ATTACHMENT B
Astro Digital U.S., Inc.
FCC Form 312, Exhibit 43

LINK BUDGETS

Tables B-1 and B-2 summarize the link budgets provided in this attachment. The Landmapper Constellation will change over time as technology improves. We propose to divide the satellites into three groups (Phase 1, Phase 2 and Phase 3). There are two satellite types also contained in the constellation:

- CORVUS-BC: 22m GSD Resolution and 3 Colors
- CORVUS-HD: 2.5m GSD Resolution and 5 Colors

While the amount of data generated per image is different between the two spacecraft types, both systems are data rate limited (i.e., more data is generated by the camera system than can, effectively, be downloaded to the Earth each day). Astro Digital, as a part of its on-going control and operations mission will selectively download image data at the highest "prevailing" Ka-band data rate. Both spacecraft types will use the same telemetry and command equipment. And, we will use the same high-speed Ka-band data transmitter on the –BC and –HD satellites. However, Astro Digital, by design, plans to increase the effective data rate of our Ka-band system on both satellite types in Phases, as device technology improves. While such an approach was not possible to carry out reliably in the past, we have confidence such an approach will work and that the technology we *will* use can be reliably forecast to be available. It is imperative to our business success that we take advantage of these technology improvements.

In summary:

- *Phase 1* of our constellation will consist of satellites launched during the experimental phase of the program (already in progress) to about the end of 2017, into the commercial phase.
- *Phase 2* of our constellation will consist of satellites launched during the timeframe from early 2018 to early 2019.
- *Phase 3* of our constellation will consist of satellite launched during the time frame after early 2019. Ultimately, satellites taken out of service will be replaced with Phase 3 satellites Replacement satellites will be launched carrying Phase 3 Ka-band equipment. Thus, eventually, all satellites will contain transmitters occupying 600 MHz of bandwidth and operating at a symbol rate of 500 Msps.

The characteristics of our Ka-band transmitter are based on the ETSI data standard DVB-S2[1], which has been widely used in the Fixed Satellite and Broadcast Service (FSS/BSS). To the extent supported by software still evolving at Astro Digital we will operate the system at the highest data rate and highest spectral efficiency supported by the available link conditions. To do this we will use two modes supported by DVB-S2, namely: VCM (variable coding and modulation) and ACM (adaptive coding and modulation). The use of VCM implies that the link data rate, modulation and coding are adjusted by a pre-programmed method using an open-loop system. ACM implies that there is a feedback loop from the Earth station to the spacecraft. In ACM mode the Earth station measures the link C/No value on the link and uses this value to determine which modulation (MOD) and coding (COD) [taken together this is referred to as MODCOD] will be selected and the Earth station commands or adjusts the setting of the transmitter to take advantage of the instant conditions of the link.

Tables B-1 and B-2 summarize the link budgets required to demonstrate that the Landmapper system Astro Digital has proposed, will operate over all three program phases and over the full range of MODCOD steps, each of which require a minimum C/No threshold to be achieved. While the MODCOD setting can change with meteorological conditions (for which DVB-S2 was originally designed) the primary adjustments to be made for Landmapper will result from changes in satellite range and elevation angle. These changes are, of course, fundamental to NGSO systems. In this context, like other new EESS operators using DVB-S2, we are breaking new ground by using this advanced modulation and coding standard in NGSO orbits and now at Ka-band.

We note here, while the telemetry and command links are traditional links, which carry appropriate link margins, the DVB-S2 high-speed links are intended to be adaptive and margin has no specific meaning except with respect to the margin compared to the lowest MODCOD level setting (MODCOD Step 1). For DVB-S2 links, where margin is called out, it refers to the *C/No margin with respect to that required to close the link at MODCOD Step 1.*

For each link budget provided for high-speed data at Ka-band we will report the data rate achieved by the link result (MODCOD step achieved) under two link conditions: 1) Clear Sky conditions and 2) Rain and Clouds under 99.5% link availability conditions.

[1] ETSI EN 302 307 V1.2.1 (2009-08)

TABLE B-1: Telemetry & Command Link Budget List:		Worst Case Links - Low Elevation Angle Only (5°)					
Phase 1 through Phase 3		Early 2017 and Beyond					
Link Budget No.:	*Link/Sub-System:*	*Purpose:*	*Elevation Angle:*	*Data Rate:*	*S/C TX Power:*	*Bandwidth:*	Frequency:
B-TC-1	UHF Downlink	Telemetry	5.0 deg.	38.4 kbps	2.0 watts	40.00 kHz	400.175 MHz
B-TC-2	UHF Uplink	Cmd/Camera Cont.	5.0 deg.	38.4 kbps	N/A	40.00 kHz	402.600 MHz
B-TC-3	G* Forward	Cmd/Camera Cont.	5.0 deg.	9.6 kbps	1.0 watts	1.228 MHz	2483.5-2500 MHz
B-TC-4	G* Return	Telemetry	5.0 deg.	9.6 kbps	N/A	1.228 MHz	1616.5-1626.5 MHz
Phase 2	Early 2018						
B-TC-5	UHF Downlink	Telemetry	5.0 deg.	38.4 kbps	4.0 watts	40.00 kHz	400.175 MHz
B-TC-6	S-Band Uplink	Command	5.0 deg.	250 kbps	N/A	300.00 kHz	2025.600 MHz
Phase 3	Early 2019						
B-TC-7	S-band Uplink	Command	5.0 deg.	800 kbps	N/A	1.0 MHz	2025.600 MHz

TABLE B-2: High-Speed Ka-band Data Link Budget List:		Links at Low and High Elevation Angles (5° and 75°)							
Phase 1	Eary 2017*					--------Step 1-----DVB-S2------Step 28 --------			
Link Budget No.:	*Link/Sub-System:*	*Purpose:*	*Elevation Angle:*	*Symbol Rate:*	*Bandwidth:*	*Min. Data Rate:*	*Max. Data Rate:*	*S/C TX Power:*	Frequency:
B-HSD-8	Ka-band TX	Image Data	5.0 deg.	72.00 Msps	86.400 MHz	35.30 Mbps	320.62 Mbps	0.6 watts	26.800 GHz
B-HSD-9	Ka-band TX	Image Data	75.0 deg.	72.00 Msps	86.400 MHz	35.30 Mbps	320.62 Mbps	0.6 watts	26.800 GHz
Phase 2	Early 2018								
B-HSD-10	Ka-band TX	Image Data	5.0 deg.	183.33 Msps	220.000 MHz	89.88 Mbps	816.39 Mbps	2.0 watts	26.800 GHz
B-HSD-11	Ka-band TX	Image Data	75.0 deg.	183.33 Msps	220.000 MHz	89.88 Mbps	816.39 Mbps	2.0 watts	26.800 GHz
B-HSD-12	Ka-band RX	Data Flow Control	5.0 deg.	12.50 Msps	15.000 MHz	6.13 Mbps	55.66 Mbps	N/A	29.950 GHz
B-HSD-13	Ka-band RX	Data Flow Control	75.0 deg.	12.50 Msps	15.000 MHz	6.13 Mbps	55.66 Mbps	N/A	29.950 GHz
Phase 3	Early 2019								
B-HSD-14	Ka-band TX	Image Data	5.0 deg.	500.00 Msps	600.000 MHz	245.12 Mbps	2226.51 Mbps	4.0 watts	26.700 GHz
B-HSD-15	Ka-band TX	Image Data	75.0 deg.	500.00 Msps	600.000 MHz	245.12 Mbps	2226.51 Mbps	4.0 watts	26.700 GHz
B-HSD-16	Ka-band RX	Data Flow Control	5.0 deg.	25.00 Msps	30.000 MHz	12.26 Mbps	111.33 Mbps	N/A	29.950 GHz
B-HSD-17	Ka-band RX	Data Flow Control	75.0 deg.	25.00 Msps	30.000 MHz	12.26 Mbps	111.33 Mbps	N/A	29.950 GHz

Orbit Considerations: The orbit assumed for the link budgets is the worst-case high altitude orbit. In accordance with our Exhibit 43, Description of Application, Table 1, the highest instant orbital altitude for any satellite in the constellation is 648 km, which is the orbit apogee position and is consistent with an orbit mean altitude of 625 km with an eccentricity of 0.0033. The perigee of this same orbit is 602 km. Hence, the condition occurs at the apogee of the highest and most eccentric orbit acceptable in our constellation. Details of the orbit used in these link analyses are given in Figure B-1.

The high-speed links at Ka-band make use of the ITU-R P618-Version 6 Rain Model to calculate losses associated with atmospheric gas absorption, rain attenuation, cloud attenuation and scintillation effects. These are tabulated in the link budgets for the location: Svalbard, Norway (78.23° N, 15.41° E). Two link results, which determine using the C/No for each case, will be presented. The first presents the case for Clear Sky conditions and includes only the atmospheric components of the link excess path loss. The RAIN ON condition reported represents 99.5% link availability scenario at Svalbard. The rain statistical data is taken again from P618-6 and is based on a 25-year global weather model (on a grid size of 0.25° in LAT/LONG).

Orbit Elements and Properties:

Slant Range to Spacecraft vs. Elevation Angle

Parameter:	*Value:*	*Unit:*
Earth Radius:	6,378.17	km
Height of Apogee (ha):	648.000	km
Height of Perigee (hp):	602.000	km
Semi-Major Axis (a):	7,003.166	km
Eccentricity (e):	0.003284	
Inclination (*i*):	97.89	degrees
Argument of Perigee (ω):	90.0	degrees
R.A.A.N. (Ω):	0.0000	degrees
Mean Anomaly (M):	180.00	degrees
Period:	97.207	minutes
dω/dt:	-3.2520	deg./day
dΩ/dt:	0.9857	deg./day
dM/dt:	Not Implemented	deg./day
Worst Case Orbit Altitude:	648.000	km
Worst Case Orbit Radius:	7,026.166	km
Sun-Synchronous Inclination:	97.89	degrees

CMD Uplink Earth Station:

Elevation Angle (δ1):	5.00	degrees
Slant Range (**S1**): (At Mean Orbit Altitude)	2,443.28	km.

TLM Downlink Earth Station:

Elevation Angle (δ2):	5.00	degrees
Slant Range (**S2**): (At Mean Orbit Altitude)	2,443.28	km.

Figure B-1a: Worst Case Orbital Characteristics and Slant Range for 5° Elevation Angle Used in the Link Analysis

Orbit Elements and Properties:

Slant Range to Spacecraft vs. Elevation Angle

Parameter:	*Value:*	*Unit:*
Earth Radius:	6,378.17	km
Height of Apogee (ha):	648.000	km
Height of Perigee (hp):	602.000	km
Semi-Major Axis (a):	7,003.166	km
Eccentricity (e):	0.003284	
Inclination (*i*):	97.89	degrees
Argument of Perigee (ω):	90.0	degrees
R.A.A.N. (Ω):	0.0000	degrees
Mean Anomaly (M):	180.00	degrees
Period:	97.207	minutes
dω/dt:	-3.2520	deg./day
dΩ/dt:	0.9857	deg./day
dM/dt:	Not Implemented	deg./day
Worst Case Orbit Altitude:	648.000	km
Worst Case Orbit Radius:	7,026.166	km
Sun-Synchronous Inclination:	97.89	degrees

CMD Uplink Earth Station:

Elevation Angle (δ1):	75.00	degrees
Slant Range (**S1**): (At Mean Orbit Altitude)	668.65	km.

TLM Downlink Earth Station:

Elevation Angle (δ2):	75.00	degrees
Slant Range (**S2**): (At Mean Orbit Altitude)	668.65	km.

Figure B-1b: Worst Case Orbital Characteristics and Slant Range for 75° Elevation Angles Used in the Link Analysis

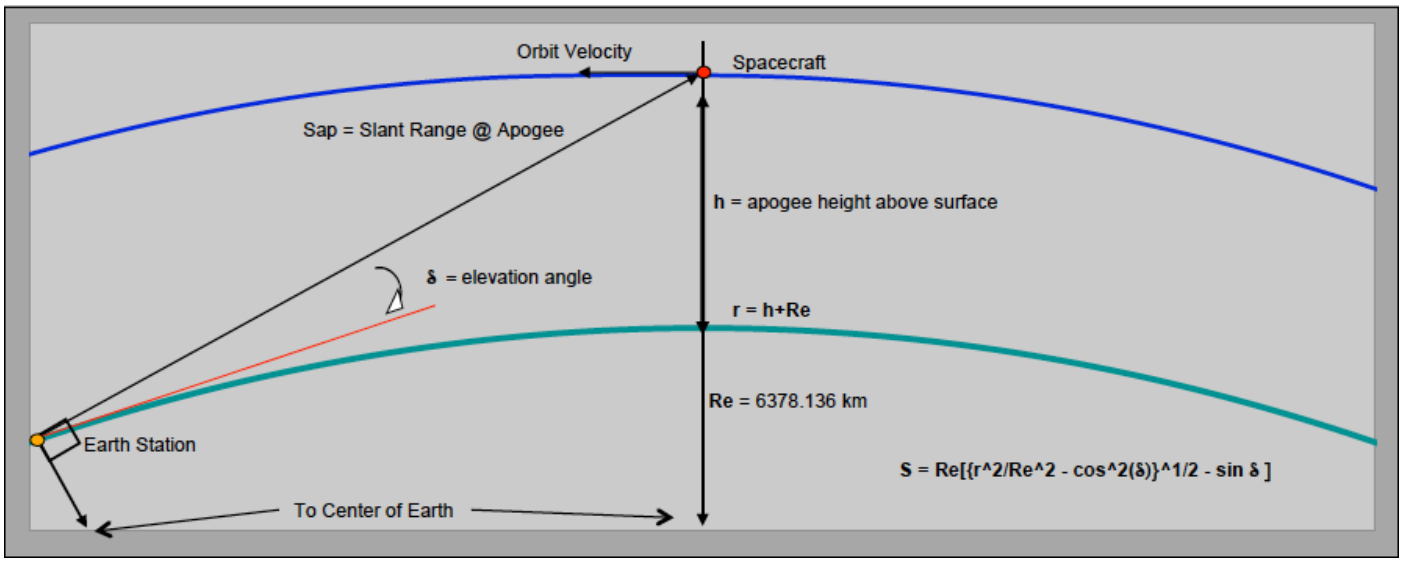

Figure B-1c: Orbit Geometry for Worst-Case Link Analysis

Globalstar Range and Off-Point Angles: The satellite-to-satellite range when Landmapper uses the Globalstar configuration is shown in Figure B-1d. The Landmapper system is situated below Globalstar, which operates at an altitude of 1414 km. The maximum range during times when Landmapper satellites are within the -3 dB beamwidth of one of the 16 Globalstar beams is approximately 1500 km, as can be seen in the figure. Link budget from/to Globalstar were prepared using this maximum range-while-within beam value.

The following link budgets are presented with the Telemetry and Command/Control links given first (Links B-TC-1 through B-TC-7). These are followed by the high-speed Ka-band links (Links B-HSD-8 through B-HSD-17).

A value for Boltzmann's Constant of K = -228.6 dBW/K/Hz is used in the preparation of these link budgets.

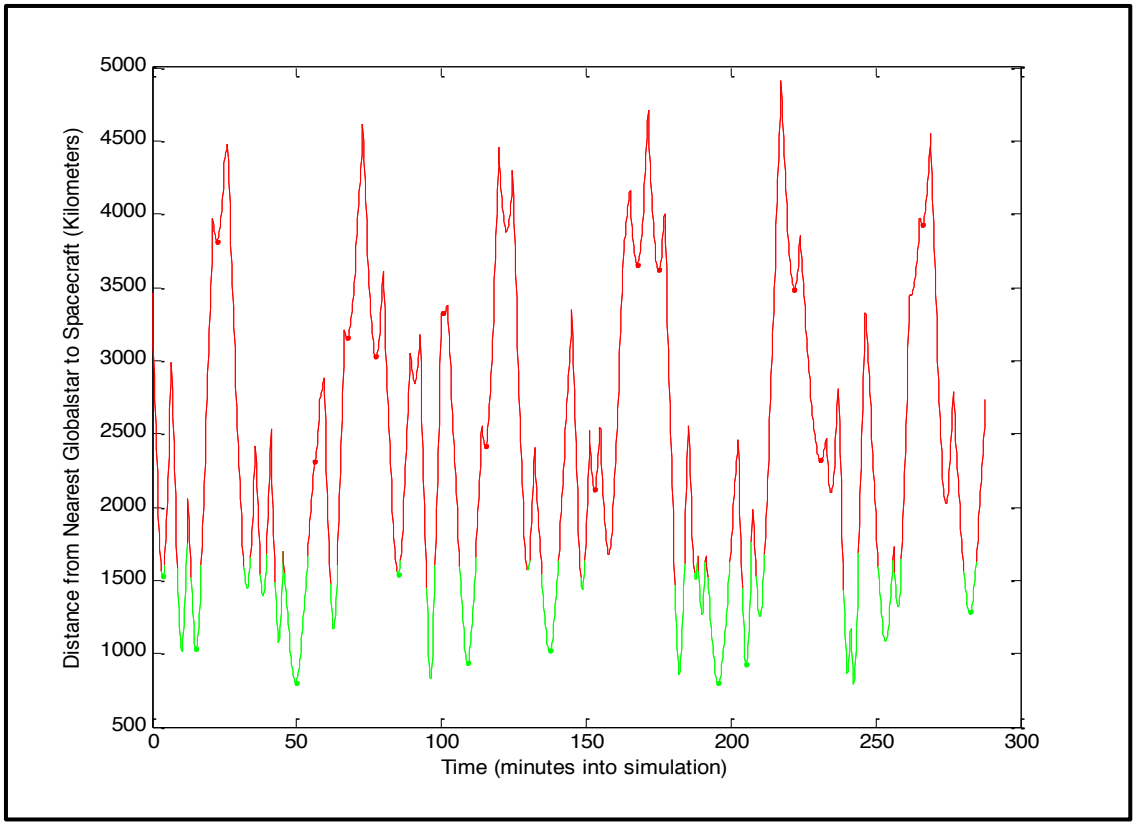

Figure B-1d: Range between Globalstar and Typical Landmapper Satellite [NOTE: Landmapper is within G* beams during times shown in Green]

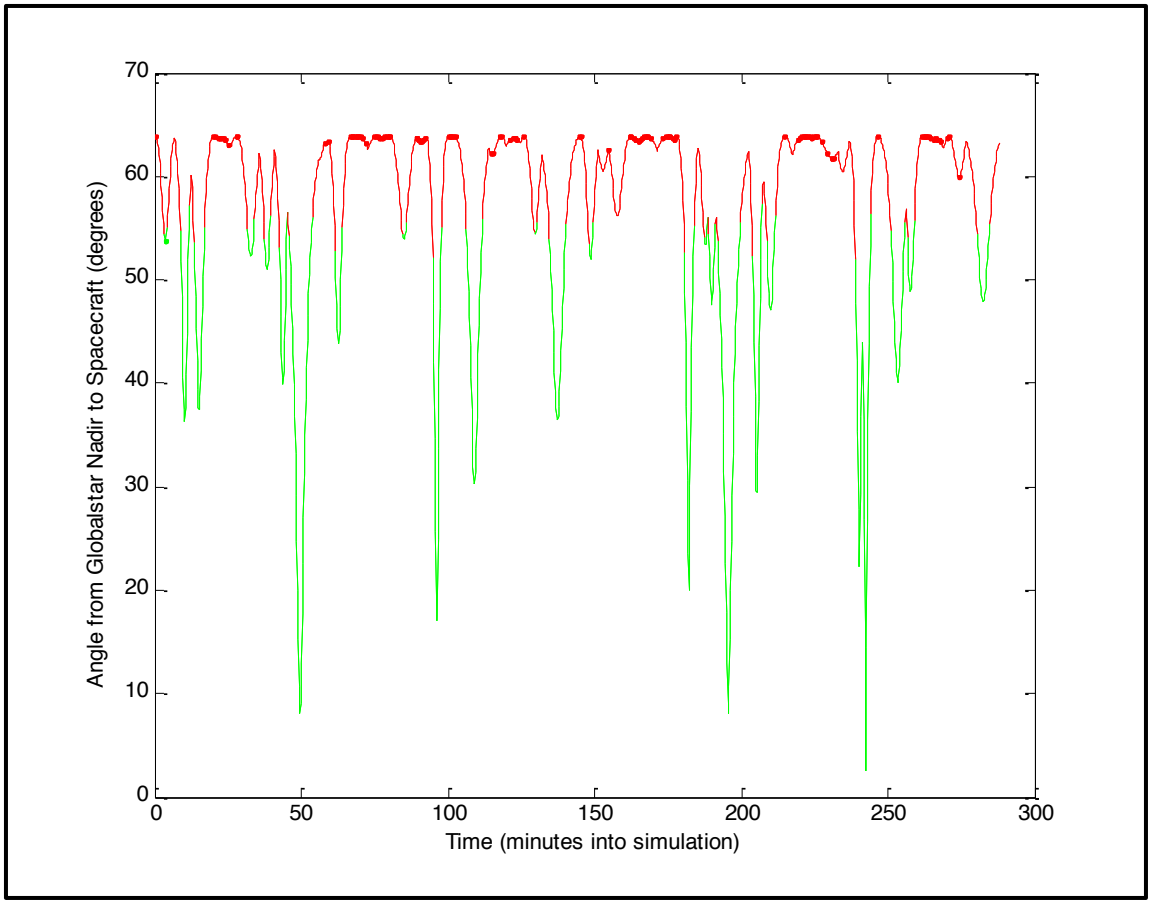

Figure B-1e: Off-NADIR Angle between Globalstar and Typical Landmapper Satellite
[NOTE: Landmapper is within G* beams during times shown in Green]

Link Budget B-TC-1
@ f = 400.175 MHz

Corvus-BC and HD Link Budget B-TC-1
Downlink Telemetry Budget:

Parameter:	*Value:*	*Units:*
Spacecraft:		
Spacecraft Transmitter Power Output:	2.0	watts
In dBW:	3.0	dBW
In dBm:	33.0	dBm
Spacecraft Transmission Line Losses:	-0.3	dB
S/C Connector, Filter or In-Line Switch Losses:	-0.2	dB
Spacecraft Antenna Gain:	0.0	dBiL
Spacecraft EIRP:	2.6	dBW
Downlink Path:		
Spacecraft Antenna Pointing Loss:	-1.0	dB
Antenna Polarization Loss:	-5.0	dB
Path Loss:	-152.5	dB
Atmospheric Loss:	-2.1	dB
Ionospheric Loss:	-0.4	dB
Rain Loss:	0.0	dB
Isotropic Signal Level at Ground Station:	-158.4	dBW
Ground Station:		
------- Eb/No Method -------		
Ground Station Antenna Pointing Loss:	-0.4	dB
Ground Station Radome Loss:	0.0	dB
Ground Station Antenna Gain:	23.5	dBiC
Ground Station Transmission Line Losses:	-1.0	dB
Ground Station LNA Noise Temperature:	100	K
Ground Station Transmission Line Temp.:	290	K
Ground Station Sky Temperature:	275	K
G.S. Transmission Line Coefficient:	0.794	
Ground Station Effective Noise Temperature:	378	K
Ground Station Figure of Merrit (G/T):	-3.3	dB/K
G.S. Signal-to-Noise Power Density (C/No):	66.5	dBHz
System Desired Data Rate:	38400	bps
In dBHz:	45.8	dBHz
Telemetry System Eb/No:	20.7	dB
Telemetry System Required Bit Error Rate:	1.00E-05	
Telemetry System Required Eb/No:	14.8	dB
System Link Margin:	5.9	dB

Link Budget B-TC-2
@ f = 402.600 MHz

Corvus-BC and HD Link Budget B-TC-2
Uplink Command Budget:

Parameter:	*Value:*	*Units:*
Ground Station:		
Command Uplink Transmitter Power Output:	100.0	watts
In dBW:	20.0	dBW
In dBm:	50.0	dBm
Transmission Line Losses:	-2.0	dB
Connector, Filter or In-Line Switch Losses:	-1.0	dB
Antenna Gain:	24.0	dBiC
Ground Station EIRP:	41.0	dBW
Uplink Path:		
Ground Station Antenna Pointing Loss:	-0.4	dB
Ground Station Radome Loss:	0.0	dB
Antenna Polarization Losses:	-5.0	dB
Path Loss:	-152.5	dB
Atmospheric Losses:	-2.1	dB
Ionospheric Losses:	-0.4	dB
Rain Losses:	0.0	dB
Isotropic Signal Level at the Spacecraft:	-119.4	dBW
Spacecraft:		
------- Eb/No Method -------		
Spacecraft Antenna Pointing Loss:	-1.0	dB
Spacecraft Antenna Gain:	0.0	dBiL
Spacecraft Transmission Line Losses:	-0.5	dB
Spacecraft LNA Noise Temperature:	310	K
Spacecraft Transmission Line Temp.:	270	K
Spacecraft Sky Temperature:	290	K
S/C Transmission Line Coefficient:	0.891	
Spacecraft Effective Noise Temperature:	598	K
Spacecraft Figure of Merrit (G/T):	-28.3	dB/K
S/C Signal-to-Noise Power Density (C/No):	79.9	dBHz
System Desired Data Rate:	38400	bps
In dBHz:	45.8	dBHz
Telemetry System Eb/No:	34.1	dB
Telemetry System Required Bit Error Rate:	1.00E-06	
Telemetry System Required Eb/No:	15.9	dB
System Link Margin:	18.2	dB

Link Budget B-TC-3: Globalstar FORWARD Link
@ f = 2491.75 MHz

Rev 5.0	FORWARD - COMMAND	Power Flux Density Calculator & Link Budget from Globalstar to Landmapper	Developed by Jan A. King; Astro Digital CTO

Revised: March 13, 2017

NOTE:

Parameter:	Value:	Unit:							
			TX Power:		TX Ant. Gain:		TX Losses:		
Transmit EIRP for 1 OCDMA Signal:	6.463	watts =	0.170 w	X	16.00 dBi	X	-0.20 dB		
Transmit EIRP for 1 OCDMA Signal (in dB)	8.10	dBW =	38.1	dBm					
Number of CDMA Codes in Use on this G* FDM:	32.00	OCDMA Codes							
Transmit Power (Watts):	5.44	watts							
Transmitter RF/DC Efficiency:	39%	%							
Transmitter Output Back-Off:	-1.0	dB							
Transmitter SSPA Intermodulation (IMR):	15.0	dB							
Transmitter DC Power per 1 FDM:	13.95	watts	Per Current Number of OCDMA Codes in Use in This FDM {Cell [D10]}						
Transmit EIRP: (Max. of 128 CDMAs = 1 FDM):	206.82	watts	This is the Satellite EIRP of ALL OCDMA Signals Currently in Use						
Transmit Station EIRP (in dBW):	23.2	dBW =	53.2	dBm					

GLOBALSTAR SPACECRAFT

Range (Distance from Transmitter to Receiver):	1,500.0	km	Maximum Range while within G* Satellite Beam		
$1/4\pi R^2$	3.53678E-14	=	-134.51	dB/m^2	
Illumination Level (at Receiver):	-111.36	dBW/m^2			
Link Data Rate:	9,600.00	bps			
			=w/R		
Spectral Efficiency:	0.0078125	bps/Hz	128.00	Hz/bit (Spreading Factor)	Using OCDMA
Bandwidth (Chipping Rate):	1,228,800	Hz (or cps)	Reference Bandwidth: (Common ITU Units)		
PFD: (at Receive Station)	-136.23	$dBW/m^2/4kHz$	**in 4 kHz**		
	-172.25	$dBW/m^2/Hz$	**in 1 Hz**		
	-112.25	$dBW/m^2/MHz$	**in 1 MHz**		
	-129.24	$dBW/m^2/20kHz$	**in 20 kHz**		

NOTE:

PFD

FCC Equation for PFD:	-112.26	$dBW/m^2/4kHz$	**in 1 MHz**

Frequency of Transmitter Emission:	2491.75	MHz			
Path Loss at Transmit Frequency:	-163.9	dB			
Globalstar TX Antenna Roll-Off:	-3.0	dB			
Satellite-to-Satellite Polarization Loss:	-0.5	dB			
Isotropic Signal Power at Receive Satellite Stn:	-159.3	dBW =	-129.31	dBm	
Isotropic Signal Power *Density* at Rx Satellite Stn:	-220.2	dBW/Hz =	-190.21	dBm/Hz	

CROSSLINK

Landmapper Receive Antenna Roll-Off:	-3.0	dB			
System Noise Temperature of Receiver:	200	K			
Noise Power in Signal Bandwidth:	-144.7	dBW =	-114.69	dBm	
Isotropic C/N:	-14.6	dB			
Landmapper Satellite Antenna Gain + Losses:	4.5	dBi			
Gnd. Terminal Nominal G/T:	-18.5	dB/K			
OCDMA Processing Gain:	21.1	dB	Gain provided by Correlator at RX = CDMA Advantage		
Net C/N (After Demod & Decorrelator):	8.0	dB			
Required C/N (Eb/No):	5.0	dB	FEC: Viterbi (Convolutional) R=1/2; K=9		
Individual AP Terminal Link Margin:	3.0	dB			

LANDMAPPER SPACECRAFT

Link Budget B-TC-4: Globalstar RETURN Link
@ f = 1622 MHz

Rev 5.0	RETURN -TELEMETRY	Power Flux Density Calculator & Link Budget from Landmapper to Globalstar	Developed by Jan A. King; Astro Digital CTO

Revised: March 11, 2017

NOTE:

Parameter:	Value:	Unit:							
			TX Power:		TX Ant. Gain:		TX Losses:		
Transmit EIRP for 1 OCDMA Signal:	0.432	watts	= 0.17 w	X	4.30 dBi	X	-0.25 dB		
Transmit EIRP for 1 OCDMA Signal (in dB):	-3.6	dBW	= 26.4	dBm					
Number of CDMA Signals from This Satellite:	1	CDMA Channels							
Transmit Power (Watts):	0.17	watts	This is the Access Point RF Power for then number of CDMA Signals in Cell [D10]						
Transmitter RF/DC Efficiency:	30%	%							LANDMAPPER SPACECRAFT
Transmitter Output Back-Off:	-1.0	dB							
Transmitter SSPA Intermodulation (IMR):	24.0	dB							
Transmitter DC Power per 1 FDM:	0.57	watts	Per 128 Users						
Transmit EIRP: (All CDMA Signals from AP):	0.43	watts	This is the Satellite EIRP of 128 OCDMA Signals						
Transmit Station EIRP (in dBW):	-3.6	dBW	= 26.4	dBm					
Range (Distance from Transmitter to Receiver):	1,500.0	km							
$1/4\pi R^2$	3.53678E-14	=	-134.51	dB/m^2					
Illumination Level (at Receiver):	-138.16	dBW/m^2							
Link Data Rate:	9,600.00	bps							
			=w/R						
Spectral Efficiency:	0.0078125	bps/Hz	128.00	Hz/bit (Spreading Factor)			Using OCDMA		PFD
Bandwidth (Chipping Rate):	1,228,800.00	Hz (or cps)		Reference Bandwidth: (Common ITU Units)					
PFD: (at Receive Station)	-163.03	$dBW/m^2/4kHz$		in 4 kHz					
	-199.05	$dBW/m^2/Hz$		in 1 Hz					
NOTE:	-139.05	$dBW/m^2/MHz$		in 1 MHz					
	-156.04	$dBW/m^2/20kHz$		in 20 kHz					
FCC Equation for PFD:	-139.06	$dBW/m^2/4kHz$		in 1 MHz					
Frequency of Transmitter Emission:	1622.00	MHz							
Path Loss at Transmit Frequency:	-160.2	dB							
Landmapper Antenna Pointing Loss	-3.0	dB							CROSSLINK
Satellite-to-Satellite Polarization Loss:	-0.5	dB							
Isotropic Signal Power at Receive Stn:	-167.3	dBW	= -137.33	dBm					
Isotropic Signal Power *Density* at Rx Stn:	-228.2	dBW/Hz	= -198.23	dBm/Hz					
Globalstar Receive Antenna Gain:	-3.0	dB							
System Noise Temperature of Receiver:	350	K							
Noise Power in Signal Bandwidth:	-142.3	dBW	= -112.26	dBm					
Isotropic C/N:	-25.1	dB							
Spacecraft Antenna Gain + Losses:	16.0	dBi							
S/C RX Nominal G/T:	-9.4	dB/K							GLOBALSTAR SPACECRAFT
CDMA Processing Gain:	21.1	dB	Gain provided by Correlator at RX = CDMA Advantage						
Net C/N (After Demod & Decorrelator):	9.0	dB							
Required C/N (Using moderate FEC):	4.8	dB	FEC: Viterbi (Convolutional) R=1/2; K=9						
Individual AP Terminal Link Margin:	4.2	dB							

Link Budget B-TC-5
@ f = 400.175 MHz

Corvus-BC and HD Link Budget B-TC-5
Downlink Telemetry Budget:

Parameter:	*Value:*	*Units:*
Spacecraft:		
Spacecraft Transmitter Power Output:	4.0	watts
In dBW:	6.0	dBW
In dBm:	36.0	dBm
Spacecraft Transmission Line Losses:	-0.3	dB
S/C Connector, Filter or In-Line Switch Losses:	-0.2	dB
Spacecraft Antenna Gain:	0.0	dBiL
Spacecraft EIRP:	5.6	dBW
Downlink Path:		
Spacecraft Antenna Pointing Loss:	-1.0	dB
Antenna Polarization Loss:	-5.0	dB
Path Loss:	-152.5	dB
Atmospheric Loss:	-2.1	dB
Ionospheric Loss:	-0.4	dB
Rain Loss:	0.0	dB
Isotropic Signal Level at Ground Station:	-155.4	dBW
Ground Station:		
------- Eb/No Method -------		
Ground Station Antenna Pointing Loss:	-0.4	dB
Ground Station Radome Loss:	0.0	dB
Ground Station Antenna Gain:	23.5	dBiC
Ground Station Transmission Line Losses:	-1.0	dB
Ground Station LNA Noise Temperature:	100	K
Ground Station Transmission Line Temp.:	290	K
Ground Station Sky Temperature:	275	K
G.S. Transmission Line Coefficient:	0.794	
Ground Station Effective Noise Temperature:	378	K
Ground Station Figure of Merrit (G/T):	-3.3	dB/K
G.S. Signal-to-Noise Power Density (C/No):	69.5	dBHz
System Desired Data Rate:	38400	bps
In dBHz:	45.8	dBHz
Telemetry System Eb/No:	23.7	dB
Telemetry System Required Bit Error Rate:	1.00E-06	
Telemetry System Required Eb/No:	15.9	dB
System Link Margin:	7.8	dB

Link Budget B-TC-6
@ f = 2025.6 MHz

Corvus-BC and HD Link Budget B-TC-6
Uplink Command Budget:

Parameter:	Value:	Units:
Ground Station:		
Command Uplink Transmitter Power Output:	60.0	watts
In dBW:	17.8	dBW
In dBm:	47.8	dBm
Transmission Line Losses:	-3.0	dB
Connector, Filter or In-Line Switch Losses:	-1.0	dB
Antenna Gain 1.5m dish, 55% A.η, 6.9° B.W.:	27.5	dBiC
Ground Station EIRP:	41.3	dBW
Uplink Path:		
Ground Station Antenna Pointing Loss:	-0.4	dB
Ground Station Radome Loss:	0.0	dB
Antenna Polarization Losses:	-0.3	dB
Path Loss:	-166.5	dB
Atmospheric Losses:	-2.1	dB
Ionospheric Losses:	-0.15	dB
Rain Losses:	0.0	dB
Isotropic Signal Level at the Spacecraft:	-128.2	dBW
Spacecraft:		
------- Eb/No Method -------		
Spacecraft Antenna Pointing Loss:	-4.0	dB
Spacecraft Antenna Gain:	6.0	dBiC
Spacecraft Transmission Line Losses:	-0.5	dB
Spacecraft LNA Noise Temperature:	50	K
Spacecraft Transmission Line Temp.:	270	K
Spacecraft Sky Temperature:	250	K
S/C Transmission Line Coefficient:	0.891	
Spacecraft Effective Noise Temperature:	302	K
Spacecraft Figure of Merrit (G/T):	-19.3	dB/K
S/C Signal-to-Noise Power Density (C/No):	77.1	dBHz
System Desired Data Rate:	300,000	bps
In dBHz:	54.8	dBHz
Telemetry System Eb/No:	22.3	dB
Telemetry System Required Bit Error Rate:	1.00E-06	
Telemetry System Required Eb/No:	15.9	dB
System Link Margin:	**6.4**	dB

Link Budget B-TC-7
@ f = 2025.6 MHz

Corvus-BC and HD Link Budget B-TC-7
Uplink Command Budget:

Parameter:	*Value:*	*Units:*
Ground Station:		
Command Uplink Transmitter Power Output:	150.0	watts
In dBW:	21.8	dBW
In dBm:	51.8	dBm
Transmission Line Losses:	-3.0	dB
Connector, Filter or In-Line Switch Losses:	-1.0	dB
Antenna Gain 1.5m dish, 55% A.η, 6.9° B.W.:	27.5	dBiC
Ground Station EIRP:	45.3	dBW
Uplink Path:		
Ground Station Antenna Pointing Loss:	-0.4	dB
Ground Station Radome Loss:	0.0	dB
Antenna Polarization Losses:	-0.3	dB
Path Loss:	-166.5	dB
Atmospheric Losses:	-2.1	dB
Ionospheric Losses:	-0.15	dB
Rain Losses:	0.0	dB
Isotropic Signal Level at the Spacecraft:	-124.2	dBW
Spacecraft:		
------- Eb/No Method -------		
Spacecraft Antenna Pointing Loss:	-4.0	dB
Spacecraft Antenna Gain:	6.0	dBiC
Spacecraft Transmission Line Losses:	-0.5	dB
Spacecraft LNA Noise Temperature:	50	K
Spacecraft Transmission Line Temp.:	270	K
Spacecraft Sky Temperature:	250	K
S/C Transmission Line Coefficient:	0.891	
Spacecraft Effective Noise Temperature:	302	K
Spacecraft Figure of Merrit (G/T):	-19.3	dB/K
S/C Signal-to-Noise Power Density (C/No):	81.1	dBHz
System Desired Data Rate:	800,000	bps
In dBHz:	59.0	dBHz
Telemetry System Eb/No:	22.0	dB
Telemetry System Required Bit Error Rate:	1.00E-06	
Telemetry System Required Eb/No:	15.9	dB
System Link Margin:	**6.1**	dB

Link Budgets B-HSD-8
@ f = 26.800 GHz

High Speed Data Downlink Budget: B-HSD-8 *At:* **Svalbard, Norway**

Parameter:	*Value:*	*Units:*	
Spacecraft Total HPA Power Allocated per User Channel:	0.6	watts	
In dBW:	-2.22	dBW	
In dBm:	27.78	dBm	
Spacecraft Transmitted IM Power:	0.005	watts	IMR Sholders (IMR) = 24 dBc
Spacecraft Total HPA Power Allocated per User Channel:	0.595	watts	
Spacecraft Transmission Line Losses:	-0.1	dB	
S/C Connector, Filter and In-Line Switch Losses:	0.0	dB	
Spacecraft Transmit Antenna Gain:	23.5	dBiC	----- Using Lens-Aided Horn at 26.8 GHz ----------> S/C Antenna Requirements
Spacecraft EIRP per User:	21.23	dBW	
Spacecraft Transmit Antenna Pointing Loss:	-0.50	dB	1.0° S/C Pointing Error Budget
Downlink Path:			
Antenna Polarization Loss:	-0.5	dB	A.R. Gnd = 2.0 dB; A.R. S/C = 1.0 dB; 90°
Path Loss:	-188.8	dB	648 km S/C height; 2,443.28 km range; 5.0° Elev. Angle
Atm. Gaseous Attenuation (1, 2)	-5.45	dB	
Rain Attenuation:	-2.94	dB	
Cloud Attenuation:	-2.78	dB	From ITU P618-6 Rain Model
Scintillation:	-2.13	dB	
Atmospheric Gases +Scintillation (Without Rain or Clouds):	-5.83	dB	Svalbard, NO Site (78.23N; 15.41E); 5.0 Elevation Angle
Total Meteorological Losses (Including Rain + Clouds):	-9.80	dB	
Isotropic Signal Level at Ground Station (Gas+Scintillation) :	-174.4	dBW	
Isotropic Signal Level at Ground Station with All Met .Losses:	-178.4	dBW	
Ground Station:			
Ground Station Antenna Pointing Loss:	-0.40	dB	2.8 m Ø; 0.05° GS Pointing Error
Ground Station Radome Loss:	0.0	dB	No Radome for first year
Ground Station Antenna Gain:	55.3	dBiC	2.8 m Ø; 55% η; 26.8 GHz; 0.28° BW
Ground Station Transmission Line Losses:	-0.1	dB	
Ground Station Filter and/or Switch Losses:	0.0	dB	
Ground Station LNA Noise Temperature:	125.0	K	Consistent with G/T Value
Ground Station Transmission Line Temp.:	290.0	K	
Ground Station Sky Temperature:	45.0	K	
Ground Station Sky Temperature faded:	234.7	K	From ITU P618-6 Rain Model
G.S. Transmission Line Coefficient:	0.7762		
Ground Station Effective Noise Temperature:	225.0	K	
Ground Station Effective Noise Temperature faded:	372.0	K	
Ground Station Figure of Merrit (G/T):	30.7	dB/K	
Ground Station Figure of Merrit (G/T) faded:	28.5	dBi/K	
G.S. Signal-to-Noise Power Density (clear sky); $(C/No)_{clear\ sky}$ =	84.7	dBHz	
G.S. Signal-to-Noise Power Density (w. rain+scintillation $(C/No)_{faded}$ =	78.5	dBHz	
Transmitter Intermodulation Ratio (C/IM or IMR):	24.0	dB	Approx. 1 dB OPBP; 4.8% TX Efficiency
G.S. Intermodulation Power Density (C/Io)	103.4	dBHz	
G.S. C/ (No+Io):	84.6	dBHz	
G.S. C/ (No+Io) [faded: with rain & scintillation):	78.5	dBHz	Compare to DVB-S2 ModCod List
Single User Signal Bandwidth:	86.4	MHz	
Single User Symbol Rate:	72.00	Msps	
G.S. C/(N+I) in User Terminal Bandwidth [clear sky]:	5.2	dB	
G.S. C/(N+I) in User Terminal Bandwidth [w. rain+scintillation]:	-0.9	dB	

Horn Antenna

Antenna Size:	76 Φ x 60	mm conical
Aper.η:	≈ 75	%
Freq:	26.8	GHz
Gain:	23.5	dBi
Beamwidth:	10.2	degrees
Polarizaton:	RHCP	

Link Budgets B-HSD-8 and B-HSD-9
@ f = 26.800 GHz (Page 2)

DVB-S2 Link Results Summary (What Was Achieved?)

Adaptive MODCOD

Symbol Rate Achieved:	72.00	Msps		
Adaptive Modulation Achieved:	QPSK		Signal Strength Within MODEM Range	MODCOD Results
Adaptive Coding Achieved:	2/5			
			TLM Downlink Stn. Elev.Angle :	Worst Case Link
Data Rate Achieved (@ Elev. Angle):	56.84	Mbps	5.0 deg.	
Rain Rate mm/Hr A.01:	9.22	mm/hr	Rain Model Results	
ITU P618-6 Downlink Fade (all sources):	9.80	dB		
Achieved Spectral Efficiency:	0.7890	Info. Bits/Symbol		
Transmitter Output Backoff :	1.00	dB	IMR: 24.0 dBc	Transmit η: 4.8%
Achieved TLM Downlink C/No:	78.49	dBHz	2.26 dB = Margin Above Threshold	
	Faded w. Rain & Clouds; 99.5% Link Avail.			

Adaptive Data Rate Results vs. Elevation Angle

B-HSD-8	Clear Sky Conditions:	*Units:*	99.5% Availabilty Conditions:	*Units:*
Elevation Angle:	5.00	deg.	5.00	deg.
Slant Range to S/C:	2443.28	km	2443.28	km
Path Loss:	-188.8	dB	-188.8	dB
Excess Path Loss (Meteorolgical Losses):	-5.83	dB	-9.80	dB
Effective Sky Temp.	45.0	K	234.7	K
C/No Achieved:	84.6	dBHz	78.5	dBHz
Sprectral Rate Achieved:	1.78	b/sym	0.789	b/sym
Adaptive Modulation Used:	8PSK		QPSK	
Adaptive Coding Used:	3/5		2/5	
Achieved Bit Rate (Using DVB-S2):	128.15	Mbps	56.84	Mbps

B-HSD-9				
Elevation Angle:	75.00	deg.	75.00	deg.
Slant Range to S/C:	668.65	km	668.65	km
Path Loss:	-177.5	dB	-177.5	dB
Excess Path Loss (Meteorolgical Losses):	-0.43	dB	-1	dB
Effective Sky Temp.	45.0	K	54.0	K
C/No Achieved:	99.2	dBHz	98.8	dBHz
Sprectral Rate Achieved:	4.453	b/sym	4.453	b/sym
Adaptive Modulation Used:	32APSK		32APSK	
Adaptive Coding Used:	9/10		9/10	
Achieved Bit Rate (Using DVB-S2):	320.62	Mbps	320.62	Mbps

DVB-S2 Modulation and Coding Table for Symbol Rate = 72 Msps
For B-HSD-8 Downlink (Page 3)

Specified Bandwidth in MHz (Per Channel)	86.40	Specify Nyquist rolloff	0.2

ETSI EN 302307 DVB S2 Theoretical Performance for Target ModCOD

MODulation	CODing Rate	Es/No	Sym rate	BW (nyq)	C/No	C/N	Spectral Efficiency	Bits/ symbol	Data Rate	Ebi/No	Eb/No	Gross Bit Rate	Info bits	code bits	"overhead"	
		dB	Msym/sec	MHz	dBHz	dB	info bit/symbol		Mbps	dB	dB	Mbit/sec	Mbit/sec	Mbit/Sec		
QPSK	1/4	-2.35	72.00	86.40	76.22	-3.14	0.490243	2	35.2975	0.746	-5.360	144.00	36.00	108.00	1.951%	99.5% Link Avail.
QPSK	1/3	-1.24	72.00	86.40	77.33	-2.03	0.656448	2	47.2643	0.588	-4.250	144.00	48.00	96.00	1.533%	@ 5° Elev. Angle
QPSK	2/5	-0.3	72.00	86.40	78.27	-1.09	0.789412	2	56.8377	0.727	-3.310	144.00	57.60	86.40	1.324%	
QPSK	1/2	1.00	72.00	86.40	79.57	0.21	0.988858	2	71.1978	1.049	-2.010	144.00	72.00	72.00	1.114%	
QPSK	3/5	2.23	72.00	86.40	80.80	1.44	1.188304	2	85.5579	1.481	-0.780	144.00	86.40	57.60	0.975%	
QPSK	2/3	3.10	72.00	86.40	81.67	2.31	1.322253	2	95.2022	1.887	0.090	144.00	96.00	48.00	0.831%	
QPSK	3/4	4.03	72.00	86.40	82.60	3.24	1.487473	2	107.0981	2.306	1.020	144.00	108.00	36.00	0.835%	
QPSK	4/5	4.68	72.00	86.40	83.25	3.89	1.587196	2	114.2781	2.674	1.670	144.00	115.20	28.80	0.800%	
QPSK	5/6	5.18	72.00	86.40	83.75	4.39	1.654663	2	119.1357	2.993	2.170	144.00	120.00	24.00	0.720%	Clear Sky Condx.
8PSK	3/5	5.50	72.00	86.40	84.07	4.71	1.779910	2	128.1535	2.996	0.729	550.00	330.00	220.00	61.166%	@ 5° Elev. Angle
QPSK	8/9	6.20	72.00	86.40	84.77	5.41	1.766451	2	127.1845	3.729	3.190	144.00	128.00	16.00	0.637%	
QPSK	9/10	6.42	72.00	86.40	84.99	5.63	1.788612	2	128.7801	3.895	3.410	144.00	129.60	14.40	0.633%	
8PSK	2/3	6.62	72.00	86.40	85.19	5.83	1.980636	3	142.6058	3.652	1.849	216.00	144.00	72.00	0.968%	
8PSK	3/4	7.91	72.00	86.40	86.48	7.12	2.228124	3	160.4249	4.431	3.139	216.00	162.00	54.00	0.972%	
16APSK	2/3	8.97	72.00	86.40	87.54	8.18	2.637201	4	189.8785	4.759	2.949	288.00	192.00	96.00	1.10%	
8PSK	5/6	9.35	72.00	86.40	87.92	8.56	2.478562	3	178.4565	5.408	4.579	216.00	180.00	36.00	0.858%	
16APSK	3/4	10.21	72.00	86.40	88.78	9.42	2.966728	4	213.6044	5.487	4.189	288.00	216.00	72.00	1.11%	
8PSK	8/9	10.69	72.00	86.40	89.26	9.90	2.646012	3	190.5129	6.464	5.919	216.00	192.00	24.00	0.77%	
8PSK	9/10	10.98	72.00	86.40	89.55	10.19	2.679207	3	192.9029	6.700	6.209	216.00	194.40	21.60	0.77%	
16APSK	4/5	11.03	72.00	86.40	89.60	10.24	3.165623	4	227.9249	6.025	5.009	288.00	230.40	57.60	1.07%	
16APSK	5/6	11.61	72.00	86.40	90.18	10.82	3.300184	4	237.6132	6.425	5.589	288.00	240.00	48.00	0.99%	
32APSK	3/4	12.73	72.00	86.40	91.30	11.94	3.703295	5	266.6372	7.044	5.740	360.00	270.00	90.00	1.25%	
16APSK	8/9	12.89	72.00	86.40	91.46	12.10	3.523143	4	253.6663	7.421	6.869	288.00	256.00	32.00	0.91%	
16APSK	9/10	13.13	72.00	86.40	91.70	12.34	3.567342	4	256.8486	7.607	7.109	288.00	259.20	28.80	0.91%	
32APSK	4/5	13.64	72.00	86.40	92.21	12.85	3.951571	5	284.5131	7.672	6.650	360.00	288.00	72.00	1.21%	
32APSK	5/6	14.28	72.00	86.40	92.85	13.49	4.119540	5	296.6069	8.132	7.290	360.00	300.00	60.00	1.13%	
32APSK	8/9	15.69	72.00	86.40	94.26	14.90	4.397854	5	316.6455	9.258	8.700	360.00	320.00	40.00	1.05%	
32APSK	9/10	16.05	72.00	86.40	94.62	15.26	4.453207	5	320.6309	9.563	9.060	360.00	324.00	36.00	1.04%	

Link Budget B-HSD-10
@ f = 26.800 GHz

High Speed Data Downlink Budget: B-HSD-10 & -11 *At:* **Svalbard, Norway**

Parameter:	*Value:*	*Units:*	
Spacecraft Total HPA Power Allocated per User Channel:	2.0	watts	
In dBW:	3.01	dBW	
In dBm:	33.01	dBm	
Spacecraft Transmitted IM Power:	0.006	watts	IMR Sholders (IMR) = 24 dBc
Spacecraft Total HPA Power Allocated per User Channel:	1.994	watts	
Spacecraft Transmission Line Losses:	-0.1	dB	
S/C Connector, Filter and In-Line Switch Losses:	-0.7	dB	
Spacecraft Transmit Antenna Gain:	23.5	dBiC	----- Using Lens-Aided Horn at 26.8 GHz ----------> S/C Antenna Requirements
Spacecraft EIRP per User:	25.81	dBW	
Spacecraft Transmit Antenna Pointing Loss:	-0.50	dB	1.0° S/C Pointing Error Budget
Downlink Path:			
Antenna Polarization Loss:	-0.5	dB	A.R. Gnd = 2.0 dB; A.R. S/C = 1.0 dB; 90°
Path Loss:	-188.8	dB	800 km S/C height; 1395.16.0 km range; 30.0° Elev. Angle
Atm. Gaseous Attenuation (1, 2)	-5.45	dB	
Rain Attenuation:	-3.73	dB	
Cloud Attenuation:	-2.78	dB	From ITU P618-6 Rain Model
Scintillation:	-2.13	dB	
Atmospheric Gases +Scintillation (Without Rain or Clouds):	-5.83	dB	Customer Selected Site (10N; 100E); 5.0 Elevation Angle
Total Meteorological Losses (Including Rain + Clouds):	-10.55	dB	
Isotropic Signal Level at Ground Station (Gas+Scintillation) :	-169.8	dBW	
Isotropic Signal Level at Ground Station with All Met .Losses:	-174.5	dBW	
Ground Station:			
Ground Station Antenna Pointing Loss:	-0.40	dB	2.8 m Ø; 0.05° GS Pointing Error
Ground Station Radome Loss:	0.0	dB	No Radome for first year
Ground Station Antenna Gain:	55.3	dBiC	2.8 m Ø; 55% η; 26.8 GHz; 0.28° BW
Ground Station Transmission Line Losses:	-0.3	dB	
Ground Station Filter and/or Switch Losses:	0.0	dB	
Ground Station LNA Noise Temperature:	210.0	K	Conservative Estimate
Ground Station Transmission Line Temp.:	290.0	K	
Ground Station Sky Temperature:	45.0	K	
Ground Station Sky Temperature faded:	239.1	K	From ITU P618-6 Rain Model
G.S. Transmission Line Coefficient:	0.9333		
Ground Station Effective Noise Temperature:	271.0	K	
Ground Station Effective Noise Temperature faded:	452.0	K	
Ground Station Figure of Merrit (G/T):	30.7	dB/K	
Ground Station Figure of Merrit (G/T) faded:	28.5	dBi/K	
G.S. Signal-to-Noise Power Density (clear sky); $(C/No)_{clear\ sky}$ =	89.1	dBHz	
G.S. Signal-to-Noise Power Density (w. rain+scintillatio $(C/No)_{faded}$ =	82.1	dBHz	
Transmitter Intermodulation Ratio (C/IM or IMR):	24.0	dB	2.0 dB OPBO; 20% PAE SSPA Efficiency
G.S. Intermodulation Power Density (C/Io)	107.4	dBHz	
G.S. C/ (No+Io):	89.0	dBHz	
G.S. C/ (No+Io) [faded: with rain & scintillation):	82.1	dBHz	Compare to DVB-S2 ModCod List
Single User Signal Bandwidth:	220.0	MHz	
Single User Symbol Rate:	183.33	Msps	
G.S. C/(N+I) in User Terminal Bandwidth [clear sky]:	5.6	dB	
G.S. C/(N+I) in User Terminal Bandwidth [w. rain+scintillation]:	-1.3	dB	

Horn Antenna

Antenna Size:	76 Φ x 60	mm conical
Aper.η:	≈ 75	%
Freq:	26.8	GHz
Gain:	23.5	dBi
Beamwidth:	10.2	degrees
Polarizaton:	RHCP	

Link Budgets B-HSD-10 and B-HSD-11
@ f = 26.800 GHz (Page 2)

DVB-S2 Downlink Results Summary (What Was Achieved?)

Adaptive MODCOD

Symbol Rate Achieved:	183.33	Msps
Adaptive Modulation Achieved:	QPSK	
Adaptive Coding Achieved:	1/3	
Data Rate Achieved (@ Elev. Angle):	120.35	Mbps
Rain Rate mm/Hr A.01:	12.53	mm/hr
ITU P618-6 Downlink Fade (all sources):	10.55	dB
Achieved Spectral Efficiency:	0.6560	Info. Bits/Symbol
Transmitter Output Backoff :	0.00	dB
Achieved TLM Downlink C/No:	82.12	dBHz
	Faded w. Rain & Clouds; 99.5% Link Avail.	

Signal Strength Within MODEM Range

MODCOD Results

Worst Case Link

TLM Downlink Stn. Elev.Angle : 5.0 deg.

Rain Model Results

IMR: 24.0 dBc

Transmit η: 20.0%

15.22 dB = Margin Above Threshold

Adaptive Data Rate Results vs. Elevation Angle

B-HSD-10	Clear Sky Conditions:	*Units:*	99.5% Availabilty Conditions:	*Units:*
Elevation Angle:	5.00	deg.	5.00	deg.
Slant Range to S/C:	2443.28	km	2443.28	km
Path Loss:	-188.8	dB	-188.8	dB
Excess Path Loss (Meteorolgical Losses):	-5.83	dB	-10.55	dB
Effective Sky Temp.	45.0	K	239.1	K
C/No Achieved:	89.0	dBHz	82.1	dBHz
Sprectral Rate Achieved:	1.766	b/sym	0.659	b/sym
Adaptive Modulation Used:	QPSK		QPSK	
Adaptive Coding Used:	8/9		1/3	
Achieved Bit Rate (Using DVB-S2):	323.85	Mbps	120.35	Mbps

B-HSD-11				
Elevation Angle:	75.00	deg.	75.00	deg.
Slant Range to S/C:	668.65	km	668.65	km
Path Loss:	-177.5	dB	-177.5	dB
Excess Path Loss (Meteorolgical Losses):	-0.43	dB	-1.16	dB
Effective Sky Temp.	45.0	K	61.5	K
C/No Achieved:	103.5	dBHz	102.9	dBHz
Sprectral Rate Achieved:	4.453	b/sym	4.453	b/sym
Adaptive Modulation Used:	32APSK		32APSK	
Adaptive Coding Used:	9/10		9/10	
Achieved Bit Rate (Using DVB-S2):	816.39	Mbps	816.39	Mbps

DVB-S2 Modulation and Coding Table for Symbol Rate = 220 Msps
For B-HSD-10 Downlink (Page 3)

Specified Bandwidth in MHz (Per Channel)	220.00	Specify Nyquist rolloff	0.2

ETSI EN 302307 DVB S2 Theoretical Performance for Target ModCOD

MODulation	CODing Rate	Es/No	Sym rate	BW (nyq)	C/No	C/N	Spectral Efficiency	Bits/ symbol	Data Rate	Ebi/No	Eb/No	Gross Bit Rate	Info bits	code bits	"overhead"	
		dB	Msym/sec	MHz	dBHz	dB	info bit/symbol		Mbps	dB	dB	Mbit/sec	Mbit/sec	Mbit/Sec		
QPSK	1/4	-2.35	183.33	220.00	80.28	-3.14	0.490243	2	89.8779	0.746	-5.360	366.67	91.67	275.00	1.951%	99.5% Link Avail.
QPSK	1/3	-1.24	183.33	220.00	81.39	-2.03	0.656448	2	120.3488	0.588	-4.250	366.67	122.22	244.44	1.533%	@ 5° Elev. Angle
QPSK	2/5	-0.3	183.33	220.00	82.33	-1.09	0.789412	2	144.7255	0.727	-3.310	366.67	146.67	220.00	1.324%	
QPSK	1/2	1.00	183.33	220.00	83.63	0.21	0.988858	2	181.2906	1.049	-2.010	366.67	183.33	183.33	1.114%	
QPSK	3/5	2.23	183.33	220.00	84.86	1.44	1.188304	2	217.8557	1.481	-0.780	366.67	220.00	146.67	0.975%	
QPSK	2/3	3.10	183.33	220.00	85.73	2.31	1.322253	2	242.4131	1.887	0.090	366.67	244.44	122.22	0.831%	
QPSK	3/4	4.03	183.33	220.00	86.66	3.24	1.487473	2	272.7034	2.306	1.020	366.67	275.00	91.67	0.835%	
QPSK	4/5	4.68	183.33	220.00	87.31	3.89	1.587196	2	290.9859	2.674	1.670	366.67	293.33	73.33	0.800%	
QPSK	5/6	5.18	183.33	220.00	87.81	4.39	1.654663	2	303.3549	2.993	2.170	366.67	305.56	61.11	0.720%	
8PSK	3/5	5.50	183.33	220.00	88.13	4.71	1.779910	2	326.3168	2.996	0.729	550.00	330.00	220.00	1.116%	Clear Sky Condx.
QPSK	8/9	6.20	183.33	220.00	88.83	5.41	1.766451	2	323.8494	3.729	3.190	366.67	325.93	40.74	0.637%	@ 5° Elev. Angle
QPSK	9/10	6.42	183.33	220.00	89.05	5.63	1.788612	2	327.9122	3.895	3.410	366.67	330.00	36.67	0.633%	
8PSK	2/3	6.62	183.33	220.00	89.25	5.83	1.980636	3	363.1166	3.652	1.849	550.00	366.67	183.33	0.968%	
8PSK	3/4	7.91	183.33	220.00	90.54	7.12	2.228124	3	408.4894	4.431	3.139	550.00	412.50	137.50	0.972%	
16APSK	2/3	8.97	183.33	220.00	91.60	8.18	2.637201	4	483.4869	4.759	2.949	733.33	488.89	244.44	1.10%	
8PSK	5/6	9.35	183.33	220.00	91.98	8.56	2.478562	3	454.4030	5.408	4.579	550.00	458.33	91.67	0.858%	
16APSK	3/4	10.21	183.33	220.00	92.84	9.42	2.966728	4	543.9001	5.487	4.189	733.33	550.00	183.33	1.11%	
8PSK	8/9	10.69	183.33	220.00	93.32	9.90	2.646012	3	485.1022	6.464	5.919	550.00	488.89	61.11	0.77%	
8PSK	9/10	10.98	183.33	220.00	93.61	10.19	2.679207	3	491.1880	6.700	6.209	550.00	495.00	55.00	0.77%	
16APSK	4/5	11.03	183.33	220.00	93.66	10.24	3.165623	4	580.3642	6.025	5.009	733.33	586.67	146.67	1.07%	
16APSK	5/6	11.61	183.33	220.00	94.24	10.82	3.300184	4	605.0337	6.425	5.589	733.33	611.11	122.22	0.99%	
32APSK	3/4	12.73	183.33	220.00	95.36	11.94	3.703295	5	678.9374	7.044	5.740	916.67	687.50	229.17	1.25%	
16APSK	8/9	12.89	183.33	220.00	95.52	12.10	3.523143	4	645.9096	7.421	6.869	733.33	651.85	81.48	0.91%	
16APSK	9/10	13.13	183.33	220.00	95.76	12.34	3.567342	4	654.0127	7.607	7.109	733.33	660.00	73.33	0.91%	
32APSK	4/5	13.64	183.33	220.00	96.27	12.85	3.951571	5	724.4547	7.672	6.650	916.67	733.33	183.33	1.21%	
32APSK	5/6	14.28	183.33	220.00	96.91	13.49	4.119540	5	755.2490	8.132	7.290	916.67	763.89	152.78	1.13%	
32APSK	8/9	15.69	183.33	220.00	98.32	14.90	4.397854	5	806.2732	9.258	8.700	916.67	814.81	101.85	1.05%	
32APSK	9/10	16.05	183.33	220.00	98.68	15.26	4.453027	5	816.3883	9.563	9.060	916.67	825.00	91.67	1.04%	

Link Budget B-HSD-12
@ f = 29.950 GHz

Corvus-BC & -HD: B-HSD-12 and B-HSD-13

Uplink High Speed Data Receiver Budget:

Parameter:		Value:	Units:
Ground Station:			
User Uplink Transmitter Power Output:		10.0	watts
	In dBW:	10.0	dBW
	In dBm:	40.0	dBm
CMD TX Transmission Line Losses:		-1.5	dB
Connector, Filter or In-Line Switch Losses:		-1.0	dB
Ground Station Command Antenna Gain:		56.3	dBiC
Ground Station EIRP:		63.8	dBW
Ground Station Antenna Pointing Loss:		-0.5	dB
Uplink Path:			
Antenna Polarization Losses:		**-0.06**	dB
Path Loss:		-189.8	dB
Atm. Gaseous Attenuation **(1, 2)**		-3.36	dB
Rain Attenuation		-3.56	dB
Cloud Attenuation		-3.42	dB
Scintillation		-2.26	dB
Atmospheric Gases +Scintillation (Without Rain or Clouds):		**-5.62**	dB
Total Meteorological Losses (Including Rain + Clouds):		**-11.65**	
Isotropic Signal Level at Ground Station (Gas+Scintillation) :		-136.1	dBW
Isotropic Signal Level at Ground Station with All Met .Losses:		-142.2	dBW
Spacecraft:			
Spacecraft Rcvr Antenna Pointing Loss:		-0.6	dB
Spacecraft Rcvr Antenna Gain:		15.0	dBiC
Spacecraft Transmission Line Losses:		-0.1	dB
Spacecraft Input Filter Insertion Loss:		-0.8	dB
Spacecraft LNA Noise Temperature:		220	K
Spacecraft Transmission Line Temp.:		270	K
Spacecraft Sky Temperature:		250	K
S/C Transmission Line Coefficient:		0.8222	
Spacecraft Effective Noise Temperature:		474	K
Spacecraft Figure of Merit (G/T):		-12.6	dB/K
S/C Signal-to-Noise Power Density (C/No) [clear sky]:		83.24	dBHz
S/C Signal-to-Noise Power Density (C/No) [All Met. Losses]:		77.21	dBHz
Receiver IF Bandwidth:		15.000	MHz
Receiver Uplink Input Noise Power		-130.1	dBW
Command Signal Uplink C/N in Rcvr Bandwidth [Clear Sky]:		11.48	dB
Command Signal Uplink C/N in Rcvr BW [w. All Met. Losses]:		5.45	
Receiver Uplink Interference Signal Density (Io):		**-260.0**	dBW/Hz
Received Uplink Total Interference Power (I):		-174.7	dBW
Receiver Uplink C/I (Power Ratio):		42.5	dB
Receiver Total Uplink Noise Power (N+I):		-130.1	dBW
Command Signal C(N+I) in Rcvr Bandwidth [Clear Sky]:		11.47	dB
Command Signal C(N+I) in Rcvr Bandwidth [w. All Met. Losses]:		5.44	
Demod Matched Filter Bandwidth:		12.5	MHz
Uplink CMD Signal C/(N+I) [Clear Sky]:		12.26	dB
Uplink CMD Signal C/(N+I) [All Meteorological Losses]:		6.24	dB
Uplink CMD Signal C/(No+Io) in Demod Filter BW [Clear Sky]:		83.23	dBHz
Uplink CMD Signal C/(No+Io) in Demod Filter Bandwidth:		77.21	dBHz
Uplink CMD Eb/No [Clear Sky]:		12.26	dB
Uplink CMD Eb/No [with All Meteorological Losses Included]:		6.24	dB
Implementation Loss of Spacecraft DVB-S2 Demodulator:		**0.5**	dB
Net Eb/No Achieved [Clear Sky]:		11.76	dB
Net Eb/No Achieved [with All Meteorological Losses Included]:		5.74	dB
Required Eb/No for 10E-7 PER:		-3.14	dB
Cmd Uplink System Margin [Clear Sky]:		14.90	dB
Cmd Uplink System Margin [with All Meteorological Losses Incl.]:		8.88	dB

From ITU P618-6 Rain Model

Link Budgets B-HSD-12 and B-HSD-13
@ f = 29.950 GHz (Page 2)

DVB-S2 Uplink Results Summary (What Was Achieved?)

Adaptive MODCOD

Symbol Rate Achieved:	12.50 Msps	
Adaptive Modulation Achieved:	QPSK	Signal Strength Within MODEM Range
Adaptive Coding Achieved:	8/9	MODCOD Results
Data Rate Achieved (@ Elev. Angle)	22.08 Mbps	TLM Downlink Stn. Elev.Angle : 5.0 deg. Worst Case Link
Rain Rate mm/Hr A.01:	12.53 mm/hr	Rain Model Results
ITU P618-6 Downlink Fade (all sources):	11.65 dB	
Achieved Spectral Efficiency:	1.7664 Info. Bits/Symbol	
Transmitter Output Backoff :	0.00 dB	IMR: 24.0 dBc Transmit η: 20.0%
Achieved TLM Downlink C/No:	77.21 dBHz Faded w. Rain & Clouds; 99.5% Link Avail.	15.22 dB = Margin Above Threshold

Adaptive Data Rate Results vs. Elevation Angle

B-HSD-12	Clear Sky Conditions:	*Units:*	99.5% Availabilty Conditions:	*Units:*
Elevation Angle:	5.00	deg.	5.00	deg.
Slant Range to S/C:	2443.28	km	2443.28	km
Path Loss:	-189.8	dB	-189.8	dB
Excess Path Loss (Meteorolgical Losses):	-5.62	dB	-11.65	dB
Effective Sky Temp.	250.0	K	250.0	K
C/No Achieved:	83.2	dBHz	77.2	dBHz
Sprectral Rate Achieved:	3.300	b/sym	1.766	b/sym
Adaptive Modulation Used:	16APSK		QPSK	
Adaptive Coding Used:	5/6		8/9	
Achieved Bit Rate (Using DVB-S2):	41.25	Mbps	22.08	Mbps

B-HSD-13				
Elevation Angle:	75.00	deg.	75.00	deg.
Slant Range to S/C:	668.65	km	668.65	km
Path Loss:	-178.5	dB	-178.5	dB
Excess Path Loss (Meteorolgical Losses):	-0.40	dB	-1.34	dB
Effective Sky Temp.	250.0	K	250.0	K
C/No Achieved:	99.7	dBHz	98.8	dBHz
Sprectral Rate Achieved:	4.453	b/sym	4.453	b/sym
Adaptive Modulation Used:	32APSK		32APSK	
Adaptive Coding Used:	9/10		9/10	
Achieved Bit Rate (Using DVB-S2):	55.66	Mbps	55.66	Mbps

DVB-S2 Modulation and Coding Table for Symbol Rate = 12.5 Msps for B-HSD-12 Uplink (Page 3)

Specified Bandwidth in MHz (Per Channel)	15.00	Specify Nyquist rolloff	0.2

ETSI EN 302307 DVB S2 Theoretical Performance for Target ModCOD

MODulation	CODing Rate	Es/No	Sym rate	BW (nyq)	C/No	C/N	Spectral Efficiency	Bits/ symbol	Data Rate	Ebi/No	Eb/No	Gross Bit Rate	Info bits	code bits	"overhead"	
		dB	Msym/sec	MHz	dBHz	dB	info bit/symbol		Mbps	dB	dB	Mbit/sec	Mbit/sec	Mbit/Sec		
QPSK	1/4	-2.35	12.50	15.00	68.62	-3.14	0.490243	2	6.1280	0.746	-5.360	25.00	6.25	18.75	1.951%	
QPSK	1/3	-1.24	12.50	15.00	69.73	-2.03	0.656448	2	8.2056	0.588	-4.250	25.00	8.33	16.67	1.533%	
QPSK	2/5	-0.3	12.50	15.00	70.67	-1.09	0.789412	2	9.8677	0.727	-3.310	25.00	10.00	15.00	1.324%	
QPSK	1/2	1.00	12.50	15.00	71.97	0.21	0.988858	2	12.3607	1.049	-2.010	25.00	12.50	12.50	1.114%	
QPSK	3/5	2.23	12.50	15.00	73.20	1.44	1.188304	2	14.8538	1.481	-0.780	25.00	15.00	10.00	0.975%	
QPSK	2/3	3.10	12.50	15.00	74.07	2.31	1.322253	2	16.5282	1.887	0.090	25.00	16.67	8.33	0.831%	
QPSK	3/4	4.03	12.50	15.00	75.00	3.24	1.487473	2	18.5934	2.306	1.020	25.00	18.75	6.25	0.835%	
QPSK	4/5	4.68	12.50	15.00	75.65	3.89	1.587196	2	19.8400	2.674	1.670	25.00	20.00	5.00	0.800%	
QPSK	5/6	5.18	12.50	15.00	76.15	4.39	1.654663	2	20.6833	2.993	2.170	25.00	20.83	4.17	0.720%	
8PSK	3/5	5.50	12.50	15.00	76.47	4.71	1.779910	2	22.2489	2.996	0.729	550.00	330.00	220.00	93.258%	99.5% Link Avail.
QPSK	8/9	6.20	12.50	15.00	77.17	5.41	1.766451	2	22.0806	3.729	3.190	25.00	22.22	2.78	0.637%	@ 5° Elev. Angle
QPSK	9/10	6.42	12.50	15.00	77.39	5.63	1.788612	2	22.3577	3.895	3.410	25.00	22.50	2.50	0.633%	
8PSK	2/3	6.62	12.50	15.00	77.59	5.83	1.980636	3	24.7580	3.652	1.849	37.50	25.00	12.50	0.968%	
8PSK	3/4	7.91	12.50	15.00	78.88	7.12	2.228124	3	27.8516	4.431	3.139	37.50	28.13	9.38	0.972%	
16APSK	2/3	8.97	12.50	15.00	79.94	8.18	2.637201	4	32.9650	4.759	2.949	50.00	33.33	16.67	1.10%	
8PSK	5/6	9.35	12.50	15.00	80.32	8.56	2.478562	3	30.9820	5.408	4.579	37.50	31.25	6.25	0.858%	
16APSK	3/4	10.21	12.50	15.00	81.18	9.42	2.966728	4	37.0841	5.487	4.189	50.00	37.50	12.50	1.11%	
8PSK	8/9	10.69	12.50	15.00	81.66	9.90	2.646012	3	33.0752	6.464	5.919	37.50	33.33	4.17	0.77%	
8PSK	9/10	10.98	12.50	15.00	81.95	10.19	2.679207	3	33.4901	6.700	6.209	37.50	33.75	3.75	0.77%	
16APSK	4/5	11.03	12.50	15.00	82.00	10.24	3.165623	4	39.5703	6.025	5.009	50.00	40.00	10.00	1.07%	Clear Sky Condx.
16APSK	5/6	11.61	12.50	15.00	82.58	10.82	3.300184	4	41.2523	6.425	5.589	50.00	41.67	8.33	0.99%	@ 5° Elev. Angle
32APSK	3/4	12.73	12.50	15.00	83.70	11.94	3.703295	5	46.2912	7.044	5.740	62.50	46.88	15.63	1.25%	
16APSK	8/9	12.89	12.50	15.00	83.86	12.10	3.523143	4	44.0393	7.421	6.869	50.00	44.44	5.56	0.91%	
16APSK	9/10	13.13	12.50	15.00	84.10	12.34	3.567342	4	44.5918	7.607	7.109	50.00	45.00	5.00	0.91%	
32APSK	4/5	13.64	12.50	15.00	84.61	12.85	3.951571	5	49.3946	7.672	6.650	62.50	50.00	12.50	1.21%	
32APSK	5/6	14.28	12.50	15.00	85.25	13.49	4.119540	5	51.4943	8.132	7.290	62.50	52.08	10.42	1.13%	
32APSK	8/9	15.69	12.50	15.00	86.66	14.90	4.397854	5	54.9732	9.258	8.700	62.50	55.56	6.94	1.05%	
32APSK	9/10	16.05	12.50	15.00	87.02	15.26	4.453027	5	55.6628	9.563	9.060	62.50	56.25	6.25	1.04%	

Link Budget B-HSD-14
@ f = 26.700 GHz

High Speed Data Downlink Budget: B-HSD-14 & B-HSD-15 *At:* **Svalbard, Norway**

Parameter:	*Value:*	*Units:*	
Spacecraft Total HPA Power Allocated per User Channel:	4.0	watts	
In dBW:	6.02	dBW	
In dBm:	36.02	dBm	
Spacecraft Transmitted IM Power:	0.010	watts	IMR Sholders (IMR) = 24 dBc
Spacecraft Total HPA Power Allocated per User Channel:	3.990	watts	
Spacecraft Transmission Line Losses:	-0.05	dB	
S/C Connector, Filter and In-Line Switch Losses:	-0.65	dB	
Spacecraft Transmit Antenna Gain:	23.5	dBiC	----- Using Lens-Aided Horn at 26.8 GHz ----------> S/C Antenna Requirements
Spacecraft EIRP per User:	28.81	dBW	
Spacecraft Transmit Antenna Pointing Loss:	-0.50	dB	1.0° S/C Pointing Error Budget
Downlink Path:			
Antenna Polarization Loss:	-0.5	dB	A.R. Gnd = 2.0 dB; A.R. S/C = 1.0 dB; 90°
Path Loss:	-188.8	dB	800 km S/C height; 1395.16.0 km range; 30.0° Elev. Angle
Atm. Gaseous Attenuation (1, 2)	-5.45	dB	
Rain Attenuation:	-3.73	dB	
Cloud Attenuation:	-2.78	dB	From ITU P618-6 Rain Model
Scintillation:	-2.13	dB	
Atmospheric Gases +Scintillation (Without Rain or Clouds):	-5.83	dB	Customer Selected Site (10N; 100E); 5.0 Elevation Angle
Total Meteorological Losses (Including Rain + Clouds):	-10.55	dB	
Isotropic Signal Level at Ground Station (Gas+Scintillation) :	-166.8	dBW	
Isotropic Signal Level at Ground Station with All Met .Losses:	-171.5	dBW	
Ground Station:			
Ground Station Antenna Pointing Loss:	-0.40	dB	2.8 m Ø; 0.05° GS Pointing Error
Ground Station Radome Loss:	0.0	dB	No Radome for first year
Ground Station Antenna Gain:	55.3	dBiC	2.8 m Ø; 55% η; 26.8 GHz; 0.28° BW
Ground Station Transmission Line Losses:	-0.3	dB	
Ground Station Filter and/or Switch Losses:	0.0	dB	
Ground Station LNA Noise Temperature:	210.0	K	Conservative Estimate
Ground Station Transmission Line Temp.:	290.0	K	
Ground Station Sky Temperature:	45.0	K	
Ground Station Sky Temperature faded:	239.1	K	From ITU P618-6 Rain Model
G.S. Transmission Line Coefficient:	0.9333		
Ground Station Effective Noise Temperature:	271.0	K	
Ground Station Effective Noise Temperature faded:	452.0	K	
Ground Station Figure of Merit (G/T):	30.7	dB/K	
Ground Station Figure of Merit (G/T) faded:	28.5	dBi/K	
G.S. Signal-to-Noise Power Density (clear sky); $(C/No)_{clear\ sky}$ =	92.1	dBHz	
G.S. Signal-to-Noise Power Density (w. rain+scintillatio $(C/No)_{faded}$ =	85.1	dBHz	
Transmitter Intermodulation Ratio (C/IM or IMR):	24.0	dB	2.0 dB OPBO; 20% PAE SSPA Efficiency
G.S. Intermodulation Power Density (C/Io)	111.8	dBHz	
G.S. C/ (No+Io):	92.0	dBHz	
G.S. C/ (No+Io) [faded: with rain & scintillation):	85.1	dBHz	Compare to DVB-S2 ModCod List
Single User Signal Bandwidth:	600.00	MHz	
Single User Symbol Rate:	500.00	Msps	
G.S. C/(N+I) in User Terminal Bandwidth [clear sky]:	4.3	dB	
G.S. C/(N+I) in User Terminal Bandwidth [w. rain+scintillation]:	-2.7	dB	

Horn Antenna

Antenna Size:	76 Φ x 60	mm conical
Aper.η:	≈ 75	%
Freq:	26.8	GHz
Gain:	23.5	dBi
Beamwidth:	10.2	degrees
Polarizaton:	RHCP	

Link Budgets B-HSD-14 and B-HSD-15
@ f = 26.700 GHz (Page 2)

DVB-S2 Downlink Results Summary (What Was Achieved?)

Adaptive MODCOD

Symbol Rate Achieved:	500.00	Msps		
Adaptive Modulation Achieved:	QPSK		Signal Strength Within MODEM Range	MODCOD Results
Adaptive Coding Achieved:	1/4			
			TLM Downlink Stn. Elev.Angle :	Worst Case Link
Data Rate Achieved (@ Elev. Angle):	245.12	Mbps	5.0 deg.	
Rain Rate mm/Hr A.01:	12.53	mm/hr		
ITU P618-6 Downlink Fade (all sources):	10.55	dB	Rain Model Results	
Achieved Spectral Efficiency:	0.4902	Info. Bits/Symbol		
Transmitter Output Backoff :	0.00	dB	IMR: 24.0 dBc	Transmit η: 20.0%
Achieved TLM Downlink C/No:	85.13	dBHz	0.49 dB	= Margin Above Threshold
	Faded w. Rain & Clouds; 99.5% Link Avail.			

Adaptive Data Rate Results vs. Elevation Angle

B-HSD-14	Clear Sky Conditions:	*Units:*	99.5% Availabilty Conditions:	*Units:*
Elevation Angle:	5.00	deg.	5.00	deg.
Slant Range to S/C:	2443.28	km	2443.28	km
Path Loss:	-188.8	dB	-188.8	dB
Excess Path Loss (Meteorolgical Losses):	-5.83	dB	-10.55	dB
Effective Sky Temp.	45.0	K	239.1	K
C/No Achieved:	92.0	dBHz	85.1	dBHz
Sprectral Rate Achieved:	1.587	b/sym	0.490	b/sym
Adaptive Modulation Used:	QPSK		QPSK	
Adaptive Coding Used:	4/5		1/4	
Achieved Bit Rate (Using DVB-S2):	793.60	Mbps	245.12	Mbps

B-HSD-15				
Elevation Angle:	75.00	deg.	75.00	deg.
Slant Range to S/C:	668.65	km	668.65	km
Path Loss:	-177.5	dB	-177.5	dB
Excess Path Loss (Meteorolgical Losses):	-0.43	dB	-1.16	dB
Effective Sky Temp.	45.0	K	61.5	K
C/No Achieved:	107.0	dBHz	106.3	dBHz
Sprectral Rate Achieved:	4.453	b/sym	4.453	b/sym
Adaptive Modulation Used:	32APSK		32APSK	
Adaptive Coding Used:	9/10		9/10	
Achieved Bit Rate (Using DVB-S2):	2226.51	Mbps	2226.51	Mbps

DVB-S2 Modulation and Coding Table for Symbol Rate = 500 Msps
For B-HSD-14 Downlink (Page 3)

Specified Bandwidth in MHz (Per Channel)	600.00	Specify Nyquist rolloff	0.2

ETSI EN 302307 DVB S2 Theoretical Performance for Target ModCOD

MODulation	CODing Rate	Es/No	Sym rate	BW (nyq)	C/No	C/N	Spectral Efficiency	Bits/ symbol	Data Rate	Ebi/No	Eb/No	Gross Bit Rate	Info bits	code bits	"overhead"	
		dB	Msym/sec	MHz	dBHz	dB	info bit/symbol		Mbps	dB	dB	Mbit/sec	Mbit/sec	Mbit/Sec		99.5% Link Avail.
QPSK	1/4	-2.35	500.00	600.00	84.64	-3.14	0.490243	2	245.1215	0.746	-5.360	1000.00	250.00	750.00	1.951%	@ 5° Elev. Angle
QPSK	1/3	-1.24	500.00	600.00	85.75	-2.03	0.656448	2	328.2240	0.588	-4.250	1000.00	333.33	666.67	1.533%	
QPSK	2/5	-0.3	500.00	600.00	86.69	-1.09	0.789412	2	394.7060	0.727	-3.310	1000.00	400.00	600.00	1.324%	
QPSK	1/2	1.00	500.00	600.00	87.99	0.21	0.988858	2	494.4290	1.049	-2.010	1000.00	500.00	500.00	1.114%	
QPSK	3/5	2.23	500.00	600.00	89.22	1.44	1.188304	2	594.1520	1.481	-0.780	1000.00	600.00	400.00	0.975%	
QPSK	2/3	3.10	500.00	600.00	90.09	2.31	1.322253	2	661.1265	1.887	0.090	1000.00	666.67	333.33	0.831%	
QPSK	3/4	4.03	500.00	600.00	91.02	3.24	1.487473	2	743.7365	2.306	1.020	1000.00	750.00	250.00	0.835%	Clear Sky Condx.
QPSK	4/5	4.68	500.00	600.00	91.67	3.89	1.587196	2	793.5980	2.674	1.670	1000.00	800.00	200.00	0.800%	@ 5° Elev. Angle
QPSK	5/6	5.18	500.00	600.00	92.17	4.39	1.654663	2	827.3315	2.993	2.170	1000.00	833.33	166.67	0.720%	
8PSK	3/5	5.50	500.00	600.00	92.49	4.71	1.779910	2	889.9550	2.996	0.729	550.00	330.00	220.00	-169.683%	
QPSK	8/9	6.20	500.00	600.00	93.19	5.41	1.766451	2	883.2255	3.729	3.190	1000.00	888.89	111.11	0.637%	
QPSK	9/10	6.42	500.00	600.00	93.41	5.63	1.788612	2	894.3060	3.895	3.410	1000.00	900.00	100.00	0.633%	
8PSK	2/3	6.62	500.00	600.00	93.61	5.83	1.980636	3	990.3180	3.652	1.849	1500.00	1000.00	500.00	0.968%	
8PSK	3/4	7.91	500.00	600.00	94.90	7.12	2.228124	3	1114.0620	4.431	3.139	1500.00	1125.00	375.00	0.972%	
16APSK	2/3	8.97	500.00	600.00	95.96	8.18	2.637201	4	1318.6005	4.759	2.949	2000.00	1333.33	666.67	1.10%	
8PSK	5/6	9.35	500.00	600.00	96.34	8.56	2.478562	3	1239.2810	5.408	4.579	1500.00	1250.00	250.00	0.858%	
16APSK	3/4	10.21	500.00	600.00	97.20	9.42	2.966728	4	1483.3640	5.487	4.189	2000.00	1500.00	500.00	1.11%	
8PSK	8/9	10.69	500.00	600.00	97.68	9.90	2.646012	3	1323.0060	6.464	5.919	1500.00	1333.33	166.67	0.77%	
8PSK	9/10	10.98	500.00	600.00	97.97	10.19	2.679207	3	1339.6035	6.700	6.209	1500.00	1350.00	150.00	0.77%	
16APSK	4/5	11.03	500.00	600.00	98.02	10.24	3.165623	4	1582.8115	6.025	5.009	2000.00	1600.00	400.00	1.07%	
16APSK	5/6	11.61	500.00	600.00	98.60	10.82	3.300184	4	1650.0920	6.425	5.589	2000.00	1666.67	333.33	0.99%	
32APSK	3/4	12.73	500.00	600.00	99.72	11.94	3.703295	5	1851.6475	7.044	5.740	2500.00	1875.00	625.00	1.25%	
16APSK	8/9	12.89	500.00	600.00	99.88	12.10	3.523143	4	1761.5715	7.421	6.869	2000.00	1777.78	222.22	0.91%	
16APSK	9/10	13.13	500.00	600.00	100.12	12.34	3.567342	4	1783.6710	7.607	7.109	2000.00	1800.00	200.00	0.91%	
32APSK	4/5	13.64	500.00	600.00	100.63	12.85	3.951571	5	1975.7855	7.672	6.650	2500.00	2000.00	500.00	1.21%	
32APSK	5/6	14.28	500.00	600.00	101.27	13.49	4.119540	5	2059.7700	8.132	7.290	2500.00	2083.33	416.67	1.13%	
32APSK	8/9	15.69	500.00	600.00	102.68	14.90	4.397854	5	2198.9270	9.258	8.700	2500.00	2222.22	277.78	1.05%	
32APSK	9/10	16.05	500.00	600.00	103.04	15.26	4.453027	5	2226.5135	9.563	9.060	2500.00	2250.00	250.00	1.04%	

Link Budget B-HSD-16
@ f = 29.950 GHz

Corvus-BC & -HD: B-HSD-16 and B-HSD-17

Uplink High Speed Data Receiver Budget:

Parameter:		Value:	Units:
Ground Station:			
User Uplink Transmitter Power Output:		10.0	watts
	In dBW:	10.0	dBW
	In dBm:	40.0	dBm
CMD TX Transmission Line Losses:		-1.5	dB
Connector, Filter or In-Line Switch Losses:		-1.0	dB
Ground Station Command Antenna Gain:		56.3	dBiC
Ground Station EIRP:		63.8	dBW
Ground Station Antenna Pointing Loss:		-0.5	dB
Uplink Path:			
Antenna Polarization Losses:		**-0.06**	dB
Path Loss:		-189.8	dB
Atm. Gaseous Attenuation **(1, 2)**		-3.36	dB
Rain Attenuation		-3.56	dB
Cloud Attenuation		-3.42	dB
Scintillation		-2.26	dB
Atmospheric Gases +Scintillation (Without Rain or Clouds):		**-5.62**	dB
Total Meteorological Losses (Including Rain + Clouds):		**-11.65**	
Isotropic Signal Level at Ground Station (Gas+Scintillation) :		-132.2	dBW
Isotropic Signal Level at Ground Station with All Met .Losses:		-138.2	dBW
Spacecraft:			
Spacecraft Rcvr Antenna Pointing Loss:		-0.6	dB
Spacecraft Rcvr Antenna Gain:		15.0	dBiC
Spacecraft Transmission Line Losses:		-0.1	dB
Spacecraft Input Filter Insertion Loss:		-0.8	dB
Spacecraft LNA Noise Temperature:		220	K
Spacecraft Transmission Line Temp.:		270	K
Spacecraft Sky Temperature:		250	K
S/C Transmission Line Coefficient:		0.8222	
Spacecraft Effective Noise Temperature:		474	K
Spacecraft Figure of Merrit (G/T):		-12.6	dB/K
S/C Signal-to-Noise Power Density (C/No) [clear sky]:		**83.24**	dBHz
S/C Signal-to-Noise Power Density (C/No) [All Met. Losses]:		**77.21**	dBHz
Receiver IF Bandwidth:		30.000	MHz
Receiver Uplink Input Noise Power		-127.1	dBW
Command Signal Uplink C/N in Rcvr Bandwidth [Clear Sky]:		**8.47**	dB
Command Signal Uplink C/N in Rcvr BW [w. All Met. Losses]:		**2.43**	
Receiver Uplink Interference Signal Density (Io):		**-260.0**	dBW/Hz
Received Uplink Total Interference Power (I):		-171.7	dBW
Receiver Uplink C/I (Power Ratio):		39.5	dB
Receiver Total Uplink Noise Power (N+I):		-130.1	dBW
Command Signal C(N+I) in Rcvr Bandwidth [Clear Sky]:		**8.46**	dB
Command Signal C(N+I) in Rcvr Bandwidth [w. All Met. Losses]:		**2.43**	
Demod Matched Filter Bandwidth:		25.0	MHz
Uplink CMD Signal C/(N+I) [Clear Sky]:		**9.25**	dB
Uplink CMD Signal C/(N+I) [All Meteorological Losses]:		**3.23**	dB
Uplink CMD Signal C/(No+Io) in Demod Filter BW [Clear Sky]:		**83.23**	dBHz
Uplink CMD Signal C/(No+Io) in Demod Filter Bandwidth:		**77.21**	dBHz
Uplink CMD Eb/No [Clear Sky]:		**9.25**	dB
Uplink CMD Eb/No [with All Meteorological Losses Included]:		**3.23**	dB
Implementation Loss of Spacecraft DVB-S2 Demodulator:		**0.5**	dB
Net Eb/No Achieved [Clear Sky]:		8.75	dB
Net Eb/No Achieved [with All Meteorological Losses Included]:		2.73	dB
Required Eb/No for 10E-7 PER:		-3.14	dB
Cmd Uplink System Margin [Clear Sky[:		**11.89**	dB
Cmd Uplink System Margin [with All Meteorological Losses Incl.]:		**5.87**	dB

From ITU P618-6 Rain Model

Link Budgets B-HSD-16 and B-HSD-17
@ f = 29.950 GHz (Page 2)

DVB-S2 Uplink Results Summary (What Was Achieved?)

Adaptive MODCOD

Symbol Rate Achieved:	25.00 Msps	
Adaptive Modulation Achieved:	QPSK	Signal Strength Within MODEM Range
Adaptive Coding Achieved:	2/3	MODCOD Results
Data Rate Achieved (@ Elev. Angle):	33.06 Mbps	TLM Downlink Stn. Elev.Angle : Worst Case Link: 5.0 deg.
Rain Rate mm/Hr A.01:	12.53 mm/hr	
ITU P618-6 Downlink Fade (all sources):	11.65 dB	Rain Model Results
Achieved Spectral Efficiency:	1.3222 Info. Bits/Symbol	
Transmitter Output Backoff :	0.00 dB	IMR: 24.0 dBc ransmit η: 20.0%
Achieved TLM Downlink C/No:	77.21 dBHz Faded w. Rain & Clouds; 99.5% Link Avail.	15.22 dB = Margin Above Threshold

Adaptive Data Rate Results vs. Elevation Angle

	Clear Sky Conditions:	*Units:*	99.5% Availabilty Conditions:	*Units:*
Elevation Angle:	5.00	deg.	5.00	deg.
Slant Range to S/C:	2443.28	km	2443.28	km
Path Loss:	-189.8	dB	-189.8	dB
Excess Path Loss (Meteorolgical Losses):	-5.62	dB	-11.65	dB
Effective Sky Temp.	250.0	K	250.0	K
C/No Achieved:	83.2	dBHz	77.2	dBHz
Sprectral Rate Achieved:	2.637	b/sym	1.322	b/sym
Adaptive Modulation Used:	16APSK		QPSK	
Adaptive Coding Used:	2/3		2/3	
Achieved Bit Rate (Using DVB-S2):	65.93	Mbps	33.06	Mbps

Elevation Angle:	75.00	deg.	75.00	deg.
Slant Range to S/C:	668.65	km	668.65	km
Path Loss:	-178.5	dB	-178.5	dB
Excess Path Loss (Meteorolgical Losses):	-0.40	dB	-1.34	dB
Effective Sky Temp.	250.0	K	250.0	K
C/No Achieved:	99.7	dBHz	98.8	dBHz
Sprectral Rate Achieved:	4.453	b/sym	4.453	b/sym
Adaptive Modulation Used:	32APSK		32APSK	
Adaptive Coding Used:	9/10		9/10	
Achieved Bit Rate (Using DVB-S2):	111.33	Mbps	111.33	Mbps

DVB-S2 Modulation and Coding Table for Symbol Rate = 25.0 Msps
For B-HSD-16 Uplink (Page 3)

Specified Bandwidth in MHz (Per Channel)	30.00	Specify Nyquist Rolloff	0.2

ETSI EN 302307 DVB S2 Theoretical Performance for Target ModCOD

MODulation	CODing Rate	Es/No	Sym rate	BW (nyq)	C/No	C/N	Spectral Efficiency	Bits/ symbol	Data Rate	Ebi/No	Eb/No	Gross Bit Rate	Info bits	code bits	"overhead"	
		dB	Msym/sec	MHz	dBHz	dB	info bit/symbol		Mbps	dB	dB	Mbit/sec	Mbit/sec	Mbit/Sec		
QPSK	1/4	-2.35	25.00	30.00	71.63	-3.14	0.490243	2	12.2561	0.746	-5.360	50.00	12.50	37.50	1.951%	
QPSK	1/3	-1.24	25.00	30.00	72.74	-2.03	0.656448	2	16.4112	0.588	-4.250	50.00	16.67	33.33	1.533%	
QPSK	2/5	-0.3	25.00	30.00	73.68	-1.09	0.789412	2	19.7353	0.727	-3.310	50.00	20.00	30.00	1.324%	
QPSK	1/2	1.00	25.00	30.00	74.98	0.21	0.988858	2	24.7215	1.049	-2.010	50.00	25.00	25.00	1.114%	
QPSK	3/5	2.23	25.00	30.00	76.21	1.44	1.188304	2	29.7076	1.481	-0.780	50.00	30.00	20.00	0.975%	99.5% Link Avail.
QPSK	2/3	3.10	25.00	30.00	77.08	2.31	1.322253	2	33.0563	1.887	0.090	50.00	33.33	16.67	0.831%	@ 5° Elev. Angle
QPSK	3/4	4.03	25.00	30.00	78.01	3.24	1.487473	2	37.1868	2.306	1.020	50.00	37.50	12.50	0.835%	
QPSK	4/5	4.68	25.00	30.00	78.66	3.89	1.587196	2	39.6799	2.674	1.670	50.00	40.00	10.00	0.800%	
QPSK	5/6	5.18	25.00	30.00	79.16	4.39	1.654663	2	41.3666	2.993	2.170	50.00	41.67	8.33	0.720%	
8PSK	3/5	5.50	25.00	30.00	79.48	4.71	1.779910	2	44.4978	2.996	0.729	550.00	330.00	220.00	86.516%	
QPSK	8/9	6.20	25.00	30.00	80.18	5.41	1.766451	2	44.1613	3.729	3.190	50.00	44.44	5.56	0.637%	
QPSK	9/10	6.42	25.00	30.00	80.40	5.63	1.788612	2	44.7153	3.895	3.410	50.00	45.00	5.00	0.633%	
8PSK	2/3	6.62	25.00	30.00	80.60	5.83	1.980636	3	49.5159	3.652	1.849	75.00	50.00	25.00	0.968%	
8PSK	3/4	7.91	25.00	30.00	81.89	7.12	2.228124	3	55.7031	4.431	3.139	75.00	56.25	18.75	0.972%	Clear Sky Condx.
16APSK	2/3	8.97	25.00	30.00	82.95	8.18	2.637201	4	65.9300	4.759	2.949	100.00	66.67	33.33	1.10%	@ 5° Elev. Angle
8PSK	5/6	9.35	25.00	30.00	83.33	8.56	2.478562	3	61.9641	5.408	4.579	75.00	62.50	12.50	0.858%	
16APSK	3/4	10.21	25.00	30.00	84.19	9.42	2.966728	4	74.1682	5.487	4.189	100.00	75.00	25.00	1.11%	
8PSK	8/9	10.69	25.00	30.00	84.67	9.90	2.646012	3	66.1503	6.464	5.919	75.00	66.67	8.33	0.77%	
8PSK	9/10	10.98	25.00	30.00	84.96	10.19	2.679207	3	66.9802	6.700	6.209	75.00	67.50	7.50	0.77%	
16APSK	4/5	11.03	25.00	30.00	85.01	10.24	3.165623	4	79.1406	6.025	5.009	100.00	80.00	20.00	1.07%	
16APSK	5/6	11.61	25.00	30.00	85.59	10.82	3.300184	4	82.5046	6.425	5.589	100.00	83.33	16.67	0.99%	
32APSK	3/4	12.73	25.00	30.00	86.71	11.94	3.703295	5	92.5824	7.044	5.740	125.00	93.75	31.25	1.25%	
16APSK	8/9	12.89	25.00	30.00	86.87	12.10	3.523143	4	88.0786	7.421	6.869	100.00	88.89	11.11	0.91%	
16APSK	9/10	13.13	25.00	30.00	87.11	12.34	3.567342	4	89.1836	7.607	7.109	100.00	90.00	10.00	0.91%	
32APSK	4/5	13.64	25.00	30.00	87.62	12.85	3.951571	5	98.7893	7.672	6.650	125.00	100.00	25.00	1.21%	
32APSK	5/6	14.28	25.00	30.00	88.26	13.49	4.119540	5	102.9885	8.132	7.290	125.00	104.17	20.83	1.13%	
32APSK	8/9	15.69	25.00	30.00	89.67	14.90	4.397854	5	109.9464	9.258	8.700	125.00	111.11	13.89	1.05%	
32APSK	9/10	16.05	25.00	30.00	90.03	15.26	4.453027	5	111.3257	9.563	9.060	125.00	112.50	12.50	1.04%	