Thales InFlyt Experience
Experimentation Description for a Ka-band Airborne Earth Station Modular Connectivity Terminal (MCT)
(Updated October 12, 2016)

Thales InFlyt Experience, with operations in Melbourne, FL and Irvine, CA is a global leader in providing leading-edge, connected inflight entertainment systems and services, including high-speed Internet connectivity. Thales is currently developing and will be testing an end-to-end, Ka satellite-based connectivity solution including an airborne Modular Connectivity Terminal (or ESAA), that will serve multiple airline customers in the North American region. When operational, this solution will enable airline carriers to reach their full potential by offering global inflight coverage that supports the increasing demands of passengers' inflight connectivity needs and provides airlines access to critical real-time inflight data.

Thales InFlyt Experience seeks an experimental license to operate a fixed and mobile (ground-based) antenna Modular Connectivity Terminal (MCT) in system performance and characterization tests over Ka-band satellite capacity on AMC-15 and AMC-16 satellites, at GSO locations 105.1º W and 85º W respectively, beginning October 26, 2016. The MCT is an integral component of an Earth Station Aboard Aircraft (ESAA) that will support Thales' Ka-band, broadband inflight connectivity and entertainment service offerings to airline customers. The AMC-15 and AMC-16 SES satellites have been authorized to serve and provide coverage to North America (AMC-15 and AMC-16), Central America (AMC-16), and the Caribbean (AMC-16) regions. The MCT operates in the Ka-band range of 28.35-28.6 GHz and 29.1-30.0 GHz (transmit), and 17.8-20.2 GHz (receive).

Note that during experimental testing, the MCT will not transmit in the LMDS spectrum between 29.1 and 29.25 GHz, to preclude any potential for interference with LMDS or NGSO operations in the static and mobile testing areas (these areas are detailed later in this narrative).

The MCT will be functionally similar to the Thales Ka-band terminals already authorized to communicate with Inmarsat-5 F2. ISAT-US currently holds a blanket license authorization under call sign E140114 (SES-LIC-20141030-00832) to operate up-to 8,000 terminals in the 19.7-20.2 GHz, and 29.5-30.0 GHz bands using the Inmarsat-5 F2 satellite.

The Thales MCT proposed in this application will operate in the above mentioned Ka-band frequency ranges when communicating with the AMC-15 and AMC-16 satellites. As such, Thales would like to request the Commission to grant an experimental license for this Modular Connectivity Terminal (ESAA) to be operated and tested infrequently from 8 AM to 6 PM EST in close coordination with SES. Static tests will be conducted on the roof top of Thales building located at 700 S. Babcock Street, Melbourne, FL 32901 and mobile tests will be conducted as described later in this narrative.

Figure 1 below shows the exemplar configuration of the MCT system on the rooftop of Thales Building with the end-to-end system operations.

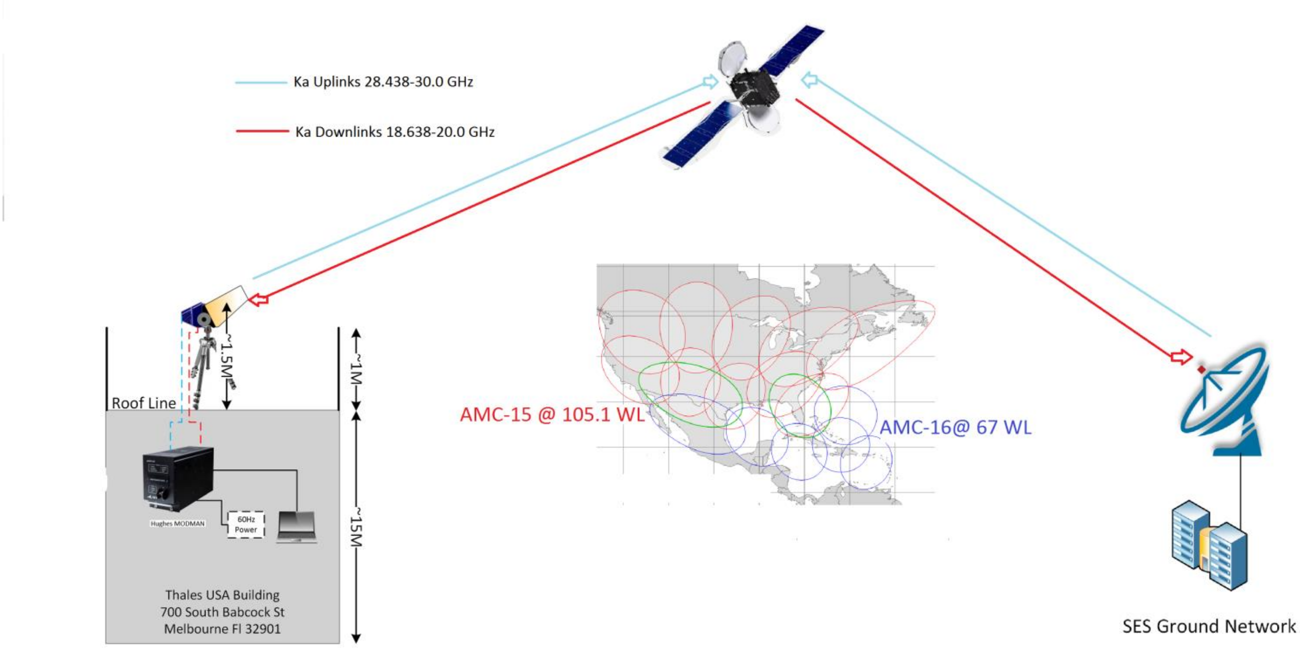


Figure 1: Airborne Earth Station Modular Connectivity Terminal System on Thales USA Building Rooftop

Thales will be using the MCT system in a static configuration on the rooftop to experiment the two-way communications over AMC-15 and AMC-16 satellites to/from SES's associated gateway earth station, and the SES terrestrial connectivity network. Thales also plans to test the MCT in a mobile fashion, on land only, within an 80-mile radius of Germantown, MD and within a 350-mile radius of Charleston, SC. Within the 350-mile radius area, testing will be conducted mainly (but not only) in the areas of central FL (near Apopka, FL), and along the US coastal regions of Georgia, South Carolina and North Carolina as shown in Figure 2 below.

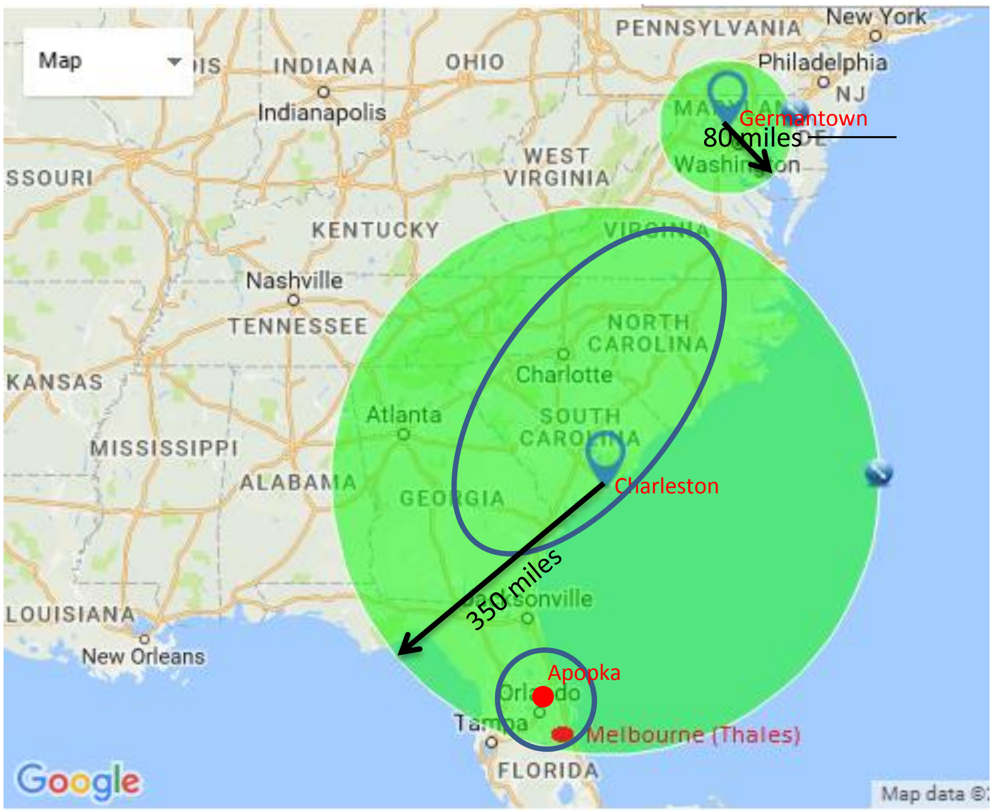


Figure 2: Intended Areas (Land-Based Only) for Mobile Testing of Modular Connectivity Terminal

The MCT will use an antenna pointing algorithm (described later in this narrative) to precisely point to the intended satellite before establishing two-way communication links.

The Ka-band antenna will receive the satellite RF downlink signals in the frequency range of 17.8 GHz-20.2 GHz, and transmit RF signals with a maximum EIRP of 45.0 dBW in the frequency ranges of 28.35-28.6 GHz and 29.3-30.0 GHz. The MCT transmit RF waveform will use various modulation and coding formats as per the DVB-S2 standard, and the transmitted power spectral density will be compliant as per FCC 47 CFR 25.138.

Land-based mobile testing in the areas indicated in Figure 2 will allow Thales to test and verify terminal and system performance in the footprints of multiple Ka spot beams, as well as performance during beam-to-beam and satellite-to-satellite handover scenarios.

The mobile testing will be conducted using a truck with the MCT mounted on a custom rig on the truck's flatbed. Terminal system test equipment, hardware, and software will also be carried in the truck, and the driver/operator will be in frequent contact via cellular phone with Thales and SES engineering and operations personnel. The driver/operator will also have the ability to quickly mute the terminal's transmit signal if necessary.

In the case of any inadvertent, reported interference, Thales will cease terminal transmissions as soon as possible upon notification to Thales' 24/7 point of contact (POC):

Martin Matura
mobile: 321-292-0878
email: martin.matura@us.thalesgroup.com

The SES controlling Ka-band earth stations to be used during experimental tests are:
FCC callsign E160017 – Shenandoah, VA 22842
FCC callsign E160021 – Mt. Airy, Carroll, MD 21771

The SES Network Operations Center (NOC) in Manassas, VA 24/7 phone number is:
703-330-3305 (option #1), or 1-866-244-5012 (option #1).

Parameters to be tested and verified in both static and mobile tests include:

- satellite link closure thresholds
- end-to-end system latency
- achievable information rates using various modulation/coding schemes
- antenna system gain and noise temperature performance versus design specification
- calibration and enhancement of the antenna pointing system's algorithm (tracking, pointing, and stabilization)
- end-to-end connectivity to SES's supporting terrestrial network via multiple gateway earth stations, to/from an Internet Service Provider (ISP).

AES MCT System Description

The Airborne Earth Station Modular Connectivity Terminal (MCT) consists of:

- One Thales Modular Dorsal Antenna - Ka-band (MDA-A), Part # LV10-160801
- One Thales Antenna System Interface (ASI), Part # LV10-150701-101
- One Hughes Modem Manager (MODMAN), Part # E71-200-0001

Modular Dorsal Antenna – Ka-band (MDA-A), Part # LV10-160801

The MDA-A is a Ka-band aeronautical subsystem that generates and steers an antenna beam, and transmits and receives RF signals in a full duplex fashion over that beam, to and from a geosynchronous equatorial orbit (GEO) satellite.

When coupled to a modem via the ASI, the MDA-A becomes an integral part of an airborne satellite connectivity terminal.

The MDA-A consists of an antenna aperture, RF up/down converter subsystems, an antenna positioning subsystem, and an antenna control subsystem.

The MDA-A includes antenna aperture panel consisting of a micro-horn array that supports two orthogonal linear polarizations.

The up/down converter is used for frequency conversions and RF signal amplification. The block upconverter converts IF frequencies (1.888 GHz to 3.45 GHz) from the MODMAN to Ka-band RF frequencies (28.35 GHz to 30.0 GHz) and amplifies the RF signal to be transmitted to the satellite. The block downconverter converts the received Ka-band frequencies (18.638 GHz to 20.2 GHz) to IF (1.388 GHz to 2.95 GHz) to feed the MODMAN IF receive input.

The antenna positioning and control subsystems provide mechanical beam steering in azimuth and elevation using a software-based algorithm. The entire algorithm has 3 parts – tracking, pointing, and stabilization.

Tracking essentially lobes the beam around the satellite in an elliptical pattern. With perfect alignment the received signal strength is equal at all points on the ellipse and the centroid of power is at the major/minor axis intersection. Any misalignment causes the ellipse to have unequal power at different points, and the centroid of power occurs somewhere inside of the ellipse. Where the centroid falls determines how far off-peak the antenna is, and in what direction. Offset is then added to get back to the center of the beam. More spins around the ellipse provide a better time average and eventually drives the offset to zero. This process is a trade-off of scan duration, how often scans are done, and how much offset is gotten on each pass.

When the antenna is peaked, the satellite's location in AZ/EL space is known, and its location in inertial space is calculated. That location is compared to data from the aircraft's inertial navigation system (INS) to obtain another offset.

Pointing is based on the aircraft's INS, obtained via the ARINC 429 data bus. (Note during mobile testing, a portable INS "black box" will be used to provide ARINC 429 data). Stabilization is done by nulling gyro rate output. If there is no motion, gyro output rate is 0. If there is motion, gyro output rate is non-zero, and the Az/El gimbals counter-rotate very quickly (on the order of kHz) to null the gyro output. While the scale factor of a gyro does drift over long periods of time, because the system is nulling the gyros to zero, this is a non-issue.

In general, the pointing and stabilization methodologies keep the antenna peaked on the intended satellite very accurately. Pointing accuracy is further improved by adding the offsets calculated during the tracking process. The methodologies provide sufficient observability into pointing error, and the control logic state machine and hardware implementation will mute the transmit signal within 100 milliseconds if pointing error exceeds 0.2°.

Antenna System Interface (ASI), Part # LV10-150701-101

Antenna System Interface converts 115 VAC aircraft power to +28 VDC power for the MDA-A. ASI enables communication between the Modem Manager (MODMAN) and the Modular Dorsal Antenna (MDA-A).

Modem Manager (MODMAN), Part # E71-200-0001

The Modem Manager (MODMAN) provides data communications between system elements on board the aircraft and the Ka-band satellite service provider (SES).

The MODMAN subsystem is an aeronautical modem that provides the MDA-A a transmit IF signal which is up-converted to RF frequencies and transmitted from the antenna. The MDA-A provides the MODMAN the IF signal which is a down-converted version of the satellite RF signal collected by the antenna.

In the forward link direction (ground to aircraft), the MODMAN demodulates the received IF signal, and forwards baseband IP datagrams via an Ethernet LAN port to the on-board inflight connectivity system.

In the return link direction (aircraft to ground), user IP data from the LAN is encapsulated by software and proprietary firmware, then coded, modulated, upconverted, and transmitted to the ground network via Ka satellite.

MCT Antenna Description

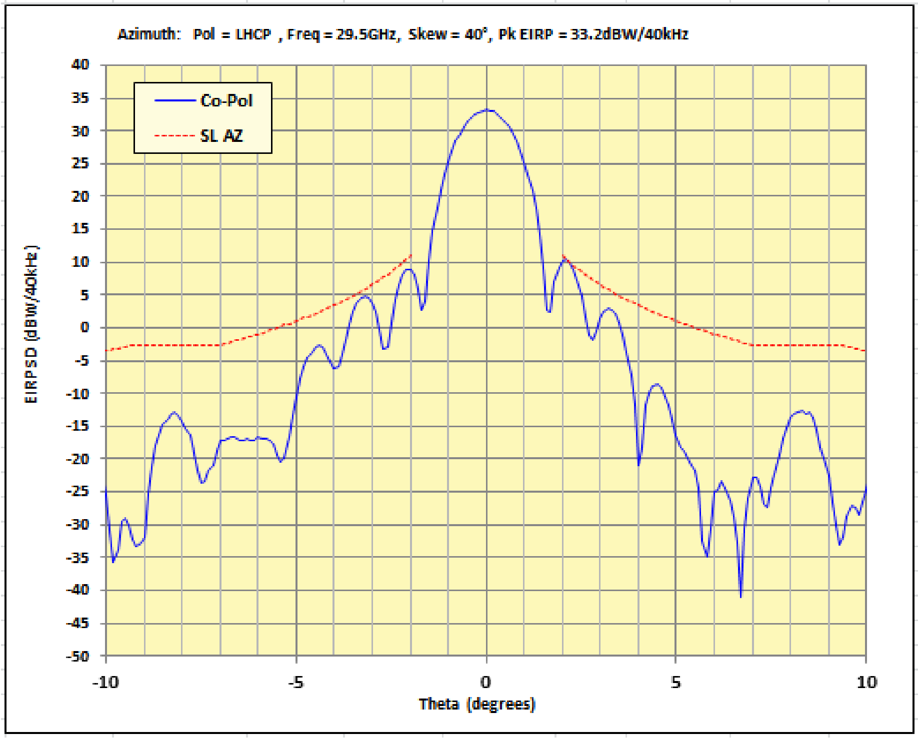
The Thales MCT antenna is a two-axis (azimuth & elevation) motorized antenna with rectangular micro-horn array aperture dimensions of 61.8 cm (width) and 16.1 cm (height). Due to its low profile, rectangular shape, the antenna presents an asymmetrical directional beam with the following beamwidth patterns:

3 dB beamwidth in AZ = 1° - 1.8° (depending on skew angle)
3 dB beamwidth in EL = 3.6° - 4.5° (depending on skew angle)

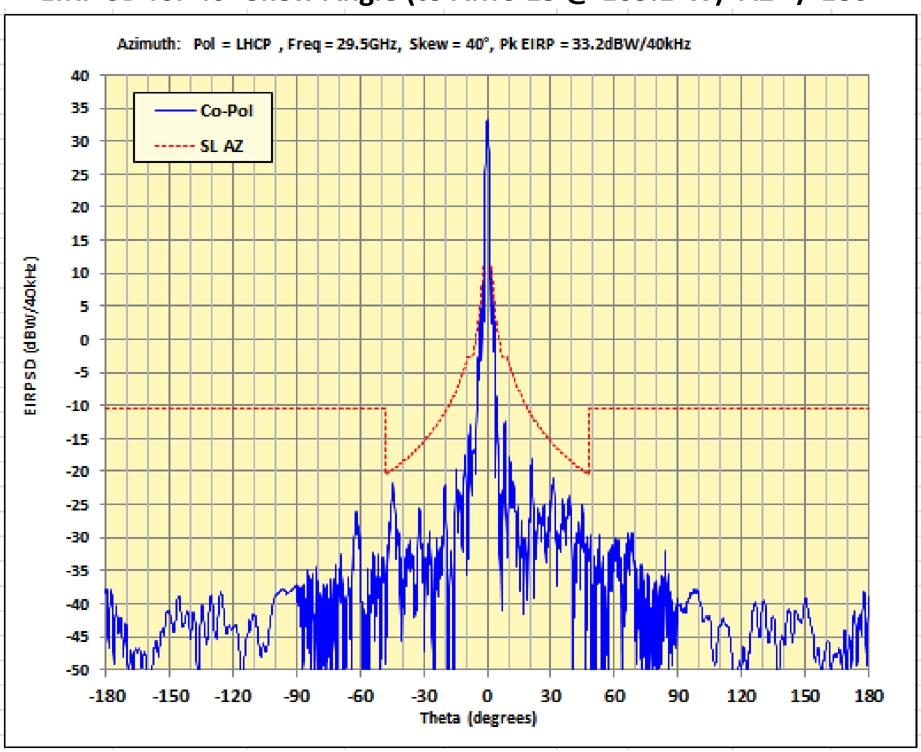
The static test location (Melbourne, FL) coordinates are 28.1°N, 80.62°W. The corresponding skew angle to AMC-15 is 37.7° (worst-case), and to AMC-16 is 8.2°.

On the following pages, measured co-pol (LHCP) EIRP spectral density patterns are provided for skew angles of 40° and 10° at 29.5 GHz, approximating the skew angles from Melbourne to AMC-15 and AMC-16 respectively (note that Melbourne will be the worst-case skew location in Thales' desired static and mobile testing locations, discussed earlier). The antenna performance is fully compliant with the requirements in FCC 47 CFR Section 25.138(a) (FCC masks shown as red dashed line).

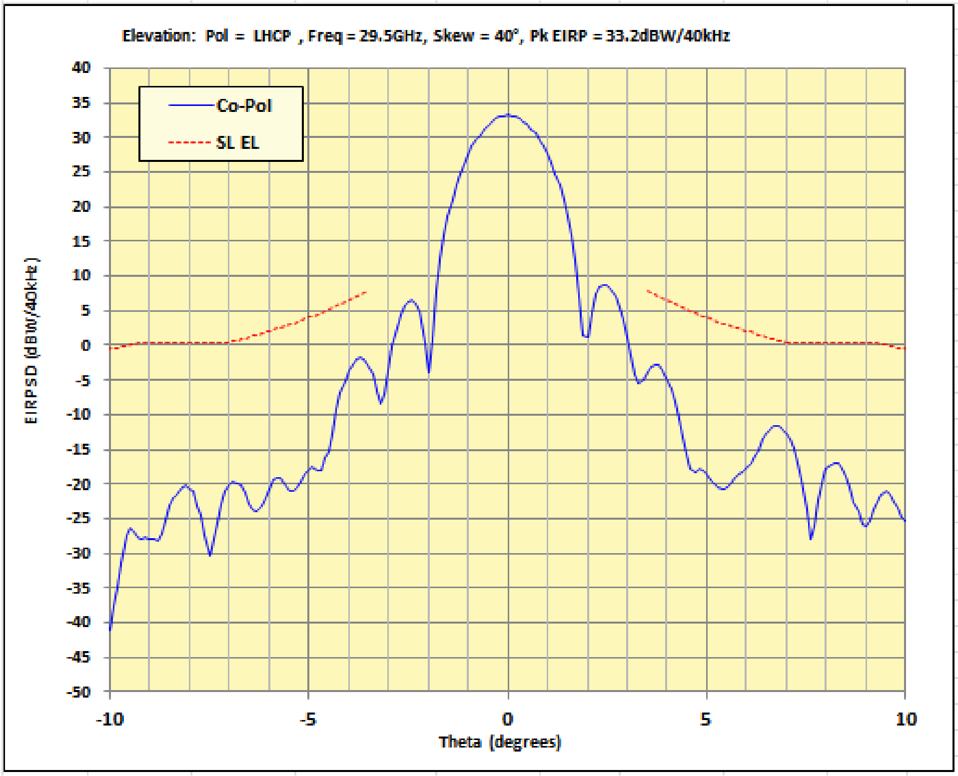
EIRP SD for 40° Skew Angle (to AMC-15 @ 105.1°W) AZ +/-10°



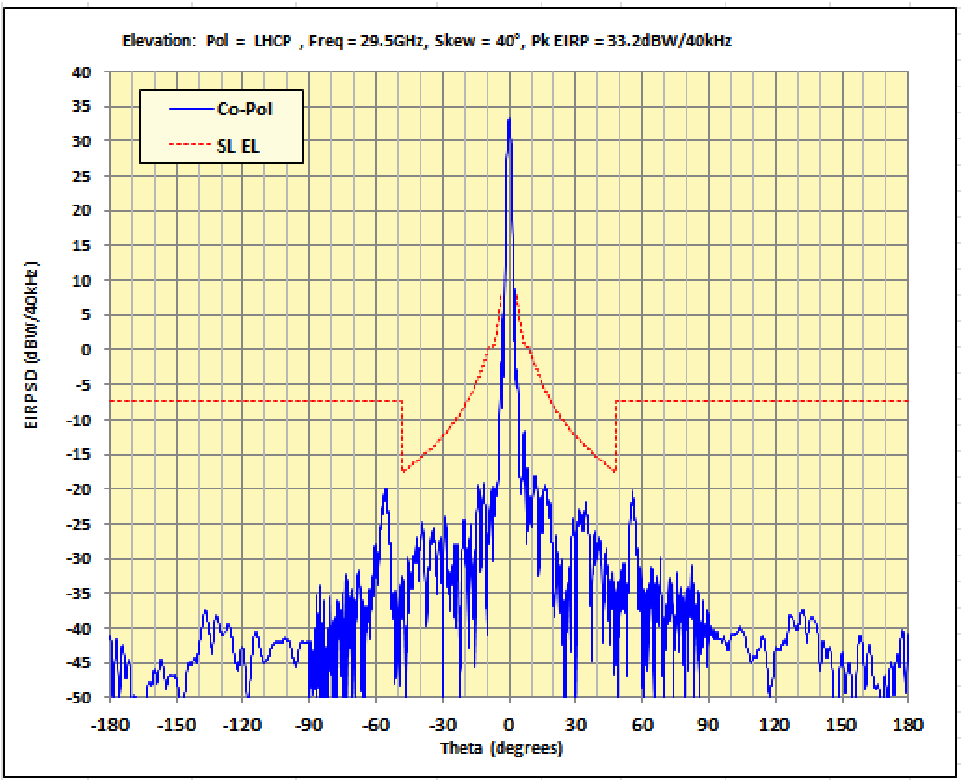
EIRP SD for 40° Skew Angle (to AMC-15 @ 105.1°W) AZ +/-180°



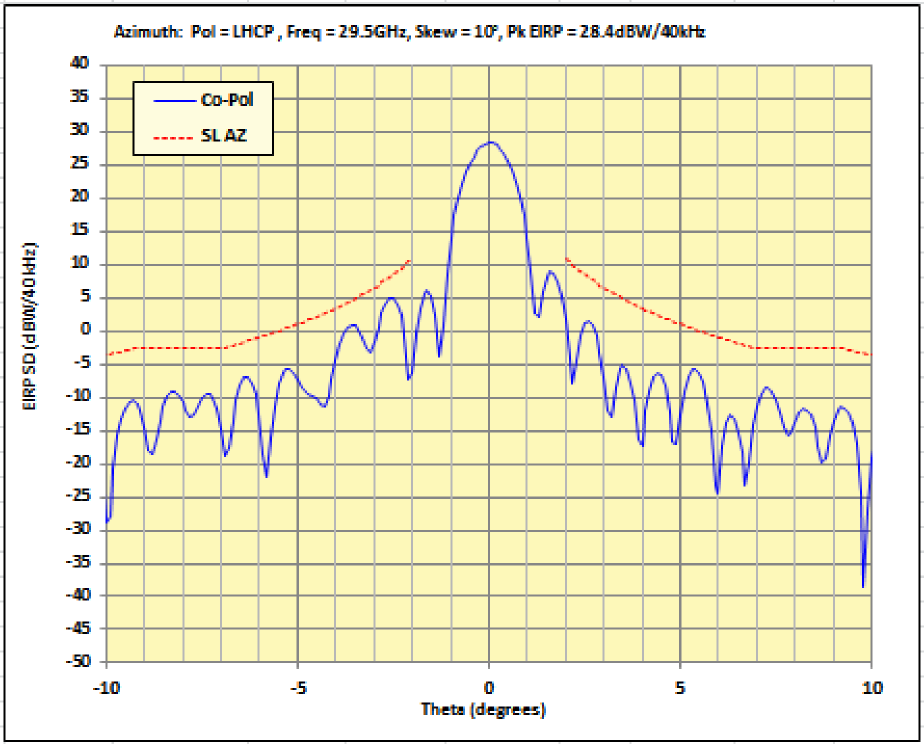
EIRP SD for 40° Skew Angle (to AMC-15 @ 105.1°W) EL +/-10°



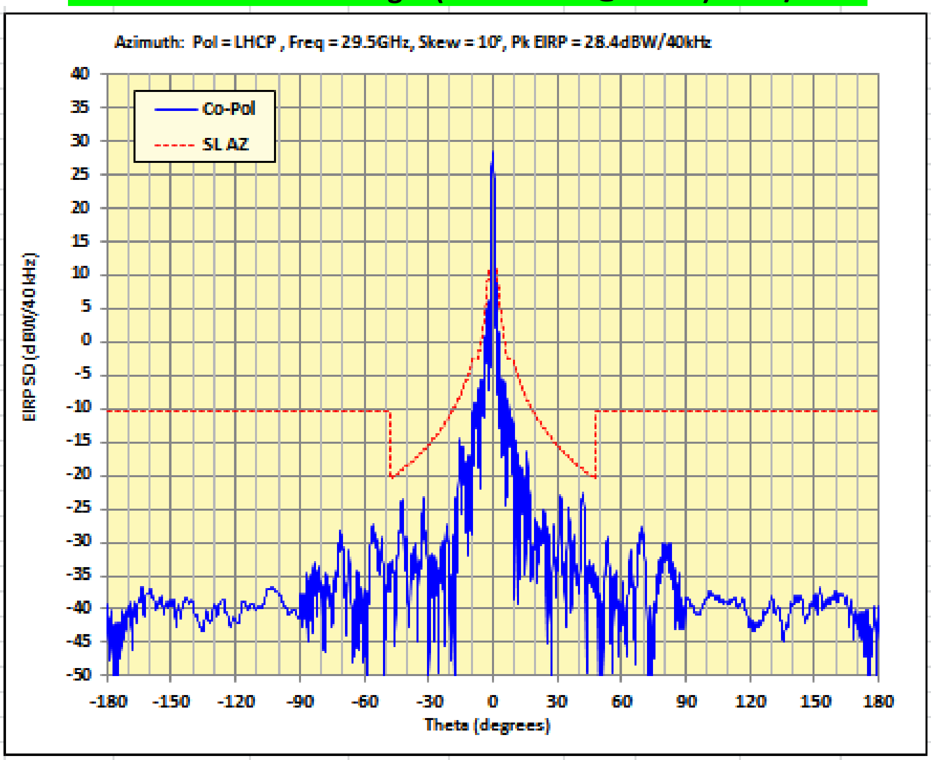
EIRP SD for 40° Skew Angle (to AMC-15 @ 105.1°W) EL +/-180°



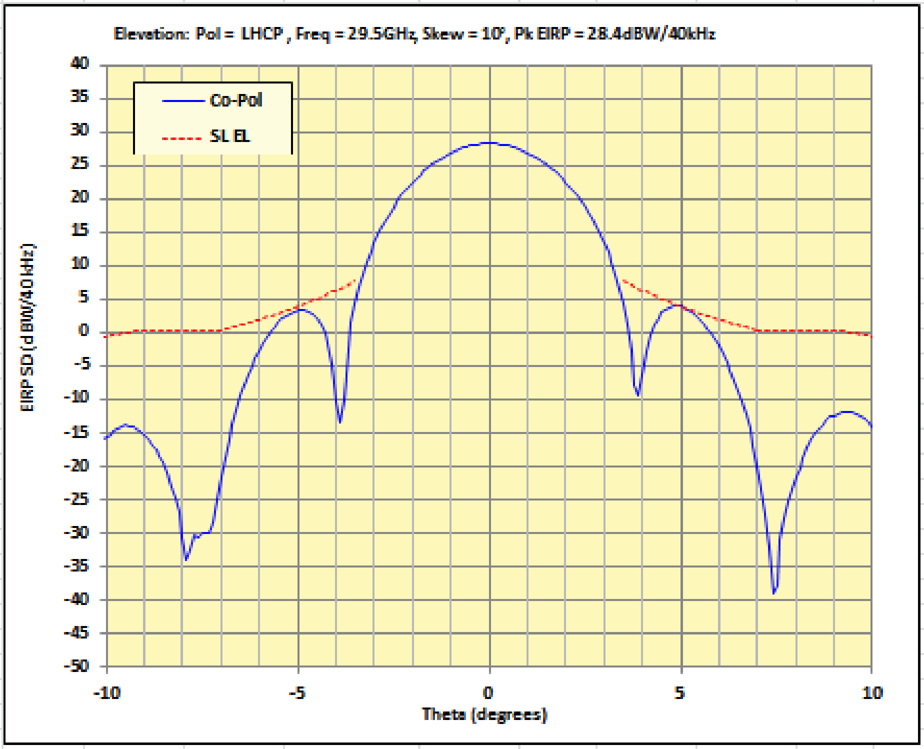
EIRP SD for 10° Skew Angle (to AMC-16 @ 85°W) AZ +/-10°



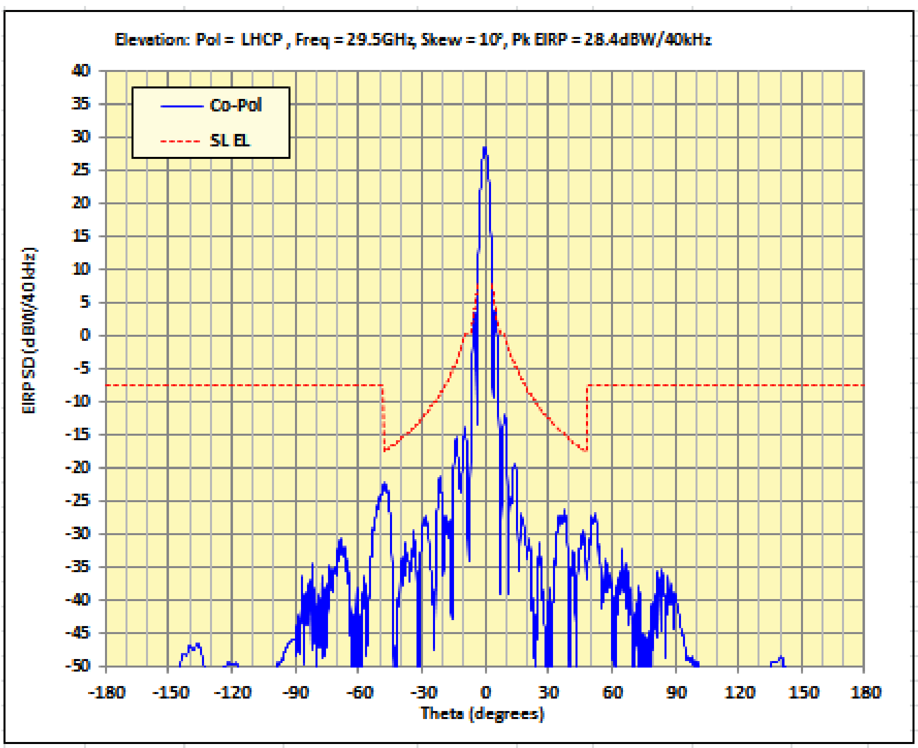
EIRP SD for 10° Skew Angle (to AMC-16 @ 85°W) AZ +/-180°



EIRP SD for 10° Skew Angle (to AMC-16 @ 85°W) EL +/-10°



EIRP SD for 10° Skew Angle (to AMC-16 @ 85°W) EL +/-180°



Proposed Transmission Plan and Inbound Carrier Summary

The range of possible inbound carrier (terminal-to-satellite-to-gateway earth station) modulation and coding formats (modcods) is shown in Table 1 below. Thales expects that inbound carriers using the modcods shaded in blue will be tested most often during the experimental operation of the MCT.

Modulation	FEC Rate	Spread Factor
SS-OQPSK	1/2	2
SS-OQPSK	2/3	2
SS-OQPSK	4/5	2
SS-OQPSK	9/10	2
OQPSK	1/2	1
OQPSK	2/3	1
OQPSK	4/5	1
OQPSK	9/10	1

Table 1: Range of Possible MODCODs for Inbound Carriers

Table 2 below provides a summary of the inbound carriers and parameters corresponding to the shaded modcods above. This data assumes inbound transmissions over AMC-15 at 29.5 GHz during static testing at Thales Melbourne.

	Terminal location in AMC-15 U/L spot beam	MODCOD	Symbol Rate (Msps)	Info Rate (Mbps)	Occupied BW (MHz)	EIRP SD @antenna flange (dBW/40 kHz)	Transmit EIRP SD (dBW/40 kHz)
Inbound Carrier 1	average G/T	OQPSK 2/3	2.0	2.7	2.5	-10.4	**28.0***
Inbound Carrier 2	G/T edge of coverage	OQPSK ½ SF2	2.0	1.0	2.5	-13.4	25.0
Inbound Carrier 3	peak G/T	OQPSK ½	8.0	8.0	10.1	-16.5	21.9

*** worst-case transmit EIRP spectral density during experimental testing**

Table 2: Representative Inbound Carrier Parameters

Other terminal/transmission parameters:

- Antenna transmit gain (at 29.5 GHz): 38.4 dBi
- SSPB maximum output power (before losses): 18 watts
- SSPB-to-antenna flange insertion losses: 4 dB
- Peak transmit EIRP at antenna: 45 dBW

A representative clear-sky link budget for **Inbound Carrier 1** (worst-case EIRP SD) from Table 2 above follows below:

Satellite Input Parameters	***Value***	***Units***
Satellite longitude	105.00W	degrees
Transponder type	LTWTA	
G/T Reference	10.5	dB/K
SFD Reference	-86	dBW/m2
Receive G/T	10.5	dB/K
Attenuator pad (gain step)	0	dB
Effective SFD	-86.00	dBW/m2
Satellite ALC	0	dB
EIRP (saturation)	61.7	dBW
Transponder bandwidth	39	MHz
Input back off total	3.25	dB
Output back off total	3.25	dB
C/IM	18.00	dB
Carriers per transponder	AUTO	

Carrier/Link Input Parameters	***Value***	***Units***
Modulation	4-PSK	
Required Eb/No	2.8	dB
Information rate	2.66	Mbps
Information rate overhead	0	%
FEC code rate	0.6611	
Spreading gain	0	dB
(1 + Roll off factor)	1.25	
Carrier spacing factor	1.25	
Bandwidth allocation step size	.5	MHz
Implementation loss	0	dB
System margin	1.5	dB

Calculations at Saturation	***Value***	***Units***
Gain 1m^2	50.87	dB/m2
Uplink C/No	102.23	dB.Hz
Downlink C/No	120.56	dB.Hz
Total C/No	102.17	dB.Hz
Uplink EIRP for saturation	77.14	dBW

General Calculations	Up	Down	Units
Elevation	38.18	36.43	degrees
True azimuth	180.00	220.26	degrees
Compass bearing	171.16	231.10	degrees
Path distance to satellite	37921.27	38062.54	km
XPD during rain	0.00	0.00	dB
Propagation time delay	0.126492	0.126963	seconds
Antenna efficiency	45.05	65.00	%
Antenna gain	38.40	64.45	dBi
Availability (average year)	N/A	N/A	%
Link downtime (average year)	N/A	N/A	hours
Availability (worst month)	N/A	N/A	%
Link downtime (worst month)	N/A	N/A	hours

Uplink Calculation	Clear	Rain Up	Rain Dn	Units
Transmit EIRP	45.01	45.01	45.01	dBW
Uplink power control used	0.00	0.00	0.00	dB
Transponder input back-off (total)	3.25	3.25	3.25	dB
Input back-off per carrier	32.13	32.13	32.13	dB
Antenna mispoint	0.20	0.20	0.20	dB
Free space loss	213.44	213.44	213.44	dB
Atmospheric absorption	0.37	0.37	0.37	dB
Tropospheric scintillation	0.00	0.00	0.00	dB
Cloud attenuation	0.00	0.00	0.00	dB
Rain attenuation	0.00	0.00	0.00	dB
Total attenuation (gas-rain-cloud-scintillation)	0.37	0.37	0.37	dB
Other path losses	0.00	0.00	0.00	dB
C/No (thermal)	70.10	70.10	70.10	dB.Hz
C/N (thermal)	7.06	7.06	7.06	dB
C/ACI	27.00	27.00	27.00	dB
C/ASI	16.97	16.97	16.97	dB
C/CCI	27.00	27.00	27.00	dB
C/IM	15.00	15.00	15.00	dB
C/(N+I) [= Es/(No+Io)]	5.98	5.98	5.98	dB
Eb/(No+Io)	4.77	4.77	4.77	dB

Downlink Calculation	Clear	Rain Up	Rain Dn	Units
Satellite EIRP total	61.70	61.70	61.70	dBW
Transponder output back-off (total)	3.25	3.25	3.25	dB
Output back-off per carrier	32.13	32.13	32.13	dB
Satellite EIRP per carrier	29.57	29.57	29.57	dBW
Antenna mispoint	0.00	0.00	0.00	dB
Free space loss	209.97	209.97	209.97	dB
Atmospheric absorption	0.46	0.46	0.46	dB
Tropospheric scintillation	0.00	0.00	0.00	dB
Cloud attenuation	0.00	0.00	0.00	dB
Rain attenuation	0.00	0.00	0.00	dB
Total attenuation (gas-rain-cloud-scintillation)	0.46	0.46	0.46	dB
Other path losses	0.00	0.00	0.00	dB
Noise increase due to precipitation	0.00	0.00	0.00	dB
Downlink degradation (DND)	0.00	0.00	0.00	dB
Total system noise	237.70	237.70	237.69	K
Figure of merit (G/T)	40.69	40.69	40.69	dB/K
C/No (thermal)	88.43	88.43	88.43	dB.Hz
C/N (thermal)	25.39	25.39	25.39	dB
C/ACI	27.00	27.00	27.00	dB
C/ASI	31.02	31.02	31.02	dB
C/CCI	27.00	27.00	27.00	dB
C/IM	18.00	18.00	18.00	dB
C/(N+I) [= Es/(No+Io)]	16.29	16.29	16.29	dB
Eb/(No+Io)	15.07	15.07	15.07	dB

Totals per Carrier (End-to-End)	Clear	Rain Up	Rain Dn	Units
C/No (thermal)	70.04	70.04	70.04	dB.Hz
C/N (thermal)	7.00	7.00	7.00	dB
C/ACI	23.99	23.99	23.99	dB
C/ASI	16.80	16.80	16.80	dB
C/CCI	23.99	23.99	23.99	dB
C/IM	13.24	13.24	13.24	dB
C/I (total)	11.17	11.17	11.17	dB
C/(No+Io)	68.63	68.63	68.63	dB.Hz
C/(N+I) [= Es/(No+Io)]	5.59	5.59	5.59	dB
Eb/(No+Io)	4.38	4.38	4.38	dB
Implementation loss	0.00	0.00	0.00	dB
System margin	1.50	1.50	1.50	dB
Net Eb/(No+Io)	2.88	2.88	2.88	dB
Required Eb/(No+Io)	2.80	2.80	2.80	dB
Excess margin	0.08	0.08	0.08	dB

EIRP Density Calculations	Clear	Rain Up	Rain Dn	Units
Flange transmit (up)	-56.43	-56.43	-56.43	dBW/Hz
Antenna off axis transmit toward 107W	-30.49	dBW/Hz		
Satellite (down)	-33.47	-33.47	-33.47	dBW/Hz
Flange receive (down)	-179.45	-179.45	-179.45	dBW/Hz

Earth Station Power Requirements	Value	Units
EIRP per carrier	45.01	dBW
Available uplink power control	0.00	dB
Total EIRP required	45.01	dBW
Antenna gain	38.40	dBi
Antenna feed flange power per carrier	6.61	dBW
HPA output back off	0.00	dB
Waveguide loss	4	dB
Number of HPA carriers	1	
Total HPA power required	10.6070	dBW
Required HPA power	11.5000	W

Space Segment Utilization	Value	Units
Overall availability	N/A	%
Information rate	2.6600	Mbps
Information rate (inc overhead)	2.6600	Mbps
Transmit rate	4.0236	Mbps
Symbol rate	2.0118	Mbaud
Noise Bandwidth	63.04	dB.Hz
Occupied bandwidth	2.5147	MHz
Minimum allocated bandwidth required	2.5147	MHz
Allocated transponder bandwidth	3.0000	MHz
Link efficiency	0.887	bps/Hz
Percentage transponder bandwidth used	7.69	%
Used transponder power	29.57	dBW
Percentage transponder power used	0.13	%
Max carriers / transponder	13.00	
Limited by:	Bandwidth	
Power equivalent bandwidth usage	0.0505	MHz