Viasat

Attachment A

1 Description of Experiment

As an antenna manufacturer, Viasat, Inc. ("Viasat") designs and produces a variety of fixed and aeronautical antennas supporting a wide variety of frequencies for both commercial and Government users.

This requests for experimental authority to conduct performance testing on its mobile antennas, in the 14.0 – 14.5 GHz band. Specifically, grant of this license will allow Viasat to demonstrate the performance of its mobile antennas with the non-geo-stationary orbit satellite system (NGSO) operated by Kepler Communications Inc. The Canadian licensed satellite network has been granted U.S market access[1] and has been assigned the callsign S2981.

2 Technical Information

2.1 Antenna Characteristics

Two types of antennas are employed in this experiment, large fixed earth station and mobile terminals.

The large earth station is an ASC 3.8 m antenna that complies with the antenna gain pattern in 25.202.

The mobile terminals are a 30 cm, 45 cm and 75 cm. The 30 and 45 cm have parabolic reflectors while the 75 cm is a rectangular waveguide horn array with linear, electronically switchable cross and co-polarization and polarization tracking. The effective area of the aperture is 75 cm. The two parabolic reflector antennas are 30 cm and 45 cm and have gain patterns shown in Appendix B. The 30 cm has been granted blanket authority by the commission[2] while the 45 cm has been operating under experimental authority[3].

2.2 Antenna Emissions

Viasat's terminal emissions will comply with the conditions stated in paragraph 25 of the Order and Declaratory Ruling. Specifically, Viasat terminals will comply with the following two requirements:

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[1] *See* Order and Declaratory Ruling, FCC Docket 18-162, IBFS File No. SAT-PDR-20161115-00114
[2] *See* Viasat, Inc., File No. SES-AFS-20091117-01463, Call Sign E050318 (granted June 24, 2010)
[3] *See* Viasat, Inc., File number 0085-EX-CM-2019, Call Sign WE2XBE (granted July 3, 2019)

1. Operations in the 14.0-14.5 GHz (Earth-to-space) frequency band are authorized up to the equivalent power-flux density limits of Article 22 of the ITU Radio Regulations.

2. In the 14.47-14.5 GHz band, operations are subject to footnote US342 to the U.S. Table of Frequency Allocations, 47 CFR § 2.106, and all practicable steps must be taken to protect the radio astronomy service from harmful interference.

To protect GSO satellite networks Earth stations transmitting to the Kepler NGSO satellites will maintain an exclusion angle across all latitudes as high as 20º.[4] This minimum separation angle ensures that inline events do not occur.

Because Viasat's operations with Kepler's NGSO network will only use a single antenna at any given time, the equivalent power flux density (EPFD) produced by the full system is just the power flux density (PFD) produced by a single antenna. As shown below, the PFD analysis for a single antenna more than adequately meets the $EPFD_{up}$ limits when operated with a 5-degree exclusion angle from the GSO arc. Indeed, the employment of such exclusion angles is a practice that Kepler maintains for all of its ground stations, as discussed further in its request for U.S. market access.[5]

Provided below is a summary of the calculated EPFD for 14.0-14.5 GHz frequency band with emission designator 36M0G7D and the associated powers, 30kW ERP and 6MW ERP. Detailed calculations are in Appendix A of this document.

Table 1: Summary of Viasat compliance with Article 22 $EPFD_{up}$ limits.

ID	ERP	Designator	Spectral Flux Density	Unit
Article 22 EPFD	-	-	-160	dBW/m^2/40kHz
Viasat Config 1	30 kW	34M0G7D--	-173.81	dBW/m^2/40kHz
Viasat Config 2	6 MW	36M0G7D--	-163.09	dBW/m^2/40kHz

[4] *See* IBFS File No. SAT-PDR-20161115-00114, Attachment Technical Narrative page 9

[5] *See Kepler Communications Inc., Petition for a Declaratory Ruling*, IBFS File No. SAT-PDR-20161115-00114 (filed Nov. 15, 2016). Kepler has designed its system to operate with GSO exclusion angles as high as 20 degrees to comply with EPFD limits when servicing hundreds to thousands of user terminals. However, Kepler currently has two prototype satellites in orbit, neither of which have multi-access capability. Therefore, they can support no more two links at a time, one for each satellite. The stringent exclusion angles considered by Kepler's market access grant are therefore not necessary to meet the limits of Article 22 for the scope of this license, and as the calculations show, a 5-degree exclusion angle meets the limit with ample margin.

2.3 NGSO Orbital Characteristics

Below are listed the relevant orbital characteristics of the Kepler NGSO system:

- Inclination angle (in degree): 90º
- Apogee (in km) - Perigee (in km): 600 km, 600 km
- Period (in hour): 1.62
- Number of satellites in the system: 140
- Number of planes: 7
- Number of satellites per plane: 20
- Number of transmitting satellites: 140
- Number of receiving satellite: 140

3 Stop Buzzer

In the case of interference contact Steven Hemple at (760) 476-4812 to cease transmissions.

Appendix A

Table 2: PFD/EPFD for Viasat terminal operating at 4 W input power (boresight EIRP of 30 kW) with designator 34M0G7D--

PFD/EPFD Limits

Parameter	Value	Units	Symbol
Article 22 EPFD	-160	dBW/m^2/40kHz	P_{lim}

Constants

Parameter	Value	Units	Symbol
Radius of Earth	6371	km	R
Speed of Light	299792458	m/s	c

Inputs

Input Parameter	Value	Units	Value (log)	Units	Symbol
Carrier Frequency	1.43E+10	Hz	-		f
Bandwidth	3.40E+07	Hz	-		B
Reference Bandwidth	4.00E+04	Hz	-		B_{ref}
Angle from GSO arc	5	degrees	-		θ
Antenna Input Power	4	W	6.02	dBW	P
Orbit Altitude	35,789	km			r
Ground Elevation Angle	90	deg.			φ
Atmospheric Loss	-	-	0	dB	L_{atm}
Antenna Loss	-	-	0	dB	L_{ant}

Results

Calculated Parameters	Value	Units	Value (log)	Units	Symbol	Formula
Gain (at θ deg. off-axis)[6]	-	-	11.53	dBi	G	$29 - 25*\log_{10}(\theta)$
EIRP (E)	-	-	17.55	dBW	E	$G + P - L_{ant}$
Slant distance	35789.00	km	-	-	D	$\sqrt{[R\cos(90-\varphi)^2 + (R + r)^2 - R^2]} - R\cos(90-\varphi)$
Spreading Loss	-	-	162.07	dB	L_{sp}	$1/4\pi R^2$
Power Flux Density			-144.52	dBW/m^2	F_P	$E - L_{sp} - L_{atm}$
Spectral Flux Density			-173.81	dBW/m^2/40kHz	F_S	$F_P + (10*\log_{10}(B_{ref}/B))$

[6] Using the maximum earth station antenna performance standard given by 47 C.F.R. § 25.209(h) for communication between transmitting gateway stations and NGSO satellites in the FSS. Even when using a user terminal, the standards for gateway transmissions serve as a good approximation of performance. From 25.209(h), the permitted max off-axis gain = $29 - 25\log_{10}(\theta)$, where θ is the angle from the antenna boresight to the GSO arc.

Table 3: PFD/EPFD for Viasat terminal operating at 50 W input power (boresight EIRP of 6 MW) with designator 36M0G7D--

PFD/EPFD Limits

Parameter	Value	Units	Symbol
Article 22 EPFD	-160	dBW/m^2/40kHz	P_{lim}

Constants

Parameter	Value	Units	Symbol
Radius of Earth	6371	km	R
Speed of Light	299792458	m/s	c

Inputs

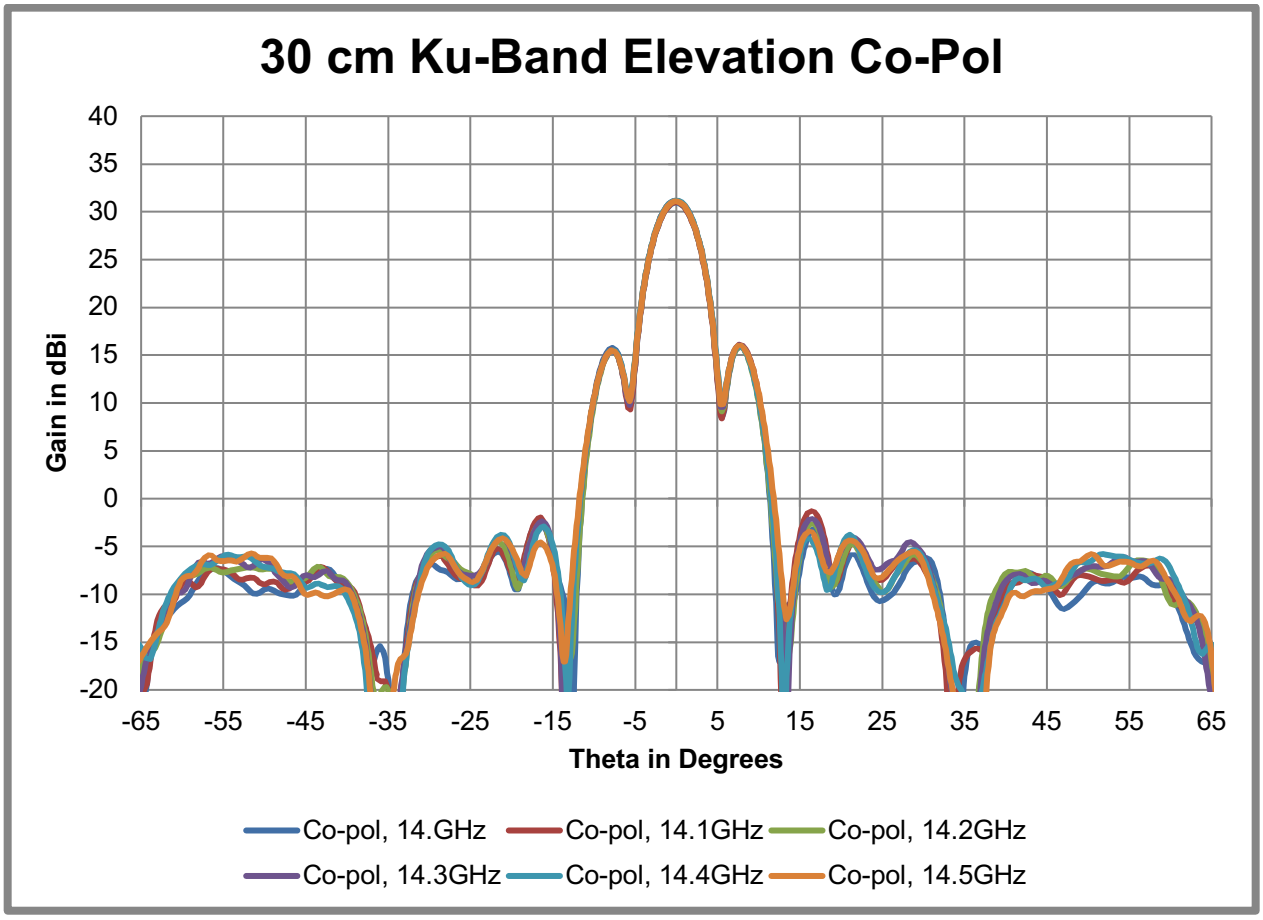
Input Parameter	Value	Units	Value (log)	Units	Symbol
Carrier Frequency	1.43E+10	Hz	-		f
Bandwidth	3.60E+07	Hz	-		B
Reference Bandwidth	4.00E+04	Hz	-		B_{ref}
Angle from GSO arc	5	degrees	-		θ
Antenna Input Power	50	W	16.99	dBW	P
Orbit Altitude	35,789	km			r
Ground Elevation Angle	90	deg.			φ
Atmospheric Loss	-	-	0	dB	L_{atm}
Antenna Loss	-	-	0	dB	L_{ant}

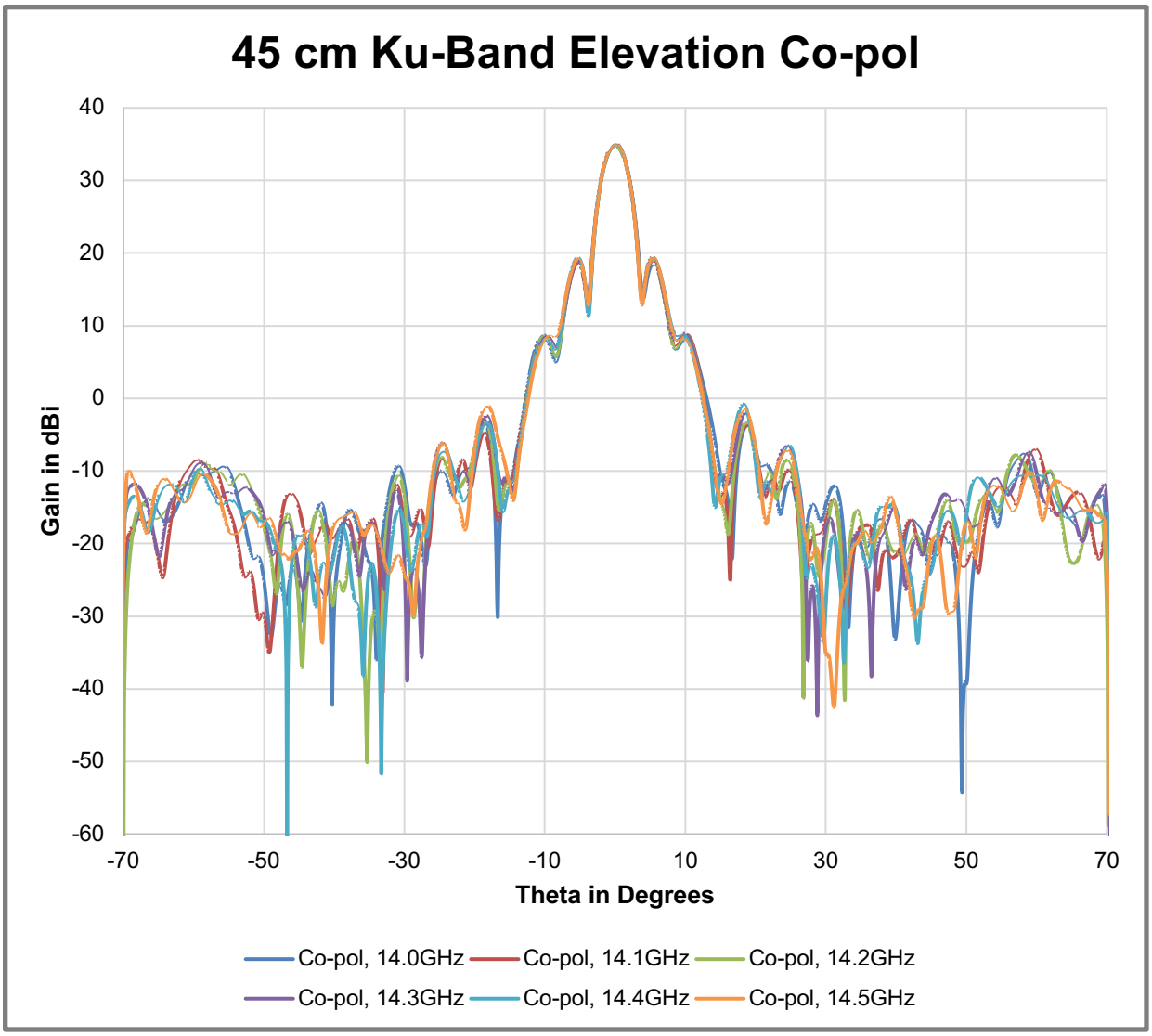
Results

Calculated Parameters	Value	Units	Value (log)	Units	Symbol	Formula
Gain (at θ deg. off-axis)[7]	-	-	11.53	dBi	G	$29 - 25*\log_{10}(\theta)$
EIRP (E)	-	-	28.52	dBW	E	$G + P - L_{ant}$
Slant distance	35789.00	km	-	-	D	$\sqrt{[R\cos(90-\varphi)^2 + (R + r)^2 - R^2]} - R\cos(90-\varphi)$
Spreading Loss	-	-	162.07	dB	L_{sp}	$1/4\pi R^2$
Power Flux Density			-133.55	dBW/m^2	F_P	$E - L_{sp} - L_{atm}$
Spectral Flux Density			-163.09	dBW/m^2/40kHz	F_S	$F_P + (10*\log_{10}(B_{ref}/B))$

[7] *See Id.*

Appendix B


30 cm Ku-Band Elevation Co-Pol
Gain in dBi
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-65
-55
-45
-35
-25
-15
-5
5
15
25
35
45
55
65
Theta in Degrees
Co-pol, 14.GHz
Co-pol, 14.1GHz
Co-pol, 14.2GHz
Co-pol, 14.3GHz
Co-pol, 14.4GHz
Co-pol, 14.5GHz



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