

Section 25.222(a)(7) Protection Claims. KVH will not claim protection from interference from any authorized terrestrial stations to which frequencies are already assigned or may be assigned in the future, in the 10.95-11.2 GHz and 11.45-11.7 GHz frequency bands.

Section 25.222(b)(3) Geographic Area of Service. KVH is seeking authorization to operate within the continental United States (CONUS), Alaska and Hawaii, as well as U.S. territories and possessions and adjacent waters within the satellite coverage zones. The service is designed as a regional service, covering the North American continent and its coastal waters, Central America, the Gulf of Mexico and the Caribbean, as well as large portions of the Atlantic and Pacific Oceans as shown in Exhibit 1, Section 3.

Section 25.222(b)(5) Radiation Hazard. KVH has included a radiation hazard analysis with this application as Exhibit 2.

4. Protection of Other Users in the 14.0-14.5 GHz Band

KVH's operation of the V3 antennas will protect other users in the 14.0-14.5 GHz band consistent with the requirements of the Commission's ESV rules.

Protection of Fixed-Satellite Service. As discussed above, KVH's terminals will operate in compliance with the ESV off-axis EIRP spectral density limits, even taking the declared pointing accuracy values into consideration. The ESV limits are consistent with those for routinely licensed VSAT earth stations and are consistent with the Commission's two-degree spacing policies.

Protection of Potential NGSO FSS Systems – Request for Waiver. KVH acknowledges that non-geostationary orbit ("NGSO") systems are also permitted to operate in

the Ku-band. However, no such systems are currently authorized. KVH will undertake adequate protection measures if such systems are authorized in the future. In any event, the V3 terminal meets the required FCC off-axis EIRP mask in directions other than the GSO arc.

Protection of Terrestrial Radio Services. KVH has examined current spectrum use in the 14.0-14.5 GHz band and has determined that there are no active FCC-licensed terrestrial services in this band in North America with which its proposed operations would potentially conflict.

Protection of the Radio Astronomy Service. KVH will comply with its prior coordination agreement with the National Science Foundation to protect radio astronomy service sites listed in Section 25.222(d) of the rules.[25]

Protection of Space Research Service. KVH recognizes the utilization of the frequency band from 14.0-14.05 GHz and the possible use of the band from 14.05-14.2 GHz allocated to the NASA TDRSS for space research conducted at White Sands, New Mexico and Blossom Point, Maryland. For purposes of this application, KVH will avoid ESV operation within 125 km of these earth stations until a coordination agreement is executed with NASA.[26]

C. Compliance With International Requirements

Although the Commission's ESV rules are consistent with the conclusions of ITU-R World Radiocommunication Conference ("WRC-03") and the intent of international ESV operational standards, including ITU-R Resolution 902, there are apparent inconsistencies between U.S. and international provisions governing Ku-band ESV operations. Specifically, the

[25] Coordination Agreement with the National Science Foundation, submitted with a letter dated November 20, 2008 in IBFS File No. SES-LIC-20081104-01450.

[26] *See* 47 C.F.R. § 25.222(c).

U.S. rules appropriately do not contain antenna size and pointing accuracy specifications. As a result, and in connection with the divergent operating parameters only, it is appropriate for the Commission to authorize ESV operations pursuant to Article 4.4 of the ITU Radio Regulations (operation in derogation of ITU provisions on an unprotected, non-harmful interference basis) to support operations within 125 km of foreign coasts.

1. U.S. ESV Rules Provisions

Although Resolution 902 contains minimum antenna size specifications, the Commission declined to adopt a minimum antenna size and nonetheless found that its approach was consistent with the conclusions of WRC-03 that adopted the ESV regulatory provisions.[27] In this connection, the Commission noted that smaller Ku-band ESV antennas were permissible so long as they did not cause more interference to FS operations than a 1.2m antenna.[28] Given its unique transmission scheme and power levels, the V3 terminal will cause no more interference to co-frequency, land-based services than a 1.2m antenna and KVH will not claim greater protection than a compliant terminal.

In addition, in the ESV Order on Reconsideration, the Commission moved away from requiring a 0.2° pointing accuracy and now permits ESV operators to specify a declared maximum pointing error, subject to compliance with the off-axis EIRP spectral density limits or alternative levels established in satellite operator coordination agreements.[29] The relaxed

[27] *See* ESV Report and Order, ¶ 104 ("Incorporating a smaller antenna size for Ku-band ESV operations into our rules is supported by current ESV operators and complies with the conclusions of WRC-03. We find, however, that we can provide the same protection to adjacent satellite operators by adopting off-axis EIRP. limits for ESV operations. As a result, we eliminate the need to regulate the specific size of the antenna being used." (citations omitted)).

[28] *See id.*, n.270.

[29] *See* ESV Order on Reconsideration, ¶ 22-27 and 47 C.F.R. § 25.222(a)(1)(ii)(B).

pointing accuracy requirements were based on a revised definition for off-axis EIRP spectral density, which essentially includes pointing accuracy as part of the EIRP spectral density mask thereby making the maximum pointing accuracy less relevant to adjacent satellite interference.[30] Therefore, even though Resolution 902 requires an antenna tracking accuracy of 0.2°, the Commission has determined that its off-axis EIRP spectral density limits toward every point in the GSO arc will adequately protect adjacent satellites.[31]

The Commission also sought to protect co-frequency services – in the U.S. case, NASA TDRRS operations – from harmful interference by adopting power and power spectral density limits towards the horizon set forth in ITU-R Resolution 902 for Ku-band ESVs.[32] These limits also protect terrestrial fixed service ("FS") operations from harmful interference and formed part of the basis for the minimum distance for "prior agreement" established in Resolution 902. The V3 terminal has a maximum EIRP towards the horizon of 11.8 dBW, and a maximum EIRP spectral density towards the horizon of -0.79 dBW/MHz, and thus is compliant with the values adopted by the Commission and embodied in Resolution 902.

2. Operating Authority Under ITU Radio Regulation Article 4.4

Notwithstanding the V3 terminal's compliance with applicable off-axis EIRP spectral density limits (to protect FSS operations) and power limits towards the horizon (to protect

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[30] *See* ESV Order on Reconsideration, n.59.

[31] *See id.*, ¶ 25 ("…ESV applicants that request to operate with a pointing error that is greater than 0.2 degrees must declare and justify, in their application, the maximum antenna pointing error that will be achieved without exceeding the off-axis EIRP spectral density limits.") In the instant application, KVH has declared a maximum antenna pointing error for the V3 terminal of 1.5° and has shown how the V3 will comply with the Commission's ESV spectral density limits to protect adjacent satellites. *See supra* Section II.B.1-2 and Technical Appendix.

[32] *See* ESV Report and Order, ¶ 102 ("Specifically, we adopt the two limits contained in ITU Resolution 902, an EIRP towards the horizon of no greater than 16.3 dBW, and an EIRP density towards the horizon of no greater than 12.5 dBW/MHz."). *See also* 47 C.F.R. § 25.204(i).

terrestrial FS and other land-based services such as NASA TDRSS and radio astronomy sites), KVH believes that it is appropriate for the Commission to expressly authorize operation of the V3 terminal pursuant to Article 4.4 of the ITU Radio Regulations with respect to antenna size and pointing accuracy.[33] Resolution 902 provides that the minimum antenna diameter for Ku-band ESVs is 1.2m, but permits authorization of ESVs as small as 0.6m in diameter.[34] It also provides for a peak tracking accuracy of 0.2 degrees.[35] Some administrations may view the 0.6m diameter and 0.2° values as a "hard limits" on antenna size and pointing accuracy, respectively, even though the Commission has adopted rules that afford more operational flexibility to Ku-band ESV operators consistent with protection of other co-frequency services. Accordingly, KVH requests express authority to operate the V3 terminal under Article 4.4.

a. Antenna Size

Resolution 902 explicitly recognizes that ESVs can be authorized in the 14.0-14.5 GHz band pursuant to Article 4.4 of the Radio Regulations if they do not claim protection from, nor cause interference to, other services having allocations in the band.[36] The Commission has also explicitly recognized this avenue to authorization for foreign-licensed ESVs.[37] In fact, the

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[33] Article 4.4 provides that administrations of member states should not authorize a station in derogation of the Regulations, "except on the express condition that such a station, when using such a frequency assignment, shall not cause harmful interference to, and shall not claim protection from harmful interference caused by, a station operating in accordance with the provisions of the Constitution, the Convention and these Regulations."

[34] *See* Resolution 902, Annex 2.

[35] *See id.*

[36] *See* Resolution 902 at 1.

[37] *See* ESV Report and Order, n.330. *See also Procedures to Govern the Use of Satellite Earth Stations on Board Vessels in the 5925-6425 MHz/3700-4200 MHz Bands and 14.0-14.5 GHz/11.7-12.2 GHz Bands*, IB Docket No. 02-10, Notice of Proposed Rulemaking, FCC 03-286, ¶ 103 (2003).

Commission has stated that it "expects[s] some administrations to authorize ESV operations on its registered vessels based solely on ITU RR 4.4."[38] U.S.-licensed ESVs should have similar opportunity to operate under Article 4.4, particularly where the proposed ESV operations are fully compliant with U.S. rules and the off-axis EIRP spectral density limits and limits towards the horizon (the parameters associated with potential interference to adjacent satellite and terrestrial networks, respectively) embodied in Resolution 902.

In this case, the V3 otherwise complies with all of the requirements of Resolution 902 adopted by the Commission and the Commission's ESV rules. The Commission explicitly declined to adopt a minimum antenna size requirement because its off-axis EIRP spectral density requirements would adequately protect adjacent satellites,[39] and power limits towards the horizon would protect land-based networks.[40] This is consistent with the goals of Resolution 902. Since V3 operations will not cause interference to other services in the 14.0-14.5 GHz band and KVH will not claim protection from other services in the band for the V3, it can be authorized pursuant to Article 4.4.

b. Pointing Accuracy

The Commission has authorized greater maximum pointing accuracy values than contemplated in Resolution 902 in its revised ESV rules. In fact, the currently authorized V7 and other ESV terminals utilize deliberate conscan (rotation around boresight to the target satellite) in excess of 0.2° to peak signal strength and maintain consistent pointing towards their serving

[38] *See id.*, ¶ 127.

[39] *See id.*, ¶ 103 ("We decline to adopt our proposal, set forth in the *ESV NPRM*, to require a minimum antenna size for Ku-band ESVs. (citation omitted) We are satisfied that the off-axis EIRP limits in this *Order* adequately protect adjacent satellite systems and ensure that ESVs do not cause harmful interference to adjacent FSS satellite operators.").

[40] *See id.*, ¶ 102.

satellites. Furthermore, the Commission's new approach to off-axis EIRP spectral density limitations (which specifies every point along the GSO arc) actually incorporates a pointing accuracy component (because antenna mispointing is necessarily a factor in the spectral density produced by ESV transmissions along the GSO arc). The Commission has correctly concluded that its spectral density mask will adequately protect adjacent satellite operations regardless of antenna pointing error values.

Pursuant to the Commission's ESV rules, KVH has declared a maximum pointing error value of 1.5° and will meet the spectral density limits. The KVH V3 terminal uses a spreading technique that allows the EIRP spectral density for each ESV to be significantly lower than typical ESV systems, and will not cause interference to adjacent FSS satellites at its declared maximum pointing error value. KVH also will not claim protection from other services in the band. Thus, the V3 can be authorized pursuant to Article 4.4 with respect to pointing accuracy.

Grant of Article 4.4 authority with respect to antenna diameter and pointing accuracy will serve the public interest by enabling KVH to operate the V3 terminal internationally in a manner fully consistent with the Commission's rules and the underlying intent of international guidelines, and will help mitigate potential complications associated with claims of non-conformance to international standards. Although there are no other concerned Administrations with respect to the Ku-band in the Americas, KVH notes that regional guidance from CITEL includes reference to the ITU pointing accuracy and minimum antenna size specifications. In addition, other licensing administration often look to FCC guidance when authorizing international satellite operations such as ESV services, and express exemption from those international specifications under Article 4.4 will greatly assist KVH (as a U.S.-based service provider) in obtaining

authority from individual administrations to operate the V3 terminal in foreign territorial waters and ports throughout the region.

III. CONCLUSION

For the reasons set forth herein, modification of KVH's ESV network license, Call Sign E090001, to consolidate its three existing ESV licenses and make other conforming changes (including adjusting the number of terminals, frequencies and emission designators) would further the interests of administrative and operational efficiency. In addition, addition of ALSAT authority is fully consistent with the Commission's rules and policies.

The Commission should also authorize operation of up to 1,000 V3 terminals as part of KVH's ESV network to extend broadband communications to smaller vessels. The V3 terminal complies with the Commission's ESV rules and policies, and can be authorized pursuant to ITU Radio Regulation Article 4.4 to facilitate operations in international and foreign waters.

All of these modifications would strongly serve the public interest by enhancing competition in broadband maritime services and maintaining U.S. leadership in advance communications connectivity. Because the requested modifications are consistent with the Commission's ESV rules and policies, KVH respectfully requests action on this application at the earliest practicable time.

Technical Certificate

I, Ken Ryan, hereby certify that I am the technically qualified person responsible for the preparation of the technical discussion contained in KVH Industries, Inc.'s Application for License Modification, that I am familiar with Part 25 of the Commission's Rules (47 C.F.R. Part 25), and that I have either prepared or reviewed the technical information submitted in this Application and found it to be complete and accurate to the best of my knowledge and belief.

By: 

Ken Ryan
Skjei Telecom, Inc.

January 26, 2011

Exhibit 1

V3 ESV Terminal Technical Appendix

1. Introduction

KVH Industries, Inc. ("KVH") has developed a small aperture, broadband, highly efficient and affordable earth stations onboard vessels ("ESV") terminal for use with its global maritime communications network. This ESV – the KVH V3 terminal – operates in Ku-band FSS frequencies (14.0-14.5 GHz transmit, 11.7-12.2 GHz receive, 10.95-11.2 GHz and 11.45-11.7 GHz receive). The V3 terminal will automatically search for and acquire the designated satellite, and maintain precise pointing via automatic control of the azimuth, elevation and polarization angles.

The antenna being used in this ESV terminal is 14.5" (37 cm) in diameter, and its main lobe does not conform to the standards specified in Section §25.209(a) and (b). In order to compensate for this performance, KVH will operate with a spread spectrum modulation technique that will bring the off-axis EIRP spectral density of the terminal well within the spectral density limits specified in Section §25.222 of the Commission's rules. This technical exhibit provides the showing required pursuant to Section §25.222, including detailed information regarding the ESV antenna patterns and off-axis emissions, and a summary of the remote ESV to hub link analysis.

2. Description of Antenna

KVH has developed the small aperture, broadband, highly efficient and affordable V3 ESV terminal for use with its global ESV network. The ESV terminal operates in the Ku FSS frequency band, 14.0-14.5 GHz transmit and 10.95-11.2 GHz, 11.45-11.7 GHz and 11.7-12.2 GHz receive. The antenna is a 37 cm parabolic reflector with a rear-fed sub-reflector feed assembly design. The ESV terminal will automatically search for and acquire the designated satellite and maintain precise pointing via automatic control of the azimuth, elevation and polarization angles. The RF equipment is integrated into the base of the terminal and includes a 3 watt block upconverter.

The proposed ESV uplink return transmission (inbound) channel supports data rates of 32 kbit/s, 64 kbit/s, 128 kbit/s, 256 kbit/s, and 512 kbit/s. The ESV uplink transmission utilizes a spread spectrum modulation. This authorization will require channel bandwidths of 18 MHz and 36 MHz. The forward channel (outbound from the hub earth station to the ESV) will be between 3-10 Mbits/s aggregate with individual end user rates at 0.5-2Mbit/s. The forward channel is also spread over the 18 MHz or 36 MHz channel and is overlaid onto the same transponder spectrum using a technique called PCMA.[1]

[1] Paired Carrier Multiple Access is a proprietary technique developed by ViaSat for their spread spectrum ArcLight service.

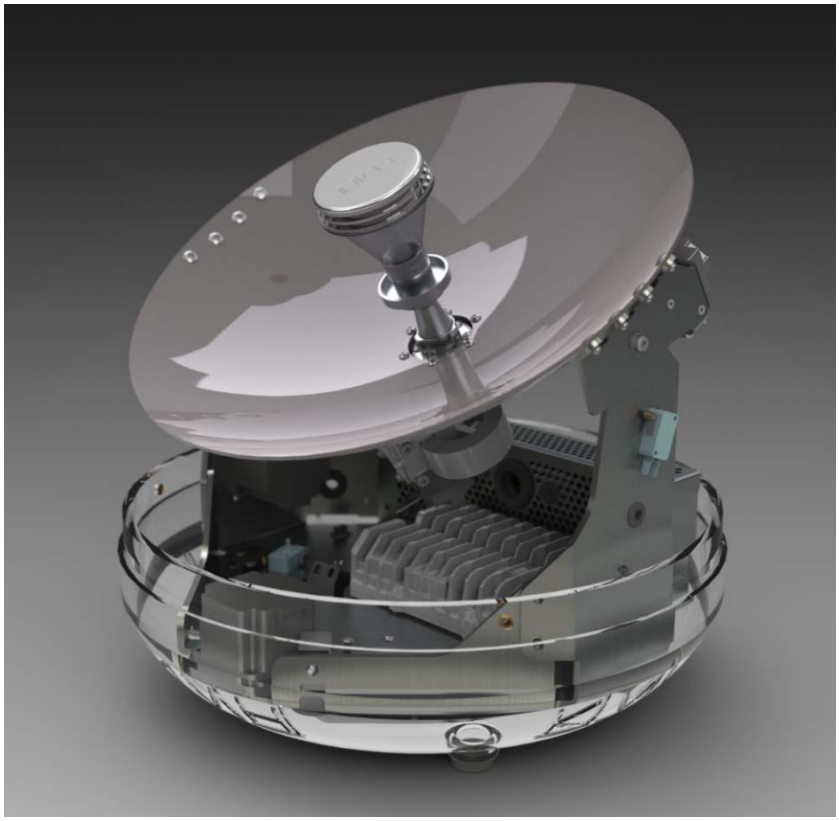

Figure 1 - KVH 37 cm Ku-band antenna

3. Description of Service

As is shown in Figure 2 below, the V3 terminal will be operated within KVH's existing broadband mobile maritime service network, authorized by the Commission.[2] KVH is seeking authorization to operate within the continental United States (CONUS), Alaska and Hawaii, as well as U.S. territories and possessions, and adjacent waters within the satellite coverage zones.

KVH would like to operate the terminals with the following satellites: AMC-15 @ 105° W.L., AMC-21 @ 125º W.L. and GE-23 @ 172º E.L. The ESVs will communicate with existing hub earth stations in Miami, Florida, Carlsbad, California, and Kapolei, Hawaii.[3] KVH will control all V3 operations using its standard network control capabilities and network management services. Additionally, since this service will operate under the control of the KVH ESV network operations center there will be a record of the ESV's location and operating parameters as specified in Section 25.222(a)(4). The service is designed as a regional service, covering the North American continent and its coastal

[2] *See* File No. SES-LIC-20060824-01502 (Call Sign E060335); File No. SES-LIC-20070504-00563 (Call Sign E070085); and File No. SES-LIC-20081104-01450 (Call Sign E090001).

[3] Call Signs E040267, E030131 and E010236, respectively.

waters, Central America, the Gulf of Mexico and the Caribbean, as well as the Pacific Ocean region, as shown in blue shade in Figure 3 below.

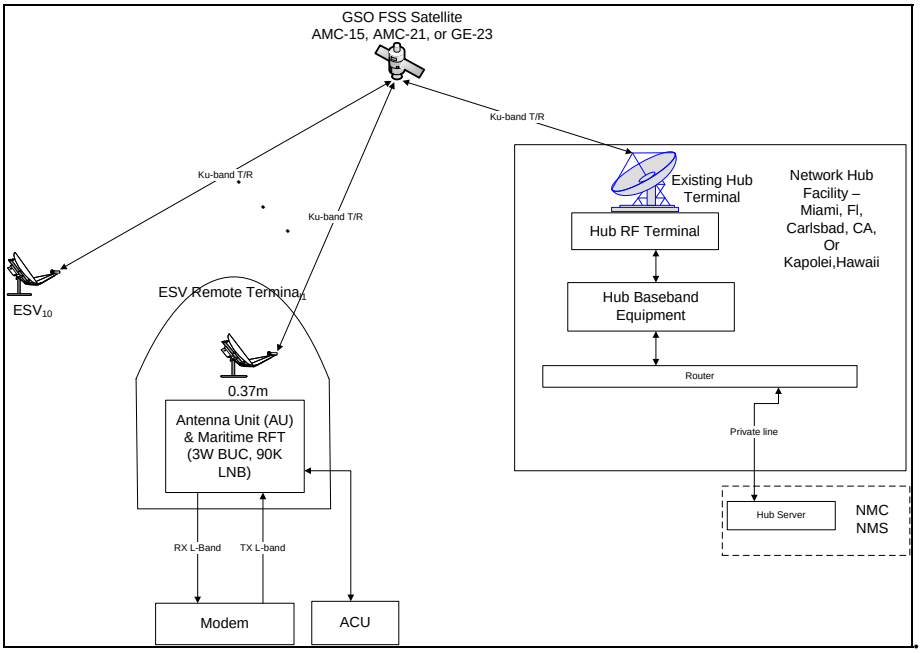

Figure 2 – ESV Network Architecture

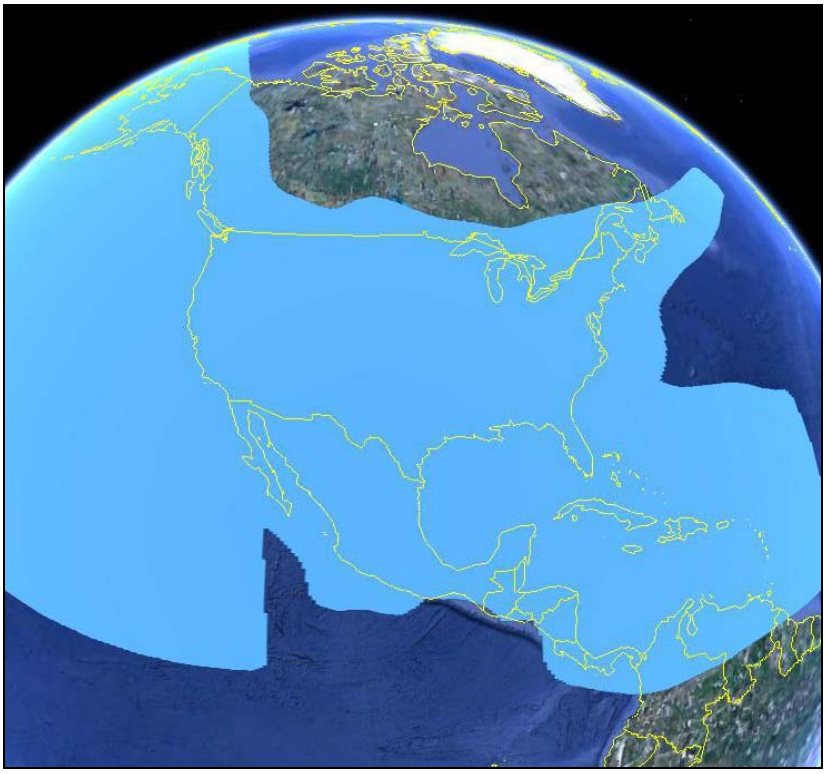

Figure 3 – ESV Coverage Area

The ESV terminal will operate in compliance with KVH's coordination agreement with the National Science Foundation with respect to Radio Astronomy Service ("RAS") sites and will not operate within 125 km of the Tracking and Data Relay Satellite System (TDRSS) sites for space research conducted at White Sands, New Mexico and the U.S. Naval Research Lab at Blossom Point, Maryland.[4]

4. Off-Axis EIRP Analysis

The data rates transmitted from the terminal will vary from 32 kbits/s to 512 kbits/s. Additionally, the ESVs will transmit using CRMA spreading[5] over either an 18 MHz channel bandwidth or a 36 MHz channel bandwidth. KVH acknowledges that the small diameter V3 antenna does not meet the FCC 25.209 antenna pattern. However, KVH certifies that the aggregate EIRP levels do not exceed the limits specified for Ku-band ESVs in Section 25.222 of the Commission's rules. The co-pol off-axis EIRP spectral density levels of the KVH ESV terminal are shown in Figures 4 through 7 below. Note that a calculated worst case aggregate EIRP occurs when N=13 users for the 36 MHz channel and when N=6 users for the 18 MHz channel. Figure 8 below shows the V3 worst case cross-pol off-axis EIRP density plots versus the FCC §25.222 mask.

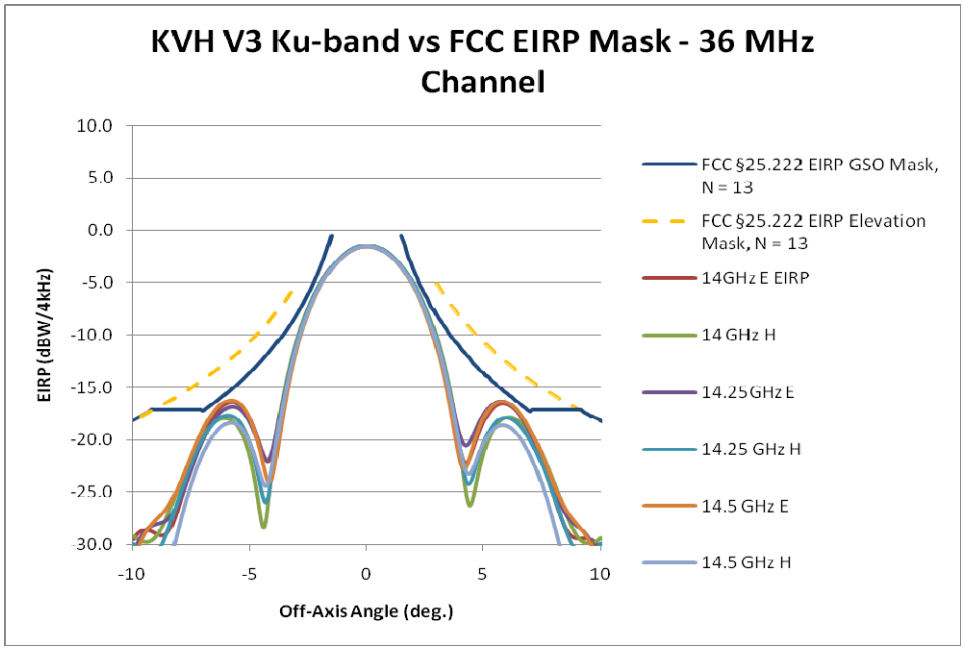

Figure 4 - V3 Off-Axis EIRP Spectral Density – 36 MHz Channel

[4] *See* Coordination Agreement with the National Science Foundation, submitted with a letter dated November 20, 2008 in IBFS File No. SES-LIC-20081104-01450. KVH will accept technical limitations imposed on other Ku-band ESV operations necessary to protect TDRSS operations. *See* 47 C.F.R. § 25.222(c).

[5] CRMA, or Code Reuse Multiple Access, is a ViaSat proprietary spread spectrum technique, similar to CDMA, used in the ArcLight satellite system.

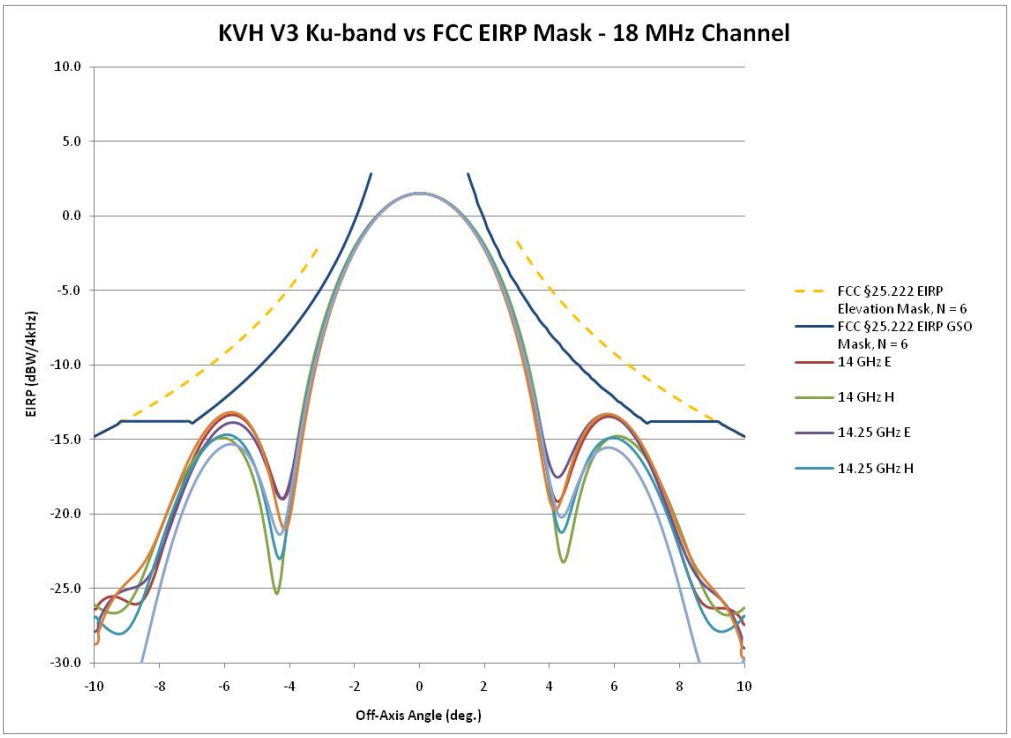

Figure 5 - V3 Off-Axis EIRP Spectral Density – 18 MHz Channel

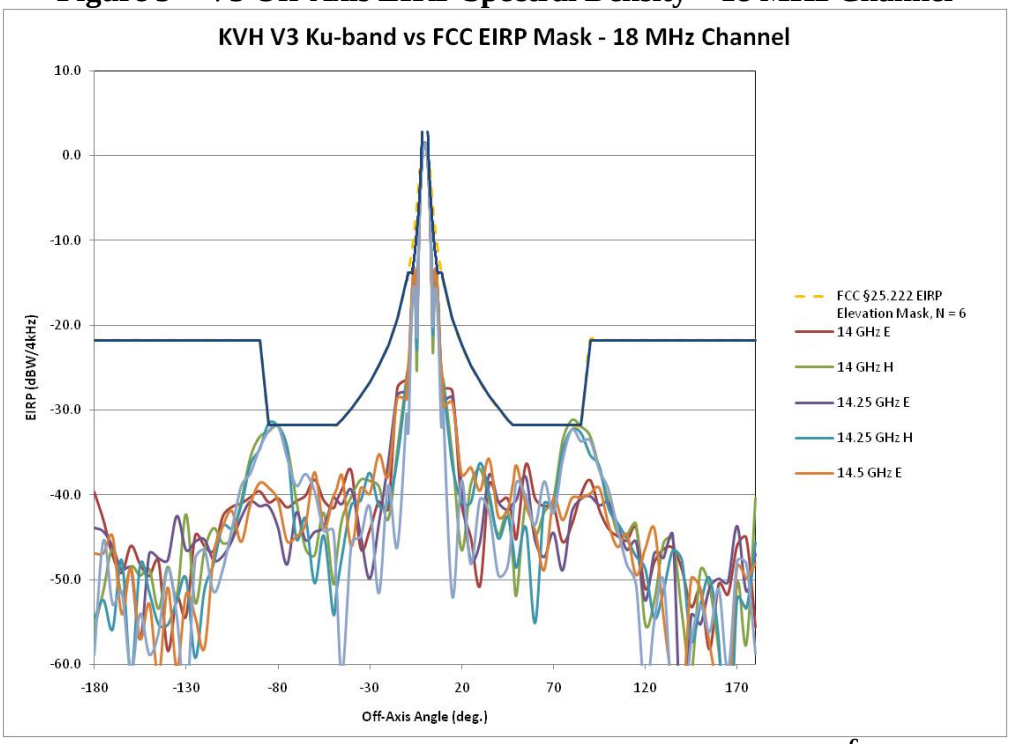

Figure 6 – 18 MHz Off-Axis EIRP Spectral Density[6]

[6] EIRP envelope exceeds mask by as much as 1.55 dB between -75 to -85 degrees and +75 to 85 degrees, <5.7% of sidelobes. Per FCC §25.222(a)(1)(i)(A) for angles greater than 7.0°, the envelope may be exceeded by no more than 10% of the sidelobes, provided no individual sidelobe exceeds the envelope given above by more than 3 dB.

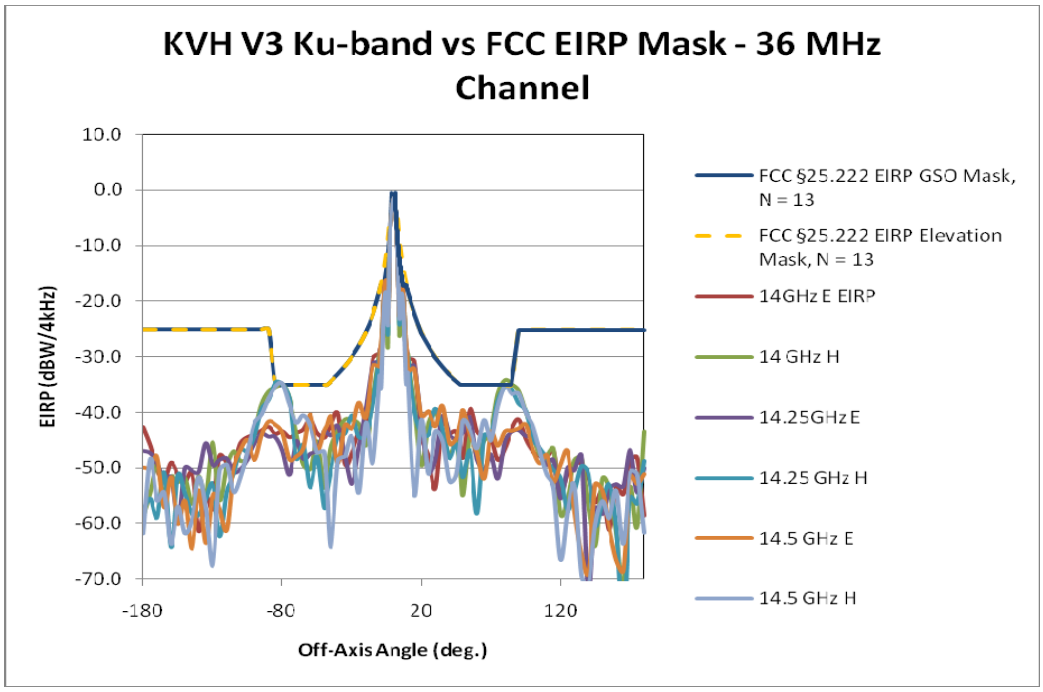

Figure 7 – 36 MHz Channel Off-Axis EIRP Spectral Density

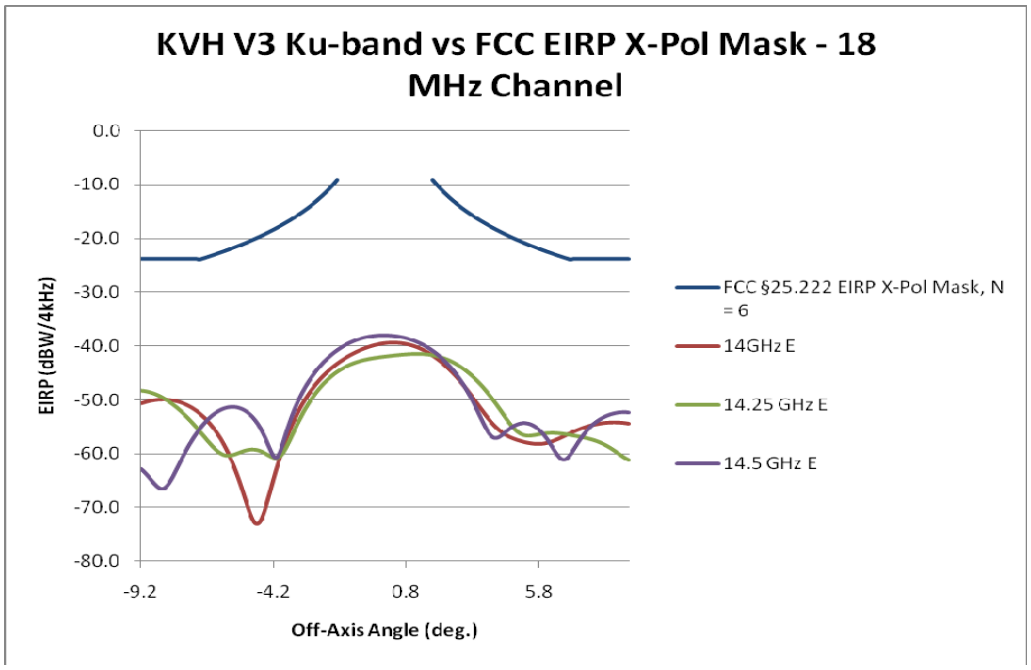

Figure 8 – 18 MHz Channel Cross-Pol Off-Axis EIRP Spectral Density

Per § 25.222(b)(1)(i), Table 1 below provides the co-pol the E and H plane antenna patterns for the parabolic antenna, as well as the E and H plane EIRP charts, and the FCC GSO and Elevation masks. Table 2 below provides the X-Pol E and H plane antenna gain and EIRP charts versus the FCC mask.

Table 1	Antenna Gain (dBi)									ESV EIRP (dBW/4 kHz)							
Off-Axis Angle	14 GHz E	14 GHz H	14.25 GHz E	14.25 GHz H	14.5 GHz E	14.5 GHz H	Off-Axis Angle	FCC §25.209	FCC §25.222 EIRP GSO Mask, N = 6	FCC §25.222 EIRP Elevation Mask, N = 6	14 GHz E	14 GHz H	14.25 GHz E	14.25 GHz H	14.5 GHz E	14.5 GHz H	Meets Mask
-180	-7.9	-24.1	-12.1	-22.8	-15.1	-27.0	-180	0.0	-21.8	-21.8	-39.6	-55.8	-43.9	-54.6	-46.9	-58.8	Y
-175	-11.2	-19.5	-12.5	-20.7	-15.1	-13.6	-175	0.0	-21.8	-21.8	-43.0	-51.3	-44.3	-52.4	-46.9	-45.3	Y
-170	-15.4	-14.6	-14.3	-24.1	-13.2	-21.1	-170	0.0	-21.8	-21.8	-47.1	-46.3	-46.1	-55.9	-44.9	-52.8	Y
-165	-17.4	-19.9	-17.1	-15.9	-22.3	-19.7	-165	0.0	-21.8	-21.8	-49.2	-51.7	-48.9	-47.7	-54.1	-51.4	Y
-160	-14.2	-16.7	-16.9	-29.4	-16.9	-29.0	-160	0.0	-21.8	-21.8	-46.0	-48.4	-48.6	-61.2	-48.6	-60.7	Y
-155	-16.4	-17.7	-25.2	-16.5	-25.2	-22.2	-155	0.0	-21.8	-21.8	-48.2	-49.5	-57.0	-48.3	-57.0	-53.9	Y
-150	-17.8	-17.0	-15.1	-19.8	-21.1	-27.0	-150	0.0	-21.8	-21.8	-49.6	-48.8	-46.9	-51.5	-52.9	-58.8	Y
-145	-16.0	-21.7	-15.7	-23.5	-29.7	-24.5	-145	0.0	-21.8	-21.8	-47.8	-53.4	-47.4	-55.3	-61.5	-56.2	Y
-140	-26.6	-16.7	-15.9	-23.6	-19.2	-16.9	-140	0.0	-21.8	-21.8	-58.3	-48.5	-47.7	-55.4	-50.9	-48.7	Y
-135	-20.4	-20.0	-10.7	-20.7	-28.7	-22.5	-135	0.0	-21.8	-21.8	-52.1	-51.8	-42.5	-52.5	-60.5	-54.3	Y
-130	-22.5	-10.5	-14.7	-18.1	-20.0	-32.8	-130	0.0	-21.8	-21.8	-54.3	-42.3	-46.5	-49.9	-51.7	-64.6	Y
-125	-13.0	-21.0	-13.7	-27.5	-22.7	-15.7	-125	0.0	-21.8	-21.8	-44.8	-52.7	-45.5	-59.2	-54.4	-47.5	Y
-120	-14.3	-14.8	-13.5	-19.5	-26.3	-14.6	-120	0.0	-21.8	-21.8	-46.0	-46.5	-45.2	-51.2	-58.1	-46.4	Y
-115	-14.8	-12.1	-15.9	-16.4	-15.4	-19.6	-115	0.0	-21.8	-21.8	-46.6	-43.9	-47.7	-48.1	-47.1	-51.4	Y
-110	-10.8	-13.9	-15.4	-11.9	-11.9	-16.9	-110	0.0	-21.8	-21.8	-42.5	-45.7	-47.2	-43.6	-43.7	-48.7	Y
-105	-9.6	-13.4	-13.6	-12.2	-10.2	-12.1	-105	0.0	-21.8	-21.8	-41.4	-45.1	-45.3	-44.0	-41.9	-43.9	Y
-100	-9.2	-9.0	-10.9	-9.5	-13.8	-7.2	-100	0.0	-21.8	-21.8	-41.0	-40.8	-42.7	-41.3	-45.6	-38.9	Y
-95	-8.5	-3.8	-9.0	-4.7	-9.4	-5.7	-95	0.0	-21.8	-21.8	-40.3	-35.6	-40.8	-36.4	-41.1	-37.4	Y
-90	-7.8	-1.4	-9.5	-2.9	-6.9	-2.7	-90	0.0	-21.8	-21.8	-39.6	-33.2	-41.3	-34.7	-38.6	-34.5	Y
-85	-9.1	-0.7	-9.6	0.2	-7.4	-0.6	-85	-10.0	-31.8	-31.8	-40.9	-32.5	-41.3	-31.6	-39.2	-32.4	N
-80	-8.6	-0.1	-12.0	-0.2	-8.9	0.0	-80	-10.0	-31.8	-31.8	-40.4	-31.8	-43.8	-31.9	-40.6	-31.8	Y
-75	-9.7	-2.6	-16.4	-2.7	-13.7	-3.8	-75	-10.0	-31.8	-31.8	-41.5	-34.3	-48.2	-34.5	-45.5	-35.5	Y
-70	-9.0	-8.8	-10.3	-13.4	-13.2	-7.1	-70	-10.0	-31.8	-31.8	-40.7	-40.6	-42.1	-45.1	-44.9	-38.9	Y
-65	-8.3	-14.6	-13.5	-11.0	-11.7	-5.7	-65	-10.0	-31.8	-31.8	-40.1	-46.3	-45.3	-42.8	-43.5	-37.5	Y
-60	-6.4	-15.3	-12.6	-18.7	-5.6	-7.8	-60	-10.0	-31.8	-31.8	-38.2	-47.1	-44.4	-50.4	-37.3	-39.5	Y
-55	-8.9	-10.4	-12.0	-13.1	-12.1	-12.4	-55	-10.0	-31.8	-31.8	-40.7	-42.1	-43.7	-44.8	-43.8	-44.2	Y
-50	-9.8	-18.6	-8.6	-22.2	-8.6	-12.3	-50	-10.0	-31.8	-31.8	-41.6	-50.4	-40.3	-54.0	-40.3	-44.1	Y
-48	-8.9	-15.6	-8.8	-19.5	-7.5	-19.2	-48	-10.0	-31.8	-31.8	-40.7	-47.3	-40.6	-51.2	-39.3	-50.9	Y
-45	-7.5	-11.1	-9.3	-15.4	-6.0	-29.4	-45	-9.3	-31.1	-31.1	-39.3	-42.8	-41.0	-47.1	-37.8	-61.2	Y
-40	-5.4	-8.4	-7.6	-9.5	-14.3	-13.9	-40	-8.1	-29.8	-29.8	-37.2	-40.2	-39.4	-41.2	-46.1	-45.7	Y
-35	-14.5	-6.5	-12.9	-8.9	-7.5	-13.1	-35	-6.6	-28.4	-28.4	-46.3	-38.2	-44.7	-40.7	-39.2	-44.9	Y

-30	-12.4	-6.6	-18.1	-5.7	-8.1	-9.6	-30	-4.9	-26.7	-26.7	-44.1	-38.3	-49.8	-37.4	-39.9	-41.4	Y
-25	-9.0	-7.2	-11.6	-9.6	-3.5	-19.8	-25	-2.9	-24.7	-24.7	-40.8	-39.0	-43.3	-41.3	-35.2	-51.5	Y
-20	-9.9	-11.1	-4.5	-9.3	-6.1	-7.1	-20	-0.5	-22.3	-22.3	-41.6	-42.9	-36.2	-41.1	-37.8	-38.8	Y
-15	4.3	-3.0	3.5	-4.0	3.1	-14.3	-15	2.6	-19.2	-19.2	-27.4	-34.7	-28.3	-35.8	-28.6	-46.1	Y
-10	5.3	5.6	3.9	4.8	3.0	1.4	-10	7.0	-14.8	-14.8	-26.4	-26.2	-27.9	-26.9	-28.8	-30.4	Y
-9.9	5.7	5.5	4.5	4.6	3.7	1.0	-9.9	7.1	-14.7	-14.7	-26.1	-26.3	-27.3	-27.1	-28.0	-30.8	Y
-9.8	5.9	5.3	5.0	4.4	4.4	0.6	-9.8	7.2	-14.6	-14.6	-25.9	-26.4	-26.8	-27.4	-27.4	-31.1	Y
-9.7	6.1	5.2	5.4	4.2	4.9	0.3	-9.7	7.3	-14.5	-14.5	-25.7	-26.5	-26.4	-27.6	-26.8	-31.5	Y
-9.6	6.2	5.1	5.8	4.0	5.4	-0.1	-9.6	7.4	-14.3	-14.3	-25.6	-26.6	-26.0	-27.7	-26.4	-31.8	Y
-9.5	6.2	5.1	6.0	3.9	5.8	-0.4	-9.5	7.6	-14.2	-14.2	-25.6	-26.7	-25.7	-27.9	-25.9	-32.2	Y
-9.4	6.2	5.1	6.3	3.8	6.2	-0.7	-9.4	7.7	-14.1	-14.1	-25.6	-26.7	-25.5	-28.0	-25.6	-32.4	Y
-9.3	6.2	5.1	6.4	3.7	6.5	-0.9	-9.3	7.8	-14.0	-14.0	-25.6	-26.6	-25.3	-28.0	-25.3	-32.6	Y
-9.2	6.1	5.2	6.6	3.7	6.7	-1.0	-9.2	8.0	-13.8	-13.9	-25.7	-26.5	-25.2	-28.0	-25.0	-32.7	Y
-9.1	6.0	5.4	6.6	3.8	7.0	-1.0	-9.1	8.0	-13.8	-13.8	-25.8	-26.4	-25.1	-28.0	-24.8	-32.7	Y
-9	5.8	5.6	6.7	4.0	7.2	-0.8	-9	8.0	-13.8	-13.6	-25.9	-26.2	-25.0	-27.8	-24.6	-32.5	Y
-8.9	5.7	5.9	6.8	4.3	7.4	-0.4	-8.9	8.0	-13.8	-13.5	-26.0	-25.9	-25.0	-27.5	-24.4	-32.2	Y
-8.8	5.7	6.3	6.8	4.6	7.6	0.1	-8.8	8.0	-13.8	-13.4	-26.1	-25.5	-24.9	-27.1	-24.2	-31.7	Y
-8.7	5.7	6.7	6.9	5.1	7.8	0.7	-8.7	8.0	-13.8	-13.3	-26.1	-25.1	-24.9	-26.7	-23.9	-31.0	Y
-8.6	5.8	7.2	7.0	5.6	8.1	1.5	-8.6	8.0	-13.8	-13.1	-26.0	-24.6	-24.7	-26.1	-23.6	-30.2	Y
-8.5	6.0	7.7	7.2	6.2	8.4	2.4	-8.5	8.0	-13.8	-13.0	-25.7	-24.1	-24.6	-25.6	-23.3	-29.4	Y
-8.4	6.4	8.3	7.4	6.8	8.8	3.3	-8.4	8.0	-13.8	-12.9	-25.4	-23.5	-24.3	-24.9	-23.0	-28.5	Y
-8.3	6.8	8.8	7.7	7.5	9.2	4.2	-8.3	8.0	-13.8	-12.8	-24.9	-22.9	-24.0	-24.3	-22.6	-27.6	Y
-8.2	7.4	9.4	8.1	8.2	9.6	5.1	-8.2	8.0	-13.8	-12.6	-24.3	-22.3	-23.7	-23.6	-22.1	-26.7	Y
-8.1	8.1	10.0	8.5	8.9	10.1	6.0	-8.1	8.0	-13.8	-12.5	-23.7	-21.8	-23.2	-22.9	-21.7	-25.8	Y
-8	8.8	10.6	9.1	9.5	10.6	6.8	-8	8.0	-13.8	-12.4	-23.0	-21.2	-22.7	-22.2	-21.1	-24.9	Y
-7.9	9.5	11.2	9.6	10.2	11.2	7.7	-7.9	8.0	-13.8	-12.2	-22.2	-20.6	-22.1	-21.6	-20.6	-24.1	Y
-7.8	10.3	11.7	10.2	10.8	11.7	8.5	-7.8	8.0	-13.8	-12.1	-21.5	-20.0	-21.6	-20.9	-20.0	-23.3	Y
-7.7	11.0	12.2	10.8	11.5	12.3	9.3	-7.7	8.0	-13.8	-11.9	-20.8	-19.5	-20.9	-20.3	-19.5	-22.5	Y
-7.6	11.7	12.8	11.4	12.0	12.9	10.0	-7.6	8.0	-13.8	-11.8	-20.1	-19.0	-20.3	-19.7	-18.9	-21.8	Y
-7.5	12.4	13.2	12.0	12.6	13.4	10.7	-7.5	8.0	-13.8	-11.7	-19.4	-18.5	-19.7	-19.2	-18.4	-21.1	Y
-7.4	13.0	13.7	12.6	13.1	13.9	11.3	-7.4	8.0	-13.8	-11.5	-18.7	-18.1	-19.1	-18.6	-17.8	-20.4	Y
-7.3	13.7	14.1	13.2	13.6	14.5	11.9	-7.3	8.0	-13.8	-11.4	-18.1	-17.6	-18.5	-18.1	-17.3	-19.8	Y
-7.2	14.2	14.5	13.8	14.1	15.0	12.5	-7.2	8.0	-13.8	-11.2	-17.5	-17.2	-18.0	-17.7	-16.8	-19.3	Y
-7.1	14.8	14.9	14.3	14.5	15.4	13.0	-7.1	8.0	-13.8	-11.1	-17.0	-16.8	-17.5	-17.2	-16.3	-18.7	Y
-7	15.3	15.3	14.8	15.0	15.9	13.5	-7	7.9	-13.9	-10.9	-16.5	-16.5	-17.0	-16.8	-15.9	-18.2	Y
-6.9	15.8	15.6	15.2	15.3	16.3	14.0	-6.9	8.0	-13.8	-10.8	-16.0	-16.2	-16.5	-16.4	-15.5	-17.8	Y
-6.8	16.2	15.9	15.7	15.7	16.7	14.4	-6.8	8.2	-13.6	-10.6	-15.6	-15.9	-16.1	-16.1	-15.1	-17.4	Y
-6.7	16.6	16.1	16.1	16.0	17.0	14.8	-6.7	8.3	-13.4	-10.4	-15.2	-15.7	-15.7	-15.8	-14.8	-17.0	Y

-6.6	17.0	16.3	16.4	16.2	17.3	15.1	-6.6	8.5	-13.3	-10.3	-14.8	-15.4	-15.3	-15.5	-14.4	-16.6	Y
-6.5	17.3	16.5	16.7	16.5	17.6	15.4	-6.5	8.7	-13.1	-10.1	-14.5	-15.3	-15.0	-15.3	-14.2	-16.3	Y
-6.4	17.6	16.6	17.0	16.7	17.9	15.7	-6.4	8.8	-12.9	-9.9	-14.2	-15.1	-14.7	-15.1	-13.9	-16.1	Y
-6.3	17.8	16.8	17.3	16.8	18.1	15.9	-6.3	9.0	-12.8	-9.8	-14.0	-15.0	-14.5	-14.9	-13.7	-15.9	Y
-6.2	18.0	16.8	17.5	17.0	18.2	16.1	-6.2	9.2	-12.6	-9.6	-13.8	-14.9	-14.3	-14.8	-13.5	-15.7	Y
-6.1	18.2	16.9	17.6	17.0	18.4	16.2	-6.1	9.4	-12.4	-9.4	-13.6	-14.9	-14.1	-14.7	-13.4	-15.5	Y
-6	18.3	16.8	17.8	17.1	18.5	16.3	-6	9.5	-12.2	-9.2	-13.5	-14.9	-14.0	-14.7	-13.3	-15.4	Y
-5.9	18.4	16.8	17.9	17.1	18.5	16.4	-5.9	9.7	-12.1	-9.1	-13.4	-15.0	-13.9	-14.7	-13.2	-15.4	Y
-5.8	18.4	16.7	17.9	17.0	18.6	16.4	-5.8	9.9	-11.9	-8.9	-13.4	-15.1	-13.9	-14.7	-13.2	-15.3	Y
-5.7	18.4	16.5	17.9	17.0	18.5	16.4	-5.7	10.1	-11.7	-8.7	-13.4	-15.3	-13.9	-14.8	-13.2	-15.4	Y
-5.6	18.3	16.3	17.9	16.8	18.5	16.3	-5.6	10.3	-11.5	-8.5	-13.4	-15.5	-13.9	-15.0	-13.3	-15.4	Y
-5.5	18.2	16.0	17.8	16.6	18.3	16.2	-5.5	10.5	-11.3	-8.3	-13.5	-15.8	-14.0	-15.2	-13.4	-15.6	Y
-5.4	18.1	15.6	17.6	16.3	18.2	16.0	-5.4	10.7	-11.1	-8.1	-13.7	-16.1	-14.2	-15.4	-13.6	-15.8	Y
-5.3	17.8	15.2	17.4	16.0	17.9	15.7	-5.3	10.9	-10.9	-7.9	-13.9	-16.6	-14.4	-15.8	-13.8	-16.0	Y
-5.2	17.6	14.6	17.1	15.6	17.6	15.4	-5.2	11.1	-10.7	-7.7	-14.2	-17.2	-14.6	-16.2	-14.1	-16.4	Y
-5.1	17.2	13.9	16.8	15.1	17.3	15.0	-5.1	11.3	-10.5	-7.5	-14.5	-17.8	-15.0	-16.7	-14.5	-16.8	Y
-5	16.8	13.1	16.4	14.5	16.8	14.5	-5	11.5	-10.3	-7.3	-15.0	-18.6	-15.3	-17.3	-14.9	-17.2	Y
-4.9	16.3	12.2	16.0	13.8	16.3	14.0	-4.9	11.7	-10.0	-7.0	-15.4	-19.6	-15.8	-18.0	-15.5	-17.8	Y
-4.8	15.8	11.0	15.4	12.9	15.7	13.3	-4.8	12.0	-9.8	-6.8	-16.0	-20.7	-16.3	-18.8	-16.1	-18.5	Y
-4.7	15.2	9.7	14.9	12.0	14.9	12.6	-4.7	12.2	-9.6	-6.6	-16.6	-22.0	-16.9	-19.8	-16.8	-19.2	Y
-4.6	14.5	8.3	14.2	10.9	14.1	11.8	-4.6	12.4	-9.4	-6.4	-17.2	-23.5	-17.5	-20.9	-17.7	-19.9	Y
-4.5	13.9	6.9	13.6	9.8	13.2	11.1	-4.5	12.7	-9.1	-6.1	-17.9	-24.8	-18.1	-21.9	-18.6	-20.7	Y
-4.4	13.3	6.4	13.1	9.0	12.2	10.5	-4.4	12.9	-8.9	-5.9	-18.5	-25.4	-18.6	-22.8	-19.6	-21.2	Y
-4.3	12.9	7.2	12.8	8.8	11.3	10.4	-4.3	13.2	-8.6	-5.6	-18.9	-24.6	-18.9	-23.0	-20.5	-21.4	Y
-4.2	12.7	8.9	12.8	9.4	10.8	10.7	-4.2	13.4	-8.4	-5.4	-19.0	-22.8	-18.9	-22.4	-21.0	-21.0	Y
-4.1	13.0	10.9	13.2	10.7	10.8	11.6	-4.1	13.7	-8.1	-5.1	-18.7	-20.8	-18.5	-21.1	-21.0	-20.2	Y
-4	13.7	12.9	14.0	12.3	11.5	12.8	-4	13.9	-7.8	-4.8	-18.0	-18.9	-17.8	-19.5	-20.2	-19.0	Y
-3.9	14.7	14.6	15.0	13.9	12.8	14.1	-3.9	14.2	-7.6	-4.6	-17.1	-17.1	-16.8	-17.9	-19.0	-17.6	Y
-3.8	15.8	16.2	16.1	15.4	14.2	15.5	-3.8	14.5	-7.3	-4.3	-15.9	-15.6	-15.7	-16.3	-17.5	-16.3	Y
-3.7	17.0	17.6	17.2	16.9	15.7	16.8	-3.7	14.8	-7.0	-4.0	-14.8	-14.2	-14.5	-14.9	-16.1	-15.0	Y
-3.6	18.2	18.8	18.4	18.2	17.1	18.0	-3.6	15.1	-6.7	-3.7	-13.6	-12.9	-13.4	-13.6	-14.7	-13.7	Y
-3.5	19.3	20.0	19.5	19.4	18.4	19.2	-3.5	15.4	-6.4	-3.4	-12.5	-11.8	-12.3	-12.4	-13.4	-12.6	Y
-3.4	20.3	21.0	20.5	20.4	19.6	20.3	-3.4	15.7	-6.1	-3.1	-11.4	-10.8	-11.3	-11.3	-12.2	-11.5	Y
-3.3	21.3	21.9	21.4	21.5	20.7	21.2	-3.3	16.0	-5.7	-2.7	-10.5	-9.8	-10.3	-10.3	-11.1	-10.5	Y
-3.2	22.2	22.8	22.3	22.4	21.7	22.2	-3.2	16.4	-5.4	-2.4	-9.5	-8.9	-9.4	-9.4	-10.1	-9.6	Y
-3.1	23.1	23.6	23.2	23.2	22.6	23.0	-3.1	16.7	-5.1	-2.1	-8.7	-8.1	-8.6	-8.5	-9.1	-8.7	Y
-3	23.9	24.4	24.0	24.0	23.5	23.8	-3	17.1	-4.7	-1.7	-7.9	-7.4	-7.8	-7.7	-8.3	-7.9	Y
-2.9	24.6	25.1	24.7	24.8	24.3	24.6	-2.9	17.4	-4.3		-7.1	-6.7	-7.0	-7.0	-7.5	-7.2	Y

-2.8	25.3	25.7	25.4	25.5	25.0	25.3	-2.8	17.8	-4.0		-6.4	-6.0	-6.3	-6.3	-6.7	-6.5	Y
-2.7	26.0	26.4	26.1	26.1	25.7	25.9	-2.7	18.2	-3.6		-5.8	-5.4	-5.7	-5.7	-6.0	-5.8	Y
-2.6	26.6	26.9	26.7	26.7	26.4	26.5	-2.6	18.6	-3.2		-5.2	-4.8	-5.1	-5.1	-5.4	-5.2	Y
-2.5	27.2	27.5	27.2	27.3	27.0	27.1	-2.5	19.1	-2.7		-4.6	-4.3	-4.5	-4.5	-4.8	-4.7	Y
-2.4	27.7	28.0	27.8	27.8	27.5	27.6	-2.4	19.5	-2.3		-4.1	-3.8	-4.0	-4.0	-4.2	-4.1	Y
-2.3	28.2	28.5	28.3	28.3	28.0	28.1	-2.3	20.0	-1.8		-3.5	-3.3	-3.5	-3.5	-3.7	-3.6	Y
-2.2	28.7	28.9	28.8	28.8	28.5	28.6	-2.2	20.4	-1.3		-3.1	-2.9	-3.0	-3.0	-3.2	-3.1	Y
-2.1	29.1	29.3	29.2	29.2	29.0	29.1	-2.1	20.9	-0.8		-2.6	-2.4	-2.6	-2.6	-2.8	-2.7	Y
-2	29.5	29.7	29.6	29.6	29.4	29.5	-2	21.5	-0.3		-2.2	-2.1	-2.2	-2.2	-2.3	-2.3	Y
-1.9	29.9	30.1	30.0	30.0	29.8	29.9	-1.9	22.0	0.2		-1.8	-1.7	-1.8	-1.8	-1.9	-1.9	Y
-1.8	30.3	30.4	30.4	30.4	30.2	30.2	-1.8	22.6	0.8		-1.5	-1.3	-1.4	-1.4	-1.6	-1.5	Y
-1.7	30.6	30.7	30.7	30.7	30.6	30.6	-1.7	23.2	1.5		-1.1	-1.0	-1.1	-1.1	-1.2	-1.2	Y
-1.6	31.0	31.0	31.0	31.0	30.9	30.9	-1.6	23.9	2.1		-0.8	-0.7	-0.8	-0.8	-0.9	-0.9	Y
-1.5	31.2	31.3	31.3	31.3	31.2	31.2	-1.5	24.6	2.8		-0.5	-0.4	-0.5	-0.5	-0.6	-0.6	Y
-1.4	31.5	31.6	31.6	31.6	31.5	31.5	-1.4				-0.2	-0.2	-0.2	-0.2	-0.3	-0.3	Y
-1.3	31.8	31.8	31.8	31.8	31.7	31.7	-1.3				0.0	0.0	0.0	0.0	0.0	0.0	Y
-1.2	32.0	32.0	32.0	32.0	31.9	32.0	-1.2				0.2	0.3	0.3	0.3	0.2	0.2	Y
-1.1	32.2	32.2	32.2	32.2	32.2	32.2	-1.1				0.4	0.5	0.5	0.5	0.4	0.4	Y
-1	32.4	32.4	32.4	32.4	32.4	32.4	-1				0.6	0.6	0.7	0.7	0.6	0.6	Y
-0.9	32.6	32.6	32.6	32.6	32.5	32.5	-0.9				0.8	0.8	0.8	0.8	0.8	0.8	Y
-0.8	32.7	32.7	32.7	32.7	32.7	32.7	-0.8				0.9	1.0	1.0	1.0	0.9	0.9	Y
-0.7	32.8	32.8	32.9	32.9	32.8	32.8	-0.7				1.1	1.1	1.1	1.1	1.1	1.1	Y
-0.6	32.9	32.9	33.0	33.0	32.9	32.9	-0.6				1.2	1.2	1.2	1.2	1.2	1.2	Y
-0.5	33.0	33.0	33.1	33.1	33.0	33.0	-0.5				1.3	1.3	1.3	1.3	1.3	1.3	Y
-0.4	33.1	33.1	33.2	33.2	33.1	33.1	-0.4				1.4	1.4	1.4	1.4	1.3	1.4	Y
-0.3	33.2	33.2	33.2	33.2	33.2	33.2	-0.3				1.4	1.4	1.5	1.5	1.4	1.4	Y
-0.2	33.2	33.2	33.3	33.3	33.2	33.2	-0.2				1.5	1.5	1.5	1.5	1.5	1.5	Y
-0.1	33.2	33.2	33.3	33.3	33.2	33.2	-0.1				1.5	1.5	1.5	1.5	1.5	1.5	Y
0	33.3	33.3	33.3	33.3	33.3	33.3	0				1.5	1.5	1.5	1.5	1.5	1.5	Y
0.1	33.2	33.2	33.3	33.3	33.2	33.2	0.1				1.5	1.5	1.5	1.5	1.5	1.5	Y
0.2	33.2	33.2	33.3	33.3	33.2	33.2	0.2				1.5	1.5	1.5	1.5	1.5	1.5	Y
0.3	33.2	33.2	33.2	33.2	33.2	33.2	0.3				1.4	1.4	1.5	1.5	1.4	1.4	Y
0.4	33.1	33.1	33.2	33.2	33.1	33.1	0.4				1.4	1.4	1.4	1.4	1.3	1.3	Y
0.5	33.0	33.0	33.1	33.1	33.0	33.0	0.5				1.3	1.3	1.3	1.3	1.3	1.3	Y
0.6	32.9	33.0	33.0	33.0	32.9	32.9	0.6				1.2	1.2	1.2	1.2	1.2	1.2	Y
0.7	32.8	32.8	32.9	32.9	32.8	32.8	0.7				1.1	1.1	1.1	1.1	1.0	1.1	Y
0.8	32.7	32.7	32.7	32.7	32.7	32.7	0.8				0.9	1.0	1.0	1.0	0.9	0.9	Y
0.9	32.5	32.6	32.6	32.6	32.5	32.5	0.9				0.8	0.8	0.8	0.8	0.8	0.8	Y

1	32.4	32.4	32.4	32.4	32.3	32.4	1				0.6	0.7	0.7	0.7	0.6	0.6	Y
1.1	32.2	32.2	32.2	32.2	32.1	32.2	1.1				0.4	0.5	0.5	0.5	0.4	0.4	Y
1.2	32.0	32.0	32.0	32.0	31.9	31.9	1.2				0.2	0.3	0.3	0.3	0.2	0.2	Y
1.3	31.8	31.8	31.8	31.8	31.7	31.7	1.3				0.0	0.1	0.0	0.0	-0.1	0.0	Y
1.4	31.5	31.6	31.5	31.6	31.4	31.5	1.4				-0.3	-0.2	-0.2	-0.2	-0.3	-0.3	Y
1.5	31.2	31.3	31.3	31.3	31.2	31.2	1.5	24.6	2.8		-0.5	-0.4	-0.5	-0.5	-0.6	-0.6	Y
1.6	30.9	31.1	31.0	31.0	30.9	30.9	1.6	23.9	2.1		-0.8	-0.7	-0.8	-0.8	-0.9	-0.9	Y
1.7	30.6	30.8	30.7	30.7	30.5	30.6	1.7	23.2	1.5		-1.1	-1.0	-1.1	-1.1	-1.2	-1.2	Y
1.8	30.3	30.4	30.3	30.4	30.2	30.2	1.8	22.6	0.8		-1.5	-1.3	-1.4	-1.4	-1.6	-1.5	Y
1.9	29.9	30.1	30.0	30.0	29.8	29.9	1.9	22.0	0.2		-1.8	-1.7	-1.8	-1.8	-2.0	-1.9	Y
2	29.5	29.7	29.6	29.6	29.4	29.5	2	21.5	-0.3		-2.2	-2.0	-2.2	-2.1	-2.4	-2.3	Y
2.1	29.1	29.3	29.2	29.2	29.0	29.1	2.1	20.9	-0.8		-2.6	-2.4	-2.6	-2.5	-2.8	-2.7	Y
2.2	28.7	28.9	28.7	28.8	28.5	28.6	2.2	20.4	-1.3		-3.1	-2.8	-3.0	-3.0	-3.3	-3.1	Y
2.3	28.2	28.5	28.3	28.3	28.0	28.2	2.3	20.0	-1.8		-3.5	-3.3	-3.5	-3.4	-3.7	-3.6	Y
2.4	27.7	28.0	27.8	27.8	27.5	27.7	2.4	19.5	-2.3		-4.0	-3.7	-4.0	-3.9	-4.3	-4.1	Y
2.5	27.2	27.5	27.2	27.3	26.9	27.1	2.5	19.1	-2.7		-4.6	-4.2	-4.5	-4.4	-4.8	-4.6	Y
2.6	26.6	27.0	26.7	26.8	26.3	26.6	2.6	18.6	-3.2		-5.2	-4.8	-5.1	-5.0	-5.4	-5.2	Y
2.7	26.0	26.4	26.1	26.2	25.7	26.0	2.7	18.2	-3.6		-5.8	-5.3	-5.7	-5.6	-6.1	-5.8	Y
2.8	25.3	25.8	25.4	25.5	25.0	25.3	2.8	17.8	-4.0		-6.4	-6.0	-6.3	-6.2	-6.8	-6.4	Y
2.9	24.7	25.2	24.7	24.9	24.3	24.7	2.9	17.4	-4.3		-7.1	-6.6	-7.0	-6.9	-7.5	-7.1	Y
3	23.9	24.5	24.0	24.1	23.5	23.9	3	17.1	-4.7	-1.7	-7.9	-7.3	-7.8	-7.6	-8.3	-7.8	Y
3.1	23.1	23.7	23.2	23.4	22.6	23.2	3.1	16.7	-5.1	-2.1	-8.7	-8.1	-8.5	-8.4	-9.1	-8.6	Y
3.2	22.3	22.9	22.4	22.5	21.7	22.3	3.2	16.4	-5.4	-2.4	-9.5	-8.9	-9.3	-9.2	-10.1	-9.4	Y
3.3	21.3	22.0	21.5	21.7	20.7	21.5	3.3	16.0	-5.7	-2.7	-10.4	-9.7	-10.2	-10.1	-11.0	-10.3	Y
3.4	20.4	21.1	20.6	20.7	19.7	20.5	3.4	15.7	-6.1	-3.1	-11.4	-10.7	-11.1	-11.1	-12.1	-11.2	Y
3.5	19.3	20.1	19.7	19.7	18.5	19.5	3.5	15.4	-6.4	-3.4	-12.4	-11.7	-12.1	-12.1	-13.2	-12.2	Y
3.6	18.2	19.0	18.7	18.6	17.3	18.5	3.6	15.1	-6.7	-3.7	-13.5	-12.8	-13.1	-13.2	-14.5	-13.3	Y
3.7	17.1	17.8	17.7	17.4	16.0	17.3	3.7	14.8	-7.0	-4.0	-14.7	-14.0	-14.1	-14.4	-15.7	-14.4	Y
3.8	15.9	16.5	16.7	16.1	14.8	16.2	3.8	14.5	-7.3	-4.3	-15.9	-15.3	-15.1	-15.7	-17.0	-15.6	Y
3.9	14.7	15.0	15.8	14.8	13.6	15.0	3.9	14.2	-7.6	-4.6	-17.0	-16.7	-16.0	-17.0	-18.2	-16.8	Y
4	13.7	13.5	15.0	13.4	12.6	13.8	4	13.9	-7.8	-4.8	-18.0	-18.3	-16.8	-18.3	-19.2	-18.0	Y
4.1	13.0	11.9	14.5	12.2	12.1	12.8	4.1	13.7	-8.1	-5.1	-18.8	-19.9	-17.3	-19.6	-19.7	-19.0	Y
4.2	12.6	10.3	14.2	11.2	12.0	12.0	4.2	13.4	-8.4	-5.4	-19.2	-21.5	-17.5	-20.6	-19.7	-19.8	Y
4.3	12.6	9.0	14.3	10.6	12.4	11.6	4.3	13.2	-8.6	-5.6	-19.1	-22.7	-17.5	-21.2	-19.3	-20.2	Y
4.4	13.0	8.5	14.5	10.6	13.1	11.6	4.4	12.9	-8.9	-5.9	-18.7	-23.3	-17.2	-21.2	-18.7	-20.2	Y
4.5	13.6	8.8	14.9	11.0	13.8	11.8	4.5	12.7	-9.1	-6.1	-18.2	-23.0	-16.8	-20.8	-17.9	-19.9	Y
4.6	14.3	9.7	15.4	11.7	14.6	12.3	4.6	12.4	-9.4	-6.4	-17.5	-22.1	-16.3	-20.1	-17.2	-19.4	Y
4.7	14.9	10.7	15.9	12.5	15.3	12.9	4.7	12.2	-9.6	-6.6	-16.8	-21.0	-15.8	-19.3	-16.5	-18.9	Y

4.8	15.5	11.8	16.4	13.2	15.9	13.5	4.8	12.0	-9.8	-6.8	-16.2	-20.0	-15.4	-18.5	-15.8	-18.3	Y
4.9	16.1	12.8	16.8	13.9	16.5	14.0	4.9	11.7	-10.0	-7.0	-15.7	-19.0	-14.9	-17.8	-15.3	-17.7	Y
5	16.6	13.6	17.2	14.5	16.9	14.5	5	11.5	-10.3	-7.3	-15.2	-18.2	-14.6	-17.2	-14.8	-17.3	Y
5.1	17.0	14.3	17.5	15.1	17.3	14.9	5.1	11.3	-10.5	-7.5	-14.8	-17.5	-14.2	-16.7	-14.4	-16.8	Y
5.2	17.4	14.9	17.8	15.5	17.7	15.3	5.2	11.1	-10.7	-7.7	-14.4	-16.9	-14.0	-16.2	-14.1	-16.5	Y
5.3	17.6	15.4	18.0	15.9	17.9	15.6	5.3	10.9	-10.9	-7.9	-14.1	-16.4	-13.7	-15.9	-13.8	-16.2	Y
5.4	17.9	15.8	18.2	16.2	18.1	15.8	5.4	10.7	-11.1	-8.1	-13.9	-15.9	-13.6	-15.5	-13.6	-15.9	Y
5.5	18.1	16.2	18.3	16.5	18.3	16.0	5.5	10.5	-11.3	-8.3	-13.7	-15.6	-13.4	-15.3	-13.5	-15.8	Y
5.6	18.2	16.4	18.4	16.6	18.4	16.1	5.6	10.3	-11.5	-8.5	-13.6	-15.3	-13.4	-15.1	-13.4	-15.6	Y
5.7	18.2	16.6	18.4	16.8	18.4	16.2	5.7	10.1	-11.7	-8.7	-13.5	-15.1	-13.3	-15.0	-13.3	-15.6	Y
5.8	18.3	16.8	18.4	16.9	18.4	16.2	5.8	9.9	-11.9	-8.9	-13.5	-15.0	-13.3	-14.9	-13.3	-15.6	Y
5.9	18.3	16.9	18.4	16.9	18.4	16.2	5.9	9.7	-12.1	-9.1	-13.5	-14.9	-13.4	-14.9	-13.3	-15.6	Y
6	18.2	17.0	18.3	16.9	18.3	16.1	6	9.5	-12.2	-9.2	-13.6	-14.8	-13.5	-14.9	-13.4	-15.7	Y
6.1	18.1	17.0	18.2	16.8	18.2	16.0	6.1	9.4	-12.4	-9.4	-13.7	-14.8	-13.6	-14.9	-13.5	-15.8	Y
6.2	17.9	16.9	18.0	16.7	18.1	15.8	6.2	9.2	-12.6	-9.6	-13.8	-14.8	-13.8	-15.0	-13.7	-15.9	Y
6.3	17.8	16.9	17.8	16.6	17.9	15.7	6.3	9.0	-12.8	-9.8	-14.0	-14.9	-14.0	-15.2	-13.8	-16.1	Y
6.4	17.5	16.7	17.6	16.4	17.7	15.4	6.4	8.8	-12.9	-9.9	-14.2	-15.0	-14.2	-15.3	-14.1	-16.3	Y
6.5	17.3	16.6	17.3	16.2	17.5	15.2	6.5	8.7	-13.1	-10.1	-14.5	-15.2	-14.5	-15.5	-14.3	-16.6	Y
6.6	17.0	16.4	17.0	16.0	17.2	14.8	6.6	8.5	-13.3	-10.3	-14.8	-15.3	-14.8	-15.8	-14.6	-16.9	Y
6.7	16.7	16.2	16.6	15.7	16.9	14.5	6.7	8.3	-13.4	-10.4	-15.1	-15.6	-15.1	-16.1	-14.9	-17.3	Y
6.8	16.3	16.0	16.3	15.4	16.5	14.1	6.8	8.2	-13.6	-10.6	-15.5	-15.8	-15.5	-16.4	-15.3	-17.6	Y
6.9	15.9	15.7	15.9	15.0	16.1	13.7	6.9	8.0	-13.8	-10.8	-15.9	-16.1	-15.9	-16.7	-15.6	-18.1	Y
7	15.4	15.4	15.4	14.7	15.7	13.2	7	7.9	-13.9	-10.9	-16.3	-16.4	-16.3	-17.1	-16.0	-18.5	Y
7.1	15.0	15.0	15.0	14.3	15.3	12.7	7.1	8.0	-13.8	-11.1	-16.8	-16.7	-16.8	-17.5	-16.5	-19.0	Y
7.2	14.4	14.6	14.5	13.8	14.8	12.2	7.2	8.0	-13.8	-11.2	-17.3	-17.1	-17.3	-17.9	-16.9	-19.5	Y
7.3	13.9	14.2	13.9	13.3	14.3	11.7	7.3	8.0	-13.8	-11.4	-17.9	-17.5	-17.8	-18.4	-17.4	-20.1	Y
7.4	13.3	13.8	13.4	12.8	13.8	11.0	7.4	8.0	-13.8	-11.5	-18.4	-18.0	-18.4	-18.9	-18.0	-20.7	Y
7.5	12.7	13.3	12.8	12.3	13.3	10.4	7.5	8.0	-13.8	-11.7	-19.1	-18.4	-18.9	-19.4	-18.5	-21.4	Y
7.6	12.1	12.9	12.3	11.8	12.7	9.7	7.6	8.0	-13.8	-11.8	-19.7	-18.9	-19.5	-20.0	-19.0	-22.0	Y
7.7	11.4	12.3	11.7	11.2	12.1	9.0	7.7	8.0	-13.8	-11.9	-20.4	-19.4	-20.1	-20.6	-19.6	-22.7	Y
7.8	10.7	11.8	11.1	10.6	11.6	8.3	7.8	8.0	-13.8	-12.1	-21.1	-19.9	-20.7	-21.2	-20.2	-23.5	Y
7.9	10.0	11.3	10.5	9.9	11.0	7.5	7.9	8.0	-13.8	-12.2	-21.8	-20.5	-21.3	-21.8	-20.8	-24.3	Y
8	9.3	10.7	9.9	9.3	10.5	6.7	8	8.0	-13.8	-12.4	-22.5	-21.1	-21.8	-22.5	-21.3	-25.1	Y
8.1	8.6	10.1	9.4	8.7	9.9	5.8	8.1	8.0	-13.8	-12.5	-23.1	-21.6	-22.4	-23.1	-21.8	-25.9	Y
8.2	8.0	9.5	8.9	8.0	9.4	5.0	8.2	8.0	-13.8	-12.6	-23.8	-22.2	-22.9	-23.8	-22.3	-26.8	Y
8.3	7.3	9.0	8.4	7.4	8.9	4.1	8.3	8.0	-13.8	-12.8	-24.4	-22.8	-23.4	-24.4	-22.8	-27.6	Y
8.4	6.8	8.4	8.0	6.7	8.5	3.3	8.4	8.0	-13.8	-12.9	-25.0	-23.4	-23.8	-25.0	-23.2	-28.5	Y
8.5	6.3	7.8	7.6	6.2	8.1	2.5	8.5	8.0	-13.8	-13.0	-25.4	-23.9	-24.1	-25.6	-23.6	-29.3	Y

8.6	6.0	7.3	7.3	5.6	7.8	1.8	8.6	8.0	-13.8	-13.1	-25.8	-24.5	-24.4	-26.1	-24.0	-30.0	Y
8.7	5.7	6.8	7.1	5.1	7.5	1.1	8.7	8.0	-13.8	-13.3	-26.0	-25.0	-24.7	-26.6	-24.3	-30.7	Y
8.8	5.5	6.3	6.9	4.7	7.2	0.5	8.8	8.0	-13.8	-13.4	-26.2	-25.4	-24.9	-27.0	-24.5	-31.2	Y
8.9	5.5	5.9	6.7	4.4	7.0	0.1	8.9	8.0	-13.8	-13.5	-26.3	-25.8	-25.1	-27.4	-24.8	-31.6	Y
9	5.4	5.6	6.5	4.1	6.7	-0.1	9	8.0	-13.8	-13.6	-26.3	-26.1	-25.2	-27.6	-25.0	-31.9	Y
9.1	5.4	5.4	6.4	4.0	6.5	-0.3	9.1	8.0	-13.8	-13.8	-26.3	-26.4	-25.4	-27.8	-25.3	-32.0	Y
9.2	5.4	5.2	6.2	3.9	6.2	-0.2	9.2	8.0	-13.8	-13.9	-26.3	-26.6	-25.6	-27.9	-25.5	-32.0	Y
9.3	5.4	5.0	5.9	3.9	5.9	-0.1	9.3	7.8	-14.0	-14.0	-26.3	-26.7	-25.8	-27.9	-25.8	-31.9	Y
9.4	5.4	5.0	5.7	3.9	5.6	0.1	9.4	7.7	-14.1	-14.1	-26.4	-26.8	-26.1	-27.9	-26.2	-31.7	Y
9.5	5.4	4.9	5.4	4.0	5.2	0.3	9.5	7.6	-14.2	-14.2	-26.4	-26.8	-26.4	-27.8	-26.6	-31.4	Y
9.6	5.3	5.0	5.0	4.1	4.7	0.6	9.6	7.4	-14.3	-14.3	-26.5	-26.8	-26.7	-27.6	-27.0	-31.1	Y
9.7	5.1	5.1	4.6	4.3	4.2	1.0	9.7	7.3	-14.5	-14.5	-26.6	-26.7	-27.2	-27.5	-27.5	-30.8	Y
9.8	4.9	5.2	4.1	4.5	3.6	1.3	9.8	7.2	-14.6	-14.6	-26.8	-26.6	-27.7	-27.3	-28.1	-30.5	Y
9.9	4.6	5.3	3.5	4.7	2.9	1.6	9.9	7.1	-14.7	-14.7	-27.1	-26.5	-28.3	-27.1	-28.9	-30.1	Y
10	4.3	5.4	2.8	4.9	2.1	2.0	10	7.0	-14.8	-14.8	-27.5	-26.3	-29.0	-26.9	-29.7	-29.8	Y
15	4.0	-3.6	3.2	-4.8	2.6	-20.2	15	2.6	-19.2	-19.2	-27.8	-35.4	-28.6	-36.6	-29.1	-52.0	Y
20	-9.3	-14.7	-7.1	-9.0	-5.8	-6.5	20	-0.5	-22.3	-22.3	-41.0	-46.5	-38.9	-40.7	-37.6	-38.3	Y
25	-13.2	-7.0	-16.0	-9.1	-5.0	-16.3	25	-2.9	-24.7	-24.7	-45.0	-38.7	-47.7	-40.9	-36.8	-48.1	Y
30	-19.0	-5.1	-13.8	-4.5	-7.8	-8.7	30	-4.9	-26.7	-26.7	-50.7	-36.9	-45.6	-36.3	-39.5	-40.5	Y
35	-7.0	-8.8	-5.9	-8.1	-4.0	-10.2	35	-6.6	-28.4	-28.4	-38.7	-40.6	-37.6	-39.9	-35.8	-42.0	Y
40	-9.0	-12.9	-9.1	-13.4	-10.8	-17.6	40	-8.1	-29.8	-29.8	-40.8	-44.7	-40.8	-45.2	-42.6	-49.4	Y
45	-8.6	-10.2	-10.0	-10.8	-10.0	-16.7	45	-9.3	-31.1	-31.1	-40.4	-41.9	-41.8	-42.6	-41.8	-48.4	Y
48	-11.4	-16.0	-9.2	-14.4	-6.9	-10.6	48	-10.0	-31.8	-31.8	-43.2	-47.8	-41.0	-46.2	-38.7	-42.4	Y
50	-13.3	-19.9	-8.7	-16.8	-4.8	-6.6	50	-10.0	-31.8	-31.8	-45.0	-51.7	-40.5	-48.6	-36.6	-38.4	Y
55	-4.6	-8.9	-6.1	-12.1	-9.4	-8.3	55	-10.0	-31.8	-31.8	-36.4	-40.7	-37.9	-43.9	-41.2	-40.1	Y
60	-8.6	-12.9	-13.6	-23.4	-12.4	-11.7	60	-10.0	-31.8	-31.8	-40.4	-44.7	-45.3	-55.1	-44.2	-43.5	Y
65	-9.6	-10.2	-15.5	-9.3	-17.1	-6.6	65	-10.0	-31.8	-31.8	-41.3	-42.0	-47.3	-41.0	-48.9	-38.4	Y
70	-9.6	-8.7	-12.7	-9.6	-8.7	-10.4	70	-10.0	-31.8	-31.8	-41.3	-40.4	-44.4	-41.4	-40.5	-42.1	Y
75	-13.8	-1.8	-17.1	-3.1	-11.2	-4.1	75	-10.0	-31.8	-31.8	-45.5	-33.6	-48.9	-34.8	-43.0	-35.9	Y
80	-11.7	0.6	-10.3	-0.6	-8.6	-0.5	80	-10.0	-31.8	-31.8	-43.5	-31.2	-42.0	-32.3	-40.4	-32.2	N
85	-8.2	-0.2	-8.7	-1.0	-8.6	-1.9	85	-10.0	-31.8	-31.8	-39.9	-31.9	-40.4	-32.7	-40.3	-33.6	Y
90	-6.5	-1.3	-8.4	-3.6	-8.1	-1.8	90	0.0	-21.8	-21.8	-38.2	-33.0	-40.1	-35.3	-39.9	-33.5	Y
95	-10.0	-5.2	-9.4	-4.9	-7.4	-5.3	95	0.0	-21.8	-21.8	-41.8	-36.9	-41.2	-36.6	-39.2	-37.1	Y
100	-12.2	-8.9	-9.1	-9.8	-11.7	-7.6	100	0.0	-21.8	-21.8	-44.0	-40.7	-40.9	-41.6	-43.5	-39.4	Y
105	-13.1	-12.8	-11.9	-11.6	-14.4	-12.2	105	0.0	-21.8	-21.8	-44.9	-44.5	-43.6	-43.4	-46.2	-44.0	Y
110	-13.6	-13.0	-14.7	-13.5	-12.9	-16.4	110	0.0	-21.8	-21.8	-45.4	-44.7	-46.5	-45.2	-44.7	-48.2	Y
115	-12.1	-11.7	-13.8	-15.5	-17.7	-18.8	115	0.0	-21.8	-21.8	-43.9	-43.5	-45.5	-47.3	-49.5	-50.6	Y
120	-19.3	-23.5	-20.7	-17.0	-14.6	-31.8	120	0.0	-21.8	-21.8	-51.1	-55.2	-52.4	-48.7	-46.3	-63.5	Y

125	-16.1	-20.6	-15.1	-22.8	-12.3	-23.0	125	0.0	-21.8	-21.8	-47.9	-52.4	-46.8	-54.6	-44.0	-54.7	Y
130	-14.6	-13.8	-15.6	-19.5	-22.8	-18.4	130	0.0	-21.8	-21.8	-46.4	-45.6	-47.4	-51.2	-54.5	-50.2	Y
135	-14.5	-13.5	-13.0	-14.8	-30.7	-34.6	135	0.0	-21.8	-21.8	-46.3	-45.2	-44.8	-46.6	-62.5	-66.3	Y
140	-17.1	-22.3	-38.2	-16.0	-34.0	-36.5	140	0.0	-21.8	-21.8	-48.8	-54.1	-69.9	-47.8	-65.8	-68.2	Y
145	-21.4	-29.2	-22.4	-25.5	-18.2	-25.4	145	0.0	-21.8	-21.8	-53.2	-61.0	-54.2	-57.3	-49.9	-57.2	Y
150	-19.6	-17.1	-23.5	-21.2	-19.3	-21.2	150	0.0	-21.8	-21.8	-51.3	-48.9	-55.3	-53.0	-51.0	-53.0	Y
155	-26.5	-19.2	-19.1	-18.1	-25.9	-24.4	155	0.0	-21.8	-21.8	-58.2	-50.9	-50.9	-49.8	-57.6	-56.1	Y
160	-18.7	-26.6	-18.1	-25.5	-31.7	-19.3	160	0.0	-21.8	-21.8	-50.5	-58.4	-49.8	-57.2	-63.5	-51.1	Y
165	-19.9	-37.0	-18.5	-43.5	-33.7	-28.9	165	0.0	-21.8	-21.8	-51.7	-68.8	-50.2	-75.3	-65.4	-60.7	Y
170	-14.2	-18.7	-11.9	-20.4	-16.7	-16.0	170	0.0	-21.8	-21.8	-46.0	-50.4	-43.7	-52.2	-48.4	-47.8	Y
175	-13.3	-25.8	-19.6	-21.6	-18.1	-16.3	175	0.0	-21.8	-21.8	-45.1	-57.6	-51.3	-53.4	-49.8	-48.1	Y
180	-23.8	-8.6	-15.2	-13.9	-16.3	-26.9	180	0.0	-21.8	-21.8	-55.6	-40.4	-47.0	-45.6	-48.1	-58.7	Y

Table 2	Antenna Gain X-Pol						ESV EIRP X-Pol				
OffAxis Angle (degree)	14GHz E	14.25 GHz E	14.5 GHz E	OffAxis Angle (degree)	FCC 25.209(b)(1)	§25.222 X-Pol Mask,N=6	14GHz E	14.25 GHz E	14.5 GHz E	Worst case Exceedance EIRP (dB)	Meets Mask
-9.2	-18.83	-16.455	-31.01	-9.2	-2.0	-23.8	-50.6	-48.2	-62.8	26.8	Y
-9.1	-18.67	-16.509	-31.47	-9.1	-2.0	-23.8	-50.4	-48.3	-63.2	26.7	Y
-9.0	-18.53	-16.594	-31.99	-9.0	-2.0	-23.8	-50.3	-48.4	-63.7	26.5	Y
-8.9	-18.41	-16.708	-32.56	-8.9	-2.0	-23.8	-50.2	-48.5	-64.3	26.4	Y
-8.8	-18.3	-16.853	-33.16	-8.8	-2.0	-23.8	-50.1	-48.6	-64.9	26.3	Y
-8.7	-18.22	-17.028	-33.74	-8.7	-2.0	-23.8	-50.0	-48.8	-65.5	26.2	Y
-8.6	-18.15	-17.232	-34.25	-8.6	-2.0	-23.8	-49.9	-49.0	-66.0	26.1	Y
-8.5	-18.11	-17.464	-34.59	-8.5	-2.0	-23.8	-49.9	-49.2	-66.4	26.1	Y
-8.4	-18.09	-17.725	-34.7	-8.4	-2.0	-23.8	-49.8	-49.5	-66.5	26.1	Y
-8.3	-18.09	-18.014	-34.51	-8.3	-2.0	-23.8	-49.9	-49.8	-66.3	26.1	Y
-8.2	-18.12	-18.329	-34.03	-8.2	-2.0	-23.8	-49.9	-50.1	-65.8	26.1	Y
-8.1	-18.18	-18.67	-33.3	-8.1	-2.0	-23.8	-49.9	-50.4	-65.1	26.2	Y
-8.0	-18.26	-19.036	-32.42	-8.0	-2.0	-23.8	-50.0	-50.8	-64.2	26.2	Y
-7.9	-18.36	-19.427	-31.45	-7.9	-2.0	-23.8	-50.1	-51.2	-63.2	26.3	Y
-7.8	-18.49	-19.841	-30.45	-7.8	-2.0	-23.8	-50.3	-51.6	-62.2	26.5	Y
-7.7	-18.65	-20.279	-29.45	-7.7	-2.0	-23.8	-50.4	-52.0	-61.2	26.6	Y
-7.6	-18.84	-20.74	-28.48	-7.6	-2.0	-23.8	-50.6	-52.5	-60.2	26.8	Y
-7.5	-19.06	-21.222	-27.56	-7.5	-2.0	-23.8	-50.8	-53.0	-59.3	27.0	Y
-7.4	-19.31	-21.726	-26.67	-7.4	-2.0	-23.8	-51.1	-53.5	-58.4	27.3	Y
-7.3	-19.59	-22.25	-25.84	-7.3	-2.0	-23.8	-51.4	-54.0	-57.6	27.6	Y
-7.2	-19.91	-22.794	-25.06	-7.2	-2.0	-23.8	-51.7	-54.6	-56.8	27.9	Y
-7.1	-20.26	-23.355	-24.32	-7.1	-2.0	-23.8	-52.0	-55.1	-56.1	28.2	Y
-7.0	-20.64	-23.931	-23.64	-7.0	-2.1	-23.9	-52.4	-55.7	-55.4	28.5	Y
-6.9	-21.07	-24.519	-23.02	-6.9	-2.0	-23.8	-52.8	-56.3	-54.8	29.1	Y
-6.8	-21.53	-25.112	-22.44	-6.8	-1.8	-23.6	-53.3	-56.9	-54.2	29.7	Y
-6.7	-22.04	-25.702	-21.91	-6.7	-1.7	-23.4	-53.8	-57.5	-53.7	30.4	Y
-6.6	-22.6	-26.279	-21.44	-6.6	-1.5	-23.3	-54.4	-58.0	-53.2	31.1	Y
-6.5	-23.21	-26.826	-21.02	-6.5	-1.3	-23.1	-55.0	-58.6	-52.8	31.9	Y
-6.4	-23.87	-27.326	-20.64	-6.4	-1.2	-22.9	-55.6	-59.1	-52.4	32.7	Y
-6.3	-24.59	-27.758	-20.32	-6.3	-1.0	-22.8	-56.3	-59.5	-52.1	33.6	Y
-6.2	-25.38	-28.103	-20.05	-6.2	-0.8	-22.6	-57.1	-59.9	-51.8	34.5	Y
-6.1	-26.23	-28.347	-19.84	-6.1	-0.6	-22.4	-58.0	-60.1	-51.6	35.6	Y
-6.0	-27.16	-28.481	-19.67	-6.0	-0.5	-22.2	-58.9	-60.2	-51.4	36.7	Y

-5.9	-28.17	-28.511	-19.56	-5.9	-0.3	-22.1	-59.9	-60.3	-51.3	37.9	Y
-5.8	-29.28	-28.451	-19.51	-5.8	-0.1	-21.9	-61.0	-60.2	-51.3	39.2	Y
-5.7	-30.47	-28.323	-19.51	-5.7	0.1	-21.7	-62.2	-60.1	-51.3	40.6	Y
-5.6	-31.76	-28.152	-19.57	-5.6	0.3	-21.5	-63.5	-59.9	-51.3	42.0	Y
-5.5	-33.15	-27.962	-19.69	-5.5	0.5	-21.3	-64.9	-59.7	-51.4	43.6	Y
-5.4	-34.62	-27.774	-19.87	-5.4	0.7	-21.1	-66.4	-59.5	-51.6	45.3	Y
-5.3	-36.15	-27.608	-20.13	-5.3	0.9	-20.9	-67.9	-59.4	-51.9	47.0	Y
-5.2	-37.68	-27.477	-20.45	-5.2	1.1	-20.7	-69.4	-59.2	-52.2	48.8	Y
-5.1	-39.12	-27.392	-20.85	-5.1	1.3	-20.5	-70.9	-59.2	-52.6	50.4	Y
-5.0	-40.31	-27.363	-21.34	-5.0	1.5	-20.3	-72.1	-59.1	-53.1	51.8	Y
-4.9	-41.07	-27.394	-21.93	-4.9	1.7	-20.0	-72.8	-59.2	-53.7	52.8	Y
-4.8	-41.22	-27.489	-22.62	-4.8	2.0	-19.8	-73.0	-59.2	-54.4	53.2	Y
-4.7	-40.71	-27.649	-23.42	-4.7	2.2	-19.6	-72.5	-59.4	-55.2	52.9	Y
-4.6	-39.62	-27.868	-24.36	-4.6	2.4	-19.4	-71.4	-59.6	-56.1	52.0	Y
-4.5	-38.13	-28.137	-25.42	-4.5	2.7	-19.1	-69.9	-59.9	-57.2	50.8	Y
-4.4	-36.41	-28.429	-26.58	-4.4	2.9	-18.9	-68.2	-60.2	-58.3	49.3	Y
-4.3	-34.61	-28.707	-27.73	-4.3	3.2	-18.6	-66.4	-60.5	-59.5	47.8	Y
-4.2	-32.83	-28.912	-28.64	-4.2	3.4	-18.4	-64.6	-60.7	-60.4	46.2	Y
-4.1	-31.11	-28.967	-28.91	-4.1	3.7	-18.1	-62.9	-60.7	-60.7	44.8	Y
-4.0	-29.47	-28.798	-28.31	-4.0	3.9	-17.8	-61.2	-60.6	-60.1	43.4	Y
-3.9	-27.94	-28.362	-27.04	-3.9	4.2	-17.6	-59.7	-60.1	-58.8	42.1	Y
-3.8	-26.5	-27.67	-25.49	-3.8	4.5	-17.3	-58.3	-59.4	-57.2	41.0	Y
-3.7	-25.16	-26.783	-23.91	-3.7	4.8	-17.0	-56.9	-58.5	-55.7	39.9	Y
-3.6	-23.91	-25.775	-22.42	-3.6	5.1	-16.7	-55.7	-57.5	-54.2	39.0	Y
-3.5	-22.75	-24.717	-21.06	-3.5	5.4	-16.4	-54.5	-56.5	-52.8	38.1	Y
-3.4	-21.66	-23.657	-19.81	-3.4	5.7	-16.1	-53.4	-55.4	-51.6	37.4	Y
-3.3	-20.65	-22.624	-18.67	-3.3	6.0	-15.7	-52.4	-54.4	-50.4	36.7	Y
-3.2	-19.71	-21.637	-17.62	-3.2	6.4	-15.4	-51.5	-53.4	-49.4	36.1	Y
-3.1	-18.83	-20.703	-16.67	-3.1	6.7	-15.1	-50.6	-52.5	-48.4	35.5	Y
-3.0	-18.01	-19.824	-15.78	-3.0	7.1	-14.7	-49.8	-51.6	-47.5	35.1	Y
-2.9	-17.24	-19.002	-14.97	-2.9	7.4	-14.3	-49.0	-50.8	-46.7	34.7	Y
-2.8	-16.53	-18.233	-14.21	-2.8	7.8	-14.0	-48.3	-50.0	-46.0	34.3	Y
-2.7	-15.86	-17.517	-13.5	-2.7	8.2	-13.6	-47.6	-49.3	-45.3	34.1	Y
-2.6	-15.23	-16.85	-12.85	-2.6	8.6	-13.2	-47.0	-48.6	-44.6	33.8	Y
-2.5	-14.65	-16.229	-12.23	-2.5	9.1	-12.7	-46.4	-48.0	-44.0	33.7	Y
-2.4	-14.1	-15.652	-11.66	-2.4	9.5	-12.3	-45.9	-47.4	-43.4	33.6	Y
-2.3	-13.58	-15.117	-11.13	-2.3	10.0	-11.8	-45.3	-46.9	-42.9	33.5	Y
-2.2	-13.1	-14.622	-10.64	-2.2	10.4	-11.3	-44.9	-46.4	-42.4	33.5	Y

-2.1	-12.64	-14.163	-10.18	-2.1	10.9	-10.8	-44.4	-45.9	-41.9	33.6	Y
-2.0	-12.22	-13.74	-9.747	-2.0	11.5	-10.3	-44.0	-45.5	-41.5	33.7	Y
-1.9	-11.81	-13.35	-9.349	-1.9	12.0	-9.8	-43.6	-45.1	-41.1	33.8	Y
-1.8	-11.43	-12.992	-8.979	-1.8	12.6	-9.2	-43.2	-44.8	-40.7	34.0	Y
-1.7	-11.08	-12.664	-8.639	-1.7			-42.8	-44.4	-40.4		Y
-1.6	-10.74	-12.365	-8.324	-1.6			-42.5	-44.1	-40.1		Y
-1.5	-10.42	-12.093	-8.036	-1.5			-42.2	-43.9	-39.8		Y
-1.4	-10.12	-11.846	-7.773	-1.4			-41.9	-43.6	-39.5		Y
-1.3	-9.835	-11.624	-7.533	-1.3			-41.6	-43.4	-39.3		Y
-1.2	-9.568	-11.424	-7.316	-1.2			-41.3	-43.2	-39.1		Y
-1.1	-9.318	-11.244	-7.12	-1.1			-41.1	-43.0	-38.9		Y
-1.0	-9.084	-11.084	-6.946	-1.0			-40.8	-42.8	-38.7		Y
-0.9	-8.866	-10.941	-6.792	-0.9			-40.6	-42.7	-38.6		Y
-0.8	-8.663	-10.814	-6.657	-0.8			-40.4	-42.6	-38.4		Y
-0.7	-8.477	-10.7	-6.541	-0.7			-40.2	-42.5	-38.3		Y
-0.6	-8.307	-10.599	-6.443	-0.6			-40.1	-42.4	-38.2		Y
-0.5	-8.152	-10.507	-6.362	-0.5			-39.9	-42.3	-38.1		Y
-0.4	-8.015	-10.425	-6.297	-0.4			-39.8	-42.2	-38.1		Y
-0.3	-7.894	-10.35	-6.249	-0.3			-39.7	-42.1	-38.0		Y
-0.2	-7.791	-10.28	-6.217	-0.2			-39.6	-42.0	-38.0		Y
-0.1	-7.705	-10.215	-6.201	-0.1			-39.5	-42.0	-38.0		Y
0.0	-7.637	-10.153	-6.199	0.0			-39.4	-41.9	-38.0		Y
0.1	-7.588	-10.095	-6.213	0.1			-39.3	-41.9	-38.0		Y
0.2	-7.557	-10.038	-6.242	0.2			-39.3	-41.8	-38.0		Y
0.3	-7.546	-9.983	-6.286	0.3			-39.3	-41.7	-38.0		Y
0.4	-7.554	-9.93	-6.345	0.4			-39.3	-41.7	-38.1		Y
0.5	-7.582	-9.879	-6.42	0.5			-39.3	-41.6	-38.2		Y
0.6	-7.63	-9.831	-6.511	0.6			-39.4	-41.6	-38.3		Y
0.7	-7.699	-9.787	-6.618	0.7			-39.5	-41.5	-38.4		Y
0.8	-7.789	-9.748	-6.742	0.8			-39.5	-41.5	-38.5		Y
0.9	-7.901	-9.714	-6.884	0.9			-39.7	-41.5	-38.6		Y
1.0	-8.034	-9.688	-7.044	1.0			-39.8	-41.4	-38.8		Y
1.1	-8.19	-9.67	-7.223	1.1			-40.0	-41.4	-39.0		Y
1.2	-8.368	-9.662	-7.421	1.2			-40.1	-41.4	-39.2		Y
1.3	-8.568	-9.666	-7.641	1.3			-40.3	-41.4	-39.4		Y
1.4	-8.792	-9.682	-7.882	1.4			-40.6	-41.4	-39.6		Y
1.5	-9.039	-9.712	-8.145	1.5			-40.8	-41.5	-39.9		Y
1.6	-9.31	-9.758	-8.433	1.6			-41.1	-41.5	-40.2		Y

1.7	-9.605	-9.821	-8.744	1.7			-41.4	-41.6	-40.5		Y
1.8	-9.923	-9.901	-9.082	1.8	12.6	-9.2	-41.7	-41.7	-40.8	32.5	Y
1.9	-10.27	-10	-9.446	1.9	12.0	-9.8	-42.0	-41.8	-41.2	32.3	Y
2.0	-10.63	-10.119	-9.839	2.0	11.5	-10.3	-42.4	-41.9	-41.6	32.1	Y
2.1	-11.03	-10.259	-10.26	2.1	10.9	-10.8	-42.8	-42.0	-42.0	31.9	Y
2.2	-11.44	-10.42	-10.71	2.2	10.4	-11.3	-43.2	-42.2	-42.5	31.9	Y
2.3	-11.88	-10.604	-11.2	2.3	10.0	-11.8	-43.6	-42.4	-43.0	31.8	Y
2.4	-12.35	-10.81	-11.72	2.4	9.5	-12.3	-44.1	-42.6	-43.5	31.8	Y
2.5	-12.84	-11.04	-12.28	2.5	9.1	-12.7	-44.6	-42.8	-44.0	31.9	Y
2.6	-13.36	-11.295	-12.87	2.6	8.6	-13.2	-45.1	-43.1	-44.6	32.0	Y
2.7	-13.9	-11.574	-13.51	2.7	8.2	-13.6	-45.7	-43.3	-45.3	32.1	Y
2.8	-14.47	-11.879	-14.18	2.8	7.8	-14.0	-46.2	-43.6	-45.9	32.3	Y
2.9	-15.06	-12.209	-14.91	2.9	7.4	-14.3	-46.8	-44.0	-46.7	32.5	Y
3.0	-15.67	-12.565	-15.68	3.0	7.1	-14.7	-47.4	-44.3	-47.4	32.7	Y
3.1	-16.3	-12.948	-16.5	3.1	6.7	-15.1	-48.1	-44.7	-48.3	33.0	Y
3.2	-16.95	-13.358	-17.37	3.2	6.4	-15.4	-48.7	-45.1	-49.1	33.3	Y
3.3	-17.62	-13.795	-18.3	3.3	6.0	-15.7	-49.4	-45.6	-50.1	33.6	Y
3.4	-18.29	-14.26	-19.27	3.4	5.7	-16.1	-50.1	-46.0	-51.0	34.0	Y
3.5	-18.98	-14.754	-20.28	3.5	5.4	-16.4	-50.7	-46.5	-52.0	34.4	Y
3.6	-19.66	-15.276	-21.32	3.6	5.1	-16.7	-51.4	-47.0	-53.1	34.7	Y
3.7	-20.33	-15.827	-22.36	3.7	4.8	-17.0	-52.1	-47.6	-54.1	35.1	Y
3.8	-20.99	-16.406	-23.34	3.8	4.5	-17.3	-52.7	-48.2	-55.1	35.5	Y
3.9	-21.62	-17.014	-24.19	3.9	4.2	-17.6	-53.4	-48.8	-55.9	35.8	Y
4.0	-22.22	-17.648	-24.83	4.0	3.9	-17.8	-54.0	-49.4	-56.6	36.1	Y
4.1	-22.78	-18.308	-25.2	4.1	3.7	-18.1	-54.5	-50.1	-57.0	36.4	Y
4.2	-23.28	-18.99	-25.28	4.2	3.4	-18.4	-55.0	-50.8	-57.0	36.7	Y
4.3	-23.74	-19.689	-25.12	4.3	3.2	-18.6	-55.5	-51.4	-56.9	36.9	Y
4.4	-24.14	-20.399	-24.8	4.4	2.9	-18.9	-55.9	-52.2	-56.6	37.0	Y
4.5	-24.49	-21.109	-24.4	4.5	2.7	-19.1	-56.2	-52.9	-56.2	37.1	Y
4.6	-24.79	-21.805	-23.97	4.6	2.4	-19.4	-56.5	-53.6	-55.7	37.2	Y
4.7	-25.04	-22.471	-23.57	4.7	2.2	-19.6	-56.8	-54.2	-55.3	37.2	Y
4.8	-25.27	-23.085	-23.22	4.8	2.0	-19.8	-57.0	-54.8	-55.0	37.2	Y
4.9	-25.46	-23.627	-22.93	4.9	1.7	-20.0	-57.2	-55.4	-54.7	37.2	Y
5.0	-25.63	-24.077	-22.71	5.0	1.5	-20.3	-57.4	-55.8	-54.5	37.1	Y
5.1	-25.79	-24.423	-22.56	5.1	1.3	-20.5	-57.5	-56.2	-54.3	37.1	Y
5.2	-25.92	-24.659	-22.48	5.2	1.1	-20.7	-57.7	-56.4	-54.2	37.0	Y
5.3	-26.05	-24.794	-22.48	5.3	0.9	-20.9	-57.8	-56.6	-54.2	36.9	Y
5.4	-26.15	-24.842	-22.56	5.4	0.7	-21.1	-57.9	-56.6	-54.3	36.8	Y

5.5	-26.24	-24.824	-22.71	5.5	0.5	-21.3	-58.0	-56.6	-54.5	36.7	Y
5.6	-26.31	-24.762	-22.94	5.6	0.3	-21.5	-58.1	-56.5	-54.7	36.6	Y
5.7	-26.35	-24.676	-23.26	5.7	0.1	-21.7	-58.1	-56.4	-55.0	36.4	Y
5.8	-26.36	-24.582	-23.65	5.8	-0.1	-21.9	-58.1	-56.3	-55.4	36.2	Y
5.9	-26.33	-24.493	-24.13	5.9	-0.3	-22.1	-58.1	-56.3	-55.9	36.0	Y
6.0	-26.27	-24.417	-24.69	6.0	-0.5	-22.2	-58.0	-56.2	-56.5	35.8	Y
6.1	-26.18	-24.359	-25.33	6.1	-0.6	-22.4	-57.9	-56.1	-57.1	35.5	Y
6.2	-26.05	-24.324	-26.05	6.2	-0.8	-22.6	-57.8	-56.1	-57.8	35.2	Y
6.3	-25.89	-24.311	-26.82	6.3	-1.0	-22.8	-57.7	-56.1	-58.6	34.9	Y
6.4	-25.71	-24.32	-27.6	6.4	-1.2	-22.9	-57.5	-56.1	-59.4	34.5	Y
6.5	-25.5	-24.349	-28.34	6.5	-1.3	-23.1	-57.3	-56.1	-60.1	34.2	Y
6.6	-25.28	-24.396	-28.93	6.6	-1.5	-23.3	-57.0	-56.2	-60.7	33.8	Y
6.7	-25.05	-24.457	-29.25	6.7	-1.7	-23.4	-56.8	-56.2	-61.0	33.4	Y
6.8	-24.81	-24.529	-29.25	6.8	-1.8	-23.6	-56.6	-56.3	-61.0	33.0	Y
6.9	-24.57	-24.61	-28.91	6.9	-2.0	-23.8	-56.3	-56.4	-60.7	32.6	Y
7.0	-24.34	-24.696	-28.31	7.0	-2.1	-23.9	-56.1	-56.5	-60.1	32.2	Y
7.1	-24.11	-24.785	-27.58	7.1	-2.0	-23.8	-55.9	-56.5	-59.3	32.1	Y
7.2	-23.89	-24.876	-26.79	7.2	-2.0	-23.8	-55.7	-56.6	-58.6	31.9	Y
7.3	-23.68	-24.97	-26.02	7.3	-2.0	-23.8	-55.4	-56.7	-57.8	31.7	Y
7.4	-23.49	-25.066	-25.28	7.4	-2.0	-23.8	-55.3	-56.8	-57.0	31.5	Y
7.5	-23.31	-25.167	-24.61	7.5	-2.0	-23.8	-55.1	-56.9	-56.4	31.3	Y
7.6	-23.15	-25.275	-24	7.6	-2.0	-23.8	-54.9	-57.0	-55.8	31.1	Y
7.7	-23	-25.394	-23.46	7.7	-2.0	-23.8	-54.8	-57.2	-55.2	31.0	Y
7.8	-22.86	-25.526	-22.97	7.8	-2.0	-23.8	-54.6	-57.3	-54.7	30.8	Y
7.9	-22.74	-25.676	-22.54	7.9	-2.0	-23.8	-54.5	-57.4	-54.3	30.7	Y
8.0	-22.64	-25.846	-22.16	8.0	-2.0	-23.8	-54.4	-57.6	-53.9	30.6	Y
8.1	-22.55	-26.039	-21.83	8.1	-2.0	-23.8	-54.3	-57.8	-53.6	30.5	Y
8.2	-22.48	-26.257	-21.54	8.2	-2.0	-23.8	-54.2	-58.0	-53.3	30.5	Y
8.3	-22.42	-26.502	-21.29	8.3	-2.0	-23.8	-54.2	-58.3	-53.1	30.4	Y
8.4	-22.38	-26.774	-21.08	8.4	-2.0	-23.8	-54.1	-58.5	-52.8	30.4	Y
8.5	-22.35	-27.07	-20.9	8.5	-2.0	-23.8	-54.1	-58.8	-52.7	30.3	Y
8.6	-22.33	-27.389	-20.75	8.6	-2.0	-23.8	-54.1	-59.1	-52.5	30.3	Y
8.7	-22.33	-27.725	-20.63	8.7	-2.0	-23.8	-54.1	-59.5	-52.4	30.3	Y
8.8	-22.35	-28.071	-20.55	8.8	-2.0	-23.8	-54.1	-59.8	-52.3	30.3	Y
8.9	-22.37	-28.418	-20.49	8.9	-2.0	-23.8	-54.1	-60.2	-52.3	30.4	Y
9.0	-22.42	-28.753	-20.47	9.0	-2.0	-23.8	-54.2	-60.5	-52.2	30.4	Y
9.1	-22.48	-29.064	-20.48	9.1	-2.0	-23.8	-54.2	-60.8	-52.2	30.5	Y
9.2	-22.56	-29.335	-20.53	9.2	-2.0	-23.8	-54.3	-61.1	-52.3	30.5	Y

5. Pointing Accuracy

The ESV V3 terminal will utilize a motion stabilized tracking antenna and a direct sequence spread spectrum (DSSS) burst modem manufactured by ViaSat to access the satellite. The ESV terminal uses a common spreading code and a random access method called code reuse multiple access ("CRMA") to access the satellite. CRMA is closely analogous to the more generally understood code division multiple access (CDMA) multiple access method, but differs in that all terminals use a common spreading code rather than a number of individual codes for each transmitter. Individual bursts are distinguished by time difference of arrival. The use of this spreading technique allows the RF spectral density for each ESV to be significantly lower that typical TDMA systems operating at Ku-band.

The antenna system utilizes a conical scanning function and rate gyros to stabilize the antenna and keep it pointed properly at the desired satellite. The conscan is currently set to worst case 0.6º from boresight. The mean dynamic pointing error for the vessel accelerations expected during testing operation is expected to be 0.2º, with a standard deviation of 0.9º. Thus the total expected mean pointing error for each vessel while under way, including both conscan and dynamic error, is 0.8º with a declared maximum pointing error of 1.5º.

During the small percentage of time when conditions cause the antenna pointing error to exceed the specified maximum pointing error limit of 1.5º, the antenna system will send a message to the modem, and the modem will inhibit transmission until the aggregate conscan plus dynamic pointing error value is back to within 0.8º. The time lag from detection of exceedance of mispointing to time when transmit is inhibited will be less than 100 ms. This error limit of 1.5º is the declared maximum antenna pointing error as described in §25.222(b)(1)(iv)(A).

As described above, the ESVs in this network use a spread spectrum multiple access technique whereby the individual off-axis EIRP density of each ESV terminal is well below the maximum aggregate network limit. Thus, each antenna individually will not generate harmful levels of interference – even if the antenna was pointed directly at an adjacent satellite. Random pointing errors across this ESV fleet will not cause objectionable levels of adjacent satellite interference because the antenna on each ESV will be pointing in a different direction with a different error component. There is an extremely low probability that multiple antennas will be mispointed at an adjacent satellite at the same time in such a way that their power results in harmful interference levels. Because the pointing error is random and momentary, each ESV antenna actually has a higher likelihood of being pointed away from the geostationary satellite arc than at an adjacent satellite in the arc.

The following plots show how random pointing error adds up for several cases. In the first plot, Figure 9, a number of different standard deviations of pointing error are plotted: 1.666º, 1.0º, 0.666º, 0.5º, 0.333º and 0.166º. Each plot represents a long term statistical

sampling of 1,000,000 random errors for the specified standard deviation. The FCC mask is shown as adjusted to account for the spreading used by each terminal.

The ±12.8º of topocentric angle used for theta represent ±10º of geostationary satellite arc. The reference dBi plot on the charts is representative of the average of the antenna pattern for the topocentric angles to the geostationary arc from various locations across CONUS.

The second plot, Figure 10, shows the same reference dBi plot representing the aggregate population of terminals with no pointing error. A single ESV with 2º of pointing error is shown. It can be seen that even when the ESV is pointed directly at an adjacent satellite, the power density is well below the FCC off-axis EIRP density mask. In this case the ESV's input power density has been reduced by an additional 11.8 dB from the network aggregate – equivalent to a population of 15 co-frequency ESVs transmitting simultaneously.

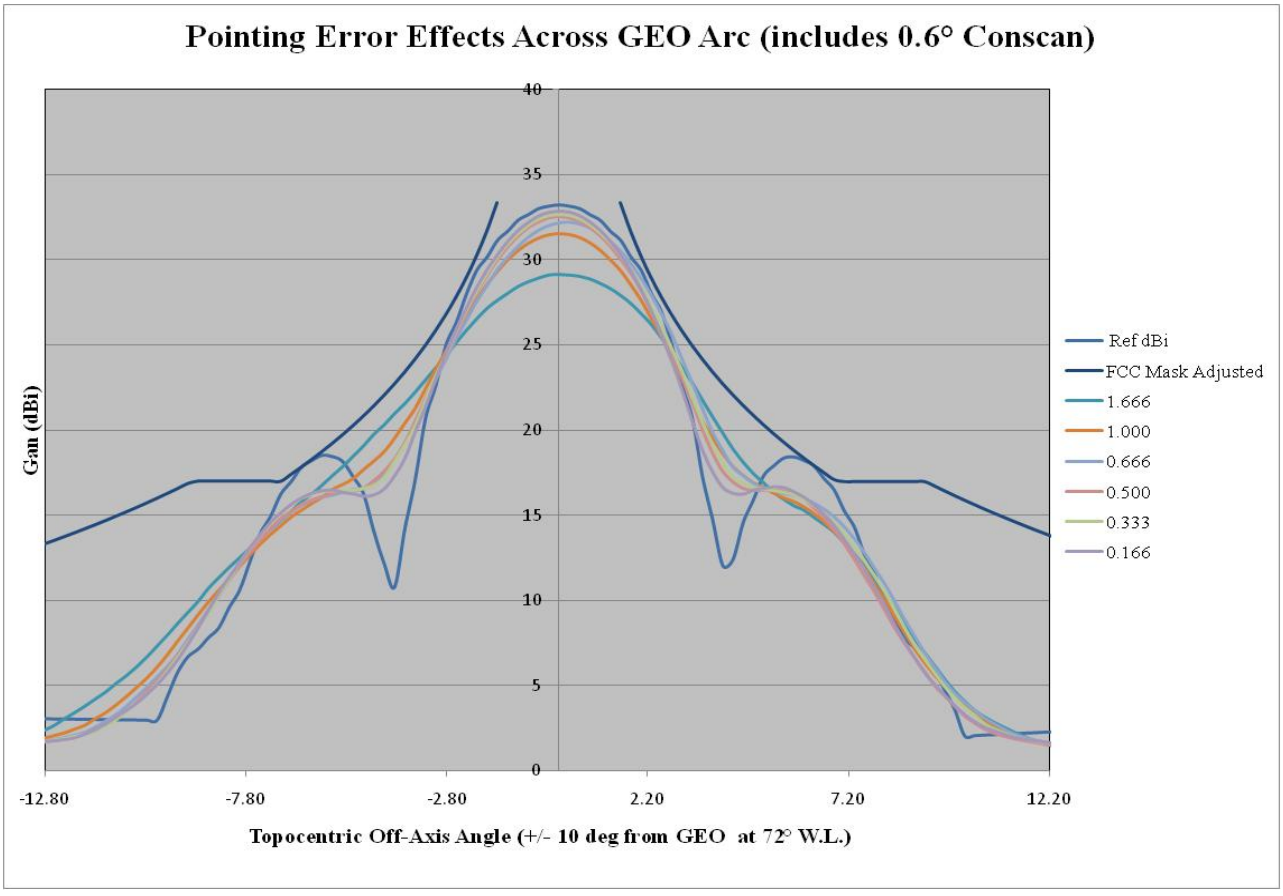

Figure 9 – Aggregate pointing error for several standard deviations

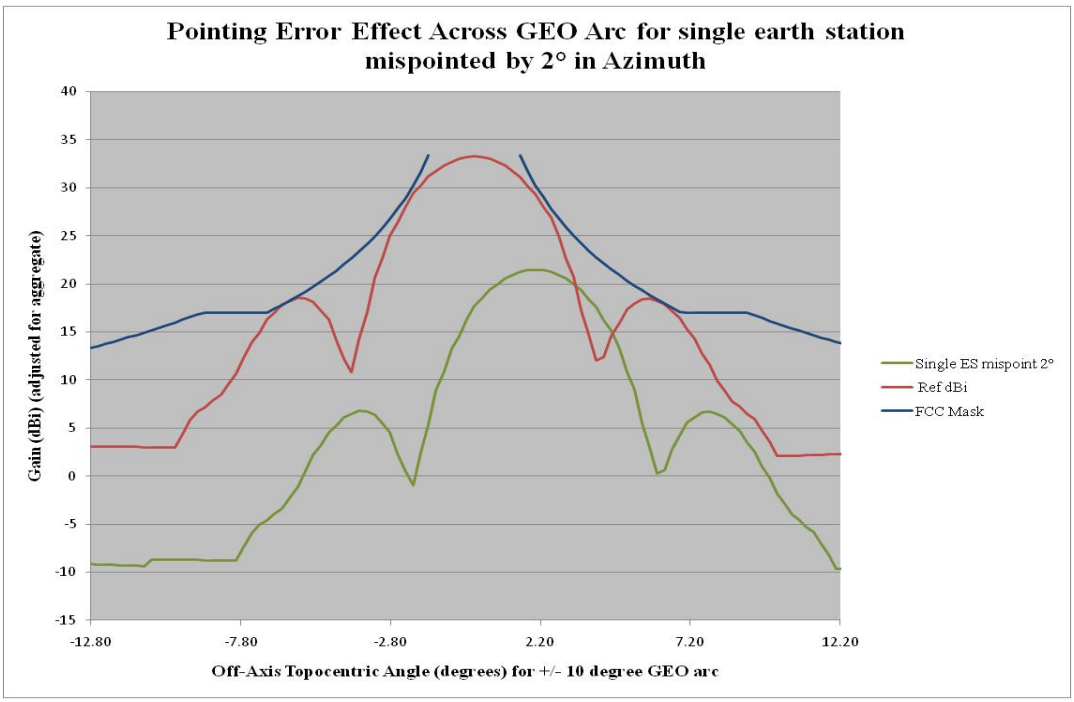

Figure 10 – Impact of a single ESV with 2º of pointing error

Figure 11 shows 15 co-frequency ESVs transmitting simultaneously, each with random error and with conscan active. The aggregate power summation of all 15 ESVs is also plotted along with the reference dBi and adjusted FCC mask.

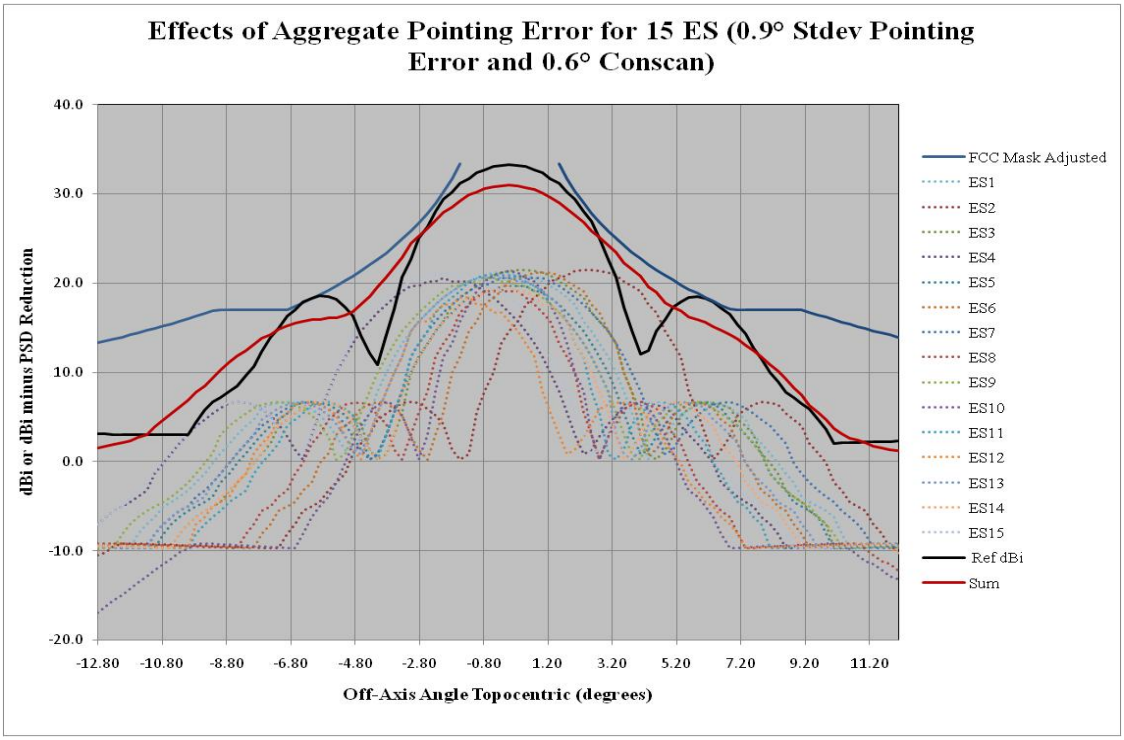

Figure 11 – Aggregate pointing error for 15 co-frequency ESVs

In summary, the V3 will maintain a deliberate conscan of 0.6º, assumes additional pointing error of 0.2º for a mean pointing accuracy of 0.8º (within which it will resume transmission after automated shut-down) and a declared maximum pointing error of 1.5º (beyond which it will automatically cease transmissions within 100ms). Even considering worst case excursions and additional conservative assumptions, the analysis shows that the ESV system will not cause adjacent satellite interference due to the very low RF power density of the spread spectrum return link.

6. Summary of Technical Parameters

The return link channel will support data rates for of 32 kbit/s, 64 kbit/s, 128 kbit/s, 256 kbit/s, and 512 kbit/s. The forward channel will be operated with data rates of 3-10 Mbits/s aggregate with individual end user rates between 512- 2Mbit/s. A summary of the V3 operating parameters is shown in the tables below:

Antenna diameter	37 cm
Type of Antenna	Parabolic rear-fed
Peak Power (SSPA)	3 watts
Transmit Bandwidth	18, 36 MHz
Transmit Gain	33 dBi at 14 GHz
EIRP	38 dBW
Transmit Data Rate	32 kbps to 512 Mbps
Transmit Polarization	Horizontal or Vertical
Transmit Max PSD	<10 dBW/4kHz
Transmit Azimuth, Elevation Beamwidth	3.5 degrees
Receive G/T	10 dB/K minimum
Receive Bandwidth	500 MHz
Receive Polarization	Dual Vertical and Horizontal

V3 ESV Terminal Parameters

Azimuth	continuous coverage over full 360º
Elevation	10 to 80º antenna elevation
Position accuracy	Static pointing error 0.6º RMS (AZ); 0.8º RMS (AZ) in-motion, Declared Maximum Pointing Error 1.5º)
Dynamic Tracking capability	Roll: +/-25° at 8 second period Pitch: +/-15° at 5 second period Yaw: +/-8° at 50 second period Azimuth Turn rate: 12°/s and 15°/s^2 acceleration

Antenna Control Parameters

Power a feed Flange	3	Watts
Channel; Bandwidth	36	MHz
RF Power Density at Flange	-34.8	dBW/4,kHz
Maximum Horizon EIRP Density (10° Elevation Angle)	-3.79	dBW/MHz*
Maximum Horizon EIRP	11.77	dBW*
Maximum Number Simultaneous Users N	13	

Uplink Transmission Parameters - 36 MHz Channel

Power a feed Flange	3	Watts
Channel; Bandwidth	18	MHz
RF Power Density at Flange	-31.8	dBW/4 kHz
Maximum Horizon EIRP Density (10° Elevation Angle)	-0.78	dBW/MHz*
Maximum Horizon EIRP	11.77	dBW*
Maximum Number Simultaneous Users N	6	

Uplink Transmission Parameters - 18 MHz Channel

Resolution 902. KVH will comply with the ESV emission limitations specified for the Ku-band in Annex 2 to Resolution 902. For each ESV terminal the maximum EIRP density toward the horizon will not exceed -0.79 dBW/MHz and the maximum EIRP toward the horizon will be 11.8 dBW.[7]

[7] Resolution 902 Annex 2 specifies a maximum of 12.5 dBW/MHz Horizon EIRP density and 16.3 dBW Horizon EIRP for ESVs operating in the 14.0-14.5 GHz band.

7. FCC §25.222 Compliance Matrix for the V3 Terminal

	FCC Part 25 Earth Station on Vessels (ESV) Rules for Ku-Band	Complies	Comments
§ 25.222	**§ 25.222 Blanket Licensing provisions for Earth Stations on Vessels (ESVs) receiving in the 10.95–11.2 GHz (space-to- Earth), 11.45–11.7 GHz (space-to-Earth), 11.7–12.2 GHz (space-to-Earth) frequency bands and transmitting in the 14.0–14.5 GHz (Earth-to-space) frequency band, operating with Geostationary Orbit (GSO) Satellites in the Fixed-Satellite Service.**		
§ 25.222(a)	(a) The following ongoing requirements govern all ESV licensees and operations in the 10.95–11.2 GHz (space-to-Earth), 11.45–11.7 GHz (space-to-Earth), 11.7–12.2 GHz (space-to- Earth) frequency bands and 14.0–14.5 GHz (Earth-to-space) bands transmitting to GSO satellites in the fixed-satellite service. ESV licensees must comply with the requirements in either paragraph (a)(1) or (a)(2) of this section and all of the requirements set forth in paragraphs (a)(3) through (a)(7) of this section. Paragraph (b) of this section identifies items that must be included in the application for ESV operations to demonstrate that these ongoing requirements will be met.	Complies	Complies with (a)(1) and remaining provisions
§ 25.222(a)(1)	(1) The following requirements shall apply to an ESV that uses transmitters with off axis effective isotropically radiated power (EIRP) spectral-densities lower than or equal to the levels in paragraph (a)(1)(i)(A) of this section. An ESV, or ESV system, operating under this section shall provide a detailed demonstration as described in paragraph (b)(1) of this section. The ESV transmitter also must comply with the antenna pointing and cessation of emission requirements in paragraphs (a)(1)(ii) and (a)(1)(iii) of this section.		
§ 25.222(a)(1)(i)	(i) An ESV system shall not exceed the off axis EIRP spectral-density limits and conditions defined in paragraphs (a)(1)(i)(A) through (a)(1)(i)(D) of this section.		
§ 25.222(a)(1)(i)(A)	(A) The off-axis EIRP spectral-density emitted from the ESV, in the plane of the GSO as it appears at the particular earth station location, shall not exceed the following values: 15-10log(N)-25logq ..... dBW/4 kHz ..... for ..... $1.5° \leq q \leq 7°$ -6 -10log(N) ..... dBW/4 kHz ..... for ..... $7° < q \leq 9.2°$ 18 -10log(N)-25logq ..... dBW/4 kHz ..... for ..... $9.2° < q \leq 48°$ -24 -10log(N) ..... dBW/4 kHz ..... for ..... $48° < q \leq 85°$	Complies	Narrative, Section II.B.1. and Exhibit 1, Section 4

	-14 -10log(N) ..... dBW/4 kHz ..... for ..... 85° < q ≤ 180° Where theta (q) is the angle in degrees from the line connecting the focal point of the antenna to the orbital location of the target satellite, the plane of the GSO is determined by the focal point of the antenna and the line tangent to the arc of the GSO at the orbital location of the target satellite. For ESV networks using frequency division multiple access (FDMA) or time division multiple access (TDMA) techniques, N is equal to one. For ESV networks using multiple co-frequency transmitters that have the same EIRP, N is the maximum expected number of co-frequency simultaneously transmitting ESV earth stations in the same satellite receiving beam. For the purpose of this section, the peak EIRP of an individual sidelobe may not exceed the envelope defined above for q between 1.5° and 7.0°. For q greater than 7.0°, the envelope may be exceeded by no more than 10% of the sidelobes, provided no individual sidelobe exceeds the envelope given above by more than 3 dB.		
§ 25.222(a)(1)(i)(B)	(B) In all directions other than along the GSO, the off-axis EIRP spectral-density for co-polarized signals emitted from the ESV shall not exceed the following values: 18-10log(N)-25logq ..... dBW/4 kHz ..... for ..... 3.0° ≤ q ≤ 48° -24-10log(N) ..... dBW/4 kHz ..... for ..... 48° < q ≤ 85° -14-10log(N) ..... dBW/4 kHz ..... for ..... 85° < q ≤ 180° Where q and N are defined in paragraph (a)(1)(i)(A) of this section. This off-axis EIRP spectral-density applies in any plane that includes the line connecting the focal point of the antenna to the orbital location of the target satellite with the exception of the plane of the GSO as defined in paragraph (a)(1)(i)(A) of this section. For the purpose of this section, the envelope may be exceeded by no more than 10% of the sidelobes provided no individual sidelobe exceeds the gain envelope given above by more than 6 dB. The region of the main reflector spillover energy is to be interpreted as a single lobe and shall not exceed the envelope by more than 6 dB.	Complies Complies	Narrative, Section II.B.1. and Exhibit 1, Section 4 Exhibit 1, Section 4
§ 25.222(a)(1)(i)(C)	(C) In all directions, the off-axis EIRP spectral-density for cross-polarized signals emitted from the ESV shall not exceed the following values: 5-10log(N)-25logq ..... dBW/4 kHz ..... for ..... 1.8° ≤ q ≤ 7.0° -16-10log(N) ..... dBW/4 kHz ..... for ..... 7.0° < q ≤ 9.2° Where q and N are defined as set forth in paragraph (a)(1)(i)(A) of this section. This EIRP spectral-density applies in any plane that includes the line connecting the focal point of the antenna to the target satellite.	Complies	Narrative, Section II.B.1. and Exhibit 1, Section 4.

§ 25.222(a)(1)(i)(D)	(D) For non-circular ESV antennas, the major axis of the antenna will be aligned with the tangent to the arc of the GSO at the orbital location of the target satellite, to the extent required to meet the specified off-axis EIRP spectral-density criteria.	N/A	
§ 25.222(a)(1)(ii)	(ii) Each ESV transmitter must meet one of the following antenna pointing requirements:		
§ 25.222(a)(1)(ii)(A)	(A) Each ESV transmitter shall maintain a pointing error of less than or equal to 0.2° between the orbital location of the target satellite and the axis of the main lobe of the ESV antenna, or		
§ 25.222(a)(1)(ii)(B)	(B) Each ESV transmitter shall declare a maximum antenna pointing error that may be greater than 0.2° provided that the ESV does not exceed the off-axis EIRP spectral density limits in paragraph (a)(1)(i) of this section, taking into account the antenna pointing error.	Complies	Narrative, Section II.B.2., Exhibit 1, Section 5
§ 25.222(a)(1)(iii)	(iii) Each ESV transmitter must meet one of the following cessation of emission requirements:		
§ 25.222(a)(1)(iii)(A)	(A) For ESVs operating under paragraph (a)(1)(ii)(A) of this section, all emissions from the ESV shall automatically cease within 100 milliseconds if the angle between the orbital location of the target satellite and the axis of the main lobe of the ESV antenna exceeds 0.5°, and transmission will not resume until such angle is less than or equal to 0.2°, or		
§ 25.222(a)(1)(iii)(B)	(B) For ESV transmitters operating under paragraph (a)(1)(ii)(B) of this section, all emissions from the ESV shall automatically cease within 100 milliseconds if the angle between the orbital location of the target satellite and the axis of the main lobe of the ESV antenna exceeds the declared maximum antenna pointing error and shall not resume transmissions until such angle is less than or equal to the declared maximum antenna pointing error.	Complies	Narrative, Section II.B.2., Exhibit 1, Section 5; resumes transmissions at 0.8 deg offset even though declared maximum point error is 1.5 deg
§ 25.222(a)(2)	(2) The following requirements shall apply to an ESV that uses off-axis EIRP spectral densities in excess of the levels in paragraph (a)(1)(i) of this section. An ESV, or ESV system, operating under this section shall file certifications and provide a detailed demonstration as described in paragraph (b)(2) of this section.	N/A	
§ 25.222(a)(2)(i)	(i) The ESV shall transmit only to the target satellite system(s) referred to in the certifications required by paragraph (b)(2) of this section.		
§ 25.222(a)(2)(ii)	(ii) If a good faith agreement cannot be reached between the target satellite operator and the operator of a future satellite that is located within 6 degrees longitude of the target satellite, the ESV operator shall accept the power-density levels that would accommodate that adjacent satellite.		

§ 25.222(a)(2)(iii)	(iii) The ESV shall operate in accordance with the off-axis EIRP spectral-densities that the ESV supplied to the target satellite operator in order to obtain the certifications listed in paragraph (b)(2) of this section. The ESV shall automatically cease emissions within 100 milliseconds if the ESV transmitter exceeds the off-axis EIRP spectral densities supplied to the target satellite operator.		
§ 25.222(a)(3)	(3) There shall be a point of contact in the United States, with phone number and address, available 24 hours a day, seven days a week, with authority and ability to cease all emissions from the ESVs, either directly or through the facilities of a U.S. Hub or a Hub located in another country with which the United States has a bilateral agreement that enables such cessation of emissions.	Complies	Narrative, Section II.B.3
§ 25.222(a)(4)	(4) For each ESV transmitter, a record of the ship location (*i.e.,* latitude/longitude), transmit frequency, channel bandwidth and satellite used shall be time annotated and maintained for a period of not less than 1 year. Records will be recorded at time intervals no greater than every 20 minutes while the ESV is transmitting. The ESV operator will make this data available upon request to a coordinator, fixed system operator, fixed-satellite system operator, NTIA, or the Commission within 24 hours of the request.	Complies	Narrative, Section II.B.3. and Exhibit 1, Section 3
§ 25.222(a)(5)	(5) ESV operators communicating with vessels of foreign registry must maintain detailed information on each vessel's country of registry and a point of contact for the relevant administration responsible for licensing ESVs.	Complies	Narrative, Section II.B.3
§ 25.222(a)(6)	(6) ESV operators shall control all ESVs by a Hub earth station located in the United States, except that an ESV on U.S.-registered vessels may operate under control of a Hub earth station location outside the United States provided the ESV operator maintains a point of contact within the United States that will have the capability and authority to cause an ESV on a U.S.-registered vessel to cease transmitting if necessary.	Complies	Narrative, Section II.B.3
§ 25.222(a)(7)	(7) In the 10.95–11.2 GHz (space-to-Earth) and 11.45–11.7 GHz (space-to-Earth) frequency bands ESVs shall not claim protection from interference from any authorized terrestrial stations to which frequencies are either already assigned, or may be assigned in the future.	Complies	Narrative, Section I.A
§ 25.222(b)	(b) Applications for ESV operation in the 14.0–14.5 GHz (Earth-to-space) band to GSO satellites in the fixed-satellite service must include, in addition to the particulars of operation identified on Form 312, and associated Schedule B, the applicable technical demonstrations in paragraphs (b)(1) or (b)(2) of this section and the documentation identified in paragraphs (b)(3) through (b)(5) of this section.		

§ 25.222(b)(1)	(1) An ESV applicant proposing to implement a transmitter under paragraph (a)(1) of this section must demonstrate that the transmitter meets the off-axis EIRP spectral- density limits contained in paragraph (a)(1)(i) of this section. To provide this demonstration, the application shall include the tables described in paragraph (b)(1)(i) of this section or the certification described in paragraph (b)(1)(ii) of this section. The ESV applicant also must provide the value N described in paragraph (a)(1)(i)(A) of this section. An ESV applicant proposing to implement a transmitter under paragraph (a)(1)(ii)(A) of this section must provide the certifications identified in paragraph (b)(1)(iii) of this section. An ESV applicant proposing to implement a transmitter under paragraph (a)(1)(ii)(B) of this section must provide the demonstrations identified in paragraph (b)(1)(iv) of this section.	Complies	Narrative, Section II.B.1 and Exhibit 1, Section 4
§ 25.222(b)(1)(i)	(i) Any ESV applicant filing an application pursuant to paragraph (a)(1) of this section must file three tables showing the off-axis EIRP level of the proposed earth station antenna in the direction of the plane of the GSO; the co-polarized EIRP in the elevation plane, that is, the plane perpendicular to the plane of the GSO; and cross polarized EIRP. In each table, the EIRP level must be provided at increments of 0.1° for angles between 0° and 10° off-axis, and at increments of 5° for angles between 10° and 180° off-axis.	Complies	Narrative, Section II.B.1 and Exhibit 1, Section 4; Note: antenna is circular so first and second tables are identical - only one table provided
§ 25.222(b)(1)(i)(A)	(A) For purposes of the off-axis EIRP table in the plane of the GSO, the off-axis angle is the angle in degrees from the line connecting the focal point of the antenna to the orbital location of the target satellite, and the plane of the GSO is determined by the focal point of the antenna and the line tangent to the arc of the GSO at the orbital position of the target satellite.		
§ 25.222(b)(1)(i)(B)	(B) For purposes of the off-axis co-polarized EIRP table in the elevation plane, the off-axis angle is the angle in degrees from the line connecting the focal point of the antenna to the orbital location of the target satellite, and the elevation plane is defined as the plane perpendicular to the plane of the GSO defined in paragraph (b)(1)(i)(A) of this section.		
§ 25.222(b)(1)(i)(C)	(C) For purposes of the cross-polarized EIRP table, the off-axis angle is the angle in degrees from the line connecting the focal point of the antenna to the orbital location of the target satellite and the plane of the GSO as defined in paragraph (b)(1)(i)(A) of this section will be used.		
§ 25.222(b)(1)(ii)	(ii) A certification, in Schedule B, that the ESV antenna conforms to the gain pattern criteria of § 25.209(a) and (b), that, combined with the maximum input power density calculated from the EIRP density less the antenna gain, which is entered in Schedule B, demonstrates that the off-axis EIRP spectral density envelope set forth in paragraphs (a)(1)(i)(A) through (a)(1)(i)(C) of this section will be met under the assumption that the antenna is pointed at the target satellite.	N/A	Demonstration provided under § 25.222(b)(1)(i)

§ 25.222(b)(1)(iii)	(iii) An ESV applicant proposing to implement a transmitter under paragraph (a)(1)(ii)(A) of this section, must provide a certification from the equipment manufacturer stating that the antenna tracking system will maintain a pointing error of less than or equal to 0.2 between the orbital location of the target satellite and the axis of the main lobe of the ESV antenna and that the antenna tracking system is capable of ceasing emissions within 100 milliseconds if the angle between the orbital location of the target satellite and the axis of the main lobe of the ESV antenna exceeds 0.5°.		
§ 25.222(b)(1)(iv)	(iv) An ESV applicant proposing to implement a transmitter under paragraph (a)(1)(ii)(B) of this section must:		
§ 25.222(b)(1)(iv)(A)	(A) Declare, in their application, a maximum antenna pointing error and demonstrate that the maximum antenna pointing error can be achieved without exceeding the off-axis EIRP spectral-density limits in paragraph (a)(1)(A) of this section; and	Complies	Narrative, Section II.B.2. and Exhibit 1, Section 5
§ 25.222(b)(1)(iv)(B)	(B) Demonstrate that the ESV transmitter can detect if the transmitter exceeds the declared maximum antenna pointing error and can cease transmission within 100 milliseconds if the angle between the orbital location of the target satellite and the axis of the main lobe of the ESV antenna exceeds the declared maximum antenna pointing error, and will not resume transmissions until the angle between the orbital location of the target satellite and the axis of the main lobe of the ESV antenna is less than or equal to the declared maximum antenna pointing error.	Complies	Narrative, Section II.B.2. and Exhibit 1, Section 5
§ 25.222(b)(2)	(2) An ESV applicant proposing to implement a transmitter under paragraph (a)(2) of this section and using off-axis EIRP spectral densities in excess of the levels in paragraph (a)(1)(i) of this section shall provide the following certifications and demonstration as exhibits to its earth station application:	N/A	KVH seeking satellite operator coordination materials out of abundance of caution.
§ 25.222(b)(2)(i)	(i) A statement from the target satellite operator certifying that the proposed operation of the ESV has the potential to create harmful interference to satellite networks adjacent to the target satellite(s) that may be unacceptable.		
§ 25.222(b)(2)(ii)	(ii) A statement from the target satellite operator certifying that the power-density levels that the ESV applicant provided to the target satellite operator are consistent with the existing coordination agreements between its satellite(s) and the adjacent satellite systems within 6° of orbital separation from its satellite(s).		
§ 25.222(b)(2)(iii)	(iii) A statement from the target satellite operator certifying that it will include the power-density levels of the ESV applicant in all future coordination agreements.		
§ 25.222(b)(2)(iv)	(iv) A demonstration from the ESV operator that the ESV system is capable of detecting and automatically ceasing emissions within 100 milliseconds when the transmitter exceeds the off-axis EIRP spectral-densities supplied to the target satellite operator.		

§ 25.222(b)(3)	(3) There shall be an exhibit included with the application describing the geographic area(s) in which the ESVs will operate.	Complies	Narrative, Section II.B.3. and Exhibit 1, Section 3
§ 25.222(b)(4)	(4) The point of contact referred to in paragraph (a)(3) of this section and, if applicable paragraph (a)(6) of this section, must be included in the application.	Complies	Narrative, Section II.B.3.
§ 25.222(b)(5)	(5) ESVs that exceed the radiation guidelines of § 1.1310 of this chapter, Radiofrequency radiation exposure limits, must provide, with their environmental assessment, a plan for mitigation of radiation exposure to the extent required to meet those guidelines.	Complies	Exhibit 2, Radiation Hazard Study
§ 25.222(c)	(c) Operations of ESVs in the 14.0–14.2 GHz (Earth-to-space) frequency band within 125 km of the NASA TDRSS facilities on Guam (located at latitude: 13°36′55″ N, longitude 144°51′22″ E) or White Sands, New Mexico (latitude: 32°20′59″ N, longitude 106°36′31″ W and latitude: 32°32′40″ N, longitude 106°36′48″ W) are subject to coordination through the National Telecommunications and Information Administration (NTIA) Interdepartment Radio Advisory Committee (IRAC). When NTIA seeks to provide similar protection to future TDRSS sites that have been coordinated through the IRAC Frequency Assignment Subcommittee process, NTIA will notify the Commission that the site is nearing operational status. Upon public notice from the Commission, all Ku-band ESV operators must cease operations in the 14.0–14.2 GHz band within 125 km of the new TDRSS site until after NTIA/IRAC coordination for the new TDRSS facility is complete. ESV operations will then again be permitted to operate in the 14.0–14.2 GHz band within 125 km of the new TDRSS site, subject to any operational constraints developed in the coordination process.	Complies	Narrative, Section II.B.4.
§ 25.222(d)	(d) Operations of ESVs in the 14.47–14.5 GHz (Earth-to-space) frequency band within (a) 45 km of the radio observatory on St. Croix, Virgin Islands (latitude 17°46′ N, longitude 64°35′ W); (b) 125 km of the radio observatory on Mauna Kea, Hawaii (at latitude 19°48′ N, longitude 155°28′ W); and (c) 90 km of the Arecibo Observatory on Puerto Rico (latitude 18°20′46″ W, longitude 66°45′11″ N) are subject to coordination through the National Telecommunications and Information Administration (NTIA) Interdepartment Radio Advisory Committee (IRAC).	Complies	Narrative, Section II.B.4.

8. Sample Link Analysis

SYSTEM PARAMETERS			
Uplink Frequency	14.18	GHz	
Forward Uplink Availability	99.75%		
Return Uplink Availability	99.75%		
Downlink Frequency	11.88	GHz	
Forward Downlink Availability	99.75%		
Return Downlink Availability	99.75%		
Mobile Site	Var - Seattle		
Hub Site	Carlsbad		
Vehicle Inclination	0	°	
F/R Transponder Input Ratio	18.4	dB	
alpha_power	0.01432		
PCMA Cancellation C/I	25	dB	
Forward Link			
Data Rate	4.00E+06	bps	4000000
Bit Error Rate	1 x 10E-7	QPSK 1/3	
Eb/No Required	1.7	dB	
C/No Required	67.72	dB-Hz	
Modulation Type	QPSK DSSS	²I/2 BPSK 3	
FEC Factor	Rate 1/3 Turbo		
Spread Factor : Spread Signal Rate	2	28800	kcps
Carrier Spacing: Authorized BW	1.2	36000	kHz
Bits per symbol	0.3333	VSAT Proprietary FL	
Signal Rate	14400	kbaud/s	
Return Link			
Data Rate	128000	bps	
Packet Error Rate	1 x 10E-3		
Eb/No Required	2.25	dB	
C/No Required	53.32	dB-Hz	
Modulation Type	GMSK DSSS		
FEC Factor	Rate 1/3 TC		
Alpha_MAI	0.859		
Beta_MAI	0.712	108	
Spread Factor : Spread Signal Rate	88	33792	kcps
Carrier Spacing	1		
Bits per symbol	0.3333		
Transponder Bandwidth	24060	kHz	
Occupied Bandwidth	29027	kHz	
Signal Rate	384.0	kbaud/s	
Number of Return Links	10		1.00E+01

Fwd Link Total Availability	**99.50%**		
Return Link Total Availability	**99.50%**		
LINK STATUS	**Clear Sky**	**U/L Rain**	**D/L Rain**
Forward Link Margin	**4.4**	**4.4**	**3.1**
Return Link Margin	**2.05**	**0.13**	**1.98**
Regulatory Limits	**Performance**	**Rqmt.**	
Return Agg. Ant. Flange Pwr Density	-23.78	-23.02	dBW/4kHz
Return Uplink Off-axis Pwr Density	4.0	16	dBW/40kHz
Forward Downlink Pwr Density at Peak	11.93	13	dBW/4kHz

Mobile Antenna Transmit Characteristics (Return Uplink)		
Antenna Type	KVH	
Uplink Frequency	14.18	GHz
Antenna Diameter	0.37	m
	17.5	wavelengths
Aperture efficiency	68%	
Antenna peak gain	33.1	dB
CW Sat Transmit Power	3	W
Transmission losses	-1.3	dB
Antenna Ohmic Losses	-0.1	dB
Radome Loss	-0.8	dB
CW Sat EIRP at peak	35.7	dBW
OBO	0.00	dB
Pointing loss, etc.	-0.07	dB
EIRP (not including pointing loss)	**35.71**	**dBW**
Clear-Sky PFD	**-127.07**	**dBW/m2**
Available UPC Boost	0.0	dB
UPC Error	0	dB
HPA Suppression	0.0	dB
Antenna Crosspol Discrimination	15.0	dB
Pointing Error (Tx and Rx)	0.31	deg

Mobile Antenna Receive Characteristics (Forward Downlink)		
Antenna Type	KVH	
Downlink Frequency	11.88	GHz
Antenna Diameter	0.37	m
	14.7	wavelengths
Aperture efficiency	60%	
Antenna peak gain	31.0	dB
LNB Noise Figure	0.94	dB
Reference Temperature	290	K
Antenna Ohmic Losses	-0.1	dB
Radome Ohmic Loss	-0.10	dB
Clear-sky Antenna Temperature	30	K
Clear-sky Tsys	117.0	K
Radome non-ohmic loss	-0.10	dB
Antenna non-ohmic loss	0.0	dB
Pointing Loss	-0.1	dB
Clear-sky G/T	**10.20**	**dB/K**
Antenna Crosspol Discrimination	15.0	dB

Spacecraft Transponder		
Spacecraft	AMC-15	
Satellite Longitude	255	deg E
Transponder Total Bandwidth	36	MHz
Transponder Allocated Bandwidth	36	MHz
Forward CW Sat EIRP	46	dBW
Forward G/T	1.25	dB/K
Return CW Sat EIRP	48.4	dBW
Return G/T	2	dB/K
Forward Min SFD	-92.94	dBW/m2
Return Min SFD	-93.69	dBW/m2

Hub Antenna Transmit Characteristics (Forward Uplink)		
Uplink Frequency	14.18	GHz
Antenna Diameter	4.5	m
	212.7	wavelengths
Antenna efficiency	65%	
Antenna peak gain	54.6	dB
Max HPA Transmit Power	400	W
Transmission losses	-2.53	dB
Antenna Ohmic Losses	0	dB
Radome Loss	0	dB
CW EIRP	78.1	dBW
OBO	-12.6	dB
Pointing loss, etc.	-0.5	dB
EIRP (not including pointing loss)	**65.05**	**dBW**
Clear-sky PFD	**-97.94**	**dBW/m2**
Available UPC Boost	12.6	dB
UPC Error	0.0	dB
HPA Suppression	0.0	dB
Antenna Crosspol Discrimination	30.0	
Half-power beamwidth	0.3	deg

Hub Antenna Receive Characteristics (Return Downlink)		
Downlink Frequency	11.88	GHz
Antenna Diameter	4.5	m
	178.2	wavelengths
Antenna efficiency	66%	
Antenna peak gain	53.2	dB
LNB Noise Figure	0.94	dB
Input Losses	0	dB
Antenna Ohmic Losses	0	dB
Radome Loss	0	dB
Clear-sky Antenna Temperature	35	K
Clear-sky Tsys	105.1	K
Pointing loss, etc.	-0.5	dB
Antenna non-ohmic loss	0.0	
Clear-sky G/T	**32.4**	**dB/K**
Half-power beamwidth	0.4	deg
Antenna Crosspol Discrimination	30.0	dB
Desired Transponder OBO point	-2	dB
Additional Forward Link Backoff	0	
IBO - Clear Sky Uplink	-5.0	dB
IBO - Rain Uplink	-5.0	dB
OBO - Clear Sky Uplink	-2.0	dB
OBO - Rain Uplink	-2.0	dB
Fwd Transponder Suppression	-0.51	dB
Rtn Transponder Suppression	-1.75	dB
Fwd EIRP- Clear Sky Uplink	43.5	dBW
Rtn EIRP - CS U/L - Single Carrier	16.3	dBW
Uplink Interfering Transponder G/T	2	dB/K

Forward Link Parameters	Uplink	Downlink
Site	Carlsbad	Var - Seattle
Frequency, GHz	14.18	11.88
Availability	99.75%	99.75 %
Antenna Size, m	4.5	0.37
Modulation	QPSK DSSS	
Coding	Rate 1/3 Turbo	
Data rate (kbps)	4000	

EndtoEnd Link Budget	Clear Sky	Rain U/L Rain D/L	Rain U/L Clear Sky D/L	Clear Sky U/L Rain D/L
Uplink C/No	89.2	89.2	89.2	89.2 dBHz
Uplink C/Io	91.9	91.9	91.9	91.9 dBHz
Downlink C/No	76.6	73.7	76.6	73.7 dBHz
Downlink C/Io	74.2	74.2	74.2	74.2 dBHz
Total C/(No+Io)	72.1	70.8	72.1	70.8 dBHz
Required C/(No+Io)	67.7	67.7	67.7	67.7 dBHz

Uplink C/No budget	Clear Sky	Rain U/L
Uplink EIRP (incl. UPC compensation)	65.5	66.9 dBW
Hub Pointing Loss	0.5	0.5 dB
Path Loss	207.0	208.3 dB
Spacecraft G/T	1.25	1.25 dB/K
Boltzmann's constant	228.6	228.6 dBW/K/Hz
Uplink C/No Transponder input	87.93	87.9 dBHz
Carrier Suppression	0.51	0.51 dB
Noise Suppression	1.74	1.74 dB
Uplink C/No Transponder output	89.2	89.2 dBHz

Downlink C/No budget	Clear Sky	Rain	Rain U/L Clear Sky D/L	Clear Sky U/L Rain D/L
Downlink EIRP	43.49	43.5	43.5	43.5 dBW
Path Loss	205.71	206.9	205.7	206.9 dB
Mobile Clearsky G/T	10.20	10.2	10.2	10.2 dB/K
Rain Noise Temperature Increase	0	1.7	0	1.7 dB
Boltzmann's constant	228.60	228.6	228.6	228.6 dBW/K/Hz
Downlink C/No	76.58	73.7	76.6	73.7 dBHz

Uplink C/Io terms	Clear Sky	Rain U/L
ASI	93.9	93.9 dBHz
CrossPol	94.6	94.6 dBHz
Uplink HPA IM	100	100 dBHz
Uplink C/Io Transponder input	90.7	90.7 dBHz
Carrier Suppression	0.51	0.51 dB
Noise Suppression	1.74	1.74 dB
Uplink C/Io Transponder output	91.9	91.9 dBHz

Downlink C/Io terms	Clear Sky	Rain U/L Rain D/L	Rain U/L Clear Sky D/L	Clear Sky U/L Rain D/L
ASI	74.50	74.50	74.50	74.50 dBHz
CrossPol	88.06	88.06	88.06	88.06 dBHz

Uplink Path Loss	Clear Sky	Rain U/L
Freespace Path Loss	206.87	206.9 dB
Gaseous Attenuation	0.10	0.10 dB
Rain Attenuation	0	1.2 dB
Cloud Attenuation	0	0.15 dB
Scintillation	0	0.16 dB
Total Attenuation	207.0	208.3 dB

Downlink Path Loss	Clear Sky	Rain D/L
Freespace Path Loss	205.60	205.6 dB
Gaseous Attenuation	0.11	0.11 dB
Rain Attenuation	0	1.0 dB
Cloud Attenuation	0	0.16 dB
Scintillation	0	0.25 dB
Total Attenuation	205.7	206.9 dB

Uplink Propagation Model	
Frequency	14.18 GHz
Availability	99.75%
Satellite Longitude	255.0 °E
Site Location	Carlsbad
Site Latitude	33.2 °N
Site Longitude	242.7 °E
Site Altitude	0.0 km
Antenna efficiency	65%
Antenna diameter	4.5 m
Polarization	V
Slant Range	37141.4 km
Elevation Angle	49.21 °
Rain Height	3.2 km
Rain Intensity @ 0.01%	25.1 mm/hr
Total Columnar Content of Liquid @ 0.01	0.6 kg/m2
Wet term of refraction coindex	45.3
Temperature	289.6 K
Water Vapor Content	7.2 g/m3
Polarization Angle	18.1 °

Downlink Propagation Model	
Frequency	11.88 GHz
Availability	99.75%
Satellite Longitude	255.0 °E
Site Location	Var Seattle
Site Latitude	46.6 °N
Site Longitude	237.8 °E
Site Altitude	0.0 km
Antenna efficiency	60%
Antenna diameter	0.4 m
Polarization	H
Slant Range	38293.1 km
Elevation Angle	33.8 °
Rain Height	2.5 km
Rain Intensity @ 0.01%	40.0 mm/hr
Total Columnar Content of Liquid @ 0.01	0.7 kg/m2
Wet term of refraction coindex	35.0
Temperature	279.0 K
Water Vapor Content	5.2 g/m3
Polarization Angle	74.4 °
Tsys, clear sky	117.0 K
Tsys, rain	173.9 K

Return Link Parameters	Uplink	Downlink
Site	Var - Seattle	Carlsbad
Frequency, GHz	14.18	11.88
Availability	99.75%	99.75 %
Antenna Size, m	0.37	4.50
Modulation	GMSK DSSS	
Coding	Rate 1/3 TC	
Data rate (kbps)	128	
Signal rate (kbaud/s)	384.0	
Transponder Bandwidth (kHz)	24060	

Uplink C/No budget	Clear Sky	Rain U/L
Uplink EIRP (incl. UPC compensation)	35.71	35.71 dBW
Terminal Pointing Loss	0.07	0.07 dB
Path Loss	207.27	209.2 dB
Spacecraft G/T	2	2 dB/K
Boltzmann's constant	228.6	228.6 dBW/K/Hz
Uplink C/No Transponder input	58.98	57.06 dBHz
Carrier Suppression	1.75	1.75 dB
Noise Suppression	1.74	1.74 dB
Uplink C/No Transponder output	58.97	57.05 dBHz

Uplink C/Io terms	Clear Sky	Rain U/L
ASI	65.0	63.0 dBHz
CrossPol	65.6	63.7 dBHz
Uplink HPA IM	100	100 dBHz
Uplink C/Io Transponder input	62.3	60.4 dBHz
Carrier Suppression	1.75	1.75 dB
Noise Suppression	1.74	1.74 dB
Uplink C/Io Transponder output	62.3	60.3 dBHz

Uplink Path Loss	Clear Sky	Rain U/L
Freespace Path Loss	207.14	207.1 dB
Gaseous Attenuation	0.13	0.13 dB
Rain Attenuation	0	1.7 dB
Cloud Attenuation	0	0.22 dB
Scintillation	0	0.27 dB
Total Attenuation	207.3	209.2 dB

EndtoEnd Link Budget		Clear Sky	Rain U/L Rain D/L	Rain U/L Clear Sky D/L	Clear Sky U/L Rain D/L
Uplink C/No		58.97	57.05	57.05	58.97 dBHz
Uplink C/Io		62.26	60.34	60.34	62.26 dBHz
Downlink C/No		71.90	67.77	69.98	69.69 dBHz
Downlink C/Io	55.9662923	62.19	60.27	60.27	62.19 dBHz
Multiple Access Interference		64.27	62.35	62.35	64.27 dBHz
Total C/(No+Io)		55.37	53.38	53.45	55.30 dBHz
Required C/(No+Io)		53.32	53.32	53.32	53.32 dBHz
Margin		**2.0**	**0.1**	**0.1**	**2.0 dB**

Downlink C/No budget	Clear Sky	Rain U/L Rain D/L	Rain U/L Clear Sky D/L	Clear Sky U/L Rain D/L
Downlink EIRP	16.27	14.4	14.4	16.3 dBW
Path Loss	205.41	206.2	205.4	206.2 dB
Hub Clearsky G/T	32.44	32.4	32.4	32.4 dB/K
Rain Noise Temperature Increase	0.00	1.4	0.0	1.4 dB
Boltzmann's constant	228.60	228.6	228.6	228.6 dBW/K/Hz
Downlink C/No	71.9	67.8	70.0	69.7 dBHz

Downlink C/Io terms	Clear Sky	Rain U/L Rain D/L	Rain U/L Clear Sky D/L	Clear Sky U/L Rain D/L
ASI	78.77	76.85	76.85	78.77 dBHz
CrossPol	73.44	71.52	71.52	73.44 dBHz
Transponder IM	63.51	61.59	61.59	63.51 dBHz
PCMA C/Io	70.01	68.09	68.09	70.01 dBHz

Downlink Path Loss	Clear Sky	Rain
Freespace Path Loss	205.3	205.3 dB
Gaseous Attenuation	0.08	0.08 dB
Rain Attenuation	0	0.7 dB
Cloud Attenuation	0	0.11 dB
Scintillation	0	0.15 dB
Total Attenuation	205.41	206.2 dB

9. Antenna Gain Data

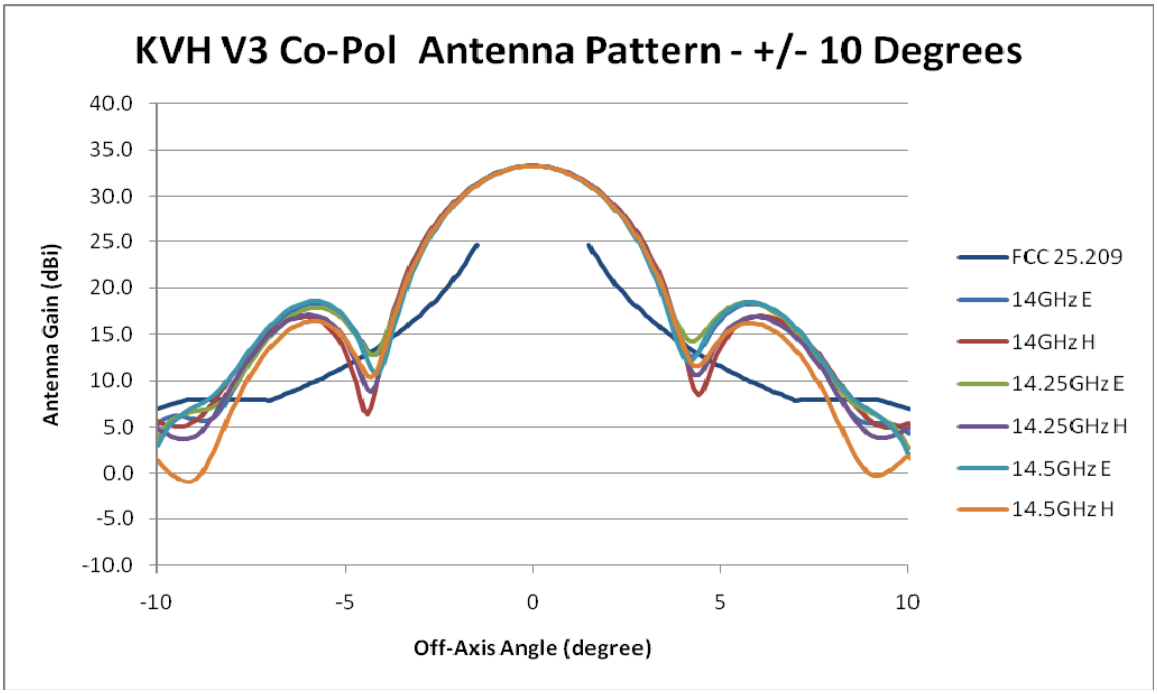

Figure 10 – C0-Pol Gain +/- 10 dgrees

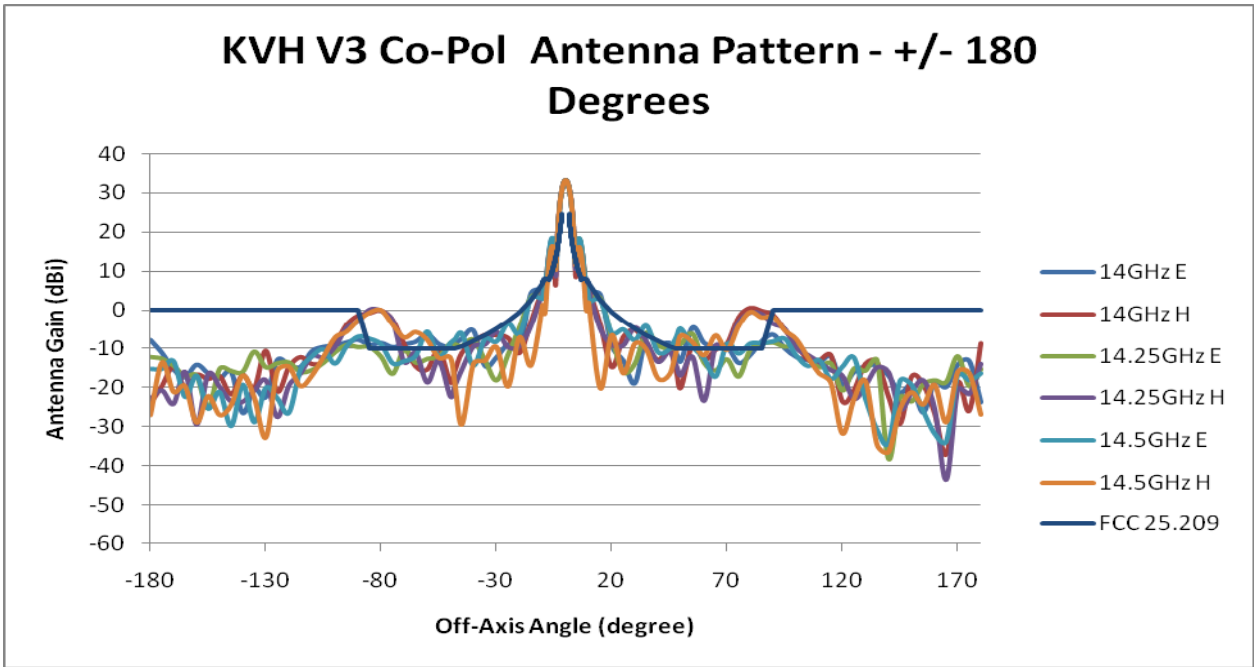

Figure 11 – Co-Pol Gain +/- 180 dgrees

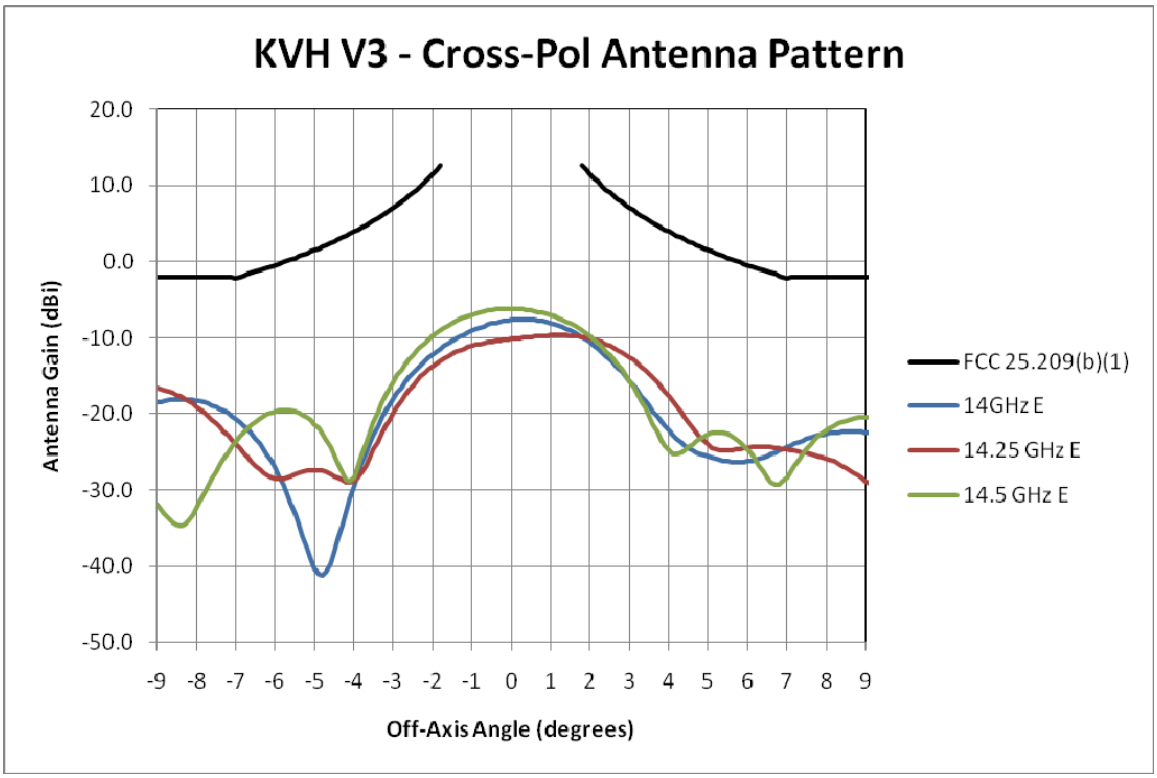

Figure 12 – Cross-pol Gain Pattern +/- 9 degrees