L/S$_1$ vs. U/V Transponders

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Since I'm likely to be the person designing the L-band receiver, at least for an analog transponder, I decided that I'd better look at its requirements. This is especially important if it is to become the primary transponder for class 0 (analog) and class 1 (low-speed digital) users in conjunction with an S$_1$-band transmitter. In this document, I compare the two uplink choices and what it would take to make an L uplink provide the same services as a U uplink. I also look at the downlink choices. Each potential configuration is then examined with the spreadsheet provided by KA9Q.

1. L vs. U

We currently have 2 services using the U receiver – class 0 analog users with 2.5 kHz wide SSB signals and class 1 users with 30-50 bps BPSK signals. The class 0 users have a 1 kW EIRP uplink signal using a directional antenna and the class 1 users have minimal power into an omnidirectional antenna. If we want both services to work as designed, the receiver and antenna on the satellite should be designed to provide the same SNR with the same uplink EIRP. Table 1 shows the receiving system characteristics.

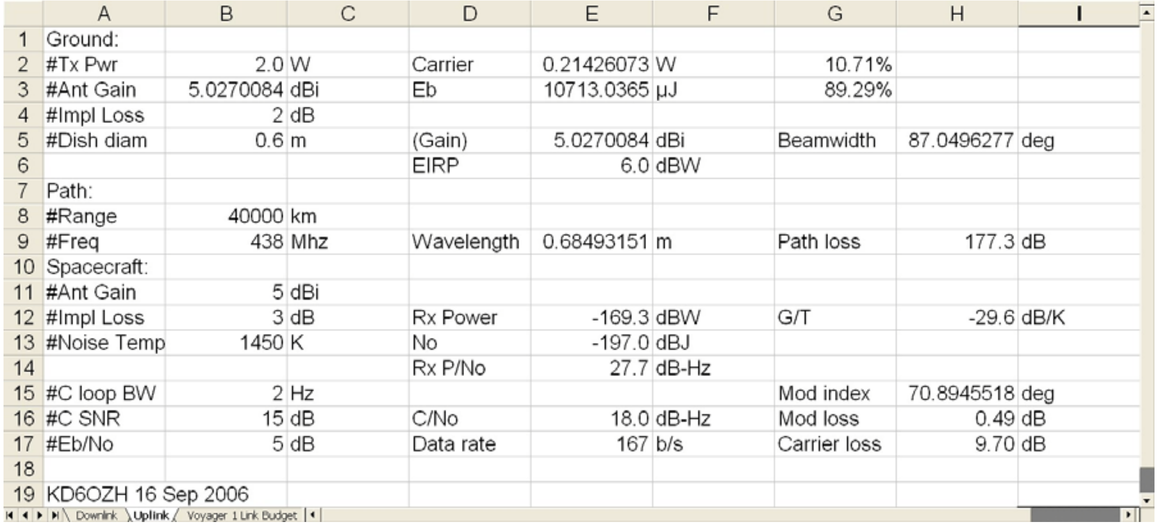
Band	U	L
Relative Propagation Loss	0 dB	+9.5 dB
Receiver Noise Figure	7 dB	3 dB
Total Relative Loss	0 dB	+5.5 dB

Table 1 – U and L Uplink Comparison

Propagation loss increases by about 9.5 dB due to the tripling of the uplink frequency, but that is offset to some extent by a lower receiver noise figure. The U receiver noise figure is high in order to tolerate PAVE PAWS interference. At L-band a 1.5-2 dB NF LNA IC with higher gain may be used to decrease the system noise figure. In order to maintain parity with the U uplink, an L uplink needs 5.5 dB more antenna gain.

This can be achieved by using an array of 4 patch antennas or 4 crossed dipoles. The array would be 250-300 mm square and fit in one corner of the satellite. It also offers the possibility of electrically steering the antenna pattern to compensate for squint and make an L/S transponder available over more of the orbit. The amount of phase adjustment and accuracy required is minimal, as the antenna gain is 11 dBic so the beamwidth is about 45°.

Assuming a 2 dB feedline loss at the ground station, the additional satellite antenna gain allows class 0 users to operate with a single long Yagi antenna (20 dBi) and a 30 W power amplifier or two long Yagi antennas and a 15 W power amplifier. Class 1 users may continue to use an omnidirectional antenna, such as crossed dipoles above a ground plane or a single patch antenna. Tables 2 and 3 compare U and L uplinks for class 1 users.



	A	B	C	D	E	F	G	H	I
1	Ground:								
2	#Tx Pwr	2.0	W	Carrier	0.21426073	W	10.71%		
3	#Ant Gain	5.0270084	dBi	Eb	10713.0365	μJ	89.29%		
4	#Impl Loss	2	dB						
5	#Dish diam	0.6	m	(Gain)	5.0270084	dBi	Beamwidth	87.0496277	deg
6				EIRP	6.0	dBW			
7	Path:								
8	#Range	40000	km						
9	#Freq	438	Mhz	Wavelength	0.68493151	m	Path loss	177.3	dB
10	Spacecraft:								
11	#Ant Gain	5	dBi						
12	#Impl Loss	3	dB	Rx Power	-169.3	dBW	G/T	-29.6	dB/K
13	#Noise Temp	1450	K	No	-197.0	dBJ			
14				Rx P/No	27.7	dB-Hz			
15	#C loop BW	2	Hz				Mod index	70.8945518	deg
16	#C SNR	15	dB	C/No	18.0	dB-Hz	Mod loss	0.49	dB
17	#Eb/No	5	dB	Data rate	167	b/s	Carrier loss	9.70	dB
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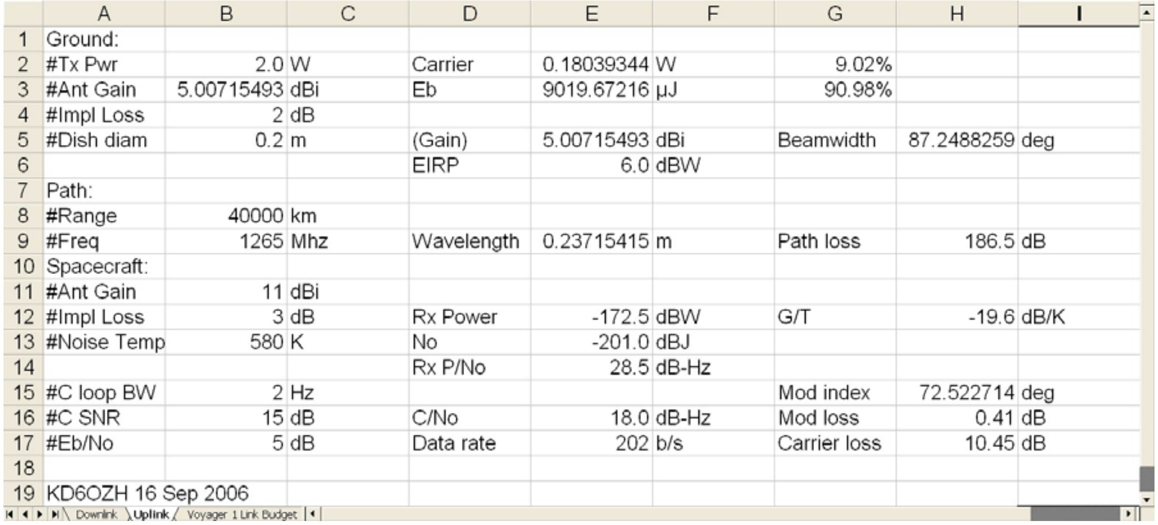
Table 2 – U Uplink Characteristics



	A	B	C	D	E	F	G	H	I
1	Ground:								
2	#Tx Pwr	2.0	W	Carrier	0.18039344	W	9.02%		
3	#Ant Gain	5.00715493	dBi	Eb	9019.67216	μJ	90.98%		
4	#Impl Loss	2	dB						
5	#Dish diam	0.2	m	(Gain)	5.00715493	dBi	Beamwidth	87.2488259	deg
6				EIRP	6.0	dBW			
7	Path:								
8	#Range	40000	km						
9	#Freq	1265	Mhz	Wavelength	0.23715415	m	Path loss	186.5	dB
10	Spacecraft:								
11	#Ant Gain	11	dBi						
12	#Impl Loss	3	dB	Rx Power	-172.5	dBW	G/T	-19.6	dB/K
13	#Noise Temp	580	K	No	-201.0	dBJ			
14				Rx P/No	28.5	dB-Hz			
15	#C loop BW	2	Hz				Mod index	72.522714	deg
16	#C SNR	15	dB	C/No	18.0	dB-Hz	Mod loss	0.41	dB
17	#Eb/No	5	dB	Data rate	202	b/s	Carrier loss	10.45	dB
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Table 3 – L Uplink Characteristics

2. S_1 vs. V

Changing from a V downlink to an S_1 downlink is dramatic as shown in tables 4 and 5. I assume a simple J310 FET preamplifier for 2 meters and a 0.7 dB NF LNA for 13 cm. The antennas are the smallest M^2 Yagi for 2 m and a 2-foot dish with -10 dB total side-lobe levels for 13 cm. The V-band ambient noise level comes from an NTIA survey of residential locations in the U.S.

Band	**V**	**S_1**
Relative Propagation Loss	0 dB	+24 dB
Ambient Noise	6 dB	-10 dB
Receiver Noise Figure	2 dB	1 dB
Receiver Noise Temperature	1830 K	104 K
Relative Receiver MDS	0 dB	-12.5 dB
Antenna Gain	12 dBic	19.5 dBic
Relative Antenna Gain	0 dB	+7.5 dB
Total Relative Loss	0 dB	+4 dB

Table 4 – Analog V and S_1 Downlink Comparison

Thus an S-band analog downlink needs moderate additional antenna gain to perform similarly to a V-band analog downlink. A 4-element array on the satellite would compensate and allow beam steering for higher availability.

Band	**V**	**S_1**
Relative Propagation Loss	0 dB	+24 dB
Ambient Noise	6 dB	-3 dB
Receiver Noise Figure	2 dB	1 dB
Receiver Noise Temperature	1830 K	220 K
Relative Receiver MDS	0 dB	-9 dB
Antenna Gain	5 dBic	5 dBic
Relative Antenna Gain	0 dB	0 dB
Total Relative Loss	0 dB	+15 dB

Table 5 – Digital V and S1 Downlink Comparison with Omni Antenna

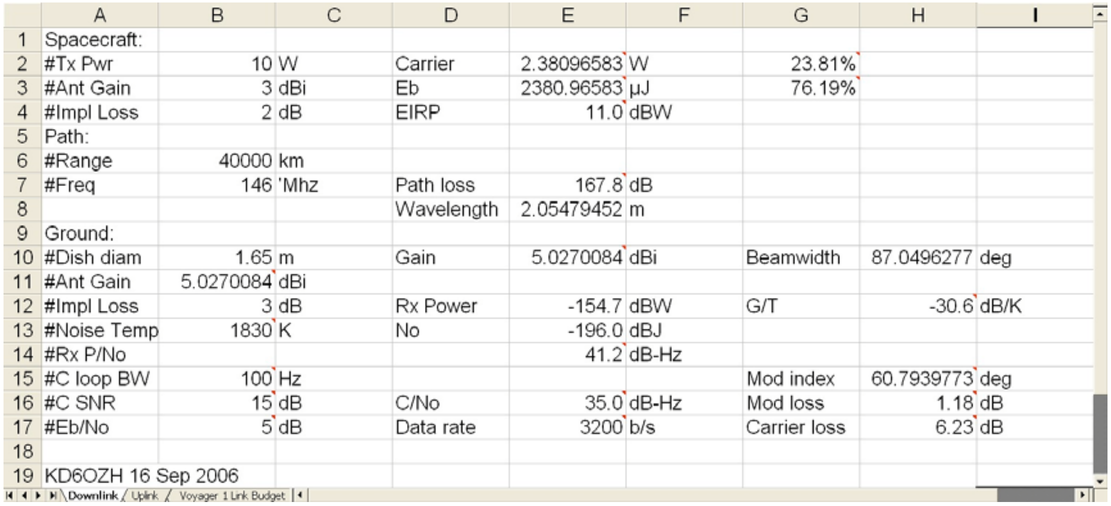
An S-band digital downlink for class 1 users is at an extreme disadvantage as omnidirectional receiving antennas pick up thermal noise. I assume that the antenna is mounted far enough above surrounding objects so that the 290 K thermal noise is attenuated by 3 dB. Making class 1 work with an omnidirectional antenna on the ground requires a large phased array on the satellite.

A better solution is smaller phased arrays at both ends of the link. Table 6 is similar to table 5, but the phased arrays are assumed to have -6 dB total side-lobe levels that have little effect in orbit, but add noise on the ground.

Band	V	S_1
Relative Propagation Loss	0 dB	+24 dB
Ambient Noise	6 dB	-6 dB
Receiver Noise Figure	2 dB	1 dB
Receiver Noise Temperature	1830 K	150 K
Relative Receiver MDS	0 dB	-11 dB
Total Relative Loss	0 dB	+13 dB

Table 6 – Digital V and S_1 Downlink Comparison with Directional Antenna

A 4-element phased array at the satellite plus a 4-element phased array on the ground should allow class 1 operation with a SNR on S_1 similar to that on V. Tables 7 and 8 show digital link characteristics for these cases.



	A	B	C	D	E	F	G	H	I
1	Spacecraft:								
2	#Tx Pwr	10	W	Carrier	2.38096583	W	23.81%		
3	#Ant Gain	3	dBi	Eb	2380.96583	µJ	76.19%		
4	#Impl Loss	2	dB	EIRP	11.0	dBW			
5	Path:								
6	#Range	40000	km						
7	#Freq	146	'Mhz	Path loss	167.8	dB			
8				Wavelength	2.05479452	m			
9	Ground:								
10	#Dish diam	1.65	m	Gain	5.0270084	dBi	Beamwidth	87.0496277	deg
11	#Ant Gain	5.0270084	dBi						
12	#Impl Loss	3	dB	Rx Power	-154.7	dBW	G/T	-30.6	dB/K
13	#Noise Temp	1830	K	No	-196.0	dBJ			
14	#Rx P/No				41.2	dB-Hz			
15	#C loop BW	100	Hz				Mod index	60.7939773	deg
16	#C SNR	15	dB	C/No	35.0	dB-Hz	Mod loss	1.18	dB
17	#Eb/No	5	dB	Data rate	3200	b/s	Carrier loss	6.23	dB
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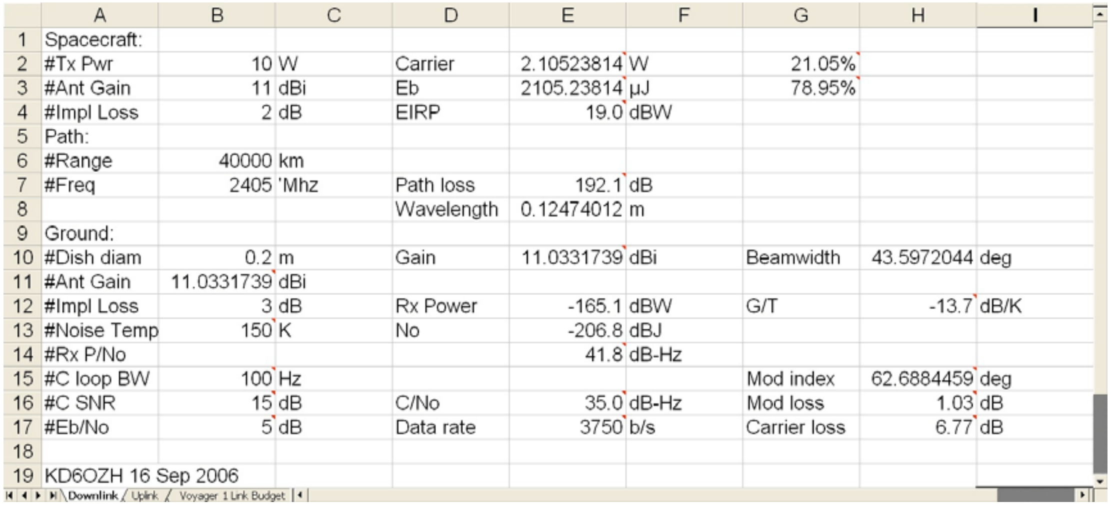
Table 7 – V Downlink Characteristics



	A	B	C	D	E	F	G	H	I
1	Spacecraft:								
2	#Tx Pwr	10	W	Carrier	2.10523814	W	21.05%		
3	#Ant Gain	11	dBi	Eb	2105.23814	µJ	78.95%		
4	#Impl Loss	2	dB	EIRP	19.0	dBW			
5	Path:								
6	#Range	40000	km						
7	#Freq	2405	'Mhz	Path loss	192.1	dB			
8				Wavelength	0.12474012	m			
9	Ground:								
10	#Dish diam	0.2	m	Gain	11.0331739	dBi	Beamwidth	43.5972044	deg
11	#Ant Gain	11.0331739	dBi						
12	#Impl Loss	3	dB	Rx Power	-165.1	dBW	G/T	-13.7	dB/K
13	#Noise Temp	150	K	No	-206.8	dBJ			
14	#Rx P/No				41.8	dB-Hz			
15	#C loop BW	100	Hz				Mod index	62.6884459	deg
16	#C SNR	15	dB	C/No	35.0	dB-Hz	Mod loss	1.03	dB
17	#Eb/No	5	dB	Data rate	3750	b/s	Carrier loss	6.77	dB
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Table 8 – S_1 Downlink Characteristics