Thales InFlyt Experience
Experimentation Description for a Ku-band Airborne Earth Station Modular Connectivity Terminal (MCT) - Mobile Testing

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 testing an end-to-end, Ku-band satellite based connectivity solution including an airborne Modular Connectivity Terminal (or ESAA), that will serve multiple airline customers in the North American, South American, African, European, Caribbean, and Middle East regions. 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.

Experimental License Modification Request

Thales InFlyt Experience seeks a modification to its FCC experimental license for a Ku-band fixed earth station - (Call Sign WI2XIT; File Number 0306-EX-PL-2016; granted August 1, 2016) - to operate the MCT in mobile, land-based tests using SES Ku-band capacity on the following satellites:

- SES-1 at 101º W (for North America coverage)
- SES-4 at 22º W (for North America, South America, Africa, Europe, and Middle East coverage)
- SES-6 at 40.5º W (for South America and Caribbean coverage)
- AMC-9 at 83º W (for North American coverage)

Thales' static MCT testing as authorized by its experimental license referenced above, and described in Thales' Experimentation Description dated April 29, 2016, will not change.

Thales is requesting the license modification to conduct mobile MCT testing, on land only, within a 60-mile radius of Kissimmee, FL as shown in Figure 1 below.

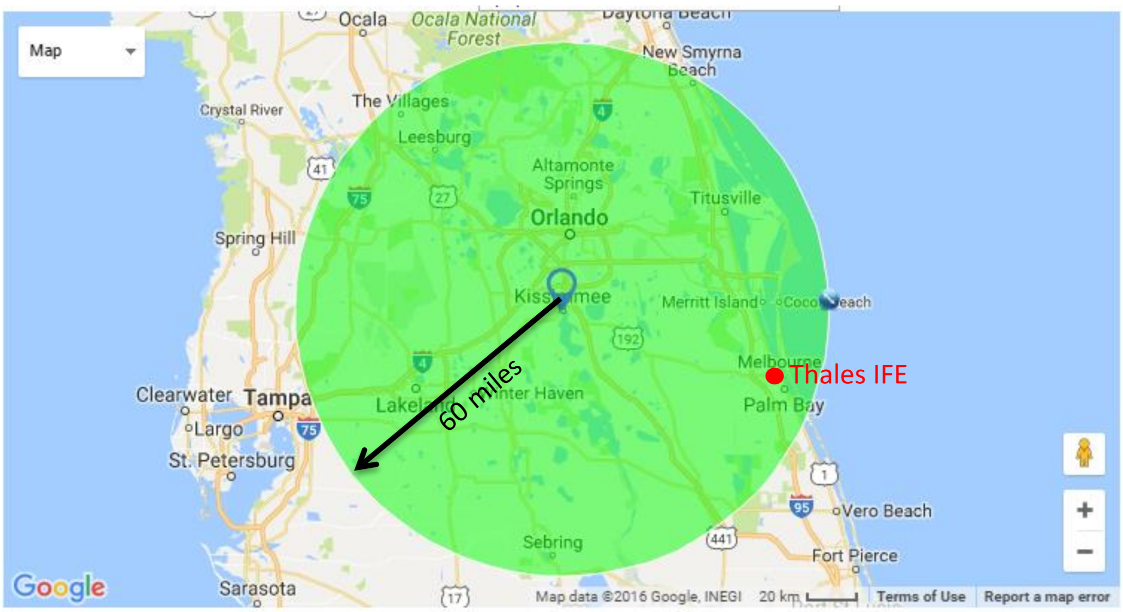


Figure 1: Intended Areas (Land-Based Only) for Mobile Testing of Ku Modular Connectivity Terminal

Thales' mobile testing of the MCT within this area of central Florida will preclude any interference into NSF and NASA sites at the following locations in CONUS:

NSF	NASA
Green Bank, WV	White Sands, NM
Socorro, NM	Blossom Point, MD
Brewster, WA	
Owens Valley, CA	
Kitt Peak, AZ	
Pie Town, NM	
Los Alamos, NM	
Fort Davis, TX	
North Liberty, IA	
Hancock, NH	
St. Croix, USVI	
Mauna Kea, HI	

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

The Ku-band antenna will operate in the frequency ranges of 10.70-12.75 GHz (receive) and 13.75-14.50 GHz (transmit), with a maximum transmit EIRP of 46.0 dBW. The MCT transmit RF waveform will use various digital modulation and coding (modcod) formats as per the DVB-S2 standard, and the transmitted power spectral density will be compliant as per FCC 47 CFR 25.227. Note that since Thales' mobile testing operations will use a vehicle, the power spectral density rules in FCC 47 CFR 25.226 for Ku-band VMES may also apply, which are equal to those in 25.227.

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 Ku-band earth station to be used during mobile experimental testing is:
FCC callsign E140059 – Mount Airy (Woodbine), 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).

Mobile Testing Objectives

Parameters to be tested and verified in the 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, including connectivity to/from an Internet Service Provider (ISP)

Antenna Pointing and Tracking Methodology

The MCT's 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°.

<u>Proposed Transmission Plan and Worst-Case EIRP Spectral Density</u>

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, using Ku-band space segment resources on SES-1 at 101° WL, will be tested most often during the experimental operation of the MCT.

Modulation	FEC Rate	Spread Factor
SS-BPSK	1/2	2
BPSK	1/2	1
BPSK	2/3	1
QPSK	1/2	1
QPSK	2/3	1
8-PSK	2/3	1

Table 1: Range of Possible MODCODs for Inbound Carriers

Link Budget and EIRP SD Patterns

A representative clear-sky link budget for an inbound carrier over SES-1 is provided below. This 2.9 Msps, QPSK ½ carrier will produce the expected worst-case EIRP spectral density of 26.0 dBW/40 kHz, assuming a skew angle of approximately 35° from Melbourne, FL to SES-1 at 101° WL. Associated EIRP SD patterns follow the link budget.

The transmission parameters are:

Satellite: SES-1 @ 101° WL
Uplink: Melbourne, FL (28.1°N/80.6°W)
Modcod: QPSK, rate ½ FEC
Symbol Rate: 2.9 Msps
Information Rate: 2.9 Mbps
Occupied BW: 3.6 MHz
Antenna transmit gain (at 14.125 GHz): 33.6 dBi
SSPB maximum output power (before losses): 28 watts
SSPB-to-antenna flange insertion losses: 3.5 dB
Transmit EIRP at antenna: 44.6 dBW (maximum 46.0 dBW)
EIRP SD at antenna flange: -7.6 dBW/40 kHz
Transmit EIRP SD: 26.0 dBW/40 kHz

Service Name	Experimental Inbound - MLB->Woodbine
Coverage	2.9 Msps; QPSK 1/2
Uplink earth station	a/c term
Downlink earth station	Wash DC (Woodbine, MD)
Satellite name	SES-1 @ 101.0
Modcod	DVBS2,normal frame,4-PSK (1/2),no pilots

Link Input Parameters	***Up***	***Down***	***Units***
Site latitude	28.1N	38.9N	degrees
Site longitude	80.6W	77.0W	degrees
Site altitude	0.000	0.000	km
Frequency	14.125	11.825	GHz
Polarization	Circular	Circular	
Rain model	Clear sky	Clear sky	
Rain zone or mm/h	0	0	
Availability (average year)	N/A	N/A	%
Antenna aperture	0.4	10	metres
Antenna efficiency or gain (+ or - prefix)	+33.6	65	% or dBi
Coupling loss	3.5	0	dB
Antenna mispoint loss	.2	0	dB
Other path losses (site diversity gain -ve)	0	0	dB
LNB noise figure or temp (+ prefix)	+100	dB or K	
Antenna noise	135.00	K	
C/ACI	26	dB	
C/ASI	42.60	dB	
C/CCI	26	dB	
HPA C/IM	15	dB	
C/ACI	27	dB	
C/ASI	44.96	dB	
C/CCI	27	dB	
Uplink station HPA output back-off	0	dB	
Uplink power control available	0	dB	
Number of carriers / HPA	1		
Required HPA power	28	W	

Satellite Input Parameters	Value	Units
Satellite longitude	101.00W	degrees
Transponder type	TWTA	
G/T Reference	5.5	dB/K
SFD Reference	-90.5	dBW/m2
Receive G/T	5.5	dB/K
Attenuator pad (gain step)	0	dB
Effective SFD	-90.50	dBW/m2
Satellite ALC	0	dB
EIRP (saturation)	49.5	dBW
Transponder bandwidth	36	MHz
Input back off total	6	dB
Output back off total	3	dB
C/IM	18.00	dB
Carriers per transponder	AUTO	

Carrier/Link Input Parameters	Value	Units
Modulation	4-PSK	
Required Eb/No	2.5	dB
Symbol rate	2.9	Mbaud
Information rate overhead	0	%
FEC code rate	0.4944	
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	44.46	dB/m2
Uplink C/No	99.14	dB.Hz
Downlink C/No	108.75	dB.Hz
Total C/No	98.69	dB.Hz
Uplink EIRP for saturation	72.22	dBW

General Calculations	Up	Down	Units
Elevation	50.22	38.53	degrees
True azimuth	218.29	215.34	degrees
Compass bearing	224.98	226.18	degrees
Path distance to satellite	37062.74	37893.93	km
XPD during rain	0.00	0.00	dB
Propagation time delay	0.123628	0.126400	seconds
Antenna efficiency	65.35	65.00	%
Antenna gain	33.60	59.99	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	44.57	44.57	44.57	dBW
Uplink power control used	0.00	0.00	0.00	dB
Transponder input back-off (total)	6.00	6.00	6.00	dB
Input back-off per carrier	27.65	27.65	27.65	dB
Antenna mispoint	0.20	0.20	0.20	dB
Free space loss	206.83	206.83	206.83	dB
Atmospheric absorption	0.15	0.15	0.15	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)	0.15	0.15	0.15	dB
Other path losses	0.00	0.00	0.00	dB
C/No (thermal)	71.49	71.49	71.49	dB.Hz
C/N (thermal)	6.87	6.87	6.87	dB
C/ACI	26.00	26.00	26.00	dB
C/ASI	14.95	14.95	14.95	dB
C/CCI	26.00	26.00	26.00	dB
C/IM	15.00	15.00	15.00	dB
C/(N+I) [= Es/(No+Io)]	5.62	5.62	5.62	dB
Eb/(No+Io)	5.67	5.67	5.67	dB

Downlink Calculation	Clear	Rain Up	Rain Dn	Units
Satellite EIRP total	49.50	49.50	49.50	dBW
Transponder output back-off (total)	3.00	3.00	3.00	dB
Output back-off per carrier	24.65	24.65	24.65	dB
Satellite EIRP per carrier	24.85	24.85	24.85	dBW
Antenna mispoint	0.00	0.00	0.00	dB
Free space loss	205.48	205.48	205.48	dB
Atmospheric absorption	0.11	0.11	0.11	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)	0.11	0.11	0.11	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)	36.23	36.23	36.23	dB/K
C/No (thermal)	84.10	84.10	84.10	dB.Hz
C/N (thermal)	19.48	19.48	19.48	dB
C/ACI	27.00	27.00	27.00	dB
C/ASI	20.31	20.31	20.31	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)]	13.93	13.93	13.93	dB
Eb/(No+Io)	13.98	13.98	13.98	dB

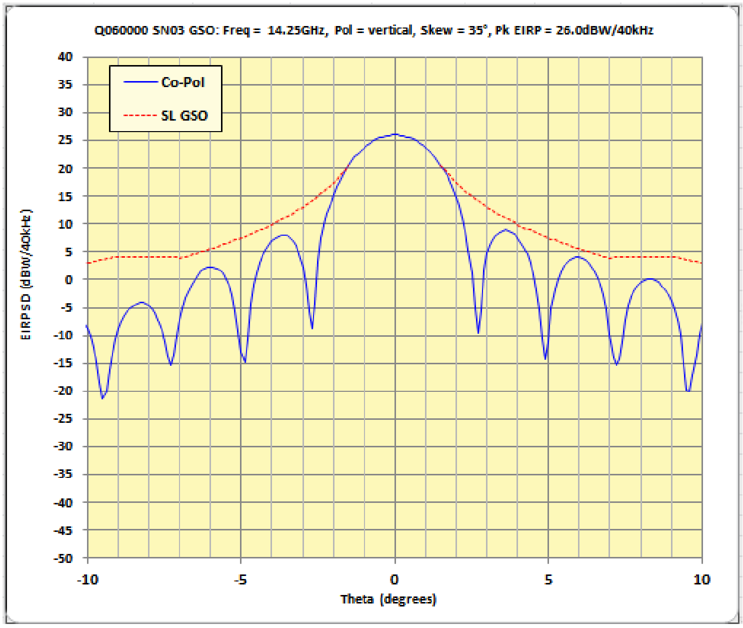
Totals per Carrier (End-to-End)	Clear	Rain Up	Rain Dn	Units
C/No (thermal)	71.26	71.26	71.26	dB.Hz
C/N (thermal)	6.64	6.64	6.64	dB
C/ACI	23.46	23.46	23.46	dB
C/ASI	13.84	13.84	13.84	dB
C/CCI	23.46	23.46	23.46	dB
C/IM	13.24	13.24	13.24	dB
C/I (total)	10.10	10.10	10.10	dB
C/(No+Io)	69.65	69.65	69.65	dB.Hz
C/(N+I) [= Es/(No+Io)]	5.02	5.02	5.02	dB
Eb/(No+Io)	5.07	5.07	5.07	dB
Implementation loss	0.00	0.00	0.00	dB
System margin	1.50	1.50	1.50	dB
Net Eb/(No+Io)	3.57	3.57	3.57	dB
Required Eb/(No+Io)	2.50	2.50	2.50	dB
Excess margin	1.07	1.07	1.07	dB

EIRP Density Calculations	Clear	Rain Up	Rain Dn	Units
Flange transmit (up)	-53.65	-53.65	-53.65	dBW/Hz
Antenna off axis transmit toward 103W	-22.57	dBW/Hz		
Satellite (down)	-39.77	-39.77	-39.77	dBW/Hz
Flange receive (down)	-185.36	-185.36	-185.36	dBW/Hz

Earth Station Power Requirements	Value	Units
EIRP per carrier	44.57	dBW
Available uplink power control	0.00	dB
Total EIRP required	44.57	dBW
Antenna gain	33.60	dBi
Antenna feed flange power per carrier	10.97	dBW
HPA output back off	0.00	dB
Waveguide loss	3.5	dB
Number of HPA carriers	1	
Total HPA power required	14.4716	dBW
Required HPA power	28.0000	W

Space Segment Utilization	Value	Units
Overall availability	N/A	%
Information rate	2.8675	Mbps
Information rate (inc overhead)	2.8675	Mbps
Transmit rate	5.8000	Mbps
Symbol rate	2.9000	Mbaud
Noise Bandwidth	64.62	dB.Hz
Occupied bandwidth	3.6250	MHz
Minimum allocated bandwidth required	3.6250	MHz
Allocated transponder bandwidth	4.0000	MHz
Link efficiency	0.717	bps/Hz
Percentage transponder bandwidth used	11.11	%
Used transponder power	24.85	dBW
Percentage transponder power used	0.68	%
Max carriers / transponder	9.00	
Limited by:	Bandwidth	
Power equivalent bandwidth usage	0.2462	MHz

EIRP SD for 35° Skew Angle (to SES-1 @ 101°W) Az +/-10°



EIRP SD for 35° Skew Angle (to SES-1 @ 101°W) Az +/-90°