

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 72° W.L, AMC-21 at 125° W.L., and GE-23 at 172° 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.

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.

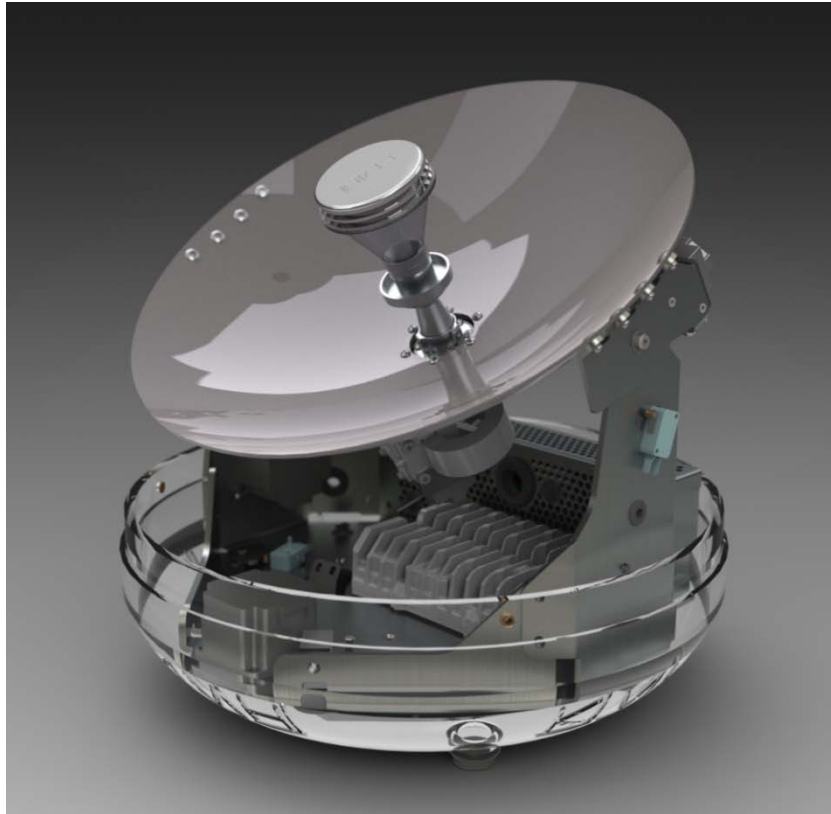


Figure 1: KVH 37cm Ku-band antenna

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.¹ KVH is seeking authorization to operate within the continental United States (CONUS), and 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.

¹ 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).

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.²

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

AMC-15 @ 72° W.L.
AMC-21 @ 125° W.L.
GE-23 @ 172° E.L.

The ESVs will communicate with existing hub earth stations in Miami, Florida,³ Carlsbad, California,⁴ and Kapolei, Hawaii.⁵ KVH will control all V3 operations using its standard network control capabilities and network management partner, ViaSat, Inc.

² Paired Carrier Multiple Access is a proprietary technique developed by ViaSat for their spread spectrum ArcLight service.

³ Call Sign E040267.

⁴ Call Sign E9030131.

⁵ Call Sign E010236.

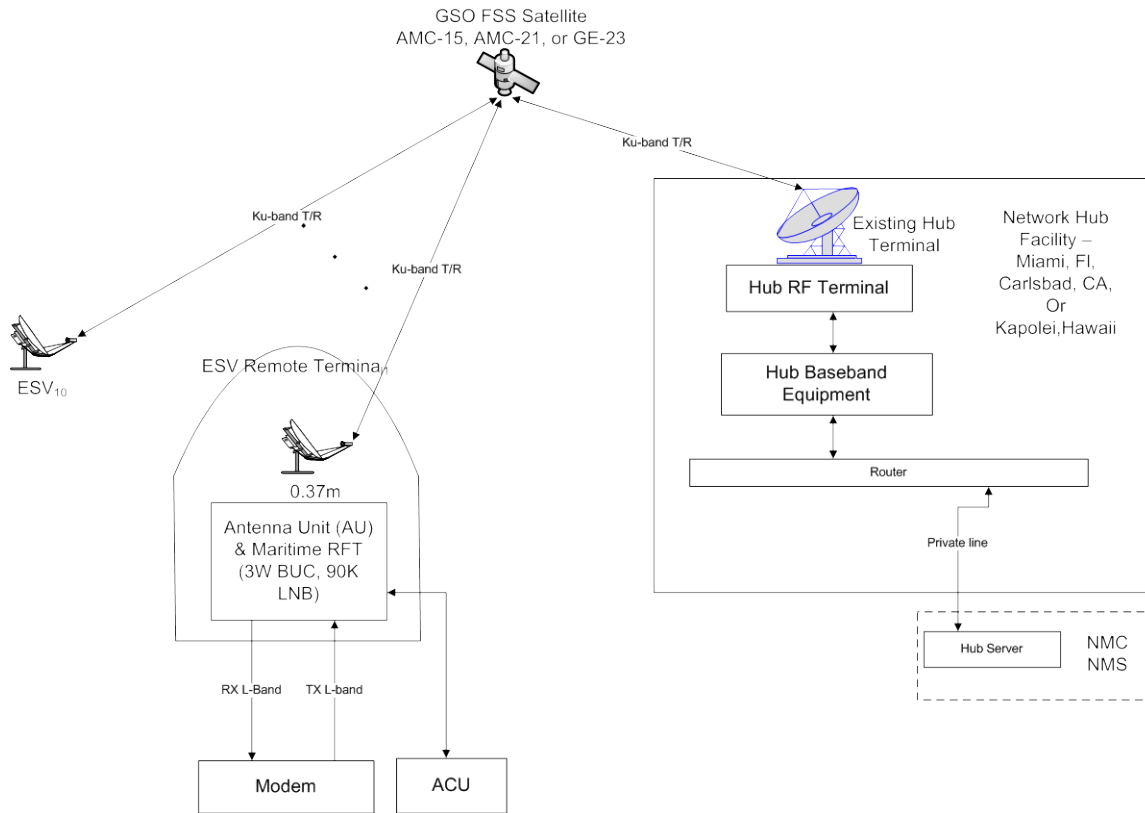


Figure 2 – ESV Network Architecture

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.⁶

Off-Axis EIRP Analysis

The data rates transmitted from the terminal will vary from 32 kbits/s to 512 Mbits/ps. Additionally, the ESVs will transmit using CRMA spreading⁷ 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.

⁶ 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.

⁷ CRMA, or Code Reuse Multiple Access, is a ViaSat proprietary spread spectrum technique, similar to CDMA, used in the ArcLight satellite system.

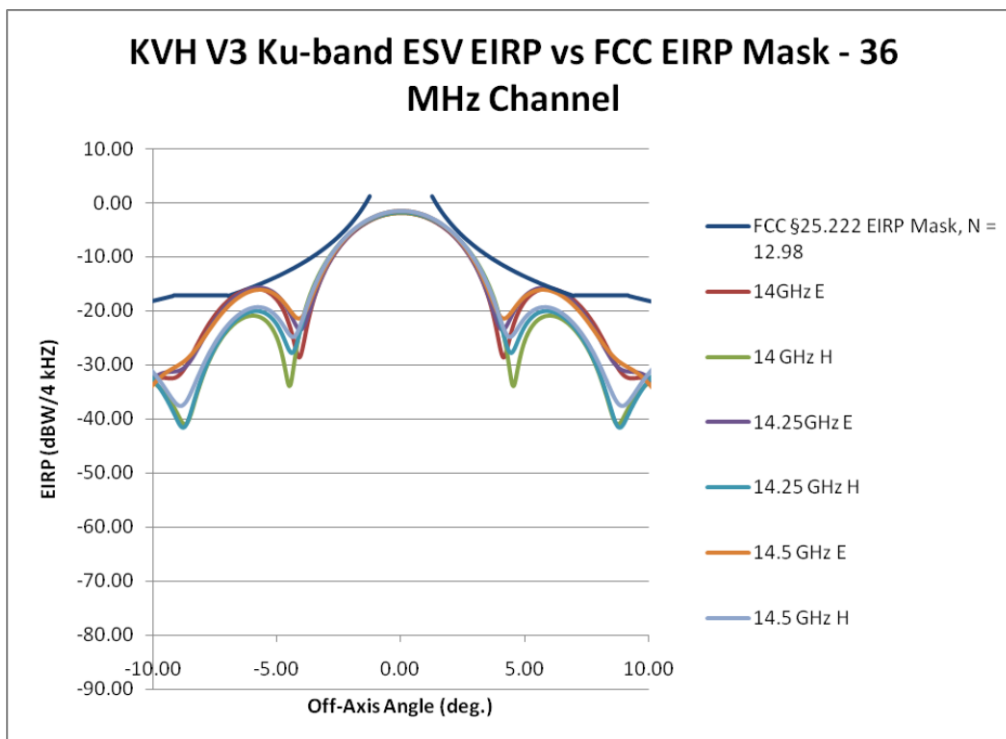


Figure 3. V3 Off-Axis EIRP Spectral Density – 36 MHz Channel

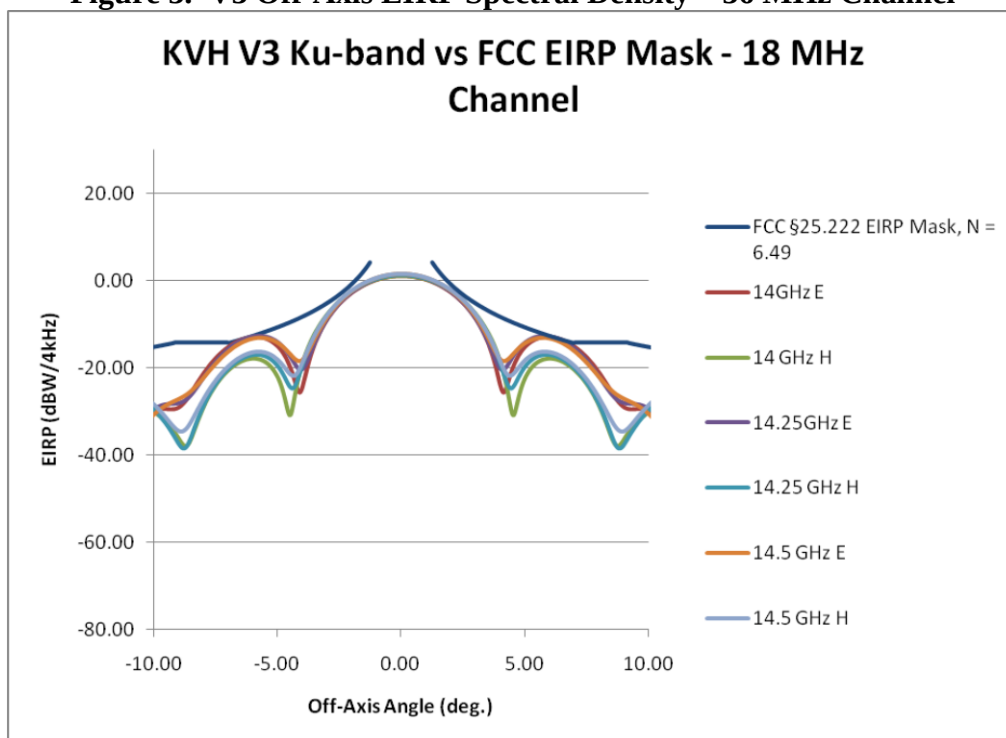


Figure4. V3 Off-Axis EIRP Spectral Density – 18 MHz Channel

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 than 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 0.4° from boresight. The dynamic pointing error for the vessel accelerations expected during testing operation is expected to be less than 0.2° s one sigma. Thus the total expected mean pointing error for each vessel while under way, including both conscan and dynamic error, is 0.4° with a standard deviation of 0.2° .

During the small percentage of time when conditions cause the antenna pointing error to exceed the specified maximum pointing error limit of 1.0° , 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 0.6° . 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 1° 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 than the Section 25.222 mask for an individual ESV terminal.

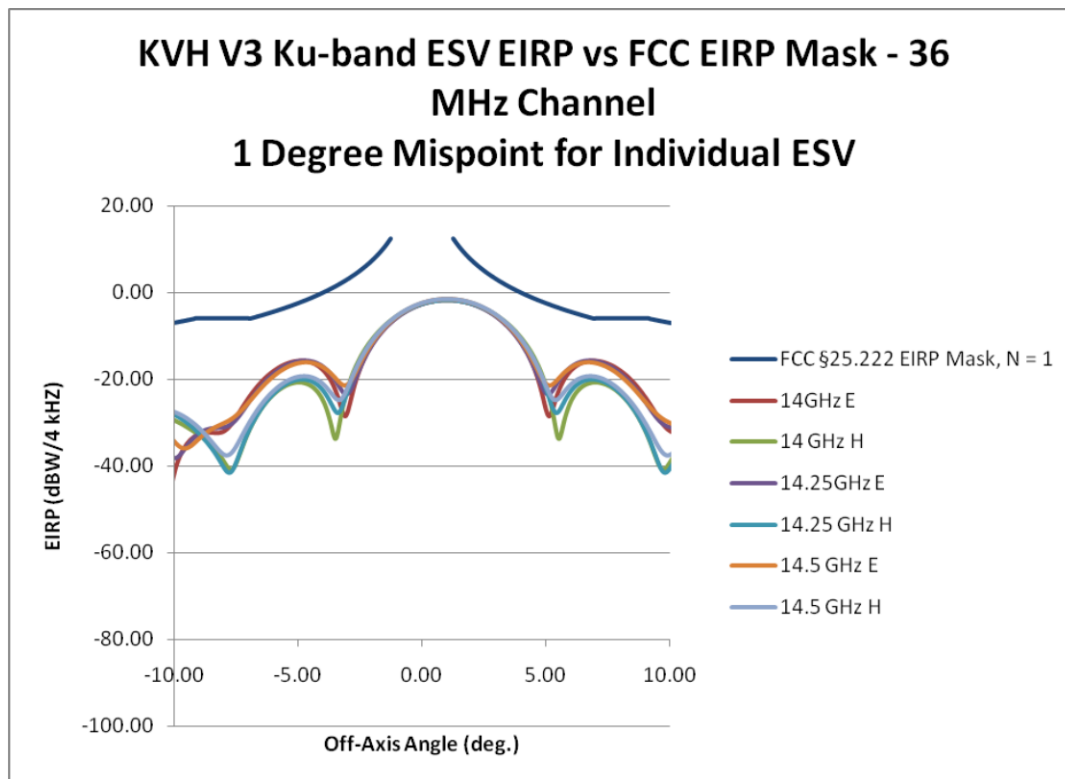


Figure 5 – V3 Terminal Off-axis EIRP with 1 degree pointing error vs 25.222 limit

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.⁸

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 dBW⁹.

⁸ See 47 C.F.R. § 25.222(c).

⁹ 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 360°
Elevation	10 to 80° antenna elevation
Position accuracy	Static pointing error 0.4° RMS (AZ); 0.6° RMS (AZ) in-motion, Declared Maximum Pointing Error 1.0°)
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

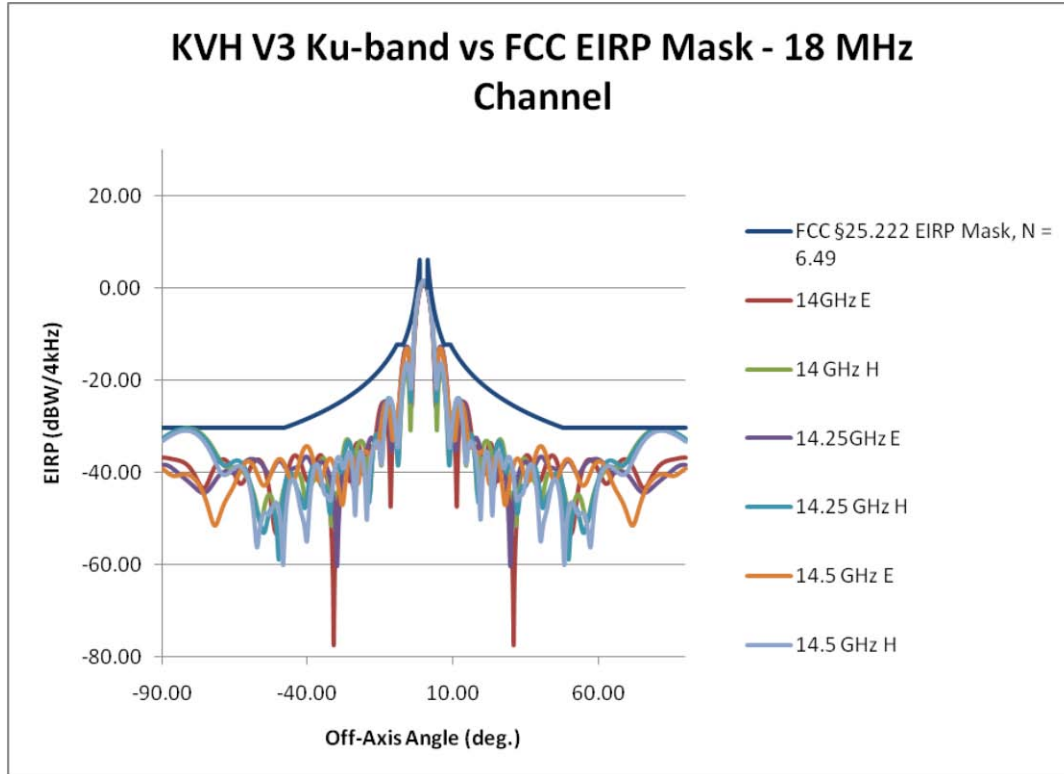


Figure 6 – 18 MHz Off-Axis EIRP Spectral Density

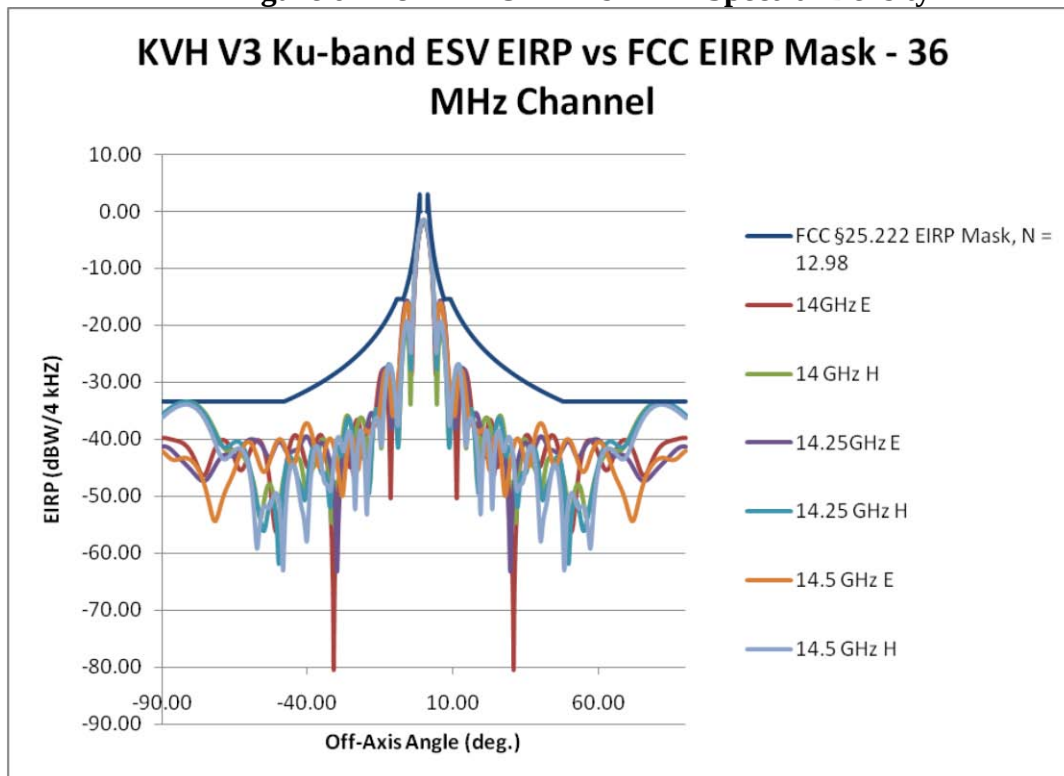


Figure 7 – 36 MHz Channel Off-Axis EIRP Spectral Density

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				Mobile Antenna Transmit Characteristics (Return Uplink)		Hub Antenna Transmit Characteristics (Forward Uplink)	
Uplink Frequency	14.18 GHz			Antenna Type	KVH	Uplink Frequency	14.18 GHz
Forward Uplink Availability	99.75%			Uplink Frequency	14.18 GHz	Antenna Diameter	4.5 m
Return Uplink Availability	99.75%			Antenna Diameter	0.37 m		212.7 wavelengths
Downlink Frequency	11.88 GHz			Aperture efficiency	68%	Antenna efficiency	65%
Forward Downlink Availability	99.75%			Antenna peak gain	33.1 dB	Antenna peak gain	54.6 dB
Return Downlink Availability	99.75%			CW Sat Transmit Power	3 W	Max HPA Transmit Power	400 W
Mobile Site	Var - Seattle			Transmission losses	-1.3 dB	Transmission losses	-2.53 dB
Hub Site	Carlsbad			Antenna Ohmic Losses	-0.1 dB	Antenna Ohmic Losses	0 dB
Vehicle Inclination	0 °			Radome Loss	-0.8 dB	Radome Loss	0 dB
F/R Transponder Input Ratio	18.4 dB			CW Sat EIRP at peak	35.7 dBW	CW EIRP	78.1 dBW
alpha_power	0.01432			OBO	0.00 dB	OBO	-12.6 dB
PCMA Cancellation C/I	25 dB			Pointing loss, etc.	-0.07 dB	Pointing loss, etc.	-0.5 dB
Forward Link				EIRP (not including pointing loss)	35.71 dBW	EIRP (not including pointing loss)	65.05 dBW
Data Rate	4.00E+06 bps	4000000		Clear-Sky PFD	-127.07 dBW/m2	Clear-sky PFD	-97.94 dBW/m2
Bit Error Rate	1 x 10E-7	QPSK 1/3		Available UPC Boost	0.0 dB	Available UPC Boost	12.6 dB
Eb/No Required	1.7 dB			UPC Error	0 dB	UPC Error	0.0 dB
C/No Required	67.72 dB-Hz			HPA Suppression	0.0 dB	HPA Suppression	0.0 dB
Modulation Type	QPSK DSSS	PI/2 BPSK 3		Antenna Crosspol Discrimination	15.0 dB	Antenna Crosspol Discrimination	30.0
FEC Factor	Rate 1/3 Turbo			Pointing Error (Tx and Rx)	0.31 deg	Half-power beamwidth	0.3 deg
Spread Factor : Spread Signal Rate	2	28800 kcps		Mobile Antenna Receive Characteristics (Forward Downlink)		Hub Antenna Receive Characteristics (Return Downlink)	
Carrier Spacing: Authorized BW	1.2	36000 kHz		Antenna Type	KVH	Downlink Frequency	11.88 GHz
Bits per symbol	0.3333	VSAT Proprietary FL		Downlink Frequency	11.88 GHz	Antenna Diameter	4.5 m
Signal Rate	14400 kbaud/s			Antenna Diameter	0.37 m		178.2 wavelengths
Return Link				Aperture efficiency	60%	Antenna efficiency	66%
Data Rate	128000 bps			Antenna peak gain	31.0 dB	Antenna peak gain	53.2 dB
Packet Error Rate	1 x 10E-3			LNB Noise Figure	0.94 dB	LNB Noise Figure	0.94 dB
Eb/No Required	2.25 dB			Reference Temperature	290 K	Input Losses	0 dB
C/No Required	53.32 dB-Hz			Antenna Ohmic Losses	-0.1 dB	Antenna Ohmic Losses	0 dB
Modulation Type	GMSK DSSS			Radome Ohmic Loss	-0.10 dB	Radome Loss	0 dB
FEC Factor	Rate 1/3 TC			Clear-sky Antenna Temperature	30 K	Clear-sky Antenna Temperature	35 K
Alpha_MAI	0.859			Clear-sky Tsys	117.0 K	Clear-sky Tsys	105.1 K
Beta_MAI	0.712	108		Radome non-ohmic loss	-0.10 dB	Pointing loss, etc.	-0.5 dB
Spread Factor : Spread Signal Rate	88	33792 kcps		Antenna non-ohmic loss	0.0 dB	Antenna non-ohmic loss	0.0
Carrier Spacing	1			Pointing Loss	-0.1 dB	Clear-sky G/T	32.4 dB/K
Bits per symbol	0.3333			Clear-sky G/T	10.20 dB/K	Half-power beamwidth	0.4 deg
Transponder Bandwidth	24060 kHz			Antenna Crosspol Discrimination	15.0 dB	Antenna Crosspol Discrimination	30.0 dB
Occupied Bandwidth	29027 kHz			Spacecraft Transponder		Desired Transponder OBO point	-2 dB
Signal Rate	384.0 kbaud/s			Spacecraft	AMC-15	Additional Forward Link Backoff	0
Number of Return Links	10	1.00E+01		Satellite Longitude	255 deg E	IBO - Clear Sky Uplink	-5.0 dB
Fwd Link Total Availability				Transponder Total Bandwidth	36 MHz	IBO - Rain Uplink	-5.0 dB
Return Link Total Availability				Transponder Allocated Bandwidth	36 MHz	OBO - Clear Sky Uplink	-2.0 dB
LINK STATUS				Forward CW Sat EIRP	46 dBW	OBO - Rain Uplink	-2.0 dB
Forward Link Margin				Forward G/T	1.25 dB/K	Fwd Transponder Suppression	-0.51 dB
Return Link Margin				Return CW Sat EIRP	48.4 dBW	Rtn Transponder Suppression	-1.75 dB
Regulatory Limits				Return G/T	2 dB/K	Fwd EIRP- Clear Sky Uplink	43.5 dBW
Return Agg. Ant. Flange Pwr Density				Forward Min SFD	-92.94 dBW/m2	Rtn EIRP - CS U/L - Single Carrier	16.3 dBW
Return Uplink Off-axis Pwr Density				Return Min SFD	-93.69 dBW/m2	Uplink Interfering Transponder G/T	2 dB/K
Forward Downlink Pwr Density at Peak							

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	
Signal rate (kbaud/s)	14400	
Spread signal rate (kcps)	28800	

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 dB-Hz
Carrier Suppression	-0.51	-0.51 dB
Noise Suppression	-1.74	-1.74 dB
Uplink C/No - Transponder output	89.2	89.2 dB-Hz

Uplink C/lo terms	Clear Sky	Rain U/L
ASI	93.9	93.9 dB-Hz
Cross-Pol	94.6	94.6 dB-Hz
Uplink HPA IM	100	100 dB-Hz
Uplink C/lo - Transponder input	90.7	90.7 dB-Hz
Carrier Suppression	-0.51	-0.51 dB
Noise Suppression	-1.74	-1.74 dB
Uplink C/lo - Transponder output	91.9	91.9 dB-Hz

Uplink Path Loss	Clear Sky	Rain U/L
Free-space 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

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 co-index	45.3
Temperature	289.6 K
Water Vapor Content	7.2 g/m3
Polarization Angle	18.1 °

End-to-End Link Budget	Rain U/L		Clear Sky U/L	
	Clear Sky	Rain D/L	Clear Sky D/L	Rain D/L
Uplink C/No	89.2	89.2	89.2	89.2 dB-Hz
Uplink C/lo	91.9	91.9	91.9	91.9 dB-Hz
Downlink C/No	76.6	73.7	76.6	73.7 dB-Hz
Downlink C/lo	74.2	74.2	74.2	74.2 dB-Hz
Total C/(No+lo)	72.1	70.8	72.1	70.8 dB-Hz
Required C/(No+lo)	67.7	67.7	67.7	67.7 dB-Hz
Margin	4.4	3.1	4.4	3.1 dB

Downlink C/No budget	Rain U/L		Clear Sky U/L	
	Clear Sky	Rain	Clear Sky D/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 Clear-sky 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 dB-Hz

Downlink C/lo terms	Rain U/L		Clear Sky U/L	
	Clear Sky	Rain D/L	Clear Sky D/L	Rain D/L
ASI	74.50	74.50	74.50	74.50 dB-Hz
Cross-Pol	88.06	88.06	88.06	88.06 dB-Hz
Transponder IM	93.09	93.09	93.09	93.09 dB-Hz
Return Link Interference	94.2	94.2	94.2	94.2 dB-Hz
	94.2126533	-0.51		
	18.3787284	-1.75		
	1.24	74.593925		

Downlink Path Loss	Rain U/L	
	Clear Sky	Rain D/L
Free-space 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

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 co-index	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 dB-Hz
Carrier Suppression	-1.75	-1.75 dB
Noise Suppression	-1.74	-1.74 dB
Uplink C/No - Transponder output	58.97	57.05 dB-Hz

Uplink C/lo terms	Clear Sky	Rain U/L
ASI	65.0	63.0 dB-Hz
Cross-Pol	65.6	63.7 dB-Hz
Uplink HPA IM	100	100 dB-Hz
Uplink C/lo - Transponder input	62.3	60.4 dB-Hz
Carrier Suppression	-1.75	-1.75 dB
Noise Suppression	-1.74	-1.74 dB
Uplink C/lo - Transponder output	62.3	60.3 dB-Hz

Uplink Path Loss	Clear Sky	Rain U/L
Free-space 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

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 co-index	35.0
Temperature	279.0 K
Water Vapor Content	5.2 g/m3
Polarization Angle	15.6 °

End-to-End 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 dB-Hz
Uplink C/lo	62.26	60.34	60.34	62.26 dB-Hz
Downlink C/No	71.90	67.77	69.98	69.69 dB-Hz
Downlink C/lo	62.19	60.27	60.27	62.19 dB-Hz
Multiple Access Interference	64.27	62.35	62.35	64.27 dB-Hz
Total C/(No+lo)	55.37	53.38	53.45	55.30 dB-Hz
Required C/(No+lo)	53.32	53.32	53.32	53.32 dB-Hz
Margin	2.0	0.1	0.1	2.0 dB

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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 Clear-sky 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 dB-Hz

Downlink C/lo 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 dB-Hz
Cross-Pol	73.44	71.52	71.52	73.44 dB-Hz
Transponder IM	63.51	61.59	61.59	63.51 dB-Hz
PCMA C/lo	70.01	68.09	68.09	70.01 dB-Hz

Downlink Path Loss	Clear Sky	Rain
Free-space 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

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 co-index	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