

## **O3B NON-GEOSTATIONARY SATELLITE SYSTEM**

### **Technical Information to Supplement the Existing Schedule S for the Virginia Earth Station**

**(FCC File No. SES-LIC-20130618-00516)**

#### **A.1 Scope**

A Schedule S for the O3b non-geostationary satellite system was filed with the Commission as part of the license application for the Hawaii gateway earth station. O3b incorporated the technical information that had been filed with the Hawaii application, including the Schedule S, in its application for an earth station in Bristow, Virginia. This filing provides further clarification and supplements the above-referenced application by providing modified and additional technical information that is tailored to the operation of the Virginia earth station.

O3b also wishes to clarify the nature of its proposed operations. The Virginia earth station will be connected via the O3b satellites to O3b's gateway earth stations and in that sense the Virginia earth station should be viewed as a user terminal. 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.

#### **A.2 Predicted Space Station Antenna Gain Contours**

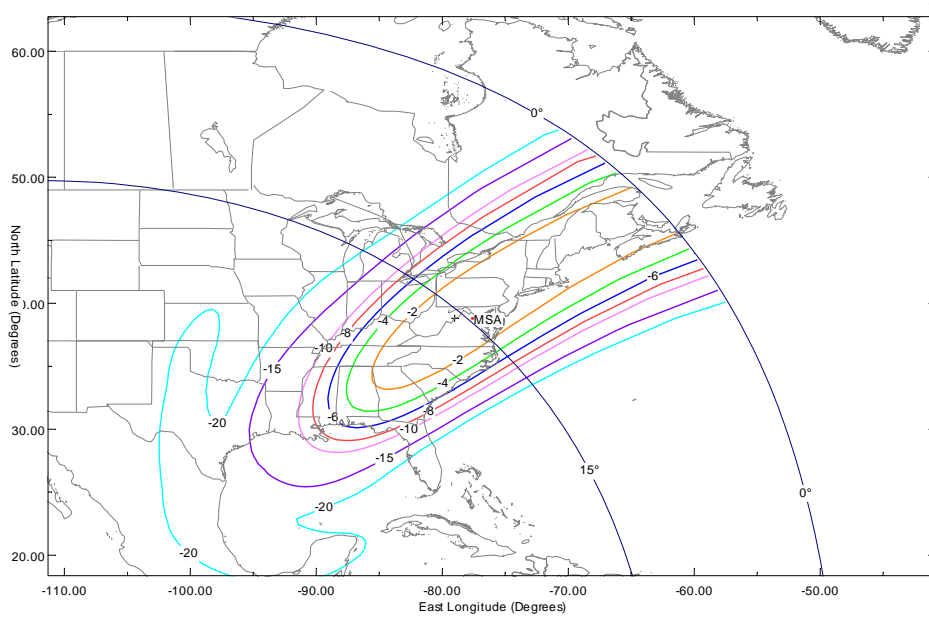
The mid-band antenna gain contours for the O3b satellite receive and transmit beams, when directed towards the Virginia earth station, are shown below. Only one set of beam patterns is provided for transmit and one set for receive because all O3b satellite transmit beams are identical and all receive beams are identical.

These beam patterns demonstrate the effects on the satellite antenna gain contours as the O3b satellite moves in its orbit. Various satellite positions are shown starting with the O3b satellite appearing at 15° elevation angle in the west as viewed from the Virginia earth station (see Figure

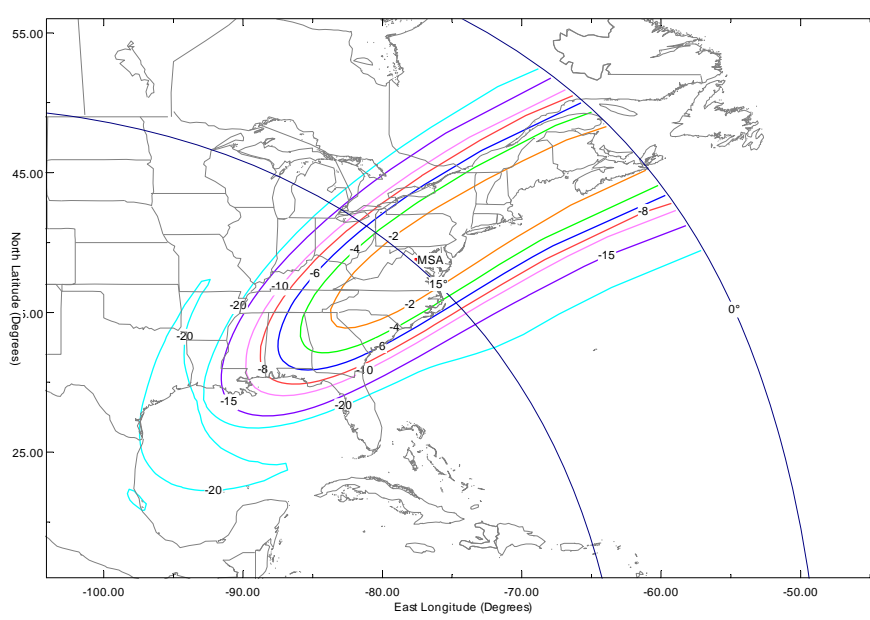
A.2-1). The next O3b satellite position (Figure A.2-2) is at the point when it is at the same longitude as the Virginia earth station. The third O3b satellite position is when the O3b satellite is disappearing below the 15° elevation angle in the east as viewed from the Virginia earth station (Figure A.2-3). For each of these Figures both the transmit and receive antenna gain contours are shown.

**Figure A.2-1: Satellite antenna gain contours when O3b satellite is at 111°W**

**(a) Transmit**

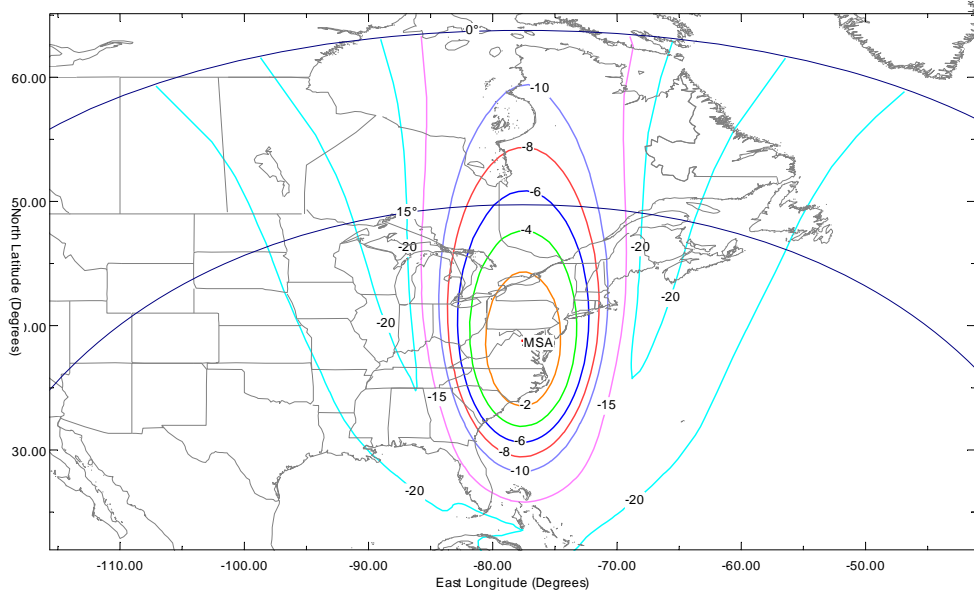


**(b) Receive**

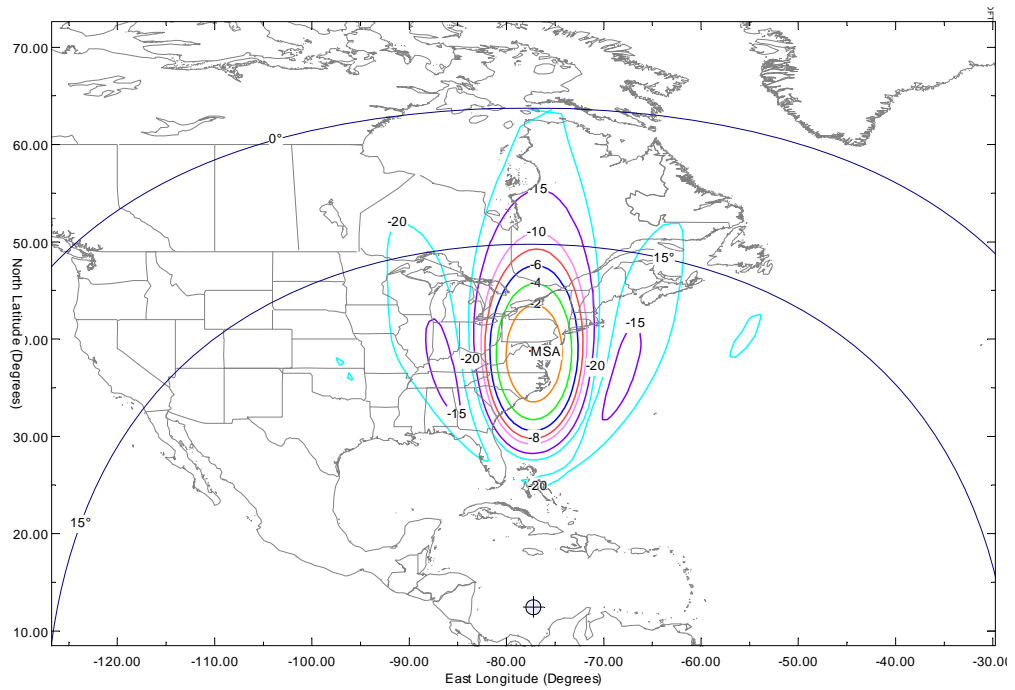


**Figure A.2-2: Satellite antenna relative gain contours when O3b satellite is at 77.6°W**

**(a) Transmit**

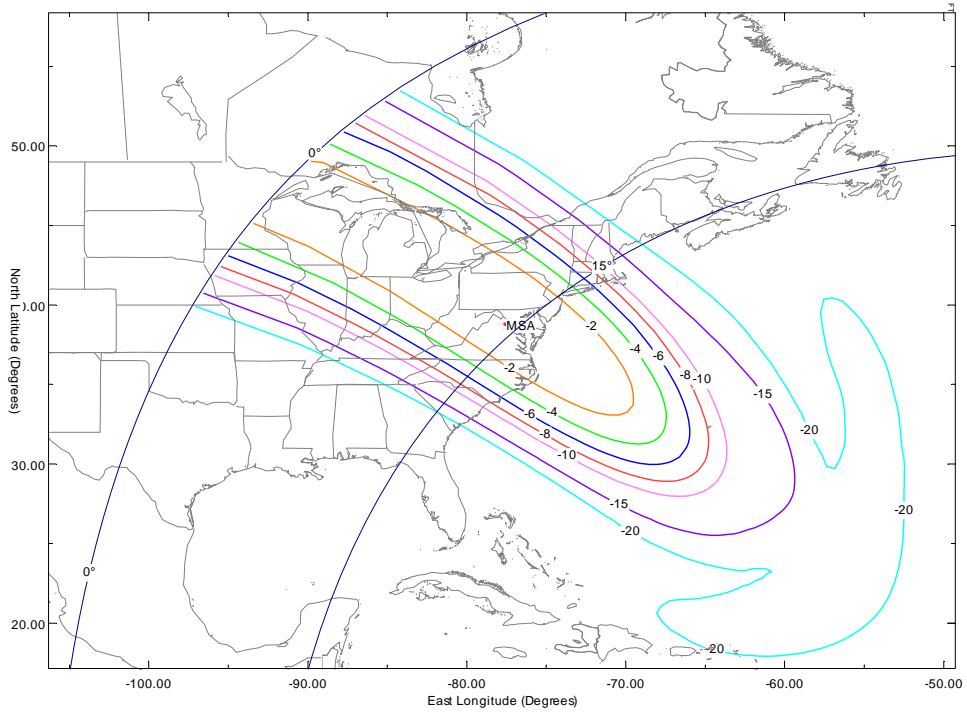


**(b) Receive**

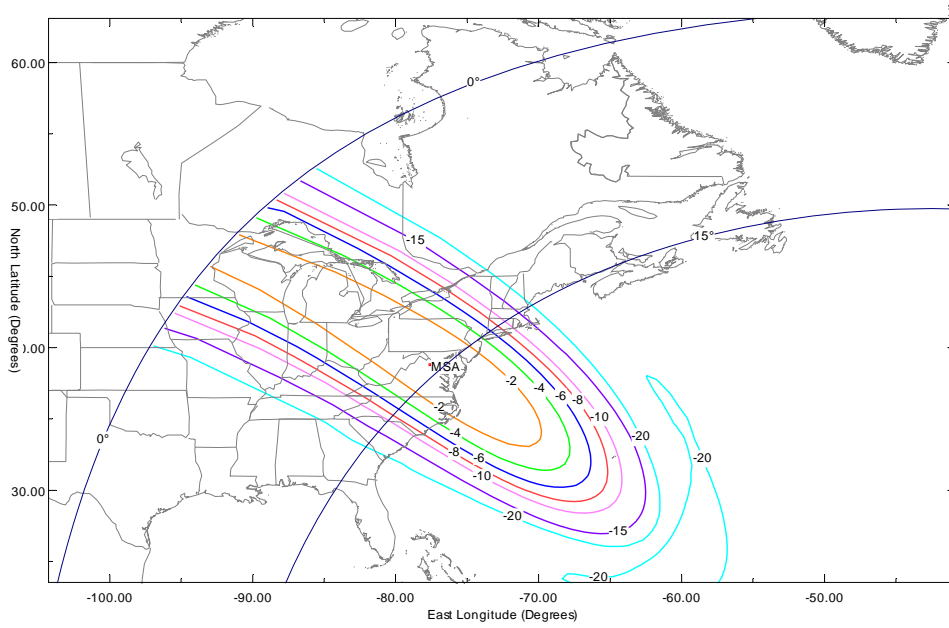


**Figure A.2-3: Satellite antenna relative gain contours when O3b satellite is at 42.5°W**

**(a) Transmit**



**(b) Receive**



### **A.3 Service Area**

The service area designated as “U” in the original Schedule S for the O3b non-geostationary satellite system covers all Earth locations with elevation angles to the operational O3b satellites of greater than 3 degrees. The minimum operational elevation angle from the Virginia earth station to the operational O3b satellite is greater than 20 degrees and so the Virginia earth station falls within the “U” service area as defined in the existing Schedule S.

### **A.4 Link Budgets for the Virginia Earth Station**

New representative link budgets are provided in Annex 1 for the Virginia earth station.

### **A.5 TT&C Characteristics**

The Virginia earth station does not have TT&C capabilities.

### **A.6 Coordination with US Government Satellite Networks and Earth Stations**

O3b has completed all necessary coordination with US government satellite networks operating in Ka-band, including GSO and non-GSO, as well as their associated specific earth stations filed under 9.7A and 9.7B of the ITU Radio Regulations through other administrations. O3b has also completed coordination, according to US footnote 334 of the FCC table of frequency allocations, with the US government, and this US334 coordination agreement specifically takes into account O3b earth stations such as the Virginia one requested herein.

### **A.7 Compliance with PFD Limits**

The O3b system, as filed in the Schedule S that accompanied the FCC application for the Hawaii gateway earth station, complies with all applicable FCC Power Flux Density (“PFD”) limits.

The various FCC rules pertaining to PFD limits in the downlink bands of operation of the O3b system are given below:

- §25.208(c) contains PFD limits that apply in the 18.3-18.6 GHz band which overlaps with O3b's frequency bands.
- §25.208(e) contains PFD limits that apply in the 18.8-19.3 GHz band which overlaps with O3b's frequency bands, and which applies to non-GSO systems.

There are no FCC PFD limits in the 17.8-18.3 GHz band that is also used by the O3b system.

In all the above-mentioned FCC rules regarding PFD limits the actual levels of PFD that O3b is required to meet are as follows:<sup>1</sup>

- $-115 \text{ dB(W/m}^2\text{)}$  in any 1 MHz band for angles of arrival between 0 and 5 degrees above the horizontal plane;
- $-115 + (\theta - 5)/2 \text{ dB(W/m}^2\text{)}$  in any 1 MHz band for angles of arrival  $\theta$  (in degrees) between 5 and 25 degrees above the horizontal plane; and
- $-105 \text{ dB(W/m}^2\text{)}$  in any 1 MHz band for angles of arrival between 25 and 90 degrees above the horizontal plane.

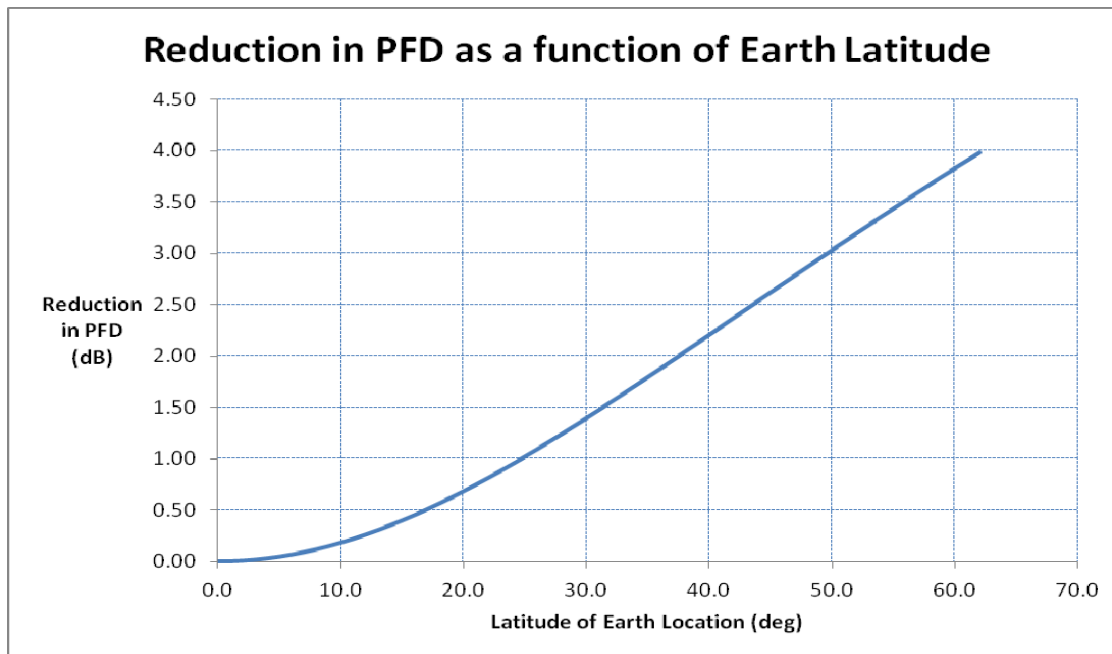
Compliance with these PFD limits is demonstrated below using a simple worst-case methodology. The maximum (saturated TWTA) downlink EIRP per channel (stated in the Schedule S for the O3b system) for the O3b satellites is 49.7 dBW. Normally this EIRP is spread across the channel bandwidth of 216 MHz which results in an EIRP density of 26.4 dBW/MHz. In some situations the spread bandwidth of this signal is reduced to 40 MHz, which increases the maximum EIRP density to 33.7 dBW/MHz. Taking the shortest distance from the O3b satellite to the Earth's surface (8,062 km) the worst case (i.e., smallest) spreading loss is 149.1 dB. Therefore the highest PFD at the Earth's surface, for the nadir situation and for the worst case EIRP density of 33.7 dBW/MHz, is  $-115.4 \text{ dBW/m}^2\text{/MHz}$ , which is less than the most

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<sup>1</sup> For the O3b system the variable "X" given in the formulae in §25.208(e) is equal to zero because the number of satellites, "n", is less than 50.

stringent  $-115 \text{ dBW/m}^2/\text{MHz}$  PFD limit value that applies at elevation angles of  $5^\circ$  and below. Therefore, provided the EIRP density of the O3b satellite downlink transmission does not exceed  $33.7 \text{ dBW/MHz}$ , as described above, then the PFD limits will be met everywhere on the surface of the Earth. The Virginia earth station will be operated with O3b downlink signals that are below this EIRP density level.

In practice the actual downlink PFD would be significantly below the worst-case numbers presented above. A reduction of at least 3 dB would be required as output back-off below the saturation level of the satellite TWTA, resulting in a maximum downlink PFD of no greater than  $-118.4 \text{ dBW/m}^2/\text{MHz}$ , based on the worst-case calculation presented in the preceding paragraph. In addition, for Earth latitudes away from the equator the minimum path length from the O3b satellites to the Earth is higher than the 8,062 km assumed in the worst-case calculation given above. This is demonstrated in the diagram below which gives the resulting reduction in PFD resulting from the increased minimum path length at latitudes away from the equator. For example, at  $38^\circ\text{N}$ , the approximate latitude of the Virginia earth station, the reduction in PFD would be an additional 2 dB.





## **Annex 1 - Representative Link Budgets**

The next nine pages contain representative link budgets for communications transmissions to and from the Virginia earth station.

Example links for the Manassas Washington Media Port (WMP) terminal.

Created on April 22, 2013 by Jim Mowat.

Rev A update on July 22, 2013.

	<b>Carrier</b>	<b>MODCOD</b>	<b>Table #</b>
	54MHz in each direction	16APSK/0.67 FWD 8PSK/0.67 RTN	1,2
	54MHz in each direction, 99% rain	8PSK/0.75 FWD QPSK/0.5 RTN	3,4
	36MHz FWD and 4.92 MHz RTN	16APSK/0.83 FWD 16APSK/0.6 RTN	5.6
	36MHz FWD and 4.92 MHz RTN, 99.5% rain	8PSK/0.75 QPSK/0.5	7, 8

## O3b Network Link Analysis - Tier 2 Service For WMP, United States

Link Budget Creator - Rev 3.2.9: July 22, 2013			Tier 2	Tier 2
Ground Parameter			Teleport	Telco
Location			Vernon (LHCP), United States	WMP, United States
Latitude	(°)		34.2	38.8
Longitude (East)	(°)		260.7	282.4
E/S Maximum Range to SV	(km)		9856.8	10600.8
E/S Minimum Elevation to SV	(°)		34.2	24.2
E/S Altitude	(km)		0.3	0.1
SV Beam Identifier	(#)		24	
Minutes Into Pass (Sample #30)	(Min)		14:2	
Telco Spot Beam Off-Angle	(°)		0.20	
Telco Spot Beam Diameter	(km)		71.80	
Maximum Roundtrip Latency	(msec)		136.48	
Modulation Parameters			Forward	Return
Enter Receiver	Type		DVB-S2	
Modem Overhead	(%)		3.0%	
Number of Carriers per Channel	(#)		1	
Available Bandwidth	(Hz)		54,000,000	
Channel Symbol Rate	(sps)		45,000,000	
Channel Modulation Type			16APSK	
Channel FEC Rate			0.67	
Channel Spectral Efficiency	(bits/Sym)		2.67	
Channel Throughput (100% / 100% of Full Rate)	(bps)		116,366,585.56	
Uplink			Forward	Return
E/S Tx Channels per HPA	(#)		5	
E/S Tx Carrier Frequency	(MHz)		28,709	
E/S Tx HPA Power Level	(W)		125	
E/S Tx OBO	(dB)		-8.00	
E/S Tx Post-HPA Losses	(dB)		-2.24	
E/S Tx Antenna Gain (7.3 m / 2.4 m)	(dB)		65.03	
E/S Tx EIRP Per Channel	(dBW)		68.77	
E/S Tx Pointing Loss	(dB)		-0.50	
E/S Tx RF Link Availability	(%)		75.000	
E/S Tx Atmospheric Losses	(dB)		-1.15	
E/S Tx Spreading Loss	(dB)		-150.87	
Satellite			Forward	Return
SV Number of Channels per HPA	(#)		1	
SV Rx G/T	(dB/K)		5.24	
SV Rx Power Per Tier	(dBW)		-129.13	
SV Rx Flux Density Per Tier	(dBW/m <sup>2</sup> )		-83.75	
SV Tx OBO (ALC / ALC)	(dB)		-15.00	
SV Tx Post-TWTA Losses	(dB)		-1.50	
SV Tx Antenna Gain	(dBi)		31.66	
SV Tx EIRP Per Channel/Carrier	(dBW)		33.28	
SV Tx Pointing Loss	(dB)		0.00	
Downlink			Forward	Return
E/S Rx Carrier Frequency	(MHz)		18,909	
E/S Rx Wavelength	(m)		0.015854	
E/S Rx RF Link Availability	(%)		50	
E/S Rx Atmospheric Losses	(dB)		-0.62	
E/S Rx Radome & Pointing Loss	(dB)		-0.50	
E/S Rx Antenna Gain (2.4 m / 7.3 m)	(dBi)		51.4	
E/S Rx Effective G/T	(dB/K)		27.7	
E/S Rx Power Per Channel	(dBW)		-114.9	
E/S Rx Flux Density Per Channel	(dBW/m <sup>2</sup> )		-119.3	
Total Link			Forward	Return
Carrier / Noise Bandwidth	(dB)		76.53	
Carrier / Noise Uplink	(dB)		22.94	
Carrier / Noise Downlink	(dB)		13.43	
Carrier / Intermodulation Im (C/Im)	(dB)		28.66	
(C/N) - Total Actual	(dB)		11.31	
(C/N) - Total Required	(dB)		11.10	
(E <sub>v</sub> /N <sub>0</sub> ) - Total Actual	(dB)		7.05	
(E <sub>v</sub> /N <sub>0</sub> ) - Total Required	(dB)		6.84	
<b>Excess Margin</b>	<b>(dB)</b>		<b>0.21</b>	
<b>Fade Margin</b>	<b>(dB)</b>		<b>13.51</b>	

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Ground Parameter			Teleport	Telco
Location			Vernon (LHCP), United States	WMP, United States
Latitude	(°)		34.2	38.8
Longitude (East)	(°)		260.7	282.4
E/S Maximum Range to SV	(km)		9856.8	10600.8
E/S Minimum Elevation to SV	(°)		34.2	24.2
E/S Altitude	(km)		0.3	0.1
SV Beam Identifier	(#)			24
Minutes Into Pass (Sample #30)	(Min)			14:2
Telco Spot Beam Off-Angle	(°)			0.20
Telco Spot Beam Diameter	(km)			71.80
Maximum Roundtrip Latency	(msec)			136.48
Modulation Parameters			Forward	Return
Enter Receiver	Type			DVB-S2
Modem Overhead	(%)			3.2%
Number of Carriers per Channel	(#)			1
Available Bandwidth	(Hz)			54,000,000
Channel Symbol Rate	(sps)			45,000,000
Channel Modulation Type				8PSK
Channel FEC Rate				0.67
Channel Spectral Efficiency	(bits/Sym)			2.00
Channel Throughput (100% / 100% of Full Rate)	(bps)			87,104,622.87
Uplink			Forward	Return
E/S Tx Channels per HPA	(#)			1
E/S Tx Carrier Frequency	(MHz)			28,709
E/S Tx HPA Power Level	(W)			40
E/S Tx OBO	(dB)			-10.00
E/S Tx Post-HPA Losses	(dB)			-0.77
E/S Tx Antenna Gain (7.3 m / 2.4 m)	(dB)			55.2
E/S Tx EIRP Per Channel	(dBW)			60.48
E/S Tx Radome & Pointing Loss	(dB)			-0.50
E/S Tx RF Link Availability	(%)			50.000
E/S Tx Atmospheric Losses	(dB)			-0.94
E/S Tx Spreading Loss	(dB)			-151.50
Satellite			Forward	Return
SV Number of Channels per HPA	(#)			5
SV Rx G/T	(dB/K)			4.68
SV Rx Power Per Tier	(dBW)			-138.39
SV Rx Flux Density Per Tier	(dBW/m <sup>2</sup> )			-92.46
SV Tx OBO (ALC / ALC)	(dB)			-15.00
SV Tx Post-TWTA Losses	(dB)			-1.50
SV Tx Antenna Gain	(dBi)			31.77
SV Tx EIRP Per Channel/Carrier	(dBW)			26.41
SV Tx Pointing Loss	(dB)			0.00
Downlink			Forward	Return
E/S Rx Carrier Frequency	(MHz)			18,909
E/S Rx Spreading Loss	(dB)			-150.87
E/S Rx RF Link Availability	(%)			75.000
E/S Rx Atmospheric Losses	(dB)			-0.76
E/S Rx Pointing Loss	(dB)			-0.50
E/S Rx Antenna Gain (2.4 m / 7.3 m)	(dBi)			62.24
E/S Rx Effective G/T	(dB/K)			39.16
E/S Rx Power Per Channel	(dBW)			-110.47
E/S Rx Flux Density Per Channel	(dBW/m <sup>2</sup> )			-125.71
Total Link			Forward	Return
Carrier / Noise Bandwidth	(dB)			76.53
Carrier / Noise Uplink	(dB)			13.68
Carrier / Noise Downlink	(dB)			18.52
Carrier / Intermodulation Im (C/Im)	(dB)			26.64
(C/N) - Total Actual	(dB)			9.08
(C/N) - Total Required	(dB)			8.20
(E <sub>b</sub> /N <sub>0</sub> ) - Total Actual	(dB)			6.07
(E <sub>b</sub> /N <sub>0</sub> ) - Total Required	(dB)			5.19
<b>Excess Margin</b>	<b>(dB)</b>			<b>0.88</b>
<b>Fade Margin</b>	<b>(dB)</b>			<b>11.28</b>

## O3b Network Link Analysis - Tier 2 Service For WMP, United States

Link Budget Creator - Rev 3.2.9: July 22, 2013			Tier 2	Tier 2
Ground Parameter			Teleport	Telco
Location			Vernon (LHCP), United States	WMP, United States
Latitude	(°)		34.2	38.8
Longitude (East)	(°)		260.7	282.4
E/S Maximum Range to SV	(km)		9856.8	10600.8
E/S Minimum Elevation to SV	(°)		34.2	24.2
E/S Altitude	(km)		0.3	0.1
SV Beam Identifier	(#)		24	
Minutes Into Pass (Sample #30)	(Min)		14:2	
Telco Spot Beam Off-Angle	(°)		0.20	
Telco Spot Beam Diameter	(km)		71.80	
Maximum Roundtrip Latency	(msec)		136.48	
Modulation Parameters			Forward	Return
Enter Receiver	Type		DVB-S2	
Modem Overhead	(%)		3.2%	
Number of Carriers per Channel	(#)		1	
Available Bandwidth	(Hz)		54,000,000	
Channel Symbol Rate	(sps)		45,000,000	
Channel Modulation Type			8PSK	
Channel FEC Rate			0.75	
Channel Spectral Efficiency	(bits/Sym)		2.25	
Channel Throughput (100% / 100% of Full Rate)	(bps)		97,988,645.58	
Uplink			Forward	Return
E/S Tx Channels per HPA	(#)		5	
E/S Tx Carrier Frequency	(MHz)		28,709	
E/S Tx HPA Power Level	(W)		125	
E/S Tx OBO	(dB)		-8.00	
E/S Tx Post-HPA Losses	(dB)		-2.24	
E/S Tx Antenna Gain (7.3 m / 2.4 m)	(dB)		65.03	
E/S Tx EIRP Per Channel	(dBW)		68.77	
E/S Tx Pointing Loss	(dB)		-0.50	
E/S Tx RF Link Availability	(%)		75.000	
E/S Tx Atmospheric Losses	(dB)		-1.15	
E/S Tx Spreading Loss	(dB)		-150.87	
Satellite			Forward	Return
SV Number of Channels per HPA	(#)		1	
SV Rx G/T	(dB/K)		5.24	
SV Rx Power Per Tier	(dBW)		-129.13	
SV Rx Flux Density Per Tier	(dBW/m <sup>2</sup> )		-83.75	
SV Tx OBO (ALC / ALC)	(dB)		-10.00	
SV Tx Post-TWTA Losses	(dB)		-1.50	
SV Tx Antenna Gain	(dBi)		31.66	
SV Tx EIRP Per Channel/Carrier	(dBW)		38.28	
SV Tx Pointing Loss	(dB)		0.00	
Downlink			Forward	Return
E/S Rx Carrier Frequency	(MHz)		18,909	
E/S Rx Wavelength	(m)		0.015854	
E/S Rx RF Link Availability	(%)		99	
E/S Rx Atmospheric Losses	(dB)		-5.59	
E/S Rx Radome & Pointing Loss	(dB)		-0.50	
E/S Rx Antenna Gain (2.4 m / 7.3 m)	(dBi)		51.4	
E/S Rx Effective G/T	(dB/K)		26.2	
E/S Rx Power Per Channel	(dBW)		-114.9	
E/S Rx Flux Density Per Channel	(dBW/m <sup>2</sup> )		-119.3	
Total Link			Forward	Return
Carrier / Noise Bandwidth	(dB)		76.53	
Carrier / Noise Uplink	(dB)		22.94	
Carrier / Noise Downlink	(dB)		11.97	
Carrier / Intermodulation Im (C/Im)	(dB)		28.66	
(C/N) - Total Actual	(dB)		10.44	
(C/N) - Total Required	(dB)		9.50	
(E <sub>b</sub> /N <sub>0</sub> ) - Total Actual	(dB)		6.92	
(E <sub>b</sub> /N <sub>0</sub> ) - Total Required	(dB)		5.98	
<b>Excess Margin</b>	<b>(dB)</b>		<b>0.94</b>	
<b>Fade Margin</b>	<b>(dB)</b>		<b>12.64</b>	

## O3b Network Link Analysis - Tier 2 Service For WMP, United States

Link Budget Creator - Rev 3.2.9: July 22, 2013			Tier 2	Tier 2
Ground Parameter			Teleport	Telco
Location			Vernon (LHCP), United States	WMP, United States
Latitude	(°)		34.2	38.8
Longitude (East)	(°)		260.7	282.4
E/S Maximum Range to SV	(km)		9856.8	10600.8
E/S Minimum Elevation to SV	(°)		34.2	24.2
E/S Altitude	(km)		0.3	0.1
SV Beam Identifier	(#)		24	
Minutes Into Pass (Sample #30)	(Min)		14:2	
Telco Spot Beam Off-Angle	(°)		0.20	
Telco Spot Beam Diameter	(km)		71.80	
Maximum Roundtrip Latency	(msec)		136.48	
Modulation Parameters			Forward	Return
Enter Receiver	Type			DVB-S2
Modem Overhead	(%)			3.5%
Number of Carriers per Channel	(#)			1
Available Bandwidth	(Hz)			54,000,000
Channel Symbol Rate	(sps)			45,000,000
Channel Modulation Type				QPSK
Channel FEC Rate				0.50
Channel Spectral Efficiency	(bits/Sym)			1.00
Channel Throughput (100% / 100% of Full Rate)	(bps)			43,439,697.13
Uplink			Forward	Return
E/S Tx Channels per HPA	(#)			1
E/S Tx Carrier Frequency	(MHz)			28,709
E/S Tx HPA Power Level	(W)			40
E/S Tx OBO	(dB)			-10.00
E/S Tx Post-HPA Losses	(dB)			-0.77
E/S Tx Antenna Gain (7.3 m / 2.4 m)	(dB)			55.2
E/S Tx EIRP Per Channel	(dBW)			60.48
E/S Tx Radome & Pointing Loss	(dB)			-0.50
E/S Tx RF Link Availability	(%)			99.000
E/S Tx Atmospheric Losses	(dB)			-11.04
E/S Tx Spreading Loss	(dB)			-151.50
Satellite			Forward	Return
SV Number of Channels per HPA	(#)			5
SV Rx G/T	(dB/K)			4.68
SV Rx Power Per Tier	(dBW)			-148.49
SV Rx Flux Density Per Tier	(dBW/m <sup>2</sup> )			-102.56
SV Tx OBO (ALC / ALC)	(dB)			-15.00
SV Tx Post-TWTA Losses	(dB)			-1.50
SV Tx Antenna Gain	(dBi)			31.77
SV Tx EIRP Per Channel/Carrier	(dBW)			26.41
SV Tx Pointing Loss	(dB)			0.00
Downlink			Forward	Return
E/S Rx Carrier Frequency	(MHz)			18,909
E/S Rx Spreading Loss	(dB)			-150.87
E/S Rx RF Link Availability	(%)			75.000
E/S Rx Atmospheric Losses	(dB)			-0.76
E/S Rx Pointing Loss	(dB)			-0.50
E/S Rx Antenna Gain (2.4 m / 7.3 m)	(dBi)			62.24
E/S Rx Effective G/T	(dB/K)			39.16
E/S Rx Power Per Channel	(dBW)			-110.47
E/S Rx Flux Density Per Channel	(dBW/m <sup>2</sup> )			-125.71
Total Link			Forward	Return
Carrier / Noise Bandwidth	(dB)			76.53
Carrier / Noise Uplink	(dB)			3.57
Carrier / Noise Downlink	(dB)			18.52
Carrier / Intermodulation Im (C/Im)	(dB)			26.64
(C/N) - Total Actual	(dB)			2.84
(C/N) - Total Required	(dB)			2.80
(E <sub>b</sub> /N <sub>0</sub> ) - Total Actual	(dB)			2.84
(E <sub>b</sub> /N <sub>0</sub> ) - Total Required	(dB)			2.80
<b>Excess Margin</b>	<b>(dB)</b>			<b>0.04</b>
<b>Fade Margin</b>	<b>(dB)</b>			<b>5.04</b>

## O3b Network Link Analysis - Tier 2 Service For WMP, United States

Link Budget Creator - Rev 3.2.9: July 22, 2013			Tier 2		Tier 2	
Ground Parameter			Teleport		Telco	
Location			Vernon (LHCP), United States		WMP, United States	
Latitude	(°)		34.2		38.8	
Longitude (East)	(°)		260.7		282.4	
E/S Maximum Range to SV	(km)		9856.8		10600.8	
E/S Minimum Elevation to SV	(°)		34.2		24.2	
E/S Altitude	(km)		0.3		0.1	
SV Beam Identifier	(#)				24	
Minutes Into Pass (Sample #30)	(Min)				14:2	
Telco Spot Beam Off-Angle	(°)				0.20	
Telco Spot Beam Diameter	(km)				71.80	
Maximum Roundtrip Latency	(msec)				136.48	
Modulation Parameters			Forward		Return	
Enter Receiver	Type		DVB-S2			
Modem Overhead	(%)		3.3%			
Number of Carriers per Channel	(#)		1			
Available Bandwidth	(Hz)		36,000,000			
Channel Symbol Rate	(sps)		30,000,000			
Channel Modulation Type			16APSK			
Channel FEC Rate			0.83			
Channel Spectral Efficiency	(bits/Sym)		3.33			
Channel Throughput (100% / 100% of Full Rate)	(bps)		96,655,879.20			
Uplink			Forward		Return	
E/S Tx Channels per HPA	(#)		5			
E/S Tx Carrier Frequency	(MHz)		28,709			
E/S Tx HPA Power Level	(W)		83			
E/S Tx OBO	(dB)		-8.00			
E/S Tx Post-HPA Losses	(dB)		-2.24			
E/S Tx Antenna Gain (7.3 m / 2.4 m)	(dB)		65.03			
E/S Tx EIRP Per Channel	(dBW)		67.01			
E/S Tx Pointing Loss	(dB)		-0.50			
E/S Tx RF Link Availability	(%)		75.000			
E/S Tx Atmospheric Losses	(dB)		-1.15			
E/S Tx Spreading Loss	(dB)		-150.87			
Satellite			Forward		Return	
SV Number of Channels per HPA	(#)		1			
SV Rx G/T	(dB/K)		5.24			
SV Rx Power Per Tier	(dBW)		-130.89			
SV Rx Flux Density Per Tier	(dBW/m <sup>2</sup> )		-85.51			
SV Tx OBO (ALC / ALC)	(dB)		-10.00			
SV Tx Post-TWTA Losses	(dB)		-1.50			
SV Tx Antenna Gain	(dBi)		31.66			
SV Tx EIRP Per Channel/Carrier	(dBW)		38.28			
SV Tx Pointing Loss	(dB)		0.00			
Downlink			Forward		Return	
E/S Rx Carrier Frequency	(MHz)		18,909			
E/S Rx Wavelength	(m)		0.015854			
E/S Rx RF Link Availability	(%)		50			
E/S Rx Atmospheric Losses	(dB)		-0.62			
E/S Rx Radome & Pointing Loss	(dB)		-0.50			
E/S Rx Antenna Gain (2.4 m / 7.3 m)	(dBi)		51.4			
E/S Rx Effective G/T	(dB/K)		27.7			
E/S Rx Power Per Channel	(dBW)		-109.9			
E/S Rx Flux Density Per Channel	(dBW/m <sup>2</sup> )		-114.3			
Total Link			Forward		Return	
Carrier / Noise Bandwidth	(dB)		74.77			
Carrier / Noise Uplink	(dB)		22.94			
Carrier / Noise Downlink	(dB)		20.19			
Carrier / Intermodulation Im (C/Im)	(dB)		28.66			
(C/N) - Total Actual	(dB)		14.41			
(C/N) - Total Required	(dB)		13.70			
(E <sub>p</sub> /N <sub>0</sub> ) - Total Actual	(dB)		9.18			
(E <sub>p</sub> /N <sub>0</sub> ) - Total Required	(dB)		8.47			
<b>Excess Margin</b>	<b>(dB)</b>		<b>0.71</b>			
<b>Fade Margin</b>	<b>(dB)</b>		<b>16.61</b>			

## O3b Network Link Analysis - Tier 2 Service For WMP, United States

Link Budget Creator - Rev 3.2.9: July 22, 2013			Tier 2	Tier 2
Ground Parameter			Teleport	Telco
Location			Vernon (LHCP), United States	WMP, United States
Latitude	(°)		34.2	38.8
Longitude (East)	(°)		260.7	282.4
E/S Maximum Range to SV	(km)		9856.8	10600.8
E/S Minimum Elevation to SV	(°)		34.2	24.2
E/S Altitude	(km)		0.3	0.1
SV Beam Identifier	(#)		24	
Minutes Into Pass (Sample #30)	(Min)		14:2	
Telco Spot Beam Off-Angle	(°)		0.20	
Telco Spot Beam Diameter	(km)		71.80	
Maximum Roundtrip Latency	(msec)		136.48	
Modulation Parameters			Forward	Return
Enter Receiver	Type			DVB-S2
Modem Overhead	(%)			3.4%
Number of Carriers per Channel	(#)			1
Available Bandwidth	(Hz)			4,920,000
Channel Symbol Rate	(sps)			4,100,000
Channel Modulation Type				16APSK
Channel FEC Rate				0.80
Channel Spectral Efficiency	(bits/Sym)			3.20
Channel Throughput (100% / 100% of Full Rate)	(bps)			12,671,029.61
Uplink			Forward	Return
E/S Tx Channels per HPA	(#)			1
E/S Tx Carrier Frequency	(MHz)			28,709
E/S Tx HPA Power Level	(W)			40
E/S Tx OBO	(dB)			-16.00
E/S Tx Post-HPA Losses	(dB)			-0.77
E/S Tx Antenna Gain (7.3 m / 2.4 m)	(dB)			55.2
E/S Tx EIRP Per Channel	(dBW)			54.48
E/S Tx Radome & Pointing Loss	(dB)			-0.50
E/S Tx RF Link Availability	(%)			50.000
E/S Tx Atmospheric Losses	(dB)			-0.94
E/S Tx Spreading Loss	(dB)			-151.50
Satellite			Forward	Return
SV Number of Channels per HPA	(#)			5
SV Rx G/T	(dB/K)			4.68
SV Rx Power Per Tier	(dBW)			-144.39
SV Rx Flux Density Per Tier	(dBW/m <sup>2</sup> )			-98.46
SV Tx OBO (ALC / ALC)	(dB)			-15.00
SV Tx Post-TWTA Losses	(dB)			-1.50
SV Tx Antenna Gain	(dBi)			31.77
SV Tx EIRP Per Channel/Carrier	(dBW)			26.41
SV Tx Pointing Loss	(dB)			0.00
Downlink			Forward	Return
E/S Rx Carrier Frequency	(MHz)			18,909
E/S Rx Spreading Loss	(dB)			-150.87
E/S Rx RF Link Availability	(%)			75.000
E/S Rx Atmospheric Losses	(dB)			-0.76
E/S Rx Pointing Loss	(dB)			-0.50
E/S Rx Antenna Gain (2.4 m / 7.3 m)	(dBi)			62.24
E/S Rx Effective G/T	(dB/K)			39.16
E/S Rx Power Per Channel	(dBW)			-110.47
E/S Rx Flux Density Per Channel	(dBW/m <sup>2</sup> )			-125.71
Total Link			Forward	Return
Carrier / Noise Bandwidth	(dB)			66.13
Carrier / Noise Uplink	(dB)			18.08
Carrier / Noise Downlink	(dB)			28.93
Carrier / Intermodulation Im (C/Im)	(dB)			26.64
(C/N) - Total Actual	(dB)			13.42
(C/N) - Total Required	(dB)			13.30
(E <sub>b</sub> /N <sub>0</sub> ) - Total Actual	(dB)			8.36
(E <sub>b</sub> /N <sub>0</sub> ) - Total Required	(dB)			8.25
<b>Excess Margin</b>	<b>(dB)</b>			<b>0.12</b>
<b>Fade Margin</b>	<b>(dB)</b>			<b>15.62</b>



## O3b Network Link Analysis - Tier 2 Service For WMP, United States

Link Budget Creator - Rev 3.2.9: July 22, 2013			Tier 2	Tier 2
Ground Parameter			Teleport	Telco
Location			Vernon (LHCP), United States	WMP, United States
Latitude	(°)		34.2	38.8
Longitude (East)	(°)		260.7	282.4
E/S Maximum Range to SV	(km)		9856.8	10600.8
E/S Minimum Elevation to SV	(°)		34.2	24.2
E/S Altitude	(km)		0.3	0.1
SV Beam Identifier	(#)		24	
Minutes Into Pass (Sample #30)	(Min)		14:2	
Telco Spot Beam Off-Angle	(°)		0.20	
Telco Spot Beam Diameter	(km)		71.80	
Maximum Roundtrip Latency	(msec)		136.48	
Modulation Parameters			Forward	Return
Enter Receiver	Type		DVB-S2	
Modem Overhead	(%)		3.2%	
Number of Carriers per Channel	(#)		1	
Available Bandwidth	(Hz)		36,000,000	
Channel Symbol Rate	(sps)		30,000,000	
Channel Modulation Type			8PSK	
Channel FEC Rate			0.75	
Channel Spectral Efficiency	(bits/Sym)		2.25	
Channel Throughput (100% / 100% of Full Rate)	(bps)		65,325,763.73	
Uplink			Forward	Return
E/S Tx Channels per HPA	(#)		5	
E/S Tx Carrier Frequency	(MHz)		28,709	
E/S Tx HPA Power Level	(W)		83	
E/S Tx OBO	(dB)		-8.00	
E/S Tx Post-HPA Losses	(dB)		-2.24	
E/S Tx Antenna Gain (7.3 m / 2.4 m)	(dB)		65.03	
E/S Tx EIRP Per Channel	(dBW)		67.01	
E/S Tx Pointing Loss	(dB)		-0.50	
E/S Tx RF Link Availability	(%)		75.000	
E/S Tx Atmospheric Losses	(dB)		-1.15	
E/S Tx Spreading Loss	(dB)		-150.87	
Satellite			Forward	Return
SV Number of Channels per HPA	(#)		1	
SV Rx G/T	(dB/K)		5.24	
SV Rx Power Per Tier	(dBW)		-130.89	
SV Rx Flux Density Per Tier	(dBW/m <sup>2</sup> )		-85.51	
SV Tx OBO (ALC / ALC)	(dB)		-10.00	
SV Tx Post-TWTA Losses	(dB)		-1.50	
SV Tx Antenna Gain	(dBi)		31.66	
SV Tx EIRP Per Channel/Carrier	(dBW)		38.28	
SV Tx Pointing Loss	(dB)		0.00	
Downlink			Forward	Return
E/S Rx Carrier Frequency	(MHz)		18,909	
E/S Rx Wavelength	(m)		0.015854	
E/S Rx RF Link Availability	(%)		100	
E/S Rx Atmospheric Losses	(dB)		-7.45	
E/S Rx Radome & Pointing Loss	(dB)		-0.50	
E/S Rx Antenna Gain (2.4 m / 7.3 m)	(dBi)		51.4	
E/S Rx Effective G/T	(dB/K)		25.7	
E/S Rx Power Per Channel	(dBW)		-116.8	
E/S Rx Flux Density Per Channel	(dBW/m <sup>2</sup> )		-121.2	
Total Link			Forward	Return
Carrier / Noise Bandwidth	(dB)		74.77	
Carrier / Noise Uplink	(dB)		22.94	
Carrier / Noise Downlink	(dB)		11.42	
Carrier / Intermodulation Im (C/Im)	(dB)		28.66	
(C/N) - Total Actual	(dB)		10.05	
(C/N) - Total Required	(dB)		9.50	
(E <sub>b</sub> /N <sub>0</sub> ) - Total Actual	(dB)		6.53	
(E <sub>b</sub> /N <sub>0</sub> ) - Total Required	(dB)		5.98	
<b>Excess Margin</b>	<b>(dB)</b>		<b>0.55</b>	
<b>Fade Margin</b>	<b>(dB)</b>		<b>12.25</b>	

## O3b Network Link Analysis - Tier 2 Service For WMP, United States

Link Budget Creator - Rev 3.2.9: July 22, 2013			Tier 2	Tier 2
Ground Parameter			Teleport	Telco
Location			Vernon (LHCP), United States	WMP, United States
Latitude	(°)		34.2	38.8
Longitude (East)	(°)		260.7	282.4
E/S Maximum Range to SV	(km)		9856.8	10600.8
E/S Minimum Elevation to SV	(°)		34.2	24.2
E/S Altitude	(km)		0.3	0.1
SV Beam Identifier	(#)			24
Minutes Into Pass (Sample #30)	(Min)			14:2
Telco Spot Beam Off-Angle	(°)			0.20
Telco Spot Beam Diameter	(km)			71.80
Maximum Roundtrip Latency	(msec)			136.48
Modulation Parameters			Forward	Return
Enter Receiver	Type			DVB-S2
Modem Overhead	(%)			3.5%
Number of Carriers per Channel	(#)			1
Available Bandwidth	(Hz)			4,920,000
Channel Symbol Rate	(sps)			4,100,000
Channel Modulation Type				QPSK
Channel FEC Rate				0.50
Channel Spectral Efficiency	(bits/Sym)			1.00
Channel Throughput (100% / 100% of Full Rate)	(bps)			3,957,839.07
Uplink			Forward	Return
E/S Tx Channels per HPA	(#)			1
E/S Tx Carrier Frequency	(MHz)			28,709
E/S Tx HPA Power Level	(W)			40
E/S Tx OBO	(dB)			-16.00
E/S Tx Post-HPA Losses	(dB)			-0.77
E/S Tx Antenna Gain (7.3 m / 2.4 m)	(dB)			55.2
E/S Tx EIRP Per Channel	(dBW)			54.48
E/S Tx Radome & Pointing Loss	(dB)			-0.50
E/S Tx RF Link Availability	(%)			99.500
E/S Tx Atmospheric Losses	(dB)			-14.84
E/S Tx Spreading Loss	(dB)			-151.50
Satellite			Forward	Return
SV Number of Channels per HPA	(#)			5
SV Rx G/T	(dB/K)			4.68
SV Rx Power Per Tier	(dBW)			-158.29
SV Rx Flux Density Per Tier	(dBW/m <sup>2</sup> )			-112.35
SV Tx OBO (ALC / ALC)	(dB)			-15.00
SV Tx Post-TWTA Losses	(dB)			-1.50
SV Tx Antenna Gain	(dBi)			31.77
SV Tx EIRP Per Channel/Carrier	(dBW)			26.41
SV Tx Pointing Loss	(dB)			0.00
Downlink			Forward	Return
E/S Rx Carrier Frequency	(MHz)			18,909
E/S Rx Spreading Loss	(dB)			-150.87
E/S Rx RF Link Availability	(%)			75.000
E/S Rx Atmospheric Losses	(dB)			-0.76
E/S Rx Pointing Loss	(dB)			-0.50
E/S Rx Antenna Gain (2.4 m / 7.3 m)	(dBi)			62.24
E/S Rx Effective G/T	(dB/K)			39.16
E/S Rx Power Per Channel	(dBW)			-110.47
E/S Rx Flux Density Per Channel	(dBW/m <sup>2</sup> )			-125.71
Total Link			Forward	Return
Carrier / Noise Bandwidth	(dB)			66.13
Carrier / Noise Uplink	(dB)			4.18
Carrier / Noise Downlink	(dB)			28.93
Carrier / Intermodulation Im (C/Im)	(dB)			26.64
(C/N) - Total Actual	(dB)			3.85
(C/N) - Total Required	(dB)			2.80
(E <sub>b</sub> /N <sub>0</sub> ) - Total Actual	(dB)			3.85
(E <sub>b</sub> /N <sub>0</sub> ) - Total Required	(dB)			2.80
<b>Excess Margin</b>	<b>(dB)</b>			<b>1.05</b>
<b>Fade Margin</b>	<b>(dB)</b>			<b>6.05</b>

**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.

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