Attachment A
Technical Annex

A.1 Scope and Purpose

The purpose of this Attachment is to provide the Commission with the salient technical characteristics of the Boeing Commercial Satellite Services Inc. (BCSS) Commercial Ka-Band Service and earth station performance over Inmarsat-5 F2 ("I5F2") High Capacity Payload (HCP) Commercial-Ka band steerable beam operations, as required by 47 C.F.R. §25.115 and other sections of the FCC's Part 25 rules.

A.2 General Description of Overall System Facilities, Operations and Services (§25.130(a))

BCSS is the preferred reseller of Inmarsat's High Capacity Commercial Ka-Band (HCC). The I5F2 satellite network will employ two large gateway antennas and will provide service to widely-deployed, small user antennas. The gateway antennas will be capable of communicating with the spacecraft throughout the 27.5-30.0 GHz and 17.7-20.2 GHz bands. The gateway antenna will be located in Lino Lakes, Minnesota (the "Lino Lakes Gateway"). The I5F2 satellite will have two identical steerable spot beams that will be pointed at the same location on earth, effectively forming one single beam, and that will be used by the gateway antennas ("Gateway Beam").

The I5F2 satellite will have two identical steerable spot beams that will be pointed at the same location on earth, effectively forming one single beam, and that will be used by the gateway antennas ("Gateway Beam"). The currently planned coverage of the Gateway Beams is shown in Figure A.2.1. The satellite service will utilize one of the six steerable spot beams ("High Capacity Spot Beams" or "HCP Spot Beams"), configured to 29-29.1 GHz (Earth-to-space) and 19.2-19.3 GHz (space-to-Earth) bands that will be used principally by user antennas. BCSS plans to install earth stations in Washington D.C. and New York City. The earth stations will be comprised of a Paradigm Connect 180 terminal with a 40 watt Block Upconverter (BUC), and a Newtec Modem. This configuration will be known as the "BCSS HCC Earth Station" throughout the remainder of this document. An example of a High Capacity Spot Beam coverage pattern is shown in the Figure A.2.2. The return link uses I5F2's HCC channel capability to route the commercial-Ka uplink carrier from the BCSS HCC Earth station into the gateway downlink which is in the commercial Ka-band. The forward link uses HCC channel capability to route the Commercial-Ka uplink carrier from Gateway into the Connect 180 user terminal downlink which is operating in commercial Ka-band.

A.3 Point of Communication: I5F2 at 55° W.L. orbital location

Coordinates of BCSS HCC Earth Stations:

1. Washington DC (WDC): 38° 56' 41.8" N, 77° 4' 9.3" W;
2. New York, NY (NYC): 40° 45' 17.4" N, 73° 58' 45.9" W;

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Figure A.2.1. Planned Coverage Pattern of Gateway Beam

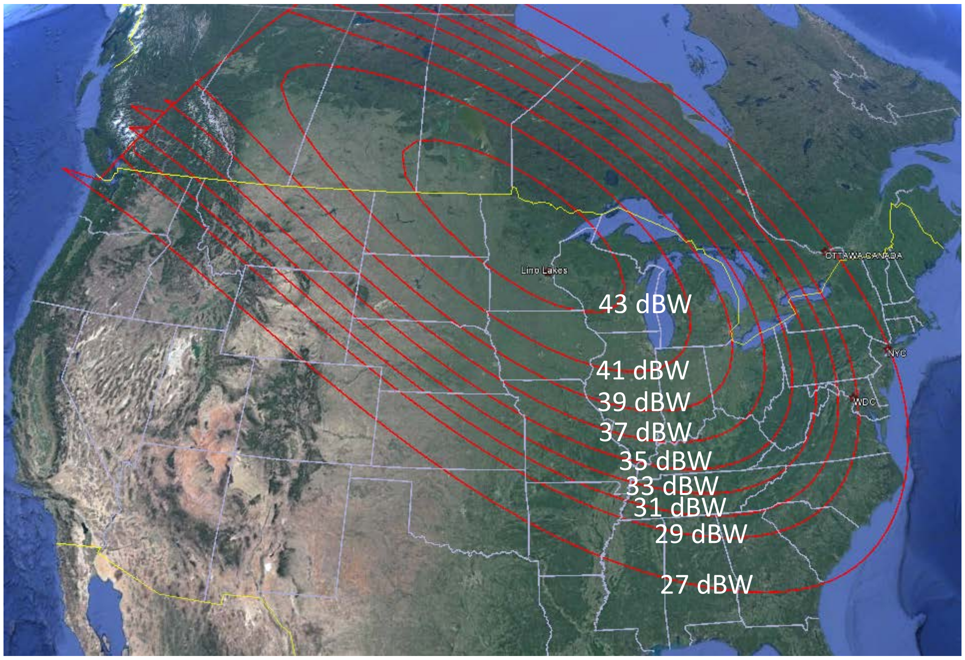
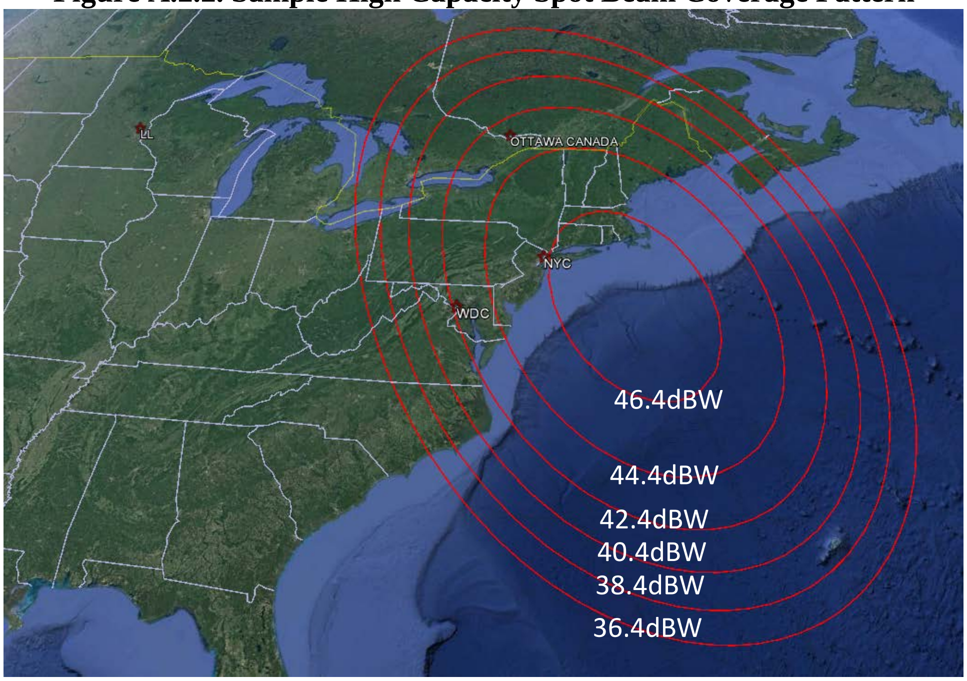


Figure A.2.2. Sample High Capacity Spot Beam Coverage Pattern



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A.4 Frequency, Polarization and Carrier Description

Location	Commercial-Ka band Uplink Frequency Band MHz	Carrier Frequency(s) MHz	Emissions Designators	Uplink Polarization	Uplink EIRP (dBW)
WDC / NYC	29000 - 29100	29017, 29051	31M5M1D	RHCP	57.0
Lino Lakes	27500 - 27600	27519, 27557	35M5M1D	RHCP	57.0

Location	Commercial-Ka band Downlink Frequency Band MHz	Carrier Frequency(s) MHz	Emissions Designators	Downlink Polarization	Downlin k EIRP (dBW)
WDC / NYC	19200 - 19300	19219, 19257	35M5M1D	LHCP	46.4
Lino Lakes	17700 - 17800	17717, 17751	31M5M1D	LHCP	43.0

All of these carriers mentioned in this section are in SCPC mode.

A.5 Identification of any random access technique, if applicable

N/A

A.6 Identification of a specific rule or rules for which a waiver is requested

The BCSS seeks authority to use spectrum in the 19.2-19.3 GHz band for Fixed Satellite Service (FSS) point-of-communication to the I5F2 satellite constellation. See Exhibit A, Section II, “Waiver Requests for Non-Conforming Use.”

A.7 A frequency coordination analysis in accordance with §25.203(b) is contained in Exhibit B and Exhibit C.

A.8 U.S. Government Coordination

BCSS will engage as directed with U.S. Government agencies pursuant to U.S. Table of Frequency Allocation footnote US334. In accordance with Section 25.103(f), the half power beam width of the BCSS HCC Earth station antenna is 0.62° at 18 GHz.

A.9 Sharing with NGSO FSS in the 28.6-29.1 GHz and 18.8-19.3 GHz Bands

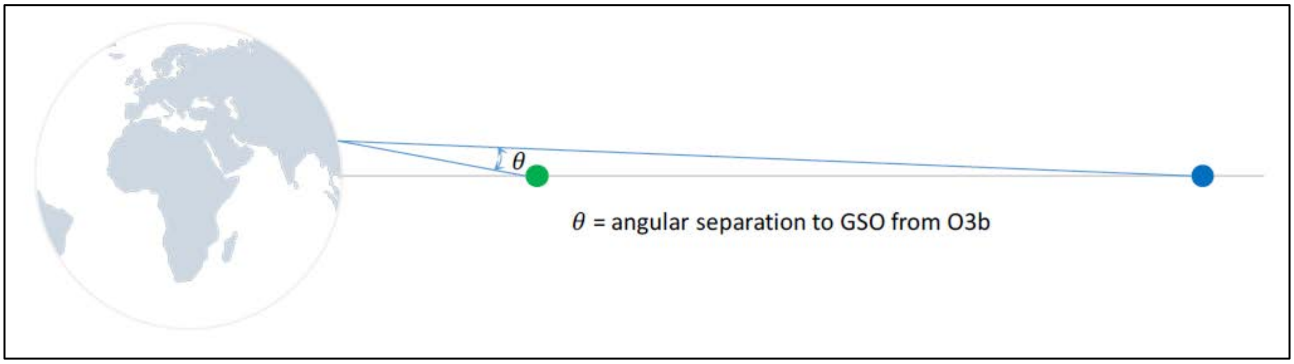
The 28.6-29.1 GHz uplink band is designated for NGSO FSS on a primary basis and it is designated for the GSO FSS on a secondary basis under FCC decisions. The 18.8-19.3 GHz downlink band is allocated exclusively to NGSO FSS. The following analysis demonstrates compatibility with NGSO FSS operations in these band segments. As the NGSO satellite continues to move within its orbit, an angle between the NGSO satellite and the GSO satellite, subtended at the GSO earth station, is created. As long as the GSO earth station does not transmit when the NGSO satellite is within a certain angle, no harmful interference to the NGSO satellite will occur. A similar situation exists on the downlink. The amount of angular separation required will be dependent on location of the ground terminals, the parameters of the NGSO FSS networks and their interference criteria.

Compatibility with O3b

O3b has received a license under FCC call sign E130107 from the Commission for an earth station located in Bristow, VA. This O3b Virginia earth station will be connected via the O3b satellites to O3b's gateway earth stations and in that sense the Virginia earth station would be viewed as a user terminal. The Virginia earth station does not have TT&C capabilities. In addition, the operational characteristics of the Virginia earth station are within all aspects of the envelope defined for user terminals in O3b's Schedule S.

O3b will facilitate sharing with GSO systems by constraining the uplink earth station EIRP density and the downlink PFD at the Earth's surface from the O3b system within these frequency ranges depending on the latitude at which the relevant beam is operating. This technique limits the interference to GSO satellite networks by exploiting the angular separation of the O3b and the GSO orbits when viewed from the surface of the Earth at latitudes away from the equator. This angular separation also protects the O3b system from interference from GSO satellite networks at latitudes away from the equator. The angular separation geometry is shown in Figure A.9.1 below, illustrating that the off-axis angle, θ, becomes larger as the latitude of the Earth location increases (either North or South of the equator).

Figure A.9.1: Example of angular separation angle of an equatorial O3b satellite relative to the GSO orbit for earth locations away from the equator.



The western most and eastern most orbital slot of NGSO O3b satellite that provides coverage to Virginia earth station are at 111°W.L and 42.5°W.L, respectively. When O3b is at 60° W.L, the smallest angular separation value of Θ = 16.04° subtended at the Bristow, VA ground station with respect to the I5F2 orbital slot. Any location of an O3b satellite further east or west of 60°W.L, will necessarily create a larger angular separation with respect to the I5F2. Given the I5F2 gateway antenna location, and with the O3b satellite assumed to be at a static 60° W.L. location, the angular separation (off-axis angle) subtended at the I5F2 earth station can be calculated.

Table A.9.1 shows the predicted interference degradations to the O3b system due to operation of the I5F2 network and vice versa. The results show that the O3b system is adequately protected. The calculated ΔT/T values in all cases are small (less than 1%), demonstrating the technical compatibility of the I5F2 satellite network with the proposed operation of O3b's Virginia earth station O3B1.WMP. O3b's ground station at Bristow, VA has been approved by the Commission. To the extent necessary, Boeing incorporates that information by reference.[1]

Table A.9.1. Interference calculations between I5F2 and O3b (Bristow, Prince William, Virginia)

Uplink			
Victim Network	Units	**O3B1.WMP**	**I5F2**
Interfering Network		**I5F2**	**O3B1.WMP**
Center Frequency	GHz	29.05	29.05
Interfering e/s uplink input power density	dBW/Hz	-70.0	-66.6
Minimum Angular separation	degrees	16.04	16.04
Interfering e/s transmit gain (off-axis)	dB	-1.13	-1.13
Slant range (Interfering path)	Km	10574	37827
Space Loss (Interfering path)	dB	202.2	213.3
Victim satellite receive antenna gain	dBi	34.5	39.2
Victim satellite Rx system noise temperature	K	1000	611.8
No	dBW/Hz	-198.6	-200.7
Io	dBW/Hz	-238.8	-241.9
Io/No	dB	-40.2	-41.1
ΔT/T	%	0.0095%	0.0077%
Downlink			
Victim Network	Units	**O3B1.WMP**	**I5F2**
Interfering Network		**I5F2**	**O3B1.WMP**
Center Frequency	GHz	19.25	19.25
Interfering satellite downlink EIRP density	dBW/Hz	-33.9	-26.3
Slant range (Interfering path)	Km	37827	10574
Space Loss (Interfering path)	dB	209.7	198.6
Minimum Angular separation	degrees	16.04	16.04
Victim e/s receive gain (off-axis)	dBi	-1.13	-1.13
Victim satellite Rx system noise temperature	K	234.4	208.9
No	dBW/Hz	-204.9	-205.4
Io	dBW/Hz	-244.7	-226.1
Io/No	dB	-39.8	-20.6
ΔT/T	%	0.0104%	0.8611%

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[1] O3b FCC authority to operate an earth station in Bristow, VA; call sign E130107; file # SES-LIC-20130618-00516.

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Sharing with HEO Systems

In order to demonstrate compatibility between the I5F2 network and other types of NGSO networks, the parameters of the GESN and ATCONTACT NGSO networks, previously authorized by the Commission to use the 28.6-29.1 GHz and 18.8-19.3 GHz bands, have been used. Both networks were to utilize highly elliptical orbits ("HEO").

Table A.9.2 summarizes the salient parameters of the GESN and ATCONTACT HEO satellite networks for the purpose of this interference assessment. These parameters are identical to those used by Northrop Grumman and ATCONTACT to demonstrate independently that their GSO operations in the 28.6-29.1 GHz and 18.8-19.3 GHz bands were compatible with the other's proposed NGSO operations. It can be seen that the two networks' orbital and transmission parameters are identical, which allows a single interference analysis to be performed.

In order to demonstrate compatibility with these two NGSO networks, a worst-case, static analysis is performed. The smallest possible angle will occur when the GSO satellite, the NGSO satellite and the relevant earth station are all on the same longitude and the earth station is at a high latitude. Assuming a minimum 10° elevation angle for the GSO earth station, this sets the latitude to 71.4°N. The GESN and ATCONTACT satellites do not transmit when they are at an altitude below 16000 km, which translates to a latitude of 31.9°N. With this information, the smallest possible angular separation is then calculated to be 27.4 degrees. Both the transmitting GSO earth station (uplink calculation) and the victim NGSO earth station (downlink calculation) have been assumed to be at a latitude of 71.4°N.

Table A.9.3 shows the results of interference calculations from the I5F2 network into the GESN and ATCONTACT networks and vice versa. The calculated $\Delta T/T$ values in all cases are less than 1%, indicating the technical compatibility of the I5F2 satellite network with the GESN and ATCONTACT networks.

The compatibility of these networks is largely due to the fact that the two NGSO networks do not communicate with earth stations when their satellites cross the equatorial plane, thus in-line events with a GSO network do not occur.

For other types of NGSO constellations that do communicate with earth stations when the satellites pass through the equatorial plane, an in-line interference event can occur. Inmarsat will coordinate with future NGSO operators in these band segments to determine the minimum angular separation required to protect any future NGSO system. If required, Inmarsat would cease transmissions in this band from the relevant beam of the I5F2 satellite and its associated earth station that is causing the in-line event, such that a minimum amount of angular separation with the NGSO network is always maintained, thereby avoiding interference in the NGSO system.

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Table A.9.2. GESN and ATCONTACT HEO satellite characteristics

	GESN	ATCONTACT
Orbital parameters		
• # of satellites	3	3
• # of planes	3	3
• # of satellites per plane	1	1
• Inclination	63.4°	63.4°
• Apogee	39352 km	39352 km
• Perigee	1111 km	1111 km
• Minimum Tx altitude	16000 km	16000 km
Satellite Rx gain	46.5 dBi	46.5 dBi
Satellite Rx system noise temp.	504 K	504 K
Earth station uplink input power density	-63.45 dBW/Hz	-63.45 dBW/Hz
Satellite downlink EIRP density	-18 dBW/Hz	-18 dBW/Hz
E/S Rx system noise temperature	315 K	315 K

A.10 §25.208 Power flux density limits at the earth's surface

§25.208 does not contain any PFD limits that apply in the 17.8-18.3 GHz or 18.8-19.3 GHz bands for GSO satellite networks, however it is noted that Article 21 of the ITU Radio Regulations does include PFD limits applicable to GSO satellites using the 17.8-18.3 GHz and 18.8-19.3 GHz bands and these limits are identical to those in §25.208(c). The PFD limits of §25.208(c) are as follows:

•-115 dB(W/m2) in any 1 MHz band for angles of arrival between 0 and 5 degrees above the horizontal plane;

•-115+(δ-5)/2 dB(W/m2) in any 1 MHz band for angles of arrival δ (in degrees) between 5 and 25 degrees above the horizontal plane; and

•-105 dB(W/m2) in any 1 MHz band for angles of arrival between 25 and 90 degrees above the horizontal plane.

Compliance with all applicable FCC and ITU PFD limits in the 19.2-19.3 GHz is demonstrated below using a simple worst-case methodology. The maximum downlink EIRP density that the I5F2 satellite will transmit in the 19.2-19.3 GHz band is 57 dBW in an occupied bandwidth of 31.5 MHz, which translates into 42 dBW/MHz. The shortest distance from the satellite to the Earth is 35,786 km, corresponding to a spreading loss of 162.06 dB. Therefore the maximum possible PFD at the Earth's surface at an elevation angle of 90° will not exceed -120.06 dBW/m2 in 1 MHz (i.e., 42-162.06). This is less than the -115 dBW/m2/MHz PFD limit value that applies at elevation angles of 5° and below. Therefore compliance with the PFD limits is ensured.

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Table A.9.3. Worst-case interference calculations between the I5F2 network and the GESN / ATCONTACT networks.

Uplink			
Victim Network	Units	**GESN / ATCONTACT**	**I5F2**
Interfering Network		**I5F2**	**GESN / ATCONTACT**
Center Frequency	GHz	29.05	29.05
Interfering e/s uplink input power density	dBW/Hz	-70.0	-63.5
Minimum Angular separation	degrees	27.4	27.4
Interfering e/s transmit gain (off-axis)	dB	-6.94	-6.94
Slant range (Interfering path)	Km	21046	40586
Space Loss (Interfering path)	dB	208.2	213.9
Victim satellite receive antenna gain	dBi	46.5	39.2
Victim satellite Rx system noise temperature	K	504	611.8
No	dBW/Hz	-201.6	-200.7
Io	dBW/Hz	-238.6	-245.1
Io/No	dB	-37.1	-44.4
ΔT/T	%	0.0196%	0.0037%
Downlink			
Victim Network	Units	**GESN / ATCONTACT**	**I5F2**
Interfering Network		**I5F2**	**GESN / ATCONTACT**
Center Frequency	GHz	19.25	19.25
Interfering satellite downlink EIRP density	dBW/Hz	-33.9	-18.0
Slant range (Interfering path)	Km	40586	21046
Space Loss (Interfering path)	dB	210.2	204.5
Minimum Angular separation	degrees	27.4	27.4
Victim e/s receive gain (off-axis)	dB	-6.94	-6.94
Victim satellite Rx system noise temperature	K	315.0	208.9
No	dBW/Hz	-203.6	-205.4
Io	dBW/Hz	-251.0	-229.4
Io/No	dB	-47.4	-24.0
ΔT/T	%	0.0018%	0.3942%

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A.11 §25.138 Licensing requirements for GSO FSS earth stations in the conventional Ka-band

Frequency Bands Subject to §25.138

For those frequency bands subject to §25.138, compliance with the Commission's two-degree spacing policy is ensured provided:

1) The uplink off-axis EIRP density levels of §25.138(a)(1) of the Rules for blanket licensing are not exceeded;

2) The maximum PFD levels are lower than the PFD values given in §25.138(a)(6) of the Rules.

The clear sky uplink off-axis EIRP density limits of §25.138(a)(1) are equivalent to a maximum uplink input power density of -56.5 dBW/Hz, assuming the transmitting earth station meets the off-axis gain mask requirements of § 25.209(a) and (b). Table A.11.1 compares the uplink input power densities derived from the uplink link budgets with clear sky limits of §25.138 (a)(1) of the Rules.

Table A.11.1. Demonstration of Compliance with the Uplink Power Limits of §25.138(a)(1) (assuming the transmitting earth station antenna meets the off-axis gain mask requirements of §25.209(a) and (b))

Uplink Antenna Size	Emission	Maximum Clear Sky Uplink Input Power Density (dBW/Hz)	Clear Sky Uplink Input Power Density Limit of §25.138 (a)(1) (dBW/Hz)	Excess Margin (dB)
1.8m	31M5M1D	-70.3	-56.5	13.8
13.2m	35M5M1D	-87.4	-56.5	30.9

As demonstrated in section A.10 above, the maximum PFD that could be transmitted by the I5F2 satellite, at a 90° elevation angle, is -120.06 dBW/m2/MHz and therefore the PFD levels at other elevation angles will necessarily be somewhat lower. No downlink transmissions from the I5F2 satellite will exceed the -118 dBW/m2/MHz limit set forth in §25.138 (a)(6) of the Rules.

Frequency Bands Not Subject to §25.138

This section demonstrates that uplink transmissions in the 29.0-29.1 GHz bands and downlink transmissions in the 19.2-19.3 GHz band are two-degree compatible.

Currently there are no operational GSO Ka-band satellites that use the 29.0-29.1 GHz and 19.2-19.3 GHz bands at or within two degrees of the 55.0º W.L. location, nor are there any pending applications before the Commission for use of these bands by a GSO satellite at or within two degrees of 55.0° W.L. Therefore, in order to demonstrate two-degree compatibility, the transmission parameters of the I5F2 satellite have been assumed as both the wanted and victim transmissions. Table A.11.2 provides a summary of the uplink and downlink transmission parameters. These parameters were used in the interference analysis. The interference calculations assumed a 1.1 factor (1 dB advantage) for topocentric-to-geocentric conversion. All wanted and interfering carriers are co-polarized and all earth station antennas conform to a sidelobe pattern of 29-25log(θ). It can be seen in table A.11.3 that the C/I margins are all positive.

Table A.11.2. I5F2 HCC transmission parameters

I5F2 E/W station keeping	0.05^{0}
Worst case separation	1.9^{0}
Worst case topo-centric angle	2.09^{0}
Transmit or Receive Antenna Gain at Off-axis Gain at 2.09^{0}	21.0 dBi

UPLINK							
Carrier ID	**Transmit Antenna Size**	**Emission Designator**	**Occupied Bandwidth (MHz)**	**Transmit E/S Gain (dBi)**	**Uplink EIRP (dBW)**	**Uplink EIRP Density (dBW/kHz)**	**C/I Criterion (dB)**
1	1.8m	31M5M1D	31.5	52.3	57.0	12.0	16.3
2	13.2m	35M5M1D	35.5	68.9	57.0	11.5	15.4

DOWNLINK							
Carrier ID	**Receive Antenna Size**	**Emission Designator**	**Occupied Bandwidth (MHz)**	**Receive E/S Gain (dBi)**	**Downlink EIRP (dBW)**	**Downlink EIRP Density (dBW/kHz)**	**C/I Criterion (dB)**
1	13.2m	31M5M1D	31.5	66.6	43.0	-2.0	16.3
2	1.8m	35M5M1D	35.5	49.2	46.4	0.9	15.4

Table A.11.3. Summary of the Uplink and Downlink C/I margins (dB)

UPLINK C/I Margins (dB)		**Interfering Carriers**	
	Carrier ID	1	2
Wanted Carriers	1	15.0	32.1
	2	15.4	32.5

DOWNLINK C/I Margins (dB)		**Interfering Carriers**	
	Carrier ID	1	2
Wanted Carriers	1	29.3	26.4
	2	15.7	12.8

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A.12 Network Monitor and Control

BCSS NOC constantly monitors transmission of BCSS HCC Earth station terminals 24x7. It is accessed through a secure enclave at I5F2 gateway facility where the return link from remote BCSS HCC Earth station is received. Furthermore, BCSS NOC will install a 1m class Inmarsat type-approved Global Xpress land terminal co-located with each of the BCSS HCC Earth station terminal. Global Xpress terminal operates outside the frequency band of operation mentioned in section A.4 of this document. This co-located Global Xpress terminal accesses BCSS HCC Earth station's monitor and control plane and it is configured to be on BCSS monitor and control network. BCSS NOC will remotely control BCSS HCC earth station, its configuration or turn ON / turn OFF by accessing it on BCSS monitor and control network through co-located Global Xpress terminal. This control includes terminal entry into the network, authorization of transmission frequencies, authorizations to change the transmit power/data rate, and enforcement of adherence to off-axis ESD limitations through control of the authorized transmit power level over a constant bandwidth. The NOC operators have the capability to control transmission parameters, or to terminate transmissions, in accordance with the Commission's Rules.

BCSS maintains 24-hour-a-day NOC in Herndon VA. The point of contact information is:

Rob Ruggeri, BCSS Operations Manager

Phone: (855) 556-1001

Email: bcssnoc@boeing.com.

Address: 460 Herndon Parkway, BLDG 95.186.1, Herndon, VA 20170-5278

CERTIFICATION OF PERSON RESPONSIBLE FOR PREPARING ENGINEERING INFORMATION

I hereby certify that I am the technically qualified person responsible for preparation of the engineering information contained in this supplement, that I am familiar with Part 25 of the Commission's rules, that I have either prepared or reviewed the engineering information submitted in this supplement and that it is complete and accurate to the best of my knowledge and belief.

_/s/ samirpatel

Samir Patel
Systems Engineering
Boeing Commercial Satellite Systems, Inc
El Segundo, Ca 90245
Tel # (310)-227-7178