Application of KVH Industries, Inc.

Experimental Special Temporary Authorization
V3 ESV Terminal Description and Concept of Operation

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). 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.

This application seeks an experimental special temporary authorization ("STA"), pursuant to Section 5.61 of the Commission's rules, 47 C.F.R. § 5.61, to test and operate a network of small ESV terminals that will communicate in the Ku-band with the following satellite points of communication: AMC-15 at 105° W.L, AMC-21 at 125º W.L., and GE-23 at 172º E.L. The proposed operation will be used to test the delivery of a two-way broadband channel to maritime vessels using the new, small-diameter antenna terminals.

An experimental license is required for KVH to refine these antenna systems and the accompanying VSAT system parameters during operations. Many of the parameters cannot be effectively simulated in a lab environment. In addition, the live operations will allow KVH to detect and correct problems that were not originally anticipated. The resolution of all potential problems is crucial to the success of this product.

Under this authorization, KVH would deploy ten (10) ESV terminals to provide an accurate measure of usage patterns and operational profiles. This information is vital to development of an operational VSAT system by providing bandwidth requirements, hub resources, number of access queues, etc. In addition, network management and terminal operating issues may not manifest themselves with a smaller number of terminals. The demonstrations will operate on an unprotected, non-interfering basis.

The proposed experimental operations will be conducted within the continental United States either at specific test facilities for a limited duration or mounted on water-borne vessels. KVH requests a period of authorization of six months.[1]

[1] This experimental STA application is a refiling of File No. 0591-EX-ST-2010, which was dismissed without prejudice on January 4, 2011 based on concerns raised by the Federal Aviation Administration and Air Force. Counsel for KVH has contacted spectrum management staff from the FAA and Air Force and cleared potential concerns. As a result, KVH believes that this follow-on application can be considered on an expedited basis.

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 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.

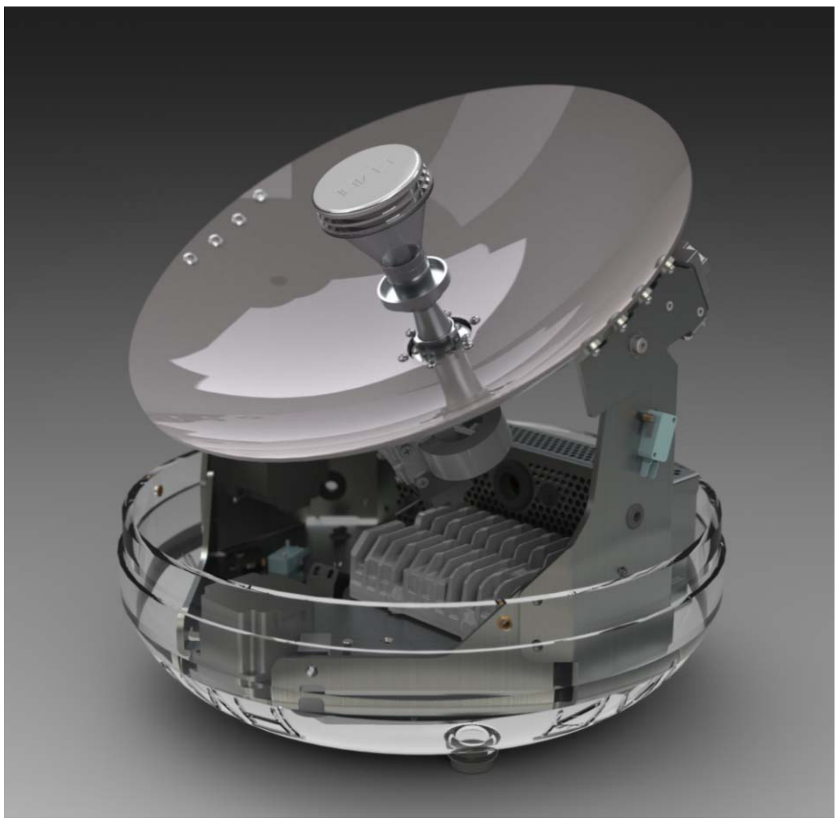

Figure 1: KVH 37cm Ku-band antenna

Description of Planned Experimental Operations

As is shown in Figure 2 below, the V3 terminal will be tested 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), and

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[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).

adjacent waters within the satellite coverage zones, for evaluation and demonstration purposes. The ESV terminals may be tested in any of the following modes: (i) fully stationary; (ii) on a three-axis table to test antenna tracking; (iii) on a ground vehicle rooftop for in-motion testing; and (iv) on a vessel operating within CONUS or adjacent waters.

Receive-only tests will be conducted first to verify antenna performance and for set-up of any transmit operation. Two-way tests requiring transmit operation will then be performed to evaluate, optimize and demonstrate return link performance as well as the user experience.

The testing will involve two-way broadband connectivity. Ultimately, the target end users of this terminal are small and medium size vessels, over 40 feet in length overall. These prospective users include both commercial/private customers, such as fishing boats and leisure vessels, and providers of public services such as the Department of Homeland Security and the Coast Guard. Testing will also include high-speed Internet access for applications such as e-mail, web access, voice, and distance learning.

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.[3]

KVH would like to operate the terminals with the following satellites:

AMC-15 @ 105° W.L.
AMC-21 @ 125º W.L.
GE-23 @ 172º E.L.

The ESVs will communicate with existing hub earth stations in Miami, Florida,[4] Carlsbad, California,[5] and Kapolei, Hawaii.[6] KVH will control all V3 operations using its standard network control capabilities and network management partner, ViaSat, Inc.

[3] Paired Carrier Multiple Access is a proprietary technique developed by ViaSat for their spread spectrum ArcLight service.
[4] Call Sign E040267.
[5] Call Sign E9030131.
[6] Call Sign E010236.

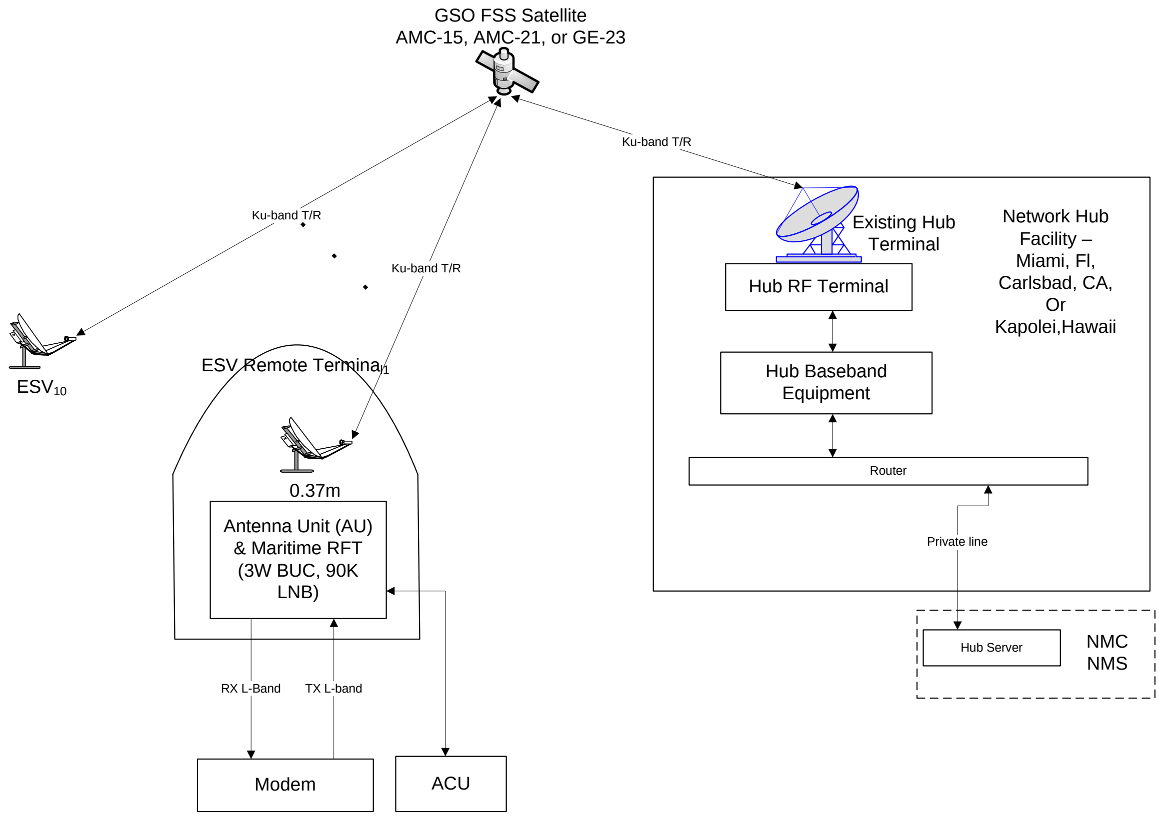

Figure 2 – ESV Network Architecture

For purposes of this experimental STA application, the ESV terminal will not operate within line-of-sight vicinity of Radio Astronomy Service (RAS) sites or the Tracking and Data Relay Satellite System (TDRSS) for space research conducted at White Sands, New Mexico and the US Naval Research Lab at Blossom Point, Maryland.[7]

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[8] over either an 18 MHz channel bandwidth or a 36 MHz channel bandwidth. The off-axis EIRP spectral density of the KVH ESV terminal is shown in the following Figures 3 and 4. 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. KVH will ensure that the aggregate EIRP levels do not exceed the limits specified for Ku-band ESVs in Section 25.222 of the Commission's rules.

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

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

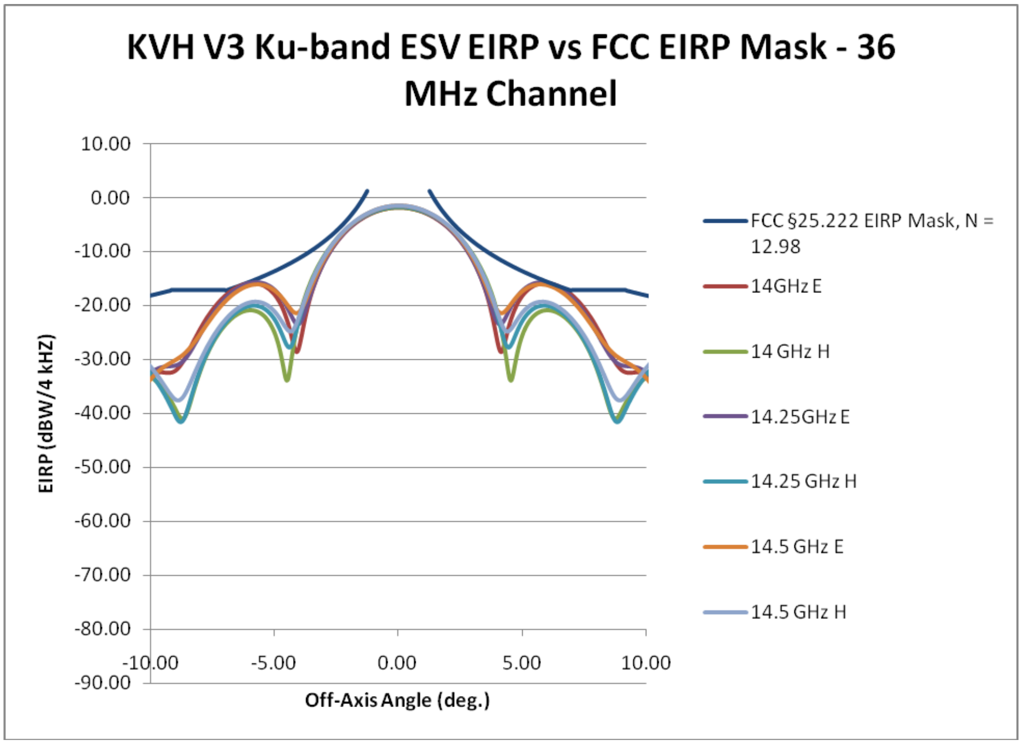

Figure 3. V3 Off-Axis EIRP Spectral Density – 36 MHz Channel

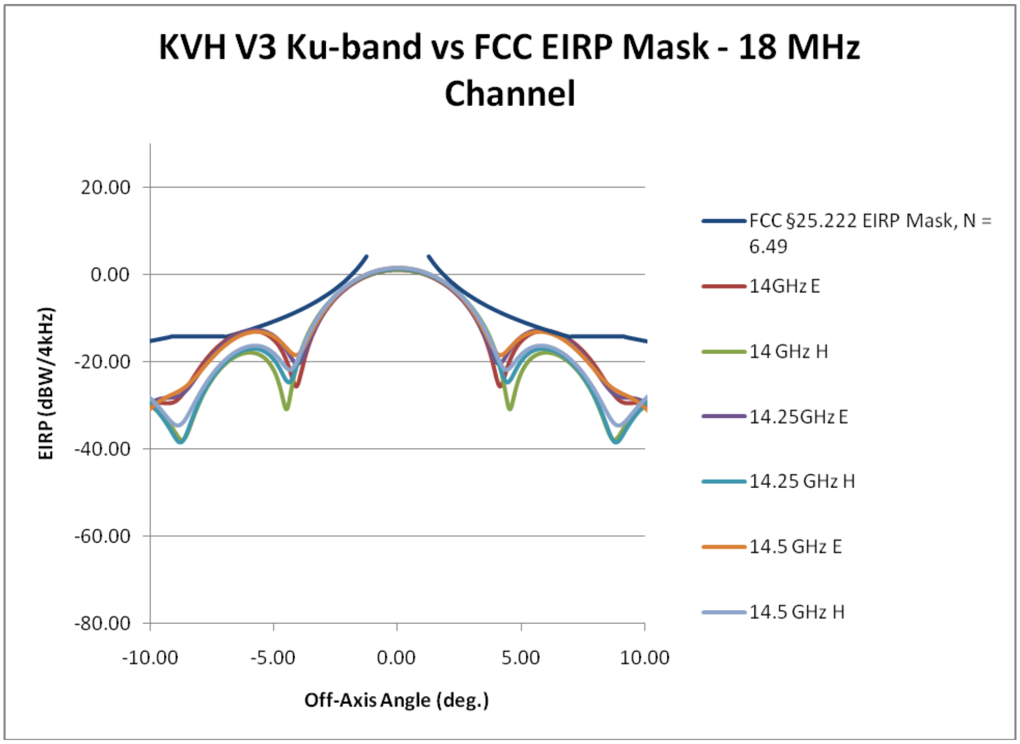

Figure 4. V3 Off-Axis EIRP Spectral Density – 18 MHz Channel

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 testing will include up to ten (10) terminals, each using 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 0.4º from boresight. The dynamic pointing error for the vessel accelerations expected during testing operation is expected to be less than 0.2ºs one sigma. Thus the total expected mean pointing error for each vessel while under way, including both conscan and dynamic error, is 0.4º with a standard deviation of 0.2º.

During the small percentage of time when conditions cause the antenna pointing error to exceed the specified maximum pointing error limit of 1.0º, 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 0.6º. The time lag from detection of exceedance of mispointing to time when transmit is inhibited will be less than 100 ms. For the purposes of this authorization this error limit of 1º is the declared maximum antenna pointing error as described in Section 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.

Figure 5 below shows the ESV off-axis EIRP considering a 1.0 degree pointing error. As can be seen the EIRP density is significantly lower that the Section 25.222 mask for an individual ESV terminal.

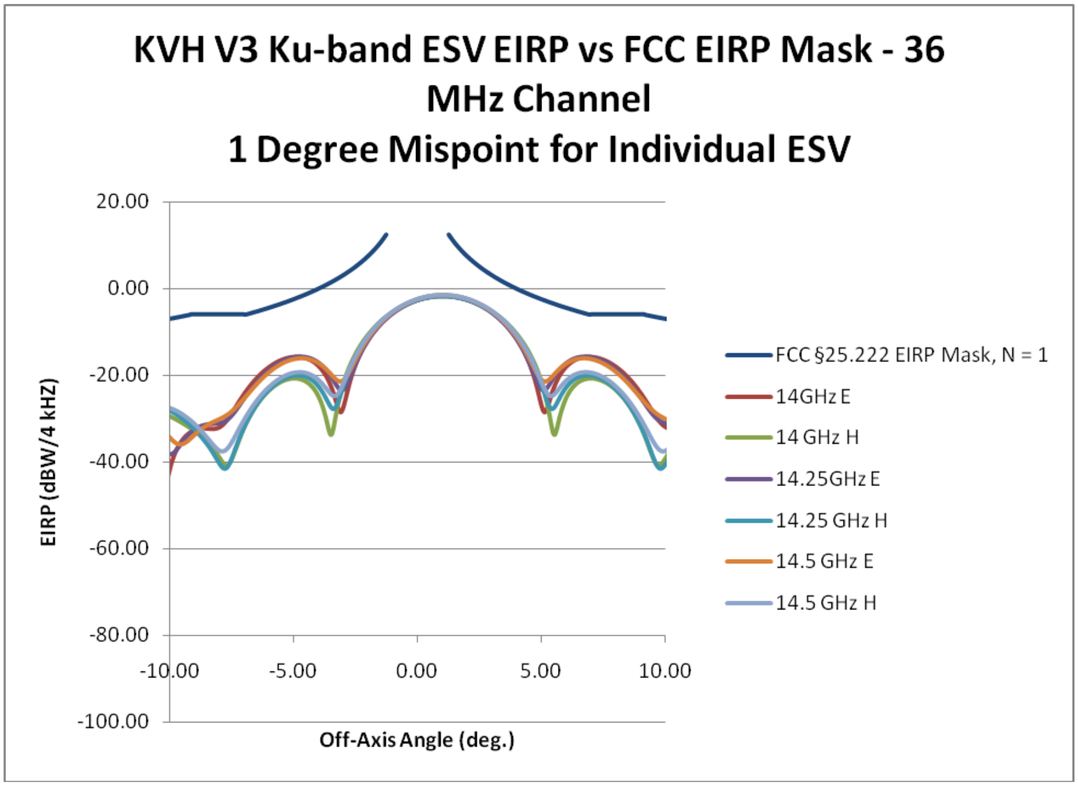

Figure 5 – V3 Terminal Off-axis EIRP with 1 degree pointing error vs 25.222 limit

Protection of Other Users in the 14.0–14.5 GHz Band

Protection of Fixed-Satellite Service. The FCC has established service rules applicable to Ku-band ESV operations, which define operational limits in Section 25.222. As discussed above, KVH's terminals will operate in such a manner that the off-axis EIRP levels are no greater than the levels established for ESV operations, which are consistent with those produced by routinely licensed VSAT earth stations. To the extent that any adjacent satellite operator experiences unacceptable interference from KVH's experimental operations, KVH will cease terminal transmissions immediately. Additionally, since this testing will be performed 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).

Protection of Potential NGSO FSS Systems. KVH acknowledges that non-geostationary orbit ("NGSO") systems are also permitted to operate in the Ku-band.

However, no such systems are currently authorized or plan to operate within the period contemplated for the proposed experimental operations.

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. For purposes of this experimental application, in addition to complying with its prior coordination agreement with NSF and complying with Section §25.222(d) of the rules, KVH terminals will not operate within line-of-sight vicinity of Radio Astronomy sites and during observation periods.

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 National Aeronautics and Space Administration ("NASA") Tracking and Data Relay Satellite System ("TDRSS") for space research conducted at White Sands, New Mexico and Blossom Point, Maryland. For purposes of this experimental STA application, KVH will avoid AES operation within line-of-sight vicinity of these earth stations.[9]

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[10].

[9] *See* 47 C.F.R. § 25.222(c).
[10] 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.

SUMMARY OF TECHNICAL PARAMETERS

The return link channel shall 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 0.4º RMS (AZ); 0.6º RMS (AZ) in-motion, Declared Maximum Pointing Error 1.0º)
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

Maximum power at Feed	3	W
Channel; Bandwidth	36	MHz
RF Power Density at Flange	-34.8	dBW/4,kHz
Maximum EIRP Density toward the Horizon	-3.79	dBW/MHz
Maximum EIRP toward the Horizon	11.77	dBW
Maximum Number Simultaneous Users N	12.98	

Uplink Transmission Parameters - 36 MHz Channel

Maximum power at Feed	3	W
Channel Bandwidth	18	MHz
RF Power Density at Flange	-31.8	dBW/4,kHz
Maximum EIRP Density toward the Horizon	-0.8	dBW/MHz
Maximum EIRP toward the Horizon	11.8	dBW
Maximum Number Simultaneous Users N	6.49	

Uplink Transmission Parameters - 18 MHz Channel

A sample link analysis for AMC-15 is included in Annex A.

Additional Off-Axis EIRP Spectral Density Plots

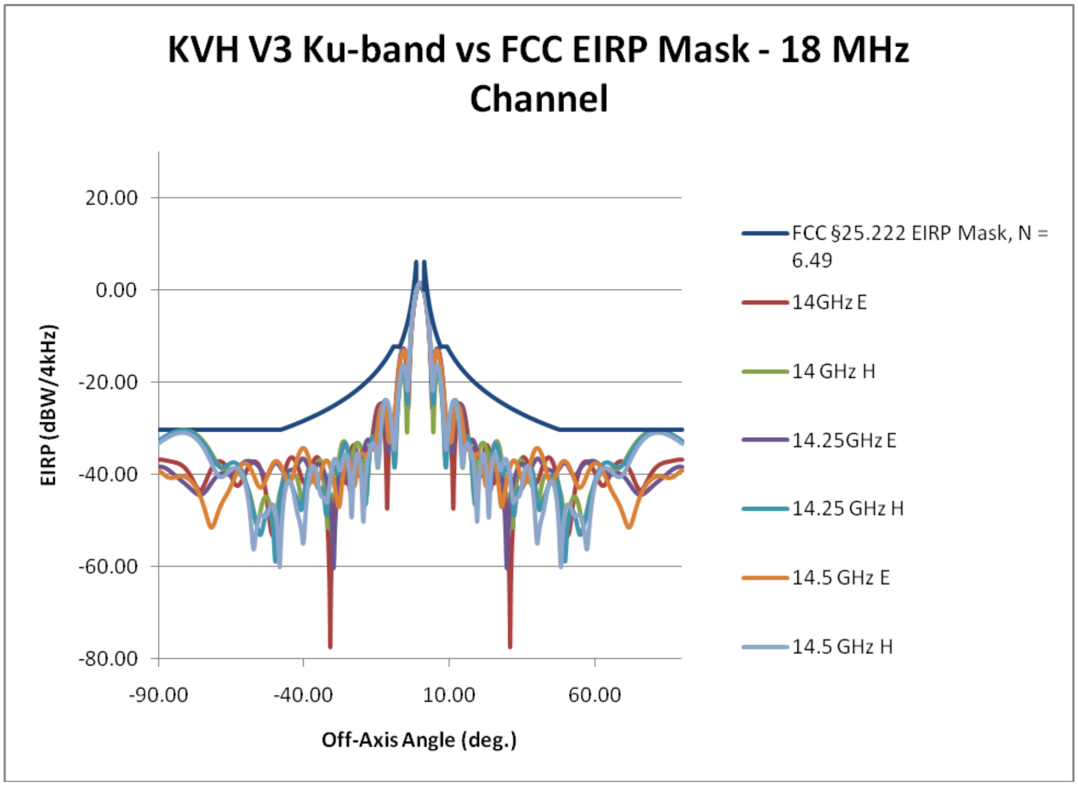

Figure 6 – 18 MHz Off-Axis EIRP Spectral Density

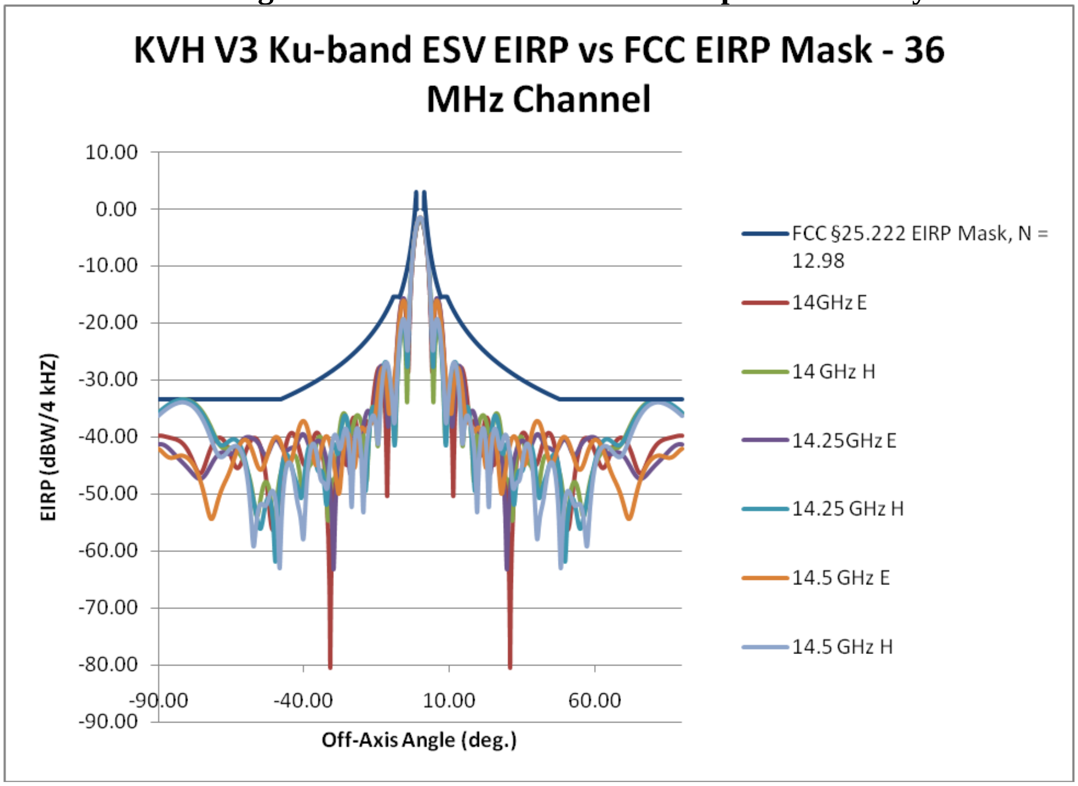

Figure 7 – 36 MHz Channel Off-Axis EIRP Spectral Density

Points of Contact

For purposes of this authorization, the KVH terminals will be operated under KVH's full supervision and control. The points of contact for the planned experimental operations are:

Marc Edwards
Program Manager
KVH Industries, Inc.
401.845.2403
Email: medwards@kvh.com

Mr. Edwards will have the ability and authority to cease all transmissions from the terminals wherever they are located.

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

Annex A

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	PI/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

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

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

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

Spacecraft Transponder					
Spacecraft	AMC-15		Desired Transponder OBO point	-2	dB
Satellite Longitude	255	deg E	Additional Forward Link Backoff	0	
Transponder Total Bandwidth	36	MHz	IBO - Clear Sky Uplink	-5.0	dB
Transponder Allocated Bandwidth	36	MHz	IBO - Rain Uplink	-5.0	dB
Forward CW Sat EIRP	46	dBW	OBO - Clear Sky Uplink	-2.0	dB
Forward G/T	1.25	dB/K	OBO - Rain Uplink	-2.0	dB
Return CW Sat EIRP	48.4	dBW	Fwd Transponder Suppression	-0.51	dB
Return G/T	2	dB/K	Rtn Transponder Suppression	-1.75	dB
Forward Min SFD	-92.94	dBW/m2	Fwd EIRP- Clear Sky Uplink	43.5	dBW
Return Min SFD	-93.69	dBW/m2	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

1.24 74.593925

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

94.2126533 0.51 18.3787284 1.75

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

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

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

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

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

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

Uplink Propagation Model	
Frequency	14.18 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	68%
Antenna diameter	0.4 m
Polarization	V
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	15.6 °

Downlink Propagation Model	
Frequency	11.88 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	66%
Antenna diameter	4.5 m
Polarization	H
Slant Range	37141.4 km
Elevation Angle	49.2 °
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	71.9 °
Tsys, clear sky	105.1 K
Tsys, rain	144.6 K