THALES

Thales Avionics, Inc.

Ka-band Earth Station Aboard Aircraft (ESAA)

FCC Authorization Submission

Modification to IBFS File No. SES-LIC-20170217-00183

Call Sign E170068

Technical Narrative

May 17, 2021

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1 Introduction

Thales Avionics, Inc. ("Thales") seeks to modify its active Ka-band ESAA blanket license[1] authorizing ESAA operation over GSO FSS Ka-band capacity as follows:

- Remove SES AMC-16 at 85° W.L. as a point of communication
- Add Telesat Telstar 19V at 63°W.L. satellite as a point of communication
- Modify Jupiter 2 at 97.1° W.L. beams and frequencies
- Modify AMC-15 at 105° W. L. beams

Thales Avionics currently has an active blanket license authorization to operate an ESAA earth station called the Advanced Connectivity Terminals, Ka-band (ACT-A) with five FCC-authorized GSO satellites whose Ka-band spot beam coverage areas include CONUS, most of Canada, and portions of Mexico and the Caribbean region. Initially, five points of communication are: AMC-15 (S2180) at 105.0° W.L., AMC-16 (S2181) at 85.0° W.L., Jupiter 1 (S2753) at 107.1° W.L., Jupiter 2 (S2834) at 97.1° W.L, and Telenor Norway satellite Thor-7 at orbital location 0.65° W.L.

In order to provide network coverage with seamless connectivity and compensate for the loss of AMC-16, Thales will be adding a new point of communication Telesat T19V and use the improved beam pointing characteristics of the AMC-15 and additional beams of Jupiter 2.

2 System Description

2.1 Overview

Complete details of the Thales remote terminal and system architecture are included in the most recent Thales modification filing[2].

2.1.1 Network Architecture

Thales's Inter-Flight Connectivity (IFC) network operations will utilize Ka-band GSO satellite, connected hub satellite earth stations and the Hughes Jupiter platform baseband hub equipment, which will communicate with Hughes Jupiter aero modems on the aircraft. A high-level network architecture diagram is shown below in Figure 1. This architecture is very similar to that provided in Thales's initial filings.

[1] *See* IBFS File No. SES-LIC-20170217, Call Sign E170068, granted July 7, 2017

[2] See IBFS File No. SES-MOD-20200818-00888, call sign E170068, granted August 26, 2020.

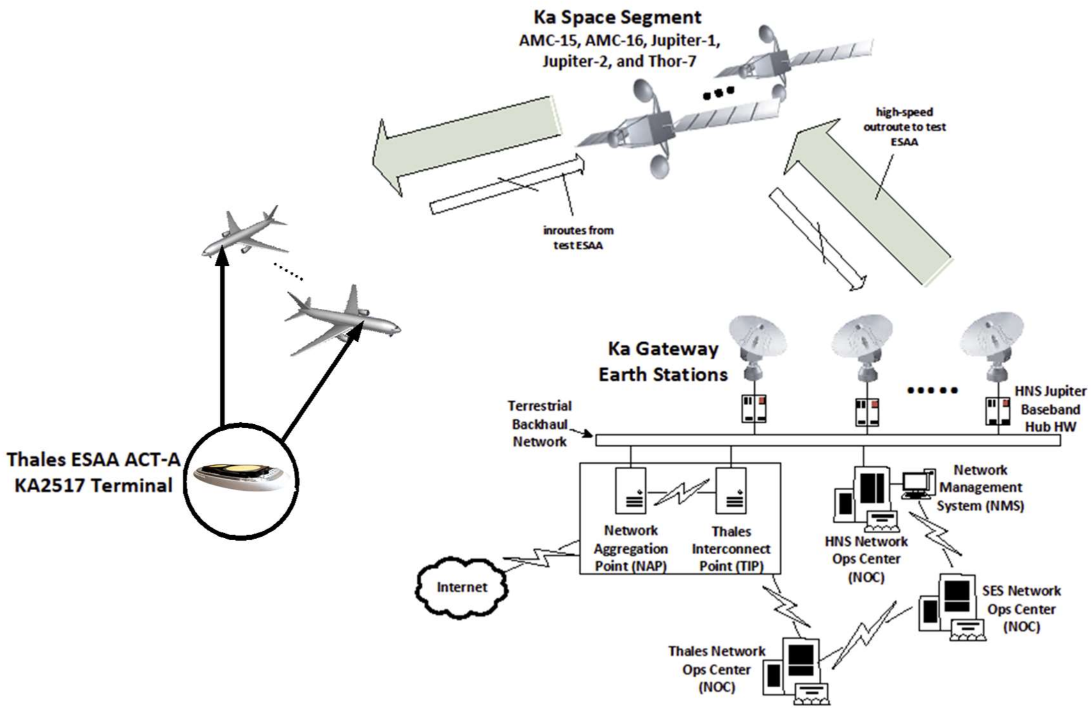


Figure 1 – Thales Aero Connectivity Network Architecture

The network is comprised of:

- a terrestrial IP backhaul network interconnecting the controlling Ka earth station gateways (detailed later in Section 2.4.2), and connecting the baseband hubs to the Virginia-based Network Aggregation Point (NAP) and Thales Interconnect Point (TIP)
- Ka space segment on five Ka-band GSO satellites.
- Thales Ka ESAAs, known as the Advanced Connectivity Terminals, Ka-band (ACT-A) including the Hughes Jupiter aero modem, installed on commercial aircraft

The SES Network Operations Center (NOC) in Bristow, VA remains as the primary NOC for the network. The SES NOC has real-time visibility into the Hughes Jupiter Network Management System (NMS) in Germantown, MD for management and control of every aero modem in the network (on aircraft) and the hub baseband instances (at gateways). The SES NOC also provides the Thales NOC in Orlando, FL with data that Thales requires to deliver and manage the overall service.

2.2 ESAA Segment Details

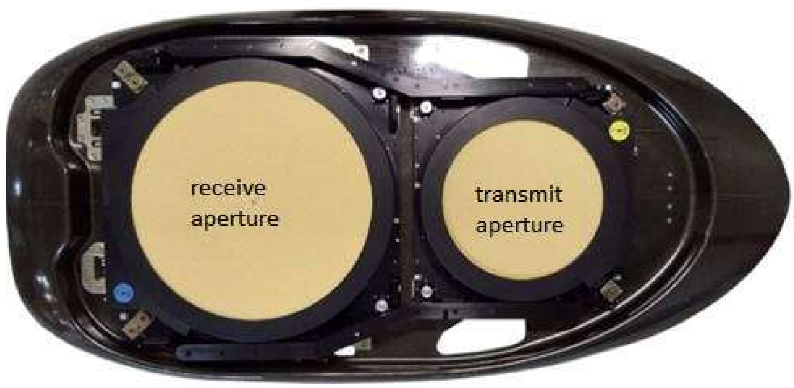
The operational details and specifications of the Thales ACT-A (ESAA) are provided below.

2.2.1 System Description

The Thales ACT-A terminal consists of:

- ThinKom Ka2517 antenna
- RF/IF Unit (KRFU)
- Antenna Control Unit (KANDU)
- Thales Modem Manager (TMM)

The ThinKom Ka2517 antenna is an array of 2 flat circular apertures, one for transmitting Ka-band signals and one for receiving, as shown in the picture below:



The ACT-A specifications are provided in Table 1 below.

Tx RF Parameter	**Performance (w/ Radome)**
Frequencies	27.5 GHz – 30.0 GHz
Antenna Coverage	360° in azimuth, 10-85° in elevation
Instantaneous Bandwidth	500 MHz
Axial Ratio (w/ Radome)	<2.5 dB typical (<29 dBW X-pol EIRP)
Polarization	Circular Switchable
EIRP (@29.5 GHz) typical[1]	49.0 dBW (P_{lin}, 85° elev)
	49.0 dBW (P_{lin}, 70° elev)
	48.0 dBW (P_{lin}, 45° elev)
	46.0 dBW (P_{lin}, 30° elev)
	44.5 dBW (P_{lin}, 20° elev)
	42.0 dBW (P_{lin}, 10° elev)
KRFU Output Flange Power	25 W (P_{lin}), 50 W (P_{sat})
KRFU Reference Signal	50 MHz
IF Input Frequency Range	950 – 1950 MHz
Beamwidth (@29.5 GHz)	<1.8° in ϕ
Sidelobe Suppression	1st E-Plane Sidelobe at least 12dB down from beam

[1] Assumes 2.5 dB SSPB-to-TX feed & interconnecting WG loss

Rx RF Parameter	**Performance (w/ Radome @ Cruise Altitude)**
Frequencies	17.8 GHz – 20.2 GHz
Antenna Coverage	360° in azimuth, 10-85° in elevation
Instantaneous Bandwidth	500 MHz (-1 dB DVB-S2)
Axial Ratio	<2.5 dB typical
Polarization	Circular Switchable
G/T (@19.7 GHz) typical	17.0 dB/K (85° elev)
	17.0 dB/K (70° elev)
	16.0 dB/K (45° elev)
	14.0 dB/K (30° elev)
	12.5 dB/K (20° elev)
	10.0 dB/K (10° elev)
LNB Reference Signal	50 MHz
IF Output Frequency Range	950 – 1950 MHz
Beamwidth (@19.7 GHz)	<1.8° in ϕ
Sidelobe Suppression	1st E-Plane Sidelobe at least 12dB down from beam

Table 1: Ka-band (ACT-A) Specifications

Antenna Pointing System Description

2.3 Space System

2.3.1 Satellite System List

Table 1 below provides the complete list of satellite modifications required. to be used for Thales's ESAA operations. This list includes the Thor-7 satellite being requested as a new Point of Communication, and the four satellites already authorized in Thales's current ESAA blanket license[3]. Thales's ESAA services using these satellites will not use Ka spectrum in the LMDS band 29.1 – 29.25 GHz and per a coordination agreement with Iridium within the first 50 MHz of the MSS band between 29.25-29.3 GHz.

Satellite (Call Sign)	**Satellite Operator**	**GSO Orbital Location (W.L.)**	**Transmit Spectrum (MHz)**	**Receive Spectrum (MHz)**	**Mod to License**
AMC-15 (S2181)	SES	105.0°	28350 – 28600 29500 – 30000	18638 – 18763 19700 – 20200	Yes, new beam pointing. See Figure 1
Jupiter-2 (S2968)	Hughes	97.1°	27850 – 29100 29250 – 30000	18300 – 19300 19700 – 20200	Yes, New Southern Beams, see Figure 2
Telstar T19V	Telstar	63.0°	29500 – 30000	19700 – 20200	Yes, New PoC

Table 1: Satellite List and Spectrum Details for Thales's ESAA Operations

Figure 1 through 3 below show the satellite coverage beams for the four satellites concerned with this modification. Also shown are the worst-case excursion with respect to skew and elevation angle for any terminal operating within these beams. A summary of these figures is outlined below:

- Figure 1 – The AMC-15 operating beams with worst case elevation of 25° and skew of 65°
- Figure 2 – The Jupiter-2 additional operating area beams with worst case elevation of 55° and skew of 35°

[3] *See* IBFS File No. SES-LIC-20170217, Call Sign E170068, granted July 7, 2017.

- Figure 3 – The Telstar 19V operating beams with worst case elevation of 15° and skew of 40°

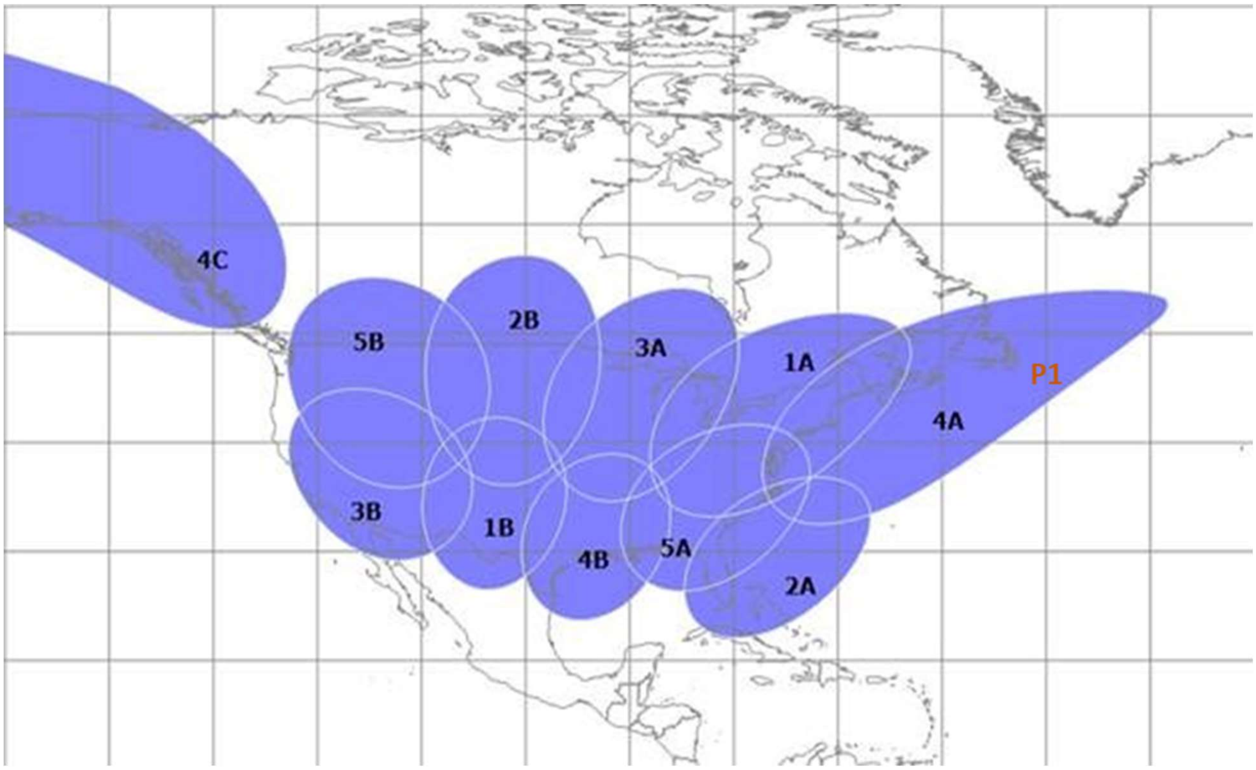


Figure 1: Thales ESAA Operating on AMC-15 – New Beam pointing Shows Worst Case Skew Angle of 40° and elevation 15° (position P1 in red) for repositioned Ka Spot Beams

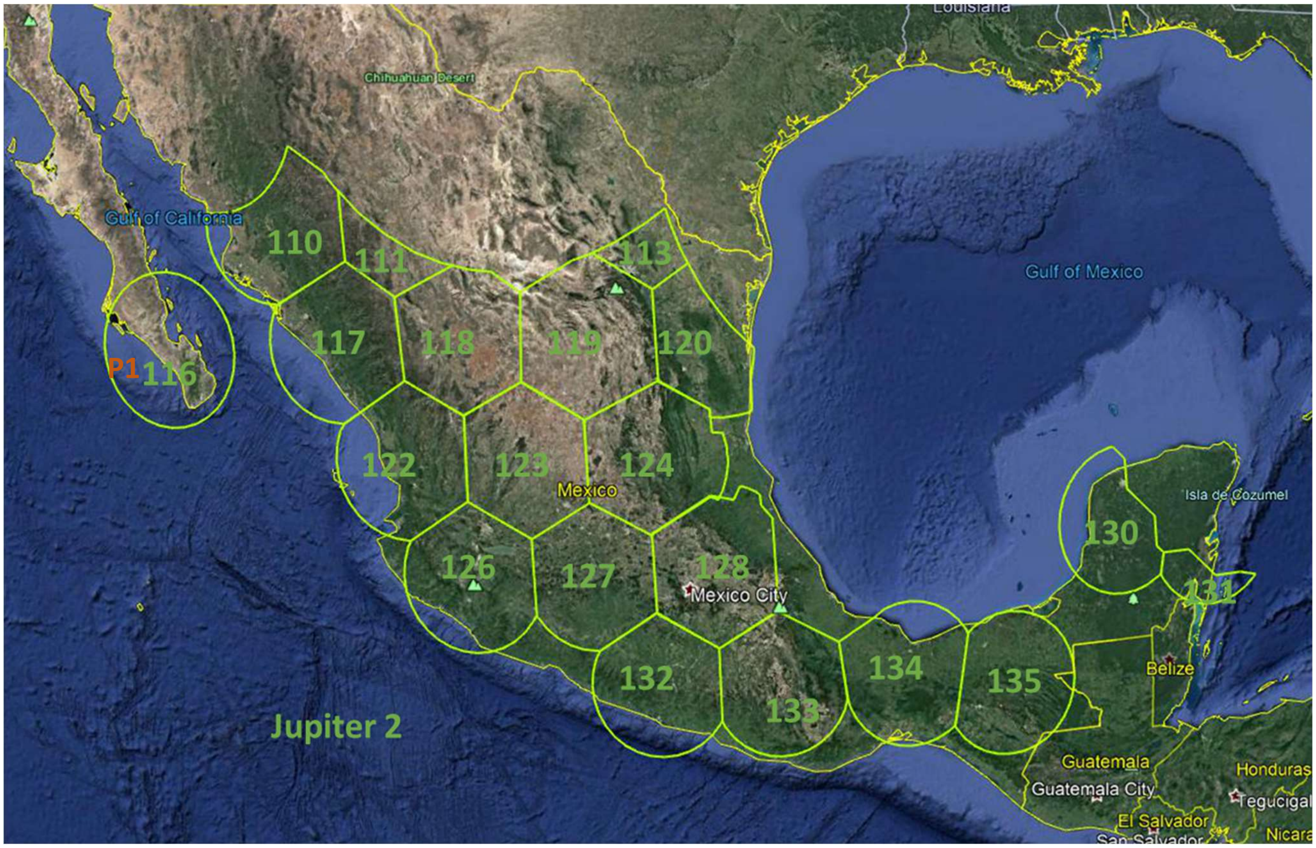


Figure 2: Jupiter-2 Additional Coverage Area Beams and Skew Angles (Worst-Case Skew 35°, Elevation 55°, position P1 in red)

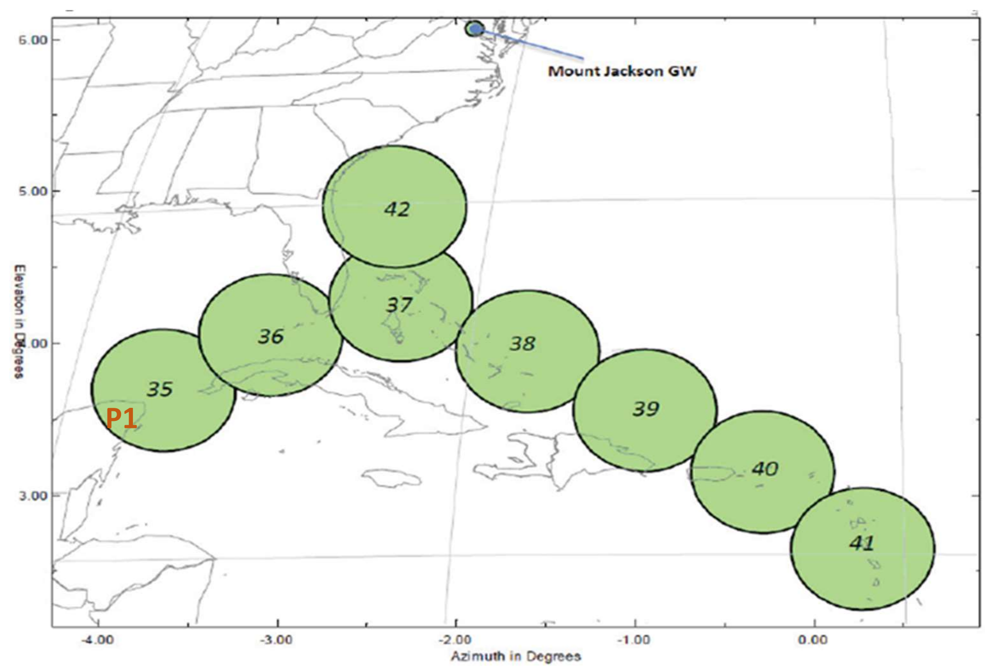


Figure 3: Telstar 19V Coverage Area and Skew Angles for Thales ESAA Operation (Worst-Case Skew Angle of ~45°, Elevation 45° at position P1 in red)

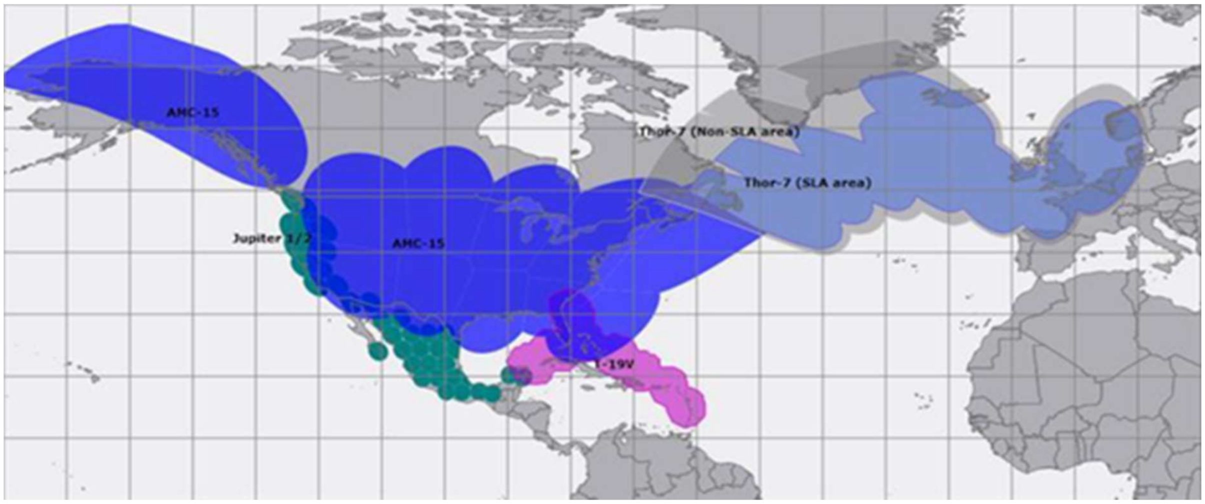


Figure 4 – Revised Thales ESAA Network showing all existing and revised beams.

2.4 Ground Segment

2.4.1 Remote Control Network Operations Centers (NOCs)

The network operations centers (NOCs) as described in Thales's current authorization are not affected by this amendment request. The SES NOC remains as the primary NOC for this network:

SES Network Operations Center - Manassas
8000 Gainsford Court
Bristow, VA 20136

The SES NOC 24/7/365 phone number is +1 703-330-3305, Option 1

The Thales NOC is also responsible for overall management of the service and can be reached 24/7/365:

Thales Network Operations Center
7415 Emerald Dunes Drive, Suite 2000
Orlando, FL 32822

The Thales NOC phone number is 407-812-2538, and the email address is: MOC@us.thalesgroup.com

2.4.2 Network Gateway Earth Stations

Thales's service will use FCC-licensed hub antennas at the gateway earth stations to communicate with AMC-15 and AMC-16. Full remote control of the ESAA terminals and the network will be possible from the Thales NOC. Satellite specific hub earth stations are identified below:

AMC-15 Earth Stations:

9815 West Hallett Road
Spokane, WA 99224
FCC callsign E040572

SES Washington Media Port
8000 Gainsford Court
Bristow, VA 20136

Jupiter 1 and Jupiter 2:

Thales's service will use Hughes's authorized gateway hub antennas to communicate with Jupiter-1 and Jupiter-2. Full remote control of the ESAA terminals and the network will be possible from the Thales NOC.

Telstar 19V

Mt Jackson Teleport:
1305 Industrial Park
Mt Jackson, VA 22842

Teleport FCC call sign: E160135

2.5 ACT-A Necessary Emission Designators and Power

The waveforms and capabilities of the return link (inbound) channels and the forward link (outbound) channels as detailed in Thales's current authorization are not changing as a result of this modification request. However, Thales's ESAA operations is requesting require higher power for the return channel (from ESAA) only for operation on Telesat T19V. Full details these higher powered carriers are shown in Table 2 below and in the Form 312 submitted with this modification request.

Link	Emission Designator	Bandwidth [MHz]	Symbol Rate [Msps]	EIRPSD [dBW/MHz]	Frequency [MHz]	
					Earth to Space	Space to Earth
Inbound	4M80G7W	4.8	3.84	41.4	27612 – 27887 27868 – 28331 29300 – 29731	18300 – 19300 19700 – 20200
Inbound	5M20G7W	5.2	4.2	41.4	27612 – 27887 27868 – 28331 29300 – 29731	18300 – 19300 19700 – 20200
Inbound	7M00G7W	7.0	5.6	41.4	27612 – 27887 27868 – 28331 29300 – 29731	18300 – 19300 19700 – 20200

Table 2: Telesat T19V Carriers and Carrier EIRP Density Levels

Link budgets have been provided in Exhibit B of this narrative to confirm that the power density level of the new return carrier requested will provide the necessary performance. authorization.

2.5.1 NOC Monitoring and Control

At all times the SES NOC and the Thales NOC will monitor and have control of the transmission parameters of all Thales ESAA operating in the network on all satellites, including the ability to remotely disable terminals in the event of harmful interference.

3 Protection of Other Services

3.1 Protection of Other Ka-band Services

3.1.1 GSO

Thales intends to operate its ESAA network compliant with FCC rule parts 25.228, 25.218, and 25.220. Specifically, the ACT-A terminal will comply with the EIRP Special Density requirements specified in 25.218(i)(1)-(5). Thales has worked with SES, Hughes, and Telenor to ensure that the off-axis emissions will comply with all applicable inter-satellite coordination agreements (see Exhibit C). The Thales system can limit emission power relative to the terminal's elevation and skew angle. For many such positions the terminal can achieve a maximum emission of 43 dBW/MHz, which is the highest EIRP spectral density requested in this filing. For other, more extreme, skew and elevation angles, Thales will limit the ESD as shown in the sections below.

3.1.1.1 AMC-15 Off-Axis EIRP Spectral Density

On AMC-15, Thales will limit their ESAA operation for the worst-case skew angle of 40° and elevation angle of 15° for off-axis EIRP emission in the GSO plane, as shown below in Figure 1 above.

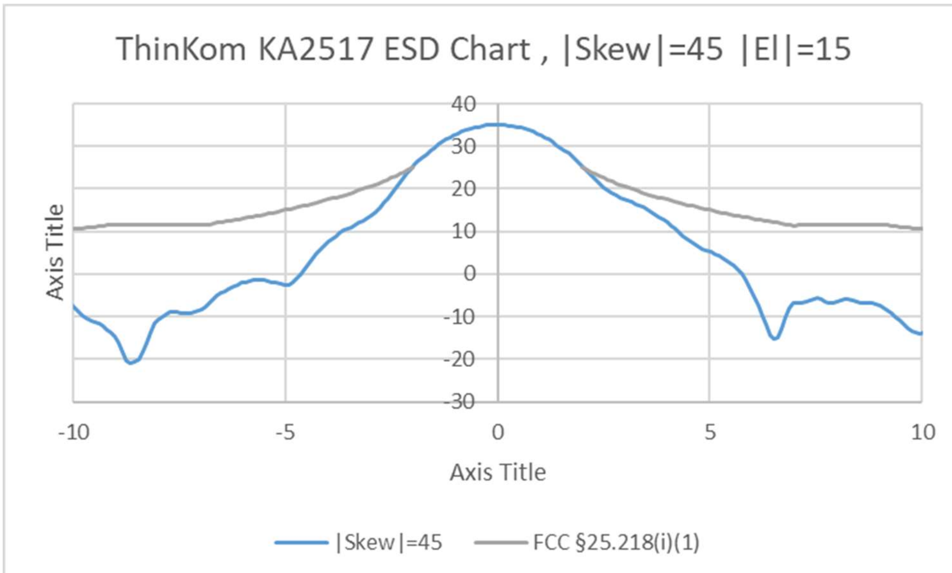


Figure 6 – AMC-15 Skew = 40 degrees and Elevation = 15 degrees ESD. The chart represents the highest allowed power level of 34.5 dBW/MHz (10.5 dBW/4kHz). Thales system will limit power to this level when at this position.

3.1.1.2 Telstar 19V Off-Axis EIRP Spectral Density

Thales ESAA operation on Telstar 19V at 63° W.L. will utilize spot beams covering southern USA and the Caribbean. As shown in Figure 3 above the worst-case skew angles will be around 50 degrees with a corresponding elevation angle of 50 degrees. Thales will maintain their uplink EIRP densities to comply with the limits set in §25.218(i)(1) or the coordination agreements set by their satellite operator.

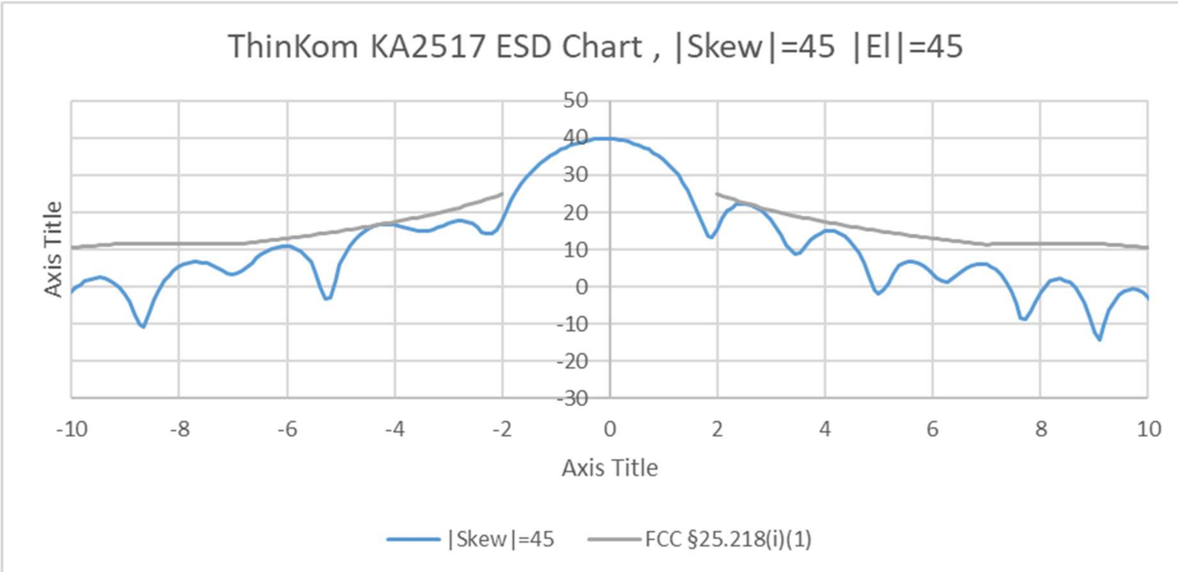


Figure 7 – T19V worst case ESD operation. The highest power level for this operation is 40.7 dBW//MHz (16.7 dBW/4kHz)

3.1.1.3 Jupiter-2 Off-Axis EIRP Spectral Density

On Jupiter-2, Thales will limit their ESAA operation to the worst-case skew performance at a skew angle of 35° and corresponding elevation angle of 55° for off-axis EIRP emission in the GSO plane, as shown in Figure 2 above. The plot below represents a worst ESD plot as provided by terminal manufacturer.

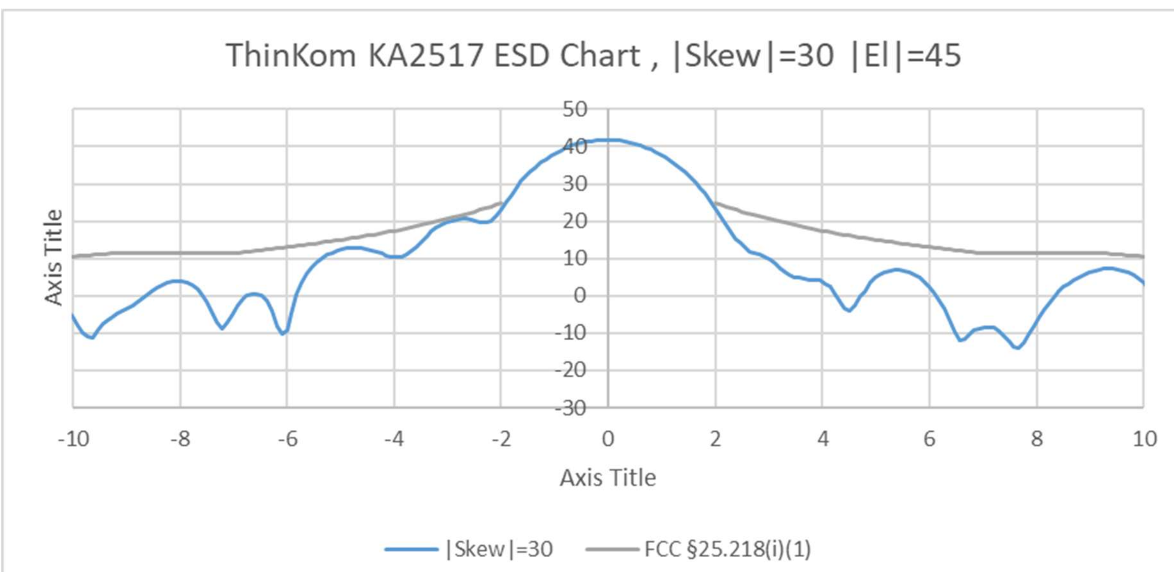


Figure 8 – Worst-case ESD for skew and elevation angles for Jupiter-2. In order to operate within the 25.218 ESD mask Thales will limit maximum EIRP Spectral Density to 41.5 dBW/MHz (17.5 dBW/4kHz) when operating at this position.

3.1.2 Protection of NGSO Systems

For operation on AMC-15, Jupiter-2, and T19V Thales does not intend to operate in spectrum allocated to NGSO systems. The NGSO transmit band is 28.6-29.1 GHz[4]. Thales will only operate as noted in Table 2 above, outside of the NGSO primary band. Thales agrees to coordinate with any authorized NGSO users in the GSO band which may be impacted by their ESAA operation. At the time of this filing there appears to be one such NGSO system authorized to use this portion of the band which will not overlap with the Thales operational spectrum[5]. Thales agrees to coordinate with any users of this band as is required in the future.

3.1.3 Protection of LMDS Systems

The nearest allocation for LMDS service is 27.5 – 28.350 GHz[6] and, as noted in Table 2 above, Thales will operate in this band when operating only on T19V. Thales will coordinate as required. 3.1.2 above, Thales will not operate within this band.

3.1.4 Protection of Mobile Satellite Systems at Ka-band

For ESAA operations on all satellites, Thales does not intend to operate in the 29.25 – 29.3 GHz band, which is allocated to GSO FSS and NGSO MSS feeder links on a co-primary basis.

3.1.5 Radiation Hazard Study

A radiation hazard study provided is provided in Exhibit D.

3.2 List of Exhibits

The following four exhibits are provided in this document:

- Exhibit A contains the link budgets for ACT-A Terminal for all new points of communication, Telstar 19V.

- Exhibit B contains the certification letters for Telesat T19V Satellite.

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[4] See, e.g., Redesignation of the 17.7-19.7 GHz Frequency Band, Blanket Licensing of Satellite Earth Stations in the 17.7-20.2 GHz and 27.5-30.0 GHz Frequency Bands, and the Allocation of Additional Spectrum in the 17.3-17.8 GHz and 24.75-25.25 GHz Frequency Bands for Broadcast Satellite-Serv. Use, 16 FCC Rcd 19808, at ¶ 23 (2001)

[5] O3B is currently authorized to operate in the 28.35-28.4 GHz band, see FCC File No.1 SES-LIC-20100723-00952. This upper band edge is below the Thales lower band edge of 28.438 GHz.

[6] Rulemaking to Amend Parts 1, 2, 21, and 25 of the Commission's Rules to Redesignate the 27.5-29.5 GHz Frequency Band, to Reallocate the 29.5-30.0 GHz Frequency Band, to Establish Rules and Policies for Local Multipoint Distribution Service and for Fixed Satellite Services, First Report and Order, 11 FCC Rcd 19005 ¶ 85 (1996).

- Exhibit C contains the radiation hazard study. The highest EIRP required for these modifications is less than considered for the initial ACT-A terminal radhaz study and so the attached is the same as was included in the 2020 modification request.[7]

4 Conclusion

The grant of this license modification will serve the public interest by enabling Thales to enhance their ESAA services using the ACT-A terminal which will be utilized by commercial airlines, their passengers, and crew, in a manner fully consistent with the FCC rules. As such, Thales respectfully requests grant of this license modification.

[7] See IBFS Mod filing No. SES-MOD-20200818-00888, call sign E170068, granted August 26, 2020.

5 Exhibit A – Link Budgets

		COB	MOB	EOB
General Parameters				
Orbital Location	oE.L	-63.0	-63.0	-63.0
Beam Assignment		COB	MOB	EOB
Uplink Frequency	MHz	29.625	29.625	29.625
Downlink Frequency	MHz	18.4250	18.4250	18.4250
Terminal Transmit				
Antenna Size	m	0.43	0.43	0.43
Antenna Latitude	Deg N	20.70	19.80	18.89
Antenna Longitude	Deg E	-85.60	-85.70	-85.79
Antenna elevation Angle	degrees	54.7	55.3	55.9
Antenna skew Angle	degrees	-45.5	-47.0	-48.5
Antenna Gain	dBi	40.1	40.0	40.0
Earth station transmit EIRP/carrier	dBW	47.6	47.6	47.6
On-axis EIRP spectral density	dBW/40kHz	27.5	27.5	27.5
Gateway Receive				
Antenna Size	m	9.40	9.40	9.40
Antenna elevation angle	degrees	42.3	42.3	42.3
Rx E/S G/T clear sky	dB/K	38.6	38.6	38.6
Carrier				
Symbol rate	Msps	4.096	4.096	4.096
Allocated bandwidth	MHz	5.1	5.1	5.1
Modulation / FEC Coding		8PSK 4/5	8PSK 2/3	QPSK 4/5
Layer 1 Information rate	Mbps	9.8	8.2	6.6
Uplink				
Uplink path loss	dB	213.2	213.2	213.2
Uplink atmospheric loss	dB	0.9	0.9	0.9
G/T	dB/K	17.0	14.5	12.2
C/N uplink	dB	13.0	10.5	8.2
C/I uplink	dB	24.0	24.0	24.0
Downlink				
Downlink atmospheric loss	dB	0.40	0.40	0.40
Downlink path loss	dB	209.3	209.3	209.3
Carrier downlink EIRP at BC	dBW	37.0	34.5	32.3
PFD at earth's surface	dBW/m^2/MHz	-132.0	-134.5	-136.7
C/N downlink	dB	28.4	25.9	23.7
C/I downlink	dB	23.7	23.7	23.7
End-to-End				
C/I ASI	dB	23.5	22.9	21.9
C/(N+I) total	dB	11.9	9.8	7.7
Link margin	dB	0.2	0.3	0.4

6 Exhibit B – Satellite Operator Certification Letters

The certification letters are being provided by Telesat for access to Telstar 19V.

TELESAT

160 Elgin Street, Suite 2100
Ottawa, ON, Canada K2P 2P7

25 March 2021

Federal Communications Commission
International Bureau
45 L Street, NE
Washington, DC 20554

Re: Engineering Certification of Telesat

To Whom It May Concern:

This letter certifies that Telesat is aware that Thales is planning to file an application to the Federal Communications Commission ("FCC") seeking to operate Ka-band earth stations aboard aircraft ("ESAA"). The application will seek authority for Thales ESAA terminals to communicate with the T19V satellite at 63°W.L. under the current FCC rules, including Section 25.228.

Based on the information provided by Thales, Telesat understands the technical characteristics associated with the operation of the Thales ESAA terminals and:

- Telesat certifies that the operation of these terminals at the power density levels provided to Telesat is consistent with the existing coordination agreements with all adjacent satellite operators within +/- 6 degrees of orbital separation from T19V satellite at 63°W.L.;

- If the FCC authorizes the operations proposed by Thales, Telesat will take into consideration the power density levels associated with such operations in all future satellite network coordination with adjacent satellite operators.

Sincerely Yours,

BAHRAM BORNA
Senior Systems Engineer
Telesat

7 Exhibit C – Radiation Hazard Study

Radiation Hazard Analysis
Thales Avionics, Inc - ThinKom AES Antenna

This analysis predicts the radiation levels around a proposed earth station terminal, comprised of one array type antenna. This report is developed in accordance with the prediction methods contained in OET Bulletin No. 65, Evaluating Compliance with FCC Guidelines for Human Exposure to Radio Frequency Electromagnetic Fields, Edition 97-01, pp 26-30. The maximum level of non-ionizing radiation to which personnel may be exposed is limited to a power density level of 5 milliwatts per square centimeter (5 mW/cm^2) averaged over any 6 minute period in a controlled environment and the maximum level of non-ionizing radiation to which the general public is exposed is limited to a power density level of 1 milliwatt per square centimeter (1 mW/cm^2) averaged over any 30 minute period in a uncontrolled environment. Note that the worse-case radiation hazards exist along the beam axis. Under normal circumstances, it is highly unlikely that the antenna axis will be aligned with any occupied area since that would represent a blockage to the desired signals, thus rendering the link unusable and disabling the transmitter.

The Thales ThinKom AES system will typically operate above 15 degrees elevation. The main beam gain of the antenna will vary with elevation, the radhaz calculations have been performed at 45-degree elevation and maximum EIRP. The system is equipped with a 25-watt amplifier and has 0 dB of output back-off and 1.4 dB of output circuit losses. The worst-case scenario, in terms of worst power density levels, involves the high elevation angle and has been presented here.

Table 1 - Earth Station Technical Parameter Table

Antenna Aperture major axis	0.433 meters
Antenna Surface Area	0.1873 sq. meters
Antenna Isotropic Gain	36.5 dBi @45°
Number of Identical Adj. Antennas	1
Nominal Frequency	29.5 GHz
Nominal Wavelength (λ)	0.0102 meters
Maximum Transmit EIRP / Carrier	49.1 dBW
Number of Carriers	1
Total HPA Power	25 Watts
SSPA Output Back (dB)	0 dB
W/G Loss from Transmitter to Feed	1.4 dB
Total Feed Input Power	12.6 dBW1dBW
AES Terminal EIRP	49.1 dBW @45°
Near Field Limit	$R_{nf} = D^2/4\lambda = 4.600$ meters
Far Field Limit	$R_{ff} = 0.6\ D^2/\lambda = 11.0$ meters
Transition Region	R_{nf} to R_{ff}

In the following sections, the power density in the above regions, as well as other critically important areas will be calculated and evaluated. The calculations are done in the order discussed in OET Bulletin 65.

1.0 At the Antenna Surface

The power density at the antenna radiating surface can be calculated from the expression:

PD_{refl} = 4P/A = **49.29** mW/cm² (1)

Where: P = total power at feed, milliwatts

A = Total area of reflector, sq. cm

In the normal range of transmit powers for satellite antennas, the power densities at or around the reflector surface is expected to exceed safe levels. This area will not be accessible to the general public. Operators and technicians shall receive training specifying this area as a high exposure area. Procedures have been established that will assure that all transmitters are rerouted or turned off before access by maintenance personnel to this area is possible.

2.0 On-Axis Near Field Region

The geometrical limits of the radiated power in the near field approximate a cylindrical volume with a diameter equal to that of the antenna. In the near field, the power density is neither uniform nor does its value vary uniformly with distance from the antenna. For the purpose of considering radiation hazard it is assumed that the on-axis flux density is at its maximum value throughout the length of this region. The length of this region, i.e., the distance from the antenna to the end of the near field, is computed as Rnf above.

The maximum power density in the near field is given by:

$PD_{nf} = (16\varepsilon P)/(\pi D^2)$ = **12.33** mW/cm² (2) @45° Elevation

from 0 to 4.600 meters

Evaluation

Uncontrolled Environment: **Does Not Meet Uncontrolled Limits**

Controlled Environment: **Does not Meet Controlled Limits**

3.0 On-Axis Transition Region

The transition region is located between the near and far field regions. As stated in Bulletin 65, the power density begins to vary inversely with distance in the transition region. The maximum power density in the transition region will not exceed that calculated for the near field region, and the transition region begins at that value. The maximum value for a given distance within the transition region may be computed for the point of interest according to:

$PD_t =$ $(PD_{nf})(R_{nf})/R$ = dependent on R (3)

where: PD_{nf} = near field power density

R_{nf} = near field distance

R = distance to point of interest

For: $4.60 < R < 11.04$ meters

We use Eq (3) to determine the safe on-axis distances required for the two occupancy conditions:

Evaluation

Uncontrolled Environment Safe Operating Distance,(meters), R_{safeu}: 56.7m @45° elevation

Controlled Environment Safe Operating Distance,(meters), R_{safec}: 11m @45° elevation

4.0 On-Axis Far-Field Region

The on- axis power density in the far field region (PD_{ff}) varies inversely with the square of the distance as follows:

$PD_{ff} =$ $PG/(4\pi R^2)$ = dependent on R (4)

where: P = total power at feed

G = Numeric Antenna gain in the direction of interest relative to isotropic radiator

R = distance to the point of interest

For: $R > R_{ff} = 11.0$ meters

$PD_{ff} =$ 4.196 mW/cm^2 at R_{ff} @45° ,

We use Eq (4) to determine the safe on-axis distances required for the two occupancy conditions:

Evaluation

Uncontrolled Environment Safe Operating Distance,(meters), R_{safeu} : See Section 3

Controlled Environment Safe Operating Distance,(meters), R_{safec} : See Section 3

5.0 Off-Axis Levels at the Far Field Limit and Beyond

In the far field region, the power is distributed in a pattern of maxima and minima (sidelobes) as a function of the off-axis angle between the antenna center line and the point of interest. Off-axis power density in the far field can be estimated using the antenna radiation patterns prescribed for the antenna in use. This will correspond to the antenna gain pattern for an off-axis angle. For the Thales AES antenna at 1.5 degrees off axis the antenna gain is:

G_{off} = 26.50 dBi at 1.5 degree @45°

Considering that satellite antenna beams are aimed skyward, power density in the far field will usually not be a problem except at low look angles. In these cases, the off-axis gain reduction may be used to further reduce the power density levels.

For example: At 1.5 degree off axis at the far-field limit, we can calculate the power density as:

G_{off} = 26.50 dBi = 3981.07 numeric @45° elevation

$PD_{1.5\ deg\ off\text{-}axis} = PD_{ff} x\ 446.68/G = .5927\ mW/cm^2$ (5)

6.0 Off-Axis power density in the Near Field and Transitional Regions

According to Bulletin 65, off-axis calculations in the near field may be performed as follows: assuming that the point of interest is at least one antenna diameter removed from the center of the main beam, the power density at that point is at least a factor of 100 (20 dB) less than the value calculated for the equivalent on-axis power density in the main beam. Therefore, for regions at least Deff meters away from the center line of the antenna, whether behind, below, or in front under of the antenna's main beam, the power density exposure is at least 20 dB below the main beam level as follows:

$PD_{nf(off\text{-}axis)} = PD_{nf} /100 =$ $0.1233\ mW/cm^2$ at D off axis (6) @45°

See Section 7 for the calculation of the distance vs. elevation angle required to achieve this rule for a given object height.

7.0 Evaluation of Safe Occupancy Area in Front of Antenna

The distance (S) from a vertical axis passing through the antenna center to a safe off axis location in front of the antenna can be determined based on the effective antenna diameter rule (Item 6.0). Assuming a flat area in front of the antenna, the relationship is:

$$S = (Deff/ \sin \alpha) + (2(h-GDeff) - Deff - 2)/(2 \tan \alpha) \quad (7)$$

Where: α = minimum elevation angle of antenna

D = effective antenna diameter in meters

h = maximum height of object to be cleared, meters

For distances equal or greater than determined by equation (7), the radiation hazard will be below safe levels.

For	D =	0.433 meters
	h =	2.0 meters
	GD =	1 meters - elevated height of earth station above ground (min)

Then:

α	S
15	0.9 meters
25	0.6 meters
35	0.4 meters
45	0.4 meters

This is fuselage mounted antenna, and all persons working on or near the antenna will be properly trained regarding radiation hazard. The antenna transmitter will be disabled any time work inside the radome is in progress.

8.0 Summary

The earth station site will be protected from uncontrolled access. The terminal is mounted, under a radome, on the top of the aircraft fuselage and it is pointed upward. The terminal may also be mounted on top of a test van. Access to the terminal will be limited to trained operations personnel. There will also be proper emission warning signs placed and all operating personnel will be aware of the human exposure levels at and around the earth station. The applicant agrees to abide by the conditions specified in Condition 5208 provided below:

> *Condition 5208 - The licensee shall take all necessary measures to ensure that the antenna does not create potential exposure of humans to radiofrequency radiation in excess of the FCC exposure limits defined in 47 CFR 1.1307(b) and 1.1310 wherever such exposures might occur. Measures must be taken to ensure compliance with limits for both occupational/controlled exposure and for general population/uncontrolled exposure, as defined in these rule sections. Compliance can be accomplished in most cases by appropriate restrictions such as fencing. Requirements for restrictions can be determined by predictions based on calculations, modeling or by field measurements. The FCC's OET Bulletin 65 (available on-line at www.fcc.gov/oet/rfsafety) provides information on predicting exposure levels and on methods for ensuring compliance, including the use of warning and alerting signs and protective equipment for worker.*

The following table summarizes all of the above calculations:

Table - Summary of All RadHaz Parameters				ThinKom AES Antenna
Parameter	Abbr.		Units	Formula
Antenna Elevation Angle Operation Scenario		@45°		
Antenna Dimensions	Dma	0.433	meters	major axis (azimuth)
Effective Aperture Diameter	Deff	0.43	meters	
Antenna Centerline	ACL	3.0	meters	Typically over 10 m
Antenna Surface Area	Sa	0.1873	$meters^2$	$(\pi * Deff^2)/4$
Frequency of Operation	f	29.5	GHz	
Wavelength	λ	0.0102	meters	c / f
HPA Output Power	P_{HPA}	25.00	watts	
HPA to Antenna Loss	L_{tx}	1.4	dB	3 dB OBO + 1 dB OCL
Transmit Power at Flange	P	12.58	dBW	$10 * Log(P_{HPA}) - L_{tx}$
Antenna Gain	G_{es}	36.50	dBi	Varies with elevation
		4466.8	n/a	
PI	π	3.1416	n/a	
Antenna Aperture Efficiency	η	25.01%	n/a	$G_{es} / (PI * Df/\lambda)^2$
Maximum EIRP	EIRP	49.1	dBi	Varies with elevation
1. Reflector Surface Region Calculations		@45°		
Reflector Surface Power Density	PDas	492.92	W/m^2	$(16 * P)/(\pi * Deff^2)$
Reflector Surface Power Density	PDas	**49.292**	mW/cm^2	**Does Not Meet Uncontrolled Limits**
				Does not Meet Controlled Limits
2. On-Axis Near Field Calculations		@45°		
Extent of Near Field	Rnf	4.600	meters	$Dma^2 / (4 * \lambda)$
Extent of Near Field	Rnf	15.09	feet	
Near Field Power Density	PDnf	123.30	W/m^2	$(16 * \eta * P)/(\pi * Deff^2)$
Near Field Power Density	PDnf	12.330	mW/cm^2	**Does Not Meet Uncontrolled Limits**
				Does not Meet Controlled Limits
3. On-Axis Transition Region Calculations		@45°		
Extent of Transition Region (min)	Rtr	4.60	meters	$Dma^2 / (4 * \lambda)$
Extent of Transition Region (min)		15.09	feet	
Extent of Transition Region (max)	Rtr	11.04	meters	$(0.6 * Dma^2)/\lambda$
Extent of Transition Region (max)		36.21	feet	
Worst Case Transition Region Power Density	PDtr	123.30	W/m^2	$(16 * \eta * P)/(\pi * Deff^2)$
Worst Case Transition Region Power Density	PDtr	**12.330**	mW/cm^2	**Does Not Meet Uncontrolled Limits**
		@45°		**Does not Meet Controlled Limits**
Uncontrolled Environment Safe Operating Distance	Rsu	56.7	m	=(PDnf)*(Rnf)/Rsu
Controlled Environment Safe Operating Distance	Rsc	11.3	m	=(PDnf)*(Rnf)/Rsc
4. On-Axis Far Field Calculations		@45°		
Distance to the Far Field Region	Rff	11.0	meters	$(0.6 * Dma^2)/\lambda$
		36.21	feet	
On-Axis Power Density in the Far Field	PDff	41.96	W/m^2	$(G_{es} * P) / (4 * \pi * Rf^2)$
On-Axis Power Density in the Far Field	PDff	**4.196**	mW/cm^2	**Does Not Meet Uncontrolled Limits**
				Meets Controlled Limits
5. Off-Axis Levels at the Far Field Limit and Beyond		@45°		
Reflector Surface Power Density	PDs	5.927	W/m^2	$(G_{es} * P) / (4 * \pi * Rf^2)*(Goa/Ges)$
Goa/Ges at example angle θ 1.5 degree		0.141		GoA approx 10 dB down at 1.5 deg
Off-Axis Power Density		0.5927	mW/cm^2	**Meets Uncontrolled Limits**
6. Off-axis Power Density in the Near Field and Transitional Regions Calculations				
6. Off-axis Power Density in the Near Field and Transitional Regions Calculations		@45°		
Power density 1/100 of Wn for one diameter removed	PDs	1.2330	W/m^2	$((16 * \eta * P)/(\pi * Deff^2))/100$
		0.12330	mW/cm^2	**Meets Uncontrolled Limits**
7. Off-Axis Safe Distances from Earth Station				S = (Deff/ sin α) + 2(h - GD - 2)/(2 tan α)
α = minimum elevation angle of antenna			deg	
h = maximum height of object to be cleared, meters		2.0	m	
GD = Ground Elevation Delta antenna-obstacle		1.0	m	
		S		
15		0.9	m	
25		0.6	m	
35		0.4	m	
45		0.4	m	
Note: Maximum FCC power density limits for 14 GHz is 1 mW/cm^2 for general population/uncontrolled exposure as per FCC OE&T Bulletin No. 65, Edition 97-01 August 1997, Appendix A page 67.				