The Promise of Ka-Band for Deep Space Communications

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Ka-band offers a potential performance improvement over X-band equal to the square of the frequency ratio. For the Deep Space Band frequencies, this ratio is 3344/880 for coherently related frequencies. Squared, the factor is 14.44 or 11.59 db. After the stochastically described atmospheric effects of 3.5+ db are removed, the remaining possible improvement factor is 4 to 6 or 6 db to 8 db. This net improvement in performance can be used for smaller antennas, reduced RF transmitter power, higher data rates, or perhaps less tracking time.

Flight experience to date is limited. Mars Observer (before it failed) and Mars Global Surveyor were low powered experiments with early DSN equipment. Deep Space 1 in January 1999 demonstrated an operational level of performance with an operational Ka-band receiving capability at DSS25 at Goldstone, CA. Cassini operated its dual Ka-band downlinks , both unmodulated carriers, in December 1998 during its Instrument check out sequence. The Deep Space 1 performance was particularly noteworthy, showing 8 to 9 db of advantage. Because of the favorable atmospheric conditions in the California desert on winter nights, such experience will not be typical, however.

The above described flight experience, though limited, has served to demonstrate reliable performance for the 34 meter beam wave guide antenna design. Performance of the low noise amplifiers is such that the G/T performance advantage over X-band approaches 8 db over much of the elevation angle space. This is as good as has been projected. For long term use, 70 meter performance is critical. Experiments in the first quarter of 1999 at DSS 14 show how a flat plate deformable mirror together with a focal plane array can improve performance of the antenna by as much as 2.8 db over much of the elevation space. Ka-band aperture efficiency of 60% at the rigging angle, compared to 71% for X-band is achievable and is as good as JPL has ever projected.

Flight components are progressing. The Small Deep Space Transponder, an existing product, has built in X- and Ka- band exciters. The Spacecraft Transponding Modem, a smaller and lighter version, will have an engineering model in 10 months and flight units in 2 years. An RFP has been released for a flight Ka-TWTA with 15-30W RF, 40-50% DC to RF efficiency, 2.5kg mass, and 1L volume. Delivery is expected in less than two years. This development is as crucial as the 70 meter antenna performance, because solid state amplifiers are at best 25-30% efficient. That shortfall relative to the TWTA substantially dilutes the otherwise expected Ka-band performance improvement. Microwave components and antennas are not technology issues, though they do require careful design work.

There are three upcoming missions that can in three different ways take advantage of Ka-band. These benefits are potential only, because at present, all three are planning to use X-band communications systems.

Space Interferometry Mission is a likely high bandwidth user in the 300kbps to 5Mbps range. Such spectral bandwidth will wreak havoc with the rapidly crowding Deep Space X-band allocation. The international Space Frequency Coordination Group is putting significant pressure on NASA to use this band more efficiently. Ka-band offers a natural way out.

Solar Probe will travel to about .05 AU from the Sun where the Solar corona effects will significantly effect the X-band signal. At present, the scheme for combating the scintillation is a 100,000bit interleaver. For a 10kbps link, the resulting 10 second separation of adjacent symbols will allow protection against all but the most violent solar activity. However, this is a dead end solution with no other user and it has obviously undesirable acquisition and synchronization characteristics. Ka-band offers a 14.44 factor reduction in scintillation effects and seems a natural solution. There is legitimate concern over the potential for weather outage during real time data return. This risk is greatly mitigated by link margin.

The Pluto Kuiper Express can take advantage of Ka-band by planning on a 75% reduction of the playback time. Once the images are on board after a 30 minute encounter, they are literally priceless until they are on the ground. Reducing playback time reduces the opportunity for S/C problems before playback is complete. Of course, the prospect of an X-band up with Ka-band only downlink carries its own version of risk. That combination of components is the least costly in $, mass, and volume.

With dependable Ka-band performance demonstrated by the DSN and with the prospect of flight qualified efficient Ka-TWTAs in 2 years, missions with launch dates in late 2003 and beyond are credible users.

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Ka-Band Promise

Agenda

Performance Advantages

Flight Experience

Deep Space Network Performance

Flight Components

Future Mission What Ifs

Conclusions

Ka-Band Promise

Performance Advantage

Frequency squared ratio is 14.4 or 11.6db

Atmospherics removes 3+db (stochastic)

Other inefficiencies leave 6 to 8 db net gain

Can use for smaller antennas, less RF power, higher data rates, and perhaps less tracking time.

Ka-Band Promise

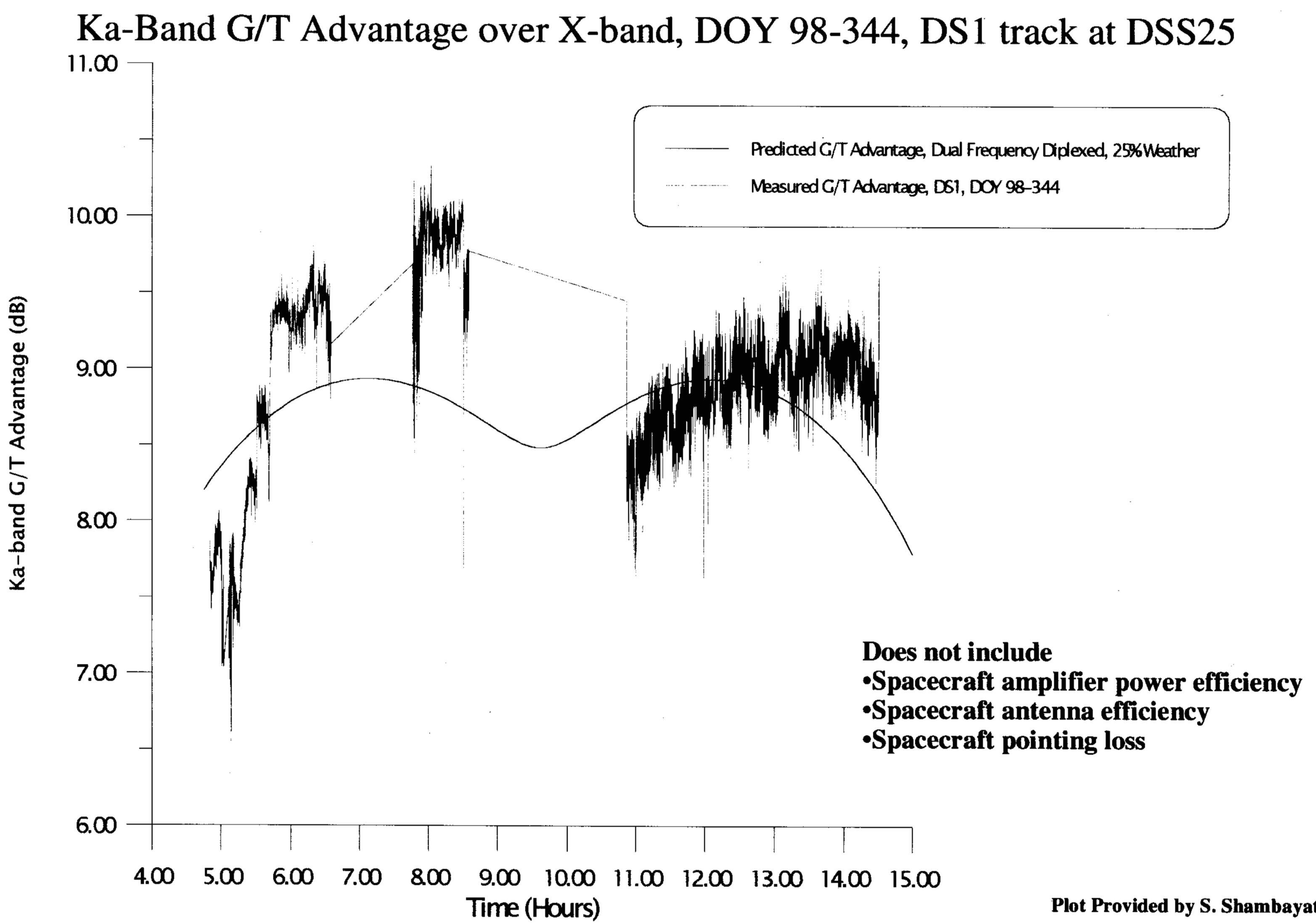
Flight Experience

Mars Observer (before it failed)

Mars Global Surveyor

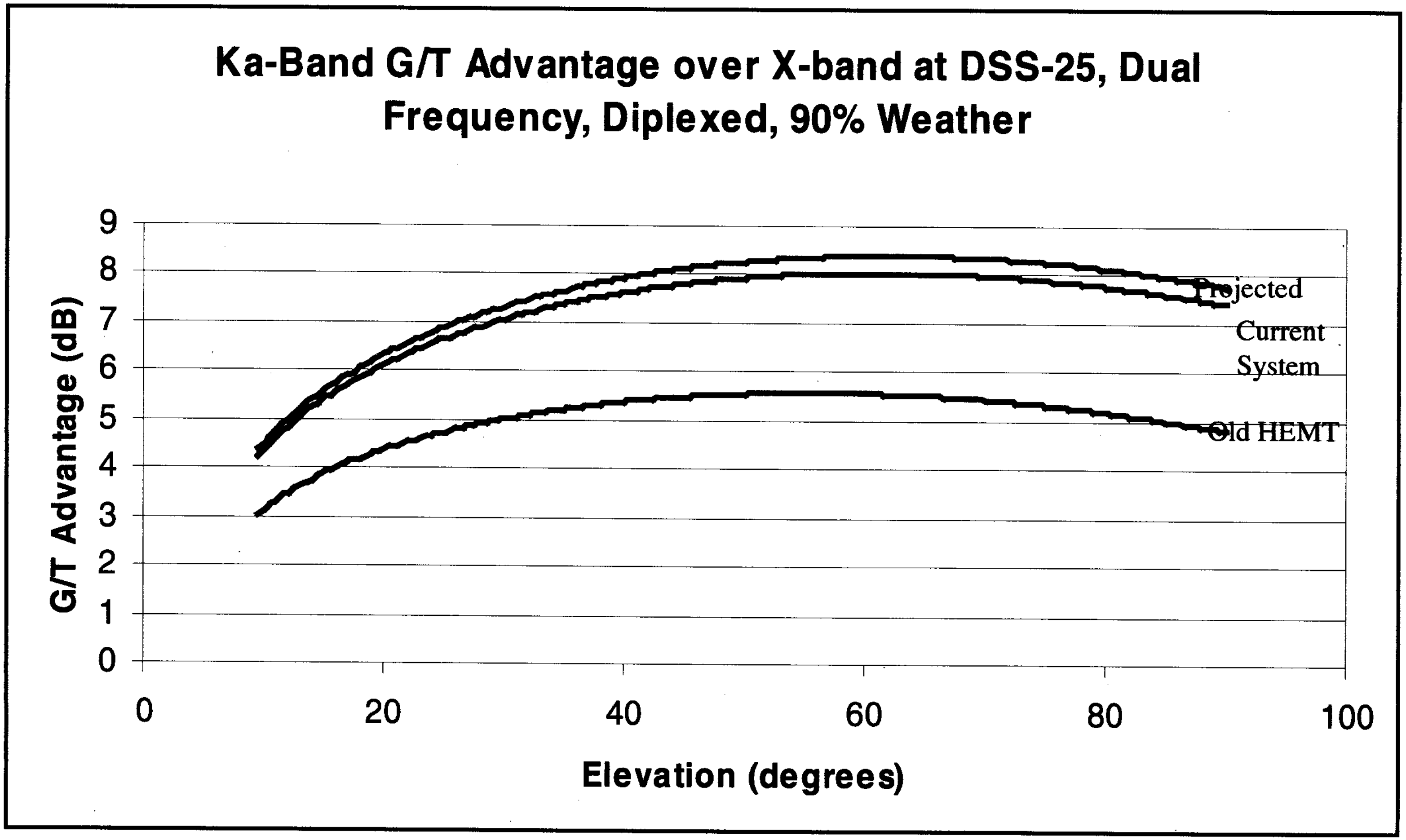
Deep Space 1

Cassini



Plot Provided by S. Shambayati

Ka-Band Promise



Plot provided by S. Shembayati

Ka-Band Promise

70 Meter Performance

Long Term Ka-band usage depends on efficiency approaching that of X-Band

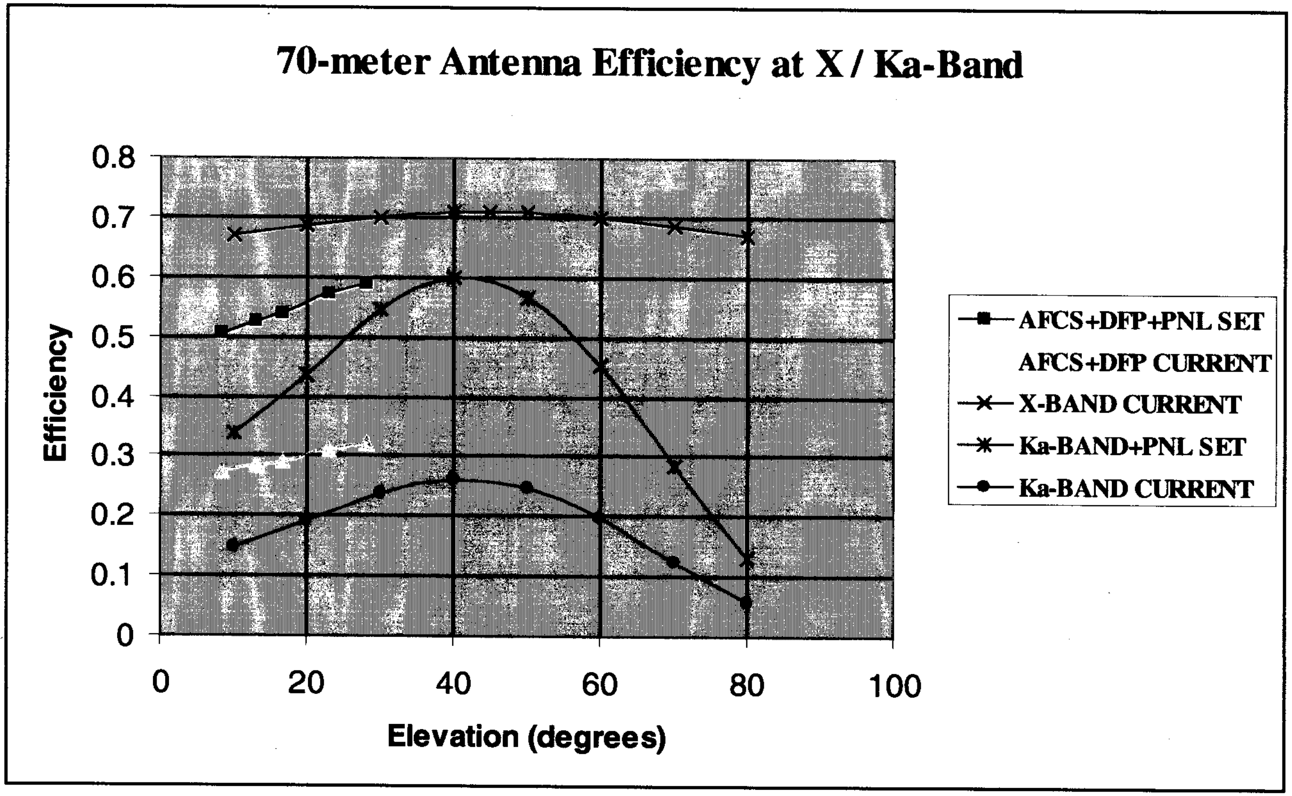
Degradation from gravity deformation and surface quality significantly exceeds those effects on 34M BWG

Use of Focal Plane Array and Deformable Flat Plate Mirror offer major improvements at Ka-band

Each improves by 1.8db, together 2.8db at 20deg EL

Implementation awaits customers and $$$

Ka-Band on the 70-m Antennas



Plot provided by Dave Rochblatt

Ka-Band Promise

Flight Components

Small Deep Space Transponder - now

Spacecraft Transponding Modem - EM in
10 months, Flight Units in 2 years

Ka-TWTA: 15-30W, 2.5kg, 1L, 40-50%, 2 years

Antennas are not a technology issue

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Future Mission What Ifs?

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Space Interferometry Mission - SIM

Data Rates from 300 kbps to 5 Mbps
X-band allocation will be difficult, if not impossible to get.
Space Frequency Coordination Group (SFCG) is close to requiring severe spectral mask on telemetry data at S-, and X-band.
There are modulation schemes that work:
- Filtered BPSK - lossy
- T-OQPSK (Trellis Coded Offset Quadrature Phase Shift Keyed)

Ka-band is proper domain for such bandwidth usage (SIRTF should be there, but started too soon)

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Solar Probe

Solar scintillation:

X-Band Links may need 100,000 bit interleaving - technically possible, but of questionable practicality

- one time use, not multi mission
- big time synchronization decoding issue

Ka-Band reduces scintillation effects by factor of 14.5

Clearly weather outage risk exists

Link margin mitigates risk

Note: there will be occasions when DSS-25 will support Ka-Band and DSS-15 at X-Band will be “off the air”

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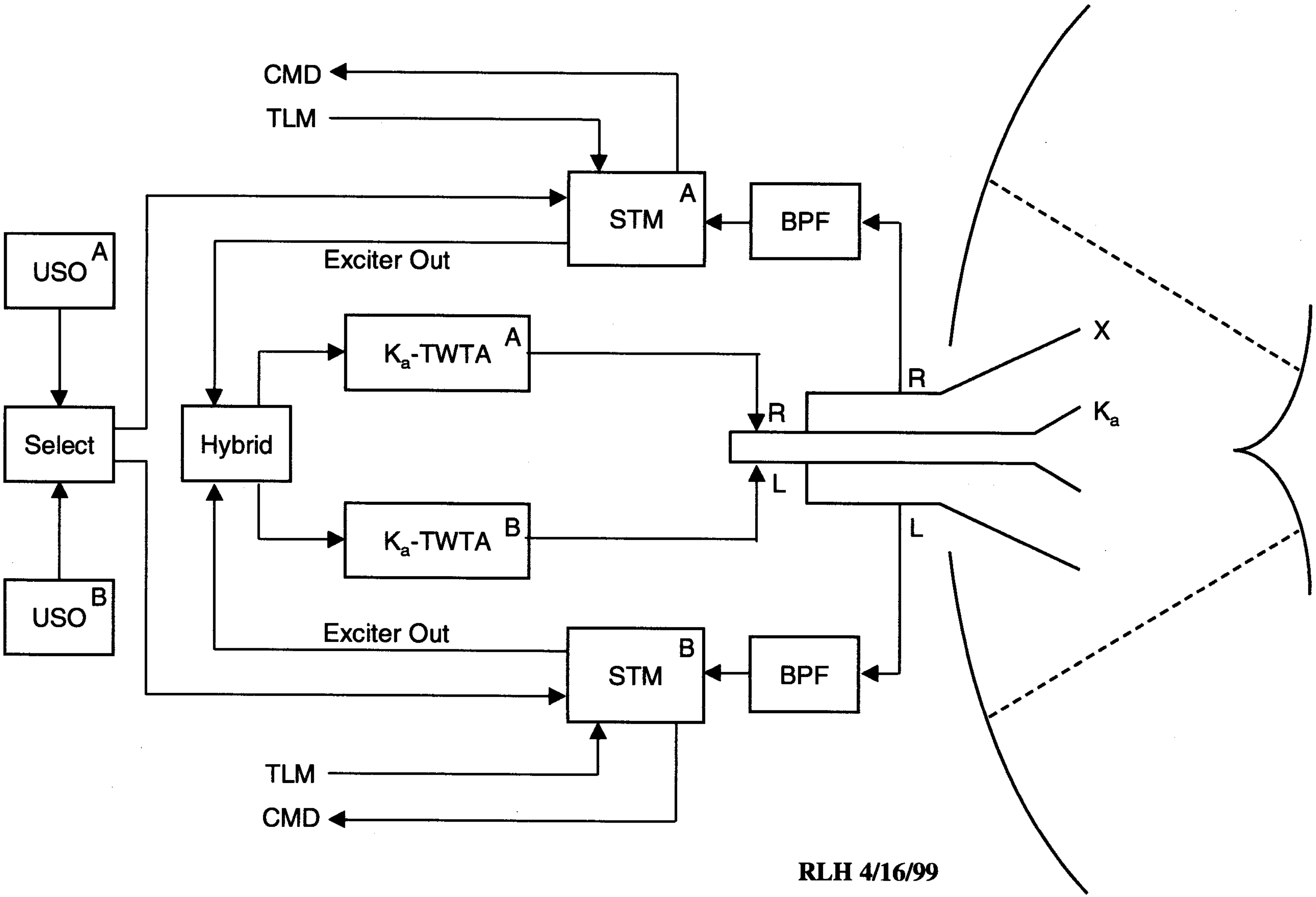
Pluto Kuiper Express

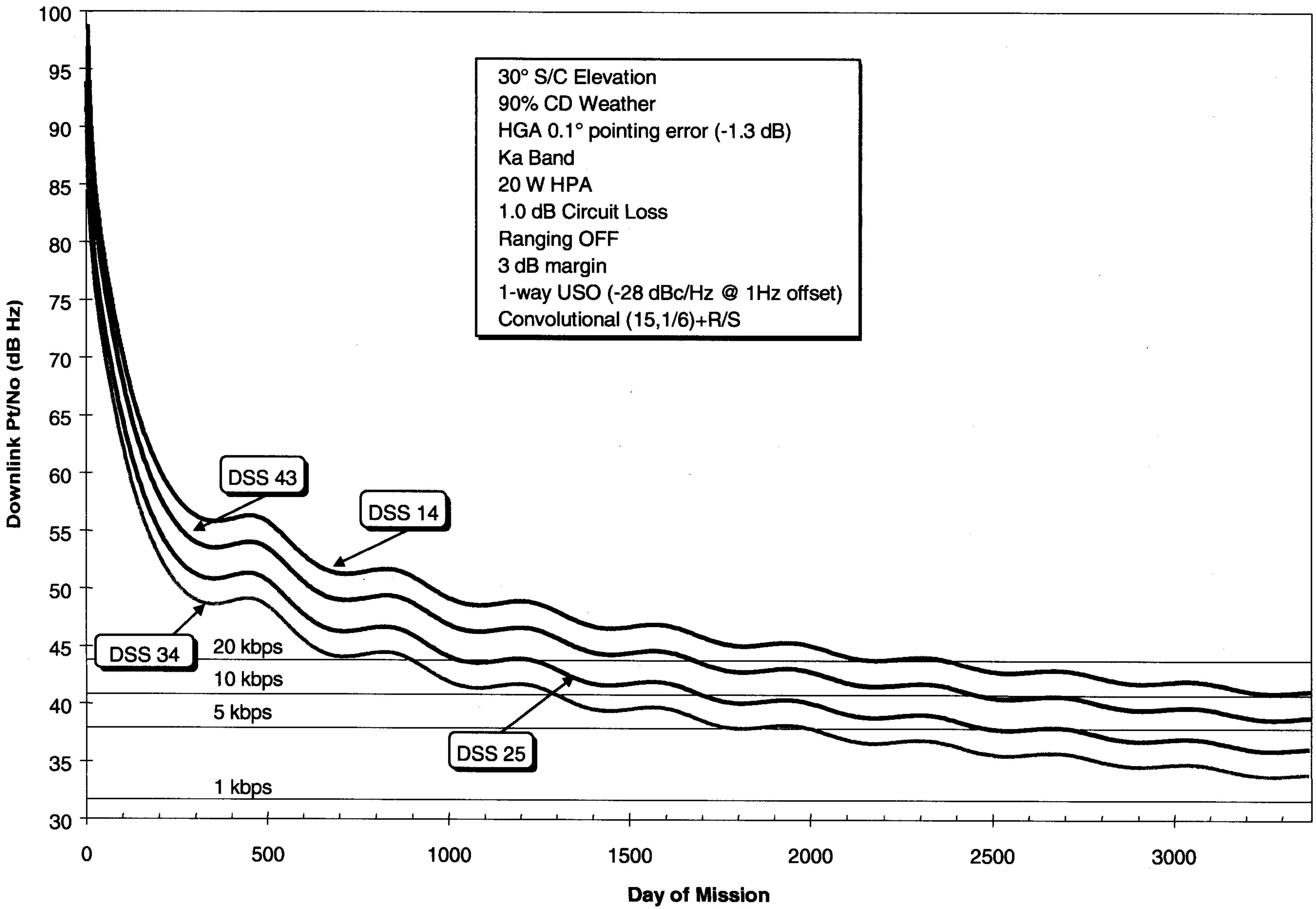
Reduce data return time by 75%
X-up, Ka-down (No X-band down link hardware)
Displaced axis feed HGA (improved efficiency)
Variable geometry feed (avoids separate LGA, waveguide and RF switches)
Most favorable Ka-case. Least Mass and Volume

What if K_a-Band on PKE?



RLH 4/16/99

HGA Earth Pointed - Ka Band TLM Link



Ka-Band Promise

Conclusion

With dependable 34M performance, promising 70M performance, and a flight qualified TWTA in 2 years:

Late ‘03 Launches are viable users.