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RADIOASTRON COMMUNICATION LINK PARAMETERS

L. R. D'Addario
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At the Tenth Radioastron Review Meeting (Helsinki, 23-26 May 1990), attempts were made to establish the requirements on both the space and ground portions of the three radio links: phase reference uplink, phase reference downlink, and wideband data downlink. Discussions are still underway, but preliminary information was exchanged.

Representatives of NASA and NRAO wanted to have the Soviets establish the spacecraft parameters and thus to specify minimum requirements on the ground segment's EIRP (uplink) and sensitivity (downlinks). A draft document was prepared which, when completed by the Soviet side, will give these requirements, among other things. But the Soviets preferred that the ground segment parameters be given so that they could determine requirements on the space segment (so as to minimize the transmitter powers, for example). It became clear in the discussions that neither side has actually built the necessary hardware, not even in prototype form. Neither side can wait for the other to produce a prototype before proceding with its own design. Therefore, regardless of which side provides requirements to which, they will have to be based on estimated rather than measured performance. It seems to me that this means that the performance of each side must be specified in terms of guaranteed minimum values as well as nominal values, and that -- to be conservative -- we must ensure that there is adequate margin even when each side achieves only its minimums. It will take some iterative negotiation in order to get everyone to "sign off" on acceptable values.

In this memo, I attempt to provide a preliminary set of minimum requirements for each side. I propose that we adopt the criterion that, for each of the three links, there should be a minimum margin of 4 dB when the spacecraft elevation at the earth station is 5 degrees, the atmospheric loss is 3 dB, and each side achieves only its guaranteed minimum performance.

Table I covers the wideband data link. First some basic characteristics of the channel are given; these are taken to be fixed requirements (but note that the maximum range corresponds to the 1-day orbit only, and that the maximum bit error rate is somewhat arbitrary). Next the space segment and finally the ground segment parameters are given, each in two columns: the first is the current estimate of the achievable performance (as given at the Helsinki meeting by V. Rogalski for the space segment and by myself for the ground), and the second is my guess of what a prudent engineer would be willing to guarantee. The ground segment numbers are based on the preliminary design of the Green Bank station. The resulting margins are then calculated.

Tables II and III cover the phase links in the same way. Here the required SNR is based on allowing the thermal noise on each link to degrade coherence by 0.996 at 22 GHz.

It will be seen that the suggested criterion is easily satisfied for the phase downlink, but not for the others. For the phase uplink, I propose that this be improved by reducing the PLL noise bandwidth on the spacecraft from 1000 Hz to 400 Hz. The latter corresponds to 16.6 m/sec velocity, which should be more than adequate. For the data downlink, we will have to study which of the guaranteed values must be improved. My guesses have degraded the estimated spacecraft performance by a total of 4 dB, whereas we are 3 dB short of the proposed goal. Further tests on the Green Bank antenna may enable a better value of effective area to be guaranteed.

TABLE I: DATA DOWNLINK corrected 90/08/01

General

Frequency	15 063 MHz	
Maximum range	75 000 km	
Data rate	144 Mb/sec	
Modulation	QPSK	Differentially encoded.
Polarization	right circular	
Required bit error rate, max	5E-4	Requires Eb/No > 7.6 dB.

Spacecraft	Estimated	Guaranteed (proposal)		Remarks
Transmitter power to antenna	10	7	W	
Modulator non-ideality	-2.0	-2.5	dB	
Antenna gain (0.9 m dia. reflector)	+37	+35	dB	Including feed, polarization, and pointing loss.
EIRP (ideal equivalent)	31620	12450	W	
Earth Station				
Antenna effective area (13.7 m dia.)	73.7	66.3	m^2	Aperture efficiencies 50% and 45%, respectively.
Pointing loss at 5 deg elevation	-1.0	-1.5	dB	
Polarization loss	-0.2	-0.5	dB	
Atmosphere loss, 5 deg elevation	-0.5	-0.5	dB	Assumed, good weather.
System temperature, 5 deg elevation	75	100	K	Good weather. Receiver=25K, spillover=20K, sky=30K.
Demodulator non-ideality	-1.3	-2.0	dB	
Minimum flux required	2.32E-14	4.86E-14	W/m^2	
Margin Calculation				
Flux at maximum range	4.47E-13	1.76E-13	W/m^2	
Margin (good weather)	12.8	5.6	dB	
Effect of 3 dB atmosphere loss	-7.2	-6.4	dB	Includes increase in system temperature.
Margin with 3 dB atmosphere loss	5.6	-0.8	dB	

TABLE II: PHASE UPLINK

General

Frequency	7 215 MHz	
Maximum range	75 000 km	
Polarization	left circular	
Required signal-to-noise ratio	2 350	P/kTB for coherence 0.996 at 22 GHz.

	Estimated	Guaranteed (proposal)		Remarks
Spacecraft				
Antenna effective area (0.4 m dia.)	.0275	.020	m^2	Including feed, polarization, and pointing losses.
System temperature	1000	1300	K	Including antenna temp., looking at Earth.
Noise bandwidth of phase locked loop	1000	1000	Hz	
Minimum flux required	1.18E-12	2.11E-12	W/m^2	
Earth Station				
Transmitter power to antenna	1.0	0.8	W	
Antenna gain on boresight (13.7 m dia.)	58.4	57.7	dB	Aperture efficiencies 65% and 55%, respectively.
Atmosphere loss (assumed)	-0.1	-0.1	dB	Good weather.
Pointing loss	-0.5	-1.0	dB	
Polarization loss	-0.2	-0.5	dB	
EIRP toward spacecraft	5.82E+5	3.24E+5	W	
Margin Calculation				
Flux at maximum range	8.43E-12	4.69E-12	W/m^2	
Margin in good weather	8.4	3.4	dB	
Margin with 3 dB atmosphere loss	5.5	0.5	dB	

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Maximum range	75 000 km	
Data rate	144 Mb/sec	
Modulation	QPSK	Differentially encoded.
Polarization	right circular	
Required bit error rate, max	5E-4	Requires Eb/No > 7.6 dB.

	Estimated	Guaranteed (proposal)		Remarks
Spacecraft				
Transmitter power to antenna	10	7	W	
Modulator non-ideality	-2.0	-2.5	dB	
Antenna gain (0.9 m dia. reflector)	+37	+35	dB	Including feed, polarization, and pointing loss.
EIRP (ideal equivalent)	31620	12450	W	
Earth Station				
Antenna effective area (13.7 m dia.)	73.7	66.3	m^2	Aperture efficiencies 50% and 45%, respectively.
Pointing loss at 5 deg elevation	-1.0	-1.5	dB	
Polarization loss	-0.2	-0.5	dB	
Atmosphere loss, 5 deg elevation	-0.5	-0.5	dB	Assumed, good weather.
System temperature, 5 deg elevation	75	100	K	Good weather. Receiver=25K, spillover=20K, sky=30K.
Demodulator non-ideality	-1.3	-2.0	dB	
Minimum flux required	2.32E-14	4.86E-14	W/m^2	
Margin Calculation				
Flux at maximum range	4.47E-13	1.76E-13	W/m^2	
Margin (good weather)	12.8	5.6	dB	
Effect of 3 dB atmosphere loss	-7.2	-6.4	dB	Includes increase in system temperature.
Margin with 3 dB atmosphere loss	5.6	-0.8	dB	