Report on the Exposure Calculation of:

Iridium Satellite LLC
Transceiver Module, Model: Certus™ 9770

In accordance with EN 50665, FCC CFR 47 Part 2.1091 and ISED RSS-102

Prepared for: IRIDIUM SATELLITE LLC
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FCC ID: Q639770 IC: 4629A-9770

Document Number: 75946605-05 | Issue: 01

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Jonathan Kenny	Senior Engineer (RF)	Authorised Signatory	20 November 2019

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ENGINEERING STATEMENT
The calculation of exposure for this product was found to be compliant at 30 cm with RED EN 50665, FCC CFR 47 Part 2.1091 and ISED RSS-102.

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EXECUTIVE SUMMARY
The calculation of exposure for this product was found to be compliant at 30 cm with RED EN 50665, FCC CFR 47 Part 2.1091 and ISED RSS-102.

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1 Report Summary

1.1 Report Modification Record

Alterations and additions to this report will be issued to the holders of each copy in the form of a complete document.

Issue	Description of Change	Date of Issue
1	First Issue	20 November 2019

Table 1

1.2 Introduction

Objective	To perform electromagnetic field exposure assessment to determine the equipment under test's (EUT's) compliance with the applied specifications.
Applicant	Iridium Satellite LLC
Manufacturer	Iridium Satellite LLC
Model Number(s)	Certus™ 9770
Hardware Version(s)	P3142-009a change note P3142-CN-017 v0.2
Software Version(s)	PPDO v0.2.1
Specification/Issue/Date	• EN 50665:2017 Generic standard for assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz - 300 GHz) • FCC 47 CFR Part 2 Subpart J 2.1091: 2018 • ISED Canada: Health Canada Safety Code 6:2015
Order Number Date	59151 17 July 2019
Related Document(s)	• EN 62311:2008 Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz to 300 GHz) • Directive 2013/35/EU on minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields). • European Council Recommendation 1999/519/EC of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz), Official Journal, L199, of 1999-7-30, p.59-70. • FCC 47 CFR Part 1.1310: 2018 • OET65:97 Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields

Related Document(s)	• IEEE C95.3:2002 IEEE Recommended Practice for Measurements and Computations of Radio Frequency Electromagnetic Fields with Respect to Human Exposure to Such Fields, 100 kHz–300 GHz • RSS-102 Issue 5 Radio Frequency (RF) Exposure Compliance of Radiocommunication Apparatus (All Frequency Bands)

1.3 Brief Summary of Results

The wireless device described within this report was compliant with the restrictions related to human exposure to electromagnetic fields for both general public and worker/occupational exposures.

The calculations shown in this report were made in accordance with the procedures specified in the applied test specification(s).

1.3.1 Configuration 1 - Single Iridium Transmitter

Regional Requirement	Calculated RF exposure level at compliance boundary of 0.3 m							
	S Power Density (W/m^2)		E Field (V/m)		H Field (A/m)		B Field (μT)	
	Result	Limit	Result	Limit	Result	Limit	Result	Limit
EU	1.79	N/A	25.94	120.60	0.0688	N/A	0.0865	0.4020
FCC	1.79	50.00	25.94	N/A	0.0688	N/A	0.0865	N/A
CANADA	1.79	25.95	25.94	98.91	0.0688	0.2624	0.0865	N/A

Table 2 – Worker/Occupational Exposure Results

The calculations show that the EUT complies with the worker/occupational exposure levels described in in the listed specifications in Annex A at the point of investigation, 0.3 m.

Regional Requirement	Calculated RF exposure level at compliance boundary of 0.3 m							
	S Power Density (W/m^2)		E Field (V/m)		H Field (A/m)		B Field (μT)	
	Result	Limit	Result	Limit	Result	Limit	Result	Limit
EU	1.79	8.08	25.94	55.27	0.0688	0.1487	0.0865	0.1849
FCC	1.79	10.00	25.94	N/A	0.0688	N/A	0.0865	N/A
CANADA	1.79	4.08	25.94	39.22	0.0688	0.1040	0.0865	N/A

Table 3 – General Public Exposure Results

The calculations show that the EUT complies with the general public exposure levels described in in the listed specifications in Annex A at the point of investigation, 0.3 m.
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1.4 Product Information

1.4.1 Technical Description

Module for the transmission and reception of data to and from the Iridium Satellite network.

1.4.2 Transmitter Description

The following radio access technologies and frequency bands are supported by the equipment under test.

Radio Access Technology	Antenna Port	Frequency Band	Minimum Frequency	Output Power	Duty Cycle
		MHz	MHz	dBm	%
Iridium	1	1616-1626.5	1616	40.414	9.2

Table 4 – Transmitter Description

1.4.3 Antenna Description

The following antennas are supported by the equipment under test.

Antenna No	Radio Access Technology	Antenna Model	Gain	Antenna length	Minimum Separation Distance
			dBi	cm	cm
1	Iridium	Not Declared	3	17	30

Table 5 – Antenna description

1.4.4 Equipment Configuration

Single transmitter operating.

2 Assessment Details

2.1 Assessment Method

The assessment method is by calculation of the power density S, electric field strength E, magnetic field strength H or magnetic flux density B.

The calculation uses the spherical model applicable under far field conditions.

$$S = E \times H = \frac{E^2}{\eta} = H^2 \times \eta = \frac{P \times G_i}{4 \times \pi \times r^2}$$

Where:
η - Impedance of free space (377 ohm in far field)
P – Transmitter power W
G_i – Antenna gain ratio relative to isotropic
R – Separation distance m

The magnetic flux density is related to the magnetic field strength by a constant:

$$B = \mu_o \times H$$

Where:
μo – Permeability of free space 4xπ E-7 H/m

Where additional calculations are required by the regional specifications these are detailed below.

The far field region boundary depends on the frequency and wavelength and also on the antenna dimension. The boundary of the far field region is calculated below to demonstrate the validity of using the spherical model.

2.2 Individual Antenna Port Exposure Results

2.2.1 Calculation of Exposure at Specified Separation Distance

The frequencies shown in the tables below have been chosen based on the lowest possible frequency that the EUT can transmit. A full list of the regional requirements is shown in Annex A.

Regional Requirement	Antenna Port	RAT	Frequency (MHz)	RF Exposure Level at compliance boundary of 0.3 m							
				S Power Density (W/m^2)		E Field (V/m)		H Field (A/m)		B Field (µT)	
				Result	Limit	Result	Limit	Result	Limit	Result	Limit
EU	1	Iridium	1616	1.79	N/A	25.94	120.60	0.0688	N/A	0.0865	0.4020
FCC	1	Iridium	1616	1.79	50.00	25.94	N/A	0.0688	N/A	0.0865	N/A
CANADA	1	Iridium	1616	1.79	25.95	25.94	98.91	0.0688	0.2624	0.0865	N/A

Table 6 – Worker/Occupational Individual Transmitter Result

The calculations show that the EUT complies with the worker/occupational exposure levels described in in the listed specifications in Annex A at the point of investigation, 0.3 m.

Regional Requirement	Antenna Port	RAT	Frequency (MHz)	RF Exposure Level at compliance boundary of 0.3 m							
				S Power Density (W/m^2)		E Field (V/m)		H Field (A/m)		B Field (µT)	
				Result	Limit	Result	Limit	Result	Limit	Result	Limit
EU	1	Iridium	1616	1.79	8.08	25.94	55.27	0.0688	0.1487	0.0865	0.1849
FCC	1	Iridium	1616	1.79	10.00	25.94	N/A	0.0688	N/A	0.0865	N/A
CANADA	1	Iridium	1616	1.79	4.08	25.94	39.22	0.0688	0.1040	0.0865	N/A

Table 7 – General Public Individual Transmitter Result

The calculations show that the EUT complies with the general public exposure levels described in in the listed specifications in Annex A at the point of investigation, 0.3 m.

2.3 Combined Antenna Port RF Exposure Results

Not applicable as the device is a single transmitter.

2.4 Far Field Region Boundary Results

The far field region boundary calculation result is shown in Table 8:

Near Field / Far Field Boundary (Ref: IEEE C95.3 Annex B.2, EN 62311 Annex A, Technical Guide for Interpretation and Compliance Assessment of Health Canada's Radiofrequency Exposure Guidelines 7.1)			
RAT Name	Frequency MHz	Reactive Near Field Boundary (Wave Impedance Dependent)	Far Field Boundary (Antennas on axis)
		λ/4 (m)	$2D^2/\lambda$ (m)
Iridium	1616	0.0464	0.3113

Table 8 – Far Field Boundary

The table below shows the maximum calculated near field / far field region boundaries. The compliance boundary of 0.3 m is in the radiating near field region and therefore, the approach described in section 2.1 is an over estimate of the exposure and therefore a conservative assessment.

Field Region	Reactive Near Field Region	Radiating Near Field Region	Far Field Region
Maximum Boundary	< 0.0464 m	0.0464 – 0.3113 m	> 0.3113 m
Validity of Regions	Spherical model potential under-estimate: SAR assessment required	Spherical model over-estimate and conservative	Spherical model valid
Compliance Boundary Location	N/A	0.3 m	N/A

Table 9 – Assessment Method Validity

2.5 Uncertainty

The basic computation formulas presented in section 2.1 are conservative formulas for the estimation of RF field strength or power density. No uncertainty estimations are required when using these formulas but there is clear guidance on where and when these formulas are applicable.

For the estimate of S, E or H to be conservative, the transmitter power P and antenna gain G_i values shall be the upper bounds of uncertainty therefore maximum values are used.

The spherical formula is valid under far field conditions which are established in section 2.4.

ANNEX A

REGIONAL REQUIREMENTS

Frequency Range (MHz)	Power Density (W/m^2)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m) (Converted from µT)	Magnetic Flux Density (µT)
0.1 - 1	-	610	N/A	2/f
1 - 10	-	610/f	N/A	2/f
10 - 400		61	N/A	0.2
400 - 2000		3*f^0.5	N/A	1E-2*f^0.5
2000 - 6000		140	N/A	0.45
6000 -300000	50	140	N/A	0.45

Table A.1 – EU: Action levels in Directive 2013/35/EU Annex III Table B1 Worker/Occupational Limits

Frequency Range (MHz)	Power Density (W/m^2)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Magnetic Flux Density (µT)
0.003 - 0.15	-	87	5	6.25
0.15 - 1	-	87	0.73/f	0.92/f
1 - 10	-	87/f^0.5	0.73/f	0.92/f
10 - 400	2	28	0.073	0.092
400 - 2000	f/200	1.375*f^0.5	0.0037*f^0.5	0.0046*f^0.5
2000 - 300000	10	61	0.16	0.2

Table A.2 – EU: Council Recommendation 1999/519/EC Annex II Table 1 General Public Limits

Frequency Range (MHz)	Power Density (mW/cm^2) Note 1	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)
0 - 0.3	-	-	-
0.3 - 3	100	614	1.63
3 - 30	900/f^2	1842/f	4.89/f
30 - 300	1	61.4	0.163
300 - 1500	f/300	-	-
1500 - 100000	5	-	-

Table A.3 – CFR 47 Pt1.1310 (2019) Worker/Occupational Limits

Frequency Range (MHz)	Power Density (mW/cm^2) Note 1	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)
0 - 0.3	-	-	-
0.3 - 3	100	614	1.63
3 - 30	180/f^2	824/f	2.19/f
30 - 300	0.2	27.5	0.073
300 - 1500	f/1500	-	-
1500 - 100000	1	-	-

Table A.4 – CFR 47 Pt1.1310 (2019) General Public Limits

Note 1: The calculations and limits presented in this report for power density are in units of W/m^2. The conversion factor is; 1 mW/cm^2 = 10 W/m^2.

Frequency Range (MHz)	Power Density (W/m^2)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)
10 - 20	10	61.4	0.163
20 - 48	44.72/f^0.5	129.8/f^0.25	0.3444/f^0.25
48 - 100	6.455	49.33	0.1309
100 - 6000	0.6455*f^0.5	15.60*f^0.25	0.04138*f^0.25
6000 - 150000	50	137	0.364

Table A.5 – Health Canada Safety Code 6 Worker/Occupational Limits

Frequency Range (MHz)	Power Density (W/m^2)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)
10 - 20	2	27.46	0.0728
20 - 48	8.944/f^0.5	58.07/f^0.25	0.1540/f^0.25
48 - 300	1.291	22.06	0.05852
300 - 6000	0.02619*f^0.6834	3.142*f^0.3417	0.008335*f^0.3417
6000 - 15000	10	61.4	0.163

Table A.6 – Health Canada Safety Code 6 General Public Limits