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

ANALYSIS OF LANDMAPPER INTERFERENCE POTENTIAL TO THE RADIO ASTRONOMY SERVICE WHILE USING THE GLOBALSTAR MSS SYSTEM IN AN INTERSATELLITE LINK MODE

In order to determine the feasibility of using the Globalstar system on its RETURN link (in the band 1610-1626.5 MHz) and in order to execute an in-orbit crosslink it is important that we demonstrate that our emissions will not cause interference to highly sensitive receivers on the Earth used for Radio Astronomy purposes.

We note that the band 1610.0 to 1613.8 MHz:

1) Is co-allocated to both RAS (Radio Astronomy Service) and to the MSS (Mobile Satellite Service) on a primary basis.

2) Is used by Radio Astronomers with protection from MSS via various domestic and international regulations.[1]

3) Is used primarily by Radio Astronomy to make spectral-line observations of distant astronomical objects.

We propose to avoid co-channel emissions that might reach radio astronomy sites in-band by confining our transmissions to the Globalstar RTN channels 5 through 7 (from 1615.000 MHz to 1618.725 MHz). However, we must also assure that the roll-off of our space station transmitter is adequate to meet radio astronomy protection criteria outside this band of frequencies. Hence we need to not only assure that the co-channel level is reasonable but, that the space station transmitter rolls off sufficiently to meet defined threshold interference levels computed by the Radio Astronomy community.

After reviewing a variety of ITU-R documents we propose to use the following Table as a reference for the protection of Radio Astronomy sites internationally. This is Table 2 from ITU-R RA 769-2. It is particularly relevant for this analysis as the band 1610-1613.8 MHz is used primarily to make radio astronomy spectral-line observations and Table 2 assumes a "typical" channel integration time of 2000 seconds for just such an

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[1] *See* 47 CFR §25.213(a)(1)

[2] *See* Table 2, Row 3; particularly column 9: Entry value is -238 dBW/m^2/Hz.

[3] This is a very pessimistic assumption in terms of range variation (and consequential path loss) compared to what would actually occur during the 300

application. A typical Globalstar transmission contact time between satellites is typically 300 seconds by comparison.

TABLE 2*

Threshold levels of interference detrimental to radio astronomy spectral-line observations

Frequency f (MHz)	Assumed spectral line channel bandwidth Δf (kHz)	Minimum antenna noise temperature T_A (K)	Receiver noise temperature T_R (K)	System sensitivity(2) (noise fluctuations) Temperature ΔT (mK)	System sensitivity(2) (noise fluctuations) Power spectral density ΔP_S (dB(W/Hz))	Threshold interference levels(1) (2) Input power ΔP_H (dBW)	Threshold interference levels(1) (2) pfd $S_H \Delta f$ (dB(W/m^2))	Threshold interference levels(1) (2) Spectral pfd S_H (dB(W/(m^2 · Hz)))
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
327	10	40	60	22.3	–245	–215	–204	–244
1 420	20	12	10	3.48	–253	–220	–196	–239
1 612	20	12	10	3.48	–253	–220	–194	–238
1 665	20	12	10	3.48	–253	–220	–194	–237
4 830	50	12	10	2.20	–255	–218	–183	–230
14 488	150	15	15	1.73	–256	–214	–169	–221
22 200	250	35	30	2.91	–254	–210	–162	–216
23 700	250	35	30	2.91	–254	–210	–161	–215
43 000	500	25	65	2.84	–254	–207	–153	–210
48 000	500	30	65	3.00	–254	–207	–152	–209
88 600	1 000	12	30	0.94	–259	–209	–148	–208
150 000	1 000	14	30	0.98	–259	–209	–144	–204
220 000	1 000	20	43	1.41	–257	–207	–139	–199
265 000	1 000	25	50	1.68	–256	–206	–137	–197

* This Table is not intended to give a complete list of spectral-line bands, but only representative examples throughout the spectrum.

(1) An integration time of 2 000 s has been assumed; if integration times of 15 min, 1 h, 2 h, 5 h or 10 h are used, the relevant values in the Table should be adjusted by +1.7, –1.3, –2.8, –4.8 or –6.3 dB respectively.

(2) The interference levels given are those which apply for measurements of the total power received by a single antenna. Less stringent levels may be appropriate for other types of measurements, as discussed in § 2.2. For transmitters in the GSO, it is desirable that the levels need to be adjusted by –15 dB, as explained in § 2.1.

We note that (at least) one particular spectral line falls within the Radio Astronomy allocation at 1610-1613.8 MHz,[2] where an observation would be made at 1612 MHz with an observation bandwidth of 20 kHz and with a typical integration time of 2000 seconds. In this analysis we focus on the spectral PFD threshold given in the last column of the table. Our interpretation, taken from §2.2 of RA 769-2 is, this column gives the threshold value for an arriving signal at an isotropic antenna (with 0 dBi gain) in terms of its spectral power flux density (watts/m^2 in any 1 Hz bandwidth) in the receiver's 20 kHz wide passband. Potentially interfering emissions below the threshold value (in this instance) of -238 dBW/m^2/Hz, at a 0 dBi gain reference antenna, (corresponding to observing a stellar emission at 1612

[2] *See* Table 2, Row 3; particularly column 9: Entry value is -238 dBW/m^2/Hz.

MHz) would not be detectable by the radio telescope victim receiver (during an integration period of 2000 sec).

We understand that a method for using an *equivalent* spectral PFD is often used as a coordination method between NGSO MSS systems and RA sites. This would require an integration of the satellite signal during a satellite pass over the RA station as the space station passes through the sidelobe structure of the Earth station's antenna. We choose here to conduct a simpler analysis for the time being, however, a more precise method of analysis, using spectral EPFD and using the prescribed integration method, can be carried out by AD in the future.

In order to determine the proximity effects of a satellite signal at the RA Earth station we first carry out a co-channel analysis. We place the emitting satellite at a worst-case location with respect to the Earth station.

- The satellite is at it's lowest possible operating altitude of 300 km
- The satellite is at elevation w.r.t. the Earth station of 90°
- The satellite remains in this location transmitting for 300 seconds (of a 2000 second integration period)[3]

We then compute the co-channel spectral flux density received by the RA Earth station from the satellite.

Figure I-1 shows the computation under co-channel conditions. We note, in particular, that the Landmapper satellites direct their Globalstar L-band beam in the zenith direction (away from the Earth) and that the net gain over the back hemisphere where the beam falls on the Earth has an average gain of approximately -17 dBi. We apply in this calculation the maximum power of the transmitter, although it is controlled by Globalstar dynamically, hence this is also a worst-case assumption. We observe the result is a received emission spectral flux density of -202.7 dBW/m^2/Hz at the Earth Station. This means that there would be an interference from the Landmapper satellite to the victim station of (-202.7 –(-238)= +35.3 dB I/N under co-channel conditions. However, this was assuming a 2000 sec. integration time. Per Note (2) of Table 2 above, given the Landmapper TX is only on an average of 300 seconds, the RA receiver detection threshold can be increased by a value of 10log (2000/300) = +8.3 dB. Hence, the adjusted spectral PFD interference threshold becomes -229.7 dB/m^2/Hz, and the co-channel signal level causes an I/N value of approximately 35.3-8.3 = +**27.0 dB.**

[3] This is a very pessimistic assumption in terms of range variation (and consequential path loss) compared to what would actually occur during the 300 second ON period of a Landmapper satellite.

We must now deal with the space station transmitter roll-off characteristics to determine if there could be *adjacent channel interference*. The spacing between the high side of the victim receiver passband and the edge of the closest Globalstar/Landmapper channel is: 1615.000 – 1612.010 = 2.990 MHz. Thus, in order to assure that our transmitter is below the RA interference threshold our transmitter must roll of by 27 dB in 3 MHz in order to assure no adjacent channel interference to Radio Astronomy.

Parameter:	*Value:*	*Unit:*	*TX Power:*		TX Ant. Gain:		*TX Losses:*
Transmit Station EIRP (in Watts):	0.01	watts	0.40 w	X	-17.00 dBi	X	-0.25 dB
Transmit Station EIRP (in dBW):	-21.23	dBW =					
Range (Distance from Transmitter to Receiver):	300.000	km					
$1/4\pi R^2$	8.84195E-13	=	-120.53	dB/m²			
Illumination Level (at Receiver):	-141.76	dBW/m²					
Link Data Rate:	9,600.00	bps					
Spectral Efficiency:	0.00781	bps/Hz	=w/R 128.00	Hz/bit (Spreading Factor)			
Signal Bandwidth:	1,228,800.00	Hz		Reference Bandwidth: *(Common ITU Units)*			
PFD: (at Receive Station)	-166.64	dBW/m²/4kHz		**in 4 kHz**			
	-202.66	dBW/m²/Hz		**in 1 Hz**			
NOTE:	-142.66	dBW/m²/MHz		**in 1 MHz**			
	-159.65	dBW/m²/20kHz		**in 20 kHz**			

Figure I-1: Spectral PFD Calculation for Co-Channel Worst-Case Interference

A typical modulation spectrum for a Globalstar OCDMA system is derived from hardware using a time domain synthesized finite impulse response filter. Current design practices can produce Nyquist roll-off rates of 20% but, very recent technology improvements allow filters as good as 5% roll-off rate. However the true roll-off of the modulation spectrum isn't the limiting case in our analysis. Figure I-2 below shows a typical transmitter output response mask for an IS-95/IS-141 class transmitter occupying a single 1.25 MHz bandwidth channel. We note that in determining our out-of-band performance, we can start measuring from the edge of the channel, not the center. Hence 2.99 MHz below the edge of the channel is: 2.990 + 1.250/2 = 3.615 MHz below the channel center. This is well off to the left-hand side of the graph in Figure I-2. The modulation spectrum itself for a proper

CDMA system rolls off very rapidly with frequency, however, the intermodulation spectrum does not. These IM "shoulders" seen on either side of the main modulation characteristic may also not be suppressed as much as given in the graphic presented.

Figure I-2 example. This depends on the linearity properties of the transmitter solid state power amplifier used.

A more typical hard driven amplifier may have IM shoulders only 15 to 20 dB below the main modulation spectrum at f = fc – 625 kHz. However, it is clear that even the IM-generated portion of the spectrum has rolled off easily by 50 to 60 dB by the time the power density is measured as far as 3.615 MHz below the spacecraft transmitter center frequency.

Conclusion: We can thus conclude: if the co-channel I/N was computed to be +27 dB (as in our case), in an adjacent channel 2.99 MHz away (edge-to-edge) the I/N in these worst-case circumstances would be at least -20 to -40 dB, depending on transmitter intermodulation conditions. We note that additional filtering could be provided on the transmitter side to further reduce emission levels in the region immediately below 1615.000 MHz. However, this simplified analysis doesn't seem to suggest that this precaution is actually necessary.

Figure I-2: Modulation Spectrum Mask of Typical Globalstar L-band Transmitter